Opening Lecture: On the memory of Ernst Mayr

Born on July 5, 1904, in Kempten in southern Germany, Ernst Mayr passed away peacefully at the age of 100 on February 3, 2005. Mayr was not only the greatest evolutionary biologist of the 20th century, but was one of the greatest biologist of our ages. Thomas Henry Huxley was called as “Darwin's bulldog” because he was fighting for the acceptance of Darwinian ideas in the last decades of the 19th century. Similarly, Ernst Mayr has been called as “Darwin of the 20th century” for promoting and dispersing Darwin's hypotheses throughout the past century. Mayr is also credited with inventing modern philosophy of biology, particularly the part related to evolutionary biology, which he distinguished from physics due to its introduction of (natural) history into science. He was an eminent naturalist-systematist and ornithologist, leading evolutionary biologist and influential philosopher of biology.

Although Charles Darwin and other evolutionary biologists claimed that there should be a single common ancestor for the whole diversity of life, the mechanism by which this occurred was not understood, creating the species problem. Ernst Mayr approached the problem with a new definition for species. In his book Systematics and the Origin of Species (1942) he wrote that a species is not just a group of morphologically similar individuals, but a group that can breed only among themselves, excluding all others. When populations within a species become isolated by geography, feeding strategy, mate choice, or other means, they may start to differ from other populations through genetic drift and natural selection, and over a very long time these process may lead the relevant species to evolve into new species. This speciation process could be the one of the very important dynamics of evolution. Accordingly, biologist have to take “population genetics” into account more often.

Like Charles Darwin during the 19th century, Ernst Mayr worked indefatigably for a better understanding of the central importance of organic evolution, and he fought for the recognition of the independence and autonomy of biology among the natural sciences. He was one of the main architect of both philosophy of biology and modern synthesis. He had spent all his academic life of 80 years on explaining and studying these issues. Because of the fact
that he is one of the greatest scientists ever in biology, all biologist and biology students have to try to understand his contributions. He could be one of the very best model for the young scientists to take as an example.

**The life and the achievements of Ernst Mayr**

Mayr lived for a century and accomplished more than several lifetime's worth of science in different biological disciplines. He was the second son of Helene and Otto Mayr. His father was a jurist but took an interest in natural history and took the children out on field trips. He learnt all the local birds where they live. He also had access to a natural history magazine for amateurs, Kosmos. Brought up by parents who loved nature and who took the young Ernst on long hikes, he was exposed to natural history early on, but although birds were his passion all his life. His father died just before he was thirteen. This sudden death lead him to study medicine at first. After a while within his medical school education, he got chance to make an observation of a rare species of duck (*Netta rufina*) that had not seen in Germany for many years.

Such observation also let him to met and get into touch with Erwin Stresemann, a very prominent birdwathcer and expert. Erwin proposed him to switch biology and continue PhD on bird. Mayr abandoned medicine for biology and published his first scientific paper (of a total of almost 700) at the age of 19 in 1923, receiving his PhD degree from Humboldt University in Berlin after only 16 months of graduate work and dissertation research; he was just 22. After his quick step in academy, his academic life of 80 years started till his last book, *“What Makes Biology Unique?”* (of a total of 25) was published in August 2004, a month after he turned 100.

In 1931, thinking that he would not be offered a permanent post in Germany, he moved from Berlin to the American Museum of Natural History in Manhattan. In New York he called himself an ornithologist, and believed then, like many of his contemporaries, in Lamarkian inheritance. Sent by his advisor Erwin Stresemann from Berlin and financed by Lord Rothschild, he had just returned from over two years of perilous fieldwork in New Guinea and the Solomon Islands. The parallels to the lives of Darwin and Wallace may not be...
coincidental. During these expeditions, he collected thousands of specimens. Mayr also named 26 new species and over 400 new subspecies. In over 300 publications throughout his life, he discussed and described the geographic variation and distribution of birds and he also edited the last eight volumes of the *Checklist of the Birds of the World*.

In the 1930s, Mayr's friendship and interactions with the Russian-born Columbia University population geneticist Theodosius Dobzhansky started to influence his thinking. Mayr's interests subsequently began to diversify beyond taxonomy into evolutionary biology, and this expansion of his interests culminated in his first, and possibly still most important book, *Systematics and the Origin of Species*, published in 1942. This was his main contribution to the so-called Modern Synthesis of the 1930s and 1940s, a scientific sea change that came about largely through the contributions of Mayr and Dobzhansky and other scientists such as Ronald A. Fisher and George G. Simpson. Mayr's first book combined insights and methods from paleontology, population genetics, systematics, and natural history, thus providing a unified modern evolutionary theory. Patterns and processes in natural populations would now be seen as consistent with Darwinian natural selection and Mendelian mechanisms of inheritance, and the behavior of genes in populations came to be understood through laboratory population genetic experiments and theoretical mathematical predictions. Mayr was the last survivor, and historical eyewitness, among the architects of the Modern Synthesis.

Ernst Mayr had many fundamental insights into evolutionary biology, and almost every topic of importance in evolution was advanced by his ideas. Perhaps his most widely known contribution is to the current notion of what constitutes a species. Darwin did not think that species were real in the philosophical sense, but rather that they were the result of the human predilection to perceive discontinuity among continuously varying individuals. Most biologists nowadays disagree with Darwin's view of species, largely because of Mayr's “biological species concept”.

Species are one of the fundamental units of comparison in virtually all subfields of biology, from anatomy to behavior, development, ecology, evolution, genetics, molecular biology, paleontology, physiology, and systematics. In large part, the importance of species in biology derives from their importance in systematics, which is responsible for the taxonomic framework used in all branches of biology. Systematics is one of the oldest scientific disciplines and, from its beginning, one of its central concepts has been the concept of species. Systematics can be characterized generally as the branch of science devoted to the study of the different kinds of organisms (biological diversity, in contemporary terms), and the term “species” is Latin for “kind.” Moreover, systematics, for the last 250 years, has been strongly influenced by the familiar hierarchy of taxonomic categories originating from the work of Carolus Linnaeus, of which the species is the lowest, and in some sense the most fundamental, of the principal categories. Accordingly, species is “the basic category of biological classification. So that is making it very important to define carefully.
Together with Dobzhansky, Mayr developed this definition of species “as groups of interbreeding populations in nature, unable to exchange genes with other such groups living in the same area”. Barriers to gene flow between species—termed reproductive isolating mechanisms—keep biological species distinct through processes such as species-specific mate choice and hybrid sterility. Although there are theoretical and operational problems with the biological species concept (e.g., it does not apply to asexually reproducing organisms such as bacteria), it is still, by far, the most widely used species concept that have been proposed in the past several decades. Students of biology all over the world have memorized Mayr's definition of species for more than half a century.

The biological species concept made it possible to study how species arise, since the criterion of reproductive isolation provided a scientifically rigorous litmus test. The origin of species is a topic to which Darwin himself, in spite of the promising title of his famous book, did not say all that much. Mayr's understanding of the biogeographic distributions of bird species, overlaid with extensive knowledge about variation in morphology, led him to develop concepts about the geographic mechanisms of speciation—cornerstones for those studying speciation today. The geographic separation of populations, such as by rivers or valleys, he argued, prohibits homogenizing gene flow between them. If such isolated (termed allopatric) populations accumulate mutations over time, this might lead to the divergence of such populations from each other, and reproductive isolation might arise as a simple byproduct of these separate evolutionary histories.

After establishing the Society for the Study of Evolution and serving as the first editor of its journal, *Evolution*, Mayr moved to Harvard University in 1953 as the Alexander Agassiz Professor of Zoology and curator of birds at the Museum of Comparative Zoology. By this time, one surely would have labeled him primarily an evolutionary biologist rather than an ornithologist. Ernst Mayr also served as director of the Museum of Comparative Zoology before his retirement in 1975 and oversaw the building of a new addition to the museum, whose library was renamed after him ten years ago.

What of his retirement? Following his retirement, he went on to publish more than 200 articles, more than 10 books. Actually 14 of his 25 books were published after he was 65. During the last two decades of his life, Mayr began to think and write more about the history and philosophy of biology. His most important work of this period was *The Growth of Biological Thought*. He argued that biology is a science that is based on historical contingency as well as on many unpredictable and coincidental factors that make it impossible to discover laws. Rules, not laws, are all that one will be able to find in biology.

Being a biologist, he is an important person in constructing the synthesis theory of evolution; being a philosopher, he has advocated a new philosophy, which, he claims, synthesizes the achievement of different biologies and physics, while at the same time getting rid of the influences of the traditional philosophy of science.

He received almost 20 honorary degrees from major universities, was a member of more academies than any other scientist before him, and received most of the prizes that could
possibly be awarded to a biologist, including the Japan Prize, the Balzan Prize, and the Crafoord Prize, the “Nobel Prize for ecologists and evolutionary biologists.”

How could one person possibly fit so much into one lifetime, even such an astonishingly long one? For a start, he was a man of stringent self-discipline, who would get up with (or before) the birds, like a good ornithologist should. Writing (longhand or dictation) was done mostly in the mornings, and long walks were part of every day, as were extended periods of reading and corresponding with his colleagues. Just like Darwin, Mayr wrote thousands of letters minding the business of others, telling his fellow scientists what he thought of their work, praising them but also advising them on missed literature and new directions for further study. He did not like to be bothered with those other menial things that also belong to living on this planet, and, luckily for him, Gretel, his wife of 55 years, mostly took care of that part. So after her death ten years ago, when he was in his early 90s, he had to learn how to cook a hamburger for himself. Fifteen years after her death, Mayr passed away on 3 February 2005. He was survived by two daughters, five grandchildren and 10 great-grandchildren, beyond his such academic outputs…
BEES AND POLLINATION

Introduction

Insects are a class (Insecta) of hexapod invertebrates within the arthropod phylum that have a chitinous exoskeleton, three part of body (head, thorax and abdomen), three pairs of jointed legs, compound eyes and one pair of antennae. They are the most diverse group of animals on the planet, including more than a million described species and representing more than half of all known living organisms. The number of extant species is estimated at between six and ten million. Insect biodiversity accounts for a large proportion of all biodiversity on the planet and they may be found in nearly all environments.

Among many insect groups, bees are spritely creatures that move about on pleasant bright days and visit pretty flowers. They are flying insects closely related to wasps and ants. Anyone studying their behavior should find them attractive, partly because they work in warm sunny places, during pleasant seasons and times of day. But quite apart from their practical importance, people have been interested in bees because they are fascinating creatures. We are social animals; some bees are also social. Their interactions and communications have long been matters of interest for scientist. For a biologist bees are also fascinating because of their many adaptations to diverse flowers; their ability to find food and nesting materials and carry them over great distances back to a nest; their ability to remember where resources were found; their architectural devices, which permit food storage… These are only a few of the interesting things that bees do.

Although some people may think that they are summertime nuisance or they are just related with honey or beewax, their main contrubition to human life is their role in pollination. The next time you see a bee buzzing around, remember that much of the food we eat depends
significantly on natural insect mediated pollination – the key ecosystem service that bees and other pollinators provide. These small and hard-working insects actually make it possible for many of your favorite foods to reach your table. From apples to almonds to the pumpkin in our pumpkin pies, we have bees to thank.

Bees are one of a myriad of other animals, including birds, bats, beetles, and butterflies, called pollinators. Pollinators transfer pollen and seeds from one flower to another, fertilizing the plant so it can grow and produce food. Cross-pollination helps at least 30 percent of the world’s crops and 90 percent of our wild plants to thrive. Without bees to spread seeds, many plants—including food crops—would die off. Keeping bee populations safe is critical for keeping our agriculture sector running smoothly.
The Phylum Arthropoda and General Features of the Insects

The members of the phylum Arthropoda (from Greek arthro-, joint + podos, legs) have an exoskeleton (external skeleton), a segmented body, and jointed appendages (legs, antenna...ect). They include the insects, arachnids, myriapods, and crustaceans. They have hardened exoskeleton (cuticle) made of chitin. This chitin layer may sometimes be mineralised with calcium carbonate and get extra strength. The arthropod body plan consists of segmented units such as head, thorax and abdomen. Besides they have well developed sensory mechanisms and mouthparts.

The phylum Arthropoda contains about 78% of all known species of animals. Over a million species have been identified. They live on land, in the sea and air, and make up over three-fourths of all currently known living and fossil organisms. They have been called the dominant animals on earth.
Major Characteristics

1. **Arthropoda** means *jointed foot*. Members of this phylum have *jointed appendages*.
   - These appendages may be *modified* in a number of ways to form *antennae*, *mouthparts*, and *reproductive organs*.

2. Arthropods are *bilaterally symmetrical*

3. They are *triploblastic*

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### Arthropods

<table>
<thead>
<tr>
<th>Class of Arthropods</th>
<th>Common Name</th>
<th>Distinguishing Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecta</td>
<td>Insects</td>
<td>Three body regions (head, thorax, and abdomen), 6 legs and usually 2 pair wings on thorax, 1 pair of antennae.</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Crayfish, Sowbugs, Fairy Shrimp</td>
<td>Have 10 to 14 legs, 2 body regions (cephalothorax and abdomen) and 2 pair of antennae.</td>
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<tr>
<td>Arachnida</td>
<td>Spiders, Ticks, Mites, Scorpions</td>
<td>Have 8 legs, no antennae, 2 body regions (cephalothorax and abdomen)</td>
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<tr>
<td>Diplopoda</td>
<td>Millipedes</td>
<td>Have long bodies composed of about 50 segments, each of which has 2 pair of legs.</td>
</tr>
<tr>
<td>Chilopoda</td>
<td>Centipedes</td>
<td>Have long bodies composed of 14 to 20 segments, each of which has 1 pair of legs.</td>
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![Arthropod Classification](image-url)
Insects make up more than 90% of all species of the phylum Arthropoda. They are the most diverse group of living animal on earth. They can be found nearly on every habitat and they can live in all kind of environments. Thus, they have impact on both ecosystem and human life. So, they are economically and ecologically important animals.

Insects are a class of the arthropod phylum that have a chitinous exoskeleton, a three-part body (head, thorax and abdomen), three pairs of jointed legs (totally six legs), two compound eyes and one pair of antennae. They are among the most diverse groups of animals on the planet, including more than a million described species and representing more than half of all known living organisms.

- Insects live in all kinds of environments.
- Thus they impact man and have an important economic impact on man's activities.

The study of insects is called entomology and a person that specializes in entomology is called an entomologist.
Adult insects typically move about by walking, flying, or sometimes swimming. Insects are the only invertebrates to have evolved flight. Many insects spend at least part of their lives under water, with larval adaptations that include gills, and some adult insects are aquatic and have adaptations for swimming. Some species, such as water striders, are capable of walking on the surface of water. Insects are mostly solitary, but some, such as certain bees, ants and termites, are social and live in large, well-organized colonies.

Humans regard certain insects as pests, and attempt to control them using insecticides and a host of other techniques. Some insects damage crops by feeding on sap, leaves or fruits. A few parasitic species are pathogenic or may be vectors of other type of pathogens. Some insects perform complex ecological roles; blow-flies, for example, help consume carrion but also spread diseases. Insect pollinators are essential to the life-cycle of many flowering plant species on which most organisms, including humans, are at least partly dependent; without them, the terrestrial portion of the biosphere (including humans) would be devastated. Many other insects are considered ecologically beneficial as predators and a few provide direct economic benefit. Silkworms and bees have been used extensively by humans for the production of silk and honey, respectively. In some cultures, people eat the larvae or adults of certain insects.
Insects have segmented bodies that were organized as three distinctive but interconnected units: head, thorax and abdomen.

- **Head** - bears the sense organs (eyes, etc) and mouth parts
- **Thorax** - bears 3 pairs of legs and 1 or 2 pair of wings
- **Abdomen** - bears or contains most of the internal organs

The head supports a pair of sensory antennae, a pair of compound eyes, and, if present, one to three simple eyes (or ocelli) and three sets of variously modified appendages that form the mouthparts (mandible, maxilla, labium), labrum (upper lip), clypeus, frons, vertex and genae portions.
The thorax carries three body segments prothorax, mesothorax and the metathorax, consecutively. All of these segments carry one pair of legs. That counts six or three pairs of legs for each thorax and for an insect. Because of that insect also called as “Hexapoda” means “carrying six (hexa) legs”. Thorax segments also bear wings. However only second and third segments carry one pair of wings. Some insects do not carry wings, some carry only one pairs and many of them carry two pairs, four wings.

The abdomen consists of eleven segments, though in many group of insects, these segments may be fused together or reduced in size. The abdomen also contains most of the digestive, respiratory, excretory and reproductive internal structures. Abdomen do not carry and jointed appendages, legs or any wings. Only cerci which is used for sensory purposes, sexual organs and ovipositors may be found.

Insects can be divided into two groups historically treated as subclasses: wingless insects, known as Apterygota, and winged insects, known as Pterygota. The Apterygota consist of the primitively wingless order of the silverfish (Thysanura). From the pterygot insects; order Isoptera (termites), order Orthoptera (grasshoppers and crickets), order Lepidoptera (moths and butterflies), order Hemiptera (bugs), order Homoptera (cicadas), order Diptera (flies and mosquitoes), order Odonata (dragonflies), order Hymenoptera (bees, wasps and ants) and order Coleoptera (beetles) are the most famous ones that can be encountered frequently in a summer time.
What are the Characteristics of Hymenoptera?

Hymenoptera is a holometabolous (having a complete metamorphosis) group, with generally apodous (without legs) larvae, exarate (with the appendages free, not glued to the body) pupa and a cocoon. The adults have two pairs of membranous wings, the hind wings are smaller than the forewings which they connected to by a series of interlocking hooks (hamuli). Their mouth parts also adapted for lapping and sucking. They are normally thin waisted to some extent and an ovipositor is always present in some form or other, often adapted for sawing and or piercing and especially for stinging.

The Success of the Order Hymenoptera

Hymenoptera is an important insect group from man’s point of view for three main reasons: Firstly they include the bees who as everybody knows make honey and its products, secondly the parasitic groups and the ants are important enemies of crop pests; ants consume huge numbers of lepidopteran caterpillars as well as other pests and were first deliberately used to protect plants from pests in China 4,000 years ago. Moreover, hymenopteran parasites are regularly used in biological pest control and are among the first creatures screened by scientists when they are searching for a control mechanism for insect and other invertebrate pests. Thirdly and perhaps most importantly many of bees are pollinators of most of our crop plants. Because they work for free it is impossible to estimate their economic importance but it easily amounts to billions of dollars every year. It is humbling to realize that if all the Hymenopterans were to suddenly disappear from this earth among the numerous changes would be the collapse of human society.
Some scientists estimate that there are more than 300,000 species of Hymenoptera in the world, though only up to 130,000 have been named so far. With this species accounts, Hymenoptera are the second largest order of insects in the world, after the Beetles (Coleoptera) which boast the greatest number of species.

Given the huge size of the order, it is interesting to consider what features have enabled hymenopterans to be so successful in terms of both individuals and total number of species. Most attention has focused on their morphological and behavioral features such as the evolution of the thin waist, their ovipositor and use of venom, the selection of oviposition site, modification of that site and their different life styles. In addition, the unusual form of sex determination mechanism (haplodiploidy) may have been particularly important in the evolution of sociality.

**The thin waist (petiole)** is absolutely one of the key feature in that it greatly increased the mobility of the posterior abdomen relative to the thorax. It seems like a kind of bridge between thorax and abdomen. However actually it does not located between thorax and abdomen. In hymenoptera the first abdominal segment is fused with thorax and after this segment this bridge-like waist forms. So waist can be said to be located between the first and second abdominal segment. To avoid any confusion in hymenoptera, another terminology was created for thorax and abdomen. Thorax (including the first abdominal segment) is called as
mesosoma; abdomen (starting from the second segment) is called as metasoma. So the waist is located between mesosoma and metasoma. There is a very good reason for the waist to be positioned after the first abdominal segment. Higher hymenopterans are typically strong fliers, and their longitudinal flight muscles are consequently large. Because these muscles are attached internally on the anterior of thorax (actually the mesonotum) and posteriorly on a large internalized chitinous phragma that slants posteriorly, if there were a constriction immediately behind the last (third) thoracic segment, the size of the flight muscles would be greatly restricted. By having the first abdominal segment fused to the thorax, larger flight muscles can be accommodated.

The thin waist (petiole) in turn allowed greater control of the ovipositor and greater variety in its use; later, it allowed the sting, which is in fact just a derived ovipositor, to be much more effective as a weapon of defense and offense. Male in Hymenoptera never possess stings (because the males do not have an ovipositor), they are harmless in this respect. Often, however, males very effectively mimic female stinging movements such that people, and probably many experienced predators, do not take the risk and quickly release them. Moreover they have to bend their abdomen freely for copulation and the thin waist also give advantages to male in this respect.

The morphology of the ovipositor has been crucial in this respect. The hymenopteran ovipositor is used not only for laying eggs, it is also used to pass venom and/or other secretions to the place of oviposition. In the parasitoid taxa, these venoms either cause paralysis of the host or are important in overcoming the host's immune response against the parasitoid. The ovipositor is typically well supplied with sensilla, and the insects receive and interpret the resulting sensory information and use it in deciding whether they have located a site or host suitable for egg laying.
In bees and wasps the egg-laying role has been lost, but the same structure are still present and are used for envenomation of prey or enemies. The venoms of most of these act on the nervous systems or nerve-muscle junctions of their prey insects, permanently paralyzing them. In this sense, the venoms are rendering their larval food sources manipulable and safe from any damage.

"Venoms" were important even before stinging. For example, at least some and possibly most wood wasps inject venomous chemicals into their host trees along with their eggs and these toxins probably either kill the living cambium cells or propagate it to form a plant gall. The plant galls mostly develop directly after the female insect lays the eggs. The inducement for the gall formation is largely unknown; discussion speculates as to chemical, mechanical, and viral triggers. A gall provides the developing gall wasp with a safe refuge for the most vulnerable stage of its life cycle, but many other wasps have found a way to penetrate this defence and parasitise the larva(e) within. Some of these parasitoids use their long, hardened egg-laying tube (ovipositor) to bore into the gall and lay an egg on the helpless gall maker.

**Parthenogenesis (haplodiploidy)** is more common among the Hymenoptera: fertilized eggs become female or worker and unfertilized eggs males (drones). In honeybees the drones (males) are entirely derived from the queen, their mother. The diploid queen has 32 chromosomes and the haploid drones have 16 chromosomes. Drones produce sperm cells that contain their entire genome, so the sperm are all genetically identical except for mutations. The male bees' genetic makeup is therefore entirely derived from the mother, while the genetic makeup of the female worker bees is half derived from the mother, and half from the father. Thus, if a queen bee mates with only one drone, any two of her daughters will share, on average, ¼ (0.75) of their genes (>0.5). The diploid queen's genome is recombined for her daughters, but the haploid father's genome is inherited by his daughters "as is".

**Parasitism, cleptoparasitism** (brood parasites or cuckoo) and **social lifestyle** (eusocialism) is a common way of life among a number of Hymenopterans. Females of the cuckoo bees lack pollen collecting structures (the scopa) and do not construct their own nests. They typically enter the nests of pollen collecting species, and lay their eggs in cells provisioned by the host bee. When the cuckoo bee larva hatches it consumes the host larva's pollen ball, and often kills the host egg and larva.
**Classification of Hymenoptera**

The Hymenoptera are divided into two suborders: Symphyta more commonly known as the Sawflies which are the most primitive members of the Hymenoptera; and the Apocrita which contains all the rest. The Apocrita are customarily divided into two groups, the Aculeata (Stingers) and the Parasitica. In general the Aculeata have their ovipositor modified into a sting which is retractable into the body and is not used for egg laying, whereas in the Parasitica the ovipositor is nonretractable and is only used for egglaying. Further to this the Parasitica are mostly, as their name implies parasites i.e. Ichneumonids and Chalcids. This is however not a strict biological division as some Parasitica members are not parasites, too.

The other major group of the order Hymenoptera is the Section Aculeata, i.e., Hymenoptera whose females have stings— modifications of the ovipositors of ancestral groups of Hymenoptera. The Aculeata (stingers) include the wasps, ants, and bees. For a practical purpose we can summarize that if we find a creature with four membranous wings, burrowing in the ground or making a nest in any way, it is probably an aculeate. Also, that if we find a hairy-bodied insect with four clear wings collecting pollen or sucking nectar from a flower it is probably a bee. Bees are usually more robust and hairy than wasps and wasps seems to be more brightly colored than bees, but some bees (e.g., *Hylaeus, Nomada*) are slender, sparsely
haired, and sometimes wasp-like even in coloration. Also, a fly when it settles remains quiet, whereas an aculeate if in a flower sets to work collecting pollen, On a flower, if an insect is seen quietly sitting with its head away from the center of the flower, it is almost certain to be a fly, not a bee.

Bees differ from nearly all wasps in their dependence on pollen collected from flowers as a protein source to feed their larvae and probably also for ovarian development of females. Unlike the wasps, bees do not capture spiders or other insects to provide food for their offspring. Thus nearly all bees are plant feeders; they have abandoned the ancestral carnivorous behavior of sphecoid wasp larvae. (Adult wasps, like bees, often visit flowers for nectar; adult sphecoid wasps do not collect or eat pollen.)

Bees and the sphecoid wasps together constitute the superfamily Apoidea (formerly called Sphecoidea). This can be separated as: the sphecoid wasps, or Spheciformes, and the bees, or Apiformes. Some authors also used the term Anthophila for the bees. Structural characters of bees that help to distinguish them from sphecoid wasps are (1) the presence of branched, often plumose hairs, and (2) the hind (meta) basitarsi, which are broader than the succeeding tarsal segments. The proboscis is in general longer than that of most wasps, too.

A conveniently visible character that easily distinguishes nearly all bees from most sphecoid wasps is the golden or silvery hairs on the lower face of most such wasps, causing the face to glitter in the light. Bees almost never exhibit this characteristic, because their facial hairs are duller, often erect, often plumose, or largely absent. This feature is especially useful in distinguishing small, wasp-like bees such as Nomada and Hylaeus from similar-looking wasps.

Although bees and wasps are often mistaken for one another, these two types of insects are quite different. First, bees and wasps have different temperaments. While bees are often characterized as aggressive, they are typically docile and harmless, using only their stings when provoked near the hive. Yellow jackets (common wasp), on the other hand, can be quite aggressive, even when away from the nest. Moreover, it is wasps that are likely to invade your picnic, not bees. Indeed, bees are misunderstood, and their bad reputation is a result of being confused with their more aggressive cousins.

**Is it a Bee or Not?**

For a beginner, this is surprisingly difficult to decide. Bees can be differentiated from almost all other Hymenoptera on the basis of their possessing branched hairs somewhere on their bodies. Moreover the hind leg and especially metatibia and basitarsi of a bee is flattened, possess scopa that covered with dense hairs to collect pollen on it.
The Diversity and the Importance of Bees

There are approximately 21,000 species of bees in the world. Scientists have always distinguished one species from another by observing the details of their mouthparts, wing veins, size, body hair, tongue, and pollen-carrying structures, and by their nesting and foraging behaviors. Now that DNA analysis is available as an additional tool, relationships and differences among species are being further clarified. Accordingly, bees might have possess 21,000 different unique adaptations that had helped scientist to determine them among each other.

Probably the most important activity of bees, in terms of benefits to humans, is their pollination of natural vegetation, something that is rarely observed by nonspecialists and is almost never appreciated. Of course the products of honey bees—i.e., wax and honey plus small quantities of royal jelly—are of obvious benefit, but are of trivial value compared to the profoundly important role of bees as pollinators. Most of the tree species of tropical forests are insect-pollinated, and that usually means bee-pollinated. In temperate climates, most forest trees (pines, oaks, etc.) are wind-pollinated, but many kinds of bushes, small trees, and herbaceous plants, including many wild flowers, are bee-pollinated. Desertic and xeric scrub areas are extremely rich in bee-pollinated plants whose preservation and reproduction may be essential in preventing erosion and other problems, and in providing food and cover for wildlife. Conservation of many habitats thus depends upon preservation of bee populations, for if the bees disappear, reproduction of major elements of the flora may be severely limited.
Closer to our immediate needs, many cultivated plants are also bee-pollinated. The plants that require bee pollination have to be pollinated to produce fruit. If no bees arrive, these plants may self-pollinate; but inbreeding depression might give some serious problems. Thus crops produced by such plants are usually better if bee-pollinated than if not; that is, the numbers of seeds or sizes of fruits may be decreased and the quality may fail.

Estimates made in the late 1980s of the value of insect-pollinated crops (mostly by bees) in the USA ranged from $4.6 to $18.9 billion, depending on various assumptions on what should be included and how the estimate should be calculated. A rough estimate that 80 percent of the crop pollination by bees is by honey bees, the rest mostly by wild bees. But whatever estimates the values of insect-pollinated crops are increasing year by year. Wild bees may now become even more important as pollinators than in the past, because of the dramatic decrease in feral honey bee populations in north-temperate climates due to the introduction into Europe and the Americas of mites such as Varroa and tracheal mites, which are parasites of honey bees. Moreover, there are various crops for which honey bees are poor pollinators compared to wild bees. Examples of wild bees already commercially used are Osmia which pollinates fruit trees in Japan, Megachile which pollinates alfalfa in many areas, Bombus which pollinates tomatoes in European greenhouses.

Since honey bees do not sonicate tubular anthers to obtain pollen, they are not effective pollinators of Ericaceae, such as blueberries and cranberries, or Solanaceae such as eggplants, chilies, and tomatoes. Many bees are pollen specialists on particular kinds of flowers, and even among generalists, different kinds of bees have different but often strong preferences. Therefore, anyone investigating the importance of wild bees as pollinators needs to know about kinds of bees.
In many countries the populations of wild bees have been seriously reduced by human activity. Destruction of natural habitats supporting host flowers, destruction of nesting sites (most often in soil) by agriculture, roadways, etc., and overuse of insecticides, among other things, appear to be major factors adversely affecting wild bee populations.

**Morphological Terminology of Adult Bees**

*The head*

The *head*, or *prosoma*, is the first body tagma and according to the categorization of the head positions of insects, it is hypognathous. The *compound eyes* are situated laterally on the head and are composed of numerous minute facets representing the individual lenses of the ommatidia. At the top of the face, arranged in the pattern of an inverted triangle, are three simple eyes termed *ocelli*. At the extreme lower apex of the head is the *labrum*, a freely movable sclerite that covers the mouthparts upwardly. The labrum broadly articulates at the apical margin of the *clypeus*, the lowermost, immovable sclerite of the head capsule. The *antennal sockets* are the points at which the antennae articulate. *Subantennal sutures* are lying just below this area and serve to demarcate a poorly defined region of the head referred to as the *supraclypeal area*. The face above the level of the antennal sockets to the level of the ocelli and between is the *frons*. In some bee lineages (e.g., Andrenidae) the inner margin of the compound eye bears a shallow integumental impression called *facial fovea* which can sometimes covered with dense, microscopic setae. At the lower part of the lateral sides of face there is *malar area* between the lower end of compound eye and mandibular articulation. On the top of the head and immediately behind the ocelli is the *vertex*. The appendages of the next two head segments are intimately tied together and form the primary mouthparts of the bee. Frequently referred to as the proboscis or the labiomaxillary complex, these structures represent the *mandible*, the *maxillae*, and the *labium*. Lastly, the *antennae* are somewhat geniculate, bending at the pedicel, and, as mentioned above, articulate with the face above the level of the clypeus. The antennae are composed of three units: *scape, pedicel;* and the *flagellum*. In bees the number of flagellomeres (flagellum segments) is dimorphic: females almost always having 10 and males 11.
The waist or petiole seems like a kind of bridge between thorax and abdomen. However actually it does not located between thorax and abdomen. In hymenoptera the first abdominal segment is fused with thorax and after this segment this bridge-like waist forms. So this is located between the first and second abdominal segment. To avoid any confusion in hymenoptera, another terminology was created for thorax and abdomen. Thorax (including the first abdominal segment) is called as mesosoma; abdomen (starting from the second segment) is called as metasoma. So the waist is located between mesosoma and metasoma.

Mesosoma

The mesosoma is a combination of the true thoracic tagma with the first abdominal segment (propodeum). It is thus composed of four primary segments: prothorax, mesothorax, metathorax, and propodeum. The pronotum is the dorsal surface of the first thoracic segment. The dorsal surface of the mesothoracic segment called as mesonotum, is divided into two primary units: the mesoscutum (or scutum) and the mesoscutellum (or scutellum). The mesoscutum is the larger one and it is the anterior part. Then it comes metanotum (metathoracic segment), and the hindmost portion the propodeum which is ancestrally the first segment of the abdomen. The propodeum is frequently angled basally to form a dorsal-facing basal area and a posterior surface.
The mesosomal appendages (legs and wings) are all born on the true thorax (pro-meso-meta-thorax). The legs are composed of the typical series of segments (from base to apex): coxa, trochanter, femur, tibia, tarsus, and pretarsus; the tarsus is further subdivided into the long and enlarged basitarsus (basalmost subsegment) and the other small units. The metathoracic legs (especially the tibia and basitarsus) are typically modified for the transport of pollen (this is called scopa) However scopa may develop on metasoma (ventral part of metasoma) in Megachilidae. The scopa is developed to varying degrees and consists of elongate, frequently plumose setae on a variety of metathoracic leg segments of females except in parasitic species and the queen caste of some eusocial species. Thus, among bees there are metasomal scopae, femoral scopae, tibial scopae… Perhaps the most distinctive pollen-carrying apparatus is the corbicula or “pollen basket” found in Apis. There is a single protibial spur and two metatibial spurs on the legs. The protibial spur is modified as antenna cleaner. The pretarsi bear the paired claws. Between the claws is a membranous lobe or arolium, the presence or absence of which is an important character for distinguishing taxa in a variety of lineages.

The wings are borne on the meso- and metathoracic segments. The leading edge of the hind wing is equipped with a series of minute hooks termed hamuli.

Metasoma

The metasoma consists of the true abdomen minus the first segment that is fused to the thorax. The sting is the modified ovipositor and genital organ of males also present at the end of the metasoma.

At the outset, a question arises about the names for the three tagmata, or main parts of the body. Logically, they should be “head, thorax, and abdomen” or “prosoma, mesosoma, and metasoma.” Because the first true abdominal segment is incorporated into the thorax as the propodeum, the numbering of segments in the remainder of the abdomen should begin with 2.

To make it clear here we use the term “metasoma” rather than abdominal terga and sterna. Thus the first metasomal segment is the segment behind the propodeal-metasomal constriction. Abbreviations such as T1 (first metasomal tergum), S1 (first metasomal sternum), and so forth, are regularly used to save space.

The sexes in bees are often quite different from one another, and in the keys the sexes are sometimes treated separately. Most males have 13 antennal segments (11 flagellum segments); females have 12 antennal segments (10 flagellum segments). Males usually have seven exposed metasomal terga; females have six. Sometimes the apical terga are retracted, so that female usually appear to have only 6 terga (but only 5 of them visible), while male bees have 7 (6 of them visible clearly). Females have stings, and males have sclerotized genitalia, but both are usually retracted (sealed inside before use). The sting and associated structures are reduced and not (or weakly) functional in many Andrenidae; more reduced, not at all useful for stinging, in the Meliponini (stingless bees).
Pollen – Nectar Collecting Adaptations in Bees

1. Branched or plumose hairs on the body

2. Scopae, brushes of hairs on the hind legs of many bees or the hairs on the abdomen of Megachilidae.

3. Corbiculae, basket-like structures on the hind tibia, as in the honey bee and related groups, (corbiculate Apidae).

4. The mouthparts
Taxonomy of bee families

Bees are a monophyletic lineage within the superfamily Apoidea, presently considered as a clade of Apiformes or Anthophila. There are nearly 21,000 known species of bees from seven recognized families, Apidae, Halictidae, Andrenidae, Melittidae, Colletidae, Megachilidae, Anthophoridae, though many are undescribed and the actual number is probably higher. They are found on every continent except Antarctica, in every habitat on the planet that contains insect-pollinated flowering plants.

The bee family Apidae is the largest family of bees in the world (>5000 species) and includes many charismatic bee groups, such as bumble bees, stingless bees, orchid bees, allodapine bees, and honey bees. Many of the bees in this family carry pollen on their hind legs, although some species are cleptoparasitic (meaning they steal the nest provisions of other bees) and don’t carry pollen at all. The Apidae includes all the advanced eusocial bees and many important managed pollinators. Apidae also includes an enormous diversity of cleptoparasitic bees; approximately 20% of all apid bees are cleptoparasites.

Andrenidae family comprises the mining bees, all of which live underground. The bees carry pollen on their hind legs and many species are incapable of stinging.

Colletidae family includes the yellow-faces bees, polyester bees, cellophane bees, and the plasterer bees. Depending on the species, these bees live in the ground or in hollow stems. All of the Colletidae species line their nests with a plastic-like substance that is secreted from their abdomens. The female carries pollen back to the nest inside her body rather than outside.

Halictidae is a large and varied family that nest in the soil mainly. Some are solitary, some live in social groups. Some are cleptoparasitic and some are not.

Megachilidae family includes carder bees, mason bees, leafcutters, and resin bees. The bees in this family carry pollen on their abdomens instead of in pollen baskets. Also, they build homes by carrying construction materials. Depending on the species, they use mud, leaves, plant fibers, resins, or other materials to build their nests in pre-existing holes or cavities.

Melittidae is a small family includes the oil-collecting bees. These bees nest in the soil in dry regions and collect oils from specific species of plants. The bees mix pollen with the plant oils (instead of nectar) to form larval food stores.
### Key features of the bee groups

<table>
<thead>
<tr>
<th>Family: COLLETIDAE</th>
<th><a href="#">Image</a></th>
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</thead>
<tbody>
<tr>
<td><em>Colletes, Hylaeus spp.</em></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>1. One subantennal suture.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>2. Facial foveae usually present.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>3. Tip of glossa bilobed or truncate.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>4. Basitibial plate absent.</td>
<td><img src="#" alt="Image" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Family: ANDRENIDAE</th>
<th><a href="#">Image</a></th>
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</thead>
<tbody>
<tr>
<td><em>Andrena spp.</em></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>1. Two subantennal sutures.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>2. Facial foveae present, but difficult to see.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>3. Tip of glossa acute or rounded.</td>
<td><img src="#" alt="Image" /></td>
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</table>

<table>
<thead>
<tr>
<th>Family: MEGACHILIDAE</th>
<th><a href="#">Image</a></th>
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</thead>
<tbody>
<tr>
<td><em>Megachile, Osmia, Anthidium, Lithurgus, Hoplitis spp.</em></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>1. One subantennal suture.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>2. Facial foveae absent.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>3. Tip of glossa acute or rounded.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>4. Flabellum present.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>5. Scopa present on abdominal sterna, absent on tibia.</td>
<td><img src="#" alt="Image" /></td>
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</table>

<table>
<thead>
<tr>
<th>Family: HALICTIDAE</th>
<th><a href="#">Image</a></th>
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<tbody>
<tr>
<td><em>Halictus, Lasioglossum spp.</em></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>1. One subantennal suture.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>2. Facial foveae absent.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>3. Tip of glossa acute or rounded.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>4. Flabellum absent.</td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>5. M1 vein curved (arched) strongly</td>
<td><img src="#" alt="Image" /></td>
</tr>
</tbody>
</table>
Family: ANTHOPHORIDAE
(Anthophora, Eucera, Amegilla, Nomada, Ceratina, Xylocopa)
1. One subantennal suture.
2. Facial foveae absent.
3. Tip of glossa acute or rounded.
4. Flabellum usually present.

Family: APIDAE (Apis, Bombus spp.)
1. One subantennal suture.
2. Facial foveae absent.
3. Tip of glossa acute or rounded.
4. Flabellum present.
5. Scopa replaced by corbiculum on hind tibia
Biology of the Bees

As in all insects that undergo complete metamorphosis (holometabola), each bee passes through egg, larval, pupal, and adult stages. So everything starts with a simple egg. The egg could be either male or female. Like all Hymenopterans, honeybees have haplo-diploid sex determination system: Eggs that have been fertilized develop into females; those that are not fertilized develop into males (drones). In other words, Unfertilized eggs (no paternal genetic contribution) develop into males (drones), and fertilized eggs (both maternal and paternal genetic contribution) develop into females. Female larvae that are fed the standard diet of pollen, nectar, and brood food become adult workers. Female larvae fed a rich diet of royal jelly, pollen, and nectar develop into queens.

Because that males are produced from unfertilized eggs, this means that the queen can control the sex of her offspring. In some species workers may also lay eggs, but because they haven’t mated, these eggs become male.

When she mates, a female stores sperm cells in her spermatheca (sperm sac); she usually receives a lifetime supply. She can then control the sex of each egg by liberating or not liberating sperm cells from the spermatheca as the egg passes through the oviduct. Probably the cell size may stimulate the queen in choosing so. Because in many bees there is sexual
dimorphism (different morphology) the cells that larvae develops would be proportional to its body size so it must be different according to the sex. For example in *Apis*, male-producing cells are larger than worker-producing cells because male are normally much larger than female. Moreover, among bees that construct cells in series in burrows, the female can place male-producing eggs in cells near the entrance, from which the resultant adults can escape without disturbing the slower developing females.

The eggs of nearly all bees are elongate and gently curved, whitish with a soft, membranous chorion (“shell”), usually laid on the food mass (pollen or nectar/honey) provided by workers for larval consumption. In bees that feed the larvae progressively (*Apis* and *Bombus*), the eggs are laid with little food or without any food. The food generally will be added soon after the hatching larvae. Eggs are commonly of moderate size, but are much smaller in which lay many eggs. They are also small in many *cleptoparasitic* bees that hide their eggs in the brood cells of their hosts, often inserted into the walls of the cells; such eggs are often quite specialized in shape. Conversely, eggs may be very large in some bees like *Xylocopa*. Indeed, the eggs of this genus are probably the largest of all bees, which may attain a length of 16.5 mm, about half the length of the bee’s body. Normally the size of the eggs may be 1-2 mm.

Larvae of bees are soft, whitish, legless worms. In mass-provisioning bees, larvae typically lie on the upper surface of the food mass and eat what is below, until the food is gone. They commonly grow rapidly, molting about four times (or five larval instars) as they do so. For the honeybee (*Apis*) there are five larval instars before molting into the pupal stage. As in other aculeate Hymenoptera, the young larvae of bees have no connection between the midgut and the hindgut, so cannot defecate. The last larval stage is called the prepupa or defecated larva. Prepupae are often the stage that passes unfavorable seasons, survives in the cell for one to several years before development resumes. When conditions are appropriate, pupation occurs; soon after larval feeding, defecation, and prepupal formation are completed. In other species pupation occurs only after a long prepupal stage.

Pupae are relatively delicate, and their development proceeds rapidly; among bees the pupa is never the stage that survives long unfavorable periods. Adults finally appear, leave their nests, fly to flowers and mate, and, if females, either return to their nests or construct new nests elsewhere. Many bees have rather short adult lives of only a few weeks. Some, however, pass unfavorable seasons as adults; if such periods are included, the adult life becomes rather long. For example, in most species of *Andrena*, pupation and adult maturation occur in the late summer or fall, but the resulting adults remain in their cells throughout the winter, leaving their cells and coming out of the ground in the spring or summer to mate and construct new nests. In most Halictinae, however, in late summer or autumn, the resulting adults emerge, leave the nest, visit autumn flowers for nectar, and mate. The males soon die, but the females dig hibernaculum a new nest or inside the old nest, for the winter.

In some bees, females tend to mate only once. Males in such species attempt to mate with freshly emerged young females, even digging into the ground to meet them. In other species females mate repeatedly. Most male bees can mate more than once, but in some genera such
as *Apis*, the male genitalia is torn away in mating, so that after the male mates he soon dies. In bees the male mating strategy also varies greatly with body size. Large males usually fly about the nesting sites, finding young females as they emerge from the ground or even digging them out of the ground, presumably guided by odor. Small males seek females on flowers or in vegetation near the nesting area.

At the end of foraging season (in autumn) workers of honeybees can *evict* drones from their colony. Workers stop feeding drones, deny them access to honey stores and drag them from the nest. It can take even few weeks to remove all drones from a colony. Under starvation conditions drones are removed from colony faster. Evicted drones starve to death because they do not collect food from flowers even if it is available for them. *Drone eviction* does not occur in queenless colonies.

**The life of the honeybee**

In the honey bee colony, labor is divided among individuals based on caste and age. A drone’s only purpose is to mate with a virgin queen. The queen is the sole egg layer in the colony and is responsible for producing all of the colony’s offspring (up to 1500-2000 eggs/day). Worker honey bees are thusly named because they perform all colony maintenance tasks. Each worker will perform different tasks exclusively in a predictable order based on their age. This is called *age-related polytheism*. The youngest workers tend the brood (eggs, larvae, and pupae) while older workers build wax comb, handle food stores within the colony, and guard the colony entrance. The oldest workers are foragers; these are the honeybees people encounter most.

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**LIFE OF A WORKER BEE**

<table>
<thead>
<tr>
<th>21 days</th>
<th>42 days</th>
<th>63 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brood</td>
<td>Hive (nurse) Bee</td>
<td>Field (forager) Bee</td>
</tr>
</tbody>
</table>

- Develop from egg – larvae – pupae – to adult bee
- Clean cells
- Feed older larvae
- Feed young larvae
- Feed queen
- Build comb
- Clean hive
- Ventilation of hive

- Collect water
- Collect pollen
- Collect nectar
- Collect propolis
The colony of honeybees consists of a queen, several thousand workers, and a few hundred drones (at certain seasons of the year). Worker honey bees are non-reproductive females. They are the smallest in physical size of the three castes and their bodies are specialized for pollen and nectar collection. Both hind legs of a worker honey bee have a scopa (corbicula) specially designed to carry large quantities of pollen back to the colony. Worker honey bees produce wax scales from ventral part of their metasoma. The scales are used to construct the wax comb (beeswax) within the colony. Workers have a barbed stinger that is torn, with the poison sac, from the end of their abdomen when they deploy the sting into a tough-skinned victim.

The queen is the only reproductive female in the colony (exception: some workers can lay unfertilized male eggs in the absence of a queen). Her head and thorax are similar in size to that of the worker. However, the queen has a longer and plumper abdomen than does a worker. This abdomen is full of ovaries and eggs. The queen also has a stinger but its barbs are reduced. Consequently, she does not die when she uses it.

Drones are the male caste of honey bees. The drone’s head and thorax are larger than those of the female castes, and their large eyes appear more ‘fly-like,’ touching in the top center of the head. Their abdomen is thick and blunt at the end, appearing bullet-shaped rather than pointy at the end as with the female castes.

In the wild, the natural nesting sites of *A. mellifera* are caves, rock cavities and hollow trees. The nest usually has a single entrance. Colonies are composed of relatively large populations, usually between 15,000 and 60,000.

The architectural design of the comb consists of adjoining hexagonal cells made of wax secreted by the workers' wax glands. The bees use these cells to rear their brood and to store their food. The general utilization of comb space is also similar among the species: honey is stored in the upper part of the comb, with, beneath it, rows of pollen-storage cells, worker-brood cells, and drone-brood cells, in that order. The groundnut-shaped queen cells are normally built at the lower edge of the comb.

Typical developmental time from egg to adult varies by caste. Drones have the longest development (24 days), workers are intermediate (21 days), and queens are the fastest (15-16 days).

Eggs: Honeybee eggs measure 1 to 1.5 mm long and look like a tiny grain of rice. The queen lays eggs in individual hexagonal wax cells in the brood area of the comb. After 3 days, eggs hatch and larvae emerge.

Larvae: In the honey bee colony, larvae are referred to as “open brood” because the cells are uncapped. The number of days a honeybee spends as a larvae varies by caste (worker: 6 days, drone: 6.5 days, queen: 5.5 days). Larvae are white and lay in a curled “C” shape at the bottom of their wax cell. When the mature larvae are ready to molt into pupae they extend
their bodies into an upright position in the cell, and adult workers tending to the brood cover the prepupal larvae with a wax capping.

Pupae: Beneath the wax capping, prepupal honey bee larvae molt into pupae. The pupae remain under the wax capping until they molt into an adult and chew their way out of the cell. Pupae are referred to as “capped brood” because the cells are capped. Similar to the larval stage, pupal developmental time varies by caste (worker: 12 days, drone: 14.5 days, queen: 8 days).

**Communication**

The cohesiveness of the honey bee colony is dependent on effective communication. Honey bees primarily communicate within the colony through chemical signals called **pheromones**. Workers, drones, and queens have various glands that produce pheromones. These pheromones include the queen mandibular pheromone that enables a colony to detect the presence of their queen, brood pheromones that signal the type of care required by the immature bees in the colony, and **Nasanov** pheromone that communicates the location of the colony to workers who may have been displaced in a colony disturbance. Another communication way of honeybees is **dance language**.

Nectar and pollen sources are located by foraging bees. After finding a valuable food source, the bee will return to the colony and communicate its finding to other bees through a 'bee dance'.

**Dance Language**

Honeybee dancing, perhaps the most intriguing aspect of their biology, is also one of the most fascinating behaviors in animal life. Performed by a worker bee that has returned to the honey comb with pollen or nectar, the dances, in essence, constitute a language that “tells” other workers where the food is. By signaling both distance and direction with particular movements, the worker bee uses the dance language to recruit and direct other workers in gathering pollen and nectar.

Karl von Frisch, a professor of zoology at the University of Munich in Germany, is credited with interpreting the meaning of honey bee dance movements. He and his students carried out decades of research in which they carefully described the different components of each dance. Their experiments typically used glass-walled observation hives and paint-marked bee foragers. First, they trained the foragers to find food at sources placed at known distances from the colony. When the bees returned from gathering food from those sources, von Frisch and his students carefully measured both the duration and angle of the dances the foragers performed to recruit other bees to help gather food. Their findings led them to the concept of a dance language. Von Frisch’s work eventually earned him the Nobel Prize for Medicine in 1973.

34
When an experienced forager bee (or scout bee) returns to the colony with a load of nectar or pollen that is sufficiently nutritious to warrant a return to the source, she performs a dance on the surface of the honey comb to tell other foragers where the food is. The dancer “spells out” two items of information—distance and direction—to the target food patch. Recruits then leave the hive to find this nectar or pollen source. Distance and direction are presented in separate components of the dance.

![Figure 1. Round dance](image1)

![Figure 2. Waggle dance](image2)

When a food source is very close to the hive (less than 50 meters), a forager performs a **round dance**. She does so by running around in narrow circles, suddenly reversing direction to her original position. She may repeat the dance several times at the same location or move to another location on the comb to repeat it. After the round dance has ended, she often distributes food to the bees following her. This is the “**kissing** behavior” that forager gives some amount of honey with her proboscis to the other worker’s proboscis. By the way she shows the quality of the food. A round dance, therefore, communicates distance (“close to the hive,” in this example), but not direction.

Food sources that are at intermediate distances, between 50 and 150 meters from the hive, are described by the sickle dance. This dance is crescent-shaped and represents a transitional dance between the round dance and a waggle dance.

The **waggle dance**, or wag-tail dance, is performed by bees foraging at food sources that are more than 150 meters from the hive. This dance, unlike the round dance, communicates both distance and direction. A bee that performs a waggle dance runs straight ahead for a short distance, returns in a semicircle to the starting point, runs again through the straight course, then makes a semicircle in the opposite direction to complete a full figure-eight circuit. While running the straight-line course of the dance, the bee’s body, especially the abdomen, wags vigorously from side to side. This vibration of the body produces a tail-wagging motion. At the same time, the bee emits a buzzing sound, produced by wing beats at a low audio frequency of 250 to 300 hertz or cycles per second.
While several variables of the waggle dance relate to distance (such as dance “tempo” or the duration of buzzing sounds), the duration of the straight-run portion of the dance, measured in seconds, is the simplest and most reliable indicator of distance. As the distance to the food source increases, the duration of the waggling portion of the dance (the “waggle run”) also increases. For example, a forager that performs a waggle run that lasts 2.5 seconds is recruiting for a food source located about 2.5 km away.

The orientation of the dancing bee during the straight portion of her waggle dance indicates the location of the food source relative to the sun. The angle that the bee adopts, relative to vertical, represents the angle to the flowers relative to the direction of the sun outside the hive. In other words, the dancing bee transposes the solar angle into the gravitational angle. A forager recruiting to a food source in the same direction as the sun will perform a dance with the waggle-run portion traveling directly upward on the honey comb. Conversely, if the food source is located directly away from the sun, the straight run will be performed vertically downward. If the food source is 60 degrees to the left of the sun, the waggle run will be 60 degrees to the left of vertical.
Because directional information is given relative to the sun’s position and not to a compass direction, a forager’s dance for a particular resource will change during a day. This is because the sun’s position moves during the day. For example, a food source located due east will cause foragers to dance approximately straight up in the morning (because the sun rises in the east), but in the late afternoon, the foragers will dance approximately straight down (because the sun sets in the west). Thus, the location of the sun is a key variable in interpreting the directional information in the dance.

*Other behaviors of honeybee*

One of the most notable honey bee behaviors is **stinging**. Stinging is a defensive behavior worker bees use to protect the colony. When a colony intruder is detected, guard bees release an alarm pheromone that elicits a defensive response by the colony. Moreover, when a honey bee stings, it releases alarm pheromone to attract more bees to sting the location that was stung. All worker honey bees die after stinging.

Due to their highly social life history, honey bee colonies can be considered **superorganisms**. This means the entire colony, rather than the bees individually, is viewed as the biological unit. With that in mind, honey bees reproduce not by producing more individual bees, but rather by producing more colonies. The reproductive process of creating a new colony is called **swarming**. European honey bees typically swarm in the spring and early summer when pollen and nectar resources are plentiful. To initiate the swarming process, 10 to 20 daughter queens are produced by the colony. When the daughter queens are in the late pupal stage, the mother queen and about 2/3rds of the adult workers leave the colony and travel to a location where they will coalesce while they send scout workers in search of a place to establish a new colony (typically an enclosed cavity, like a tree hollow).

The daughter queens in the original colony then emerge as adults and fight until a single queen remains alive, unless one queen emerges earlier than her sisters, in which case she will hunt for and kill her unborn siblings. After a short time of further maturation, the remaining daughter queen leaves the colony to mate with about 15 drones. All mating occurs in the first 2 weeks of a queen’s life, outside of the hive and in the air at drone **congregation areas**. The queen then stores the collected sperm in her spermatheca for the remainder of her life. Once successfully mated, the daughter queen begins laying eggs, thus completing both halves of the swarming process.

*The lifecycle of a bumblebee*

In general, *Bombus* species have an annual life cycle. Queens emerge from hibernation in late winter or spring, and at this time of the year they can often be seen searching for suitable nest sites. The timing of emergence differs markedly between species; some, such as *Bombus terrestris*, emerge early in February or March while others, such as *B. sylvarum*, emerge as late as May or June.
Some bumblebee species always nest underground using pre-existing holes, very often the disused burrows of rodents and some nest on the surface of the ground within tussocks of grass or other dense vegetation. A few bumblebee species such as *B. pratorum* are opportunistic, employing a variety of nest sites both above and below ground, including old birds’ nests, squirrel’s dreys and artificial cavities.

The reason that bumblebees often use old nests constructed by other creatures is that they require a supply of moss, hair, dry grass, feathers or other insulating material from which they form the nest. These materials are arranged into a ball within which is a central chamber with a single entrance. Bumblebees generally do not gather their own nesting material, at least not by flying with it back to the nest. However, they will expend considerable effort in dragging materials from nearby into the nest, and in rearranging existing nesting materials.

The queen provisions the nest with pollen, and molds it into a lump within which she lays her eggs. Generally, between 8 and 16 eggs are laid in this first batch. The pollen lump is covered on the outside with a layer of wax (secreted from the ventral abdominal surface of the queen) mixed with pollen. The queen also forms a wax pot by the entrance to the nest, in which she stores nectar. Queens generate a great deal of heat after egg incubation, maintaining an internal temperature of 37–39°C, which enables them to maintain a brood temperature of about 30–32°C. The eggs hatch within about 4 days, and the young larvae start to consume the pollen. At this early stage, they live together within a cavity inside the pollen, known as the brood clump. In addition to incubating the brood, the queen has to forage regularly to provide a sufficient supply of pollen. It seems probable that this is one of the most delicate stages of the bumblebee life cycle, when a shortage of forage in close proximity or inclement weather could cause the queen and her colony to perish.

The larvae have four instars. After approximately 10–14 days of development, they spin a strong silk cocoon and pupate. It takes a further 14 days or so for the pupae to hatch, so that the total development time is about 4–5 weeks, depending on temperature and food supply. When the pupae hatch, the adults must bite their way out of the cocoon, often aided by the queen. In newly enclosed bumblebees, the hairs are entirely white at first giving them a ghostly appearance; they develop their characteristic coloration after about 24 h. The first batch of offspring are almost invariably workers. From this point onwards nest growth accelerates; the nest can increase in weight by 10-fold within 3–4 weeks.

Males play little part in the life of the colony, although their presence does help keep the brood warm; after a few days within the colony they leave, never to return. Once they have left the nest, the males occupy themselves with feeding on flowers (often rather sluggishly), and with searching for a mate. Most bumblebee species they mate only once.
Spring

The lifecycle begins in spring, when rising temperatures awaken a queen bumblebee that has been hibernating alone in the soil. The queen that have mated in late summer of the previous year will have spent the entire winter underground, using up reserves of energy stored as fat in her body. When she first emerges, she is hungry. She have to feed on flowers, drink some nectar to gain energy. This is why it is vitally important that they find early flowers to feed. Newly emerged queens eat both nectar and pollen, and it is the pollen that helps her ovaries to develop. She will then begin to search for a suitable nest site. Frequent nesting sites include holes in the ground, tussocky grass, bird boxes and under garden sheds.

When she has chosen her nest, the queen will begin to collect pollen from flowers, to bring back to the nest. She forms a mound of pollen and wax (which she secreted from between the segments of the abdomen) and lays her first brood of eggs. She also collects nectar which she stores in a pot-shaped structure made of wax which is positioned in front of her mound. The queen also builds up a store of pollen, some of this she eats, and the rest she forms into a ball moistening it with nectar and saliva, this is sometimes called "bee bread". It is believed that the saliva provides some protection against spoiling by fungi and bacteria. This store of pollen and nectar will enable the queen to survive a day or two of bad weather without foraging.
The pollen stimulates the ovaries to produce eggs, which the queen lays in batches of 4 -16 on the ball of pollen, this is then covered with wax. The eggs are pearly white and slightly curved like a sausage, and are about 2.5 - 4.0 mm long. The ball of pollen with the eggs is placed within reach of the honey pot; this enables the queen to brood the eggs and drink honey at the same time. Like birds queen bumblebees brood their eggs to keep them warm. Bumblebees are very hairy, but the underside of the abdomen has a bare patch, and so the heat from the queen's body can pass directly to the clump of wax-covered eggs. The queen keeps the eggs warm by sitting on her wax ‘nest’ and shivering her muscles to keep warm. During this stage the queen rarely leaves the eggs for long and she keeps them at about 30 C. After about 4 days the eggs hatch. So you see it is not really correct to say that the bumblebee is cold blooded. She can regulate the temperature by heating or cooling the nest.

Once the larvae have eaten enough bee breads, after around two weeks, they spin a cocoon, inside which they develop into adult bees. In the early days of the nest it is estimated that a queen may have to visit as many as 6000 flowers per day in order to get enough nectar to maintain the heat needed to brood her eggs. And during every foraging trip the brood will cool down, so the trips should be short. This is why it is vital that the nest is located close to rewarding flowers.

Early summer

This first brood of offspring are all ‘worker’ females, and will carry out work inside and outside of the nest. Some will guard or clean the nest, while others will forage for nectar and pollen from flowers. Some of the nectar will be consumed by the working bees, but much of it will be brought back to the colony to feed to other workers and the next batch of offspring. From this point on, the queen will not leave the nest. Instead, she will remain inside, laying more eggs and ordering her workers around.

Late summer

As the season progresses nests begin producing offspring which are not workers. New queens (gynes) and males are produced in order to allow the colony to reproduce. The gynes, like the workers, are born from a fertilised eggs and after mating they will become the following year’s queens. It is thought that the queen prevents the early production of gynes by releasing a pheromone, which she subsequently stops. Gynes are feed more during the larval stage to assist their development and give them their increased size. At roughly the same time the queen and possibly some dominant workers will lay unfertilised eggs, which will develop into smaller males. The male bees leave the nest and do not normally return. They do not collect pollen and spend their time feeding on nectar from flowers and trying to mate. Gynes will also leave the hive to mate, but will return to build up fat reserves necessary to survive the winter. This fat will be used to provide energy during a long hibernation. The old queen and her nest will and eventually come to an end as summer turns in to autumn. Only the gynes survive until the following spring, by hibernating underground. The old one will die. Most of the gynes will leave the hive to find a new suitable over-wintering holes (hibernaculum), and the cycle begins again the coming spring.
Social Life of Bees

Some female bees are solitary; others live in colonies. A solitary bee constructs her own nest and provides food for her offspring; she has no help from other bees and usually dies or leaves before the maturation of her offspring. Sometimes such a female feeds and cares for her offspring rather than merely storing food for them; such a relationship is called subsocial.

For many people, bees are thought of as honey-producing social insects living in perennial colonies. This is indeed the way of life for the honeybees. Queens and workers in these cases are morphologically very different, and the queen is unable to live alone (e.g., she never forages); nor do workers alone form viable colonies (they cannot mate and therefore cannot produce female offspring). These are the highly eusocial bees. Such bees always live in colonies, and new colonies are established socially, by groups or swarms.

Most bumble bees and many Halictidae species and carpenter bees (Xylocopa) may live in small colonies, mostly started by single females working as solitary individuals performing all necessary functions of nest construction, foraging, provisioning cells or feeding larvae progressively, and laying eggs. Later, on the emergence of daughters, colonial life may arise, including division of labor between the nest foundress (queen) and workers. These are primitively eusocial colonies. Queens and workers are essentially alike morphologically, although often differing in size; they differ more distinctly in physiology and behavior.
Since in primitively eusocial bees the individual that becomes the queen cannot always be recognized until she has workers, the word \textit{gyne} has been introduced for both potential queens and functional queens. The word is most frequently used for females that will or may become queens. Thus it is proper to say that a gyne establishes her nest by herself in the spring, and becomes a queen when the colony develops.

Both permanent honey bee colonies and temporary bumble bee or halictid colonies are called \textbf{eusocial}, meaning that they have division of labor (egg-layer vs. foragers) among cooperating adult females of two generations, mothers and daughters.

Not all bees that live in colonies are eusocial. Sometimes a small colony consists of females of the same generation, probably sisters that show division of labor, with a principal egg-layer or queen and one or more principal foragers or workers. Such colonies, called \textit{semisocial}. Some bee colonies lack division of labor or castes: all colony members behave similarly. Some such colonies are \textit{communal}; two or more females use the same nest, but each makes and provisions her own cells and lays an egg in each of them. Thus colonial life is facultative. A possible precursor of communal behavior arises when a nest burrow, abandoned by its original occupant, is then occupied by another bee of the same species.

A little-used additional term is \textit{quasisocial}. It applies to the relatively rare case in which a few females occupying a nest cooperate in building and provisioning cells, but different individuals (as opposed to a single queen) lay eggs in cells as they are completed. That is, all the females have functional ovaries, mate, and can lay eggs. This may not be the terminal or most developed social state for any species of bees, but at times some colonies exhibit this condition.

A nest may contain a single female, a gyne who has provided for and is protecting her immature progeny in a subsocial relationship. After emergence of the first adult workers, however, the nest contains a eusocial colony. There are species of Halictinae that have eusocial colonies in warmer climates but are solitary in cold climates. A single population may consist of some individuals functioning like solitary bees while others are eusocial, as observed in some populations of \textit{Halictus rubicundus}.

\section*{Bee Behavior During Foraging}

Insect pollinators, including honeybees, evolved together with flowering plants for millions of years. Plants developed floral parts with increasingly specialized features to attract visiting insects who, in turn, would distribute pollen grains and optimize the plant’s reproductive capabilities. Simultaneously, these wasp-like insects underwent physiological adaptations to take advantage of the nutritional benefits offered by flowering plants. Physical adaptations were augmented by changes in foraging and nesting behavior that proved mutually beneficial to flora and fauna. Some of the physical adaptations of the honeybee include:
Sense Organs

Vision

Each compound eye is spherical in shape and comprised of some 6,300 cone-shaped facets or eyes. Bees can easily distinguish high contrast shapes and patterns. The visual spectrum of the bee has shifted towards shorter wavelengths, enabling it to detect ultra-violet, while red, with its longer wavelength, appears as a dull grey. Bees are particularly sensitive to blue, yellow and blue-green colors.

The sensitivity to ultra-violet and polarized light enables the bee to observe the sun under cloudy conditions. Its spherical-shaped eyes allow the honeybee to measure angles accurately between the relative positions of the sun, the food source and the nest. These field observations are then interpreted and communicated to other bees inside the hive through a 'dance'. Scout bees can direct their fellow worker bees to the location of a food source. Unlike most other insect pollinators, the adaptation of communication has enabled honeybees to utilize floral resources of a large area. As a result, honeybee colonies can attain a biomass at the height of season far greater than any other pollinating insect. Bumble bees and all solitary bees do not communicate and hence, each individual relies on its own foraging success. The foraging range of these pollinators is limited to a comparatively small area.

Odor

The bee’s olfactory sense is estimated to be 40 times better than man’s and plays a critical role in locating food sources and communication in and outside the nest. Some 5,000 - 6,000 olfactory detectors are located on each antenna.

Taste

Taste is detected through the mouthparts and forelegs. Bees have a limited range of taste and many substances detected by humans are tasteless to bees. Within the narrow range of substances they can taste, bees display high sensitivity. Sugar solutions as low as 2% can be detected although for foraging purposes, bees are not interested unless the sugar concentration is 30% or more.

Economics of Foraging

Foraging requires energy and the honeybee's evaluation as to where, what and how long to forage is all related to the economics of energy consumption and the net gain of food to the colony. For example, foraging bees may not access a high quality food source because its distance requires energy expenditure exceeding the energy value of the food source. Generally bees fly only as far as necessary to secure an acceptable food source from which there is a net-gain. Factors that influence foraging behavior and determine profitability:

- weather e.g. wind, temperature, and sunlight,
- distance of the food source from the hive (including differences in elevation),
• food quality (concentration of sugar, protein content of the pollen),
• quantity of nectar or pollen.

Foraging Range

Bees are known to fly as far as 12 km, but usually foraging is limited to food sources within 3 km. Approximately 75% of the bees from a colony forage within one kilometer while young field bees only fly within the first few hundred meters.

Foraging Fidelity

Foraging bees tend to limit their visits to a single species of plant during each trip. This is also called foraging constancy. This behavioral adaptation is critically important for plants since it assures the transfer of pollen from one plant to another plant of the same species. In commercial crops, foraging constancy is essential for optimizing seed set and fruit development. Many researches showed that honeybees can learn the color of the corolla of the currently visited flower species which enables flower constancy during foraging.

Individual foragers will acquire a sample through scouting in the morning and tend to fly to the same source as long as it remains profitable. Bees will shift to another plant species if the nectar or pollen fails. Even then, memory will cause these foragers to return several times and re-check. In areas with great floral diversity and small plantings, a higher percentage of foraging bees will visit different kinds of plants during the same trip. This would account for the mixed pollen loads of returning bees.

Speed of Work

Bees visit up to about 40 flowers per minute depending on floral type, nectar availability and weather conditions. Floral visitation rate by honeybees of some important crops:

• apricots 10 sec
• apples 68 sec
• cherries 82 sec
• raspberry 116 sec

The longer the time period, the greater the nectar availability. It takes twice as much time to collect a load of nectar compared with a load of pollen.

Honeybees are foraging generalists and capable of utilizing a wide range of floral sources. On the other hand, some bees are specialists and only visit certain floral sources. Foraging specialization by the bees coincides with higher efficiency of utilizing the food source, which means improved pollination for the plant.
Highly pubescent (hairy) body of bumblebees is an advantage for them to forage under inclement weather, and they are capable of "buzzing" while on the flower to cause the release of pollens. As such, bumblebees have proven highly efficient in crops such as blueberry, cranberry and blackberry.

Temperature conditions that are suitable for honeybee and bumblebee:

- Below 8 C - no foraging (for honeybees; but maybe for bumblebees)
- 8 C - 16 C - some activity (bumblebees and some megachilids)
- 16 C - 32 C - optimal conditions
- Above 32 C - reduction in foraging, increase in water collection.

**Speed of Flight**

- Loaded bee - approx. 25 km/h (15 mph) on average;
- Empty bee leaving hive - 20 km/h (12.5 mph) on average.

Increased wind reduces foraging activity. At a wind speed of 40 km/h (25 mph) foraging will stop.

**Number of Trips per Day**

The number of trips will depend on various conditions including weather, forage availability, strength of colony, etc. In general, 5-15 trips are made while a water collector may make as many as 100 trips per day.

**Gathering Nectar**

The bee's specialized tongue, called the proboscis, is a suction pump. The nectar passes through the esophagus into the nectar sac where a valve prevents the nectar from passing into the digestive stomach or ventriculus. The nectar sac is essentially a widening of the esophagus and functions as a collecting chamber of liquid foods during transportation. The weight of a full nectar sac may be as much as 90% of the body weight of the bee.

During the return trip to the hive, saliva is added to the nectar which contains the enzyme invertase. Invertase reduces complex sugars into simple sugars, which is part of the conversion from nectar into honey. Should the bee require more energy for the flight home, the valve between the nectar sac and the ventriculus will open allowing nectar to pass into the digestive stomach, so the bee itself can also use the nectar for short term energy. The rest will become the long term storage.

**Handling Nectar on Return to the Hive**

After return to the hive, the forager passes the nectar on to 'house' bees. She opens her mandibles with her proboscis retracted, and a drop of liquid appears at the base of the glossa
while the house bee extends her proboscis fully, and sucks up the drop. The speed of food transmission and processing is determined by various factors, including temperature, the age of the bees, colony strength, its food reserves and the total colony intake of nectar and pollen.

*Ripening Honey*

Partially processed nectar or raw honey contains too much water. Water is removed through evaporation during the ripening process, which involves two phases.

A bee, actively involved in processing nectar, pumps out the contents of her nectar sac into a flat drop on the underside of the proboscis which she then draws up again. This back-and-forth action is repeated rapidly for 15-20 minutes. The liquid is thereby exposed to the warm air of the hive, causing evaporation. In this way, the bees produce half-ripened honey containing about 50-60% (maximum 70%) of dry substance.

The second, passive phase of honey ripening involves the deposit of half-ripened honey in small droplets on the cell walls, or in a thin film on the cell floor. As a rule, 1/4 to 1/3 of the cell is filled; but during a strong flow, or if there is lack of space, 1/2 or 3/4 of each cell is filled straight away. Normally, when the honey is nearly ripe, the bees move it again, and the cells are then filled to 3/4 of their capacity. The final ripening takes 1 - 3 days, depending on the water content when the honey is first put into the cells, the level to which the cells are filled, the amount of air movement achieved, and temperature and relative humidity. Under good conditions the % of water in the honey will be reduced to below 20% in about 4 days.

**Pollen Collecting and Storage**

Pollen is dislodged from the anther of the flower and adheres to the branched hairs of the bee by the help of electrostatic forces. The tongue and mandibles (jaws) are often used to lick and bite the anther. Pollen becomes stuck to the mouthparts and is moistened. While the bee is resting or hovering in the air she removes the pollen from her body and transfers it to the corbicula (pollen basket) of her hind legs.
The process involves all of the bee's three pairs of legs. The wet pollen is removed from the mouthparts, head and antenna by the forelegs. Small amounts of nectar are used to moisten the pollen mixture. The second pair of legs (mid legs) comb pollen from the underside of the thorax and receive it from the forelegs. The inside of the basi-tarsi of the hind legs contain combs which remove the pollen from the brushes of the mid legs. By rapidly rubbing the hind legs, pollen is gradually moved up to the opening between the basi-tarsus and tibia of the rear leg. The rake of the opposite leg will then force the pollen into the corbicula or "pollen basket". A pollen load contains up to 10% nectar, which is necessary for packing.

**Thief Bees**

*Apis* workers steal pollen from the well filled scopae of female *Diadasia*, and occasionally from the scopae of *Halictus*. Also but rarely, *Halictus* females theiving pollen from *Diadasia*. Also we observed a pollen collecting *Apis* biting at the corbicular pollen load of another *Apis* worker in an apparent attempt to steal pollen.

**Nectar robbing** is the removal floral nectar from a flower, most often by chewing or piercing a hole in the corolla, rather than by entering through the flower's natural opening. In this way bees can access the nectar without touching the stars.
Colony Collapse Disorder

A condition known as Colony Collapse Disorder is causing bee populations to plummet, which means these foods are also at risk. In the United States alone, more than 25 percent of the managed honey bee population has disappeared for some years.

Beekeepers first sounded the alarm about disappearing bees in the United States in 2006. Seemingly healthy bees were simply abandoning their hives en masse, never to return. Researchers are calling the mass disappearance Colony Collapse Disorder, and they estimate that nearly one-third of all honey bee colonies in the United States have vanished. The number of hives in the United States is now at its lowest point in the past 50 years.

What’s Causing Colony Collapse Disorder

Researchers think this Colony Collapse Disorder may be caused by a number of interwoven factors:

- Global warming, which has caused flowers to bloom earlier or later than usual. When pollinators come out of hibernation, the flowers that provide the food they need to start the season have already bloomed.

- Pesticide use on farms. Some toxic pesticides meant to kill pests can harm the honey bees needed for pollination. Many pesticides banned by other countries because they harm bees are still available in the United States.

- Habitat loss brought about by development, abandoned farms, growing crops without leaving habitat for wildlife, and growing gardens with flowers that are not friendly to pollinators. Moreover, many researches showed that destruction of habitats and intensification of land use have resulted in the loss of species richness and abundance of wild bees (Hymenoptera: Apoidea) in many European regions. The decline of bees may negatively affect seed set of wild plants and yields of crops requiring insect pollination. In the long term, the loss of plant-pollinator interactions may alter terrestrial ecosystems. The main reasons for the decline of wild bees are the loss of habitats with suitable nesting sites and diverse vegetation providing a temporal continuum of pollen and nectar sources. Bees mainly depend on extensively used man-made habitats. Therefore, changes in the agricultural landscape are of special importance for their conservation.

- Parasites such as harmful mites (Varroa).
PLANT THESE

HERBS
- Lavender
- Catmint
- Sage
- Cilantro
- Thyme
- Fennel
- Borage

PERENNIALS
- Crocus
- Buttercup
- Aster
- Hollyhocks
- Anemone
- Snowdrops
- Geranium

ANNUALS
- Calendula
- Sweet Asylum
- Poppy
- Sunflower
- Zinnia
- Cleome
- Heliotrope

TO HELP SAVE BEES
BEES AROUND US

Bees are flying insects closely related to wasps and ants, known for their role in pollination and production of honey and beeswax. There are nearly 21,000 known species of bees in the world. In Turkey the most common bee families are Apidae, Halictidae, Andrenidae, Colletidae, Megachilidae, Anthophoridae. *Bombus* species (bumblebees) and *Apis mellifera* (honeybees) are the most common members of the family Apidae. *Halictus* and *Lasioglossum* are the most common genera of Halictidae; *Andrena* and *Panurgus* are the most common genera of Andrenidae; *Colletes* and *Hylaeus* are the most common genera of Colletidae; *Megachile, Lithurgus, Osmia* and *Anthidium* are the most common genera of Megachilidae; *Anthophora, Eucera, Ceratina* and *Xylocopa* are the most common genera of Anthophoridae. They are very common in Turkey, as well. Actually Turkey has a rich bee fauna. There are nearly 2000 bee species found in Turkey.

There are nearly 250 bumblebee live in the world. 20% of these species (nearly 50 species) also can be found in Turkey. Among them, *Bombus terrestris, B. niveatus, B. pascuorum, B. argillaceus, B. lapidaries* are the most common ones. Moreover nearly 40% of the *Halictus* species (from Halictidae) of the world can be found in Turkey. Such amounts of bee species displays the importance of the bee studies in Turkey. This great species richness might be due to Turkey’s habitat diversity, geological history and rich flora.

*Apis mellifera* is the only species of honeybees in Turkey. However there are other honeybee species in the world. Although the question of how many honeybee species exist is still debated among taxonomists, at least four species are commonly recognized: the dwarf honeybee *Apis florea*, the giant honeybee *Apis dorsata*, the oriental (India, China, and Japan; Far East Asian) honeybee *Apis cerana*, and the common (Europe, Asia and Africa; mainly West Palaearctic) honeybee *Apis mellifera*. The existence of another giant tree honeybee, *Apis laboriosa*, has recently been confirmed from Nepal, but little is known about its biology. All of these honeybee species are social, that means form a colony likewise *Apis mellifera*. However their body and colony size, their habitat preferences are different. Among the four commonly-recognized species of *Apis*, only *A. cerana* and *A. mellifera* are kept commercially by human being. Because of the behavioral limitations of the dwarf and giant honeybees, it is nearly impossible to keep them in commercial hives likewise *Apis mellifera*. In general they love to make their colony in an open area and thus open-air nesting behavior prevents them from being kept by human for traditional apiculture.

The common honeybee, *Apis mellifera* is the most common domesticated species in the world. Today it has been spread extensively beyond its natural range and can be found on all continents except Antarctica. It has many subspecies or races in the world.

*Apis mellifera ligustica* is known as Italian honeybee. They are very gentle, not very likely to swarm, and produce a large surplus of honey. They have few undesirable characteristics. Colonies tend to maintain larger populations through winter, so they require more winter stores (or feeding) than other temperate zone subspecies.
*Apis mellifera carnica* is known as Carniolan honeybee. It is originated from eastern Alps of Slovakia and Balkans. It is very popular with beekeepers due to its extreme gentleness. The Carniolan colonies are known to shrink to small populations over winter, and build very quickly in spring. It is a mountain bee in its native range, and it suits very well to colder climates.

*Apis mellifera caucasia* is known as Caucasian honeybee. It is regarded as being very gentle and fairly industrious.

*Apis mellifera mellifera* is also called as German honeybee. It is one of the most used race in apiculture.

The hybrid populations of *A. m. mellifera* x *A. m. ligustica* found in Western Europe, have the reputation of aggressiveness that they sting people without any reason. Normally *A. m. mellifera* is not considered randomly aggressive.

*Apis mellifera cypria* is known as Cyprus honeybee. It has rather aggressive nature.

*Apis mellifera anatoliaca* is known as Anatolian honeybee. This race is native to the central region of Anatolia in Turkey and Iraq (Range extends as far east as Armenia). It has many good characteristics but is rather unpleasant to deal with in and around the hive.

*Apis mellifera scutellata* known as African honeybee. It is native to Central and West Africa. This race have made hybrids with other European *Apis mellifera* races. Neither its honey production nor aggression are suitable for apiculture but its strength to diseases is remarkable. Moreover its hybrids gain such strength and high yields of honey production. So these hybrids
have become target for producers. Its hybrids also in South America, Central America and the southern USA. Actually the foundation of such hybrid was coincidental. In an effort to address concerns by Brazilian beekeepers and to increase honey production in Brazil, Warwick Kerr, a Brazilian geneticist, was asked by Brazilian Federal and State authorities in 1956 to import several pure African queens from Tanzania to the south of Brazil. But because of the misfortune some queens escaped. The African queens eventually mated with local drones and produced what are now known as Africanized honeybees (the hybrid race). This new race was also known as “killer bees” because of their aggression. Africanized bees are characterized by far greater defensiveness than European honey bees. They are more likely to attack a perceived threat and, when they do so, attack in larger numbers. Also, they have been known to pursue a perceived threat for a distance of well over 500 meters. The Africanized honey bee thrives in tropical and warm areas and is not well adapted for cold areas that receive heavy rainfall. After the escape of these colonies, hybrids have spread throughout South and Central America and arrived in North America in 1985. For example in the Tucson region of Arizona, a study of trapped swarms in 1994 found that only 15 percent had been Africanized; this number had grown to 90 percent by 1997.

The intense struggle for survival of honeybees in Africa was resulted an intense defense behavior in A. m. scutellata. Because of this, they tend to attack all animals and humans nearby their hives (within 500 meter range). Moreover, their attack is recruited by several troops that sense the alarm pheromones of pioneering stingers. A single African bee sting is no more venomous than a single European bee sting, though African honeybees respond more quickly when disturbed. They send out three to four times as many workers in response to a threat. People may have died as a result of 100-300 stings. While African bee sting cases can become very serious, they remain relatively rare.

In areas of suitable temperate climate, the Africanized colonies outperform European colonies. They work harder than European bees. This is the reason why they have gained a reputation as superior honey producers because one single colony produce nearly 100 kg honey in one year. This is nearly 5 times greater than the average production in Turkey. Because of this fact beekeepers seem to prefer Africanized races. Studies show that in areas of Florida that contain Africanized honey bees, the honey production is higher than in areas in which they do not live. Africanized bees have another advantage over European bees in that they seem to show a higher resistance to several diseases. And their third advantage is that; since they work harder, their role in pollination is greater than European bees. So despite all its negative factors (their aggression), it is possible that the Africanized honey bee might be new trend in apiculture.
Biologist Warwick E. Kerr interbred honeybees from Europe and southern Africa to create the Africanized honeybee. In 1957, the hybrid bee was accidentally released in Brazil by a replacement beekeeper. Since then, the Africanized honeybee has invaded the US and earned the debated nickname of “killer bee.” Their aggressive protective behavior has instilled a fear in humans and contributed to their alias.

Africanized Honeybees are moving north at a rate of 100–300 miles per year.

A total of 2,440,000 Honeybee colonies in the United States - 1997

AFRICANIZED VS EUROPEAN HONEYBEE COMPARISON

An Africanized Honeybee is 16 times more likely to initiate and attack or sting.

European and Africanized Honeybees can only be distinguished by molecular or morphometric analysis.

THE DISTANCE BEES WILL TRAVEL DURING AN ATTACK!!!

FACT: Africanized Honeybees follow victims up to 440 yards, while European Honeybees follow for only 58 yards.
POLLINATION

The goal of every living organism, including plants, is to create offspring for the next generation. One of the ways that plants can produce offspring is making seeds. Seeds contain the embryo so the genetic information to produce a new plant.

The seeds of a plant is the core part of its fruit; and the fruit of a plant is nothing but the transformation/metamorphosis of the flowers. The pollen produced by the male organs are the key signal in here provoking the change in flower’s morphology, from flower to fruit that carry the seeds. The pollen grains are the male gametes, like the sperm cells of animals. Because when the pollens are transferred between flowers of the same species the fertilization occurs and fruits and the seeds are produced. Fertilization (also called as double fertilization) is the process that the pollen grains on the stigma germinate and grow down the stem of the stigma to unite with the ovules in the ovary of the flower and subsequently produce seed. In here the transfer of pollen from male to female flower (or organ) is called pollination. All plants must be pollinated before seed (or fruit) will set, but also this would not be enough. Flowers may be fully pollinated but not necessarily fertilized because they have received incompatible pollen. So the pollens that have pollinated/transferred must be fertile, as well.

After fertilization, the ovule and associated tissues develop into seeds and fruits. Therefore, pollination is crucial for fertilization and the development of seeds and fruits.

Not all plants require pollination and fertilization; they are able to produce fruit which is called as parthenocarpy (or parthenocarpic fruit); that is, the fruit will develop without fertilization of the flower and flower do not produce the seeds, as well.

Pollens are produced from anthers, the male organs; and female organs are called as stigma and ovule. So the route of a pollen must be from anther to stigma for the exact fertilization and so the pollination. The story may be summed up as getting the right pollen to the right place at the right time. Since the plants do not move, some agents (vectors) have to help the
pollen to be transferred from one flower to another. These agents are called as pollinators. The wind, water, gravity, mammals, birds and insects are the pollinator agents in nature. Also humans do some artificial pollination for some plants.

Both gymnosperms and angiosperms undergo pollination process. The angiosperms (so called flowering plants) that produce seeds often enclosed within an edible fruit are among the planet’s most successful life forms. More than 250,000 species of flowering plants have been described. Humans derive food, fiber, drugs, and fuel, either directly or indirectly from angiosperms. Moreover, angiosperms have enhanced aesthetic, recreational, and cultural pursuits since before recorded history. So their presence in the vegetation is crucial for human. And their presence depends to the pollination.

Pollination can be accomplished by cross-pollination or by self-pollination:

Cross-pollination occurs when pollen is delivered from the stamen of one flower to the stigma of a flower on another plant of the same species.

Self-pollination (autogamy) occurs when pollen from one flower pollinates the same flower.

Plants that can pollinate themselves and produce viable offspring are called self-fertile. Plants that cannot fertilize themselves are called self-sterile. Self-sterile plants have to make cross-pollination.

Flowers can be staminate (bearing only male reproductive organs), pistillate (bearing only female reproductive organs), or perfect (bearing male and female reproductive organs). Individual plants can be monoecious (bearing staminate and pistillate flowers), dioecious (staminate and pistillate flowers borne on separate plants), or even trioecious (staminate, pistillate, and perfect flowers borne on separate plants).
Pollination can occur within the flowers of a single plant, among different flowers of a single plant, and among flowers of different plants. A plant that is self-fertile and self-pollinating is called autogamous (self-pollination) if pollination and fertilization take place within the same flower. If a plant is cross-pollinated and cross-fertilized, it is xenogamous. It is common for plants to receive mixtures of self and outcross (nonsel) pollen grains, especially if the male and female parts are in the same flower.

Self-fertilization could be problematic for plants because of the many potential genetic complications associated with inbreeding. Accordingly, adaptations that reduce the likelihood of selfing exist in many taxa. Dioecy and monoecy promote outcrossing, although monoecious plants can receive self-pollen from male flowers on the same plant. Many monoecious species produce male and female flowers at different times, so the probability of selfing is reduced. Similarly, in plants with hermaphrodite flowers, self-pollination within flowers is avoided when the male and female floral parts mature at different times. In some species, the chance of self-pollination is reduced because the male and female parts of the same flowers are separated. In a subset of those species, the male and female parts of the flower move closer together as the flower ages, allowing self-pollination as a “last resort” before the flower is too old to set fruit.

A plant may be spoken of as self-fertile or self-compatible if it can produce fruit without the need for the transfer of pollen to it from another cultivar. If the plant is not receptive to its own pollen, it is self-sterile. Even self-pollinating plants are frequently benefited by cross-pollination. A plant is cross-compatible if it can normally be pollinated with pollen of another cultivar, but it is cross-incompatible if it is not receptive to pollen of certain cultivars.

Plants adapted for cross-pollination have several mechanisms to prevent self-pollination; the reproductive organs may be arranged in such a way that self-fertilisation is unlikely, or the
stamens and carpels may mature at different times. Plants adapted to self-fertilize often have similar stamen and carpel lengths. Plants adapted to outcross or cross-pollinize have taller stamens than carpels to better spread pollen to other flowers.

Many flowering plant species are self-incompatible; that is, pollen that is deposited on a stigma within the same flower (or another flower on the same plant) is unable to achieve fertilization. Self-incompatibility is controlled by complex genetic and physiological internal effects. The effectiveness of self-incompatibility mechanisms ranges from absolute to weak, and the mechanisms for blocking self-fertilization can break down as a result of aging or external factors, especially heat.

Breaking those barriers down ensures sexual reproduction (seed set and fruit set) even when cross-pollination is not possible. It is important to note, however, that despite the ubiquity of outbreeding, many species persist exclusively and successfully with self-pollinating and self-fertile flowers. Moreover, some self-fertile plants that can self-pollinate (including some legumes) are of agricultural importance. They can establish themselves in nonindigenous areas where their natural pollinators are absent.

An estimated 48.7% of plant species are either dioecious or self-incompatible, obligate cross-pollinators.

Pollination also requires consideration of pollenizers. The terms "pollinator" and "pollenizer" are often confused: a pollinator is the agent that moves the pollen, whether it be bees, flies, bats, moths, or birds; a pollenizer is the plant that serves as the pollen source for other plants. Some plants are self-compatible (self-fertile) and can pollinate and fertilize themselves. Other plants have chemical or physical barriers to self-pollination.

**Flower Structure**

In order to understand the entire pollination process, the knowledge of the flower structure is necessary. Typically, the flower is composed of the sexual organs, protected by delicate colorful petals (collectively corolla); green, more durable sepals (collectively calyx). The calyx and corolla combined are referred to as the perianth. There may be leaf like bracts just below the sepals.

The male part (or androecium) of the sexual organs are the stamens, which consist of the hair like filaments bearing the pollen-producing anthers on the extremities.

The sepals (collectively the calyx) is the lowermost circle (green) functions to protect the entire flower in the bud as its other parts are developing. As the flower opens the calyx often folds out of the way. The petals (collectively the corolla) constitute the second ring of a flower (colored part). Their primary function is to attract animal pollinators via a visual signal, such as color, pattern, and shape. Neither the calyx nor corollas are involved directly in
production of gametes; however, their roles are critical to the success of the reproductive process in flowering plants.

The **stamens** constitute the third ring of the floral parts. Each generally consists of a stalk-like filament tipped by an **anther**. The anthers (usually yellowish-whitish) are the structures in which the pollen grains are produced. The female part of the flower (the **pistil**) consist of three parts: The **ovary**, the chamber that contains the **ovules/seeds**; the **style**, the tissue through which the pollen tube cell grows to the vicinity of the ovules; and the **stigma**, the receptive tissue that recognizes legitimate pollen and promotes the germination of the pollen grain.

![Parts of a simple flower](image)

**Figure 1**

**Nectaries and Nectar Secretion**

Flowers frequently have one or more **nectarines**. The nectary is most often located within the flower, usually at the base of the sexual column inside the circle of petals and secrete nectar to attract pollinators. However some of them may locate near some leaves. These are called as extrafloral nectaries. Nectar secretion within the flower usually starts about the time the flower opens and ceases soon after fertilization.
Pollinating Agents

The process of pollination requires pollinators as agents that carry or move the pollen grains from the anther to the receptive part of the carpel. **Biotic pollination** in which the pollen dispersal agent is an animal (i.e., either an invertebrate or a vertebrate); and **abiotic pollination** where pollen is dispersed by an inanimate physical agent, such as wind or water.

**Wind pollination** (also called as anemophily) is the dominant type of abiotic pollination and is especially prevalent in several plant families, including the **grasses** (Poaceae) and **gymnosperms** (such as **pines**). Such **anemophilous flowers** are generally try to avoid self-pollination. One common arrangement is for the female flowers to be located higher on the plant than male flowers so that pollen will not just fall down onto stigmas of the same plant. Because of the high inefficiency of wind pollination, anemophilous species produce huge numbers of pollen grains. Pollen grains of anemophilous species are usually very small which increases their buoyancy. Great quantities of pine pollen have been found hundreds of kilometers away from the nearest forests. Also contributing to buoyancy is the tendency of grains of anemophilous species not to adhere to each other but to be smooth and dry. To capture wind-borne pollen, anemophilous flowers usually have greatly enlarged stigmas.

**Biotic pollinating** agents (biotic agents) include **bees**, wasps, **butterflies**, birds, bats, and flies. Biological pollination is also called **zoophily**. Animals visit flowers for nectar and/or pollen, and they incidentally transfer pollen grains from one flower to another flower of the same or another plant. Characteristics of biotic pollination:

1. Specific/strict relationship between pollinator and plant.
2. The production of relatively small amounts of pollen,
3. Pollen grains that vary in size and external sculpture and are sticky,
4. The production of flowers of attractive colours and odours,
5. Flowers that have nectaries that produce nectar.

Most plant species have adopted one of two very different kinds of relationships with biotic pollen vectors: One option is to be a **generalist** and try to attract a wide variety of different pollinators. The other is to **specialize** (and often coevolve) with a single type of pollinator.
What do Pollinators Gain from Pollination Process?

In general, pollination is a mutually beneficial interaction; pollinating animals receive some form of nutritional “reward” for visitation and pollen delivery. Pollen itself can be a reward, serving as the primary food resource for most larval bees and as an important source of protein for some flies, butterflies, birds, and bats. Other plants provide nectar, oils, resins, fragrances, pheromone precursors, and other resources to induce visitation and pollen delivery.

Effective pollinators often have behavioral and anatomical traits that greatly increase the efficiency and accuracy of pollen delivery.

Pollination Syndromes

Often it is possible to guess what pollinates a plant just by looking at the shape, color and scent of a flower. These characteristics that help us predict the pollinator are called pollination syndromes. Pollinator syndromes describe flower characteristics, or traits, that may appeal to a particular type of pollinator. In table below, the flower traits were summarized according to its pollinator type. This is also called as floral syndromes.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Bat</th>
<th>Bee</th>
<th>Beetle</th>
<th>Bird</th>
<th>Butterfly</th>
<th>Fly</th>
<th>Moth</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>White, green or purple</td>
<td>Bright white, yellow, blue, or UV</td>
<td>White or green</td>
<td>Scarlet, orange, red or white</td>
<td>Bright red and purple</td>
<td>Pale, or dark brown, purple</td>
<td>Pale red, purple, pink or white</td>
<td>Pale green, brown, or colorless</td>
</tr>
<tr>
<td>Nectar guides</td>
<td>None</td>
<td>Present</td>
<td>None</td>
<td>Present</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Odor</td>
<td>Strong and musty; emitted at night</td>
<td>Fresh, mild, pleasant</td>
<td>None to strongly fruity or foul</td>
<td>None</td>
<td>Faint but fresh</td>
<td>Putrid</td>
<td>Strong sweet; emitted at night</td>
<td>None</td>
</tr>
<tr>
<td>Nectar</td>
<td>Abundant; somewhat hidden</td>
<td>Usually present</td>
<td>Sometimes present</td>
<td>Ample; deeply hidden</td>
<td>Ample; deeply hidden</td>
<td>Usually absent</td>
<td>Ample; deeply hidden</td>
<td>None</td>
</tr>
<tr>
<td>Pollen</td>
<td>Ample</td>
<td>Limited; often sticky, scented</td>
<td>Ample</td>
<td>Limited</td>
<td>Limited</td>
<td>Limited</td>
<td>Limited</td>
<td>Abundant; small, smooth</td>
</tr>
<tr>
<td>Flower Shape</td>
<td>Bowl shaped; closed during day</td>
<td>Shallow; with landing platform; tubular</td>
<td>Large and bowl-shaped</td>
<td>Large, funnel-like; strong perch support</td>
<td>Narrow tube with spur; wide landing pad</td>
<td>Shallow; funnel-like or complex with trap</td>
<td>Regular; tubular without a lip</td>
<td>Regular and small</td>
</tr>
</tbody>
</table>

Why Are Pollinators Important For Human Life?

Since the majority of flowering plants need pollinators to set fruit and seeds, they play a significant role in the food production process and provide ecosystem services beneficial to human nutrition, health and wellbeing.

Around 70% of the world’s most produced crop species rely to some extent on insect pollination, contributing an estimated €153 billion to the global economy. The estimated value of insect pollination for European agriculture is €22 Billion.
Pollination is an ecosystem service, it is a natural ecological process that benefits mankind. Insects pollinate crops, assisting with the process of food production and significantly increasing the yield of certain crops.

Cereal crops such as wheat, rice, and corn are either wind or self-pollinated and do not require insect pollination. However, some crops rely on biotic pollination. For example, insect pollination can increase yields in cherry and plum crops by 80% and 30% respectively. The honey bee is the primary pollinator for these fruit crops; however solitary bees, bumble bees and other insects are also important contributors.

Globally, 264 crop species have been identified as being dependent or partially dependent on pollination. In fact, 39 of the world’s most produced 57 crop species exhibit an increase in yield due to biotic pollination. Importance of pollinators in changing landscapes for world crops. Between 15% and 30% of food consumed by humans in developed countries requires an animal pollinator.
Factors that influence pollinator diversity

The health of pollinators is closely linked with the composition of the landscape and the availability of suitable habitats. Approximately 25% of the European landscape is used for permanent crops and arable land, it is therefore no surprise that agriculture is an influential factor for pollinator species.

The survival of a bee colony depends upon many factors, including the availability of suitable habitats other than agricultural areas. Moreover the pesticide usage is one of the main factors that decrease the survival of the bee populations.

MANAGED POLLINATORS

Recognition of the mechanisms of biotic pollination led to important agricultural innovation, with extensive economic consequences; management of pollinator species allowed for enhanced crop productivity and for commercialization (and export) of numerous crop plants.

Of these, *Apis mellifera*, the honey bee, is the premier actively managed pollinator worldwide, highly valued for its activity as a pollinator and for its production of wax and honey.

Honey bees pollinate more than 100 commercially grown crops in North America. In the United States, about 135,000 beekeepers manage 2.4 million colonies of honey bees. Most beekeepers (about 94 percent) are hobbyists with 25 colonies or fewer. Another 5 percent are called sideliners, each managing 25–300 colonies. Only about 1 percent are commercial beekeepers and they generally manage between 300 and 60,000 colonies each to provide most of the nation’s pollination services.

Other species of pollinators for which active management systems have been developed include several species of bumble bees (*Bombus*), mainly for pollination of greenhouse tomatoes; and leaf cutting bees (*Megachile rotundata*; from Megachilidae) which pollinate most of the alfalfa crops. *Osmia* species (from Megachilidae) are managed to some extent, mainly for pollination of apple and cherry orchards in United States, Canada and especially in Japan.

Common figs (*Ficus carica*) are primarily pollinated by fig wasps that was reared on a pollinizer fig variety. To produce its fruits, both wasp and pollinizer trees have to be in the garden. Because of this fact in California, the growers couldn’t able to produce the fruit before importing the fig wasps. After importing, growers learned to identify the proper species for pollination and determine overwintering requirements to synchronize wasp life cycles with the plants and get success to produce. Today California is the second largest fig market after Turkey in the world.
Advantages of Honeybees

*A. mellifera* is highly suitable as a commercial pollinator because of its biology. In contrast to most other species of bees that have annual nests founded by individual, overwintered females each spring, honey bee colonies are perennial. Honey bee populations range between 30,000 and 60,000 individual worker bees. So their pollinator recruits much greater than any other wild bees. As a generalist, the honey bee can pollinate many agricultural crops, including almond and blueberry. Because it forages over long distances (up to 14 km from its nest), it is useful in expansive monocultures where wild bees of other species with more limited foraging ranges are restricted to field margins. In addition, honey bees exhibit sophisticated communication, which increases foraging efficiency, and floral constancy; individuals repeatedly visit a single plant species during each foraging trip and thus, honey bees’ behavior increases the efficiency of pollination by ensuring that compatible pollen is transferred among conspecific flowers when needed.

Advantages of Bumblebees

In comparison with other pollinating insects like honeybees, bumblebees are very effective pollinators. They are first of all fast workers (for instance, they visit twice as many flowers per minute as honeybees), and because of their size, they can carry relatively heavy loads, which enables them to make long foraging trips. Also due to their relatively large size they often achieve better contact with stamens and pistils than smaller insects.

Furthermore, bumblebees make relatively few demands on the circumstances under which they work. They feel more at ease in greenhouses/tunnels than honeybees for instance,
particularly where restricted areas are concerned. Bumblebees are still active at relatively **low temperatures** (around 10°C) and low light intensity levels. Even strong wind and drizzle will not keep them from doing their job.

One important advantage of bumblebees over honeybees is the absence of a communication system. Honeybees inform each other by means of the so-called bees' dance of the presence of an attractive food source outside the crop in which their pollination activities are required, as a result of which the bees may leave collectively. Bumblebees do not have such a communication system. Should an individual bumblebee find an attractive food source elsewhere, it cannot inform its companions, so that the other bumblebees will continue to work in the crop in which their services are required.

When selecting a suitable candidate for large-scale production, the following criteria are used:

- the species must be widely spread;
- the species must produce large, long-lived colonies;
- it must be possible to produce the species in captivity;
- the species must be suitable for pollination of a wide range of crops;
- and the species must show the vibrating behavior (buzz pollination) that is required for pollination of a number of crops, including tomato and aubergine.

On the basis of these criteria, *Bombus terrestris* was chosen for the European market. This species is also produced in Israel and New Zealand for the local markets. For the North American market the locally produced species *Bombus impatiens* and *Bombus occidentalis* were chosen for the eastern and western parts of North America respectively. On the Canaries the local species *Bombus canariensis* is used.