**SOCIAL LIFE IN BEE AND TERMITES**

**Chapter 8**

Social behavior is defined as “*Interactions among individuals, normally within the same species, those are usually beneficial to one or more of the individuals*”. Social behavior ranges from simple attraction between individuals to life in complex societies characterized by division of labor, cooperation, altruism, and a great many individuals aiding the reproduction of a relative few. It is the suite of interactions (*individual social* *interactions*) that occur between two or more individual animals, usually of the same species, when they form simple aggregations, cooperate in sexual or parental behavior, engage in disputes over territory and access to mates or simply communicate across space.

It is believed that social behavior evolved because it was beneficial to those who engaged in it, which means that these individuals were more likely to survive and reproduce. Social behavior serves many purposes and is exhibited by an extraordinary wide variety of animals, including invertebrates, fish, birds, and mammals. Thus, social behavior is not only displayed by animals possessing well-developed brains and nervous systems.

Any aggregation of individuals that is cohesive in space and time in which individuals tolerate one another and interact with one another is called a **social group.** A colony or community of organisms, usually of the same species forms an **animal society**. The state of being social or living in a social group is known as **sociality.** The typical size and composition of a social group for a given species determines its **social structure**. The specific pattern of group living and social interaction that characterizes a given species, including its social structure and social organization is known as its **social system.** The interaction of a species with other members of the society constitutes the **social life** of a particular organism

**Social Organization**

Social organization is defined as “*The formation of a stable structure of relations inside a group, which provides a basis for order and patterns relationships for new members*”. The concept of social organization is found in all level of living organism’s right from the smallest microbes to the giant mammals. The interest in study of these social organizations started with some of the common insect self-organizational behavior available to us like ants and termites. This has led to more scientific study and categorization for social organizations. The following categories of social organization are generally recognized within the animal kingdom

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**1. Eusocial:** This is a term used for the highest level of social organization in a hierarchical classification. It was originally defined to include those organisms (originally, only invertebrates) that had certain features such as reproductive division of labor (with or without sterile castes), overlapping generations and cooperative care of young. Two forms of eusociality are generally recognized

**a.Primitively Eusocial:** This refers to cases such as many wasps and bees where there is little or no morphological caste differentiation, and as a consequence, there is often considerable flexibility in social roles that a given animal may adopt. Reversal of roles from queen to worker and vice-versa is also sometimes seen. Caste differentiation takes place at least partly after eclosion and usually involves simple behavioral mechanisms. The primitively eusocial species are being increasingly studied as there are obvious advantages in using them as model systems to understand the evolution of eusociality.

**b. Highly Eusocial:** This as the name implies, refers to the most advanced societies where there is clear cut morphological caste differentiation and little, if any, flexibility in the social roles that adult insects may adopt. Caste determination occurs almost exclusively before eclosion and involves rather complicated nutritional and hormonal mechanisms. All termites, most ants and many bees and wasps such as the honey bees and the vespine wasps, respectively, are highly social. Without exception the highly eusocial state is restricted to the orders Hymenoptera and Isoptera in the entire animal kingdom.

**2. Presocial:** This is a phenomenon in which animal’s exhibit more than just sexual interactions with members of the same species, but fall short of qualifying as eusocial. That is, presocial animals can display communal living, cooperative care of young or primitive reproductive division of labor, but they do not display all of the three essential traits of eusocial animals. Hence this refers to everything beyond the solitary and before the eusocial i.e., it includes the subsocial, communal, quasisocial and the semisocial.

**a. Semisocial:** This refers to a situation which incorporates two features of eusociality namely, cooperative brood care as well as reproductive caste differentiation but lacks overlapping of generations. Many wasps and bees are semisocial.

**b. Subsocial:** This is a term used simply to refer to when an organism exhibits any form of parental behavior. It is the most common and widespread form of sociality. In many species the mother, father or both parents either care for the young directly or simply build a nest.

**c. Quasisocial:** This is one step higher than communal because it also involves cooperative brood care. Again spiders are good examples of this. Thus, quasisocial includes one of the three features of eusociality namely, cooperative brood care but not the other two.

**d. Communal:** These species are those where members of the same generation use the same composite nest or nesting area but show no cooperative brood care or any other feature of eusociality. Many spiders are excellent examples of this.

**3. Solitary:** This is the term that characterizes the absence of any extent of sociality so that members of a species may not interact with each other at all except during courtship and mating.

**Key Features of Insect Societies**

All the social insects possess certain traits in common, which are as follows:

**1.** **Large Populations (Colonies).** Many individuals of a species of social insects live
together in an integrated manner in a comparatively large group or population. Term colony is commonly applied to the complex society they form. Number of individuals forming a colony ranges from 35,000 to 50.000 in honey bees, up to 600.000 in ants and several millions in termites.

**2. Elaborate Nests**. Social insects construct more or less elaborate nests for protection, storage of food and maintenance of broods.

**3. Polymorphism** **(Caste System)**. Typically, social insects an elaborate caste system. Principal castes are the reproductive (king and queen) and the sterile members (workers and soldiers). Workers are the smallest in size. Queen is the largest with a long abdomen and lays eggs. It lives for several years. Males are intermediate in size and develop parthenogenetically from unfertilized eggs.

4. **Cooperative Brood Care**. Contrastingly to many different animals, social insects all tend the brood together taking care of offspring from other individuals. Along with it is the phenomenon of **overlapping generations** wherein an overlap of two or more generations with offspring assist with brood care.

5. **Division of Labour.** In organized societies, animals of different status, sexes or age groups have different functions in attaining the society. In insects, members are differentiated into distinct castes which are specialized in structure, function (reproduction, feeding, guarding. etc.) and behaviour. The queen reproduces almost exclusively while other members of the colony specialize on different tasks.

**6.** **Progressive Provisioning of Food**. True social insects (bees. ants and termites) feed their young extensively and continuously from day to day until they metamorphose into the adults. This is known as progressive provisioning or food.

**7.** **Trophallaxis**. Exchange of food between one insect and other is known trophallaxis. Ants and termites feed one another from mouth to mouth. Young exchange food with the adult. Some ants feed some beetles. coccids and aphids and in return imbibe a fluid secreted by them.

In termites, trophallaxis plays an important role in the regulation and determination of castes.

 **8. Swarming**. Swarming occurs as a means of alleviating congestion in the overcrowded
colony or as a means of distribution. In many, swarming occurs for feeding migration and
mating. Mostly mating takes place between the queen and the males during swarming, called the nuptial or marriage flight. Honeybees propagate colonies by swarming.

 **9. Protective Devices**. Social insects develop several devices for protection. Stings are developed in most bees and certain ants. Jaws are highly developed in stingless and soldiers of ants and termites to ward off enemies. Nests are also built in protective localities such as ground, hollow trees, mud, paper etc. and have numerous side-exits through which rapid escape is possible at the time of danger.

 **10. Communication**. Both social and non-social insects utilize chemical, tactile, visual and
auditory signals as methods of communicating with each other. Chemical communication occurs with the help of body secretions called pheromones. Pheromones include sex attractants, the queen substance and other types whose influences are useful to the colony. Substances deposited on the ground by ants returning from a foraging trip serve as a trail marker for other ants. Substances released by the dead body of an ant within the colony stimulate other workers to remove the body. In honey bees, a queen substance produced by the queen's mandibulate glands controls nursing behaviour of the workers. caste determination and swarming.

**SOCIAL LIFE OF HONEY BEES**

Bees represent a large and successful branch of the insect's family tree:  more than 25,000 species have been described worldwide.  Although most bees are solitary or sub-social, the family *Apidae* contains three distinct groups that exhibit eusocial behaviour

**1. Social bees.** Social bees are certain types of bees that form large colonies. This is the type of bee that most people commonly think of when discussing bees. Social bee hives contain dozens upon dozens of bees crawling over each other, creating combs, feeding their larvae and creating honey.

**a. Bumble bees.** Bumble bees are very large, black and yellow. They obsessively seek out flowers in search of nectar and pollen. They are one of the biggest pollinators, probably second only to the honey bee, on the planet and vital to the overall ecosystem of Earth.Bumble bees tend to make their homes in the ground and will gladly use abandoned rodent burrows and areas beneath patio stones, piles of compost, between piles of wood, and even within very long grass.

**b.** **Honey bees.** One of the most common social insects on the planet, honey bees create colonies that can be as large as 80,000 individual insects, live in hives and create honey. Honey bees are quite simply the number one pollinator insect on the entire planet and one of the most vital links in the entire ecosystem. The difference between honey bees and other bees, wasps and hornets, is that they have a barbed stinger. This means that when a honey bee stings someone, that stinger gets stuck in the flesh and, when they fly away, their own insides get pulled out with them. This causes the death of the bee, but leaves behind the mechanisms that pump venom into their intended victim.

**c.** **Africanized honey bees.** Africanized honey bees are also known as “killer bees” and originated on the African continent. They were cross-bred with regular honey bees to create a new version that eventually escaped a lab in South America and have worked their way north over the years. They are infamous for being bad tempered, for taking over areas once populated by standard honey bees and for their willingness to attack en masse anyone or anything that comes near their nest and literally sting them to death.

**2. Solitary bees.** Not every type of bee is social. There are bees that prefer to operate on their own or with very small colonies. All creatures, of course, want to find a mate and create offspring. These bees do, too, but solitary bees tend to have very small nests, fly by themselves, and generate enough food just to feed what larvae they have and that’s it. There are a lot of species of solitary bees, and most of them are relatively harmless to humans. The more common ones are Carpenter bees, Ground bees, Digger bees, Mining bees, Leaf cutting and mason bees, Sweat bees, Plasterer bees etc.

**Honey Bees**

Honey bees (*Apis*) are one of mankind’s most well-known, popular and economically beneficial insects. For thousands of years, humans have plundered natural honey bee colonies to get honey, bee larvae and beeswax. In more recent centuries, bee plundering has given way to bee management. Today, honey bees are kept in artificial hives and a large and sophisticated beekeeping industry provides valuable honey, beeswax and pollination services.

The honey bee is a highly evolved eusocial insect species that engage in a variety of complex tasks not practiced by the multitude of solitary insects. Communication, complex nest construction, environmental control, defense, and division of the labor are just some of the behaviors that honey bees have developed to exist successfully in social colonies. These fascinating behaviors make social insects in general, and honey bees in particular, among the most fascinating creatures on earth.

Several thousand worker bees cooperate in nest building, food collection, and brood rearing. Each member has a definite task to perform, related to its adult age. But surviving and reproducing take the combined efforts of the entire colony. Individual bees (workers, drones, and queens) cannot survive without the support of the colony.

**Caste Differences in Honey Bee**

Honey bees enlist a caste system (Fig 8.1) to accomplish the tasks that ensure survival of the colony. The advanced nature of the honeybee colony is based on this **differentiation** of labor along with integration of the community through a communication system. Each member of the community fulfills a need that serves the group. In honey bees there are two genders, the females of which are further divided into two castes – sterile workers and fertile queens:



Fig 8.1. Castes of honey bee

**1. Queen:** The most powerful bee in the hive is the queen. Each colony has only one queen which is a diploid individual. The queen establishes the colony after a reproductive flight. She mates with many drones, up to 15, and stores their sperm in her spermatheca. Throughout her life, she lays eggs up to 1,500 eggs a day (both fertilized and unfertilized) and secretes a pheromone that keeps all other females in the colony sterile. A queen is easily distinguished from other members of the colony by her longer body especially the abdomen during the egg laying period, shorter wings, absence of pollen baskets and a long and curved stinger. The queen can live for several years—sometimes for as long as 5, but average productive life span is 2 to 3 years.

**2. Drone**:Drones (male bees) the largest bees in the colony are haploid and are produced from the unfertilized egg of the queen. The drone’s head is much larger than that of either the queen or worker, and its compound eyes meet at the top of its head. Drones have no stinger, pollen baskets, or wax glands. Their main function is to fertilize the virgin queen during her mating flight. Drones become sexually mature about a week after emerging and die instantly upon mating. They tend to eat more than workers and do not usually gather food of their own. When cold weather begins in the fall and pollen/nectar resources become scarce, drones usually are forced out into the cold and left to starve. Queen less colonies, however, allow them to stay in the hive indefinitely.

**3. Workers**:These are sexually undeveloped females and diploid. Workers are the smallest and constitute the majority of bees occupying the colony. Female worker bees accomplish every chore unrelated to reproduction. Workers have specialized structures, such as brood food glands, scent glands, wax glands, and pollen baskets, which allow them to perform all the labors of the hive. In their first days, workers tend to the queen. They build the comb in which honey is stored and eggs are laid, guard the entrance, and air-condition and ventilate the hive during their initial few weeks as adults. Later as field bees they forage for nectar, pollen, water, and evaporate the nectar to make honey for times when food is scarce. They tend to the queen, the young drones, and the larvae. When threatened, the workers defend the colony. If the hive does not have a queen, then worker bees can develop the ability to mate.

**Communication**

The social structure of the colony is maintained by the presence of the queen and workers and depends on an effective system of communication. The distribution of chemical pheromones among members and communicative “dances” are responsible for controlling the activities necessary for colony survival. The pheromone that the queen produces serves as a social “glue” unifying and helping to give individual identity to a bee colony. One major pheromone—termed queen substance—is produced by her mandibular glands, but others are also important. The qualities of the colony depend largely on the egg-laying and chemical production capabilities of the queen. Her genetic makeup—along with that of the drones she has mated with—contributes significantly to the quality, size, and temperament of the colony.

**Swarming**

When the first virgin queen is almost ready to emerge, and before the main nectar flow, the colony will swarm during the warmer hours of the day. The old queen and about half of the bees will rush en masse out the entrance. After flying around in the air for several minutes, they will cluster on the limb of a tree or similar object. This cluster usually remains for an hour or so, depending on the time taken to find a new home by scouting bees. When a location is found, the cluster breaks up and flies to it. On reaching the new location, combs are quickly constructed, brood rearing starts, and nectar and pollen are gathered.

After the swarm departs, the remaining bees in the parent colony continue their field work of collecting nectar, pollen, and water. They also care for the eggs, larvae, and food, guard the entrance, and build combs. Emerging drones are nurtured so that there will be a male population for mating the virgin queen. When she emerges from her cell, she eats honey, grooms herself for a short time, and then proceeds to look for rival queens within the colony. Mortal combat eliminates all queens except one. she flies out to mate with one or more drones in the air.

**Nuptial Flight of the Queen**

When the survivor is about a week old, the queen leaves the hive to mate with several drones in flight. Because she must fly some distance from her colony to mate (nature’s way of avoiding inbreeding), she first circles the hive to orient herself to its location. She leaves the hive by herself and is gone approximately 13 minutes. The queen mates, usually in the afternoon, with seven to fifteen drones at an altitude above 20 feet. Drones are able to find and recognize the queen by her chemical odor (pheromone). The drones die after mating, but the mated queen returns to the nest as the new queen mother. Nurse bees care for her, whereas prior to mating she was ignored.

**Attendance of the Queen**

After mating the queen returns to the hive and begins laying eggs in about 48 hours. She releases several sperm from the spermatheca each time she lays an egg destined to become either a worker or queen. If her egg is laid in a larger drone-sized cell, she does not release sperm. The queen is constantly attended and fed royal jelly by the colony’s worker bees. The number of eggs the queen lays depends on the amount of food she receives and the size of the worker force capable of preparing beeswax cells for her eggs and caring for the larva that will hatch from the eggs in 3 days. When the queen substance secreted by the queen is no longer adequate, the workers prepare to replace (supersede) her. The old queen and her new daughter may both be present in the hive for some time following supersedure.

**Laying Workers**

When a colony becomes queen less, the ovaries of several workers develop and workers begin to lay unfertilized eggs. Development of the workers’ ovaries is believed to be inhibited by the presence of brood and the queen and her chemicals. The presence of laying workers in a colony usually means the colony has been queen less for one or more weeks. However, laying workers also may be found in normal “queenright” colonies during the swarming season and when the colony is headed by a poor queen. Colonies with laying workers are recognized easily: there may be anywhere from five to fifteen eggs per cell and small-bodied drones are reared in worker-sized cells. In addition, laying workers scatter their eggs more randomly over the brood combs, and eggs can be found on the sides of the cell instead of at the base, where they are placed by a queen. Some of these eggs do not hatch, and many of the drone larvae that do hatch do not survive to maturity in the smaller cells.

**A New Queen**

New queens are raised under three different circumstances: emergency, supersedure, or swarming. When an old queen is accidentally killed, lost, or removed, the bees select younger worker larvae to produce emergency queens. These queens are raised in worker cells modified to hang vertically on the comb surface. When an older queen begins to fail (decreased production of queen substance), the colony prepares to raise a new queen. Queens produced as a result of supersedure are usually better than emergency queens since they receive larger quantities of food (royal jelly) during development. Like emergency queen cells, supersedure queen cells typically are raised on the comb surface. In comparison, queen cells produced in preparation for swarming are found along the bottom margins of the frames or in gaps in the beeswax combs within the brood area.

**Effects of Weather**

In the winter a reduction in the amounts of nectar and pollen coming into the hive causes reduced brood rearing and diminishing population. When nectar in the field becomes scarce, the workers drag the drones out of the hive and do not let them return, causing them to starve to death. Eliminating drones reduces the consumption of winter honey stores. As temperatures drop, the bees draw closer together to conserve heat. The outer layer of bees is tightly compressed, insulating the bees within the cluster. As the temperature rises and falls, the cluster expands and contracts. The bees within the cluster have access to the food stores. During warm periods, the cluster shifts its position to cover new areas of comb containing honey. An extremely prolonged cold spell can prohibit cluster movement, and the bees may starve to death only inches away from honey.

With the lengthening days and new sources of pollen and nectar stimulate brood rearing. The bees also gather water to regulate temperature and to liquefy thick or granulated honey in the preparation of brood food. Drones will be absent or scarce at this time of the year. As the days lengthen and the temperature continues to increase, the cluster expands further and drones are produced. With an increase in brood rearing and the accompanying increase in adult bees, the nest area of the colony becomes crowded. More bees are evident at the entrance of the nest. A telltale sign of overcrowding is to see the bees crawl out and hang in a cluster around the entrance on a warm afternoon.

**DANCE LANGUAGE OF HONEY BEES**

Honey bees are masters of orientation with the honey bee dance being one of the most intriguing and fascinating behaviors in animal kingdom. The dance is 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.

The details of this communication language of honey bees were first unraveled by the pioneering research of Professor Karl - Von Frisch (1886—1982). He was a professor of zoology at Munich University. He and his students carried out decades of research in which they carefully described the different components of each dance. 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. Two types of dance (Fig x) are recognized in the honey bee



Fig 8.2.Honey bee dance types

**1. Circle Dance or Round Dance.** If a food source is close to the hive, let’s say within approximately 100 meters, then a collecting bee performs a “circle dance” or “round dance.” She moves in a circle about twice the size of a quarter, then turns around and follows the circle backward. During the dance, the bee stops to give samples of the nectar, or to allow the pollen on her back legs to be inspected. Several bees of collecting age follow her and recognize through the kind of dance and the scent she carries that there is something with this scent to collect nearby. The dance then appears to say simply that there is food close to the hive. No distance or directional information is given (Fig 8.2).

**2.** **Figure of Eight Dance or Tail-Wagging Dance:** If the food source is more than 100 meters from the hive, the collecting bee chooses a different form of dance wherein she outlines a broad figure eight. 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. One can view the waggle dance as a sort of symbolic walk. During this walk, her wings beats at a low audio frequency of 250 to 300 hertz or cycles per second and produce a buzzing tone that her followers can “hear” only over a distance almost tantamount to touching the dancer. Silent dancers do not attract any followers. This form of dance is known as the figure of eight dance or tail waggle dance and conveys information both about the direction and distance of the source from the honey comb.

**a. Direction or Compass Information*:*** The important midsection of the dance communicates the direction of the food source from the hive (Fig 8.3).

* If the dancing bee points directly upward, it tells her followers to look in the direction of the sun.
* If she moves with her head pointed directly down, she signals her followers to look opposite the sun.

The angle she waggles her abdomen reveals the food source’s angle to the sun.

* If she waggles 60 degrees to the right of vertical, the food source lies 60 degrees to the right of the sun.
* If she dances 45 degrees to the left of vertical, the food source lies 45 degrees to the left of the sun.

**b. Information about Distance and Food Quality**: The speed of the dance tells the followers the food source’s distance from the hive. The faster the dance, the closer the food is. The slower the dance, the farther away the food is. The rate at which the dance figures are repeated provides information about the quality of the food source (its abundance, sugar content, etc.). With increasing distance, the number of circuits (the figure of eight’s drawn) per unit time decreases and the length and duration of the individual circuit’s increases. For example, for a goal at 100 meters it makes 10 short circuits in 15 seconds but at 3 km only 3 long circuits in the same time. The duration of the wagging part has the best correlation with distance. The distance is calculated based on the expenditure of energy on the flight towards the source (ahead-wind increases it). Each recruited bee averages many dance circuits or even several dances from different bees to calculate the distance. For each bee species a distance-frequency curve can be plotted. It is remarkably precise, especially if the distance is not close to their foraging range limit.



Fig 8.3.Waggle dance: Angle a between the axis of the dance and the vertical corresponds to the angle between the sun and the food source

**c. The Dance Floor**: Bees returning to the beehive after finding a good supply of food will communicate to other bees by dancing at a particular region in the comb: the dance floor. The dance floor is generally close to the entrance but sometimes moves, *e.g.,* goes further inside when it is cold or closer to the entrance when there is lots of activity. In Nature honey combs are vertical, so the dance is generally performed on a vertical plane. *This is of great significance for the bee dance as the language must provide information of horizontal directions on a vertical plane.* However, when the weather is very warm the dance floor may move outside the entrance to a horizontal flight board. It is also horizontal in some primitive bee species and can always be made horizontal by the human experimenter. Dances on oblique dancing floors can also happen, mainly on the obliquely rounded lower edge of a free-hanging comb or on the rounded swarm cluster bees form when looking for a new nesting place. In nature the vertical dancing floor is inside the hive and thus quite dark while the horizontal one is generally under the open sky.

**d. Relation of the Position of the Sun to the Waggle Dance**: 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. The sun’s position also is governed by geographic location and time of year. The sun will always move from east to west over the course of the day. However, above the Tropic of Cancer, the sun will move from southeast to southwest, whereas below the Tropic of Capricorn, the sun will move from northeast to northwest. Within the tropics, the sun may be located to the south or to the north, depending on the time of year. Thus, to translate the directional information contained in the honey bee dance, one must know the angle of the waggle run (with respect to gravity) and the compass direction of the sun, which depends on location, date, and time of the day

**Recent Views**

The concept of a honey bee dance language, however, has had its skeptics. Several scientists, among them Adrian M. Wenner, professor emeritus of natural history at the University of California at Santa Barbara, have a different idea. They believe the dance exists, but they are not certain it communicates the location of a food source. These critics have argued that floral odors on a forager’s body are the primary cues that enable the recruit-bees to locate new food sources. Many experiments have directly tested this alternate hypothesis and demonstrated the importance of floral odors in food location. In fact, von Frisch held this same opinion before he changed his mind and developed the theory of the dance language. The biological reality probably lies somewhere between these two extremes. The most commonly accepted view is that recruits go to the area depicted in the dance, but then home in on the flower patch using odor cues. Indeed, researchers have built a robotic honey bee that is able to perform the dance language and recruit foragers to specific locations. But the robot is unable to properly recruit foragers to a food source unless it carries an odor cue on its surface. Nevertheless, it is clear that honey bees use the distance and directional information communicated by the dance language.

**SOCIAL LIFE OF TERMITES**

Termites are classified in the order Isoptera, which contains nearly 3000 species organized into 282 genera (Krishna et al. 2013). Termites are soft-bodied insects that feed on wood and other dead plant material. Termites may look like white ants, but new genetic research confirms they are really a social kind of cockroach. They live in colonies, mostly in tropical regions. Termites build large nests underground, in trees or in large mounds above the ground. They can be made of mud, wood, or faeces mixed with saliva, depending on the species of termite. Their nests help to keep the termites moist and cool. Inside each nest can be found at least one royal couple: a large king and even larger queen. Soldier termites protect the colony from attack by their greatest enemy: ants. Worker termites forage for food, feed the others and look after the young.

Termites are of crucial ecological significance since they decompose plant material, such as wood, grass, and leaf litter, and modify the distribution and properties of soils. Even though termites are, by far, the most abundant in the tropics, their distribution in nature is actually very broad, ranging from the northern Palearctic to the temperate rainforests of New Zealand. African rainforests contain the greatest number of genera, whereas temperate rainforests are generally species poor; termites also occur in semi-desert and savanna woodland ecosystems (Jones and Eggleton 2011).

**Lower and Higher Termites**

Out of the seven termite families that exist, six of them are categorized as lower termites. Termitidae is the only family of termites that is considered to be of a higher order and includes the majority (over 70%) of living termite species. Lower termites are more closely related to the earliest termite species that existed on earth. Higher termites have undergone more evolutionary changes than lower termites. In terms of behavior and anatomy. Higher termites live within social structures that are more complicated and advanced than lower termite colonies. The nests built by higher termites are also more advanced than the nests built by lower termites. The most advanced type of termite nest is the mound that contains a complicated network of tunnels directly below its base.

**Caste Differences**

**1. Reproductives:** The principal reproductive caste (the king and the queen) consists of highly sclerotized, flying individuals with fully developed reproductive systems. They leave the nest at a certain time of year in suitable weather, disperse, and form pairs. Wings are broken off either before or sometimes after the pair is formed. They are held together both physically by the male gripping the female near the abdominal tip (to form a tandem) and by means of an attractant produced in the sternal gland. They then fly or walk to a crevice and start excavating a cell; their gonads develop, then they copulate and start producing fertile eggs. During the ensuing phase the wing and mandibular muscles of both sexes dissolve and contribute to gonadal growth. The female's fat body also becomes reduced at the expense of her ovaries, and she becomes physogastric and immobile. Colony founding thus involves a complex behaviour repertoire absent from other castes; workers, however, are better at building and feeding, and soldiers at defence.

**2. Workers:** Across most species of termites, a worker termite looks like an insect in the larval stage. Worker termites have soft exteriors and tend to be white or pale brown.They termites lack a flight system, eyes, and fully developed gonads but are sclerotized and pigmented; they have a complicated and active behaviour, unlike larvae that are pale, have soft mouthparts, are unable to feed themselves, and are relatively quiescent. Workers' jaws are strong and large and they can collect and prepare food for larvae, reproductives, and soldiers. They are derived from larvae suddenly in a single moult, and though they retain their prothoracic glands (their ability to moult and some developmental plasticity), they are, in fact, precociously matured larvae. In spite of belonging to a hemimetabolous group of insects, termites have evolved a sharp distinction between young dependent stages and old service stages. Sex and size often affect task bias; in general, the large female workers forage and the small male ones work in the nest. Age too gives a task bias viz. in *Nasutitermes costalis* stage 3 workers preponderate as nest repairers after a breach has been made in the wall, but under less urgent conditions smaller, younger workers are found building, in proportions greater than expected from the general population (McMahan, 1970).

**3. Soldiers:** Termite soldiers (Fig 8.4) are specialized for defense. They are dependent on workers for food, they lack sternal glands for trail-laying and their reproductive system is abortive. On the positive side they have an enlarged, strengthened head with hypertrophied jaws and jaw muscles which operate on a number of different principles. They may be toothed and bite together in the midline; they may be sickle-shaped and cross over when closed; or they may lock together and spring shut. In the subfamily Nasutitermitinae the enlarged frontal glands of the head are open into a rostrum through which repellent and toxic chemicals can be ejected when the mandibular muscles are contracted. In these species the jaws are reduced. In most species one or other sex, rarely both, produces soldiers. When two soldier sizes occur, they usually are formed from different-stage larvae or workers, not from different sexes. The defensive behaviour of soldiershas been described by Noirot (1969). When a nest is disturbed, they may rush actively to the site or they may block up the local galleries; many stand in a regular series facing outward along the margin of foraging or other columns. In attack they not only bite with their mandibles but use a glutinous saliva and the nasute form can eject material over several centimetres.

**4. Substitute Sexuals.** In the Termitidae there is evidence that if the initial pair dies, substitutes takeover. They are normally imaginal, winged forms although their pigmentationmay be imperfect; often several substitute sexuals may occur. There is alsoevidence that nymphs can become reproductives after an adaptive moult. Manysubstitutes are made; more females than males. There is some doubt whetherworker-derived replacements exist, for it is known that the nymphs may moultregressively or that workers may become nymph-like if the sexual pair is removed(Noirot, 1969).



Fig 8.4. Showing castes of termites

**Types of Termite Colonies**

The presence of a true worker caste is a key feature when it comes to classifying termites.

**1.** **One-piece-type.** Termites without a true worker caste are called **“****one-piece-type”** termites. They form small colonies and inhabit a single piece of wood upon which they also feed. This type of social organization is generally considered to be primitive type of organization and mostly found among the members belonging to the family Kalotermitidae, Termopsidae, and in some Rhinotermitidae (*Prorhinotermes*, *Termitogeton*), and the Serritermitidae (*Glossotermes*), (Roisin and Korb 2011).

**2.** **Separate-type.** More advanced social organization is observed in **“****separate-type”** termites. They are characterized by a true worker caste, forage for food outside the nest (which they often build de novo), and usually live in large colonies, which can reach up to a few million individuals in extreme cases.

In termite evolution, the transition from one-piece-type nesting to separate-type nesting was accompanied by an increase in the complexity of social interactions and communication as well as by the development of different modes of signaling.

**Development of Castes (Polymorphism and Polyphenism)**

The development of termite castes is of particular interest when studying the evolution of sociality because, in comparison to other eusocial insects, termites demonstrate a high degree of **polymorphism** as well as a significant amount of **polyphenism** (the phenomenon where two or more distinct phenotypes are produced by the same genotype) as a result of their hemimetabolous development. Both males and females are present in all societies, although the sex ratio may vary depending on the caste (Roisin and Korb 2011). Hemimetabolous development in termites allows for a significant degree of plasticity: an undifferentiated larva can become either a worker or a nymph and more advanced larval stages (workers and nymphs) can eventually develop into **soldiers, neotenics,** or **adults**. This temporal developmental polymorphism appears to be unique among insects. Termites also exhibit a high degree of neoteny (the ability of immature forms to reproduce); workers and nymphs can rapidly initiate individual reproduction without leaving the natal nest and without becoming adults. This trait is essential to their remarkable reproductive flexibility and has led to a wide variety of social structures from the one-piece-type termites, whose immatures retain the ability to reproduce at all stages, to the advanced separate-type species, whose workers are almost all permanently sterile. The extremely **altruistic** defense behavior displayed by some termite castes is remarkable. For instance, soldiers of some species sacrifice themselves for the colony by causing their *dehiscent defense glands* to explode, a specialized suicidal adaptation (Bordereau et al. 1997); in other species, aged termites carry out **suicide missions** on behalf of their nestmates (Sobotník et al. 2012).

**Communication and Social Recognition**

Communication plays a central role in the recognition of nestmates or foreigners by social groups, which fits with the idea that communication is a key element in all social behavior. Communication is particularly important for termites because they live in dark environments and most castes are blind. As a result, visual signaling does not appear to mediate recognition in termites; instead, other means of communication are well developed. Communication mechanisms vary depending on nesting and foraging habits and are also affected by social organization. Termites rely primarily on chemical communication, employing recruitment pheromones, alarm pheromones, and colony-specific odors. Trophallaxis, the exchange of liquid food, is prominent in the sharing of food and transmission of chemicals used for communication. Nestmate recognition in termites is based primarily on heritable odors (Adams, 1991). Many messages are conveyed by volatile signals and can generally be perceived at a distance or require only limited contact. However, physical contact is also a necessary part of numerous behaviors. As a general rule and as in other eusocial insects (ants, wasps, and bees), social recognition in termites is mediated by chemical communication and contact is often required. It has been indicated that **contact-mediated signals** are involved in termite recognition, with epicuticular compounds, namely **cuticular hydrocarbons**, playing a primary role in nestmate recognition (Clément, 1982).

**1. Vibratory Communication in Termite Society:** The perception and active production of vibrations are relatively well documented in termites; vibrations are used in a variety of contexts from the exploration of the abiotic environment to social interactions such as alarm and disease signaling. Vibratory movements in termites belong to one of three categories (Leis et al. 1994):

* Longitudinal oscillatory movement (LOM)
* Vertical oscillatory movement (VOM) or head-banging/drumming
* Complex oscillatory movement (COM) or zig–zag movement, which comprises a combination of horizontal and vertical jerking motions.

Virtually all termite species demonstrate sensitivity to vibrations propagated by the substrate, and they respond immediately to mechanical disturbances, showing accelerated movement and alarm behavior. Body vibration, a widespread behavior in termite is characterized by a series of bursts of movement, each of which comprises several horizontal or vertical body jerks, and is often accompanied by the drumming of the head or the abdomen against the roof (and/or floor) of a gallery or nest. Vibrations are most often used to propagate alarm signals in response to biotic and abiotic disturbances.

**2.** **Visual Communication and Recognition in Termite Society.** In termites, developed compound eyes are only found in imagoes, future kings and queens, who use them during their dispersal flights. The subsequent search for mates is mediated chemically, and vision plays a negligible or no role (Nutting 1969). The single exception to this rule is the family Hodotermitidae, whose workers possess functional compound eyes. *Hodotermes mossambicus* workers forage at night or during the day in the open air. They employ a more individual style of foraging as opposed to the classical column foraging seen in most other termites. When light conditions are favorable, they visually orient themselves using an internal compass that responds to sunlight or moonlight; simultaneously, they mark their path using pheromones produced by their sternal glands. Optical cues are given preference over chemical cues and are more precise. However, when light conditions are poor and also in the vicinity of their foraging holes, chemical communication dominates and workers are perfectly able to find their way back home solely on the basis of the chemical trail (Heidecker and Leuthold 1984).

**3. Chemical Communication and Social Recognition.** The dominant role of chemicalsin communication, orientation, and recognition is an important characteristic of social insects in general, and termites in particular. The variety of chemical signals used by termites and their production organs are shown in Fig 8.5.



Fig 8.5. Schematic drawing of a termite body depicting major glandular sources or deposition sites for chemicals used in communication and defense in the termite genus *Prorhinotermes*.

**a. Foraging and Food Marking.** Although termites demonstrate diverse feeding ecologies and nesting habits, their capacity to mark and follow trails is ubiquitous. The sternal gland is present in all termite castes and all species studied to date. Foraging in termites consists of two phases **exploration** and **recruitment**. During the search for food, scouts lay down an **exploratory trail**. Once food has been found, the termites return to the nest using this exploratory trail while simultaneously laying down a **recruitment trail** that is far more attractive to foragers (Traniello 1982). Foraging is often initiated by workers, who are later eventually accompanied by soldiers. However, in many cases, the soldiers themselves precede the foraging columns and patrol foraging trails and sites. Once food has been located, termites often tend to aggregate at that spot and feed in groups. It has been shown in a number of species that aggregation is mediated by the saliva secreted from the labial (salivary) glands (Sillam-Dussès et al. 2012). **Hydroquinone** has been identified as the active chemical in the saliva and is thought to be the **food marking pheromone** and a general **phagostimulant** in termites (Reinhard et al. 2002). Pheromone communication is also used during building, which has reached its most complex form in the fungus-growing termites of the genus *Macrotermes*. *Macrotermes* workers use soil pellets that are cemented together using salivary secretions. Freshly deposited pellets are attractive to workers and stimulate them to add new pellets. This building behavior is coordinated by a **“cement pheromone”,** whose chemistry is unknown; it is secreted by workers during pellet deposition and combined with trail-following pheromone from the sternal gland.

**b. Mate Attraction and Recognition***.* In termites, long-range, short-range, and contact chemical cues are used by future kings and queens in mate attraction, recognition, and choice, following their dispersal flights from their natal nests. Sex pheromones, also known as sex-pairing pheromones are produced by the sternal glands, posterior sternal glands, tergal glands, or a combination thereof. In the more advanced families of termites, only the females call the males (Bordereau and Pasteels 2011). Once a pair has formed, the male usually follows the female during the search for a suitable nesting site in a **“tandem run”,** during which the male touches the female’s posterior abdomen with his antennae and mouthparts. In some species, the female may use her sternal gland to mark the trail during the tandem run to prevent accidental separation. The mating itself takes place only after the nesting site has been chosen and the future royal chamber has been built.

**c. Chemical Alarm.** Sociality involving the chemical alarms is widespread among the members of the family belonging to Rhinotermitidae, Serritermitidae, and Termitidae. Chemical alarms serve to initiate local recruitment by means of shortrange attractants. Secretions produced by the frontal glands of soldiers are involved. Alarm pheromones are included in the blend of defensive chemicals and are released when excited and/or fighting soldiers discharge their frontal glands.

**d. Nestmate Recognition and Agonism.** Termites have aggressive encounters with heterospecific competitors, and agonistic, often lethal interactions between conspecifics from different colonies frequently take place. These ultimately lead to the territorial isolation, usurpation, or death of the defeated colonies. Depending on the context, various castes, namely soldiers, workers, or reproductives, may display aggressive behavior. Agonistic interactions may occur as early as during colony founding. In some species (one-piece-type), the onset of aggressiveness towards conspecific reproductives can be observed as soon as the royal pair is established in the colony. Conflicts take place as the colonies develop and compete for food and space within a single log, and these conflicts often result in the death of one or both primary reproductives; colonies may subsequently merge and behave as a single unit, and the lost reproductives are replaced by neotenic reproductives (Johns et al. 2009). In separate-type termites, aggressive encounters between foraging parties are common and both soldiers and workers participate in the agonism.

**e. Caste Recognition and Social Regulation.**Mutual recognition of caste identity within the colony is vital to the effective division of labor, the coordination of social activities, and the care of dependent immatures, soldiers, and reproductives. Caste recognition in termites involves an instantaneous contact event that is followed by mutual antennal inspection. Non-volatile chemical signatures on body surfaces serve as recognition cues and cuticular hydrocarbons are potentially be involved.

**f. Recognition of Reproductives, Reproductive Status, and Queen Dominance.** The reproductive division of labor between the minority of breeders and the sterile majority of helpers requires that nestmates effectively recognize the presence of reproductives in a variety of contexts. First, reproductives convey that they are present and fertile, thus maintaining their reproductive dominance and inhibiting the development of neotenic reproductives (primer pheromone function). Second, kings and queens signal their presence to elicit tending behavior, such as grooming, feeding, defense, and egg care. These two types of signaling, referred to as fertility signals.

**PRACTICE QUESTIONS**

**Multiple choices**

**1. Which one of the following is a social insect?**

 a. Termites b. Ants and bees

 c. Wasps d. All

**2. In a bee colony which one of the following shows altruistic behavior?**

 a. Queen b. Workers

 c. Drones d. None

**3. Highest level of social organization is referred to as**

 a. Presocial b. Eusocial

 c. Parasocial d. Quasisocial

**4. Overlap between generations occurs in**

 a. Semisocial b. Quasisocial

 c. Communal d. Eusocial

**5. Which one of the following adults cooperates in building a nest but rear their brood separately**

 a. Solitary b. Communal

 c. Quasi social d. Eusocial

**6. Social behavior is**

 a. The interaction among individuals of the same species

 b. Generally beneficial to one or more individuals

 c. Serves many purposes

 d. All of the above

**7. Social organization allows organisms to**

 a. Share labor b. Coordinate efforts

 c. Specialize in tasks d. All

**8. Drones are**

 a. Haploid fertile males b. Diploid fertile males

 c. Haploid sterile males d. Diploid sterile females

**9. How is the distance to a food source communicated by a dancing honeybee?**

 a. By the direction it waggles its abdomen

b. By how far it moves during the straight run portion of the dance

 c. By which direction it turns after making the straight run

 d. By the tempo or degree of vigor of the dance

**10. Termite workers are**

a) Male b) Female

c) Both a and b d) None of the above

**Very short answer type**

1. Define social behavior.

2. Which insect orders exhibit the highest form of eusocial behavior?

3. Give one characteristic of a quasisocial animal.

4. Name the bees which exhibit eusocial behavior.

5. Why does the queen bee undertake nuptial flight?

6. What is a recruitment trail?

7. Name the castes of termites.

8. Give the difference between polymorphism and polyphenism.

9. What is a tandem run?

10. What is the role of substitute sexuals in termites?

**Write short notes on**

1. Africanized honey bees

2. Sociobiology

3. Eusociality

4. Separate-type termite colony

5. Trophallaxis

**Long answer type**

1. What are the key features of animal societies? Write a note on their advantages and disadvantages.

2. Describe communication behavior in honey bees.

3. What do you understand by the term social organization? Give an account of social organization in termites.

**Answers to Multiple Choice Questions**

1. (d) 2. (b) 3. (b) 4. (d) 5. (b)

6. (d) 7. (d) 8. (a) 9. (d) 10. (c)