PHEROMONES (CHEMICAL SIGNALLING)

A pheromone (Greek: pherein = to carry; harman = to excite) is a chemical that is produced and released into the environment by one organism and affects the behaviour of another organism of the same species. Pheromones have a wide range of functions. For example, they are present on faeces or in urine and are used to mark territory in badgers or foxes; they provide information about sex and reproductive state of dogs and can delay and hasten sexual maturity in mice.

Pheromones are species-specific and produced by exocrine glands that are often hormone dependent. They are used as chemo signals in intraspecific communication, i.e., in conveying information between individuals of a species. **Karlson and Luscher (1959) coined the term pheromone** for substances that are secreted by an animal in the external environment and cause a specific reaction in a receiving individual of the same species, i.e., an occurrence of certain behaviour or determination of physiological development.

Pheromones are also called ectohormones and released in minute quantity bringing about major effect by functioning as chemical messengers. They can be differentiated from hormones on the following bases:

1. Pheromones are released by the exocrine glands and transmitted externally through the environment.
2. Pheromones are species-specific and produce specific behavioural, reproductive and developmental responses in the bodies of other members of the same species.
3. On the other hand, hormones are released by endocrine glands and bring about changes in physiology of same organism.

Pheromones differ from some other types of chemicals used as signals among animals. Allochemics is the term given to those chemical signals that convey information between members of two different species (interspecific communication). Allochemics have been recognised into two groups: **allomones and kairomones. An allomone** is a type of semiochemical produced and released by an individual of one species that affects the behaviour of a member of another species to the benefit of the originator but not the receiver. Examples of allomones include repellents of certain insects, spray of skunk, etc. **A kairomone** is a semiochemical, emitted by an organism, which mediates interspecific interactions in a way that benefits an individual of another species which receives it and harms the emitter. Example of kairomones include signals that enable the predator to locate its prey.

DISCOVERY OF PHEROMONES:

The discovery of pheromones took place by chance. A French **biologist Bonnet in 18th century discovered** the long trails of ants which were communicating about food using certain chemicals. He conducted certain experiments and came to a conclusion that ants communicated using certain chemicals.

TYPES OF PHEROMONES:

Bruce (1970) had recognised following three types of main pheromones based on their mechanism of action.

1. Releaser pheromone,
2. Primer pheromone,
3. Imprinting pheromone.

Based on the chemical composition, the pheromones are of 2 types.

1. Volatile pheromone,
2. Non-volatile pheromone.

- **RELEASER PHEROMONES:**

These pheromones induce immediate and reversible behavioural responses mediated directly by the central nervous system through first acting on neurohumoral pathways. These are used mainly in recognition of species members, sex, sexual status, aggression, ejection of milk, etc.

Releaser pheromone is also called as "**signalling pheromone**" with the reasoning that pheromones only transfer information and never dictate the type of response in the receiver. Releaser pheromones are represented by sex attractant, trail and alarm substances of insects, fish, toad, mammals, etc.

In mammals, releaser pheromone is present in the urine and foot pads. The pheromone present in footpads initiates the aggressive behaviour in a mouse on encountering an unfamiliar male. In mice, urine of male contains releaser pheromone for attracting females or organising aggressive activities and communicating fear between individuals.

Ants produce alarm pheromones in the form of **formic acid** from the abdomen to protect themselves from enemies. Honeybees and wasps also release alarm pheromones. In honeybee, while stinging she releases alarm pheromones along with poison and immediately after stinging, she will move to other fellow members of the colony to show her sting and flatter her wing to aggravate the fellow members.

PRIMER PHEROMONE:

These pheromones evoke a prolonged or long-term endocrine or physiological responses in receivers mediated by the neuroendocrine pathways or through direct effects on the target organs. The common example of primer pheromones is those involved in suppression and induction of oestrous cycle, termination of pregnancy and sexual maturation cycle etc.

If several female mice are caged together, they affect each other's oestrus cycles. The effect seems to result from an odour passed on from one female to the other. However, if a male mouse is introduced in the same cage it will shorten the oestrus cycle. The pheromone responsible for the latter effect is present in the urine of male mouse and it is thought to be an androgen (testosterone) metabolite.

A pregnant female mouse will abort the litter she is carrying if she is exposed to the urine of strange male mouse. This is an example of the "Bruce effect".

IMPRINTING PHEROMONE:

These pheromones act at critical period of developmental age and cause permanent change in the adult behaviour. Such pheromones have been found in some rodents, viz., mice and rats etc. Examples include release of pheromones by mother rat to initiate the milk sucking behaviour in the new born.

VOLATILE PHEROMONES:

1. Some chemical signals are designed to last only a short time, they are volatile and tend to have low molecular weights.
2. The chemicals used by some ants to signal alarm, fall into this category of being short-lived.
3. Ant alarm pheromones disperse well over a short range of 3-5 m, but they usually fade below detection levels within a minute or even less.
4. It is even possible to make use of volatility of scent to achieve patterning in time.
5. For example, some moths release their sex attractants (pheromones) in pulses at approximately 1 second intervals.

NON-VOLATILE PHEROMONES:

These types of chemical signals are designed to last for a long time, allowing a message to persist in the absence of the signaller. Territory markers, for example need to be persistent and therefore constituents must have a fairly

high molecular weight. The molecular weight cannot not be too high or the substance will be difficult to secrete and may not disperse well, e. g., territory marker pheromone of spotted hyaenas which is secreted by sub-caudal scent glands.

INSECT PHEROMONES:

Insects communicate majorly using the pheromones and these pheromones are specific for specific activity. Different insect groups employ variety of pheromones and few among them are;

❖ PHEROMONES OF ORTHOPTERA (LOCUSTS AND COCKROACHES):

Mature male *Schistocerca* which are bright yellow in colour accelerate the maturation of other less mature locusts of either sex. The pheromone responsible is secreted by the epidermal cells. Its effect is to stimulate the activity of corpora allata probably via nervous system. Cockroach is known to produce sex attractants.

❖ PHEROMONES OF LEPIDOPTERANS (BUTTERFLIES AND MOTHS):

The males of Lepidoptera often produce scent from glands which are commonly associated with scales are known as androconia and are located on wings.

Pheromones in case of lepidoptera are used to induce mating as in the case of the queen butterfly *Danaus gilippus*. The pheromone is released by the male and brushed on the female by a pair of brush-like structures, called hair pencils which are everted from the tip of the abdomen.

Female silk moth (*Bombyx mori*) emits a sex pheromone, called **bombykol** to attract males from a pair of sacs that are present in the last segment on the abdomen.

The female gypsy moth attracts males from over 4500 meters by releasing a sex attractant called glupleure.

❖ PHEROMONES OF HYMENOPTERA (HONEY BEES AND ANTS):

PHEROMONES OF HONEYBEES:

Honeybees have following two main glands which produce pheromones:

a) **MANDIBULAR GLANDS:** They are sac-1like structures located in head and their ducts open at the base of the mandible. Mandibular glands are well developed in queens and workers but reduced in drones. They produce **9-keto-decanoic acid** which inhibits ovarian development of worker bees and obstructs the formation of new queen cells in the hive. The queen bee attracts drones by a pheromone, the principal component of which is **9-oxo-decanoic acid** produced in the mandibular gland.

b) **NASSANOFF'S GLAND OR NASNOV GLAND:** It 1s found below the inter-segmental membrane between 6th and 7th abdominal segments mainly in the worker bees. The gland emits a mixture of seven terpenoids which serve primarily in orientation. Bees use the scent to help sisters locate home, food, and water sources. It acts with queen substance in a pheromone concert to keep the bees of the swarm together.

PHEROMONES OF ANTS:

The social behaviour of ants is controlled mainly by pheromones: they also use visual and auditory signals, but most of their signalling is by means of smells (pheromones).

Not only mating is controlled pheromonally in ants, but also finding and exploiting food, recruiting nest mates for battle, warning about enemies. The total number of scent glands employed by an ant such as *Iridomyrmex humilis* is enormous more than one dozen and all the ant's scent are meaningful. For example, if a lone ant finds a food source too large for it to bring back to the nest by itself, it runs back to the nest leaving a pheromone trail on the way.

Different kinds of ants leave trails from different pheromone- releasing organs. *Solenopsis* releases its trail pheromone from its Pavan's gland; *Myrmica* from its poison gland; *Lasius* from its rectal gland. When the forager (food-finder) ant arrives at its nest it uses another pheromone to recruit other ants to come and collect the food; *Myrmica rubra*, for instance, having laid its trail from its poison gland, attracts its nest mates back to the food with a pheromone from its Dufour's gland.

FUNCTIONS OF INSECT PHEROMONES:

i. Insect pheromones as sex attractants: pheromones are used by both males and females to attract the other sex during copulation.
ii. Pheromones are used by social insects in greater extent.

iii. In a colony, pheromones are used to communicate between conspecific species.
iv. In a social colony, the pheromones are used as command signal for maintenance of the colony, maintenance of structure of colony and caste system.
v. Insects use pheromones to aggregate at food or to attack the predator of the colony.
vi. Insects use pheromones to produce alarm calls during danger condition.

PHEROMONES IN REPTILES:

Male garter snakes can follow chemical trails left by females and can even determine the direction in which the female was going. As the female moves along, she pushes against certain objects, thus leaving more scent on the side in her direction of travel. The male tests each side of these objects with his forked tongue and recognizes which side the female has pushed against.

PHEROMONES IN MAMMALS:

Like insects, mammals too make use of pheromones for various activities. The production of pheromones in mammals is different and they have adopted 2 different ways. They are;

A. Scent marking by urine and faeces,
B. Scent marking by special glands.

SCENT MARKING BY URINE AND FAECES:

Urine and/or faeces of many mammals have pheromones through which they can communicate with conspecifics. The most common use of urine and faeces is to scent mark a core area, home or territory. Some animals use urine and faeces for marking pathways, resting grounds, feeding grounds, and sleeping sites. Some animals urinate or defaecate on rivals, opponents, defeated conspecifics, etc.

1. Male *Hippopotamus* marks its pathway between aquatic resting place and grassy feeding ground by the deposition of dung at places along the trail, usually close to some conspicuous objects. With the smell of this dung, it communicates between resting and feeding place.
2. Rhinos too mark their path by depositing dung and urine and use this smell to commute between the places and also giving hint to enemies about their presence.

3. Tigers produce a pheromone called tigeramine which has strong smell. Male tigers use this for marking the boundary.
4. Polecat and civet deposit urine and faeces at particular place along their trail.
5. Antelope has fixed pathway of movements and its initially marked by their droppings which have strong scent or odour.
6. The male giant rats have unique style to mark the area at nose level for easy detection of the moving path.
7. Dogs, foxes use urine to mark their territory.
8. Bears use two different methods to mark territory. They first mark a tree by scratching and chewing the bark, then they frequently urinate on such trees.
9. Slow loris and slender loris sprinkle urine on trees to ensure their territory.

SCENT MARKING BY SPECIAL GLANDS:

Many species of mammals have evolved special glands producing the scent. This special gland helps the animal to restrict the release of pheromone to minimum level and also can be released when need.

a) **ANAL GLANDS:** In this case, the animals which intent to release the pheromones have to rub their anal glands which have secretions, on the ground or on the objects to be marked. Such method is seen in monotremes, marsupials etc. Examples: The brown hyaena, spiny ant eater, ring tailed lemur, squirrel monkey etc have this gland and use to mark the boundary.
b) **SALIVARY GLANDS:** Saliva is used as marking agent by variety of mammals such as bears, dogs, pigs, rats etc. Most marsupials deposit saliva on twigs by chewing them and hence marking the foliage of territory with saliva.
c) **MISCELLANEOUS GLANDS:** There are few mammals which employ other organs and glands to mark their territories. Example: Roe deer which lives in small group with secretions from glands on forehead, anal glands, metacarpal gland and urine mark their territory.

FUNCTIONS OF PHEROMONES IN VERTEBRATES:

1. Scent making or pheromone productions provides a sense of belonging.
2. Pheromone production enhances self-confidence.
3. Pheromone production helps in regulation of sexual behaviour.
4. Pheromone helps any animal to mark its trail (movement between resting place and source of food).
5. Territorial marking helps in avoiding recurring fights.

6. Miscellaneous function which includes males marking their females via pheromones. Ex: Rabbit marks its female with its chin glands secretions.
7. Pheromones helps in avoiding inbreeding.

PHEROMONES IN HUMAN:

- A case of pheromone base sex recognition and sex attraction has been described in humans.
- Olfactory communication in humans is as important as in dogs, but its dominance is suppressed in adults due to psyco-sexual development.
- There exists a difference between the two sexes of humans in their ability to smell. Women are more sensitive.
- The smell-sensitivity also greatly varies during different phases of menstrual cycle and pregnancy in female, and following castration and male hormone supplementation in males.
- Women perceive musky odour of synthetic perfumes and sensitivity is highest during ovulatory period.
- Axillary sweating contains pheromonal substance in man. Similarly, vaginal secretion contains a pheromone called copaline containing volatile vaginal fatty acids with peaks at the time of ovulation.

MODE OF ACTION OF PHEROMONES:

Insect pheromones exert their effect by olfaction, physical contact and absorption. Although, mammalian pheromones are olfaction sensitive, but physical contact is important for some primer pheromones in their influence on the ovarian cyclicity.

Pheromones influence hormonal secretions which in turn directs behavioural change. While releaser pheromones directly affect neurohumoral activity of the central nervous system; primer pheromones influence neuroendocrine machinery through olfactory bulbo-nasal passage-vomeronasal organ -amygdala and stria-hypothalamus pathways. Hypothalamus triggers endocrine mechanisms and thus an effect is observed on the target tissue/organ.

ECONOMIC USES OF PHEROMONES:

1. Pheromones such as civetone (from civet) and muscone (from musk deer) are used commercially in the preparation of perfume.
2. They are also used increasingly as a method of biological control in insect pest species such as the gypsy moth. In these cases, the artificial release of the pheromone gyplure, attracts males to the source of release where they can be captured and killed.