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Review Article

Pheromones in Animal World: Types, Detection and its Application

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Abstract: Animals and humans release masses of biological chemicals in tears, saliva and perspiration. These chemicals used for communication between the organisms are known as semio-chemicals or info-chemicals. Semiochemicals means behaviour modifying chemicals which can be classified into two categories: (i) Allelochemicals (interspecific) (ii) Pheromones (intraspecific- in most cases).Pheromones is a chemical substance, secreted externally by certain animals, such as insects, affecting the behaviour or physiology of other animals of the same species often functioning as an attractant of the opposite sex. Pheromones are very important but unfortunately limited information is available, hence the present review focuses on pheromones including its type, detection and application.
Keywords: Pheromones,ectohormone, insects, animals, vomeronasal organ, behavior.

INTRODUCTION

Pheromones are a naturally occurring chemical compound found in all insects, animals, and humans. The term pheromone was introduced by Peter Karlson and Martin Lusche in (1959), based on the Greek word *pherein* means to transport and *hormone* means to stimulate. They are also sometimes classified as ectohormones [1, 2]. Pheromones are molecules that are evolved signals, in defined ratios in the case of multiple component pheromones, which are emitted by an individual and receivedby a second individual of the same species, in which they cause effect on hormone levels orbehavioural changeor specific reaction [3, 4].For example, stereotyped behaviour or developmental process.Pheromones are found in living things and are the most ancient form of animal communication [3]. Pheromones are natural scents which play an important role in sexual communication. These Pheromones aromas convey signals relating to mood, status, drive and health to the subconscious awareness of the opposite sex. This philosophy holds well in the animal world, pheromones are consciously detected over considerable distances and serve at times in place of real communication. They help animals to mark territory, recognize mates, and signal sexual interest. For example, female dogs in heat leave their pheromones and can attract male dogs over a mile away.Pheromones are produced by ectodermal glands on the abdomen and associated with mandibles of hymenopterans and wings of lepidopteran insects. Butenandt *et al*. first discovered sex pheromone in the silk worm (*Bombyx mori*) [5].Unlike higher animals, the insects communicate between sex of their own species or with its sub-species or very rarely, with different species of a genus or family or species of a different order.

TYPES OF PHEROMONES

Insects communicate through six different modes for life activities, are as follows: (i) Hormones, (ii) Sound, (iii) Pheromone, (iv) Motion, (v) Exocrine glandsresponsible for secretions to theexterior of the body or into the lumen of body cavity and (vi) Enzymes.On the basis of interaction mediated, pheromones are sub-divided into following category;

Territorial pheromones

The territorial pheromones can be classified based onpurpose and characteristics interactive evolution ofbehaviour and ecology;

- Type A- Large defended area: Courtship, mating, nestingand food gathering
- Type B: Large defended area: Used for breeding but notforaging
- Type C: Small defended area around nest
- Type D: Mating territory for courtship activities only
- Type E: Roosting or shelter positions

In dogs, these pheromones are present in the urine, which they deposit on landmarks serving to mark the perimeter of the claimed territory. Boars, cats do possess territorial pheromones.

Trail pheromones

These pheromones are common in social insects. For example, ants mark their paths with these pheromones, which are non-volatile hydrocarbons [6]. Certain ants lay down an initial trail of pheromones as they return to the nest with food. This trail attracts other ants and serves as a guide. As long as the food source remains, the pheromone trail will be continually renewed. The pheromone must be continually renewed because it evaporates quickly. When the supply begins to dwindle, the trail making ceases.

Alarm pheromones

Some species release a volatile substance when attacked by a predator that can trigger flight (in aphids) or aggression (in ants, bees, termites) in members of the same species [7]. Alarm pheromones serve to rapidly disperse a group of insects usually as a response to predation. These kinds of pheromones are usually of short duration and the dispersed individuals usually reform aggregations. Some individuals release this pheromone to exhibit aggressive behaviour in the presence of predators. Alarm pheromones have been recorded in the mites, tree hoppers, aphids and the true bugs etc.

Aggregation pheromones

Aggregation pheromones function in defence against predators, mate selection, and overcoming host resistance by mass attack. A group of individuals at one location is referred to as an aggregation, whether consisting of one sex or both sexes. Male-produced sex attractants have been called aggregation pheromones, because they usually result in the arrival of both sexes at a calling site, and increase the density of conspecifics surrounding the pheromone source. Most sex pheromones are produced by the females and small percentage of sex attractants are produced by males. Aggregation pheromones have been found in members of the Coleoptera, Diptera, Hemiptera, Dictyoptera and Orthoptera. In recent decade, the importance of applying aggregation pheromones in the management of the boll weevil (*Anthonomus grandis*), stored product weevils(*Sitophilus zeamais*), *Sitophilus granarius*, *Sitophilus oryzae*, and pea and bean weevil (*Sitona lineatus*) has been demonstrated. Aggregation pheromones are among the most ecologically selective pest suppression methods. They are nontoxic and effective at very low concentrations [8].

Sex pheromone

In animals, sex pheromones indicate the availability of the female for breeding. Male animals may also emit pheromones that convey information about their species and genotype.At the microscopic level, a number of bacterial species (e.g. *Bacillus subtilis, Streptococcus pneumoniae, Bacillus cereus*) release specific chemicals into the surrounding media to induce the "competent" state in neighbouring bacteria [9]. Competence is a physiological state that allows bacterial cells to take up DNA from other cells and incorporate this DNA into their own genome, a sexual process called transformation. Among eukaryotic microorganisms, pheromones promote sexual interaction in numerous species [10]. These species include the yeast *Saccharomyces cerevisiae,* the filamentous fungi *Neurospora crassa* and *Mucor mucedo,* the water mold *Achlya ambisexualis,* the aquatic fungus *Allomyces macrogynus,* the slime mold *Dictyostelium discoideum*, the ciliate protozoan *Blepharisma japonicum* and the multicellular green algae *Volvox carteri*. In addition, male copepods can follow a three-dimensional pheromone trail left by a swimming female, and male gametes of many animals use a pheromone to help find a female gamete for fertilization [11].Many insect species, such as the ant *Leptothorax acervorum*, release sex pheromones to attract a mate, and many lepidopterans such as moths and butterflies can detect a potential mate from as far away as 10 km (6.2 mi).

Releaser pheromones

Releaser pheromones are pheromones that cause an alteration in the behaviour of the recipient. For example, some organisms use powerful attractant molecules to attract mates from a distance of two miles or more. In general, this type of pheromone elicits a rapid response, but is quickly degraded. In contrast, a primer pheromone has a slower onset and a longer duration. For example, rabbit (mothers) release mammary pheromones that trigger immediate nursing behaviour by their babies [12].

Epideictic pheromones

Epideictic pheromones are different from territory pheromones, when it comes to insects. Fabre observed and noted how females who lay their eggs in these fruits deposit these mysterious substances in the vicinity of their clutch to signal to other females of the samespecies they should clutch elsewhere.

Signal pheromones

Signal pheromones cause short-term changes, such as the neurotransmitter release that activates a response. For instance, Gonadot ropic releasing hormone (GnRH) molecule functions as a neurotransmitter in rats to elicit lordosis behaviour [1].

Information pheromones

Information pheromones are indicative of an animal's identity or territory. For example, dogs and cats deposit chemicals in and around their territory, which then serve as an indicator for other members of the species about the presence of the occupant in that territory.

DETECTION

Pheromones have evolved in all animal phyla, to signal sex and dominance status, and are responsible for stereotypical social and sexual behaviour among members of the same species. In mammals, these chemical signals are believed to be detected primarily by the vomeronasal organ (VNO), a chemosensory organ located at the base of the nasal septum [13]. The VNO is present in most amphibia, reptiles, and non-primate mammals but is absent in birds, adult catarrhine monkeys, and apes [14]. Three distinct families of putative pheromone receptors have been identified in the vomeronasal organ (V1Rs, V2Rs, and V3Rs). All are G protein-coupled receptors but are only distantly related to the receptors of the main olfactory system, highlighting their different role [13].Understanding the mechanism of activation of TRPC2 is critical to understanding its role in pheromone detection and other physiological processes. Despite the importance of this problem, it has remained refractory to study and there is presently no single agreed-upon mechanism for its activation. In heterologous cells, mTRPC2 (splice variants A and B) was reported to be activated by depletion of Ca+2 stores by thapsigargin and to function as a capacitive Ca+2 entry channel [15-17]. In sperm cells thapsigargin induces a rise in Ca+2 that can be partially blocked by an antibody against an extracellular domain of TRPC2, suggesting that in these cells TRPC2 may be store operated[18]. In sensory neurons from the VNO, TRPC2 is unlikely to be activated by depletion of Ca+2 stores, because the channel is localized in sensory microvilli at a considerable distance from Ca+2 stores [19, 20].Theessential function and nearly exclusive expression of TRPC2 in the vomeronasal organ have made it an excellent marker to study changes in VNO function during evolution. In fish, which do not have a structurally distinct VNO, TRPC2 is expressed in the olfactory epithelium in a population of apical microvillar cells that also express VRs, and it is not expressed in the basal ciliated cells that express [21] ormicrovillar cells appear specialized for detecting amino acids [22]. And send segregated projections to the lateral portion of the olfactory bulb [21]. It is thus likely that the VNO arose by segregation of the microvillar cells from the ciliated cells, possibly as a response to terrestrial life. The main olfactory epithelium is well suited for detecting airborne chemicals that enter the nasal cavity during the respiratory cycle, whereas the VNO is better suited for detecting non-volatile chemicals whose delivery is based on the presence of coinciding sensory and neuroendocrine signal [23]. Whether humans have a functional VNO has been difficult to determine using histological or functional techniques and therefore it has been the subject of intense debate.

MECHANISM OF ACTION OF PHEROMONES

Pheromones can be a stimulus leading to a prompt behavioural response by nerve impulses from the brain (CNS, central nervous system) (releaser effects) or can act indirectly by stimulation of hormone secretion resulting in physiological changes, “priming” the animal for a different behavioural repertoire (primer effects). Hormonal effects can be rapid, and memories, sometimes facilitated by local neurochemistry changes, can be long-lasting (Fig. 1) [12].

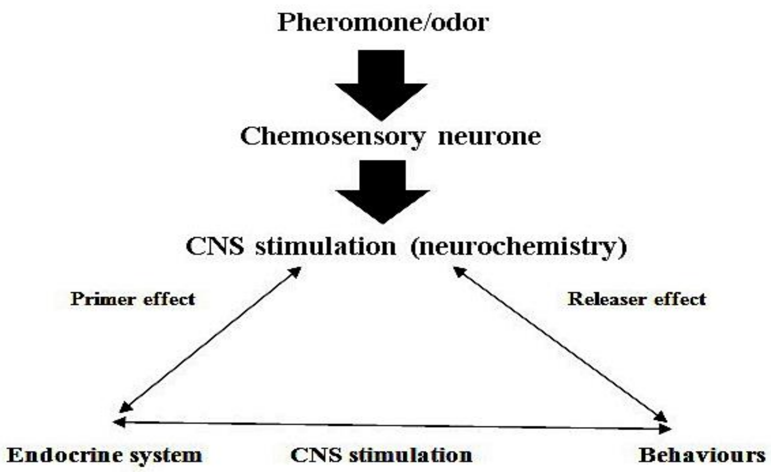

Fig. 1: Mechanism of action of Pheromones

APPLICATION

There are three main uses of pheromones in the integrated pest management of insects. The most important application is in monitoring a population of insects to determine if they are present or absent in an area or to determine if enough insects are present to warrant a costly treatment [24]. This monitoring function is the keystone of integrated pest management. Monitoring is used extensively in urban pest control of cockroaches, in the management of stored grain pests in warehouses or distribution centres, and to track the nationwide spread of certain major pests such as the gypsy moth, Medfly, and the Japanese beetle With major increases in worldwide trade, exotic pests are being brought into ports of entry in cargo containers and packing materials (ship dunnage). Sometimes containers from ships are transferred uninspected to semi-trailers and trucked far inland. When the containers are opened and packaging materials are removed, the exotic insect pests are able to disperse without the usual level of scrutiny provided at ports of entry. Pheromone traps are currently in use to monitor the movement of such exotic insect pests into most major North American ports of entry. A second major use of pheromones is to mass trap insects to remove large numbers of insects from the breeding and feeding population [25]. Massive reductions in the population density of pest insects ultimately help to protect resources such as food or fibre for human use. Mass trapping has been explored with pine bark beetles and has resulted in millions of insects attracted specifically into traps and away from trees. Relatives of bark beetles called ambrosia beetles have been mass trapped from log sorting and timber processing areas throughout British Columbia. These trapping operations have reduced damage to the wood in raw logs and newly cut boards. Mass trapping has also been used successfully against the codling moth, a serious pest of apples and pears. Another common example of mass trapping involves yellowjackets, which can become bothersome at the end of the summer season. However, mass trapping of yellowjackets in colourful yellow-green traps is carried out with a food attractant, rather than pheromone bait. A third major application of pheromones is in the disruption of mating in populations of insects [26]. Thishas been most effectively used with agriculturally important moth pests. In this scenario, synthetic pheromone is dispersed into crops and the false odour plumes attract males away from females that are waiting to mate. This causes a reduction of mating, and thus reduces the population density of the pests. In some cases, the effect has been so great that the pests have been locally eradicated.

CONCLUSION

Pheromones are species-specific chemicals that affect insect behaviour, but are not toxic to insects. They are active (e.g. attractive) in extremely low doses (one millionth of an ounce) and are used to bait traps or confuse a mating population of insects. Over the last 40 years, scientists have identified pheromones from over 1,500 different species of insects. Pheromones have also been isolated from many higher animals such mammals and reptiles. Human pheromones remain elusive. Scientists have found certain chemical effects associated with the human reproductive cycle, but have not identified any powerful attractants for humans so far. With insects, though, pheromones have found wide application in the fields of agriculture, forestry, and urban pest management, and there are companies that specialize in the discovery, manufacturing, and sales of pheromone-related products.

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