Lectures Insect behavior and pheromones
PhD graduate students
First Course
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Lecture-1-Introduction of insect behavior and Orientation   Tuesday 4/9/2022

Introduction

Insects make up a significant proportion of the world's biota (Fig. 1). The approximately 920,000 species that have been described represent almost 85% of all known animal species; many more have yet to be been given scientific names. Insects belong to the phylum Arthropoda, a very large assemblage of animals with jointed legs and a hard outer skeleton.

The class Insecta is divided into a number of orders. The exact lines along which these divisions should be made remain a matter of dispute, but in general, ordinal divisions reflect the present understanding of the evolutionary history of the class (Fig. 2). More than one-third of the named species of insects are beetles, the Coleoptera. The next largest orders, in descending numbers, are Lepidoptera (butterflies, moths, and skippers), Hymenoptera (wasps and bees, and Diptera (flies). Together, these four orders include more than 80% of the named species of insects.

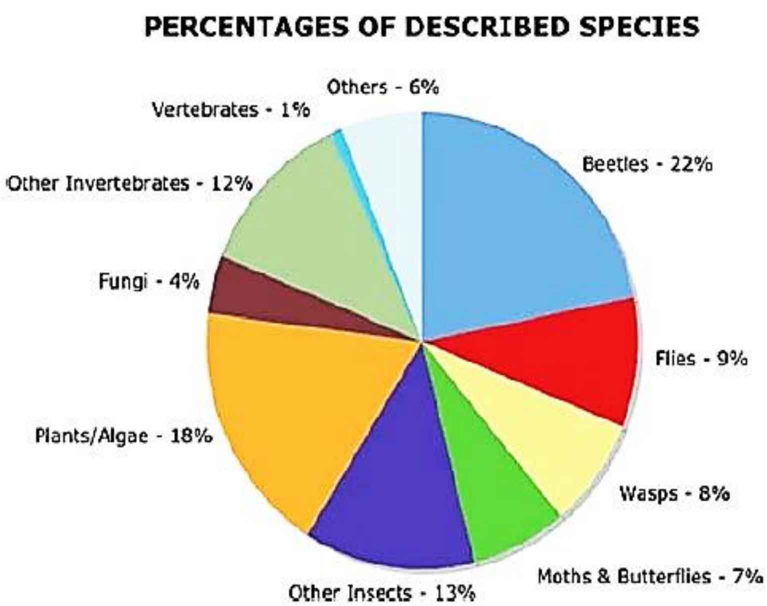
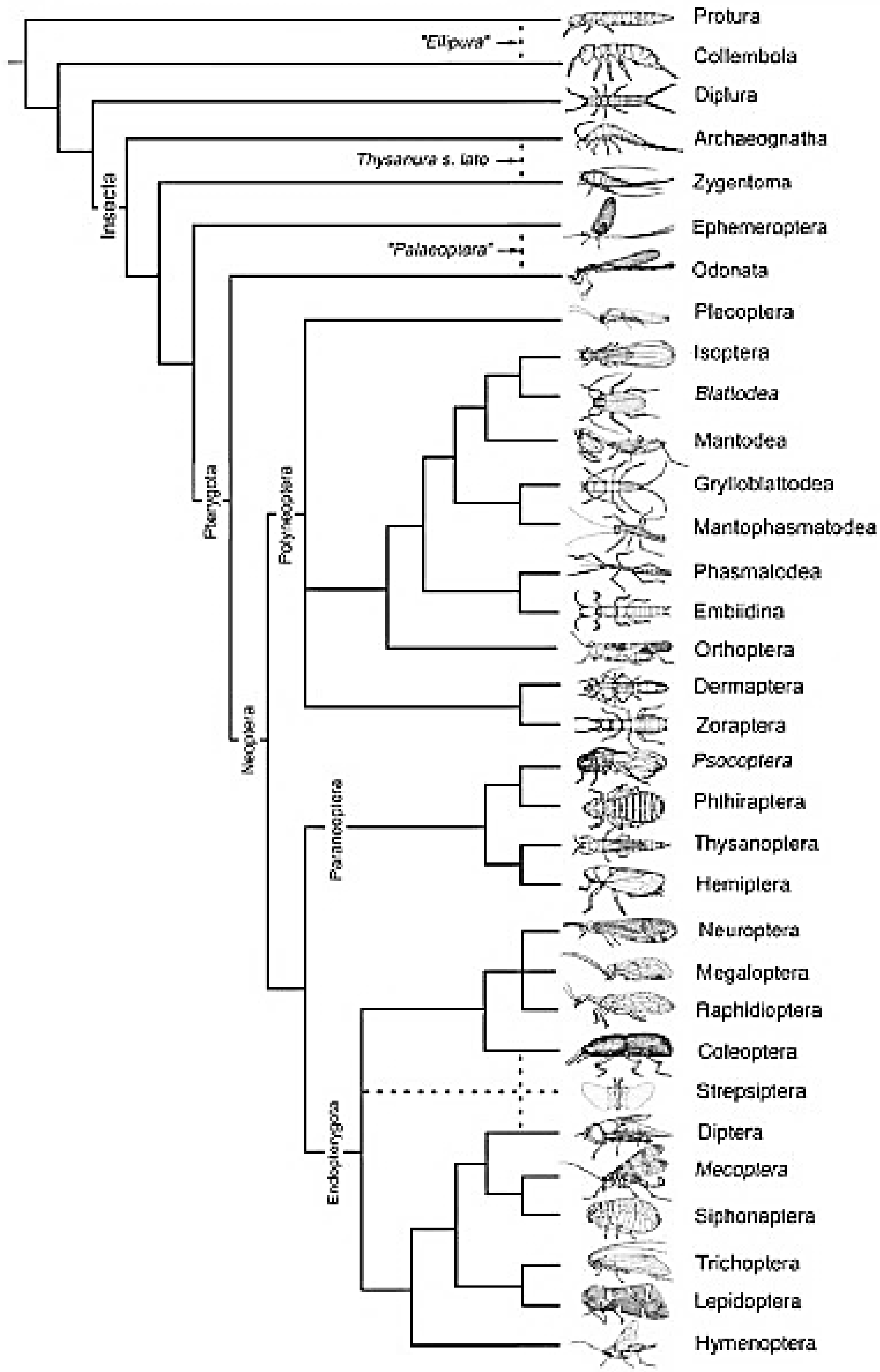


Fig. 1



Protura
"Ellipura"
Collembola
Diplura
Archaeognatha
Thysanura s. lato
Zygentoma
Ephemeroptera
"Palaeoptera"
Odonata
Plecoptera
Isoptera
Blattodea
Mantodea
Grylloblattodea
Mantophasmatodea
Phasmatodea
Embiidina
Orthoptera
Dermaptera
Zoraptera
Psocoptera
Phthiraptera
Thysanoptera
Hemiptera
Neuroptera
Megaloptera
Raphidioptera
Coleoptera
Strepsiptera
Diptera
Mecoptera
Siphonaptera
Trichoptera
Lepidoptera
Hymenoptera
Insecta
Pterygota
Neoptera
Polyneoptera
Paraneoptera
Endopterygota

Fig. 2

The many volumes of observations about animals compiled by scholars such as Aristotle (384–322 B.C.E.) and Pliny (C.E. 23–79) show that animal natural history has been a matter of extensive interest for some time.

In the days before microscopes and careful scientific investigations, the ideas seemed quite reasonable to most people, but how could spontaneous generation. As the seventeenth century turned to the eighteenth, experiments and natural history observations began to rebut the prevailing opinions. Studies of insects led the way. One of the first experiments in the modern sense (with the use of controls) was the classic study of Francesco Redi (1668) who showed that maggots did notarise spontaneously from rotten meat.

Published between 1734 and 1742, his six large volumes of Memoirs pour *Server al'Histoire des Insects* applied precise observation, detailed experimentation, and accurate recording to phenomena as varied as social life, parasitic habits, and leaf-mining.

When the tenth edition (1758–1759) of his *Systema Naturae* was chosen as the starting point for zoological nomenclature. three kinds of entomological texts were prevalent. First, there were beautifully colored illustrative works such as hoset of Maria Merian. Second were descriptive classificatory works, such as Linneaus' Systema Naturae with its system of binomial nomenclature. Third were detailed works such as those of Reaumur's Memoirs, detailing specific aspects of insects such as their development, physiology, or internal anatomy.

During the latter half of the 1800s, three conceptual advances occurred that were so revolutionary they deserve independent mention: evolution by natural selection, the discovery of the genetic bases of biology and the development of a comparative approach to biological study.

What Is Insect Behavior?

Behavior can be simply defined as what animals do. More precisely, it is the ways in which an organism adjusts to and interacts with its total environment. As such, insect behavior encompasses the relationships an insect has with members of its own species, with members of other species, and with the physical environment.

A species must behave in the 'right' ways in order to survive, and its members must survive (at least long enough to successfully reproduce) if it to be evolutionarily successful.

The term 'behavior' covers a very wide range of activities, and it can be helpful to recognize some subcategories. General locomotion, grooming, and feeding, for example, are essentially individual matters. These maintenance activities keep an insect in good shape but usually have little influence on others of its kind.

kinds of Insect behavior

Broadly speaking the manner in which an organism responds to various exogenous and endogenous stimuli is termed as behavior. Insects mainly exhibit two kinds of behavior viz. (1) Innate behavior which include reflexes, kineses and taxes and (2) Learned behavior i.e. experienced behavior.

The innate behavior largely consists of more or less fixed response or series of responses to a given stimulus or the pattern of stimuli. It may be added here that the innate behavior may be modified by experience or learning. The innate behavior is hereditary whereas the learned behavior is not inherited but it is acquired through interaction with the environment during the life of the individual. In the following pages a brief account of both the types of behavior innate and learned is given.

1-innate behavior

The simplest innate behaviors found in insects are reflexes. This may involve only a part of the body as in the case of extension of proboscis or the whole body as in the case of direct reflex which occurs when an insect is placed on its dorsal side. The reflexes can be classified into two groups: 1. phasic and 2. tonic. The phasic reflexes are much rapid and short lived and are involved in rapid e.g. the ion of proboscis in flies. On the other hand, the *tonic* reflexes are slow and long lived and are involved with the maintenance of posture, body turgor, muscle tone and equilibrium. The reflexes also vary in complexity, the simplest being mediated by a single afferent impulse from a receptor to an interneuron and then along an efferent neuron to an effector i.e. the reflex arc. However, most of the reflexes are very complex involving many neural connections. Reflex autonomy has been shown by ganglia of the ventral nerve cord e.g. in the silk moth, *Bombyx mori* (Fig.3) the oviposition reflex which results from the ovipositor making contact with a surface, resides totally on the last abdominal ganglion. More complex innate behavior includes various types of orientation patterns.

Fig. 3

Orientation

may be defined as "the capacity and activity of controlling locomotion and attitude in space and time with the help of exogenous (external) and endogenous (internal) stimuli (Jander, 1963). Orientation in insects has been variously classified by different workers. For the sake of convenience, here it has been broadly classified into three types (1) kineses, (2) taxes and (3) transverse orientation which are based on the mechanisms of orientations. Kineses and taxes can be defined with respect of the type of stimulus.

1- Kineses: 'The kinesis 1s an unorientated or undirected action of an organism which varies according to the intensity of stimulus e.g. in Glossina species, there is an increase in activity in dry atmosphere relative to activity in a moist one. This behavior causes the insect to find and remain in a humid atmosphere. The body louse, *Pediculus* makes fewer and fewer directional changes as the temperature, humidity and odour increase as the louse moves closer to a potential host. In addition to the providing specific environmental input, impulses from sensory neurons also increase overall excitability of the central nervous system turning on the insect as it were e.g. increasing temperature above the preferred range for an insect, generates increased locomotor activity resulting ultimately in the insect's moving into a cooler area. This kinesis may appear to be directed movement, the insect seems to avoid the heat by remaining in motion and turning until in a cooler place (Wigglesworth, 1972).

- **Orthokinesis:** It is defined as a response to a stimulus in which the rate of response such as speed of movement is positively proportional to the intensity of the stimulus.
- **Klinokinesis:** movement resembling a random walk in which changes in direction are made when unfavorable stimuli are encountered with of turning dependent upon the stimulus intensity.
- **Akinesis:** It is a state of immobility due to lack of any stimulus. An overall lack of movement is controlled by sensory input normally by tarsal contact with a surface. Tarsal contact combined with other stimuli e.g. for dragonfly (Fig.4), lowered temperatures and reduced intensity of light in the evening inhibits central nervous system function in most insects (Wigglesworth, 1972).

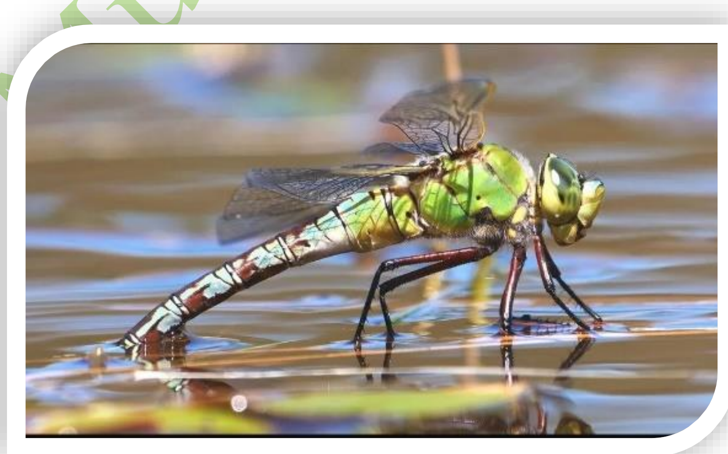


Fig.4

2-Taxes Fig.5: An oriented or directed movement of an organism towards or away from the stimulus is known as taxis. The taxes are different from the kineses in the sense that they are directed relative to a stimulus source. Taxes may be responses to physical or biological factors or a combination of both. The insect may move towards (positive) or away (negative) from the source of stimulus. Thus, moth's attraction to light is positive phototaxis while maggots are negatively phototactic.

The taxes may be classified according to the environmental stimuli involved e.g. phototaxis (light), geotaxis (gravity), anemotaxis (air current), rheotaxis (water current), chemotaxis (chemicals), hygrotaxis (humidity), scototaxis (darkness), thigmotaxis (contact) for details see: Wigglesworth (1965).

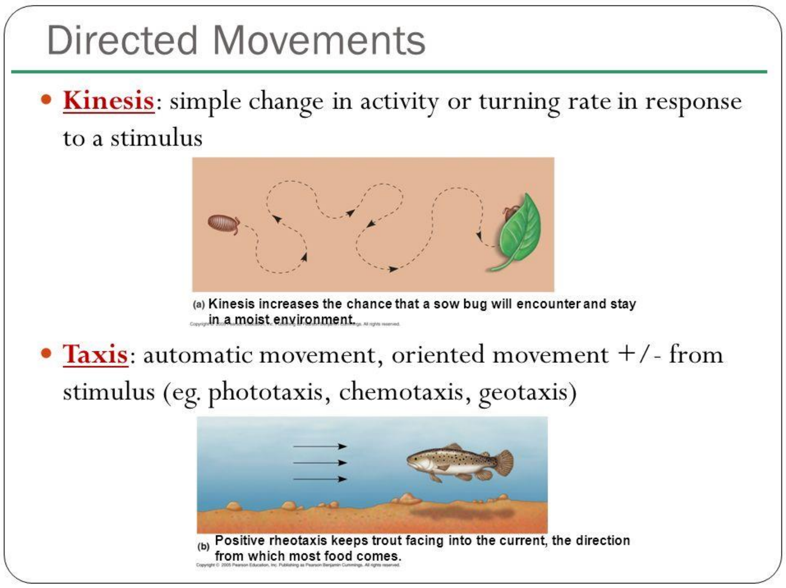


Fig.5

- **Klinotaxis Fig 6:** In klinotaxis behavior an insect moves relative to a gradient of stimulus intensity such as light source or a sound emission. Thus, a movement in a definite direction relative to a stimulus either directly towards or away from the source is known as klinotaxis.

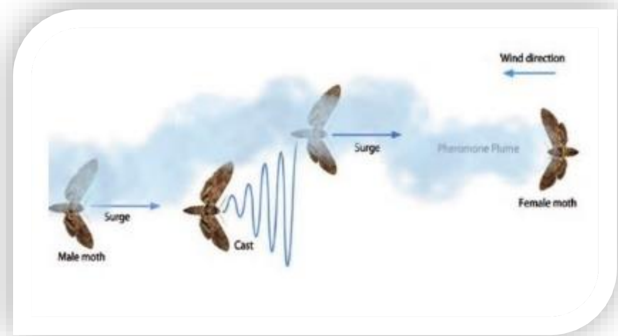


Fig6

- **Menotaxis:** Movement that maintains a constant orientation relative to a light source e.g. the orientation with respect to a constant angle of light source is termed menotaxis.
- **Telotaxis:** The visual fixation of an object such as prey is termed telotaxis *i.e.* orientation and movement directly towards a visual stimulus.
- **Tropotaxis:** Movement whose direction is dependent on the composition of stimulation on bilateral sense organs. Attainment of orientation is directed and no deviations are required. The tropotaxis is more efficient than klinotaxis and shows the selective advantage of having paired sensory structures viz. eyes, cerci, antennae. If an antenna is removed or an eye is painted over, the insect will not orient properly. If antennae are crossed and then glued in their new position, an insect will turn towards the wrong side when orienting to an odour source. It must be remembered, when attempting to analyze the behavior of an insect that the mechanism involved may change from moment to moment and even at the same instant more than one mechanism may be involved.

3- Transverse Orientation

The transverse orientations are those in which the body is oriented at a fixed angle relative to the direction of the stimulus. The transverse orientations are of two types: (1) the light-compass reaction and (2) the dorsal light reaction (Fraenkel and Gunn, 1961). The light compass reaction consists of an orientation such that locomotion occurs at a fixed angle relative to light rays. This orientation was demonstrated in ants, caterpillars, bees, certain beetles and bugs. In the dorsal or ventral light reaction, both the long and transverse axes of the body are kept perpendicular to a directed source of light (Fraenkel and Gunn, 1961). This type of reaction is different from phototaxis because in this case, orientation is transverse to the light rays and not parallel to them e.g. both dorsal and ventral light responses are found in certain aquatic bugs. When the air bubbles trapped between the head and the antennae are removed, the back swimmer, Notonecta (Fig.7), depends entirely upon a ventral light reaction for the maintenance of its normal swimming position, while the converse is true for the water boatman, (Corixa Fig.8) and the creeping water bug, Naucoris (Rabe, 1953).

Fig.7

Fig.8

fixed action patterns

The most complex innate behavior patterns are the fixed action patterns. These are characterized by being unlearned, species specific and adaptive. They differ from reflexes and orientations in that they require an internal readiness before they can occur and the evoking stimulus i.e. releaser is commonly not required to act during the entire course of the pattern. The releasing stimulus may be internal in the form of hormone secretion or an excitatory signal from a higher neural center. The stimulus may be in the form of light, temperature, mechanical contact, odour etc. A variety of factors may affect the development of a state of internal readiness or motivation necessary for a given behavior pattern to occur. ‘These may be either internal or external in origin (Romoser, 1981).

The internal motivational factors are hormonal or neural in nature e.g. the relative concentration of juvenile hormone and the moulting h d the behavior of the caterpillar of several moths and other insects. Internal receptors are commonly involved when a behavior pattern appears spontaneously without any discernible external stimulus. An excellent example of this has been found in the blow fly, *Phormia* (Fig.9), in which receptors associated with the crop carry stimuli that inhibit food ingestion as long as the crop is full. No inhibitory stimuli arise from these receptors when the foregut is empty and feeding can occur. In other cases of spontaneous behavior, regular cycles of behavioral activity of internal origin determine when a particular pattern may be released e.g. crickets are active only during a certain period each day and this daily rhythm continues for several days when the insects are kept in constant darkness in the laboratory.

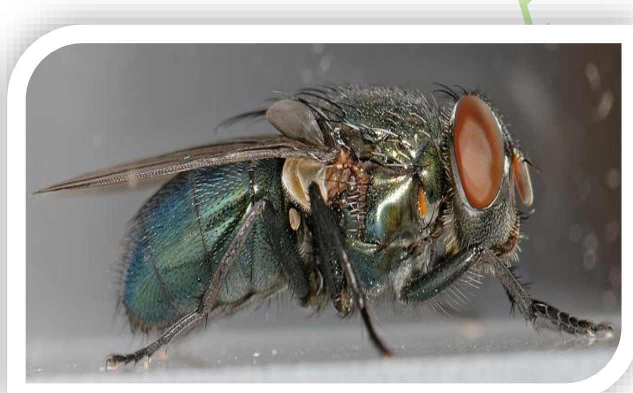


Fig.9