EXTERNAL DEGREE PROGRAMME
BACHELOR OF EDUCATION (SCIENCE)
BIOLOGY

BASIC ENTOMOLOGY- UNIT SZL 404

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This Unit is intended to introduce you to the study of a group of animals; the insects. Insects belong to the group of Invertebrate animals called Arthropoda.

Have you come across animals such as millipedes, centipedes, crabs, and spiders? These animals along with the insects are called Arthropods.

Arthropods comprise at least 85 per cent of all known animals.

You may have come across the Arthropods in the Invertebrate course you undertook in the past. In this Unit our focus will be solely Insects and you will be exposed to a subject referred to as "Entomology" which simply means the study of Insects.

As you progress with the unit you will discover that insects are diverse and that they also occupy diverse habitats. Basic information on Insect structures and how these relate to functions will be emphasized. General aspects on Insect evolution, Ecology, Social behaviour, Development and Metamorphosis will be mentioned. The last part of the Unit will focus on and the economic importance of insects.

The unit is therefore broadly divided broadly into five parts namely:

- The classification and morphology of insects and identification of insects to the level of order
- Systemic i.e. structure and functions of insect external and internal anatomy
- Types of insect development;
- Insect origin, behaviour and ecology
- The economic importance of insects or the relationship between insects and man.

There are a total of twenty specific lectures with increasing levels of complexity reflective of phylogenetic relationships among the various insect groups. Illustrations have been provided where applicable and lecture objectives have been stated at the beginning of each lecture. Revision questions, Activity portions, and summaries are included in the Unit. These will facilitate your comprehension of unit contents as well as prepare you for final examinations.

The practical aspects of the unit will be covered in eight practical exercises during the residential period.
UNIT OBJECTIVES

At the end of this unit you should be able to:

1. Identify common Insects and classify them into their respective taxa (orders)
2. Describe the external morphology and internal Anatomy of a typical Insect
3. Relate the various insect body structures to their functions
4. Identify the developmental stages of insects.
5. Differentiate the different types of development stages exhibited by various insect groups
6. Describe the various social organization among insects
7. State the economic importance of Insects
8. Discuss Insect origin, behaviour and ecology.
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LECTURE NUMBER ONE

1.0: INSECTS AND RELATED ARTHROPODS
   1.1: Introduction to the study of insects
   1.2: Classification of insects and related arthropods
      1.2.1: Insect taxonomy and classification
      1.2.2: Features of the class Insecta

1.1: INTRODUCTION TO THE STUDY OF INSECTS
Insects comprise the most diverse group of animals on the earth, with 800,000 species described, more than all other animals groups combined. Insects may be found in nearly all environments on the planet, but with few species in oceans. There are approximately 5,000 dragonfly species, 2,000 praying mantis, 20,000 grasshopper, 170,000 butterfly and moth, 120,000 fly, 80,000 true bug, 350,000 beetle, and 110,000 bee and ant species.

In this lecture we shall learn that the study of insects has a special name known as **Entomology**. We shall relate the insects to their closest relatives as we classify them under a broader category known as Phylum Arthropoda. We shall begin by identifying key features unique to the Phyla. Finally we shall examine the distinguishing features of the class Insecta and examine some of the criteria used in the classification of specific insects such as the common house fly. There are several numbered activities for you. Take all of them and check the correct answers in the appendices where applicable. Note that some activities are purely practical exercises and therefore do not have answers appended.

Can you still remember that the study of insects is called **ENTOMOLOGY**?
At the end of this lecture you should be able to:

- Define the terms Taxonomy, Entomology and Species
- Name taxa used in the classification of living organisms.
- State the criteria used to grouping insects
- List features of the phylum Arthropoda and class Insecta.
- Describe other classes of phylum Arthropoda related to class Insecta.
- Name the taxa used in the classification of insects

1.2: CLASSIFICATION OF INSECTS AND RELATED ARTHROPODS

1.2.1: Insect Taxonomy and Classification

Have you ever thought about why we name things at all? If you have you probably realized, names are very important for identifying things, especially when communicating with other people. However not everybody uses the same name for the same animal. For instance "Rwagi" and "mbuu" and "Suna" are all different names for the mosquito in different parts of Kenya. These are known as common names and can vary so much thereby causing confusion. It is for this reason that Carl Linnaeus in the 1750's suggested a method of naming things that could be used by scientists all over the world.

He introduced the binomial nomenclature, which means two names. The two names were both in Latin. The first name identifies the genus and the second the species. A fly such as the housefly is scientifically known Musca domestica although it has many different names in different parts of the world. Such scientific names follow a specific format. Because the names are Latin, they often appear in italics. Note that the first letter to the Genus is always capitalized.

The science of naming things is called taxonomy and though it can become quite complicated the basics are easy to understand. There are rules governing the naming of animals. These rules are referred to as the International Code of Zoological Nomenclature (ICZN). The current provisions of ICZN are set out in 87 articles grouped into 18 Chapters further to the International Congress of Zoology, 1961-64. The code consists of mandatory rules some of them operating only from specific dates, together with non-mandatory recommendations.

Now that we know what taxonomy is let us look at classification categories.

Any classification category or unit regardless of its level is called a taxon.

Below are the various taxonomic categories beginning from the broader groupings to the most specific groups:

- ANIMAL-
- KINGDOM-
- PHYLM-
- Subphylum-
- CLASS-
- Subclass-
- Superorder-
- ORDER-
- Suborder-
- Superfamily-
- FAMILY-
- Subfamily-
- Tribe-
- Subtribe-
- GENUS-
- Subgenus-
What not all the taxa are always used; but you are expected to be familiar with the taxa indicated above in block letters.

Animals belong to approximately thirty six (36) phyla.

ACTIVITY 1.1 (All answers available under Appendices)

1. Write the taxa but this time starting with the species.
2. The study of insects is called …………………………………….
3. The science of naming living things is called ………………………………
4. Any classification category is referred to as a ……………………………
5. Animals belong to approximately …………………………………… number of phyla. (2, 36, 120,2000)

What criteria do we use to classify animals?

As scientists, we divide living things into a series of sets and subsets (taxa) depending on evolutionary relationships (Phylogeny) and structural or morphological similarities.

We shall now look at the major taxa and how each applies to insects starting with the highest to the lowest taxon. The highest taxon is called Kingdom, and the lowest taxon is species.

Kingdom
All living things are first divided into 5 kingdoms namely Plants, Animals, Fungi, Protista and Bacteria. These last two are so small you can't see them without a microscope.

To which Kingdom do insects belong?

Phylum
All organisms within a kingdom are then divided into groups based on common characteristics. The living members of the kingdom Animalia are divided into approximately 36 smaller groups called phyla singular phylum. One such phylum is known as Arthropoda. Arthropoda is a Greek word that means "jointed foot." The phylum Arthropoda is of interest to us because this is where insects belong. It contains animals that generally have the following features:

1. Having a characteristic tough chitinous protective exoskeleton flexible only at the joint.
2. Having the nervous system running along the ventral side of the body.
3. Growing by ecdysis or molting
4. Bearing pairs of legs along all or part of length of the body, which are modified for different functions.
5. Nervous system of a dorsal brain connected to a ventral double nerve cord.
6. Possessing reduced coelomic body cavities called haemocoels, often filled
8. Sexes separate (dioecious).
9. Excretion by mandibluar glands, labial glands or Malphigian Tubules.

Are insects members of the phylum arthropoda?

**Class**
Phylum is a very broad classification and is therefore broken down into smaller taxa called Classes. Arthropoda contain the following classes:

1. Trilobita - These are extinct animals that had a pair of antennae, a pair of eyes and many biramous appendages.
2. Crustacea - These include the Lobsters, Crabs and Woodlice
3. Diplopoda - These are the millipedes
4. Chilopoda - These are the centipedes
5. Symphyla - these are centipede-like animals.
6. Pauropoda
7. Chelicerata (Arachnida) - Spiders, Scorpions, ticks and mites.
8. **Insecta** (Uniramia) - the true insects, such as beetles, bees, and butterflies.

Note that centipedes, millipedes, Symphylans and pauropods are collectively referred to as Myriapods. These arthropods have long trunks with many segments and appendages, most of which are walking legs.

Since we are interested in insects let us look at the features of members in the class Insecta more detail.

**1.2.2. Features of the class Insecta**
Insects are the largest and the most widely distributed taxon within the phylum Artropoda.
Insects are referred as Invertebrates because they lack a backbone.

The class Insecta is characterized by the following features:

1. Body with well-defined head, thorax and abdomen. Abdomen may be separated by constrictions.
2. Head of a number (probably 6) fused segments.
3. Thorax of 3 segments and abdomen of 11 segments, primitively, and a vestigial telson.
4. Head appendages are pair each of antennae, mandibles, 1st maxillae and 2nd maxillae (fused medially to form a labium).
Each thoracic segment bears a pair of legs and in apterygote insects, a pair of wings on 2nd and 3rd thoracic segments, (one or both pairs lost in some insects or non-functional flight).

6. Except in the apterygote insects, there are no abdominal appendages except on the genital segments.

7. Appendages (where present), on 11th segments, are called cerci.

8. External body form varies greatly in different orders.

9. Where soft-bodies (e.g. caterpillars), the unsclerotised cuticle is held taut by internal pressure of blood (hydrostatic skeleton).

10. They are tracheate.

11. They have exposed mouthparts

The three body regions are head, thorax and abdomen and other features of the class Insecta are represented in the generalized figure 1. below:

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**Figure 1.1.** General external morphology of an insect. (Based on a grasshopper)

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**ACTIVITY 1.2.** This is a practical activity do be done in a practical book to be submitted to the tutor during the residential phase of the course

1. Using any insect that is locally available and with the help of a hand lens, examine the insect and identify all the parts labeled in the diagram above.

**Orders**
The next subdivision is orders. The uniramia or insecta are divided into even smaller, though still pretty large groups called orders. For example the housefly belongs to the order Diptera.

The other Insect groups (Orders) that exist are listed below:

- Thysanura (Silverfish, Bristle-tails, Fire Brats)
- Diplura (some Bristle tails)
- Protura (cone heads)
- Collembola (Spring-tails)
- Ephemeroptera (Mayflies)
- Odonata (Dragonflies)
- Dictyoptera (Cockroaches and praying mantids)
- Isoptera (Termites)
- Plecoptera (Stoneflies)
- Grylloblattodea (small rare group)
- Dermaptera (Earwigs)
- Phasmida (Stick and Leaf-insects)
- Orthoptera (Crickets and grasshoppers)
- Embioptera (Web-spinners)
- Zoraptera (small rare group)
- Psocoptera (Book-lice and Psocids)
- Thysanoptera (Thrips)
- Mallophaga (Biting Lice)
- Anoplura (Sucking lice)
- Hemiptera (Bed bugs)
- Neuroptera (Ant-; lions, Lace-wings, Alderflies etc.)
- Mecoptera (Scorpionflies)
- Tricoptera (Caddiaflies)
- Lepidoptera (Butterflies and Moths)
- Diptera (flies, mosquitoes, fruit flies, tsetse flies)
- Siphonaptera (Fleas)
- Hymenoptera (Bees, Wasps, Ants, etc.)
- Coleoptera (Beetles)
- Strepsiptera (twisted wing parasites)
- Homoptera (Aphids, scale insects, leafhoopers)

**ACTIVITY 1.3**

Have you encountered any of the insects listed above?

If your answer is no, then collect at least ten different insects that are representative of ten different orders and present your findings as tabulated above.

If your answer is yes, then present your answer in a tabular form. i.e. list the common names against the respective orders.
Orders are then divided into families. For example, within the order Diptera (the flies) there are several families; within each family several genera and within each genus a number of species.

The hierarchy used to classify the house fly or honey bee scientifically, is as follows:

- Phylum - Arthropoda
- Class - Insecta
- Order - Diptera
- Family - Muscidae for housefly and Apidae for honeybee.
- Genus - Musca for housefly and Apis for honeybee.
- species domestica for housefly and mellifera for honeybee.

This universal method is used to prevent confusion among geographic regions of the world. Consequently, Musca domestica refers to the same insect species in Kenya as it does in Asia or anywhere else in the world. Similarly Apis mellifera refers to the same insect species in Kenya as it does in Asia or anywhere else in the world.

The Species
A species may be defined as a group of individuals or a population in nature that are capable of interbreeding and producing fertile offspring, and under natural conditions, are reproductively isolated from other such groups, i.e., they do not interbreed

The species is the lowest category in the classification hierarchy. It is a critical category, because the grouping of individuals into species is the most specific level of classification. Most often, insect species are classified based on similarities in appearance (morphology).

Is it necessary to group insects under specific groups/names?

YES! It is necessary to classify insects so that we can organize what we know about them and determine their relationships with other animals, plants and with man.

SUMMARY
In this lecture we have learnt that:

- The study of insects is called Entomology
- There are advantages of using scientific names as opposed to common names of insects. The advantage is that scientific names do not change from region to region and are therefore useful worldwide
- The science of naming living things is called Taxonomy
- Animals can be classified based on Phylogeny and morphology
Insects are so diverse that they can be grouped into 30 different orders based on morphological characteristics.

- There is a hierarchy of classifying insects. Using such a hierarchy we have been able to classify the common housefly and honeybee.
- Arthropods are characterized by a chitinous exoskeleton and a linear series of segments some of which bear jointed appendages.
- Within the phylum Arthropoda there are several classes namely Trilobita (extinct), Crustacea, Archnida, Pauropoda, Symphla, Diplopoda, Chilopoda and Insecta.
- Three body regions, a tracheal system, possession of antennae, three thoracic segments, each bearing a pair of legs, at least 11 abdominal segments, and one or two pairs of wings characterize the class Insecta.
- The grasshopper or locust or cockroach can be used as models to study the general morphological features of insects.

ACTIVITY 1.4. The answers to these short essay questions are within the text.
1. List three features of the Phylum arthropoda. Using specific common examples, differentiate the classes within this phylum.

2. Define the terms taxonomy and species and mention two criteria that can be used for grouping animals. Mention the disadvantages of using common names as opposed to scientific names when referring to insects.

3. List 5 kingdoms into which you can classify living things and classify the honeybee from kingdom to species.

SUGGESTED FURTHER READING:
LECTURE NUMBER TWO

2.0: INSECT EXTERNAL MORPHOLOGY: THE EXOSKELETON

2.1 Introduction
2.2 The exoskeleton
2.3 The insect integument.
2.4 The epidermis
2.5 The basement membrane
2.6 The cuticle
   2.6.1 The endocuticle
   2.6.2 The exocuticle
   2.6.3 The procuticle
   2.6.4 The procuticle
2.7 Functions of the cuticle
2.8 Modifications of the integument

2.1: INTRODUCTION

In lecture one we learnt that one of the distinctive features of Arthropods including insects is the possession of the exoskeleton. In this lecture we shall describe the features of the insect exoskeleton and examine how it has contributed to the success of insects as a group.

OBJECTIVES

At the end of this lecture we should be able to:

- Illustrate the structure of the insect integument.
- State the functions of the insect cuticle.
- Relate the structure of the integument to its function.
- Discuss how the exoskeleton has contributed to the success of Insects.
- Indicate how the integument has been modified in various insect groups.

2.2: THE EXOSKELETON

In insects and other arthropods the skeleton is on the outside. It is therefore, called exoskeleton.

The exoskeleton is the hard outer covering made mostly of a substance called chitin. The best way for you to get a feel of the exoskeleton is to examine any beetle that you can find. A beetle looks like a bean seed. Imagine that the outer coat of a bean seed is equivalent to the exoskeleton covering the back of a beetle.
Now that you have seen the exoskeleton, we can continue to describe it in more detail. The exocuticle and basement membrane form the insect body wall also known as the integument. The insect integument is composed of four layers, which, are described and presented in figure 2.1 below:

2.3: THE INSECT INTEGUMENT (BODY WALL)

ACTIVITY 2.1 The correct answers are in the appendices.

Based on the above diagram the key components of the insect integument are:

a.……………………………………………………
b.……………………………………………………
c.……………………………………………………
d.……………………………………………………

2.4: THE EPIDERMIS

The epidermis is the outer cell layer. It is a single cell layer derived from the embryonic ectoderm. The cross section of an epidermal cell is almost hexagonal and closely packed tiger the. The cells vary at different sites. They also vary among different species in height and shape from cuboidal to columnar to irregular. The epidermis secretes the cuticle. It plays the key role in ecdysis by secreting the molting fluid. The fluid loosens the cuticle from the cell layers through enzymatic action. It also absorbs the resulting digested products.

2.5: THE BASEMENT MEMBRANE

The epidermal cells stand on the basement membrane. The basement membrane is an extremely thin, entirely continuous sheet. It is composed of flattened satellite cells these
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are loosely bound together with intracellular material. This membrane resembles the connective tissue of vertebrates although it has no fibers.

2.6: THE CUTICLE

The cuticle is a secretion of the epidermis that covers the whole of the outside of the insect body and is also a lining of the foregut, hindgut and trachea.

The cuticle is hard due to a horny substance called sclerotin. The process of hardening of the cuticle is called sclerotization. Certain areas of the cuticle however contain an elastic protein called resin, which provides the elasticity of the cuticle. The cuticle is laminated and consists of the layers stated below:

2.6.1: The End cuticle. This is the layer next to the epidermis. Between the epidermis and the endocuticle is an amorphous layer called the Schmidt's layer.

2.6.2: The Exocuticle. The exocuticle contains a substance called sclerotin. The color of an insect is due to pigments in the body wall. These pigments are usually in the exocuticle.

2.6.3: The Procuticle. The procuticle is laminated and strengthened by vertical diagonal rods of homogeneous composition. It is penetrated by minute, helical canals known as pore canals. These lead to the outer layers. Chitin, a nitrogenous polysaccharide is a characteristic constituent of the practice. Chitin is more abundant in the softer parts.

2.6.4: The Epicuticle. The Epicuticle consists of four layers as follows:

1. An innermost cuticulin layer which contains lipoproteins
2. A waxy layer (randomly oriented wax)
3. A waxy layer (evenly oriented waxy monolayer)
4. An outermost cement layer (epicuticula)

Molecules of the monolayer are very closely packed. This provides the waterproof layer of the cuticle. The cement layer is very thin and outside the waxy layer. It is absent in insects with scales.

The epicuticle is impermeable to water and therefore protects the insect from desiccation.

ACTIVITY 2.2 The correct answers are in the appendices
1. The process of hardening of the cuticle is called sclerotization.
2. Other than being on the outside body of the insect, the cuticle lines the... (continued)
3. Which layer of the integument contributes to waterproofing the integument?
4. ... contributes to the elasticity of the cuticle.
The cuticle is one of the features of insects, which is primarily responsible for their success in that:

1. It plays an important part in supporting the insects.
2. The hard jointed appendages made of cuticle make movements possible with minimum muscles. This results in economy of muscles.
3. Flight in insects depends on the rigidity in the wings. The cuticle provides this rigidity.
4. Parts of the cuticle are modified to form sense organs.
5. Protection from predators, parasites, harsh environment, and dehydration is provided by the cuticle.

SUMMARY
In this lecture we have learnt that:

- The insect skeleton is on the outside and is called the exoskeleton.
- The exoskeleton, basement membrane and epidermis form the insect body wall.
- The exoskeleton provides insects with adequate protection against mechanical injuries, enemies, infections and water loss.
- The cuticle is hardened by a substance known as sclerotin through a process referred to as sclerotization.
- The cuticle is made up of several layers comprising of endocuticle, exocuticle, procuticle and epicuticle.
- The cuticle has pigments, a waxy component in addition to having some degree of elasticity and flexibility.
- The cuticle is responsible for the success of insects as it contributes to the following: body protection, body support, movement, and flight.
- Parts of the cuticle have been modified to form sense organs.
- The cuticle is shed off during molting to permit growth of immature stages of insects.

ACTIVITY 2.3 These are essay questions whose answers are within the text.

1. State how the exoskeleton has contributed to the success of insects.
2. Describe the main components of the insect integument and show how it has been modified to perform functions other than being the outer body cover.
3. Name at least four functions of the exoskeleton and state the significance of the fact that the cuticle has some degree of elasticity.
SUGGESTED FURTHER READING:
3.0: THE INSECT HEAD

3.1 Introduction

3.2 The Insect head

3.3 Orientation of insect heads

3.4 Grooves and areas of an insect head

3.4.1 The Frons

3.4.2 The vertex

3.4.3 The Clypeus

3.4.4 The labrum

3.4.5 The Gena

3.1: INTRODUCTION

In the last lecture we studied the exoskeleton as part of the external morphology of an insect. In this lecture we will examine the insect head in more detail as part of the insect external morphology. We will continue studying the exoskeleton because it covers the insect head as well. We will also learn that insect heads have different types of orientations with respect to the rest of the body.

OBJECTIVES

At the end of this lecture you should be able to:

- Draw and label the various regions of a typical insect head
- List important organs and parts found on the insect head.
- Name with specific examples the different orientations of insect heads
- Relate the different head orientations to the mode of life of particular insect groups.

3.2: THE INSECT HEAD

Below are a few points you need to know about a typical insect head:

- The insect's head is sometimes referred to as the head-capsule. An insect head is enclosed by the exoskeleton. The exoskeleton that covers the insect head consists of several hardened plates or sclerites, fused together.

- The insect head is of great interest as it is the insect's feeding and sensory center. It supports the eyes, antennae and mouthparts of the insect.
The insect head capsule has a number of grooves dividing it into many areas. There are also lines called sutures and sulcus. Grooves on the insect head vary in structure and form depending on the head orientation.

**ACTIVITY 3.1** Answers are in the Appendices.

1. Is the insect head covered by the Exoskeleton?
2. Define sclerites
3. State the other name for the insect head

### 3.3: ORIENTATION OF INSECT HEADS

Insect heads are oriented in 3 different positions with respect to the rest of the body. The various types of insect heads are an adaptation to different modes of life and habitats. The types of orientations are indicated below.

1. **Hypognathous** e.g. Grasshopper as shown on Figure 3.1. This is the orientation in which the mouthparts are in continuous series with legs. Occurs mainly in phytophagous insects. It is probably the most primitive evolutionarily.

![Fig. 3.1: Insect head showing hypognathous orientation](image)

2. **Prognathous**, e.g. Beetle larvae as shown on figure 3.2. In this type, the orientation is such that the mouthparts point forwards. It occurs in carnivorous insect species, which pursue their prey, or in burrowing forms.

![Fig.3.2: Insect head showing prognathous orientation](image)
Opistognathous, e.g. Aphid as shown on figure 3.3. In this type, the orientation of the head is such that the mouthparts are elongated and slope backwards between the front legs. It occurs in insects that insert their mouthparts into plant tissues, particularly among members of the orders Hemiptera and Homoptera.

**Fig. 3.3: Insect head showing opisthognathous orientation**

**ACTIVITY 3.2** This is a practical exercise. Check your own illustration against figures 3.1, 3.2, and 3.3 above.

1. Collect insects from vegetation, water bodies, soil and off animals nearby. Observe the orientation of the head in relation to the rest of the body. Sketch the head and indicate the type of orientation and the possible type of diet of your specimen.

3.4: GROOVES AND AREAS OF INSECT HEAD

3.4.1: The frons
The upper-mid portion of an insects face is called the 'frons'
The 'frons' = that area of the face below the top two 'ocelli' and above the 'frontoclypeal sulcus' (if and when this is visible) and in between the two 'frontogenal sulci', it supports the 'pharyngeal dilator' muscles and in immature forms it bears the lower two arms of the ecdysial cleavage lines

**Fig. 3.4: A typical insect head: frontal view**
Vertex is the dorsal part of the frons.

3.4.3: The clypeus

The 'clypeus' = that area of the face immediately below the frons (with which it may be fused in the absence of the frontoclypeal sulcus) and the frontoclypeal sulcus. It is the face of an insect. It supports the 'cibarial dilator' muscles and may be divided horizontally into a 'post.' and 'anteclypeus'. Below the clypeus is the labrum.

3.4.4: The 'labrum' = is equivalent to the insect's upper lip and is generally moveable, it articulates with the clypeus by means of the 'clypeolabral suture'. On either sides of the clypeus are the edges of the 'mandibles'.

3.4.5: The gena

The sides of the head are known as the 'gena'. Gena is the lateral area of the head beneath eyes. The subgenal sulcus divides into two, subgena below and postgena above. The gena is equivalent to the cheek.

<table>
<thead>
<tr>
<th>ACTIVITY 3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Match the words in column A to those in column B by inserting serial numbers preceding words in column A inside bracketed spaces in column B</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1 Vertex</td>
</tr>
<tr>
<td>2 Clypeus</td>
</tr>
<tr>
<td>3 Beetle larvae</td>
</tr>
<tr>
<td>4 Gena</td>
</tr>
<tr>
<td>5 Grasshopper</td>
</tr>
<tr>
<td>6 Aphid</td>
</tr>
<tr>
<td>7 Frons</td>
</tr>
<tr>
<td>8 Labrum</td>
</tr>
<tr>
<td>9 Ocelli</td>
</tr>
<tr>
<td>10 sulcus</td>
</tr>
<tr>
<td>11 Sclerite</td>
</tr>
<tr>
<td>12 Sensory</td>
</tr>
</tbody>
</table>
SUMMARY
In this lecture we have learnt that:-

- An insect head is enclosed by the exoskeleton which consists of several plates called sclerites.
- The insect head bears several structures such as the eyes, the antenna, and mouthparts all of which are of tremendous importance to the functioning and survival of the insect.
- The orientation of an insect head is related to its mode of life. Particularly its feeding habits.
- The insect head may appear small and simple, is however quite complex with elaborate grooves, regions, and line.
- Certain areas of the insect head are comparable to the human head such that the frons is equivalent to the temple, the gena to the cheek, and the clypeus to the face.

ACTIVITY 3.4 Answers to be found within the text
1. Illustrate the grooves and regions of a typical insect head capsule and cite three important structures found on the head.
2. Discuss the significance and importance of the fact that insects have different head orientations.

SUGGESTED FURTHER READING:
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
4.0: THE INSECT ANTENNAE

4.1 Introduction
4.2 Typical insect antennal structure
4.3 Antennal variety
  4.3.1 Sexual dimorphism in relation to insect antennae
  4.3.2 Significance of insect antennal variation
4.4 Functions of the insect antennae
  4.4.1 Antennae as sensory structures
  4.4.2 Antennae as mating structure
  4.4.3 Antennae as organs for seizing prey
  4.4.4 Antennae as respiratory structures

4.1: INTRODUCTION
In the last lecture we encountered the insect antenna as one of the most important structures on the insect head.
In this lecture you will study the insect antenna beginning with how its basic parts. You will then examine the different forms and sizes of antennae found in various insect groups.

OBJECTIVES
At the end of this lecture you should be able to:

- Illustrate the structure of a typical insect antenna
- Outline the main function of the insect antenna
- Describe the different types of insect antennae
- Cite other functions of insect antennae besides the sensory function
- State the significance of the insect antennal variation

Antennae are sensory structures to help the insect find out more about its surroundings

Except in the Order Protura, all insects possess a pair of antennae.
The antennae are the insect's primary, non-visual, sense organs.
Antennae come in a wide variety of shapes and sizes. This wide variation of insect antennae has adaptive advantage in that it enables the insect to be sensitive to a wide
The insect antenna is also of taxonomic importance in that it can be used to distinguish and classify different insect groups.

Do all insects have antennae?

**ACTIVITY 4.1** Answers are in the appendices

Antennae are primarily sensory, defense, mating, egg-laying, feeding structures.

**4.2: THE TYPICAL INSECT ANTENNAL STRUCTURE**

The structures of a typical insect antenna is described below in the section below and also illustrated in figure 4.1

**Basal Scape.** This structure is inserted into a membranous region of the head wall. The pivot is a single marginal point called **antennifer.** This arrangement enables the antenna to move in all directions. Generally the first segment of the antenna is known as the 'scape'
and after the basal scape is called the as the 'pedicel'. The second segment second after the basal scape is called the as the 'pedicel'. The second segment contains a special sensory organ called Organ of Johnstons. In two orders (Diplura and Collembola) the antennae lack a 'Johnston’s organ' and all but the last segment contains intrinsic muscles, thus allowing far greater controlled movement of the antennae as is demonstrated by the rolling and unrolling of the antennae observed in the Collembola, Tomocerus longicornus.

Flagellum. After the pedicel, the rest of the antennae are the flagellum. It is divided into several annuli. The annuli are similar and joined by membrane so that the whole antenna is flexible. Annuli are not equivalent to segments, for example of legs. However, annuli of Collembola and Diplura (primitive orders) are true segments. This is because each has an intrinsic musculature in addition to unifying external muscles.

Meriston: This meriston is the proximal annulus, which divides to give to other annuli. In segmented antennae of Collembola and Diplura, antennal growth is apical.

ACTIVITY 4.2 Answer in the appendices

1.List five parts of a typical insect antenna

4.3: ANTENNAL VARIETY

The structure of some antennae, such as the cockchafer, moth and mosquito are adapted in different ways to increase the surface area for sensory cells. The bee’s antennae have a simpler, more robust shape.

There is a great variety of form among insect antennae. Antennae of larval homometabolous insects are usually considerably reduced. Antennae of larval Neuroptera and Megaloptera contain a number of annuli. But antennae of larval Coleoptera and Lepidoptera are reduced to 3 simple segments. Finally, in some larval Diptera and Hymenoptera, antennae are very small and may be more than swelling of head wall. Since antennae are often used as aids in the identification of insects, knowledge of the common forms will be useful. Study the antennae exhibited by the following selected insects and label the drawings as to the type of antennae.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>DESCRIPTION</th>
<th>FOUND ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>SETACEOUS</td>
<td>Bristle like</td>
<td>Cicada/Dragon fly</td>
</tr>
<tr>
<td>MONOLIFORM</td>
<td>String of beads</td>
<td>Rove beetle</td>
</tr>
<tr>
<td>SERRATE</td>
<td>Saw toothed</td>
<td>Flat headed borer</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>CAPITATE</td>
<td>With a distinct head</td>
<td>Field cricket/ground beetle</td>
</tr>
<tr>
<td>LAMELLATE</td>
<td>Tip with large, flat plates</td>
<td>Darkling beetle/ladybird beetle</td>
</tr>
<tr>
<td>PLUMOSE</td>
<td>With many plumes</td>
<td>Nautili beetle</td>
</tr>
<tr>
<td>PILESE</td>
<td>With few plumes</td>
<td>June beetle</td>
</tr>
<tr>
<td>ANNELATE</td>
<td>With rings</td>
<td>Male mosquito/Cecelia moth</td>
</tr>
<tr>
<td>ARISTATE</td>
<td>With an aristae</td>
<td>Female mosquito</td>
</tr>
<tr>
<td>GENICULATE</td>
<td>Elbowed</td>
<td>Horse fly</td>
</tr>
<tr>
<td>PECTINATE</td>
<td>Feather like</td>
<td>Male Bombyx</td>
</tr>
</tbody>
</table>

**INSECT ANTENNAE**

![Fig. 4.2](image1)

![Fig. 4.3 moth](image2)

![Fig. 4.4 honey bee](image3)

![Fig. 4.5 tsetsefly](image4)

![Fig. 4.6 cockchafer](image5)

![Fig. 4.7 mosquito](image6)
ACTIVITY 4.3
Below are eight illustrations of different types of insect antennae. Copy each illustration in your laboratory notebook. Describe each type of antenna and give the common name of an insect in which each type of antenna is found on. Hand in this work to the course lecturer.

4.3.1: Sexual dimorphism in relation to insect antennae
In some insects antennae of the male is different from that of the female a phenomenon known as sexual dimorphism. Antennae of the male insects are usually more complex than those of females although in some species it is the reverse. It is quite usual that the males of a species have more elaborate antennae than the females; this is because it is normally the males who have to find the females.

The more elaborate the antennae (see fig.4.2) the greater the surface area of the antennae. Antennae with larger surface area are more sensitive and can detect the more dilute scents, thus male insects with feathery antennae, such as those seen in many moths, are far more sensitive than the purely filamentous ones of crickets and cockroaches.

4.3.2: Significance of antennal variation
Insect antennae are useful in identifying insects. This is of great importance when we want to differentiate the vectors and plant pests from other insects, which are not harmful. In some insect groups such as mosquitoes it is only one sex, the female that sucks blood.
In such cases if the male and female antennae are different, they can be used as a simple tool of differentiating males from females.

ACTIVITY 4.4 Answers are in the text.
1.1.List six different types of insect antennae

4.4: FUNCTIONS OF THE INSECT ANTENNAE.
The various ways in which insects use the antenna are stated in the sections below:

4.4.1. Antennae as sensory structures
The variations found in insect antennae are for serving precise functions. Basically, antennae are sense organs. They carry special organs called sensilla. These are often concentrated in particular areas. Their arrangement can be used for classification of species.

In most insects the antennae possesses a mechanosensory organ on the pedicel (the second antennal segment) called 'Johnston’s organ' and, normally, only the basal antennal segment contains intrinsic muscles.

Various antennal sensilla function as follows:
1. Contact (tactile or mechanoreceptors)
2. Smell (odor receptors)
3. Chemical (chemoreceptors)
4. Gravity (hygroreceptors)
5. Pressure (proprioceptors)
6. Temperature (thermoreceptors)

However, sometimes insect antennae are used for other functions. Other functions of the insect antennae are stated in sections below:

4.4.2: Insect antenna as a mating structure
Some male insects use the antennae to hold females during mating (i.e. the males of Meloe sp. {Coleoptera})
Fleas and Collembola also use antennae for mating purposes.

4.4.3: Insect antenna as structure for seizing prey
In a few rare instances antennae have become adapted for other purposes such as seizing prey items (i.e. the larva of Chaoborus sp. {Diptera})

4.4.4: Insect antenna as a respiratory structure:
In the adult water beetle terminal annuli of the antennae are clothed with hydrofuge hairs. They facilitate formation of air bubble with which the insect submerges for respiration. You shall learn more about insect respiration in lecture 12.
SUMMARY

In this lecture we have learnt that:

- The main function of the insect antenna is sensory. Sensory structures in the antenna can detect heat, pressure, chemicals etc. The insect benefits by responding appropriately to these and any other stimuli.
- The typical insect antenna is made up of the following components; the basal scape, antennifer, the pedicel, meriston and flagellum.
- In addition to being a sensory apparatus, the insect antennae can be used for prey capture, mating and as a respiratory structure among some insect groups.
- Insect antennae exist in various forms, shapes and sizes in various insect groups. In some cases the antenna vary between the two sexes of the same species exemplified in mosquitoes and certain species of moths.
- There are adaptative advantages of the various insect antennae.

ACTIVITY 4.4  Answers are in the text

Describe a typical insect antenna and outline the significance of antennal variation in insects.
Discuss the functions of insect antennae and relate such functions to řsexual dimorphismř seen in insect antennae.

SUGGESTED FURTHER READING:
LECTURE NUMBER FIVE

5.0: INSECT MOUTHPARTS

5.1: Introduction
5.2: Mandibulate or chewing mouthparts
5.3: Variations in insect mouthparts
5.3.1: Combination (Chewing-sucking) mouthparts
5.4: Haustellate or sucking mouthparts
5.5: Orientation of insect mouthparts
5.5.1: Ectognathus mouthparts
5.5.2: Endognathus mouthparts
5.6: Vestigial mouthparts

5.1: INTRODUCTION

In the previous section we learnt about one of the head appendages; the antennae. In this lecture we are still studying the insect head but we shall consider a different head appendage; the mouthparts. We shall define two major types of insect mouthparts; the chewing and sucking mouthparts. You will observe how the basic chewing insect mouthpart has been modified for different feeding habits. In the first section of your lesson you will study the grasshopper mouthpart as a representative of the basic chewing mouthpart. The next item you will study is the modified chewing mouthpart found in other insects like honeybees. The final section of the lecture is an illustration of eight different types of sucking mouthparts.

You will require a hand lens and a pair of scissors or a razor blade to dissect the grasshopper mouthpart

OBJECTIVES

Having studied this lecture you should be able to:

- Mention the two major types of insect mouthparts
- Draw the basic chewing mouthparts of a grasshopper
- List insects with either chewing or sucking mouthparts
- Discuss how the basic chewing mouthpart has been modified in the housefly and the honeybee.
- Describe the eight different sucking mouthparts found insects such as thrips, plant bugs, mosquitoes, robber flies, stable and housefly, tsetse flies, fleas, lice and butterflies.
No groups of arthropods present a greater diversity of mouthparts than insects. Generally, however, insect mouthparts are two types:

1. Mandibulate (Chewing) type.
2. Haustellate (Sucking) type.

The chewing type is the more evolutionarily primitive. It occurs in adult Thysanura, Odonata, Plecoptera, Isoptera, Neuroptera, Mecoptera, Trichoptera, Coleoptera and Hymenoptera. They considerably vary between these different insect groups.

The most generalized condition of the mandibulate mouthparts type is found in the grasshoppers, locusts and crickets. The various mouth-part structures are most easily seen and studied by removing them from the insect one at a time and studying them under a lens or microscope. They consist of 5 parts listed below:-

![Generalized Insect Head with Chewing Type Mouthparts](image)
Mandibles: They are paired; short strong, heavily sclerotized, unsegmented jaws. They lie immediately behind the labrum. They articulate with the head capsule at 2 points, one at anterior and one at posterior and move laterally. Biting surface is differentiated into distal incisor region and proximal moral region. Modifications are found in predaceous beetles where the mandibles are long and sickle like.

Maxillae
They are paired structures lying behind the mandibles. They are segmented, and each maxilla bears a feeler like organ the palp. The basal segment of the maxilla is the cardo, the second segment is the stipes. The palp is borne on a lobe of the strips called palprifer. The stipes bears at its apex 2 lobe like structures and the gelea, a lobe like structure. Variations in the maxillae in different chewing insects involve chiefly the palps and the terminal lobes. The palps are sensory organs. They test the quality of food. The terminal lobes are used to clean antennae, palps and front legs.
The Labrum

This is the upper lip. It is broad flap like lobe situated below the clypeus on the anterior side of the head, in front of the other mouthpart structures. On the ventral or posterior side of the labrum is a swollen area, the epipharynx.

Hypopharynx

This is a short tongue-like structure, which can easily be seen if the mandible and maxilla on one side are removed. It is located immediately in front of or above the labium and between the maxillae. In most insects the ducts from the salivary glands open on or near the hypopharynx. Mostly membranous in structure, but the dorsal surface is sclerotised distally. Proximally it contains a pair of sensory sclerites. In Apterygota, larval Ephemeroptera and Demopterida there are two lateral lobes of he hypopharynx called superliguae.
Labium
This is the lower lip. Structurally, similar to maxillae, but appendages of the two sides are fused together to form a single structure. It is divided by a transverse suture, into portions, a basal postmentum and a distal prementum. The postmentum in the grasshopper locust or cricket is divided into a basal submentum and a distal mentum.

The prementum bears a pair of palps and group of apical lobes which form the ligula, consisting of a pair of small mesal lobes, the glossae, and a pair of larger lateral lobes, the para-glossae, the labial palps are borne on lateral lobes of the prementum, called palpigers. All the muscles of the labium have their insertion distal of the labial suture. The variations in labial structures in chewing insects involve primarily the structure of the ligula and the sclerotization of the basal portion of the labium. The pre-mentum closes the preoral cavity from behind. The labial palps function like those of the maxillae.

Fig.5: Labium
ACTIVITY 5.1

1. Tabulate the various components found in a basic chewing mouthpart of an insect

5.3: VARIATIONS IN INSECT MOUTHPARTS

From the simple generalized structures found in the mandibulate or chewing insect mouthparts several phylegenetic lines have arisen through adaptations. These adaptations have occurred to enable puncturing plant and animal tissues and (ii) also for sucking juices. Other adaptations are for drinking nectar from flowers. Still other insects have evolved defensive adaptations not directly concerned with feeding. Some of these adaptations are as follows:

Insect mouthparts have evolved for chewing (beetles, caterpillars), piercing-sucking (aphids, bugs), sponging (flies), sucking (moths and butterflies), rasping-sucking (thrips), cutting-sponging (biting flies), and chewing-lapping (bees and wasps).

Mouthparts of moths and butterflies are adapted to form a galea for sucking liquid food such as nectar from flowers and when the insect is not feeding the long feeding tube is coiled.

Piercing and sucking mouthparts are found in herbivorous insects such as aphids, leaf hoppers, which feed on plant juices.

In biting flies such as horseflies the mouthparts function as knife-like mandibles, to produce the wound. Blood is then collected from the wound by a sponge-like labium and conveyed to the mouth by a tube formed from the hypopharynx and epipharynx.

Some predatory flies and Hemiptera inject salivary secretions into the prey and suck up already digested tissues.

Certain non-biting flies such as houseflies use a sponge-like labium a lone for obtaining food, the mandibles and maxillae being reduced. Insects such as the houseflies are not limited to liquid food. Saliva can be exuded through the labium to liquefy the solid food and the fluid sucked back into the mouth. Such mouthparts are referred to as sponging mouthparts.

Assassin bugs and mosquitoes, which feed on fluids of other animals, have specialized needle-like mouthparts that form a stylet.
Have you been to the doctor and had your blood drawn with the help on an injection needle?

The mouthpart of a mosquito is just like the injection needle!

That's a lot of ways to eat!

We have seen that insects have different types of mouthparts.

Why is it so?

Answer: It is so because they have adapted to different types of foods found in different types of habitats.

Now let us study a modified mouthpart found in the honey bee. This is the combination mouthpart.

5.3.1: Combination (chewing-sucking/lapping) mouthparts

Chewing-Lapping - Bees and wasps have mouthparts sometimes referred to as combination mouthparts. Mouthparts are modified to utilize liquid food, honey and nectar. A central "tongue" is used to draw liquid into the body. The mandibles are not used for feeding but function to cut floral tissue to gain access to nectar, for defense, and for manipulating wax.

This means that the mouthpart is a combination of both chewing and sucking. The bee mouthparts are greatly elongated as shown on figs. 5.7 a and 5.7 b below. The labium and maxillae are modified into a tongue like structure through which liquid food is sucked. Fused glossae form a long, slender flexible tongue. This, together with small paraglossae, can be partly retracted into prementum. Labial palps are as long as the tongue and flattened. The galeae are also elongated and flat. The maxillary palps are vestigial pegs and the laciniae are entirely absent. The mandibles are spatulate or spoon-shaped but not used for feeding. They are instead used for nest construction, e.g. to work the wax and fashion the hexagonal cells in the honeybee. To feed, the bees form a proboscis by bringing the flat galeae and labial palps together over the tongue. Movements of the tongue within the proboscis bring liquid to the mouth. It is
then sucked in by the pumping action of the muscles around the buccal cavity and gathered by the elongate maxillae and labium while the labrum and mandibles handle pollen and wax, which have retained the chewing form. Modifications of the tongue provide useful taxonomic characters in separating bee species.

Combination mouthparts are also found in larvae of some Neuroptera e.g. ant lions, and larvae of predaceous diving beetles. The larvae of some Neuroptera, e.g. ant lions, owl flies, have the mandibles and maxillae elongated, and suck up the body fluids of their prey through a channel between the mandibles and maxillae. The larvae of predaceous diving beetles suck the body fluids of their prey through channels in the mandibles.

**ACTIVITY 5.2** Answers are in the appendices

1. State two insects with a combination mouthpart
2. What role do mandibles play in the bee mouthpart?
3. What part of the bee mouthparts gathers nectar and pollen respectively
4. Are there parts that are vestigial in relation to bee mouthparts?
5. Name the part that is entirely absent from the bee mouthpart.

**5.4: HAUSTELLATE OR SUCKING MOUTHPARTS**

**Piercing-Sucking** - Found in a variety of insects, such as herbivorous and predacious bugs and mosquitoes. Mandibles and maxillae are formed into stylets, which are enclosed by the labium. Once the stylets penetrate, a secretion is injected to dissolve tissue, act as a toxin in predacious species, or as anticoagulant for mosquitoes.

Insects with haustellate mouthparts have them in the form of elongated proboscis or beak. Through it liquid food is sucked. The mandibles are either elongate and style like or are lacking. Like in the mandibulate insects, haustellate mouthparts have undergone considerable variation in different insects. There are eight principal variations as follows:

(i) **Thrips type**: the proboscis is a short, stout, asymmetrical, conical structure. It is located ventrally in the rear of the head. The labrum forms the front of the proboscis; the basal portions of the maxillae form the sides. The labium forms the rear.

There are 3 styles: the left mandible (the right mandible is rudimentary), and 2 maxillary stylets. Both maxillary and labial palps are present, but short. The hypopharynx is a small medium lobe in the proboscis. The mouthparts of thrips have been termed "rasping sucking." However, it is probable that the stylets piece rather than rasp the tissues fed upon. The food ingested is generally in liquid form, but very minute spores are sometimes ingested.
Did you know that thrips are agricultural pests?

ACTIVITY 5.3 Answer is in the text above

In your own words, briefly describe the mouthparts of thrips

(ii) **Hemiptera (Bug) Type**: This is found in Hemiptera and Homoptera. The beak or rostrum or proboscis is elongate, usually segmented and arises from the front (Hemiptera) of the head. It is carried under the body between the legs.

The external segmented structure of the beak is the labium. It is sheath-like and encloses 4 piercing stylets

- The 2 mandibles
- The 2 maxillae

The labrum is a short lobe at the base of the beak on the anterior side. The hypopharynx is a short lobe within the base of the beak.

![Fig 5.8 a: plant bug mouthpart](image)

The labium does not piercing, but folds up as the stylets penetrates the plant tissues fed upon as shown on figure 5. The inner styles in the beak, the maxillae and mandibles are structured in such a way as to form 2 channels, a food channel and a salivary channel. It is divided into section. The palps are absent.
The lower Diptera (Mosquito) Type: These are found in the biting lower Diptera comprising sand flies, culicids and the mosquitoes, these insects have 6 piercing stylets: the labium, the paired mandibles, the paired maxillae and the hypopharynx enclosed within a grooved of the labium.

The stylets may be very slender and needlelike (mosquitoes) or broader and knifelike (the other groups). The maxillary palps are well developed, but labial palps are lacking (some Dipterists regard the labella lobes as labial palps). The salivary channel is in the hypopharynx and the food channel is between the grooved labrum and the hypopharynx (for e.g. mosquitoes), or between the labrum and the mandibles (for e.g. Culicoides and the horse flies. The labium does no piercing and folds up or back as the stylets enter the tissue being pierced.
Did you know that mosquitoes can transmit many blood parasites including the parasite that causes malaria? Are the mosquito mouthparts suited for blood feeding and thus disease transmission?

(iv) **The Robber Fly (Asilidae) Type**: In these insects, the mouthparts are similar to those of the piercing group, but there are no mandibles. The principal piercing organ is the hypopharynx. There are 4 stylets: the labrum, the paired maxillae and the hypopharynx. The food channel is between the labrum and the hypopharynx. The robber flies feed on other insects or spiders, and only rarely bite man.

(v) **The Higher Diptera (Cyclorrhapha) Type**: By "higher" Diptera comprises of flies that belong to the suborder Cyclorrhapha. The mandibles in these flies lack palps. The maxillae are represented by maxillary palps. The proboscis consists of the labrum, hypopharynx and labium. There are 2 modifications of the mouthparts in these flies.

(a) a piercing (Hippoboscide) type, and
(b) a sponging or lapping type.

(a) **Piercing (Hippoboscidae) Type**:

The higher Diptera with piercing mouthparts include the stable fly, tsetse fly, horn and the louse fly (Hippoboscidae). The principal piercing structure in these flies is the labrum.
The labrum and hypopharynx are slender and stylet-like, and lie in a dorsal groove of the labium. The later terminates in a pair of small hard plates, the labella. There may be sharp teeth on the pseudotracheae to rasp flesh and draw up blood. The labella is the fleshy distal end of the labium that functions as a sponge-like organ to sop up liquids. These are armed with teeth the salivary channel is between the labrum and hypopharynx. The proboscis is the horse flies is somewhat retracted into a proud on the ventral side of the head when not in use.

(b) Sponging or Lapping (Muscidae) Type:

**Sponging** - Found in adults of specialized flies. During feeding the proboscis (modified labium) is lowered and salivary secretions are pumped onto the food. The dissolved or suspended food then moves by capillary action into the pseudotracheae (sponge) and is ingested. There may be sharp teeth on the pseudotracheae to rasp flesh and draw up blood. The labella is the fleshy distal end of the labium that functions as a sponge-like organ to suck up liquids.

The higher Diptera with sponging or lapping mouthparts include the non-biting Cyclorrhapha such as the housefly, blowfly and fruit fly. The mouthparts structures are suspended from a rostrum. The maxillary palps, arise at the distal end of the rostrum. That part of the proboscis beyond the palp is termed the haustellum.

The labrum and hypopharynx are slender and lie in an anterior groove of the labium. The labium forms the bulk of the haustellum. The salivary channel is in the hypopharynx. The food channel lies between the labrum and the hypopharynx. At the apex of the labium are the labella a pair of large, soft oval lobes.
The lower surface of these lobes bears numerous transverse grooves, which serve as food channels. The proboscis can usually be folded up against the lower side of the head or into a cavity on the lower side of the head. These flies lap up liquid food. This food may be already in liquid form, or it may first be liquidified by salivary secretions of the fly.

(vi) **Flea (Siphonaptera)** Type: These mouthpart types are similar to those of the mosquito but without mandibles. Adult fleas feed on blood. Their mouthparts contain 3 piercing stylets. The epipharynx and the laciniae of the maxillae. The labrum is a very small lobe on the upper surface of the head. It lies in front of the base of the epipharynx.

It is the epipharyngeal of the labrum that is elongated into piercing stylets. The maxillae consist of large plates or lobes. Each bears a piercing lacinia and a large palp.

The labium is short and slender. It bears short palps, the labium and its palps serve to guide the stylets. The hypopharynx is a small lobe like structure. It lies within the base of the beak.

The food channel is found between the epipharynx and the maxillary stylets. The salivary channel lies between the edges of the maxillary stylets.

(vii) **The Sucking Lice (Anoplura)** Type: The mouthparts of these insects are highly specialized. Therefore they are different to homologise with those of other sucking insects. There is a short rostrum. This is probably the labrum. It occurs at the anterior end of the head. From this structure 3 piercing stylets arise. The rostrum is eversible and it is armed internally with small recurved teeth.

The stylets are about as long as the head. When not in use, they are withdrawn into a long saclike structure lying below the alimentary canal. The dorsal stylet probably represents the fused maxillae. Its edges are curved upward and inward to form a tube. This tube serves as a food channel. The intermediate stylet is probably the hypopharynx. It is very slender and contains the salivary channel. The ventral stylet is probably the labium. It is the principal piercing organ. It is a trough-shaped structure. There are no palps.

**ACTIVITY 5.4** Answers are in the appendices

1. Fleas, tsetse flies and lice have sucking mouthparts what do you think they feed on? State their food source.
2. Why is it not possible to see the mouthparts of lice when they are not in use?
3. What kind of mouthparts do we find in the common house fly?
**Siphoning**

Siphoning is found in moths and butterflies. When feeding, the proboscis is uncoiled and extended. Nectar is sucked into the mouth or oral cavity. The proboscis is a modified maxillae.

In these mouthparts type, the proboscis is formed from the 2 maxillary galeae. These are enormously elongated with a medium groove. This groove forms a tube between the galeae when they are pressed together, forming the food channel. The two elements are held together by interlocking hooks and spines. Galeae are annulated externally and very flexible.

Fig. 5.12: Butterfly mouthparts

The labrum is reduced to a narrow transverse band across the lower margin on the face. The mandibles and hypopharynx are present in the adult. The maxillary palps are usually vestigial or absent. The cardo and stipes are reduced. The labium is usually represented by a small plate with usually well-developed labial palps. There is no special salivary channel.

This type of mouthparts structure is sometimes called siphoning-sucking. This is because there is no piercing. The insect merely sucks or siphons liquid up though the proboscis. When in use, the proboscis is uncoiled by blood pressure, it recoils by its elasticity.

### 5.5: ORIENTATION OF INSECT MOUTHPARTS

In a previous lecture, we learnt that the insect head had three different types of orientations in relation to the rest of the body. Similarly, the insect mouthpart is oriented in different ways in relation to the head. The two different types of mouthpart orientations are stated below:

#### 5.5.1: ECTOGANTHOUS MOUTHPARTS

When mouthparts are visible and exteriorly situated, they are known as ectognathous. Flies, fleas, grasshoppers, and butterflies are examples of ectognathous conditions.
5.5.2: ENDOGNATHOUS MOUTHPARTS

Endognathous mouthparts are enclosed within the head. Collembola and sucking-lice have this kind of mouthparts. Endognathous situation results from two conditions:

(I) Enclosed by skeletal flaps that grow around them, e.g. Collembola.
(ii) Enclosed by he process of invagination e.g. in Anoplura (sucking lice). They are also called crytoganthous.

5.6 VESTIGIAL MOUTHPARTS

A few adult insects have non-functional vestigial mouthparts. These insects cannot feed and have a very short adult life spans. Vestigial mouthparts are found in may flies.

SUMMARY

In this lecture we have learnt that:

- The two major insect mouthparts are the chewing and the sucking types.
- The grasshopper mouthpart can be representative of the typical chewing insect mouthpart.
- The basic chewing mouthpart is composed of the mandibles, the maxillae, the labium, the labrum and a tongue like hypopharynx.
- The chewing mouthpart has been modified in various insect groups to suit different types of feeding modes.
- Some insects such as the honey bee have a combination mouthpart suited for both chewing and sucking.
- The butterfly mouthpart has been modified to form an extremely elongate tube suited for sucking plant juices.
- Mouthparts of blood sucking insects such as mosquitoes have stylets which are needle-like projections suited for piercing tissues of man and animals to draw a blood meal.
- Mouthparts of house flies are described as lapping or sponging and can lap liquid food. Such flies can also liquefy their food with salivary secretions before lapping the material.
- Some predatory insects inject salivary secretions into their prey before sucking up the liquefied tissues.
- Endognathous insect mouthparts such as those found in lice are enclosed within the head and are not visible when not in use.
- Ectognathous insect mouthparts are visible exteriorly. Such mouthparts are found in butterflies, grasshoppers, fleas and most flies.
- Some insects such as mayflies have nonfunctional vestigial mouthparts.
ACTIVITY 5.5 These are important review questions whose answers are in the text above.
1. List eight different insects with different kinds of sucking mouthparts and explain the adaptive advantage insects derive from the fact that they have diverse types of mouthparts.
2. Compare and contrast the mouthpart of a butterfly with that of a grasshopper.
3. Describe with specific examples insects with endognathous; ectognathous and vestigial mouthparts.
4. Name six insect orders with chewing mouthparts.

SUGGESTED FURTHER READING:
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
LECTURE NUMBER SIX

6.0: THE INSECT NECK, THORAX AND LEGS

6.1: Introduction
6.2: The neck
6.3: The insect thorax
6.4: The typical insect leg
6.5: Various types of insect legs and their functions
6.6: Other functions of the insect leg
6.6.1: Sound production
6.6.2: Auditory organ
6.6.3: Gustatory
6.6.4: Silk production

6.1: INTRODUCTION

In the last lectures we have been studying the head and its appendages. In this lecture we will move to the neck and thorax. We shall learn the basic plates of the exoskeleton within the thorax. Next we shall note that within the thorax there are the legs and the wings, both of which are important locomotory apparatus for insects. The insect legs will be examined in this lecture while the wings will be studied in the following lecture.

After you have studied a typical insect leg, you will consider insect legs that have been modified to suit various modes of insect life.

In order to be able to see the basic components of the insect leg, you will require a hand lens, a pair of scissors or a sharp razor blade. You will also require either a cockroach or grasshopper.

OBJECTIVES

Upon completion of lessons in this lecture you should be able to:

- Briefly describe the insect neck.
- Name the main plates (sclerites) found in the thorax.
- List the three segments of the insect thorax.
- Illustrate the typical insect leg.
- Discuss different types of the insect leg including a running, jumping, grasping, digging, swimming and pollen carrying legs.
- Mention other functions of insect legs other than movement.

6.2: NECK
The neck or cervix of an insect is a membranous region. It links the head to the thorax. Lateral to the cervical membrane are the cervical sclerites. Typically, there are 2 on each side. Running through to the head are longitudinal muscles, dorsal muscles and ventral muscles. They serve to retract the head on the prothorax. Their differential contraction cause lateral head movements.

**THE INSECT THORAX**

The thorax of an insect is the middle region of the body. It consists of 3 segments: the prothorax, mesothorax and metathorax. In most insects all 3 segments bear a pair of legs each. Exceptions are larval Diptera, larval Hymenoptera, some larval Coleoptera and small number of adults. In addition, winged insects have a pair of wings on the meso and metathorax. For this reason, these 2 segments are collectively called pterothorax.

Each thoracic segment is composed of a number of sclerites. The entire arrangement of thoracic sclerites is for muscle attachment and provision of rigidity to thorax. Any of these sclerites may be identified on a particular segment by using the appropriate prefix, either pro-, meson-or meta-. For example the notum of the prothorax is called the pronotum. In grasshoppers, locusts and crickets; this structure is a large conspicuous saddle like plate between the head and the base of the wings. The nota of the mesothorax are often divided by sutures into 2 or more sclerites each. In winged insects, there are 2 principal notal sclerites: the alinotum and the postnotum. The former occupies most of the notum. The alinotum is divided into...
Each pleuron is divided into 2 sclerites by a pleural suture. The suture extends dorsoventrally between the base of the leg and the base of the wing. The anterior sclerite is the episternum, and posterior sclerite is the epimeron.

In a wing-bearing segment, the pleuron is produced into a pleural wing process at the upper end of the pleural suture. This process serves as fulcrum for the movement of the wing. There are usually one or two small sclerites, the epipleurites, in the membranous area between the pleuron and the base of the wing. These are important to the wing movements. Certain muscles that move the wing are attached to these sclerites.

Each sternum may be divided into 2 or more sclerites. The spiracles are slit like openings, one between the prothorax and the other one between the mesothorax and metathorax, on each side of the thorax. These are the external openings of the respiratory system.

**ACTIVITY 6.1**
1. How many segments are in an insect thorax? Name them
2. Name the sclerites found in the following areas of the insect thorax: dorsal side, ventral side and lateral side
3. Describe the position of the spiracles in relation to the insect thorax

**6.4:A TYPICAL INSECT LEG**

![Figure 6.2: A typical insect leg](image)
As it has already been noted, with a few exceptions, all insects have 3 pairs of legs. Each leg consists typically of 6 elements or segments: the coxa, the basal segment, the trochanter, a small segment following the coxa, the femur, the 1st long segment of the leg: the tibia, the second long segment of the leg, the tarsus, a series of small segments beyond the tibia, the first of which is post-tarsus consisting of the tarsal claws and other structures, at the end of the tarsus.

The coxa bears articulation with thorax. It is strengthened by a ridge called basicoxite. The trochanter is small and can only move vertically. Rarely in some insects (Odonata) may the trochanter be 2 segmented. They are immovable and fixed on each other. The femur is the largest leg segment in most insects. It is fixed on the trochanter without muscles to move it. The tibia is the long slender shank of the leg. It is joined with the femur in a way permitting the 2 segments to be drawn close together into a nearly parallel position.

The tarsus, in most insects, is subdivided into 1-5 tarsomeres, these subdivisions of the tarsus, do not have muscles of their own. Therefore, they are not true leg segments. Hence they are called sub segments or tarsomeres. The number of the tarsomeres in different insects is important for classification. The basal tarsomere is called the metatarsus. It articulates with the tibia. The rest have no articulation. The proximal tarsomere is the post tarsus. Muscles that move the tarsus come from the tibia to the metatarsus. In Protura and Collembola, the tarsus, is a single segment.

The post tarsus or pretarsus in Protura and Collembola is a single claw-like segment. In most insects, it consists of 4 elements:

1. A membranous base with a median lobe, the arolium.
2. A pair of claws articulating with a medium process of the last tarsomere known as the unguifer.
3. Ventrally is a basal sclerotised plate, the unguicurator.
4. Between this unguicurator and claws are small plates called auxillae.

In Diptera, a membranous pulvillus arises from the base of each auxillum. It may be a spine or lobe-like. Claws may or may not be equal in size.

**ACTIVITY 6.2** Answers are in the text
1. Diagrammatically illustrate the structure of a typical insect leg
2. State the significance of tarsomeres of the insect leg
3. Name the four elements of post tarsus
INSECT LEGS AND THEIR FUNCTIONS:

The insect legs may be variously modified in different insects. The various characters provided as a result of these modifications are of considerable importance in identification. The different segments of the leg may vary in size, shape or spination. For example as we have already seen, the number of tarsal segments varies in different insects. Some of the adaptations of locomotory legs in insects are described below;

1. Jumping or leaping leg
The hind leg of the grasshopper and locusts produces the leap when suddenly extended. Most of the power comes from the hind legs

![Figure 6.3: Jumping leg of a grasshopper](image)

2. Running or crawling leg
This kind of leg is illustrated below and is found in insects such as cockroaches
3. Swimming leg
Larval and pupal Diptera, larval and adult Heteroptera and Coleoptera form the bulk of free-swimming insects and most of these use the hind legs or the middle legs, in swimming. The hind tibiae and tarsi are greatly flattened to form an oar or paddle, which is greatly increased in surface area by inflexible hairs as in *Gyrinus* (Coleoptera). As shown on figure 6.5 above.

The hind leg of the hydrophilic beetle is provided with a fringe of (setae) which serve as oar for swimming. An unusual adaptation is found in the Geriddae, water striders. They belong to the order Hemiptera. The lightness of these on the middle tarsi, enable them to skim along on the water without breaking through the surface film.

4. Raptorial or grasping leg
For grasping prey, the fore leg of the praying mantis is equipped with a formidable array of spines along the opposing edges of the femur and tibia. A different device for grasping prey is found on the foreleg of the predaceous water bug *Naucoria* (Hemiptera). In this insect the tarsus is formed as a single sharply pointed segment. The bird louse
5. Digging leg

The digging fore leg of the mole cricket (Orthoptera) is one of the most striking adaptations of all. Short and strong, it is tipped by a hand-like arrangement of tibia and tarsus. Phasmids (Stick-insects) of the tropical family Phyllidae are dramatically adapted in shape and coloration to stimulate foliage. The femora and tibia have leaf-like expansions to contribute to the illusion.

![Digging leg of a mole cricket](image1)

![Raptorial leg of a praying mantis](image2)
The front legs have clusters of hairs that the worker bee uses to brush pollen from her body to the "pollen baskets" or corbicula that are on her back legs. The front legs have an extra joint and a comb that the bee uses to clean herself.

The middle legs are covered with stiff hairs that help the worker bee brush pollen back to the "pollen baskets" and remove pollen from the baskets upon return to the hive. The hind legs have "pollen baskets," or bare spots surrounded by stiff hairs. The hairs help hold the pollen in place. Nectar is often added to the pollen to make it clump. This makes it easier to transport in the baskets.

The antennae are drawn through this structure so that the fine hairs in the cavity remove pollen and other things clinging to them. Bees transport pollen to their hives by means of special equipment on the hind leg called the pollen basket or corbicula. The pollen basket or corbicula is part of the tibia on the hind legs of honey bees. A honeybee moistens the forelegs with a protruding tongue and brushes the pollen that has collected on head, body and forward appendages to the hind legs. First, the pollen is transferred to the pollen comb on the hind legs and then combed, pressed, compacted, and transferred to the outside surface of the tibia of the hind legs.

**Figure 6.8:** hind tibia and tarsus of honey bee, from inside and outside, showing the pollen collecting apparatus
The enlarged 1st tarsal sub segment (basitarsus) of each hind leg has a row of stiff setae known as scopa or pollen comb. Pollen adheres to the hairy bodies and legs of bees. It is then transferred to the pollen basket. The pollen collected on the combs of one side is then removed by the rake of the opposite hind legs and collects in the pollen press. By closure of the press pollen is forced outwards and upwards onto the outside of the tibia and is then held in place by hairs and spines of the pollen basket. On returning to the hive the pollen is kicked off by the middle legs into an empty cell.

If you were an insect, what kind of leg would you have preferred?

### ACTIVITY 6.3

Answers are in the appendices

Fill in the blanks in the following sentences

1. The pollen basket found in the fore tibiae of Hymenoptera is called aééééééééééééééé.

2. Water striders haveéééééééé.legs (digging, crawling, swimming)

3. Insects haveéééééé pairs of legs.

4. The large conspicuous saddle like plate between the insect head and the base of the wings is calledéééééééééééééééé (prota, pleura, pronotum)

5. The trochanter is two-segmented inéééééé (Diptera, Odonata)

6. The large terminal spur on the fore tibiae of Hymenoptera is calledéééééééééééééééé (coxa, calcar, radius)

### 6.6 OTHER FUNCTIONS OF THE INSECT LEG

#### 6.6.1: sound production

Certain functions in addition to locomotion sometimes are performed by legs. These are functions that require special structures or special adaptations of existing structures. One such extra function is stridulation. However, stridulation does always involve the legs. When a leg is used for this purpose, it has a roughened area. When this area is drawn across a ridge or projection on some conveniently located part of the body, it produces sound. In the Acrididae (Orthoptera) the males and females of a few species produce a buzzing sound when the hind femur is drawn across an enlarged vein of the forewing. In this family, the inner surface of he hind femur is usually has a row of pegs on the wing and the femur has a longitudinal ridge.

#### 6.6.2: auditory organ

An ėarô may be present on the tibia of many Orthoptera. The flat tympanum is some times uncovered and easily seen. The internal organization of this auditory apparatus is
6.6.3: gustatory
The tarsi of Diptera contain sensilla that can detect different food tastes

6.6.4 Silk production
Some insects have silk glands in their fore tarsi sub segments. Their legs are used to spin this silk either into a living house like in the Embioptera. In the male Empididae, the silk is used to enclose other animals for food which is often offered to the female as part of the mating ritual, sort of a bridge to ensure her co-operation.

SUMMARY
In this lecture we have learnt that:
- A neck or cervix is a membranous region that links the insect head to the thorax
- The thorax, which is the middle region of an insect has three segments namely, the prothorax, mesothorax, and metathorax. Each of these segments bear a pair of legs. Winged insects have the wings on the meso and metathorax.
- Each thoracic segment is composed of a number of sclerites
- The entire arrangement of thoracic sclerites is for muscle attachment and provision of rigidity to thorax.
- All insects have three pairs of legs and each leg has a cox, trochanter, femur, tibia tarsus and tarsomeres
- Insect legs have adapted to various habits such that there are jumping, running, swimming, grasping, digging and pollen carrying legs.
- Other functions of the insect leg include sound production, silk production and hearing (auditory organ)

ACTIVITY 6.4
1. Describe five several types of the insect leg
2. Name three functions of an insect leg apart from being a locomotory apparatus
3. State a unique feature of the stick insect leg
SUGGESTED FURTHER READING:
LECTURE NUMBER SEVEN

7.0: INSECT WINGS

7.1: Introduction
7.2: The insect wing
  7.2.1: Typical insect wing structure and texture
  7.2.2: Internal wing structure
  7.2.3: Wing venation
7.3: The Archedictyon insect wing
7.4: Various types of insect wings
  7.4.1: special structures in insect wings
7.5: Sound production by the insect wing
  7.5.1: Functions/ Significance of sounds produced by insects

7.1: INTRODUCTION
In the last lecture we discussed the insect legs within the thorax. The other thoracic appendage alongside the legs are the wings. In this lecture, we shall study the typical structure of an insect wing. We shall then progress to examine the more specialized insect wings found in beetles, stick insects, moths, thrips and lacewings. We shall note that some insects are wingless secondarily in that they have lost their wings in the course of evolution. In the last section of the lecture we shall observe that wings are used by insects to produce sound. A fossil insect wing will be mentioned in this lecture, find out its name!

In order to practically see the insect wing variations you will need a grasshopper a housefly, a butterfly, a beetle, a praying mantis, a bedbug, dragon fly, lacewing and an ant. Do not worry if you cannot get all these but try to get at least five of them. You will also require a hand lens.

OBJECTIVES

At the end of this lecture you should be able to :-

- Describe the typical structures of an insect wing
- Outline the system used in describing the insect wing veins and cells
- State the changes that the insect wing has undergone in the course of evolution
- Define and draw special kinds of wings such as elytra, tegmina, hemelytron, and halteres.
- Explain how insects use wings to produce sound.
- Understand that the success of the insects as terrestrial animals is at least partly due to their ability to fly.
7.2 : THE INSECT WING

All winged arthropods are insects, but not all insects have wings. The wings of insects are outgrowth of the body wall, which have been flattened. They are not modified appendages, as in birds and bats.

Most adult insects have two pairs of wings. The 1st pair is located on the mesothorax and the second on the metathorax. But some have only one pair. It is usually the mesothoracic pair. Flies and mosquitoes have one pair of wings. Wings can be prominent as in the lacewing and butterfly, or modified to be less obvious. The beetle's front pair of wings provide a hard or leather-like covering that protects the back pair when they are not being used.

In most insects, the wings are membranous. In other words, they are like cellophane and may bear tiny hairs (microtrichia) or scales or spines (macrotrichia). In some insects the forewings are thickened, leathery or hard and sheath like. Some wings are semitransparent; the typical semi-transparent wing is found in Dragon flies, bees and wasps.

Most insects are able to fold their wings over the abdomen when at rest. But the dragonflies, damselflies and mayflies cannot do this. They hold their wings either outstretched or together above the body when at rest.

It is important to note that the success of the insects as terrestrial animals is at least partly due to their ability to fly.

Functional wings exist only during the adult stage of an insect's life cycle. The wings develop embryologically as evaginations of the exoskeleton -- they may be membranous, parchment-like, or heavily sclerotized. Most insects have two pairs of wings -- one pair on the mesothorax and one pair on the metathorax (never on the prothorax). Wings serve not only as organs of flight, but also may be adapted variously as protective covers (Coleoptera and Dermaptera), thermal collectors (Lepidoptera), gyroscopic stabilizers (Diptera), sound producers (Orthoptera), or visual cues for species recognition and sexual contact (Lepidoptera).

7.2.1: Typical insect wing structure and texture

Wings are located dorsolaterally between the nota and pleura of the meso- and metathoracic segments. They arise as saclike outgrowths. But in the adult insect they are solid structures. The only cavities in them are the veins. The solid structures consist of two closely united layers of integument. The layers are then strengthened by sclerotised veins. The Fully developed and functional wings occur only in adult insects..

7.2.2 : Internal structure
7.2.3 : Wing Venation

Veins
Insect wings have venation, a system of thickened lines in the wing. In most cases, a characteristic network of veins runs throughout the wing tissue. These veins are extensions of the body's circulatory system. They are filled with hemolymph and contain a tracheal tube and a nerve. In membranous wings, the veins provide strength and reinforcement during flight. Wing shape, texture, and venation are quite distinctive among the insect taxa and therefore highly useful as aides for identification. The number and arrangement of the veins is of great taxonomic value. This is because there is considerable variation in the wing venation of different insects. For this reason, a system of terminology has been developed that is applicable to all insects. This is known as the Cosmstock (or Comstock-Needham) system, devised by John Comstock and George Needham.

The Comstock-Needham system recognizes eight major longitudinal veins, abbreviated by capital letters. Starting from the anterior margin of the wing they are: costa (C), subcosta (Sc), radius (R), medius (M), cubitus (Cu) and 3 anal (1A, 2A, 3A). The major veins have been illustrated on Fig 7.1 below:

![Fig 7.1: Hypothetical primitive insect wing](image)

**Key to major veins**

Costa (C) -- the leading edge of the wing
Subcosta (Sc) -- second longitudinal vein (behind the costa), typically unbranched
Radius (R) -- third longitudinal vein, one to five branches reach the wing margin
Media (M) -- fourth longitudinal vein, one to four branches reach the wing margin
A vein may have several segments or abscissae. They are delimited by the intersection of other veins, usually crossveins. Thus a vein that is intersected by two other veins has three abscissae, numbered consecutively from the base to the apex of the wing, e.g., when Cu has three abscissae, they are 1Cu (the basal portion of Cu), 2Cu and 3Cu (the apical portion of Cu). Vein abscissae may vary interspecifically, therefore 3Cu of one species is not necessarily homologous with 3Cu of another.

The branches of the longitudinal veins are named from anterior to posterior around the wing. The two branches of the subcosta are designated sc1 and sc2. The radius (R) gives off a posterior branch the radial sector (RS) usually near the wing's base. The anterior branch of the radius is R1. The radial sector forks twice, with 4 branches reaching the wing margin. The cubitus, L (CU2) according to authorities, CU1 forks again distally, the two branches being CU1 and CU2. according to some authorities, CU1 forks again distally, the branches being CU1a and CU1b. The anal veins are unbranched and are designated from anterior to posterior as the 1st anal (1A), 2nd anal (2A) and so on.

When a vein is branched the most anterior branch is given the subscript 1 and the more posterior branches the subscripts 2, 3,... This is done for all veins except R. When R branches the most anterior branch is called R1 but the second branch is called the radial sector (RS).

**Fusion of veins**

Two veins may fuse for part or all of their length, appearing as one vein. The resulting vein takes the name of both component veins joined by a plus (+) sign. For example, Rs and M are often fused for portions of their lengths. The fused portion is called Rs+M. Veins may fuse end to end so that it is impossible to know exactly where the first one ends and the second begins. In these cases the composite veins are joined with an ampersand (&). For example, in all Ichneumonidae and many Braconidae the first abscissa of vein RS+M is often completely lost and in these cases veins 1RS and 1M cannot be distinguished from one another: the composite vein is therefore termed RS&M.

**Crossveins**

Names of cross veins are based on their position relative to longitudinal veins: Cross veins, indicated by lower case letters, take the name of the veins they connect, with the anterior vein given first. Thus, a cross vein that connects R with M is r-m. If there are several r-m cross veins they take numerical values as well e.g. 1r-m, 2r-m, etc. If a crossvein joins two branches of the same vein the crossvein takes the name of the major longitudinal vein, e.g. a crossvein between R1 and Rs is called r. This simplification is possible due to the rarity of this type of crossvein.

The cross veins are named accordingly to their location in the wing or the longitudinal veins they connect. The humeral cross veins (h) is located near the wing base, between...
The radial cross vein \( r \) connects \( R_1 \) and the anterior branch of the radial sector. The sectorial cross vein \( s \) connects \( R_3 \) and \( R_4 \). The radio-medial cross vein \( r-m \) connects the posterior branch of the radius and the anterior branch of the medial vein. The medial cross vein \( m \) connects \( M_2 \) and \( M_3 \). The medio-cubital cross veins \( m-Cu \) connects the posterior branch of the media and the anterior branch of the cubits. The cubitoanal cross vein \( Cu-a \) connects the posterior branch of the cubits and the and the first anal vein.

**Wing cells.**

The spaces between the veins are called cells. Each cell is named using the name of veins forming the anterior and posterior boundary veins. e.g. the spaces between 2nd and 3rd medial branches are named either as \( M_2 \) or \( M_2-M_3 \). Cells may also be designated by descriptive terms, indicating position. e.g. distal cell, marginal cell and so on.

Wing cells, abbreviated with capital letters, take the name of the vein lying anterior to them. If several fused veins form the anterior boundary of a cell, the cell takes the name of the vein that is theoretically most posterior. Thus, the cell posterior to \( C+Sc+R \) is the radial cell \( R \). If more than one cell is directly behind a vein, the cells are numbered consecutively from the base of the wing, e.g. three medial cells would be 1M, 2M, and 3M.

**ACTIVITY 7.1**

Using either a grasshopper of a dragon fly or both, carefully remove the fore and hind wings from the base. Lay each one on a flat surface preferably a glass surface. Make careful drawings of both the fore and hind wings. Try to identify the cells and veins described under section 7.2. 3 above.

**7.3: THE ARCHEDICTYON INSECT WING**

The *Archedictyon* is the name given to a hypothetical scheme of wing venation proposed for the very first winged insect. It is based on a combination of speculation and fossil data. Since all winged insects are believed to have evolved from a common ancestor, the Archedictyon represents the "template" that has been modified (and streamlined) by natural selection for 200 million years. According to current dogma, the Archedictyon contained 6-8 longitudinal veins.

Fossil insects show that the primitive insect wing had areas between longitudinal veins (cells) densely reticulated. Such a wing is known as the Archedictyon. The Archedictyon persists at the base of the forewings of grasshoppers, Ephemeroptera and in Odonata (dragonfly).
ACTIVITY 7.2
Respond to the following statements by writing YES or NO answers are in the appendices.

1. All winged arthropods are insects, but not all insects have wings
2. Flies and mosquitoes have two pair of wings
3. Orthoptera and Ephemeroptera have wing venation close to fossil insects.
4. The primitive insect wing that is densely reticulated is known as the Archecdyton
5. The number and arrangement of the veins is of great taxonomic value
6. A broad evolitional trend among insects is complication of the wing by increase in venation
7. The spaces between wing veins are called cells
8. Insect wings are located in the abdomen
9. The Archecdyton wing has persisted in the present day Fruit fly (Diptera).
10. The Comstock-Needham system is a system of letters and numbers for naming various parts of the insect wing.

7.4: VARIOUS TYPES OF INSECT WINGS
A broad evolitional trend among insects is simplification of the wing venation. This has occurred in 2 ways: first, by the strengthening of the anterior margin. Second, by reduction of veins in the rest of the wing. The wing of Ephemeroptera Orthoptera and Odonata are closest to the fossil insect wing. At the other end of the scale, are some Hymenoptera (suborder- Chalcidoidea ) whose wings have only the subcosta and part of the radius left.

In between, there are numerous modifications with regard to wing venation. The majority of insects have lost the anterior medial veins. In addition to variation in wing venation
1. Wings with patterns, scale or hairs

Scaly wings: front and hind wings covered with flattened setae (scales).

Some insects have membranes patterned by pigments contained in the epidermal cells, e.g., Mecoptera and Tryptidae. Some insects have wings clothed with scales, e.g., Lepidoptera (Butterflies and Moths). The wings of butterflies and moths are not membranous. Rather, they are covered with small dust-like scales. Pigments in the scales are responsible for the colours of many Lepidoptera. If the scales are removed, even bright butterflies lose their colors.

The wings of caddis flies are clothed with hair-like structures. Hairs and scales occur on wing membranes. Microtrichia are no-inverted spines on the wing membrane. Machrotrichia are inverted sensory hairs confined to wing veins; except in Trichoptera they occur also on wing membrane.

2. Elytra

Elytra is the hard, sclerotized front wings that serve as protective covers for membranous hind wings.

Fore wings of beetles (Coleoptera) and Dermaptera that are hardened and heavily sclerotized are called elytra. They protect the inner hind wings and the insect body. In some Coleoptera, elytra are fused along the dorsal line. In these, flight is impossible. In Staphylinidae (Coleoptera), elytra are shortened covering only the abdomen.

3. Tegmina

The hardened (sclerotized fore wing of a grasshopper or locust is called Tegmen, plural tegmina. Such front wings are completely leathery or parchment-like in texture.
4. Hemelytra
A variation of the elytra is the hemelytra. The forewings of Hemipterans are said to be hemelytrous because they are hardened throughout the proximal two-thirds, while the distal portion is membranous. Unlike elytra, hemelytra function primarily as flight wings. These are the front wings that are leathery or parchment-like at the base and membranous near the tip found in Hemiptera and Heteroptera. In Heteroptera, only the basal part of the forewing is sclerotized. The distal parts remain membranous. Such a wing is called hemelytron.

5. Halteres and the Dipterans wing
Halteres are small, club-like hind wings that serve as gyroscopic stabilizers during flight.
Diptera use only forewings in flight. The hind ones are reduced to tiny articulating knobs called halteres. They are used as balancers during flight.

6. Fringed wings
Wings of Thysanoptera are peculiarly reduced. Each consists of a flattened rod with heavily fringed with long setae. **Fringed wings** -- slender front and hind wings with long fringes of hair.

7. Brachypterous wings
In some insect order, one or both pairs of wings are short. They are called brachypterous wings. Such a wing is found in stick insects as shown below and also in the praying Mantis.

8. Hairy wings
Tricoptera have front and hind wings clothed with setae (hairs).
Have you ever come across a stick insect or a praying mantis? If not look for one so that you may see this type of wing!

9. Lace like wings

The lace wings (Neuroptera) take their name from the many cross veins in the wings. The four wings are alike and membranous with many cross veins giving the appearance of lacy material as shown below:

10. Wingless insects

Some insects - such as the ants and termites - are wingless. Wingless insects are found in nearly every order. Social insects e.g. ants (Hymenoptera) and termites (Isoptera), frequently are wingless. Their adult sexual forms are winged. But after mating flight and migration to a new colony site, wings are dropped. But the lack of wings in termite worker soldier castes is embryological. True adult wingless insects are found in parasitic forms. E.g. bedbugs *Cimex* (Hemiptera), all members of Anoplura, Mallophaga and a Siphonaptera. Their wingless is secondarily acquired. They are descended from winged ancestors. Grylloblattioidea are the adult wingless non-parasitic group.

7.4.1: Special wing structures

1. Hamuli: Hymenoptera have tiny hooks on their hind wings that hold front and hind wings together. These hooks are known as hamuli.
2. **Frenulum**: Lepidoptera have a bristle near base of hind wing that holds front and hind wings together. The bristle is known as a frenulum.

**ACTIVITY 7.3**

1. Name three different types of wingless insects
2. Describe the type of wing found in
   - A Thrips (Thysanoptera)
   - B Lace wings (Neuroptera)
   - C Stick insects (Phasmida)
   - D Moths and butterflies (Lepidoptera)
3. Define the following terms: A Hemelytron, B Elytron, C Halteres, D Tegmen
4. State a major difference between the insect wing and that of a bird.
In various groups of insects, the wings are modified for sound production and they may be retained for this function when they are no longer used in flight.

Started ridge along the edge of are rubbed by a ridged area on the hind femur to produce sound in same coleopteran.

Some Lepidoptera produce sound by rubbing veins on the wings. In most Orthoptera e.g. crickets and sound is produced by rubbing the hind femora against the elytra. In crickets each species has a number of different songs used in different situations.

7.5.1 Functions/ Significance of sounds produced by insects
The sounds produced by insects can be classified according to whether they represent signals to other species, that is they are extraspecific, or whether they are signals to other members of the same species, that is they are intraspecific. Extra specific sounds are usually unorganized having no regular pulse repetition frequency and covering a broad spectrum of frequencies. Usually they are produced by both sexes and sometimes even the immature stages. Such sounds include stridulation and are concerned with defense or alarming others of a potential predator or alarming the predator. Sound mimicry is also common amongst insects of different species. Intra specific sounds serve the following purposes:
Calling, courtship, copulation, territoriality (aggression and alarm). Aggressive stridulation is well illustrated by crickets. Each male oecanthus has a territory of some 50 sq. cm. In which he sings his normal song. If another male cricket intrudes the male sings an aggressive song quite distinct from other songs and the intruding males replies. Fighting may occur and the dominant male maintains the territory. Aggressive stridulation has the effect of spacing males over the largest possible area and at the same time reduces the interference during mating. Similarly the alternation of singing in some species may help an approaching female to locate the male. In bees sound together with visual cues indicate the distance of food source to other members of the same colony.

SUMMARY
In this lecture we have learnt that:

- The primitive insect wing was densely reticulated like the wing of the present day dragonfly. With time the wing became simpler with decreased venation.
- The primitive insect wing is known as the "Archedictyon".
- All winged arthropods are insects but not all insects have wings. Wingless insects include fleas, lice, bedbugs, ants, and certain termite castes.
- Wings, just like the legs are thoracic appendages that arise from the meso and metathoracic segments.
- The structure of a typical wing can be described by referring to the wing veins and cells using letters and numbers, based on the Comstock Needham system.
Insect wings vary in number, size, texture, and venation. Apart from the flies (Diptera), that have one pair of wing, all the other winged insects have two pairs of wings. The second pair of the Dipteran wing has been reduced to a knob-like structure called halteres.

- Unique wings exist among certain insect groups as follows: moths and butterflies have wings with scales. The scales and hairs are responsible for the colorful wings seen in these insects. Stick insects and praying mantis have reduced wings that are referred as Brachypterous. Thrips have fringed wings, while lace wings have wings with cross veins that give a lace-like appearance. Beetles and grasshoppers have the fore wings sclerotized and such wings are called elytra and tegmina respectively. The plant bugs (Heteroptera) have a type of wing called the hemelytra.
- The rubbing of certain parts of the insect body against the wings can result in sound production.
- Possession of wings has contributed to the success of insects. We shall mention this in a later chapter.

ACTIVITY 7.4
1 Describe how insects use their wings to produce sound
2 Explain why the possession of wings is advantageous to insects
3 State the significance of learning the detailed insect wing structure

SUGGESTED FURTHER READING:


LECTURE NUMBER EIGHT

8.0: THE INSECT ABDOMEN

8.1: Introduction
8.2: The Abdomen
8.3: Abdominal appendages
   8.3.1: Primitive abdominal appendages
   8.3.2: Abdominal appendages in immature insects

8.1: INTRODUCTION
In lecture six and seven above, we studied the thorax and its appendages. Let us remind ourselves that the thorax is the second body part of an insect after the head. The third body part after the thorax is the abdomen. In this lecture we shall examine the abdomen of a grasshopper or locust by way of study notes as well as illustrations. You will be expected to construct as many as three illustrations of the abdomen of three different insects. You will need a hand lens and three different insects that are available in your surroundings.

OBJECTIVES
The objectives of this lecture are to:
- Illustrate the insect abdomen to show the arrangement and number of the abdominal segments.
- Compare and contrast the abdomen of two different insects.
- Differentiate a female from a male insect using the external genitalia within the abdomen.
- Examine, draw and label all the basic structures found in the abdomen of a male and female insect.
- Identify abdominal appendages, where applicable and define their functions.
- Describe the abdomen and abdominal appendages found in certain immature insects.

8.2: THE INSECT ABDOMEN
The abdomen is composed of nine to eleven segments, but the eleventh segment is complete only in Proturans and in embryos. The abdominal segments are more equally developed than are those of other regions of the body. The tergites and sternites are usually simple, undivided plates whilst the pleura are membranous. In some Diptera the tergites may be so strongly developed as to encircle the sternites completely so that they are hidden from view; this allows the abdomen to expand after a large meal, or when eggs are developing. The telson is vestigial, the only abdominal appendage in adult insects are a terminal pair of sensory cerci borne on the eleventh segment. As shown on the diagram below. The abdomen contains the organs of digestion, reproduction,
Fig. 8.1: A typical insect abdomen

ACTIVITY 8.1: self evaluation

Using either a grasshopper or locust, examine the abdomen.
How many tergites do you find?
How many sternites do you find?
Towards the base of the first tergite on each side you will find the **tympanum**, a large ear drum or auditory membrane.
Can you find the spiracles?

The **cerci** (singular circus) are slender appendages found posteriorly. They resemble little horns and are found on both males and females. The **male** genitalia are terminal but are largely enclosed. The **female** has a conspicuous ovipositor. The ovipositor consists of a pair of dorsal and ventral valves. These valves are moveable and are used by the female for digging a hole in the ground in which eggs are deposited.
Having learnt all these, can you identify the sex of your specimen?

The anus and reproductive organs are at the apex of the abdomen. The male usually possesses a median intermittent organ and a pair of claspers, which help to grip the female during copulation. The complexity of the external male genitalia varies widely and their structure is often of great taxonomic importance.
In the female the external genitalia consist typically of three pairs of processes, which form together an egg laying organ called the **ovipositor**. In bees and wasps this is modified to form a **sting** organ. On the abdomen there usually ten pairs of spiracles which open into the tracheal system. The first segment of the abdomen in insects such as the grasshopper bears on each side an oval tympanic membrane that covers the auditory sac of hearing.
ACTIVITY 8.2; self evaluation

Using a hand lens, examine the lateral sides of your insect. Describe the structures that you see. Can you locate slit-like openings on either side of the abdomen? These are the spiracles! Do you know their function? If you do not their function there is no cause for alarm. You will learn more about them in a subsequent lecture.

8.3 : ABDOMINAL APPENDAGES
Insects are believed to have originated from some myriapod-like ancestor with a pair of typical walking legs on each abdominal segment.

Typical legs found on the thorax never occurred in the ancestral insect. Some abdominal appendages occurring in present time insects are secondary structures, which have developed quite independently of the primitive appendages. Primitive appendages on segment 8 and 9 have been modified as external genitalia. In some female insects there is an egg laying structure in the posterior abdominal appendages. This enables the female to insert her eggs into special situations, within plant or animal tissue. This structure is the ovipositor.

Appendages are absent from pregenital segments of the abdomen of adult winged insects except in the wingless groups.

There are pairs of appendages on each of the first three segments of Protura. These function as locomotory organs.

8.3.1: Primitive abdominal appendages

Cerci
Appendages of segment 11 form a pair of structures called Cerci, which arise from the membranes between the paraproct and epiproct. In cases where segment 11 is absent cerci arises from segment 10. Cerci is present in wingless insects and hemimetabolous orders other than Hemiptera.

Among the holometabolous insects only order Mecoptera have cerci.

Cerci variations
Cerci may be simple unsegmented structures as in Orthoptera or annulated as in Dictyoptera. Some are forceps and pincer like. Cerci may be very short and barely visible or extremely long or even longer than the insect body as in Thysanura, Ephemeroptera and Plecoptera. Even within a family the range and form of cerci vary considerably. Some cerci are featherlike as in Ephemeroptera Prosopistoma.

Sometimes cerci are different in two sexes of a species suggesting that they play a role in copulation e.g. cerci of female Calliptamas (Orthoptera) are simple cones but in the male they are elongate flattened structures with two or more lopes at the apex and armed with strong pointed structures. Similar dimorphism is found in the Embioptera where the left male circus is asymmetrical forming a clasping organ.

Functions of Cerci

Movement ĭ Ceri of Prosopistoma sp beat against water to produce a forwards driving force:

Respiratory ĭ In larval insect groups e.g. Zygoptera cerci are modified to form gills. These are known as tracheal gills or caudal lamellae. Larval Zygoptera also have tracheal gills.

Food gathering ĭ Forceps ĭ pincers like cerci of Japygidae are used in catching prey.

Copulation ĭ In Orthoptera and Embioptera cerci are used by males as claspers to hold onto the females.

Sense organs ĭ Cerci are usually armed with trichoid sensilla. These sensilla are sensitive to tactile stimuli and to air movement and sometimes may act as sound receivers.

Defense - against enemies?

Note that adult Thysanura and Ephemeroptera ĭ have median caudal filament, which resembles cerci.

ACTIVITY 8.3

Respond to the following statements by writing YES or NO. Answers are in the appendices.

1. Tergites are the plates found on the ventral (underside) of the insect abdomen.
2. The abdomen enclose the organs of digestion, reproduction, circulation and Excretion.
3. The only abdominal appendage in adult insects are a terminal pair of cerci.
4. There are no spiracles in the abdomen of a terrestrial adult insect.
5. Abdominal appendages are present in aquatic larval forms as gills.
6. In some insect groups prolegs are modified into defense apparatus.
7. The abdomen is the second part of the insect body after the head.
8. Sternites are plates found laterally on the insect abdomen.
2. Furca and Retinaculum
Arising from the posterior end of the third and the fourth abdominal segment of many Collenbola is a structure called furca and retinaculum. These are used for locomotion.

3. Adhesive tubes
From the first segment a median lobe projects between the last pair of legs. This lobe is the ventral tube. These tubes have two functions, as adhesive organs enabling the insect to walk over smooth or steep surfaces. The second function of these tubes is the absorption of water from substratum.

4. Styli
Segments 1-9 of members of Thysanura are some pairs of small unjointed styli each inserted on a basal sclerite associated with the Styli. These styli act as an eversible vesicle in Diploura. The styli function as locomotory organs while the vesicles in collembola can absorb water from the substratum.

5. Cornicles
Aphids have a pair of tubes known as cornicles, projecting from the dorsum segment 6. They function to permit the escape of a waxy fluid, which protects the aphid from predators.

8.3.2: Abdominal appendages in immature insects
A variety of abdominal appendages serving different functions are present in many insect larvae. Abdominal appendages present in the larval forms of holometabolous insects and other diverse aquatic larval forms are outlined below:

1. Tracheal gills
Gills are present on the abdomen of larvae of the following insect groups.

1. Ephemeroptera: gills six or seven pairs of gills on first two or three abdominal segments.

2. Plecoptera: Gill tufts present in the anal region of the abdomen of *Sialis*.

3. Megaloptera: seven pairs of five segmented gills, each arising from the basal sclerite on sides of the abdomen and terminal filament arising from abdominal segment 9.

4. Tricoptera: Larval Tricoptera have filaments gills on the dorsal lateral and ventral sides.

5. Coleoptera: Similar but unsegmented gills occur in larvae of some larval Coleoptera.

6. Larval Zygoptera: have a median terminal gill on the epiproct.
2. Prolegs
Holometabolous larval ï possess leg-like outgrowths of the body wall. These are called prolegs. Normally they are armed with spines or crochets, which grip the substratum.

Prolegs also serve to hold onto prey in some diptera e.g. larva of Vermileo lives in a pit of dry soil. It lies ventral side up and prey which fall into the pit are quickly grasped against the thorax using the prolegs.

Diversity of prolegs indicates that they have evolved along separate lines to serve various functions.

Well developed prolegs are also found in lepidopteran larval which usually have a pair on each abdominal segments 3-6, & 10 climbing forms have prolegs pointed out, and suitable for grasping onto twigs.

Even within the order Lepidoptera, the larval prolegs vary in position and number prolegs are also absent in some free living forms and in some leaf mining larvae prolegs are also absent. Some prolegs in other insect groups totally lack crochets. When prolegs are not well developed their position is occupied by a raised pad armed with spines called creeping welts.

In some insect grubs prolegs are modified for defensive purposes. In Cerura sp. the prolegs are slender projections. If larvae is touched the tip of the abdomen projects forward a slender pink process is everted from the end of each projection.

Prolegs are common in larval diptera. Some Diptera larvae even possess several prolegs on each abdominal segment.
Larval Tricoptera—possess anal prolegs on segment 10. They terminate in a claw, which enables the larvae to hold on to its larval case.

Have you come across a caterpillar? It has prolegs.

3. Suckers
Larvae of some insect groups possess suckers which enable them to maintain their position along the sides of waterfalls, fast flowing streams and other turbid environments.

Some larval Coleoptera have a pair of processes called Urogomphi, which are outgrowths of the tergum of segment 9.

4. Anal papillae
In larval mosquitoes and chironomids a group of papillae surrounds the anus. These papillae are concerned with salt regulation. In larval Sphingidae, a terminal spine arises from dorsum of abdominal segment 10.

SUMMARY
- The ancestral insect had abdominal appendages, which were lost in the course of evolution.
- Abdominal appendages occurring in present time insects are secondary structures, which have developed quite independently of the primitive appendages.
- Tergites are the plates found on the ventral (underside) of the insect abdomen.
- Sternites and pleurites are plates found ventrally and laterally on the insect abdomen respectively.
- The abdomen enclose the organs of digestion, reproduction, circulation and excretion.
- The abdominal appendage in adult insects are a terminal pair of sensory cerci.
- Cerci is a primitive appendage arising from the 10th or 11th abdominal segment of wingless insects and hemimetabolous insects other than Hemiptera.
- Arising from the posterior end of the third and the fourth abdominal segment of many Collembola are a structure called furca and retinaculum; these are used for locomotion.
- The anus and reproductive organs are at the apex of the insect abdomen.
- Abdominal appendages are present in aquatic larval forms of Tricoptera, Plecoptera and Ephemeroptera as gills.
- Prolegs are abdominal appendages found in immature stages of some terrestrial insects. Some larval Coleoptera have a pair of processes called Urogomphi, which are outgrowths of the tergum of segment 9. Aphids have a pair of tubes known as cornicles, projecting from the dorsum segment 6.
In female insects, the external genitalia consists of three pairs of processes which form together an egg-laying organ called the ovipositor.

- In bees and wasps the ovipositor is modified to form a sting organ.

**ACTIVITY 8.4 Answers in the text above**

1. Describe the following, naming the particular insects that have them; Urogomphi, Cornicles, Crochets, and Prolegs
2. Write short notes on Furca and Retinaculum
3. List four functions of the insect cerci
4. State the taxonomic significance of the external genitalia in insects

**SUGGESTED FURTHER READING:**

1.0 FEEDING MODES AND THE DIGESTIVE SYSTEM

9.1: Introduction
9.2: Insect feeding modes
  9.2.1: Plant feeders
  9.2.2: Predators
  9.2.3: Saprophagous insects
  9.2.4: Parasitic insects
  9.2.5: Trophallaxis
9.3: The insect digestive system
  9.3.1: The foregut
  9.3.2: The midgut
  9.3.3: The hindgut
9.4: Other structures associated with the insect gut

9.1: INTRODUCTION

In all the previous lectures we have been examining the insect external structures starting from the head to the abdomen. We have completed studying the external morphology. We shall now start studying the internal systems.

We shall start with feeding systems and the digestive system.

Remember that in lecture eight we learnt that the insect abdomen encloses certain organs such as the digestive system and other systems. In order to accomplish certain tasks in this lecture you will need ordinary pins, a rectangular tray, large enough to hold a freshly killed grasshopper or cockroach, a sharp pair of scissors, forceps, clean water and a hand lens.

Before we study the digestive system we shall first study the various ways in which insects feed.

OBJECTIVES. At the end of this lecture you should be able to:-

- Cite with specific examples, the various ways in which insects feed.
- Draw and label the various parts of the generalized insect digestive system, starting from the mouth to the anus.
- Describe the functions of the insect buccal cavity. Oesophagus, pharynx, crop, proventriculus, ventriculus, ileum, rectum and anus.

9.2: INSECT FEEDING MODES
Insects feed on a very wide variety of animal, vegetable and dead organic materials. The wide variety of foods has contributed to their success in that it enables them to exploit a wide range of habitats.

Insects have adapted to all types of diets. The mouthparts are therefore highly modified to suit different types of feeding habits and this was already discussed in lecture number five. The finding and recognition of such food involves various mechanisms depending on the insects. In most insects, vision and olfaction plays an important role in food finding. Feeding and ingestion involves modifications of mouthparts and physiological adaptations in various groups. Fluid feeders for instance often inject enzymes into the food and in blood sucking insects, an anticoagulant may be injected. Predacious insects restrain their prey by force or by means of venom injected with the saliva or via a sting. A few insects grow fungus food and social insects go a step further and even store food and feed one another! There are four broad categories of the feeding modes (habits) of insects as follows:

9.2.1: Plant feeders

Nearly half of the species of insects feed on plants. Plant feeders may further be divided into two categories:

(a) Phytophagous – Those feeding on green plants.
(b) Mycetophagous – Those feeding on fungi.

Phytophagous insects are predominantly: Orthoptera, Lepidoptera, Homoptera, Thysanoptera Phasmida, Isoptera, Coleoptera (families calambcidae, Curculiomdae and chrysomelidae) Hymenoptera (symphyta) and some Diptera. Most of these feed on higher plants but the aquatic larvae of some Plecoptera, Tricoptera and Ephemeroptera feed on algae. Fungus feeding larvae are common amongst Diptera. Dung/feeder include various Coleoptera, termites, the termites cultivate their fungi. You will learn more about this in lecture eighteen.

9.2.2: Predators

Some predators occur in a number of the insect orders. Some insects are partially predaceous while others are predominantly predaceous. Predominantly predaceous groups are Odonata, Dictyoptera (manntodea), Heteroptera (reduviidae e.g. assassin bugs), larval Neuroptera, Mecoptera, Diptera and Hymenoptera. These predaceous groups feed mainly on other insects, but larval Lambyridae for instance, prey on snails.

9.2.3: Saprophagous

In these insects, larval food is quite different from the food of the adult insect. Decaying organic matter is a common source of food. Predominantly Saprophagous insects are larvae of Diptera and Coleoptera. In this habit of feeding, fungi may also form an important part of the diet.
Parasitic – Insect parasites may live on the outside (ectoparasites) or inside (endoparasites) of their hosts. Insect **Ectoparasites** comprises of the following:-

(a) All Siphonaptera

(b) All Mallophaga and Anoplura

(c) Some Heteroptera e.g *Cimex* sp. and some Reduviidae

(d) Various Diptera such as mosquitoes, black flies, biting midges and gnats, sand flies, horseflies and some Muscidae. Many of these suck vertebrate blood. In some cases such as mosquitoes and horse flies only females suck blood. In other cases as in tse-tse flies and stable flies, both sexes suck blood. Blood sucking insects are known as haematophagous insects.

Insect **Endoparasites** comprises of the following:-

Internal parasites, most of which are parasitic only as larva are found in the following insect groups

Diptera (warble flies, bot flies, blow flies, flesh flies) Internal parasites are also found in some Hymenoptera and Strepsiptera

**ACTIVITY 9.1**

1. List the four broad categories of feeding modes in insects.
2. Mention a group of insects that cultivate their food.
3. State the sex(s) that suck vertebrate blood in these flies:
   (a) Tse-tse flies
   (b) mosquitoes

3. Define the following terms with specific insect examples:
4. (a) Phytophagous

   (b) Mycetophagous
   (c) Saprophagous
   (d) Predation
   (e) Parasitism
Quite often in social insects, mutual exchange of food occurs, such behavior is known as *trophallaxis*.

Social feeding occurs in Hymenoptera e.g. bees, warps, ants and in a few non-social insects. During courtship, Empidae (Diptera) male present food to females.

Do you think trophallaxis is a good idea?

### 9.3: THE INSECT DIGESTIVE SYSTEM

The insect digestive system is also known as the alimentary canal or the gut. The alimentary canal comprises of three regions, **foregut, midgut** and **hindgut** as shown on Fig 9.1 below:

Various parts of the gut may become modified anatomically and physiologically to perform various functions depending on the diet of the insects.

The foregut is commonly concerned with the storage of food and fragmentation of food into smaller particles before it passes to the mid gut.

The mid gut, which is lined by a delicate membrane, is primarily concerned with the production of enzymes and absorption of the products of digestion.

In some fluid feeding insects such as Heteroptera and Homoptera the gut has been modified to provide for rapid eliminations of the excess water taken in.
The midgut, also called the ventriculus or stomach, is usually tubular. Most insects possess outpocketings of the midgut called gastric caeca.

The position of the gastric caeca varies with groups, but they are commonly located at the anterior end of the midgut.

The hindgut or proctodeum consists of an anterior intestine (ileum) and a posterior rectum. Both of which are lined by cuticle. The hindgut conducts undigested material to the exterior via the anus but it also maintains the water and salt balance.

Digestion of cellulose by termites and certain wood-eating insects is made possible by the action of enzymes produced by protozoans, which inhabit the hindgut. Acetic acid formed by the breakdown of wood is actively absorbed by the hindgut epithelium in such insects.

The length of the gut is roughly correlated with the diet; insects feeding largely on protein diet tend to have a shorter gut than those feeding largely on carbohydrates although this is not always the rule.

**ACTIVITY 9.2**

1. Name two words that are used to refer to the digestive system.
2. Describe the three regions of the insect gut.
3. State the other names for ventriculus and proctodeum respectively.
4. Explain how cellulose is broken down in the gut of termites.
5. Indicate why the insect gut may not be exactly the same in structure among all insect groups.

### 9.3.1. The Foregut

1. **Pharynx**
   The pharynx is the 1st part of the foregut after the buccal cavity. The pharynx has a series of dilator muscles inserted into it. These muscles are best developed in sucking insects especially Lepidoptera and Hymenoptera where the pharynx functions as a pump.

2. **Oesophagus.** The oesophagus is an undifferentiated part of the foregut serving to pass food from the pharynx to the crop.

3. **Crop**
   The crop is an enlargement of the foregut in which food is stored. When not filled with food in some groups e.g. cockroaches it is filled with air in some fluid feeders. It is a lateral diverticulum. In general, secretions and
4. Proventriculus

The proventriculus is a part of the foregut and is quite variable in structure and function. In insects that eat solid food, the proventiculus is usually modified as a gizzard and bears teeth or hard protuberances (teeth) for macerating and shredding food.

In fluid feeders it could be absent or present in the form of a simple valve opening into the mid gut. It thus retains food in the crop while permitting the forward passage of enzymes in some insects.

In between the extremes are some butter flies and honey bees in which the proventriculus has been specialized to form a regulatory function. It permits fluids and not solid food to enter the mid gut. This function is particularly important in the separation of pollen from nectar in bees.

9.3.2. The midgut

The midgut consists of the

- ventriculus, where most digestion is carried out
- gastric caeca which, if present provide greater area for digestion and absorption.
- peritrophic membrane; a semi-permeable membrane or matrix composed of chitin, and proteins. The membrane surrounds the food bolus and protects insects’ gut from abrasion and invasion by micro organisms and parasites but facilitates the digestive process by being permeable to digestive enzymes.

9.3.3: The hindgut

The hind gut consists of the

- ileum or anterior hindgut
- rectum

Both these areas reabsorb water and salts.

Valves are present to prevent back-flow of material within the gut

- cardiac (stomodeal) valve between fore and mid gut
- pyloric valve between mid and hindgut
ACTIVITY 9.3: self evaluation

Using a locust, grasshopper or cock roach carry out a dissection as follows:-

1. Cut off the legs and wings.
2. Dissect from the dorsal side
3. Make a longitudinal cut along the mid-dorsal line from the head to the posterior end of the abdomen. The trachea system will be visible as shiny white tubes.
4. Dorsally near the posterior part of the abdomen you will find the reproductive organs, testis in males and ovaries in females. Remove these.
5. Using forceps or a blunt pin carefully expose the gut by pushing aside remove the reproductive structures fat tissues and parts of the trachea.
6. Once the internal organs are exposed place the specimen inside a waxed bottom tray containing water.
7. Trace the gut from the head region to the anus.
8. Identify all the parts mentioned under section 9
9. Draw, label fully and compare your drawing with figure 9.1 above.

Take note: Once you are through with the digestive system remove the entire system from the body cavity. You will then see the double the ventral nerve cord.

9.4: OTHER STRUCTURES ASSOCIATED WITH THE INSECT GUT.

- The gut is innervated by motor nerves, which control the movements of the gut and the passage of food along it.
- Various glands, associated with the mouthparts function mainly in the production of saliva. Most insects possess a pair of salivary or labial glands. These lie below the mid gut and have a common diet opening into the buckle cavity. In addition to salivary glands, some insects possess mandible glands.
- The long, slender Malpighian Tubules of the excretory system are attached to the junction of the midget and hind gut.

SUMMARY
In this lecture we have learnt that :
- Insects have various modes of feeding, a phenomenon, which has greatly contributed to their success as it, has enabled them to exploit varied food sources.
- There are four broad categories of feeding habits, namely predation, parasitism. Saprophytic feeding and phytophagous feeding
- Some insects such as termites cultivate fungus!
- Insects engage in mutual exchange of food, a process known as trophallaxis.
The insect gut has three major parts; the fore gut, mid gut and hind gut.

- The fore gut comprises of the mouth pharynx, oesophagus, crop and proventriculus.
- The mid gut comprises of a long tube called ventriculus and gastric caecum.
- The hind gut comprises of the ileum, rectum and anus.
- The various regions of the gut perform various functions. The gut is also modified in different insect groups to suit the varied diets.

**ACTIVITY 9.4**

1. List the parts of the fore gut and hind gut
2. Differentiate insect ectoparasites from endoparasites with specific examples.
3. Name two glands associated with the insect gut.
4. State the significance of the great variation in insect diets.

**SUGGESTED FURTHER READING**

LECTURE NUMBER TEN

10.0: THE INSECT CIRCULATORY SYSTEM

10.1: Introduction
10.2: An "open" insect circulatory system
10.3: Dorsal vessel
10.4: The heart
10.4.1: Incurrent ostia
10.4.2: Excurrent ostia
10.4.3: Segmental vessels
10.4.4: Phagocytic organs
10.5: The Aorta
10.6: The alary muscles
10.7: Dorsal and ventral diaphragm
10.8: Accessory pulsatile organs
10.9: Innervation of the heart
10.10: Haemolymph
10.11: Course of circulation

10.1: INTRODUCTION

In the last lecture we examined the insect digestive system in detail. In this lecture you will study lecture notes of the circulatory system. Take note that the circulatory system is located dorsally on an insect. For this reason you were not able to see it in your first dissection which was done on the dorsal side. As you were cutting along the dorsal side you were cutting through the dorsal circulatory system. In this lecture the circulatory system will be described theoretically and you will respond to various questions in the text.

OBJECTIVES

At the end of this lecture you should be able to:

- Explain the major differences between an insect circulatory system and the vertebrate circulatory system.
- Name the three sinuses in the insect body cavity.
- List the various functions of the insect circulatory system.
- Outline the structural lay-out of the insect circulatory system.
- State the physiological functions of the insect circulatory system.
- Define haemolymph, segmental vessels, ventral and dorsal diaphragm.

10.2: AN "OPEN" CIRCULATORY SYSTEM
The circulatory system of insects differs from that of vertebrates and many other invertebrates in being "open". In an open system, blood (usually called hemolymph) spends much of its time flowing freely within body cavities where it makes direct contact with all internal tissues and organs. Haemolymph is confined to vessels during only a portion of its circuit through the body. The remainder of its journey takes place within the body cavity called the haemocoel.

The haemocoel is divided into chambers called sinuses: the pericardial, perivisceral and perineural sinuses.

The circulatory system is responsible for movement of nutrients, salts, hormones, and metabolic wastes throughout the insect's body. In addition, it plays several critical roles in defense: it seals off wounds through a clotting reaction, it encapsulates and destroys internal parasites or other invaders, and in some species, it produces distasteful compounds that provide a degree of protection against predators. The hydraulic (liquid) properties of blood are important as well. Hydrostatic pressure generated internally is used to facilitate hatching, molting, expansion of body and wings after molting, physical movements (especially in soft-bodied larvae), reproduction (e.g. insemination and oviposition), and evagination of certain types of exocrine glands. In some insects, the blood aids in thermoregulation: it can help cool the body by conducting excess heat away from active flight muscles or it can warm the body by collecting and circulating heat absorbed while basking in the sun.

10.3:DORSAL VESSEL A dorsal vessel is the major structural component of an insect's circulatory systems shown on Fig 10.1 below. This tube runs longitudinally through the thorax and abdomen, along the inside of the dorsal body wall. In most insects, it is a fragile, membranous structure that collects hemolymph in the abdomen and conducts it forward to the head. The dorsal vessel runs along the dorsal midline, just below the terga, for almost the whole length of the body.

Fig.10.1: The insect circulatory system
The dorsal vessel is divided into two regions: a posterior heart in which the wall of the vessel is perforated by incurrent and sometimes also by excurrent ostia; and an anterior aorta which is a simple, unperforated tube. The wall of the dorsal vessel in the heart and the aorta is contractile and consists of a single layer of cells in which circular or spiral muscle fibrils are differentiated. These cells are bounded on both sides by a homogeneous membrane and on the outside there is usually some connective tissue. A network of tracheoles is often present, especially round the posterior part of the heart.

10.4: THE HEART
In the abdomen, the dorsal vessel is called the heart. It is divided segmentally into chambers that are separated by valves (ostia) to ensure one-way flow of hemolymph. In front of the heart, the dorsal vessel lacks valves or musculature. The heart may be directly bound to the dorsal body wall or suspended from it by elastic filaments.

10.4.1: Incurrent ostia
The incurrent ostia are vertical, slit-like openings occurring in the heart wall. There may be nine pairs of incurrent ostia in the abdomen and up to three pairs in the thorax. The anterior and posterior lips of each ostium are reflexed into the heart so that they form a valve permitting the flow of blood into the heart at diastole, but preventing its outward passage at systole. During diastole the lips are forced apart by the inflowing blood. When diastole is complete the lips are forced together by the pressure of blood in the heart and they remain closed throughout systole. Towards the end of systole the valves tend to become evaginated by the pressure but they are prevented from turning completely inside out by unicellular thread to the inside of the heart. During systole this is pressed against the wall of the heart so that the escape of blood is prevented.

10.4.2: Excurrent ostia
These are usually paired entro-lateral openings in the wall of the heart without any internal valves. The number of excurrent ostia varies with insect groups. Externally each opening is surrounded by a papilla of spongiform multinucleate cells, which expands when the heart contracts, so that blood passes out, and contracts when the heart relaxes, so that the entry of blood is prevented.

10.4.3: Segmental vessels
Most Dictyoptera have no excurrent ostia, but there are definite segmental vessels by which the blood leaves the heart. In Blattaria sp. there are two thoracic and four abdominal vessels, but only the latter are present in mantodea. They pass out between the aliform (alar) muscles, branching distally and disappearing as fine ramifications in the fat. At the origin of each vessel is a group of loosely packed cells which functions as a valve only permitting the outward flow of blood from the heart. The walls of the vessels are non-muscular, but there is a suggestion that they may contract independently of the heart. It is possible that the small amount of muscle in the valve cause a wave of contraction to pass down the rest of the vessel.
10.4.4: Phagocytic organs

The phagocytic organs are found in the anterior part of the abdomen of Tettigoniioidea and Caryllioidea. They are flattened triangular sacs opening ventro-laterally from the heart by narrow connections, at which there are excurrent valves, and then fanning out between the aliform muscles. Two to four pairs may be present. The ventral wall of these organs is formed by the dorsal diaphragm, the dorsal wall by phagocytic cells, which are multinucleate and occupy part of the lumen of each sac. These organs appear to act as filters removing dyes and particles from the blood, which is forced into them.

10.5: THE AORTA

The aorta is a simple tube without ostia, which continues forward in front of the heart to the head and empties near the brain. Hemolymph bathes the organs and muscles of the head as it emerges from the aorta, and then haphazardly percolates back over the alimentary canal and through the body until it reaches the abdomen and re-enters the heart.

10.6: ALIFORM MUSCLES

Closely associated with the heart are the aliform, or alary muscles. These stretch from one side of the body to the other just below the heart. Usually they fan out from a restricted origin on the tergum, the muscles of each side meeting in a broad zone at the midline. The aliform muscles form an integral part of the dorsal diaphragm, which spreads between them as a fenestrated connective tissue membrane. It is usually incomplete laterally so that the pericardial sinus is broadly continuous with the perivisceral sinus in this region. The lateral limits are often indefinite and are determined by the presence of muscles or tracheae or the origins of the aliform muscles.

A pair of alary muscles are attached laterally to the walls of each chamber. Peristaltic contractions of these muscles force the hemolymph forward from chamber to chamber. During each diastolic phase (relaxation), the ostia open to allow inflow of hemolymph from the body cavity. The heart's contraction rate varies considerably from species to species -- typically in the range of 30 to 200 beats per minute. The rate tends to fall as ambient temperature drops and rise as temperature (or the insect's level of activity) increases. Some of the connective tissue fibers form a plexus, which extends to the heart wall, but in some insects, such as dipterous larvae, the aliform muscles are inserted directly into the walls of the heart instead of meeting beneath it. Orthopteroids may have as many as ten abdominal and two thoracic pairs of aliform muscles, but in other insects the number is reduced. *Geocorisae sp.*, for instance have from four to seven pairs.

10.7: VENTRAL AND DORSAL DIAPHRAGM

The ventral diaphragm is a horizontal septum just above the nerve cord cutting off the perineural sinus from the main perivisceral sinus it is present in both larvae and adults of Odonata, Orthoptera, Hymenoptera and Neuroptera, but is only found in adults of
No ventral diaphragm is present in the other orders of insects except in Lepidoptera where it is unusual in having the nerve cord bound to its ventral surface by connective tissue.

In several orders the ventral diaphragm is restricted to the abdomen, but in Orthoptera it is also present in the thorax. Posteriorly it does not extend beyond the posterior end of the nerve cord.

The structure of the ventral diaphragm varies. For instance, in the thorax of grasshoppers it is a delicate membrane with little or no muscle, but in the abdomen it becomes a solid muscular sheet. Its structure may also vary with age and in Corydalis sp. it forms a solid sheet in the larva, but a fenestrated membrane in the adult.

The contractions of the ventral diaphragm are probably myogenic and are propagated by tension, while nervous inhibition reduces the frequency with which contractions occur.

10.8: ACCESSORY PULSATILE ORGANS
In some insects, in addition to the dorsal vessel, pulsatile organs are located near the base of the wings or legs. They are concerned with maintaining circulation through the appendages. These muscular "pumps" do not usually contract on a regular basis, but they act in conjunction with certain body movements to force hemolymph out into the extremities. In the mesothorax and sometimes also in the metathorax there is a pulsatile organ concerned with the circulation through the wings.

10.9: INNERVATION OF THE HEART
In some insects, such as Anopheles sp., the heart is entirely without any nerve supply although there are segmental nerves to the aliform muscles. On the other hand the heart of Periplaneta sp. is innervated from three sources. Nerves from the corpora cardiaca and from the segmental ganglia combine to form a longitudinal nerve on either side of the heart from which nerve endings ramify in the wall of the heart and the aliform muscles. In addition, supposedly sensory fibers arise from the heart and join the sensory nerves in the dorsal body wall. Between these two extremes are various intermediate degrees of Innervation and Prodenia sp., for instance, has only segmental nerves. In the cockroach, and probably in most orthopteroids, scattered nerve cells, known as ganglion cells, occur along the lateral heart nerves, but these are not always present in other insects.

10.10: HAEMOLYMPH
About 90% of insect hemolymph is plasma: a watery fluid usually clear, but sometimes greenish or yellowish in color. Compared to vertebrate blood, it contains relatively high concentrations of amino acids, proteins, sugars, and inorganic ions. Over wintering insects often sequester enough ribulose, trehalose, or glycerol in the plasma to prevent it
The remaining 10% of hemolymph volume is made up of various cell types (collectively known as hemocytes); they are involved in the clotting reaction, phagocytosis, and/or encapsulation of foreign bodies. The density of insect hemocytes can fluctuate from less than 25,000 to more than 100,000 per cubic millimeter, but this is significantly fewer than the 5 million red blood cells, 300,000 platelets, and 7000 white blood cells found in the same volume of human blood. With the exception of a few aquatic midges, insect hemolymph does NOT contain hemoglobin (or red blood cells). Oxygen which have haemoglobin is delivered by the tracheal system, not the circulatory system.

10.10: THE COURSE OF CIRCULATION

In normal circulation the blood is pumped forwards through the heart at systole, passing out of the heart via the excurrent ostia and, anteriorly, from the aorta. The valves on the incurrent ostia prevent the escape of blood through these openings. The blood driven forwards by the heart increases the blood pressure anteriorly in the perivisceral sinus so that blood tends to pass backwards along a pressure gradient. Blood percolates down to the perineural sinus where it is agitated by movements of the ventral diaphragm, which assist the blood supply to the nervous system and possibly produce a backward flow of blood. The dorsal diaphragm is usually convex above so that contraction of the alary muscles tends to flatten it. This flattening increases the volume of the pericardial sinus at the expense of the perivisceral sinus. Coordinated movements of the body muscles gradually bring the blood back to the dorsal sinus surrounding the hearts. Between contractions, tiny valves in the wall of the hearts open and allow blood to enter and pass up into the pericardial sinus and then at diastole is drawn into the heart through the incurrent ostia.

Insects have an open blood system in which circulation is produced by the activity of a dorsal longitudinal vessel comprising a posterior heart and an anterior aorta. When the heart relaxes blood passes into it through valved openings, while waves of contraction, which normally start posteriorly, pump the blood anteriorly and out through the aorta. The heart is usually cut off from the major part of the body cavity by a muscular diaphragm, while in some insects a second diaphragm overlies the nerve cord. These diaphragms, together with accessory pulsatile organs associated with the appendages supplement the activity of the dorsal vessel.

ACTIVITY 10.1

Write True or False against the following statement:-
1. Insects have a closed circulatory system.
2. The incurrent and excurrent ostia are found in the aorta of insects.
3. The major structural component of an insect's circulatory system is a dorsal vessel.
4. Peristaltic contractions of alary muscles force the hemolymph forward from chamber to chamber in insects.

5. Insect blood is called haemolymph.
6. The key function of the insect circulatory system is to transport oxygen.
7. The dorsal vessel is referred to as the heart when it is within the insect’s abdomen.
8. The heart is innervated by nerves in all insects.
9. Glycerol in plasma helps to prevent it from freezing in overwintering insects.
10. The Dorsal vessel is located ventrally in insects.

**SUMMARY**
In this lecture we have learnt that:

- The insect circulatory system is responsible for the following:
  1. Movements of nutrients, salts, hormones, and metabolic wastes throughout the insect body
  2. Sealing off of wounds through a clotting reaction
  3. Encapsulates and destroys internal parasites or other foreign bodies
  4. Generates hydrostatic pressure and aids in thermoregulation.

- Insects, unlike vertebrates, have an open circulatory system with blood (Haemolymph) occupying the general body cavity (haemocoel).
- To facilitate circulation the haemocoel is divided into three sinuses namely pericardial, perineural and perivisceral.
- The major structural component of an insect’s circulatory system is a dorsal vessel that runs along the dorsal line for almost the whole length of the insect body.
- Within the abdomen the dorsal vessel is called the heart. The heart is separated into chambers by structures (valves) called ostia. This is to ensure one-way flow of haemolymph.
- The aorta is a simple tube without ostia, which continuous forward in front of the head and runs into the head.
- Haemolymph is made up of hemocytes, Phagocytes, plasma, (amino acids, proteins, sugars, and inorganic ions).
- Closely associated with the heart are the aliform or alary muscles. These stretch from one side of the body to the other just below the heart.
- Other structures that could be related to the insect circulatory system include:
  1. Segmental vessels
  2. Phagocytic organs
  3. Ventral diaphragm
  4. Dorsal diaphragm
  5. Accessory pulsatile organs
The heart is innervated by nerves in some insects such as the cockroach, but is entirely without innervation in others such as the mosquito.

SUGGESTED FURTHER READING
11.O: THE EXCRETORY SYSTEM

11.1: Introduction.
11.2: The Malphigian Tubules
11.3: Insect Excretory products
11.4: Nephrocytes
11.5: Excretion by the gut
11.6: Labial glands
11.7: Male accessory glands
11.8: Storage excretion
11.9: Salt and water regulation in terrestrial insects
11.10: Salt water regulation in fresh water insects
11.11: Salt water regulation in salt-water insects.
11.12: Other functions of the Malphigian Tubules

11.1: INTRODUCTION

In the last lecture we learnt that the Malphigian Tubules are associated with the insect gut. In this lecture we shall learn that the Malphigian Tubules are the main excretory structures found in the body of an insect. The physiological functioning of the Malphigian Tubule will be demonstrated. Excretory products will be mentioned and excretory structures other than the Malphigian Tubules will be discussed. Salt and water regulation in terrestrial, fresh water and salt water insects will be covered as part of the wider topic of excretion.

OBJECTIVES

At the end of this lecture you should be able to:-

- Name the main Excretory organ in insects
- Describe the Malphigian Tubules
- Locate and draw the Malphigian Tubules from a general insect dissection.
- List excretory structures found in insects other than the Malphigian Tubules.
- Discuss salt and water regulation in terrestrial and aquatic insects
- State functions of the Malphigian Tubules other than excretion

11.2: THE MALPHIGIAN TUBULES

The Malphigian Tubules (M.T.) are long thin, blindly ending tubules arising from the gut near the junction of midgut and hindgut and lying freely in the body cavity. The tubules may open independently into the gut or may join into groups to form a ureter, which then enters into the gut. The wall of the M.T is usually one cell thick on a tough basement
11.3. INSECT EXCRETORY PRODUCTS
What are the excretory products in insects? They are:

- **Ammonia**- ammonia is highly toxic so it can be excreted in insects with ample supply of water such as those in fresh water or extremely moist environments.
- **Uric acid**- excreted in terrestrial insects
- **Urea**- excreted in small amounts
- **Allantoin**- excreted in some insects e.g. *Dysdercus* spp.
- **Arginine/Histidine/other nitrogenous wastes**- these are excreted unchanged by blood feeders such as the Tse-tse flies.

11.4: NEPHROCYTES
Nephrocytes or **pericardial cells** are special types of excretory cells with a single nucleus that occur singly or in groups in various parts of the insect body. They are usually present on the surface of the heart. The nephrocytes undergo cycles of development and they bud off pinosomes. Within the nephrocytes pinosomes are believed to coalesce and their contents are degraded and products held in a large vacuole, which is ultimately discharged into haemolymph. It is believed in this way materials too complex for
101 immediate excretion are removed from haemolymph. Nephrocytes also take up dyes and colloidal particles from haemolymph.

11.5: EXCRETION BY THE GUT
In some insects such as cockroaches the M.T contain uric acid, but uric acid granules are also present in the wall of hindgut. This suggests that the hindgut may have an excretory function. Uric acid also occurs in the midgut of various caterpillars, larval Hymenoptera, some larval Diptera. Some insects (blow fly larvae) excrete ammonia directly to the gut without involving the M.T. In aquatic insects the ammonia may be secreted into the rectum.

11.6: LABIAL GLANDS
In Collembola where M.T are absent labial glands take up dyes from haemolymph and are also believed to be excretory in function.

11.7: MALE ACCESSORY GLANDS
In the cockroach Blatella uric acid accumulates in a part of the male accessory glands. Here it is temporarily stored and then is poured out over the spermatophore during copulation.

11.8: STORAGE EXCRETION
Waste materials may be retained in the insect body in a harmless form instead of being passed out with urine. This is known as storage excretion. There are specialized cells in the insect fat body called Urate cells that serve this function. In such insects, uric acid accumulates in the urate cells and is subsequently discharged through the M.T. In caterpillars special cells known as goblet cells in the midgut accumulate heavy metals such as sulphides which are eventually discharged from the body. Uric acid may also accumulate in the epidermis of some insects e.g. Rhodnius during molting and is subsequently removed after each molt is completed. Similarly in Pieris (Lepidoptera) uric acid produced during pupal instars is stored mainly in the scales of the wing.

Activity 11.1
Write True or False against the following statements:

1. Ammonia is excreted by insects in extremely dry environments.
2. Malpighian Tubules are absent in Collembola.
3. Histidine, arginine and other nitrogenous waste are excreted by some blood-sucking insects such as tse-tse flies.
4. The cryptonephridial arrangement is present in the majority of aquatic insects.
5. Uric acid is excreted in terrestrial insects.
The Malpighian Tubule may occur in the form of a simple papillae as in Diplura and Protura.

Another name for Nephrocytes is pericardial cells.

Urate and goblet cells are associated with storage excretion.

The Malpighian tubules are long tubules found in the insect head.

Urea is excreted by insects in small amounts.

11.9: SALT AND WATER REGULATION IN TERRESTRIAL INSECTS

The water content of insects vary from 50 to 90% of the body weight. Reduction of water content ultimately leads to death. Inorganic salts are also important in tissues. Together salts, and water produce osmotic effects which will affect the distribution of water. Hence it is essential that the salt and water content of tissues is regulated so as to maintain an optimal balance. The problems of insects in regulating salts and water vary according to their habitats and so terrestrial insects, fresh water and salt water have to be considered separately.

The balance of salts in terrestrial insects is done by the M.T and subsequent selective reabsorption in the rectum.

Terrestrial insects lose water in the following ways:

- Evaporation
- Respiratory/excretory surfaces
- Faeces and urine

If terrestrial insects must survive, water loss must be kept to a minimum and must be offset by water gain from other sources. Water loss through the cuticle is restricted by the presence of a waxy layer in the exoskeleton. Insects living in dry environments, such as the flour beetles conserve most of their water and excrete very dry faeces and solid uric acid.

To offset the inevitable water loss by evaporation and excretion, water must be gained from other sources as outlined below:

- **Water gain from moist food**: most insects gain water from their food and may select foods with high water content. Other insects have efficient regulatory mechanisms and therefore require very little water. If food content is low in water the insect may eat more than it ordinarily requires in order to extract extra water from it.

- **Absorption of water through cuticle**: some insects are able to absorb any little water that drops onto the cuticle especially in the immature stages. Some insects have also developed special structures, which are capable of absorbing water from water vapor.

- **Water gain through drinking**: many adult insects and larvae of holometabolous insects actively drink water. They have specific receptors and sensilla and stimulation of these leads to drinking.
10.3 Water as an end product; when water is known as metabolic water and is an end product of oxidative metabolism, such water is made use of by dehydrated insects.

- **Fluid feeding**: Insects, which feed on fluids, are unusual among terrestrial insects in that at least for a time after feeding, their bodies contain excess water. In such insects the excess is reduced by rapid elimination of water from the body (rapid diuresis). Other insects such as Homoptera have anatomical adaptations for rapid elimination of water. Diptera and Lepidoptera store excess fluid in an impermeable crop so that the haemolymph does not become over diluted.

11.10: SALT AND WATER REGULATION IN FRESH WATER INSECTS
To avoid passage of water into the insect the cuticle of some of these have a reversed monolayer on the outside of the waxy cuticular layer.
If insects in fresh water take up excess water through the papillae the excess is offset by production of copious urine.
In the event that fresh water insects lose salts to the environment, the salts are actively reabsorbed by the rectum. Sodium, Potassium and Chloride are known to be actively reabsorbed by the rectum, anal papillae and rectal gills.

11.11: SALT AND WATER REGULATION IN SALT WATER INSECTS
Insects living in salt water environments have the problem of osmotic water loss and excess salt gain. The lost water is replaced by controlled drinking and absorption in the midgut. The midgut of such insects is able to withstand high salt concentration. Excess salts taken in with food is eliminated in the urine after controlled reabsorption from the rectum.

Do you know of any other insect system(s) where we mentioned the functions of the **rectum** and **haemolymph**?

11.12: OTHER FUNCTIONS OF THE MALPHIGIAN TUBULES
In a few insects the M.T are modified for functions other than excretion. In larval Neuroptera the M.T. are silk producing and the silk is used to form the pupal cocoon. In some insects the M.T. can produce sticky substances for covering eggs after they have been laid.
In larvae of a fly (**Bolitophila lumunosa**) the enlarged distal ends of the M.T. form a **luminous** (light producing) organ.
SUMMARY

- Malpighian Tubules are the main excretory structures found in the body of an insect.
- The excretory products in insects are:
  - Ammonia; Uric acid; excreted in terrestrial insects
  - Urea; excreted in small amounts; Allantoin; excreted in some insects e.g. Dysdercus spp.
  - Arginine; Histidine; and other nitrogenous wastes
- The balance of salts in terrestrial insects is done by the M.T and subsequent selective reabsorption in the rectum.
- Other organs or structures in an insect that play an excretory role are nephrocytes, gut, labial glands and the male accessory glands
- Other functions of the Malphigian tubules include silk production; light production and production of a sticky substances for covering eggs after they have been laid.
- When waste materials are retained in the insect body in a harmless form instead of being passed out with urine the process is termed storage excretion.
- Urate and goblet cells play a role in storage excretion.

ACTIVITY 11.2 Answers in the text above
1. How do insects that live in dry environments conserve water?
2. Discuss the Cryptonephridial arrangement.
3. List three other functions of the Malpighian Tubules besides excretion.
4. Write short notes on the following :- goblet cells, urate cells, nephrocytes, diuresis and pinosomes.

SUGGESTED FURTHER READING:
   New York and London.
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
12.0: THE INSECT RESPIRATORY SYSTEM

12.1 Introduction

12.2 The tracheal system
   12.2.1 The trachea
   12.2.2 The air sacs
   12.2.3 The tracheoles

12.3 Arrangement and distribution of the tracheal system

12.4 Insects obtaining oxygen from air

12.5 Insect obtaining oxygen from water

12.6 Aquatic insects obtaining oxygen from plants

12.7 Respiration in parasitic insects

12.8 Haemoglobin respiration

12.1: INTRODUCTION

OBJECTIVES

At the end of this lecture you should be able to:-

- Diagrammatically illustrate the generalized structure of the insect tracheal system.
- Describe spiracles, trachea, tracheoles, air sac and taenidium,
- Define these terms; Ploypneustic, Oligpneustic and Aphneustic
- Discuss how insects obtain oxygen from air and water
- Explain when and how haemoglobin respiration occurs in insects.
- Write short notes on respiration in parasitic insects.

12.2: The Tracheal System.

Diffusion alone can account for the gaseous requirements of the tissues of most insects at rest, but in larger insects and during activity, demands for oxygen is greater. To meet this demand the insects have a **tracheal system** (Figs. 12.1 through which air is pumped in and out of the body.

The Tracheal system comprises of:

12.2.1: The Trachea are the internal tubes which branch into finer tubes and these extend to all parts of the insect body and become intracellular in the muscle fibres. Oxygen is therefore carried directly to its sites of utilization and blood is not concerned with gas transport. The trachea open to the outside through pores called spiracles.

The spiracles are situated laterally in the body. Generally, there is one pair of
12.2.2: The spiracles.

The spiracles are situated laterally in the body. Generally, there is one pair of spiracle per segment.

The spiracles have some closing mechanism, which limits water loss from the respiratory surfaces. The spiracles open in response to a low concentration of oxygen or a high concentration of carbon Dioxide in tissues. The trachea are lined with a cuticle called intima. A spiral thickening of the intima is called teanidium. The teanidium prevent the collapse of the trachea if pressure within is reduced. Trachea pump air in and out of the tracheal system by expanding and collapsing air sacs. Air sacs are enlarged parts of the trachea whose volume can be changed by movements of the insect body.

12.2.3: The tracheoles; trachea give rise to finer tubes called tracheoles. Tracheoles are intracellular and are closely associated with tissues and muscle fibres where they end blindly as shown above to the right.

Where are spiracles located on an insect body?

Were you able to see the tracheal system after the first dissection of an insect?

**ACTIVITY 12.1**

Fill in the blanks in the following sentences:

1. Trachea open to the outside of an insect through …………
2. The cuticle lining the trachea is called …………. …………
3. Large parts of the trachea, whose volume can be changed by movements of the insect body are called …………. …………
4. …………. …………. prevent the collapse of three trachea if pressure within is reduced.
5. …………. …………. branch and give rise to finer tubes called tracheoles.
6. The spiral thickening of the intima is called …………. …………
7. Spiracles open due low concentration of …………. gas and high concentration of …………. gas.
8. …………. …………. are intracellular and are closely associated with tissues and muscles.
9. Apart from the tracheal system small-bodied insects can get sufficient oxygen through the process known as …………. …………. through the cuticle.
10. Trachea pump air in and out of the tracheal system by expanding and collapsing of …………. …………. ………….
Trachea arise from spiracles. Trachea from neighboring spiracles anatomes to form lateral longitudinal trunks running the length of the body. These lateral longitudinal trunks are on either side of the body and are the largest trachea. There are also Dorsal and Ventral longitudinal trunks depending on the insect group.

The longitudinal trachea are connected to those of the other side of the body by transverse commissural trachea. Smaller branches of trachea give rise to tracheoles, which run into body tissues and cells (see fig A). From the spiracles oxygen that has passed through the tracheal system ultimately reach the mitochondria in order to play a
dioxide follows the reverse path back into the

The arrangement and distribution of the tracheal system varies with different insect groups but the generalized structure is depicted in fig. In general the heart and dorsal muscles are supplied by tracheal branches from the dorsal trunks. The gut, gonads, legs and wings are supplied by the lateral trunks and the central nervous system by the ventral trunks or commissural trachea. The antennae is supplied by air from spiracle no.1 through the dorsal trunk while the mouthparts and related muscles are supplied by the ventral trunk.

ACTIVITY 12.2 Self evaluation
1. Name the largest tracheal trunk.
2. State the tracheal trunk that connects longitudinal trachea of the other side of the body.
3. Indicate the tracheal trunk that supplies oxygen to the insect;
   (a) heart and dorsal muscles
   (b) gonads, legs and wings
   © central nervous system
   (d) Antennae
   (e) Mouthparts
4. Draw the tracheal system, showing the structural arrangement of the spiracles, trachea, tracheoles, body tissues and organs.

Gaseous exchange in insects is carried out through a system of internal tubes called tracheal system. The tracheal system is significant in terrestrial insects. Aquatic and parasitic insects have devised other modes of respiration.

To some extent the distribution and abundance of the trachea and spiracles reflect the demand for oxygen by different tissues. With the exception of the order Diplura, the largest number of spiracles found in insects is ten (10) pairs, two in the thorax and eight in the abdomen. The insect respiratory system may be classified on the basis of the number and distribution of the functional spiracles as follows:

A. POLYPNEUSTIC - At least 8 functional spiracles on each side of the body.
B. OLIGOPNEUSTIC- One or two functional spiracles on each side of the body.
C. APNEUSTIC- No functional spiracle. Apneustic does not mean that insects have no tracheal system, the insect has a tracheal system but the trachea do not open to the outside.

Aquatic insects obtain oxygen directly from air, or from air dissolved in water

12.4: AQUATIC INSECTS OBTAINING OXYGEN FROM AIR
The majority of aquatic insects obtain oxygen from air during periodic visits to the surface of water.

**b. Respiratory siphons**
A few insects maintain a semi-permanent connection with air via a long respiratory siphon. In many aquatic insects with siphons, only the posterior spiracles are functional and these are normally carried on the siphons. Such a structure is referred to as a **telescopic respiratory siphon**.

Problems facing all insects, which come to the surface, are those of breaking the surface film and prevention of water entry into spiracle. The problem is solved in two ways;
1. The nature of the cuticle waxy layer provides some resistance to wetness.
2. The whole surface of the cuticle may possess hydrofuge hairs or valves so that it is not readily wetted. Insects also produce oily secretions in the immediate neighborhood of the spiracles, which also gives resistance to wetting.

![Fig.12.5: telescopic respiratory siphon of *Eristalis sp.* larva](image)

**C. Air stores**
Some insects have extra-tracheal air store. Such insects carry a bubble of air down into water as they dive. The spiracles open into this bubble so that it provides a store of air, additional to that contained in the tracheal system.

**12.5: AQUATIC INSECTS OBTAINING OXYGEN FROM WATER.**
The spiracles of aquatic insect will open into a film of air so that oxygen readily passes from water into the tracheal system.

**Diffusion through the cuticle**
In all insects living in water, particularly larval forms some inward diffusion of oxygen takes place through the cuticle in these forms the cuticle is very permeable. In these forms the tracheal system is fluid filled and oxygen obtained in this way oxygen passes through the cuticle into haemolymph and is sufficient to support the normally small size larvae such as black fly (*Simulium*) larvae and *Chironomus* larvae.

**Tracheal gills.**
Tracheal gills or caudal lamellae are a network of leaf-like extensions of the body to form gills. The cuticle is very thin in these extensions. The extensions contain a network of tracheoles and the tracheal system is closed and spiracles are not functional. Oxygen diffuses through the cuticle into the tracheal system. Tracheal gill are found in larval Plecoptera and larval Tricoptera.

12.6: AQUATIC INSECTS OBTAINING OXYGEN FROM PLANTS
A number of insects obtain oxygen by thrusting their spiracles into the aerenchyma of aquatic plants. This habit occurs in the larvae and pupae of a mosquito (Mansonia spp.). It also occurs in larval stages of some beetle, larval and pupal stages of some Diptera, which inhabit mud containing very little oxygen.

ACTIVITY 12.3
1. Define caudal lamellae and aerenchyma and state their role in insect respiration.
2. Cite circumstances under which diffusion alone, through the cuticle could sustain an insect.
3. State why water is prevented from entering spiracles of aquatic insects.

12.7: RESPIRATION IN PARASITIC INSECTS
Endoparasitic insects employ various methods of obtaining oxygen, generally comparable with those used by aquatic insects. The majority of endoparasites obtain some oxygen by diffusion through the cuticle from host tissues. Endoparasites with greater oxygen requirements communicate with the outside air either through the body wall of the host or via a respiratory system. They use a posterior spiracle to obtain oxygen. The spiracles of
12.8: HAEMOGLOBIN RESPIRATION  In some very rare cases insects have respiratory pigments such as haemoglobin to provide a short-term store for oxygen. The best-known examples are the aquatic larva of *Chironomus* and related insects, the aquatic *Anisops sp.* and endoparasitic larvae of *Gasterophilus SP.*

ACTIVITY 12.4
1. Define the terms Ploypneustic, oligopneustic and aphneustic.
2. Outline the two ways by which aquatic insects obtain oxygen
3. Compare and contrast salt and water regulation in terrestrial and aquatic insects.
4. Write short notes on haemoglobin respiration and respiration by parasitic insects.

SUMMARY
In this lecture we have learnt that:-

- In larger insects and during activity, demands for oxygen is greater. To meet this demand the insects have a *tracheal system* through which air is pumped in and out of the body.

- The tracheal system consists of tubes that open to the outside through spiracles. The tracheal system is significant in terrestrial insects. Aquatic and parasitic insects have devised other modes of respiration.

- Trachea branch into finer tubes called tracheoles and these extend to all parts of the insect body and become intracellular in the muscle fibres and organs. Oxygen is therefore carried directly to its sites of utilization and Haemolymph (blood) is not concerned with gas transport.

- The insect respiratory system may be classified on the basis of the number and distribution of the functional spiracles as follows:
  - **POLYPNEUSTIC** - At least 8 functional spiracles on each side of the body.
  - **OLIGOPNEUSTIC** - One or two functional spiracles on each side of the body.
Apneustic - No functional spiracle. Apneustic does not mean that the insect has a tracheal system but the trachea do not open to the outside.

- The tracheal system is significant in terrestrial insects. Aquatic and parasitic insects have devised other modes of respiration.
- Aquatic insects obtain oxygen from air through telescopic respiratory siphon, air stores, and by periodic visits to the surface.
- Aquatic insects obtain oxygen from water by diffusion through the cuticle, and by means of tracheal gills.
- A number of insects obtain oxygen by thrusting their spiracles into the aerenchyma of aquatic plants. This habit occurs in the larvae and pupae of a mosquito (Mansoninae spp). It also occurs in larval stages of some beetle, larval and pupal stages of some Diptera, which inhabit mud containing very little oxygen.
- The majority of endoparasites obtain some oxygen by diffusion through the cuticle from host tissues. Endoparasites with greater oxygen requirements communicate with the outside air either through the body wall of the host or via a respiratory system. They use a posterior spiracle to obtain oxygen. The spiracles of such larva open into the funnel-shaped inner end of a pedicel and make contact with the outside air. Other parasitic larva use the posterior spiracle to pierce the body wall of the host.
- In some very rare cases insects have respiratory pigments such as haemoglobin to provide a short term store for oxygen. The best-known examples are the aquatic larva of Chironomus and related insects, the aquatic Anisops sp. and endoparasitic larvae of Gasterophilus SP.

**SUGGESTED FURTHER READING:**

LECTURE NUMBER THIRTEEN

13.0: THE INSECT NERVOUS SYSTEM AND SENSE ORGANS

13.1: INTRODUCTION

13.2: THE NERVOUS SYSTEM

The insect nervous system is basically like that of other arthropods. The generalized insect nervous system consists of the brain, a suboesophageal ganglion, a ventral nerve cord with paired ganglia. One to three pairs of thoracic ganglia are found in each thoracic segment and five to eight pairs of abdominal ganglia are found in the abdomen as shown in the diagram below:

![Diagram of an insect nervous system](image)

**Fig.13.1: A generalized insect nervous system**

13.3: INSECT SENSE ORGANS

13.3.1 Thermoreceptors
13.3.2 Chemoreceptors
13.3.3 Chordotonal organs
13.3.4 Campaniform sensillae
13.3.5 Auditory receptors
13.3.6 Visual receptors

**OBJECTIVES**

At the end of this lecture you should be able to:

- Make a general diagrammatic representation of the insect nervous system
- List at least six different types of insect sense organs.
- Give a brief account of the insect compound eye and ocelli
The brain is composed of a protocerebrum, and a tritocerebrum. This mass also contains secretory cells, which produce endocrine materials.

The ventral nerve cord forms a chain of median segmental ganglia. The subesophageal ganglion is composed of three pairs of fused ganglia, which control the mouthparts, the salivary glands, and some of the cervical muscles. The brain is connected to the subesophageal ganglion by a connective known as the circumoesophageal connectives.

13.3 THE SENSE ORGANS

Sense organs, other than eyes and ocelli, are scattered over the body but are especially numerous on the appendages. The various types of sense organs are described below:

13.3.1: Themoreceptors are mounted on peg-like structures (olfaction) or on hairs (contact chemoreception), and the endings of the receptor cells pass to the surface of the cuticle through fine canals.

13.3.2: Chemoreceptors are especially abundant on the antennae, legs, and mouth parts. Perception of chemicals is important in many aspects of the life of insects. Smell may assist in finding food, or a mate, while contact chemoreception may be of importance in the final recognition of food, oviposition site or mate. Chemoreceptors that detect smell are mounted on peg like structures. They are also found on hairs on the insect body where they function as contact chemoreceptors. The endings of the receptor cells pass through canals to the surface of the cuticle.

13.3.2: Chordotonal organs are composed of one or more units called scolopidia. Each Scolopidium is a structure consisting of a cilium-like sensory process, which is covered and surrounded cell. The top of the scolopidium is attached to the underside of the integument. Chordotonal organs are important proprioreceptors and are typically located in joints and wing bases, although they may be found elsewhere. There are a number of specialized or modified chordotonal organs. Contact, pressure, vibrations, and changes in cuticular tension as a consequence of movement are detected by tactile hairs and chordotonal organs.

13.3.3: Companiform sensillae, which are common in joints, have the sensory process in contact with a thin layer of cuticle in the shape of a dome or plate, which is altered by tension changes in the surrounding skeleton.

13.3.4: Auditory receptors, called tympanal organs and are found in grasshoppers, crickets, and cicadas, which also have sound-producing organs. Tympanal organs develop from the fusion of parts of a tracheal dilation and the body wall. The scolopidia are attached to the tympanum. An air sac beneath the tympanum permits vibrations, which excite the attached receptors.

13.3.5: The visual receptors are the compound eyes and the ocelli. There are usually three found on the anterior dorsal surface of the head. Compound eyes are laterally situated on the head. Each compound eye is made up of several visual organs (facets) called ommatidia. The surface of each ommatidium is a hexagonal lens, below which is
A second conjunctifical lens. Light entering the ommatidium is focused by these lenses down a central structure, called the rhabdom, where an inverted image forms on the light-sensitive retinular cells. Optic nerve fibers transmit information from each rhabdom separately to the brain, where it is combined to form a single image of the outside world. The number of facets is greatest in flying insects, which depend on vision for feeding. Extreme reduction of facets is found in certain parasitic and caves-dwelling insects. The facets are larger in nocturnal than in diurnal insects, and in some crepuscular flying neuropterans the eye are divided into upper small-faceted, and lower larger-faceted areas. There are also some insects, such as the water each ocellus are organized somewhat like those of a single ommatidium of a compound eye. Ocelli can detect changes in light intensity and may be very sensitive to low intensities.

They function in orientation and in some way appear to have a general stimulatory effect on the nervous system, enhancing the reception of stimuli by other sensory structures.

**SUMMARY**

- The insect nervous system is basically composed of a brain a suboesophageal ganglion and a ventral nerve cord
- The brain is composed of a protecerebrum, and a tritocerebrum
- The various types of insect sense organs are thermoreceptors, chemoreceptors, chordotonal organs, campaniform sensillae
- Auditory receptors, called tympanal organs and are found in grasshoppers, crickets, and cicadas
- The visual receptors of an insect are the compound eyes and the ocelli
- Each compound eye is made up of several visual organs (facets) called ommatidia

**ACTIVITY 13.1** Answers in the text above

1. Illustrate by use of a diagram the generalized arrangement of insect nervous system.
2. List four types of insect sense organs.
3. Name the units that make up the compound eye.
SUGGESTED FURTHER READING:
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
14.0 REPRODUCTION AND THE REPRODUCTIVE SYSTEM

14.1 Introduction
14.2 The male system
   14.2.1 Testis
   14.2.2 Vas deferens
   14.2.3 Ejaculatory duct
14.3 The insect female reproductive system
   14.3.1 Ovaries
   14.3.2 Oviducts
   14.3.3 Accessory glands
   14.3.4 Spermatheca

14.1: INTRODUCTION

OBJECTIVES

At the end of this lecture you should be able to:

- Differentiate a male from a female insect from a general dissection
- Draw and name all the parts of a male and female insect, particularly the grasshopper
- Write short notes on reproductive structures such as ovipositor, spermatheca

14.2: THE REPRODUCTIVE SYSTEM

The sexes are always separate in insects, and fertilization is internal. Most are oviparous, but a few are viviparous and bring forth young alive. Parthenogenesis occurs in some insects such as Aphids, gall wasps and others. In a few (for example Master sp., a type of a fly) a process called paedogenesis occurs. This involves parthenogenesis by larval stages rather than by the adults. Many larvae are produced, some of which pupate to become male and female adults. Methods of attracting the opposite sex are often complex in insects. Some, like the female moth, give off a scent that can be detected by males. Fireflies use flashes of light for this purpose, whereas many insects find opposite sexes by sounds. In most insects copulation occurs sperm is deposited in the female vagina and fertilization is internal. In some orders sperm encased in spermatophores can be transferred to the female during copulation or may be deposited on a substratum to be found and picked up by the female who places it in her vagina.

Insects usually lay a large number of eggs. The queen bee for instance may lay more than a million eggs in her life time. Insects reveal marvelous instincts in laying their eggs. Butterflies will lay their eggs only on a particular kind of plant on which the caterpillar feeds. Many, however, drop their well protected eggs in the right environment.
The male and female reproductive systems generally consist of paired gonads connected to a median duct which leads to the opening to the outside called the gonopore. Accessory glands are often present in both sexes.

14.3: THE MALE SYSTEM
The male reproductive system (See figure 14.1) consists of a pair of testis, which connect with paired seminal vesicle and a median ejaculatory duct. In most insects there are also a number of accessory glands, which open into the vasa deferentia or ejaculatory duct.

14.3.1: The testis. The testis lie above or below the gut in the abdomen and are often close to the midline. Each testis usually consists of a number of tubes or follicle, which contain spermatozoa. The number of follicles vary with insect groups.

The follicle empty into a lateral duct, the vas deferens, which join the duct from the other side to form a common ejaculatory duct. A section of each vas deferens is usually enlarged into a seminal vesicle where sperm are stored. Accessory glands are concerned with spermatophore formation and sperm maintenance. Accessory glands secrete the
I14.3.2: The vas deferens
From each testis follicle a fine and short vas deferens connects with the main vas deferens. The vas deferens runs backwards to lead into the distal end of the ejaculatory duct and often they are dilated to form the seminal vesicle.

14.3.3: The ejaculatory duct
The ejaculatory duct leads into a structure called the aedegus. The aedagus is lined with muscles. The aedagus vary with insect groups.

4.3.4: The accessory glands
The male accessory glands empty into the vas deferens or the distal end of the ejaculatory duct. The number of accessory glands varies considerably with insect groups.

14.4: THE FEMALE REPRODUCTIVE SYSTEM

The female reproductive system (see figure 14.2) consists of a pair of ovaries, which connect with a pair of lateral duct called oviducts. These join to form a median oviduct which open posteriorly into a genital chamber. In some insect groups the genital chamber is closed to form a tube the vagina. The vagina is further developed to form the bursa copularix, which is the part that receives the penis. Opening from the genital chamber is a spermtetheca whose function is to store sperms after copulation. A pair of accessory glands also open into the genital chamber or vagina.

14.4.1: The Ovaries
The ovaries lie in the abdomen lateral to the gut. Each consists of a number of egg tubes, the ovarioles comparable with the follicles in the testis. The number of ovarioles is usually constant within a species. Distally each ovariole is produced into a long terminal filament. The filaments from each ovary join to form a suspensory ligament. The ligaments of the two merge into a median ligament. The ligaments are inserted into the body wall so that the developing ovaries are suspended in the body cavity. proximally the ovariole narrows to a fine duct, the pedicel, which connects with the oviduct.

14.4.2: The Oviducts
Oviducts are tubes, which join to form the median oviduct. The median oviduct opens into the gonopore or the genital chamber. When the genital chamber is a continuation of the oviduct it is called the vagina and the opening of the vagina is called the vulva. The vulva leads to the bursa copularix.
14.4.3: The Accessory gland. The Accessory glands usually arise from the genital chamber. They produce a substance for attaching the eggs to the substratum during egg laying (ovidpositor). In some insects the spermtheca produce poison for defense. They may also serve to lubricate the ovipositor. In some ants these glands produce Pheromones used in marking trails.

14.4.4: The Spermtheca

A Spermtheca is present in most insects with numbers varying from one to three. In some insects the spermtheca opens into the oviduct whereas in others it opens into the genital chamber. It consists of a storage pouch. Its glandular cells produce secretions, which provide nutrients to sperms.

**SUMMARY**

- The male reproductive system consists of a pair of testis, the vas deferens, the ejaculatory duct, the accessory glands and the aedagus.
- Each testis usually consists of a number of tubes or follicle which contain spermatozoa.
- A section of each vas deferens is usually enlarged into a seminal vesicle where sperm are stored.
- Accessory glands of the male insect are concerned with spermatophore formation and sperm maintenance. Accessory glands also secrete the seminal fluid for these purposes.
- The female reproductive system consists of a pair of ovaries.
Each ovary consists of a number of egg tubes, the ovarioles. The female insect accessory glands usually arise from the genital chamber. They produce a substance for attaching the eggs to the substratum during egg laying (ovipositor). They may also serve to lubricate the ovipositor. In some ants these glands produce pheromones used in marking trails.

- A Spermtheca is present in most female insects and is a storage pouch for sperms after copulation. Its glandular cells produce secretions, which provide nutrients to sperms. In some insects the spermtheca they produce poison for defense.

**ACTIVITY 14.1** Answers in the text

1. Illustrate the insect male reproductive system
2. Define spermtheca
3. Define ovipositor
4. List two functions of accessory glands

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**SUGGESTED FURTHER READING:**

1. Borror and DeLongs 2005 *Introduction to the Study of Insects, 7th edition*

Website(s):
- www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html
- www.calsomology.uni.edu/ent801/repro.html
- Ncsu.edu/course/ent425/tutorial/repro.html.ent
15.0: INSECT GROWTH AND DEVELOPMENT (METAMORPHOSIS OR LIFE CYCLES)

15.1: Introduction
15.2: Life cycles of Insects
15.2.1: Ametabolous insects
15.2.2: Hemimetabolous insects
15.3: Heteromorphosis
15.4: Types of insect larvae
15.5: Types of insect pupae and significance of pupal stage
15.6: Significance of insect metamorphosis

15.1: INTRODUCTION

OBJECTIVES
At the end of this lecture you should be able to:
- Define Ametabolous, Hemimetabolous and Holometabolous life cycle.
- Identify different types of immature stages of insects.
- Describe the terms; heteromorphosis, naiads, ecdysis, instar, nymph, eucephalus, hemicephalus, and paurametabola.
- Discuss the significance of insect metamorphosis.

15.2: INSECT LIFE CYCLES
Insects reproduce sexually. Usually the opposite sexes mate and eggs are reproduces. Most insect eggs hatch outside the body. Insects, which lay eggs, which hatch outside the body, are said to be oviparous. Insects which protrude larvae are termed larviparous e.g. the tse tse flies. A few species retain the eggs inside the body until they hatch and give birth to young, these are the viviparous insects. After the immature stages of the insect leave the egg, it undergoes a change of form or metamorphosis until the adult stage is reached. To accomplish this change of form and to grow, the insect must shed its hard exoskeleton. This shedding process is called ecdysis or molting. The stages between the molts are referred to as Instars. Most weight gain (sometimes > 90%) occurs during the last one or two instars. In general, neither eggs, pupae, nor adults grow in size; all growth occurs during the larval or nymphal stages. Insects may be placed into three groups with respect to their type of metamorphosis. These groups are:
- Ametabola
- Hemimetabola
- Holometabola
15.2.1: Ametabola — The Ametabolous insects are said to have no metamorphosis because the young do not really change form as they mature. The immature forms look very much like the adults but are smaller and sexually immature. These insects lack wings even as adults. The stages in the life cycle of an ametabolous insects are the egg, the young and adult. A typical example of an Ametabolous insect is the silverfish (Order Thysanura) as depicted below:

Egg → Young → Adult

Fig 15.1: Pictorial representation of ametabolous development

*Only the more primitive insects are truly ametabolous. Fleas for example are wingless as adults, but they are holometabolous.*

15.2.2: Hemimetabola — These insects have a gradual type of development comprising of the following stages: egg, nymph and adult. In gradual metamorphosis, the nymphal stages resemble the adult except that they lack wings and are sexually immature. The nymphs, may also be colored differently than the adults. Nymphs and adults usually occupy similar habitats and have similar hosts. Gradual metamorphosis is typical of true bugs and grasshoppers. In aquatic forms nymphs, such as those of dragon flies are called naiads. Some Entomologists, therefore, call the group with nymphs *Paurometabola* and the group with naiads hemimetabola.

15.2.3: Holometabola — These are the insects that undergo complete metamorphosis comprising of four distinct stages as follows: egg, larva, pupa and adult. Complete metamorphosis is typical of beetles, flies, moths, and wasps. The immatures of these latter species do not resemble the adults, may occupy different habitats, and feed on different hosts. Some moth and wasp larvae weave a silken shell (cocoon) to protect the pupal stage; in flies, the last larval skin becomes a puparium that protects the pupal stage. There are generally several larval or nymphal stages (instars), each progressively larger and requiring a molt, or shed of the outer skin, between each stage as shown in the diagrams below:
15.3: HETEROMORPHOSIS.

When successive larva forms are quite different in form the development is called Heteromorphosis or hyper metamorphosis. Heteromorphosis is common in predaceous and parasitic insects in which a change in habitat occurs during the course of larval development. Two types of heteromorphosis occur, one in which the eggs are laid in the open and the first instar larva searches for the host, and a second in which the eggs are laid in or on the host.

15.4: TYPES OF INSECT LARVAE

On the basis of general appearance, insect larvae can be grouped into broad categories:

1. Nymph is the term applied to young hemimatabolous insects. They differ from holometabolous larvae in wing development. Their wings develop as external buds. They become larger at each molt. They finally enlarge into adult wings in the last molt to adult.

2. Larva is the term applied to the immature stage of holometabolous insect, which differ in structure and habits from their adults. Their wings develop in invaginations beneath the cuticle, so are not visible externally. The invaginations are finally everted to make wings visible. This happens when larval forms molts to a pupa.

There are many different larval forms among holometabolous insects, which may be classified into the following types:

(a) Protopod larvae. These are primitive parasitic larvae with barely incipient limb-buds and with no segmentation of the abdomen. They are found in some parasitic hymenoptera.
(b) **Polypod or Eruciform** larvae. These are the typical caterpillar with six legs on the thorax and a number of prolegs on the abdomen. They are found in Lepidoptera and saw flies.

![Figure 15.4 A Polypod larva](image)

(c) **Oligopod or Campodeiform** larvae. These are usually predatory and therefore have efficient sense organs and long legs but no prolegs. They have six thoracic legs with well-developed head capsule. The mouthparts are similar to the adult form. They are common among beetles.

![Figure 15.5 An Oligopod larva](image)

(d) **Scarabaeiform** larvae. These are fat with poorly sclerotized thorax and abdomen. They are short legged inactive, burrowing in wood or soil. They are found in beetles such as the rhinoceros beetle.

![Figure 15.6 A Scarabaeiform](image)

(e) **Apodous** larvae. These are legless larvae with segmented bodies with a minute head and a few sense organs. They are either fed by other members of the colony as in bees, or the eggs are laid in suitable food material such as dung. These are common among Diptera e.g. houseflies. And some parasitic hymenoptera. They are divided into three as show below in figures 15.5, 15.6 and 15.7

**Eucephalus**- with well sclerotized head capsule as in Neuroptera.

![Figure 15.7 An Eucephalus apodous larva](image)
Hemicephalous — with reduced head capsule. Head can be retracted within the thorax as in horseflies.

Acephalous — without head capsule as in some parasitic Hymenoptera.

15.5: TYPES OF INSECT PUPAE

(a) Exarate pupae

In some pupae the appendages are free from the body. This condition is known as exarate

(b) Obtect pupae

In most pupae the appendages are glued down to the body by a secretion produced at the larva/pupa molt. This is the obtect condition.
15.6: SIGNIFICANCE OF KNOWLEDGE ON INSECT METAMORPHOSIS

Insects are cold-blooded, so that the rate at which they develop is mostly dependent on the temperature of their environment. Cooler temperatures result in slowed growth; higher temperatures speed up the growth process. If a season is hot, more generations may occur than during a cool season. A better understanding of how insects grow and develop has contributed greatly to their management. For example, knowledge of the hormonal control of insect metamorphosis led to the development of a new class of insecticides called insect growth regulators (IGR). The insect growth regulators are very selective in the insects they affect. Based on information about insect growth rates relative to temperature, computer models can be used to predict when insects will be most abundant during the growing season and, consequently, when crops are most at risk.

SUMMARY

- Most insects hatch from eggs, others are ovoviviparous or viviparous, and all undergo a series of moult as they develop and grow in size.
- Moulting is a process by which the individual escapes the confines of the exoskeleton in order to increase in size, then grows a new outer covering.
- In most types of insects, the young, called nymphs or larvae.
- The Ametabolous insects are said to have no metamorphosis because the young do not really change form as they mature.
- Nymphs are basically similar in form to the adults (an example is the grasshopper), though wings are not developed until the adult stage. This is called incomplete metamorphosis. Insect that undergo incomplete metamorphosis are termed hemimetabolous. (Exopterygota)
- Exopterygota undergo gradual metamorphosis.
- Insects that undergo complete metamorphosis are termed holometabolous (Enopterygota). Enodpteyrgota undergo complete metamorphosis, and includes many of the most successful insect groups.
- In holometabolous insects, an egg hatches to produce a larva, which is generally worm-like in form, and can be divided into five different forms; eruciform (caterpillar-like), scarabaeiform (grublike), campodeiform (elongated, flattened, and active), elateriform (wireworm-like) and vermiform (maggot-like). The larva
Grows and eventually becomes a pupa, a stage sealed within a cocoon or chrysalis.

- There are three types of pupae; obtect, exarate and coarctate. In the pupal stage, the insect undergoes considerable change in form to emerge as an adult, or imago.
- Butterflies are an example of an insect that undergoes complete metamorphosis.
- Some insects have even evolved hypermetamorphosis. Other development traits are haplodiploidy, polymorphism, paedomorphosis (metathetely and prothetely), sexual dimorphism, parthenogenesis and more rarely hermaphroditism.

**ACTIVITY 15.1**

1. Distinguish with named example, three types of Insect metamorphosis
2. List and draw at least five different types of insect larvae
3. and name two types of insect pupae
4. Define these terms with specific examples; instar, ecdysis, naiad, heteromorphosis

**SUGGESTED FURTHER READING:**
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
16.0: RECOGNITION OF INSECT ORDERS PART 1

16.1: Introduction

16.2: Insect orders part I

16.3: Insect Order Anoplura - sucking lice

16.4.1: Insect Order Coleoptera - the beetles and weevils

16.4.2: Insect Order Collembola - the springtail

16.5.1: Insect Order Dictyoptera - cockroaches and mantids

16.5.2: Insect Order Diplura - Bristle tails

16.5.3: Insect Order Diptera - true flies

16.6.1: Insect Order Embioptera - Webspinners

16.6.2: Insect Order Ephemeroptera - mayflies

16.7.1: Insect Order Hemiptera (Heteroptera)

16.7.2: Insect Order Homoptera - cicadas, hoppers, whiteflies, aphids

16.7.3: Insect Order Hymenoptera - ants, bees, wasps, sawflies

16.8: Insect Order Isoptera - termites / white ant

16.9: Insect Order Lepidoptera - butterflies, moths

16.1: INTRODUCTION

OBJECTIVES

At the end of this lecture you should be able to:-

1. List several insect orders to depict their great diversity.
2. Relate the diversity of insects to their habits.
3. Identify any insects up to the level of order.
4. Use both pictorial and dichotomous key to identify insects to orders.

16.2: INSECT ORDERS PART I

This lecture will demonstrate insect abundance and diversity. The insects have been classified into their respective orders according to some common features (similarities) unique to each order. Similarities in certain structures is a reflection of evolutionary relationships or phylogeny among insect groups. The lecture will help us identify commonly encountered insects in our houses, gardens, on our animals and crops and sometimes even on our bodies! This basic insect taxonomy should serve as the first step to more complex insect taxonomy. The insect orders we shall examine in this particular lecture include the following:

- Anoplura (sucking lice), Coleoptera (beetles and weevils), Collembola (springtails), Dictyoptera (cockroaches and mantids), Diplura, Diptera (true flies), Embioptera
The class Insect has two subclasses; namely Apterygota and Pterygota. Apterygota are the primitive wingless insects that have not evolved from the winged ancestor; they have little or no metamorphosis and they have stylet like abdominal appendages, in addition to the cerci. Orders Protura, Collembola and Thysanura are apterygotaes. Sub class Pterygota are usually winged and have no abdominal appendages except cerci. and it includes 97% of all insects. There are two divisions in this subclass: Exopterygota and Enopterygota. Exopterygota undergo gradual metamorphosis while Enopterygota undergo complete metamorphosis.

16.3: Insect Order Anoplura – sucking lice

Sucking lice are pests that feed on the blood of their host. They attack humans and animals and their bites are often very irritating. Each species usually attacks one or a few related species of hosts, and generally lives on a particular part of the host’s body. Eggs are usually attached to hair of the host; egg of the body louse are laid on clothing. Sucking lice spend their life on their host and do not survive long away from it. They are small, usually less than 4mm in length, flattened and wingless. Their mouthparts are made for sucking and they withdraw into the head when not in use. The antennae are short, threadlike or tapering distally, 3 to 5 segmented. The head is small and nearly always narrower than the thorax. There are two subspecies of the common human louse: Pediculus humanus capitis, the head louse, and P. humanus humanus, the body louse. The body louse is an important carrier of epidemic typhus; other louse-borne human diseases are trench fever and relapsing fever.

16.4.1: Insect Order Coleoptera - the beetles and weevils
The Coleoptera is the largest order of insects; it contains about forty percent of all known species. It includes the beetles and weevils. Among the more than 250,000 species are many of the largest and most beautiful of all insects. Some have brilliant metallic colors, showy patterns or striking forms.

Beetles can usually be recognized by their two pairs of wings. The first pair is modified into horny covers (elytra) that hide the rear pair and most of the abdomen. They usually meet down the back in a straight line. Coleoptera occur in nearly all climates. They may be divided into four groups: the first three, the Archostemata, the Adephaga, and the Myxophaga, contain relatively few families; the majority of beetles are placed in the fourth group, the Polyphaga.

16.4.2: Insect Order Collembola - the springtail

The springtail are small, primitive wingless insects. Although crawling is their usual method of locomotion, they have a jumping apparatus at the end of their abdomen. They range in length from 1 to 10 mm (0.04 to 0.4 inches), called a furcula. It permits some mighty leaps, which is the origin of the common name "springtail." There are about 3,500 species. Springtail are found in all types of soil and leaf litter throughout the world from Antarctica to the Arctic, and are one of the most widely distributed insects. Certain springtails known as snow fleas are active at near-freezing temperatures and may appear in large numbers on snow surfaces. Springtails live in soil and on water and feed on decaying vegetable matter, sometimes damaging garden crops and mushrooms. Fossil springtails are among the oldest insect fossils known.
Insect order Dermaptera: earwigs

Characteristics
Earwigs are a distinctive group of insects of small to medium size, ranging from 5 to 50 millimeters in length. Earwigs are sometimes confused with Staphylinid beetles, but can be distinguished from the latter by the presence of pincer-like cerci, which Staphylinid beetles lack. Earwigs are mostly dark coloured (brown to black) and can be recognised by the following features:

- Flattened elongated body
- Heavily sclerotised pincer-like cerci. Females have straight cerci with an inward pointing tip and males have curved cerci
- 2 pairs of wings. The forewings are short and protectively hardened. The hind wings are membranous and folded in a fan-like way underneath the forewings when not in use. Some species are also wingless
- Chewing (mandibulate) mouthparts
- Moderately long antennae

The LABIDURIDAE family of earwigs consists of relatively primitive species that are predominantly a red-brown color and range from 10 to 45 millimeters in length. Members of this family are found all over Australia. *Labidura truncata* is by far the commonest species, particularly in sandy habitats. It is approximately 35 millimeters long and dull brown with straw colored markings. The male have long slender pincers with a distinctive tooth near the middle of the inner edge.
16.5.1: Insect Order Dictyoptera - cockroaches and mantids

Dictyoptera are described as variably sized insects with generally filiform (long and thin) antennae usually composed of many small segments. They have mandibulate or biting mouthparts and legs that are roughly similar (except the Mantids which have raptorial forelegs), most have 5 tarsi. Many species are winged and the forewings are generally hardened into a tegmina while the hind wings are often fan-like, the wing buds of the nymphs do not undergo reversal (i.e. the hind wings are not folded back over the forewings). The genitalia of both sexes are generally concealed, behind the 7th abdominal segment in the female and behind the 9th in the male. Cerci are present and males bear a pair of styles as well. No specialized stridulatory organs are present though some Mantids do have a single ear on the metathorax, which allows them to hear the sonar of bats. The eggs are laid in an ootheca.

16.5.2: Insect Order Diplura: two pronged bristle tails

Apterygote (primarily flightless) insects with entognathous mouthparts, many segmented antennae, ten large abdominal segments followed by one small abdominal segment which carries the variably formed paired cerci. They have no eyes at all.

The Diplura or two pronged bristle-tails (from diplos = double and oura = a tail) are another group of soil and leaf-litter insects of ancient origin, they are mostly small (the largest being about 5cm long), often white in color and occur all over the world. There
Apterygote (primarily flightless) insects with entognathous mouth-parts, many segmented antennae, ten large abdominal segments followed by one small abdominal segment which carries the variably formed paired cerci. They have no eyes at all. The name Diplura, derived from the Greek words "diplo-" meaning two and "ura" meaning tails, refers to the large cerci at the rear of the abdomen.

The Diplura or two pronged bristle-tails (from diplos = double and oura = a tail) are another group of soil and leaf-litter insects of ancient origin, they are mostly small (the largest being about 5cm long), often white in colour and occur all over the world. There are around 800 known species 11 of which occur in Great Britain and 70 in North America. The cerci or (tails) are often long, but may be short and stubby or even pincer like.

**Life History & Ecology:**

These small, eyeless arthropods are considered to be among the most primitive of all hexapods. They have a pair of long, beaded antennae on the head and a pair of segmented sensory structures (cerci) at the rear. In one common family (Japygidae), these cerci are developed into strong pincers.

Diplura are tiny, cryptozoic animals that live in moist soil, leaf litter, or humus. They have small, eversible vesicles on the ventral side of most abdominal segments that seem to help regulate the body's water balance, perhaps by absorbing moisture from the environment.

Most Diplura are predators; their diet probably includes a wide variety of other soil-dwellers, including collembola, mites, symphyla, insect larvae, and even other diplurans. They may also survive on vegetable debris and fungal mycelia, but most species seem to prefer animal prey.

**Classification:** Ametabola lacking metamorphosis eggs hatch into young, which are smaller than adults, but similar in appearance. Apterygota primitively wingless

**Physical Features for adults and immatures:**

- Compound eyes absent
- Antennae longer than head, with 10 or more bead-like segments
- Abdomen with 10 visible segments
- Cerci present --
- long and slender, or
- forceps-like in appearance
- Tarsi one-segmented
Short, lateral styli and eversible vesicles present on most of the first 7 abdominal segments.

Economic Importance:

Diplurans are common inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of the Diplura are considered pests.

Fact File:

The sexes are separate and fertilization is external. Males produce sperm packets (spermatophores) and glue them to the substrate on the end of little stalks. Females use their genital opening to gather spermatophores and then lay their eggs on little stalks inside a crevice or small cavity in the ground.

Male Diplura produce large numbers of spermatophores up to 200 per week. This large number is probably necessary because sperm only remain viable in the spermatophore for about two days.

The cerci of some diplurans are designed to break off near the base if they are mishandled. This spontaneous autotomy is probably an adaptation for avoiding predation. A similar adaptation is found in the legs of some walking sticks and the tails of some lizards.

Diplura and some walking sticks (Phasmatodea) are the only terrestrial arthropods known to be able to regenerate lost body parts. Legs, antennae, and cerci can be regenerated over the course of several molts. Some crustaceans (e.g. crabs and lobsters) can regenerate missing legs or claws.

16.5.3: Insect Order Diptera – true flies

Although many winged insects are commonly called "flies," the name is strictly applicable only to members of the Diptera. It is one of the largest insect orders and contains over 85,000 species; all are relatively small and have soft bodies. Mouthparts are of the sucking type, but there is great variation. Diptera have one pair of wings. Some, like the blood-sucking tse-tse flies, are serious
Flies are beneficial as scavengers and predators or other insect pests. Diptera are divided into three large groups: *Nematocera* (mosquitoes, crane flies, midges, and gnats); the *Brachycera* (horse flies, robber flies and bee flies); and *Cyclorrhapha* (houseflies, blow flies, flesh flies, botflies, stable flies, camel flies, horse flies etc. that breed in vegetable or animal material, both living and dead.)


Small, slender, soft bodied insects with large heads and eyes. They feed on plants and live in silken tunnels, which they weave ahead of themselves to create routes. They are gregarious and live in large colonies. They are found in the tropics and semi tropics. Metamorphosis is gradual.

16.6.2: Insect Order Ephemeroptera - mayflies

16.7.1: Insect Order Hemiptera  also called Order - Heteropteran
These are "the true bugs." They are found worldwide, in climates from tropical to arctic. There are 30,000 known species; most live in tropical areas.

Heteropterans range in size from under one millimeter (0.04 inch) to more than 100 mm. They are distinguished from other insects by the presence of a pair of simple eyes in front of and above the compound eyes, a hardened gula (the area below the mouthparts), and an "X" formed on the back by the overlapped wings. They live chiefly on plant or animal juices. Heteropterans are important to man in several ways. Some, such as plant bugs (Miridae) and stinkbugs (Pentatomidae), may damage crops while feeding. On the other hand, certain predatory heteropterans are used to control infestations of other crop-damaging insects. Some, like the bedbugs, are biting pests, and still other may serve as carriers of various diseases. The order is divided into three suborders. Families comprise of the aquatic Hydrocorisae Water Bug (giant water bugs, water boatmen, water scorpions, and backswimmers) and terrestrial Geocorisae (bedbugs, stinkbugs, assassin bugs, lace bugs, fire bugs, and plant bugs).

16.7.2: Insect Order Homoptera - cicadas, hoppers, whiteflies, aphids

The Homoptera are a large group of sucking insects. There are more than 32,000 species and there is great diversity in body size. All are plant feeders and have mouth parts adapted for sucking plant sap from trees and plants. They can cause injury and destroy valuable food crops such as fruit trees and grain crops. Some carry plant diseases, but a few provide secretion or other products that are beneficial and have commercial value.

The mouth parts are adapted for sucking, the beak arises from the back of head, wings, when present, number four, the front wings have uniform structure, either membranous or slightly thickened; wings at rest usually held roof-like over body; male scale insects with only 1 pair of wings; ocelli present or absent; compound eyes usually well developed. Most members of the Homoptera fall into one of two large groups: The Auchenorrhyncha, which consists of the cicadas, treehoppers, froghoppers or spittlebugs, leafhoppers, and planthoppers or fulgorids; The Sternorrhyncha.
which includes aphids or plant lice, phylloxerans, coccids, scales, whiteflies, and mealy bugs.

16.7.3: Insect Order Hymenoptera - ants, bees, wasps, sawflies

Two pairs of membranous wings, venation often much reduced; the hind wings are smaller and connected to fore wings by a row of hooklets; the mouthparts are primarily of biting type but often adapted for sucking fluids; the abdomen usually constricted at the base (except sawflies) with first segment fused to metathorax; ovipositor always present and modified for sawing, piercing or stinging; larvae usually legless with distinct head.

The Hymenoptera are divided into two suborders: **Symphyta** (mainly sawflies and horntails) and **Apocrita** (wasps, ants, bees, and most parasitic forms)

16.8: Insect Order Isoptera - termites / white ants

Termite
Termites are well known both for their destruction of human property and for their construction of huge mounds or 'termitaria' which allow them to have a great degree of control over the temperature and humidity of the environment they live in. They are common in the tropics and occur in most warm habitats as well. They are often called 'white ants' because the majority of them are white and small and live in large colonies much like ants. They are not actually closely related to the ants at all but are closely related to the Cockroaches. The most primitive Termite known is *Mastotermes darwiniensis* from northern Australia. *Mastotermes darwiniensis* lives in the soil in nests consisting of up to 1,000,000 individuals, has very catholic tastes (will eat almost anything) and has been described as the most destructive insect in Northern Australia, its workers are very similar to nymphs of the Cockroach *Cryptocercus punctulatus*. Some of the most advanced species are the Macrotermite family, which grow fungi for food (Termomycetes) inside their nests on piles of faecal pellets. The oldest known Termites are fossils of *Cretotermes carpenteri* from the Cretaceous. The sterile workers live for 2-4 years while primary sexual live for at least 20 and perhaps 50 years.

They are described as hemimetabolous, medium sized polymorphic (having more than one form) social insects. They have biting mouthparts, short cerci and moniliform (appearing as if composed of a series of beads) antennae comprising 9 to 30 segments. The alate forms (winged primary reproductives) have four almost equal wings and compound eyes; however the sterile workers and the secondary reproductives have no or greatly reduced compound eyes some forms have two ocelli.

16.9: Insect Order Lepidoptera - butterflies, moths

Lepidoptera are Holometabolous insects (insects which have larvae that look nothing like the adults/imagos and having a complete metamorphosis with a pupal stage). They possess two pairs of membranous wings with few cross veins, (though these may be absent in the females of some moths). The mandibles are present in the larvae but nearly always absent in the imagos/adults in whom the principal mouth parts are a sucking tube or proboscis formed from the maxillae which is held curled up in a spiral under the head when not in use (in a number of species of Moths the mouthparts are all degenerate in the imagos and these do not feed at all. The antennae are variable in length and may be quite complicated in some male moths The imagos have two large compound eyes with as many as 6 000 ommatidium and two ocelli, while the larva often have simple
The wings and body of the imagos are covered in scales and the body of the larva are generally covered in hairs (though these may be very fine and short). The salivary glands of the larvae have become modified to form the silk glands. The larvae are 'eruciform' (which means they look like a caterpillar) and in most cases have 13 body segments with three pairs of jointed legs on the first three segments, (which are roughly equivalent to a thorax in the imago).

Segments 3 to 6 of the abdomen (6,7,8,9 counting back from the head with the head as 0) each have a pair of unjointed pro- or false-legs, these end in a contractile pad surrounded by a ring of minute hooks; there is also a pair of unjointed claspers on the final segment.

16.10: Insect Order Mallophaga- biting lice

The Mallophaga are described as wingless (Apterous), hemimetabolous (having a simple metamorphosis i.e. no pupa) ectoparasites (living on the outside of their hosts) of mostly birds but also of some mammals, there are about 2,800 species worldwide. The range in size from 0.5 to 10 mm long dorsoventrally flattened with reduced compound eyes and no ocelli. The antennae are 3 to 5 segmented and capitate (with a knob on the end) and recessed into the head in the Amblycera but filiform (thin and linear) in the Ischnocera and may be modified as claspers organs in the male. Their mouthparts are designed for biting and they have no cerci, there is some suggestion that they may have evolved from the Psocoptera (Book and Bark Lice).

SUMMARY

- evolutionary relationships among insect groups is referred to as or phylogeny
- The class Insecta has two subclasses; namely Apterygota and Pterygota
- Apterygota are the primitive wingless insects that have not evolved from the winged ancestor; they have little or no metamorphosis and they have stylet like abdominal appendages, in addition to the cerci. Orders Protura, Collembola and Thysanura are apterygoites
- Sub class Pterygota are usually winged and have no abdominal appendages except cerci. and it includes 97% of all insects.
bed bugs are pests that feed on the blood of their host. The body louse is an important carrier of epidemic typhus; other louse-borne human diseases are trench fever and relapsing fever.

- The weevils and beetles (Coleoptera) form the largest order of insects and can be recognized by the hard wing called elytra.

- Diptera have one pair of wings. Some, like the blood-sucking mosquitoes and tse-tse flies, are serious pests. Flies are however beneficial as scavengers and predators of other insect pests.

- Ants, bees, wasps (Hymenoptera) have a constricted abdomen, while butterflies and moths (Lepidoptera) can be recognized by the colourful patterns in their wings.

**ACTIVITY 16.1**

1. Define these terms; apterygota, pterygota, exopterygota and endopterygota
2. Classify the following into orders; butterfly, sucking lice, biting lice, beetle, ant, bees, housefly, aphid, cockroach, assassin bug, termite, bristle tails
3. Name three insect orders that are parasites of mammals.
4. Name the insect order whose members have only one pair of wings.

**SUGGESTED FURTHER READING:**

Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
17.0: RECOGNITION OF INSECT ORDERS PART.2
17.1: Introduction
17.2: insect orders part II
17.3: Insect Order Mecoptera- scorpion flies
17.4: Insect Order Neuroptera- lacewings
17.5.1: Insect order Odonata- dragonflies
17.5.2: Insect Order Orthoptera- grasshoppers and crickets
17.6.1: Insect Order Phasmida - stick insects
17.6.2: Insect Order Plecoptera- stoneflies
17.6.3: Insect Order Protura-cone heads
17.6.4: Insect Order Psocoptera - book lice or psocids
17.7.1: Insect Order Siphonaptera- fleas
17.7.3: Insect Order Strepsiptera- stylops
17.8.1: Insect Order Thysanoptera - the thrips
17.8.2: Insect Order Thysanura- silverfish
17.8.3: Insect Order Trichoptera - the caddis flies
17.9: Insect Order Zoraptera-angel flies

17.1: INTRODUCTION
This lecture is essentially a continuation of the previous lecture but we shall examine
different types of insect orders from those you that you have studied.

OBJECTIVES
Relate the diversity of insects to their habit

17.2: INSECT ORDERS PART II
This lecture will demonstrate insect abundance and diversity. The insects have been
classified into their respective orders according to some common features unique to each
order. Similarities in certain structures is a reflection of evolutionary relationships or
phylogeny among insect groups. The lecture will help us identify commonly encountered
insects in our houses, gardens, on our animals and crops and sometimes even on our
bodies! This basic insect taxonomy should serve as the first step to more complex insect
taxonomy.
Mecoptera- scorpion flies, Neuroptera- lacewings, Odonata,dragonflies
Orthoptera, grasshoppers and crickets, Phasmida stick insects, Plecoptera,stoneflies,
 PROTura, Psocoptera  book lice or psocids, Siphonaptera fleas
Siphunculata sucking lice, Strepsiptera stylops, Thysanoptera thrips
Thysanura silverfish, Trichoptera caddisflies and Zoraptera
17.3: Insect Order Mecoptera- scorpion flies

Mecoptera are small to medium sized slender insects with long filiform antennae. The head is extended into a deflexed rostrum or beak with biting mouthparts at its end and is not broader than the front of the thorax, the eyes are prominent and semi-globose. The legs are long and slender, as are the 2 pairs of nearly equal wings, which are also membranous and clear with various dark patterns. The larva are generally eruciform (like a caterpillar), but may be modified Scarabaeiform (grub like, with a well developed head, a thick cylindrical body and 3 pairs of thoracic legs, but no prolegs) i.e. Boride and Panorpidae, or campodeiform (elongate and flattened with well developed legs and antennae) as in the Nanochoristidae. They have biting mouthparts and 3 pairs of thoracic legs. The pupa is exarate (having its appendages i.e. legs antennae etc. free outside of the main body of the pupa) and dectitious

17.4: Insect Order Neuroptera- lacewings

Neuroptera are soft-bodied insects of variable size usually with longish antennae. They have biting and chewing mouthparts both as larvae and as adults, though some of the adults do not feed. They generally have 2 pairs of wings, of which the hind pair are usually larger to some extent. The wings are normally held tent-like over their abdomen when not in flight. They have no cerci. They have ten segments to their abdomen and 5 to their tarsi.
They have large compound eyes. Their legs are all similar, except in the mantispidae, which have raptorial grasping forelegs. Those adults who feed do so on dead insects, nectar and other liquids. The larvae are all carnivorous. Many of the adults are relatively weak flyers and the larvae of some species attach the empty skins of their prey to backs as a disguise.

17.5.1: Insect order Odonata- dragonflies

Dragonflies have two pairs of almost equally sized long thin membranous wings; both pairs of wings usually have a stigma (a dark or colored patch near the middle of the leading edge) and a mass of cross veins giving them the appearance of being a mesh. Unlike most insects, which either flap both pairs of wings in unison (i.e. Bees and Butterflies), or only flap the hind pair (i.e. Beetles), or only have one pair (i.e. Flies), Dragonflies can flap or beat their wings independently. This means the front wings can be going down while the back ones are coming up. You can see this happening if you watch closely. Dragonflies are excellent fliers, particularly the Anisopterans and can loop-the-loop, hover and fly backwards quite easily. It is not unusual for the larger species to reach 30kph and the Australian Austrophlebia sp. has been clocked in at an impressive 58kph or 36 mph for short bursts. They flap their wings relatively slowly though, at less than 30 beats per second. Compare this with 200 bps for a hoverfly or 300 bps for a honeybee.

17.5.2: Insect Order Orthoptera- grasshoppers and crickets

Orthoptera are hemimetabolous (having nymphs that look like small adults and no pupa) medium or large insects that are usually winged as adults but may be apterous (wingless). They have a large pronotum (the plate covering the first thoracic segment or prothorax) and enlarged (often greatly so) hind femur, which are used for jumping. In the winged forms the fore wings are toughened and strengthened to form tegmina, the hind wings are membranous and folded fan like. They normally have large well-developed compound eyes as well as three ocelli, their cerci are normally short and one segmented and their mouthparts are designed for biting. Females usually have well developed ovipositor, this is more obvious in the Crickets and Bush-crickets. Their antennae are long and filiform in the Ensifera consisting of a large numbers segments, but short consisting of less than 30 segments in the Caelifera. It is considered by most scientist that the Orthoptera arose in the late Upper Carboniferous more than 300 million
Insect Order Phasmida - stick insects

Phasmida are hemimetabolous and generally elongate, though some forms (Leaf-Insects) are broad and flattened. Some forms are apterous (winged) though often only the male flies. They have biting and chewing mouthparts and are all phytophagous (leaf-eating). They all possess compound eyes and some of the winged forms possess 2 ocelli. Their antennae are generally filiform ranging from to over 100 segments and their cerci are short. They are often adorned with numerous spines and other protuberances.

Insect Order Plecoptera - stoneflies

There are about 2 000 named species all with aquatic larva, most of whom live only in cool
17.6.3: Insect Order Protura Protura / Cone heads

The name Protura, derived from the Greek words "proto-" meaning first (or original) and "ura" meaning tail, refers to the lack of advanced or specialized structures at the back of the abdomen.

**Life History & Ecology:**

Proturans are usually regarded as the most primitive of all hexapods. They have six legs and three body regions (head, thorax, and abdomen), but they lack most of the other physical features that are common to arthropods. Most species are very small (0.5-2.0 mm) and unpigmented. They are always found in moist habitats -- usually in the humus and leaf mold of temperate deciduous forests. Both adults and immatures feed on organic matter released by decay.

Proturans do not have eyes or antennae. The front pair of legs are usually held in front of the body and apparently serve as sense organs. Newly hatched proturans have nine abdominal segments. Each time they molt, another segment is added near the end of the abdomen until they are fully grown (and sexually mature) with 12 abdominal segments. Additional molts may occur during adulthood, but the body does not grow any longer.

**Classification**

Ametabola lacking metamorphosis eggs hatch into young, which are smaller than adults, but similar in appearance. Apterygota primitively wingless

**Physical Features: Adults and Immatures**

- Antennae absent
- Compound eyes absent
- Head conical, all mouthparts enclosed within the head capsule
- Pseudoculi present on head (these may be remnants of vestigial antennae)
- Front legs directed forward (probably sensory in function)
- Small ventral styli located on abdominal segments 1-3
Abdomen with 9-12 complete segments
- Cerci and abdominal filaments entirely absent
- Body unpigmented, usually white or ivory in color

**Economic Importance:**

Proturans are primarily inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of these arthropods are considered pests.

**Fact File:**

- Proturans were first discovered by Antonio Sylvestri in 1907 near Syracuse, New York. He found them in samples of leaf litter he had collected for a post-doctoral project on soil-dwelling invertebrates.
- Proturans do not have eyes or antennae. The front pair of legs are usually held in front of the body and apparently serve as sensory organs.
- Two of the three North American families of Protura lack a tracheal system. All gas exchange occurs through the integument.
- With only about 500 species worldwide, Protura is the smallest class in the phylum Arthropoda.

17.6.4: Insect Order Psocoptera - book lice or psocids
Psocoptera are Hemimetabolous with thread like antennae of 12 to 50 segments, the compound eyes of many species look like hemispheres that have been stuck on the outside of the head, though in a few species of Liposcelidae they are greatly reduced. Some are winged, with delicate membranous wings and some are not, the winged species possess 3 ocelli while the apterous (wingless) species have none. They have biting mouthparts, no cerci and date from the Permian times.

17.7.1: Insect Order Siphonaptera- fleas

Fleas are small laterally compressed (flattened from side to side) holometabolous (having a complete metamorphosis) insects. They are all apterous (flightless [from a = not, and pteron = wing]). They have no eyes though 2 simple ocelli may be present, their antennae short and stout and their adult mouthparts are adapted for piercing and sucking. The larvae are eruciform and apodous meaning they look like a caterpillar with no legs The adults are all blood sucking ectoparasites (a parasite which lives on the outside of its host) of mammals and birds, while in general the larvae are detritivores feeding on minute particles of discarded organic matter still adhering to the host, or on the substrate of a commonly used sleeping place or nest. The bodies of both adults and larvae have many backward pointing hairs for holding onto hosts.

17.7.2: Insect Order Strepsiptera - stylops

These are small (1.5 to 4.0 mms long), rather unusual looking insects. They are 'endoparasites' (parasites that live inside the bodies of their hosts, as compared with ectoparasites which live on the outside) of solitary bees, solitary wasps and other aculeates as well as various true bugs. The female is mostly flightless and are degenerate in that she has no legs and a body that looks rather like a maggot. The males have only one pair of functional wings, and these are the hind wings, the forewings are greatly reduced to look and function like the halteres of flies. They are not that common and few people other than entomologists have or are likely to see them. Their common name of Stylops becomes an adjective when describing the hosts that are carrying them, hence an
Strepsiptera are small endoparasitic insects. The males are free living and have unusual 'labellate' (with projecting flaps on one side) antennae, biting mouthparts and the fore wings reduced to small club-like appendages. The hind wings are relatively large and leathery with longitudinal but no cross veins. The abdomen is 10 segmented and the aedeagus (the organ used to transfer sperm to the female) is on the 9th sternum. They have no cerci. The females, except in the Mengenillidae, are larviform (look like a larva) and lives entirely within the last larval skin within which she also pupated, inside the body of her host. The head and thorax are united to form a cephalothorax. She also has no antennae or eyes and very reduced mouthparts. In the Mengenillidae the females are free living and have legs eyes and antennae.

17.8.1: Insect Order Thysanoptera - the thrips

They are described as holometabolous (having a complete metamorphosis even though the nymphs look like small wingless adults) insects with 2 or 3 inactive pupa-like instars. Thrips are 'Exopterygotes. They have asymmetrical mouthparts, having only one (the left) mandible, short 6- to 10-segmented antennae and no cerci. Their wings when present are nearly equal, very thin with little venation and a lot of hairs making a fringe around the edge, these hairs greatly increase the effective size of the wings. Fully winged, brachypterous (with reduced wings) and apterous (wingless) forms may occur in the same species. They have piercing sucking mouthparts.
17.8.2: Insect Order Thysanura

Flightless insects with ectognathous mouth parts (externally visible as compared to entognathous mouth parts of the Diplura, Protura and Collembola which are sunk into the head and thus not immediately visible). They have long filiform antennae with as many as, or more than 30 segments. The abdomen has eleven segments generally ending in three 'tails' consisting of two cerci and a telson. They are commonly represented by the Silverfish and the firebrats often found in houses and bakeries respectively.

Small to moderate moth-like insects with bristle-like antennae; mandibles vestigial or absent; wings membranous, hairy, at rest held roof like over the back; larvae aquatic, more or less eruciform, usually living in cases held by means of hooked caudal appendages; pupae exarate with strong mandibles.

17.9: Insect Order Zoraptera

The Zoraptera are a very small order of insects, there are about 30 known species. They are also
small in size being less than 3 mm long. They are hemimetabolous, have biting mouthparts, very short, 1 segmented cerci, and 9 segmented antennae. They are generally found under bark or in humus and leaf-litter. They are unusual in that each species comes in 2 different forms, one of which is 'alate' (has wings) and the other is 'apterous', i.e. doesn't have wings. The apterous form is the more common, generally white in color and has no compound eyes or ocelli, whereas the alate forms have both compound eyes and ocelli, and are more pigmented. Though less than 3 mm long an alate Zorapteran can have a total wingspan of about 7mm. Another interesting thing is that like their relatives the Termites (Isoptera) they can voluntarily shed their wings. Though little is known about the biology of Zorapterans it is known that 2 forms of nymphs occur that equate with the 2 different life-forms. They are usually found in rotting timber and or sawdust, well composted leaf-litter and Termites nests. They feed on fungal spores and smaller arthropods. The name Zoraptera comes from the Greek words "zor" meaning pure and "aptera" meaning wingless (they were named before the winged forms were discovered.

**SUMMARY**

- Scorpion flies (Mecoptera) can be recognized by means of the head which is extended into a deflexed rostrum or beak
- Lacewings (Neuroptera) are soft bodied insects that can be easily identified by their lace-like wings
- Dragonflies (Odonata) can flap or beat their wings independently. This means the front wings can be going down while the back ones are coming up. Dragonflies are excellent fliers, particularly the Anisopterans and can loop-the-loop, hover and fly backwards quite easily.
- Fleas (Siphonaptera) are small laterally compressed (flattened from side to side) l The adults are all blood sucking ectoparasites of mammals and birds, The bodies of both adults and larvae have many backward pointing hairs for holding onto hosts.
- Thrips (Thysanoptera) have asymmetrical mouthparts, having only one (the left) mandible, their wings when present are nearly equal, very thin with little venation and a lot of hairs making a fringe around the edge
- Angel flies (Zoraptera) are interesting in that like their relatives the Termites (Isoptera) they can voluntarily shed their wings

**ACTIVITY 17.1**
Indicate the Insect order against each insect listed below:-

1. Thrips
2. Silverfish
3. Book lice
SUGGESTED FURTHER READING:

Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html
LECTURE NUMBER EIGHTEEN

THE SOCIAL INSECTS

18.0: Social insects
18.1: Introduction
18.2: Overview of social insects.
18.2.1: Group(s) of insects are Social?
18.2.2: Important definitions in relation to social insects.
18.2.3: Traits of Asocial Insects.
18.2.4: Advantages and disadvantages of sociality.
18.3: Termites.
18.4: Social ants.
18.5: Social wasps.
18.6: Comparison of Isoptera and Hymenoptera caste systems.
18.7: Complex activities of insect societies.
18.7.1: Slavery
18.7.2: Warfare.
18.7.3: Farming.
18.7.4: Air conditioning.
18.7.5: Dances.

OBJECTIVES

At the end of this lecture you should be able to :-
- Identify the social insects and discuss their traits.
- Outline the advantages and disadvantages of insect sociality.
- Compare and contrast caste systems among the different social insects.
- Describe the unique social activities of bees, termites, ants and wasps.

18.1: INTRODUCTION
In the last two lectures we learnt about all the various insect orders. In this lecture you shall examine two orders namely: Isoptera (termites) and Hymenoptera (bees, ants and wasps), the "social" insects.
You shall learn the general traits and features of Isoptera and Hymenoptera. You shall discover that members of these two orders are unique in that they live in communities with well defined social organizations. The existence of different castes among the Isoptera and Hymenoptera will be elaborated. You will finally be able to compare the caste systems among the different social insects.

18.2: OVERVIEW OF SOCIAL INSECTS
Most insects are solitary but few insects are found in large groups or swarms or colonies. Insects that exhibit complicated patterns of social instincts with marked division of labour among the different individuals are termed social.

Most insects are not social, some aggregate or contact other members of their species for short periods to mate or for other functions. Some even dispense with mating and reproduce asexually.

Which group(s) of insects are Social?

18.2.1: Groups of insects are Social

Only a few groups are truly social.

All termites (Isoptera), some Hymenoptera (all ants, honey bees, sting less bees, bumble bees, and some members of other bee groups, and at least one wasp sp.).

True social insects, esp. the ants and termites, are dominant ecological groups. Social life and organization occurs among the following insect groups:

ants   termites   Honeybees   some wasps

18.2.2: Important definitions in relation to social insects

Caste - A specialized segment of the population of social insects, castes have different functions within the society and sometimes different morphologies. Castes have distinct divisions of labor.

Eusocial - Social systems characterized by parental care of young, overlap of generations, and reproductive division of labor. True sociality.
Homeostasis - The maintenance of a functional steady state in an organism or superorganism.

Polyethism - Behavioral differences among castes

Polymorphism - Caste members are radically different in appearance, as results from environmental (food) differences

Social Insects - Insects that live cooperatively in colonies and exhibit a division of labor among distinct castes. e.g. termites, ants, bees, some wasps.

18.2.3: Traits of Eusocial Insects
1) Parental care of young (young couldn't survive without parental care)
2) Overlap of generations (essential for 1)
3) Reproductive division of labor, i.e., there are egg-laying females and other females, may be other castes

For societies to persist, they must survive and reproduce more successfully than solitary individuals.

18.2.4: Castes among the social insects

- Reproductives - queen king or drones
- Workers
- Soldiers
  - May be distinct morphological types, esp. in ants.
  - Lacking in wasps and bees.

18.2.4: Advantages and disadvantages of sociality

<table>
<thead>
<tr>
<th></th>
<th>Solitary Insects</th>
<th>Social Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>Hide from predators</td>
<td>Colony productivity increased</td>
</tr>
<tr>
<td></td>
<td>No competition with others of your species</td>
<td>Group defense and alarm</td>
</tr>
<tr>
<td></td>
<td>Live in small spaces</td>
<td>Food gathering</td>
</tr>
<tr>
<td></td>
<td>Exploit small food resources</td>
<td>Nest building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Care of young</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>Lack of social benefits</td>
<td>Intense predation, parasitism, disease</td>
</tr>
</tbody>
</table>

ACTIVITY 18.1
Write true or false against the following statements:-
1. The behavioral differences among castes is called Polytheisn
2. Social insects live cooperatively in colonies and exhibit division of labor.
3. All termites, all wasps, all Hymenoptera and all ants are social insects.
4. The majority of insects live in colonies.
5. Some insects even dispense with mating and reproduce asexually.
6. The soldier caste is lacking in bees and wasps.
7. All the different castes are morphologically similar among the social ants.
8. An advantage among solitary insects is that they can exploit small food resources.
9. Polymorphic insect forms are radically different in appearance, as a result from environmental (food) differences.
10. The reproductive castes are usually the soldiers and the workers.

18.3: TERMITES
Termites (often called white ants) differ from ants in being soft bodied and usually light colored and having a broad joint between the thorax and abdomen. Ants are hard bodied and have a narrow constriction between the thorax and abdomen.

18.4: HONEYBEES
Honey bees have one of the most complex organizations in the insect world. Instead of lasting one season, their organization continues indefinitely. As many as 60,000 to 70,000 honeybees may be found in a single hive. Of these there are three different types (castes).
few hundred **drones** (males) and the rest are

Three Castes of Honey Bees are illustrated below:

- **A Queen Bee**
- **A Drone Bee**
- **A Worker Bee**

**Honey Bees castes and their respective duties**

- **Reproductive Castes** - queen and drone
  - **The Queen Bee**
    - Rules the bee hive
    - Produces eggs to maintain the colony
    - Lays all the eggs and regulates sex of offspring (parthenogenesis).
      - Unfertilized eggs -> males
      - Fertilized eggs -> females
    - All members of the hive are the queen's progeny.
  - The queen's pheromones identify hive members
- **Drones** - mate with new queens
  - **The Worker Bees**
    - Workers determine type of egg laid by queen.
      - Large cells receive unfertilized eggs that develop into males -- males haploid.
fertilized eggs that develop into females -- female.

- Workers determine whether a female egg develops into a reproductive or worker.
  - Workers receive royal jelly only their first three days.
  - Queens receive royal jelly throughout the larval stage.

The workers carry on all the activities of the hive except the laying of eggs. They gather nectar from flowers, manufacture honey, collect pollen, secrete wax, take care of the young and ventilate and guard the hive. Each worker appears to do a specific task in all this multiplicity of duties. Their life span is only a few weeks. One drone fertilizes the queen and stores sperm enough in her spermtheca to last her a lifetime. The drone is thereafter killed by workers. Thereafter the queen is concerned solely with egg laying. During the discharge of an egg, she is able to release or to withhold sperm, thereby determining whether or not the egg is fertilized. In so doing she effects the distinction between females and males. Males can only arise from unfertilized eggs and females from fertilized ones. A new queen mates during a mating flight. She then starts a new colony where she may lay as many as a million eggs. The queen can differentiate the larger beehive cells in which she lays her fertilized eggs (which develop into males) and the smaller worker cells in which she lays her unfertilized eggs. Whether larvae destined to become female will develop into a queen will depend on the kind of food it is fed by the workers. Workers that will become queens are fed royal jelly, a secretion from the salivary glands produced by workers only when there is no queen or when the queen is too old to produce enough pheromones or queen substance. The queen secretes from her mandibular glands the queen substance, which is licked off by the worker bees. This substance inhibits ovarian development in the workers and prevents them from becoming queens. In the absence of the queen from the hive the workers quickly begin rearing a new one. In an over-crowded colony the queen substance may not be distributed to all the workers so that reproductive individuals may swarm and a new queen mates with a drone and she starts another colony.

WHO RULES THE BEE HIVE?

18.4: SOCIAL ANTS
Did you know that the science of studying ants is called Myrmecology?

There are thousands of species of ants found all over the world and in just about every type of land environment. Ants are common social insects that live in colonies. Some colonies have millions of ants. Each ant colony consists of the following:

- **Queen** - the queen begins her life with wings, which she uses while mating. After mating with a male ant or many males, she flies to her nesting area. She then loses her wings and spends her life laying eggs.
- **Workers** - Most ants in a colony are workers. Workers are the many sterile, wingless female worker ants that are the daughters of the queen. These workers
Soldiers - Soldiers are large workers (sterile females) who defend the colony and often raid other colonies.

Male reproducitives - these are small male ants that have wings. They fly from colony to mate with a queen, they die soon afterwards.

Interesting things about ants!
Some ants have a stinger at the tip of the abdomen, which can inject poisonous acid into the victim.
Ants can also bite using their jaws (mandibles).
Ants have evolved some striking patterns of economic behavior, such as making slaves, farming fungi (leafcutter ants are fungus farmers – they grow their own food), herding ant cows (aphids), sewing their nests together with silk, and using tools.

18.5: SOCIAL WASPS
Socials wasps such as the paper wasps, yellow jackets, and bald faced hornets also have a caste system of:

- Drones
- Workers
- Queens - There may be more than one queen in a vespid wasp nest. The determination of queens and workers seems to occur in the larval stages.

Social wasps include the paper wasps also known as vespids, the bald-faced hornets and the yellow jackets. The yellow jackets build their nests chiefly on the ground. The vespids construct their nests of papery material consisting of foliage or wood. There may be more than one queen in a wasp nest. There are social hierarchies established, that determine which of the many queens becomes the active one.

ACTIVITY 18.2 Answers in the text

1. Draw diagrams to differentiate the queen, drone and worker bees.
2. Outline the four different castes in an ant colony.
3. Mention three types of social wasps.
4. Write short notes on royal jelly.
5. Describe how bees form new colonies.
6. By means of a diagram differentiate the different termite castes.
7. Define the term myrmecology.
COMPARISON OF ISOPTERA AND HYMENOPTERA CASTE SYSTEMS

<table>
<thead>
<tr>
<th></th>
<th>Workers and Soldiers</th>
<th>Stage</th>
<th>Male Reproductives (Drones, Kings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>M/F</td>
<td>Immature or adult</td>
<td>Permanent attendant of the queen</td>
</tr>
<tr>
<td>Termites</td>
<td>F</td>
<td>Adults</td>
<td>Die after mating</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Unlike bees, in termites the male is not a drone but a king. Workers may be males and the king has functions other than mating. The queen may live for more than 10 years. But if she is killed or her egg production declines, secondary queens replace her.

Caste members may be radically different in appearance from one another or polymorphic and castes may have subcastes that differ in appearance and function. This usually results from environmental (food) differences not genetic differences. Behavioral differences among castes are called polyethism.

18.7: COMPLEX ACTIVITIES OF INSECT SOCIETIES

18.7.1: Slavery

A biological, not a cultural trait that is wide-spread among ants. Most ant battles you see are actually slave raids. Ant slavery is unique because ant slavery is usually between species, unlike human slavery.

Slave making ants

- Capture larvae and pupae of another species.
- Carry them back to their own nest where:
  - They acquire the nest odor.
  - Develop into adults and act as workers for their new colony.

Some slave making ant species are incapable of surviving without slave workers. They are no longer able to collect food or feed their immatures or themselves.

18.7.2: Warfare

Embodies restless aggression, territorial conquest, and genocidal annihilation of neighboring colonies. Ants war with their own and other species and use a variety of tactics.
The fire ants have colonies hundred times larger than the woodland ant and whenever they discover a woodland ant colony they completely destroy it. Yet woodland ant colonies are abundant around fire ants. Whenever, a woodland worker discovers a fire ant scout soldiers are so rapidly deployed that the scout rarely makes it back to its colony. The soldiers do not sting or spray poisons like many ants but rely on large mandibles to cut their opponents into pieces. If despite this the woodland nest is discovered the soldiers fall back to form a short perimeter around the nest, which keeps the invading, fire ants at bay temporarily. The colony evacuates the nest and after the battle and the fire ants have departed, they will return and reclaim their nest.

18.7.3: Farming

Many ants keep insect livestock in the order Homoptera. Commonly seen in our area are ants tending aphids. The ants herd the aphids and protect them from predators and parasites, in turn, the aphids reward the ants by providing with droplets of sweet and nourishing honeydew. Besides aphids, scale insects, other Homoptera, are farmed and some insects in other orders. This is a good example of symbiosis.

Other ants and some termites are gardeners. They collect plant material, bring it into their nests, compost it, and use it to grow fungi, which they feed on. Leaf cutter and parasol ants are examples.

18.7.4: Air conditioning

Some social insects are able to maintain steady state conditions in their colonies or nests, e.g. in temperature and humidity. This is called homeostasis and is essential for colony health.

Honey bees

- Ventilate their hives - if too hot, wax melts.
- Cluster to stay warm in the winter - if too cold, individuals die.

Termites

- Soft bodied, very susceptible to desiccation.
- "Air conditioned" termite mounds - vent heat and retain humidity.

Did you know that bees have a complex bee language?

18.7.5: Dances
Bees have developed a language expressed by a sort of dancing ritual by which workers can inform the other workers in the hive the whereabouts, distance to, and type of food source they have discovered. There are two types of dances the waggling dance and the round dance. These two dances are described in detail in the last lecture.

**SUMMARY**

We have learnt that:

- Insects that exhibit complicated patterns of social instincts with marked division of labour among the different individuals are termed social.
- Social life and organization occurs among all termites (Isoptera), some Hymenoptera, (all ants, some bees, and some wasp species).
- For these insect societies to persist, they must survive and reproduce more successfully than solitary individuals. To achieve this, social insects provide parental care of young, have reproductive division of labor, i.e. there are females whose sole role is egg-laying and there is overlap of generations. Social insects also have complex modes of communications that ensures harmony within colonies.
- The three castes of termites are a winged adult reproductive, a wingless worker and a wingless soldier.
- The three caste in honey bee colonies are the queen, drone and worker. The queen bee rules such a colony and the drone is killed by workers after it has mated with the queen.
- Ants colonies, which can consist of as many as millions of ants are found all over the world. Each ant colony consists of the Queen, Workers soldiers and male reproductives. Most ants in a colony are the wingless, sterile females who are the daughters of the queen. Soldiers are large workers (sterile females) who defend the colony and often raid other colonies. Male reproductives are small winged male ants that fly from colony to colony to mate with a queen and die soon afterwards.
- Some wasps are social and have a caste system of drones, workers and queens. There may be more than one queen in a wasp nest.
- There are differences in the social organization of Isoptera(termites) and Hymenoptera.
- Complex activities of insect societies include slavery, warefare, farmingair conditioning.

**ACTIVITY 18.3**

1. Name four different insect groups that live in colonies
2. List three different castes among social insects
3. Compare and contrast caste systems among different social insects
4. List five striking patterns of economic behavior exhibited by social insects.

SUGGESTED FURTHER READING

Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html. 79.
LECTURE NUMBER NINETEEN

19.0: BENEFICIAL AND DESTRUCTIVE INSECTS
19.1: Introduction
19.2: Insects and the Ecosystem
19.3: Beneficial insects
19.4: Destructive Insects
19.5: Control of destructive insects

19.1: INTRODUCTION
The relationship between insects and man is mentioned by outlining some of the beneficial and destructive insects. The concept of insect pest management is mentioned as a stepping stone to more specialized studies of pest management.

OBJECTIVES
At the end of this lecture you should be able to:

- Discuss the importance of insects in the ecosystem.
- Recognize the useful insects.
- Distinguish the insects that cause harm to crops, stored products etc.
- Identify parasitic insects that affect man and animals.
- State the major diseases of man and animals caused by insects
- Outline the various methods employed in controlling insect pests.

19.2: ROLE OF INSECTS IN THE ECOSYSTEM AND HUMAN SOCIETY
Insects are a dominant component of biodiversity in terrestrial ecosystems and play a key role in mediating the relationship between plants and ecosystem processes.

19.3: BENEFICIAL INSECTS:
Although pest insects attract the most attention, many insects are beneficial to the environment and to humans

Do you know any beneficial insect?
If the answer is yes, name them and identify any others from the pictures below.
If the answer is no, you may learn some of them from Fig 19.1 below.
1. **Products useful to man**

Insects also produce useful substances such as honey, wax, lacquer and silk. Honeybees, have been cultured by humans for thousands of years for honey, although contracting for crop pollination is becoming more significant for beekeepers. The silkworm has greatly affected human history, as silk-driven trade established relationships between China and the rest of the world.

The wax is used in the making of shellac. Several kinds of silkworms especially *Bombyx mori* are reared for the production of silk.

Various dyes have been made from insects. Certain drugs such as cantharidin, is made from the Spanish fly, a blister beetle.

2. **Cross pollination**

Insects are important in the cross pollination of fruits and crops. The bees are indispensable in this respect. Insects and higher plants have evolved an intimate relationship of mutually advantageous adaptations. Insects exploit flowers for food and flowers exploit insects for pollination. Pollination is a trade between plants that need to reproduce, and pollinators that receive rewards of nectar and pollen. A serious environmental problem today is the decline of populations of pollinator insects, and a number of species of insects are now cultured primarily for pollination management in order to have sufficient pollinators in the field, orchard or greenhouse at bloom time.
Although mostly unnoticed by most humans, the most useful of all insects are insectivores, those that feed on other insects. Many insects, such as grasshoppers, can potentially reproduce so quickly that they could literally bury the earth in a single season. However, there are hundreds of other insect species that feed on grasshopper eggs, and some that feed on grasshopper adults. This role in ecology is usually assumed to be primarily one of birds, but insects, though less glamorous, are much more significant. Among these are ladybird beetles, aphid lions, ant lions, praying mantids, wasps and many others. For any pest insect one can name, there is a species of wasp that is either a parasitoid or predator upon that pest, and plays a significant role in controlling it. Predaceous insects destroy a variety of harmful insects.

Some insects lay their eggs on the larvae of injurious insects, and the parasitic larvae hatched from these eggs devour their host.

4. Cleaning the environment
Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees, recycling the biological materials into forms found useful by other organisms. The ancient Egyptian religion adored beetles and represented them as scarabeums. Beetles and flies feed on decaying plant and animal refuse. The tumblebugs roll up balls of dung in which they lay their eggs; the developing larvae eat up the dung.

5. Source of food
In some parts of the world, insects are used for human food ("Entomophagy"), while being a taboo in other places. There are proponents of developing this use to provide a major source of protein in human nutrition. Since it is impossible to entirely eliminate pest insects from the human food chain, insects already are present in many foods, especially grains. Most people do not realize that food laws in many countries do not prohibit insect parts in food, but rather limit the quantity. According to cultural materialist anthropologist Marvin Harris, the eating of insects is taboo in cultures that have protein sources that require less work, like farm birds or cattle. Insects are a source of food for birds and many other animals.

6. Research tools
Insects such as the fruit flies have been used in laboratories to carry out useful scientific investigations.

Fly larvae (maggots) were formerly used to treat wounds to prevent or stop gangrene, as they would only consume dead flesh. This treatment is finding modern usage in some hospitals. Insect larvae of various kinds are also commonly used as fishing bait.

7. Aesthetic value
Insects such as the butterflies are beautiful to watch.
19.4: DESTRUCTIVE INSECTS

Many insects are considered pests by humans. Insects commonly regarded as pests include those that are parasitic (mosquitoes, lice, bedbugs), transmit diseases (mosquitoes, flies), damage structures (termites), or destroy agricultural goods (locusts, weevils).

Injurious insects affect man in some of the ways stated below:

1. **Agricultural pests:** Nearly all cultivated crops are bothered to some extent by insects. Insects that eat and destroy crops include grasshoppers, corn borers, cotton boll weevils, scales, armyworms, fruit flies, and many others. The amount of damage is usually enormous.

2. **Nuisance:** Flies are normally a nuisance and can cause discomfort during man’s activities. The night fliers can interrupt sleep. Some insects inflict painful bites.

3. **Venomous bites:** Insects such as bee, wasps, inject painful venoms with their stings.

4. **Parasitism:** Insects such as lice, fleas, and bed bugs are ectoparasites of man and other animals. The larvae of blow flies, warble flies, and botflies are internal parasites of animals; infestation of tissues of man and animals is by fly larvae causes an undesirable condition termed *Myiasis*.

5. **Disease transmission:** Among the chief vectors of disease are mosquitoes, which transmit malaria, yellow fever, and filariasis; houseflies, which can transmit typhoid, dysentery, and other diseases; tsetse flies, which transmit animal and human trypanosomiasis. Other insects, which can transmit diseases, include sand flies, black flies, fleas, and lice. The list is not exhaustive.

6. **Household pests:** Larval stages of moths such as the cloth moth build their cocoons from fabrics, upon which they feed and ruin. Carpet beetles are equally destructive. Weevils, cockroaches damage stored food products; ants and termites can cause serious damage to household fittings and timber.

19.5: CONTROL OF DESTRUCTIVE INSECTS

Many entomologists are involved in various forms of pest control, often using insecticides, but more and more relying on methods of biocontrol.
insecticides can backfire, because important but unrecognized insects already helping to control pest populations are also killed by the poison, leading eventually to population explosions of the pest species.

The control of insects is one of the problems confronting man in his search for sound methods of ecologic management. Insects are interwoven into the ecologic system and serve many useful as well as destructive roles. The big problem is to find ways of controlling only the destructive insects without destroying the rest. Two kind of tactics are being emphasized in efforts no insect control; tactics that involve developing animals and plants that are resistant to insect pests and tactics that directly destroy the insect pests in question. Some of the current methods being applied to control certain insects include the following:

1. Chemical control
2. Physical control
3. Biological control
   a. Viruses
   b. Natural predators
   c. Sterile insect technique
   d. Insect sex attractants

SUMMARY
In this lecture we have learn that:

- Insects are interwoven into the ecologic system and serve many useful as well as destructive roles
- Biocontrol of insect pests is one of the sound methods of ecologic management

ACTIVITY 19.1

1. List five ways in which insects benefit man
2. List five ways in which insects are injurious to man
3. Define the term myiasis
4. State some of the methods of insect control.
SUGGESTED FURTHER READING:
C.V.Mosby Co. Saint Louis. pp.343-378
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html.
20.0: INSECT ORIGIN, BEHAVIOUR AND ECOLOGY

20.1: Introduction
20.2 Origin of insects
20.3: Insect behavior
20.3.1 Light production
20.3.2: Reactions to chemical signals
20.3.2.1: Insect Pheromones
20.3.3: Sound production
20.3.4: Visual communication
20.3.5: Rhythms of Activity (Biological clock)
20.4: Insect ecology
20.4.1: Factors contributing to the success of Insects
20.4.2: Role of insects in the environment

20.1: INTRODUCTION

OBJECTIVES
At the end of this lecture you should be able:

1. Give a brief account on the origin of insects
2. Outline some of the unique and complex behavior patterns of insects.
7. List the factors that have contributed to the success of insects

20.2 ORIGIN OF INSECTS

The relationships of insects to other animal groups remain unclear. Although more traditionally grouped with millipedes and centipedes, evidence has emerged favoring closer evolutionary ties with the crustaceans.

One theory suggests that insects arose from the ancestral stock of the class Symphyla. In the Pancrustacea theory insects, together with Remipedia and Malacostraca, make up a natural clade.

Most entomologists, however, believe that insects probably evolved from worm like sea creatures.

The study of fossilized insects is called paleoentomology

Fossil records indicate that the first insects were wingless dated back to the Devonian period, which lasted from 410 million to 355 million years ago.
By early Bashkirian age, about 350 million years ago, insect species were already diverse and highly specialized by this time, with fossil evidence reflecting the presence of more than a dozen different orders. Thus, the first insects probably emerged earlier in the Carboniferous period, or even in the preceding Devonian. Research to discover these earliest insect ancestors in the fossil record continues.

The origin of insect flight remains obscure but it is generally believed that approximately 200 to 350 million years ago (late carboniferous period) insects developed wings and the ability to fly. Insects were the first group of animals to have the power to fly. The early wings were primitive and could not be folded.

Insects were therefore dominant in the carbiniferous and permian period (290-250 million years ago).

Late Carboniferous and early Permian insect orders include both several current very long-lived groups and a number of Paleozoic forms. During this era, some giant dragonfly-like forms reached wingspans of 55 to 70 cm, making them far larger than any living insect. Also their nymphs must have had a very impressive size. This gigantism may have been due to higher atmospheric oxygen levels that allowed increased respiratory efficiency relative to today.

Most extant orders of insects developed during the Permian era that began around 270 million years ago. Towards the end of the permian period carboniferous insects became extinct and other species appeared. This period is referred to as the Permian-Triassic extinction event, the largest mass extinction in the history of the earth, around 252–205 million years ago.

By the Jurassic period, which lasted from about 213 to 145 million years ago, all present-day insect orders had apparred.

The remarkably successful Hymenopterans appeared in the Cretaceous period (135-65 million years ago) but achieved their diversity more recently, in the Cenozoic era. Many modern insect genera developed during the Cenozoic era (at least 65 million years). Insects from this period on are often found preserved in amber, often in perfect condition. Such specimens are easily compared with modern species.

A number of highly-successful insect groups evolved in conjunction with flowering plants, a powerful illustration of co-evolution.
20.3.1 Light production:

The production of light by living organisms is called bioluminescence. It may be for sex signaling, for kin recognition, for frightening enemies, for allurement, or to act as a lamp to guide the animals' movement. In fire flies light production functions to attract the opposite sex.

20.3.2 Reactions to chemical signals

The chemical signals that insects produce and use to communicate are called Pheromones. Many examples of chemical communication are known in insects. A few striking examples are as follows: the male of some moths can locate females by means of air-borne substances detected from a distance as great as 2.7 miles. Substances deposited on the ground by ants returning from foraging trips serve as trail marker for other ants. More remarkable is the fact that a substance produced by the death and decomposition of the body of an ant within a colony will stimulate other workers to remove the body. If a live ant is painted with an extract from a decomposing body, the painted ant will be carried live out of the nest as it struggles.

If an ant colony is attacked the other members of the colony respond by assuming aggressive postures or attacking the intruder. The workers are stimulated by pheromones from the mandibular or anal glands, which is released by any individual being attacked. Pheromones can also induce gathering, mutual grooming and trophallaxis in ants. Trophallaxis refers to mutual exchange of food amongst insects, particularly the social insects.

20.3.2.1 Insect pheromones

Pheromones are substances that are secreted onto the outside of the body where they influence the behavior of other members of the same species.

Insects possess very refined organs of perceiving pheromones that surpasses even the human perception. For example, some male moths have a specialized sense of smell that enables them to detect the pheromones of the female moths over distances of several kilometers! They are sometimes called "social hormones." They are chemical communication signals. Insect pheromones include odor trails by ants, sex attractants, alarm substances, and territorial markers. Pheromones are most numerous in the social insects.
**20.3.3: Sound production**

Stridulation is the production of sound by rubbing two parts of the body together; this mechanism is best known in crickets, grasshoppers, and cicadas. Other insects which stridulate include Black imported fire ant (*Solenopsis richteri*) and larval Lucanidae (stag beetle), Passalidae (Bessbug), and Geotrupidae (earth-boring dung beetles).

Sound production are concerned with calling, courtship, copulation, aggression and alarm. Sound production is especially notable in grasshoppers, crickets, and cicadas. Crickets produce sounds by rubbing of the front margin against the vein of the forewing. Each species of cricket produces a number of songs, which differ from the songs of other species. The static-like sounds of cicadas, which serve to aggregate individuals, are produced by vibrations of special chitinous abdominal membranes. Grasshoppers produce sound by the rubbing of the forewing against the hind femur. The role of songs in courtship has been greatly studied in grasshoppers; where the female responds to the male only at certain times. In some insect groups only one sex produces sound, to which the opposite sex responds accordingly.

**ACTIVITY 20.1** Answers in the appendices

1. Write short notes on insect pheromones
2. Define the term bioluminescence
3. Define the term stridulation

**20.3.4: Visual communication**

Communication is simply the influencing of one individual by the behavior of another. Among the most interesting behavior patterns is the power of many insects have of finding their directions and communicating the same to others. Honey bees for instance have a bee language for conveying information on food source to others members of the hive. The illustrations below show the two types of bee dances that communicate the source, distance and location of the food.

- **The waggling dance**

If the food source is more than 100 meters away from the hive, a honey bee performs the waggling dance illustrated below: The direction of the food source is indicated by the direction of the waggle dance in relation top the sun. This dance is roughly in the pattern of a figure eight that she makes against the vertical side of the comb. In the performance of this act she waggles her abdomen from side to side in a characteristic manner. She repeats the dance over and over, the number of dances decreasing per unit time the farther
The position of the food source is also indicated by the direction of the waggle dance in relation to the position of the sun. When the waggle dance is upward on the comb, the source of food is toward the sun. A waggle run downward on the comb, indicates that the food source is opposite the position of the sun. If the food source is at an angle to the sun, the direction of the waggle dance is at a corresponding angle. Insects thus make use of polarized light.

During a dance other bees keep in contact with the scout bee with their antennae, and each performance results in several bees taking off in search of the food.

**Figure 20.1 Diagrammatic representation of the honey bee wagging dance**
When the food source is less than 100 metres from the hive, the pattern of dance is less complex. In this case the scout bee simply turns round in a circle first to the right and then to the left, a performance she repeats several times. She is able in this way to convey to other bees the information to seek around the hive food of the same same odors she bears.

**20.3.5. Rhythms of Activity (Biological clock)**

Some insects are more active at night (nocturnal), others in daylight (diurnal), and still others in dim light (crepuscular). Locusts are active during daylight and almost completely inactive at night, while mosquitoes, cockroaches and other insects are wholly nocturnal in their flight activity. The recurring rhythmic activities is determined by some "biological clock". The timing of the activities is believed to be controlled by both external and internal factors.

**ACTIVITY 20.2** The answers are in the appendices

Write YES or NO against the following statements.

1. The bee dances communicate the source, distance and direction of the food.

2. Insects that are active in dim light are described as being diurnal.

3. Mosquitoes and cockroaches are largely nocturnal.
5. Each species of cricket produces a number of songs, which differ from the songs of other species.

6. In fireflies, light production functions to attract the opposite sex.

7. If the food source is less than 100 meters away from the hive, bees perform the waggling dance.

8. Fossil records indicate that the ancestral insects were wingless.

9. The study of fossilized insects is called paleoentomology.

10. Bees perform the round dance when the food source is more than 100 meters from the hive.

### 20.3: INSECT ECOLOGY

Ecology is the study of the interrelationships between organisms and their environment. An insect's environment may be described by physical factors such as temperature, wind, humidity, light, and biological factors such as other members of the species, food sources, natural enemies, and competitors (organisms using the same space or food source).

You learnt in lecture 19 that although pest insects attract the most attention many insects play varied roles in the ecosystem. An understanding or at least an appreciation of these physical and biological (ecological) factors and how they relate to insect diversity, activity (timing of insect appearance or phenology), and abundance is critical for successful pest management.

Some insect species have a single generation per season (univoltine), while others may have several (multivoltine). The striped cucumber beetle, for example, over winters as an adult, emerges in the spring, and lays eggs near the roots of young cucurbit plants. The eggs hatch, producing larvae that emerge as adults later in the summer. These adults over winter to start the cycle again the next year. In contrast, egg parasitoids like Trichogramma over winter as immatures within the egg of their host. During the summer they may have several generations.

Insects adapt to many types of environmental conditions during their seasonal cycle. To survive the harsh winters, cucumber beetles enter a dormant state. While in this dormant state, metabolic activity is minimal and no reproduction or growth occurs. Dormancy can also occur at other times of the year when conditions may be stressful for the insect.
It is often better to consider insects as populations rather than individuals, especially within the context of an agro ecosystem. Populations have attributes such as density (number per unit area), age distribution (proportion in each life stage), and birth and death rates. Understanding the attributes of a pest population is important for good management. Knowing the age distribution of a pest population may indicate the potential for crop damage. For example, if most of the striped cucumber beetles are immatures, direct damage to the above ground portions of the plant is unlikely. Similarly, if the density of a pest is known and can be related to the potential for damage, an action may be required to protect the crop. Information about death rates due to natural enemies can be very important. Natural enemies do nothing but reduce pest populations and understanding and quantifying their impact is important to effective pest management. This is all the more reason to conserve their numbers.

20.4.1. Factors contributing to the success of Insects

Are you aware that Insects are amongst the most successful terrestrial animals?

Insects are enormous in terms of numbers and have also undergone adaptive radiation that enables them to live in a wide variety of habitats. Their success is attributed to a number of factors, which include the following:

- **Possession of the Exoskeleton:** The exoskeleton protects insects from the harsh environment, natural enemies and desiccation.
- **Adaptability to wide range of habitats:** Insects can live in nearly all types of places except the deep sea.
- **Varied food source:** The ability to utilize a wide variety of foods enables insects to live successfully in various types of habitats. They have varied mouthparts suitable for different types of foods.
- **High reproductive potential:** Insects have very short life cycles. This results in very large number of progeny within a short time. Some such as bees and aphids can even reproduce parthenogenetically. This ensures survival of the species even in harsh environment.
- **Communal life:** The ability of some insects to live together in colonies has been an important factor in their success. The social organization in Isoptera and hymenoptera results in efficient division of labour among the individuals for the benefit of the whole colony.
- **Complex behavior:** Insects have some complex behaviour patterns that ensures their survival; for example, some insects will lay eggs only with view to the future needs of the young. Males of the family Empididae (Diptera) offer well [prepared food to females as a present as part of the mating ritual, a sort of a bribe to ensure her cooperation. Some insects can communicate information on food source and danger to members of their community.
Sensory adaptations include:

- **Sensory organs of small size**: Insects require only small amounts of food due to their small size. They are not always visible and can hide from enemies.

- **Sensitive sense organs**: Insects are able to respond quickly and favorably to changes in their environment.

- **Defense mechanisms**: Insects have interesting and effective means of defense from enemies such as protective coloration, stings.

- **Possession of wings**: The power of flight has greatly contributed to the success of insects by:
  - Allowing them access to many habitats
  - Permitting maximum dispersal (thus reducing competition and overcrowding)
  - Making escape from natural enemies possible and undesirable situations.
  - Enabling them to search for food over long distances.

**SUMMARY**

In this lecture we have learnt that:

- The study of fossilized insects is called **paleoentomology**. And insects first appear in the fossil record during the Carboniferous age, about 350 million years ago.

- Insects have evolutionary relationships with either annelids, crustaceans, millipedes or centipedes. It generally believed that insects evolved from some wingless ancestor.

- Although pest insects attract the most attention, many insects play varied roles in the ecosystem.

- Many insects possess refined organs and mechanisms for complex communication hence complex behavior. Pheromones found in ant trails, territorial markers, and sex attractants play a key role as the chemical signals that elicits certain behavior patterns, such as aggregation, courtship, etc. The social insects are so tightly integrated that they are sometimes considered super organisms.

- Among the many complex behavior patterns displayed by insects are phenomena such as stridulation, bioluminescence, and trophallaxis, visual and chemical communication.

- Several factors have contributed to the success of insects among them being:
  - Possession of the exoskeleton and wings, effective defense mechanisms, sensitive sense organs, small body size, varied food source, communal life, complex behavior, high reproductive potential and adaptability to a wide range of habitats.
ACTIVITY 20.3 Review questions
These are important review questions. You will find the answers in the text.
1 Write short notes on some of the conventional theories with respect to the origin of insects.

2. Outline the factors that have contributed to the success of insects.

3 Insects display some complex behavior patterns. Discuss this statement with specific examples.

SUGGESTED FURTHER READING:
New york and London.
Website(s) www.uwrf.edu/~W1083004/333/SG-ext.anatomy.html
www.cals.ncsu.edu/course/ent425/tutorial/integ.html
www.earthlife.net/insects/ecology.html
http://en.wikipedia.org/wiki/Insect
ANSWERS TO TEXT QUESTIONS

CHAPTER ONE

Activity 1.1
No. 1 Species genus, family, order, class phylum kingdom
No. 2 Entomology
No. 3 Taxonomy
No. 4. Taxon
No. 5. Thirty

Activity 1.2 A diagram

Activity 1.3 A table

Activity 1.4 Answers in text

CHAPTER TWO

Activity 2.1
No. 1 (a) Epicuticle (b) Endocuticle
© Exocuticel (d) Epidermis

Activity 2.2
No. 1. Sclerotization
2. Foregut, hindgut and trachea
3. Epicuticle
4. Resin

Activity 2.3. Answers in text

CHAPTER THREE

Activity 3.1
No.1. Yes
2. Plates covering the insect body
3. Head capsule

Activity 3.2
No. 1 A Sketch

Activity 3.3
1. Vertex - Top of the insect head
2. Clypeus - Upper mid portion of insect head
3. Beetle larvae - Prognathous
4. Gena - Cheek
1. **Grasshopper** - Hypognathous
2. **Aphi** - Opisthognathous
3. **Frons** - Face of an insect
4. **Labrum** - Insect upper lip
5. **Ocelli** - Simple eyes
6. **Sulcus** - Lines
7. **Sclerites** - Plates
8. **Sensory** - Antennae

**Activity 3.4**
Answers in text

**CHAPTER FOUR**

**Activity 4.1**
No. 1 Sensory

**Activity 4.2**
No. 1 Basal Scape, antennifer, pedical, flagellum, meristom.

**Activity 4.3**
A sketch of insect antennae

**CHAPTER FIVE**

**Activity 5.1**
No. 1 mandibles, maxillae, Labium, Labrum, Hypopharynx

**Activity 5.2**
No. 1 Neuroptera (ant lions), Hymenoptera (honey bees)
No. 2 Cutting floral tissues and nest const
No. 3 Labium and maxillae
No. 4 Yes
No. 5 Lacinae

**Activity 5.4**
No. 1 Haematophagous
No. 2 Retractable or coiled when not in use
No. 3 Sponging or lapping

**Activity 5.5. Answers in the text**

**CHAPTER SIX**

**Activity 6.1**
No. 1 Prothorax, Mesothorax, Metathorax
No. 2 Tergites sternites, pleurites
No. 3 Lateral

**Activity 6.2**
Answers in the text
Activity 6.3
No. 1  Corbicula
No. 2  Swimming
No. 3  3 pairs
No. 4  Pronotum
No. 5  Odonata
No. 6  Calcar

Activity 6.4
No. 1.  Crawling, Grasping, Jumping, Pollen carrying, Digging, Swimming
No. 2  Sound production, Silk production, auditory

CHAPTER SEVEN
Activity 7.1
No. 1.  A drawing

Activity 7.2
1. Yes
2. NO
3. Yes
4. Yes
5. Yes
6. NO
7. Yes
8. No
9. NO
10. Yes

Activity 7.3
No. 1.  (a) Fleas
(b) Lice
(c) Bedbugs

No. 2  (a) Thrips - Fringed
(b) Lacewings - Lacelike
© Stick insect - Brachypterous
(d) Moths and butterflies – Scales

No. 3  (a) Hemelytron
(b) Elytra
(c) Halteres
(d) Tegmina

No. 4  Wings of insects are flattened outgrowths of the body wall. Wings of
CHAPTER EIGHT
Activity 8.1 - Self-evaluation

Activity 8.2 - self-evaluation

Activity 8.3
No. 1. NO No. 6 Yes
2. yes 7 NO
3. Yes 8 NO
4. NO 9 Yes
5. Yes 10 No

Activity 8.4
No. 1. Answer in text
2. Answers in text
3. Defense, Copulation, Locomotion, Food gathering, Sense organ
4. Taxonomic insect to species.

CHAPTER NINE
Activity 9.1
No. 1. Parasitism, predation
Saprophagous, Haematophagous, Phytophagous
2. Termites - Cultivation of fungi
3.(a) Tsetse flies - Males and females
(b) Mosquitoes - Females only.

Activity 9.2
No. 1. Gut, gastric system, alimentary canal
2. Foregut, Midgut and hindgut
3. (a) Ventriculus - Midgut
(b) Proctodaeum - Foregut
4. Enzymes produced by symbiotic flagellates
5. Diverse diets

Activity 9.3 Self-evaluation

CHAPTER TEN
Activity 10.1
1. False
2. True
3. True
4. True
5. True
6. False
CHAPTER ELEVEN
Activity 11.1
1. False
2. True
3. True
4. False
5. True
6. False
7. True
8. False
9. True
10. False

Activity 11.2  Answers in text

CHAPTER TWELVE
Activity 12.1
1. Spiracles
2. Intima
3. Air Sacs
4. Taenidium
5. Trachea
6. Taenidium
7. Oxygen, Carbon dioxide
8. Tracheoles
9. Diffusion
10. Air Sacs

Activity 12.2  -  Self-evaluation

CHAPTER THIRTEEN
Activity 13.1  Answers in the text

CHAPTER FOURTEEN
Activity 14.1.  Answers in the text

CHAPTER FIFTEEN
No. 1  (a) Ametabola - Metamorphosis e.g. Thysanura egg Young-adult
      (b) Hemimetabola - Incomplete metamorphosis e.g Locust, egg ñymph ñ adult
      © Holometabola - complete metamorphosis e.g Housefly-, egg ñ larva-pupa-adult
(a) Eruciform or Polyopod, caterpillar - like
  (c) Scarabaeiform, grub - like
  (d) Campaedian or oligopod, elongated, flattened and active
  (e) Vermiform, maggot - like
  (f) Elateriform, wireworm - like

No. 3
  (a) Exarate pupa - pupa with free appendages
  (b) Obtect pupa - pupa with appendages glued onto the body

No. 4
  (a) Instar - Stages between moults
  (b) Ec dysis - Shedding of the exoskeleton
© Naiad - Aquatic nymphal stage of a hemimetabolous insect
(d) Heteromorphism - Occurs when successive larval stages are quite different in form and habits, common in predaceous insects.

CHAPTER SIXTEEN
Activity 16.1
No. 1.
  (a) Apterygota - Wingless insect
  (b) Pterygota - Winged insect
© Exopterygote - Subclass consisting of insects whose wings develop outside the body and thus have externally visible wing buds in the late nymphal and pupal stages
  (b) Endopterygote - Subclass consisting of insects whose wings develop inside the body and thus not visible until after metamorphosis.

No. 2
  (a) Lepidoptera
  (b) Anoplura
  (c) Mallophaga
  (d) Coleoptera
  (e) Hymenoptera
  (f) Hymenoptera
  (g) Diptera
  (h) Homoptera
  (i) Dictyoptera
  (j) Hemiptera
  (k) Isoptera
  (l) Diplura

No. 3.
  (a) Lice - Anoplura
  (b) Fleas - Siphonaptera
  (c) Bedbugs - Hemiptera
CHAPTER SEVENTEEN
Activity 17.1
1. Thysanoptera
2. Thysanura
3. Psocoptera
4. strepsiptera
5. Plecoptera
6. Protura

CHAPTER EIGHTEEN
Activity 18.1
No. 1. True 6. True
2. True 7. False
3. False 8. True
4. False 9. True
5. True 10 False

Activity 18.2 Answers in the text

Activity 18.3
No 1. Bees, ants, termites, wasps
2. Queen, King, worker, Soldier
3. Answers in the text
4. Slavery and warfare, herding and farming, air conditioning, Trophallaxis

CHAPTER NINETEEN
Activity 19.1
No. 1. (a) Source of food
(b) Aesthetic value
(c) Research
(d) Biological control
(e) Production of silk, honey, bees and wax
(f) Pollination
(g) Soil Aeration
(h) Scavengers clean the environment

2. (a) Pests of crops, stored products
(b) Disease vectors
(c) Nuisance

3. Infestation of animal tissues by fly larvae (Myiasis)
CHAPTER TWENTY

Activity 20.1
No. 1 Chemical substances produced by insects to elicit a response by others of the same species
No. 2 Light production by living organisms
No. 3 Sound production by the rubbing of one part against another by insects

Activity 20.2
No. 1 True
No. 2 False
No. 3 True
No. 4 True
No. 5 True
No. 6 True
No. 7 False
No. 8 True
No. 9 True
No. 10 False

Activity 20.3 Review questions
1. Write an essay on social insects.
2. Describe the basic insect mandibulate mouthpart and show how the honeybee and butterfly mouthparts have been derived from it.
3. Discuss respiration in aquatic insects.
4. Write an essay on insect growth and metamorphosis.
5. Outline any two of the following: - The insect Digestive, Circulatory, Nervous, Excretory or Reproductive system.
6. Discuss insect classification and Morphology.
GLOSSARY

A

**Abdomen.** The hindmost of the three main body divisions of an insect.

**Acaricide.** A chemical employed to kill and control mites and ticks.

**Acetyl choline.** A substance present in many parts of the body of animals and important to the function of nerves.

**Acrostichal Bristles.** The two rows of hairs or bristles lying one on either side of the mid-line of the thorax of a true fly.

**Active Space.** The space within which the concentration of a pheromone or other behaviourally active substance is concentrated enough to generate the required response, remembering that like light and sound pheromones become more dilute the further they radiate out from their source.

**Aculeate.** (Hymenoptera) Those members of the Hymenoptera which possess a sting.

**Acuminate.** Tapering to a long point.

**Adeagus.** The part of the male genitalia which is inserted into the female during copulation and which carries the sperm into the female. Its shape is often important in separating closely related species.

**Adecticous.** Of pupa: referring to the state in which the pupa does not possess movable mandibles, the opposite being Decticous.

**Aestivation.** Summer dormancy, entered into when conditions are unfavourable for active life i.e. it is too hot or too dry.

**Age Polyethism.** The regular changing of roles of colony members as they get older.

**Air sac.** A dilated portion of a trachea

**Alar Squama.** The middle of three flap-like outgrowths at the base of the wing in various flies.

**Alate.** Winged; having wings.

**Alitrunk.** Name given to the thorax and propodeum of 'wasp-waisted' hymenopterans.

**Allopatric.** Two or more forms of a species having essentially separate distributions.

**Alternating Generations.** When two generations are produced within a life cycle each producing individuals of only one sex, either male first and then female or visa-versa.

**Alula.** In insects (not birds) the outermost of the three flap-like outgrowths at the base of the wing in various flies: really a part of the wing membrane.

**Aldrin.** (common name). A synthetic insecticide; a chlorinated hydrocarbon of not less than 95 per cent 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene; moderately toxic to mammals, acute oral LD,, for rats 44 mg/kg; phytotoxicity: none when properly formulated, but some crops are sensitive to solvents in certain formulations.

**Aliphatic.** A term applied to the "open chain" or fatty series of hydrocarbons.

**Alkaloids.** Substances found in plants, many having powerful pharmacologic action, and characterized by content of nitrogen and the property of combining with acids to form 'salts'.

**Alloparental.** When individuals other than the parent assist in the caring for that parents offspring.
Altruistic. Self-destructive or potentially self-destructive behaviour performed for the benefit of others.

Ambrosia. The fungus cultivated by wood-boring beetles of the family Scolytidae.

Ametabola. The insects which develop without metamorphosis, namely the Protura, Thysanura, and Collembola.

Amide. Compound derived from carboxylic acids by replacing the hydroxyl of the -COOH by the amino group, -NH₂-.

Amine. An organic compound containing nitrogen, derived from ammonia, NH₃, by replacing one or more hydrogen atoms by as many hydrocarbon radicals.

Amino acid. Organic compounds that contain the amino (NH,) group and the carboxyl (COOH) group. Amino acids are the "building stones" of proteins.

Ammonia. A colorless alkaline gas, NH₃, soluble in water.

Anal. Pertaining to last abdominal segment which bears the anus.

Anal angle. The small apical area enclosed by the inner and outer margins of the hindwing.

Anal fold. A fold in the inner margin of the hindwing.

Anaplasmosis. Infection with Anaplasma, a genus of Sporozoa that infests red blood cells.

Anasa wilt. A wilt disease of cucurbits caused solely by the feeding of the squash bug, no parasitic microorganism involved.

Androconia. (singula = Androconium) In male butterflies, specialised wing scales (often called scent scales) possessing special glands which produce a chemical attractive to females.

Anemic. Deficient in blood quantity or quality.

Annulate. Formed in ring-like segments or with ring-like markings.

Antenna. (pl., antennae). Pair of segmented appendages located on the head and usually sensory in function - the 'feelers'.

Antennation. Touching with the antenna.

Antenodal Veins. Small cross-veins at the front of the dragonfly or damselfly wing, between the wing base and the nodus.

Anterior. Concerning or facing the front, towards the head.

Antibiosis. An association between two or more organisms that is detrimental to one or more of them.

Anticoagulin. A substance antagonistic to the coagulation of blood.

Anus. The posterior opening of the digestive tract.

Anal veins. The hindmost, or most posterior longitudinal wing veins.

Aorta. The anterior, non-chambered, narrow part of the insect heart which opens into the head.

Apex. The point where the costal vein and the outer margin of the forewing meet.

Apiary. A place where bees are kept, normally a group of hives.

Apical. At or concerning the tip or furthest part of any organ: apical cells, for example are at the wing-tip.

Apical area. Of the forewing, the area just inside of and contiguous with the apex.

Appendage. Any limb or other organ, such as an antenna, which is attached to the body by a joint.

Appendix. In insects, a short vein, especially a short continuation after the main vein has
Apterygote. Any member of the Apterygota - primitively wingless insects (i.e. insects which have never developed wings during their evolutionary history) in modern classifications this includes the Thysanura but not Collembola Diplura and Protura which are no longer considered insects, but are termed Hexapods instead.

Aquatic. Living in water.

Arachnida. A class of arthropods which include the scorpions, spiders, mites, ticks, among others.

Arboreal. Living in, on, or among trees.

Arista. A bristle-like outgrowth from the antenna in various flies.

Aristate. Bearing an arista or bristle.

Arolium. A small pad between the claws on an insect's foot. Usually very small, but well developed in grasshoppers and some other insects.

Arrhenopyko. The production of males from unfertilised eggs.

Arthropoda. A phylum of animals with segmented body, exoskeleton, and jointed legs.

Arthropods. Animals belonging to the phylum Arthropoda.

Asymmetrical. Organs or body parts not alike on either side of a dividing line or plane.

Asteloycttarsus. Pertaining to nests, normally those of social wasps, in which the comb is attached directly to the support.

Aster yellows. A virus disease of many kinds of plants transmitted by the six spotted leaf hopper and characterized by stunting of plants, sterility, and chlorosis in foliage.

Attractants. Substances which elicit a positive directional response; chemicals having positive attraction for animals such as insects, usually in low concentration and at considerable distances.

Axon. The process of a nerve cell that conducts impulses away from the cell body.

Basal. Concerning the base of a structure - that part nearest the body. Basal cells in Diptera are generally small cells near the base of the wing.

Basitarsus. The 1st segment of the tarsus - usually the largest.

Batumen. A protective layer of propilis or hard cerumen that encloses the nest cavity of a stingless bee colony.

Benzene hexachloride. (chemical name) or BHC. (common name). A synthetic insecticide, a chlorinated hydrocarbon, 1,2,3,4,5,6-hexachlorocyclohexane of mixed isomers; slightly more toxic to mammals than DDT, acute oral LD50 for rats about 200 mg/kg; phytotoxicity: more toxic than DDT, interferes with germination, suppresses growth and reduces yields except at low concentration; certain crop plants, as potato absorb crude BHC with consequent tainting of tubers.

Bilateral symmetry. Similarity of form, one side with the other.

Biological control. The control of pests by employing predators, parasites, or disease; the natural enemies are encouraged and disseminated by man.

Bionomics. The study of the habits, breeding, and adaptations of living forms.

Bipectinate. Feathery, with branches growing out oil both sides of the main axis: applied mainly to antennae.
Bisexual. Having two sexes distinct and separate; i.e. a species with males and females.

Bivoltine. Having two generations per year.

Blastogenesis. The origination of different castes, within a species, from the egg by means other than genetic.

Bivouac. The mass of army ant workers within which the queen and brood, live while the colony is not on the move.

Book lung. A respiratory cavity containing a series of leaflike folds.

Bot. The larva of certain flies that are parasitic in the body of mammals.

Brachypterous. With short wings that do not cover the abdomen, used of individuals of a species which otherwise has longer wings.

Bract. A small leaf at the base of the flower.

Brood. In insects, a group of individuals of a given species which have hatched into young or which have become adult at approximately the same time and which live together in a defined and limited area. Often referring to the immature stages of ants, bees and wasps.

Bubonic plague. A bacterial disease of rodents and man caused by Pasteurella pestis and transmitted chiefly by the oriental rat flea; marked by chills, fever, and inflammatory swelling of lymphatic glands.

Budding. Colony fission, the creation of new colonies by the departure of one or more reproductive females accompanied by a group of workers specifically to establish a new colony.

Bursa Copulatrix. That part of the female genitalia which receives the aedeagus and sperm during copulation. Its structure is often important in separating closely related species.

Caecum. (pl., caeca). A sac or tubelike structure open at only one end.

Calcareaous. Referring to soils or rocks, possessing those elements which result in alkaline or basic reactions.

Callow. Newly eclosed workers in social insect colonies whose exoskeletons are still soft and whose colour has not fully matured.

Callus. A rounded swelling; applied especially to swollen regions at the front or back of the thorax in various flies.

Calypter. Innermost of the three flap-like outgrowths at the base of the wing in various flies. Also known as the thoracic squama, it generally conceals the haltere.

Calyptdomous. Of the nests of wasps, referring to those which are surrounded by an envelope.

Campodeiform. (applied to a larva) Grub-like, flattened and elongated with well-developed legs and antennae. Many beetle larvae are of this type, and so are those of the lacewings.

Capitate. With an apical knob like enlargement.

Capitulum. Head like structure of ticks which bears the feeding organs.

Carabiform larva. A larva shaped like the larva of a carabid beetle, that is etiolate, flattened, and with well-developed legs; with no filaments on the end of the abdomen.

Carbohydrate. Any of a group of neutral compounds made up of carbon, hydrogen, and
Carina. A ridge or keel.
Carnivorous. Preying or feeding on animals.
Castes. Groups of individuals that become irreversibly behaviorally distinct at some point prior to reproductive maturity. One of three or more distinct forms which make up the population among social insects. The usual three castes are queen, drone (male), and worker. The termites and some of the ants have one or more soldier castes as well.
Caterpillar. The larva of a moth, butterfly, or saw-fly.
Catfacing. The injury caused by the feeding of such insects as plant bugs and stink bugs on developing fruit which results in uneven growth and a deformed mature fruit.
Cauda. The pointed end of the abdomen in aphids.
Caudal. Concerning the tail end.
Cell. An area of the wing bounded by a number of veins. A cell is closed if it is completely surrounded by veins and open if it is bounded partly by the wing margin.
Cellulose. An inert carbohydrate, the chief component of the solid framework or woody part of many plants.
Cement layer. A thin layer on the surface of insect cuticles formed by the hardened secretion of the dermal glands.
Cephalic. Of or pertaining to the head.
Cephalothorax. A body region consisting of head and thoracic segments, as in spiders.
Cerci. (singular: cercus) The paired appendages, often very long, which spring from the tip of the abdomen in many insects.
Cerumen. A mixture of wax and propolis used by social bees in nest construction.
Cervical. Concerning the neck region, just behind the head.
Chaetae. Stiff hairs or bristles (singular: chaeta).
Chaetotaxy. The arrangement of the bristles or chaetae on an insect: especially important in the classification of the Diptera, Collembla and several other groups.
Chelicera. (pl., chelicerae). The anterior pair of appendages in arachnids, the fangs.
Chigger. The parasitic larva of trombiculid mites.
Chitin. The tough horny material, chemically known as a nitrogenous polysaccharide, which makes up the bulk of the insect cuticle, also occurs in other arthropods.
Chorion. The inner shell or covering of the insect egg.
Chromosomes. At cell division the dark-staining, rod-shaped structures which contain the hereditary units called genes.
Chrysalis. The pupa of a butterfly.
Ciliated. Bearing minute hairs (cilia).
Cladogram. A diagram showing nothing more than the sequence in which groups of organisms are interpreted to have originated and diverged in the course of evolution.
Class. A division of the animal kingdom lower than a phylum and higher than an order, for example the class Insecta.
Clavate. Club-shaped, with the distal end swollen: most often applied to antennae.
Claustral Foundation. A way of setting up of a new colony by a queen, or king and queen in the termites, which involves her/them being sealing her/themselves a way in a small chamber and raising the first group of workers entirely (or almost so) on stored body reserves (fat and often the flight muscles).
Clavus. Posterior part of the forewing of heteropteran bugs.

Cleptoparasitism. Where one female uses the resources and nest of another individual (of either the same or a different species) to provide for her young thus usurping the owners efforts and preventing her from using them.

Cline. A progressive, usually continuous change in one or more characters of a species over a geographic or altitudinal range.

Club. The thickened terminal (farthest from the head) end of the antennae.

Clypeus. Lowest part of the insect face, just above the labrum.

Coarctate. (applied to pupae) Enclosed within the last larval skin, which therefore acts as a cocoon and protects the pupa. Such pupae are found in the flies (Diptera, of the suborder Cyclorrhapha.).

Cocoon. A case, made partly or completely of silk, which protects the pupa in many insects, especially the moths. The cocoon is made by the larva before it pupates.

Colony. A small or large locally isolated population.

Colony. Of social insects, a group which co-operates in the construction of a nest and in the rearing of the young.

Comb. The grouped cells of the nests of social many hymenoptera.

Comb. A group of spines on the leg of an insect specifically used for cleaning other parts of the insects body.

Commensalism. Symbiosis, one or more individuals from two or more species living together such that one benefits but neither loses fitness.

Commissure. A bridge connecting any two bodies or structures on a body.

Communal. Where females of one species co-operate in nest building but not in brood care.

Complete metamorphosis or Complex metamorphosis. Metamorphosis in which the insect develops through four distinct stages, e.g., ova or egg, larva, pupa, and adult or imago; the wings (when present) develop internally during the larval stage.

Compound eye. An eye consisting of many individual elements or ommatidia each of which is represented externally by a facet.

Connective. A longitudinal cord of nerve fibers connecting successive ganglia.

Contiguous. Touching - usually applied to eyes (see also Holoptic).

Conspecific. Belonging to the same species.

Construction Gland. A gland of wasps producing a size-like substance which enables them to make paper out of wood-pulp.

Copularium. The first chamber built by a newly mated pair of sexual termites.

Corbicula. The pollen basket on the hind leg of many bees, formed by stout hairs on the borders of the tibia.

Corium. The main part of the forewing of a heteropteran bug.

Cornicle. One of the pair of small tubular outgrowths on the hind end of the aphid abdomen.

Corpora allata. A pair of small endocrine glands located just behind the brain.

Cosmopolitan. Occurring throughout most of the world.

Costa. One of the major longitudinal veins, usually forming the front margin of the wing and usually abbreviated to C. The costal margin is the front edge of the wing.

Costal Cell. The cell between the costa and the sub-costal vein.

Costal Fold. A narrow, thin membrane folded back on the upper surface of the costa of
androconia

Crawler. The active first instar of a scale insect.

Cremaster. The cluster of minute hooks (sometimes just one larger hook) at the hind end of a lepidopterous pupa: used to grip the pupal support.

Crochets. (Pronounced crow-shays). Hooked spines at tip of the prolegs of lepidopterous larvae.

Crop. The dilated section of the foregut just behind the esophagus.

Cross-vein. A short vein joining any two neighboring longitudinal veins.

Cryptic. Colouring and or pattern adapted for the purpose of protection from predators or prey by concealment.

Cryptobiotic. Leading a hidden or concealed life.

Cubitus. One of the major longitudinal veins, situated in the rear half of the wing and usually with 2 or 3 branches: abbreviated to Cu.

Cuneus. A more or less triangular region of the forewing of certain heteropteran bugs, separated from the corium by a groove or suture.

Cursorial. Adapted for running.

Cuspidal. Two segments of curved lines meeting and terminating at a sharp point.

Cuticle. The outer noncellular layers of the insect integument secreted by the epidermis.

Cyclorrhaphous Diptera. The group of flies which emerge from the puparium through a circular opening at one end of the puparium. These flies belong to the more advanced families.

Cytology. The study of cells and their functioning.

DDT. (common name). A widely used synthetic insecticide; a chlorinated hydrocarbon, dichloro diphenyl trichloroethane.

Dealate. Wingless as a result of the insect casting or breaking off its own wings, as in newly mated queen ants and termites.

Decicous. Of pupa: referring to the state in which the pupa possesses movable mandibles which can be used for biting, the opposite being Adecticous.

Dengue. (pronounced deng’ee). A virus disease of man marked by severe pains in head, eyes, muscles, and joints and transmitted by certain mosquitoes.

Dentate. Toothed, possessing teeth or teeth-like structures.

Denticulate. Bearing very small tooth-like projections.

Deutonymph. The third instar of a mite.

Diapause. A period of suspended animation of regular occurrence in the lives of many insects, especially in the young stages.

Diaphragm. A horizontal membranous partition of the body cavity.

Differentiation. Increase in visible distinctive morphology.

Dimorphic. Occurring in two distinct forms.

Dimorphism. A difference in size, form, or color, between individuals of the same species, characterizing two distinct types.

Discal. The central portion of a wing from the costa to the inner margin.

Discal Cell. Name given to a prominent and often quite large cell near the middle of the
Distal. In a direction away from the body.
Distal. Concerning that part of an appendage furthest from the body.
D.N.A. An abbreviation for Dioxiribonucleic Acid a large molecule which stores the data in our genes in the form of a 3 character code. D.N.A. is a self replicating molecule.
Dorsal. On or concerning the back or top of an animal.
Dorsal Nectary Organ. In the larvae of many species of Lycaenidae (Blue Butterflies) a gland located in the dorsal region of the 7th abdominal segment, it secretes a sweet substance which is attractive to ants.
Dorsal ocellus. The simple eye in adult insects and in nymphs and naiads.
Dorsal shield. The scutum or sclerotized plate covering all or most of the dorsal surface in males and the anterior portion in females, nymphs, and larvae of hard-backed ticks.
Dorso-central Bristles. The 2 rows of bristles running along the thorax of a fly on the outer side of the acrostichal bristles.
Dorso-lateral. Towards the sides of the dorsal (upper) surface.
Dorso-ventral. Running from the dorsal (upper) to the ventral (lower) surface.
Dorsum. The upper surface or back of an animal.
Drone. The male honey bee.
Dulosis. The act of slave making in ants, a species which makes a slave of another is often referred to as Dulotic.

Ecdysis. The moulting process, by which a young insect changes its outer skin or pupal case.
Eclosion. Emergence of the adult or imago from the pupa
Ectoderm. The outer embryological layer which gives rise to the nervous system, integument, and several other parts of an insect.
Ectohormone. A substance secreted by an animal to the outside of its body causing a specific reaction, such as determination of physiological development, in a receiving individual of the same species.
Ectoparasite. A parasite that lives on the outside of its host.
Egg pod. A capsule which encloses the egg mass of grasshoppers and which is formed through the cementing of soil particles together by secretions of the ovipositing female.
Elateriform larva. A larva with the form of a wireworm; i.e. long and slender, heavily sclerotized, with short thoracic legs, and with few body hairs.
Elbowed Antenna. Antenna, particularly of ants, in which there is a distinct angle between two of the segments - usually between the 1st and 2nd segments, in which case the 1st segment is usually much longer than the others.
Elytron. (plural elytra) The tough, horned forewing of a beetle or an earwig (See also Hemi-elytron)
Emarginate. With a distinct notch or indentation in the margin.
Emery’s Rule. The rule resulting from the observation that species of social parasite are very closely related to their host.
Embolium. A narrow region along the front margin of the forewing in certain heteropteran bugs: separated from the rest of the corium by a groove or suture.
Empodium. An outgrowth between the claws of a fly's foot: it may be bristle-like.

Endemic. Restricted to a well-defined geographical region.

Endocrine. Secreting internally, applied to organs whose function is to secrete into blood or lymph a substance which has an important role in metabolism.

Endocuticle. The innermost layer of the cuticle.

Endoparasite. A parasite which lives inside its host's body. Most of the ichneumons, are endoparasites during their larval stages.

Endopterygote. Any insect in which the wings develop inside the body of the early stages and in which there is a complete metamorphosis and pupal stage.

Entomogenous. Growing in or on an insect, for example certain fungi.

Envelope. The carton or wax outermost later of the nest of a social insect, particularly those of wasps.

Enzyme. An organic catalyst, normally a protein formed and secreted by a living cell.

Epicuticle. The thin, non-chitinous, surface layers of the cuticle.

Epidermis. The cellular layer of the integument that secretes or deposits a comparatively thick cuticle on its outer surface.

Epigaeic. Living or foraging primarily above ground, compared to Hypogaecic the opposite.

Epimeron. The posterior part of the side wall of any of the three thoracic segments.

Epinotum. The first abdominal segment when it is fused with the last thoracic one, relating to the higher thin waisted hymenoptera. Also called a propodeum.

Epipharynx. A component of many insect mouth-parts which is attached to the posterior surface of the labrum or clypeus. In chewing insects it is usually only a small lobe, but in the fleas it is greatly enlarged and used for sucking blood.

Epiproct. An appendage arising from the mid-line of the last abdominal segment, just above the anus. In the bristletails and some mayflies it is very long and forms the central 'tail'.

Episternum. The anterior part of the side wall of any of the three thoracic segments.

Epithelium. The layer of cells that covers a surface or lines a cavity.

Ergatogyne. Any female member of a eusocial group whose morphological development is somewhere between that of a worker and a queen.

Eruciform. (applied to a larva) Caterpillar like; more or less cylindrical with a well developed head and stumpy legs at the rear as well as the true thoracic legs. The caterpillars of butterflies and moths are typical examples.

Eusocial. A specie which lives in a society such that individuals of the species cooperate in caring for the young, which not all of them have produced; there is a reproductive division of labor, with more or less sterile individuals working on behalf of fecund individuals; and there is an overlap of at least two generations in life stages capable of contributing to colony labor, so that offspring assist parents during some period of their life.

Exarate Pupa. A pupa in which all the appendages, legs etc., are free and capable of movement.

Excavate. Hollowed out: applied to the coxae of many beetles, which are hollowed out to receive the femora when the legs are folded.

Excretion. The elimination of the waste products of metabolism.

Exocuticle. The hard and usually darkened layer of the cuticle lying between the
endocuticle and epicuticle. Exoskeleton. Collectively the external plates of the body wall.

Exopterygote. Any insect in which the wings develop gradually on the outside of the body, in which there is only a partial metamorphosis and no pupal stage.

Exuvia. The cast-off outer skin of an insect or other arthropod.

Eye-cap. Hood formed by the base of the antenna and partly covering the eye in certain small moths.

F
Facet. The surface of an ommatidium - one of the units making up the compound eye.
Family. A taxonomic subdivision of an order, suborder, or superfamily that contains a group of related subfamilies, tribes and genera. Family names always end in -idae.
Fascicle. A small bundle; the bundle of piercing stylets of insects with piercing sucking mouthparts.
Femur. The 3rd (counting out from the body) and often the largest segment of the insect leg.
Filament. A thread-like structure, especially one at the end of an antenna.
Filiform. Thread-like or hair-like, applied especially to antennae.
Flabellate. With projecting flaps on one side, applied especially to antennae.
Flagellum. The distal (furthest away from the body) part of the antenna, beyond the 2nd segment.
Foregut. The anterior part of the alimentary canal from the mouth to the midgut.
Fossorial. Adapted for digging.
Foveola. (pl. foveolae) One of the paired depressions on each side of the vertex in grasshoppers.
Frenulum. The wing-coupling mechanism found in many moths.
Frons. Upper part of the insect face, between and below the antennae and usually carrying the median ocellus or simple eye. In true flies (Diptera) it occupies almost all of the front surface of the head apart from the eyes.
Frontal Bristles. The two vertical rows of bristles running down the face of a fly from the ocelli to the antennae
Fronto-orbital Bristles. The short row of bristles on each side of a fly's head between the eye and the frontal bristles.
Furcula. The forked spring of a springtail.
Fuscos. Smokey grey-brown in colour, normally applied to wings.

G
Galea. the outer branch of the maxillae, the inner one being the lacinia.
Gall. An abnormal growth of a plant caused by the presence in its tissues of a young insect or some other organism. Aphids, gall wasps, and gall midges are among the major gall-causing insects.
Ganglion. A nerve mass that serves as a center of nervous influence.
Gastric caeca. The sac-like diverticula at the anterior end of the midgut.
Gaster. The hymenopteran abdomen - apart from the 1st segment (the propodeum) which
Genal Comb. A row of stout spines on the lower border of the cheek of certain fleas.

Generation. The group of individuals of a given species that have been reproduced at approximately the same time; the group of individuals of the same genealogical rank.

Geniculate. Abruptly bent or elbowed (see Elbowed Antenna).

Genital claspers. Organs of the male genitalia which serve to hold the female during copulation.

Genitalia. The copulatory organs of insects and other animals. The shape and arrangement of the genitalia are often used to distinguish closely related and otherwise very similar species.

Genotype. The total genetic character of an organism, i.e. all its D.N.A. or genes.

Genus. A group of closely related species (plural: genera). The name of the genus is incorporated into the scientific names of all the member species: *Pieris napi* and *Pieris rapae*, for example, both belong to the genus *Pieris*.

Gill. Breathing organ possessed by many aquatic creatures, including numerous young insects. Insect gills are usually very fine outgrowths from the body and they contain numerous air-tubes, or tracheae. Oxygen passes into the tubes from the water by diffusion.

Girdle. A silken thread supporting the midsection of a pupa.

Glabrous. Without hairs.

Glossa. (plural glossae) One of a pair of lobes at the tip of the labium or lower lip: usually very small, but long in honey bees and bumble bees, in which the two glossae are used to suck up nectar.

Gnathosoma. The anterior part of the body of mites and ticks which bears the mouth and mouthparts.

Gregarious. Living in groups.

Grub. A scarabaeiform larva, i.e. a thick bodied larva with thoracic legs and well developed head; usually sluggish.

Gynandromorph. An individual creature with a mixture of male and female characteristics. One half of the body may be male and the other half female. This is particularly noticeable when it occurs among the blue butterflies and others in which the sexes are differently coloured.

H

Haemolymph. The blood plasma or liquid part of the blood, though generally synonymous for blood of insects.

Habitus. Body-build, general appearance.

Haltere. One of the club-shaped 'balancers' found on each side of the metathorax among the true flies (Diptera). They are the much-modified hind wings.

Hamuli. The minute hooks on the front edge of the hind wing of bees and other hymenopterans, used to link the front and hind wings together. The hook which holds the springtail's spring in place is also called the hamula.

Haustellate. Adapted for sucking liquids rather than biting solid food.

Heart. The chambered, pulsatile portion of the dorsal blood vessel.
Hematophagous. Feeding or subsisting on blood.
Hemelytron (plural hemielytra). The forewing of a heteropteran bug, differing from the beetle elytron in having the distal portion membranous.
Hemimetabola. Insects with simple metamorphosis, with no pupal stage.
Hemimetabolous. Having an incomplete metamorphosis, with no pupal stage in the life history.
Hermaproditic. Containing the sex organs of both sexes in one individual.
Heteromerous. (of beetles) Having unequal numbers of tarsal segments on the three pairs of legs.
Hexapod. An animal possessing six legs, more specifically the parent group that contains insects and their close kin.
Hibernation. Dormancy during the winter.
Hindgut. The posterior part of the alimentary canal between the midgut and anus.
Histosiphon. Same as stylostome. The tube formed by the host as a result of the feeding of a chigger secreting salivary fluids, the chigger partially digests skin tissues, which induces the host to form a proteinaceous tube walling off the injury.
Holometabola. The higher insects which have complex metamorphosis.
Homologous. Organs or parts which exhibit similarity in structure, in position with reference to other parts, and in mode of development, but not necessarily similarity of function, are said to be homologous.
Holometabola. The higher insects which have complex metamorphosis.
Holometabolous. Having a complete metamorphosis, with larval and pupal stages in the life history.
Holoptic. With the eyes touching or almost touching on the top of the head: used mainly when describing flies (Diptera).
Holotype. The type specimen of a species is the actual insect from which the original description of that species was produced. If several specimens were used for this purpose, one of them should have been designated as the type. Because the type can be of only one sex, it is usual to designate a certain individual of the opposite sex as the allotype. The original type specimen is then called the holotype. These ḍype specimens’ are very important in taxonomy and classification.
Homonym. A scientific name which has been given to two different species. When such an instance comes to light one of the species must be given another name.
Hormone. A chemical substance formed in some organ of the body, secreted directly into the blood, and carried to another organ or tissue where it produces a specific effect.
Honeydew. The sweet liquid emitted from the anus of aphids and some other sap sucking bugs.
Host. The organism in or on which a parasite lives; the plant on which an insect or other arthropod feeds.
Humeral Angle. The front basal part of the wing, close to its attachment to the body.
Humeral Vein. A small cross-vein running from the costa to the sub-costa in the humeral (basal) region of the wing.
Hyaline. Clear and colourless, like the wings of most dragonflies.
Hygrophilus. Moisture loving.
Hypermetamorphosis. A type of life history in which the larvae adopts 2 or more distinct forms during its development.

Hyperparasite. A parasitic organism which attacks another parasite.

Hypognathous. Having a vertical head and face with the mouth-parts at the bottom.

Hypopharynx. A component of the insect mouth-parts arising behind the mouth and just in front of the labium or lower lip. Usually short and tongue-like in species with biting jaws, but often drawn out to form a tube for the salivary duct in those species with sucking mouths.

Hypopleural Bristles. A curved row of bristles on the side of the thorax of certain true flies just below and in front of the haltere and just above the base of the hind leg.

Hypostome. In ticks, the median ventral dart-like mouthpart that is immovably attached to basal part of the capitilum.

Hysterosoma. In mites, the posterior part of the body when there is a demarcation of the body between the second and third pair of legs.

Imago. The adult insect (Plural imagines)

Incomplete metamorphosis or Simple metamorphosis. Metamorphosis in which the wings (when present) develop externally during the immature stage and there is no prolonged resting stage (i.e. pupa) preceding the last molt; stages included are the egg, nymphal, and adult. Also called gradual or partial metamorphosis, and paurometabolous development.

Inquiline. A creature that shares the home of another species without having any obvious effect on that species.

Insecta. A 'class' of the 'phylum' Arthropoda, distinguished by adults having three body regions: head, thorax, and abdomen; and by having the thorax three-segmented with each segment bearing a pair of legs.

Instar. The stage in an insect's life history between any two molts. A newly-hatched insect which has not yet moulted is said to be a first-instar nymph or larva. The adult (imago) is the final instar.

Integument. The insect's outer coat.

Intermediate host. The host which harbors the immature stages or the asexual stages of a parasite, a separate organism to that which harbours the sexual stage.

Intercalary Vein. An additional longitudinal vein, arising at the wing margin and running inwards but not directly connected to any of the major veins.

Joint. Strictly speaking, an articulation between neighbouring parts, such as the femur and tibia of the leg, but the word is commonly used as a synonym of segment - meaning any of the divisions of the body or its appendages.

Johnston's organ. A sense organ located in the second antennal segment of many insects
and particularly well developed in male mosquitoes and certain other Diptera.

**Jugum.** A narrow lobe projecting from the base of the forewing in certain moths and overlapping the hind wing, thereby coupling the two wings together.

**K**

**Keel.** A narrow ridge: also called a carina

**L**

**Labellum.** The expanded tip of the labium, used by many flies to mop up surface fluids.

**Labial.** Concerning the labium.

**Labial palpus.** (pl., labial palpi). The labial palps, one of the pair of sensory appendages (feeler-like and 2 to 5 segments long) of the insect labium.

**Labium.** The 'lower lip' of the insect mouth-parts, formed by the fusion of two maxilla-like appendages.

**Labrum.** The 'upper lip' of the insect mouth-parts: not a true appendage but a movable sclerite on the front of the head.

**Labrum-epipharynx.** A mouthpart composed of the labrum and epipharynx and usually elongate.

**Lacinia.** The inner branch of the maxilla, the outer one being the galea

**Lamella.** A thin, leaf-like flap or plate, the name being applied to the outgrowths of certain antennae.

**Lamellate.** Possessing lamellae: applied especially to antennae.

**Larva.** Name given to a young insect which is markedly different from the adult: caterpillars and fly maggots are good examples.

**Lateral.** Concerning the sides.

**Lateral ocellus.** The simple eye in holometabolous larvae. Also called stemma (pl., stemmata).

**Lateral oviduct.** In insects, one of the paired lateral ducts of the female genital system connected with the ovary.

**Life history.** Habits and changes undergone by an organism from the egg stage to its death as an adult.

**Ligulae.** Name given to the lobes at the tip of the labium: usually divided into glossae and paraglossae.

**M**

**Maggot.** A vermiform larva; a larva without legs and without well-developed head capsule.

**Malpighian tubes.** Excretory tubes of insects arising from the anterior end of the hindgut and extending into the body cavity.

**Mandible.** The jaw of an insect. It may be sharply toothed and used for biting, as in grasshoppers and wasps, or it may be drawn out to form a slender needle as in
Mandibles are completely absent in most flies and lepidopterans. Mandibulate. Having mandibles suited for biting and chewing.

Marginal Cell. One of a number of cells bordering the front margin of the wing in the outer region.

Maxilla. (plural maxillae) One of the two components of the insect mouth-parts lying just behind the jaws. They assist with the detection and manipulation of food and are often drawn out into tubular structures for sucking up liquids.

Maxillary. Concerning or to do with the maxillae.

Meconium. The reddish fluid ejected by a member of the lepidoptera after emerging from the pupa/chrysalis.

Media. The longitudinal vein running through the central region of the wing in most insects: often the 4th and abbreviated to M.

Median oviduct. In insects, the single duct formed by the merging of the paired lateral oviducts; this duct opens posteriorly into a genital chamber or vagina.

Membranous. Thin and transparent (in reference to wings); thin and pliable (in reference to integument).

Mesonotum. The dorsal surface of the 2nd thoracic segment - the mesothorax: usually the largest thoracic sclerite.

Mesopleuron. The sclerite or sclerites making up the side wall of the mesothorax.

Mesoscutellum. Hindmost of the three major divisions of the mesonotum, often triangular or shield-shaped: usually abbreviated to scutellum.

Mesoscutum. The middle and usually the largest division of the mesonotum.

Mesosternum. The ventral surface or sclerite of the mesothorax.

Mesothorax. The 2nd segment of the thorax.

Metamorphosis. Name given to the changes that take place during an insect's life as it turns from a young animal to an adult. These changes may be gradual and not too large, as in the grasshopper, and metamorphosis is then said to be partial or incomplete. On the other hand, the changes may be much greater and they may take place in one big step - as in the butterflies and moths, which change from caterpillars to adults during the pupal stage. Metamorphosis of this kind is said to be complete.

Metanotum. The dorsal surface of the metathorax. It is often very small and its subdivisions are usually obscured.

Metapleuron. The sclerite or sclerites making up the side wall of the metathorax.

Metasternum. The ventral surface or sclerite of the metathorax.

Metatarsus. The basal segment of the tarsus or foot: usually the largest segment.

Metathorax. The 3rd and last segment of the thorax.

Micropyle. A minute opening or group of openings into the insect egg through which the spermatozoa enter in fertilization.

Microtrichia. Minute hairs projecting from the integument, they are formed around cellular filaments.

Midgut. The middle part of the alimentary canal and the main site of digestion and absorption.

Moniliform. (of antennae) Composed of bead-like segments, each well separated from the next.

Monophagous. Feeding upon only one kind of food, for example one species or one genus of plants.
To moult is to shed the outer covering of the body - the exoskeleton. Myiasis, infestation of the body by the larvae of flies.

N
Naiad. An aquatic, gill-bearing nymph.
Nasutus. (pl., nasuti). A type of soldier caste in certain termites; this form bears a median frontal rostrum through which it ejects a defensive fluid; the jaws are small or vestigial.
Nectar. The sugary liquid secreted by many flowers.
Nectary. A floral gland which secretes nectar.
Neurone. The entire nerve cell including all its processes.
Nit. The egg of a louse.
Nocturnal. Active at night.
Nodus. The kink or notch on the costal margin of the dragonfly wing. The name is also used for the strong, short cross-vein just behind the notch.
Notaulix. One of a pair of longitudinal grooves on the mesonotum of certain hymenopterans, dividing the mesonotum into a central area and two lateral areas (plural notaulices)
Notopleuron. A triangular area on the thorax of certain flies, just behind the humeral callus and occupying parts of both dorsal and lateral surfaces.
Notum. The dorsal or upper surface of any thoracic segment; usually prefixed by pro-, meso-, or meta- to indicate the relevant segment.
Nucleus. The spheroid body within a cell that has the major role in controlling and regulating the cell's activities and contains the hereditary units or genes.
Nurse cells. Cells that are located in the ovarian tubes of certain insects and that furnish nutriment to the developing eggs.
Nymph. Name given to the young stages of those insects which undergo a partial metamorphosis. The nymph is usually quite similar to the adult except that its wings are not fully developed. It normally feeds on the same kind of food as the adult.

O
Obiect Pupa. A pupa in which the legs and other appendages are closely appressed to the rest of the body and not capable of free movement - as in the butterfly chrysalis.
Occipital Suture. A groove running round the posterior region of the head of some insects and separating the vertex from the occiput. On the sides of the head the same groove marks the posterior boundary of the cheeks or genae.
Occiput. Hindmost region of the top of the head, just in front of the neck membrane. In some insects it is separated from the vertex by the occipital suture, but it is not usually present as a distinct plate or sclerite.
Ocellar Bristles. Bristles arising around or between the ocelli in various flies.
Ocellar Triangle. A triangular area, usually quite distinct from the rest of the head, on which the ocelli of true flies are carried.
Ocellus. (Plural Ocelli) One of the simple eyes of insects, usually occurring in a group of three on the top of the head, although one or more may be absent from many insects.
Oesophagus. The narrow part of the alimentary canal immediately posterior to the
Ommatidium. (pl., ommatidia). One of the units which make up the compound eyes of arthropods.

Ootheca. (pl., oothecae). An egg case formed by the secretions of accessory genital glands or oviducts, such as the purse-like structure carried around by cockroaches or the spongy mass in which mantids lay their eggs.

Oral Vibrissae. The pair of large bristles just above the mouth in certain flies: usually simply called vibrissae.

Order. A subdivision of a class or subclass containing a group of related families.

Organophosphates. Organic compounds containing phosphorus; an important group of synthetic insecticides belong to this class of chemicals.

Oribatid mite. A mite belonging to the Oribatei, a large unit of mites containing about 35 families in the suborder Sarcoptiformes.

Oviparous. Producing eggs which are hatched outside the body of the female.

Ovipositor. The tubular or valved egg-laying apparatus of a female insect: concealed in many insects, but extremely large among the bush-cricket and some parasitic hymenopterans.

Ovoviviparous. Producing living young by the hatching of the egg while still within the female.

Palp. A segmented leg-like structure arising on the maxilla or labium. Palps have a sensory function and play a major role in tasting food.

Paraglossa. One of a pair of lobes at the outer edges of the tip of the labium: with the central glossae, the paraglossae make up the ligula.

Paraproct. One of the 2 lobes bordering the sides of the anus.

Parasite. An organism that spends all or part of its life in close association with another species, taking food from it but giving nothing in return. Ectoparasites live on the outside of their hosts, while endoparasites live inside the host's body.

Parthenogenesis. A form of reproduction in which eggs develop normally without being fertilised. This is the usual method of reproduction among stick insect species and among some generations of gall wasps and aphids.

Pathogenic. Giving origin to disease.

Pecten. A comb-like structure found at the base of the antenna in some insects.

Pectinate. Having branches which arise from the main axis like the teeth of a comb: usually applied to antennae.

Pedicel. The 2nd antennal segment: the name is also given to the narrow waist of an ant.

Pedipalp. The second pair of appendages of an arachnid, used to crush prey.

Petiolate. Attached by a narrow stalk.

Petiole. The narrow waist of bees and wasps and some other hymenopterans: often known as the pedicel when referring to ants.

Pharynx. The anterior part of the foregut between the mouth and the esophagus.

Pheromone. A substance secreted by an animal which when released externally in small amounts causes a specific reaction, such as stimulation to mate with or supply food to a receiving individual of the same species.
Phoresis. The usage by one animal of another solely as a means of transport, i.e. certain mites on various other insects.

Phylum (pl., phyla). A major division of the animal kingdom, containing various suborders and classes etc.

Phytophagous. Feeding upon plants.

Phytotoxic. Poisonous to plants.

Platyform larva. A very flattened larva.

Plumose. Feather-like, as in plumose antennae

Pictured. A term used to describe wings, especially among the Diptera, which have dark mottling on them.

Pilose. Densely clothed with hair.

Plural. Concerning the side walls of the body.

Pleural Suture. A vertical or diagonal groove on each of the thoracic pleura, separating the episternum at the front from the epimeron at the back.

Pleuron. The side wall of a thoracic segment.

Plumose. With numerous feathery branches: applied especially to antennae.

Pollen. The mass of microspores or male fertilizing elements of flowering plants.

Pollen Basket. The pollen-carrying region on the hind leg, of a bee: also known as the corbicula.

Pollinate. To transfer pollen grains from a stamen to a stigma or ovule of a plant.

Polyembryony. The production of several embryos from a single egg, as in some chalcids.

Polyphagous. Feeding on a variety of plants and or animals.

Porrect. Extending horizontally forward: applied especially to antennae.

Posterior. Concerning or facing the rear.

Postmentum. The basal region of the labium.

Postscutellum. A small division of the mesonotum just behind the scutellum: usually very small or absent, but well developed in certain flies.

Post-vertical Bristles. A pair of bristles - divergent, parallel, or crossing - on the back of the head of various flies, some way behind the ocelli.

Pre-apical. Arising just before the tip: many flies, for example, have pre-apical bristles just before the tip of the tibia.

Precostal area. The area in front of , or to the fore of the costa.

Predaceous. Preying on other animals.

Predator. An animal that attacks and feeds on other animals, usually smaller and weaker than itself.

Prementum. The distal region of the labium, from which spring the labial palps and the ligula.

Preovipositional period. The period between the emergence of an adult female and the start of its egg laying.

Prepupa. The last larval instar after it ceases to feed; often it takes on a distinctive appearance becoming quiescent and rather shrunken, and often looks dead.

Presumptive organization. Arrangement of cells in the embryo into groups which in normal development become a particular organ or tissue.

Pretarsus. In insects the terminal segment of the leg bearing the pretarsal claws.

Primary reproductives. Those members of a social group of insects whose primary role
is reproduction, (often the founders of the colony). Compared to secondary reproductive
insects, secondary reproductive are primarily involved in some other activity.

**Proctodeal valve.** In insects, a valve in the anterior end of the hindgut that serves as an
occlusor mechanism.

**Proboscis.** Name given to various kinds of sucking mouths in which some of the mouth-
parts are drawn out to form tubes.

**Prognathous.** Having a more or less horizontal head, with the mouth-parts at the front.

**Proleg.** One of the fleshy, stumpy legs on the hind region of a caterpillar.

**Pronotal Comb.** A row of stout spines on the hind margin of the pronotum of certain
fleas.

**Pronotum.** The dorsal surface or sclerite of the 1st thoracic segment.

**Propodeum.** The 1st abdominal segment in the hymenopteran group known as the
Apocrita: it is completely fused with the thorax.

**Propupa.** In thrips, the next to the last nymphal instar in which the wing pads are present
and the legs short and thick. Also in male scale insects.

**Prosternum.** Ventral surface of the 1st thoracic segment.

**Proterosoma.** In mites, the anterior part of the body when there is a demarcation of the
body between the second and third pair of legs.

**Prothoracic gland.** One of a pair of endocrine glands located in the prothorax near the
prothoracic spiracles.

**Prothorax.** The 1st or anterior thoracic segment.

**Protonymph.** The second instar of a mite.

**Proventriculus.** The posterior section of the foregut.

**Pseudoscorpions.** Small arachnids, seldom over 5 mm. long, scorpion-like in general
appearance but without sting.

**Pseudovipositor.** The slender tube to which the posterior part of the abdomen is reduced
in the female of certain insects.

**Proximal.** Concerning the basal part of an appendage - the part nearest to the body.

**Pruinose.** Covered with a powdery deposit, usually white or pale blue: especially applied
to Odonata.

**Pterostigma.** A small coloured area near the wing-tip of dragonflies, bees, and various
other clear-winged insects: also called the stigma.

**Pterygote.** Any member of the sub-class Pterygota, which includes all winged and some
secondarily wingless insects.

**Ptilinum.** In Diptera an organ that can be inflated to a bladder-like structure and thrust
out through a frontal suture of the head at the time of emergence from the puparium.

**Pubescent.** Covered with short, soft hair

**Pulvillus.** The little pad beneath each claw on the foot of a fly.

**Punctate.** Covered with tiny pits or depressions, like the elytra of many beetles and the
thoraxes of many hymenopterans.

**Pupa.** (pl., pupae). The 3rd stage in the life history of butterflies and other insects
undergoing a complete metamorphosis during which the larval body is rebuilt into that of
the adult insect a non-feeding and usually inactive stage.

**Puparium.** (pl., puparia). The barrel-shaped case which conceals the pupa of the house-
fly and many other true flies. It is formed from the skin of the last larval instar.

**Pupate.** To turn into and exist as a pupa.
Pupiparous. Insects which give birth to fully-grown larvae which pupate almost immediately are said to be pupiparous. The main examples are various blood-sucking flies.

Q
Quadrilateral. A cell near the base of the damselfly wing, whose shape is important in separating the families.
Queen cell. The special cell in which a queen honey bee develops from egg to the adult stage.

R
Race. A variety of a species; a subspecies.
Radial Sector. The posterior of the two main branches of the radius, usually abbreviated to Rs. It usually has several branches of its own.
Radius. One of the main longitudinal veins, running near the front of the wing and usually the 3rd and abbreviated to R. It gives off a posterior branch - the radial sector - and the smaller branches of these veins are numbered R1, R2, etc.
Raptorial. Adapted for seizing and grasping prey, like the front legs of a mantis.
Rectum. In insects, the posterior expanded part of the hindgut, typically pear shaped.
Reticulate. Covered with a network pattern.
Reproductives. In termites the caste of kings and queens in other social insects only the queens.
Rostrum. A beak or snout, applied especially to the piercing mouth-parts of bugs and the elongated snouts of weevils.
Rudimentary. Poorly or imperfectly developed.
Salivary glands. Glands that open into the mouth and secrete a fluid with digestive, irritant, or anticoagulatory properties.
Saprophytic. Living on dead or decaying organic matter.
Scale. A scale insect; a member of the order Homoptera.
Scape. The 1st antennal segment, especially if it is longer than the other segment.
Scarabaeiform. A grub like larva having a thick, soft body with a well-developed head and strong thoracic legs but with no legs on the hind region: often permanently curved into a C. The larvae of the lamellicorn beetles are of this type.
Sclerite. Any of the individual hardened plates which make up the exoskeleton.
Sclerotization. The hardening and darkening processes in the cuticle (involves the epicuticle and exocuticle with a substance called sclerotin).
Scopa. The pollen-collecting apparatus of a bee, whether it be the pollen basket on the leg or a brush of hairs on the abdomen.
Scopula. A small tuft of hairs.
Scorpion. Any member of the arachnid order Scorpionidae; they have an elongate body and a poison sting at the end of abdomen.
Scutellum. The 3rd of the major divisions of the dorsal surface of a thoracic segment:
usually obvious only in the mesothorax and very large in some bugs.

Scutum. The middle of the three main divisions of the dorsal surface of a thoracic segment. Also, in ticks, the sclerotized plate covering all or most of the dorsum in males, and the anterior portion in females, nymphs, and larvae of the Ixodidae.

Sebaceous gland. A gland producing a greasy lubricating substance.

Secondary parasite. A parasite on another parasite.

Segment. One of the rings or divisions of the body, or one of the sections of a jointed limb.

Segmentation. The embryological process by which the insect body becomes divided into a series of parts or segments.

Serrate. Toothed like a saw.

Sessile. Attached to one place and unable to move, like many female scale insects.


Setaceous. Bristle-like, applied especially to antennae.

Simple eye. An Ocellus.

Simple metamorphosis. Metamorphosis in which the wings (when present) develop externally during the immature stage and there is no prolonged resting stage (i.e. pupa) preceding the last molt; stages included are the egg, nymphal, and adult. Also called gradual or partial metamorphosis, and paurometabolous development.

Skeletal muscle. In insects, a muscle that stretches across the body wall and serves to move one segment on another.

Social. Living in more or less organized communities of individuals.

Soldier. In termites, sterile males or females with large heads and mandibles; they function to protect the colony.

Solitary. Occurring singly or in pairs, not in colonies.

Species. The basic unit of living things, consisting of a group of individuals which all look more or less alike and which can all breed with each other to produce another generation of similar creatures.

Spermatheca. A small sac-like branch of the female reproductive tract of arthropods in which sperm may be stored.

Spermatophore. A packet of sperm.

Spine. A multicellular, thorn like process or outgrowth of the integument not separated from it by a joint.

Spinose. Spiny.

Spiracle. One of the breathing pores - openings of the tracheal system - through which diffusion of gases takes place. They usually occur on the third thoracic segment and all the abdominal.

Spiracular plate. A plate like sclerite next to or surrounding a spiracle.

Spittle. In insects, a frothy fluid produced by the nymphs of spittlebugs (Cercopidae).

Spur. A large and usually movable spine, normally found on the legs.

Spurious Vein. A false vein formed by a thickening of the wing membrane and usually unconnected with any of the true veins.

Squama. Any of the membranous flaps that arise near the base of the wing in many true flies (plural: squamae).

Stadium. (pl., stadia). The time interval between molts in a developing insect.

Stage. A distinct, sharply differentiated period in the development of an insect, e.g., egg
Sternite. The plate or sclerite on the underside of a body segment.

Stigma. A small coloured area near the wing-tip of dragonflies, bees, and various other clear-winged insects: also called the pterostigma.

Stomodeal valve. In insects, the cylindrical or funnel-shaped invagination of the foregut into the midgut.

Striae. Grooves running across or along the body: applied especially to the grooves on beetle elytra.

Striated muscle. Muscle that is composed of fibers with alternate light and dark bands.

Stridulation. The production of sounds by rubbing two parts of the body together: best known in grasshoppers and other orthopterans.

Style. A slender bristle arising at the apex of the antenna.

Style. One of the small paired appendages on the male subgenital plate of some Orthoptera.

Stylet. A needle-like object: applied to the various components of piercing mouthparts and also to a part of the sting of a bee or other hymenopteran.

Stylostome. The tube formed by the host as a result of the feeding of a chigger; in secreting salivary fluids, the chigger partially digests skin tissues, which induces the host to form a proteinaceous tube walling off the injury.

Sub-apical. Situated just before the tip or apex.

Subcosta. Usually the first of the longitudinal veins behind the front edge of the wing, although it is often missing or very faint: abbreviated to Sc.

Sub-imago. Found only among the mayflies, the sub-imago or dun is the winged insect which emerges from the nymphal skin. It is rather dull in colour, but very soon moults again - the only example of a winged insect undergoing a moult - to reveal the imago.

Sub-marginal Cells. Cells lying just behind the stigma in the hymenopteran forewing: important in the identification of bees and sphexid wasps.

Sub-species. A sub-division of a species, usually inhabiting a particular area: visibly different from other populations of the same species but still able to interbreed with them.

Superfamily. A group of closely related families; superfamily names end in -oidea.

Supplementary reproductives. In termites the caste of males and females with short wings, light pigmentation, and small compound eyes. The females lay eggs in the colony supplementing the work of the queen.

Suture. A groove on the body surface which usually divides one plate or sclerite from the next: also the junction between the elytra of a beetle.

Synonym. One of two or more names which have been given to a single species. The earliest name usually (should) takes precedence.

Systemic insecticide. An insecticide capable of absorption into plant sap or animal blood and lethal to insects feeding on or within the treated host.

T

Tarsus. (pl., tarsi). The insect's foot: primitively a single segment but consisting of several segments in most living insects.
Tegmen. A small lobe or scale overlying the base of the forewing like a shoulder-pad.
Tergite. The primary plate or sclerite forming the dorsal surface of any body segment.
Tergum. The dorsal surface of any body segment.
Thorax. The middle of the three major divisions of the insect body. The legs and wings (if present) are always attached to the thorax.
Tibia. (pl., tibiae) The forth leg segment between the femur and the tarsus.
Tetipotency The potential, throughout life, to express the full behavioral repertoire of the population (even if never actually expressed), and the ability to produce offspring like oneself, exhibiting the full behavioral repertoire of the population, without help.
Trachea. (Plural tracheae). One of the minute tubes which permeate the insect body and carry gases to and from the various organs etc. They open to the air at the spiracles.
Transverse Suture. A suture running across the thorax of many flies and dividing the mesonotum into a scutum and a prescutum.
Triangle. A triangular region near the base of the dragonfly wing, often divided into smaller cells.
Triungulin. Name given to the active 1st- instar larva of oil beetles and some of their relatives: they appear to have 3 claws on each foot.
Trochanter. The second segment of the leg, between coxa and femur: often very small and easily overlooked.
Truncate. Ending abruptly: squared off.
Tubercle. A small knob like or rounded protuberance.
Tymbal. The sound-producing 'drum-skin' of a cicada.
Tympnum. The auditory membrane or ear-drum of various insects.
Type. The type specimen of a species is the actual insect from which the original description of that species was produced. If several specimens were used for this purpose, one of them should have been designated as the type. Because the type can be of only one sex, it is usual to designate a certain individual of the opposite sex as the allotype. The original type specimen is then called the holotype. These type specimens' are very important in taxonomy and classification.

U

Uric acid. The chief nitrogenous waste of birds, reptiles and insects--; chemically, C,H,N,O.,

V

Valve. One of the paired components of the ovipositor.
Veins. In insects, the rib like tubes that strengthen the wings.
Vermiform larva. A legless wormlike larva without a well developed head
Venation. The arrangement of veins in the wings of insects. Ventral. Concerning the lower side of the body.
Vertex. The top of the head, between and behind the eyes.
Vestigial. Poorly developed, degenerate or atrophied, more fully functional in an earlier
Visceral muscle. A muscle which invests an internal organ.

Vibrissae. The pair of large bristles just above the mouth in certain flies: usually simply called vibrissae.

Viviparous. Bringing forth living or active young instead of laying eggs.

Wing pads. The undeveloped wings of nymphs and naiads, which appear as two flat structures on each side.

Woollybear. A very hairy caterpillar belonging to the family Arctiidae, the tiger moths.

Workers. In termites, the sterile males and females that perform most of the work of the colony; they are pale, wingless, and usually lack compound eyes; in social Hymenoptera, females with undeveloped reproductive organs that perform the work of the colony.