BENHA UNIVERSITY,

FACULTY OF SCIENCE,

ENTOMOLOGY DEPARTMENT

NOTES ON

GENERAL ENTOMOLOGY 2 (112E)

Prepared by

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CONTENTS

Introduction

We humans are such a self-centered species that we seldom stop to acknowledge or appreciate the importance of other living organisms in our environment. Our prowess in science and technology has given us unparalleled control over our physical environment, and as a result, we have developed an inflated view of our own importance in the web of life. Although we have learned to use tools, dam rivers, level mountains, and harness atomic power, we are still dependent on environmental resources for the countless housekeeping chores that keep our environment stable and healthy. Indeed, we are relatively minor players in the ecological drama that continually unfolds all around us. Sadly, the earth would probably be better off without us.

In simplest terms, life (as we know it) exists on planet earth because of a global cycle of production and consumption that hinges almost exclusively on green plants as primary producers and insects as primary consumers. These two life-forms overshadow all other multi-cellular organisms in terms of abundance and diversity. They are mutually dependant on one another for survival, and form a nucleus around which all terrestrial and fresh-water ecosystems are built. Without green plants and the organic molecules they produce

through photosynthesis, all animal life would collapse from starvation. Without insects and other decomposers, green plants would quickly exhaust their nutrient supplies, dead organic matter would accumulate in putrid, rotting heaps, and many species of flowering plants would become extinct for lack of insect pollinators.

We expend considerable resources trying to eliminate insects from every facet of our daily lives, but in fact, we could never hope to survive without them. Nothing else -- animal, vegetable, or mineral -- could ever take their place. By virtue of their diversity, their world-wide distribution, their ecological importance, and their impact on other life-forms, the insects are indeed a class of distinction.

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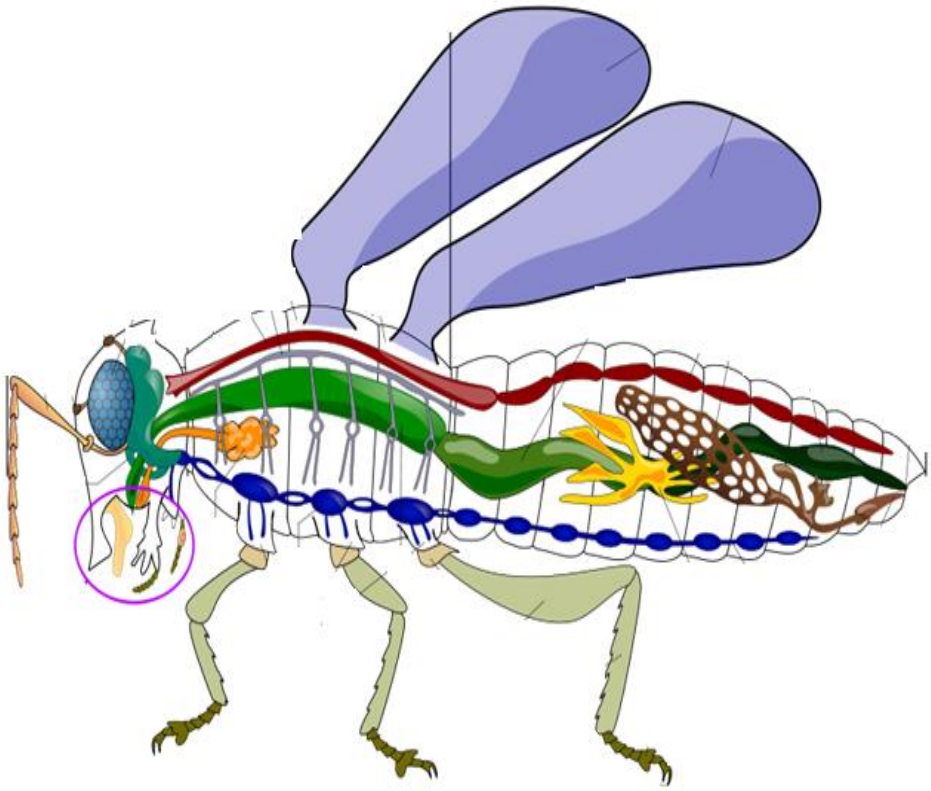
Aim of the Course

Providing the students a general knowledge and understanding of the internal anatomy of insects and the way by which different systems function and the classification of main insect orders. The prctical skills for dissection and identification of different insects will be provided.

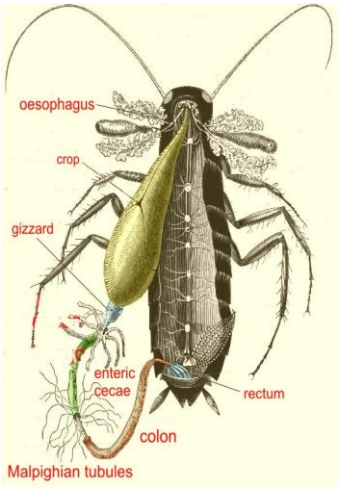
Evaluation

There will be oral, a midterm exam and a final written exams. These may be a combination of multiple choice, true/false, fill-in, and discussion questions. There will be worth 100 points. The midterm will be announced.

INTERNAL ANATOMY



Digestive Systems

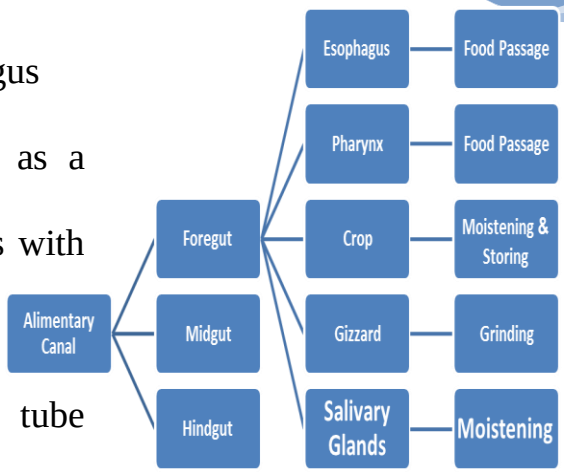


- The Digestive system of an insect is usually a long straight tube running from the mouth to the anus.
- It is often divided into the 'foregut', the 'midgut' and the 'hindgut'.
- Behind the mouth are the Salivary Glands,
- Which secrete saliva that lubricates the food and contains a few enzymes to begin food digestion?
- In some carnivorous insects the saliva is composed entirely of digestive enzymes (external digestion).

The Foregut

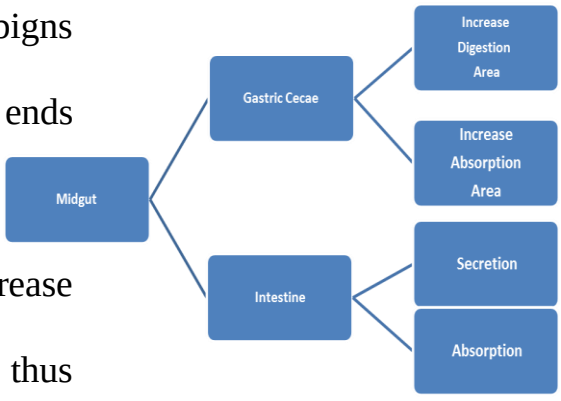
- The foregut consist of, the Pharynx, the Esophagus, the Crop and the Proventriculus.
- It is also known as the Stomodaeum.

- The pharynx connects the mouth area (Buccal Cavity) with the Esophagus
- The pharynx sometimes serves as a pump to suck up food of insects with external digestion.
- The Esophagus is basically a tube leading to the crop.
- The crop is used for storing and lubricating food.
- The proventiculus (gizzard) is used to grind the food up into smaller particles.
- The foregut and the midgut are separated by a valve.



The Midgut

- The midgut (Mesenteron) bigns with gastric caeca and ends Malpighian tubules.
- The gastric caeca serve to increase the surface area of the midgut, thus

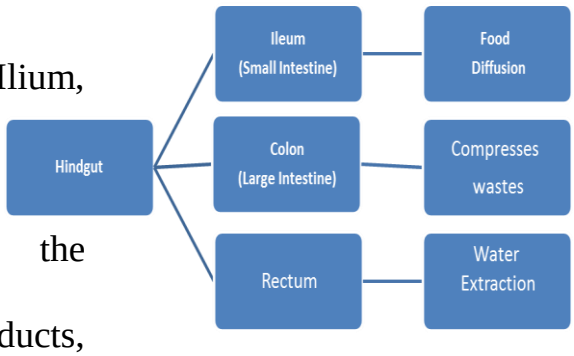


increases its ability to secrete digestive enzymes and absorption.

- The midgut is lined by a semipermeable membrane composed of protein and chitin which allows the passage of liquids and dissolved substances to the midgut.
- The midgut and the hindgut are separated by the 'proctodeal valve.

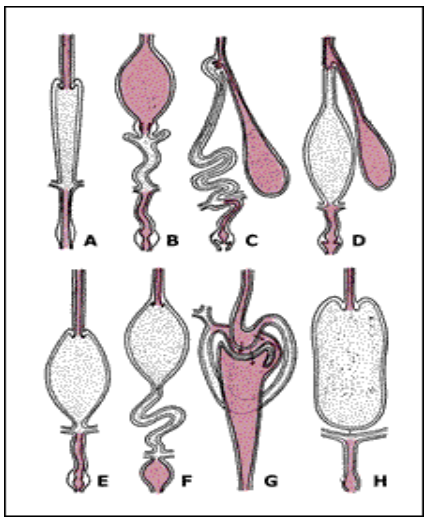
The Hindgut

- The hind gut comprises the 'intestines' where much of the diffusion into the insects' body occurs.
- The hind gut consists of the Ilium, colon and rectum.
- The 'rectum' compresses the undigested food and waste products, extracts excess water from feces before it is passed out through the 'anus'.



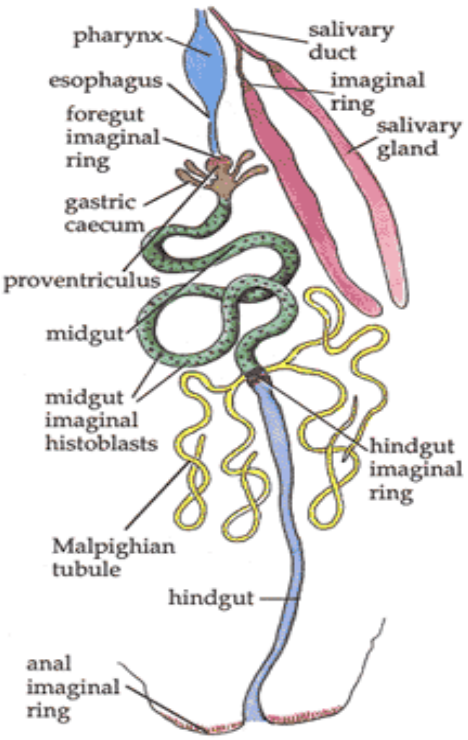
- Insects have a large number of digestive enzymes, and may have symbiotic microorganisms, such as protozoa in the case of the termites which feed on wood.

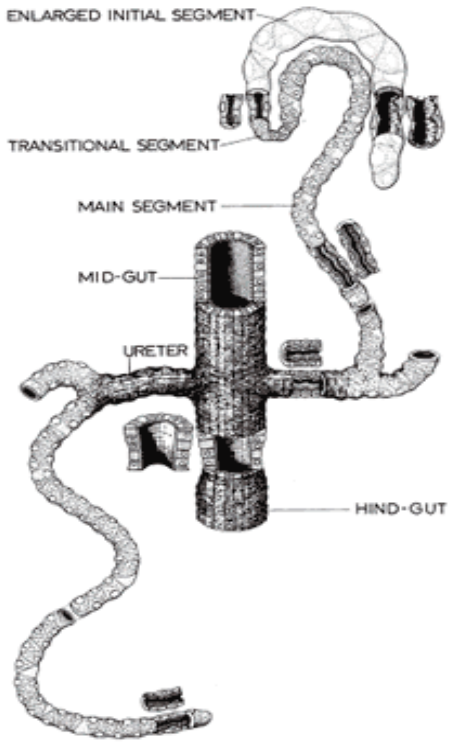
Some modifications of the digestive system in insects according to the type and nature of food.



Excretory System

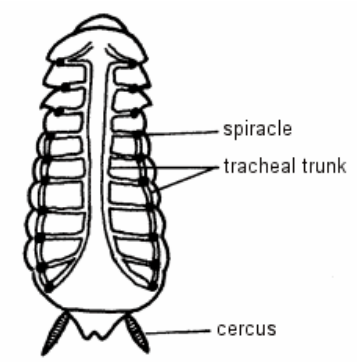
- The main excretory organ in insects is the Malpighian tubules.
- Malpighian tubules are blind-ending, tube-like appendages of the intestine and open between the mid- and hindgut.
- The number of Malpighian tubules is species-specific.
- The main function of Malpighian tubules is the absorption of uric acid (as sodium and potassium salts) into the lumen of the intestine, and excretes them with the feces.
- Water reabsorption usually occurs in the rectum, avoiding the waste of water.



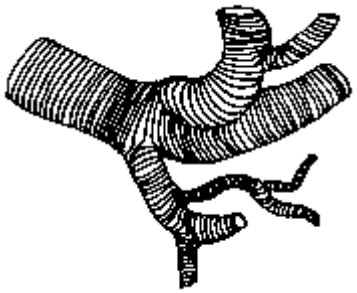


Respiratory System

- The respiratory system is a complex network of tubes (called a tracheal system) that delivers O_2 -containing air to every cell of the body and remove (CO_2).
- The respiratory system of insects is separate from the circulatory system.
- The blood of insects has no respiratory function.

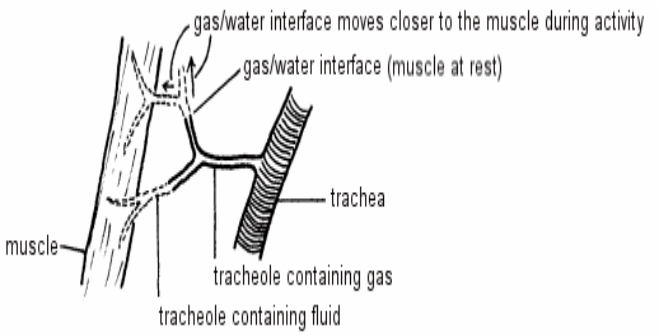


- Air enters the insect's body through openings (spiracles) located laterally along the thorax and abdomen of most insects.
- Usually each body segment has one pair of spiracles.
- Air flow is regulated by contraction and relaxation of small muscles around the spiracles.
- To prevent its collapse under pressure, a thin, reinforcing "wire" of

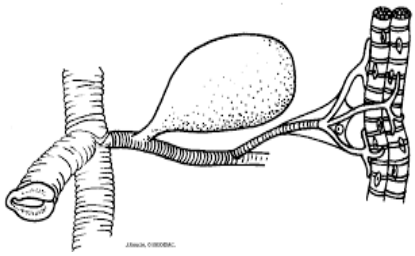


cuticle (the taenidia) winds spirally through the wall tracheal tubes.

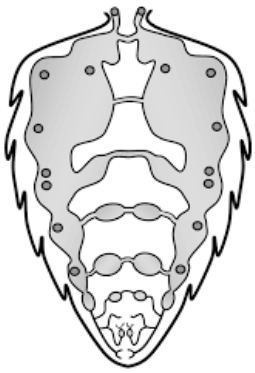
- After passing through a spiracle, air enters a longitudinal tracheal trunk, then to a complex, branching network of tracheal tubes that subdivides into smaller tracheoles and reaches every part of the body.



- Gas exchange takes place between tracheoles and adjacent cells.



- The absence of taenidia in certain parts of the tracheal system allows the formation of collapsible air sacs,



balloon-like structures that may store a reserve of air.

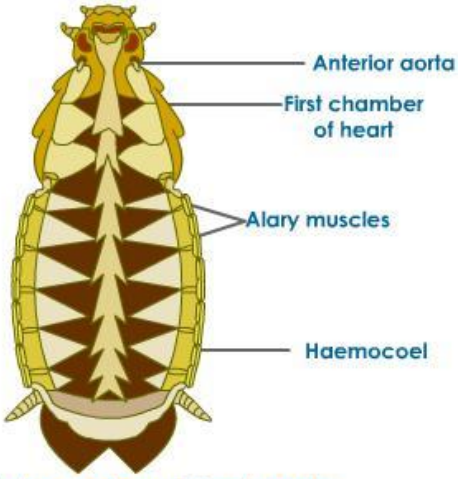
- Aquatic insects consume the stored air while under water or use it to regulate buoyancy. During a molt, air sacs fill and enlarge as the insect breaks free of the old exoskeleton and expands a new one.

Hemogoblin

- Hemoglobin is a respiratory pigment that facilitates the capture of oxygen molecules. It is an essential component of all human red blood cells, but it occurs only rarely in insects -- most notably in the larvae of certain midges (family Chironomidae) known as bloodworms.

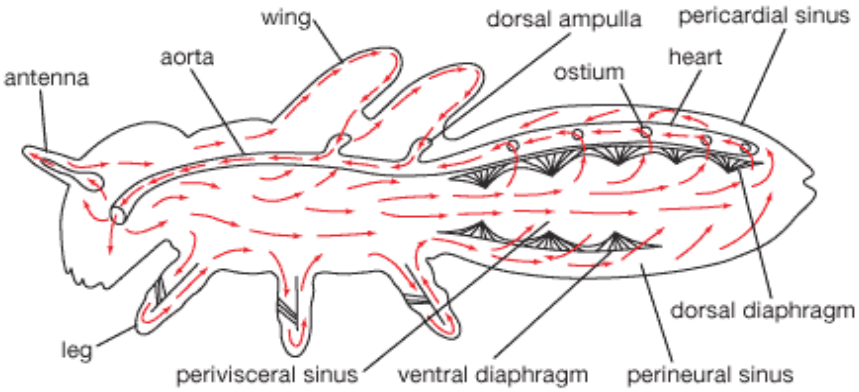
Circulatory System

- Insects have an **open circulatory system**.
- In a closed system, blood is always contained within vessels (arteries, veins, capillaries, or the heart itself).
- In an open system, blood (usually called **hemolymph**) flow freely within body cavities where it makes direct contact with all internal tissues and organs.
- The circulatory system is responsible for movement of nutrients, salts, hormones, and metabolic wastes throughout the insect's body and plays critical roles in defense against parasites and microbes.



Circulatory System of Cockroach

- A dorsal vessel is the major structural component of an insect's circulatory system.
- This tube runs dorsally through the thorax and abdomen.



- In the abdomen, the dorsal vessel is called the heart. It is divided into chambers that are separated by valves (ostia) to ensure one-way flow of hemolymph.
- A pair of alary muscles is attached laterally to the walls of each chamber. Contractions of these muscles force the hemolymph forward from chamber to chamber.
- In front of the heart a simple tube (called the aorta) continues forward to the head.
- Hemolymph washes the organs and muscles of the head as it emerges from the aorta, and then goes back over the alimentary canal and through the body until it reaches the abdomen and re-enters the heart.

- To facilitate circulation of hemolymph, the body cavity is divided into three compartments (called blood sinuses) by two thin sheets of muscle and/or membrane known as the dorsal and ventral diaphragms.
- The dorsal diaphragm is formed by alary muscles and related structures. The ventral diaphragm usually covers the nerve cord.

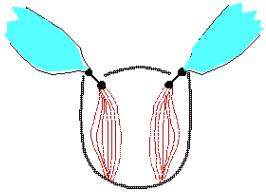
- In some insects, **pulsatile organs** are located near the base of the wings or legs to force hemolymph into the extremities.
- About 90% of insect hemolymph is **plasma**: a watery fluid - usually clear, but sometimes greenish or yellowish in color.
- The remaining 10% of hemolymph is made up of various cell types known as **hemocytes**; they are involved in the clotting reaction, phagocytosis, and/or encapsulation of foreign bodies.
- With the exception of a few aquatic midges, insect hemolymph does NOT contain hemoglobin (or red blood cells).
- Oxygen is delivered by the tracheal system, not the circulatory system.

Insect Muscles

- insects muscles are attached to the inside of their skeleton because they have their skeletons on the outside of their body.
- The musculature of even the smallest insect can be as complicated as our own.
- Indirect muscles are more efficient and capable of a higher wing beat frequency.

Insect Wing beat frequency and flight speed

Insect	beats/second	flight speed km/hour
dragonfly	20-28	25
beetles	46-90	5
butterflies	9-12	9
hawk moth	70-85	18
mosquito	300-550	32
horsefly	100	22
honey bee	200	22
wasp	110	9

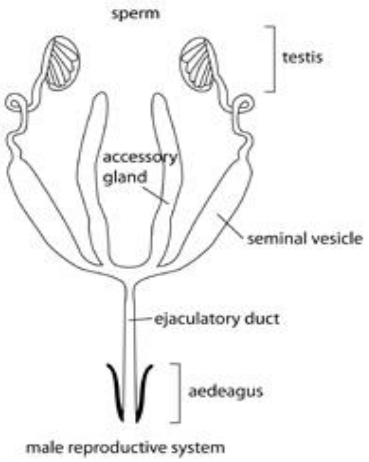


Reproductive System

- The reproductive organs of insects are similar in structure and function to those of vertebrates
- A male's testes produce sperm and a female's ovaries produce eggs (ova). Both types of gametes are haploid and unicellular, but eggs are usually much larger in volume than sperm.
- Most (but not all) insect species are bisexual and biparental.
- There are some species that are able to reproduce by parthenogenesis, a form of asexual reproduction in which new individuals develops from an unfertilized egg (virgin birth).

Male Reproductive System

- The male's reproductive system contains a pair of testes, each testis is subdivided into units (called follicles) where sperm are produced.
- Mature sperm pass out of the testes through short ducts (vasa efferentia) and collect in storage chambers (seminal vesicles).



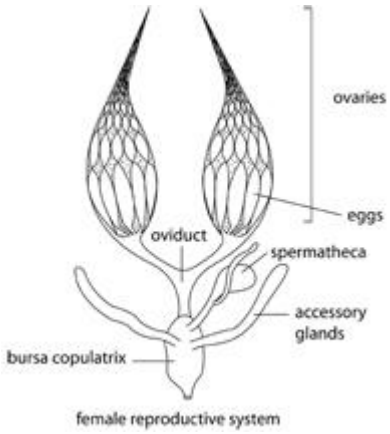
male reproductive system

- Similar ducts (vasa deferentia) join to form a single ejaculatory duct that leads to the copulatory organ.
- One or more pairs of accessory glands are usually associated with the male's reproductive system.
- The glands secretes **seminal fluid**, that sustains, feeds and protect sperms.

Female Reproductive System

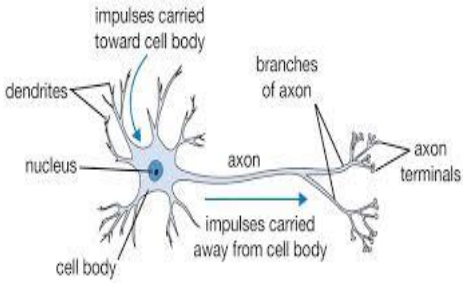
- The female's reproductive system contains a pair of ovaries. Each ovary is subdivided into functional units (called ovarioles) where the eggs (oocytes) are produced.
- Mature eggs leave the ovaries through short lateral oviducts.
- Lateral oviducts join to form a common oviduct which opens into a genital chamber.

  Female accessory glands secrete egg shell (chorion) that surrounds the entire egg.



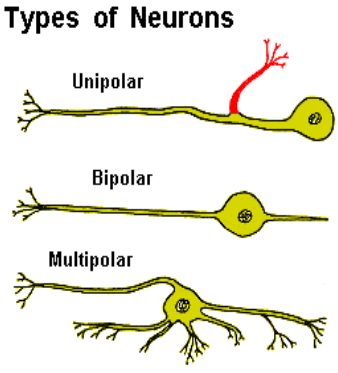
female reproductive system

The Nervous System



- An insect's nervous system is a network of specialized cells (called neurons).
- Every neuron has a nerve cell body (where the nucleus is found) and filament-like processes (dendrites, axons, or collaterals) that propagate the action potential.
- Neurons are usually divided into three categories, depending on their function within the nervous system:

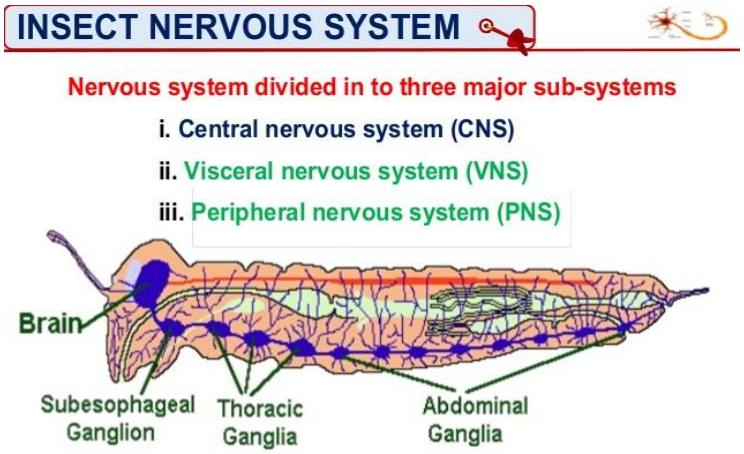
1. **Sensory neurons** (bipolar or multipolar cells associated with sense organs or receptors). They always carry information <u>toward</u> the central nervous system.



2. **Motor neurons** (unipolar cells that conduct signals from the central nervous system and

stimulate responses in muscles and glands.

3. **Association neurons** (multipolar cells (often with several collaterals and/or branching axons) that conduct signals within the central nervous system.



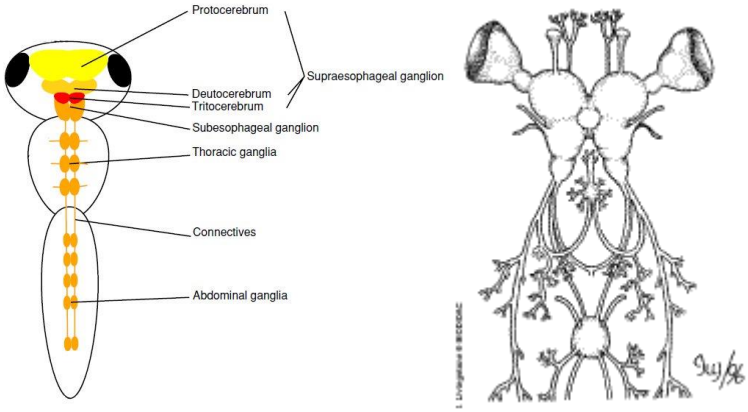
The Central Nervous System

- The CVS consists of a brain linked to a ventral nerve cord that consists of paired segmental ganglia along the ventral midline of the thorax and abdomen.
- Ganglia within each segment are linked to one another by a short medial nerve (commissure) and also joined by

intersegmental connectives to ganglia in adjacent body segments.

- In more "advanced" insect orders some ganglia combine (both laterally and longitudinally) into larger ganglia that serve multiple body segments.
- An insect's brain is six fused ganglia located dorsally within the head capsule.
- The brain consists of 3 parts Protocerebrum, Deutocerebrum and Tritocerebrum.
- Each part of the brain controls (innervates) a limited spectrum of activities in the insect's body.
- The subesophageal ganglion (complex of fused ganglia) lies just below the brain and esophagus.
- The subesophageal ganglion innervates mouth parts, salivary glands, and neck muscles.
- A pair of circumesophageal connectives inks the brain and subesophageal ganglion together.
- Thoracic ganglia control locomotion of legs and wings.
- Abdominal ganglia control movements of abdominal muscles.

- A pair of terminal abdominal ganglia (usually fused to form a large caudal ganglion) innervates the anus, internal and external genitalia, and sensory receptors.



The Stomodaeal Nervous System

- An insect's internal organs are largely innervated by a stomodaeal (or stomatogastric) nervous system.
- A pair of frontal nerves arising near the base of the tritocerebrum links the brain with a frontal ganglion.
- This ganglion innervates all internal non voluntary organs.

The Peripheral Nervous System

- It consists of sensory and motor neurons that connect between the central nervous system and the integument, muscles and sense organs.

Classification

Animals are classified into the animal kingdom. Each kingdom is then further divided into increasingly smaller groups based on similarities. The different levels of groups are named by the convention of taxonomists (scientists who study classifications). The standard groups in a typical complete classification of species are (the example is for a honey bee, *Apis mellifera* Linnaeus):

Kingdom (Animal)
Phylum (Arthropoda)
Class (Insecta)
Order (Hymenoptera)
Family (Apidae)
Genus (*Apis*)
Species (mellifera)

Terminology, Classification and Use of Scientific Names

Scientific names (genus, species and subspecies) are italicized or underlined with the genus (first) name capitalized. Names of the authors of species follow.

Insects belong to a larger group call Arthropoda which includes all animals with segmented legs, segmented bodies and exoskeletons. The phylum Arthropoda includes: spiders, ticks, mites, centipedes, millipedes, shrimps, and many other organisms.

Class Hexapoda (Insecta) Insect Characteristics

Most adult insects have the following characteristics:

1. A body divided into three parts (head, thorax and abdomen)
2. Three pairs of legs
3. Usually one pair of antennae and a pair of compound eyes (a few exceptions to these characteristics are found)
4. Usually two pairs of wings (absent in many insects such as lice, fleas, ants; flies have one pair of wings)

Insect Orders - Introduction

The Class Hexapoda is generally studied under a classificati with approximately 32 orders. Many of these are of minor i and are studied only from the standpoint of scientific Considered here are some of the more important orders likely to be encountered. Many taxonomists disagree on the orders and their names. Thus, this scheme will often vary witl authors.

Major Insect Orders	
Order	**Examples**
Thysanura	silverfish
Orthoptera	grasshoppers
Hymenoptera	bees
Diptera	flies and mosquitoes
Lepidoptera	butterflies
Coleoptera	beetles
Blattaria	cockroaches
Odonata	dragonflies
Hemiptera	true bugs
Siphonaptera	fleas
Phthiraptera	lice
Isoptera	termites

Apterygota

Order Thysanura

- Thysanura are usually found in moist locations around houses or out-of-doors under stones, bark and boards. They are fast run rapidly and hide in cracks and crevices. Occasionally they damage book bindings, curtains, wallpaper, etc. Silverfish can be a nuisance in houses.
- Thysanura are wingless insects with flattened elongate bodies, long antennae and usually with three, long, tail like appendages. Mouth parts are formed for chewing. Metamorphosis is minimal (young resemble adults except for size). They are up to 3/8 inches long.
- Insects in this order: silverfish

Order Odonata

- Odonata are large insects with two pairs of membranous, many-veined wings; the hind pair are as large as or larger than the front pair. Mouthparts are formed for chewing. They have large conspicuous eyes. Aquatic immature stages, called nymphs (or naiads) live in flowing or still water. Adults are common around water.
- Immature Odonata have chewing mouthparts. Naiads have elongated extensible labium with piercing jaws used to capture prey.
- Both the adults and the naiads feed on insects. They are beneficial, because they feed to some extent on mosquitoes and other small flies. Adult dragonflies and damselflies can hover like a helicopter or fly and dart around rapidly. Dragonflies tend to hold their wings flat out from their sides when at rest. Damselflies tend to hold their wings together over the abdomen. They have been called **"mosquito hawks"** and **"snake doctors**."
- Odonata have incomplete metamorphosis. They are 1/4 inch to over 1 inch in length.

- Some insects in this order: dragonfly, damselfly

damselfly

Naiad

dragonfly

Order Orthoptera

- The order Orthoptera is a large one. Orthoptera generally have two pairs of wings. The front pair is usually slender and the hind pair is broad and fan-like. Wings are reduced to small pads in some grasshoppers and crickets. Mouthparts are formed for chewing. Nymphs resemble the adults. Metamorphosis is gradual.
- Some members of this group are quite destructive to crops
- Insects in this order: Grasshopper

Order Blattaria

- They have flattened bodies and their head is concealed from above by their pronotum. They have two pairs of wings, but in some species the wings are greatly reduced.
- Cockroaches are somewhat general feeders. They deposit their eggs in a capsule called an ootheca. Several species invade homes where they can contaminate food. They have an unpleasant odor and can be very annoying in the home. Cockroaches go through incomplete metamorphosis.

- Some insects in this order: American cockroach, German cockroach.

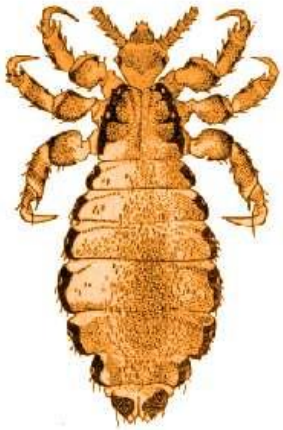
Order Isoptera

- Are small, soft-bodied insects that live in colonies in wood. Colonies consist of three castes: workers, soldiers and swarmers. Workers and soldiers are wingless and never leave the colony. Swarmers, or the reproductive forms, have dark bodies and four long, veined wings. The front and hind wings of termites are nearly identical in size and venation. Termites also have beadlike antennae and thick waists which distinguish them from ants. Termites have chewing mouthparts.
- Swarmers leave the colonies on sunny days to mate and search for new homes. Termites are important to man. They do millions of dollars in damage to houses each year. Termites undergo simple metamorphosis (egg, nymph, adult). Most termites are less than 1/4 inch long.
- Insects in this order: Termites.

Worker Termites Soldier Termites Swarmer Termites

Order Phthiraptera

- Phthiraptera are divided into the chewing lice (Mallophaga) and sucking lice (Anoplura).
- These insects are wingless parasites that live on most birds and mammals. The chewing lice feed on bits of hair, feathers or skin of the host. The sucking lice feed mainly on blood. Lice deposit their eggs on the hair or feathers of the host.
- These insects are irritating pests that can be carriers of disease. Only the sucking lice contain members that attack humans.
- Phthiraptera undergo simple metamorphosis.
- Example of this order: louse.

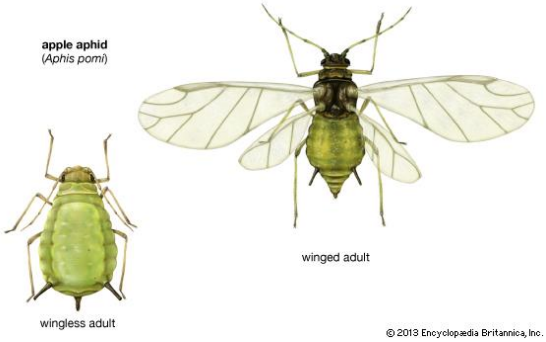


Order Hemiptera

- Hemiptera usually have four wings folded flat over the body. There is often a visible triangle at the center of the back that the wing bases do not cover called the scutellum. The front pair are thickened and leathery at the base with membranous tips or ends.
- Mouthparts are formed for piercing and sucking.
- They are found on plants and animals, or in water. Some true bugs cause considerable plant damage by their feeding. Some are beneficial because they prey on other insects. A few bite humans on occasion.
- Metamorphosis is gradual, with immatures usually quite like the adults but wingless. Most are under 1/2-inch long but some forms especially aquatic ones may be over 2 inches long.
- Insects in this order: The giant water bug,

Order Homoptera

- Homoptera may or may not have wings.
- All have sucking mouthparts.
- Wings, when present, are four in number and are held roof-like over the body and are usually membranous. Cicadas and leafhoppers all have wings. Aphids may or may not have wings. Scale insects are wingless; live on branches, roots and leaves; and move around little, if any, after beginning to feed. The body is covered with a hard or waxy covering. Mealybugs are usually wingless; whitish or gray in color; covered with a waxy substance; and move slowly.
- All Homoptera feed on plants.
- Some species in the order Homoptera give birth.
- Metamorphosis is gradual. Most forms are small or microscopic, cicadas are nearly 3/4-inch long.
- Insects in this order are: aphids and mealybugs.



Order Coleoptera

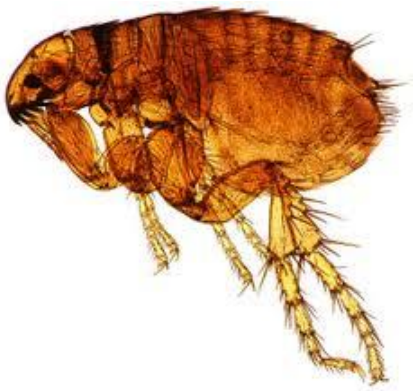
- The largest order by number of species is Coleoptera. One in five living animal species is a beetle.
- Coleoptera usually have two pairs of wings. The front pair of wings, called elytra, are thick and form a hard shell over the abdomen of the most beetles. Elytra meet in a straight line down the middle of the back. Some have short elytra and may be confused with earwigs but the caudal appendages on beetles are segmented rather a single piece like in earwigs.

The hind wings are membranous and are folded under the front wings when at rest. Mouthparts are formed for chewing in adult beetles and immatures but some are modified considerable for piercing or pollen feeding.

- Coleoptera is the largest order of insects, including about 1/4 of all known insects with about 280,000 different species in the world. Food habits are varied. Some feed on living plants; some are predaceous; some are scavengers; and others bore in wood. This order includes some of the best known and most important of our insect enemies. Most of the members are terrestrial, but some are aquatic. Beetles go through complete metamorphosis. They are microscopic to over 2 inches long.
- Insects in this order: tiger beetle, rice beetle

Order Siphonaptera

- Siphonaptera are small, wingless insects with the body flattened laterally (from side to side).
- Mouthparts are formed for piercing and sucking.
- Larvae are found in the nests of various animals, in carpets in the home or in the soil in areas where animals frequent. They are rarely seen and feed on organic matters.
- Fleas are well known as pests of domestic animals and man. One species transmits the bacterium that causes plague. Plague has killed more than 125,000,000 people over the past 3,000 years. These insects are blood-feeders only as adults.
- Metamorphosis is complete. Most fleas are under 1/8 inch.
- Insects in this order: flea.

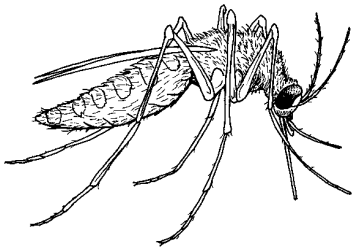


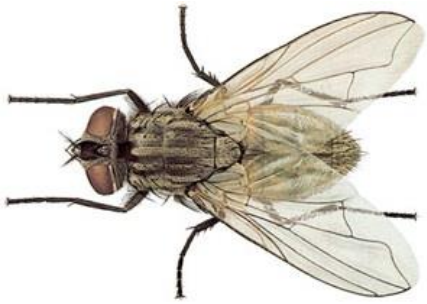
Order Diptera

- Diptera are usually winged, but have only one pair of wings with few veins. Hind wings are represented by a pair of slender, knobbed structures called **halteres**.
- Mouthparts are formed for sucking or piercing and sucking.
- Fly larvae are entirely different from the adults and are usually found in different habitats. Immatures usually are known as maggots.
- Many fly larvae are associated with aquatic habitats or very moist areas with organic matter. Some are internal parasites of mammals.
- Diptera occur in many shapes and sizes and are a very important group. The order includes forms that are parasitic, predaceous and others that live on either living or dead plant or animal material. Some members of the order cause a great amount of damage to crops. Many harmful flies spread diseases, such as mosquitoes, which are responsible for millions of human deaths. This is one of the most important orders from the standpoint of human health because of the species that carry diseases.

- Flies have complete metamorphosis. Flies can be very small to over 1 inch in length.

- Some insects in this order: house fly, and mosquito





Order Lepidoptera

- This is a large order of insects and one of the best known. It contains some of our most important pests; such as the bollworm, cutworms, clothes moth and cabbageworm.
- Lepidoptera usually have four well developed wings covered with overlapping scales as adults.
- Mouthparts of the adults are formed for sucking but some have reduced or non-functional mouthparts.
- Butterflies generally fly during the day and can be recognized by the clubbed antennae. Skippers are much like butterflies but have the end of the antennae hooked rather than clubbed. Moths generally fly at night but there are exceptions. Moths have antennae that are linear or feathery but not clubbed.

- Immature stages (larvae) are known as caterpillars. Their mouthparts are formed for chewing.
- Most Lepidoptera feed on leaves of plants in the larval stage.
- All Lepidoptera have complete metamorphosis.
- Insects in this order: moth and butterfly.

Order Hymenoptera

- Adult Hymenoptera are winged or wingless insects.
- Mouthparts are formed for chewing or modified like in honey bees for both chewing and sucking.
- They can be microscopic to over 1 inch long. Immature stages have chewing mouthparts and are maggot-like for ants, bees and wasps.
- This order includes some of our most harmful, as well as some of our most beneficial insects. The abdomen in the females ends in an ovipositor which may be modified into a stinger or a saw-like organ. Many Hymenoptera have a painful sting and should be avoided if possible.
- Insects in this order: honey bee.

References

- Charles A. Triplehorn and Norman F. Johnson, Borror and DeLong's Introduction to the Study of Insects, 7th edition (Thomas Brooks/Cole, 2005) - a classic textbook in North America
- General Entomology Notes, Department of Entomology, Texas A&M University (2008)