

Handouts | 2022

Zoo – 201



Effort by:

Kainat Azhar

Usman Irshad

VU: BS ZOOLOGY

ZOO – 201 ANIMAL DIVERSITY (INVERTEBRATES)

1

Architecture Patterns of Animals (Patterns of Organization)

Symmetry

- It describes how parts of an animal are arranged around a point or an axis.

1.Radial symmetry

2.Bilateral symmetry

Asymmetry

- Absence of a central point or axis around which body parts are equally distributed
- e.g. Protists and many sponges.

Other patterns of Organization:

1. **Unicellular organization**

2. **Diploblastic organization** (a. two germ layered gastrula)

3. **Triploblastic organization** (b. three germ layered gastrula)

I. The Triploblastic Acoelomate Pattern

II. The Triploblastic Pseudocoelomate

III. The Triploblastic Coelomate

1. **Unicellular organization**

Characteristics:

- Consist of single cell
- Also known as “Cytoplasmic”
- They are not simple
- They provide function of locomotion, food acquisition, digestion, Water and ion regulation, sensory perception and reproduction.

Water and ion regulation, sensory perception and reproduction.

- They can also form cellular aggregates i.e., colonies

2. Diploblastic organization

- IT is simplest tissue level organization
- Body parts are organized into two layers i.e.

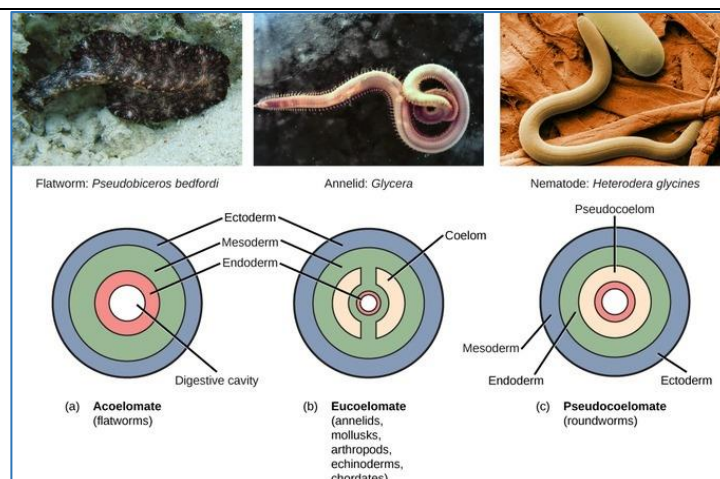
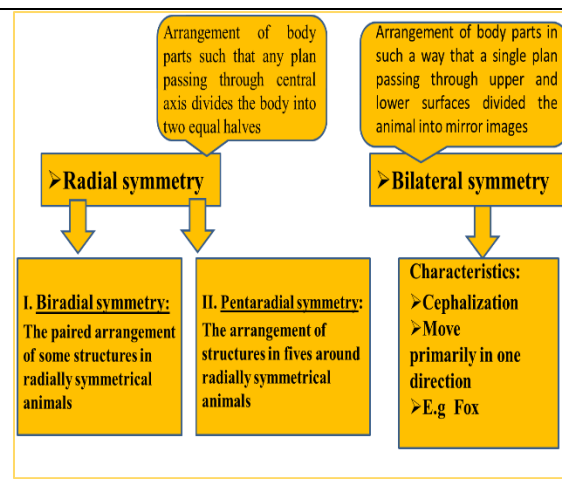
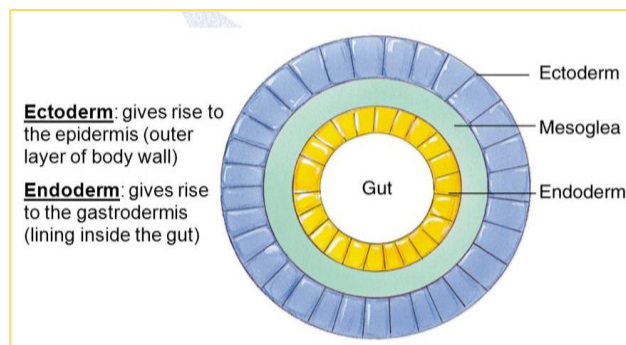
Ectoderm and Endoderm

Ectoderm

Give rise to epidermis, outer layer of the body wall

Endoderm

Give rise to gastrodermis, the tissues that line gut cavity



2

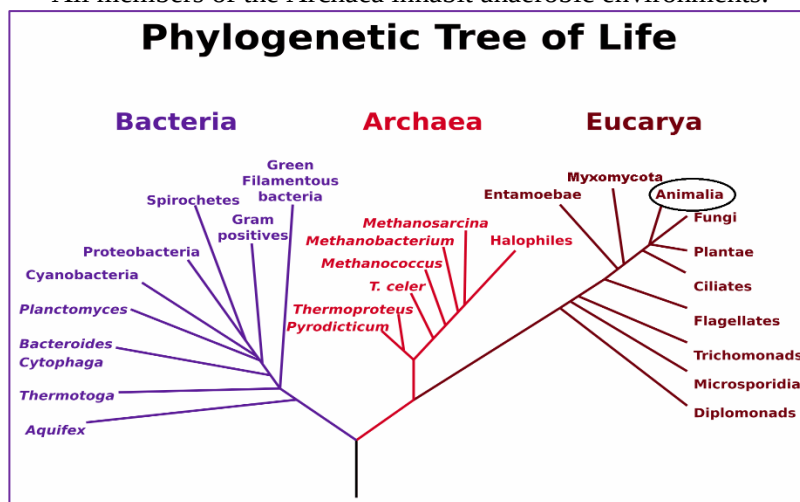
Taxonomy

- The binomial system of nomenclature is universal and clearly indicates the level of classification involved in any description.
- No two kinds of animals have the same binomial name, and every animal has only one correct name.
- The entire scientific name is italicized or underlined because it is derived from Latin or is latinized.
- Thus, the scientific name of humans is written *Homo sapiens*.
- When the genus is understood, the binomial name can be abbreviated *H. sapiens*.

KINGDOMS OF LIFE

In 1969, Robert H. Whittaker described a system of classification that distinguished between kingdoms according to cellular organization and mode of nutrition.

- According to this system, members of the kingdom **Monera** are the **bacteria** and the **cyanobacteria**.
- They are distinguished from all other organisms by being prokaryotic.
- Members of the kingdom **Protista** are eukaryotic and consist of single cells or colonies of cells.
- This kingdom includes Amoeba, Paramecium, and many others.
- Members of the kingdom **Plantae** are **eukaryotic, multicellular**, and photosynthetic.
- Plants have walled cells and are usually nonmotile.
- Members of the kingdom **Fungi** are **also eukaryotic and** multicellular.
- They also have walled cells and are usually nonmotile.
- Mode of nutrition distinguishes fungi from plants.
- Fungi digest organic matter extracellularly and absorb the breakdown products.
- Members of the kingdom **Animalia** are **eukaryotic and** multicellular, and they usually feed by ingesting other organisms or parts of other organisms.
- Their cells lack walls and they are usually motile.
- The emerging picture is that the five previously described kingdoms do not represent distinct evolutionary lineages.
- **Ribosomal RNA** is excellent for studying the evolution of early life on earth.
- Evolutionary conservation of this molecule means that closely related organisms (recently diverged from a common ancestor) are likely to have similar ribosomal RNAs.
- Distantly related organisms are expected to have ribosomal RNAs that are less similar, but the differences are small enough that the relationships to some ancestral molecules are still apparent.
- **Studies of ribosomal RNA have led systematists to the** conclusions that all life shares a common ancestor and that there are three major evolutionary lineages.
- Each of these lineages is called a domain.
- The **Archaea** are **prokaryotic microbes that live in extreme environments**, such as high-temperature rift valleys on the ocean floor, or high-salt or acidic environments.
 - All members of the Archaea inhabit anaerobic environments.

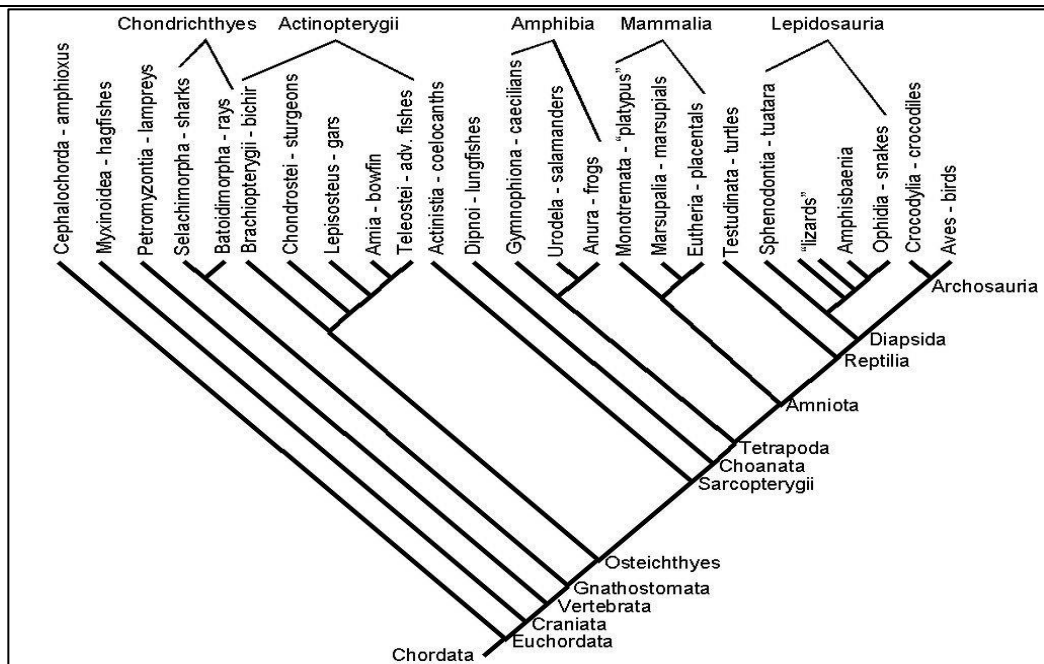


3

Animal Systematics

- **The goal of animal systematics is to arrange animals into** groups that reflect evolutionary relationships.
- Ideally, these groups should include a single ancestral species and all of its descendants.
- Such a group is called a **monophyletic group**.
- A **character is virtually anything that has** a genetic basis and can be measured—from an anatomical feature to a sequence of nitrogenous bases in DNA or RNA.
- **Polyphyletic** groups have members that can be traced to separate ancestors.
- A **paraphyletic group includes some, but not** all, members of a lineage.
- **Evolutionary systematics** is the oldest of the three approaches, sometimes called the “traditional approach.”

	• A basic assumption is that organisms closely related to an ancestor will resemble that ancestor more closely than they resemble distantly related organisms. • Homologies are resemblances that result from common ancestry and are useful in classifying animals. • Analogies are resemblances that result from organisms adapting under similar evolutionary pressures. • The latter process is sometimes called convergent evolution. • Numerical taxonomy emerged during the 1950s and 1960s and represents the opposite end of the spectrum from evolutionary systematics. • The founders of numerical taxonomy believed that the criteria for grouping taxa had become too arbitrary and vague. • Numerical taxonomists use mathematical models and computer-aided techniques to group samples of organisms according to overall similarity. • They do not attempt to distinguish between homologies and analogies. • Phylogenetic systematics (cladistics) is a third approach to animal systematics. • The goal of cladistics is similar to that described for evolutionary systematics—the generation of hypotheses of genealogical relationships among monophyletic groups of organisms. • Cladists contend, however, that their methods are more open to analysis and testing, and thus are more scientific, than those of evolutionary systematists. • Characters that all members of a group share are referred to as symplesiomorphies (Gr. <i>sym</i>, together <i>plesio</i>, near <i>morphe</i>, form). • Characters that have arisen since common ancestry with the outgroup are called derived characters or synapomorphies (Gr. <i>syn</i>, together <i>apo</i>, away <i>morphe</i>, form). • Taxa that share a certain synapomorphy form a subset called a clade (Gr. <i>klados</i>, branch).
4	Phylogeny • Depicting phyla or classes as ancestral is misleading because evolution occurs in species groups (populations), not at higher taxonomic levels. • Also, even though phyla or classes are depicted as ancestral, modern representatives of these “ancestral phyla” have had just as long an evolutionary history as animals in other taxonomic groups that may have descended from the common ancestor. • All modern representatives of any group of animals should be visualized at the tips of a “tree branch,” and they may be very different from ancestral species. • Zoologists use modern representatives to help visualize general characteristics of an ancestral species, but never to specify details of the ancestor’s structure, function, or ecology. • In addition to these problems of interpretation, evolutionary trees often imply a ladderlike progression of increasing complexity. • This is misleading, because evolution has often resulted in reduced complexity and body forms that are evolutionary failures. • In many cases, evolution does not lead to phenotypes that permit survival under changing conditions, and extinction occurs. • Further, the common representation of a phylogeny as an inverted cone, or a tree with a narrow trunk and many higher branches, is often misleading. • This implies that evolution is a continuous process of increasing diversification. • The fossil records show that this is often wrong. • For example, 20 to 30 groups of echinoderms (sea stars and their relatives) are in the fossil record, but there are only five modern groups. • This evolutionary lineage, like many others, underwent rapid initial evolutionary diversification. • After the initial diversification, extinction—not further diversification—was the rule. • Contemporary paleontologist Stephen J. Gould uses the term contingency to refer to rapid evolutionary explosion followed by a high likelihood of extinction.



5 Patterns of Organization: Unicellular Organization

- One of the most strikingly ordered series of changes in evolution is reflected in body plans in the animal kingdom and the protists.
- **Evolutionary** changes do not always mean “progress” and increased complexity.
- Evolution frequently results in backtracking, in failed experiments, and in inefficient or useless structures.
- **SYMMETRY**

The bodies of animals and protists are organized into almost infinitely diverse forms.

- Within this diversity, however, are certain patterns of organization.
- The concept of symmetry is fundamental to understanding animal organization.

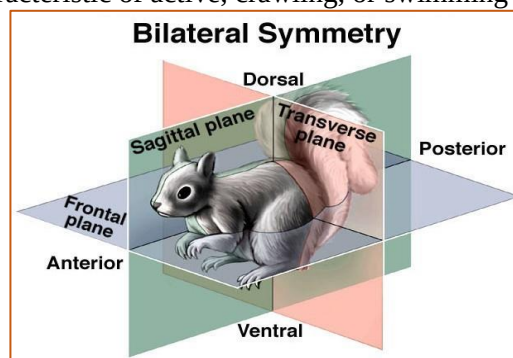
Symmetry describes how the parts of an animal are arranged around a point or an axis.

Asymmetry, which is the absence of a central point or axis around which body parts are equally distributed, characterizes most protists and many sponges.

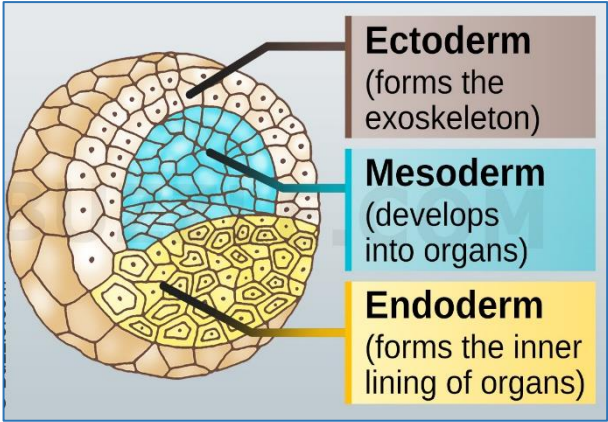
- Asymmetry cannot be said to be an adaptation to anything or advantageous to an organism.
- Asymmetrical organisms do not develop complex communication, sensory, or locomotor functions.
- Clearly, however, protists and animals whose bodies consist of aggregates of cells have flourished.

Radial symmetry is the arrangement of body parts such that any plane passing through the central oral-aboral axis divides the animal into mirror images.

- Radial symmetry is often modified by the arrangement of some structures in pairs, or in other combinations, around the central oral-aboral axis.
- The paired arrangement of some structures in radially symmetrical animals is called **biradial symmetry**.
- The arrangement of structures in fives around a radial animal is called **pentaradial symmetry**.
- **Bilateral symmetry** is the arrangement of body parts such that a single plane, passing between the upper and lower surfaces and through the longitudinal axis of an animal, divides the animal into right and left mirror images.
- Bilateral symmetry is characteristic of active, crawling, or swimming animals.



6	Diploblastic Organization - Cells are organized into tissues in most animal phyla. Diploblastic (Gr. <i>diplóos</i>, twofold <i>blaste</i>, to sprout) organization is the simplest tissue-level organization. - Body parts are organized into layers derived from two embryonic tissue layers. Ectoderm (Gr. <i>ektos</i>, outside <i>derm</i>, skin) gives rise to the epidermis, the outer layer of the body wall. Endoderm (Gr. <i>endo</i>, within) gives rise to the gastrodermis, the tissue that lines the gut cavity. - Between the epidermis and the gastrodermis is a noncellular layer called mesoglea. - In some diploblastic organisms, cells occur in the mesoglea, but they are always derived from ectoderm or endoderm. - The cells in each tissue layer are functionally interdependent. - The gastrodermis consists of nutritive (digestive) and muscular cells, and the epidermis contains epithelial and muscular cells. - The feeding movements of <i>Hydra</i> or the swimming movements of a jellyfish are only possible when groups of cells cooperate, showing tissue-level organization.
---	--

7	Triploblastic Patterns of Organization 3. Triploblastic Organization ➤ These animals are usually bilaterally symmetrical animals. ➤ Their tissues are derived from three embryological layers i.e. ectoderm, mesoderm and endoderm. Ectoderm Give rise to epidermis, outer layer of the body wall Mesoderm It forms skeletal muscle, bone, connective tissue, the heart, and the urogenital system. Endoderm Give rise to gastrodermis, the tissues that line gut cavity Triploblastic Organization - Acoelomate pattern - Pseudocoelomate pattern - Coelomate pattern I. Triploblastic acoelomate pattern - The Acoelomates are represented by Phyla Platyhelminthes, Nemertea (ribbon worms), and Gastrotricha (free-living and fresh water species). - Important characteristics include bilateral symmetry, true mesoderm, have muscles and other organs, have nervous system – brain and spinal cord - Lack body cavity due to the filling of mesodermal mass between the epidermis and the digestive tract - Dorsoventrally flattened animals commonly called flatworms - Parasitic and a member of Class Turbellaria - Representatives of Classes Monogenea, Trematoda and Cestidea II. Triploblastic Pseudocoelomate pattern A. General Characteristics of pseudocoelomates - bilateral, unsegmented, triploblastic, complete gut (tube within a tube), lack circulatory and respiratory systems, dioecious, 2 cavities - gut cavity + pseudocoel formed from blastocoel - lack true coelom (peritoneal cavity), not lined w/ peritoneum - body wall (epidermis)/dermis/muscles surrounding pseudocoel 
---	--

III. Triploblastic coelomate pattern

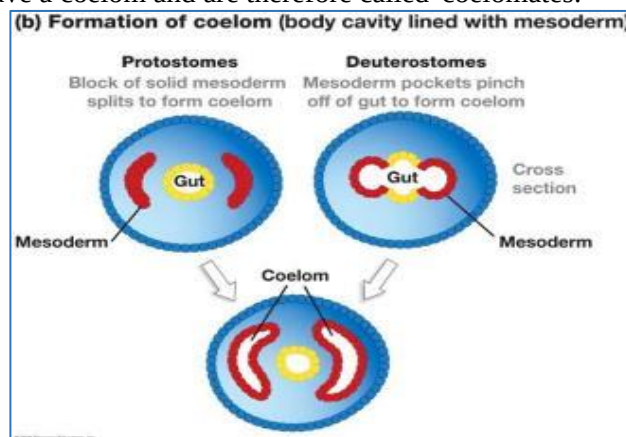
The Triploblastic Coelomate Pattern

- Coelom is a body cavity completely surrounded by mesoderm
- Peritoneum- mesodermal sheet that lines the inner body wall and serosa (outer covering of visceral organs)
- Having mesodermally derived tissue (muscle, connective tissue) enhances the function of all internal body systems.

8

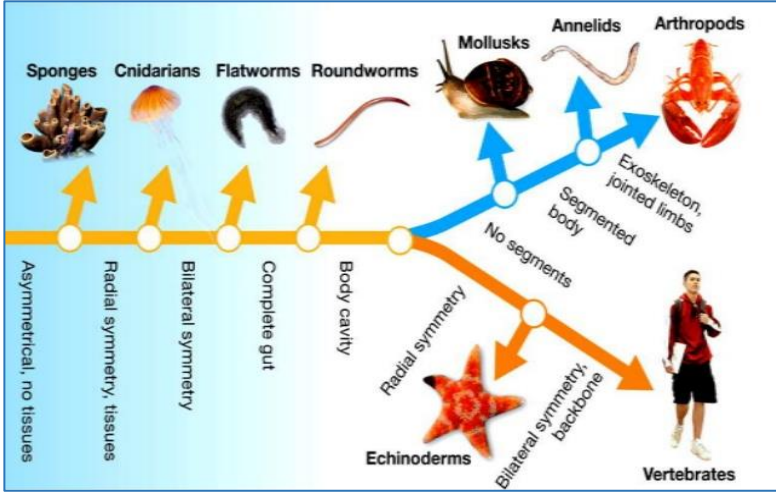
Advantages of Coelom

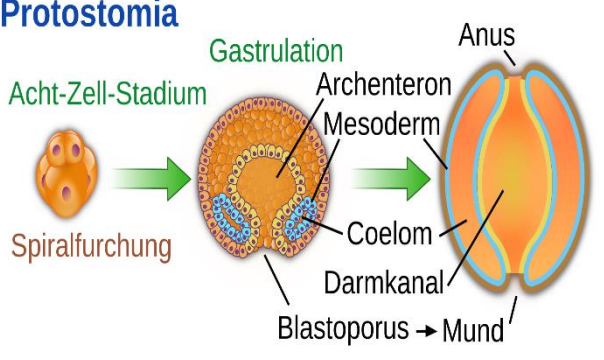
- Triploblastic animals are organized into several subgroups based on the presence or absence of a body cavity and, for those that possess one, the kind of body cavity present.
- A body cavity is a fluid-filled space in which the internal organs can be suspended and separated from the body wall.
- Body cavities are advantageous because they;
 1. Provide more room for organ development.
 2. Provide more surface area for diffusion of gases, nutrients, and wastes into and out of organs.
 3. Provide an area for storage.
 4. Often act as hydrostatic skeletons.
 5. Provide a vehicle for eliminating wastes and reproductive products from the body.
 6. Facilitate increased body size.
- Body-cavity fluids give support, while allowing the body to remain flexible.
- 4. Often act as hydrostatic skeletons.
- 5. Provide a vehicle for eliminating wastes and reproductive products from the body.
- 6. Facilitate increased body size.
- Body-cavity fluids give support, while allowing the body to remain flexible.
- Hydrostatic skeletons can be illustrated with a water filled balloon, which is rigid yet flexible.
- Because the water in the balloon is incompressible, squeezing one end causes the balloon to lengthen.
- Compressing both ends causes the middle of the balloon to become fatter.
- In a similar fashion, body-wall muscles, acting on coelomic fluid, are responsible for movement and shape changes in many animals.
- Coeloms are important because they allow for the separation and compartmentalization of different biological functions in the body.
- Animals lacking coelom have to rely on diffusion to transport important nutrients throughout the body.
- The coelom usually refers to the main body cavity.
- It surrounds and contains the digestive tract and helps prevent injury to the digestive organs.
- Inside the coelom, there is a fluid called coelomic fluid.
- This fluid allows the internal organs to freely move.
- Most vertebrates have a coelom and are therefore called 'coelomates.'

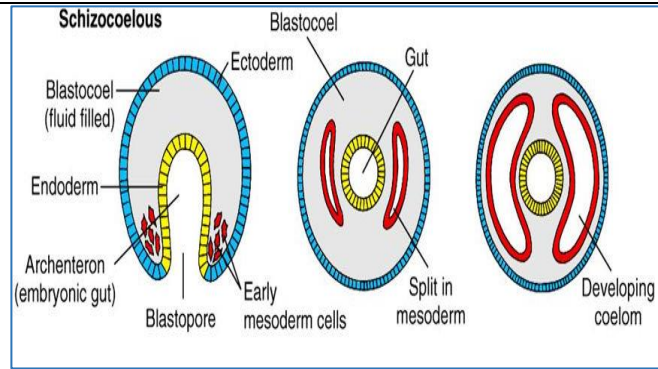


9	Triploblastic Acoelomate pattern • Triploblastic animals whose mesodermally derived tissues form a relatively solid mass of cells between ectodermally and endodermally derived tissues are called acoelomate (Gr. <i>a</i>, without <i>kilos</i>, hollow). • The Acoelomate are represented by Phyla Platyhelminthes, Nemertea (ribbon worms), and Gastrotricha (free-living and fresh water species) • Important characteristics include bilateral symmetry, mesoderm, have muscles and other organs, have nervous system-brain and spinal cord. • Lack body cavity due to the filling of mesodermal mass between the epidermis and digestive tract. • Dorsoventrally flattened animals commonly called flatworms. • Some cells between the ectoderm and endoderm of acoelomate animals are loosely organized cells called parenchyma. • Parenchymal cells are not specialized for a particular function. • Acoelomate organs are not protected from crushing forces applied to the animal's outer surface, hence why the majority of acoelomate organisms live some type of liquid environment and utilize diffusion.
10	Triploblastic Pseudocoelomate Pattern • A pseudocoelom (Gr. <i>pseudes</i>, false) is a body cavity not entirely lined by mesoderm. • No muscular or connective tissues are associated with the gut tract, no mesodermal sheet covers the inner surface of the body wall, and no membranes suspend organs in the body cavity. • Nematodes or roundworms (Nematoda), rotifers (Rotifera), acanthocephalans (spiny-headed worms), kinorhynchs (Kinorhyncha) and nematomorphs or horsehair worms (Nematomorpha) are pseudocoelomates. • Pseudocoelomates lack a circulatory system, and the pseudocoelom itself lacks the endothelial lining of a coelom. • The hydrostatic pressure of the pseudocoelom gives the body a supportive framework that acts as a skeleton. The diagram illustrates the body wall structure of a pseudocoelomate. It shows a cross-section with concentric layers. The outermost layer is the Ectoderm (blue). Inside it is the Pseudocoelom (white space). The next layer is the Mesoderm (red ring). The innermost layer is the Endoderm (yellow ring). The center is the Digestive cavity. Labels with leader lines point to each of these structures.
11	Triploblastic Coelomate Pattern • A coelom is a body cavity completely surrounded by mesoderm. • A thin mesodermal sheet, the peritoneum, lines the inner body wall and is continuous with the serosa, which lines the outside of visceral organs. • The peritoneum and the serosa are continuous and suspend visceral structures in the body cavity. • These suspending sheets are called mesenteries. • Having mesodermally derived tissues, such as muscle and connective tissue, associated with internal organs enhances the function of virtually all internal body systems. • It enables independent movement of the gut wall and the body wall. The diagram compares an Annelid (earthworm) with a Coelomate cross-section. On the left, an Annelid is shown with a red arrow pointing to a cross-section on the right. The cross-section shows concentric layers: Ectoderm (outermost, blue), Coelom (white space), Endoderm (innermost, yellow ring), and Mesoderm (red ring). Labels with leader lines point to each of these structures.

	• It provides space of the enlargement and development of internal organs. • It may act as a circulatory medium for transport of materials or a storage area of excess or waste materials. • Coelomates include mollusks, arthropods, echinoderms, and chordates.
12	Major Subdivisions of Animal kingdom • Kingdom Animalia divided into two major groups: • Invertebrates • Vertebrates Invertebrates: • An invertebrate is an animal without a backbone • About 98 % of all animals are invertebrate Vertebrates: • Only about two percent of all animals are vertebrates which belong to the phylum <i>chordata</i> • Vertebrates include fish, amphibians, reptiles, birds and mammals. Animals share following characteristics: • Animals are multicellular and have eukaryotic cells. • Animal's cells lack cell walls. • Animals have a period of embryonic development. • Animals are consumers. • Animals are diploid. • Most animals have muscle and nervous tissue. • Animals have different levels of organization. • All animals have sex cells that are haploid and are produced by meiosis. • As animals evolved and became more complex, they developed organ systems to perform basic functions. Some important organ systems are: • Skeletal • Muscular • Circulatory • Digestive • Nervous • Reproductive Traditional groupings based on embryological and anatomical characters Branch A (Mesozoa): Phylum Mesozoa, the mesozoa Branch B (Parazoa): Phylum Porifera, the sponges and phylum placozoa Branch C (Eumetazoa): all other phyla • Grade I (Radiata): Phyla Cnidaria, Ctenophora • Grade II (Bilateria): all other phyla • Division A (Protostomia) • Acoelomates: Phyla Platyhelminthes, Gnathostomulida, Nemertea • Pseudocoelomates: Phyla Rotifera, Gastrotricha, Kinorhyncha, Nematoda, Nematomorpha, Acanthocephala, Entoprocta, Priapulida, Loricifera • Eucoelomates: Phyla Mollusca, Annelida, Arthropoda, Echiurida, Spiunculida, Tardigrade, Onychophora • Division B (Deuterostomia): Phyla Phoronida, Ectoprocta, Chaetognatha, Brachiopoda, Echinodermata, Hemichordata, Chordata • Sponges: Sponges belong to the phylum porifera (pore bearing) • They are asymmetrical and do not have a body cavity • They feed by pulling water into the pores of their bodies and filtering out food particles Cnidarians: The phylum cnidarians include jelly fish, coral, sea anemones and hydra • They have a radial symmetry and do not have a body cavity

	- Many cnidarians have specialized stinging cells to capture food or defense themselves Flatworms: Planarians belong to the phylum platyhelminthes-the flatworms - Flatworms are the simplest animals having bilateral symmetry - They have a sac like gut but no body cavity - They digest food in a gastro vascular cavity 
13	Comparative Embryology Embryology is the study of the development of embryos from fertilization until they become fetuses, or the point at which you can distinguish the species. Comparative embryology is the comparison of embryo development across species. - The study of comparative embryology is based on the observation that embryological events may be similar because of shared ancestry. - Aristotle was the earliest person in recorded history to study embryos. - As with other comparative studies, however, embryologists must sort homologous developmental sequences from analogous developmental sequences. - All embryos pass from single cells to multi-celled zygotes, clumps of cells called morulas, and hollow balls of cells called blastulas, before they differentiate, creating the organs and systems of the body. - Karl Ernst von Baer made observations on the embryos of many species and noted marked similarities, or homologies, in the development of all vertebrates. - Von Baer's work was later used by Charles Darwin to support his theory of evolution. - As the result of his research, von Baer formulated four principles of comparative embryology. - The first principle was that general features appear before specialized features. - The second was that general features progressively develop into more specialized features. - The third is that embryos of more evolved animals diverge more and more from those of more primitive animals. - Finally, he observed that the embryos of higher animals resemble the embryos, but not the adults, of more primitive animals.
14	Protostomes (General Features) - A multicellular organism whose mouth develops from a primary embryonic opening. - The protostomes ("first mouth") in which the oral end of the animal develops from the first developmental opening, the blastopore. - Protostomes include animals in the phyla Platyhelminthes, Nematoda, Mollusca, Annelida, Arthropoda and others. - The coelomic cavities are variable in number in different groups. - In sipunculans and echiurans the body cavities are two in numbers. - In echiurans a septum separates the body cavity into two. - In annelids the single coelom is divided by many septa. General Features One characteristic is the pattern of early cleavage of the zygote. - In spiral cleavage, the mitotic spindle is oriented obliquely to the axis of the zygote.

	• This orientation produces an eight-celled embryo in which the upper tier of cells is twisted out of line with the lower cell. • A second characteristic common to many protostomes is that early cleavage is determinate. • Determinate means that the fate the cells is established very early in development. • If cells of the two or four-celled embryo are separated, none develops into a complete organism. • Compound cilia from multi-ciliated cells. • Other characteristics of protostome's development include the manner in which the embryonic gut tract and the coelom form. • Many protostomes have a top-shaped larva, called a trochophore larva. • Mesodermal tissue is formed by the division of a single blastomere 4d cell. • Origin of coelom takes place by schizocoely by splitting of the mesodermal cell mass.	Protostomia 
15	Protostomes (Spiral and Determinate Cleavage) Cleavage is a process of rapid and synchronous mitotic cell divisions of the zygote to form numerous cells for building up the offspring's body • Cleavage differs from other forms of cell division in that it increases the number of cells without increasing the mass. • Cleavage ends with the formation of the blastula. • In Protostome development, cleavage is spiral and determinate. • In deuterostome development, cleavage is radial and indeterminate. • With indeterminate cleavage, each cell in the early stages of cleavage retains the capacity to develop into a complete embryo. • Indeterminate cleavage makes possible identical twins and embryonic stem cells. Spiral Cleavage Holoblastic cleavage that is typical of protostomes. • Spiral cleavage is characterized by arrangement of the blastomeres of each upper tier over the cell junctions of the next lower tier. • So that the blastomeres spiral around the pole-to-pole axis of the embryo. Determinate Cleavage Determinate cleavage (also called mosaic cleavage) is in most protostomes. • It results in the developmental fate of the cells being set early in the embryo development. • Each blastomere produced by early embryonic cleavage does not have the capacity to develop into a complete embryo.	
16	Protostomes (Schizocoelous Coelom Formation) • The coelom is formed during the embryonic stage of development. • Formation differs in that protostome form a coelom when the mesoderm splits. • The deuterostomes form a coelom when mesoderm cells combine, resulting in the body cavity. Schizocoelous Coelom Schizocoely (adjective forms: schizocoelous or schizocoelic) is a process by which some animal embryos develop. • Animals which develop through schizocoely are known as schizocoelomates. • Schizocoely occurs when a coelom (body cavity) is formed by splitting the mesodermal embryonic tissue. • Schizocoelous development is typically attributed to protostomes, but some deuterostomes can exhibit schizocoely as well.	



- The term refers to the order of organization of cells in the gastrula leading to development of the coelom.
- In protostomes, the mesoderm (the middle germ layer) forms as a solid mass of migrated cells from the single layer of the gastrula.
- The new mesoderm then splits, creating the pocket-like cavity of the coelom.
- A coelom is a hollow, fluid-filled cavity found in many living things.
- It acts as a protective cushion for their internal organs.
- In some animals, such as worms, the coelom acts as a skeleton.
- The coelom also allows the internal organs to move and grow independently of the outer layer of the **body** wall.
- **Coelom** also allows organs to grow and change in position or shape.
- A **coelom** allows compartmentalization to separate biological systems that carry out differing major functions.
- For instance, animals without **coelom** (acoelomates) would have to rely on diffusion to transport nutrients around the body.

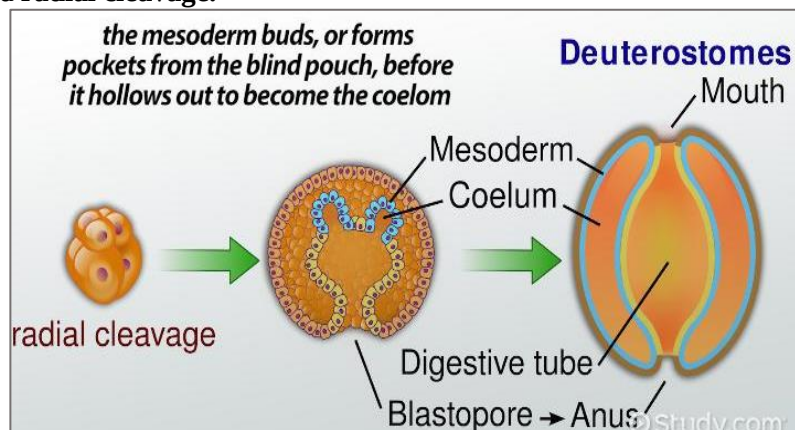
17 Deuterostomes (General Features)

- **Deuterostomes** are also known as enterocoelomates because their coelom develops through enterocoely.
- There are three major clades of **deuterostomes**:
 1. Chordata (vertebrates and their kin)
 2. Echinodermata (starfish, sea urchins, sea, cucumbers, etc.)
 3. Hemichordata (acorn worms and graptolites).
- Extinct deuterostome groups may include the phylum Vetulicolia.
- It is a sister clade of Protostomia, with which it forms the Nephrozoa clade.

General Features

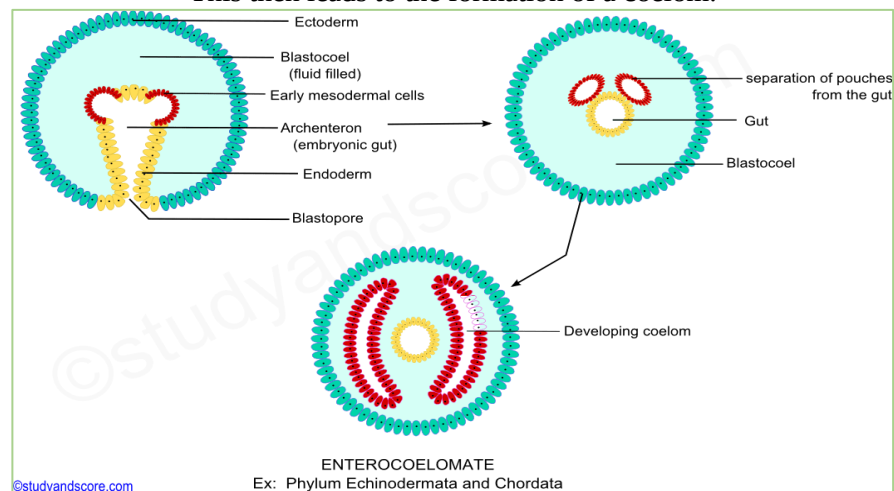
The defining characteristic of the deuterostome is the fact that the blastopore (the opening at the bottom of the forming gastrula) becomes the anus.

- The deuterostome mouth develops at the opposite end of the embryo from the blastopore.
- A digestive tract develops in the middle, connecting the two.
- In deuterostomes, a zygote first develops into a hollow ball of cells, called a blastula.
- In deuterostomes, the early divisions occur parallel or perpendicular to the polar axis.
- This is called **radial cleavage**.



	- Radial cleavage occurs when the mitotic spindle is oriented perpendicular to the axis of the zygote and results in embryonic cells directly over one another. - Most deuterostomes display indeterminate cleavage. - In that the developmental fate of the cells in the developing embryo are not determined by the identity of the parent cell. - Thus, if the first four cells are separated, each cell is capable of forming a complete small larva. - If a cell is removed from the blastula, the other cells will compensate. - In deuterostomes the mesoderm forms as evaginations of the developed gut that pinch off, forming the coelom. - This is called enterocoely. - In deuterostomes, arrangement of coelomic cavities form a Tripartite coelom. - Some deuterostomes possess a kidney-bean-shaped larva called a dipleurula. - There is, however no single kind of deuterostome larval stage.
18	Deuterostomes (Radial and Indeterminate Cleavage) Cleavage is a process of rapid and synchronous mitotic cell divisions of the zygote to form numerous cells for building up the offspring's body - Cleavage differs from other forms of cell division in that it increases the number of cells without increasing the mass. - Cleavage ends with the formation of the blastula. - In deuterostome development, cleavage is radial and indeterminate. - With indeterminate cleavage, each cell in the early stages of cleavage retains the capacity to develop into a complete embryo. - Indeterminate cleavage makes possible identical twins and embryonic stem cells. - A cell can only be indeterminate (also called regulative) if it has a complete set of undisturbed animal/vegetal cytoarchitectural features. Radial Cleavage Holoblastic cleavage that is typical of deuterostomes and that is characterized by arrangement of the blastomeres of each upper tier directly over those of the next lower tier resulting in radial symmetry around the pole-to-pole axis of the embryo. Indeterminate Cleavage A type of cleavage on the basis of the potentiality of blastomeres in which the blastomeres (resulting from cleavage) are qualitatively equipotential and each has the ability to develop into a complete embryo when isolated since its developmental fate is not determined in the early embryonic stage.
19	Deuterostome (Enterocoelous Coelom Formation) - The coelom is formed during the embryonic stage of development. - Formation differs in that protostome form a coelom when the mesoderm splits. - Deuterostomes form a coelom when mesoderm cells combine, resulting in the body cavity. Enterocoely (Adjective forms: enterocoelic and enterocoelous) is a process by which some animal embryos develop. - In enterocoely, a mesoderm (middle layer) is formed in a developing embryo, in which the coelom forms from pouches "pinched" off of the digestive tract (also known as the embryonic gut, or archenteron). - This type of coelom formation occurs in deuterostome animals, which for this reason are also known as enterocoelomates. - Enterocoelous development begins once the embryo reaches the gastrula phase of development. - At this point, there are two layers of cells: the ectoderm (outermost) and the endoderm (innermost) layers. - The mesoderm begins to form as two "pockets" of tissue (one above the endoderm, and one below) are formed via folding of the endoderm. Coelom Formation The diagram illustrates two types of coelom formation. On the left, 'Protostome development' (examples: molluscs, annelids, arthropods) shows 'Schizocoelous' formation where 'solid masses of mesoderm split and form coelom'. On the right, 'Deuterostome development' (examples: echinoderms, chordates) shows 'Enterocoelous' formation where 'folds of archenteron form coelom'. Both diagrams label the 'Archenteron', 'Coelom', 'Mesoderm', and 'Blastopore'.

- These "pockets" begin to grow larger, and as they do so, they extend towards each other.
- When the two "pockets" of cells meet, the mesoderm is formed - a complete layer of tissue right in between the endoderm and ectoderm layers.
 - This then leads to the formation of a coelom.



- A coelom is a hollow, fluid-filled cavity found in many living things.
- It acts as a protective cushion for their internal organs.
- In some animals, such as worms, the coelom acts as a skeleton.
- The coelom also allows the internal organs to move and grow independently of the outer layer of the **body** wall.
- **Coelom** also allows organs to grow and change in position or shape.
- A **coelom** allows compartmentalization to separate biological systems that carry out differing major functions.
- For instance, animals without **coelom** (acoelomates) would have to rely on diffusion to transport nutrients around the body.

20	Phylum Protozoa (Life within a single plasma membrane; nutrition) • Protozoa (Gr. <i>Proto</i>, first and <i>zoa</i>, animal) are microscopic and unicellular which does not mean that they are simple organisms. • A protozoan is a complete organism in which all life activities are carried on within the limits of a single plasma membrane. • Historically, the protozoa were regarded as "one-celled animals". • As they often possess animal-like behaviors, such as motility, predation and lack a cell wall, as found in plants and many algae. • First discovered by Antony Von Leeuwenhoek in 1671. • Van Siebold (1845) identified protozoans as single cellular organisms. • Dobell named them as acellular or non-cellular animals. • Goldfuss named these organisms as Protozoans • About 50,000 species have been identified and named. • This phylum includes free and parasitic forms and cosmopolitan in distribution. • Protozoans are first formed animals • Small microscopic animalcules • Originated in Precambrian period of Paleozoic era. • Shape: Some of them are spherical, oval, ball shaped, while some other are shapeless (or) irregular. • A regular arrangement of microtubules, called the pellicle, underlies the plasma membrane of many protozoa. • The pellicle is rigid enough to maintain the shape of the protozoan, but it is also flexible. • The cytoplasm of protozoan is differentiated into two regions: • The portion of the cytoplasm just beneath the pellicle is called ectoplasm. • The inner cytoplasm, called endoplasm, is usually granular and more fluid. • Habitat: Distributed all over the world, free living symbionts, commensals and parasites. • Lives in water, soil, air, on animals and inside the animals. Symmetry: Radial or spherical, bilateral symmetry and A symmetrical.
----	--

	• Nucleus: Usually only one nucleus. • Eilophores have two nuclei (dimorphic) One nucleus is large and called macronucleus, it carries all vegetative metabolic activities. • The other is small and called micronucleus which is exclusively for reproduction. • Locomotion: Locomotor organelles are finger - like pseudopodia or wiper like flagella or hair like cilia or absent. • Most are naked, but some have a simple endoskeleton or exoskeleton. Nutrition: Holozoic (animal like), holophytic (plant like), saprophytic or parasitic. Digestion occurs intracellular inside of food vacuoles. Respiration: No special respiratory organs, Respiration is carried by general body surface through diffusion. Excretion: Through diffusion or through contractile vacuoles which serves mainly for osmoregulation. • In some protozoan phyla, individuals' group to form colonies, association of individuals that are not dependent on one another for most function. Reproduction: Asexually and Sexually • Asexual reproduction by binary fusion, multiple fusion or budding. • Sexual reproduction by conjugation or by fusion of gametes (syngamy). • Life history often completed with alternation of asexual and sexual phases. • Encystment is a common protective phase, commonly occurs to resist the unfavorable conditions of food.
21	Protozoa (Symbiotic life-styles) • Protozoa (Gr. <i>Proto</i>, first and <i>zoa</i>, animal) are microscopic and unicellular which does not mean that they are simple organisms. • A protozoan is a complete organism in which all life activities are carried on within the limits of a single plasma membrane. • Historically, the protozoa were regarded as "one-celled animals". • As they often possess animal-like behaviors, such as motility, predation and lack a cell wall, as found in plants and many algae. Many protozoa have symbiotic lifestyles. • Symbiosis is an intimate association between two organisms. There are following types of symbiosis in protozoans: 1. Parasitism: An association in which one organism lives in or on a second organism, host and causes disease in the host is called parasitism. • The host is harmed. But this host usually survives till the completion of one or more life cycle. • The relationships between a parasite and its host are complex. Some parasites have multiple hosts. These hosts may be: (a) Definitive host: The sexual stages of the parasite occur in definite host. (b) Intermediate host: The offspring of sexual stages enter into another host, called intermediate host. • They reproduce asexually in intermediate host. • Some life cycles require more than one intermediate host and more than one immature stage. • The final asexual stage reaches the definitive host. Therefore, the life of the parasite is completed. 2. Commensalism: The symbiotic relationship in which one member of the relationship benefits and the second member are neither benefited nor harmed is called commensalism. 3. Mutualism: The symbiotic relationship in which both species get benefit is called mutualism.
22	Protozoan Taxonomy (Protozoan taxonomy up to phyla, subphyla and super classes) Protozoa as a sub-kingdom contains 7 phyla: • Phylum Sarcomastigophora • Phylum Labyrinthomorpha • Phylum Apicomplexa • Phylum Microspora • Phylum Ascetosporea • Phylum Myxozoa

- Phylum Ciliphora

Phylum Sarcomastigophora:

- Protists that have a single type of nucleus
- Protozoa that possess flagella, pseudopodia or both for locomotion
- About 18000 species
- Both sexual and asexual reproduction

Subphylum Mastigophora:

- One or more flagella for locomotion
- Autotrophic, heterotrophic or saprozoic
- Contains both phytoflagellates and zooflagellates

Examples: *Trypanosoma*, *Giardia*, *Trichomonas*, *Leishmania*, *Trichonympha*

Class Phytomastigophorea

- Chloroplast usually present
- Mainly autotrophic, some heterotrophic
- Examples: *Euglena*, *Volvox*, *Chlamydomonas*

Class Zoomastigophora

- Lack chloroplast
- Heterotrophic or saprozoic
- *Trichonympha*, *Giardia*, *Leishmania*

Subphylum Sarcodina:

- Contains amoeboid protist
- Pseudopodia for both movement and food gathering
- Naked or white shell or test

Superclass Rhizopoda:

- Lobopodia, filopodia, reticulopodia or no distinct pseudopodia
- Examples: *Amoeba*, *Entamoeba*, *Naegleria*, *Arcella*, *Diffugia*

Superclass Actinopoda:

- Spherical, planktonic
- Axopodia supported by microtubules
- Includes marine radiolarians with siliceous tests and freshwater heliozoans
- About 3000 species

Subphylum Opalinata:

- Cylindrical
- Covered with cilia
- Example: *Opalina*, *Zelleriella*

Phylum Labyrinthomorpha:

- Trophic stage as ectoplasmic network with spindle-shaped or spherical
- Nonamoeboid cells
- Saprozoic and parasitic on algae and sea grass
- Mostly marine and estuarine
- Example: *Labyrinthula*

Phylum Apicomplexa:

- Parasitic with an apical complex used for penetrating host cells
- Cilia and flagella lacking, except in certain reproductive stages
- The gregarines (Monocystis) coccidians (Eimeria, Isopora, Sarcocystis, Toxoplasma), plasmodium
- About 5500 species

Phylum Microspora:

- Unicellular spores
- Intracellular parasites in nearly all major animal groups
- The microsporeans (*Nosema*)
- About 850 species

Phylum Acetospora:

- Multicellular spore
- All parasitic in invertebrates
- The acetosporans (*Paramyxa*, *Haplosporidium*)

Phylum Myxozoa:

- Spores of multicellular origin
- All parasitic

	- Found in freshwater and marine - The myxzoan (Myxosoma) - About 1250 species Phylum Ciliophora: - Protozoa with simple or compound cilia at some stages in the life history - Heterotrophs with a well-developed cytostome and feeding organelles - At least one macronucleus and micronucleus present - Examples: Paramecium, Stentor, Vorticella, Balantidium - About 9000 species
23	Phylum Sarcomastigophora - With over 18,000 described species, Sarcomastigophora (Gr. <i>sarko</i>, fleshy <i>mastigo</i>, whip <i>phoros</i>, to bear) is the largest protozoan phylum and has the following - Unicellular or colonial - Locomotion by flagella, pseudopodia, or both - Autotrophic (self-nourishing), saprozoic (living in decaying organic matter), or heterotrophic (obtains energy from organic compounds) - Single type of nucleus - Sexual reproduction (usually) SUBPHYLUM MASTIGOPHORA: - Members of the subphylum Mastigophora use flagella in locomotion. - Flagella may produce two-dimensional, whip like movements or helical movements that push or pull the protozoan through its aquatic medium. CLASS PHYTOMASTIGOPHOREA - Members of the class Phytomastigophorea (Gr. <i>phytos</i>, plant) possess chlorophyll and one or two flagella. - Phytomastigophoreans produce a large portion of the food in marine food webs. - Several genera, such as <i>Gymnodinium</i>, have representatives that produce toxins. - Periodic “blooms” of these organisms are called “red tides” and result in fish kills along the continental shelves. - Humans who consume tainted molluscs or fish may die. <i>Volvox</i> is a colonial flagellate consisting of up to 50,000 cells embedded in a spherical, gelatinous matrix. - Individual cells possess two flagella, which cause the colony to roll and turn gracefully through the water. <i>Volvox</i> is a colonial flagellate consisting of up to 50,000 cells embedded in a spherical, gelatinous matrix. - Individual cells possess two flagella, which cause the colony to roll and turn gracefully through the water. - Some species are dioecious (having separate sexes); other species are monoecious (having both sexes in the same colony). In autumn, specialized cells differentiate into macrogametes or microgametes. - Macrogametes are large, filled with nutrient reserves, and nonmotile. - One of the products of meiosis then undergoes repeated mitotic divisions to form a colony consisting of just a few cells. - The other products of meiosis degenerate. - This colony is released from the protective zygotic capsule in the spring. CLASS ZOOMASTIGOPHOREA - Members of the class Zoomastigophorea (Gr. <i>zoion</i>, animal) lack chloroplasts and are heterotrophic. - Some members of this class are important parasites of humans. - One of the most important species of zoomastigophoreans is <i>Trypanosoma brucei</i>.

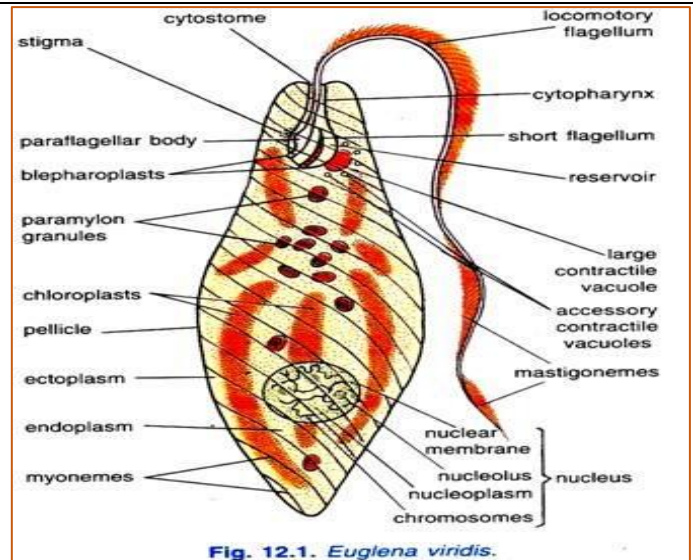
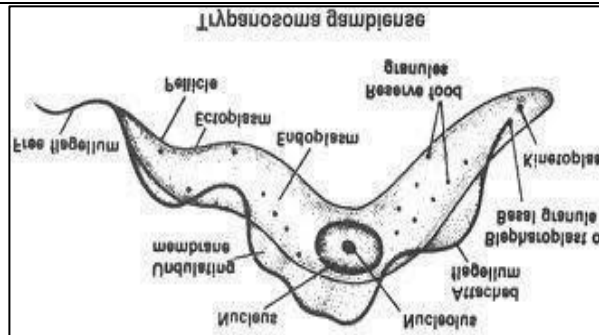


Fig. 12.1. *Euglena viridis*.



- This species is divided into three subspecies: *T. b. brucei*, *T. b. gambiense*, and *T. b. rhodesiense*, often referred to as the *Trypanosoma brucei* complex.
- The first of these three subspecies is a parasite of nonhuman mammals of Africa.
- The latter two cause sleeping sickness in humans.
- Tsetse flies (*Glossina spp.*) are intermediate hosts and vectors of all three subspecies.
- When a tsetse fly bites an infected human or mammal, it picks up parasites in addition to its meal of blood.
- Trypanosomes multiply asexually in the gut of the fly for about 10 days, then migrate to the salivary glands.
- While in the fly, trypanosomes transform, in 15 to 35 days, through a number of body forms.
- When the infected tsetse fly bites another vertebrate host, the parasites travel with salivary secretions into the blood of a new definitive host.
- Parasites may live in the blood, lymph, spleen, central nervous system, and cerebrospinal fluid.
- When trypanosomes enter the central nervous system, they cause general apathy, mental dullness, and lack of coordination.

- 24 **Phylum Apicomplexa**
- Members of the phylum Apicomplexa (L. *apex*, point *com*, together, *plexus*, interweaving) are all parasites.

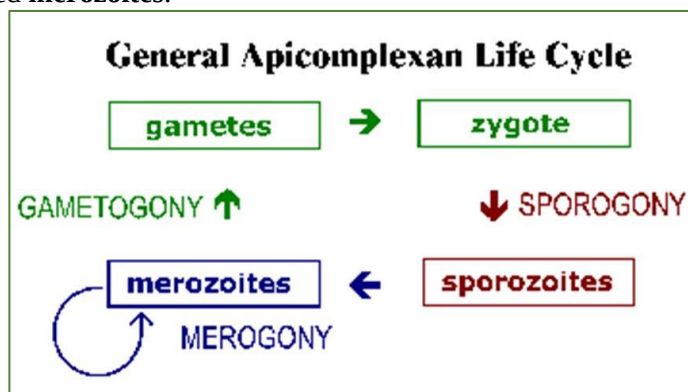
Characteristics of the phylum include:

1. Apical complex for penetrating host cells
2. Single type of nucleus
3. No cilia and flagella, except in certain reproductive stages
4. Life cycles that typically include asexual (schizogony, sporogony) and sexual (gametogony) phases

CLASS SPOROZOEIA

The most important species in the phylum Apicomplexa are members of the class Sporozoea (sporo-zoe).

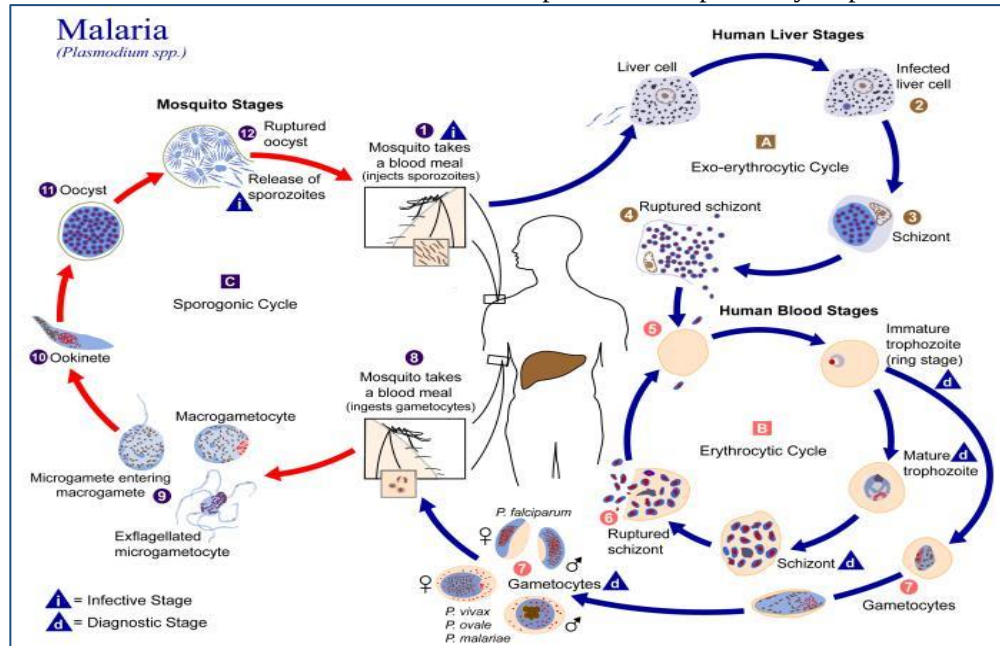
- The class name derives from most sporozoeans producing a resistant spore or oocyst following sexual reproduction.
- Some members of this class, including *Plasmodium* and *coccidians*, cause a variety of diseases in domestic animals and humans.
- Although the life cycles of sporozoeans vary considerably, certain generalizations are possible.
- Many are intracellular parasites, and their life cycles have three phases.
- **Schizogony is multiple** fission of an asexual stage in host cells to form many more (usually asexual) individuals, called **merozoites**.



- Merozoites leave the host cell and infect many other cells.
- Schizogony to produce merozoites is also called **merogony**.

	- Some of the merozoites undergo gametogony, which begins the sexual phase of the life cycle. - The parasite forms either microgametocytes or macrogametocytes. - Microgametocytes undergo multiple fission to produce biflagellate microgametes that emerge from the infected host cell. - The macrogametocyte develops directly into a single macrogamete. - A microgamete fertilizes a macrogamete to produce a zygote that becomes enclosed and is called an oocyst. - The zygote undergoes meiosis, and the resulting cells divide repeatedly by mitosis. - This process, called sporogony, produces many rodlike sporozoites in the oocyst. - Sporozoites infect the cells of a new host after the new host ingests and digests the oocyst, or sporozoites are otherwise introduced (e.g., by a mosquito bite). - One sporozoan genus, <i>Plasmodium</i>, causes malaria and has a long history. - Other members of the class Sporozoa also cause important diseases. - Coccidiosis is primarily a disease of poultry, sheep, cattle, and rabbits. - Two genera, <i>Isospora</i> and <i>Eimeria</i>, are particularly important parasites of poultry. - Yearly losses to the U.S. poultry industry from coccidiosis have approached \$35 million. - Another coccidian, <i>Cryptosporidium</i>, has become more well-known with the advent of AIDS since it causes chronic diarrhea in AIDS patients, is the only known protozoan to resist chlorination. - Toxoplasmosis is a disease of mammals, including humans, and birds. - Sexual reproduction of Toxoplasma occurs primarily in cats. - Infections occur when oocysts are ingested with food contaminated by cat feces, or when meat containing encysted merozoites is eaten raw or poorly cooked. - Most infections in humans are asymptomatic, and once infection occurs, an effective immunity develops. - However, if a woman is infected near the time of pregnancy, or during pregnancy, congenital toxoplasmosis may develop in a fetus. - Congenital toxoplasmosis is a major cause of stillbirths and spontaneous abortions. - Feruses that survive frequently show signs of mental retardation and epileptic seizures. - Congenital toxoplasmosis has no cure. - Toxoplasmosis also ranks high among the opportunistic diseases afflicting AIDS patients. - Steps to avoid infections by Toxoplasma include keeping stray and pet cats away from children's sandboxes; using sandbox covers; and awareness, on the part of couples considering having children, of the potential dangers of eating raw or very rare pork, lamb, and beef.
25	Life cycle of malarial parasite, the plasmodium - One sporozoan genus, <i>Plasmodium</i>, causes malaria and has a long history. - Accounts of the disease go back as far as 1550 B.C. - Malaria contributed significantly to the failure of the Crusades during the medieval era, and along with typhus, has devastated more armies than has actual combat. - Recently (since the early 1970s), malaria has resurged throughout the world. - Over 100 million humans are estimated to annually contract the disease. - The Plasmodium life cycle involves vertebrate and mosquito hosts. - Schizogony occurs first in liver cells and later in red blood cells, and gametogony also occurs in red blood cells. - A mosquito takes in gametocytes during a meal of blood, and the gametocytes subsequently fuse. - The zygote penetrates the gut of the mosquito and transforms into an oocyst. - Sporogony forms haploid sporozoites that may enter a new host when the mosquito bites the host. - The symptoms of malaria recur periodically and are called paroxysms. - Chills and fever correlate with the maturation of parasites, the rupture of red blood cells, and the release of toxic metabolites. Four species of Plasmodium are the most important human malarial species. <i>P. vivax</i> causes malaria in which the paroxysms recur every 48 hours. - This species occurs in temperate regions and has been nearly eradicated in many parts of the world. <i>P. falciparum</i> causes the most virulent form of malaria in humans. - Paroxysms are more irregular than in the other species. <i>P. falciparum</i> was once worldwide, but is now mainly tropical and subtropical in distribution. - It remains one of the greatest killers of humanity, especially in Africa. <i>P. malariae</i> is worldwide in distribution and causes malaria with paroxysms that recur every 72 hours.

4. *P. ovale* is the rarest of the four human malarial species and is primarily tropical in distribution.



26 Protozoa (Pseudopodia and Amoeboid Locomotion)

- In Amoeba, movement of the animal is made by the throwing of pseudopodium, called **amoeboid movement**.
- This is the most primitive kind of movement which is caused by contractility.
- In the direction of movement of Amoeba, a new pseudopodium is formed and the pseudopodium at the opposite side gradually disappears.
- Members of the subphylum sarcodina are the amoebae, when feeding and moving, they form temporary cell extensions called **pseudopodia** (Gr. *pseudes* means false and *podium* means little foot).
- Excepting a few Suctorians which are sessile in adult stage most protozoa possess definite locomotor organelles which are closely associated with the body surface.
- A pseudopodium may be defined as a temporary projection of a part of cytoplasm, mainly formed from the ectoplasm.
- These are characteristic organelles of Sarcodina, certain Sporozoa and many Mastigophora where the pellicle is ill defined.
- They act as locomotory and feeding organs.

According to form, structure and activity four different kinds of pseudopodia are recognized

These are:

- Lobopodium
- Filopodium
- Reticulopodium or Rhizopodium
- Axopodium or Actinopodium

(a) Lobopodium [Gk. lobes = lobe; podium = foot]:

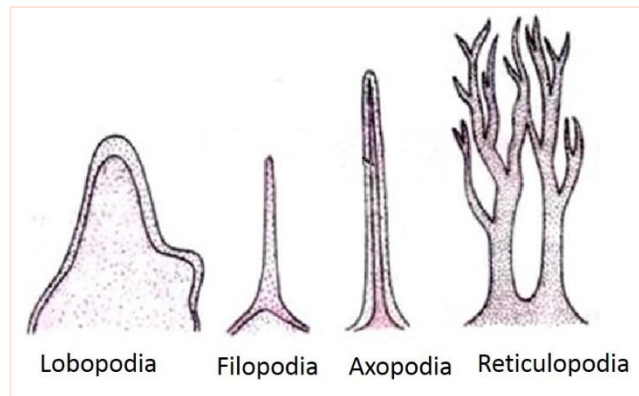
- It is a short, finger or tongue-like projection which is accompanied by a flow of endoplasm and ectoplasm.
- The pseudopodium is broad with rounded or blunt tips.

The ectoplasmic area is distinctly clear, called the hyaline cap.

- It is the characteristic of many amoebas such as *Amoeba*, *Chaos*, *Entamoeba*, *Arcella*, *Diffugia*.

(b) Filopodium [L. filo = a thread; podium = foot]:

- The filopodium is a slender, thread-like or filamentous projection.
- It is formed by the ectoplasm alone and without a hyaline cap.
- The filaments are narrow and may be branched but do not anastomose.
- Filopodium is the characteristic in Filosea (e.g., *Gromia*, *Euglypha* etc.).
- They provide a constant two way streaming that delivers food in a conveyor belt fashion.



(c) Reticulopodium or Rhizopodium [L. reticulos = a net, podium = foot]:

- Similar in structure to that of filopodium but the branches anastomose.
- The numerous branched and anastomosed pseudopodia form a dense network, help primarily in capturing the prey and the secondary function is locomotion.
- It is found in *Elphidium*.
- They are similar to filopodia, except that they branch and rejoin to form a net like series of cell extensions.

(d) Axopodium or Actinopodium [Gk. axo = an axle; podium = foot; aktis = ray]:

- It is a semi-permanent structure and is made up of an axial rod enveloped by cytoplasm.
- The axopodia are thin, filamentous and supported by a central axis of microtubules.
- The cytoplasm covering the central axis is adhesive and movable.
- Food caught on axopodia can be delivered to the central cytoplasm of the amoeba.
- Axopodia are found in *Actinophrys*, *Actinosphaerium*, etc.

Mechanism of Amoeboid Movement:

Formation of pseudopodia:

In amoeboid progression, pseudopodia are formed in two different ways:

- (a) Profluent
- (b) Eruptive

(a) Profluent type:

- In profluent type, the ectoderm bulges out as a blunt projection and endoplasm flows into this projection in an even manner.
- By profluent method a single pseudopodium (*Limax*) or many pseudopodia (*Lobose*) may be formed at a time.

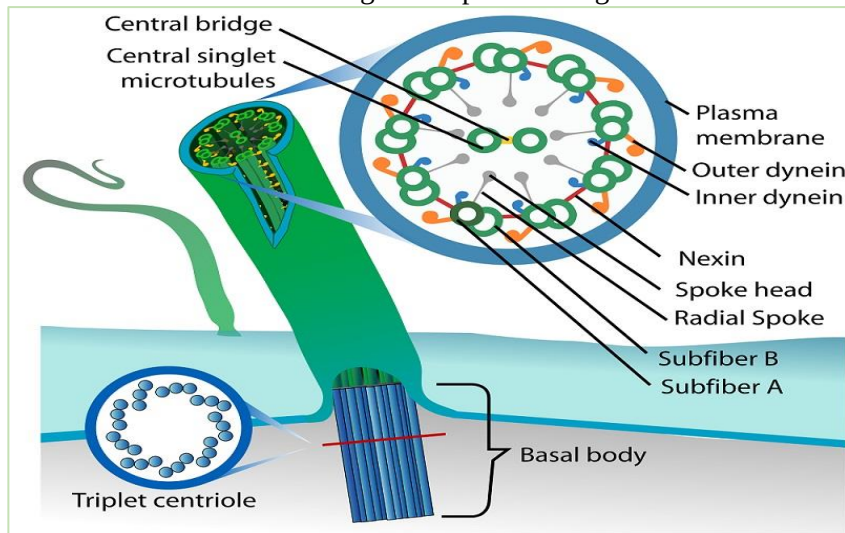
(b) Eruptive type:

- In eruptive type ectoplasm and endoplasm burst out in an eruptive manner by dissolving the cell surface.
- Eruptive type of pseudopodium is restricted to small forms of amoeba where the gelated ectoplasm layer is very thin.

27 Phylum Protozoa (Cilia and other pellicle structures)

- Cilia are generally similar to flagella, except that they are much shorter and more numerous.
- Cilia are widely distributed over the surface of the protozoan.
- Ciliary movements are coordinated so that ciliary waves pass over the surface of the ciliate.
- Many ciliates can reverse the direction of ciliary beating and the direction of cell movement.
- Cilia are tiny, hair-like fine projections covering the entire animal body.
- Size ranges measuring 10-12 micrometers in length and about 0.27 micrometers in diameter.
- They arise by penetrating the pellicle from basal bodies located within the ectoplasm of the cell.
- Each cilium is bounded by plasma membrane (PM).
- Cilium has a core axoneme consisting of 9 doublet microtubules with dynein arms around the periphery.
- Two singlet central microtubules surrounded by a sheath.
- Nexin and radial spokes provide elastic connections between microtubule of the doublets.
- A tubule of each doublet to the central sheath respectively.
- The function of cilia is food capture and locomotion.

- Basal bodies (kinetosomes) of adjacent cilia are inter connected with an elaborate network of fibres.
- That are believed to anchor the cilia and gave shape to the organism.



- Some ciliates have evolved specialized cilia.
- Cilia may cover the outer surface of protozoan.
- They may join to form **cirri** which are used in movement.
- Alternatively, cilia may be lost from large regions of the ciliate.
- They are about 10,000 to 14,000 arranged in regular longitudinal rows having more or less uniform length throughout.
- **Trichosysts** are pellicular structures primarily used for protection.
- They are rod-like or oval organelles oriented perpendicular to the plasma membrane.
- In Paramecium, they have a “golf tree” appearance.
- The pellicle can discharge trichosysts, which then remain connected to the body by a sticky thread.

28	Phylum Protozoa (Genetic control and reproduction Symbiotic ciliates) • Ciliates have two kinds of nuclei: • A large, polyploid macronucleus regulates daily metabolic activities. • One or more smaller micronuclei are the genetic reserve of the cell. • Ciliates may reproduce sexually (conjugation) or asexually (transverse binary fission and budding). • Budding occurs in suctorians and results in the formation of ciliated, free-swimming organisms that attach to the substrate and take the form of the adult. • Ciliates reproduce sexually by conjugation. • The partners involved are called conjugants. • Many species of ciliates have numerous mating types, not all of which are compatible. • Initial contact between individuals is apparently random and sticky secretions of the pellicle facilitate adhesion. • Ciliate plasma membrane then fuses and remain that way for several hours. • During conjugation (sexual reproduction), two ciliates come in contact with each other forming a cytoplasmic bridge between them. • This is followed by a process known as meiosis of the micronuclei of either cell to produce haploid micronuclei. • Some of the haploid nuclei undergo disintegration while the remaining ones divide into two through a process known as mitosis in both cells. • The macronucleus does not participate in the genetic exchange that follows. • Instead, the macronucleus breaks up during or after micronuclear events and reforms from micronuclei of the daughter ciliates. • After separation, the exconjugants undergo a series of nuclear divisions to restore the nuclear characteristics of the particular species, including the formation of macronucleus from one or more micronuclei. • • Most ciliates are free living; however, some are commensalistic or mutualistic and a few are parasitic. • Balantidium coli is an important parasitic ciliate that lives in the large intestine of humans, pigs and other mammals.
----	---

	- At times, it is a ciliary feeder; at other times, it produces proteolytic enzymes that digest host epithelium, causing a flask-shaped ulcer. - Its pathology resembles that of <i>Entamoeba histolytica</i>. <i>B. coli</i> is passed from one host to another in cysts that form as feces begin to dehydrate in the large intestine. - Fecal contamination of food or water is the most common form of transmission. - Its distribution is potentially worldwide, but it is most common in the Philippines. - Large numbers of different species of ciliates also inhabit the rumen of many ungulates (hoofed animals). - These ciliates contribute to the digestive process of their hosts.
29	Phylum protozoa (Further Phylogenetic Considerations) - Protozoa probably originated about 1.5 billion years ago. - Although known fossil species exceed 30,000, they are of little use in investigations of the origin and evolution of the various protozoan groups. - Only protozoa with hard parts (tests) have left much of a fossil record and only the foraminiferans and radiolarians have well-established fossil records in Precambrian rocks. - Recent evidence from the study of base sequences in ribosomal RNA indicates that each of the seven protozoan phyla probably had separate origins. - Each is sufficiently different from the others to warrant elevating all of these groups to phylum status. - Additional modifications to the present scheme of protozoan classification are continually being proposed as the results of new ultrastructural and molecular studies are published. - For example, in 1993, T. Cavalier-Smith proposed that the protozoa be elevated to kingdom status with 18 phyla. - Whether protozoologist will accept this new classification, however remains to be determined.
30	Origins of Multicellularity; Animal Origins - Multicellular life has been a part of the earth's history for approximately 550 million years. - Although this seems a very long time, it represents only 10% of the earth's geological history. - Multicellular life arose quickly in the 100 million years prior to the Precambrian/Cambrian boundary in which scientists view as an evolutionary explosion. - These evolutionary events resulted not only in the appearance of all of the animal phyla recognized today, but also 15 to 20 animal groups that are now extinct. - Since this evolutionary explosion, most of the history of multicellular life has been one of extinction. - The evolutionary events leading to multicellularity are shrouded in mystery. - Many zoologists believe that multicellularity could have arisen as dividing cells remained together in the fashion of many colonial protists. - Although variations of this hypothesis exist, they are all treated here as the colonial hypothesis. - A second proposed mechanism is called the syncytial hypothesis. - A syncytium is a large multinucleate cell. - The formation of plasma membranes in the cytoplasm of a syncytial protist could have produced a small, multicellular organism. - Both the colonial and syncytial hypotheses are supported by the colonial and syncytial organization that occurs in some protist phyla. - A fundamental question concerning animal origins is whether animals are; Monophyletic (derived from a single ancestor) Diphyletic (derived from two ancestors) Polyphyletic (derived from many ancestors). - The view that animals are polyphyletic is attractive to a growing number of zoologists. - The nearly simultaneous appearance of all animal phyla in fossils from the Precambrian/Cambrian boundary is difficult to explain if animals are monophyletic. - If animals are polyphyletic, more than one explanation of the origin of multicellularity could be possible and more than one body form could be ancestral. - Conversely, the impressive similarities in animal cellular organization support the view that all or most animals are derived from a single ancestor. For example - asters form during mitosis in most animals. - Cell junctions are similar in all animal cells. - Most animals produce flagellated sperm.

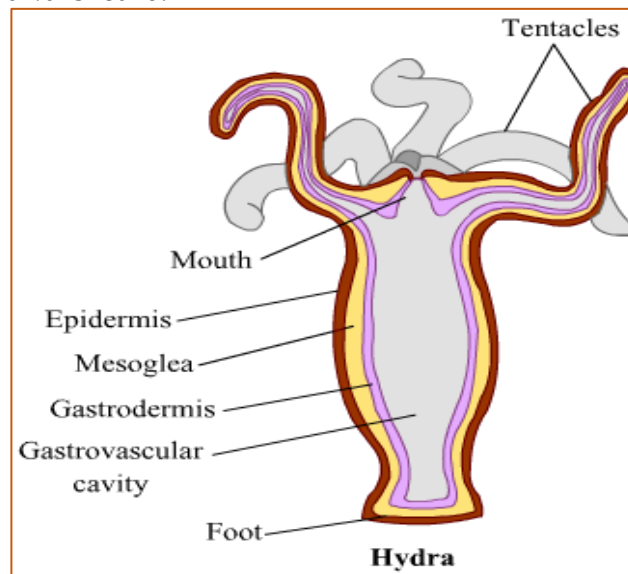
	• The proteins that accomplish movement are similar in most animal cells. • These common features are difficult to explain, assuming polyphyletic origins. • If you assume one or two ancestral lineages, then only one or two hypotheses regarding the origin of multicellularity can be correct
31	Phylum porifera (Cell types, body wall and skeletons) • The Porifera (L. <i>porus</i> means pore and <i>fera</i> means to bear), or sponges, are primarily marine animals consisting of loosely organized cells. • The approximately nine thousand species of sponges vary in size from less than a centimeter to a mass that would more than fill your arms. • Characteristics of the phylum porifera include: • Asymmetrical or radially symmetrical • Three cell types: pinacocytes, mesenchyme cells and choanocytes • Central cavity or a series of branching-chambers through which water circulates during filter feeding. • No tissues or organs • In spite of their relative simplicity, sponges are more than colonies of independent cells. • As in all animals, sponge cells are specialized for particular functions. • This organization is often referred to as division of labor. • Thin, flat cells, called pinacocytes, line the outer surface of a sponge. • Pinacocytes may be mildly contractile and their contraction may change the shape of some sponges. • In a number of sponges, some pinacocytes are specialized into tube like, contractile porocytes, which can regulate water circulation. • Openings through porocytes are pathways for water moving through the body wall. • Just below the pinacocyte layer of a sponge is a jelly like layer called the mesohyl (Gr. <i>meso</i> means middle and <i>hyl</i> means matter). • Amoeboid cells called mesenchyme cells move about in the mesohyl: • Specialized for reproduction • Secreting skeletal elements • Transporting and storing food • Forming contractile rings around openings in the sponge wall. • Below the mesohyl and lining the inner chamber (s) are choanocytes, or collar cells. • Choanocytes (Gr. <i>choane</i> means funnel and <i>cyte</i> means cell) are flagellated cells that have collar like ring of microvilli surrounding a flagellum. • Microfilaments connect the microvilli, forming a net like mesh within the collar. • The flagellum crates water currents through the sponge, and the collar filters microscopic food particles from the water. • The presence of choanocytes in sponges suggests an evolutionary link between the sponges and a group of protists called choanoflagellates. • Sponges are supported by a skeleton that may consists of microscopic needle like spikes called spicules. • Spicules are formed by amoeboid cells, are made of calcium carbonate or silica, and may take on a variety of shapes. • Alternatively, the skeleton may be made of spongin (a fibrous protein made of collagen), which is dried, beaten, and washed until all cells are removed to produce a commercial sponge. • The nature of the skeleton is an important characteristic in sponge taxonomy.
32	Phylum Porifera (Classification up to class Level) Phylum Porifera The animal phylum whose members are sessile and either asymmetrical or radially symmetrical. • Body organized around a system of water canals and chambers. • Cells not organized into tissues or organs. • Approximately 9,000 species. Class Calcarea • Spicules composed of calcium carbonate. • Spicules are needle shaped or have three or four rays; ascon, leucon, or sycon body forms. • All marine. • Calcareous sponges. • <i>Grantia (Scypha)</i>, <i>Leucosolenia</i>.

	Class Hexactinellida • Spicules composed of silica and usually six rayed. • Spicules often fused into an intricate lattice. • Cup or vase shaped. • Sycon or leucon body form. • Found at 450 to 900 m depths in tropical West Indies and eastern Pacific. • Glass sponges. • <i>Euplectella</i> (<i>Venus flower-basket</i>). Class Demospongiae • Brilliantly colored sponges with needle-shaped or four-rayed siliceous spicules or spongin or both. • Leucon body form. • Up to 1 m in height and diameter. • Includes one family of freshwater sponges, Spongillidae, and the bath sponges. • <i>Cliona</i>, <i>Spongilla</i>.
33	Phylum porifera (Water currents and body forms: Ascon) • The life of a sponge depends on the water currents that choanocytes creates. • Water currents bring food and oxygen to a sponge and carry away metabolic and digestive wastes. • Methods of food filtration and circulation reflect the body forms in the phylum. • Zoologist have described three sponge body forms: 1. Asconoid 2. Syconoid 3. Leuconoid 1. The simplest and least common sponge body form is the ascon. • Simplest type of canal system found in asconoid sponges. Ascon sponges are vase-like. Ostia are the outer openings of porocytes and lead directly to a chamber called the spongocoel. • Spongocoel is single, large, spacious central cavity in sponge's body. • Choanocytes line the spongocoel, and their flagellar movements draw water into the spongocoel through the ostia. • Water exists the sponge through the osculum, which is a single, large opening at the top of the sponge. • Surrounding sea water enters canal system through ostia. • Flow of water is maintained by beating of flagella of collar cells. • Rate of water flow is slow because large spongocoel contains much water which can't be pushed by single osculum. • Ingressing Water Through Ostia • Spongocoel Through Osculum • To Outside
34	Phylum porifera (Sycon body form) • The life of a sponge depends on the water currents that choanocytes creates. • Water currents bring food and oxygen to a sponge and carry away metabolic and digestive wastes. • Methods of food filtration and circulation reflect the body forms in the phylum. • Zoologist have described three sponge body forms: 1. Asconoid 2. Syconoid 3. Leuconoid • In the sycon body form, the sponge wall appears folded. • Water enters a sycon sponge through openings called dermal pores. • Dermal pores are the openings of invaginations of the body wall, called incurrent canals. • Pores in the body wall connect incurrent canals to radial canals, and the radial canals lead to the spongocoel. • Choanocytes line radial canals (rather than the spongocoel).

	- The beating of choanocytes flagella moves water from the ostia, through incurrent and radial canals, to the spongocoel, and out of the osculum. Prosopyles are simple intercellular spaces. - Radial canal are flagellated chambers lined by collar cells. - Open into spongocoel by apopyles (internal ostia). - Spongocoel is a narrow, non-flagellated cavity lined by pinacocytes.
35	Phylum porifera (Leucon body form) - The life of a sponge depends on the water currents that choanocytes creates. - Water currents bring food and oxygen to a sponge and carry away metabolic and digestive wastes. - Methods of food filtration and circulation reflect the body forms in the phylum. - Zoologist have described three sponge body forms: 1. Asconoid 2. Syconoid 3. Leuconoid Leucon sponges have an extensively branched canal system. - Water enters the sponge through ostia and moves through branched incurrents canals, which lead to choanocyte-lined chambers. - Canals leading away from the chambers are called excurrent canals. - Proliferation of chambers and canals has resulted in the absence of a spongocoel, and often, multiple exit points (oscula) for water leaving the sponge. - In complex sponges, an increased surface area for choanocytes in large volumes of water being moved through the sponge and greater filtering capabilities. - Although the evolutionary pathways in the phylum are complex and incompletely described. - Most pathways have resulted in the leucon body form. - In many calcareous sponges leucon type is developed directly without passing through ascon and sycon types in their embryogeny. - In Demospongiae leuconoid condition is derived from a larval stage known as rhagon. - Spongocoel of rhagon is lined by flagellated chambers opening via apopyles.
36	Phylum porifera (Maintenance Functions) - Sponges feed on particles that range in size from 0.1 to 50µm. - Their food consists of bacteria, microscopic algae, protists and other suspended organic matter. - The prey is slowly drawn into the sponge and consumed. - Large population of sponges play an important role in reducing the turbidity of coastal waters. - A single leucon sponge, 1 cm in diameter and 10 cm high, can filter in excess of 20 liters of water every day. - Recent investigations have discovered that a few sponges are carnivorous. - These deep-water sponges (Asbestopluma) can capture small crustaceans using spicule-covered filaments. - Choanocytes filter small, suspended particles. - Water passes through their collar near the base of the cell and then moves into a sponge chamber at the open end of the collar. - Suspended food is trapped on the collar and moved along microvilli to the base of the collar, where it is incorporated into a food vacuole. - Digestion begins in the food vacuole by lysosomal enzymes and pH changes. - Partially digested food is passed to amoeboid cells, which distribute it to other cells. - Filtration is not the only way that sponges feed. - Pinacocytes lining in current canals may phagocytize larger food particles (up to 50 µm). - Sponges also may absorb by active transport nutrients dissolved in sea water. - Because of extensive canal systems and the circulation of large volumes of water through sponges, all sponge cells are in close contact with water. - Thus, nitrogenous wastes (principally ammonia) removal and gas exchange occur by diffusion. - Sponges do not have nerve cells to coordinate body functions. - Most reactions result from individual cells responding to a stimulus. - For example, water circulation through some sponges is at a minimum at sunrise and at a maximum just before sunset because light inhibits the constriction of porocytes and other cells surrounding ostia, keeping incurrent canals open.

	• Other reactions, however, suggest some communication among cells. • For example, the rate of water circulation through a sponge can drop suddenly without any apparent external cause. • Amoeboid cells transmitting chemical messages and ion movement over cell surfaces and possible control mechanisms. • This reaction can be due only choanocytes ceasing activities more or less simultaneously, and this implies some form of internal communication. • The nature of this communication is unknown.
37	Phylum porifera (Reproduction) • Most sponges are monoecious (both sexes occur in the same individual) but do not usually self-fertilize because individual sponges produce eggs and sperm at different times. • Certain choanocytes lose their collars and flagella and undergo meiosis to form flagellated sperm. • Other choanocytes (and amoeboid cells in some sponges) probably undergo meiosis to form eggs. • Eggs are retained in the mesohyl of the parent. • Sperm cells exit one sponge through the osculum and enter another sponge with the incurrent water. • Sperms are trapped by choanocytes and incorporated into a vacuole. • The choanocytes lose their collar and flagellum, become amoeboid, and transport sperm to the eggs. • In some sponges, early development occurs in the mesohyl. The diagram illustrates the reproductive cycle of sponges. It starts with a parent sponge. For asexual reproduction, a bud forms and grows into a new sponge. For sexual reproduction, the parent sponge releases sperm cells (modified collar cells) and egg cells. These cells undergo fertilization to form an embryo, which develops into a planktonic amphiblastula larva. The larva settles and attaches to a bottom or other surface, eventually developing into a new sponge. • Cleavage of a zygote results in the formation of a flagellated larval stage. • A larva is an immature stage that may undergo a dramatic change in structure before attaining the adult body form. • The larva breaks free, and water currents carry the larva out of the parent sponge. • After no more than two days of a free-swimming existence, the larva settles to the substrate and begins to develop into the adult body form. • Asexual reproduction of fresh water and some marine sponges involves the formation of resistant capsules, called gemmules, containing masses of amoeboid cells. • When the parent sponge dies in the winter, it releases gemmules, which can survive both freezing and drying. • When favorable conditions return in the spring, amoeboid cells stream out of a tiny opening, called the micropyl, and organize into a sponge. • Some sponges possess remarkable powers of regeneration. • Portions of a sponge that are cut or broken from one individual regenerate new individuals.
38	Phylum Cnidaria (Coelenterata) • Members of the phylum Cnidarian (Gr. <i>knide</i> means nettle) possess radial or biradial symmetry. • Biradial symmetry is a modification of radial symmetry in which a single plane, passing through a central axis, divides the animal into mirror images. • It results from the presence of a single or paired structure in a basically radial animal and differ from bilateral symmetry in that dorsal and ventral surfaces are not differentiated. • Radially symmetrical animals have no anterior or posterior ends.

- Thus, terms of direction are based on the position of the mouth opening.
- The end of the animal that contains the mouth is the **oral end**, and the opposite end is the **aboral end**.
- Radial symmetry is advantageous for sedentary animals
- Because sensory receptors are evenly distributed around the body.
- The cnidarians include over nine thousand species, are mostly marine, and are important in coral reef ecosystem.
- These organisms can respond to stimuli from all directions.
- Characteristics of phylum cnidaria include:
 1. Radial or biradial symmetry
 2. Diploblastic, tissue-level organization
 3. Gastrovascular cavity
 4. Gelatinous mesoglea between the epidermal and gastrodermal tissue layers.
 5. Nervous system in the form of a nerve net.
 6. Specialized cells called cnidocytes, used in defense, feeding, and attachment.
 7. Endocrine have hormones, secreted by nervous system.
 8. No circulatory system, use cellular diffusion and mesoglea.
 9. Ciliated planula larva is found.



39 Phylum Cnidaria (The Body Wall and Nematocysts)

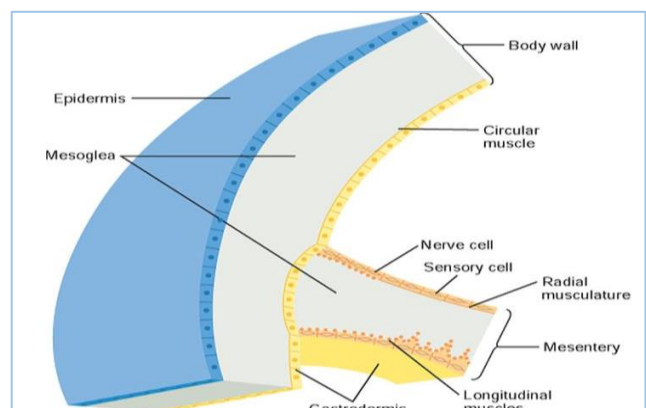
- Cnidarians possess diploblastic, tissue-level organization.
- Cells organize into tissues that carry out specific functions.

All cells are derived from two embryological layers.

- The ectoderm of the embryo gives rise to an outer layer of the body wall, called the **epidermis**.
- The inner layer of the body wall, called the **gastrodermis**.
- **Gastrodermis** is derived from **endoderm**.
- Cells of epidermis and gastrodermis differentiate into a number of cell types for:

protection
food gathering
coordination
movement
digestion
absorption

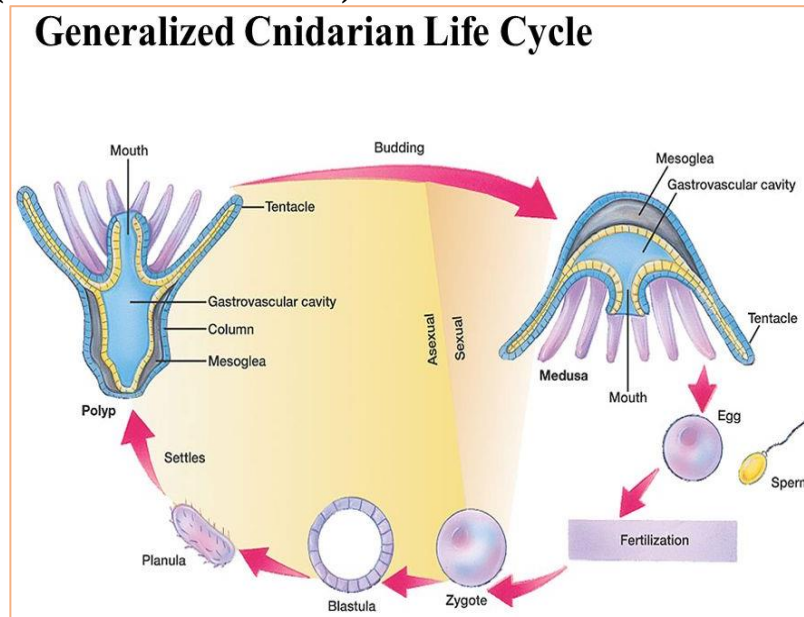
- Between the epidermis and gastrodermis is a jellylike layer called **mesoglea**.
- Cells are present in the middle layer of some cnidarians, but they have their origin in either the epidermis or the gastrodermis.
- One kind of cell is characteristics of the phylum.



- Epidermal and/or gastrodermal cells called **cnidocytes** produce structures called **nematocysts**, which are used for attachment, defense and feeding.
- A **nematocyst** is a fluid-filled, intracellular capsule enclosing a coiled hollow tube.
- A lid like operculum caps the capsule at one end.
- The cnidocyte has a modified cilium, called a **cnidocil**.
- Stimulation of the cnidocil forces open the operculum, discharging the coiled tube.
- Zoologists have described nearly 30 kinds of nematocysts.
- Nematocysts used in food gathering and defense may discharge a long tube armed with spines that penetrates the prey.
- The spines have hollow tips that deliver paralyzing toxins.
- Other nematocysts contain unarmed tubes that wrap around prey or a substrate.
- Still other nematocysts have sticky secretions that help the animal anchor itself.
- Six or more kinds of nematocysts may be present in one individual.

40

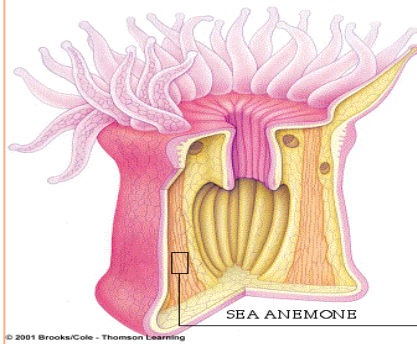
Phylum Cnidaria (Alternation of Generations)



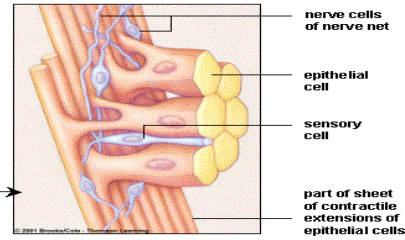
- Most cnidarians possess two body form in their life histories.
- The **polyp** is usually asexual and sessile.
- It attaches to a substrate at the aboral end.
- It has a cylindrical body, called the **column**.
- It has a mouth surrounded by food-gathering tentacles.
- The **medusa** is dioecious and free swimming.
- It is shaped like an inverted bowl, and tentacles dangle from its margins.
- The mouth opening is centrally located facing downward.
- The medusa swims by gentle pulsations of body wall.
- The mesoglea is more abundant in a medusa than in a polyp, giving the former a jellylike consistency.
- When a cnidarians life cycle involves both polyp and medusa stages, the phrase “alternation of generation” is often applied.
- Dioecious medusae produce gametes that may be shed into the water for fertilization.
- Early in development, a ciliated planula larva form.
- After a brief free-swimming existence, the planula settles to a substrate and forms a polyp.
- Budding of the polyp produces additional polyps and medusa buds.
- Medusae break free of the polyp and swim away.
- The polyp or medusa stage of many species is either lost or reduced and asexual or sexual stages have been incorporated into one body form.
- A blastula forms early in the development, and migration of surface cells to the interior fills the embryo with cells that will eventually form the gastrodermis.
- Most cnidarians are dioecious.
- Sperm and eggs may be released into the gastrovascular cavity or to the outside of the body.
- In some instances, eggs are retained in the parent until after fertilization.

	• The embryo elongates to form a ciliated, free-swimming larva, called planula. • The planula attaches to a substrate, interior cells split to form the gastrovascular cavity. • A young polyp develops. • Medusae nearly always form by budding from the body wall of a polyps by budding. • Buds may detach from the polyp, or they may remain attach to the parent to contribute to a colony of individuals
41	Phylum Cnidaria (Maintenance Functions) • The gastrodermis of all cnidarians lines a blind-ending gastrovascular cavity. • This cavity functions in digestion, exchange of respiratory gases, metabolic wastes, and the discharge of gametes. • Food, digestive wastes, and reproductive stages enter and leave the gastrovascular cavity through the mouth. • The food of most cnidarians consists of very small crustaceans, although some cnidarians feed on small fish. • Nematocysts entangle and paralyze prey, and contractile cells in the tentacles cause the tentacles to shorten, which draws food toward the mouth. • As food enters the gastrovascular cavity, gastrodermal gland cells secrete lubricating mucus and enzymes, which reduce food to a soupy broth. • Certain gastrodermal cells, called nutritive-muscular cells, phagocytize partially digested food. • Then, incorporate it into food vacuoles, where digestion is completed. • During peristalsis, ring like contractions move along the body wall. • Nutritive-muscular cells also have circularly oriented contractile fibers that help move materials into or out of the gastrovascular cavity by peristaltic contractions. • Pushing contents of the gastrovascular cavity ahead of them, expelling undigested material through the mouth. • Cnidarians derive most of their support from the buoyancy of water around them. • In addition, a hydrostatic skeleton aid in support and movement. • A hydrostatic skeleton is water or body fluids confined in a cavity of the body and against which contractile elements of the body wall act. • In the Cnidaria, the water-filled gastrovascular cavity act as a hydrostatic skeleton. • Certain cells of the body wall, called epitheliomuscular cells, are contractile and aid in movement. • When a polyp closes its mouth (to prevent water from escaping) and contracts longitudinal epitheliomuscular cells on one side of the body, the polyp bends towards that side. • If these cells contract while the mouth is open, water escapes from the gastrovascular cavity. • The polyp collapses. • Contraction of circular epitheliomuscular cells causes constriction of a part of the body. • If the mouth is closed, water in the gastrovascular cavity is compressed, and the polyp elongates. • Polyps use a variety of forms of locomotion. • They may move by somersaulting from base to tentacles and from tentacles to base again. • May move in an inchworm fashion, using their base and tentacles as point of attachment. • Polyps may also glide very slowly along a substrate while attached at their base or walk on their tentacles. • Medusae move by swimming and floating. • Water currents and wind are responsible for most horizontal movements. • Vertical movements are the result of swimming. • Contractions of circular and radial epitheliomuscular cells cause rhythmic pulsations of the bell. • It drives water from beneath the bell, propelling the medusae through the water. • Cnidarian nerve cells have been of interest to zoologists for many years because they may be the most primitive nervous elements in the animal kingdom. • By studying these cells, zoologist may gain insight into the evolution of animal nervous system. • Nerve cells are located below the epidermis, near the mesoglea, and interconnect to form a two-dimensional nerve net.

Nerve Net

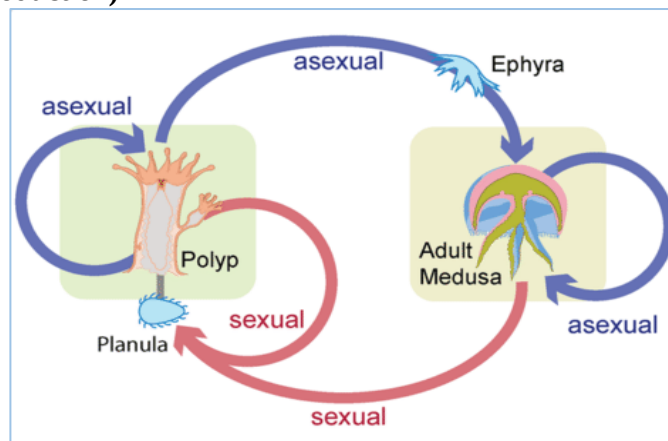


- Diffuse mesh of nerve cells that take part in simple reflex pathways
- Nerve cells interact with sensory and contractile cells



- This net conducts nerve impulses around the body in response to a localized stimulus.
- The extent to which a nerve impulse spreads over the body depends on stimulus strength.
- For example, a weak stimulus applied to a polyp's tentacle may cause the tentacle to be retracted.
- A strong stimulus at the same point may cause the entire polyp to withdraw.
- Sensory structures of cnidarians are distributed throughout the body and include receptors for perceiving touch and certain chemicals.
- More specialized receptors are located at specific sites on a polyp or medusa.
- Because cnidarians have large surface area-to volume ratios, all cells are a short distance from the body surface, and oxygen, carbon dioxide, and nitrogenous wastes exchange by diffusion.

42 Phylum Cnidaria (Reproduction)



- One of the most amazing adaptations is the ability of some cnidarians to regenerate lost parts or even a complete body
- Asexual reproduction is common with new individuals being produced by **budding**
- Sea anemones engage in a form of asexual reproduction called **pedal laceration**
- Cnidarians are dioecious
- Fertilization is external, with the zygote becoming an elongated, ciliated, radially symmetrical larva - **planula larva**
- In general, polyps primarily reproduce asexually by budding, however, some produce gametes (eggs and sperm) and reproduce sexually.
- Medusae usually reproduce sexually using eggs and sperm.
- Depending on the species, cnidarians can be **monoecious** (also called hermaphroditic), with individuals capable of producing both eggs and sperm.
- They can be **dioecious**, with individuals of separate sexes for gamete production.
- Typically, the hermaphroditic species cannot self-fertilize, so sexual reproduction requires at least two individuals.
- Jellyfish of the class Scyphozoa are dioecious.
- Cnidarians switch from the polyp to the medusa stage by a form of asexual reproduction in which the polyp develops a stack of medusoid structures that can then bud off to become independent medusae.
- This process is called **strobilation**

	- The polyp stage can be regenerated when medusae reproduce sexually to form a ciliated larva called a planula. - The planula can then develop into a polyp and continue the cycle. There are many variations on this general life cycle, depending on the species. - For example, exclusively polyp species in the class Anthozoa will obviously exhibit a truncated version of the life cycle omitting the medusa stages. - There are also some species that are exclusively medusae and do not form polyps. - Another variable in the sexual reproduction of cnidarians is whether fertilization takes place internally or externally. - In some species, sperm released by the males must be ingested by the females in order to reach eggs within the female body for fertilization. - In other species, both sperm and eggs are released into the aquatic environment by the organisms, and fertilization takes place externally.
43	Phylum Cnidaria (Classification up to class: Class Hydrozoa) - Cnidarians include Hydras, jellyfish, sea anemones and corals. - Radial or biradial symmetry - Diploblastic organization - Two basic forms: Polyp: Cylindrical form which attach bases to substratum Medusa: Flattened, mouth down version of the polyp, moves freely - A gastrovascular cavity - Cnidocytes - Over 9,000 species 3 Major classes Class Hydrozoa: Hydras Class Scyphozoa: Jellyfish Class Anthozoa: Anemones and corals Class Hydrozoa - Hydrozoans are small, relatively common cnidarians. - The vast majority are marine, but this is the one cnidarian class with freshwater representatives. - Most hydrozoans have life cycles that display alternation of generations; however, in some, the medusa stage is lost, while in others, the polyp stage is very small. - Three features distinguish hydrozoans from other cnidarians: (1) nematocysts are only in the epidermis (2) gametes are epidermal and released to the outside of the body rather than into the gastrovascular cavity (3) the mesoglea never contains amoeboid mesenchyme cells - Most hydrozoans have colonial polyps in which individuals may be specialized for feeding, producing medusae by budding, or defending the colony. - In Obelia, a common marine cnidarian, the planula develops into a feeding polyp, called a Gastrozoid. - The gastrozoid has tentacles, feeds on microscopic organisms in the water, and secretes a skeleton of protein and chitin, called the perisarc, around itself. - Growth of an <i>Obelia</i> colony results from budding of the original gastrozoid. - Rootlike processes grow into and horizontally along the substrate. - They anchor the colony and give rise to branch colonies. - The entire colony has a continuous gastrovascular cavity, body wall, and perisarc, and is a few centimeters high. - Gastrozooids are the most common type of polyp in the colony; however, as an <i>Obelia</i> colony grows, <i>gonozooids</i> are produced. - A gonozooid is a reproductive polyp that produces medusae by budding. <i>Obelia</i> 's small medusae form on a stalklike structure of the gonozooid. - When medusae mature, they break free of the stalk and swim out an opening at the end of the gonozooid. - Medusae reproduce sexually to give rise to more colonies of polyps. Gonionemus is a hydrozoan in which the medusa stage predominates. - It lives in shallow marine waters, where it often clings to seaweeds by adhesive pads on its tentacles. - The biology of <i>Gonionemus</i> is typical of most hydrozoan medusae.

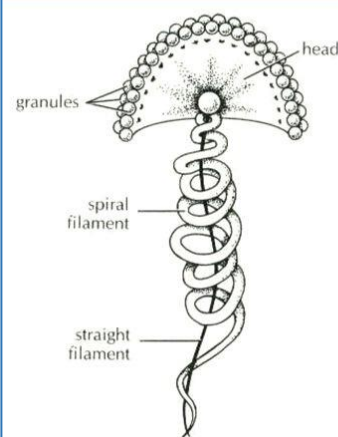
	• The margin of the <i>Gonionemus</i> medusa projects inward to form a shelflike lip, called the velum. • velum is present on most hydrozoan medusae but is absent in all other cnidarian classes. • The velum concentrates water expelled from beneath the medusa to a smaller outlet, creating a jet-propulsion system. • The mouth is at the end of a tubelike manubrium that hangs from the medusa's oral surface. • The gastrovascular cavity leads from the inside of the manubrium into four radial canals that extend to the margin of the medusa. • An encircling ring canal connects the radial canals at the margin of the medusa. • In addition to a nerve net, <i>Gonionemus</i> has a concentration of nerve cells, called a nerve ring, that encircles the margin of the medusa. • The nerve ring coordinates swimming movements. • Embedded in the mesoglea around the margin of the medusa are sensory structures called statocysts. • A statocyst consists of a small sac surrounding a calcium carbonate concretion called a statolith. • When <i>Gonionemus</i> tilts, the statolith moves in response to the pull of gravity. • This initiates nerve impulses that may change the animal's swimming behavior. • Gonads of <i>Gonionemus</i> medusae hang from the oral surface, below the radial canals. • <i>Gonionemus</i> is dioecious and sheds gametes directly into seawater. • A planula larva develops and attaches to the substrate, eventually forming a polyp (about 5 mm tall). • The polyp reproduces by budding to make more polyps and medusae. • Hydra is a common freshwater hydrozoan that hangs from the underside of floating plants in clean streams and ponds. • <i>Hydra</i> lacks a medusa stage and reproduces both asexually by budding from the side of the polyp and sexually. • Hydras are somewhat unusual hydrozoans because sexual reproduction occurs in the polyp stage. • Testes are conical elevations of the body surface that form from the mitosis of certain epidermal cells, called interstitial cells. • Sperm form by meiosis in the testes. • Mature sperm exit the testes through temporary openings. • Ovaries also form from interstitial cells. • One large egg forms per ovary. • During egg formation, yolk is incorporated into the egg cell from gastrodermal cells. • As ovarian cells disintegrate, a thin stalk of tissue attaches the egg to the body wall. • After fertilization and early development, epithelial cells lay down a resistant chitinous shell. • The embryo drops from the parent, overwinters, hatches in the spring, and develops into an adult. • Large oceanic hydrozoans belong to the order Siphonophora. • These colonies are associations of numerous polypoid and medusoid individuals. • Some polyps, called dactylozooids, possess a single, long (up to 9 m) tentacle armed with cnidocytes for capturing prey. • Other polyps are specialized for digesting prey. • Various medusoid individuals form swimming bells, sac floats, oil floats, leaflike defensive structures, and gonads. • <i>Physalia physalis</i>, commonly called the Portuguese man-of-war, is a large, colonial siphonophore. • It lacks swimming capabilities and moves at the mercy of wind and waves. • Its cnidocyte-laden dactylozooids are lethal to small vertebrates and dangerous to humans.
44	Phylum Cnidaria (Class Scyphozoa) • Members of the class Scyphozoa are all marine and are “true jellyfish” because the dominant stage in their life history is the medusa. • Unlike hydrozoan medusae, scyphozoan medusae lack a velum, the mesoglea contains amoeboid mesenchyme cells, cnidocytes occur in the gastrodermis as well as the epidermis, and gametes are gastrodermal in origin. • Many scyphozoans are harmless to humans; others can deliver unpleasant and even dangerous stings. • For example, <i>Mastigias quinquecirrha</i>, the so-called stinging nettle, is a common Atlantic scyphozoan whose populations increase in late summer and become hazardous to swimmers. • A rule of thumb for swimmers is to avoid helmet-shaped jellyfish with long tentacles and fleshy lobes hanging from the oral surface. • <i>Aurelia</i> is a common scyphozoan in both Pacific and Atlantic coastal waters of North America. • The margin of its medusa has a fringe of short tentacles and is divided by notches.

	• The mouth of <i>Aurelia</i> leads to a stomach with four gastric pouches, which contain cnidocyte-laden gastric filaments. • Radial canals lead from gastric pouches to the margin of the bell. • In <i>Aurelia</i>, but not all scyphozoans, the canal system is extensively branched and leads to a ring canal around the margin of the medusa. • Gastrodermal cells of all scyphozoans possess cilia to continuously circulate seawater and partially digested food. • <i>Aurelia</i> is a plankton feeder. • At rest, it sinks slowly in the water and traps microscopic animals in mucus on its epidermal surfaces. • Cilia carry this food to the margin of the medusa. • Four fleshy lobes, called oral lobes, hang from the manubrium and scrape food from the margin of the medusa. • Cilia on the oral lobes carry food to the mouth. • In addition to sensory receptors on the epidermis, <i>Aurelia</i> has eight specialized structures, called rhopalia, in the notches at the margin of the medusa. • Each rhopalium consists of sensory structures surrounded by rhopalial lappets. • Two sensory pits (presumed to be olfactory) are associated with sensory lappets. • A statocyst and photoreceptors, called ocelli, are associated with rhopalial. • <i>Aurelia</i> displays a distinct negative phototaxis, coming to the surface at twilight and descending to greater depths during bright daylight. • Scyphozoans are dioecious. • <i>Aurelia</i> 's eight gonads are in gastric pouches, two per pouch. • Gametes are released into the gastric pouches. • Sperm swim through the mouth to the outside of the medusa. • In some scyphozoans, eggs are fertilized in the female 's gastric pouches, and early development occurs there. • In <i>Aurelia</i>, eggs lodge in the oral lobes, where fertilization and development to the planula stage occur. • The planula develops into a polyp called a scyphistoma. • The scyphistoma lives a year or more, during which time budding produces miniature medusae, called ephyrae. • Repeated budding of the scyphistoma results in ephyrae being stacked on the polyp—as you might pile saucers on top of one another. • After ephyrae are released, they gradually attain the adult form. • The class Cubozoa was formerly classified as an order in the Scyphozoa. • The medusa is cuboidal, and tentacles hang from each of its corners. • Polyps are very small and, in some species, are unknown. • Cubozoans are active swimmers and feeders in warm tropical waters.
45	Phylum Cnidaria (Class Anthozoa) • Members of the class Anthozoa are colonial or solitary, and lack medusae. • They include anemones and stony and soft corals. • Anthozoans are all marine and are found at all depths. • Anthozoan polyps differ from hydrozoan polyps in three respects: (1) the mouth of an anthozoan leads to a pharynx, which is an invagination of the body wall that leads into the gastrovascular cavity. (2) mesenteries (membranes) that bear cnidocytes and gonads on their free edges divide the gastrovascular cavity into sections. (3) the mesoglea contains amoeboid mesenchyme cells. • Externally, anthozoans appear to show perfect radial symmetry. • Internally, the mesenteries and other structures convey biradial symmetry to members of this class. • Sea anemones are solitary, frequently large, and colorful. • Some attach to solid substrates, some burrow in soft substrates, and some live in symbiotic relationships. • The polyp attaches to its substrate by a pedal disk. • An oral disk contains the mouth and hollow, oral tentacles. • At one or both ends of the slitlike mouth is a siphonoglyph, which is a ciliated tract that moves water into the gastrovascular cavity to maintain the hydrostatic skeleton. • Mesenteries are arranged in pairs.

	• Some attach at the body wall at their outer margin and to the pharynx along their inner margin. • Other mesenteries attach to the body wall but are free along their entire inner margin. • Openings in mesenteries near the oral disk permit water to circulate between compartments the mesenteries set off. • The free lower edges of the mesenteries form a trilobed mesenterial filament. • Mesenterial filaments bear cnidocytes, cilia that aid in water circulation, gland cells that secrete digestive enzymes, and cells that absorb products of digestion. • Threadlike acontia at the ends of mesenterial filaments bear cnidocytes. • Acontia subdue live prey in the gastrovascular cavity and can be extruded through small openings in the body wall or through the mouth when an anemone is threatened. • Muscle fibers are largely gastrodermal. • Longitudinal muscle bands are restricted to the mesenteries. • Circular muscles are in the gastrodermis of the column. • When threatened, anemones contract their longitudinal fibers, allowing water to escape from the gastrovascular cavity. • This action causes the oral end of the column to fold over the oral disk, and the anemone appears to collapse. • Reestablishment of the hydrostatic skeleton depends on gradual uptake of water into the gastrovascular cavity via the siphonoglyphs. • Anemones have limited locomotion. • They glide on their pedal disks, crawl on their sides, and walk on their tentacles. • When disturbed, some “swim” by thrashing their bodies or tentacles. • Some anemones float using a gas bubble held within folds of the pedal disk. • Anemones feed on invertebrates and fishes. • Tentacles capture prey and draw it toward the mouth. • Radial muscle fibers in the mesenteries open the mouth to receive the food. • Anemones show both sexual and asexual reproduction. • In asexual reproduction, a piece of pedal disk may break away from the polyp and grow into a new individual in a process called pedal laceration. • Alternatively, longitudinal or transverse fission may divide one individual into two, with missing parts being regenerated. • Unlike other cnidarians, anemones may be either monoecious or dioecious. • In monoecious species, male gametes mature earlier than female gametes so that self-fertilization does not occur. • This is called protandry (Gr. <i>protos</i>, first <i>andros</i>, male). • Gonads occur in longitudinal bands behind mesenterial filaments. • Fertilization may be external or within the gastrovascular cavity. • Cleavage results in the formation of a planula, which develops into a ciliated larva that settles to the substrate, attaches, and eventually forms the adult. • Other anthozoans are corals. Stony corals form coral reefs and, except for lacking siphonoglyphs, are similar to the anemones. • Their common name derives from a cuplike calcium carbonate exoskeleton that epithelial cells secrete around the base and the lower portion of the column. • When threatened, polyps retract into their protective exoskeletons. • Sexual reproduction is similar to that of anemones, and asexual budding produces other members of the colony. • The colorful octacorallian corals are common in warm waters. • They have eight pinnate (featherlike) tentacles, eight mesenteries, and one siphonoglyph. • The body walls of members of a colony are connected, and mesenchyme cells secrete an internal skeleton of protein or calcium carbonate. • Sea fans, sea pens, sea whips, red corals, and organ-pipe corals are members of this group
46	Phylum Ctenophora • Animals in the phylum Ctenophora (Gr. <i>kteno</i> means comb and <i>phoros</i> means to bear) are called sea walnuts or comb jellies. • The approximately 90 described species are all marine. • Most ctenophorans have a spherical form, although several groups are flattened and/ or elongate. Characteristics of the phylum ctenophora include: • Diploblastic, tissue level organization

- Biradial symmetry
 - Gelatinous mesoglea between the epidermal and gastrodermal tissue layers
 - Gastrovascular cavity
 - 5 Nervous system in the form of a nerve net
 - 6 Adhesive structures called colloblasts
 - 7 Eight rows of ciliary bands, called comb rows, for locomotion
- Pleurobranchia*** has a spherical or ovoid, transparent body about 2 cm in diameter.
- It occurs in the colder waters of the Atlantic and Pacific Oceans.
 - *Pleurobranchia*, like most ctenophorans, has eight meridional bands of cilia, called comb rows.
 - Comb rows present between the oral and aboral poles.
 - Comb rows are locomotor structures that are coordinated through a **statocyst** at the aboral pole.
 - *Pleurobranchia* normally swims with its aboral pole oriented downward.
 - The statocyst detects tilting, and the comb rows adjust the animal's orientation.
 - Two long, branched tentacles arise from pouches near the aboral pole.
 - Tentacles possess contractile fibers that retract the tentacles, and adhesive cells, called **colloblasts**, that capture prey.
 - Ingestion occurs as the tentacles wipe the prey across the mouth.

Colloblasts



- Sticky retractile tentacle used to catch prey
 - Colloblast discharge an adhesive thread which is sticky to the touch
- Some spp. lack tentacles and the body is studded with colloblasts

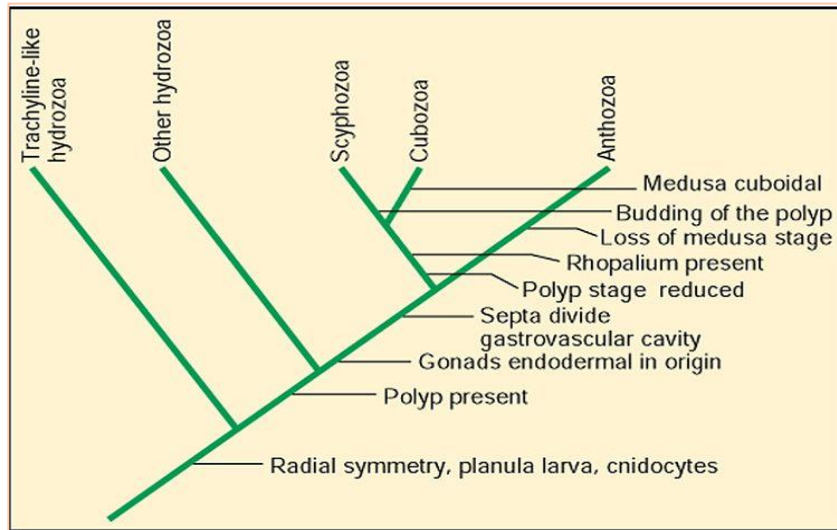
- The mouth leads to a branched gastrovascular canal system.
- Some canals are blind; however, two small anal canals open to the outside near the apical sense organ.
- Thus, unlike the cnidarians, ctenophores have an anal opening.
- Some undigested wastes are eliminated through these canals and some are probably also eliminated through the mouth.
- ***Pleurobranchia*** is monoecious, as are all ctenophores.
- Two band like gonads are associated with the gastrodermis.
- One of these is an ovary, and the other is a testis.
- Gametes are shed through the mouth.
- Fertilization is external.
- A slightly flattened larva develops.

47 Phylum Ctenophora (Further Phylogenetic Considerations)

- If the animal kingdom is polyphyletic, then all phyla could have had separate origins.
- Although scientists who believe in multiple origins agree that the number of independent origins is probably small.
- Some zoologists believe the animal kingdom to be at least diphyletic, with the porifera being derived separately from all other phyla.
- The similarity of poriferan choanocytes and choanoflagellates protists suggest evolutionary ties between these groups.
- Many other zoologists believe that the sponges have a common, although remote, ancestry with other animals.
- The amoeboid and flagellated cells in sponges and higher animals support this view;

“One thing that nearly everyone agrees upon, however, is that the porifera are evolutionary “dead ends” .

- If two origins are assumed, the origin of the nonporiferan lineage is also debated.
- One interpretation is that the ancestral animal was derived from a radially symmetrical ancestor, which, in turn, may have been derived from a colonial flagellate similar in front to *Volvox*.
- If this is true, then the radiate phyla (Cnidaria and Ctenophora) could be closely related to that ancestral group.



- Other zoologists contend that bilateral symmetry is the ancestral body form and that a bilateral ancestor gave rise to both the radiate phyla and bilateral phyla.
- In this interpretation, the radiate phyla are further removed from the base of the evolutionary tree.
- The classical interpretation is that primitive *Hydrozoa* were the ancestral radial animals and that the medusoid body form is the primitive body form.
- This ancestry is suggested by medusa being the adult body form in the *Hydrozoa* and the only body form in some trachylina hydrozoans.
- The polyp may have evolved secondarily as a larval stage.
- In the evolution of other three orders, septa appeared-dividing the gastrovascular cavity-and gonads became endodermal in origin.
- The Scyphozoa and Cubozoa are distinguished from the Anthozoa by the evolutionary reduction of the polyp stage in the former classes and the loss of the medusa stage in the latter class.
- The Scyphozoa and Cubozoa are distinguished from each other by budding of the polyp (Scyphozoa) and the cuboidal shape of the medusa (Cubozoa).
- The relationship of the Ctenophora to any other group of animals are uncertain.
- The Ctenophora and Cnidaria share important characteristics, such as radial (biradial) symmetry, diploblastic organization, nerve nets and gastrovascular cavities.
- In spite of these similarities, differences in adult body forms and embryological development make it difficult to drive the Ctenophora from any group of cnidarians.
- Relationships between the Cnidaria and Ctenophora are probably distant.

48

Triploblastics and Acoelomate Body Plan

EVOLUTIONARY PERSPECTIVE

- Members of the phyla **Platyhelminthes**, **Nemertea** and **Gastrotricha** show following advance characters:
 1. They are first bilaterally symmetrical animals. Therefore, they are more complex than the cnidarians.
 2. All these animals are triploblastic.
 3. They are acoelomate (without a coelom).

They are classified into three phyla:

(a) **Phylum Platyhelminthes:** It includes the flatworms. They are free living (e.g., turbellarians) or parasitic (e.g., flukes and tapeworms)

(b) **Phylum Nemertea:** It includes a small group of worms. These worms are elongated, un segmented and soft bodied. They are mostly marine and free living.

(c) **Phylum Gastrotricha:** These animals live in the space between bottom sediments.

	There are three views about this evolution: (I) Triploblastic acoelomate is an intermediate group between the radial, diploblastic plan and the triploblastic coelomate plan. Therefore, the flatworms are an evolutionary side branch from a triploblastic acoelomate ancestor. • Thus, evolution of flat worms took place from radial ancestors. • It formed a larval stage. • This larva became sexually mature. • Sexual maturity in a larval body form is called paedomorphosis. (II) Other zoologists believe that triploblastic acoelomate was formed from a bilateral ancestor. • Primitive acoelomates and triploblastic were formed earlier than the radiate phyla. • Therefore, the radial, diploblastic plan was secondarily derived from it. (III) There is recent discovery of a small group of worms (Lobatocercebridae, Annelida). • These worms show both flatworm and annelid characteristics. • It suggests that the acoelomate body plan is secondary characteristic. • Thus, the flatworms represent a side branch. • It is formed as a result of loss of a body cavity.
49	Phylum Platyhelminthes • The Phylum Platyhelminthes (Gr. <i>platys</i> means flat and <i>helmins</i> means worm) contains over 20,000 animal species. • Flatworms range in adult size from 1mm or less to 25m (Taeniarrhynchus saginatus), in length. • Their mesodermally derived tissues include a loose tissue called parenchyma (Gr. <i>parenck</i> means anything poured in beside) that fills spaces between other more specialized tissues, organs, and the body wall. • Depending on the species, parenchyma may provide; • Skeletal support • Nutrient storage • Motility • Reserves of regenerative cells • Transport of materials • Structural interactions with other tissues • Modifiable tissue for morphogenesis • Oxygen storage • Perhaps other functions yet to be determined. • This is the first phylum covered that has an organ system level of organization. • “A significant evolutionary advancement over the tissue level of organization” . • The phylum is divided into four classes: 1. Turbellaria consists of mostly free-living flatworms 2. Monogenea 3. Trematoda 4. Cestoidea • Monogenea, trematoda and cestoidea contain solely parasitic species Characteristics of the Phylum Platyhelminthes include: 1. Usually flattened dorsoventrally, triploblastic, acoelomate, bilaterally symmetrical. 2. Unsegmented worms (Members of the class Cestoidea are strobilated). 3. Incomplete gut usually present; gut absent in cestoidea 4. Somewhat cephalized, with an anterior cerebral ganglion are usually longitudinal nerve cords. 5. Protonephridia as excretory/osmoregulatory structures 6. Hermaphroditic; complex reproductive systems
50	Phylum Platyhelminthes (Classification up to class) • Commonly known as flat worms • They are acoelomate • Triploblastic • Bilaterally symmetrical animals which have no skeleton, respiratory and circulatory systems. • Alimentary canal when present is in blind sac plan. • They are unsegmented and soft-bodied invertebrate animals having flattened shapes that help in diffusion of oxygen and nutrients through their bodies. Class TURBELLARIA (<i>Dugesia</i>; <i>Bipalium</i>; <i>Leptoplana</i>; <i>Notoplana</i>; <i>Convoluta</i>)

	• Mostly free-living and aquatic • External surface usually ciliated • Predaceous • Possess rhabdites • Protrusible proboscis • Frontal glands and many mucous glands • Mostly hermaphroditic • Over 3,000 species Example: Flat worm. Planeria Class MONOGENEA (<i>Polystoma</i>; <i>Polystomoidella</i>; <i>Gyrodactylus</i>; <i>Disocotyle</i>) • Monogenetic flukes • Mostly ectoparasites on vertebrates (usually on fishes, occasionally on turtles, frogs, copepods, squids) • One life cycle form in only one host • All monogeneans are parasite found on gills and external surface of fishes. • Bear opisthaptor • About 1,100 species Class TREMATODA • Trematodes • All are parasitic • Several holdfast devices present • Have complicated life cycles involving both sexual and asexual reproduction • Over 10,000 species Subclass ASPIDOGASTREA (<i>Cotylaspis</i>; <i>Aspidogaster</i>; <i>Cotylogaster</i>; <i>Multicotyl</i>) • Mostly endoparasites of molluscs • Possess large opisthaptor • Most lack an oral sucker • About 32 species Subclass DIGENEA (<i>Fasciola</i>; <i>Schistosoma</i>; <i>Fasciolopsis</i>; <i>Opisthorchis</i>; <i>Paragonimus</i>; <i>Clonorchis</i>) • Adults endoparasites in vertebrates • At least two different lifecycle forms in two or more hosts • Have oral sucker and acetabulum • About 1,350 species Class CESTOIDEA • All parasitic with no digestive tract • Have great reproductive potential • Tapeworms • About 3,500 species Subclass CESTODARIA (<i>Gyrocotyle</i>; <i>Amphilina</i>) • Body not subdivided into proglottids • Larva in crustaceans • Adult in fishes • About 15 species Subclass EUCESTODA (<i>Taenia</i>; <i>Protocephalus</i>; <i>Diphyllobothrium</i>; <i>Taeniarhynchus</i>; <i>Echinococcus</i>) • True tapeworms • Body divided into scolex, neck, and strobila • Strobila composed of many proglottids • Both male and female reproductive systems in each proglottids • Adults in digestive tract of vertebrates • About 1,000 species
51	Phylum Platyhelminthes (The Free-living Flatworms: Body wall, Locomotion, Digestion and Nutrition) CLASS TURBELLARIA: THE FREE-LIVING FLATWORMS • Members of the class Turbellaria (L. <i>turbellae</i> means a commotion and <i>aria</i> means like) are mostly free-living. • They are bottom dwellers in freshwater and marine environments. • They crawl on stones, sand, or vegetation. • Turbellarians are named for the turbulence that their beating cilia create in the water. • Over three thousand species have been described.

- Turbellarians are predators and scavengers.
- The few terrestrial turbellarians known live in the humid tropics and subtropics.
- Although most turbellarians are less than 1 cm long, the terrestrial, tropical ones may reach 60 cm in length.
- Coloration is mostly in shades of black, brown, and gray, although some groups display brightly colored patterns.

Body Wall

As in the Cnidaria, the ectodermal derivatives include an epidermis that is in direct contact with the environment.

- Some epidermal cells are ciliated, and others contain microvilli.
- A basement membrane of connective tissue separates the epidermis from mesodermally derived tissues.
- An outer layer of circular muscle and an inner layer of longitudinal muscle lie beneath the basement membrane.
- Other muscles are located dorsoventrally and obliquely between the dorsal and ventral surfaces.
- Between the longitudinal muscles and the gastrodermis are the loosely organized parenchymal cells.
- The innermost tissue layer is the endodermally derived gastrodermis.
- It consists of a single layer of cells that comprise the digestive cavity.
- The gastrodermis secretes enzymes that aid in digestion, and it absorbs the end products of digestion.
- On the ventral surface of the body wall are several types of glandular cells of epidermal origin.

Rhabdites are rodlike cells that swell and form a protective mucous sheath around the body, possibly in response to attempted predation or desiccation.

Adhesive glands open to the epithelial surface and produce a chemical that attaches part of the turbellarian to a substrate.

Releaser glands secrete a chemical that dissolves the attachment as needed.

Locomotion

Turbellarians are the first group of bilaterally symmetrical animals.

- Bilateral symmetry is usually characteristic of animals with an active lifestyle.
- Turbellarians are primarily bottom dwellers that glide over the substrate.
- They move using cilia and muscular undulations.
- As they move, turbellarians lay down a sheet of mucus that aids in adhesion and helps the cilia gain traction.
- The densely ciliated ventral surface and the flattened body of turbellarians enhance the effectiveness of this locomotion.

Digestion and Nutrition

Some marine turbellarians lack the digestive cavity characteristic of other turbellarians.

- This blind cavity varies from a simple, unbranched chamber to a highly branched system of digestive tubes.
- Other turbellarians have digestive tracts that are lobed.

From an evolutionary perspective, highly branched digestive systems are an advancement that results in more gastrodermis closer to the sites of digestion and absorption, reducing the distance nutrients must diffuse.

- This aspect of digestive tract structure is especially important in some of the larger turbellarians and partially compensates for the absence of a circulatory system.
- The turbellarian pharynx functions as an ingestive organ.
- It varies in structure from a simple, ciliated tube to a complex organ developed from the folding of muscle layers.
- In the latter, the free end of the tube lies in a pharyngeal sheath and can project out of the mouth when feeding.
- Most turbellarians, such as the common planarian, are carnivores and feed on small, live invertebrates or scavenge on larger, dead animals; some are herbivores and feed on algae that they scrape from rocks.
- Sensory cells (chemoreceptors) on their heads help them detect food from a considerable distance.
- Food digestion is partially extracellular.
- Pharyngeal glands secrete enzymes that help break down food into smaller units that can be taken into the pharynx.
- In the digestive cavity, phagocytic cells engulf small units of food, and digestion is completed in intracellular vesicles.

52-53 **Phylum Platyhelminthes (The Free-living Flatworms: Exchange with the environment, Nervous system and Sense organs)**

EXCHANGES WITH THE ENVIRONMENT

- The turbellarians do not have respiratory organs, the respiratory gases (CO₂ and O₂) are exchanged by diffusion through the body wall.
- Most metabolic wastes (e.g., ammonia) are also removed by diffusion through the body wall.
- In marine environments, invertebrates are often in osmotic equilibrium with their environment.
- In freshwater, invertebrates are hypertonic to their aquatic environment and thus must regulate the osmotic concentration (water and ions) of their body tissues.
- **The evolution of osmoregulatory structures in the form of** protonephridia enabled turbellarians to invade freshwater.
- **Protonephridia (Gr. *protos*, first *nephros*, kidney) (sing., protonephridium)** are networks of fine tubules that run the length of the turbellarian, along each of its sides.
- Numerous, fine side branches of the tubules originate in the parenchyma as tiny enlargements called **flame cells**.
- **Flame cells** (so named because, in the living organism, they resemble a candle flame) have numerous cilia that project into the lumen of the tubule.
- Slitlike fenestrations (openings) perforate the tubule wall surrounding the flame cell.
- The beating of the cilia drives fluid down the tubule, creating a negative pressure in the tubule.
- As a result, fluid from the surrounding tissue is sucked through the fenestrations into the tubule.
- The tubules eventually merge and open to the outside of the body wall through a minute opening called a **nephridiopore**.
- **Nervous System and Sense Organs**

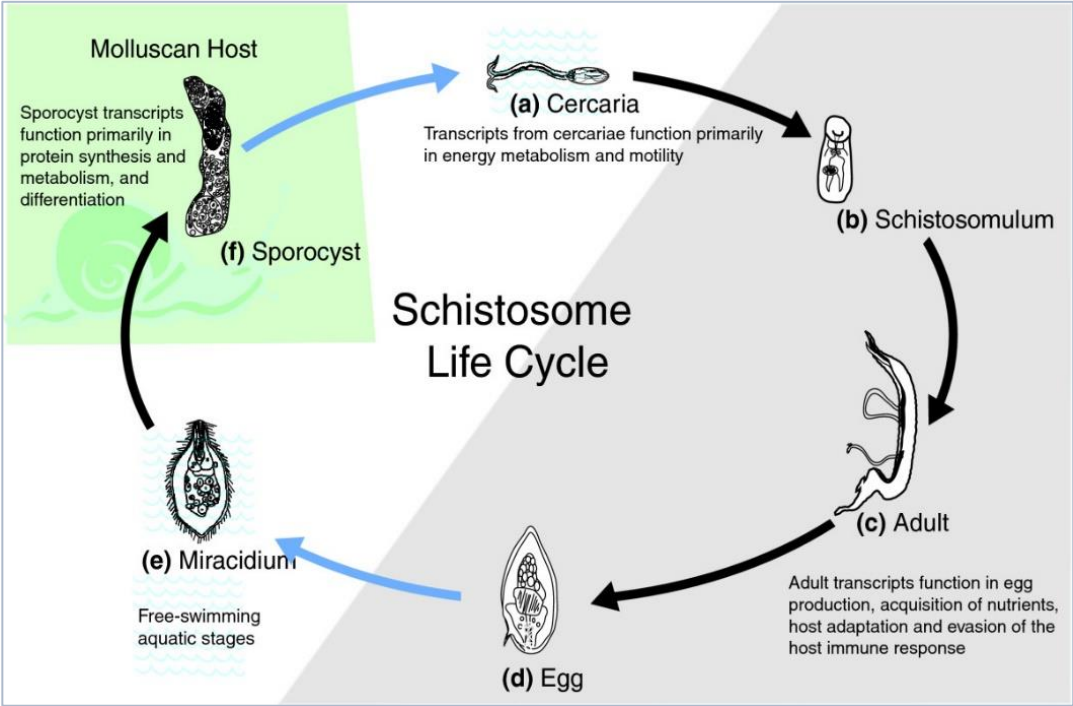
The most primitive type of flatworm nervous system, found in worms in the order Acoela (e.g., *Convoluta spp.*), is a subepidermal nerve plexus.

- This plexus resembles the nerve net of cnidarians.
- A statocyst in the anterior end functions as a mechanoreceptor (a receptor excited by pressure) that detects the turbellarian's body position in reference to the direction of gravity.
- Some turbellarians have a more centralized nerve net with cerebral ganglia.

Nervous System

- The nervous system of most other turbellarians, such as the planarian *Dugesia*, consists of a subepidermal nerve net and several pairs of long nerve cords.
- Lateral branches called commissures (points of union) connect the nerve cords.
- Nerve cords and their commissures give a ladderlike appearance to the turbellarian nervous system.
- **Neurons are organized** into sensory (going to the primitive brain), motor (going away from the primitive brain), and association (connecting) types—an important evolutionary advance with respect to the nervous system.
- Anteriorly, the nervous tissue concentrates into a pair of cerebral ganglia (sing., ganglion) called a primitive brain.
- Turbellarians respond to a variety of stimuli in their external environment.
- Many tactile and sensory cells distributed over the body detect touch, water currents, and chemicals.
- **Auricles** (sensory lobes) may project from the side of the head.
- Chemoreceptors that aid in food location are especially dense in these auricles.
- Most turbellarians have two simple eyespots called **ocelli** (sing., ocellus).
- These ocelli orient the animal to the direction of light.
- Most turbellarians are negatively phototactic and move away from light.
- Each ocellus consists of a cuplike depression lined with black pigment.
- Photoreceptor nerve endings in the cup are part of the neurons that leave the eye and connect with a cerebral ganglion.

54	Phylum Platyhelminthes (Class Trematoda: General Features of Flukes and Characteristics of Body Wall) - The approximately eight thousand species of parasitic flatworms in the class Trematoda (Gr. <i>trematodes</i>, perforated form) are collectively called flukes, which describes their wide, flat shape. - Almost all adult flukes are parasites of vertebrates, whereas immature stages may be found in vertebrates or invertebrates, or encysted on plants. - Many species are of great economic and medical importance. - Most flukes are flat and oval to elongate, and range from less than 1 mm to 6 cm in length. - They feed on host cells and cell fragments. - The digestive tract includes a mouth and a muscular, pumping pharynx. - Posterior to the pharynx, the digestive tract divides into two blind-ending, variously branched pouches called cecae (sing., cecum). - Some flukes supplement their feeding by absorbing nutrients across their body walls. Body-wall structure is similar for all flukes and represents an evolutionary adaptation to the parasitic way of life. - The epidermis consists of an outer layer called the tegument. - Tegument forms a syncytium (a continuous layer of fused cells). - The outer zone of the tegument consists of an organic layer of proteins and carbohydrates called the glycocalyx. - The glycocalyx aids in the transport of nutrients, wastes, and gases across the body wall, and protects the fluke against enzymes and the host's immune system. - Also found in this zone are microvilli that facilitate nutrient exchange. - Cytoplasmic bodies that contain the nuclei and most of the organelles lie below the basement membrane. - Slender cell processes called cytoplasmic bridges connect the cytoplasmic bodies with the outer zone of the tegument.
55	Phylum Platyhelminthes (Some important trematode parasites of humans: <i>Fasciola hepatica</i> (Liver Fluke)) <i>Fasciola hepatica</i> is called the sheep liver fluke because it is common in sheep-raising areas and uses sheep or humans as its definitive host. - The adults live in the bile duct of the liver. - Eggs pass via the common bile duct to the intestine, from which they are eliminated. - Eggs deposited in freshwater hatch, and the miracidia must locate the proper species of snail. - If a snail is found, miracidia penetrate the snails' soft tissue and develop into sporocysts that develop into rediae and give rise to cercariae. - After the cercariae emerge from the snail, they encyst on aquatic vegetation. - Sheep or other animals become infected when they graze on the aquatic vegetation. - Humans may become infected with <i>Fasciola hepatica</i> by eating a freshwater plant called watercress that contains the encysted metacercariae. The diagram illustrates the life cycle of the Fasciola hepatica (Liver fluke) in a circular flow. It is divided into two main environments: the Aquatic Environment and the HUMAN BODY OR OTHER HERBIVORES. Aquatic Environment: Miracidia hatch, penetrates snail: The cycle begins with miracidia hatching from eggs and penetrating a snail. Swimming Cercariae: Develop within the snail and eventually emerge as free-swimming cercariae. Metacercariae Encysts on plants: Cercariae encyst on aquatic plants, becoming metacercariae. HUMAN BODY OR OTHER HERBIVORES: Ingested by sheep or cattle: Animals graze on plants containing metacercariae. Ingested by humans: Humans eat the contaminated plants. Excysts in duodenum: Metacercariae excyst in the duodenum of the definitive host. Adults in hepatic biliary ducts: Adults migrate to and reside in the liver's biliary ducts. Eggs in Feces (diagnostic stage): Eggs are passed in the host's feces, which can be identified as a diagnostic stage. Arrows indicate the progression of the cycle between these stages and environments. <i>Fasciola hepatica</i> Life Cycle, Trematode (Liver fluke)

56	Phylum Platyhelminthes (Chinese Liver Fluke: <i>Clonorchis sinensis</i>) - The Chinese liver fluke, <i>Clonorchis sinensis</i>, is a common parasite of humans in Asia, where over 30 million people are infected. - The adult lives in the bile ducts of the liver, where it feeds on epithelial tissue and blood. - The adults release embryonated eggs into the common bile duct. - The eggs make their way to the intestine and are eliminated with feces. - The miracidia are released when a snail ingests the eggs. - Following the sporocyst and redial stages, cercariae emerge into the water. - If a cercaria contacts a fish (the second intermediate host), it penetrates the epidermis of the fish, loses its tail, and encysts. - The metacercaria develops into an adult in a human who eats raw or poorly cooked fish, a delicacy in Asian countries and gaining in popularity in the Western world.
57	Phylum Platyhelminthes (Representative life cycle of a schistosomes fluke) - Schistosomes are blood flukes with vast medical significance. - The impact these flukes have had on history is second only to that of Plasmodium. - They infect over 200 million people throughout the world. - Infections are most common in Africa (<i>Schistosoma haematobium</i> and <i>S. mansoni</i>), South and Central America (<i>S. mansoni</i>), and Southeast Asia (<i>S. japonicum</i>). - The adult dioecious worms live in the human bloodstream. - The male fluke is shorter and thicker than the female, and the sides of the male body curve under to form a canal along the ventral surface (schistosoma means “split body”). - The female fluke is long and slender, and is carried in the canal of the male. - Copulation is continuous, and the female produces thousands of eggs over her lifetime. - Each egg contains a spine that mechanically aids it in moving through host tissue until it is eliminated in either the feces or urine. - Unlike other flukes, schistosome eggs lack an operculum. - The miracidium escapes through a slit that develops in the egg when the egg reaches freshwater. - The miracidium seeks via chemotaxis a snail. - The miracidium penetrates it, and develops into a sporocyst, then daughter sporocysts, and finally forkedtailed cercariae. - There is no redial generation. - The cercariae leave the snail and penetrate the skin of a human. - Anterior glands that secrete digestive enzymes aid penetration. - Once in a human, the cercariae lose their tails and develop into adults in the intestinal veins, skipping the metacercaria stage.  The diagram illustrates the Schistosome Life Cycle, divided into two main environments: the Molluscan Host (green background) and the Human Host (grey background). The cycle proceeds through the following stages: (a) Cercaria: Transcripts from cercariae function primarily in energy metabolism and motility. It is shown swimming in the water between the two hosts. (b) Schistosomulum: The stage immediately following penetration into the human host. (c) Adult: Adult transcripts function in egg production, acquisition of nutrients, host adaptation and evasion of the host immune response. The adult worms are shown in the human host. (d) Egg: Released from the adult in the human host. (e) Miracidium: Free-swimming aquatic stages. It hatches from the egg in the water. (f) Sporocyst: Sporocyst transcripts function primarily in protein synthesis and metabolism, and differentiation. The miracidium penetrates the molluscan host and develops into a sporocyst. Arrows indicate the progression of the life cycle: from the human host (c) to (d), (d) to (e), (e) to (f), (f) to (a), and (a) to (b).

CLASS CESTOIDEA: THE TAPEWORMS

The most highly specialized class of flatworms are members of the class Cestoidea (Gr. *keistos*, girdle *eidos*, form), commonly called either tapeworms or cestodes.

- All of the approximately 3,500 species are endoparasites that usually reside in the vertebrate digestive system.
- Their color is often white with shades of yellow or gray.
- Adult tapeworms range from 1 mm to 25 m in length.
- Two unique adaptations to a parasitic lifestyle characterize tapeworms:

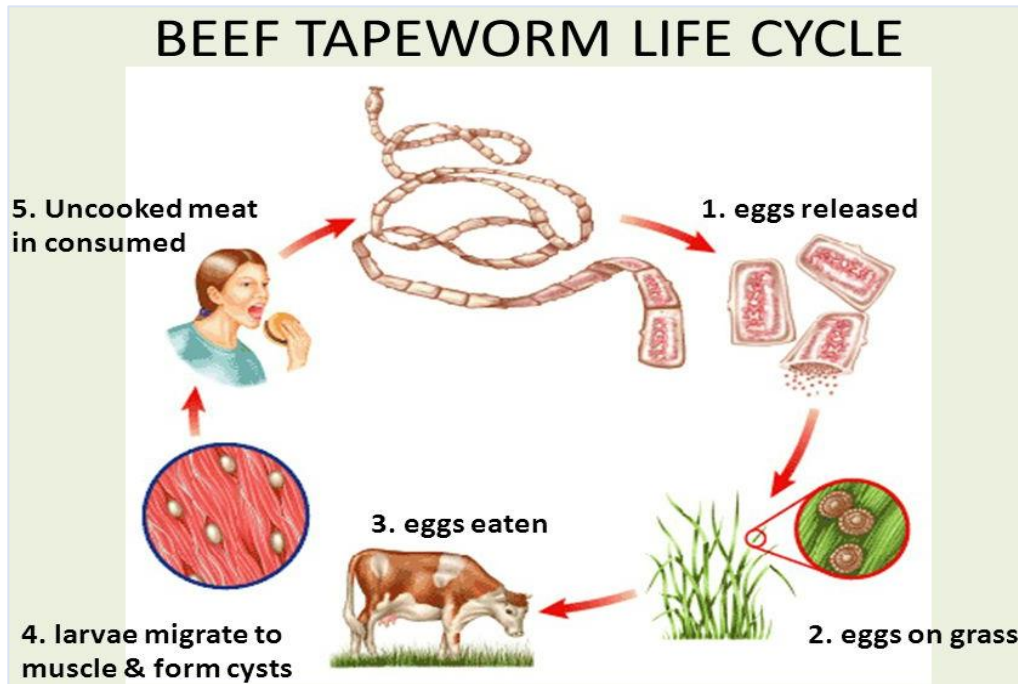
(1) Tapeworms lack a mouth and digestive tract in all of their life-cycle stages; they absorb nutrients directly across their body wall.

(2) Most adult tapeworms consist of a long series of repeating units called **proglottids**.

- **Each proglottid contains a complete** set of reproductive structures.
- As with most endoparasites, adult tapeworms live in a very stable environment.
- The vertebrate intestinal tract has very few environmental variations that would require the development of great anatomical or physiological complexity in any single tapeworm body system.
- The physiology of the tapeworm's host maintains the tapeworm's homeostasis (internal constancy).
- **In adapting** to such a specialized environment, tapeworms have lost some of the structures believed to have been present in ancestral turbellarians.
- Tapeworms are, therefore, a good example of evolution not always resulting in greater complexity.
- The outer body wall of tapeworms consists of a tegument similar in structure to that of trematodes.
- It plays a vital role in nutrient absorption because tapeworms have no digestive system.
- The tegument even absorbs some of the host's own enzymes to facilitate digestion.
- With the exception of the reproductive systems, the body systems of tapeworms are reduced in structural complexity.
- The nervous system consists of only a pair of lateral nerve cords that arise from a nerve mass in the scolex and extend the length of the strobila.
- A protonephridial system also runs the length of the tapeworm.
- Tapeworms are monoecious, and most of their physiology is devoted to producing large numbers of eggs.
- Each proglottid contains a complete set of male and female reproductive organs.
- Numerous testes are scattered throughout the proglottid and deliver sperm via a duct system to a copulatory organ called a **cirrus**.
- The cirrus opens through a genital pore, which is an opening shared with the female system.
- The male system of a proglottid matures before the female system, so that copulation usually occurs with another mature proglottid of the same tapeworm or with another tapeworm in the same host.
- As previously mentioned, the avoidance of self-fertilization leads to hybrid vigor.
- A single pair of ovaries in each proglottid produces eggs.
- Sperm stored in a seminal receptacle fertilize eggs as the eggs move through the oviduct.
- Vitelline cells from the vitelline gland are then dumped onto the eggs in the ootype.
- The ootype is an expanded region of the oviduct that shapes capsules around the eggs.
- The ootype is also surrounded by the Mehlis' gland, which aids in the formation of the egg capsule.
- Most tapeworms have a blind-ending uterus, where eggs accumulate.
- As eggs accumulate, the reproductive organs degenerate; thus, gravid proglottids can be thought of as "bags of eggs."
- Eggs are released when gravid proglottids break free from the end of the tapeworm and pass from the host with the host's feces.
- In a few tapeworms,
- the uterus opens to the outside of the worm, and eggs are released into the host's intestine.
- Because proglottids are not continuously lost, adult tapeworms usually become very long.

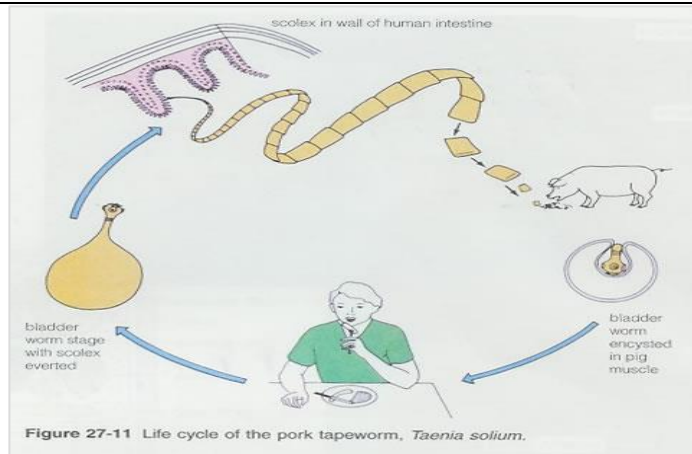
59 **Phylum Platyhelminthes (Some important cestode parasites of humans: *Taeniarhynchus saginatus* (Beef tapeworm))**

- One medically important tapeworm of humans is the beef tapeworm, *Taeniarhynchus saginatus*.
- Adults live in the small intestine and may reach lengths of 25 m.
- About 80,000 eggs per proglottid are released as proglottids break free of the adult worm.
- As an egg develops, it forms a six-hooked (hexacanth) larva called the **oncosphere**.
- **As cattle** (the intermediate host) graze in pastures contaminated with human feces, they ingest oncospheres (or proglottids).
- Digestive enzymes of the cattle free the oncospheres, and the larvae use their hooks to bore through the intestinal wall into the bloodstream.
- The bloodstream carries the larvae to skeletal muscles, where they encyst and form a fluid-filled bladder called a **cysticercus (pl., cysticerci) or bladder worm**.
- When a human eats infected meat (termed “measly beef” ’) that is raw or improperly cooked, the cysticercus is released from the meat, the scolex attaches to the human intestinal wall, and the tapeworm matures.

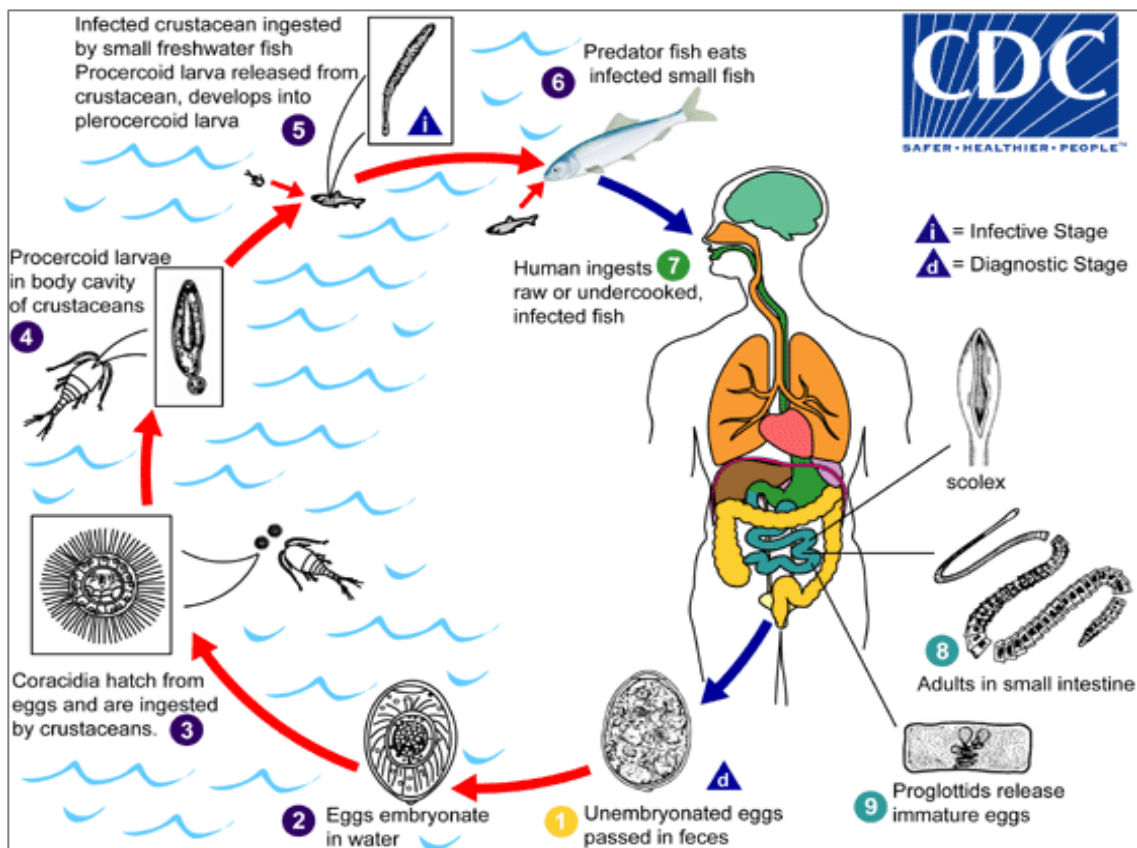


60 **Phylum Platyhelminthes The Tapeworms (*Taenia solium*:.) (Pork tapeworm)**

- A closely related tapeworm, *Taenia solium* (the pork tapeworm), has a life cycle similar to that of *Taeniarhynchus saginatus*, except that the intermediate host is the pig.
- The strobila has been reported as being 10 m long, but 2 to 3 m is more common.
- The pathology is more serious in the human than in the pig.
- Gravid proglottids frequently release oncospheres before the proglottids have had a chance to leave the small intestine of the human host.
- When these larvae hatch, they move through the intestinal wall, enter the bloodstream, and are distributed throughout the body, where they eventually encyst in human tissue as cysticerci.
- The disease that results is called **cysticercosis and can be fatal if the cysticerci encyst in the brain**.

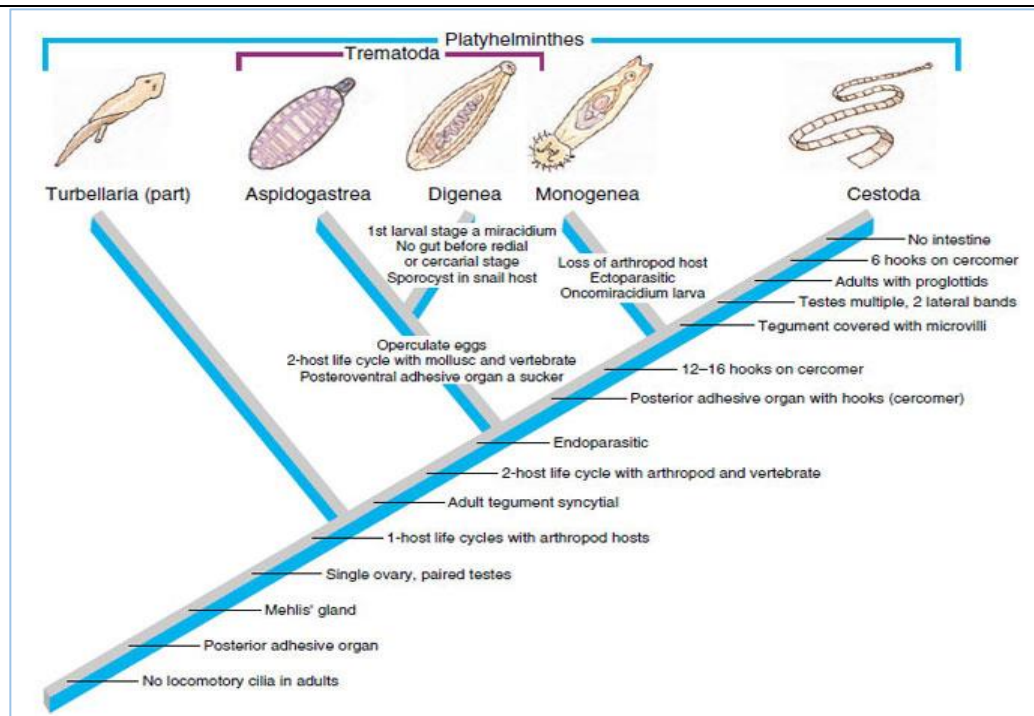


- 61 **The Tapeworms** *Diphyllobothrium latum*: (Broad fish tapeworm)
- The broad fish tapeworm, *Diphyllobothrium latum*, is relatively common in the northern parts of North America and in the Great Lakes area of the United States.
 - This tapeworm has a scolex with two longitudinal grooves (bothria; sing., bothrium) that act as hold-fast structures.
 - The adult worm may attain a length of 10 m and shed up to a million eggs a day.
 - Many proglottids release eggs through uterine pores.
 - When eggs are deposited in freshwater, they hatch, and ciliated larvae called **coracidia** (sing., coracidium) emerge.
 - These coracidia swim about until small crustaceans called copepods ingest them.
 - The larvae shed their ciliated coats in the copepods and develop into **procercoid larvae**.
 - When fish eat the copepods, the procercoids burrow into the muscle of the fish and become **plerocercoid larvae**.
 - Larger fishes that eat smaller fishes become similarly infected with plerocercoids.
 - When humans (or other carnivores) eat infected, raw, or poorly cooked fishes, the plerocercoids attach to the small intestine and grow into adult worms.



62	Phylum Nemertea • There are nine hundred species of nemerteans. • They are elongate, flattened worms. • They are found in marine mud and sand. • They have a long proboscis. • Therefore, nemerteans are commonly called proboscis worms. • Adult worms' range in size from a few millimeters to several centimeters in length. • Most nemerteans are pale yellow, orange, green or red. • Characteristics of the phylum Nemertea include: • They are triploblastic, acoelomate. • They are bilaterally symmetrical unsegmented worms. • They possess a ciliated epidermis containing mucous glands • They have complete digestive tract with an anus • Excretory structures are protonephridia. • Nervous system is composed of cerebral ganglion, longitudinal nerve cords, and transverse commissures. • They have closed circulatory system. • Body musculature forms two or three layers. • The nemerteans have long proboscis. • It is the most distinctive feature of this group. • This proboscis is held in a sheath called a rhynchocoel. • The proboscis has a barb called a stylet. • Carnivorous species use the proboscis to capture annelid and crustacean prey. • The nemerteans have a complete one-way digestive tract. • They have a mouth for ingestion of food and an anus for eliminating digestive wastes. • The food moves from anterior to posterior part of digestive cavity. • This enables mechanical breakdown of food, digestion, absorption, and feces formation take place. • It is a great innovation in nemerteans. • They also have nervous system. • It is another major innovation. • Its circulatory system consists of two lateral blood vessels. • These lateral blood vessels have branched tributary. • Heart is absent in them. • The contractions of the walls of the large vessels propel blood. • Blood does not circulate. • It simply moves forward and backward through the longitudinal vessels. • Blood cells are present in some species. • The nemerteans have two advance characters. • Therefore, they are much larger than the flattest worms. (a) The presence of blood vessels. • These blood vessels provide blood to local tissues. (b) They have one-way digestive system. • It can process nutrient efficiency. • Nemerteans are dioecious. • Male and female reproductive structures develop from parenchymal cells from each side of the body. • External fertilization results in the formation of a helmet-shaped, ciliated pilidium larva. • The adult nemerteans glide on a trail of mucus cilia and peristaltic contractions of body muscles provides the propulsive forces.
63	Phylum Gastrotricha The GASTROTRICHA (Gr. <i>gastros</i>, stomach and <i>trichos</i>, hair) are members of small phylum. • About five hundred free- living marine and freshwater species. • They live in the space between bottom sediments. • Their size is from 0.01 to 4 mm in length. • They use cilia on their ventral surface to move over the substrate. • The phylum contains a single class divided into two orders. • They have following characteristics:

	• The dorsal cuticle often contains scales, bristles, or spines. • A forked tail is often present. • A syncytial epidermis is present beneath the cuticle. • Sensory structures are tufts of long cilia and bristles on the rounded head. • The nervous system includes a brain and a pair of lateral nerve trunks. • The digestive system is a straight tube. • It has a mouth, a muscular pharynx, a stomach-intestine, and an anus. • They ingest microorganisms and organic detritus by the ^{pumping} action of pharynx from the bottom sediment and water. • Digestion is mostly extracellular. • Adhesive glands are present in the forked tail. • They secrete material that attaches the animal to solid objects. • Paired protonephridia occur in freshwater species but rarely in marine species. • But their protonephridia are morphologically different from other acoelomates. • Each protonephridia possesses a single flagellum. • But other acoelomates have cilia in flame cells. • Most of the marine species reproduce sexually. • They are hermaphroditic. • Most of the freshwater species reproduce asexually by parthenogenesis. • The females lay two kinds of unfertilized eggs; (a) Thin-shelled eggs: It is hatched into females during favorable environmental conditions. (b) Thick-shelled resting eggs can withstand unfavorable conditions for long periods. Then they are hatched into females. • There is no larval stage. • Development is direct. • The juveniles have the same form as the adults.
64	Phylum Platyhelminthes (Further Phylogenetic Consideration) • There are different views about the evolution of platyhelminthes: • Zoologists believe that the platyhelminthes body form is central to animal evolution. • They believe that an ancestral flatworm was similar to turbellarians. • The Cladogram emphasizing the uniqueness of the tegument as a synapomorphy uniting the Monogenea, Trematoda and Cestoidea. • Synapomorphy is a shared, evolutionary derived character used to describe common descent among two or more species. • Recent molecular data suggest that the acoelomate flatworms are not members the Phylum Platyhelminthes. • They are very close to the first ancestral bilateral animals. • More evidence links the parasitic flatworms to ancient, free-living ancestors. • The free-living and parasitic ways of life formed in the Cambrian period, 600 million years ago. • The first flatworm parasites were probably associated with primitive molluscs, arthropods and echinoderms. • They later acquired the vertebrate hosts and complex life cycles. • The gastrotriches show some distant relationships to the acoelomates. • For example, many gastrotriches lack a body cavity. • They are monoecious and small. • Their ventral cilia may have been derived from the same ancestral sources as those of the turbellarians flatworms.



65 Pseudocoelomate Body Plan (Aschelminths: General characteristics)

EVOLUTIONARY PERSPECTIVE

- The group Aschelminths has seven different phyla.
- They are very diverse animals.
- They have unclear phylogenetic affinities and very few fossils of these organisms are found.
- Two hypotheses have been proposed for their phylogeny:

First hypothesis:

- It describes that these phyla are related due to following common structures: a pseudocoelom, a cuticle, a muscular pharynx and adhesive glands.

Second hypothesis:

- This hypothesis describe that these phyla are not related to each other.
- Therefore, they are polyphyletic.
- There is absence of any single unique feature found in all groups.
- It strongly suggests that there is independent evolution of each phylum.
- The similarities among the living aschelminths may simply the result of convergent evolution as these various animals adapted to similar environment.
- The correct phylogeny is in between the two hypotheses.
- All phyla have some common anatomical and physiological features.
- Thus, they are distantly related to each other.
- True convergent evolution may have also produced some analogous similarities.
- But each phylum probably arose from a common acoelomate ancestor.
- It diverged very early in evolutionary history.
- Such an ancestor might have been a primitive ciliated acoelomate turbellarian.
- Therefore, it is concluded that the first ancestor was ciliated, acoelomate, marine and probably monoecious.
- It lacked a cuticle.

Aschelminths show following characters:

- They are first invertebrates which possess body cavity.
- But they lack peritoneal linings and mesenteries.
- These structures are found in more advanced animals.
- Therefore, the various internal organs lie free in the cavity.
- Such a cavity is called a **pseudocoelom** or **pseudocoel**.
- Therefore, these animals are called Pseudocoelomates.
- The pseudocoelom is often fluid filled.
- Or it may contain a gelatinous substance with mesenchyme cells.
- The pseudocoelom performs following functions:

	(i) This cavity is used for circulation. (ii) It helps in digestion. (iii) It acts as an internal hydrostatic skeleton that functions in locomotion. • Most aschelminths (the acanthocephalans and nematomorphs are exceptions) have a complete tubular digestive system. • It extends from an anterior mouth to posterior anus. • This complete digestive tract was first encountered in the nemerteans. • It is characteristic of almost all other higher animals. • It permits, for the first time, the mechanical breakdown of food, digestion, absorption, and feces formation to proceed sequentially and continually from anterior to posterior direction. • An evolutionary advancement over the blind-ending digestive system. • Most aschelminths also have a specialized muscular pharynx. • It is adapted for feeding. • Many aschelminths show eutely (Gr. <i>euteia</i>, thrift). • A condition in which numbers of cells (or nuclei in syncytia) is constant both for the entire animal and for each given organ in all the animals of that species. • For example, the number of body cells in cells in all adult <i>Caenorhabditis elegans</i> is 959 and the number of cells in the pharynx of every worm in the species is precisely 80. • For example, the number of body (somatic) cells in all adult <i>Caenorhabditis elegans</i> nematodes is 959 and the number of cells in the pharynx of every worm in the species is precisely 80. • Most aschelminths are microscopic, but some are meter in length. • They are bilaterally symmetrical, unsegmented, triploblastic animals. • They are cylindrical in cross section. • Most aschelminths have an osmoregulatory system of protonephridia. • This system is best developed in freshwater forms, in which osmotic problems are the greatest. • No separate blood or gas exchange systems are present in them. • Some cephalization (head formation) is present in them. • The anterior end contains a primitive brain, sensory organs, and a mouth. • Majority of aschelminths are dioecious. • Both reproductive systems are relatively uncomplicated. • Their life cycle is simple, except in parasites. • Cilia are generally absent on external surface. • A thin, tough external cuticle is present. • The cuticle may bear spines, scales or other form of ornamentation. • These structures protect the animal and are useful to taxonomists. • Some aschelminths shed this cuticle for growth. • This process is called molting or ecdysis. • Beneath the cuticle is a syncytial (multinucleate) epidermis that actively secretes the cuticle. • Several longitudinal muscle layers lie beneath the epidermis. • Most aschelminths are freshwater animals. • Only a few live in marine environments. • The nematomorphs and acanthocephalans, and many of the nematodes are parasitic. • The remaining aschelminths are mostly free-living. • Some rotifers are colonial.
66	Phylum Rotifera (External Features) PHYLUM ROTIFERA (<i>rota</i>, wheel + <i>fera</i>, to bear) derived their name from the characteristic ciliated organ, the corona (Gr. <i>krowe</i>, crown). • Corona is present around lobes on the head. • The cilia of the corona do not beat simultaneously. • Rather each cilium beat earlier than the next cilium. • A wave of beating cilia appears. • It passes around the periphery of the ciliated lobes. • It gives the impression of a pair of spinning wheels. • That is why the rotifers were earlier called wheel animalcules. • Rotifers are small animals (0.1 to 3 mm in length). • They are abundant in most freshwater habitats. • A few species (less than 10 %) are marine.

	• The approximately two thousand species of rotifera are divided into three classes. • The body has approximately a thousand cells. • The organs are eutely. • Rotifers are solitary, free- swimming animals. • Some are colonial. • Others occur between grains of sand. • Characteristics of the Phylum Rotifera include: • They are triploblastic, bilateral, unsegmented, pseudocoelomate. • They have complete digestive system with specialized organs. • Anterior end has a ciliated organ called a corona. • Posterior end has toes and adhesive glands. • Well-developed cuticle is present. • Protonephridia with flame cells are present • Males are reduced in number or absent, therefore, parthenogenesis is common in them. EXTERNAL FEATURES • An epidermally secreted cuticle covers rotifers external surface. • In many species, the cuticle thickens to form an encasement called a lorica. • The cuticle or lorica provides protection and is the main supportive element. • Although, the fluid in the pseudocoelom provides hydrostatic support. • The epidermis is syncytial. • In this case plasma membranes are absent between the nuclei. • The head contains the corona, mouth, sensory organs and brain. • The corona surrounds buccal field. • Buccal field is a large ciliated area. • The trunk is the largest part of a rotifer. • It is elongated and saclike. • The anus occurs dorsally on the posterior end of trunk. • The posterior narrow portion of rotifers is called foot. • The terminal portion of the foot usually bears one or two toes. • At the base of the foot are many pedal glands whose ducts open on the toes. • The foot is attached to substratum with the secretions of these glands.
67	Phylum Rotifera (Feeding and the Digestive System; Other Organ Systems) • Most rotifers feed on small microorganisms and suspended organic material. • The coronal cilia create a current of water. • This current brings food particles to the mouth. • Pharynx contains a unique structure called the mastax (jaws). • The mastax is a muscular organ that grinds food. • The inner walls of the mastax contain several sets of jaws called trophi. • The trophi vary in morphological detail, and taxonomists use them to distinguish species. • Food passes from the mastax through a short, ciliated esophagus. • It then enters into the ciliated stomach. • Salivary and digestive glands secrete digestive enzymes into the pharynx and stomach. • Complete extracellular digestion and absorption of food takes place in the stomach. • In some species, a short, ciliated intestine extends posteriorly and becomes a cloacal bladder. • It receives water from the protonephridia and eggs from the ovaries. • It also receives digestive waste. • The cloacal bladder opens to the outside by anus. • Anus is present at the junction of the foot with the trunk. • All visceral organs lie in a pseudocoelom. • Pseudocoelom is filled with fluid and interconnecting amoeboid cells. • Protonephridia empty into the cloacal bladder, function in osmoregulation. • Rotifers exchange gases and remove nitrogenous wastes through body surfaces. • The nervous system is composed of two lateral nerves and a bilobed ganglionic brain. • Brain is present on the dorsal surface of the mastax. • Numerous ciliary clusters and sensory bristles act as sensory structures. • They are concentrated on either one or more short antennae or the corona. • One to five photosensitive eyespots may be present on the head.

68	Phylum Rotifera (Reproduction and Development) - Some rotifers reproduce sexually although several types of parthenogenesis occur in most species. Male: Smaller male appears only sporadically in one class (Monogononta). But in another class (Bdelloidea) no male are produced. In the class Seisonidea, fully developed males and females are equally common in the population. - Most rotifers have a single ovary. - A syncytial (multinucleate) vitellarium is attached. - It produces yolk that is incorporated into the eggs. - The ovary and vitellarium often fuse to form a single germovitellarium. - After fertilization, each egg travels through a short oviduct. - It enters into cloacal bladder and passes out through its opening. - The mouth, cloacal bladder, and other digestive organs are either degenerate or absent in males. - A single testis produces sperm. - Sperms travel through a ciliated vas deferens and enter into the gonopore. - Male rotifers typically have an eversible penis. - It injects sperm like a hypodermic needle, into the pseudocoelom of the female. - It is called hypodermic impregnation. In one class (Seisonidea), the females produce haploid eggs. This egg is fertilized to develop into either males or females. In another class (Bdelloidea), all females are parthenogenetic. They produce diploid eggs. Eggs hatch into diploid females. The third class (Monogononta) produces two different types of eggs: Amictic (Gr. <i>a</i>, without and <i>miktos</i>, mixed or blended; thin shelled summer eggs). Mictic (Gr. <i>miktos</i>, mixed or blended eggs). - Amictic females produce amictic eggs by mitosis. - These eggs are diploid. - These cannot be fertilized. - Therefore, they develop directly into amictic females. - Therefore, first amictic cycle starts. - This female develops large populations quickly. - Another amictic cycle starts, more dormant eggs are produced. - It occurs before the yearly cycle is over. Winds or birds disperse dormant eggs, accounting for the unique distribution patterns of many rotifers. - Some amictic females produce mictic eggs in summer by meiosis. - These are thin-shelled eggs. - Mictic eggs are haploid. - If the mictic eggs is not fertilized, it develops parthenogenetically into a male. - If the mictic eggs is fertilized and secrete a thick, heavy shell and become dormant or resting winter eggs. - Dormant eggs always hatch with melting snows and spring rains. - They develop into amictic females which begin a first amictic cycle. - Most females lay either amictic or mictic eggs but not both. - The physiological condition during of the female oocyte development determines whether her eggs will be amictic or mictic.
69	Phylum Nematoda (External Features) - Nematodes (Gr. <i>nematos</i>, thread) or round worms are some of most abundant animals on earth. - Some five billion may be in every acre (4,046 square meters) of fertile garden soil. - Number of round worm species ranges from 16, 000 to 500,000. - There are following characteristic of these animals: - Roundworms feed on every conceivable source of organic matter from rotting substances to the living tissues of other invertebrates, vertebrates and plants. - They range in size from microscopic to several meters long. - Many nematodes are parasites of plants or animals; most other are free- living in marine, freshwater, or soil habitats. - Some nematodes play an important role in recycling nutrients in soils and bottom sediments. - There are two common characteristics between nematodes and arthropods:

	(a) Nematodes and arthropods lack cilia. (b) The sperm of nematode and arthropods are amoeboid. • Zoologists recognize two classes of nematodes. • They are triploblastic, bilateral, vermiform (resembling a worm in shape; long and slender), unsegmented, pseudocoelomate. • Their body is rounded in cross section. • Body is covered by a layered cuticle; molting usually accompanies growth in juveniles. They have complete digestive tract. Mouth is surrounded by lips bearing sensory organs. • They have unique excretory system. It is composed of one or two renette cells or a set of collecting tubules. • Their body wall contains only longitudinal muscles. External Features: • A typical nematode body is slender, elongate and cylindrical and tapered at both ends. • Much of the success of nematode is due to their outer, noncellular, collagenous cuticle. • Cuticle is continuous with the foregut, hindgut, sense organs and parts of the female reproductive system. • The cuticle may be smooth, or it may contain spines, bristles, papillae (small, nipplelike projections), warts or ridges, all of which are of taxonomic importance. • Cuticle is composed of three primary layers; cortex, matrix layer, and basal layer. • The cuticle maintains internal hydrostatic pressure, provides mechanical protection. • It resists digestion by the host in parasitic species. • The cuticle is usually molted four times during maturation. • Epidermis or hypodermis is present beneath the cuticle which surrounds the pseudocoelom. • The epidermis may be syncytial and its nuclei are present in four epidermal cords (one dorsal, one ventral, and two laterals) that project inward. • They longitudinal muscles are the principal means of locomotion in nematodes. • Contraction of these muscles produce undulatory waves that pass from the anterior to posterior end of the animal, creating characteristic thrashing movements. • Nematodes lack circular muscles and therefore, they cannot crawl as do worms with more complex musculature. • Some nematodes have lips surrounding the mouth and some species bear spines or teeth on or near the lips. In others, the lips have disappeared. • Some roundworms have head shields that afford protection. • Sensory organs include amphids, phasmids and ocelli. • The nematodes are classified on the basis of presence or absence of these sense organs. Amphids are anterior depressions in the cuticle that contains modified cilia and functions in chemoreception. Phasmids are near the anus and also functions in chemoreception. Paired ocelli (eyes) are present in aquatic nematodes.
70	Phylum Nematoda (Feeding and the digestive system; other organ systems) • The pseudocoelom of nematode is a spacious, fluid-filled cavity that contains visceral organs and forms a hydrostatic skeleton. • All the nematodes are round because the body muscles contracting against the pseudocoelom, fluid generates an equal outward force in all directions. • Depending on the environment, nematodes are capable of feeding on a wide variety of foods; they may be carnivores, herbivores, omnivores, or saprobes (saprotrophs) that consume decomposing organisms, or parasitic species. • The parasitic species feed on blood and tissue fluids of their hosts. • Nematodes have a complete digestive system consisting of a mouth, which may have teeth, jaws, or stylets (sharp, pointed structures); buccal cavity; muscular pharynx; long tubular intestine where digestion and absorption occur. • They have short rectum and anus. • Hydrostatic pressure in the pseudocoelom and the pumping action of the pharynx push food through the alimentary canal. • Nematodes accomplish osmoregulation and excretion of nitrogenous waste products (ammonia, urea) take place by two unique systems.

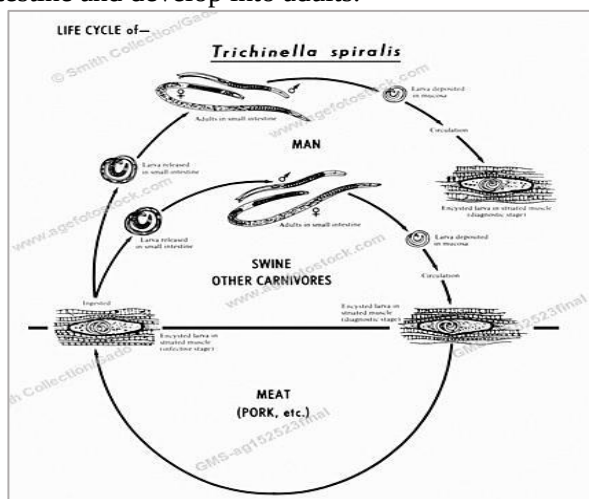
	• The Glandular system is present in aquatic species and consists of ventral gland cells, called renettes, posterior to the pharynx. • Each gland absorbs wastes from the pseudocoelom and empties them to the outside through an excretory pore. • Parasitic nematodes have a more advanced system, called the tubular system that developed from the renette system. • In this system, the renettes unite to form a large canal which opens outside through an excretory pore. • The nervous system consists of an anterior nerve ring. • Nerves extend anteriorly and posteriorly; many connect to each other via commissures. • Certain neuroendocrine secretions are involved in growth, molting, cuticle formation, and metamorphosis.
71	Phylum Nematoda (Reproduction and Development) • Most nematodes are dioecious and dimorphic (different shapes) with the males being smaller than the females. The long, coiled gonads lie freely in the pseudocoelom. • The female system consists of a pair of convoluted ovaries. • Each ovary is continuous with an oviduct with the proximal end is swollen to form a seminal receptacle. • Each oviduct becomes a tubular uterus; the two uteri unite to form a vagina. • Vagina opens to the outside through a genital pore. • The male system consists of a single testis which is continuous with a vas deferens that eventually expand into a seminal vesicle. • The seminal vesicle connects to the cloaca. • Males are commonly armed with a posterior flap of tissue called a bursa. • The bursa helps in the transfer of sperm to the female genital pore during copulation. • After copulation, the hydrostatic forces in the pseudocoelom move each fertilized egg to the gonopore (genital pore). • The number of eggs produced varies with the species. • Some nematodes produce only several hundred eggs whereas others may produce hundreds of thousands daily. • Some nematodes give birth to larvae (ovoviviparity). • External factors like temperature and moisture influence the development and hatching of the eggs. • Hatching produces a larva (some parasitologists refer to it as a juvenile) that has most adult structures. • The larva (juvenile) undergoes four molts, although in some species, the first one or two molts may occur before the eggs hatch.
72	Phylum Kinorhyncha • Kinorhynchs are small (less than 1 mm long), elongate, bilaterally symmetrical worms. • They are found exclusively in marine environments where they live in mud and sand. • Because they have no external cilia or locomotory appendages, they simply burrow through the mud and sand with their snouts. • In fact, the phylum takes its name (Kinorhyncha (<i>kinein</i>, motion + <i>rhynchos</i> snout) from this method of locomotion. • The phylum Kinorhyncha contains about 150 known species. • The body surface of kinorhynch is devoid of cilia and is composed of 13 or 14 definite units called zonites. • The head, represented by zonite 1, bears the mouth, an oral cone, and spines. • The neck, represented by zonite 2, contains spines called scalids and plates called placids. • The head can be retracted into the neck. • The trunk consists of the remaining 11 or 12 zonites and terminates with the anus. • Each trunk zonite bears a pair of lateral spines and one dorsal spine. • The body wall consists of a cuticle, epidermis and two pairs of muscles: dorsolateral and ventrolateral. • The pseudocoelom is large and contains amoeboid cells. • A complete digestive system is present, consisting of a mouth, buccal cavity, muscular pharynx, esophagus, stomach, intestine (where digestion and absorption take place), and anus. • Most kinorhynchs feed on diatoms, algae, and organic matter. • A pair of protonephridia is present in zonite 11. • The nervous system consists of brain and single ventral nerve cord with a ganglion (a mass of nerve cells) in each zonite. • Some species have eyespots and sensory bristles.

	• Kinorhynchs are dioecious with paired gonads. • Several spines that may be used in copulation surround the male gonopore. • The young hatch into larvae that do not have all of the zonites. • As the larvae grow and molt, the adult morphology appears. • Molting no longer occurs in adult.
73	Some important nematode parasites of humans (<i>Ascaris lumbricoides</i>: The Giant Intestinal Roundworm of Humans) • Parasitic nematodes show a number of evolutionary adaptations to the way of their life. These adaptations are: 1. They have high reproductive potential. 2. Their life cycles increase the likelihood of transmission from one host to another. 3. They develop an enzyme resistant cuticle, resistant eggs, and encysted larvae. 4. Only one host is usually involved in the life cycle of nematodes. Therefore, Nematode life cycles are not as complicated like cestodes or trematodes. <i>Ascaris lumbricoides</i>: The Giant Intestinal Roundworm of Humans • Approximately 800 million people may be infected with <i>Ascaris lumbricoides</i> throughout the world. Adult <i>Ascaris</i> (Gr. <i>askaris</i>, intestinal worm) live in the small intestine of humans. • They produce large numbers of eggs that with feces. • A first-stage larva develops rapidly in the egg, molts, and matures into a second-stage larva, the infective stage. • When a human ingests embryonated eggs, they hatch in the intestine. • The larvae penetrate the intestinal wall and are carried via the circulation to the lungs. • They molt twice in the lungs and migrate up the trachea, and are swallowed. • The worms attain sexual maturity in the intestine, mate, and begin egg production.
74	Some important nematode parasites of humans (<i>Enterobius vermicularis</i>: The Human Pinworm) • Parasitic nematodes show a number of evolutionary adaptations to the way of their life. These adaptations are: 1. They have high reproductive potential. 2. Their life cycles increase the likelihood of transmission from one host to another. 3. They develop an enzyme resistant cuticle, resistant eggs, and encysted larvae. 4. Only one host is usually involved in the life cycle of nematodes. Therefore, Nematode life cycles are not as complicated like cestodes or trematodes. <i>Enterobius vermicularis</i>: The Human Pinworm (<i>enteron</i>, intestine + <i>bios</i>, life) are the most common roundworm parasites in the United States. • Adult <i>Enterobius vermicularis</i> become established in the lower region of the large intestine. • At night, the gravid females migrate out of the cecum to the perianal area, where they deposit egg containing a first stage larva. • When human ingest these eggs, the eggs hatch. • The larva molt four times in the small intestine and migrates to the large intestine. • Adult's mate, and females soon begin egg production.
75	Some important nematode parasites of humans (<i>Necator americanus</i>: The New World Hookworm) <i>Necator americanus</i>: The New World or American hookworm, <i>Necator americanus</i> (L. <i>necator</i>, killer), is found in the southern United States. • The adults live in the small intestine where they hold onto the intestinal wall with teeth and feed on blood and tissue fluids. • Individual females may produce as many as 10,000 eggs daily which pass out of the body in the feces. • An egg hatches on warm, moist soil and releases a small rhabditiform (the first and second-stage juvenile of some nematodes) larva. • It molts and becomes the infective filariform (the infective third-stage larva of some nematodes) larva. • Humans become infected when the filariform larva penetrates the skin, usually between the toes. • Outside defecation and subsequent walking barefoot through the immediate area maintains the life cycle in humans. • The larva burrows through the skin to reach the circulatory system. • The rest of its life cycle is similar to that of <i>Ascaris</i>.

Some important nematode parasites of humans (*Trichinella spiralis*: The Porkworm)

Trichinella spiralis: The Porkworm

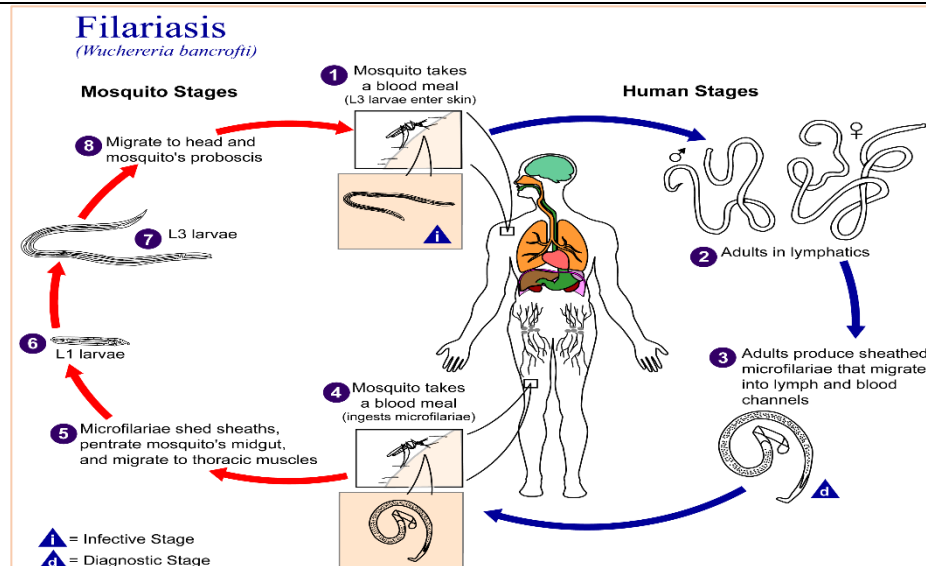
- Adult *Trichinella* (Gr. *trichinos*, hair) *spiralis* live in the mucosa of the small intestine of humans and other omnivores.
- In the intestine, adult females produce young larvae in the intestine that then enters the circulatory system and are carried to the skeletal (striated) muscles of the same host.
- The young larva encysts in the skeletal muscles and remain infective for many years.
- The disease this nematode causes is called **trichinosis**.
- Another host must ingest infective meat (muscle) to continue the life cycle.
- Humans most often become infected by eating improperly cooked pork (flesh of pig) products.
- Once ingested, the larvae excyst in the stomach and make their way to the small intestine, where they molt four times in intestine and develop into adults.



Some important nematode parasites of humans (*Wuchereria spp*: The Filarial Worms, further phylogenetic considerations)

Wuchereria spp: The Filarial Worms

- In tropical countries, over 250 million humans are infected with filarial (*L. filium*, thread) worms.
- Two examples of human filarial worms are *W. bancrofti* and *W. malayi*.
- These elongate, thread like nematodes live in the lymphatic system where they block the lymph vessels.
- Because lymphatic vessels return tissue fluids to the circulatory system, when the filarial nematodes block these vessels, fluids and connective tissue tend to accumulate in peripheral tissues.
- This fluid and connective tissue accumulation causes the enlargement of various appendages, a condition called **elephantiasis**.
- In the lymphatic vessels, filarial nematodes adults copulate and produce larvae called **microfilariae**.
- The microfilariae are released into the bloodstream of the human host and migrate to the peripheral circulation at night.
- When a mosquito takes another meal of blood on a human, the mosquito's proboscis injects the infective third-stage larvae into the blood of the human host.
- The filarial two molts take place as the larvae enter the lymphatic vessels.
- A filarial worm prevalent in the United States *Dirofilaria immitis*, a parasite of dogs.
- Since the adult worms live in the heart and large arteries of the lungs, the infection is called **heartworm** disease.
- Once established, these filarial worms are difficult to eliminate and the condition can be fatal.
- Prevention with heartworm medicine is thus advocated for all dogs.



- The aschelminths are clearly a diverse assemblage of animals.
- Despite the common occurrence of a cuticle, pseudocoelom, muscular pharynx, and adhesive glands, no distinctive features occur in every phylum.
- The rotifers have certain features in common with the acoelomates.
- The protonephridia of rotifers closely resemble those of some freshwater turbellarians, and zoologists generally believed that rotifers originated in freshwater habitats.
- Both flatworms and rotifers have separate ovaries and vitellaria.
- Rotifers probably had their origins from the earliest acoelomates and may have had a common bilateral, metazoan ancestor.
- The kinorhynchs, acanthocephalans, loriciferans, and priapulids all have a spiny anterior end that can be retracted; thus, they are probably related.
- Loriciferans and kinorhynchs appear to be most closely related.
- The affinities of the nematodes to other phyla are vague.
- No other living group is believed to be closely related to these worms.
- Nematodes probably evolved in freshwater habitats and then colonized the oceans and soils.
- The ancestral nematodes may have been sessile, attached at the posterior end, with the anterior end protruding upward into the water.
- The nematode cuticle, feeding structures, and food habits probably preadapted these worms for parasitism.
- In fact, free-living species could become parasitic without substantial anatomical or physiological changes.
- Nematomorphs may be more closely related to nematodes than to any other group by virtue of both groups being cylindrical in shape, having a cuticle, and being dioecious and sexually dimorphic.
- However, because the larval form of some nematomorphs resembles priapulids, the exact affinity to the nematodes is questionable.

78	Molluscan Success (Relationship to other animals; origin of the coelom) • Molluscs are protostomes. Similarities between molluscs and Arthropods The similarities in the embryological development of the molluscs and other protostomes, especially the annelids (segmented worms), are striking. • Some embryological stages, for example the <u>trochophore larvae</u> are virtually indistinguishable in molluscs and annelids. • Certain adult structures of molluscs and annelids, for example the <u>excretory organs</u> and their duct systems, are very similar in structure. Even though most zoologists accept the protostomes affiliation of the molluscs. ORIGIN OF THE COELOM A number of hypotheses focus on the origin of the coelom.
----	---

	• The schizocoel hypothesis (Gr. <i>schizen</i>, to split <i>koilos</i>, hollow) This hypothesis is patterned after the method of mesoderm development and coelom formation in many protostomes. Mesoderm fills the area between ectoderm and endoderm. The coelom arises from a splitting of this mesoderm. If the coelom formed in this way during evolution, mesodermally derived tissues would have preceded the coelom. This implying that a triploblastic, acoelomate (flatworm) body form could be the forerunner of the coelomate body form. • The enterocoel hypothesis (Gr. <i>enteron</i>, gut and <i>koilos</i>, hollow) suggests that the coelom may have arisen as outpocketings of a primitive gut tract. This hypothesis is patterned after the method of coelom formation in deuterostomes (other than vertebrates). The implication of this hypothesis is that mesoderm and the coelom formed from the gut of a diploblastic animal. If this is true, the triploblastic, acoelomate body form would have been secondarily derived by mesoderm filling the body cavity of a coelomate animal. Note: Unfortunately, zoologists may never know which, if either, of these hypotheses is accurate.
79	Molluscan characteristics Molluscs range in size and body form from the giant squid, measuring 18 m in length, to the smallest garden slug, less than 1 cm long. a. In spite of this diversity, the phylum Mollusca (mol-luskah) (L. <i>molluscus</i>, soft) is not difficult to characterize. Characteristics of the phylum Mollusca include: b. Body of two parts: head-foot and visceral mass. c. Mantle that secretes a calcareous shell and covers the visceral mass. d. Mantle cavity functions in excretion, gas exchange, elimination of digestive wastes, and release of reproductive products. e. Bilateral symmetry f. Protostome characteristics, including <u>trochophore larvae</u>, spiral cleavage, and schizocoelous coelom formation. g. <u>Coelom reduced</u> to cavities surrounding the heart, nephridia, and gonads. h. <u>Open circulatory</u> system in all but one class (Cephalopoda). i. <u>Radula</u> usually present and used in scraping food. Body Parts The body of a mollusk has <u>three main regions</u>—the head foot, the visceral mass, and the mantle. The head foot is elongate with an anterior head, containing the mouth and certain nervous and sensory structures, and an elongate foot, used for attachment and locomotion. The visceral mass contains the organs of digestion, circulation, reproduction, and excretion and is positioned dorsal to the head-foot. The mantle of a mollusc usually attaches to the visceral mass, enfolds most of the body, and may secrete a shell that overlies the mantle. Shell The shell of a mollusc is secreted in three layers. a. The outer layer of the shell is called the periostracum. Mantle cells at the mantle's outer margin secrete this protein layer. b. The middle layer of the shell, called the prismatic layer, is the thickest of the three layers and consists of calcium carbonate mixed with organic materials. c. The inner layer of the shell, the nacreous layer, forms from thin sheets of calcium carbonate alternating with organic matter. Cells along the entire epithelial border of the mantle secrete the nacreous layer. Nacre secretion thickens the shell. Mental Cavity Between the mantle and the foot is a space called the mantle cavity. The mantle cavity opens to the outside and functions in gas exchange, excretion, elimination of digestive wastes, and release of reproductive products. Radula • The mouth of most molluscs possesses a rasping structure called a radula, which consists of a chitinous belt and rows of posteriorly curved teeth. • The radula overlies a fleshy, tongue like structure supported by a cartilaginous odontophore

80	Class Gastropoda (The characteristics of shell and associated structures) - The class Gastropoda (gas-tropo-dah) (Gr. <i>gaster</i>, gut <i>podos</i>, foot) includes the snails, limpets, and slugs. - With over 35,000 living species, Gastropoda is the largest and most varied molluscan class. - Its members occupy a wide variety of marine, freshwater, and terrestrial habitats. Medical importance One important impact of gastropods on humans is that gastropods are intermediate hosts for some medically important trematode parasites of humans. TORSION: - One of the most significant modifications of the molluscan body form in the gastropods occurs early in gastropod development. Torsion is a 180° , counterclockwise twisting of the visceral mass, mantle, and mantle cavity. Torsion positions the gills, anus, and openings from the excretory and reproductive systems just behind the head and nerve cords, and twists the digestive tract into a U shape. The adaptive significance of torsion is speculative; however, three advantages are plausible. - First, without torsion, withdrawal into the shell would proceed with the foot entering first and the more vulnerable head entering last. With torsion, the head enters the shell first, exposing the head less to potential predators. In some snails, a proteinaceous covering, called an operculum, on the dorsal, posterior margin of the foot enhances protection. When the gastropod draws the foot into the mantle cavity, the operculum closes the opening of the shell, thus preventing desiccation when the snail is in drying habitats. - A second advantage of torsion concerns an anterior opening of the mantle cavity that allows clean water from in front of the snail to enter the mantle cavity, rather than water contaminated with silt stirred up by the snail's crawling. The twist in the mantle's sensory organs around to the head region is a third advantage of torsion because it makes the snail more sensitive to stimuli coming from the direction in which it moves. After torsion, the anus and nephridia empty dorsal to the head and create potential fouling problems. However, a number of evolutionary adaptations seem to circumvent this problem. Various modifications allow water and the wastes it carries to exit the mantle cavity through notches or openings in the mantle and shell posterior to the head. Some gastropods undergo detorsion, in which the embryo undergoes a full 180° torsion and then untwists approximately 90° . The mantle cavity thus opens on the right side of the body, behind the head. SHELL COILING The earliest fossil gastropods had a shell that was coiled in one plane.
81	Class Gastropoda (Feeding, digestion, gas exchange, locomotion) - Nearly all gastropods have a <u>flattened foot that is often ciliated</u>, covered with gland cells, and used to creep across the substrate. The smallest gastropods use cilia to propel themselves over a mucous trail. Larger gastropods use waves of muscular contraction that move over the foot. The foot of some gastropods is modified for clinging, as in abalones and limpets, or for swimming, as in sea butterflies and sea hares. FEEDING AND DIGESTION - Most gastropods feed by <u>scraping algae</u> or other small, attached organisms from their substrate. Others are herbivores that feed on larger <u>plants, scavengers, parasites, or predators</u>. The anterior portion of the digestive tract may be modified into an extensible proboscis, which contains the <u>radula</u>. Food is trapped in mucous strings and incorporated into a mucoid mass called the protostyle, which extends to the stomach and is rotated by cilia. A digestive gland in the visceral mass releases enzymes and acid into the stomach, and food trapped on the protostyle is freed and digested. Wastes form fecal pellets in the intestine. Gas exchange - Gas exchange always involves the mantle cavity. Primitive gastropods had two gills; modern gastropods have lost one gill because of coiling. Some gastropods have a rolled extension of the mantle, called a siphon, that serves as an inhalant tube. Burrowing species extend the siphon to the surface of the substrate to bring in water. Gills are lost or reduced in land snails (pulmonates), but these snails have a richly vascular <u>mantle for gas exchange</u> between blood and air. Mantle contractions help circulate air and water through the mantle cavity.
82	Phylum Mollusca (Reproduction and Development)

	- Many marine snails are dioecious. Gonads lie in spirals of the visceral mass. Ducts discharge gametes into the sea for external fertilization. Many other snails are monoecious, and <u>internal, cross fertilization is the rule</u>. - Copulation may result in mutual sperm transfer, or one snail may act as the male and the other as the female. A penis has evolved from a fold of the body wall, and portions of the female reproductive tract have become glandular. It secrete mucus, a protective jelly, or a capsule around the fertilized egg. Development - In marine gastropods, spiral cleavage results in a free-swimming trochophore larva that develops into another free-swimming larva with foot, eyes, tentacles, and shell, called a veliger larva. Sometimes, the trochophore is suppressed, and the veliger is the primary larva. Torsion occurs during the veliger stage, followed by settling and metamorphosis to the adult.
83	Class Gastropoda (Other Maintenance Functions) Circulatory system of Gastropods - Gastropods, like most molluscs, have an open circulatory system. During part of its circuit around the body, blood leaves the vessels and directly bathes cells in tissue spaces called sinuses. Molluscs typically have a heart consisting of a single, muscular ventricle and two auricles. Most gastropods have lost one member of the pair of auricles because of coiling. Skeleton System - In addition to transporting nutrients, wastes, and gases, the blood of molluscs acts as a hydraulic skeleton. A hydraulic skeleton consists of blood confined to tissue spaces for support. A mollusc uses its hydraulic skeleton to extend body structures by contracting muscles distant from the extending structure. For example, snails have sensory tentacles on their heads, and if a tentacle is touched, retractor muscles can rapidly withdraw it. However, no antagonistic muscles exist to extend the tentacle. Nervous System - The nervous system of primitive gastropods is characterized by six ganglia located in the head-foot and visceral mass. In primitive gastropods, torsion twists the nerves that link these ganglia. The evolution of the gastropod nervous system has resulted in the untwisting of nerves and the concentration of nervous tissues into fewer, larger ganglia, especially in the head. Gastropods have well-developed sensory structures. Eyes - Eyes may be at the base or at the end of tentacles. They may be simple pits of photoreceptor cells or consist of a lens and cornea. <u>Statocysts</u> are in the foot. <u>Osphradia</u> are chemoreceptors in the anterior wall of the mantle cavity that detect sediment and chemicals in inhalant water or air. The osphradia of predatory gastropods help detect prey. Excretion - Primitive gastropods possessed two nephridia. In modern species, the right nephridium has disappeared, probably because of shell coiling. The nephridium consists of a sac with highly folded walls and connects to the reduced coelom, the pericardial cavity. Excretory wastes are derived largely from fluids filtered and secreted into the coelom from the blood. The nephridium modifies this waste by selectively reabsorbing certain ions and organic molecules. The nephridium opens to the mantle cavity or, in land snails, on the right side of the body adjacent to the mantle cavity and anal opening. Aquatic gastropod species excrete ammonia because they have access to water in which toxic ammonia is diluted. Terrestrial snails must convert ammonia to a less-toxic form—uric acid. Because uric acid is relatively insoluble in water and less toxic, it can be excreted in a semisolid form, which helps conserve water
84	Class Gastropoda (Gastropods Diversity) Subclass Prosobranchia The largest group of gastropods is the subclass Prosobranchia. - Its 20,000 species are mostly marine, but a few are freshwater or terrestrial. - Most members of this subclass are herbivores or deposit feeders; however, some are carnivorous. - Some carnivorous species inject venom into their fish, mollusc, or annelid prey with a radula modified into a hollow, harpoonlike structure. - Prosobranch gastropods include most of the familiar marine snails and the abalone. - This subclass also includes the heteropods. - These animals are voracious predators, with very small shells or no shells. - The foot is modified into an undulating “fin” that propels the animal through the water.

	Subclass Opisthobranchia - Members of the subclass Opisthobranchia include sea hares, sea slugs, and their relatives. - They are mostly marine and include fewer than two thousand species. - The shell, mantle cavity, and gills are reduced or lost in these animals, but they are not defenseless. - Many acquire undischarged nematocysts from their cnidarian prey, which they use to ward off predators. - The pteropods have a foot modified into thin lobes for swimming. Subclass Pulmonata The subclass Pulmonata contains about 17,000 predominantly freshwater or terrestrial species. - These snails are mostly herbivores and have a long radula for scraping plant material. - The mantle cavity of pulmonate gastropods is highly vascular and serves as a lung. - Air or water moves in or out of the opening of the mantle cavity, the pneumostome. In addition to typical freshwater or terrestrial snails, the pulmonates include terrestrial slugs.
85	Class Bivalvia (The Shell and associated structures) - With close to 30,000 species, the class Bivalvia (L. <i>bis</i>, twice <i>valva</i>, leaf) is the second largest molluscan class. - This class includes the clams, oysters, mussels, and scallops. - A sheetlike mantle and a shell consisting of two valves (hence, the class name) cover these laterally compressed animals. - Many bivalves are edible, and some form pearls. - Because most bivalves are filter feeders, they are valuable in removing bacteria from polluted water. SHELL AND ASSOCIATED STRUCTURES The two convex halves of the shell are called valves. Along the dorsal margin of the shell is a proteinaceous hinge and a series of tongue-and-groove modifications of the shell, called teeth, that prevent the valves from twisting. - The oldest part of the shell is the umbo, a swollen area near the shell's anterior margin. - Although bivalves appear to have two shells, embryologically, the shell forms as a single structure. - The shell is continuous along its dorsal margin, but the mantle, in the region of the hinge, secretes relatively greater quantities of protein and relatively little calcium carbonate. - The result is an elastic hinge ligament. - The elasticity of the hinge ligament opens the valves when certain muscles relax. - Adductor muscles at either end of the dorsal half of the shell close the shell. - Anyone who has tried to force apart the valves of a bivalve mollusc knows the effectiveness of these muscles. - This is important for bivalves because their primary defense against predatory sea stars is to tenaciously refuse to open their shells. - The bivalve mantle attaches to the shell around the adductor muscles and near the shell margin. - If a sand grain or a parasite lodge between the shell and the mantle, the mantle secretes nacre around the irritant, gradually forming a pearl. - The Pacific oysters, <i>Pinctada margaritifera</i> and <i>Pinctada mertensi</i>, form the highest-quality pearls.
86	Class Bivalvia (Feeding, Digestion, Gas Exchange, Locomotion) Digestion - Bivalve adaptations to sedentary, filter-feeding lifestyles include the loss of the head and radula and, except for a few bivalves, the expansion of cilia-covered gills. The gills trap food particles brought into the mantle cavity. Zoologists originally thought that cilia action was responsible for the trapping. However, the results of a recent study indicate that cilia and food particles have little contact. - The food-trapping mechanism is unclear, but once food particles are trapped, cilia move them to the gills' ventral margin. Cilia along the ventral margin of the gills then move food toward the mouth. Cilia covering leaflike labial palps on either side of the mouth also sort filtered food particles. - A consolidated mucoid mass, the crystalline style, projects into the stomach from a diverticulum, called the style sac. Enzymes for carbohydrate and fat digestion are incorporated into the crystalline style. Cilia of the style sac rotate the style against a chitinated gastric shield Gas Exchange - Gills form folded sheets (lamellae), with one end attached to the foot and the other end attached to the mantle. The mantle cavity ventral to the gills is the inhalant region, and the cavity dorsal to the gills is the exhalant region. A bivalve buried in the substrate can extend its siphon to the surface and still

	feed and exchange gases. Water moves from the mantle cavity into small pores in the surface of the gills, and from there, into vertical channels in the gills, called water tubes. In moving through water tubes, blood and water are in close proximity, and gases exchange by diffusion. Water exits the bivalve through a part of the mantle cavity at the dorsal aspect of the gills, called the suprabranchial chamber, and through an excurrent opening in the mantle.
87	Class Bivalvia (Reproduction and Development) • Most bivalves are dioecious. A few are monoecious, and some of these species are protandric. Gonads are in the visceral mass, where they surround the looped intestine. Ducts of these gonads open directly to the mantle cavity or by the nephridiopore to the mantle cavity. Most bivalves exhibit external fertilization. Gametes exit through the suprabranchial chamber of the mantle cavity and the exhalant opening. Development proceeds through trochophore and veliger stages. When the veliger settles to the substrate, it assumes the adult form. Most freshwater bivalves brood their young. Fertilization occurs in the mantle cavity by sperm brought in with inhalant water. Some brood their young in maternal gills through reduced trochophore and veliger stages. Young clams are shed from the gills. • Others brood their young to a modified veliger stage called a glochidium, which is parasitic on fishes. These larvae possess two tiny valves, and some species have toothlike hooks. Larvae exit through the exhalant aperture and sink to the substrate. Most die. If a fish contacts a glochidium, however, the larva attaches to the gills, fins, or another body part and begins to feed on host tissue. • The fish may form a cyst around the larva. The mantles of some freshwater bivalves have elaborate modifications that present a fishlike lure to entice predatory fish. When a fish attempts to feed on the lure, the bivalve ejects glochidia onto the fish. After several weeks of larval development, during which a glochidium begins acquiring its adult structures, the miniature clam falls from its host and takes up its filter-feeding lifestyle. The glochidium is a dispersal stage for an otherwise sedentary animal and is usually harmless to the fish
88	Class Bivalvia (Other Maintenance Functions) Circulatory system • In bivalves, blood flows from the heart to tissue sinuses, nephridia, gills, and back to the heart. The mantle is an additional site for oxygenation. In some bivalves, a separate aorta delivers blood directly to the mantle. Excretion • Two nephridia are below the pericardial cavity (the coelom). Their duct system connects to the coelom at one end and opens at nephridiopores in the anterior region of the suprabranchial chamber. Nervous System • The nervous system of bivalves consists of three pairs of interconnected ganglia associated with the esophagus, the foot, and the posterior adductor muscle. The margin of the mantle is the principal sense organ. It always has sensory cells, and it may have sensory tentacles and photoreceptors. Receptors • In some species (e.g., scallops), photoreceptors are in the form of complex eyes with a lens and a cornea. • Other receptors include statocysts near the pedal ganglion and an osphradium in the mantle, beneath the posterior adductor muscle.
89	Class Bivalvia (Diversity in Bivalves) BIVALVE DIVERSITY • Bivalves live in nearly all aquatic habitats. They may completely or partially bury themselves in sand or mud, attach to solid substrates, or bore into submerged wood, coral, or limestone. The mantle margins of burrowing bivalves are frequently fused to form distinct openings in the mantle cavity (siphons). This fusion helps to direct the water washed from the mantle cavity during burrowing and helps keep sediment from accumulating in the mantle cavity. • Some surface-dwelling bivalves attach to the substrate either by proteinaceous strands called byssal threads, which a gland in the foot secretes, or by cementation to the substrate. • The common marine mussel, <i>Mytilus</i>, uses the former method, while oysters employ the latter. • Boring bivalves live beneath the surface of limestone, clay, coral, wood, and other substrates. • Boring begins when the larvae settle to the substrate, and the anterior margin of their valves mechanically abrades the substrate. • Acidic secretions from the mantle margin that dissolve limestone sometimes accompany physical abrasion. • As the bivalve grows, it is often imprisoned in its rocky burrow because the most recently bored portions of the burrow are larger in diameter than portions bored earlier.

90	Class Cephalopoda (The Shell and associated structures) - The class Cephalopoda (L. <i>cephalic</i>, head <i>Gr. podos</i>, foot) includes the <u>octopuses, squid, cuttlefish</u>, and nautili. They are the most complex molluscs and, in many ways, the most complex invertebrates. - The anterior portion of their foot has been modified into a circle of tentacles or arms used for prey capture, attachment, locomotion, and copulation. - The foot is also incorporated into a funnel associated with the mantle cavity and used for jetlike locomotion. - The molluscan body plan is further modified in that the cephalopod head is in line with the visceral mass. - Cephalopods have a highly muscular mantle that encloses all of the body except the head and tentacles. - The mantle acts as a pump to bring large quantities of water into the mantle cavity. SHELL Ancestral cephalopods probably had a conical shell. - The only living cephalopod that possesses an external shell is the nautilus. - Septa subdivide its coiled shell. As the nautilus grows, it moves forward, secreting new shell around itself and leaving an empty septum behind. - Only the last chamber is occupied. - When formed, these chambers are fluid filled. A cord of tissue called a siphuncle perforates the septa, absorbing fluids by osmosis and replacing them with metabolic gases. - The amount of gas in the chambers is regulated to alter the buoyancy of the animal. - In all other cephalopods, the shell is reduced or absent. - In cuttlefish, the shell is internal and laid down in thin layers, leaving small, gas-filled spaces that increase buoyancy. Cuttlefish shell, called cuttlebone, is used to make powder for polishing and is fed to pet birds to supplement their diet with calcium. - The shell of a squid is reduced to an internal, chitinous structure called the pen. In addition, squid also have cartilaginous plates in the mantle wall, neck, and head that support the mantle and protect the brain. - The shell is absent in octopuses.
91	Class Cephalopoda (Feeding, Digestion, Gas Exchange, Locomotion) Feeding and digestion - Cephalopods locate their prey by sight and capture prey with tentacles that have adhesive cups. In squid, the margins of these cups are reinforced with tough protein and sometimes possess small hooks. All cephalopods have jaws and a radula. The jaws are powerful, beaklike structures for tearing food, and the radula rasps food, forcing it into the mouth cavity. - Cuttlefish and nautili feed on small invertebrates on the ocean floor. - Octopuses are nocturnal hunters and feed on snails, fish, and crustaceans. Octopuses have salivary glands that inject venom into prey. - Squid feed on fishes and shrimp, which they kill by biting across the back of the head. - The digestive tract of cephalopods is muscular, and peristalsis (coordinated muscular waves) replaces ciliary action in moving food. - Most digestion occurs in a stomach and a large cecum. - Digestion is primarily extracellular, with large digestive glands supplying enzymes. - An intestine end at the anus, near the funnel, and exhalant water carries wastes out of the mantle cavity. Gas exchange LOCOMOTION - As predators, cephalopods depend on their ability to move quickly using a jet-propulsion system. The mantle of cephalopods contains radial and circular muscles. When circular muscles contract, they decrease the volume of the mantle cavity and close collarlike valves to prevent water from moving out of the mantle cavity between the head and the mantle wall. Water is thus forced out of a narrow funnel. - Muscles attached to the funnel control the direction of the animal's movement. mantle muscles bring water into the mantle cavity by increasing the cavity's volume. Posterior fins act as stabilizers in squid and also aid in propulsion and steering in cuttlefish.

	• “Flying squid” (family Onycoteuthidae) have been clocked at speeds of 30 km/hr. Octopuses are more sedentary animals. They may use jet propulsion in an escape response, but normally, they crawl over the substrate using their tentacles. • In most cephalopods, the use of the mantle in locomotion coincides with the loss of an external shell, since a rigid external shell would preclude the jet-propulsion method of locomotion described.
92	Class Cephalopoda (Reproduction and Development) • Cephalopods are dioecious with gonads in the dorsal portion of the visceral mass. The male reproductive tract consists of testes and structures for encasing sperm in packets called spermatophores. • The female reproductive tract produces large, yolky eggs and is modified with glands that secrete gel-like cases around eggs. These cases frequently harden on exposure to seawater. One tentacle of male cephalopods, called the hectocotylus, is modified for spermatophore transfer. • In <i>Loligo</i> and <i>Sepia</i>, the hectocotylus has several rows of smaller suckers capable of picking up spermatophores. • During copulation, male and female tentacles intertwine, and the male removes spermatophores from his mantle cavity. The male inserts his hectocotylus into the mantle cavity of the female and deposits a spermatophore near the opening to the oviduct. Spermatophores have an ejaculatory mechanism that frees sperm from the baseball-bat-shaped capsule. Eggs are fertilized as they leave the oviduct, and are deposited singly or in stringlike masses. • They usually attach to some substrate, such as the ceiling of an octopus’ s den. Octopuses clean developing eggs of debris with their arms and squirts of water. • Cephalopods develop in the confines of the egg membranes, and the hatchlings are miniature adults. Young are never cared for after hatching.
93	Class Cephalopoda (Other maintenance functions) Circulatory System of Cephalopods • Cephalopods, unlike other molluscs, have a closed circulatory system. Blood is confined to vessels throughout its circuit around the body. Capillary beds connect arteries and veins, and exchanges of gases, nutrients, and metabolic wastes occur across capillary walls. In addition to having a heart consisting of two auricles and one ventricle, cephalopods have contractile arteries and structures called branchial hearts. The latter are at the base of each gill and help move blood through the gill. These modifications increase blood pressure and the rate of blood flow—necessary for active animals with relatively high metabolic rates. Large quantities of water circulate over the gills at all times. Excretion • Cephalopods exhibit greater excretory efficiency because of the closed circulatory system. A close association of blood vessels with nephridia allows wastes to filter and secrete directly from the blood into the excretory system. Nervous System • The cephalopod nervous system is unparalleled in any other invertebrate. • Cephalopod brains are large, and their evolution is directly related to cephalopod predatory habits and dexterity. The brain forms by a fusion of ganglia. • Large areas are devoted to controlling muscle contraction (e.g., swimming movements and sucker closing), sensory perception, and functions such as memory and decision making. Research on cephalopod brains has provided insight into human brain functions. Sensory perception The eyes of octopuses, cuttlefish, and squid are similar in structure to vertebrate eyes. This similarity is an excellent example of convergent evolution. In contrast to the vertebrate eye, nerve cells leave the eye from the outside of the eyeball, so that no blind spot exists. • The blind spot of the vertebrate eye is a region of the retina where no photoreceptors exist because of the convergence of nerve cells into the optic nerve. When light falls on the blind spot, no image is perceived. Like many aquatic vertebrates, cephalopods focus by moving the lens back and forth. Cephalopods can form images, distinguish shapes, and discriminate some colors. • The nautiloid eye is less complex. It lacks a lens, and the interior is open to seawater: thus, it acts as a pinhole camera. • Cephalopod <u>statocysts</u> respond to gravity and acceleration, and are in cartilages next to the brain. • <u>Osphradia</u> are present only in <i>Nautilus</i>. • <u>Tactile receptors</u> and additional chemoreceptors are widely distributed over the body.

	Cephalopods have pigment cells called <u>chromatophores</u>. When tiny muscles attached to these pigment cells contract, the chromatophores quickly expand and change the color of the animal. Color changes, in combination with ink discharge, function in alarm responses
94	Phylum Mollusca (Further phylogenetic considerations) Fossil records of molluscan classes indicate that the phylum is over 500 million years old. - Although molluscs have protostome affinities, zoologists do not know the exact relationship of this phylum to other animal phyla. - The discovery of <i>Neopilina</i> (class Monoplacophora) in 1952 seemed to revolutionize ideas regarding the position of the molluscs in the animal phyla. - The most striking feature of <i>Neopilina</i> is a segmental arrangement of gills, excretory structures, and nervous system. - Because annelids and arthropods also have a segmental arrangement of body parts, monoplacophorans were considered a “missing link” between other molluscs and the annelid-arthropod evolutionary line. - This idea was further supported by molluscs, annelids, and arthropods sharing certain protostome characteristics and chitons also showing a repetition of some body parts. - Most zoologists now agree that the segmentation in some molluscs is very different from that of annelids and arthropods. - Although information on the development of the serially repeating structures in <i>Neopilina</i> is not available, no serially repeating structure in any other mollusc develops in an annelid-arthropod fashion. Segmentation is probably not an ancestral molluscan characteristic. - Many zoologists now believe that molluscs diverged from ancient triploblastic stocks independent of any other phylum. - Other zoologists maintain that, in spite of the absence of annelid-like segmentation in molluscs, protostome affinities still tie the molluscs to the annelid-arthropod line. - Whichever is the case, the relationship of the molluscs to other animal phyla is distant. The diversity of body forms and lifestyles in the phylum Mollusca is an excellent example of adaptive radiation. - Molluscs probably began in Precambrian times as slow-moving, marine bottom dwellers. - The development of unique molluscan features allowed them to diversify relatively quickly. - By the end of the Cambrian period, some were filter feeders, some were burrowers, and others were swimming predators. - Later, some molluscs became terrestrial and invaded many habitats, from tropical rain forests to arid deserts. - Zoologists believe that the lack of a shell in the classes Caudofoveata and Aplacophora is a primitive character. - All other molluscs have a shell or are derived from shelled ancestors. - The multipart shell distinguishes the Polyplacophora from other classes. - Other selected synapomorphies, discussed earlier in this chapter, are noted in the cladogram. - There are, of course, other interpretations of molluscan phylogeny. - The extensive adaptive radiation of this phylum has made higher taxonomic relationships difficult to discern.
95	Annelida (Relationship to other animals) RELATIONSHIPS TO OTHER ANIMALS Annelids are protostomes. Protostome characteristics, such as spiral cleavage, a mouth derived from an embryonic blastopore, schizocoelous coelom formation, and trochophore larvae, are present in most members of the phylum Evolution A number of hypotheses account for annelid origins. These hypotheses are tied into hypotheses regarding the origin of the Coelom. Schizocoelous Hypothesis If a schizocoelous origin of the coelom is correct, as many zoologists believe, then the annelids evolved from ancient flatworm stock. Enterocoeles hypothesis On the other hand, if an enterocoelous coelom origin is correct, then annelids evolved from ancient diploblastic animals, and the triploblastic, acoelomate body may have been derived from a triploblastic, coelomate ancestor.

	The recent discovery of a worm, <i>Lobatocerebrum</i>, that shares annelid and flatworm characteristics has lent support to the enterocoelous origin hypothesis.
96	Phylum Annelida (General Characteristics) Characteristics of the phylum Annelida include: 1. Body metameric, bilaterally symmetrical, and wormlike. 2. Protostome characteristics include spiral cleavage, trochophore larvae (when larvae are present), and schizocoelous coelom formation. 3. Paired, epidermal setae. 4. Closed circulatory system. 5. Dorsal suprapharyngeal ganglia and ventral nerve cord(s) with ganglia. 6. Metanephridia (usually) or protonephridia.
97	Phylum Annelida (Metameric Body Form) Metamerism Segmental arrangement of body parts in an animal is called metamerism (Gr. <i>meta</i>, after, <i>mere</i>, part). • Two related functions are probably the primary adaptive features of metamerism: flexible support and efficient locomotion. • compartmentalization of the body has resulted in each segment having its own excretory, nervous, and circulatory structures. Advantages of Metamerism • One advantage of the segmental arrangement of coelomic spaces and muscles is the creation of hydrostatic compartments, which allow a variety of advantageous locomotor and supportive functions not possible in nonmetameric animals that utilize a hydrostatic skeleton. Each segment can be controlled independently of distant segments, and muscles can act as antagonistic pairs within a segment. The constant volume of coelomic fluid provides a hydrostatic skeleton against which muscles operate. Resultant localized changes in the shape of groups of segments provide the basis for swimming, crawling, and burrowing. • A second advantage of metamerism is that it lessens the impact of injury. If one or a few segments are injured, adjacent segments, set off from injured segments by septa, may be able to maintain nearly normal functions, which increases the likelihood that the worm, or at least a part of it, will survive the trauma. • A third advantage of metamerism is that it permits the modification of certain regions of the body for specialized functions, such as feeding, locomotion, and reproduction. The specialization of body regions in a metameric animal is called tagmatization (Gr. <i>tagma</i>, arrangement). Anilids and Arthropods Similarities (important) • Although it is best developed in the arthropods, some annelids also display tagmatization. • The arthropods include animals such as insects, spiders, mites, ticks, and crayfish. Because of similarities in the development of metamerism in the two groups, annelids and arthropods are thought to be closely related. • Other common features include <u>triploblastic coelomate organization, bilateral symmetry, a complete digestive tract, and a ventral nerve cord</u>. • As usual, fossil evidence documenting ancestral pathways that led from a common ancestor to the earliest representatives of these two phyla is scant. • Annelids and arthropods may have evolved from a marine, wormlike, bilateral ancestor that possessed metameric design. Muscle System • A layer of circular muscles lies below the epidermis, and a layer of longitudinal muscles, just below the circular muscles, runs between the septa that separate each segment. • In addition, some polychaetes have oblique muscles, and the leeches have dorsoventral muscles.

98	Class Polychaeta (External structure and Locomotion) - polychaetas construct tubes of cemented sand grains or secreted organic materials. Mucus-lined tubes serve as protective retreats and feeding stations. EXTERNAL STRUCTURE AND LOCOMOTION - In addition to metamerism, the most distinctive feature of polychaetes is the presence of lateral extensions called parapodia (Gr. <i>para</i>, beside <i>podion</i>, little foot). Chitinous rods support the parapodia, and numerous setae project from the parapodia, giving them their class name. Setae (L. <i>saeta</i>, bristle) are bristles secreted from invaginations of the distal ends of parapodia. They aid locomotion by digging into the substrate and also hold a worm in its burrow or tube. - The prostomium (Gr. <i>pro</i>, before <i>stoma</i>, mouth) of a polychaete is a lobe that projects dorsally and anteriorly to the mouth and contains numerous sensory structures, including eyes, antennae, palps, and ciliated pits or grooves, called nuchal organs. - The first body segment, the peristomium (Gr. <i>peri</i>, around), surrounds the mouth and bears sensory tentacles or cirri. - The epidermis of polychaetes consists of a single layer of columnar cells that secrete a protective, nonliving cuticle. - Some polychaetes have epidermal glands that secrete luminescent compounds.
99	Class Polychaeta (Feeding and the digestive system) - The digestive tract of polychaetas is a <u>straight tube</u> that <u>mesenteries</u> and septa suspend in the body cavity. The anterior region of the digestive tract is modified into a <u>proboscis</u> that special <u>protractor</u> muscles and coelomic pressure can evert through the mouth. <u>Retractor muscles</u> bring the proboscis back into the peristomium. - In some, when the proboscis is everted, paired jaws are opened and may be used for seizing prey. - Predatory polychaetes may not leave their burrow or coral crevice. When prey approaches a burrow entrance, the worm quickly extends its anterior portion, everts the proboscis, and pulls the prey back into the burrow. - Some polychaetes have poison glands at the base of the jaw. - Other polychaetes are herbivores and scavengers and use jaws for tearing food. - Filter feeding - Tube dwelling
100	Class Polychaeta (Gas Exchange and Circulation) - Respiratory gases of most annelids simply diffuse across the body wall, and parapodia increase the surface area for these exchanges. In many polychaetes, parapodial gills further increase the surface area for gas exchange. Circulatory System - Polychaetes have a closed circulatory system. Oxygen is usually carried in combination with molecules called respiratory pigments, which are usually dissolved in the plasma rather than contained in blood cells. - Blood may be colorless, green, or red, depending on the presence and/or type of respiratory pigment. - Contractile elements of polychaete circulatory systems consist of a dorsal aorta that lies just above the digestive tract and propels blood from rear to front, and a ventral aorta that lies ventral to the digestive tract and propels blood from front to rear. - Running between these two vessels are two or three sets of segmental vessels that receive blood from the ventral aorta and break into capillary beds in the gut and body wall. - Capillaries coalesce again into segmental vessels that deliver blood to the dorsal aorta.
101	Class Polychaeta (Nervous and Sensory Functions) - Nervous systems are similar in all three classes of annelids. - The annelid nervous system includes a pair of suprapharyngeal ganglia, which connect to a pair of subpharyngeal ganglia by circumpharyngeal connectives that run dorsoventrally along either side of the pharynx. - A double ventral nerve cord runs the length of the worm along the ventral margin of each coelomic space, and a paired segmental ganglion is in each segment. - The double ventral nerve cord and paired segmental ganglia may fuse to varying extents in different taxonomic groups. - Lateral nerves emerge from each segmental ganglion, supplying the body-wall musculature and other structures of that segment. - Segmental ganglia coordinate swimming and crawling movements in isolated segments.

	• Each segment acts separately from, but is closely coordinated with, neighboring segments. • The subpharyngeal ganglia help mediate locomotor functions requiring coordination of distant segments. • The suprapharyngeal ganglia probably control motor and sensory functions involved with feeding, and sensory functions associated with forward locomotion. • In addition to small-diameter fibers that help coordinate locomotion, the ventral nerve cord also contains giant fibers involved with escape reactions. • For example, a harsh stimulus, such as a fishhook, at one end of a worm causes rapid withdrawal from the stimulus. • Giant fibers are approximately 50 μm in diameter and conduct nerve impulses at 30 m/second (as opposed to 0.5 m/second in the smaller, 4 μm diameter annelid fibers). • Polychaetes have various sensory structures. • Two to four pairs of eyes are on the surface of the prostomium. • They vary in complexity from a simple cup of receptor cells to structures made up of a cornea, lens, and vitreous body. • Most polychaetes react negatively to increased light intensities. • Fanworms, however, react negatively to decreasing light intensities. • If shadows cross them, fanworms retreat into their tubes. • This response is believed to help protect fanworms from passing predators. • Nuchal organs are pairs of ciliated sensory pits or slits in the head region.
10 2	Class Polychaeta (Excretion) • Annelids excrete ammonia, and because ammonia diffuses readily into the water, most nitrogen excretion probably occurs across the body wall. • Excretory organs of annelids are more active in regulating water and ion balances, although these abilities are limited. • Most marine polychaetes, if presented with extremely diluted seawater, cannot survive the osmotic influx of water and the resulting loss of ions. • The evolution of efficient osmoregulatory abilities has allowed only a few polychaetes to invade freshwater. • The excretory organs of annelids, like those of many invertebrates, are called nephridia. • Annelids have two types of nephridia. • A protonephridium consists of a tubule with a closed bulb at one end and a connection to the outside of the body at the other end. • Protonephridia have a tuft of flagella in their bulbular end that drives fluids through the tubule. • Some primitive polychaetes possess paired, segmentally arranged protonephridia that have their bulbular end projecting through the anterior septum into an adjacent segment and the opposite end opening through the body wall at a nephridiopore. • Most polychaetes possess a second kind of nephridium, called a metanephridium. • A metanephridium consists of an open, ciliated funnel, called a nephrostome, that projects through an anterior septum into the coelom of an adjacent segment. • At the opposite end, a tubule opens through the body wall at a nephridiopore or, occasionally, through the intestine. • There is usually one pair of metanephridia per segment, and tubules maybe extensively coiled, with one portion dilated into a bladder. • A capillary bed is usually associated with the tubule of a metanephridium for active transport of ions between the blood and the nephridium. • Some polychaetes also have chloragogen tissue associated with the digestive tract. • This tissue functions in amino acid metabolism in all annelids and is described further in the discussion of oligochaetes.
10 3	Class Polychaeta (Regeneration, Reproduction and Development) • All polychaetes have remarkable powers of regeneration. • They can replace lost parts, and some species have break points that allow worms to sever themselves when a predator grabs them. • Lost segments are later regenerated. • Some polychaetes reproduce asexually by budding or by transverse fission; however, sexual reproduction is much more common. • Most polychaetes are dioecious.

	• Gonads develop as masses of gametes and project from the coelomic peritoneum. • Primitively, gonads occur in every body segment, but most polychaetes have gonads limited to specific segments. • Gametes are shed into the coelom, where they mature. • Mature female worms are often packed with eggs. • Gametes may exit worms by entering nephrostomes of metanephridia and exiting through the nephridiopore, or they may be released, in some polychaetes, after the worm ruptures. In these cases, the adult soon dies. • Only a few polychaetes have separate gonoducts, a condition believed to be primitive. • Fertilization is external in most polychaetes, although a few species copulate. • A unique copulatory habit has been reported in <i>Platynereis megalops</i> from Woods Hole, Massachusetts. • Toward the end of their lives, male and female worms cease feeding, and their intestinal tracts begin to degenerate. • At this time, gametes have accumulated in the body cavity. • During sperm transfer, male and female worms coil together, and the male inserts his anus into the mouth of the female. • Because the digestive tracts of the worms have degenerated, sperm transfer directly from the male's coelom to the egg-filled coelom of the female. • This method ensures fertilization of most eggs, after which the female sheds eggs from her anus. • Both worms die soon after copulation. • Epitoky is the formation of a reproductive individual (an epitoke) that differs from the nonreproductive form of the species (an atoke). • Frequently, an epitoke has a body that is modified into two body regions. • Anterior segments carry on normal maintenance functions, and posterior segments are enlarged and filled with gametes. • The epitoke may have modified parapodia for more efficient swimming. • Zoologists believe that swarming of epitokes accomplishes at least three things. • First, because nonreproductive individuals remain safe below the surface waters, predators cannot devastate an entire population. • Second, external fertilization requires that individuals become reproductively active at the same time and in close proximity to one another. • Swarming ensures that large numbers of individuals are in the right place at the proper time. • Third, swarming of vast numbers of individuals for brief periods provides a banquet for predators. • However, because vast numbers of prey are available for only short periods during the year, predator populations cannot increase beyond the limits of their normal diets. • Therefore, predators can dine gluttonously and still leave epitokes that will yield the next generation of animals. • Spiral cleavage of fertilized eggs may result in planktonic trochophore larvae that bud segments anterior to the anus. • Larvae eventually settle to the substrate. • As growth proceeds, newer segments continue to be added posteriorly. • Thus, the anterior end of a polychaete is the oldest end. • Many other polychaetes lack a trochophore and display direct development or metamorphosis from another larval stage.
10 4	Class Oligochaeta (External structure and Locomotion) • The class Oligochaeta has over three thousand species found throughout the world in freshwater and terrestrial habitats. • A few oligochaetes are estuarine, and some are marine. • Aquatic species live in shallow water, where they burrow in mud and debris. • Terrestrial species live in soils with high organic content and rarely leave their burrows. • In hot, dry weather, they may retreat to depths of 3 m below the surface. • Soil conditioning habits of earthworms are well known. • <i>Lumbricus terrestris</i> is commonly used in zoology laboratories because of its large size. • It was introduced to the United States from northern Europe and has flourished. • Common native species like <i>Eisenia foetida</i> and various species of <i>Allolobophora</i> are smaller.

	External Structure and Locomotion • Oligochaetes (Gr. <i>oligos</i>, few <i>chaite</i>, hair) have setae, but fewer than are found in polychaetes (thus, the derivation of the class name). • Oligochaetes lack parapodia because parapodia and long setae would interfere with their burrowing lifestyles, although they do have short setae on their integument. • The prostomium consists of a small lobe or cone in front of the mouth and lacks sensory appendages. • A series of segments in the anterior half of an oligochaete is usually swollen into a girdlelike structure called the clitellum that secretes mucus during copulation and forms a Cocoon. • As in the polychaetes, a nonliving, secreted cuticle covers the body. • Oligochaete locomotion involves the antagonism of circular and longitudinal muscles in groups of segments. • Neurally controlled waves of contraction move from rear to front. • Segments bulge and setae protrude when longitudinal muscles contract, providing points of contact with the burrow wall. • In front of each region of longitudinal muscle contraction, circular muscles contract, causing the setae to retract, and the segments to elongate and push forward. • Contraction of longitudinal muscles in segments behind a bulging region pulls those segments forward. • Thus, segments move forward relative to the burrow as waves of muscle contraction move anteriorly on the worm. • Burrowing is the result of coelomic hydrostatic pressure being transmitted toward the prostomium. • As an earthworm pushes its way through the soil, it uses expanded posterior segments and protracted setae to anchor itself to its burrow wall. • Any person pursuing fishing worms experiences the effectiveness of this anchor when trying to extract a worm from its burrow. • As an earthworm pushes its way through the soil, it uses expanded posterior segments and protracted setae to anchor itself to its burrow wall. • Any person pursuing fishing worms experiences the effectiveness of this anchor when trying to extract a worm from its burrow. • Contraction of circular muscles transforms the prostomium into a conical wedge, 1 mm in diameter at its tip. • Contraction of body-wall muscles generates coelomic pressure that forces the prostomium through the soil. • During burrowing, earthworms swallow considerable quantities of soil.
10 5	Class Oligochaeta (Feeding and the Digestive System) • Oligochaetes are scavengers and feed primarily on fallen and decaying vegetation, which they drag into their burrows at night. • The digestive tract of oligochaetes is tubular and straight. • The mouth leads to a muscular pharynx. • In the earthworm, pharyngeal muscles attach to the body wall. • The pharynx acts as a pump for ingesting food. • The mouth pushes against food, and the pharynx pumps the food into the esophagus. • The esophagus is narrow and tubular, and frequently expands to form a stomach, crop, or gizzard; the latter two are common in terrestrial species. • A crop is a thin-walled storage structure, and a gizzard is a muscular, cuticle-lined grinding structure. • Calciferous glands are evaginations of the esophageal wall that rid the body of excess calcium absorbed from food. • They also help regulate the pH of body fluids. • The intestine is a straight tube and is the principal site of digestion and absorption. • A dorsal fold of the luminal epithelium called the typhlosole substantially increases the surface area of the intestine. • The intestine ends at the anus.

10 6	Class Oligochaeta (Gas Exchange and Circulation) • Oligochaete respiratory and circulatory functions are as described for polychaetes. • Some segmental vessels expand and may be contractile. • In the earthworm, for example, expanded segmental vessels surrounding the esophagus propel blood between dorsal and ventral blood vessels and anteriorly in the ventral vessel toward the mouth. • Even though these are sometimes called “hearts,” the main propulsive structures are the dorsal and ventral vessels. • Branches from the ventral vessel supply the intestine and body wall.
10 7	Class Oligochaeta (Nervous and Sensory Functions) • The ventral nerve cords and all ganglia of oligochaetes have undergone a high degree of fusion. • Other aspects of nervous structure and function are essentially the same as those of polychaetes. • As with polychaetes, giant fibers mediate escape responses. • An escape response results from the stimulation of either the anterior or posterior end of a worm. • An impulse conducted to the opposite end of the worm initiates the formation of an anchor, and longitudinal muscles contract to quickly pull the worm away from the stimulus. • Oligochaetes lack well-developed eyes, which is not surprising, given their subterranean lifestyle. • Animals living in perpetual darkness often do not have well-developed eyes. • Other oligochaetes have simple pigment-cup ocelli, and all have a “dermal light sense” that arises from photoreceptor cells scattered over the dorsal and lateral surfaces of the body. • Scattered photoreceptor cells mediate a negative phototaxis in strong light (evidenced by movement away from the light source) and a positive phototaxis in weak light (evidenced by movement toward the light source). • Oligochaetes are sensitive to a wide variety of chemical and mechanical stimuli. • Receptors for these stimuli are scattered over the body surface, especially around the prostomium.
10 8	Class Oligochaeta (Excretion) • Oligochaetes use metanephridia for excretion and for ion and water regulation. • As with polychaetes, funnels of metanephridia are associated with the segment just anterior to the segment containing the tubule and the nephridiopore. • Nitrogenous wastes include ammonia and urea. • Oligochaetes excrete copious amounts of very dilute urine, although they retain vital ions, which is important for organisms living in environments where water is plentiful but essential ions are limited. • Oligochaetes (as well as other annelids) possess chloragogen tissue that surrounds the dorsal blood vessel and lies over the dorsal surface of the intestine. • Chloragogen tissue acts similarly to the vertebrate liver. • It is a site of amino acid metabolism. • Chloragogen tissue deaminates amino acids and converts ammonia to urea. • It also converts excess carbohydrates into energy-storage molecules of glycogen and fat.
10 9	Class Oligochaeta (Regeneration, Reproduction and Development) • All oligochaetes are monoecious and exchange sperm during copulation. • One or two pairs of testes and one pair of ovaries are located on the anterior septum of certain anterior segments. • Both the sperm ducts and the oviducts have ciliated funnels at their proximal ends to draw gametes into their respective tubes. • Testes are closely associated with three pairs of seminal vesicles, which are sites for maturation and storage of sperm prior to their release. • Seminal receptacles receive sperm during copulation. • A pair of very small ovisacs, associated with oviducts, are sites for the maturation and storage of eggs prior to egg release. • During copulation of <i>Lumbricus</i>, two worms line up facing in opposite directions, with the ventral surfaces of their anterior ends in contact with each other. • This orientation lines up the clitellum of one worm with the genital segments of the other worm. • A mucous sheath that the clitellum secretes envelops the anterior halves of both worms and holds the worms in place. • Some species also have penile structures and genital setae that help maintain contact between worms.

	• In <i>Lumbricus</i>, the sperm duct releases sperm, which travel along the external, ventral body wall in sperm grooves formed when special muscles contract. • Muscular contractions along this groove help propel sperm toward the openings of the seminal receptacles. • In other oligochaetes, copulation results in the alignment of sperm duct and seminal receptacle openings, and sperm transfer is direct. • Copulation lasts two to three hours, during which both worms give and receive sperm. • Following copulation, the clitellum forms a cocoon for the deposition of eggs and sperm. • The cocoon consists of mucoid and chitinous materials that encircle the clitellum. • The clitellum secretes a food reserve, albumen, into the cocoon, and the worm begins to back out of the cocoon. • Eggs are deposited in the cocoon as the cocoon passes the openings to the oviducts, and sperm are released as the cocoon passes the openings to the seminal receptacles. • Fertilization occurs in the cocoon, and as the worm continues backing out, the ends of the cocoon are sealed, and the cocoon is deposited in moist soil. • Spiral cleavage is modified, and no larva forms. • Hatching occurs in one to a few weeks, depending on the species, when young worms emerge from one end of the cocoon. • Freshwater oligochaetes also reproduce asexually. • Asexual reproduction involves transverse division of a worm, followed by the regeneration of missing segments.
110	Class Hirudinea (External Structure and Locomotion) • The class Hirudinea (<i>L. hirudin</i>, leech) contains approximately five hundred species of leeches. • Most leeches are freshwater; others are marine or completely terrestrial. • Leeches prey on small invertebrates or feed on the body fluids of vertebrates. EXTERNAL STRUCTURE AND LOCOMOTION Leeches lack parapodia and head appendages. • Setae are absent in most leeches. • In a few species, setae occur only on anterior segments. • Leeches are dorsoventrally flattened and taper anteriorly. • They have 34 segments, but the segments are difficult to distinguish externally because they have become secondarily divided. • Several secondary divisions, called annuli, are in each true segment. • Anterior and posterior segments are usually modified into suckers. • Modifications of body-wall musculature and the coelom influence patterns of leech locomotion. • The musculature of leeches is more complex than that of other annelids. • A layer of oblique muscles is between the circular and longitudinal muscle layers. • In addition, dorsoventral muscles are responsible for the typical leech flattening. • The leech coelom has lost its metameric partitioning. • Septa are lost, and connective tissue has invaded the coelom, resulting in a series of interconnecting sinuses. • These modifications have resulted in altered patterns of locomotion. • Rather than being able to utilize independent coelomic compartments, the leech has a single hydrostatic cavity and uses it in a looping type of locomotion. • Leeches also swim using undulations of the body.
111	Class Hirudinea (Feeding and the Digestive System) • Many leeches feed on body fluids or the entire bodies of other invertebrates. • Some feed on the blood of vertebrates, including human blood. • Leeches are sometimes called parasites; however, the association between a leech and its host is relatively brief. • Therefore, describing leeches as predatory is probably more accurate. • Leeches are also not species specific, as are most parasites. • Leeches are, however, class specific. • That is, a leech that preys on a turtle may also prey on an alligator, but probably would not prey on a fish or a frog.

	• The mouth of a leech opens in the middle of the anterior sucker. • In some leeches, the anterior digestive tract is modified into a protrusible proboscis, lined inside and outside by a cuticle. • In others, the mouth is armed with three chitinous jaws. • While feeding, a leech attaches to its prey by the anterior sucker and either extends its proboscis into the prey or uses its jaws to slice through host tissues. • Salivary glands secrete an anticoagulant called hirudin that prevents blood from clotting. • Behind the mouth is a muscular pharynx that pumps body fluids of the prey into the leech. • The esophagus follows the pharynx and leads to a large stomach with lateral cecae. • Most leeches ingest large quantities of blood or other body fluids and gorge their stomachs and lateral cecae, increasing their body mass 2 to 10 times. • After engorgement, a leech can tolerate periods of fasting that may last for months. • The digestive tract ends in a short intestine and anus.
11 2	Class Hirudinea (Gas Exchange and Circulation) • Leeches exchange gases across the body wall. • Some leeches retain the basic annelid circulatory pattern, but in most leeches, it is highly modified, and coelomic sinuses replace vessels. • Coelomic fluid has taken over the function of blood and, except in two orders, respiratory pigments are lacking. • Similar to earth worms, leeches obtain oxygen and carbon dioxide in a gas exchange through the epidermis. • Once oxygen makes it into the blood, it is carried throughout the body by the pigment hemoglobin, this pigment is specifically designed for respiration. • Leeches do not maintain any specific respiratory organ, in which they do not have a definite respiratory system. • Hemodynamics in the leech, blood flow in two hearts switching between two constriction patterns. • Two tubular, segmented hearts propel blood through the closed circulatory system of the medicinal leech and switch every 20-40 beats between two constriction patterns.
11 3	Class Hirudinea (Excretion) • Leeches have 10 to 17 pairs of metanephridia, one per segment in the middle segments of the body. • Their metanephridia are highly modified and possess, in addition to the nephrostome and tubule, a capsule believed to be involved with the production of coelomic fluid. • Chloragogen tissue proliferates through the body cavity of most leeches. • Leeches excrete the plasma from their ingested blood meals. • Excretion is activated during ingestion, which increases feeding efficiency by increasing the proportion of blood cells in the ingestate. • Leech ingestion comprises stereotyped muscular movements, secretion of saliva and excretion of plasma.
11 4	Class Hirudinea (Nervous and Sensory Functions) • The leech nervous system is similar to that of other annelids. • Ventral nerve cords are unfused, except at the ganglia. • The suprapharyngeal and subpharyngeal ganglia and the pharyngeal connectives all fuse into a nerve ring that surrounds the pharynx. • Ganglia at the posterior end of the animal fuse in a similar way. • A variety of epidermal sense organs are widely scattered over the body. • Most leeches have photoreceptor cells in pigment cups (2 to 10) along the dorsal surface of the anterior segments. • Normally, leeches are negatively phototactic, but when they are searching for food, the behavior of some leeches' changes, and they become positively phototactic, which increases the likelihood of contacting prey that happen to pass by. • Hirudo medicinalis, the medicinal leech, has a well-developed temperature sense, which helps it to detect the higher body temperature of its mammalian prey. • Other leeches are attracted to extracts of prey tissues. • All leeches have sensory cells with terminal bristles in a row along the middle annulus of each segment. • These sensory cells, called sensory papillae, are of uncertain function but are taxonomically important.

11 5	Class Hirudinea (Regeneration, Reproduction and Development) • All leeches reproduce sexually and are monoecious. • None are capable of asexual reproduction or regeneration. • They have a single pair of ovaries and from four to many testes. • Leeches have a clitellum that includes three body segments. • The clitellum is present only in the spring, when most leeches breed. • Sperm transfer and egg deposition usually occur in the same manner as described for oligochaetes. • A penis assists sperm transfer between individuals. • A few leeches transfer sperm by expelling a spermatophore from one leech into the integument of another, a form of hypodermic impregnation. • Special tissues within the integument connect to the ovaries by short ducts. • Cocoons are deposited in the soil or are attached to underwater objects. • There are no larval stages, and the offspring are mature by the following spring.
11 6	Phylum Annelida (Further Phylogenetic Considerations) • According to the traditional interpretation, the ancestral polychaetes gave rise to modern polychaetes through adaptive radiation and a group of annelids that invaded freshwater. • This freshwater invasion required the ability to regulate the salt and water content of body fluids. • The oligochaetes are assumed to have evolved from this group, and some of these early oligochaetes are believed to have given rise to the Hirudinea. • Recent cladistic analysis of the phylum Annelida has cast a shadow on this traditional interpretation. • These studies suggest that the phylum Annelida is not a monophyletic grouping and that the polychaetes arose from a metameric ancestor independently of the oligochaetes and leeches. • The oligochaetes and leeches form a single clade, and share important characteristics, including the presence of a clitellum. • No synapomorphies (derived characteristics) are unique to the oligochaetes. • Instead, the oligochaetes are defined by the absence of leech characteristics. • These facts support the conclusion that the oligochaetes and leeches should be combined into a single group—Clitellata. • If these conclusions are true, then the Polychaeta, Clitellata, Arthropoda and Pogonophora probably all had their origins in an ancestral metameric species, and the phylum name “Annelida” should be abandoned. • Adding to the uncertainty regarding annelid systematics has been the discovery of microscopic marine annelids grouped as “Archiannelida.” • Like <i>Lobatocerebrum</i>, these annelids lack a coelom, setae, and some other annelid characteristics. • The group is poorly known, and its taxonomic relationships to other annelids are not established. • Some of these worms appear to be close to an ancestral form; others are probably derived from the polychaete lineage. • When more work on these annelids has been completed, the picture of evolutionary relationships among the annelid groups may be substantially different from current ideas. • The traditional interpretations of later annelid evolution are probably still accurate. • The evolutionary history of the polychaetes is a story of impressive adaptive radiation into the variety of body forms and habits described earlier in this chapter. • A few polychaetes adapted to freshwater environments. • During the Cretaceous period, approximately 100 million years ago, oligochaetes invaded moist, terrestrial environments. • This period saw the climax of the giant land reptiles, but more importantly, it was a time of proliferation of flowering plants. • The reliance of modern oligochaetes on deciduous vegetation can be traced back to their ancestors’ exploitation of this food resource. • A few oligochaetes secondarily invaded marine environments. • Some of the early freshwater oligochaetes gave rise to the leeches. • As with the oligochaetes, the leeches colonized marine and terrestrial habitats from freshwater.

Arthropods (Blueprint for success: Classification of arthropods)

Copepods have been very successful, feeding on the vast photosynthetic production of the open oceans. After only 20 minutes of towing a plankton net behind a slowly moving boat (at the right location and during the right time of year), you can collect over three million copepods—enough to solidly pack a two-gallon pail.

- Copepods are food for fish, such as herring, sardines, and mackerel, as well as for whale sharks and the largest mammals, the blue whale and its relatives.
- Humans benefit from copepod production by eating fish that feed on copepods.

Phylum Arthropoda

Animals that show metamerism with tagmatization, a jointed exoskeleton, and a central nervous system.

- **Subphylum Trilobitomorpha**

Marine, all extinct; lived from Cambrian to Carboniferous periods; bodies divided into three longitudinal lobes; head, thorax, and abdomen present; one pair of antennae and biramous appendages.

- **Subphylum Chelicerata**

Body usually divided into prosoma and opisthosoma; first pair of appendages piercing or pincerlike (chelicerae) and used for feeding.

- **Class Merostomata**

Marine, with book gills on opisthosoma. Two subclasses: Eurypterida, a group of extinct arthropods called giant water scorpions, and Xiphosura, the horseshoe crabs. *Limulus*.

- **Class Arachnida**

Mostly terrestrial, with book lungs, tracheae, or both; usually four pairs of walking legs in adults. Spiders, scorpions, ticks, mites, harvestmen, and others.

- **Class Pycnogonida**

Reduced abdomen; no special respiratory or excretory structures; four to six pairs of walking legs; common in all oceans. Sea spiders.

- **Subphylum Crustacea**

Most aquatic, head with two pairs of antennae, one pair of mandibles, and two pairs of maxillae; biramous appendages.

- **Class Remipedia**

A single species of cave-dwelling crustaceans from the Bahamas; body with approximately 30 segments that bear uniform, biramous appendages.

- **Class Cephalocarida**

Small (3 mm) marine crustaceans with uniform, leaflike, triramous appendages.

- **Class Branchiopoda**

Flattened, leaflike appendages used in respiration, filter feeding, and locomotion, found mostly in freshwater. Fairy shrimp, brine shrimp, clam shrimp, water fleas.

- **Class Malacostraca**

Appendages possibly modified for crawling, feeding, and swimming. Lobsters, crayfish, crabs, shrimp, isopods (terrestrial).

- **Class Copepoda**

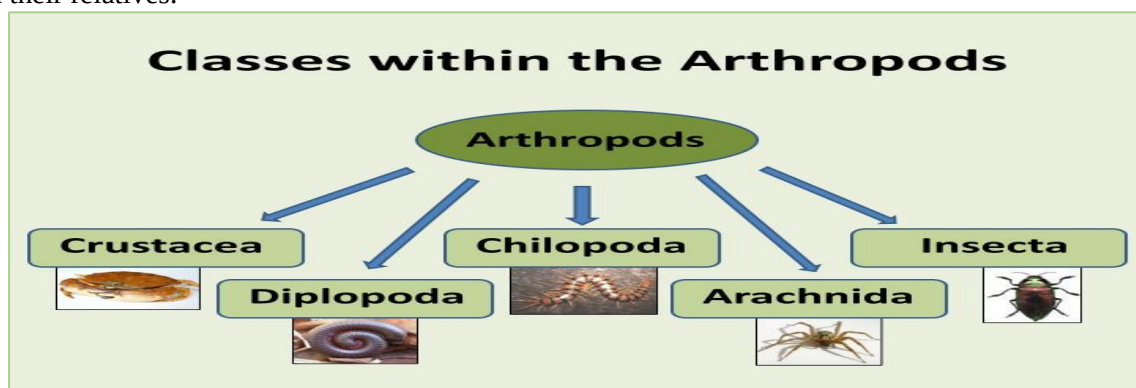
Maxillipeds modified for feeding and antennae modified for swimming. Copepods.

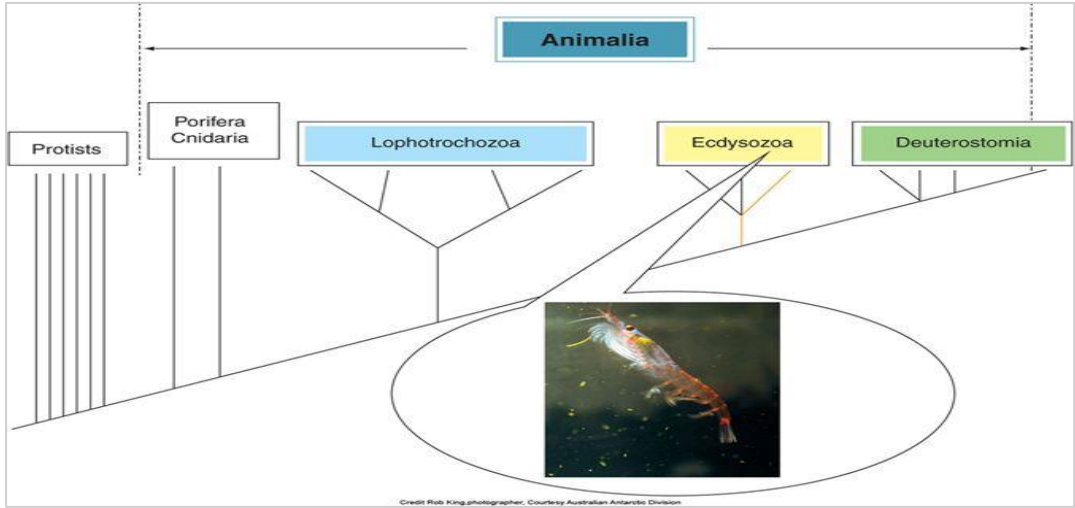
- **Class Cirripedia**

Sessile as adults, marine, and enclosed by calcium carbonate valves. Barnacles.

- **Subphylum Uniramia**

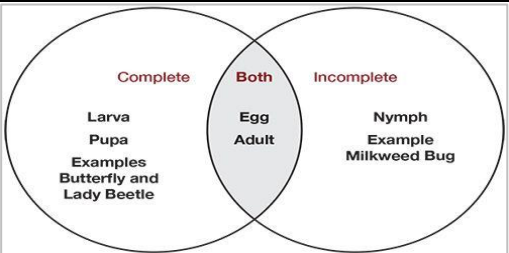
Head with one pair of antennae and usually one pair of mandibles; all appendages uniramous. Insects and their relatives.



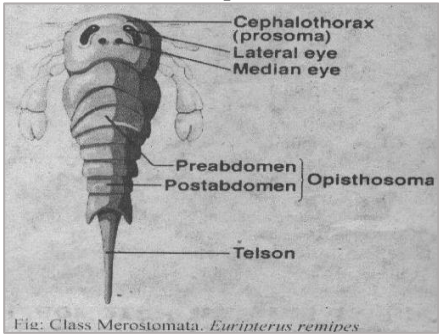
118	Phylum Arthropods (Relationship to Other Animals) • Arthropods and annelids are closely related, shared protostome characteristics, such as schizocoelous coelom formation and the development of the mouth from the blastopore. • As well as other common characteristics, such as the presence of a paired ventral nerve cord and metamerism, are evidence of a common ancestry. • Zoologists, however, disagree about the evolutionary relationships among the arthropods. • Many zoologists believe that it is not one phylum, but three. • Living arthropods are divided into three subphyla: Chelicerata, Crustacea, and Uniramia. • All members of a fourth subphylum, Trilobitomorpha, are extinct.
	 The diagram is a phylogenetic tree of the animal kingdom. At the top is a box labeled 'Animalia'. Below it, the tree branches into five main groups: Protists, Porifera/Cnidaria, Lophotrochozoa, Ecdysozoa, and Deuterostomia. Each group is represented by a box. The Ecdysozoa box is highlighted in yellow. A central image of a crayfish is shown, with lines connecting it to the Ecdysozoa box and the Lophotrochozoa box, indicating its evolutionary position. The image is credited to Rob King photographer, Courtesy Australian Antarctic Division.
119	Phylum Arthropoda (Metamerism and Tagmatization) • Three aspects of arthropod biology have contributed to their success. • One of these is metamerism. • Metamerism of arthropods is most evident externally because the arthropod body is often composed of a series of similar segments, each bearing a pair of appendages. • Internally, however, septa do not divide the body cavity of an arthropod, and most organ systems are not metamerically arranged. • The reason for the loss of internal metamerism is speculative; however, the presence of metamerically arranged hydrostatic compartments would be of little value in the support or locomotion of animals enclosed by an external skeleton. • Metamerism permits the specialization of regions of the body for specific functions. • This regional specialization is called tagmatization. In arthropods, body regions, called tagmata (sing., tagma), are specialized for feeding and sensory perception, locomotion, and visceral functions.
120	Phylum Arthropoda (General Characteristics) • Copepods are one of many groups of animals belonging to the phylum Arthropoda (Gr. <i>arthro</i>, joint <i>podos</i>, foot). Crayfish, lobsters, spiders, mites, scorpions, and insects are also arthropods. • Zoologists have described about one million species of arthropods, and recent studies estimate that 30 to 50 million species may yet be undescribed. Characteristics of the phylum Arthropoda include: 1. Metamerism modified by the specialization of body regions for specific functions (tagmatization). 2. Chitinous exoskeleton that provides support and protection and is modified to form sensory structures. 3. Paired, jointed appendages. 4. Growth accompanied by ecdysis or molting. 5. Ventral nervous system. 6. Coelom reduced to cavities surrounding gonads and sometimes excretory organs.

	7. Open circulatory system in which blood is released into tissue spaces (hemocoel) derived from the blastocoel. 8. Complete digestive tract. 9. Metamorphosis often present; reduces competition between immature and adult stages.
121	Phylum Arthropoda (The Exoskeleton) • An external, jointed skeleton, called an exoskeleton or cuticle, encloses arthropods. • The exoskeleton is often cited as the major reason for arthropod success. • It provides structural support, protection, impermeable surfaces for the prevention of water loss, and a system of levers for muscle attachment and movement. • The exoskeleton covers all body surfaces and invaginations of the body wall, such as the anterior and posterior portions of the gut tract. • It is nonliving and is secreted by a single layer of epidermal cells. • The epidermal layer is sometimes called the hypodermis because, unlike other epidermal tissues, it is covered on the outside by exoskeleton, rather than being directly exposed to air or water.
122	Phylum Arthropoda (Composition of Exoskeleton) • The exoskeleton has two layers. • The epicuticle is the outermost layer. • Made of a waxy lipoprotein, it is impermeable to water and a barrier to microorganisms and pesticides. • The bulk of the exoskeleton is below the epicuticle and is called the procuticle. • In crustaceans, the procuticle is sometimes called the endocuticle. • The procuticle is composed of chitin, a tough, leathery polysaccharide, and several kinds of proteins. • The procuticle hardens through a process called sclerotization and sometimes by impregnation with calcium carbonate. • Sclerotization is a tanning process in which layers of protein are chemically cross-linked with one another hardening and darkening the exoskeleton. • In insects and most other arthropods, this bonding occurs in the outer portion of the procuticle. • The exoskeleton of crustaceans hardens by sclerotization and by the deposition of calcium carbonate in the middle regions of the procuticle. • Some proteins give the exoskeleton resiliency. • Distortion of the exoskeleton stores energy for such activities as flapping wings and jumping. • The inner portion of the procuticle does not harden.
123	Phylum Arthropoda (Modifications in Exoskeleton) • Hardening in the procuticle provides armorlike protection for arthropods, but it also necessitates a variety of adaptations to allow arthropods to live and grow within their confines. • Invaginations of the exoskeleton form firm ridges and bars for muscle attachment. • Another modification of the exoskeleton is the formation of joints. • A flexible membrane, called an articular membrane, is present in regions where the procuticle is thinner and less hardened. • Other modifications of the exoskeleton include sensory receptors, called sensilla, in the form of pegs, bristles, and lenses, and modifications of the exoskeleton that <u>permit gas exchange</u>.
124	Phylum Arthropoda (Advantages of Exoskeleton) • One advantage an exoskeleton provides is a strong outer layer that acts as armor against predators and environmental hazards. • It also serves as a protective water barrier, and it imparts advantages related to structure and mobility. • Like endoskeletons, exoskeletons provide structure and support to an animal's body. • However, exoskeletons encase all of an animal's living tissues, protecting them from damage and attack. • Muscles used for locomotion attach directly to the exoskeleton, giving the animal better leverage for rapid movement. • One of the most important functions of an exoskeleton is to prevent land-dwelling species from drying out. This is crucial because of the vital role played by water in physiological processes.

	• On the other hand, an exoskeleton protects ocean-dwelling animals from being affected by small changes in the <u>saltiness of water</u> in their environment. • While some exoskeletons are dense, such as the hard shells of clams, the exoskeletons of insects are lightweight, making it possible for them <u>to fly</u>. • Being nonliving, an exoskeleton does not grow with an animal. • Therefore, it must be periodically shed in a process called molting. A new exoskeleton is then formed from epidermal secretions. This process consumes metabolic resources, and the animal is vulnerable until the new exoskeleton hardens.
125	Phylum Arthropoda (What is Ecdysis?) • The growth of an arthropod would be virtually impossible unless the exoskeleton were periodically shed, such as in the molting process called ecdysis (Gr. <i>ekdysis</i>, getting out). • Ecdysis is the moulting of the cuticle in many invertebrates of the clade Ecdysozoa. • Since the cuticle of these animals typically forms a largely inelastic exoskeleton, it is shed during growth and a new, larger covering is formed. • The remnants of the old, empty exoskeleton are called exuviae. • After moulting, an arthropod is described as teneral, a callow; it is "fresh", pale and soft-bodied. • Within one or two hours, the cuticle hardens and darkens following a tanning process analogous to the production of leather. • Ecdysis allows damaged tissue and missing limbs to be regenerated or substantially re-formed. • Complete regeneration may require a series of moults, the stump becoming a little larger with each moult until it is a normal, or near normal, size.
126	Phylum Arthropoda (How does Ecdysis Occur?) • The growth of an arthropod would be virtually impossible unless the exoskeleton were periodically shed, such as in the molting process called ecdysis (Gr. <i>ekdysis</i>, getting out). • Ecdysis is divided into four stages: (1) Enzymes, secreted from hypodermal glands, begin digesting the old procuticle to separate the hypodermis and the exoskeleton. (2) New procuticle and epicuticle are secreted. (3) The old exoskeleton splits open along predetermined ecdysal lines when the animal stretches by air or water intake; pores in the procuticle secrete additional epicuticle. (4) Finally, calcium carbonate deposits and/or sclerotization harden the new exoskeleton. • During the few hours or days of the hardening process, the arthropod is vulnerable to predators and remains hidden.
127	Phylum Arthropoda (Importance of Ecdysis) • Ecdysis is the process of an arthropod moulting its exoskeleton. • Moulting is necessary as the arthropod exoskeleton is inflexible and so, to grow larger, arthropods must moult. • Moulting is a critical but vulnerable time for arthropods. • Their existing cuticle weakens at specific points and by taking in water or air the animal splits its old exoskeleton. • The animal then extracts itself from the old skin and inflates its new skin. • The new exoskeleton is soft and the arthropod can't move because its musculature is attached to this exoskeleton. • Once the new exoskeleton has dried and hardened the animal can move again.

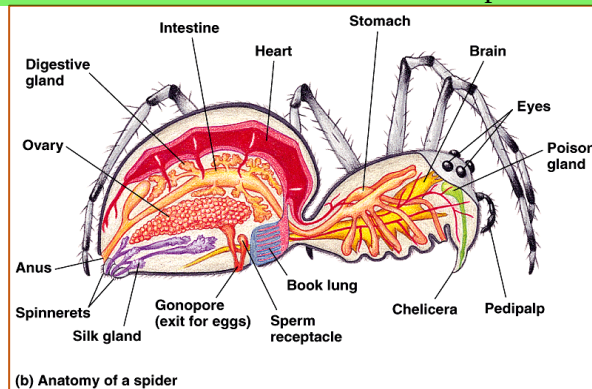
128	Phylum Arthropoda (What is Metamorphosis?) • A third characteristic that has contributed to arthropod success is a reduction of competition between adults and immature stages because of metamorphosis. • Metamorphosis is a radical change in body form and physiology as an immature stage, usually called a larva, becomes an adult. • The evolution of arthropods has resulted in an increasing divergence of body forms, behaviors, and habitats between immature and adult stages. • Adult crabs, for example, usually prowl the sandy bottoms of their marine habitats for live prey or decaying organic matter, whereas larval crabs live and feed in the plankton. • Similarly, the caterpillar that feeds on leafy vegetation eventually develops into a nectar-feeding adult butterfly or moth. • Having different adult and immature stages means that the stages do not compete with each other for food or living space. • In some arthropod and other animal groups, larvae also serve as the dispersal stage.
129	Phylum Arthropoda (Explanation of Metamorphosis with Examples) • The immature forms, or larvae, are adapted to environments and modes of life that differ from those of the adult forms. • These differences may be of significance in assuring that larvae and adults of the same species do not engage in direct competition for food or living space. • Examples of metamorphosis include the tadpole, an aquatic larval stage that transforms into the land-dwelling frog (class Amphibia). • Starfishes and other echinoderms undergo a metamorphosis that includes a change from the bilateral symmetry of the larva to the radial symmetry of the adult. • Metamorphic patterns are well-known in crabs, lobsters, and other crustaceans and also in snails, clams, and other mollusks. • The larval form of the urochordate (e.g., the tunicate, or sea squirt) is tadpole-like and free swimming; the adult is sessile and somewhat degenerate. • Among the most dramatic and thoroughly studied examples of metamorphosis are the insects. • Because development is not the same in all insects, it is convenient to group them into major categories according to the pattern of structural changes: ametabolous, hemimetabolous, and holometabolous. • In ametabolous development there is simply a gradual increase in the size of young until adult dimensions are attained. • This kind of development occurs in the silverfish, springtail, and other primitive insects. • In more advanced insects (e.g., grasshoppers, termites, true bugs) a phenomenon known as gradual, or hemimetabolous, metamorphosis occurs. • The hemimetabolous life cycle consists of egg, nymph, and adult. • The nymph, or immature insect, resembles the adult in form and eating habits, differing in size, body proportions, and color pattern. • Complete, or holometabolous, metamorphosis is characteristic of beetles, butterflies and moths, flies, and wasps. • Their life cycle includes four stages: egg, larva, pupa, and adult. • The larva differs greatly from the adult. • It is wingless, and its form and habits are suited for growth and development rather than reproduction.
	 The diagram is a Venn diagram with two overlapping circles. The left circle is labeled 'Complete' and contains the text 'Larva', 'Pupa', and 'Examples Butterfly and Lady Beetle'. The right circle is labeled 'Incomplete' and contains the text 'Nymph' and 'Example Milkweed Bug'. The overlapping area in the center is labeled 'Both' and contains the text 'Egg' and 'Adult'.

130-131	Phylum Arthropoda (Subphylum Trilobitomorpha: General Features and Characteristics) - Members of the subphylum Trilobitomorpha (Gr. <i>tri</i>, three <i>lobos</i>, lobes) were a dominant form of life in the oceans from the Cambrian period (600 million years ago) to the Carboniferous period (345 million years ago). - They crawled along the substrate feeding on annelids, molluscs, and decaying organic matter. - The trilobite body was oval, flattened, and divided into three longitudinal regions. - All body segments articulated so that the trilobite could roll into a ball to protect its soft ventral surface. - Most fossilized trilobites are found in this position. - Trilobite appendages consisted of two lobes or rami, and are called biramous (L. <i>bi</i>, twice <i>ramus</i>, branch) appendages. - The inner lobe was a walking leg, and the outer lobe bore spikes or teeth that may have been used in digging or swimming or as gills in gas exchange. - Most primitive arthropods Trilobites. Now extinct well known fossils group of marine animals.
132	Phylum Arthropoda (Subphylum Chelicerata: General Features and Characteristics) - One arthropod lineage, the subphylum Chelicerata (Gr. <i>chele</i>, claw <i>ata</i>, plural suffix), includes familiar animals, such as spiders, mites, and ticks, and less familiar animals, such as horseshoe crabs and sea spiders. - These animals have two tagmata. - The prosoma or cephalothorax is a sensory, feeding, and locomotor tagma. - It usually bears eyes, but unlike other arthropods, never has antennae. - Paired appendages attach to the prosoma. - The first pair, called chelicerae, are often pincerlike or chelate, and are most often used in feeding. - They may also be specialized as hollow fangs or for a variety of other functions. - The second pair, called pedipalps, are usually sensory but may also be used in feeding, locomotion, or reproduction. - Paired walking legs follow pedipalps. - Posterior to the prosoma is the opisthosoma, which contains digestive, reproductive, excretory, and respiratory organs.
133	Phylum Arthropoda (Class Merostomata) - Members of the class Merostomata are divided into two subclasses. - The Xiphosura are the horseshoe crabs, and the Eurypterida are the giant water scorpions. - The latter are extinct, having lived from the Cambrian period (600 million years ago) to the Permian period (280 million years ago). - Only four species of horseshoe crabs are living today. - One species, <i>Limulus polyphemus</i>, is widely distributed in the Atlantic Ocean and the Gulf of Mexico. - Horseshoe crabs scavenge sandy and muddy substrates for annelids, small molluscs, and other invertebrates. - Their body form has remained virtually unchanged for over 200 million years, as an example of stabilizing selection. - A hard, horseshoe-shaped carapace covers the cephalothorax of horseshoe crabs.

	• The chelicerae, pedipalps, and first three pairs of walking legs are chelate and are used for walking and food handling. • The last pair of appendages has leaflike plates at their tips and are used for locomotion and digging. The opisthosoma of a horseshoe crab includes a long, unsegmented telson. • If wave action flips a horseshoe crab over, the crab arches its opisthosoma dorsally, which helps it to roll to its side and flip right side up again. • The first pair of opisthosomal appendages cover genital pores and are called genital opercula. • The remaining five pairs of appendages are book gills. • The name is derived from the resemblance of these platelike gills to the pages of a closed book. • Gases are exchanged between the blood and water as blood circulates through the book gills. • Horseshoe crabs have an open circulatory system, as do all arthropods. • Blood circulation in horseshoe crabs is similar to arachnids and crustaceans. • Horseshoe crabs are dioecious. • During reproductive periods, males and females congregate in intertidal areas. • The male mounts the female and grasps her with his pedipalps. • The female excavates shallow depressions in the sand, and as she sheds eggs into the depressions, the male fertilizes them. • Fertilized eggs are covered with sand and develop unattended.  Fig: Class Merostomata. <i>Eurypterus remipes</i>
134	Phylum Arthropoda (Class Arachnida: General Characteristics) • Members of the class Arachnida (Gr. <i>arachne</i>, spider) are some of the most misrepresented members of the animal kingdom. • Their reputation as fearsome and grotesque creatures is vastly exaggerated. • The majority of spiders, mites, ticks, scorpions, and related forms are either harmless or very beneficial to humans. • Most zoologists believe that arachnids arose from the eurypterids and were early terrestrial inhabitants. • The earliest fossils of aquatic scorpions' date from the Silurian period (405 to 425 million years ago), fossils of terrestrial scorpions' date from the Devonian period (350 to 400 million years ago), and fossils of all other arachnid groups are present by the Carboniferous period (280 to 345 million years ago). • Water conservation is a major concern for any terrestrial organism, and their relatively impermeable exoskeleton preadapted ancestral arachnids for terrestrialism. • Preadaptation is when a structure present in members of a species proves useful in promoting reproductive success when an individual encounters new environmental situation. • Later adaptations included the evolution of efficient excretory structures, internal surfaces for gas exchange, appendages modified for locomotion on land, and greater deposition of wax in the epicuticle. Example: Scorpion, Spiders and Ticks

Class Arachnida (Feeding and Digestion)

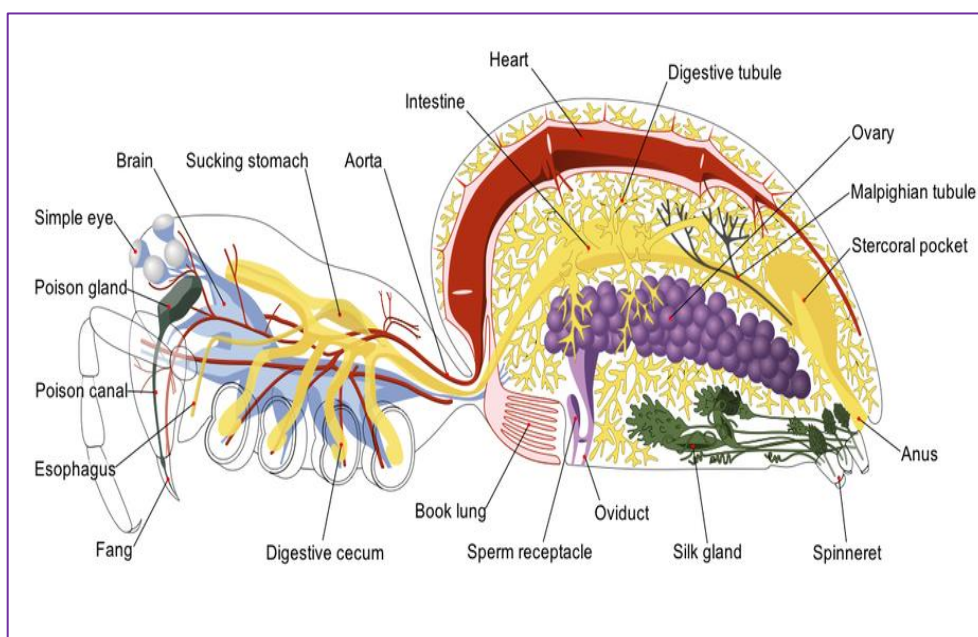
- Most arachnids are carnivores.
- They hold small arthropods with their chelicerae while enzymes from the gut tract pour over the prey.
- Partially digested food is then taken into the mouth.
- Others inject enzymes into prey through hollow chelicerae (e.g., spiders) and suck partially digested animal tissue.
- The gut tract of arachnids is divided into three regions.
- The anterior portion is the foregut, and the posterior portion is the hindgut. Both develop as infoldings of the body wall and are lined with cuticle.
- A portion of the foregut is frequently modified into a pumping pharynx, and the hindgut is frequently a site of water reabsorption.
- The midgut between the foregut and hindgut is noncuticular and lined with secretory and absorptive cells.
- Lateral diverticula increase the area available for absorption and storage.



Mid term completed

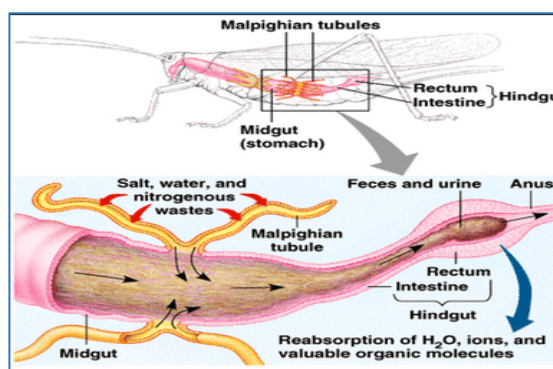
Class Arachnida Excretion: Role of Coxal Glands

- Arachnids use coxal glands and/or **Malpighian tubules for excreting nitrogenous wastes.**
- **Coxal glands are paired, thin walled,** spherical sacs bathed in the blood of body sinuses.
- Nitrogenous wastes are absorbed across the wall of the sacs, transported in a long, convoluted tubule, and excreted through excretory pores at the base of the posterior appendages.
- Arachnids that are adapted to dry environments possess blind-ending diverticula of the gut tract that arise at the juncture of the midgut and hindgut.
- These tubules, called **Malpighian tubules,** absorb waste materials from the blood and empty **them into the gut tract.**
- **Excretory wastes are then eliminated with digestive wastes.**
- The major **excretory product** of **arachnids** is **uric acid.**
- As uric acid excretion is advantageous for terrestrial animals because uric acid is excreted as a semisolid with little water loss.



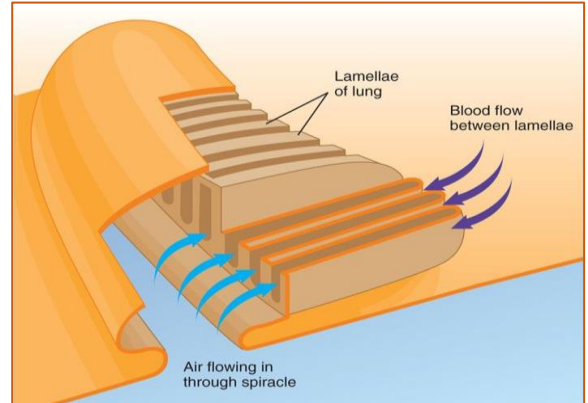
Class Arachnida: Importance of Malpighian Tubules

- Two kinds of excretory organs are found in the arachnids, coxal glands and **Malpighian** tubules.
- The **coxal glands** are considered to be ancestral, while Malpighian tubules are derived.
- The Malpighian tubules of the arachnids are not homologous to those of the hexapods.
- The Malpighian tubules arise from the midgut in arachnids and from the hindgut in hexapods.
- Malpighian tubules (named after the **17th century** Italian scientist, **Marcello Malpighi**) are blind tubules that connect to the gut near the union of the midgut and the hindgut.
- In arachnids the tubules form a branched mass that often times connects to a stercoral pocket or sac, where nitrogenous wastes are stored prior to excretion.
- The primary excretory product of arachnids is guanine, although uric acid and other compounds are also excreted.
 - Guanine, like uric acid, is insoluble in water and relatively non-toxic.
 - It can be excreted with little associated water loss.

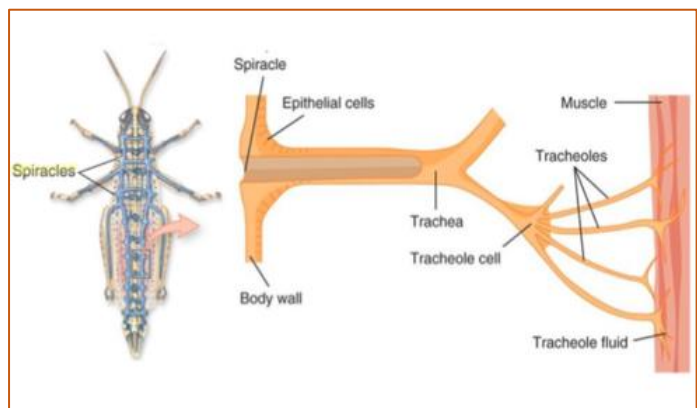


Class Arachnida**Gaseous Exchange: Book lungs**

- Gas exchange also occurs with minimal water loss because arachnids have few exposed respiratory surfaces.
- Some arachnids possess structures, called **book lungs**, that are assumed to be modifications of the book gills in the Merostomata.
- Book lungs are paired invaginations of the ventral body wall that fold into a series of leaflike lamellae.
- Air enters the book lung through a slitlike opening and circulates between lamellae.
- Respiratory gases diffuse between the blood moving among the lamellae and the air in the lung chamber.
- Other arachnids possess a series of branched, chitin-lined tubules that deliver air directly to body tissues.
- These tubule systems, called **tracheae** (sing., **trachea**), open to the outside through openings called **spiracles along the ventral** or lateral aspects of the abdomen.

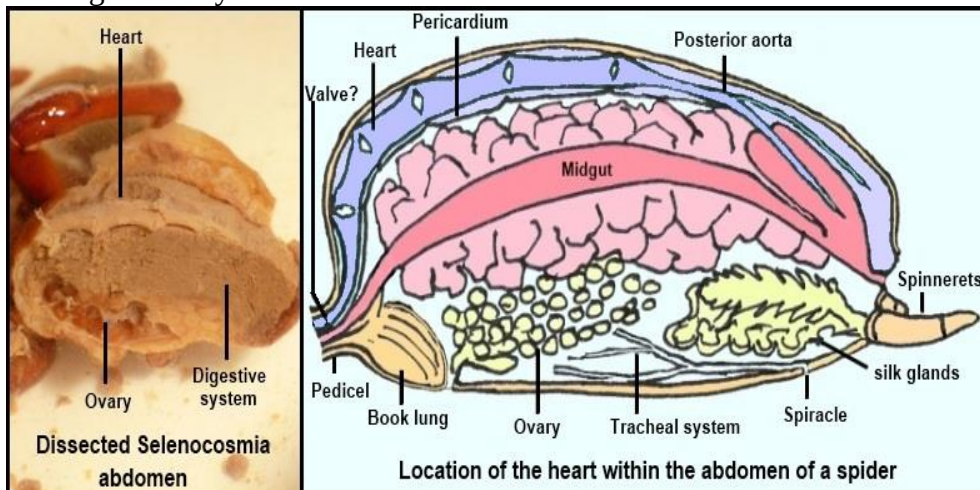
**Class Arachnida Tracheal System:****Structure and Function**

- Gas exchange with air requires a large surface area for the diffusion of gases.
- In terrestrial environments, these surfaces are also avenues for water loss.
- Respiratory water loss in insects, as in some arachnids, is reduced through the invagination of respiratory surfaces to form highly branched systems of chitin-lined tubes, called **tracheae**.
- Tracheae open to the outside of the body through spiracles, which usually have some kind of closure device to prevent excessive water loss.
- Spiracles lead to tracheal trunks that branch, eventually giving rise to smaller branches, the tracheoles.
- Tracheoles end intracellularly and are especially abundant in metabolically active tissues, such as flight muscles.
- No cells are more than 2 or 3 μm from a tracheole.
- Most insects have ventilating mechanisms that move air into and out of the tracheal system.
- For example, contracting flight muscles alternatively compress and expand the larger tracheal trunks and thereby ventilate the tracheae.
- In some insects, carbon dioxide that metabolically active cells produce is sequestered in the hemocoel as bicarbonate ions (HCO_3^-).
- As oxygen diffuses from the tracheae to the body tissues, and is not replaced by carbon dioxide, a vacuum is created that draws more air into the spiracles.
- This process is called **passive suction**.
- Periodically, the sequestered bicarbonate ions are converted back into carbon dioxide, which escapes through the tracheal system.
- Other insects contract abdominal muscles in a pumplike fashion to move air into and out of their tracheal systems.



Class Arachnida Circulatory System

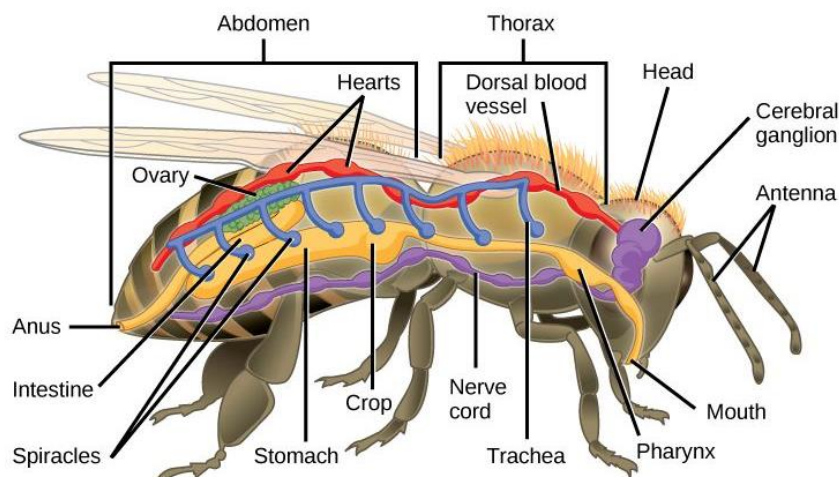
- The circulatory system of arachnids, like that of most arthropods, is an open system in which a dorsal contractile vessel (usually called the dorsal aorta or “heart”) pumps blood into tissue spaces.
- In arthropods, the coelom is reduced to cavities surrounding the gonads and sometimes the coxal glands.
- Large tissue spaces, or sinuses, are derived from the blastocoel and are called the **hemocoel**.
- Blood bathes the tissues and then returns to the dorsal aorta through openings in the aorta called ostia.
- Arachnid blood contains the dissolved respiratory pigment hemocyanin and has amoeboid cells that aid in clotting and body defenses.



Class Arachnida; Nervous System

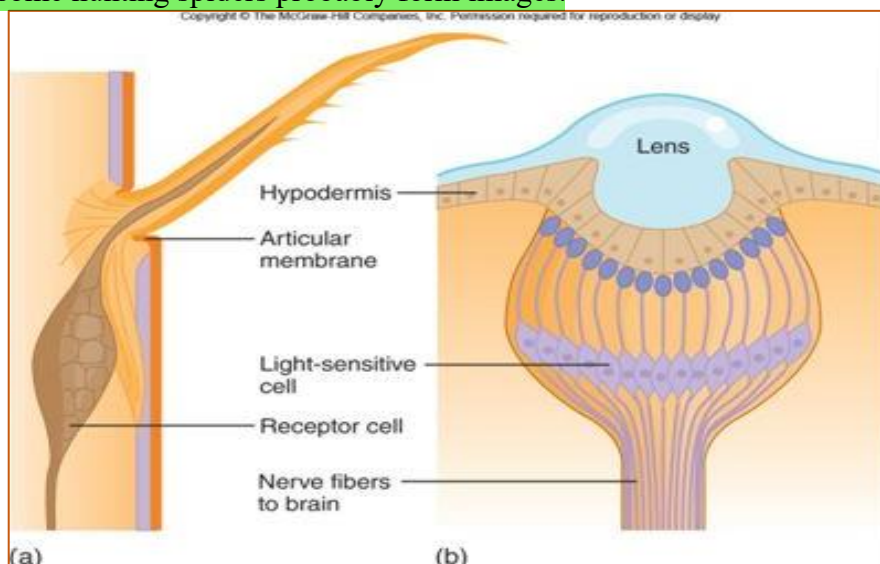
- The nervous system of all arthropods is ventral and, in ancestral arthropods, must have been laid out in a pattern similar to that of the annelids.
- With the exception of scorpions, the nervous system of arachnids is centralized by fusion of ganglia.
- The central nervous system of arachnids, like all arthropods, consists of a ventral, solid nerve cord and a series of fused ganglia associated with various body segments.
- The cerebral ganglion (brain) gives rise to the nerves to the eyes and the chelicerae.
- Opisthosomal ganglia primarily innervate the walking legs.

❖ Nervous System: brain, nerve cords, ganglia and specialized sensory organs

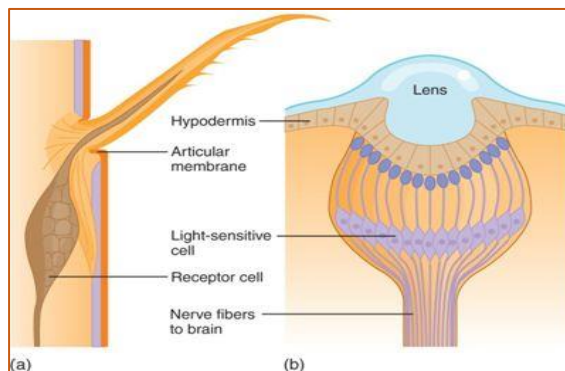


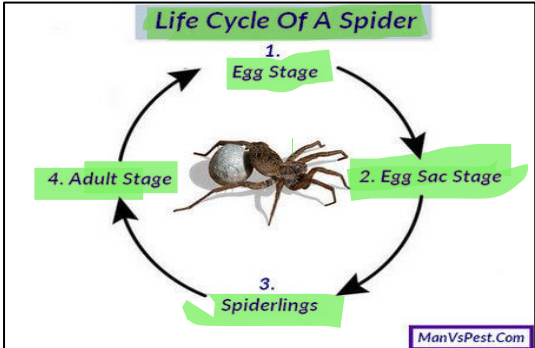
Class Arachnida**Sensory structures: Sensilla**

- The body of an arachnid has a variety of sensory structures.
- Most mechanoreceptors and chemoreceptors are modifications of the exoskeleton, such as projections, pores, and slits, together with sensory and accessory cells.
- Collectively, these receptors are called **sensilla**.
- For example, setae are hairlike, cuticular modifications that may be set into membranous sockets.
- Displacement of a seta initiates a nerve impulse in an associated nerve cell.
- Vibration receptors are very important to some arachnids.
- Spiders that use webs to capture prey, for example, determine both the size of the insect and its position on the web by the vibrations the insect makes while struggling to free itself.
- The chemical sense of arachnids is comparable to taste and smell in vertebrates.
- Small pores in the exoskeleton are frequently associated with peglike, or other, modifications of the exoskeleton, and they allow chemicals to stimulate nerve cells.
- Arachnids possess one or more pairs of eyes, which they use primarily for detecting movement and changes in light intensity.
- The eyes of some hunting spiders probably form images.

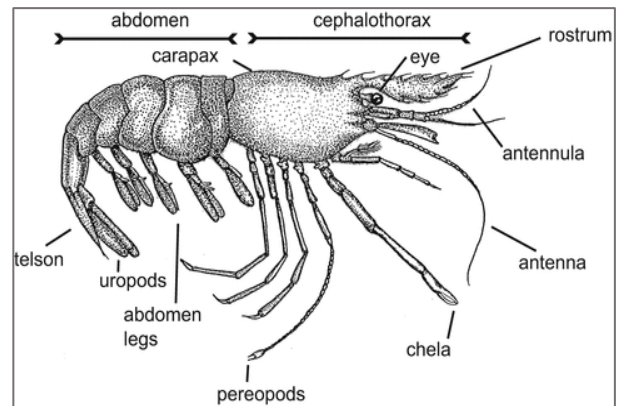
**Class Arachnida What are Setae?**

- A seta is a hairlike modification of the cuticle set in a membranous socket.
- Displacement of the seta initiates a nerve impulse in a receptor cell (sensillum) associated with the base of the seta.
- The lens of spider eye is a thickened, transparent modification of the cuticle.
- Below the lens and hypodermis are lightsensitive sensillae with pigments that convert light energy into nerve impulses.
- For all arthropods, most tactile receptors are movable bristles or setae whose internal ends are associated with sensory neurons.
- Chemoreception also occurs via setae.
- The outer layer of arthropods, the cuticle, is nearly impermeable, necessitating specialized setae with permeable cuticular coverings.
- Others have small pores or slits through the cuticle, sometimes through hollow setae, that allow chemicals to contact chemoreceptor neurons.



144	Class Arachnida <u>Reproduction and Development</u> • Arachnids are dioecious. • Paired genital openings are on the ventral side of the second abdominal segment. • Sperm transfer is usually indirect. • The male often packages sperm in a spermatophore, which is then transferred to the female. • Courtship rituals confirm that individuals are of the same species, attract a female to the spermatophore, and position the female to receive the spermatophore. • In some taxa (e.g., spiders), copulation occurs, and sperm is transferred via a modified pedipalp of the male. • Development is direct, and the young hatch from eggs as miniature adults. • Many arachnids tend their developing eggs and young during and after development.	 The diagram illustrates the life cycle of a spider. It features a central illustration of a brown spider. Surrounding it is a circular flow with four numbered stages: 1. Egg Stage (top), 2. Egg Sac Stage (right), 3. Spiderlings (bottom), and 4. Adult Stage (left). Arrows indicate the progression from one stage to the next in a clockwise direction. The title 'Life Cycle Of A Spider' is at the top, and the source 'ManVsPest.Com' is at the bottom right.
145	Phylum Arthropoda Subphylum Crustacea: <u>General Features</u> • Some members of the subphylum Crustacea (L. crustaceus, hard shelled), such as crayfish, shrimp, lobsters, and crabs, are familiar to nearly everyone. • Many others are lesser known but very common taxa. • These include copepods, cladocerans, fairy shrimp, isopods, amphipods, and barnacles. • Except for some isopods and crabs, crustaceans are all aquatic. • Crustaceans differ from other living arthropods in two ways. • They have two pairs of antennae, whereas all other arthropods have one pair or none. • In addition, crustaceans possess biramous appendages, each of which consists of a basal segment, called the protopodite, with two rami (distal processes that give the appendage a Y shape) attached. • The medial ramus is the endopodite, and the lateral ramus is the exopodite. • Trilobites had similar structures, which may be evidence that the trilobites were ancestral to the crustaceans.	 The diagram is titled 'Example Crustaceans'. It displays six different types of crustaceans: a spiny lobster, a scampi, a crayfish, a lobster, a crab, and a shrimp. Each is labeled with its name. The background is light blue with a subtle pattern.
146	Phylum Arthropoda Class Malacostraca: <u>General Features with Examples</u> • Malacostraca (Gr. malakos, soft ostreion, shell) is the largest class of crustaceans. • It includes crabs, lobsters, crayfish, shrimp, mysids, shrimplike krill, isopods, and amphipods. • They are abundant in all marine environments and have colonized freshwater and terrestrial habitats. • They are segmented animals, united by a common body plan comprising 20 body segments (rarely 21), and divided into a head, thorax, and abdomen. • The class Malacostraca includes about 40,000 species. • The digestive tract is straight and the foregut consists of a short esophagus and a two-chambered stomach, the first part of which contains a gizzard-like "gastric mill" for grinding food.	

- Like other crustaceans, malacostracans have an open circulatory system in which the heart pumps blood into the hemocoel (body cavity) where it supplies the needs of the organs for oxygen and nutrients before diffusing back to the heart.
- **The typical respiratory pigment in malacostracans is haemocyanin.**
- A brain exists in the form of ganglia close to the antennae, there are ganglia in each segment and a collection of major ganglia below the esophagus.
- The monophyly of Malacostraca is widely accepted.
- However, a number of problems make it difficult to determine the relationships between the orders of Malacostraca.
- Leptostraca is the only extant order of Phyllocarida, the other two orders, Archaeostraca and Hoplostraca being extinct.
- Stomatopoda is the only extant order of Hoplocarida, the other two orders, Aeschronectida and Archaeostomatopoda being extinct.



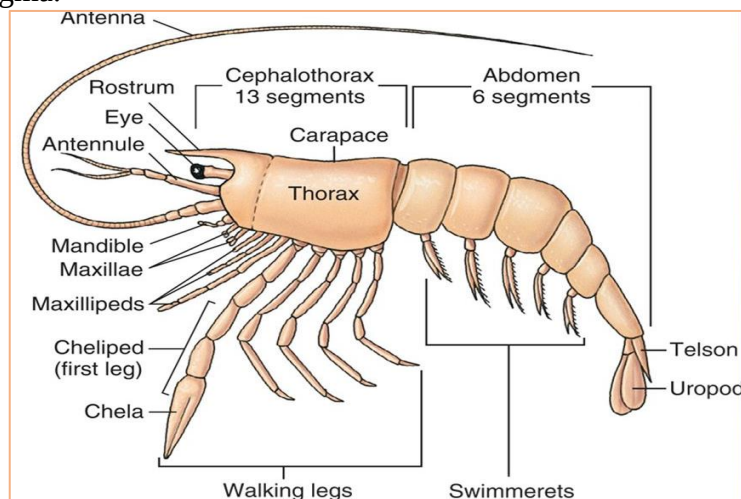
147

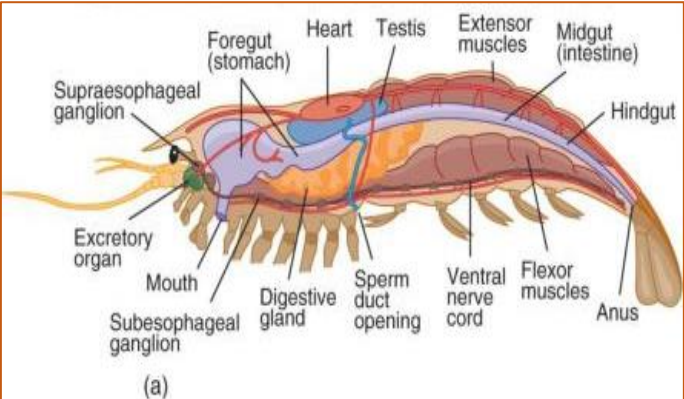
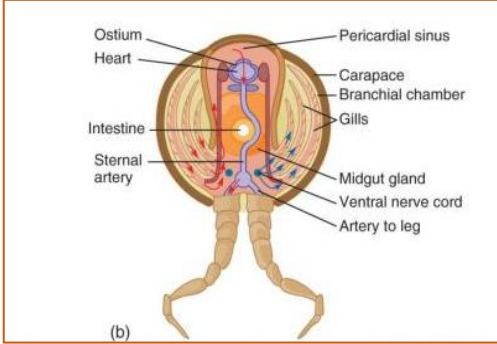
Phylum Arthropoda

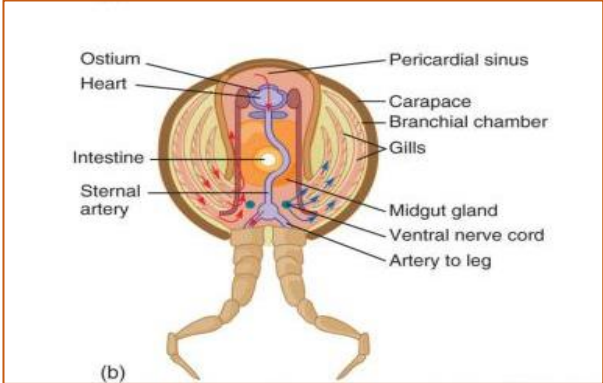
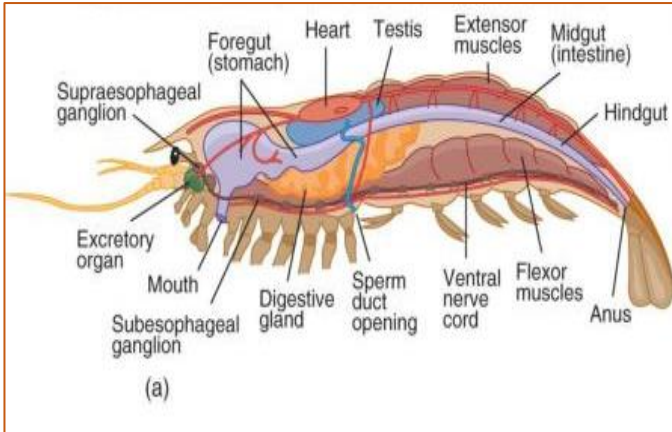
Crustacean body form:

External Anatomy of a Crustacean

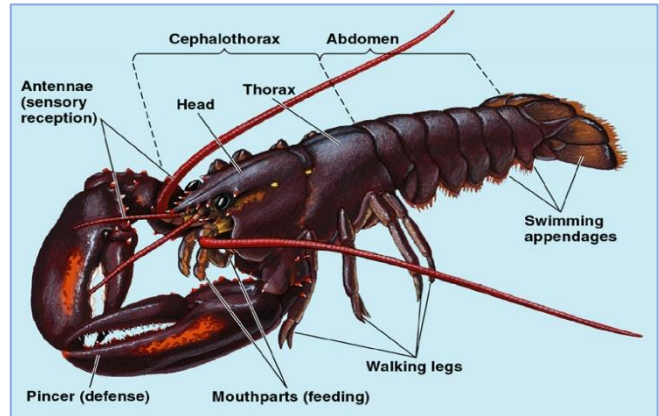
- **Crayfish illustrate general crustacean structure and function.**
- **They are convenient to study because of their relative abundance and large size.**
- **The body of a crayfish is divided into two regions.**
- **A cephalothorax is derived from developmental fusion of a sensory and feeding tagma (the head) with a locomotor tagma (the thorax).**
- **The exoskeleton of the cephalothorax extends laterally and ventrally to form a shield like carapace.**
- **The abdomen is posterior to the cephalothorax, has locomotor and visceral functions, and in crayfish, takes the form of a muscular “tail.”**
- Paired appendages are present in both body regions.
- The first two pairs of cephalothoracic appendages are the first and second antennae.
- The third through fifth pairs of appendages are associated with the mouth.
- During crustacean evolution, the **third pair of appendages** became modified into chewing or grinding structures called **mandibles**.
- The **fourth and fifth pairs of appendages**, called **maxillae**, are for food handling.
- The second maxilla bears a gill and a thin, bladelike structure, called a scaphognathite (gill bailer), for circulating water over the gills.
- The sixth through the eighth cephalothoracic appendages are called **maxillipeds** and are derived from the thoracic tagma.



	• They are accessory sensory and food-handling appendages. • The last two pairs of maxillipeds also bear gills. • Appendages 9 to 13 are thoracic appendages called periopods (walking legs). • The first periopod, known as the cheliped, is enlarged and chelate (pincherlike) and used in defense and capturing food. • All but the last pair of appendages of the abdomen are called pleopods (swimmerets) and used for swimming. In females, developing eggs attach to pleopods, and the embryos are brooded until after hatching. • In males, the first two pairs of pleopods are modified into gonopods (claspers) used for sperm transfer during copulation. • The abdomen ends in a median extension called the telson. • The telson bears the anus and is flanked on either side by flattened, biramous appendages of the last segment, called uropods. • The telson and uropods make an effective flipper like structure used in swimming and in escape responses. • All crustacean appendages, except the first antennae, have presumably evolved from an ancestral biramous form, as evidenced by their embryological development, in which they arise as simple twobranch structures. • First antennae develop as uniramous appendages and later acquire the branched form. • The crayfish and their close relatives are unique in having branched first antennae. • Structures, such as the biramous appendages of a crayfish, whose form is based on a common ancestral pattern and that have similar development in the segments of an animal, are said to be serially homologous
148	Sub-Phylum Crustacea: <u>Feeding and Digestion</u> • Crayfish prey upon other invertebrates, eat plant matter, and scavenge dead and dying animals. • The foregut includes an enlarged stomach, part of which is specialized for grinding. • A digestive gland secretes digestive enzymes and absorbs products of digestion. • The midgut extends from the stomach and is often called the intestine. • A short hindgut ends in an anus and is important in water and salt regulation. • In crustaceans, food is ingested through the mouth and passed into the digestive tract. • Depending on the species there may be a structure called the gastric mill near the beginning of the digestive tract that is used to grind down harder pieces of food.  (a)
149	Sub-Phylum Crustacea: <u>Gaseous Exchange</u> • As described, the gills of a crayfish attach to the bases of some cephalothoracic appendages. • Gills are in a branchial (gill) chamber, the space between the carapace and the lateral body wall. • The beating of the scaphognathite of the second maxilla drives water anteriorly through the branchial chamber. • Oxygen and carbon dioxide are exchanged between blood and water across the gill surfaces, and a respiratory pigment, hemocyanin, carries oxygen in blood plasma.  (b)

	• Very small aquatic crustaceans exchange gases through the process of diffusion directly across the body surface called the integument. • The oxygen then moves from the gills into the haemolymph in the circulatory system so that the oxygen can be delivered to the rest of the body.
150	Sub-Phylum Crustacea: <u>Circulation</u> • Circulation in crayfish is similar to that of most arthropods. • Dorsal, anterior, and posterior arteries lead away from a muscular heart. • Branches of these vessels empty into sinuses of the hemocoel. • Blood returning to the heart collects in a ventral sinus and enters the gills before returning to the pericardial sinus, which surrounds the heart. • Crustaceans have an open circulatory system meaning that all their blood is not contained within vessels, instead, blood is drawn in to the heart through holes called ostia, then pumped out again to circulate through the tissues and return again to the heart. 
151	Sub-Phylum Crustacea (Nervous System) • Crustacean nervous systems show trends similar to those in annelids and arachnids. • Primitively, the ventral nervous system is ladderlike. • Higher crustaceans show a tendency toward centralization and cephalization • Crustacean nervous systems show trends similar to those in annelids and arachnids. • Primitively, the ventral nervous system is ladderlike. • Higher crustaceans show a tendency toward centralization and cephalization. Nervous System • Crayfish have supraesophageal and subesophageal ganglia that receive sensory input from receptors in the head and control the head appendages. • The ventral nerves and segmental ganglia fuse, and giant neurons in the ventral nerve cord function in escape responses • When nerve impulses are conducted posteriorly along giant nerve fibers of a crayfish, powerful abdominal flexor muscles of the abdomen contract alternately with weaker extensor muscles, causing the abdomen to flex (the propulsive stroke) and then extend (the recovery stroke) • The telson and uropods form a paddle like “tail” that propels the crayfish posteriorly 
152	Sub-Phylum Crustacea (<u>Sensory structures</u>) Statocys • In addition to antennae, the sensory structures of crayfish include compound eyes, simple eyes, statocysts, chemoreceptors, proprioceptors, and tactile setae. • Chemical receptors are widely distributed over the appendages and the head. Sensory Structures: Statocyst • Many of the setae covering the mouthparts and antennae are chemoreceptors used in sampling food and detecting pheromones. • A single pair of statocysts is at the bases of the first antennae.

- A **statocyst** is a **pit like** invagination of the exoskeleton that contains setae and a group of cemented sand grains called a **statolith**.
- Crayfish movements move the statolith and displace setae.
- Statocysts provide information regarding movement, orientation with respect to the pull of gravity, and vibrations of the substrate.
- Because the statocyst is cuticular, it is replaced with each molt.
- Sand is incorporated into the statocyst when the crustacean is buried in sand.
- Other receptors involved with equilibrium, balance, and position senses are tactile receptors on the appendages and at joints.
- When a crustacean is crawling or resting, stretch receptors at the joints are stimulated.
- Crustaceans detect tilting from changing patterns of stimulation.
- These widely distributed receptors are important to crustaceans that lack statocysts



153

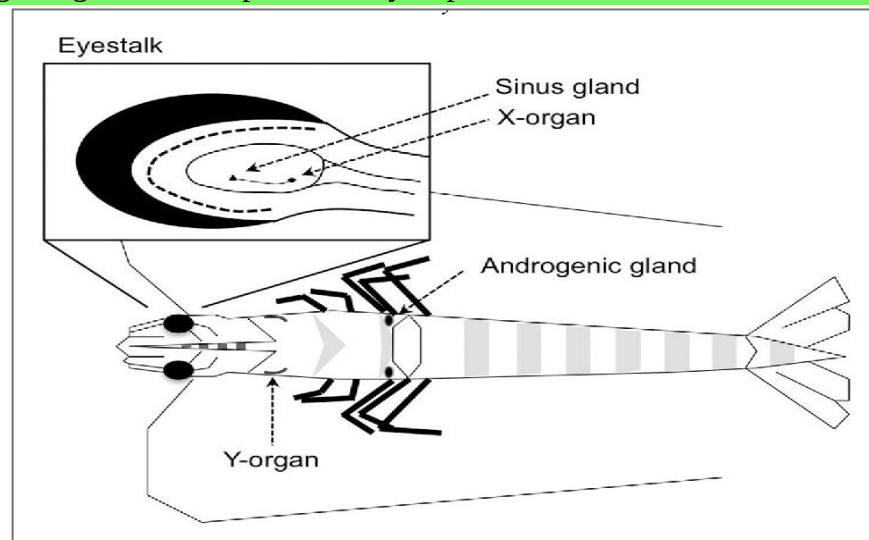
Sub-Phylum Crustacea (**Compound eyes and ocelli**)

- Crayfish have compound eyes mounted on movable eyestalks.
- The lens system consists of 25 to 14,000 individual receptors called **ommatidia**.
- Compound eyes also occur in insects
- Larval crustaceans have a single, median photoreceptor consisting of a few sensilla.
- These **simple eyes, called ocelli**, allow larval crustaceans to orient toward or away from the light, but do not form images
- Many larvae are planktonic and use their **ocelli to orient toward surface waters**

154

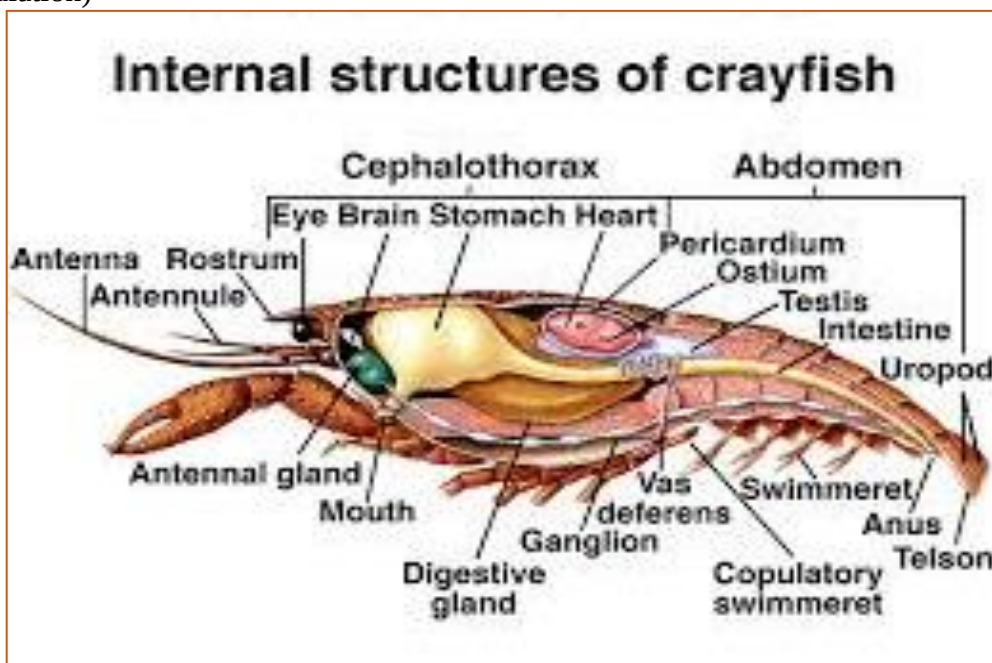
Sub-Phylum Crustacea (**Androgenic glands**)

- Androgenic glands in the cephalothorax of males mediate another endocrine function.
- Females possess rudiments of these glands during development, but the glands never mature
- **Normally, androgenic hormone(s) promotes the development of testes and male characteristics, such as gonopods**
- **The removal of androgenic glands from males results in the development of female sex characteristics, and if androgenic glands are experimentally implanted into a female, she develops testes and gonopods**
- Hormones probably regulate many other crustacean functions. • Some that have been investigated include the development of female brooding structures in response to ovarian hormones, the seasonal regulation of ovarian functions, and the regulation of heart rate and body color changes by eyestalk hormones



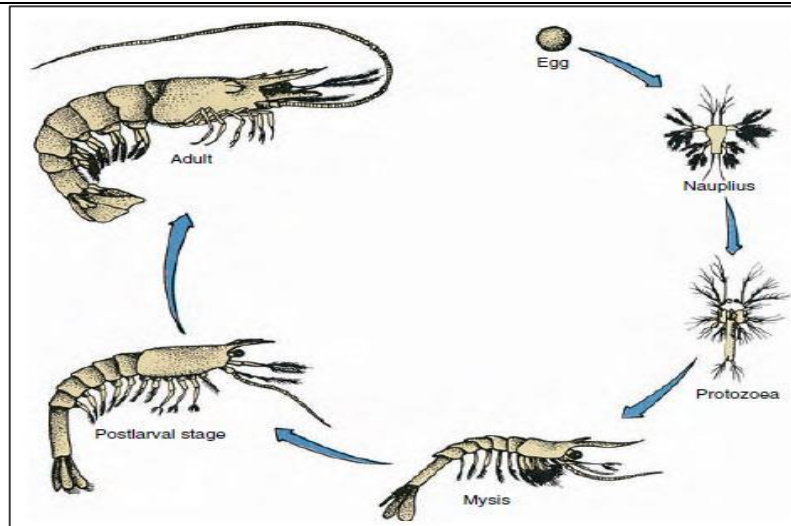
Sub-Phylum Crustacea Excretory organs: Antennal Glands/ Maxillary qGands

- The excretory organs of crayfish are called **antennal glands (green glands)** because they are at the bases of the second antennae and are green in living crayfish.
- In other crustaceans, they are called **maxillary glands** because they are at the bases of the second **maxillae**
- They are structurally similar to the coxal glands of arachnids and presumably had a common evolutionary origin.
- Excretory products form by the filtration of blood. Ions, sugars, and amino acids are reabsorbed in the tubule before the diluted urine is excreted
- As with most aquatic animals, **ammonia is the primary excretory product.**
- However, crayfish do not rely solely on the antennal glands to excrete ammonia.
- Ammonia also diffuses across thin parts of the exoskeleton
- Even though it is toxic, ammonia is water soluble, and water rapidly dilutes it.
- All freshwater crustaceans face a continual influx of freshwater and loss of ions.
- Thus, the elimination of excess water and the reabsorption of ions become extremely important functions.
- Gill surfaces are also important in ammonia excretion and water and ion regulation (osmoregulation)



Sub-Phylum Crustacea Reproduction and Development

- Crayfish, and all other crustaceans except the barnacles, are **dioecious**.
- Gonads are in the dorsal portion of the thorax, and gonoducts open at the base of the third (females) or fifth (males) pereopods.
- Mating occurs just after a female has molted
- The male turns the female onto her back and deposits non flagellated sperm near the openings of the female's gonoducts.
- Fertilization occurs after copulation, as the eggs are shed.
- The eggs are sticky and securely fasten to the female's pleopods
- Fanning movements of the pleopods over the eggs keep the eggs aerated.
- The development of crayfish embryos is direct, with young hatching as miniature adults.
- Many other crustaceans have a planktonic, freeswimming larva called a **nauplius**
- In some, the nauplius develops into a miniature adult.
- Crabs and their relatives have a second larval stage called a **zoea**.
- When all adult features are present, except sexual maturity, the immature is called the **post larva**



- Two other orders of malacostracans have members familiar to most humans.
- Members of the order Isopoda include “pillbugs.”
- Isopods are dorsoventrally flattened, may be either aquatic or terrestrial, and scavenge decaying plant and animal material
- Some have become modified for clinging to and feeding on other animals.
- Terrestrial isopods live under rocks and logs and in leaf litter.
- Members of the order Amphipoda have a laterally compressed body that gives them a shrimplike appearance
- Amphipods move by crawling or swimming on their sides along the substrate.
- Some species are modified for burrowing, climbing, or jumping.
- Amphipods are scavengers, and a few species are parasites.

157

Sub-Phylum Crustacea Class Branchiopoda

- Members of the class Branchiopoda (Gr. branchio, gill podos, foot) primarily live in freshwater.
- All branchiopods possess flattened, leaflike appendages used in respiration, filter feeding, and locomotion.
- Fairy shrimp and brine shrimp comprise the order Anostraca
- Fairy shrimp usually live in temporary ponds that spring thaws and rains form.
- Eggs are brooded, and when the female dies, and the temporary pond begins to dry, the embryos become dormant in a resistant capsule
- Embryos lay on the forest floor until the pond fills again the following spring, at which time they hatch into nauplius larvae.
- Animals, wind, or water currents may carry the embryos to other locations.
- Their short and uncertain life cycle is an adaptation to living in ponds that dry up.
- The vulnerability of these slowly swimming and defenseless crustaceans probably explains why they live primarily in temporary ponds, a habitat that contains few larger predators.
- Brine shrimp also form resistant embryos.
- They live in salt lakes and ponds (e.g., the Great Salt Lake in Utah)

Members of the order Cladocera are called **water fleas**.

- A large carapace covers their bodies, and they swim by repeatedly thrusting their second antennae downward to create a jerky, upward locomotion.
- Females reproduce parthenogenetically (without fertilization) in spring and summer, and can rapidly populate a pond or lake.
- Eggs are brooded in an egg case beneath the carapace.
- At the next molt, the egg case is released and either floats or sinks to the bottom of the pond or lake

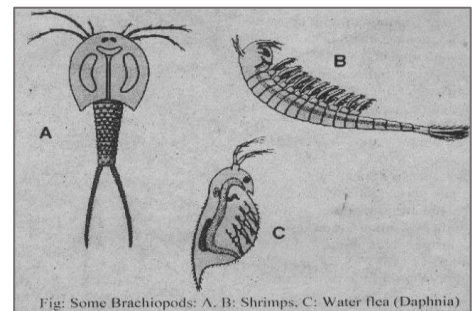
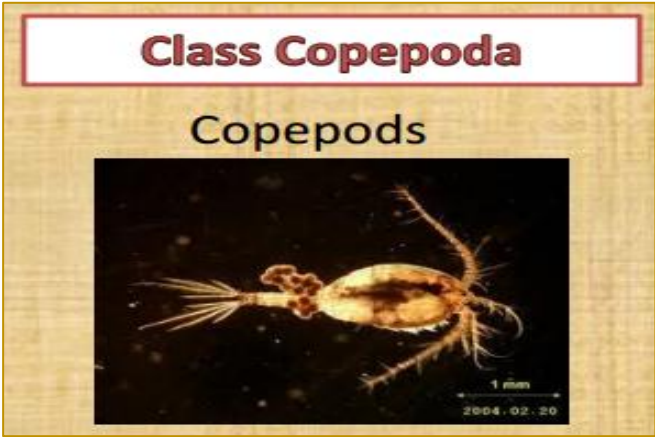
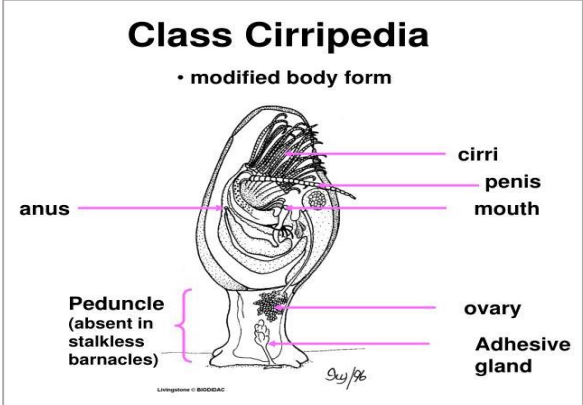


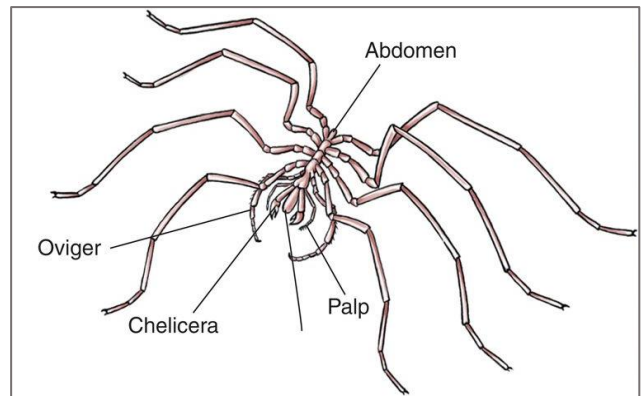
Fig: Some Branchiopods: A, B: Shrimps, C: Water flea (Daphnia)

	• In response to decreasing temperature, changing photoperiod, or decreasing food supply, females produce eggs that develop parthenogenetically into males. • Sexual reproduction produces resistant “winter eggs” that overwinter and hatch in the spring
158	Sub-Phylum Crustacea <u>Class Copepoda</u> • Members of the class Copepoda (Gr. kope, oar podos, foot) include some of the most abundant crustaceans. • There are both marine and freshwater species. • Copepods have a cylindrical body and a median ocellus that develops in the nauplius stage and persists into the adult stage • The first antennae (and the thoracic appendages in some) are modified for swimming, and the abdomen is free of appendages. • Most copepods are planktonic and use their second maxillae for filter feeding • Their importance in marine food webs was noted in the “Evolutionary Perspective”. • A few copepods live on the substrate, a few are predatory, and others are commensals or parasites of marine invertebrates, fishes, or marine mammals  Class Copepoda Copepods
159	Sub-Phylum Crustacea <u>Class Cirripedi</u> • Members of the class Cirripedia, the barnacles, are sessile and highly modified as adults. • They are exclusively marine and include about one thousand species. • Most barnacles are monoecious. • The planktonic nauplius of barnacles is followed by a planktonic larval stage, called a cypris larva, which has a bivalved carapace. • Cypris larvae attach to the substrate by their first antennae and metamorphose to adults. • In the process of metamorphosis, the abdomen is reduced, and the gut tract becomes Ushaped • Thoracic appendages are modified for filtering and moving food into the mouth. • Calcareous plates cover the larval carapace in the adult stage. • Barnacles attach to a variety of substrates, including rock outcroppings, ship bottoms, whales, and other animals. • Some barnacles attach to their substrate by a stalk. • Others are non stalked and are called acorn barnacles. • Barnacles that colonize ship bottoms reduce both ship speed and fuel efficiency. • Much time, effort, and money have been devoted to research on keeping ships free of barnacles • Some barnacles have become highly modified parasites. • The evolution of parasitism in barnacles is probably a logical consequence of living attached to other animals  Class Cirripedia • modified body form Labels: anus, cirri, penis, mouth, Peduncle (absent in stalkless barnacles), ovary, Adhesive gland

160

Sub-Phylum Chelicerata Class Pycnogonida

- Members of the class **Pycnogonida** are the sea spiders.
- All are marine and are most common in cold waters.
- **Pycnogonids live on the ocean floor and frequently feed on cnidarian polyps and ectoprocts**
- Some sea spiders feed by sucking prey tissues through a proboscis.
- Others tear at prey with their chelicerae.
- Pycnogonids are dioecious.
- Gonads are U-shaped, and branches of the gonads extend into each leg
- Gonopores are on one of the pairs of legs.
- As the female releases eggs, the male fertilizes them, and the fertilized eggs are cemented into spherical masses and attached to a pair of elongate appendages of the male, called **ovigers**, where they are brooded until hatching



161

Phylum Arthropoda Further phylogenetic considerations

- The arthropods have been very successful.
- This is evidenced by the diverse body forms and lifestyles of copepods, crabs, lobsters, crayfish, and barnacles, which demonstrate adaptive radiation.
- Few aquatic environments are without some crustaceans
- The subphylum Chelicerata is a very important group of animals from an evolutionary standpoint, even though they are less numerous in terms of numbers of species and individuals than are many of the crustacean groups
- **Their arthropod** exoskeleton and the evolution of excretory and respiratory systems that minimize water loss resulted in ancestral members of this subphylum becoming some of the first terrestrial animals
- Chelicerates, however, are not the only terrestrial arthropods.
- In terms of numbers of species and numbers of individuals, chelicerates are dwarfed in terrestrial environments by the fourth arthropod lineage—the insects and their relative

Cells of epidermis and gastrodermis differentiate into a number of cell types for:

- ✓ Protection
- ✓ food gathering
- ✓ coordination
- ✓ movement
- ✓ digestion
- ✓ absorption

• **Between the epidermis and gastrodermis is a jellylike layer called mesoglea**

• Cells are present in the middle layer of some cnidarians, but they have their origin in either the epidermis or the gastrodermis. • One kind of cell is characteristics of the phylum

• **Epidermal and/or gastrodermal cells called cnidocytes produce structures called nematocysts,** which are used for attachment, defense and feeding.

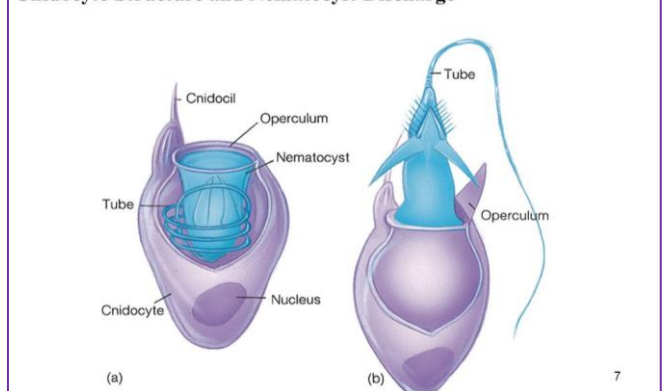
• **A nematocyst is a fluid-filled, intracellular capsule enclosing a coiled hollow tube**

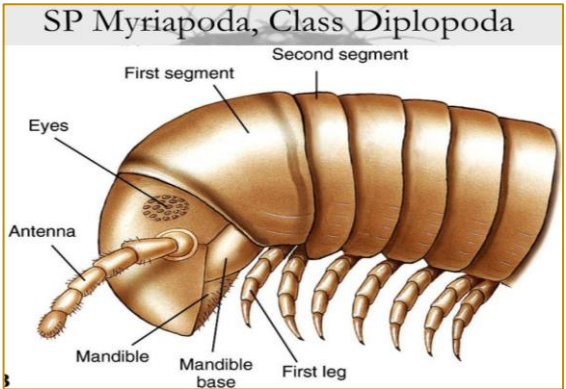
• **A lid like operculum caps the capsule at one end.**

• **The cnidocyte has a modified cilium, called a cnidocil.**

• Stimulation of the cnidocil forces open the operculum, discharging the coiled tube.

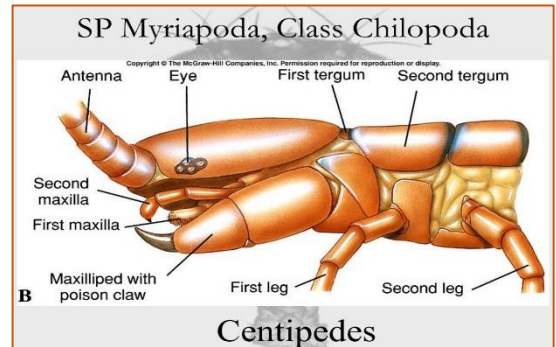
Cnidocyte Structure and Nematocyst Discharge



	• Zoologist have described nearly 30 kinds of nematocysts • Nematocysts used in food gathering and defense may discharge a long tube armed with spines that penetrates the prey. • The spines have hollow tips that deliver paralyzing toxins • Other nematocysts contain unarmed tubes that wrap around prey or a substrate. • Still other nematocysts have sticky secretions that help the animal anchor itself. • Six or more kinds of nematocysts may be present in one individual.
162	Sub-Phylum Myriapoda <u>Class Diplopoda</u> • The class Diplopoda (Gr. diploos, two fold podus, foot) contains the millipedes. • Ancestors of this group appeared on land during the Devonian period and were among the first terrestrial animals. • Millipedes have 11 to 100 trunk segments derived from an embryological and evolutionary fusion of primitive metameres. • An obvious result of this fusion is the occurrence of two pairs of appendages on each apparent trunk segment. • Each segment is actually the fusion of two segments. • Fusion is also reflected internally by two ganglia, two pairs of ostia, and two pairs of tracheal trunks per apparent segment. • Most millipedes are round in cross section, although some are more flattened. • Millipedes are worldwide in distribution and are nearly always found in or under leaf litter, humus, or decaying logs • Their epicuticle does not contain much wax; therefore, their choice of habitat is important to prevent desiccation. • Their many legs, simultaneously pushing against the substrate, help millipedes bulldoze through the habitat. • Millipedes feed on decaying plant matter using their mandibles in a chewing or scraping fashion • A few millipedes have mouthparts modified for sucking plant juices. • Millipedes roll into a ball when faced with desiccation or when disturbed. • Many also possess repugnatorial glands that produce hydrogen cyanide, which repels other animals • Hydrogen cyanide is not synthesized and stored as hydrogen cyanide because it is caustic and would destroy millipede tissues. • Instead, a precursor compound and an enzyme mix as they are released from separate glandular compartments • Repellants increase the likelihood that the millipede will be dropped unharmed and decrease the chances that the same predator will try to feed on another millipede. • Male millipedes transfer sperm to female millipedes with modified trunk appendages, called gonopods, or in spermatophores • Eggs are fertilized as they are laid and hatch in several weeks. • Immatures acquire more legs and segments with each molt until they reach adulthood 
163	Sub-Phylum Myriapoda <u>Class Chilopoda</u> • Members of the class Chilopoda (Gr. cheilos, lip and podus, foot) are the centipedes. • Most centipedes are nocturnal and scurry about the surfaces of logs, rocks, or other forest-floor debris. • Like millipedes, most centipedes lack a waxy epicuticle and therefore require moist habitats • Their bodies are flattened in cross section, and they have a single pair of long legs on each of their 15 or more trunk segments. • The last pair of legs is usually modified into long sensory appendages.

- **Centipedes** are fastmoving predators

- Food usually consists of small arthropods, earthworms, and snails; however, some centipedes feed on frogs and rodents.
- Poison claws (modified first-trunk appendages called maxillipeds) kill or immobilize prey.
- Maxillipeds, along with mouth appendages, hold the prey as mandibles chew and ingest the food
- Most centipede venom is essentially harmless to humans, although many centipedes have bites that are comparable to wasp stings; a few human deaths have been reported from large, tropical species.
- Centipede reproduction may involve courtship displays in which the male lays down a silk web using glands at the posterior tip of the body
- He places a spermatophore in the web, which the female picks up and introduces into her genital opening.
- Eggs are fertilized as they are laid.
- A female may brood and guard eggs by wrapping her body around the eggs, or they may be deposited in the soil.
- Young are similar to adults except that they have fewer legs and segments.
- Legs and segments are added with each molt.



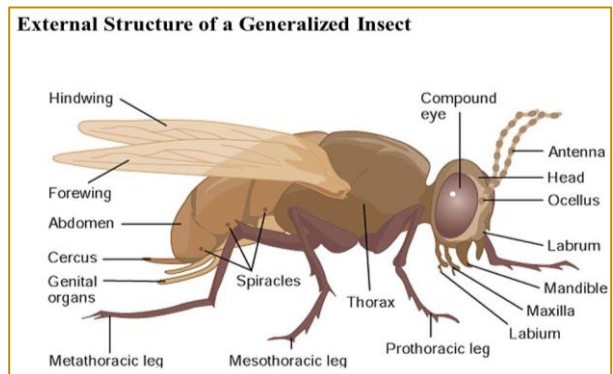
164

Phylum Euarthropoda

Class Hexapoda:

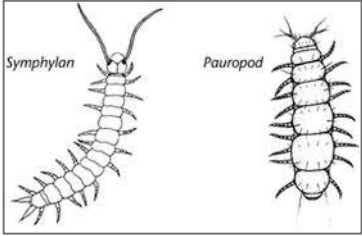
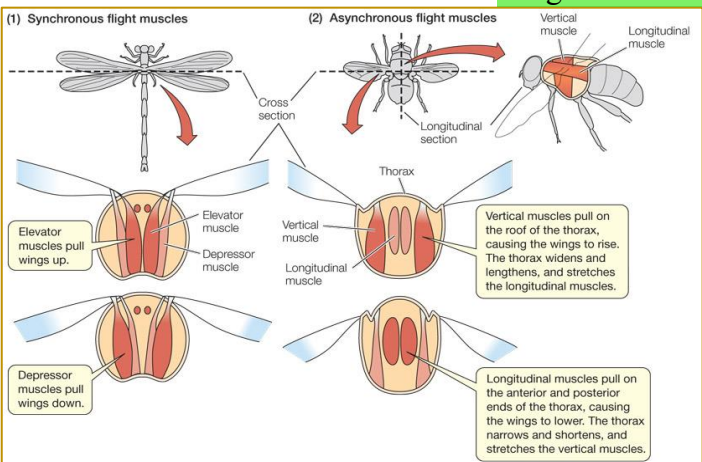
General features and external structures

- Members of the class Hexapoda (Gr. hexa, six and podus, feet) are, in terms of numbers of species and individuals, the most successful land animals.
- Order-level classification varies, depending on the authority consulted
- In spite of obvious diversity, common features make insects easy to recognize.
- Many insects have **wings** and **one pair of antennae**, and virtually all adults have **three pairs of legs**.
- The body of an insect is divided into three tagmata: head, thorax, and abdomen
- The head bears a single pair of antennae, mouthparts, compound eyes, and zero, two, or three ocelli.
- The thorax consists of three segments.
- They are, from anterior to posterior, the prothorax, the mesothorax, and the metathorax
- One pair of legs attaches along the ventral margin of each thoracic segment, and a pair of wings, when present, attaches at the dorsolateral margin of the mesothorax and metathorax.
- Wings have thickened, hollow veins for increased strength.
- The thorax also contains two pairs of spiracles, which are openings to the tracheal system.
- Most insects have **10 or 11 abdominal segments**, each of which has a lateral fold in the exoskeleton that allows the abdomen to expand when the insect has gorged itself or when it is full of mature eggs.
- Each abdominal segment has a pair of spiracles.
- Also present are genital structures used during copulation and egg deposition, and sensory structures called cerci.
- Gills are present on abdominal segments of certain immature aquatic insects

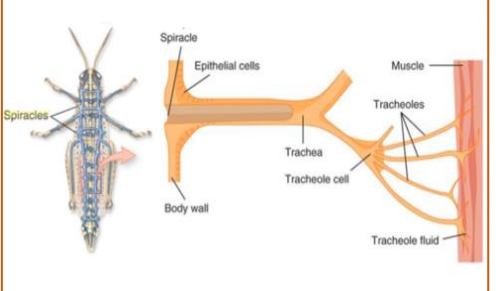
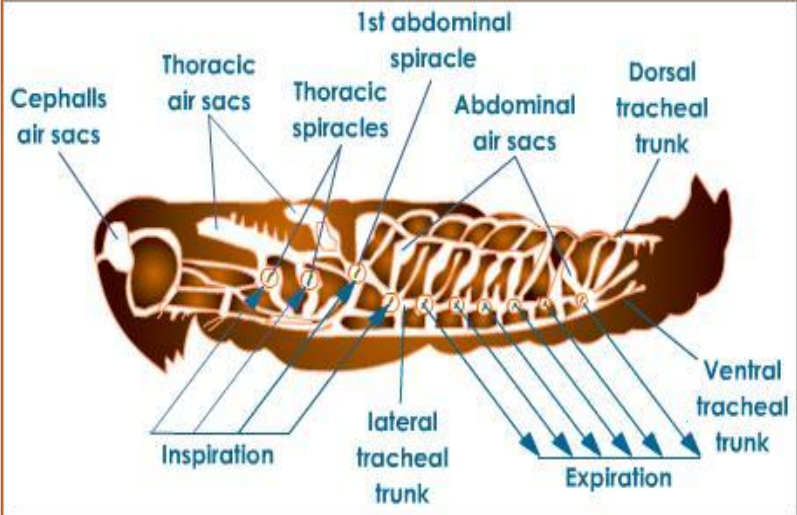


165

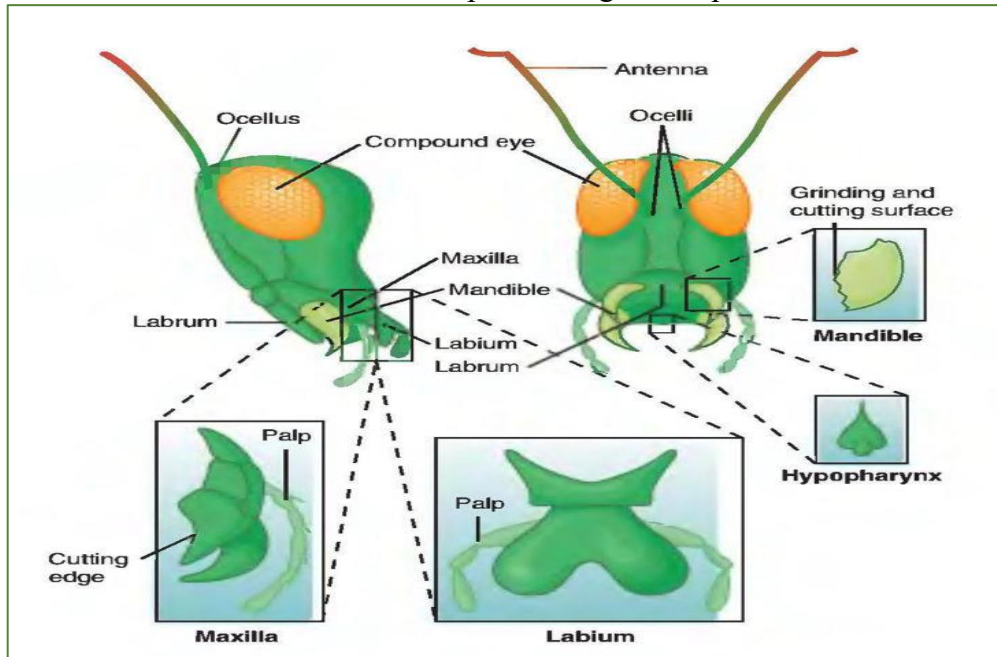
Sub-Phylum Myriapoda Classes Pauropoda and Symphyla

	• Members of the class Paupoda (Gr. pauros, small and podus, foot) are soft-bodied animals with 11 segments. • These animals live in forest-floor litter, where they feed on fungi, humus, and other decaying organic matter • Their very small size and thin, moist exoskeleton allow gas exchange across the body surface and diffusion of nutrients and wastes in the body cavity • Members of the class Symphyla (sim-filah) (Gr. sym, same phyllos, leaf) are small arthropods (2 to 10 mm in length) that occupy soil and leaf mold, superficially resemble centipedes, and are often called garden centipedes • They lack eyes and have 12 leg-bearing trunk segments. • The posterior segment may have one pair of spinnerets or long, sensory bristles. • Symphylans normally feed on decaying vegetation; however, some species are pests of vegetables and flowers 
166	Sub-Phylum Hexapoda <u>Insect Flight</u> • Insects move in diverse ways. • From an evolutionary perspective, however, flight is the most important form of insect locomotion. • Insects were the first animals to fly. • One of the most popular hypotheses on the origin of flight states that wings may have evolved from rigid, lateral outgrowths of the thorax that probably protected the legs or spiracles. • Later, these fixed lobes could have been used in gliding from the top of tall plants to the forest floor • The ability of the wing to flap, tilt, and fold back over the body probably came later. • Another requirement for flight was the evolution of limited thermoregulatory abilities • Thermoregulation is the ability to maintain body temperatures at a level different from environmental temperatures. • Relatively high body temperatures, perhaps 25° C or greater, are needed for flight muscles to contract rapidly enough for flight
167	Sub-Phylum Hexapoda <u>Synchronous flight</u> • Some insects use a direct or synchronous flight mechanism, in which muscles acting on the bases of the wings contract to produce a downward thrust, and muscles attaching dorsally and ventrally on the exoskeleton contract to produce an upward thrust • The synchrony of direct flight mechanisms depends on the nerve impulse to the flight muscles that must precede each wing beat. • Butterflies, dragonflies, and grasshoppers are examples of insects with a synchronous flight mechanism • Synchronous muscle is the most common form of muscle found within an insect's body. • It also occurs in flight muscle within insects that beat their wings less than 100 times per second 

168	Sub-Phylum Hexapoda <u>Asynchronous Flight</u> • Other insects use an indirect or asynchronous flight mechanism. • Muscles act to change the shape of the exoskeleton for both upward and downward wing strokes. • Dorsoventral muscles pulling the dorsal exoskeleton (tergum) downward produce the upward wing thrust. • The downward thrust occurs when longitudinal muscles contract and cause the exoskeleton to arch upward. • The resilient properties of the exoskeleton enhance the power and velocity of these strokes. • During a wing beat, the thorax is deformed, storing energy in the exoskeleton. • At a critical point midway into the down stroke, stored energy reaches a maximum, and at the same time, resistance to wing movement suddenly decreases. • The wing then “clicks” through the rest of the cycle, using energy stored in the exoskeleton. • Asynchrony of this flight mechanism arises from the lack of one-to-one correspondence between nerve impulses and wing beats. • A single nerve impulse can result in approximately 50 cycles of the wing, and frequencies of 1,000 cycles per second (cps) have been recorded in some midges • The asynchrony between wing beat and nerve impulses is dependent on flight muscles being stretched during the “click” of the thorax. • The stretching of longitudinal flight muscles during the upward beat of the wing initiates the subsequent contraction of these muscles. • Similarly, stretching during the downward beat of the wing initiates subsequent contraction of dorsoventral flight muscles. • Indirect flight muscles are frequently called fibrillar flight muscles. • Flies and wasps are examples of insects with an asynchronous flight mechanism • Simple flapping of wings is not enough for flight. • The tilt of the wing must be controlled to provide lift and horizontal propulsion. • In most insects, muscles that control wing tilting attach to sclerotized plates at the base of the wing
169	Sub-Phylum Hexapoda <u>Other forms of Locomotion</u> • Insects walk, run, jump, or swim across the ground or other substrates. • When they walk, insects have three or more legs on the ground at all times, creating a very stable stance. • When they run, fewer than three legs may be in contact with the ground • A fleeing cockroach (order Blattaria) reaches speeds of about 5 km/hour, although it seems much faster when trying to catch one. • The apparent speed is the result of their small size and ability to quickly change directions. • Jumping insects, such as grasshoppers (order Orthoptera), usually have long, metathoracic legs in which leg musculature is enlarged to generate large, propulsive forces. • Energy for a flea’s (order Siphonaptera) jump is stored as elastic energy of the exoskeleton. • Muscles that flex the legs distort the exoskeleton • A catch mechanism holds the legs in this “cocked” position until special muscles release the catches and allow the stored energy to quickly extend the legs. • This action hurls the flea for distances that exceed 100 times its body length. • A comparable distance for a human long jumper would be the length of two football fields.
170	Sub-Phylum Hexapoda <u>Gaseous Exchange: Tracheal system</u> • Gas exchange with air requires a large surface area for the diffusion of gases. • In terrestrial environments, these surfaces are also avenues for water loss • Respiratory water loss in insects, as in some arachnids, is reduced through the invagination of respiratory surfaces to form highly branched systems of chitin-lined tubes, called tracheae • Tracheae open to the outside of the body through spiracles, which usually have some kind of closure device to prevent excessive water loss.

	• Spiracles lead to tracheal trunks that branch, eventually giving rise to smaller branches, the tracheoles • Tracheoles end intracellularly and are especially abundant in metabolically active tissues, such as flight muscles. • No cells are more than 2 or 3 μm from a tracheole	 The diagram illustrates the tracheal system in three parts. On the left, a whole insect shows the location of spiracles along its body. In the center, a cross-section of a spiracle shows it opening through the body wall, lined by epithelial cells. On the right, a detailed view of the tracheal network shows a large trachea branching into smaller tracheae, which further branch into fine tracheoles. Tracheole cells are shown surrounding the tracheoles, and tracheole fluid is indicated at the ends of the tracheoles. Muscles are also shown in the vicinity of the tracheal system.
171	Sub-Phylum Hexapoda <u>What is Ventilating Mechanism in Insects?</u> • Most insects have ventilating mechanisms that move air into and out of the tracheal system. • For example, contracting flight muscles alternatively compress and expand the larger tracheal trunks and thereby ventilate the tracheae • In some insects, carbon dioxide that metabolically active cells produce is sequestered in the hemocoel as bicarbonate ions (HCO_3^-). • As oxygen diffuses from the tracheae to the body tissues, and is not replaced by carbon dioxide, a vacuum is created that draws more air into the spiracles • This process is called passive suction. • Periodically, the sequestered bicarbonate ions are converted back into carbon dioxide, which escapes through the tracheal system. • Other insects contract abdominal muscles in a pumplike fashion to move air into and out of their tracheal systems	 This diagram shows the internal tracheal system of an insect during two phases of ventilation. During 'Inspiration', air enters through the cephalic air sacs and thoracic spiracles, filling the thoracic air sacs and the first abdominal spiracle. During 'Expiration', the air is pushed out through the abdominal air sacs and the dorsal tracheal trunk, with the ventral tracheal trunk also shown. The diagram labels various parts including cephalic air sacs, thoracic air sacs, thoracic spiracles, 1st abdominal spiracle, abdominal air sacs, dorsal tracheal trunk, ventral tracheal trunk, lateral tracheal trunk, and the processes of inspiration and expiration.
172	Sub-Phylum Hexapoda <u>Nutrition and Digestive System, Circulation in Insects</u> • The diversity of insect feeding habits parallels the diversity of insects themselves • An upper, liplike structure is called the labrum. • It is sensory, and unlike the remaining mouthparts, is not derived from segmental, paired appendages • Mandibles are sclerotized, chewing mouthparts. • The maxillae often have cutting surfaces and bear a sensory palp. • The labium is a sensory lower lip. • All of these aid in food handling. • Variations on this plan are specializations for sucking or siphoning plant or animal fluids. • The digestive tract, as in all arthropods, consists of a foregut, a midgut, and a hindgut. • Enlargements for storage and diverticula that secrete digestive enzymes are common • The circulatory system of insects is similar to that described for other arthropods, although the blood vessels are less well developed. • Blood distributes nutrients, hormones, and wastes, and amoeboid blood cells participate in body defense and repair mechanisms.	

- Blood is not important in gas transport



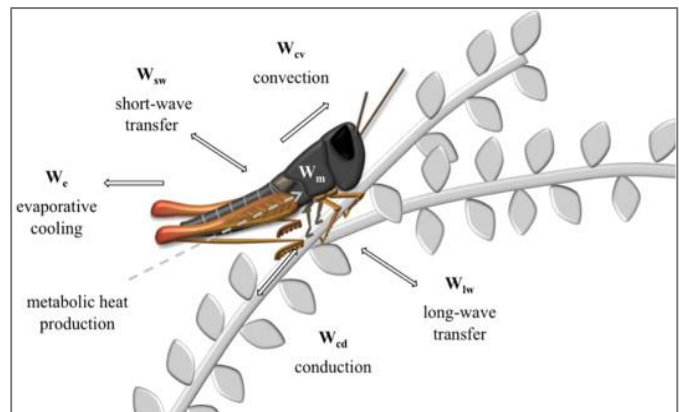
173

Sub-Phylum Hexapoda

Thermoregulation: Shivering Thermogenesis

- **Thermoregulation** is a requirement for flying insects.

- Virtually all insects warm themselves by basking in the sun or resting on warm surfaces
- Because they use external heat sources in temperature regulation, **insects** are generally considered **ectotherms**.
- Other insects (e.g., some moths, alpine bumblebees, and beetles) can generate heat by rapid contraction of flight muscles, a process called **shivering thermogenesis**.
- Metabolic heat generated in this way can raise the temperature of thoracic muscles from near **0 to 30° C**
- Because some insects rely to a limited extent on metabolic heat sources, they have a variable body temperature and are sometimes called heterotherms.
- Insects are also able to cool themselves by seeking cool, moist habitats
- Honeybees can cool a hive by beating their wings at the entrance of the hive, thus circulating cooler outside air through the hive



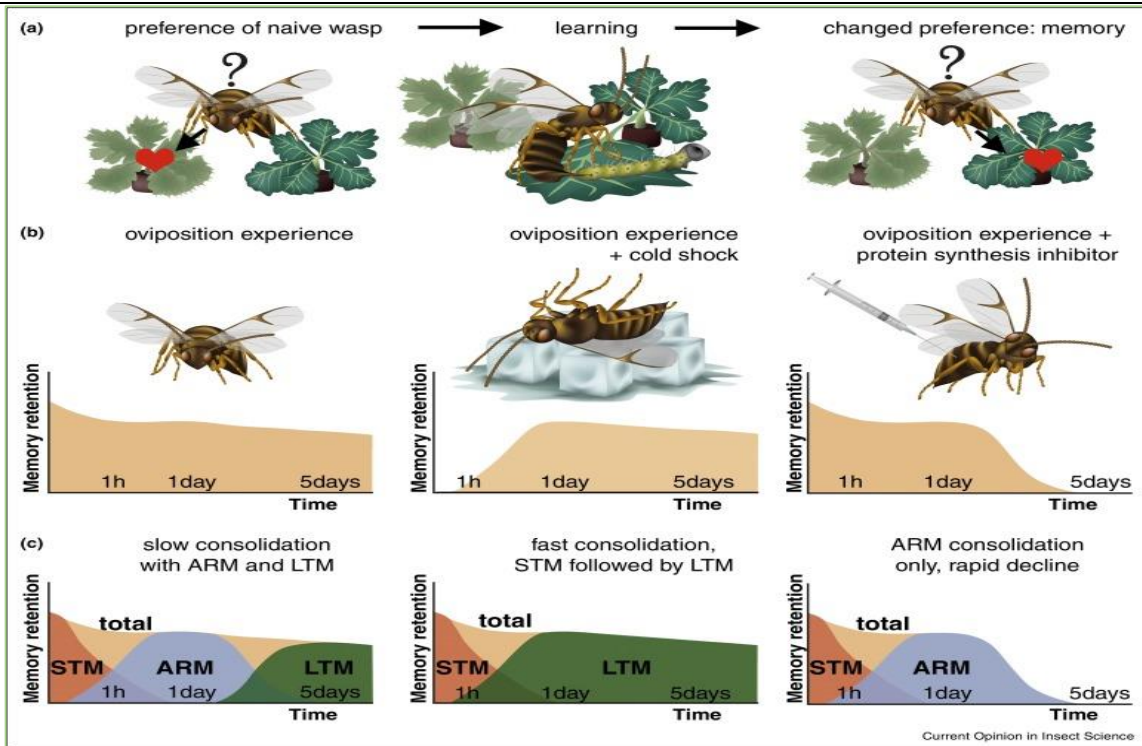
174

Sub-Phylum Hexapoda

What are ectotherms and Heterotherms?

- **Insect thermoregulation** is the process whereby insects maintain body temperatures within certain boundaries.
- While many insects are ectotherms (animals in which their heat source is primarily from the environment), others are **endotherms** (animals which can **produce** heat internally by biochemical processes)
- These endothermic insects are better described as regional heterotherms because they are not uniformly endothermic.
- The body temperatures of aquatic ectotherms are usually very close to those of the water
- Ectotherms do not require as much food as warm-blooded animals (endotherms) of the same size, but most cannot deal as well with cold surroundings

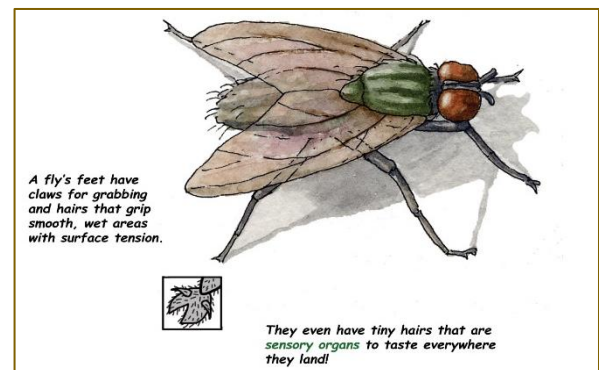
	• Heterothermy (“hetero”, different) occurs in animals which are able to switch from endothermy to ectothermy. • This usually happens in small birds and mammals with high metabolic rates (quite active and with very high energetic requirements), which decrease their body temperature during inactivity periods. • These inactivity periods usually are yearly or daily
175	Sub-Phylum Hexapoda: <u>Behavioral Adaptations to Regulate Temperature</u> • Many animals regulate their body temperature through behavior, such as seeking sun or shade or huddling together for warmth. • Endotherms can alter metabolic heat production to maintain body temperature using both shivering and non-shivering thermogenesis • Vasoconstriction shrinking and vasodilation expansion of blood vessels to the skin can alter an organism's exchange of heat with the environment • A countercurrent heat exchanger is an arrangement of blood vessels in which heat flows from warmer to cooler blood, usually reducing heat loss. • Some animals use body insulation and evaporative mechanisms, such as sweating and panting, in body temperature regulation • Heterothermic insects have adapted to make use of the excess heat produced by flight muscles to increase their thoracic temperature pre-flight. • The other described way of thermoregulation is called behavioral thermoregulation because body temperature is controlled by behavioral means, such as basking in the sun.
176	Sub-Phylum Hexapoda <u>Nervous System of Insects</u> • The nervous system of insects is similar to the pattern described for annelids and other arthropods. • The supraesophageal ganglion is associated with sensory structures of the head • Connectives join the supraesophageal ganglion to the subesophageal ganglion, which innervates the mouthparts and salivary glands and has a general excitatory influence on other body parts • Segmental ganglia of the thorax and abdomen fuse to various degrees in different taxa. • Insects also possess a well-developed visceral nervous system that innervates the gut, reproductive organs, and heart. Internal Structure of a Generalized Insect Fig. 15.8 The diagram illustrates the internal anatomy of an insect, divided into three main regions: Hindgut, Midgut, and Foregut. Key structures labeled include the Anus, Rectum, Ovary, Dorsal aorta, Crop, Supraesophageal ganglion, Ovipositor, Sperm receptacle, Genital chamber, Intestine, Malpighian tubules, Gastric cecae, Nerve cord, Salivary gland, and Mouth. The digestive system is shown in blue, the circulatory system in red, and the nervous system in green.
177	Sub-Phylum Hexapoda <u>Learning and Memory of Insects</u> • Research has demonstrated that insects are capable of some learning and have a memory. • For example, bees (order Hymenoptera) instinctively recognize flowerlike objects by their shape and ability to absorb ultraviolet light, which makes the center of the flower appear dark • If a bee is rewarded with nectar and pollen, it learns the odor of the flower. • Bees that feed once at artificially scented feeders choose that odor in 90% of subsequent feeding trials. • Odor is a very reliable cue for bees because it is more constant than color and shape. • Wind, rain, and herbivores may damage the latter.



178

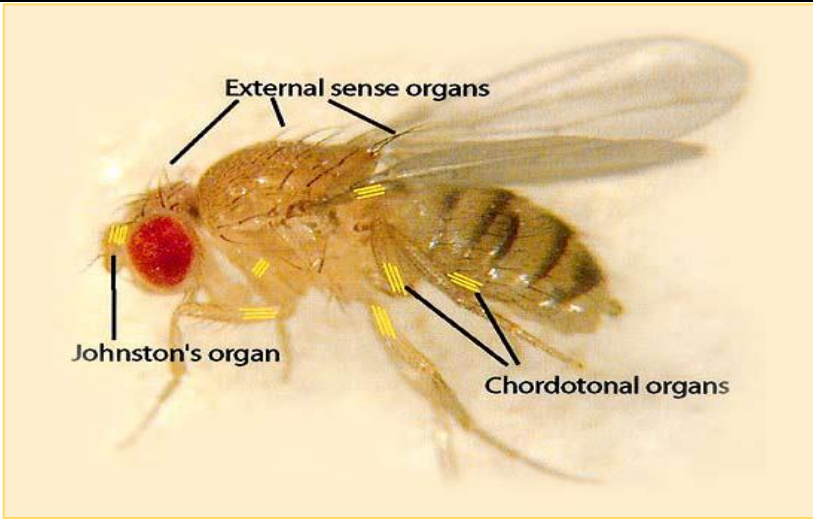
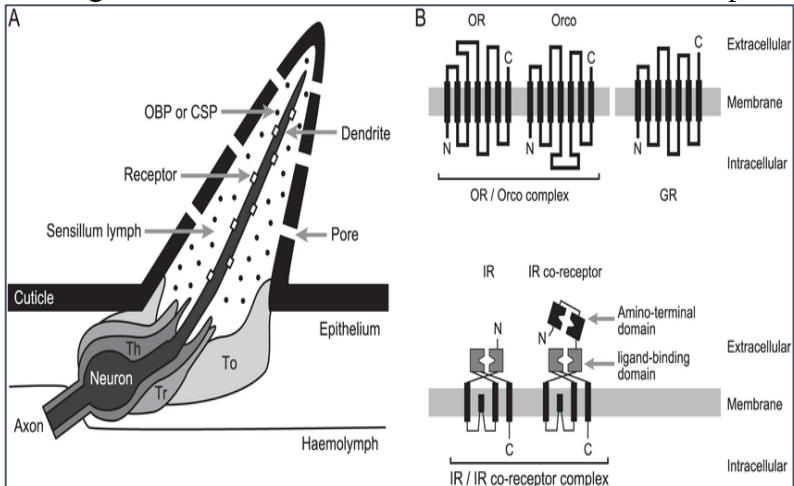
Sub-Phylum Hexapoda Sense Organs

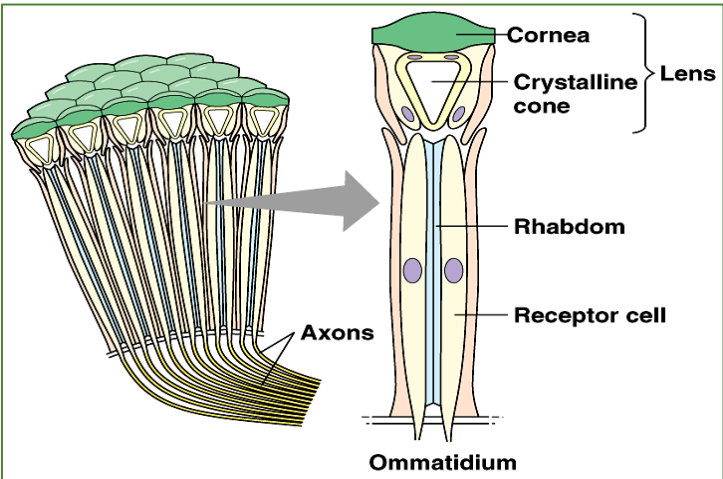
- Sense organs of insects are similar to those found in other arthropods, although they are usually specialized for functioning on land.
- **Mechanoreceptors** perceive physical displacement of the body or of body parts.
- **Setae** are distributed over the mouthparts, antennae, and legs.
- Touch, air movements, and vibrations of the substrate can displace setae.
- Stretch receptors at the joints, on other parts of the cuticle, and on muscles monitor posture and position.
- All sense organs (receptors) act as transducers, converting light energy, chemical energy, or mechanical energy from the environment into electrical energy of nerve impulses in sensory neurons.
- Signals generated by insect sensory receptors travel to the brain or ventral nerve cord where they stimulate appropriate behavioral responses: finding resources (e.g. food, mate, etc.), avoiding danger, or reacting to changes in the environment.
- All sensory receptors are derived from embryonic ectoderm and are integral parts of the insect's exoskeleton.



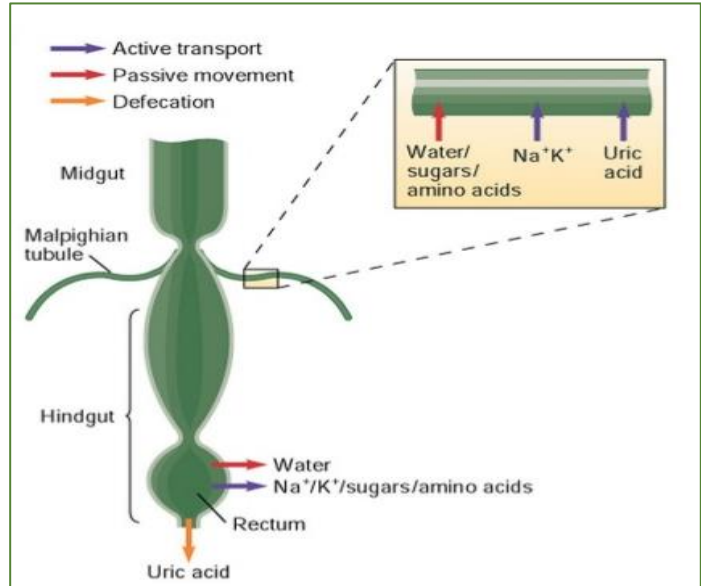
179

- **Hearing is a mechanoreceptive sense** in which airborne pressure waves displace certain receptors.
- All insects can respond to pressure waves with generally distributed setae; others have specialized receptors.
- For example, **Johnston's organs** are in the base of the antennae of most insects, including mosquitoes and midges (order Diptera).
- Long setae that vibrate when certain frequencies of sound strike them cover the antennae of these insects.
- Vibrating setae move the antenna in its socket, stimulating sensory cells.
- Sound waves in the frequency range of **500 to 550 cycles per second (cps)** attract and elicit mating behavior in male mosquitoes (*Aedes aegypti*)
- These waves are in the range of sounds that the wings of females produce.

	
180	• Tympanal (tympanic) organs are in the legs of crickets and katydids (order Orthoptera), in the abdomen of grasshoppers (order Orthoptera) and some moths (order Lepidoptera), and in the thorax of other moths. • Tympanal organs consist of a thin, cuticular membrane covering a large air sac. • The air sac acts as a resonating chamber. • Just under the membrane are sensory cells that detect pressure waves. • Grasshopper tympanal organs can detect sounds in the range of 1,000 to 50,000 cps. • The human ear can detect sounds between 20 and 20,000 cps. • Bilateral placement of tympanal organs allows insects to discriminate the direction and origin of a sound
181	Sub-Phylum Hexapoda <u>Chemoreception</u> • Insects use chemoreception in feeding, selection of egg laying sites, mate location, and sometimes, social organization. • Chemoreceptors are usually abundant on the mouthparts, antennae, legs, and ovipositors, and take the form of hairs, pegs, pits, and plates that have one or more pores leading to internal nerve endings. • Chemicals diffuse through these pores and bind to and excite nerve endings. • Insect chemoreception is mediated by a large and diverse super family of seven transmembrane domain receptors. • These receptors were first identified in <i>Drosophila</i>, but have since been found in other insects, including mosquitoes and moths. • Expression and functional analysis of these receptors have been used to identify receptor ligands and to map receptors to functional classes of neurons. • Many receptors detect general odorants or tastants, whereas some detect pheromones. 

182	Sub-Phylum Hexapoda <u>Structure and Function of Compound Eyes</u> • All insects are capable of detecting light and may use light in orientation, navigation, feeding, or other functions. • Compound eyes are well developed in most adult insects. • They are similar in structure and function to those of other arthropods, although zoologists debate their possible homology (common ancestry) with those of crustaceans, horseshoe crabs, and trilobites. • Compound eyes consist of a few to 28,000 receptors, called ommatidia, that fuse into a multifaceted eye. • The outer surface of each ommatidium is a lens and is one facet of the eye. • Below the lens is a crystalline cone. The lens and the crystalline cone are light-gathering structures. • Certain cells of an ommatidium, called retinula cells, have a special light-collecting area, called the rhabdom. • The rhabdom converts light energy into nerve impulses. • Pigment cells surround the crystalline cone, and sometimes the rhabdom, and prevent the light that strikes one rhabdom from reflecting into an adjacent ommatidium. • Although many insects form an image of sorts, the concept of an image has no real significance for most species. • The compound eye is better suited for detecting movement. • Movement of a point of light less than 0.1° can be detected as light successively strikes adjacent ommatidia. • For this reason, bees are attracted to flowers blowing in the wind, and predatory insects select moving prey. • Compound eyes detect wavelengths of light that the human eye cannot detect, especially in the ultraviolet end of the spectrum. • In some insects, compound eyes also detect polarized light, which may be used for navigation and orientation. 
183	Sub-Phylum Hexapoda <u>Structure and Function of Ocelli in Insects</u> • Ocelli consist of 500 to 1,000 receptor cells beneath a single cuticular lens. • Ocelli are sensitive to changes in light intensity and may be important in the regulation of daily rhythms. • Ocelli (singular Ocellus) are simple photo-receptors (light detecting organs). • They consist of a single lens and several sensory cells. • Unlike compound eyes, ocelli do not form a complex image of the environment but are used to detect movement. • One suggestion which has been made a number of times is that ocelli are concerned in some way with flight, and insects which are good at flying tend to have well developed ocelli.
184	Sub-Phylum Hexapoda <u>Excretion</u> • The primary insect excretory structures are the Malpighian tubules and the rectum. • Malpighian tubules end blindly in the hemocoel and open to the gut tract at the junction of the midgut and the hindgut. • Microvilli cover the inner surface of their cells. • Various ions are actively transported into the tubules, and water passively follows.

- Uric acid is secreted into the tubules and then into the gut, as are amino acids and ions.
- In the rectum, water, certain ions, and other materials are reabsorbed, and the uric acid is eliminated.
- Excretion of uric acid is advantageous for terrestrial animals because it minimizes water loss.
- There is, however, an evolutionary trade-off.
- The conversion of primary nitrogenous wastes (ammonia) to uric acid is energetically costly.
- Nearly half of the food energy a terrestrial insect consumes may be used to process metabolic wastes.
- In aquatic insects, ammonia simply diffuses out of the body into the surrounding water.

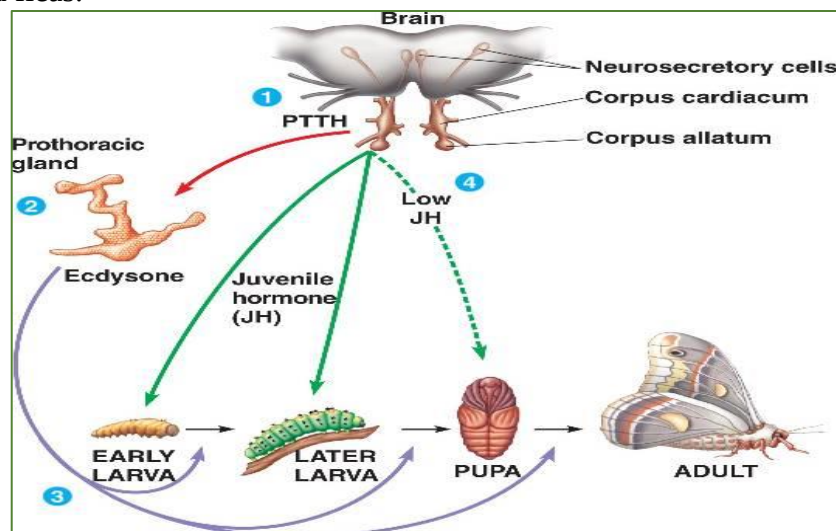


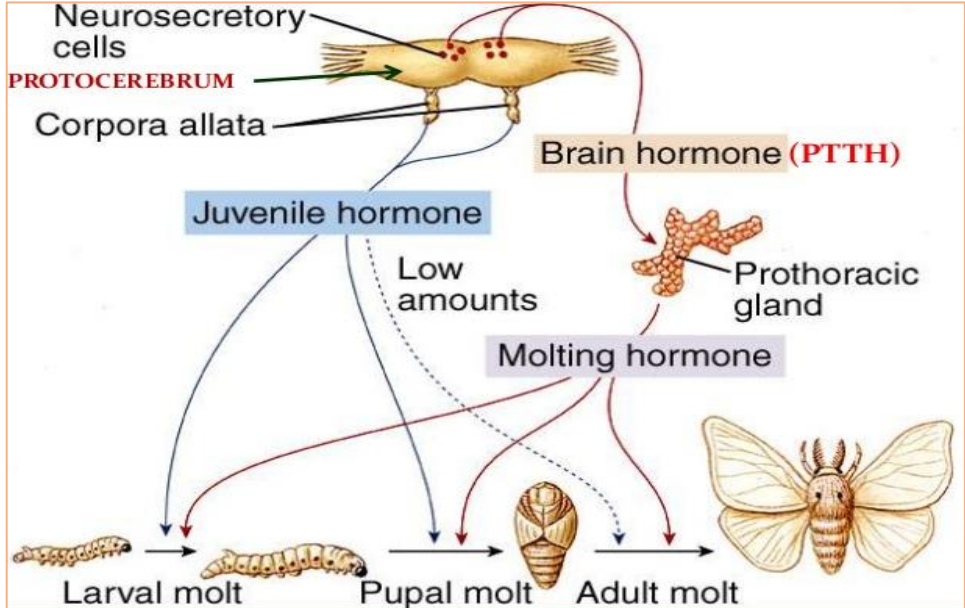
185

Sub-Phylum Hexapoda

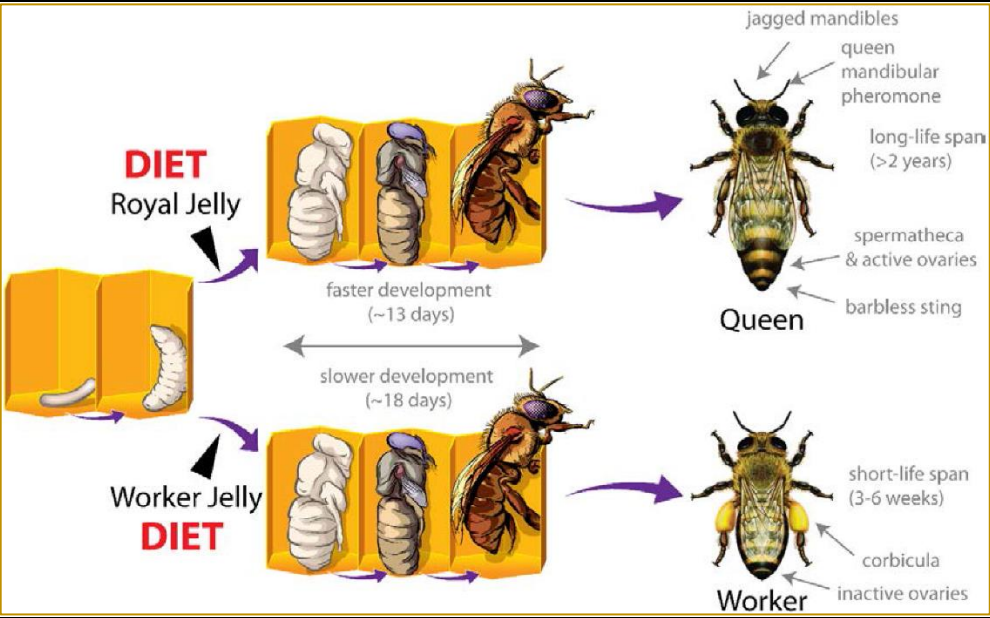
Chemical Regulation

- The endocrine system controls many physiological functions of insects, such as cuticular sclerotization, osmoregulation, egg maturation, cellular metabolism, gut peristalsis, and heart rate.
- As in all arthropods, **ecdysis is under neuroendocrine control.**
- In insects, the subesophageal ganglion and two endocrine glands the corpora allata and the prothoracic glands control these activities.
- There are two main classes of hormones in **insects**:
 - 1) the true hormones produced by epithelial glands and belonging to the ecdysteroids or juvenile hormones.
 - 2) the neuropeptide hormones produced by neurosecretory cells
- An **insect growth regulator (IGR)** is a substance (chemical) that inhibits the life cycle of an insect.
- IGRs are typically used as insecticides to control populations of harmful insect pests such as cockroaches and fleas.



186	Sub-Phylum Hexapoda <u>Control of Ecdysis by Neuroendocrine System</u> • Neurosecretory cells of the subesophageal ganglion manufacture ecdysiotropin. • This hormone travels in neurosecretory cells to a structure called the corpora cardiaca. • The corpora cardiaca then releases thoracotropic hormone, which stimulates the prothoracic gland to secrete ecdysone. • Ecdysone initiates the reabsorption of the inner portions of the procuticle and the formation of the new exoskeleton. • Other hormones are also involved in ecdysis. • The recycling of materials absorbed from the procuticle, changes in metabolic rates, and pigment deposition are a few of probably many functions that hormones control.
187	Sub-Phylum Hexapoda <u>Role of Juvenile Hormone in Metamorphosis</u> • In immature stages, the corpora allata produces and releases small amounts of juvenile hormone. • The amount of juvenile hormone circulating in the hemocoel determines the nature of the next molt. • Large concentrations of juvenile hormone result in a molt to a second immature stage, intermediate concentrations result in a molt to a third immature stage, and low concentrations result in a molt to the adult stage. • Decreases in the level of circulating juvenile hormone also lead to the degeneration of the prothoracic gland so that, in most insects, molts cease once adulthood is reached. • Interestingly, after the final molt, the level of juvenile hormone increases again, but now it promotes the development of accessory sexual organs, yolk synthesis, and the egg maturation.  The diagram illustrates the hormonal control of insect metamorphosis. At the top, the Neurosecretory cells in the PROTOCEREBRUM release Brain hormone (PTTH), which stimulates the Prothoracic gland to produce Molting hormone. The Corpora allata releases Juvenile hormone. The diagram shows the progression through Larval molt, Pupal molt, and Adult molt. Juvenile hormone levels are high during the larval stage, intermediate during the pupal stage, and low during the adult stage. Molting hormone is shown stimulating the transition from pupa to adult.
188	Sub-Phylum Hexapoda <u>Pheromones</u> • Pheromones are chemicals an animal releases that cause behavioral or physiological changes in another member of the same species. • Zoologists have described many different insect uses of pheromones. • Pheromones are often so specific that the stereoisomer (chemical mirror image) of the pheromone may be ineffective in initiating a response. • Wind or water may carry pheromones several kilometers, and a few pheromone molecules falling on a chemoreceptor of another individual may be enough to elicit a response. • Releaser pheromones initiate immediate behavioral responses in insects upon reception, while primer pheromones cause physiological changes in an animal that ultimately result in a behavior response. • Thus, a male insect may be attracted to and attempt to copulate with an inanimate object that has sex pheromone on it.

189	Sub-Phylum Hexapoda <u>Sex Pheromones</u> • Excite or attract members of the opposite sex; accelerate or retard sexual maturation. • Example: Female moths produce and release pheromones that attract males. • Sex pheromones act as a signal to attract potential mates over long distances (e.g. moths). • Sensitive chemoreceptive sensilla in insects facilitate the detection of very low concentrations of sex pheromones in the environment. • Release of sex pheromones may be governed by factors such as time of day, weather, and the availability of host plants. • Furthermore, both the immature and adult stages of insects can sequester chemicals from host plants and use them as precursors for sex pheromones. • Sex pheromones are highly species specific and, as a rule, a unique blend of the natural pheromone components is needed for attraction.
190	Sub-Phylum Hexapoda <u>Sex pheromones</u> • Excite or attract members of the opposite sex; accelerate or retard sexual maturation. • Example: Female moths produce and release pheromones that attract males. • Sex pheromones act as a signal to attract potential mates over long distances (e.g. moths). • Sensitive chemoreceptive sensilla in insects facilitate the detection of very low concentrations of sex pheromones in the environment. • Release of sex pheromones may be governed by factors such as time of day, weather, and the availability of host plants. • Furthermore, both the immature and adult stages of insects can sequester chemicals from host plants and use them as precursors for sex pheromones. • Sex pheromones are highly species specific and, as a rule, a unique blend of the natural pheromone components is needed for attraction.
191	Sub-Phylum Hexapoda <u>Caste Regulating Pheromones</u> • Used by social insects to control the development of individuals in a colony. • Example: The amount of “royal jelly” fed a female bee larva determines whether the larva will become a worker or a queen. • Termites, a major group of social insects, exhibit many interesting phenomena related to social physiology, such as mechanisms of caste regulation in a colony. • In their colonies, there are different types of individuals, i.e., castes, which show distinctive phenotypes specialized in specific colony tasks. • Termite castes comprise reproductive, soldiers and workers, and the caste composition can be altered depending on circumstances. • For the regulation of caste compositions, interactions among individuals, i.e., social interactions, are thought to be important.

	 The diagram illustrates the developmental paths of honeybees. At the top left, a cell is shown with 'Royal Jelly' as the diet, leading to 'faster development (~13 days' and resulting in a 'Queen'. The Queen is characterized by 'jagged mandibles', 'queen mandibular pheromone', a 'long-life span (>2 years)', 'spermatheca & active ovaries', and a 'barbless sting'. At the bottom left, a cell is shown with 'Worker Jelly' as the diet, leading to 'slower development (~18 days)' and resulting in a 'Worker'. The Worker is characterized by a 'short-life span (3-6 weeks)', 'corbicula', and 'inactive ovaries'.
192	Sub-Phylum Hexapoda <u>Aggregation Pheromones</u> • Produced to attract individuals to feeding or mating sites. • Example: Certain bark beetles aggregate on pine trees during an attack on a tree. • Male-produced sex attractants often are referred to as aggregation pheromones because they typically result in the arrival of both sexes at a calling site. • Aggregation pheromones have been reported for members of the Coleoptera, Dictyoptera, Hemiptera, Homoptera and Orthoptera and have been identified for hundred of species. • Aggregation pheromones function in many ways including mate selection, defense against predators, and overcoming host resistance by mass attack. • A group of individuals (more than a pair) at one location may be referred as aggregation, whether comprised of one sex or both sexes.
193	Sub-Phylum Hexapoda <u>Alarm Pheromones</u> • Warn other individuals of danger; may cause orientation toward the pheromone source and elicit a subsequent attack or flight from the source. • Example: A sting from one bee alarms other bees in the area, who are likely to attack. • Social insects, ants, bees, wasps, and the unrelated termites, all show colony defense coordinated by alarm pheromones. • Honeybees release an alarm pheromone when they sting an intruder such as a bear intent on robbing their nest of its honey. • Many freshwater fish species have an alarm pheromone released from skin glands when these are damaged by a predator's closing its jaws on the victim. • Other fish detecting the alarm pheromone show escape behavior and greater vigilance. • Alarm pheromones generally consist of low-molecularweight, highly volatile compounds that easily spread throughout a colony yet evaporate quickly to terminate the aggression when the danger no longer exists.

194

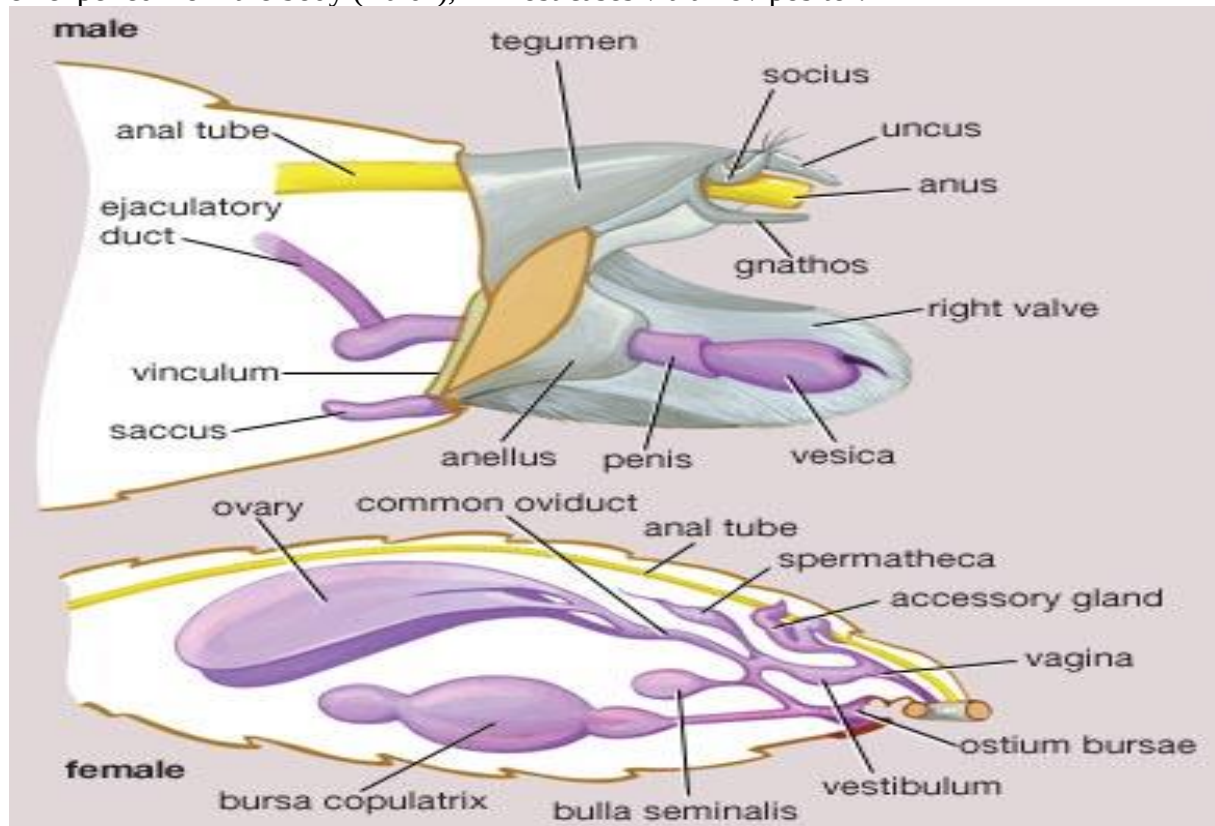
Sub-Phylum Hexapoda**Trailing Pheromones**

- Laid down by foraging insects to help other members of a colony identify the location and quantity of food found by one member of the colony.
- Example: Ants often trail on a pheromone path to and from a food source.
- The pheromone trail is reinforced each time an ant travel over it.
- Trail pheromones often serve as a multipurpose chemical secretion that leads members of its own species towards a food source, while representing a territorial mark in the form of an allomone to organisms outside of their species.
- Specifically, trail pheromones are often incorporated with secretions of more than one exocrine gland to produce a higher degree of specificity.
- Considered one of the primary chemicals signaling methods in which many social insects depend on, trail pheromone deposition can be considered one of the main facets to explain the success of social insect communication today.

195

Sub-Phylum Hexapoda**Reproductive Potential of Insects****• One of the reasons for insects' success is their high reproductive potential.**

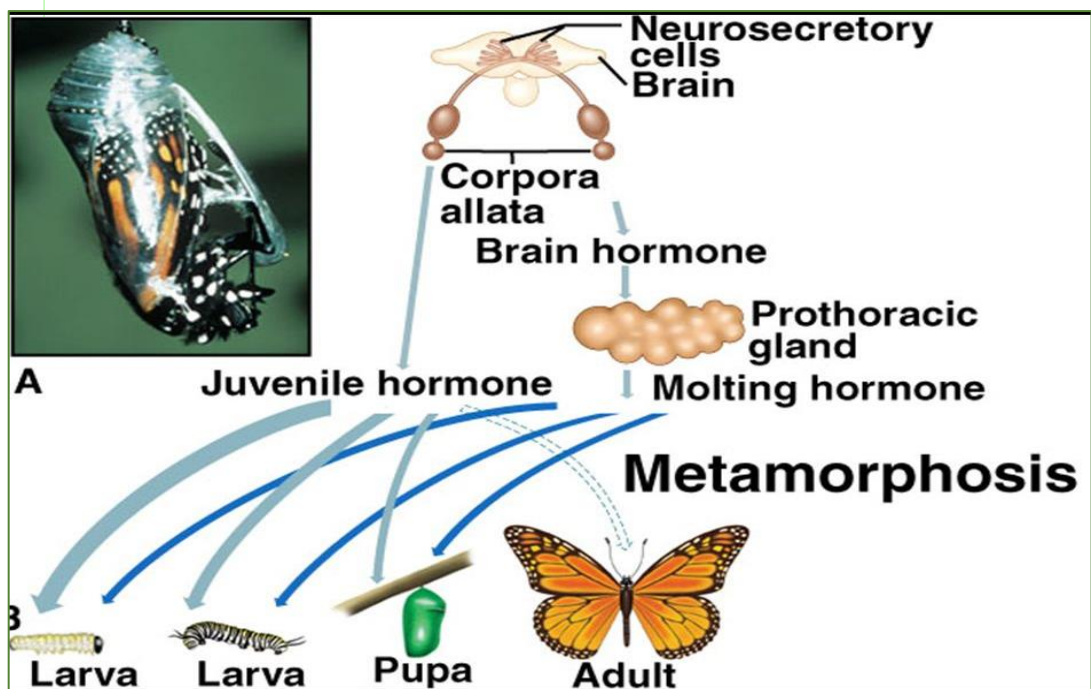
- Reproduction in terrestrial environments, however, has its risks.
- Temperature, moisture, and food supplies vary with the season.
- Internal fertilization requires highly evolved copulatory structures, because gametes dry quickly on exposure to air.
- In addition, mechanisms are required to bring males and females together at appropriate times.
- Most insects reproduce o viparously, i.e. by laying eggs.
- The eggs are produced by the female in a pair of ovaries.
- Sperm, produced by the male in one testis or more commonly two, is transmitted to the female during mating by means of external genitalia.
- The sperm is stored within the female in one or more spermathecae.
- At the time of fertilization, the eggs travel along oviducts to be fertilized by the sperm and are then expelled from the body ("laid"), in most cases via an ovipositor.



Sub-Phylum Hexapoda

Sexual Maturity of Insects by Internal Factors

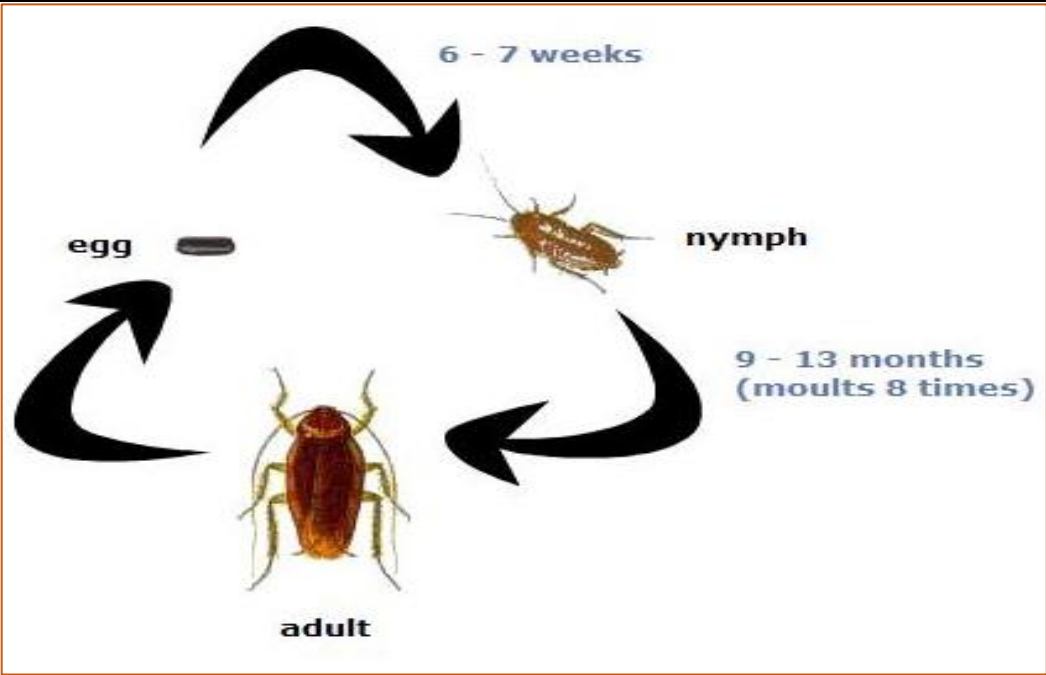
- Complex interactions between internal and external environmental factors regulate sexual maturity.
- Internal regulation includes interactions between endocrine glands (primarily the corpora allata) and reproductive organs.
- In insects, the largest and most obvious **endocrine glands are found in the prothorax**, just behind the head.
- These **prothoracic glands manufacture ecdy steroids**, a group of closely-related steroid hormones (including ecdysone) that stimulate synthesis of chitin and protein in epidermal cells and trigger a cascade of physiological events that culminates in molting.
- For this reason, the **ecdysteroids are often called “molting hormones”**.
- Once an insect reaches the adult stage, its **prothoracic glands atrophy** (wither away) and it will never molt again.
- The corpora allata, another pair of **neurohemal** organs, lie just behind the corpora cardiaca.
- They manufacture **juvenile hormone (JH for short)**, a compound that **inhibits development of adult characteristics during the immature stages and promotes sexual maturity during the adult stage**.

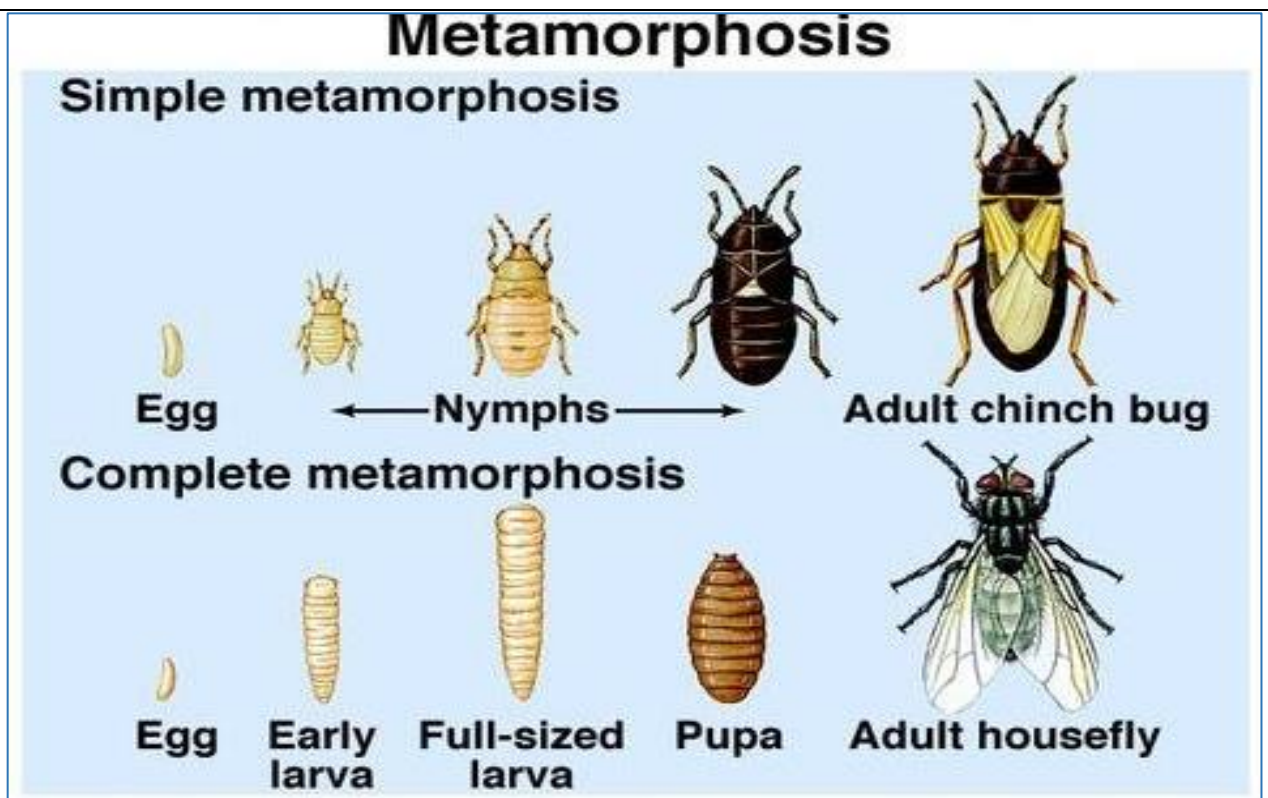


Sub-Phylum Hexapoda

Sexual Maturity of Insects by External Factors

- External regulating factors may include the quantity and quality of food.
- For example, the eggs of mosquitoes (order Diptera) do not mature until after the female takes a meal of blood, and the number of eggs produced is proportional to the quantity of blood ingested.
- Many insects use the photoperiod (the relative length of daylight and darkness in a **24-hour period**) for timing reproductive activities because it indicates seasonal changes.
- **Population density, temperature, and humidity also influence reproductive activities.**
- Males die shortly after mating, whereas females enter diapause and store sperm which fertilize eggs that mature and are deposited following diapause termination.
- Alternatively, females and males may endure the unfavorable period in non receptive and refractory states, respectively, with both mating and oviposition following diapause.
- While female and male behavioral states in this pattern appear to be controlled by similar environmental (normally photoperiodic) cues acting via the neuroendocrine system, the regulation of male refractoriness is often less stringent.

	
198	Sub-Phylum Hexapoda <u>Mating Behavior in Insects</u> • Most insects have complex mating behaviors for locating and recognizing a potential mate, for positioning a mate for copulation, or for pacifying an aggressive mate. • Mating behavior may involve pheromones (moths, order Lepidoptera), visual signals (fireflies, order Coleoptera), and auditory signals (cicadas, order Homoptera; and grasshoppers, crickets, and katydids, order Orthoptera) • Once other stimuli have brought the male and female together, tactile stimuli from the antennae and other appendages help position the insects for mating. • Mating behavior starts by locating mates. • Male and female have different strategies toward copulation and reproduction. • After locating mates is courtship; one male and female have encountered each other, they may proceed directly to copulation or may first engage in various rituals, collectively known as courtship. • The final ritual is copulation.
199	Sub-Phylum Hexapoda <u>Insect Development</u> • Insect evolution has resulted in the divergence of immature and adult body forms and habits. • For insects in the superorder Endopterygota immature stages, called larval instars, are a time of growth and accumulation of reserves for the transition to adulthood. • The adult stage is associated with reproduction and dispersal. • In these orders, insects tend to spend a greater part of their lives in juvenile stages. • The developmental patterns of insects reflect degrees of divergence between immatures and adults and are classified into three (or sometimes four) categories. • Changes occur in the insect during the development from egg to the adult. • Complete metamorphosis consists of four stages: egg, larva, pupa, and adult. - fs • Incomplete metamorphosis consists of three stages: egg, nymph, and adult.

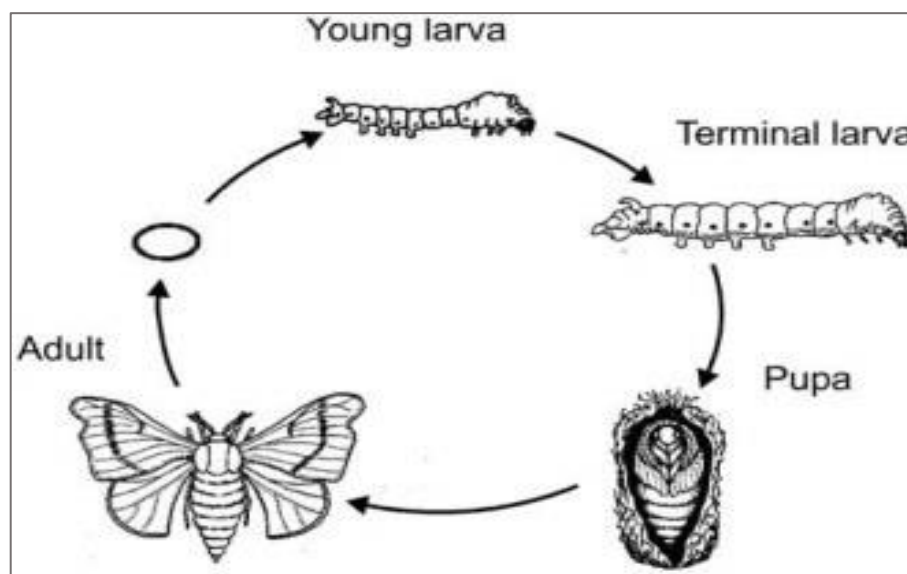


200

Sub-Phylum Hexapoda

Ametabolous Metamorphosis

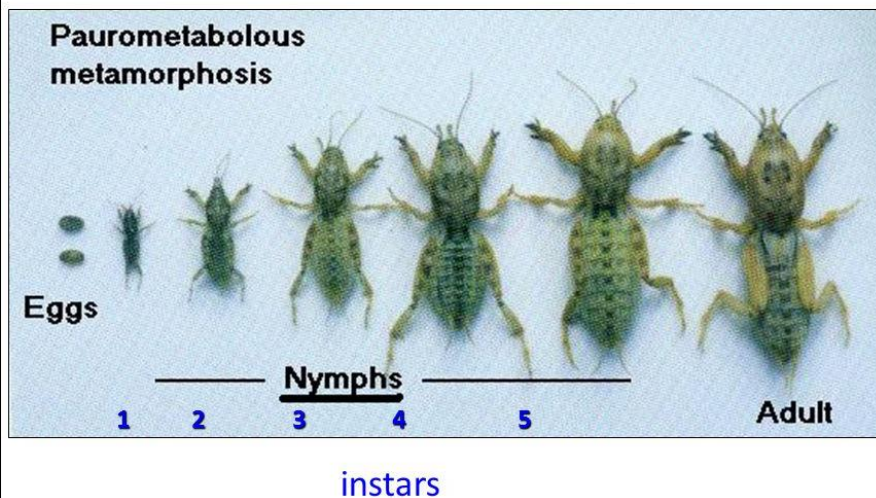
- In insects that display **ametabolous** (Gr. a, **without** and metabolos, **change**) **metamorphosis**, the **primary differences** between adults and **larvae** are body size and sexual maturity.
- Both adults and larvae are **wingless**.
- The number of molts in the ametabolous development of a species varies, and unlike most other insects, molting continues after sexual maturity.
- **Silverfish** (order Thysanura) have ametabolous metamorphosis.
- **Ametabolous** insect lifecycles are unique in that the adult lays eggs, and immature insects that first hatch from the eggs resemble miniature versions of the adult.
- **Immature silverfish molt six to seven times** until they reach their adult, sexually mature stage.



201

Sub-Phylum Hexapoda (Paurometabolous Metamorphosis)

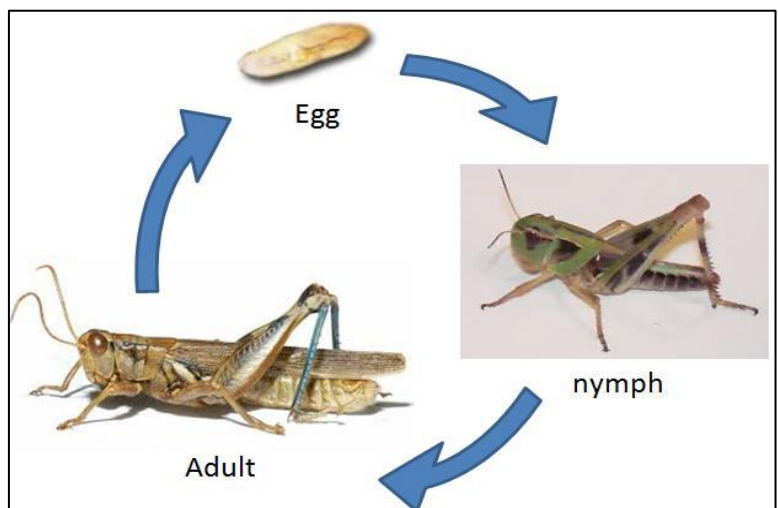
- **Paurometabolous (Gr. *pauros*, small) metamorphosis** involves a species-specific number of molts between egg and adult stages, during which immatures gradually take on the adult form.
- The external wings develop (except in those insects, such as lice, that have secondarily lost wings), adult body size and proportions are attained, and the genitalia develop during this time.
- **Immatures are called nymphs.**
- In this form of development, immature stages (nymphs) resemble small adults and typically have external wing buds.
- They live in the same habitat as adults, typically taking the same food.
- **Grasshoppers** (order Orthoptera) and **chinch bugs** (order Hemiptera) show **paurometabolous** metamorphosis.

Paurametabolous – gradual metamorphosis

202

Sub-Phylum Hexapoda (Hemimetabolous Mmetamorphosis)

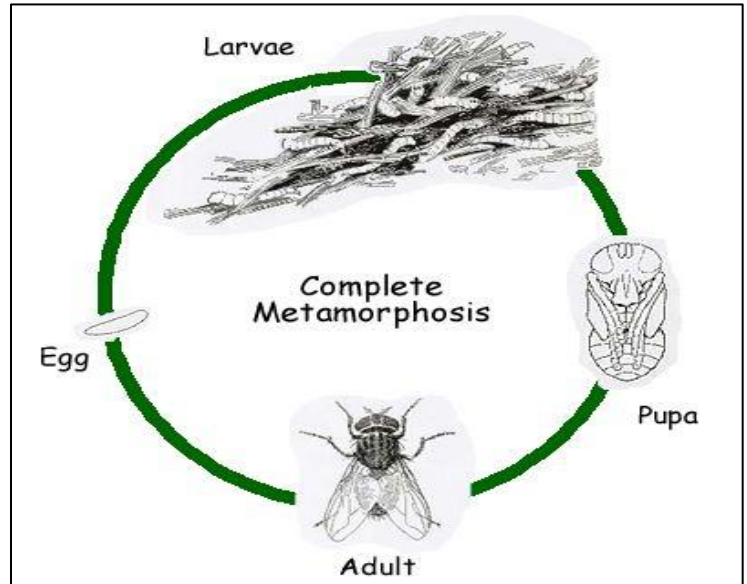
- Some zoologists use an additional classification for insects that have a series of gradual changes in their development, but whose immature form is much different from the adult form usually due to the presence of gills (e.g., mayflies, order Ephemeroptera; dragonflies, order Odonata).
- This kind of development is called **hemimetabolous (Gr. *hemi*, half) metamorphosis**, and the immatures are aquatic and called **naiads (L. *naiad*, water nymph)**.
- Insects that undergo **hemimetabolous metamorphosis** emerge from eggs into nymphs (called larvae by some entomologists) that are similar in shape to the adults.
- They go through several nymphal stages (called instars) before they undergo a final molt into their adult form.
- Also known as incomplete or simple **metamorphosis**.
- The nymph, or immature insect, resembles the adult in form and eating habits, differing in size, body proportions, and color pattern.



203

Sub-Phylum Hexapoda (Holometabolous Metamorphosis)

- In **holometabolous** (Gr. *holos*, whole) **metamorphosis**, **immatures** are called larvae because they are **very different from** the adult in **body form, behavior, and habitat**.
- The **number of larval instars is species specific**, and the **last larval molt forms the pupa**.
- The pupa is a time of apparent inactivity but is actually a time of radical cellular change, during which all characteristics of the adult insect develop.
- A protective case may enclose the pupal stage.
- **The last larval instar (e.g., moths, order Lepidoptera) constructs a cocoon partially or entirely from silk.**
- **The chrysalis (e.g., butterflies, order Lepidoptera) and puparium (e.g., flies, order Diptera)** are the last larval exoskeletons and are retained through the pupal stage.
- Other insects (e.g., mosquitoes, order Diptera) have pupae that are unenclosed by a larval exoskeleton, and the pupa may be active.
- The final molt to the adult stage usually occurs within the cocoon, chrysalis, or puparium, and the adult then exits, frequently using its mandibles to open the cocoon or other enclosure.
- **This final process is called emergence or eclosion.**



204

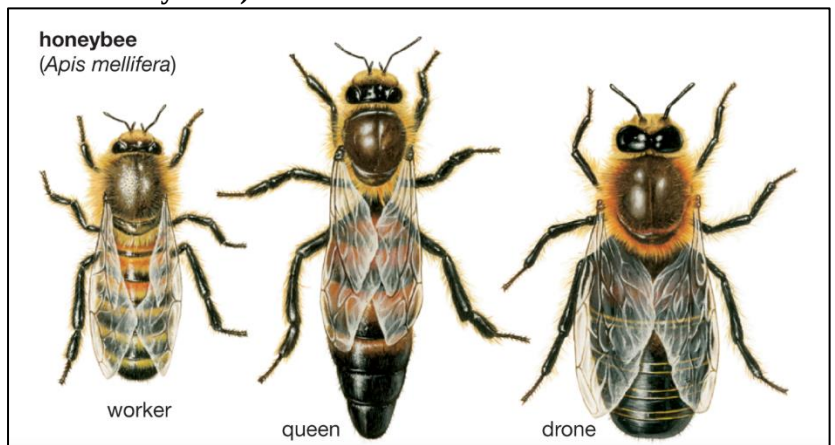
Sub-Phylum Hexapoda (Innate Behavior of Insects)

- Insects have many complex behavior patterns.
- Most of these are **innate (genetically programmed)**.
- For example, a newly emerged queen in a honeybee hive will search out and try to destroy other queen larvae and pupae in the hive.
- This behavior is innate because no experiences taught the potential queen that her survival in the hive required the death or dispersal of all other potential queens.
- Similarly, no experience taught her how queen-rearing cells differ from the cells containing worker larvae and pupae.
- Some insects are capable of learning and remembering, and these abilities play important roles in insect behavior.

205

Sub-Phylum Hexapoda (Caste System in Honey Bees)

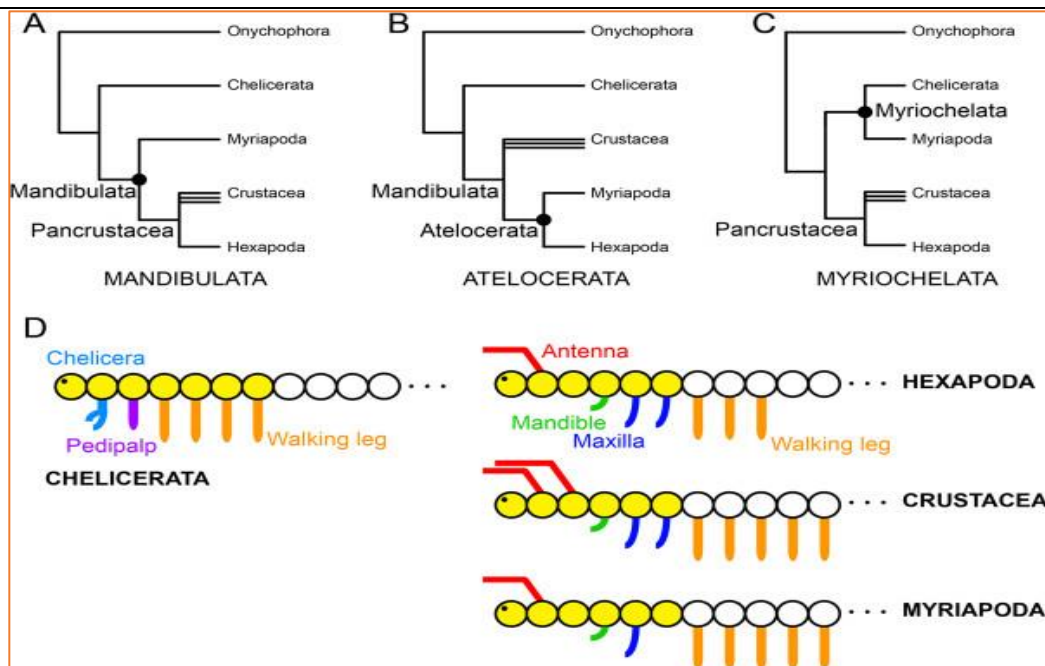
- Honeybees (order Hymenoptera) have **three** of these castes in their colonies.
- A **single queen** lays all the eggs.
- **Workers are female**, and they construct the comb out of wax that they produce.
- They also gather nectar and pollen, feed the queen and drones, care for the larvae,



	and guard and clean the hive. • These tasks are divided among workers according to age. • Younger workers take care of jobs around the hive, and older workers forage for nectar and pollen. • Except for those that overwinter, workers live for about one month. • Drones develop from unfertilized eggs, do not work, and are fed by workers until they leave the hive to attempt mating with a queen.
206	Sub-Phylum Hexapoda (Control of Honey Bee Caste System) • Honeybees (order Hymenoptera) have three of these castes in their colonies. • A single queen lays all the eggs. • Workers are female, and they construct the comb out of wax that they produce. • They also gather nectar and pollen, feed the queen and drones, care for the larvae, and guard and clean the hive. • These tasks are divided among workers according to age. • Younger workers take care of jobs around the hive, and older workers forage for nectar and pollen. • Except for those that overwinter, workers live for about one month. • Drones develop from unfertilized eggs, do not work, and are fed by workers until they leave the hive to attempt mating with a queen.
207	Sub-Phylum Hexapoda (Control of Honey Bee Caste System) • A pheromone that the queen releases control the honeybee caste system. • Workers lick and groom the queen and other workers. • In so doing, they pick up and pass to other workers a caste regulating pheromone. • This pheromone inhibits the workers from rearing new queens. • As the queen ages, or if she dies, the amount of caste-regulating pheromone in the hive decreases. • As the pheromone decreases, workers begin to feed the food for queens (“royal jelly”) to several female larvae developing in the hive. • This food contains chemicals that promote the development of queen characteristics. • The larvae that receive royal jelly develop into queens, and as they emerge, the new queens begin to eliminate each other until only one remains. • The queen that remains goes on a mating flight and returns to the colony, where she lives for several years.

208	Sub-Phylum Hexapoda (Role of Insects in Pollination) - Only about 0.5% of insect species adversely affect human health and welfare. - Many others have provided valuable services and commercially valuable products, such as wax, honey, and silk, for thousands of years. - Insects are responsible for the pollination of approximately 65% of all plant species. - Insects and flowering plants have coevolutionary relationships that directly benefit humans. - The annual value of insect-pollinated crops is estimated at \$19 billion per year in the United States. Insect pollination is crucial to most gardens and is as simple as insects like bees, butterflies and wasps flying from flower to flower in order to collect nectar. In the process, pollen collects on their bodies and rubs off on other flowers that they visit.
209	Sub-Phylum Hexapoda (Biological Control by Insects) - Insects are also agents of biological control. - The classic example of one insect regulating another is the vedalia (lady bird) beetles' control of cottony-cushion scale. - The scale insect, <i>Icerya purchasi</i>, was introduced into California in the 1860s. - Within 20 years, the citrus industry in California was virtually destroyed. - The vedalia beetle (<i>Vedalia cardinalis</i>) was brought to the United States in 1888 and 1889 and cultured on trees infested with scale. - In just a few years, the scale was under control, and the citrus industry began to recover.
210	Sub-Phylum Hexapoda (Importance of soil Dwelling Insects) - Many other insects are also beneficial. Soil-dwelling insects play important roles in aeration, drainage, and turnover of soil, and they promote decay processes. - Other insects serve important roles in food webs. - Insects are used in teaching and research, and have contributed to advances in genetics, population ecology, and physiology. - Insects have also given endless hours of pleasure to those who collect them and enjoy their beauty. Soil-dwelling insects are hidden in the soil and hard to detect until the sudden appearance of damage creates the demand for rapid, curative treatment.
211	Sub-Phylum Hexapoda (Insects as Parasites and Vectors of Disease) - Some insects, however, are parasites and vectors of disease. - Parasitic insects include head, body, and pubic lice (order Anoplura); bedbugs (order Hemiptera); and fleas (order Siphonaptera). Parasites transmitted by insects often circulate in the blood of the host, with the parasite residing in and damaging organs or other parts of the body. - Other insects transmit disease-causing microorganisms, nematodes, and flatworms. - Insect-transmitted diseases, such as malaria, yellow fever, bubonic plague, encephalitis, leishmaniasis, and typhus, have changed the course of history. - Triatomine bugs are the vectors for Chagas disease. An insect that transmits a disease is known as a vector, and the disease is referred to as a vector-borne disease. What are vectors? VECTORS are common INSECTS that carry & transmit diseases causing bacteria, viruses & parasites BITING VECTORS - Mosquito - Tick - Biting fly - Flea - Mite CARRIER VECTORS - House fly - Cockroach Transmit more than 250 food borne diseases leading to - Nausea, vomiting and diarrhoea - Malaise, headache, fever - Deaths: Globally- 19 Lakhs/year - South-East Asia- 10 Lakhs/year

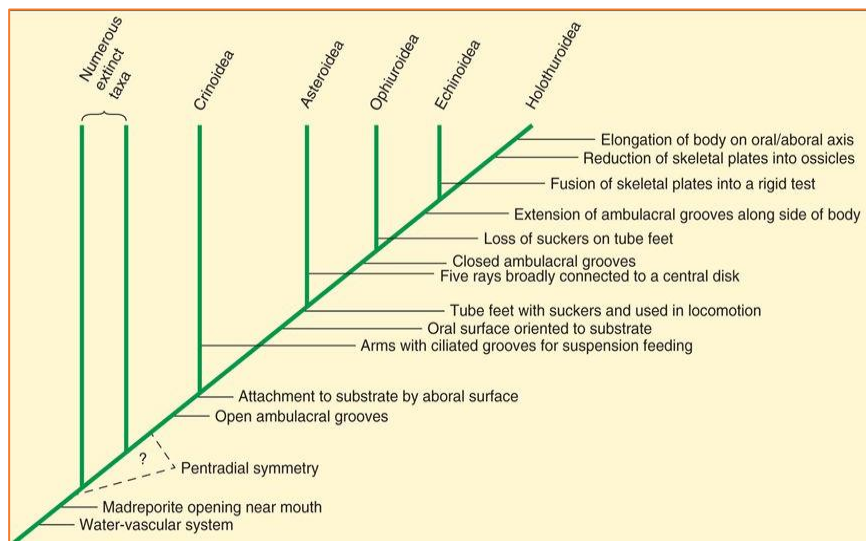
212	Sub-Phylum Hexapoda (Role of Insects as Pests) • Other insects are pests of domestic animals and plants. • Some reduce the health of domestic animals and the quality of animal products. • Insects feed on crops and transmit plant diseases, such as Dutch elm disease, potato virus, and aster yellow. • Insect pests destroy crops in the field through their biting, chewing, boring, sucking and defoliation activities. • Spots of injuries by insects may predispose crops to disease attack. • They reduce the quality of produce in the field as well as in the store e.g., Potato tuber moth (PTM) on Irish Potatoes. • They render vegetables and fruits unattractive and unmarketable e.g., damage on crucifer leaves by diamond back moth (<i>Plutella xylostella</i>). • Annual lost revenue from insect damage to crops or insect-transmitted diseases in the United States is approximately \$5 billion.
213	Phylum Arthropoda (Further Phylogenetic Consideration) • A fundamental question regarding arthropod evolution concerns whether or not the arthropod taxa represent fundamentally different evolutionary lineages. • Many zoologists believe that the living arthropods should be divided into three separate phyla: Chelicerata, Crustacea, and Uniramia. • A polyphyletic origin of these groups implies convergent evolution of remarkably similar arthropodan features in all three (or at least two of three) phyla. • Although evidence exists for dual origins of tracheae, mandibles, and compound eyes, many zoologists believe that convergence in all other arthropod traits is unlikely. • Members of all four subphyla are present in the fossil record from the early Paleozoic era, and there currently are no known fossils of arthropods from Precambrian times. • The fossil record, therefore, is of little help in discovering the evolutionary relationships among the arthropod subphyla. • Zoologists must rely on comparative anatomy, comparative embryology, and molecular studies to investigate these relationships. • Central to the questions surrounding arthropod phylogeny are two important issues. • One issue is whether or not the biramous limbs of crustaceans and trilobites are homologous. • Homology of these appendages would imply that the trilobites were closely related to the crustaceans; therefore, many zoologists view the trilobites as an important ancestral group. • It is possible to envision crustaceans, and possibly the arachnids, arising from the trilobites, but envisioning a similar origin for the myriapods and insects is more difficult. • A second important issue is whether or not the mandibles of uniramians and crustaceans are homologous. • Superficially, the mandibles of members of these groups are structurally similar and have similar functions. • Muscle arrangements and methods of articulation, however, are different enough that many zoologists doubt that these appendages are homologous. • Discussions of arthropod phylogeny also center around the origins and possible homologies of arthropod compound eyes, tracheal systems, and Malpighian tubules. • Questions regarding the evolutionary relationships within the arthropods are difficult to answer. • These questions will probably remain unanswered until new fossils are discovered or data from molecular studies provide more information on ancestral arthropods.



214

Phylum Echinodermata (Echinoderms: Relationship to other Animals)

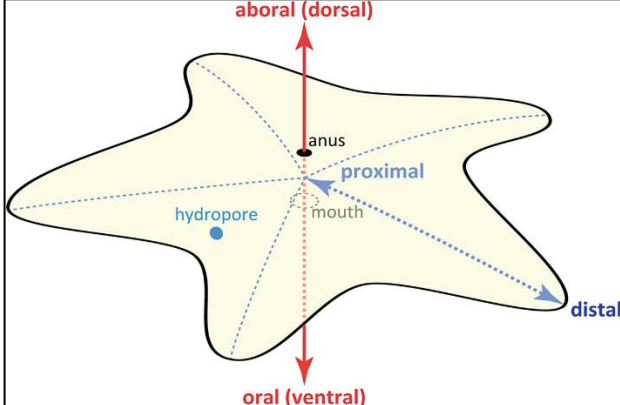
- Most zoologists believe that **echinoderms share a common ancestry with hemichordates** and chordates because of the deuterostome characteristics that they share;
- An anus that develops in the region of the blastopore,
- A coelom that forms from outpockets of the embryonic gut tract (vertebrate chordates are an exception),
- Radial, indeterminate cleavage.
- Unfortunately, no known fossils document a common ancestor for these phyla or demonstrate how the deuterostome lineage was derived from ancestral diploblastic or triploblastic stocks.
- **Although echinoderm adults are radially symmetrical,** most zoologists believe that echinoderms evolved from **bilaterally symmetrical ancestors.**



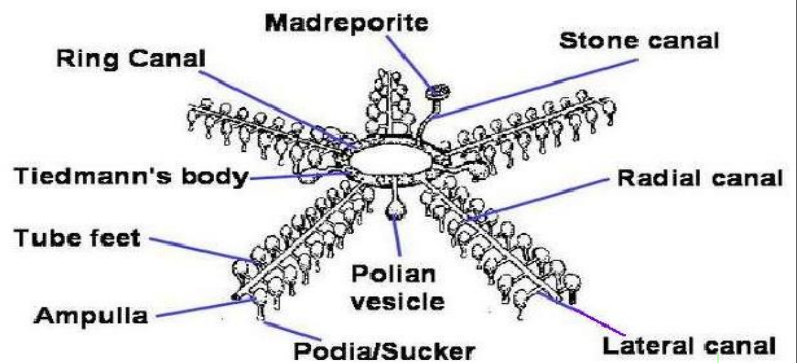
215

Phylum Echinodermata (Echinoderm: General Characteristics)

- Phylum Echinodermata (Gr. *echinos*, spiny *derma*, skin *ata*, to bear) attached to their substrates and probably lived as **filter feeders** a feature found in only one class of modern echinoderms.
- Characteristics of the phylum Echinodermata include:
- 1. Calcareous endoskeleton in the form of ossicles that arise from mesodermal tissue
- 2. **Adults with pentaradial symmetry and larvae with bilateral symmetry**
- 3. Water-vascular system composed of water-filled canals used in locomotion, attachment, and/or feeding
- 4. Complete digestive tract that may be secondarily reduced
- 5. Hemal system derived from coelomic cavities
- 6. Nervous system consisting of a nerve net, nerve ring, and radial
- The approximately **seven thousand species of living echinoderms** are exclusively marine and occur at all depths in all oceans.

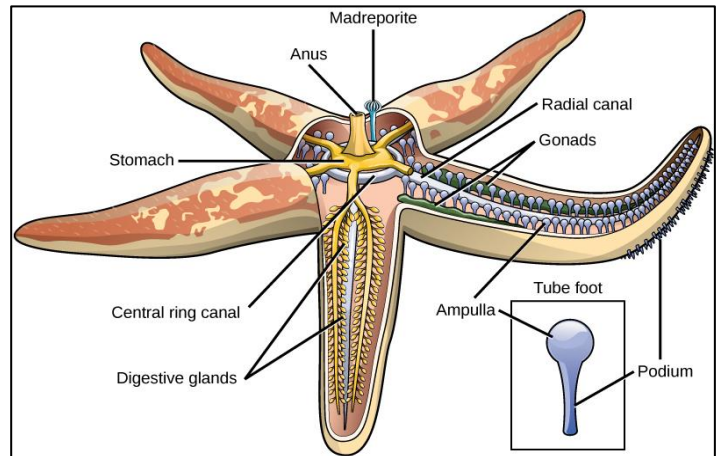
	Radial symmetry is adaptive for sedentary or slowly moving animals because it allows a uniform distribution of sensory, feeding, and other structures around the animal.
216	Phylum Echinodermata (Echinoderm Skeleton) - The echinoderm skeleton consists of a series of calcium carbonate plates called ossicles. - These plates are derived from mesoderm, held in place by connective tissues, and covered by an epidermal layer. - If the epidermal layer is abraded away, the skeleton may be exposed in some body regions. - The skeleton is frequently modified into fixed or articulated spines that project from the body surface. - Some echinoderms have very tightly interlocking plates, like sea urchins. - In sea urchins and sand dollars, these interlocking plates form an enclosure, almost like a shell, called a test. - Sea urchins also have spines protruding from their tests, in life. - Others have more movable plates, like sea stars or starfish. - Sea cucumbers, the worm-like echinoderms, have an endoskeleton that is nearly microscopic. - They may not have as strong a defense system, but they are much more flexible and movable.
217	Phylum Echinodermata (Echinoderm skeleton and Pentaradial Body form of Echinoderms) - The evolution of the skeleton may be responsible for the pentaradial body form of echinoderms. - The joints between two skeletal plates represent a weak point in the skeleton. - Pentaradial symmetry is a form of radial symmetry where body parts are organized around an oral or aboral axis in sets of five. - Pentaradial symmetry allows sedentary animals to have sensory, feeding, and other structures evenly apportioned around the body's axis. - By not having weak joints directly opposite one another, the skeleton is made stronger than if the joints were arranged opposite each other. - By not having weak joints directly opposite one another, the skeleton is made stronger than if the joints were arranged opposite each other. 
218	Phylum Echinodermata (Water Vascular System of Echinoderms) - The water-vascular system of echinoderms is a series of water-filled canals, and their extensions are called tube feet. - It originates embryologically as a modification of the coelom and is ciliated internally. - The water-vascular system includes a ring canal that surrounds the mouth. - The ring canal usually opens to the outside or to the body cavity through a stone canal and a sieve-like plate, called the madreporite. Tiedemann bodies are swellings often associated with the ring canal. - They are believed to be sites for the production of phagocytic cells, called coelomocytes. - Polian vesicles are sacs that are also associated with the ring canal. - Five (or a multiple of five) radial canals branch from the ring canal. - Radial canals are associated with arms of star-shaped echinoderms. - In other echinoderms, they may be associated with the body wall and arch toward the aboral pole. - Many lateral canals branch off each radial canal and end at the tube feet.

The Water Vascular System



219 Phylum Echinodermata (Structure and Function of Tube Feet)

- Tube feet are extensions of the canal system and usually emerge through openings in skeletal ossicles.
- Internally, tube feet usually terminate in a bulblike, muscular ampulla.
- When an ampulla contracts, it forces water into the tube foot, which then extends.
- Valves prevent the backflow of water from the tube foot into the lateral canal.
- A tube foot often has a suction cup at its distal end.
- When the foot extends and contacts solid substrate, muscles of the suction cup contract and create a vacuum.
- In some taxa, tube feet have a pointed or blunt distal end.
- These echinoderms may extend their tube feet into a soft substrate to secure contact during locomotion or to sift sediment during feeding.

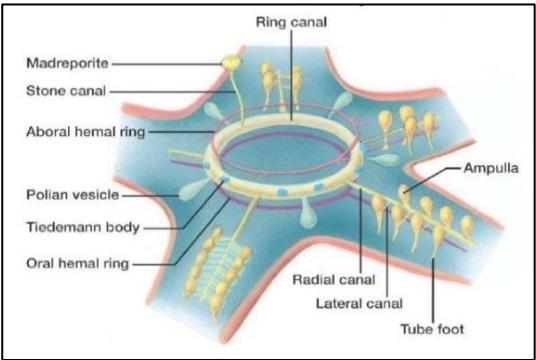
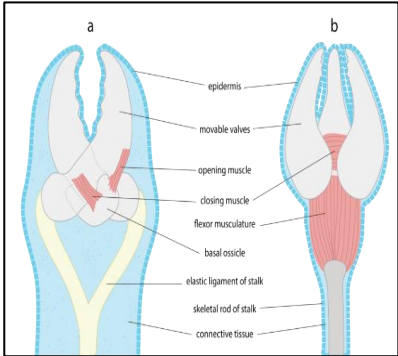


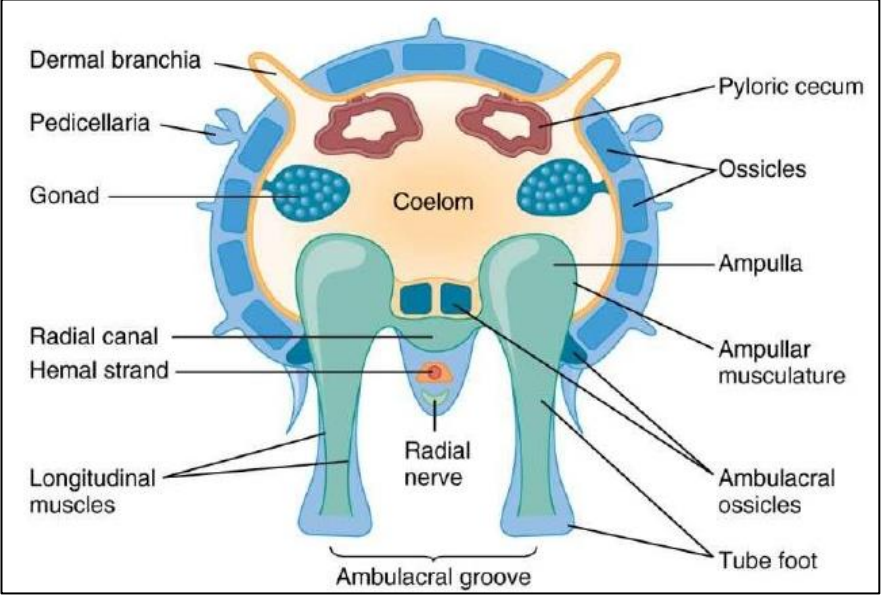
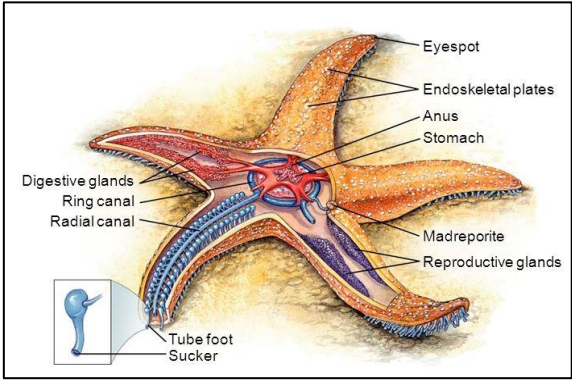
220 Phylum Echinodermata (Functions of Water Vascular System)

- The madreporite may serve as an inlet to replace water lost from the water-vascular system and may help equalize pressure differences between the water-vascular system and the outside.
- Polian vesicles function in fluid storage for the water-vascular system.
- The water-vascular system has other functions in addition to locomotion.
- The original function of water-vascular systems was probably feeding, not locomotion.
- In addition, the soft membranes of the water-vascular system permit diffusion of respiratory gases and nitrogenous wastes across the body wall.
- Other terms sometimes used to refer to the water vascular system are "ambulacral system" and "aquiferous system".

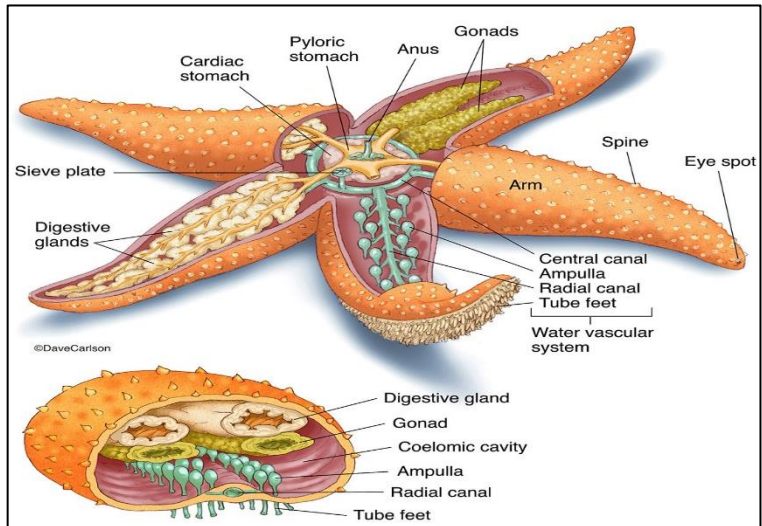
221 Phylum Echinodermata (Hemal System)

- A hemal system consists of strands of tissue that encircle an echinoderm near the ring canal of the water-vascular system and run into each arm near the radial canals.
- The hemal system has been likened to a vestigial circulatory system; however, its function is largely unknown.

	- It may aid in the transport of large molecules, hormones, or coelomocytes, which are cells that engulf and transport waste particles within the body. - Circulation in cushion star occurs in three places, the perivisceral coelom, the water vascular system, and the hemal system. - The perivisceral coelom is the area inside the body but outside of the major organs. - The water vascular system is a circulatory system which forces water into and out of the tube feet through contracting muscles. - The hemal system is a series of channels throughout the body that transport and distribute food materials. 
222	Phylum Echinodermata (Class Asteroidea: General Features) - The sea stars make up the class Asteroidea (Gr. <i>aster</i>, star <i>oeides</i>, in the form of) and include about 1,500 species. - They often live on hard substrates in marine environments, although some species also live in sandy or muddy substrates. - Sea stars may be brightly colored with red, orange, blue, or gray. - Asterias is an orange sea star common along the Atlantic coast of North America and is frequently studied in introductory zoology laboratories. - Sea stars usually have five arms that radiate from a central disk. - The oral opening, or mouth, is in the middle of one side of the central disk. - It is normally oriented downward, and movable oral spines surround it. - Movable and fixed spines project from the skeleton and roughen the aboral surface.
223	Phylum Echinodermata (Dermal Branchiae) - Thin folds of the body wall, called dermal branchiae, extend between ossicles and function in gas exchange. - Papulae, known as, Dermal branchiae or skin gills, are projections of the coelom of Asteroidea that serve in respiration and waste removal. - Papulae are soft, covered externally with the epidermis, and lined internally with peritoneum. - They extend through the mesodermal ossicles and are protected from microscopic larvae by pedicellariae. - In a living specimen, the dermal gills can be extended or withdraw.  Dermal Branchiae - Soft bumps on the body that absorb oxygen from the water
224	Phylum Echinodermata (Pedicellariae) - In some sea stars, the aboral surface has numerous pincherlike structures called pedicellariae, which clean the body surface of debris and have protective functions. - Pedicellariae may be attached on a movable spine, or they may be immovably fused to skeletal ossicles. - A pedicellaria (plural: pedicellariae) is a small wrench- or claw-shaped appendage with movable jaws, called valves. - Each pedicellaria is an effector organ with its own set of muscles, neuropils, and sensory receptors and is therefore capable of reflex responses to the environment. 

225	Phylum Echinodermata (Ambulacral Groove) • A series of ossicles in the arm form an ambulacral groove that runs the length of the oral surface of each arm. • The ambulacral groove houses the radial canal, and paired rows of tube feet protrude through the body wall on either side of the ambulacral groove. • For example, sea stars or "star fish" have an ambulacral groove on their oral side (underside). • This ambulacral groove extends from the mouth to the end of each ray or arm. • Each groove of each arm in turn has four rows of hollow tube feet that can be extended or withdrawn. • Opposite the ambulacral groove is an ambulacral ridge on the aboral side of each ray, known as an ambulacrum. • These have interambulacra between them. 
226	Phylum Echinodermata (Locomotion in Star fish) • Tube feet of sea stars move in a stepping motion. • Alternate extension, attachment, and contraction of tube feet move sea stars across their substrate. • The nervous system coordinates the tube feet so that all feet move the sea star in the same direction; however, the tube feet do not move in unison. • The suction disks of tube feet are effective attachment structures, allowing sea stars to maintain their position, or move from place to place, in spite of strong wave action. • Sea stars move using a water vascular system. • Water comes into the system via the madreporite. • It is then circulated from the stone canal to the ring canal and into the radial canals. • The radial canals carry water to the ampullae and provide suction to the tube feet. 
227	Phylum Echinodermata (Feeding and Digestion in Star Fish) • Sea stars feed on snails, bivalves, crustaceans, polychaetes, corals, detritus, and a variety of other food items. • The mouth opens to a short esophagus and then to a large stomach that fills most of the coelom of the central disk. • The stomach is divided into two regions. • The larger, oral stomach, sometimes called the cardiac stomach, receives ingested food. • It joins the smaller, aboral stomach, sometimes called the pyloric stomach. • The aboral (pyloric) stomach gives rise to ducts that connect to secretory and absorptive structures called pyloric caecae.

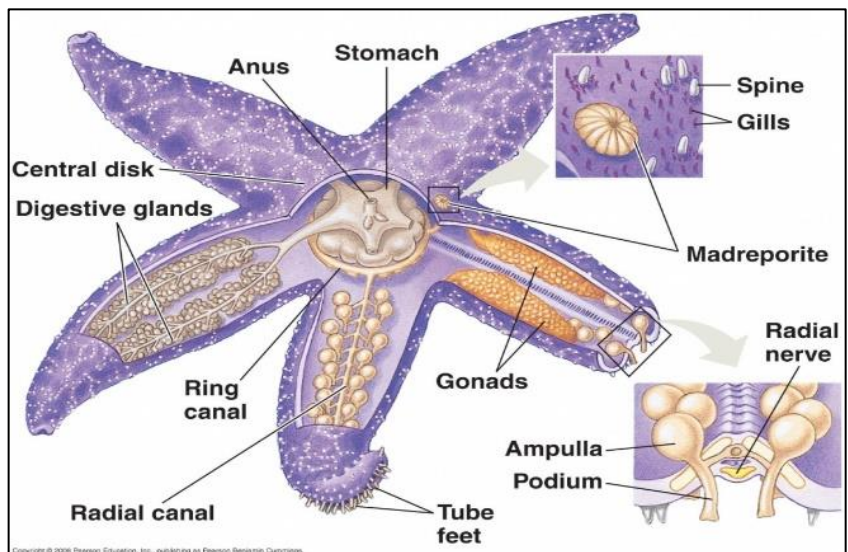
- Two pyloric caecae extend into each arm.
- A short intestine leads to rectal caecae (uncertain functions) and to a nearly nonfunctional anus, which opens on the aboral surface of the central disk.
- Some sea stars ingest whole prey, which are digested extracellularly within the stomach.
- Undigested material is expelled through the mouth.
- Many sea stars feed on bivalves by forcing the valves apart.
- When a sea star feeds on a bivalve, it wraps itself around the bivalve's ventral margin.
- Tube feet attach to the outside of the shell, and the body-wall musculature forces the valves apart.
- This is possible because the sea star changes tube feet when the muscles of engaged tube feet begin to tire.
- When the valves are opened about 0.1 mm, increased coelomic pressure everts the oral (cardiac) portion of the sea star's stomach into the bivalve shell.
- Digestive enzymes are released, and partial digestion occurs in the bivalve shell.
- This digestion further weakens the bivalve's adductor muscles, and the shell eventually opens completely.
- Partially digested tissues are taken into the aboral (pyloric) portion of the stomach, and into the pyloric caecae for further digestion and absorption.
- After feeding and initial digestion, the sea star retracts the stomach, using stomach retractor muscles.

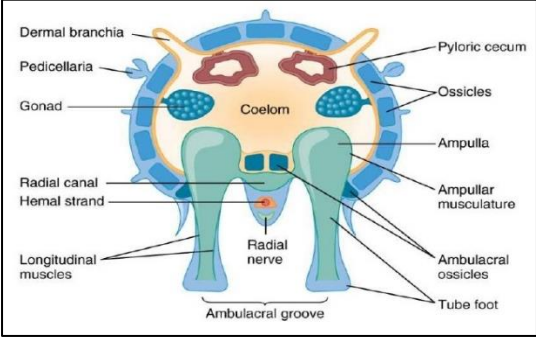
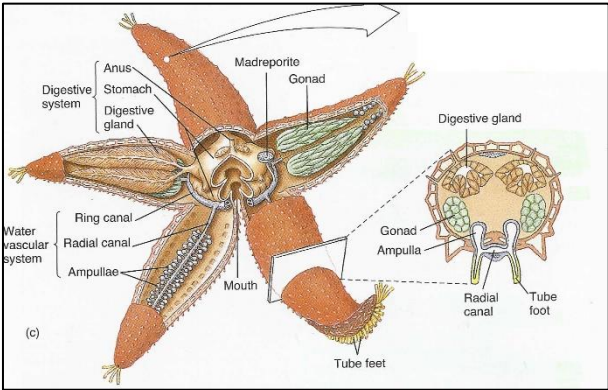


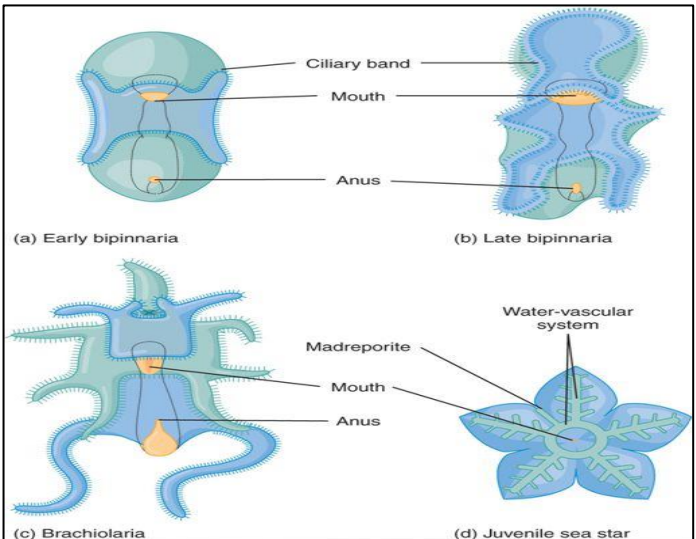
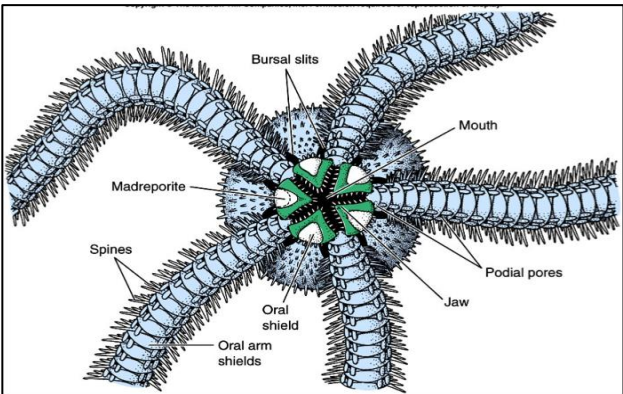
228

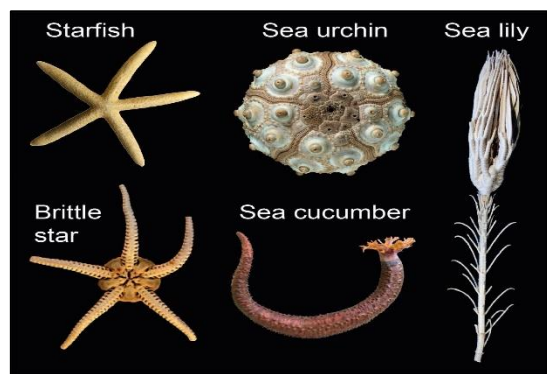
Phylum Echinodermata (Gaseous Exchange in Star Fish)

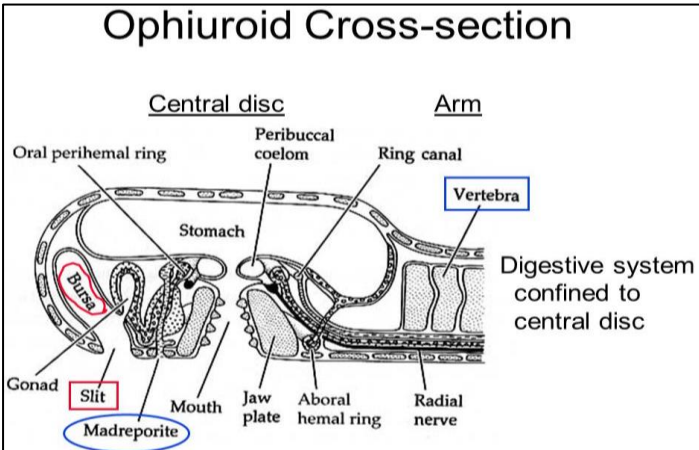
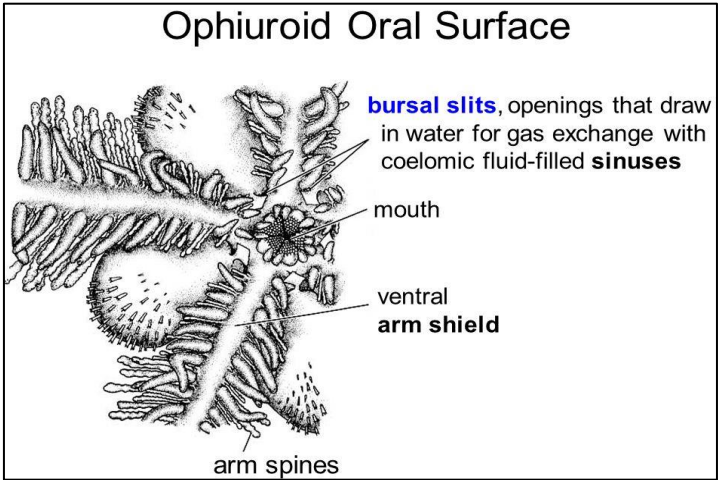
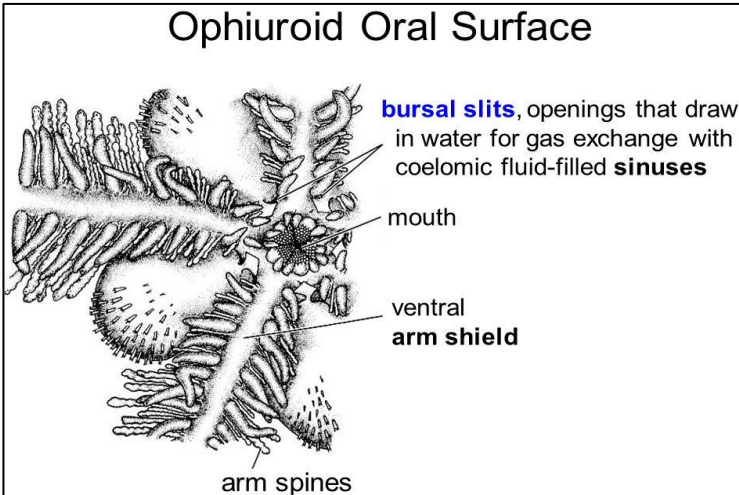
- Gases, nutrients, and metabolic wastes are transported in the coelom by diffusion and by the action of ciliated cells lining the body cavity.
- Gas exchange and excretion of metabolic wastes (principally ammonia) occur by diffusion across dermal branchiae, tube feet, and other membranous structures.
- Respiration or gas exchange occurs in two locations on a starfish.
- The first location is through the thin skin on the ends of the tube feet.
- Gas exchange also occurs in the dermal gills or papulae.
- These gills are lined with cilia that move to produce a current.
- The current brings fresh water so the starfish can absorb oxygen and freshens the surrounding water where the starfish may have just excreted carbon dioxide.
- A sea star's hemal system consists of strands of tissue that encircle the mouth near the ring canal, extend aborally near the stone canal, and run into the arms near radial canals.

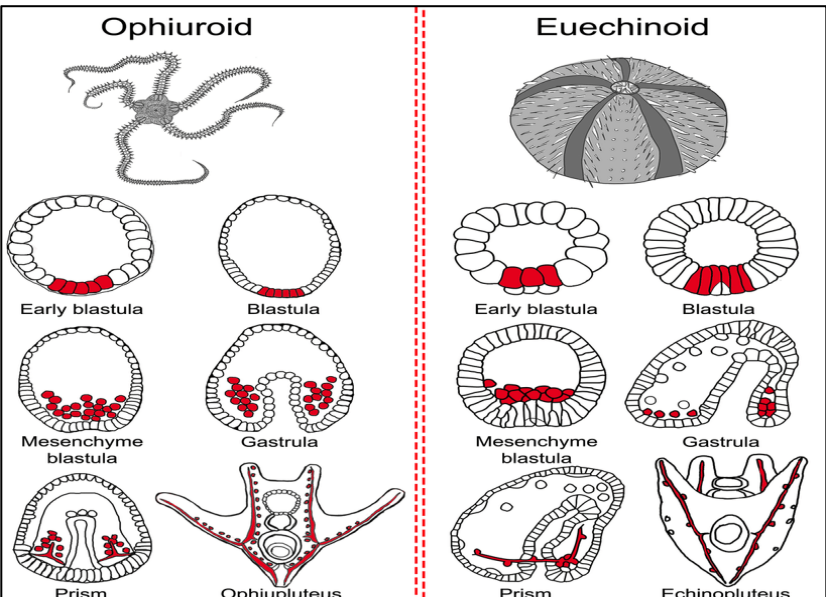


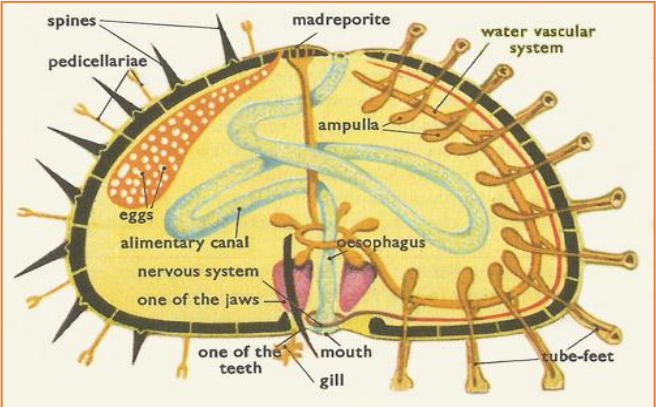
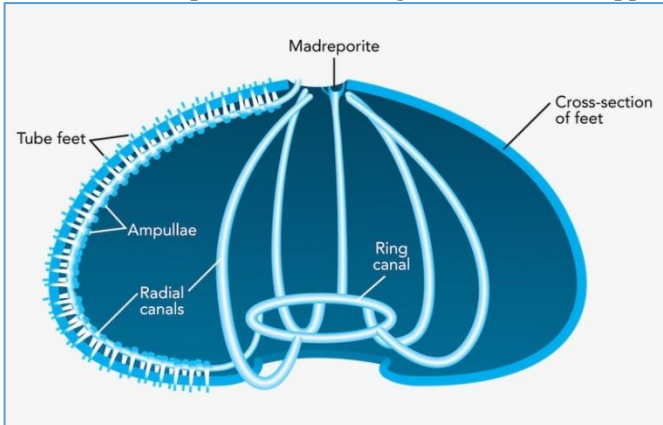
229	Phylum Echinodermata (Nervous System in Star Fish) - The nervous system of sea stars consists of a nerve ring that encircles the mouth and radial nerves that extend into each arm. - Radial nerves lie within the ambulacral groove, just oral to the radial canal of the water-vascular system and the radial strands of the hemal system. - Radial nerves coordinate the functions of tube feet. - Other nervous elements are in the form of a nerve net associated with the body wall. - The nervous system of the starfish is very simple, there is no brain and there are not even any ganglia to coordinate movement. 
230	Phylum Echinodermata (Sensory Functions in Star Fish) - Most sensory receptors are distributed over the surface of the body and tube feet. - Sea stars respond to light, chemicals, and various mechanical stimuli. - They often have specialized photoreceptors at the tips of their arms. - These are actually tube feet that lack suction cups but have a pigment spot surrounding a group of ocelli. - The ring nerves and radial nerves have sensory and motor components and coordinate the starfish's balance and directional systems. - The sensory component receives input from the sensory organs while the motor nerves control the tube feet and musculature. - The starfish does not have the capacity to plan its actions. 
231	Phylum Echinodermata (Regeneration in Sea Star) - Sea stars are well known for their powers of regeneration. - They can regenerate any part of a broken arm. - In a few species, an entire sea star can be regenerated from a broken arm if the arm contains a portion of the central disk. - Regeneration is a slow process, taking up to a year for complete regeneration. - Asexual reproduction involves division of the central disk, followed by regeneration of each half. - A sea star that has the ability to regenerate amputated limbs must first undergo a repair phase to heal the exposed wound. - Once the wound is healed, the sea star can begin to generate new cells, which in turn, sparks new growth. - Cell proliferation that results in the growth of the new limb occurs in the final phase. - If the final phase is interrupted, the resulting new limb may be deformed.
232	Phylum Echinodermata (Reproduction in sea star) - Sea stars are dioecious, but sexes are indistinguishable externally. Two gonads are present in each arm, and these enlarge to nearly fill an arm during the reproductive periods. - Gonopores open between the bases of each arm. - In sexual reproduction, fertilization occurs in the water with males and females releasing sperm and eggs into the environment. - The fertilized embryos, which are free-swimming animals, become part of the zooplankton in most species. - Eventually the larvae undergo metamorphosis, settle to the bottom and grow into adults. - The embryology of echinoderms has been studied extensively because of the relative ease of inducing spawning and maintaining embryos in the laboratory. External fertilization is the rule.

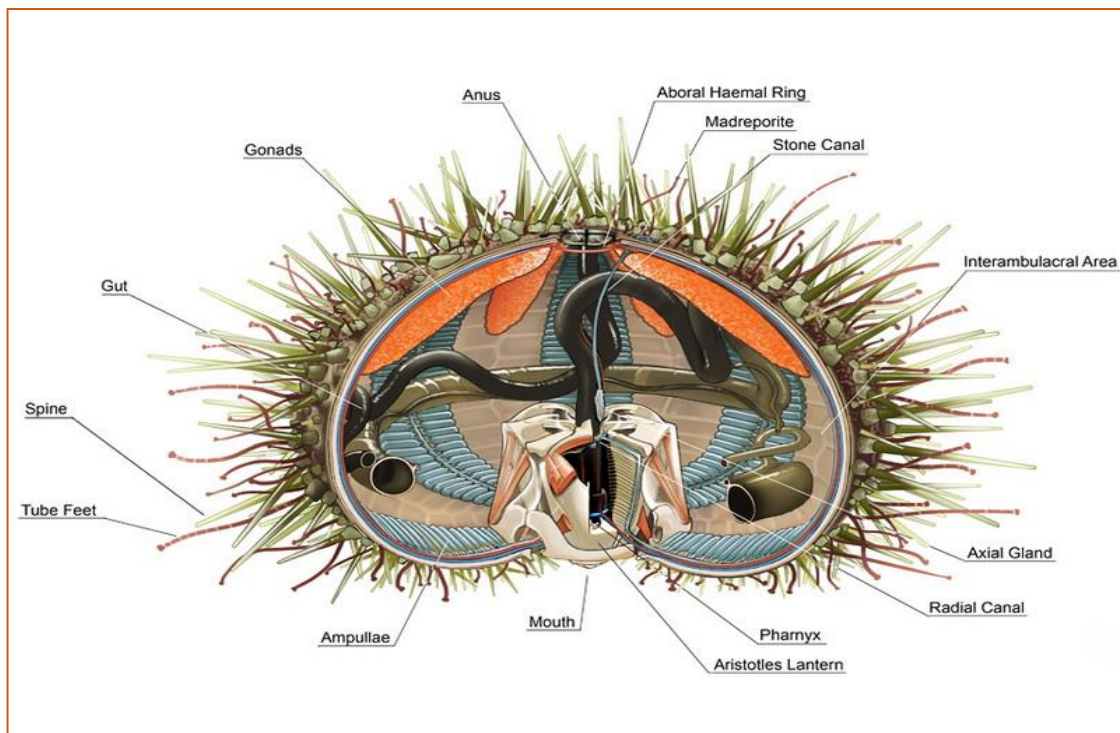
	Because gametes cannot survive long in the ocean, maturation of gametes and spawning must be coordinated if fertilization is to take place.
233	Phylum Echinodermata (Role of Photoperiod and Pheromones in Spawning) - The photoperiod (the relative length of light and dark in a 24-hour period) and temperature are environmental factors used to coordinate sexual activity. - Gametogenesis and gonadal growth in the west coast sea star <i>Pisaster ochraceus</i> normally begins in the fall and leads to large gonads full of gametes in the spring, when spawning occurs. - In addition, gamete release by one individual is accompanied by the release of spawning pheromones, which induce other sea stars in the area to spawn, increasing the likelihood of fertilization. - The first individual of a species to spawn may release a pheromone that serves to attract other starfish to aggregate and to release their gametes synchronously. - In other species, a male and female may come together and form a pair.
234	Phylum Echinodermata (Development in Sea Star) - Embryos are planktonic, and cilia are used in swimming. - After gastrulation, bands of cilia differentiate, and a bilaterally symmetrical larva, called a bipinnaria larva, forms. - The larva usually feeds on planktonic protists. - The development of larval arms results in a brachiolaria larva, which settles to the substrate, attaches, and metamorphoses into a juvenile sea star. - Later embryonic stages are ciliated and swim and feed in the plankton. - In a few species, embryos develop from yolk stored in the egg during gamete formation. - Oocytes averaged 137 μm in diameter, the smallest reported in the genus. Fertilized oocytes developed into feeding bipinnaria larvae that fed in the plankton for at least 4 weeks, and in some cases up to 33 weeks, before metamorphosis. 
235	Phylum Echinodermata (Class Ophiuroidea: General Features) - The class Ophiuroidea (Gr. <i>ophis</i>, snake <i>oura</i>, tail <i>oeides</i>, in the form of) includes the basket stars and the brittle stars. - With over two thousand species, this is the most diverse group of echinoderms. - Ophiuroids, however, are often overlooked because of their small size and their tendency to occupy crevices in rocks and coral or to cling to algae. - The arms of ophiuroids are long and, unlike those of asteroids, are sharply set off from the central disk, giving the central disk a pentagonal shape. - Neither dermal branchiae nor pedicellariae are present in ophiuroids. 

	- The tube feet of ophiuroids lack suction disks and ampullae, and the contraction of muscles associated with the base of a tube foot extends the tube foot. - Unlike the sea stars, the madreporite of ophiuroids is on the oral surface. Ophiuroidea closely related to starfish. - They crawl across the sea floor using their flexible arms for locomotion. - The ophiuroids generally have five long, slender, whip-like arms which may reach up to 60 cm (24 in) in length on the largest specimens.
236	Phylum Echinodermata (Difference Between Brittle Star and Basket Star) Brittle stars have unbranched arms, and most have a central disk that ranges in size from 1 to 3 cm. Basket stars have arms that branch repeatedly. The central disk of brittle stars and basket stars is very obvious, since the arms attach to the disc, rather than joining to each other at the base like they do in true sea stars. Brittle stars usually have 5, but may have up to 10 arms. Basket stars have 5 arms that branch into many slender, highly mobile arms. - The arms are covered with calcite plates or thick skin. - The central disk of brittle stars and basket stars is usually relatively small, under one inch, and the whole organism itself may be under an inch in size. - The arms of some species can be quite long, though, with some basket stars measuring over 3 feet across when their arms are extended.
237	Phylum Echinodermata (Difference Between Sea Star and Brittle Star) Sea stars are usually star-shaped or pentagonal. - They have a set of calcareous plates embedded into the fleshy tissue of their body wall. - The mouth is at the centre of the undersurface. - When feeding, the sea star is able move its sack-like stomach out through the mouth and partly digests the food outside its body. Brittle stars have a distinct central disc and five radiating slender, highly flexible arms. - The arms are solid and not hollow like the sea stars. - Brittle stars move by a sinuous flexing of the arms rather than movement of tube feet. - They feed on small organic particles of food. 
238	Phylum Echinodermata (Locomotion in Ophiuroids) The water-vascular system of ophiuroids is not used for locomotion. - Instead, the skeleton is modified to permit a unique form of grasping and movement. - Superficial ossicles, which originate on the aboral surface, cover the lateral and oral surfaces of each arm. - The ambulacral groove containing the radial nerve, hemal strand, and radial canal is thus said to be “closed.” - Ambulacral ossicles are in the arm, forming a central supportive axis. - Successive ambulacral ossicles articulate with one another and are acted upon by relatively large muscles to produce snakelike movements (hence the derivation of the class name) that allow the arms to curl around a stalk of algae or to hook into a coral crevice. - During locomotion, the central disk is held above the substrate, and two arms pull the animal along, while other arms extend forward and/or trail behind the animal.
239	Phylum Echinodermata (Feeding and Digestion in Ophiuroids) Ophiuroids are predators and scavengers. - They use their arms and tube feet in sweeping motions to collect prey and particulate matter, which are then transferred to the mouth.

	- Some ophiuroids are filter feeders that wave their arms and trap plankton on mucus covered tube feet. - Trapped plankton is passed from tube foot to tube foot along the length of an arm until it reaches the mouth. - The mouth of ophiuroids is in the center of the central disk, and five triangular jaws form a chewing apparatus. The mouth leads to a saclike stomach. - There is no intestine, and no part of the digestive tract extends into the arms. Ophiuroid Cross-section 
240	Phylum Echinodermata (Gaseous exchange in Ophiuroids) - The coelom of ophiuroids is reduced and is mainly confined to the central disk, but it still serves as the primary means for the distribution of nutrients, wastes, and gases. - Coelomocytes aid in the distribution of nutrients and the expulsion of particulate wastes. Ammonia is the primary nitrogenous waste product, and it is lost by diffusion across tube feet and membranous sacs, called bursae, that invaginate from the oral surface of the central disk. - Slits in the oral disk, near the base of each arm, allow cilia to move water into and out of the bursae. Ophiuroid Oral Surface 
241	Phylum Echinodermata (Gaseous Exchange in Ophiuroids) - The coelom of ophiuroids is reduced and is mainly confined to the central disk, but it still serves as the primary means for the distribution of nutrients, wastes, and gases. - Coelomocytes aid in the distribution of nutrients and the expulsion of particulate wastes. - Ammonia is the primary nitrogenous waste product, and it is lost by diffusion across tube feet and membranous sacs, called bursae, that invaginate from the oral surface of the central disk. - Slits in the oral disk, near the base of each arm, allow cilia to move water into and out of the bursae. Ophiuroid Oral Surface  Phylum Echinodermata (Regeneration in Ophiuroids) Like sea stars, ophiuroids can regenerate lost arms. If a brittle star is grasped by an arm, the contraction of certain muscles may sever and cast off the arm hence the common name brittle star. This process, called autotomy (Gr. autos, self-tomos, to cut), is used in escape reactions. The ophiuroid later regenerates the arm. - Some species also have a fission line across their central disk.

	- When an ophiuroid splits into halves along this line, two ophiuroids regenerate. - Ophiuroids use this ability to escape predators, in a way similar to lizards which deliberately shed the distal part of their tails to confuse pursuers. - Moreover, the ophiuroids can regenerate gut and gonad fragments lost along with the arms. - Discarded arms have not been shown to have the ability to regenerate.
242	Phylum Echinodermata (Reproduction in Ophiuroids) - Ophiuroids are dioecious. Males are usually smaller than females, who often carry the males. - The gonads are associated with each bursa, and gametes are released into the bursa. - Eggs may be shed to the outside or retained in the bursa, where they are fertilized and held through early development. - Embryos are protected in the bursa and are sometimes nourished by the parent. - A larval stage, called an ophiopluteus, is planktonic. - Its long arms bear ciliary bands used to feed on plankton, and it undergoes metamorphosis before sinking to the substrate. - In other species the fertilized eggs develop directly into young stars. - Some species of brittle and basket stars make both eggs and sperm, and the eggs unite with sperm and develop in pouches at the bases of the female's arms.
243	Phylum Echinodermata (Development in Ophiuroids) - Ophiuroid ova undergo germinal vesicle breakdown (GVBD) prior to or soon after spawning in most species, regardless of developmental mode. - Species with pelagic, planktotrophic larvae tend to shed thousands of small (70–200 µm diameter), oligolecithal eggs and undergo external fertilization. - They develop in the plankton into ophioplutei and have a pelagic period of about 20–90 days, depending on the water temperature. - Other species with pelagic larval stages are lecithotrophic. - These species tend to shed several thousand medium to large sized eggs (130–420 µm diameter) which are nutrient rich and opaque. - Development into non-feeding larvae with pelagic periods of roughly 1 week or less occurs in the water column or near the bottom. 
244	Phylum Echinodermata (Class Echinoidea: General features) - The sea urchins, sand dollars, and heart urchins make up the class Echinoidea (Gr. <i>echinos</i>, spiny <i>oeides</i>, in the form of). - The approximately one thousand species are widely distributed in nearly all marine environments. - Sea urchins are specialized for living on hard substrates, often wedging themselves into crevices and holes in rock or coral. - Sand dollars and heart urchins usually live in sand or mud, and burrow just below the surface. - They use tube feet to catch organic matter settling on them or passing over them. - Sand dollars often live in dense beds, which favors efficient reproduction and feeding.
245	Phylum Echinodermata (Skeleton of Sea Urchins) - Sea urchins are rounded, and their oral end is oriented toward the substrate. - Their skeleton, called a test, consists of 10 closely fitting plates that arch between oral and aboral ends.

	• Five rows of ambulacral plates have openings for tube feet, and alternate with five inter ambulacral plates, which have tubercles for the articulation of spines. • The base of each spine is a concave socket, and muscles at its base move the spine. • Spines are often sharp and sometimes hollow, and they may contain venom dangerous to swimmers.
246	Phylum Echinodermata (Role of Pedicellariae in Sea Urchins) • The pedicellariae of sea urchins have either two or three jaws and connect to the body wall by a relatively long stalk. • They clean the body of debris and capture planktonic larvae, which provide an extra source of food. • Pedicellariae of some sea urchins contain venom sacs and are grooved or hollow to inject venom into a predator, such as a sea star. • Each pedicellaria is an effector organ with its own set of muscles, neuropils, and sensory receptors and is therefore capable of reflex responses to the environment. 
247	Phylum Echinodermata (Water vascular System of Sea Urchins) • The water-vascular system is similar to that of other echinoderms. • Radial canals run along the inner body wall between the oral and the aboral poles. • Tube feet possess ampullae and suction cups, and the water-vascular system opens to the outside through many pores in one aboral ossicle that serves as a madreporite. • The madreporite of sea urchins is located within one of the plates surrounding the anus on the upper surface of the animal. • The stone canal descends from the madreporite to the ring canal, which lies around the oesophagus, and includes a number of polian vesicles. • Because sea urchins have no arms, the five radial canals simply run along the inside of the solid skeletal "test", arching upwards towards the anus. • The ampullae branching off from either side of the radial canals give rise to ten rows of tube feet, which penetrate through holes in the test to the outside. 
248	Phylum Echinodermata (Locomotion in Echinoids) • Echinoids move by using spines for pushing against the substrate and tube feet for pulling. • Sand dollars and heart urchins use spines to help burrow in soft substrates. • Some sea urchins burrow into rock and coral to escape the action of waves and strong currents. • They form cup-shaped depressions and deeper burrows, using the action of their chewing Aristotle's lantern. • Muscles in the tube wall allow the sea urchins to bend or retract their feet, while increased fluid pressure is used to elongate the feet. • Although the extremities of the feet look like suction naps, the actual mechanism used to hold on to the substrate is adhesion. • Sea urchins basically produce a sticky liquid at the end of their feet and glue themselves to their substrate. • This adhesion is reversible and the animals can detach their feet from the substrate without damaging them.



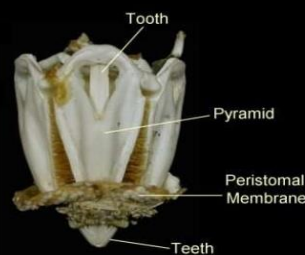
249

Phylum Echinodermata (Aristotle's Lantern in Echinoids)

- Echinoids feed on algae, bryozoans, coral polyps, and dead animal remains.
- Oral tube feet surrounding the mouth manipulate food.
- A chewing apparatus, called **Aristotle's lantern**, can be projected from the mouth.
- It consists of about 35 ossicles and attached muscles and cuts food into small pieces for ingestion.
- The mouth cavity leads to a pharynx, an esophagus, and a long, coiled intestine that ends aborally at the anus.
- The teeth of Aristotle's lantern are typically extruded to scrape algae and other food from rocks, and some urchins can excavate hiding places in coral or rock even in steel.

Phylum Echinodermata Echinoidea

- Aristotle's lantern, equipped with five strong teeth, used for scraping food from hard substrates.
- 40 skeletal ossicles and 60 muscles that support and operate the teeth.

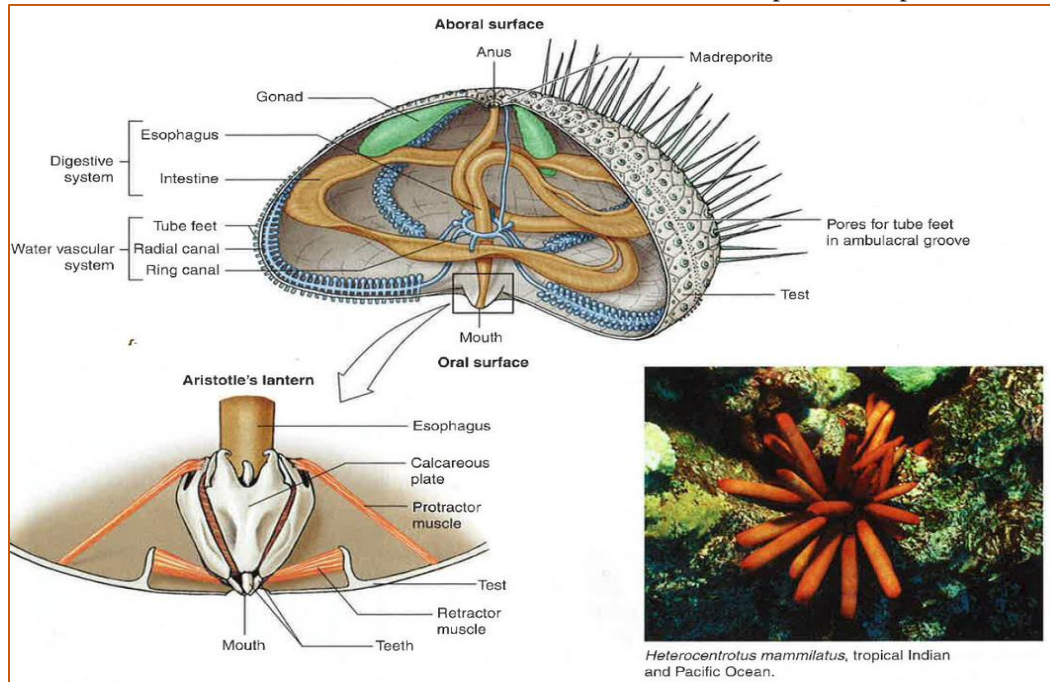


250

Phylum Echinodermata (Maintenance Functions of Echinoids: Gaseous Exchange, Excretion and Nervous System)

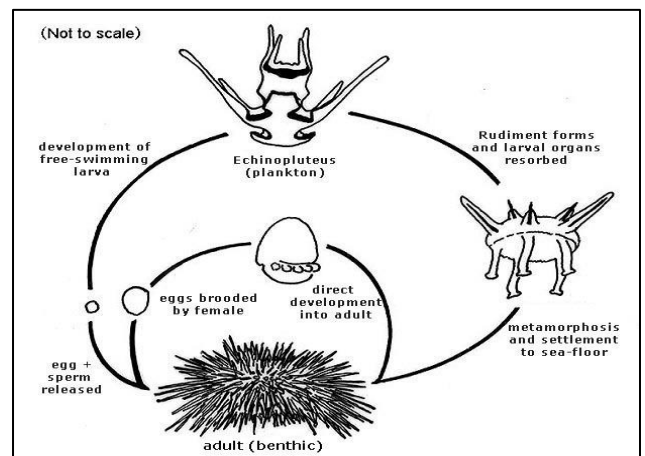
- Echinoids have a large coelom, and coelomic fluids are the primary circulatory medium.
- Small gills, found in a thin membrane surrounding the mouth, are outpockets of the body wall and are lined by ciliated epithelium.
- Gas exchange occurs by diffusion across this epithelium and across the tube feet.
- Ciliary currents, changes in coelomic pressure, and the contraction of muscles associated with Aristotle's lantern move coelomic fluids into and out of gills.
- The nervous system of sea urchins has a relatively simple layout. With no true brain, the neural center is a large nerve ring encircling the mouth just inside the lantern.

- From the nerve ring, **five nerves radiate** underneath the radial canals of the water vascular system, and branch into numerous finer nerves to innervate the tube feet, spines, and pedicellariae.



251 Phylum Echinodermata (Reproduction and Development in Echinoids)

- Echinoids are dioecious.**
- Gonads are on the internal body wall** of the inter ambulacral plates.
- During **breeding season**, they nearly fill the spacious coelom.
- One gonopore is in each of five ossicles, called **genital plates**, at the aboral end of the echinoid, although the sand dollars usually have only four gonads and gonopores.
- Gametes are shed into the water, and **fertilization is external.**
- The reproductive cycle has three main phases:
 - The **growing phase (late autumn and winter)** when gonads accumulate reserve material;
 - The **maturation phase (spring and early summer)** in which gametogenesis then spawning take place;
 - The spent/regenerating phase when relict gametes are resorbed by the nutritive phagocytes, the gonads being virtually devoid of sexual cells.
 - Development eventually results in a pluteus larva that spends several months in the plankton and eventually undergoes metamorphosis to the adult.



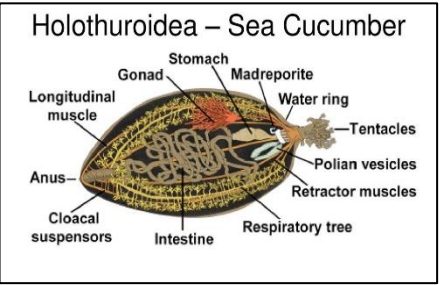
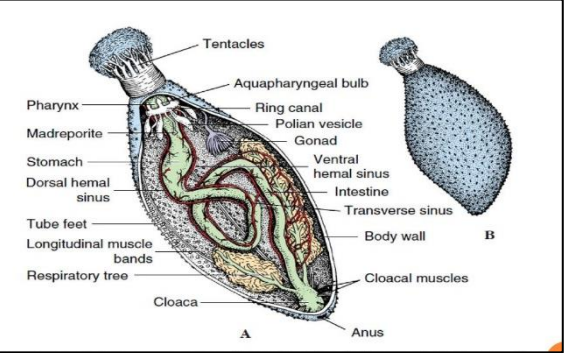
252 Phylum Echinodermata (Class Holothuroidea: General Features)

- The **class Holothuroidea** (Gr. *holothourion*, **sea cucumber** *oeides*, in the form of) has approximately **1,500 species**, whose members are commonly called sea cucumbers.
- Sea cucumbers are found at all depths in all oceans, where they crawl over hard substrates or burrow through soft substrates.
- Sea cucumbers have no arms**, and they are elongate along the oral-aboral axis.
- They lie on one side, which is usually flattened as a permanent ventral side, giving them a secondary bilateral symmetry.
- Tube feet surrounding the mouth are elongate and referred to as tentacles.
- Most adults range in length between **10 and 30 cm.**

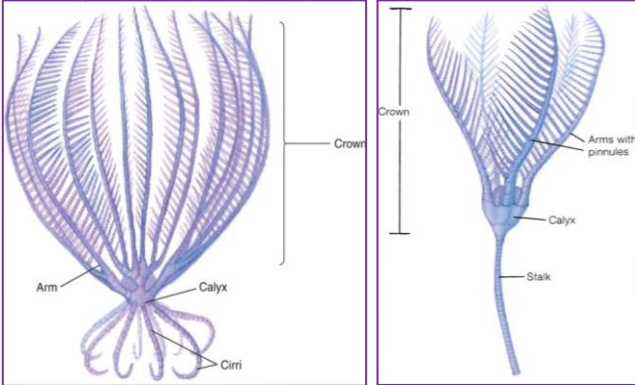
253 Phylum Echinodermata (Body Wall of Sea Cucumber)

- Their body wall is thick and muscular, and **it lacks protruding spines or pedicellariae.**
- Beneath the epidermis is the dermis, a thick layer of connective tissue with embedded ossicles.

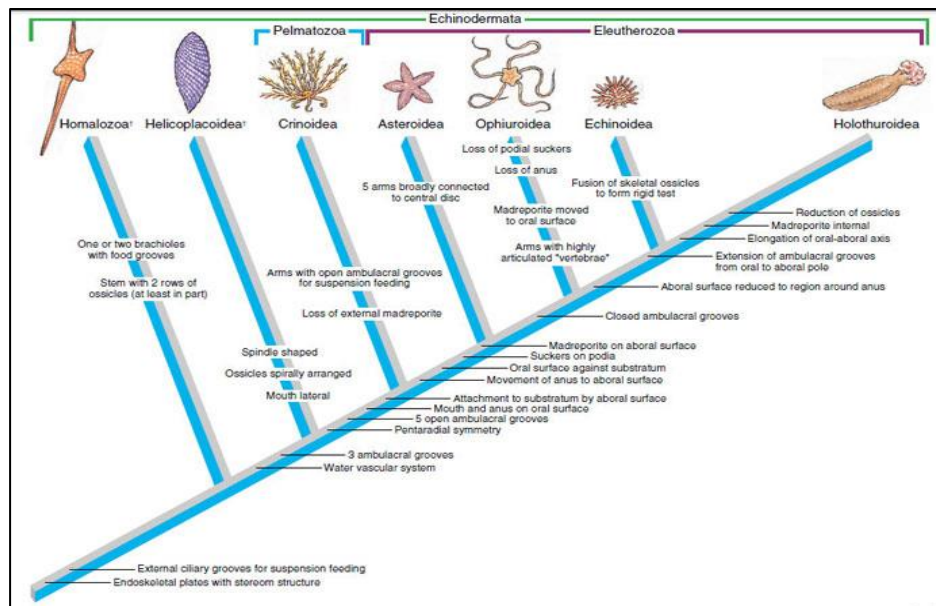
	• Sea cucumber ossicles are microscopic and do not function in determining body shape. • Larger ossicles form a calcareous ring that encircles the oral end of the digestive tract, serving as a point of attachment for body wall muscles. • Beneath the dermis is a layer of circular muscles overlying longitudinal muscles. • The body wall of sea cucumbers, when boiled and dried, is known as trepang in Asian countries. • It may be eaten as a main-course item or added to soups as flavoring and a source of protein.	Sea Cucumbers plates over a soft muscular body wall
254	Phylum Echinodermata (Water Vascular System of Sea Cucumber) • The madreporite of sea cucumbers is internal, and the water-vascular system is filled with coelomic fluid. • The ring canal encircles the oral end of the digestive tract and gives rise to one to ten Polian vesicles. • Five radial canals and the canals to the tentacles branch from the ring canal. • Radial canals and tube feet, with suction cups and ampullae, run between the oral and aboral poles. • The side of a sea cucumber resting on the substrate contains three of the five rows of tube feet, which are primarily used for attachment. • The two rows of tube feet on the upper surface may be reduced in size or may be absent. • The madreporite is present, but lies within the body cavity, just below the pharynx. • The stone canal is relatively short.	
255	Phylum Echinodermata (Locomotion in Sea Cucumber) • Sea cucumbers are mostly sluggish burrowers and creepers, although some swim by undulating their bodies from side to side. • Locomotion using tube feet is inefficient, because the tube feet are not anchored by body wall ossicles. • Locomotion more commonly results from contractions of body-wall muscles that produce wormlike, locomotor waves that pass along the length of the body. • One way that sea cucumbers can confuse or harm predators is by propelling their own toxic internal organs from their bodies in the direction of an attacker. • The organs grow back, and it may save them from being eaten.	
256	Phylum Echinodermata (Feeding and Digestion in Sea Cucumber) • Most sea cucumbers ingest particulate organic matter using their tentacles. • Mucus covering the tentacles traps food as the tentacles sweep across the substrate or are held out in seawater. • The digestive tract consists of a stomach; a long, looped intestine; a rectum; and an anus. • Sea cucumbers thrust tentacles into the mouth to wipe off trapped food. • During digestion, coelomocytes move across the intestinal wall, secrete enzymes to aid in digestion and engulf and distribute the products of digestion. • The coelom of sea cucumbers is large, and the cilia of the coelomic lining circulate fluids throughout the body cavity, distributing respiratory gases, wastes, and nutrients. • The hemal system of sea cucumbers is well developed, with relatively large sinuses and a network of channels containing coelomic fluids. • Its primary role is food distribution.	

257	Phylum Echinodermata (Respiratory Tree) • A pair of tubes called respiratory trees attach at the rectum and branch throughout the body cavity of sea cucumbers. • The pumping action of the rectum circulates water into these tubes. • When the rectum dilates, water moves through the anus into the rectum. • Contraction of the rectum, along with contraction of an anal sphincter, forces water into the respiratory tree. • Water exits the respiratory tree when tubules of the tree contract. • Respiratory gases and nitrogenous wastes move between the coelom and seawater across these tubules.	
258	Phylum Echinodermata (Nervous and Sensory Functions in Sea Cucumber) • The nervous system of sea cucumbers is similar to that of other echinoderms but has additional nerves supplying the tentacles and pharynx. • Sea cucumbers have no true brain. • A ring of neural tissue surrounds the oral cavity, and sends nerves to the tentacles and the pharynx. • The animal is, however, quite capable of functioning and moving about if the nerve ring is surgically removed, demonstrating that it does not have a central role in nervous coordination. • In addition, five major nerves run from the nerve ring down the length of the body beneath each of the ambulacral areas. • Some sea cucumbers have statocysts, and others have relatively complex photoreceptors. • Most sea cucumbers have no distinct sensory organs, although there are various nerve endings scattered through the skin, giving the animal a sense of touch and a sensitivity to the presence of light. • Some species possess small eye-spots near the bases of their tentacles.	
259	Phylum Echinodermata (Defense in Sea Cucumber) • Casual examination suggests that sea cucumbers are defenseless against predators. • Many sea cucumbers, however, produce toxins in their body walls that discourage predators. • Other sea cucumbers can evert tubules of the respiratory tree, called Cuvierian tubules, through the anus. • These tubules contain sticky secretions and toxins capable of entangling and immobilizing predators. • In addition, contractions of the body wall may result in expulsion of one or both respiratory trees, the digestive tract, and the gonads through the anus. • This process, called evisceration, is a defensive adaptation that may discourage predators. • Regeneration of lost parts follows.	
260	Phylum Echinodermata (Regeneration, Reproduction and Development in Sea Cucumber) • Sea cucumbers are dioecious. • They possess a single gonad, located anteriorly in the coelom, and a single gonopore near the base of the tentacles. • Fertilization is usually external, and embryos develop into planktonic larvae. • Metamorphosis precedes settling to the substrate. • In some species, a female's tentacles trap eggs as the eggs are released. • After fertilization, eggs are transferred to the body surface, where they are brooded. • Although rare, coelomic brooding also occurs. • Eggs are released into the body cavity, where fertilization (by an unknown mechanism) and early development occur. • The young leave through a rupture in the body wall. • Sea cucumbers can also reproduce by transverse fission, followed by regeneration of lost parts.	

261	Phylum Echinodermata (Class Crinoidea: General Features) • Members of the class Crinoidea (Gr. <i>krinon</i>, lily <i>oeides</i>, in the form of) include the sea lilies and the feather stars. • They are the most primitive of all living echinoderms and are very different from any covered thus far. • Approximately 630 species are living today; however, an extensive fossil record indicates that many more were present during the Paleozoic era, 200 to 600 million years ago. • Crinoids are pentamerous, stalked echinoderms with a cuplike body bearing five usually branched and commonly featherlike arms. • Most of a crinoid's body consists of an endoskeleton composed of numerous calcareous pieces, called plates or ossicles.
262	Phylum Echinodermata (Difference Between Sea Lily and Feather Star) • Sea lilies attach permanently to their substrate by a stalk. • The attached end of the stalk bears a flattened disk or root like extensions that are fixed to the substrate. • Disk like ossicles of the stalk appear to be stacked on top of one another and are held together by connective tissues, giving a jointed appearance. • The stalk usually bears projections, or cirri, arranged in whorls. • The unattached end of a sea lily is called the crown. • The aboral end of the crown attaches to the stalk and is supported by a set of ossicles, called the calyx. • Five arms also attach at the calyx. • They are branched, supported by ossicles, and bear smaller branches (pinnules) giving them a featherlike appearance. • Tube feet are in a double row along each arm. • Ambulacral grooves on the arms lead toward the mouth. • The mouth and anus open onto the upper (oral) surface. • Feather stars are similar to sea lilies, except they lack a stalk and are swimming and crawling animals. • The aboral end of the crown bears a ring of root like cirri, which cling when the animal is resting on a substrate. • Feather stars swim by raising and lowering the arms, and they crawl over substrate by pulling with the tips of the arms.
263	Class Crinoidea: Maintenance Functions, Regeneration, Reproduction and Development) • Circulation, gas exchange, and excretion in crinoids are similar to these functions in other echinoderms. • In feeding, however, crinoids use outstretched arms for suspension feeding. • A planktonic organism that contacts a tube foot is trapped, and cilia in ambulacral grooves carry it to the mouth. • Although this method of feeding is different from how other modern echinoderms feed, it probably reflects the original function of the water-vascular system. • Crinoids lack the nerve ring found in most echinoderms. • Instead, a cup-shaped nerve mass below the calyx gives rise to radial nerves that extend through each arm and control the tube feet and arm musculature. • Crinoids, like other echinoderms, are dioecious. • Gametes form from germinal epithelium in the coelom and are released through ruptures in the walls of the arms. • Some species spawn in seawater, where fertilization and development occur. • Other species brood embryos on the outer surface of the arms. • Metamorphosis occurs after larvae attach to the substrate. • Like other echinoderms, crinoids can regenerate lost parts.

	
264	Phylum Echinodermata (Class Concentricycloidea) • The class Concentricycloidea (ME <i>consentrik</i>, having a common center and Gr. <i>kykloides</i>, like a circle) contains a single described species, known as the sea daisy. • Sea daisies have been recently discovered on debris in deep oceans. • They lack arms and are less than 1 cm in diameter. • The most distinctive features of this species are the two circular water-vascular rings that encircle the disk like body. • The inner of the two rings probably corresponds to the ring canal of members of other classes, because it has Polian vesicles attached. • The outer ring contains tube feet and ampullae and probably corresponds to the radial canals of members of other classes. • Sea daisies lack an internal digestive system. • Instead, a thin membrane, called a velum, covers the surface of the animal applied to the substrate (e.g., decomposing organic matter) and digests and absorbs nutrients. • Internally, five pairs of brood pouches hold embryos during development. • No free-swimming larval stages are apparent. • The mechanism for fertilization is unknown.
265	Phylum Echinodermata (Further Phylogenetic Considerations) • As mentioned earlier, most zoologists believe that echinoderms evolved from bilaterally symmetrical ancestors. • Radial symmetry probably evolved during the transition from active to more sedentary lifestyles; however, the oldest echinoderm fossils, about 600 million years old, give little direct evidence of how this transition occurred. • Ancient fossils do give clues regarding the origin of the water-vascular system and the calcareous endoskeleton. • Of all living echinoderms, the crinoids most closely resemble the oldest fossils. • Because crinoids use their water-vascular system for suspension feeding, filter feeding, rather than locomotion, was probably the original function of the water-vascular system. • As do crinoids, early echinoderms probably assumed a mouth-up position and attached aborally. • They may have used arms and tube feet to capture food and move it to the mouth. • The calcium carbonate endoskeleton may have evolved to support extended filtering arms and to protect these sessile animals. • Many modern echinoderms are more mobile. • This free-living lifestyle is probably secondarily derived, as is the mouth down orientation of most echinoderms. • The mouth-down position is advantageous for predatory and scavenging lifestyles. • Similarly, changes in the water-vascular system, such as the evolution of ampullae, suction disks, and feeding tentacles, can be interpreted as adaptations for locomotion and feeding in a more mobile lifestyle. • The idea that the free-living lifestyle is secondary is reinforced by the observation that some echinoderms, such as the irregular echinoids and the holothuroids, have bilateral symmetry imposed upon a pentaradial body form. • The evolutionary relationships among the echinoderms are not clear. • Numerous fossils date into the Cambrian period, but no interpretation of the evolutionary relationships among living and extinct echinoderms is definitive.

- Most taxonomists agree that the **echinoids and holothuroids are closely related**.
- Whether the ophiuroids are more closely related to the echinoid/holothuroid lineage or the asteroid lineage is debated.
- The position of the Concentricycloidea in echinoderm phylogeny is highly speculative.



266

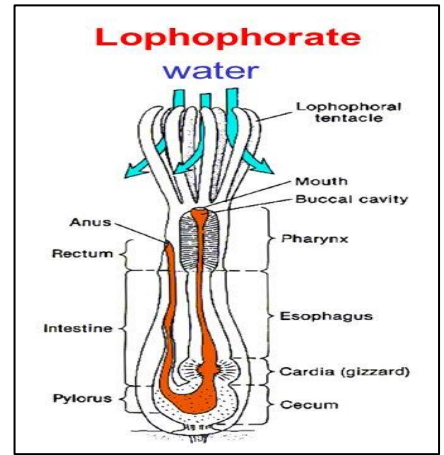
Lesser Invertebrates (The Lophophorates)

- Brachiopoda, Ectoprocta, and Phoronida discussed in one major anatomical feature, the **lophophore** (Gr. *lophos*, **crest or tuft** and *phorein*, **to bear**) is a circumoral (around the mouth) body region characterized by a circular or U-shaped ridge, with either one or two rows of ciliated, hollow tentacles.
- **An anus always opens outside of the lophophore.**
- The **lophophore is a food collecting organ and a surface for gas exchange.**
- **Sensory cells receptive to chemicals and touch are concentrated on its tentacles.**
- The lophophore can usually be extended for feeding or withdrawn for protection.
- All lophophorates are sessile or sedentary filter feeders that have a U-shaped digestive tract, a feature common in sedentary animals, and live in a secreted chitinous or calcareous tube.
- As in **deuterostomes**, these **phyla have radial cleavage** in embryonic stages and a coelom that is divided into compartments.
- As in protostomes, however, the embryonic mouth forms in the region of the blastopore.
- Recent molecular biological studies involving the sequencing of ribosomal DNA, however, suggest that the **lophophorates are protostomes**.

Phylum Brachiopoda: The Brachiopods, or Lampshells (Gr. *brachion*, arm and *podos*, foot) bear a superficial resemblance to the bivalve molluscs because they have a bivalved, calcareous and/or chitinous shell that a mantle secretes and that encloses nearly all of the body.

- However, unlike the left and right valves in molluscs, the brachiopods have dorsal and ventral valves.
- In addition, molluscs filter with their gills, whereas brachiopods use a lophophore.
- **Brachiopods are commonly called lampshells because they resemble ancient Roman oil lamps.**
- Brachiopods are exclusively marine; most species live from the tidal zone to the edge of the continental shelves (about 200 m deep).
- **The phylum contains about three hundred living species.**
- In the Articulata, the valves are composed primarily of calcium carbonate and have a hinge with interlocking teeth.
- The Inarticulata have unhinged valves that are composed primarily of calcium phosphate and held together only by muscles.
- Most members of both classes have a stalked pedicel that usually attaches to a hard surface.
- Some, such as *Lingula*, have a muscular pedicel used for burrowing and anchoring in mud or sand.
- The large, horseshoe-shaped lophophore in the anterior mantle cavity bears long, ciliated tentacles used in respiration and feeding.
- The cilia set up water currents that carry food particles (mainly organic detritus and algae) between the valves and over the lophophore into the mouth.

- A solitary, dioecious brachiopod reproduces sexually by releasing gametes from multiple gonads into the metacoel and discharging them into the water by the nephridia.
- Fertilization is usually external, and the nonfeeding, ciliated, free-swimming larva is planktonic before settling and developing into an adult.
- Development is similar to that of deuterostomes, with radial, mostly equal, holoblastic cleavage, and enterocoelous coelom formation.
- In the lophophorata, the juvenile resembles a small brachiopod with a coiled pedicel in the mantle cavity.
- There is no metamorphosis; when the juvenile settles to the bottom, the pedicel attaches to a solid object, and adult existence begins.



267

The Lophophorates (Phylum Ectoprocta (Bryozoa): Moss Animals)

- The ectoprocts (Gr. *ektos*, outside and *proktos*, anus) or bryozoans superficially resemble hydroids or corals.
- Bryozoa (Gr. *bryon*, moss and *zoon*, animal) means moss animals and refers to the moss like appearance of the colonies.
- The name ectoprocta refers to the position of the anus outside the ring of tentacles.
- The approximately four thousand living species of pseudocoelomates ectoprocts belong to three classes.
- All species are aquatic (both freshwater and marine) and less than 1.5 mm in length.
- Each body, or zooid, has a circular or horseshoe-shaped lophophore and is covered with a thin cuticle that encloses a calcified exoskeleton.
- The feeding body (lophophore, digestive tract, muscles, nerves) is called the polypide, the exoskeleton plus body wall (epidermis) is the cystid, and the secreted, nonliving part (exoskeleton) is the zooecium (Gr. *zoo*, animal and *oecus*, house).
- Ectoprocts have an eversible lophophore that can be withdrawn into the body.
- Contraction of the retractor muscle rapidly withdraws the lophophore, whereas contraction of the muscles encircling the body wall exert pressure on the coelomic fluid, everting the lophophore.
- Ectoprocts grow by budding.
- Thin portion of the body wall grow out as small vesicles or tubes, and contain a complete zooid.
- The different budding patterns reflects the genetics of the individual animal and such factors as current flow and substrate.
- The factors determine the colony shape (e.g., thin sheets, convoluted folds, massive coral-like heads, upright tangles).
- Each colony can contain about 2 million zooids.
- Most ectoprocts are monoecious.
- In some species, heterozooids produce either eggs or sperm in different colonies.
- In others, simple gonads produce both sperm and eggs in the same autozooid.
- Sperm enter the coelomic cavity, exit through pores in the tips of the tentacles, and are caught by the tentacles of other colonies.
- Eggs are fertilized as they are released and are brooded in the coelom; some species have a modified ovicell in which the embryo develops.
- Marine species have radial cleavage and a free-swimming, ciliated larva.
- This larva swims for a variable period of time, depending on the species, and then sinks and attaches to a rock or other substrate and grows into a zooid.
- A colony forms by budding.
- Some freshwater ectoprocts produce a dormant stage called a statoblast.
- A statoblast is a hard, resistant capsule containing a mass of germinative cells.
- Statoblasts are asexually produced and accumulate in the metacoel.
- They can survive long years in seasonally variable lakes and ponds.
- Some float and are carried downstream, or are blown or carried from pond to pond, spreading ectoprocts over a large area.
- When environmental conditions become favorable, the statoblasts hatch and give rise to new polypides, and eventually, new colonies.

268	The Lophophorates (Phylum Phoronida: The Phoronids) • The Phoronids consist of about a dozen marine species divided between two genera: <i>Phoronis</i> and <i>Phoronopsis</i>. • These animals live in permanent, chitinous tubes either buried in muddy or sandy sediments, or attached to solid surfaces. • A few species bore into mollusc shells or calcareous rock. • Generally, only the tentacles extend into the overlying water. • Most phoronids are small, less than 20 cm long. • The adult phoronid body consists of an anterior lophophore with two parallel rings of long tentacles. • The tentacles of the lophophore are filled with coelomic fluid that serves as a hydrostatic skeleton to hold them upright. • The cilia on the tentacles drive water into the ring of tentacles from the top of the lophophore and out through the narrow spaces between the tentacles. • Suspended food particles are directed toward the mouth. • A flap of tissue called the epistome (Gr. <i>epi</i>, around and <i>soma</i>, mouth) covers the mouth. • Some phoronids reproduce asexually by budding and transverse fission; however, the majority are hermaphroditic. • The gonads are in the coelom. • Gametes pass from the coelom through the nephridiopore to the tentacles. • Cross-fertilization is the rule, and zygote are either protected among the coils of the lophophore or released into the sea. • Cleavage is radial, and a free-swimming larva called the actinotroch develops and feeds on plankton while drifting in the sea. • It eventually settles to the bottom, metamorphoses, and begins to grow ventrally to form the body of the sedentary adult. • As the animal grows, it burrows into the substrate. • The body wall contains gland cells that eventually secrete the chitinous tube.
269	Lesser Invertebrates (Cycliophores) • Phylum cycliophores (Gr. <i>cyclion</i>, small wheel and <i>phora</i>, to carry) is the most recently described animal phylum. • Members of its single species (<i>Symbionpandora</i>) are acoelomate, marine and bilaterally symmetrical. • They live in association with the mouthparts of lobsters. • The body of the feeding stage of <i>symbion</i> consists of a buccal funnel, a trunk, and a stalk that ends in an adhesive disk. • The disk attaches to a seta on the mouthparts of the lobster host. • The buccal funnel contains the mouth and is surrounded by a ring of compound cilia used in filter feeding. • A cuticle lines the body on the outside. • The mouth leads to a U-shaped gut tract. • Protonephridia are used in excretion. • The asexual feeding stage of <i>symbion</i> is about 0.3 mm tall. • It can reproduce asexually by producing a larva stage, called the pandora, that is released and settles on the same host. • Because of this asexual reproduction, large number of <i>symbion</i> can build up on one host. • After settling and attachment, the new individual develops a buccal funnel and begins to feed. • Sexual reproduction is apparently correlated to the molt cycle of the lobster. • Some cue, possibly hormonal, from the lobster signals <i>symbion</i> that the lobster is about to molt. • Male and female stages are produced within the bodies of feeding individual containing a maturing female. • As the female escapes from its maternal feeding individual, fertilization occurs, and the female settles on the lobster's mouthparts. • The female contains a single, large fertilized egg.

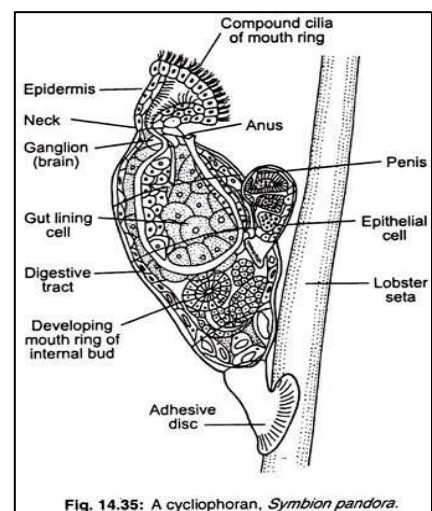
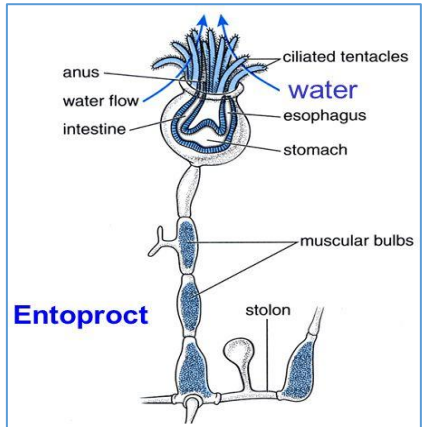
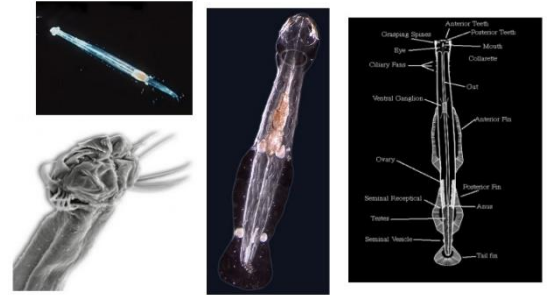


Fig. 14.35: A cycliophoran, *Symbion pandora*.

	• The female dies, leaving a cuticular shell containing a chordoid larva. • The chordoid larva is the dispersal stage. • It is free-swimming and may settle on the mouth appendages of a new lobster host.
270	Lesser Invertebrates (Entoprocts) • The entoprocts (Gr. <i>entos</i>, within and <i>proktos</i>, anus) comprise a small phylum of about one hundred species of sedentary marine filter feeders. • They are either solitary or colonial, and live in coastal waters. • One group is commensalistic on the body surface of various invertebrates. • Most entoprocts are microscopic. • Entoprocts may form large, matlike colonies on rocks. • An individual entoproct consists of a muscular stalk bearing a cup-shaped calyx with a crown of ciliated tentacles. • The stalk is surrounded by a chitinous cuticle and may bear an attachment disk with adhesive glands. • Entoprocts have a small body cavity that most zoologists consider a pseudocoelom. • Loose connective tissue, however, fills this body cavity. • How this cavity forms and its function are not well known. • Entoprocts are filter feeders, and cilia on the tentacles convey food into the mouth. • The filter-feeding apparatus is similar to the lophophore described for three previous phyla. • The entoproct feeding structure, however, is not a lophophore because the anus ends with the group of tentacles. • Lophophores, by definition, have an anal opening outside their ring of tentacles. • The digestive tract forms a U-shaped gut in the calyx. • Also in the calyx is a pair of protonephridial tubules that open through a single pore in the mouth. • The nervous system consists of a small, central ganglion and radiating nerves. • Gas exchange occurs across the body surface. • Entoprocts reproduce by asexual budding and also sexually. • Most entoprocts are monoecious, but eggs and sperm usually are produced at different times in one animal. • Sperm are released freely into the water, and fertilization occurs internally. • Embryos develop in a brood chamber, from which free-swimming larvae are released. • Eventually, larvae settle to the substrate and develop into adults. 
271	Lesser Invertebrates (Chaetognaths) • Members of the phylum Chaetognatha (Gr. <i>chaite</i>, hair or bristle and <i>gnathos</i>, jaw) are the arrow worms. • The approximately one hundred species in this phylum are distributed throughout the world's oceans. • Most are planktonic, 0.5 to 12 cm in length, streamlined, bilaterally symmetrical, and nearly transparent. • Their body consists of a head, trunk, and tail. • The trunk has paired, lateral fins, and the tail has a single fin. • The mouth is located ventrally on the head. • Large grasping spines are lateral to the mouth, and smaller spines, called teeth are in front of the mouth. • Arrow worms are active swimmers. • The near-perfect bilateral symmetry and streamlined shape of arrow worms permit a darting form of locomotion from laterally flexing the body. • Their fins stabilize the body during swimming and help prevent sinking during moments of rest. • Arrow worms are active predators. • They feed on planktonic crustaceans and small fish. • An arrow worm darts forward quickly to grab its prey with mouth spines that inject a neurotoxic venom into the prey.

- Interestingly, the neurotoxin is not produced by the arrow worm, but by commensalistic bacteria living in the head region.
- The gut of arrow worms is a simple, straight tube.
- Although much remains to be learned about arrow worm physiology, circulation, gas exchange, and excretion probably all occur by diffusion.
- The nervous system consists of a cerebral ganglion in the head and other ganglia associated with sensory organs.
- Ciliary fans that cover the body probably detect water borne vibration.
- A single pair of eyes is below the epidermis on the dorsal surface of the head.
- Arrow worms probably use these photoreceptors to orient to the direction and intensity of light during vertical migrations within the water column.
- Chaetognaths are monoecious, with paired ovaries in the trunk and paired testes in the tail.
- Arrow worms engage in a mating dance during which they deposit sperm in ball-like clusters on the mate's body.
- These sperms clusters rupture, and sperm migrate to the female gonopore.
- Fertilization is internal, and zygote in a jelly like coating float in the sea or sink to the substrate.
- One genus has a marsupial pouch within which fertilized egg develops.
- There is no larval stage or metamorphosis.

Phylum Chaetognatha – arrow worms



Effort By

Kainat Azhar VU BS ZOOLOGY