Department of Biotechology

College of Sciences, Diyala University

Subject: General Zoology

Instructor: Professor Dr. Abdul-Lateef Molan

Office hours (free for consultation): Monday (9 a.m. – 1:30 p.m.), Thursday (8.30 a.m. – 10:30 p.m.).

Lecture: Tuesday 10.30 a.m. – 12:30 p.m., Lecture room #1

Course Description:

An introduction to basic concepts in biology through study of the major lineages of invertebrate and vertebrate animals, with emphasis on the structure, and function of organ systems in an evolutionary context. Topics covered will include basic cell structure and function, development, systematics, and evolution. The laboratory will focus on observation of structural-functional relationships of living and preserved representatives of the major animal phyla.

Course Objectives:

By the end of this course, students should:

1. Understand the difference between science and non-science.

2. Be familiar with the specialized vocabulary of zoology.

3. Understand the relationship between animal structure and function.

4. Know the structural and functional characteristics of major animal groups, and be familiar with current hypotheses concerning how they evolved.

Key Definitions

Biology: Is the study of living things.

Microbiology: Is the study of microscopic organisms.

Bacteriology: The study of bacteria.

Virology: The study of viruses.

Mycology: The study of fungi.

Parasitology: The study of parasite and parasitism.

Ecology: is the study of relationships between organisms and their relationships with their environment.

Taxonomy: The classification of living things.

Entomology: The study of insects.

Medical Entomology: The study of medical insects.

Pathology - the study of the nature of disease and its causes, development, and consequences

Pharmacology - the study of preparation and use of drugs and synthetic medicines

Physiology - the study of the functions of living organisms and their parts

Psychobiology - the study of mental functioning and behavior

Toxicology - the study of how natural or man-made poisons cause undesirable effects in living organisms

Zoology - The branch of biology that deals with animals and animal life.

Ichthyology - the study of fishes

Herpetology - the study of reptiles and amphibians

Ornithology - the study of birds

Mammalogy - the study of mammals

Freshwater Biology - a science concerned with the life and ecosystems of freshwater habitats

Genetics - a science that deals with heredity, especially the mechanisms of hereditary transmission and the variation of inherited characteristics among similar or related organisms

Geobiology - a science that combines geology and biology to study the interactions of organisms with their environment

Immunobiology - a study of the structure and function of the immune system, innate and acquired immunity, the bodily distinction of self from nonself, and laboratory techniques involving the interaction of antigens with specific antibodies

Marine Biology - study of ocean plants and animals and their ecological relationships

Medicine - the science which relates to the prevention, cure, or alleviation of disease

Microbiology - the branch of biology that deals with microorganisms and their effects on other living organisms

Molecular Biology - the branch of biology that deals with the formation, structure, and function of macromolecules essential to life, such as nuclic acids and proteins, and especially with their role in cell replication and the transmission of genetic information.

Neurobiology - the branch of biology that deals with the anatomy and physiology and pathology of the nervous system

Astrobiology - branch of biology concerned with the effects of outer space on living organisms and the search for extraterrestrial life.

Anatomy - The bodily structure of an organism.

Biochemistry - The study of the chemical substances and vital processes occurring in living organisms. the study of the structure and function of cellular components, such as proteins, carbohydrates, lipids, nucleic acids, and other biomolecules, and of their functions and transformations during life processes

Bioclimatology - a science concerned with the influence of climates on organisms

Bioengineering - a discipline that deals with bio-molecular and molecular processes, product design, sustainability and analysis of biological systems.

Biogeography - a science that attempts to describe the changing distributions and geographic patterns of living and fossil species of plants and animals

Bioinformatics - information technology as applied to the life sciences, especially the technology used for the collection, storage, and retrieval of genomic data.

Biophysics - or biological physics is the science that applies the theories and methods of physical sciences to questions of biology.

Biotechnology - applied science that is concerned with biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.

Botany - the scientific study of plants.

Cell biology - the study of cells at the microscopic or at the molecular level. It includes studying the cells' physiological properties, structures, organelles, interactions with their environment, life cycle, division and apoptosis

Conservation Biology - concerned with the studies and schemes of habitat preservation and species protection for the purpose of alleviating extinction crisis and conserving biodiversity

Developmental Biology - the study of the processes by which an organism develops from a zygote to its full structure

Ecology - the study of the relationships between plants, animals, and their environment.

Ethnobiology - a study of the past and present human interactions with the environment, for instance the use of diverse flora and fauna by native societies

Evolutionary Biology - a subfield concerned with the origin and descent of species, as well as their change over time, i.e. their evolution

Characteristics of living things

1. Complex organization
2. Metabolism
3. Responsiveness
4. Growth
5. Reproduction
6. Evolution
7. Ecology

Complexity:

Living things have a level of complexity and organization not found in lifeless (**not dead**) **objects**. A living thing is composed of one or more **cells.** These units, generally too small to be seen with the naked eye, are organized into tissues**. A *tissue* is a series of cells that perform a shared function.** Tissues, in turn, form *organs*, such as the stomach and kidney. A number of organs working together compose an *organ system*. An organism is a complex series of various organ systems.

Metabolism:

The chemical processes happening within a living cell or organism that are necessary for the maintenance of life are called **metabolism.** Metabolism generally involves the release or use of chemical energy. **Nonliving things do not display metabolism.**

Growth:

To do growth, an organism expends some of the energy it gets during metabolism. A nonliving organism does not display this characteristic.

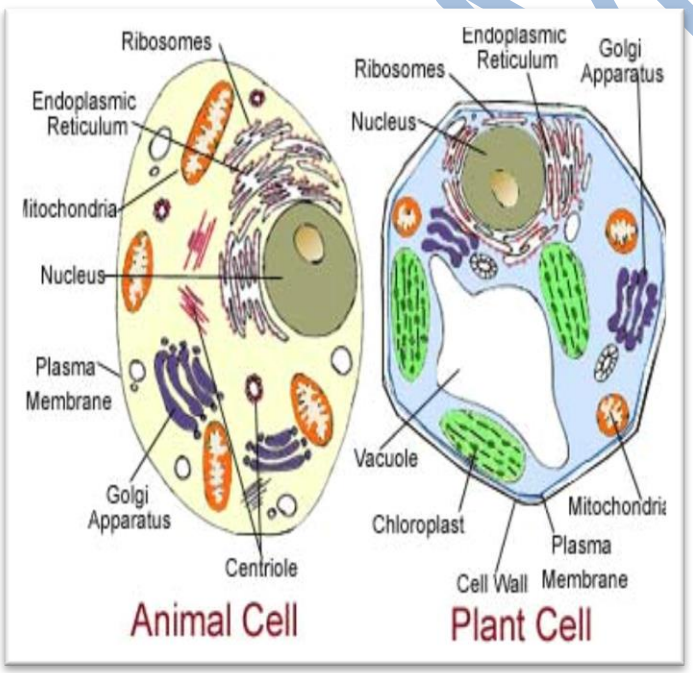
Evolution:

Populations of living organisms have the ability to adapt to their environment through the process of evolution.

Ecology:

Ecology is the study of relationships between organisms and their environment. Living things can alter their environment, but nonliving things cannot**. Living things, for example, may migrate or hibernate if the environment becomes difficult to live in. In contrast, nonliving things do not display this character.**

Animal and plant cells



Prokaryotic and eukaryotic cells

- All organisms may be classified as **prokaryotes** or **eukaryotes. The cells of all prokaryotes and eukaryotes possess two basic features: a plasma membrane and cytoplasm.**

- However, **the cells of prokaryotes are simpler than those of eukaryotes**. For example, **prokaryotic cells lack a nucleus**, while eukaryotic cells have a nucleus.
- **Prokaryotic cells lack internal cellular bodies** (organelles), while eukaryotic cells possess them. Examples of prokaryotes are bacteria. Examples of eukaryotes are protozoa, fungi, plants, and animals.

Plasma membrane

All **prokaryote and eukaryote cells have plasma membranes. The plasma membrane (also called the *cell membrane*) is the cell surface, which separates the cell from the external environment. The plasma membrane is composed primarily of proteins and lipids, especially phospholipids.**

Cytoplasm and organelles

- All prokaryote and eukaryote cells also have cytoplasm (or cytosol). Essentially, cytoplasm is the gel-like material enclosed by the plasma membrane.
- Within the cytoplasm of eukaryote cells are a number of membrane-bound bodies called organelles ("little organs") that provide a specialized function within the cell.

Organelles found in the cytoplasm:

1. **Endoplasmic reticulum (ER).** The endoplasmic reticulum is a series of membranes extending throughout the cytoplasm of eukaryotic cells. In some places, the ER is covered with small bodies called **ribosomes.** This type of ER is called **rough ER.** In other places, there are no ribosomes and this type of ER is called **smooth ER. The ER is the site of protein synthesis in a cell.**

2. **Golgi body** (also called the **Golgi apparatus**). The Golgi body is a series of flattened sacs, usually curled at the edges. **The function of the Golgi apparatus is to modify, sort, and package proteins and other materials from the endoplasmic reticulum for storage in the cell or secretion outside the cell.**

3. **Nucleus**
   - Prokaryotic cells lack a **nucleus;** the word *prokaryotic* means "primitive nucleus." Eukaryotic cells, on the other hand, have a distinct nucleus.
   - The nucleus of eukaryotic cells is composed mainly of protein and **deoxyribonucleic acid,** or **DNA.** The DNA is organized into linear units called **chromosomes,** also known as **chromatin** when the linear units are not obvious. The segments of the chromosomes are called **genes.** Approximately 100,000 genes are located in the nucleus of all human cells.

- **The *nuclear envelope,* an outer membrane, surrounds the nucleus of eukaryotic cell.**
- Within the nucleus are one or more dense organelles called **nucleoli** (the singular form is *nucleolus*). **In nucleoli, particles called *ribosomes.***
- Although prokaryotic cells have no nucleus, they do have DNA. The DNA exists freely in the cytoplasm as a closed loop. It has no protein to support it and no membrane covering it. **A bacterium typically has a single looped chromosome with about 4,000 genes.**

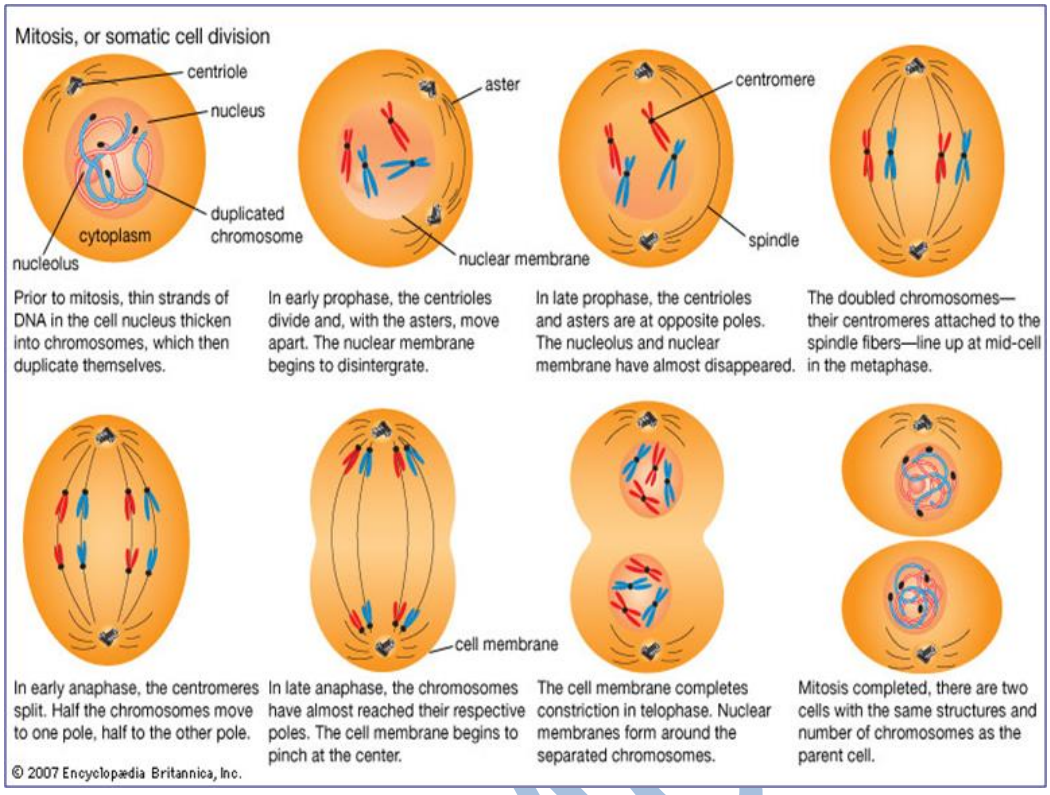
4. Cell wall
   - **Many kinds of prokaryotes and eukaryotes contain a structure outside the cell membrane called the *cell wall.*** With only a few exceptions, all bacteria have thick, rigid cell walls that give them their shape. Among the eukaryotes, fungi and plants have cell walls.
   - Cell walls provide support and help cells resist mechanical pressures.

Cell cycle

- The **cell cycle** involves many repetitions of cellular growth and reproduction. With few exceptions (for example, **red blood cells**), all the cells of living things undergo a cell cycle.
- The cell cycle is generally divided into two phases: interphase and mitosis. During **interphase,** the cell spends most of its time performing the functions that make it unique. **Mitosis** is the phase of the cell cycle during which the cell divides into two daughter cells.

Mitosis

- The term *mitosis* is derived from the Latin term *mito,* meaning "threads." When mitosis was first described a century ago, scientists had seen "threads" within cells, so they gave the name mitosis to the process of "thread movement." **During mitosis, the nuclear material becomes visible as thread like chromosomes.**
- **Mitosis** is a continuous process, but scientists divide mitosis into a series of phases (stages): prophase, metaphase, anaphase, and telophase.



1. Interphase

- During this phase, each chromosome consists of a single molecule of DNA and its associated protein. **In human cells, there are 46 chromosomes per cell (except in sex cells with 23 chromosomes and red blood cells with no nucleus and hence no chromosomes).**
- The DNA within the nucleus replicates so by the end of this phase, two DNA molecules exist for each one.
- In this phase, the cell prepares itself for mitosis. Proteins organize themselves to form a series of fibers called the *spindle*, which is involved in chromosome movement during mitosis.

2. Prophase

Mitosis begins with the condensation of the chromosomes to form visible threads in the phase called prophase. Two copies of each chromosome exist; each one is a **chromatid.** Two chromatids are joined to one another at a region called the **centromere.** As prophase unfolds, the chromatids become visible in pairs, the spindle fibers form, the nucleoli disappear, and the nuclear envelope dissolves.

In animal cells during prophase, microscopic bodies called the **centrioles** begin to migrate to opposite sides of the cell. When the centrioles reach the poles of the cell, they produce a series of radiating microtubules called an *aster*. **Centrioles and asters are not present in most plant or fungal cells.**

3. **Metaphase**

- In this stage, the spindle fully develops and the chromosomes align at the metaphase plate (a plane that is equally distant from the two spindle poles).
- The nuclear membrane disappears completely.
- In animal cell, the centrioles align at opposite poles of the cell.
- Polar fibers (microtubules that make up the spindle fibers) continue to extend from the poles to the center of the cell.
- Chromosomes move randomly until they attach (at their kinetochores) to polar fibers from both sides of their centromeres.
- Chromosomes align at the metaphase plate at right angles to the spindle poles.

4. **Anaphase**

- At the beginning of anaphase **,** the chromatids move apart from one another. The chromatids are **chromosomes** after the separation. Each chromosome is attached to a spindle fiber, and the members of each chromosome pair are drawn to opposite poles of the cell by the spindle fibers. The movement toward the poles is accomplished by several mechanisms, such as an elongation of the spindle fibers, which results in pushing the poles apart.
- The result of anaphase is an equal separation and distribution of the chromosomes. In humans cells, **a total of 46 chromosomes move to each pole as the process of mitosis continues.**

5. **Telophase**

In telophase, the chromosomes finally arrive at the opposite poles of the cell. The clear chromosomes begin to fade from sight as masses of chromatin are formed again. **The events of telophase are essentially the reverse of those in prophase**. **The spindle is dismantled and its amino acids are recycled, the nucleoli reappear, and the nuclear envelope is reformed.**

Functions of Mitosis

Mitosis serves several functions in living cells.

1. In many simple organisms, it is the method for asexual reproduction (for example, in the cells of a fungus).
2. In multicellular organisms, mitosis allows the entire organism to grow by forming new cells and replacing older cells.
3. In certain species, mitosis is used to heal wounds or regenerate body parts.
4. It is the universal process for cell division.

Animal Cells

- animal cells are “eukaryotic” cells
- much larger, much more complex,
- most genetic material is contained in prominent nucleus
- lots of internal and surface structures including organelles
- animal cells lack cell walls the thin flexible cell membrane forms the outer boundary of each cell not rigid, but flexible also acts as a gateway for things moving into and out of the cell organelles and other internal structures provide a division of labor and allow the cells to work much more efficiently.

  eg. mitochondria (energy factories)

  eg. vacuoles (storage containers)

  eg. ribosomes (energy factories)

  eg. lysosomes (cellular digestion)

- animals are generally much more active, have a much higher metabolism than the members of other kingdoms they therefore require much more energy than species in any other kingdom
- almost all this energy is the product of aerobic respiration inside mitochondria
- animal cells have many more mitochondria than those of other organisms
- animal cells make much more use of proteins for structure, movement, nerve impulses and metabolism
- many more ribosomes (protein factories)

Animal tissues

- Single celled organisms like protozoa are “jacks of all trades” move, feed, produce energy, respond to stimuli, reproduce etc
- In multicellular organisms such as animals the large size and complexity dictates that individual cells specialize rather than performing all tasks each group of cells becomes specialized to do one or a few tasks very well (much more efficiently):

  Example: muscle cells (contraction and movement).

  Example: bone cells (support).

  Example: blood (circulation).

There are 4 basic animal tissues:

1. Epithelial 2. Connective 3. Muscular 4. Nervous

1. Epithelial Tissues

Epithelial tissue is the most primitive animal tissue, presumably the first true animal tissue to evolve.

a. It forms the outer coverings of animals.

b. Lines the inner and outer surfaces of all organs.

c. Consists of cells fitted tightly together.

Functions of Epithelial Tissues:

1. Protection from microbes, physical injury, water loss, etc.

2. Absorption of food, water etc in the intestine.

3. Transport and sometimes have cilia (tiny hair-like processes) that move things along a tube such as oviducts (move egg toward uterus) and respiratory tracts (move dust and bacteria out of lungs).

4. Filtration in kidneys.

5. Gas exchange in lungs.

6. Secretion (form glands that secrete various substances such as mucous, sweat, and digestive juices).

2. Connective Tissues

a. The most widespread and abundant type of tissue.

b. In animals the most diverse in structure and function.

c. Most connective tissues are heavily vascularized.

d. Connective tissues have an abundance of matrix (the noncellular matrix often comprise the majority of the tissue volume).

e. The nature of the matrix and the fibers it contains identifies the specific kind of connective tissue fibers (composed mainly of collagen a uniquely "animal" protein (esp. skin, tendons, ligaments, cartilage)).

Functions of Connective Tissues:

1. Support and movement (eg. bone and cartilage).
2. Nutrient storage (eg. bone, adipose).
3. Temperature homeostasis (eg. fat for heat production and cold insulation).
4. Transport (eg. blood, lymph).

Functions of Muscle Tissue:

1. movement (both voluntary movements such as swimming or running and internal involuntary movements of various organs such as the pumping heart, and peristalsis of the digestive organs.
2. Posture
3. Heat generation (used for movement).

4. Nervous Tissues

a. Nerve cells are also elongated in shape.
b. Typically, large cell body with one or more long fibers extending from it grouped together to form extensive interconnected network of "wires" that extend throughout the body.
c. Nerve cells are able to conduct impulses to send signals throughout the animal body

Functions of Nervous Tissue

1. To sense internal and external environmental changes,
2. Coordination and control of muscles and glands.

Stem Cells

Most adults retain some kinds of "embryonic cells" called stem cells can later differentiate into replacement cells and tissues.

Animal (Including Human) Organ Systems

The greater specialization of cells and tissues increases the efficiency by which animals can carry out life's basic processes and allows for almost limitless opportunities for evolutionary variations and adaptations to numerous kinds of habitats and environmental conditions.

To understand and appreciate the complexity of different kinds of animals we'll focus on the most familiar (and most complex) animal (humans).

1. Skin (integumentary system)

- outer covering of the animal (plants also have outer covering, epidermis, but it's much simpler in structure and function)
- in some animals (usually relatively small ones) is a simple covering that allows food, gasses and waste products to easily diffuse in and out of the animal
- in terrestrial animals it may serve as a waterproofing layer to keep animal from drying out
- skin often contains various sense organs
- in some skin is hardened to offer support
- in some animals the skin color is important in behaviors: communication camouflage reproductive behaviors etc.
- many animals can quickly change the color of their skin (chromatophores).

2. Skeletal System

(A) Exoskeleton

- on the outside, especially good protection (eg. clams, snails, insects)
- secreted by the skin
- grows at edges (clams & snails) or must be shed periodically for growth

(insects and other arthropods)

(B) Endoskeleton

- internal (grows with the body) eg. vertebrates including humans hydrostatic skeleton muscles of body wall control fluid pressure eg. most worms, jellyfish, octopus.
- grows continuously throughout life
- very active tissue
- recycled every ~7 years
- subdivided in axial (skull, vertebrae, rib cage) & appendicular skeleton (arms & legs)
- functions in:

1. support strong and relatively light; 10% body weight

2. movement framework on which muscles act (act as levers and pivots)

3. protection some of our most delicate organs are well protected by being encased in bone eg. brain, lungs, heart, reproductive system

3. Muscular System

unique to animals: animals are much more active than any other living organisms.

General Functions of muscles:

(A) movement.

- most animals are motile (walk, run, crawl, swim, fly, climb, etc).
- a few animals are sessile but even these have internal muscles that circulate blood, move food through digestive tract, etc
- some muscle are voluntary
- some are involuntary

(B) Heat Production.

- Important for warm blooded animals like us (muscle generate lots of heat, warm blooded vs coldblooded).
- All animals alive today except birds and mammals are "cold blooded"
- Bird & mammals are warm blooded (much more active, require much more food to maintain heat production).

4. Digestive System

- Like fungi, and many protists and bacteria, animals are heterotrophs (take inorganic food).

- Animal food needs are much more complex.
- Digestive system functions to break down the food so that it can be absorbed and used by the body.
- Most animals digest the food after it is eaten, not before as in fungi or some plants but a few (eg. spiders) predigest their food
- Lots of specialization in structures depending on how an animal gets its food & what kind of food it prefers [eg. predator, herbivore, parasite, filter feeder, fluid feeder in some animals the digestive system is a simple sac, opened at one end [food is eaten, digested and the wastes are "spit out" the mouth]. eg. corals, jellyfish, flatworms
- In most animals the organs of digestive system form essentially a long continuous tube that is open at both ends [alimentary canal (GI tract) is composed of mouth, pharynx, esophagus, stomach, small intestine, large intestine, anus].
- Near the beginning of the system food is physically and chemically digested [eg. typically the mouth is armed with the appropriate tools to rip and tear the food into smaller pieces [eg. the stomach and beginning of the small intestine produces enzymes and other chemicals to break large proteins and starches into smaller molecules
- the rest of the system is used to absorb the nutrients released by digestion and to get rid of undigestible wastes [eg. most absorption occurs in the small intestine].
- A few things (water, alcohol) can be absorbed by the stomach; and the large intestine can absorb additional water and nutrients released by bacterial action].
- Our small intestine is greatly modified for absorption surface area is greatly increased for more efficient absorption of nutrients.

5. The Respiratory System

- Like plants, all animals require oxygen (O2) to produce energy and release C02 as a waste product
- Oxygen gas is needed as a nutrient
- Carbon dioxide gas is a waste product of respiration (energy production)
- Since animals are more active than plants they require more efficient ways to get oxygen (plants just used simple pores: stomata or lenticels, or pneumatophores)
- Respiratory system functions as this gas exchange system in animals in very small animals there is no specific "organ" [breath through their skin].
- Air breathing animals have different requirements than those that extract oxygen from water aquatic animals.
- Gasses diffuse much slower in water than in air
- Water contains 20 times less oxygen than air.
- aquatic organisms must have more efficient respiratory systems
- High surface area provided by gills, book gills, etc

- Numerous flaps or feather-like structures exposed on the sides of the animal must keep water moving across gills [gills in constant motion, water is constantly pumped over gills].
- Air breathers: easier to extract O2 from air
- Air contains 20 times more air than water but air dries respiratory surface [respiratory organs must be protected and kept moist] [lungs, trachea, book lungs, etc].
- Often the respiratory system is closely associated with some kind of circulatory system to more effectively collect and distribute the oxygen [eg. Human lungs].

6. Circulatory System

- The circulatory system is the major connection between external and internal environment [everything going in or out of body must go through the circulatory system to get to where its going.
- In small organisms gas exchange and food and wastes enter and leave by simple diffusion.
- In large, multicellular organisms some kind of circulatory system is needed to move things around.
- Typically, the circulatory system consists of "plumbing" =blood vessels: arteries, capillaries, veins.
- "Pumps" = heart can be "open" or "closed" system: open system (eg. insects) fluid sloshes around in body cavity.
- Pumping heart keeps fluid in motion.
- Closed system (vertebrates; humans)
- Blood flows in closed system of vessels over 60,000 miles of vessels (mainly capillaries) [arteries, capillaries, and veins].

7. The Endocrine System

- Virtually all multicellular organisms use chemicals to coordinate activities and communicate in animals, chemicals (= hormones) are used to help control long term activities such as growth, development, reproductive cycles, etc
- Virtually all organs produce various hormones but in some organs hormone production is their main job [thyroid gland, pituitary gland, pancreas, etc].

8. Nervous System

- Animals are much more active than members of the other two multicellular kingdoms
- Animals move much more quickly, must respond to things much quicker

- Chemicals may take minutes or hours to produce a response
- Animals need a system to control quick reactions: movements, emergencies, etc
- Only members of the animal kingdom have an additional systems of control
- All major animal groups except sponges have some kind of nervous system
- Cells of the nervous system are highly specialized for receiving stimuli and conducting impulses to various parts of the body
- Made up mainly of neurons long thin fiber like cells up to 4 ft long
- Very high metabolic rate (highest of any cells in body)
- Require glucose, can't use alternate fuels
- Require lots of O2 – only aerobic metabolism
- Can't survive more than a few minutes without O2
- Reflex = a rapid, automatic, predictable motor response to a stimulus:

1. unlearned
2. unplanned
3. involuntary

Nervous system is organized into 2 major subdivisions:

- CNS: brain and spinal cord
- PNS: cranial nerves and spinal nerves

9. The Senses

- Monitor and allow organism to respond to its environment.
- Senses provide direct contact between animal and its surroundings.
- No animal is completely aware of its environment [only selectively aware].
  eg. those that live in caves depend more on smell and sound.
  eg. those that live on surface of land rely heavily on sight.
  eg. those that live in water use smell, currents and vibrations.
- Sensory receptors are transducers information presents itself in different energy forms ! receptors convert one form of energy into nerve impulses that the brain can interpret
- Our body has millions of sensory receptors [most are internal, and help maintain body at an unconscious level.

Kinds of transducers:

- Photoreceptor - light
- Chemoreceptor - chemicals
- Mechanoreceptor - bending, pressure, touch
- Thermoreceptor - temperature

- Osmoreceptor – salt/water conc
- Nocioceptor ("to injure") – pain

10. Excretory System (Urinary System)

- Excretory wastes = metabolic wastes
- Chemicals & toxins produced by cells during metabolism
- All organisms must get rid of excess materials and wastes
- Fungi, protists, bacteria ! diffusion;
- Plant stomata, converted to "secondary plant products" for defense or support or stored in woody tissue).
- Having greater metabolism, animals generate more wastes
- Need more effective way to get rid of wastes
- Main job of excretory system is to collect and eliminate toxic wastes
- May also help to stabilize salt and water balance in body

11. Reproductive System

- Most animals reproduce both asexually and sexually.
- Most vertebrates reproduce only sexually.
- Animals typically go through more complex stages of development.
- Sometimes spending years in immature forms.
- Some animals go through an alternation of generations.
- Contains ovaries and testes for sexual reproduction.
- Sometimes contains organ for development of young.
- Only major human system that doesn't work continuously.
- Only activated at puberty.

Taxonomy and Classification of Animals

Animals are distinguished from all other kingdoms by the following characteristics:

♦ Eucaryotic cells that lack cell walls.

♦ lack photosynthesis, instead they are heterotrophs.

The taxonomy and classification of the different animal phyla relies on some basic differences in the following general characteristics:

- Type of symmetry: asymmetrical, radial symmetry, bilateral symmetry
- Number of Germ Layers (embryonic tissue layers): no true tissue layers, diploblastic, triploblastic
- Presence and type of body cavity: acoelomate, pseudocoelomate, coelomate (eucoelomate)
- Presence of segmentation: segmented vs unsegmented
- Embryonic formation of body cavity: schizocoelous, enterocoelous
- Embryonic mouth formation: protostomes, deuterostomes
- Embryonic cleavage patterns: spiral, radial, discoidal & some others

Some other characteristics that are important in the classification of specific phyla and classes of animals relate to the diversity of different organ systems found in the animal kingdom:

- Type of digestive system: complete vs incomplete
- Type of skeletal system: exoskeleton, endoskeleton, hydroskeleton
- Type of circulatory system: open vs closed
- Type of respiratory system: gills, tracheae, lungs (and others)
- Type of reproduction: asexual, parthogenesis, hermaphroditic, dioecious

The Animal Kingdom

Subkingdom Protozoa (single-celled animals).

This subkingdom is classified into the following main Phyla:

A. Phylum Sarcomastigophora: this Phylum includes two Subphyla, Sarcodina (*Entamoeba*) and Mastigophora (*Giardia, Leishmania*, and *Trypanosoma*).
B. Phylum Ciliophora: This phylum includes only one genus, *Balantidium* which includes pathogenic parasites.
C. Phylum Microsporidia: Microsporidium.
D. Phylum Apicomplexa: *Plasmodium* (malaria) species

Subkingdom Metazoa (multi-cellular animals)

Phylum: Porifera [Sponges]

Phylum: Cnidaria [Jellyfish & Corals]

Phylum: Ctenophora [Comb Jellys]

Phylum: Platyhelminthes [Flatworms]

Phylum: Nemertea [Ribbonworms]

Phylum: Rotifera

Phylum: Acanthocephala [Spiny-Headed Worms]

Phylum: Mollusca [Molluscs]

Phylum: Annelida [Segmented Worms]

Phylum: Nematoda [Roundworms]

Phylum: Arthropoda [Arthropods]

Class: Arachnida (spiders, scorpions, mites, ticks)

Class: Crustacea

Class: Chilopoda (centipedes)

Class: Diplopoda (millipedes)

Class: Insecta

Order: Anoplura (sucking lice)

Order: Diptera (true flies; fruit flies, house flies, mosquitoes, crane flies)

Order: Siphonaptera (fleas)

Phylum: Echinodermata [Echinoderms]

Phylum: Hemichordata [Acornworms]

Phylum: Chordata [Chordates]

Subphylum: Urochordata invertebrates

Subphylum: Cephalochordata

Subphylum: Vertebrata

Class: Amphibia

Class: Reptilia

Class: Aves

Class: Mammalia

Order: Chiroptera (bats)

Order: Rodentia (rats, mice, squirrels, gophers, beavers)

Order: Carnivora (dogs, bears, raccoons, skunks, cats)

Order: Primates (monkeys, gorillas, baboons, humans)

Family: Hominidae

Genus: Homo

Species: *Homo sapiens* (humans)

Subspecies: *Homo sapiens neanderthalis*

Subspecies: *Homo sapiens sapiens* (modern humans)

Taxonomists have categorized these distinctions by dividing each Phylum into Classes, Classes into Orders, Orders into Families, and Families into Genera. Finally, animals are sorted into unique species, the individuals of which reproduce only with one another. **Every species is designated by a unique two-word Latin name, a genus and a species name.** Notice that the first word in the name begins with a capitalized letter, while the second word in the name is in small case, and that both the genus and species names are underlined (hand writing) or italicised (typing). **[Why do we need a universal scientific names for animals?]. We need universal, scientific names for each species because people in different parts of a country, and in different countries, use different, local names for the same species or similar names for different species.** This would result in incredible confusion if we could not keep our information on each species in the right category.

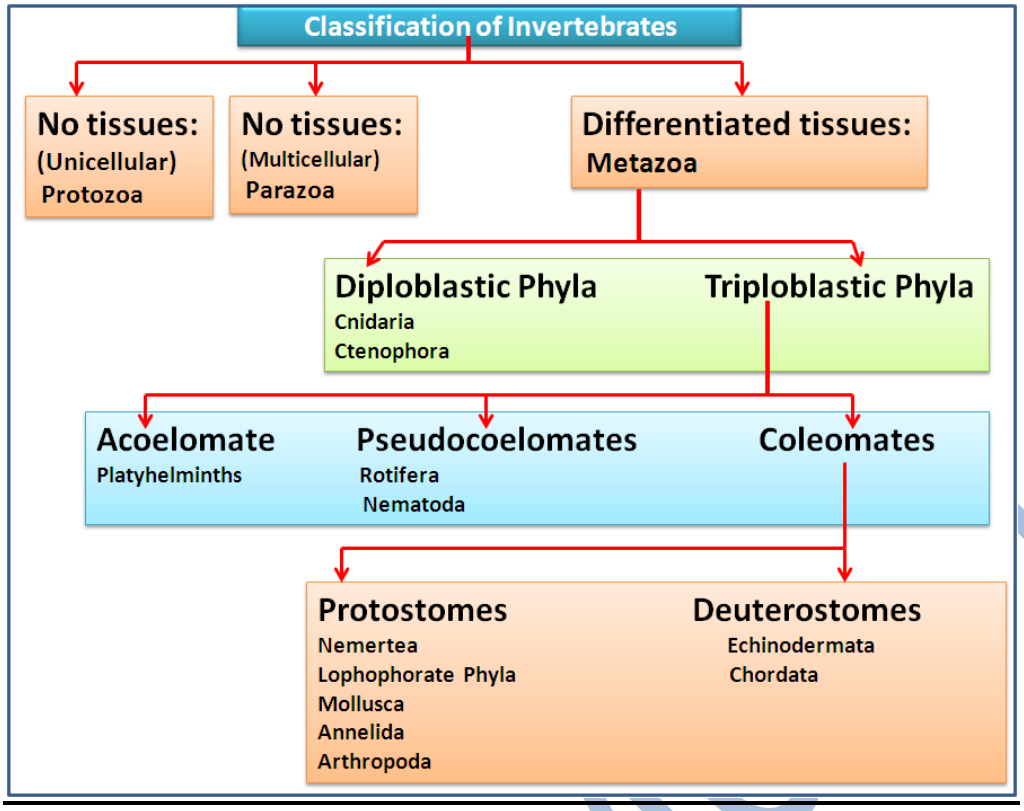


Figure 1. Classification of invertebrates.

Note: Invertebrates (**animals without a backbone**) account for 95% of known animal species. Invertebrates inhabit nearly all environments on earth. **Vertebrates** are animals with backbones.

Animal Phyla

1. The Protozoa

- Phylum Sarcomastigophora: this Phylum includes two Subphyla, Sarcodina (*Entamoeba*) and Mastigophora (*Giardia*, *Leishmania*, and *Trypanosoma*).
- Phylum Ciliophora: This phylum includes only one genus, *Balantidium* which includes pathogenic parasites.
- Phylum Microsporidia: Microsporidium.
- Phylum Apicomplexa: *Plasmodium* (malaria) species

2. The Parazoa

A. Phylum Porifera: sponges are sessile with porous bodies and choanocytes.

3. The Radiata

A. Phylum Cnidaria: cnidarians have radial symmetry, a gastrovascular cavity, and

cnidocytes
B. Phylum Ctenophora: comb jellies possess rows of ciliary plates and adhesive Colloblasts

4. The Acoelomates
A. Phylum Platyhelminthes: flatworms are dorso-ventrally flattened acoelomates.

5. The Pseudocoelomates
A. Phylum Rotifera: rotifers have jaws and a crown of cilia.
B. Phylum Nematoda: roundworms are unsegmented and cylindrical with tapered ends.

6. The Coelomates: Protostomes
A. Phylum Nemertea: The phylogenetic position of proboscis worms is uncertain.
B. The lophophorate phyla: bryozoans, phoronids, and brachiopods have ciliated tentacles around their mouths.
C. Phylum Mollusca: mollusks have a muscular foot, a visceral mass, and a mantle
D. Phylum Annelida: annelids are segmented worms.
E. Phylum Arthropoda: arthropods have regional segmentation, jointed appendages, and an exoskeleton.

7. The Coelomates: Deuterostomes
A. Phylum Echinodermata: Echinoderms have a water vascular system and secondary radial symmetry.
B. Phylum Chordata: the chordates include two invertebrate subphyla and all vertebrates.

Protozoa: The Phylum Sarcomastigophora: this Phylum includes two Subphyla, Sarcodina (*Entamoeba*) and Mastigophora (*Giardia*, *Leishmania*, and *Trypanosoma*).

Protozoa: The Phylum Ciliophora: This phylum includes only one genus, *Balantidium* which includes pathogenic parasites.

Protozoa: The Phylum Microsporidia: Microsporidium.

Protozoa: The Phylum Apicomplexa: *Plasmodium* (malaria) species

Parazoa: The Phylum Porifera (Sponges)

The Phylum Porifera includes the sponges. It is important to mention that some scientists still question whether sponges are real animals and if so, are they really individuals or colonies of individuals? Although sponges are composed of a loose collection of cells, they actually lack the true tissue-level organization that is characteristic of eumetazoans. Given that they appear to be a mass of relatively unspecialized cells, one might wonder if sponges are actually individuals or colonies of individuals. **There is evidence that supports both choices.**

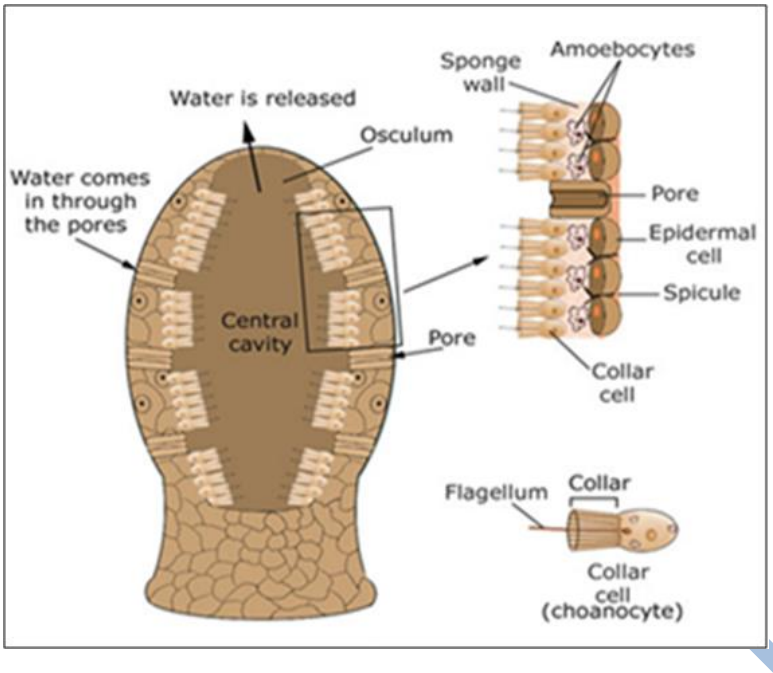


Figure 2. Sponge structure.

Sponges have an epidermis composed of tightly packed cells, underneath which lies a gelatinous matrix and a few specialized cell types that surround a central cavity called the **spongocoel**. The spongocoel is connected to the outside through an opening called the **osculum**. The spongocoel is lined with **choanocytes**, which are cells that have a central flagellum and a sticky collar that surrounds the flagellum. Water is drawn into the spongocoel through the osculum, and food particles in the water may pass the sponge's choanocytes. The flagellum of a choanocyte pulls in food particles, which get stuck in the sticky mucus of the collar and are picked up by **amoebocytes**. Amoebocytes are mobile and can transport nutrients throughout the body of the sponge.

Life cycle of sponges

A sponge has an embryonic form similar to a blastula because it is hollow. One-half of this embryonic form is flagellated, hence the embryo is free-swimming. This hollow, half-flagellated ball will eventually settle and stuck to a substrate. The flagellated half will invert, and the point where it inverts will become the **osculum**. The space created during inversion will become the **spongocoel**. It is important to mention that the **adult sponge is sessile, whereas the embryonic form is motile**.

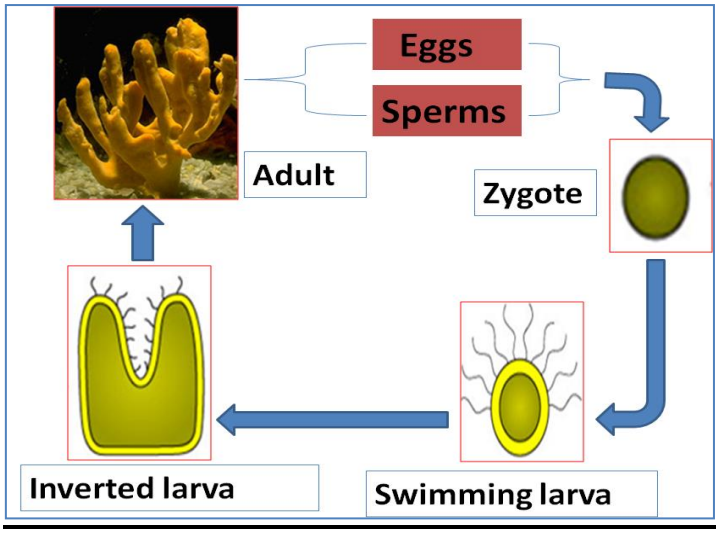


Figure 3. Life cycle of the sponges (Zygot – free-swimming larva- inverted larva- Sessile sponge).

Summary

The animals within the Phylum Porifera can be considered individuals and colonies because they have features of both. In fact, there are some biologists who argue that they really are not animals; however, they do have animal characteristics (**they are multicellular, motile, ingestive heterotrophs**), which is why they are placed in the Kingdom Animalia.

Radiata: The Phylum Cnidaria (Pron: Nee-daria)

The radiata include organisms that have a radial morphology. The radiata include two Phyla; Cnidaria and Ctenophora. Examples of **cnidarians** include jellyfish, corals, and sea anemones. Some cnidarians are bioluminescent (radiate light), and some can sting. In addition, they all obtain and digest nutrients in an organized cellular manner which means that they have true tissues and hence they are placed in the Eumetazoa. Moreover, cnidarians have an unsophisticated gastrovascular cavity.

The cnidaria have two general body plans and these are: the **polyp** and the **medusa (see Figure 4a)**. **The polyp form is sessile, attached to a substrate while the medusa form is motile**. It is important to mention that the mouth and anus are actually a single structure.

It is important to mention that the radiata have only two embryonic tissue layers (diploblastic), ectoderm and endoderm. They lack mesoderm (the tissue that gives rise to structures like muscles in triploblastic organisms). Consequently, they lack the level of sophisticated movement seen in triploblastic organisms.

Cnidarians also have **cnidocytes** (specialized cells that function in defence and the capture of prey); cnidocytes contain organelles called **cnidae**, which are able to evert. Cnidae that sting are called **nematocysts**. These nematocysts (see Figure 4b) can immobilize fish for capture, and they can also be used for defense.

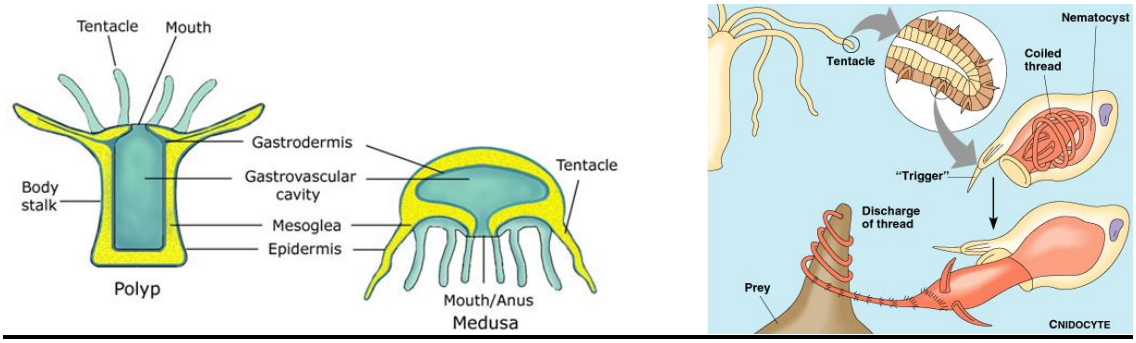


Figure 4. Body plans and nematocytes in Cnidaria.

Cnidarian Classes

There are three classes in the Phylum Cnidaria.

1. **Class Hydrozoa** which includes hydras and Obelia. Most **hydrozoans** exist in the polyp and medusa forms. For example, *Obelia* exists as an asexually reproducing polyp that alternates with a sexually reproducing medusa form.

2. **Class Scyphozoa** includes the jellyfish. **Scyphozoans** exist predominantly in the medusa form.

3. **Class Anthozoa** includes sea anemones, corals, and sea fans. **Anthozoans** exist only in the polyp form.

Members of all of the cnidarian classes can respond to external stimuli and can use stinging nematocysts for prey capture and defence.

Figure 5 shows the life cycle of *Obelia* and as you can see the medusa form is that which produces gametes. Once fertilization occurs, the animal undergoes development and a free-swimming planular larva results. The planula settles and develops into a sessile polyp that can develop asexually by budding. Mature polyps can differentiate into both feeding polyps (specialized for feeding) and reproductive polyps (specialized for reproduction). The reproductive polyp produces a medusa and the cycle continues.

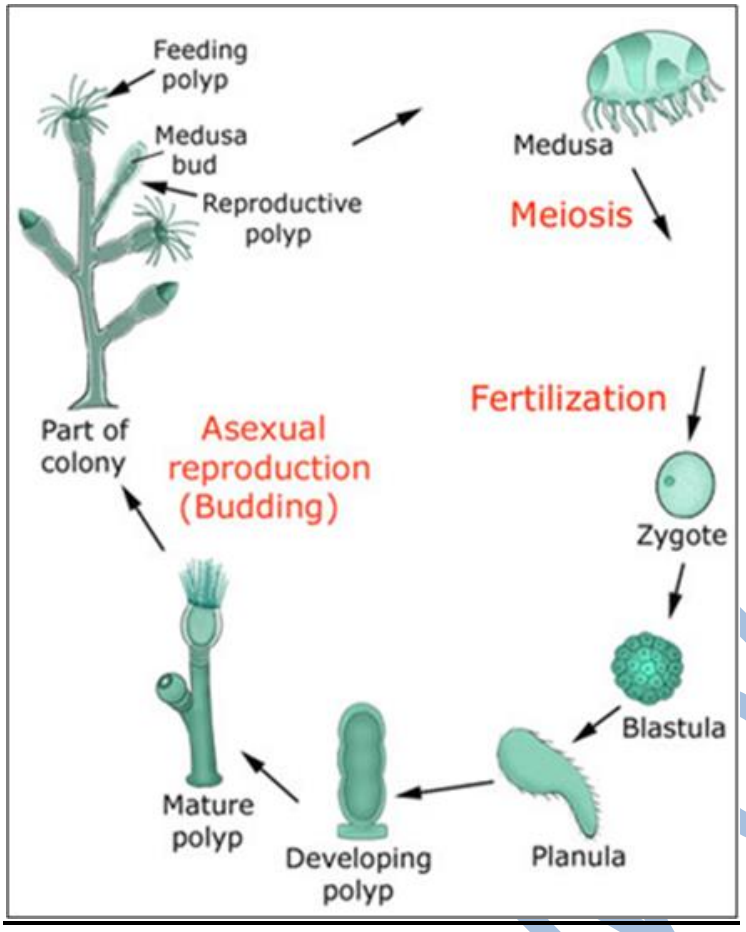


Figure 5. the life cycle of *Obelia*.

Summary

Phylum Cnidaria includes simple animals, such as the common jellyfishes. These animals do have true tissues; however, they possess only two embryonic tissues (diploblastic). The major body forms observed in this phylum are the polyp and the medusa. In many cnidarians, these forms alternate during the life cycle, **but in Class Hydrozoa the polyp is prominent, whereas in Class Scyphozoa the medusa is prominent**. Members of Class Anthozoa do not have a medusa stage (this class includes the coral reef-building animals).

Class	Polyp	Medusa
Hydrozoa	+	+
Scyphozoa	-	+
Anthozoa	+	-

Bilateria

This group of animals have true tissues and bilateral symmetry, the bilateria (have a single plane of symmetry). Beside this single plane of symmetry is the development of advanced sensory material in the **anterior** (front) part of the body. Although the eyes of **planaria** lack the resolution of our own eyes, they do detect light. They are connected to a primitive brain (Simple brains that contain a low number of neurons are sometimes referred to as **ganglia**). This trend toward a concentration of sensory and nervous material is termed **cephalization**. It is important to mention that the bilateria are triploblastic, possessing a third embryonic tissue layer (mesoderm).

Bilateria include acoelomates, pseudocoelomates, and coelomates.

1. Acoelomates: The Phylum Platyhelminthes (Flatworms)

The acoelomate animals do not have a fluid-filled internal body cavity, but instead, have a relatively solid body mass. The phylum Platyhelminthes is divided into four classes.

1. Class Turbellaria: Members of this class include carnivorous **flatworms** (e.g., planarians). Cephalization occurs in the form of eyespots and paired ganglia, as well as an actual nervous system. These features are characteristic of the level of complexity observed in the bilateria. This class consists predominantly of free-living (nonparasitic) representatives.
2. Class Monogenea: Members of this class are all parasitic. Six suckers are used to suck digested material from their hosts.
3. Class Trematoda: Members of this class are also parasitic. Some **trematodes** exhibit very complex life cycles. Examples include the various species of blood flukes in the family *Schistosoma*, and the liver flukes.
4. Class Cestoda (Cestoidea): Members of this class are also parasitic, and include the **tapeworms**. Tapeworms consist of a **scolex** (head), which has hooks for attaching to their host and suckers for extracting food. The majority of their body is actually a series of **proglottids (body segments)**, which basically are repeating units packed with sexual organs.

Phylum Platyhelminthes:

1. Flatworms are dorsoventrally flattened acoelomates.
2. The members of the phylum Platyhelminthes differ from the phylum Cnidaria in That they:
   • Exhibit bilateral symmetry with moderate cephalisation.
   • Are triploblastic (develop from three-layered embryos: ectoderm, endoderm and mesoderm).
   • Possess several distinct organs, organ systems, and true muscles.

3. Although more advanced than cnidarians, two things point to the early evolution of platyhelminths in bilateria history.
   • A gastrovascular cavity is present.
   • They have an acoelomate body plan.

4. There are more than 20,000 species of Platyhelminthes which are divided into four classes:
   • Class Turbellaria
   • Class Monogenea
   • Class Trematoda
   • Class Cestoda

1. Class Turbellaria

1. Mostly free-living, marine species; a few species are found in freshwater and moist terrestrial habitats).
2. Planarians are familiar and common freshwater forms.
3. Carnivorous, they feed on small animals.
4. Lack specialized organs for gas exchange or circulation.
5. Gas exchange is by diffusion (flattened body form places all cells close to water).
6. Fine branching gastrovascular cavity distributes food throughout the animal.
7. Flame cell excretory apparatus present which functions primarily t o maintain osmotic balance of the animal.
8. Nitrogenous waste (ammonia) diffuses directly from cells to the water.
9. Move by using cilia on the ventral dermis to glide along a film of mucus. Muscular contractions produce undulations which allow some to swim.
10. On the head are a pair of eyespots which detect light and a pair of lateral auricles that are olfactory sensors.
11. Possess a rudimentary brain which is capable of simple learning.
12. Reproduce either asexually or sexually. Asexually by regeneration: mid-body constriction separates the parent into two halves, each of which regenerates the missing portion. Sexually by cross-fertilization of these hermaphroditic forms.

2. Classes Monogenea and Trematoda

- All members of these two classes are parasitic.
- Flukes are members of the class Trematoda.
- Suckers are usually present for attaching to host internal organs.
- Primary organ system is the reproductive system; a majority are hermaphroditic.
- Life cycles include alternations of sexual and asexual stages with asexual development taking place in an intermediate host. Larvae produced by asexual development infect the final hosts where maturation and sexual reproduction occurs.
- *Schistosoma* spp. (blood flukes) infect 200 million people worldwide.
- Members of the class Monogenea are mostly external parasites of fish.
- Structures with large and small hooks are used for attaching to the host.
- All are hermaphroditic and reproduce sexually.

3. Class Cestoda (ses-toda)

- Adult tapeworms parasitize the digestive system of vertebrates.
- Possess a scolex (head) which may be armed with suckers and/or hooks that help maintain position by attaching to the intestinal lining.
- Posterior to the scolex is a long ribbon of units called proglottids.

- A proglottid is filled with reproductive organs.
- No digestive system is present.
- The life cycle of a tapeworm includes an intermediate host.
- Mature proglottids filled with eggs are released from the posterior end of the worm and pass from the body with the feces.
- Eggs are eaten by an intermediate host and a larva develops, usually in muscle tissue.
- The final host becomes infected when it eats an intermediate host containing larvae.
- Humans can become infected with some species of tapeworms by eating undercooked beef or pork containing larvae.

Platyhelminthes and Disease

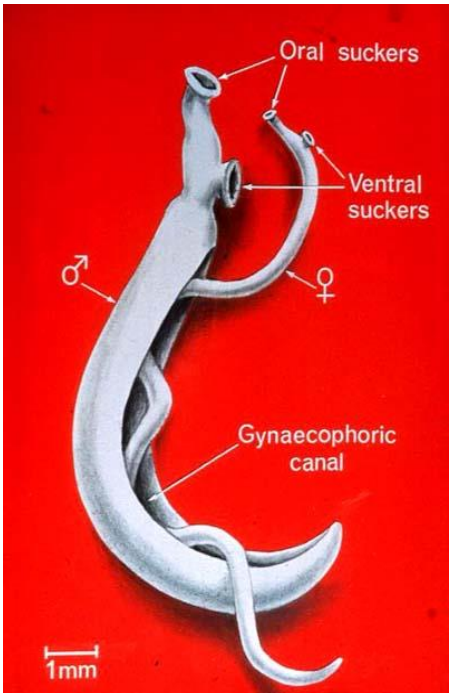
The life cycle of *Schistosoma mansoni*, from the phylum Platyhelminthes, is complicated, involving multiple symbioses. The image at the right shows a copulating pair of male and female *Schistosoma* (blood flukes). Sexual reproduction occurs inside a vertebrate host (e.g., a human).

Fertilized eggs are eliminated in the feces of the first host. The larvae that emerge parasitize a second host, a snail.

The flukes reproduce asexually within the snails, and their second-stage larvae emerge to infect yet another vertebrate host.

People who suffer from schistosomiasis exhibit various symptoms, including a distended abdomen (like that seen above). Other symptoms include pain and extreme diarrhea.

People that work in, or around, freshwater contaminated with human feces are at risk for harboring *Schistosoma* and contracting schistosomiasis.



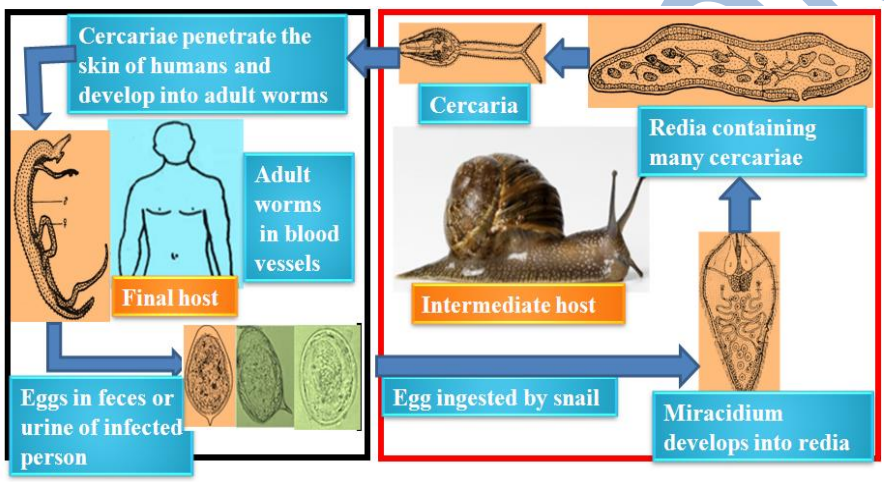


Figure 6. Adult male and female schistosomes (upper panel) and life cycle (lower panel).

Summary

Bilaterally symmetrical animals not only have a single plane of symmetry, their sensory and cephalic areas are usually displaced toward the anterior part of the animal.

The Phylum Platyhelminthes is composed of animals that are commonly called flatworms. These animals are triploblastic and show an organ level of complexity. Although many members of this phylum are free-living, some are parasitic and cause major health problems in some parts of the world.

The Pseudocoelomates

This group includes two Phyla:

A. Phylum Rotifera: rotifers have jaws and a crown of cilia

- They are small, mainly freshwater organisms, although some are marine and others are found in damp soil.
- Size ranges from 0.05-2.0 mm
- Pseudocoelomate with the pseudocoelomic fluid serving as a hydrostatic skeleton and as a medium which transports nutrients and wastes when the body moves
- *Complete digestive system* is present.
- Rotifer refers to the crown of cilia that draws a vortex of water into the mouth.
- Posterior to the mouth, a jawlike organ grinds the microscopic food organisms suspended in the water.
- Reproduction in rotifers may be by *parthenogenesis* or sexual.
- Some species consist only of females with new females developing by parthenogenesis from unfertilized eggs.
- Other species produce two types of eggs, one that develops into females, the other into degenerate males.
- Males produce sperm that fertilize eggs which develop into resistant zygotes that survive desiccation.
- When conditions improve, the zygotes break dormancy and develop into a new female generation that reproduces by parthenogenesis until unfavorable conditions return.
- Rotifers have no regeneration or repair abilities.
- Rotifers contain a certain and consistent number of cells as adults. The zygotes undergo a specific number of divisions and the adult contains a fixed number of cells.

B. Phylum Nematoda: roundworms are unsegmented and cylindrical with pointed ends

- There are about 90,000 species of roundworms, ranging in size from less than 1.0 mm to more than 1 m.
- Bodies are cylindrical with tapered ends
- Very numerous in both species and individuals
- Found in fresh water, marine, moist soil, tissues of plants, and tissues and body fluids of animals
- A complete digestive tract is present and nutrients are transported through the body in the pseudocoelomic fluid
- A tough, transparent cuticle forms the outer body covering
- Longitudinal muscles are present and provide for whip-like movements
- Dioecious with females larger than males
- Sexual reproduction only, with internal fertilization
- Female may produce 100,000 or more resistant eggs per day
- Like rotifers, nematodes have a fixed number of cells as adults
- Nematodes fill various roles in the community.
- Free-living forms are important in decomposition and nutrient cycling.
- Plant parasitic forms are important agricultural pests.
- Animal parasitic forms can be hazardous to health (*Trichinella spiralis* in humans via undercooked infected pork) (see Figure 33.13b).
- One species, *Caenorhabitis elegans*, is cultured extensively and is a model

species for the study of development.

The Coelomates: Protostomes

The protostome lineage of coelomate animals gave rise to many phyla. In many, the coelom functions as a hydrostatic skeleton (e.g., molluscs, annelids).

A. Phylum Nemertea (ribbon or proboscis worms): the phylogenetic position of these worms is uncertain.

- There are about 900 species; most are marine with a few in fresh water and damp soil.
- The Phylum Nemertea contains the proboscis worms (see Figure 7)
- Sizes range from 1 mm to more than 30 m.
- Some active swimmers, others burrow in sand.
- Possess a long, retractable hollow tube (proboscis) which is used to probe the environment, capture prey, and as defense against predators.
- Excretory, sensory, and nervous systems are similar to planarians.
- Structurally acoelomate, like flatworms.
- There are some important differences between the Nemertea and Platyhelminthes: Nemertea possess a closed circulatory system, which consists of vessels through which blood flows. Some species have red blood cells containing a form of hemoglobin which transports oxygen. No heart is present, but body muscle contractions move the blood through vessels.
- Nemertea possess a complete digestive system with a mouth and an anus.
- Although the body is structurally acoelomate, the fluid-filled proboscis sac is considered a true coelom by some researchers.
- A simple blood vascular system and a complete digestive system are characteristics shared with more advanced phyla.

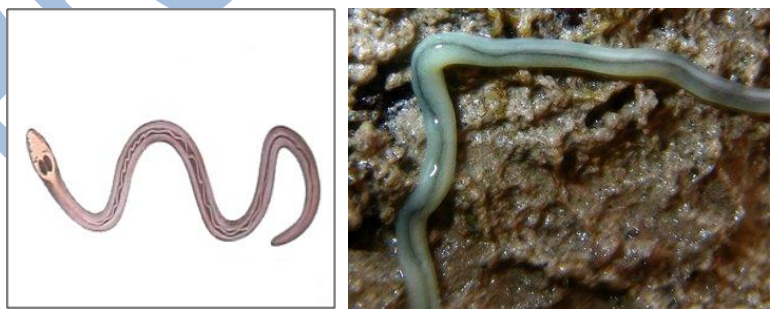


Figure 7. proboscis worms.

B. The lophophorate phyla: bryozoans, phoronids, and brachiopods have lopophores (lophophore is a fan of ciliated tentacles around the mouth).

The lophophorate animals contain three phyla: Phoronida, Bryozoa and Brachiopoda.

- These three phyla are grouped together due to presence of a lophophore.
- *Lophophore* = Horseshoe-shaped or circular fold of the body wall bearing ciliated tentacles that surround the mouth at the anterior end of the animal and used for feeding and may play role in respiration.
- Cilia direct water toward the mouth between the tentacles which trap food particles for these suspension-feeders.
- The presence of a lophophore in all three groups suggests a relationship among these phyla.
- The three phyla also possess a U-shaped digestive tract (the anus lies outside of the tentacles) and have no distinct head—both adaptations for a sessile existence.
- Lophophorates are difficult to assign as protostomes or deuterostomes.
- Their embryonic development more closely resembles deuterostomes; however, in the Phoronida, the blastopore develops into the adult mouth.
- Molecular systematics places the lophophorate phyla closer to the protostomes than the deuterostomes.

1. Phylum Bryozoa (moss animals):

- This phylum contains the moss animals. There are about 5000 species which are mostly marine and are widespread.
- Bryozoans are small, colonial forms.
- In most, the colony is enclosed within a hard exoskeleton and the lophophores are extended through pores when feeding.

2. Phylum Phoronida (phoronoid worms):

- This phylum contains about 15 species of tube-dwelling marine worms.
- Length from 1 mm to 50 cm
- Phoronids live buried in sand in chitinous tubes with the lophophore extended from the tube when feeding.

3. Phylum Brachiopoda (lamp shells):

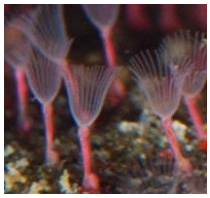
- The phylum Brachiopoda contains the lamp shells. There are approximately 330 extant species, all marine.
- The body of a brachiopod is enclosed by dorsal and ventral shell halves.
- Attach to the substratum by a stalk
- Open the shell slightly to allow water to flow through the lophophore

<u>Economic Importance</u>

1. Fossil bryozoa used extensively by petroleum companies as indicator fossils to find oil deposits.

2. Over 17 antitumor chemicals have been extracted from various species.

3. Since they grow on hard surfaces sometimes cause fouling of ship hulls and pilings.


C. Phylum Mollusca: molluscs have a muscular foot, visceral mass, and a mantle.

- There are more than 50,000 species of snails, slugs, oysters, clams, octopuses, and squids.
- Molluscs are mainly marine, though some inhabit fresh water and many snails and slugs are terrestrial.
- Molluscs are soft-bodied, but most are protected by a hard calcium carbonate shell.
- Squids and octopuses have reduced, internalized shells or no shell.
- The molluscan body consists of three primary parts: muscular *foot* for locomotion, a *visceral mass* containing most of the internal organs, and a *mantle*, which is a heavy fold of tissue that surrounds the visceral mass and secretes the shell.
- A *radula* is present in many and functions as a rasping tongue to scrap food from surfaces.
- Some species are monoecious while most are dioecious.
- Gonads are located in the visceral mass.
- Some zoologists believe the mollusks evolved from annelid-like ancestors (although true segmentation is absent in mollusca) because the life cycle of many molluscs includes a ciliated larva, called a *trochophore*, which also is characteristic of annelids, while others believe that mollusks arose earlier in the protostome lineage before segmentation evolved.

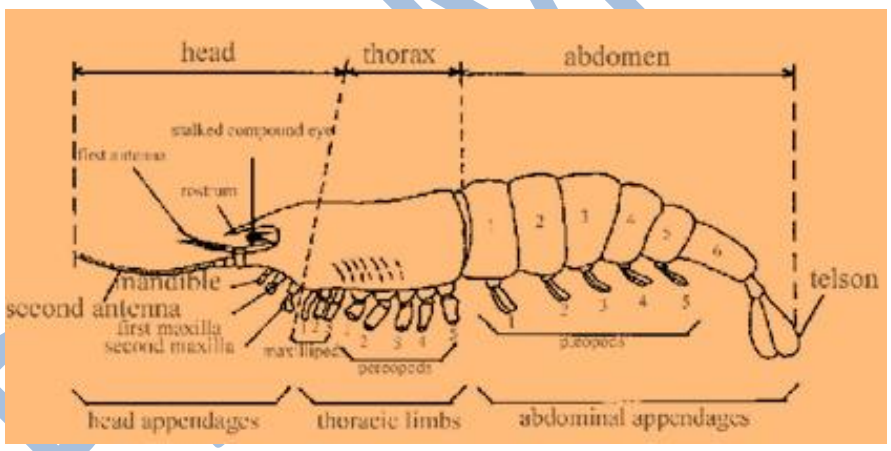


Figure 8. A generalised diagram of a crustacean, showing the basic body plan.

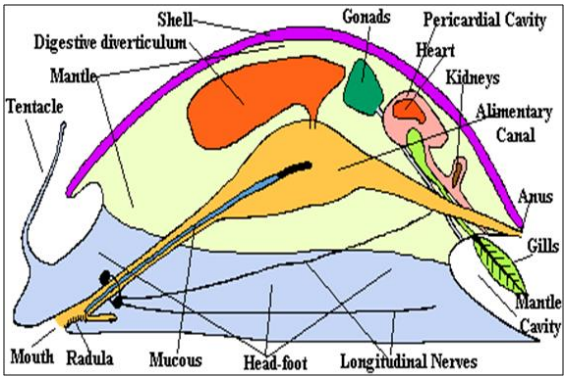


Figure 9. Structure of the snail.

1. Class Polyplacophora (poly-pla-kof'o-ra)

- The class Polyplacophora contains the marine species known as chitons.
- They have an oval shape with the shell divided into eight dorsal plates.
- Cling to rocks using the foot as a suction cup to grip the rock. This muscular foot also allows it to creep slowly over the rock surface.
- A radula is used to cut and ingest ("graze") algae.

2. Class Gastropoda (gas-trop' o-da)

- The class Gastropoda contains the snails and slugs.
- Largest molluscan class with more than 40,000 species
- Mostly marine, but many species are freshwater or terrestrial
- *Torsion* during embryonic development is a distinctive characteristic:
- Body protected by a shell (absent in slugs and nudibranchs) which may be conical or flattened.
- Many species have distinct heads with eyes at the tips of tentacles.
- Movement results from a rippling motion along the elongated foot.
- Most gastropods are herbivorous, using the radula to graze on plant material; several groups are predatory and possess modified radulae.
- Most aquatic gastropods exchange gases via gills; terrestrial forms have lost the gills and utilize a vascularized lining of the mantle cavity for gas exchange.

3. Class Bivalvia (bi-val'vi-a)

- The class Bivalvia contains the clams, oysters, mussels and scallops.
- The shell halves are hinged at the mid-dorsal line and are drawn together by two adductor muscles to protect the animal.
- The mantle cavity (between shells) contains gills which function in gas exchange and feeding.
- Most are suspension-feeders and they trap small food particles in the mucus coating of the gills and then use cilia to move the particles to the mouth.
- Water enters the mantle cavity through an incurrent siphon, passes over the gills, and then exits through an excurrent siphon.
- No radula or distinct head is present.
- Bivalves lead sedentary lives. They use the foot as an anchor in sand or mud. Sessile mussels secrete threads that anchor them to rocks or other hard surfaces.

- Scallops can propel themselves along the sea floor by flapping their shells.

4. Class Cephalopoda (sef'a-lop'o-da)

- This class contains the squids and octopuses.
- Cephalopods are carnivores
- Use beak-like jaws to crush prey
- The mouth is at the center of several long tentacles
- A mantle covers the visceral mass, but the shell is either reduced and internal (squids) or totally absent (octopuses).
- Squids swim backwards in open water by drawing water into the mantle cavity, and then firing a jetstream of water through the excurrent siphon which points anteriorly.
- Directional changes can be made by pointing the siphon in different directions.
- Most squid are less than 75 cm long but the giant squid may reach 17 m and weigh 2 tons.
- Octopuses usually don't swim in open water, but move along the sea floor in search of food.
- Cephalopods are the only mollusks with a *closed circulatory system* in which the blood is always contained in vessels.
- Cephalopods have well developed nervous systems with complex brains capable of learning. They also have well developed sense organs.
- The cephalopod ancestors were probably shelled, carnivorous forms - the *ammonites*.
- These cephalopods were the dominant invertebrate predators in the oceans until they became extinct at the end of the Cretaceous.

D. Phylum Annelida: annelids are segmented worms

The presence of a true coelom and segmentation are two important evolutionary advances present in the annelids. There are more than 15,000 species of annelids.

The most important characteristic features are:

- The coelom serves as a hydrostatic skeleton, permits development of complex organ systems, protects internal structures, and permits the internal organs to function separately from the body wall muscles.
- Segmentation also provided for the specialization of different body regions.
- They have segmented bodies and range in size from less than 1 mm to 3 m.
- There are marine, freshwater, and terrestrial (in damp soil) annelids.
- Annelids have a coelom partitioned by septa. The digestive tract, longitudinal blood vessels, and nerve cords penetrate the septa and extend the length of the animal (see Campbell, Figure 33.23.)
- The complete digestive system is divided into several parts, each specialized for a specific function in digestion: pharynx esophagus crop gizzard intestine
- Annelids have a closed circulatory system. Hemoglobin is present in blood cells. Dorsal and ventral longitudinal vessels are connected by segmental pairs of vessels. Five pairs of hearts circle the esophagus. Numerous tiny vessels in the

skin permit gas exchange is across the body surface.

- An excretory system of paired *metanephridia* is found in each segment; each metanephridium has a nephrostome (which removes wastes from the coelomic fluid and blood) and exits the body through an exterior pore.
- The annelid nervous system is composed of a pair of cerebral ganglia lying above and anterior to the pharynx. A nerve ring around the pharynx connects these ganglia to a subpharyngeal ganglion, from which a pair of fused nerve cords run posteriorly. Along the ventral nerve cords are fused segmental ganglia.
- Annelids are hermaphroditic but cross-fertilize during sexual reproduction. Two earthworms exchange sperm and store it temporarily. A special organ, the clitellum, secretes a mucous cocoon which slides along the worm, picking up its eggs and then the stored sperm. The cocoon slips off the worm into the soil and protects the embryos while they develop. Asexual reproduction occurs in some species by fragmentation followed by regeneration.
- Movement involves coordinating longitudinal and circular muscles in each segment with the fluid-filled coelom functioning as a hydrostatic skeleton. Circular muscle contraction makes each segment thinner and longer; longitudinal muscle contraction makes the segment shorter and thicker. Waves of alternating contractions pass down the body.
- Most aquatic annelids are bottom-dwellers that burrow, although some swim in pursuit of food.

1. Class Oligochaeta

- This class contains earthworms and a variety of aquatic species.
- Earthworms ingest soil, extract nutrients in the digestive system and deposit undigested material (mixed with mucus from the digestive tract) as casts through the anus.
- Important to farmers as they till the soil and castings improve soil texture.
- Darwin estimated that one acre of British farmland had about 50,000 earthworms that produced 18 tons of castings per year.

2. Class Polychaeta

- This class contains mostly marine species.
- A few drift and swim in the plankton, some crawl along the sea floor, and many live in tubes they construct by mixing sand and shell bits with mucus.
- Tube-dwellers include the fanworms that feed by trapping suspended food particles in their feathery filters which are extended from the tubes.
- Each segment has a pair of parapodia which are highly vascularized paddle-like structures that function in gas exchange and locomotion.
- Traction for locomotion is proved by several chitinous setae present on each parapodium.

3. Class Hirudinea

- This class contains the leeches.
- A majority of species are freshwater but some are terrestrial in moist vegetation.
- Many are carnivorous and feed on small invertebrates, while some attach temporarily to animals to feed on blood.
- Size ranges from 1 – 30 cm in length.

- Some blood-feeding forms have a pair of blade-like jaws that slit the host's skin while others secrete enzymes that digest a hole in the skin.
- An anesthetic is secreted by the leech to prevent detection of the incision by the host.
- Leeches also secrete hirudin which prevents blood coagulation during feeding.
- Leeches may ingest up to ten times their weight in blood at a single meal and may not feed again for several months.
- Leeches are currently used to treat bruised tissues and for stimulating circulation of blood to fingers and toes reattached after being severed in accidents.

E. Phylum Arthropoda

- Arthropods have regional segmentation, jointed appendages, and exoskeletons
- This phylum is the largest phylum of animals with approximately one million described species.
- Arthropods are the most successful phylum based on species diversity, distribution, and numbers of individuals.

1. General characteristics of arthropods

- The success and great diversity of arthropods is related to their segmentation, jointed appendages, and hard exoskeleton.
- The segmentation in this group is much more advanced than that found in annelids.
- In the arthropods, different segments of the body and their associated appendages have become specialized to perform specialized functions.
- Jointed appendages are modified for walking, feeding, sensory reception, copulation and defense.
- The arthropod body is completely covered by the *cuticle*, an *exoskeleton* (external skeleton) constructed of layers of protein and chitin.
- The cuticle is thin and flexible in some locations (joints) and thick and hard in others.
- The exoskeleton provides protection and points of attachment for muscles that move the appendages.
- The exoskeleton is also relatively impermeable to water.
- The old exoskeleton must be shed for an arthropod to grow (molting) and a new one secreted.
- Arthropods show extensive cephalization with many sensory structures clustered at the anterior end. Well-developed sense organs including eyes, olfactory receptors, and tactile receptors are present.
- An *open circulatory system* containing hemolymph is present. Hemolymph leaves the heart through short arteries and passes into the sinuses (open spaces) which surround the tissues and organs. The hemolymph reenters the heart through pores equipped with valves. The blood sinuses comprise the hemocoel. Although the hemocoel is the main body cavity, it is not part of the coelom.

- The true coelom is reduced in adult arthropods.
- Gas exchange structures are varied and include: Feathery gills in aquatic species, tracheal systems in insects, and book lungs in other terrestrial forms (e.g., spiders)

2. Arthropod phylogeny and classification

- Arthropods are segmented protostomes which probably evolved from annelids or a segmented protostome common ancestor.
- Early arthropods may have resembled onychophorans which have unjointed appendages. However, many fossils of jointed-legged animals resembling segmented worms support the evolutionary link between the Annelida and Arthropoda. Such comparisons also indicate that annelids and arthropods are *not* closely related.
- Parapodia may have been forerunners of appendages.
- Some systematists suggest that comparisons of ribosomal RNA indicate that onychophorans are arthropods and not transitional forms.
- This evidence presents an alternative hypothesis that segmentation evolved independently in annelids and arthropods. Thus, the most recent common ancestor of these two phyla would have been an unsegmented protostome.
- Although the origin of arthropods is unclear, most zoologists agree that four main evolutionary lines can be identified in the arthropods. Their divergence is represented by the subgroups: Trilobites (all extinct), Chelicerates, Uniramians, and Crustaceans.

Class Insects [*Entomology*: The study of insects**]**

- The class Insecta has greater species diversity than all other forms of life combined.
- There are about 26 orders of insects.
- They inhabit terrestrial and freshwater environments, but only a few marine forms exist.
- The oldest insect fossils are from the Devonian period (about 400 million years ago), and an increase in insect diversity can be attributed to:
- The evolution of flight during the Carboniferous and Permian
- The evolution of specialized mouth parts for feeding on gymnosperms and other Carboniferous plants. The fossil record holds examples of a diverse array of specialized mouth parts. A second major radiation of insects, which occurred during the Cretaceous period, was once thought to have paralleled radiation of flowering plants.
- Current research indicates the major diversification of insects preceded angiosperm radiation during the Cretaceous period (65 million years ago). If this is true, insect diversity played a major role in angiosperm radiation, the reverse of the original hypothesis.
- Flight is the key to the success of insects, enabling them to escape predators, find food and mates, and disperse more easily than nonflying forms.
- One or two pairs of wings emerge from the dorsal side of the thorax in most species (see Figure 33.32).
- Wings are extensions of the cuticle and not modified appendages.
- Wings may have first evolved to help absorb heat, then developed further for flight.
- Other views suggest wings may have initially served for gliding, as gills in aquatic forms, or even as structures for swimming.

- Dragonflies were among the first to fly and have two coordinated pairs of wings. Modifications are found in groups which evolved later.
- Bees and wasps hook their wings together (act as one pair).
- Butterflies have overlapping anterior and posterior wings.
- Beetles have anterior wings modified to cover and protect the posterior (flying) wings.
- Insects have complete digestive system with specialized regions, open circulatory system with hemolymph, and excretory organs are the *Malpighian tubules*, which are outpocketings of the gut
- Gas exchange is by a tracheal system, which opens to the outside via spiracles that can open or close to regulate air and limit water loss
- Nervous system is composed of a pair of ventral nerve cords (with several segmental ganglia) which meet in the head where the anterior ganglia are fused into a dorsal brain close to the sense organs. Insects show complex behavior which is apparently inherited (e.g., social behavior of bees and ants).
- Many insects undergo metamorphosis during their development.
- *Incomplete metamorphosis* = A type of development during which young resemble adults but are smaller and have different body proportions
- For example, in grasshoppers a series of molts occur with each stage looking more like an adult until full size is reached.
- *Complete metamorphosis:* A type of development characterized by larval stages (e.g., maggot, caterpillar) which are very different in appearance from adults.
- Larva eats and grows before becoming adults.
- Adults find mates and reproduce with the females laying eggs on the appropriate food source for the larval stages.
- Insects are dioecious and usually reproduce sexually with internal fertilization.
  - -In most, sperm are deposited directly into the female's vagina during copulation. Some males produce spermatophores which are picked up by the female.
  - -Inside the female, sperm are stored in the spermatheca.
  - -Most insects produce eggs although some flies are viviparous.
  - -Many insects mate only once in a lifetime with stored sperm capable of fertilizing many batches of eggs.

- Insects impact terrestrial organisms in a number of ways by:
  - -Competing for food
  - -Serving as disease vectors
  - -Pollinating many crops and orchards

Class Crustacea

- There are more than 40,000 species of crustaceans in marine and fresh waters.
- The crustaceans have extensive specialization of their appendages.
- Two pairs of antennae, three or more pairs of mouthparts including mandibles, walking legs on the thorax, appendages are present on the abdomen.
- Lost appendages can be regenerated.

Characteristics of their physiology:

- An open circulatory system is present with hemolymph.

- Nitrogenous wastes are excreted by diffusion across thin areas of the cuticle.
- Most are dioecious and some males (e.g., lobsters) have a specialized pair of appendages to transfer sperm to the female's reproductive pore during copulation.
- Most aquatic crustaceans have at least one swimming larval stage.
- The decapods are relatively large crustaceans that have a carapace (calcium carbonate hardened exoskeleton over the cephalothorax).

Examples:

1. Freshwater crayfish
2. Marine lobsters, crabs and shrimp
3. Tropical land crabs

- The isopods are mostly small marine crustaceans but include terrestrial sow bugs and pill bugs.
- Terrestrial forms live in moist soil and damp areas.
- Copepods are numerous small marine and freshwater planktonic crustaceans.
- The larvae of larger crustaceans may also be planktonic.

The most common body plan is a **tripartite** arrangement, consisting of a **head, thorax,** and **abdomen**. Unlike the insects, where the head and thorax are separated by a flexible joint, in the Crustacea they are almost always rigidly fused together. Sometimes the head and thorax are covered by a carapace, producing a single functional unit known as a **cephalothorax**. Some species have a prominent anterior projection from this cephalothorax called the **rostrum**.

The crustaceans are characterized by these features:

- Body composed of a 5-segmented head and a more or less distinct thorax and abdomen.
- Abdomen composed of 6 segments.
- Cephalic shield or carapace usually present.
- Appendages are multiarticulate and biramous (or secondarily uniramous in the case of limbs).
- Mandibles are multiarticulate limbs that function as basic jaws.
- Gas exchange is typically by aqueous diffusion across gill surface.
- Simple ocelli and compound eyes present in most taxa at some point during their life cycle.
- Compound eyes commonly raised on stalks.
- Produce a nauplius larva.

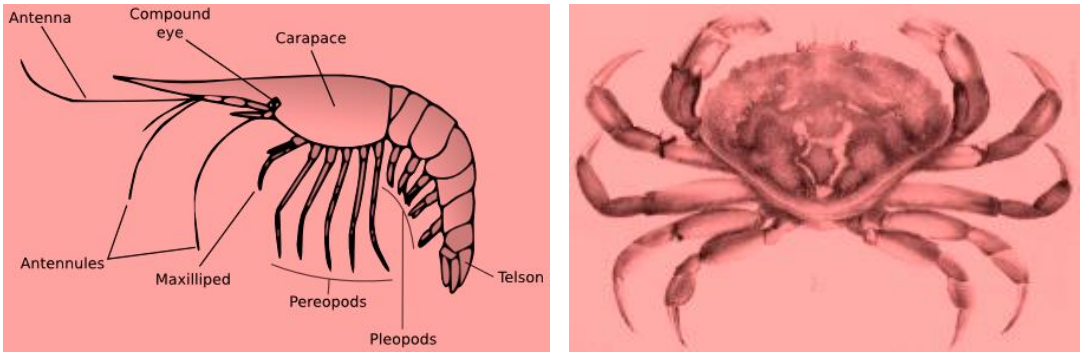


Figure 9. Basic anatomy of a decapod crustacean. In some groups such as brachyurans, the pleon is folded beneath the carapace.

The Coelomates: Deuterostomes

The deuterostomes, while a very diverse group, share characteristics which indicate their association: radial cleavage, enterocoelous coelom formation, and the blastopore forms the anus.

Phylum Echinodermata

Members of Phylum Echnodermata are exclusively marine. The name derived from the Greek word for "spiny skin". **The most striking characteristic of this phylum is their radial symmetry (the body can usually be divided into five parts arranged around a central axis,** but its larva is divided into two equal parts**), many having five or multiples of five arms.** The Phylum contains about 7,000 known species found usually on the sea floor in every marine habitat and they have calcareous exoskeletons. Although these animals have separate sexual organs, no copulation takes place. **The gonads discharge their gametes to outside and fertilization takes place in the sea water**.

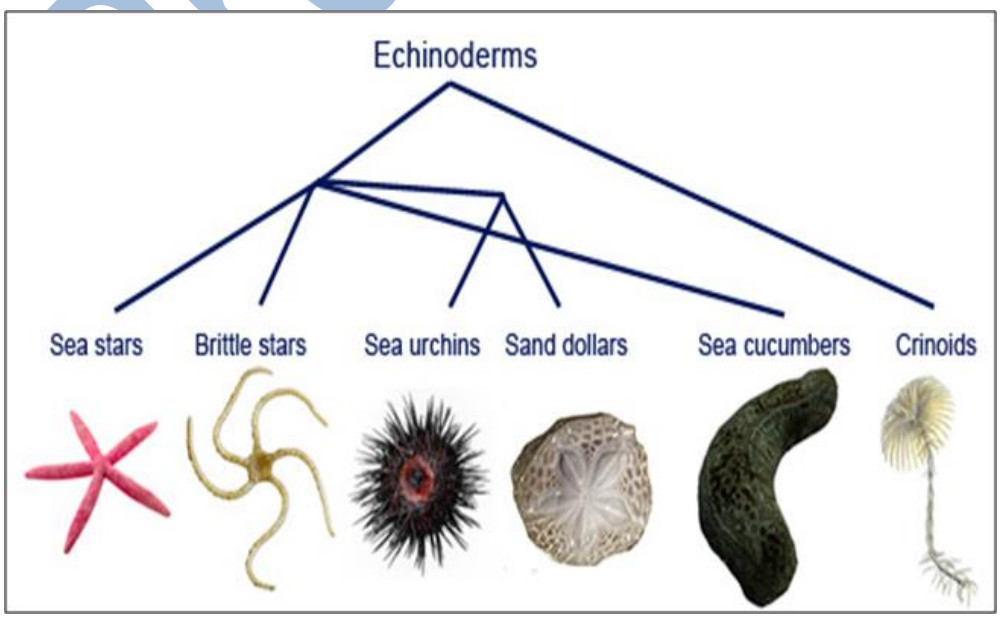


Figure 10. Examples of echinoderms.

Figure 11. Sea star with tube feet.

The Phylum Echinodermata includes more than 6000 marine species such as Sea Stars, Brittle Stars, Serpent Stars, Basket Stars, Sand Dollars, Sea Biscuits, Sea Urchins, Sea Lilies, Sea Cucumbers, and Sea Apples.

The various Echinoderms share many features such as the symmetry where they all have a round or nearly round body with body parts radiating from its center in an orderly fashion and this is called radial symmetry.

Ehinoderms also share a unique body system called the water-vascular system, which no other group of animals possess. This is a complex system of muscles, canals, pouches, bladders, tubes, and suckers that allow Echinoderms to move around and to eat. It is not easy to see it, but if you have a close look at any Sea Star, you will see that they have many suction cup-tipped "tube feet" that emerge from the grooves on their undersides. Through coordinated movement of these tube feet, the Sea Star can move quickly and also grab hold the prey for feeding. Similarly, other Echinoderms use their tube-feet, or similar extensions of the water-vascular system to capture planktonic foods, or to burrow through substrates.

Although it is not a unique character, all Echinoderms share the ability to regenerate damaged or lost body parts within a few weeks. Moreover, all Echinoderms have a skeleton of some sort which is composed of mineral calcite and is covered by an epidermis (outer skin).

Although the different species show so many similarities, still many differences can be recognised and accordingly this Phylum has been divided into five classes.

- Class Asteroidea (as'ter-oy'de-a)
- Class Ophiuroidea (ofi-uroy'de-a)
- **Class Crinoidea** (cry-noy'de-a)
- Class **Echinoidea (eki'i-noy'de-a)**
- Holothuroidea (hol' o-thu-roy' de-a)

We are going to focus on the first class only.

Class Asteroidea (as'ter-oy'de-a)

This class contains all of the true Sea Stars which are easily recognized as having a relatively thick body that spreads out into arms. All of them are also mobile, and almost all of them have 5 arms, although, some Asteroids may have as many as 40 arms.

They move about by using the tube feet on the undersides of their arms, but they don't really use the arms themselves for crawling as they cannot bend the arms (stay straight out) even when they are moving.

Like other echinoderms, the asteroids can find food by chemical detection. They "smell" things nearby, and can even find prey that is buried well below the surface. Some are active predators that will attack and eat clams, snails, sponges, corals, anemones, and just about anything else they can get a hold on with their tube feet.

Digestive System

Echinoderms have a simple digestive system with a mouth, stomach, intestine and anus. In many, the mouth is on the underside and the anus on the top surface of the animal. **Sea stars can push their stomachs outside of their body and insert it into its prey allowing them to digest the food externally.** This ability allows sea stars to hunt prey that are much larger than its mouth would otherwise allow.

Nervous System and Senses

Echinoderms do not have brains; they have nerves running from the mouth into each arm or along the body. They have tiny eyespots at the end of each arm which only detect light or dark. Some of their tube feet are also sensitive to chemicals and this allows them to find the source of smells, such as food.

Circulatory System

Echinoderms have a network of fluid-filled canals that function in gas exchange, feeding and in movement. The network contains a central ring and areas which contain the tube feet which stretch along the body or arms. They do not have a true heart and the blood often lacks any respiratory pigment (pike haemoglobin).

Respiratory System

Echinoderms have a poorly developed respiratory system. They use simple gills and their tube feet to take in oxygen and pass out carbon dioxide

Reproductive System

Echinoderms are either male or female and become sexually mature after about two to three years. Most release their eggs and sperm into the water where they are fertilized. A female can release one hundred million eggs at once. Larvae develop which eventually

settle on the sea floor in their adult form.

If an arm breaks off some echinoderms, a new arm or even a new echinoderm can regrow. Some sea stars and brittle stars have the ability to reproduce asexually by dividing in two halves while they are small juveniles.

Excretory System

Echinoderms have a simple excretory system with no kidneys and use diffusion to rid their bodies of nitrogenous waste which is mainly ammonia gas.

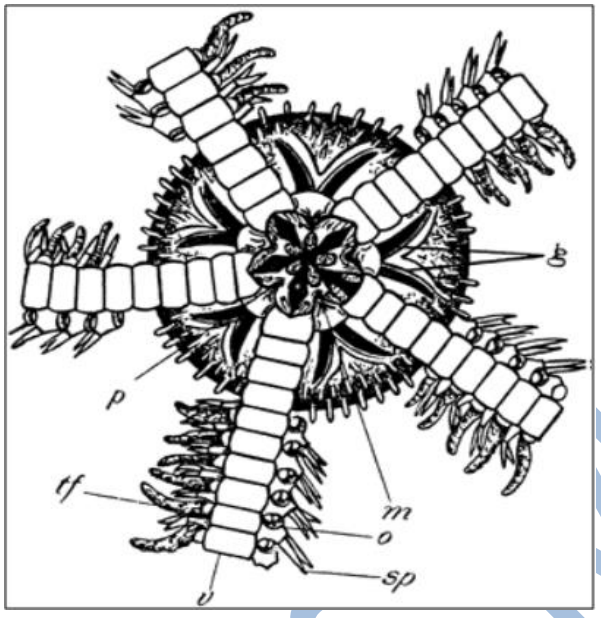


Figure 12. Excretory system of sea star.

In summary, echinoderms are deuterostomes, thus sharing with Hemichordata and Chordata several embryological features that set them apart from the rest of the animal kingdom:

- Anus developing from or near the blastopore
- Mouth developing from a structure that is not the blastopore
- Enterocoelous coelom
- Radial and regulative cleavage
- Mesoderm derived from enterocoelous pouches

Accordingly, all three phyla (Echinodermata, Hemichordata and Chordata) are presumably derived from a common ancestor.

B. Phylum Chordata: The chordates include two invertebrate subphyla and all vertebrates.

The phylum to which we belong consists of two subphyla of invertebrate animals plus the hagfishes and vertebrates.

The Chordata diverged from a common deuterostome ancestor with echinoderms at least 500 million years ago.

• The two phyla are grouped together due to similarities in early embryonic development.
• This phylum contains three subphyla: Urochordata, Cephalochordata, and Vertebrata.
