Invertebrates

Chapter 33

- Objectives
  - Describe how a sponge feeds and digests its food
  - List the characteristics of the phylum Cnidaria that distinguish it from other animal phyla
  - List the four classes of Cnidaria and distinguish among them based on life cycle morphology
  - List the characteristics of Platyhelminthes and distinguish among the four classes
  - Describe a lophophore and name two lophophorate phyla
  - Describe the features of molluscs and distinguish among the four classes

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- Describe the features of annelids and distinguish among the three classes
- List the characteristics of nematodes that distinguish them from other wormlike animals
- List three features that account for the success of arthropods
- Define and distinguish among the four major arthropod lineages
- Describe the developmental similarities between echinoderms and chordates
- Distinguish among the six classes of echinoderms

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Introduction

- Approximately 1 million animal species are recognized, grouped into about 35 phyla
  - Invertebrates are animals that lack a backbone and account for 95% of known animal species

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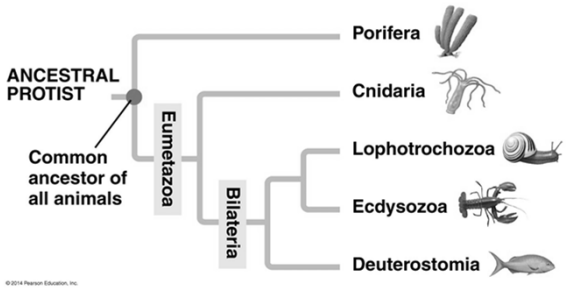

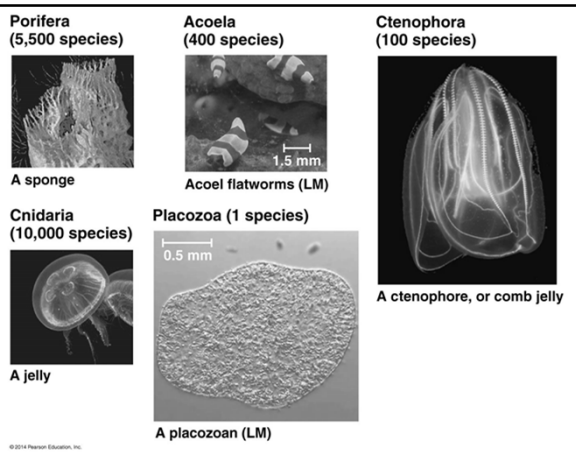

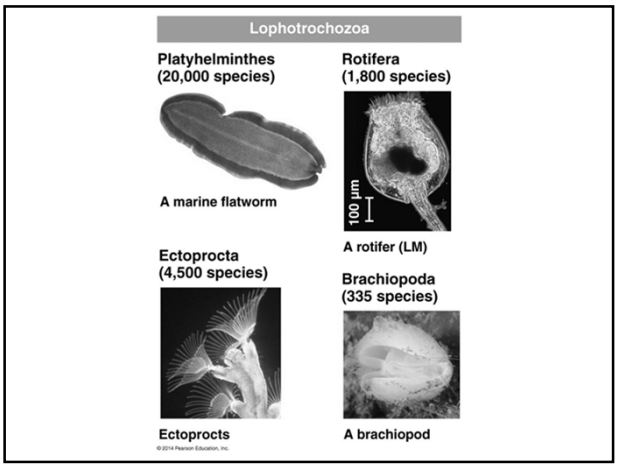
Lophotrochozoa
Platyhelminthes
(20,000 species)
A marine flatworm
Rotifera
(1,800 species)
100 µm
A rotifer (LM)
Ectoprocta
(4,500 species)
Ectoprocts
Brachiopoda
(335 species)
A brachiopod
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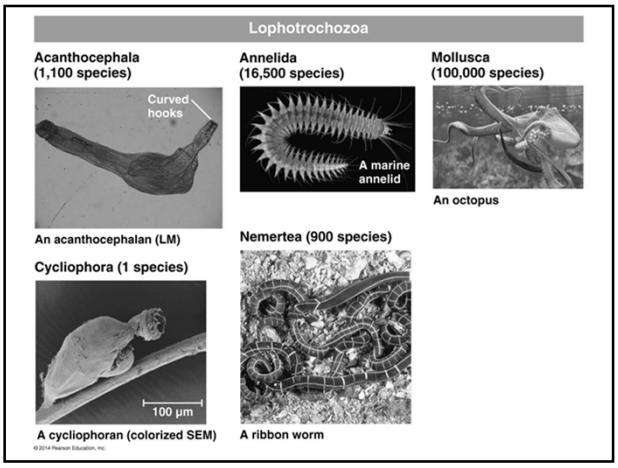
Lophotrochozoa
Acanthocephala
(1,100 species)
Curved hooks
An acanthocephalan (LM)
Annelida
(16,500 species)
A marine annelid
Mollusca
(100,000 species)
An octopus
Nemertea (900 species)
A ribbon worm
Cycliophora (1 species)
100 µm
A cycliophoran (colorized SEM)
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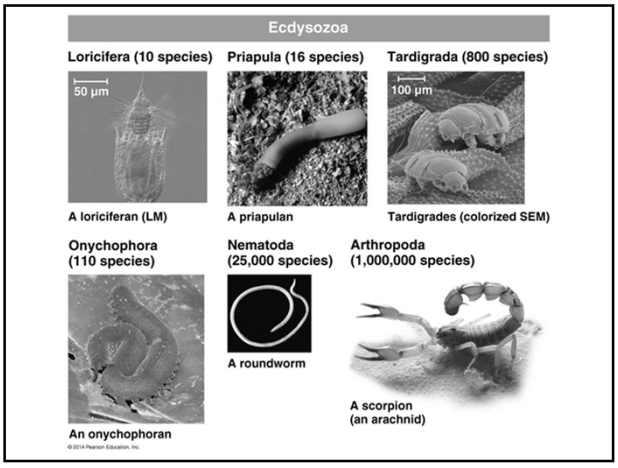
Ecdysozoa
Loricifera (10 species)
50 µm
A loriciferan (LM)
Priapula (16 species)
A priapulan
Tardigrada (800 species)
100 µm
Tardigrades (colorized SEM)
Onychophora
(110 species)
An onychophoran
Nematoda
(25,000 species)
A roundworm
Arthropoda
(1,000,000 species)
A scorpion
(an arachnid)
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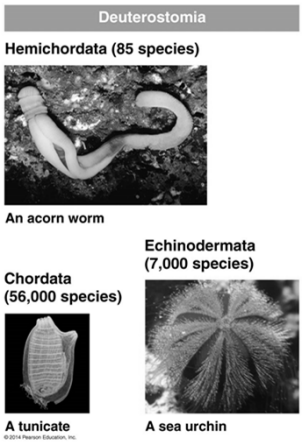

Sponges

- Sponges are sedentary animals from the phyla Calcarea and Silicea
- They live in both fresh and marine waters
- Sponges lack true tissues and organs

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- Sponges are suspension feeders, capturing food particles suspended in the water that pass through their body
- Choanocytes, flagellated collar cells, generate a water current through the sponge and ingest suspended food
- Water is drawn through pores into a cavity called the spongocoel, and out through an opening called the osculum

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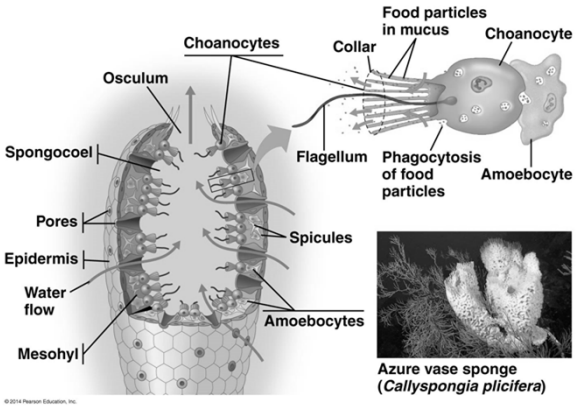

- Sponges consist of a noncellular mesohyl layer between two cell layers
- Amoebocytes are found in the mesohyl and play roles in digestion and structure
- Most sponges are hermaphrodites meaning that each individual functions as both male and female

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Eumetazoa

- All animals except sponges belong to the clade Eumetazoa, the animals with true tissues

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Cnidarians

- Phylum Cnidaria is one of the oldest groups in the Eumetazoan clade
- Cnidarians have diversified into a wide range of both sessile and floating forms including jellies, corals, and hydras but still exhibit a relatively simple diploblastic, radial body plan

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- The basic body plan of a cnidarian is a sac with a central digestive compartment, the gastrovascular cavity
  - A single opening functions as both mouth and anus
- There are two variations on this body plan the sessile polyp and the floating medusa

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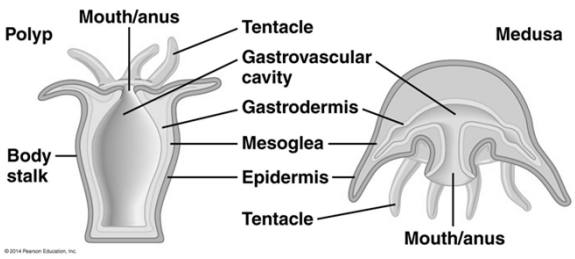

- Cnidarians are carnivores that use tentacles to capture prey
- The tentacles are armed with cnidocytes, unique cells that function in defense and the capture of prey

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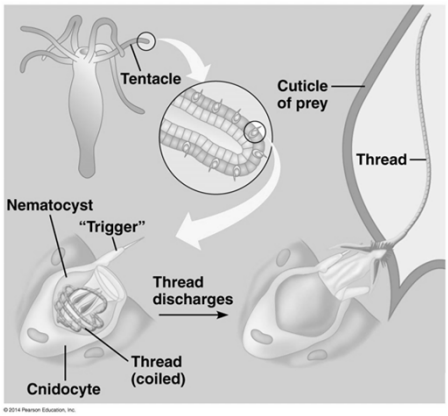

- The simplest nerves and muscles occur in Cnidaria
  - Epidermal and gastrodermal cells have bundles of microfilaments arranged in contractile bundles
  - The water-filled gastrovascular cavity acts as hydrostatic skeleton against which contractile bundles can act to change animal shape

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- The phylum Cnidaria is divided into four major classes

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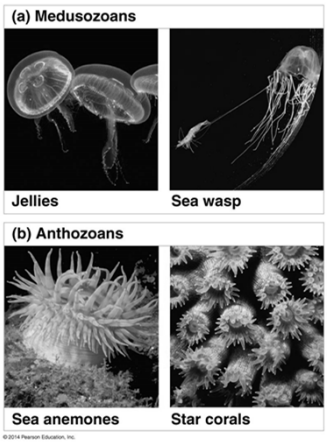

Hydrozoans

- Most hydrozoans alternate between polyp and medusa forms
  - The polyp is the dominant form
  - Some are colonial (Obelia), others solitary (Hydra)
- Hydra is unique with only the polyp stage present
  - Hydra normally reproduces asexually by budding, and sexually by forming a resistant zygote in unfavorable conditions

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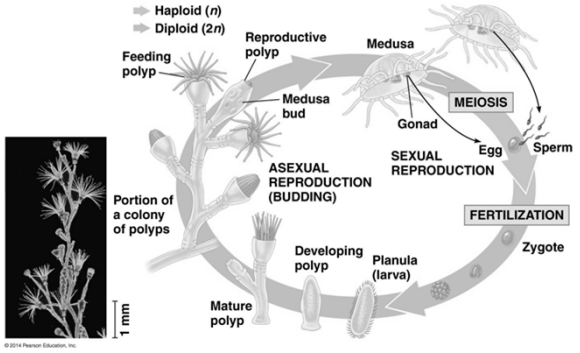

Scyphozoans

- In the class Scyphozoa jellies (medusae) are the prevalent form of the life cycle
  - Coastal species usually pass through a small polyp stage
  - Open ocean species have eliminated the polyp stage

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Cubozoans

- In the class Cubozoa, which includes box jellies and sea wasps, the medusa is box-shaped and has complex eyes

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Anthozoans

- Class Anthozoa includes the corals and sea anemones which occur only as polyps
- Coral animals may be colonial or solitary and secrete external skeletons of calcium carbonate
  - Each polyp generation builds on skeletons of previous generations
  - Coral is the rock-like external skeletons

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Bilateria

- The vast majority of animal species belong to the clade Bilateria which consists of animals with bilateral symmetry and triploblastic development
  - The clade Bilateria contains Lophotrochozoa, Ecdysozoa, and Deuterostomia

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Lophotrochozoans

- The clade Lophotrochozoa was identified by molecular data
  - Some develop a lophophore for feeding, others pass through a trochophore larval stage, and a few have neither feature
- Lophotrochozoa includes the flatworms, rotifers, ectoprocts, brachiopods, molluscs, and annelids

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Flatworms

- Members of phylum Platyhelminthes live in marine, freshwater, and damp terrestrial habitats
  - Although flatworms undergo triploblastic development, they are acoelomates
  - They are flattened dorsoventrally and have a gastrovascular cavity
  - Gas exchange takes place across the surface, and protonephridia regulate the osmotic balance
- Flatworms are divided into four classes

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Turbellarians

- Turbellarians are nearly all free-living and mostly marine
- The best-known turbellarians, commonly called planarians, have light-sensitive eyespots and centralized nerve nets

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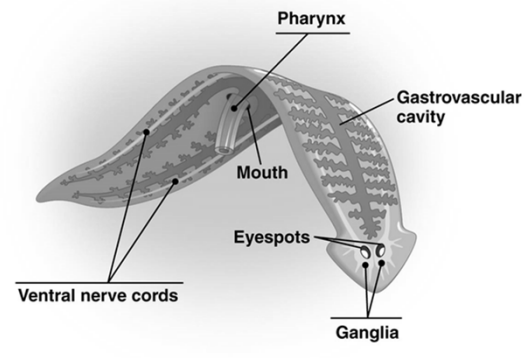

Monogeneans and Trematodes

- Monogeneans and trematodes live as parasites in or on other animals
  - Parasitize a wide range of hosts
- Trematodes that parasitize humans spend part of their lives in snail hosts
- Most monogeneans are parasites of fish

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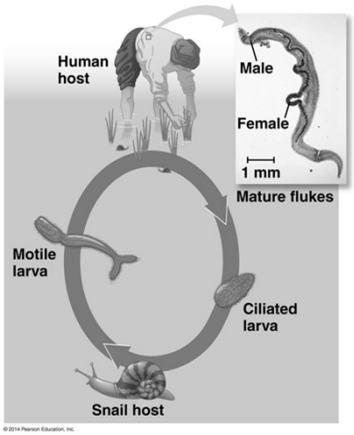

Tapeworms

- Tapeworms (Cestoidea) are also parasitic and lack a digestive system
  - The scolex (head) is armed with suckers and/or hooks that attach to intestinal lining
  - Posterior to the scolex is a long ribbon of units called proglottids which are filled with reproductive organs
- The life cycle includes an intermediate host
  - Mature proglottids filled with eggs are released from the posterior end of the worm and pass from the body in feces

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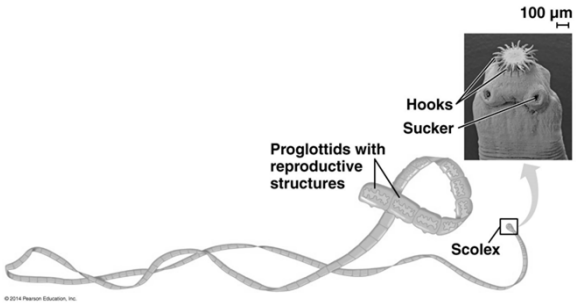

Rotifers

- Rotifers, phylum Rotifera, are tiny animals that inhabit fresh water, the ocean, and damp soil
  - Rotifers are smaller than many protists but are truly multicellular and have specialized organ systems
  - Rotifers have an alimentary canal, a digestive tube with a separate mouth and anus, that lies within a fluid-filled pseudocoelom
  - Many rotifers reproduce by parthenogenesis in which females produce more females from unfertilized eggs

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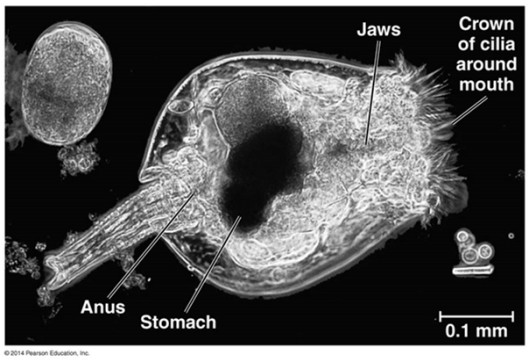

Lophophorates: Ectoprocts and Brachiopods

- Lophophorates have a lophophore, a horseshoe-shaped, suspension-feeding organ bearing ciliated tentacles
- Ectoprocts are colonial animals that superficially resemble plants (mosses)
  - The colonies are enclosed in hard exoskeleton and the lophophores extend through pores when feeding
  - Some are important reef builders
  - About 5000 species are known

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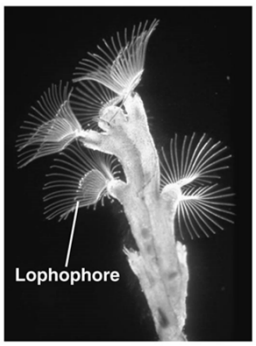

(a) Creeping bryozoan, an ectoproct

- Brachiopods superficially resemble clams and other hinge-shelled molluscs but the two halves of the shell are dorsal and ventral rather than lateral, as in clams
  - 330 species of lamp shells are known

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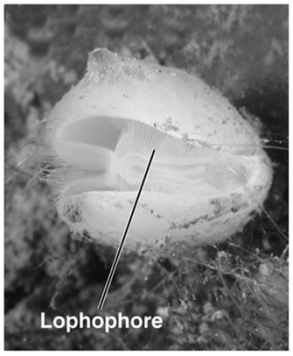

(b) Lampshell, a brachiopod

Molluscs

- Phylum Mollusca includes snails and slugs, oysters and clams, and octopuses and squids
- Most molluscs are marine though some inhabit fresh water and some are terrestrial
- Molluscs are soft-bodied animals but most are protected by a hard shell

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- All molluscs have a similar body plan with three main parts
  - A muscular foot
  - A visceral mass
  - A mantle
- Many molluscs also have a water-filled mantle cavity, and feed using a rasplike radula

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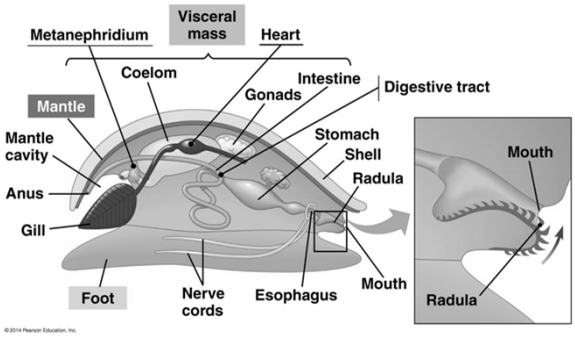

- Most molluscs have separate sexes with gonads located in the visceral mass
- The life cycle of many molluscs includes a ciliated larval stage called a trochophore
- There are four major classes of molluscs

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Chitons

- Class Polyplacophora is composed of the chitons, oval-shaped marine animals encased in an armor of eight dorsal plates
  - They cling to rocks on the sea shore using foot as suction cup
  - The muscular foot allows a creeping motion over rock surface
  - The radula is used to cut and ingest algae

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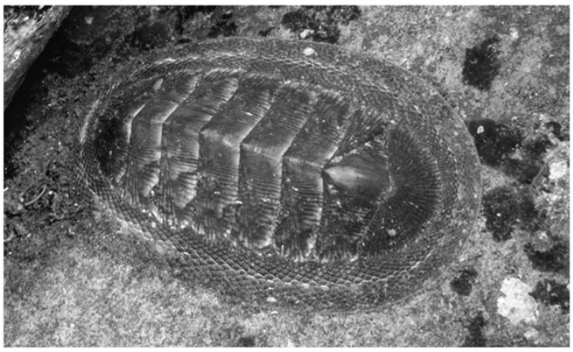

Gastropods

- About three-quarters of all living species of molluscs belong to class Gastropoda
- Most gastropods are marine, but there are also many freshwater and terrestrial species
  - Most possess a single, spiraled shell
  - Slugs lack a shell or have a reduced shell

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(a) A land snail

(b) A sea slug (nudibranch)

- The most distinctive characteristic of this class is a developmental process known as torsion, which causes the animal's anus and mantle to end up above its head
  - Most are herbivorous
  - Several groups are predatory with modified radulae
- Gas exchange is via gills
  - Terrestrial forms use the vascularized lining of the mantle cavity

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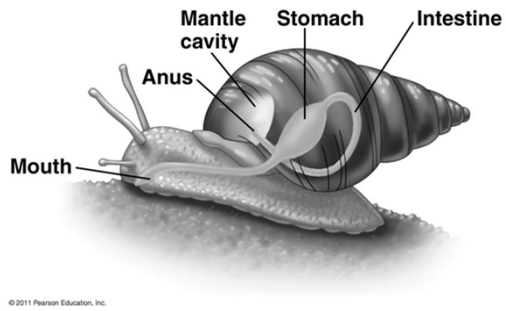

Bivalves

- Molluscs of class Bivalvia include many species of clams, oysters, mussels, and scallops
  - All have a shell divided into two halves hinged at mid-dorsal line and drawn together by two adductor muscles
  - Molluscs extend the foot for motility or anchorage when the shell is open
- The mantle cavity of a bivalve contains gills that are used for feeding as well as gas exchange

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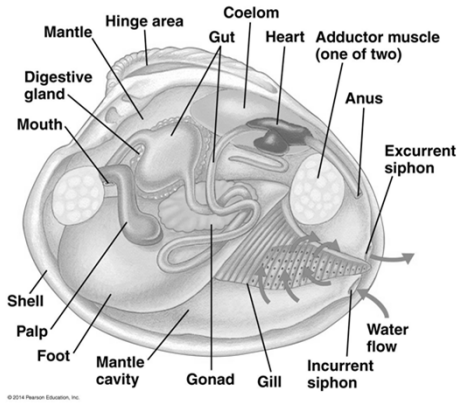

Cephalopods

- Class Cephalopoda includes squids and octopuses
  - Carnivores with beak-like jaws surrounded by tentacles of their modified foot
  - The visceral mass is covered by the mantle, but the shell is either reduced and internal (squids) or totally absent (octopuses)
  - Cephalopods are the only mollusk with a closed circulatory system

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- Cephalopods have a well developed nervous system with a complex brain
  - They capable of learning and have well developed sense organs
- Most octopuses creep along the sea floor in search of prey
- Squids use their siphon to fire a jet of water, which allows them to swim very quickly

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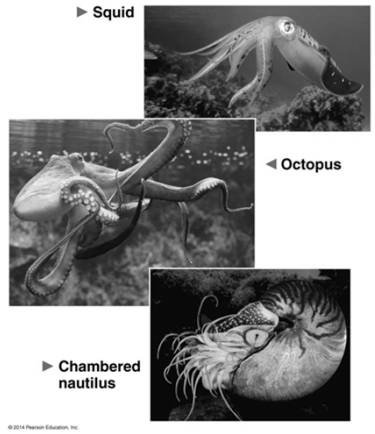

- Cephalopod ancestors were probably the ammonites
  - Ammonites were shelled, carnivorous animals and the dominant invertebrate predator until extinction at the end of the Cretaceous
- One small group of shelled cephalopods, the nautiluses, survives today

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Annelids

- Annelids have bodies composed of a series of fused rings
- They have a true coelom and a segmented body
  - The coelom serves as a hydrostatic skeleton
- Segmentation allowed specialization of body regions and permitted the development of complex organ systems

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- The phylum Annelida is divided into three classes

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Oligochaetes

- Oligochaetes (class Oligochaeta) are named for their relatively sparse chaetae, or bristles made of chitin
  - The class includes the earthworms and a variety of aquatic species
- Earthworms eat their way through the soil, extracting nutrients as the soil moves through the alimentary canal which helps till the earth, making earthworms valuable to farmers

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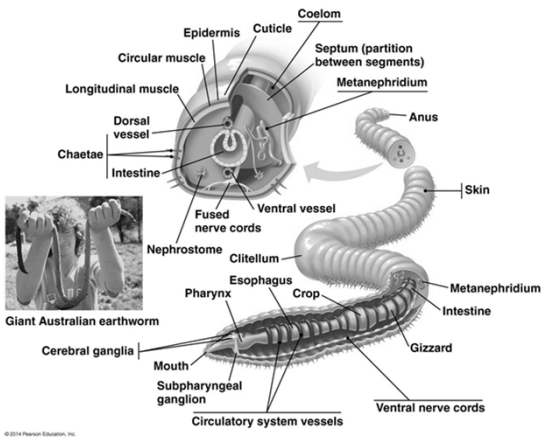

Polychaetes

- Members of class Polychaeta possess paddlelike parapodia that function as gills and aid in locomotion
  - Mostly marine species
  - Some drift in plankton, some crawl on bottom, most live in tubes built of sand and shell bits mixed with mucus
    - tube worms feed by trapping food particles in fans-feathery filters extended from tubes

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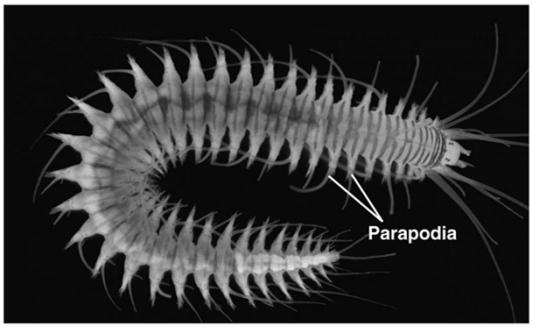

Leeches

- Members of class Hirudinea are mostly freshwater although some are terrestrial or marine
  - They are mostly carnivorous, feeding on small invertebrates
  - Some attach to animals temporarily and feed on blood

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- Some blood-feeding forms have a pair of blade-like jaws that slit host's skin, others secrete enzymes that digest a hole in the skin
  - They secrete anesthetic to prevent detection of incision and an anti-coagulant called hirudin
  - Leeches may ingest up to 10x their body weight in blood and not feed again for several months
  - Medicinal leeches are currently used to stimulate blood flow to reattached limbs

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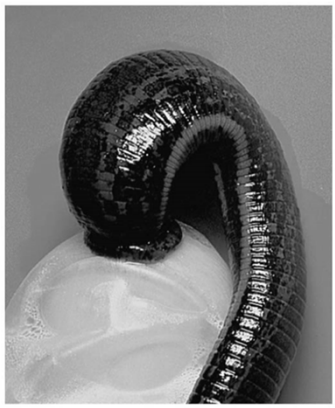

Ecdysozoans

- Ecdysozoans are covered by a tough coat called a cuticle
  - The cuticle is shed or molted through a process called ecdysis
- The two largest phyla are nematodes and arthropods

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Nematodes

- Among the most widespread of all animals, nematodes, or roundworms, are found in most aquatic habitats, in the soil, in moist tissues of plants, and in the body fluids and tissues of animals

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- Nematode bodies are cylindrical
  - They have an alimentary canal, but lack a circulatory system
  - A tough, transparent cuticle forms outer body cover
  - Longitudinal muscles are present providing a whip-like movement
  - Nematodes are dioecious and females are larger than males
    - reproduction in nematodes is usually sexual, by internal fertilization

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- Nematodes fill various roles in the community
  - Free-living forms are important in decomposition and nutrient cycling
- Some species of nematodes are important parasites of plants and animals
  - Animal parasites can be hazardous
    - Trichinella spiralis in pork causes trichinosis
  - Caenorhabitis elegans is used extensively in genetic and developmental research

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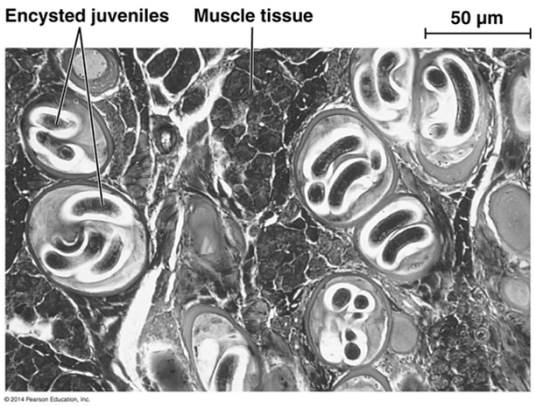

Arthropods

- Two out of every three known species of animals are arthropods
- Members of the phylum Arthropoda are found in nearly all habitats of the biosphere

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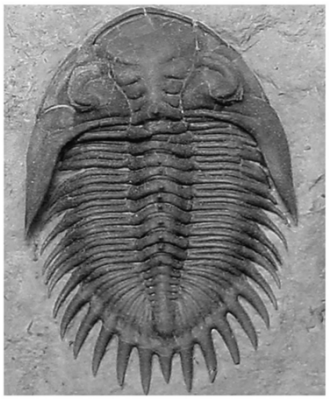
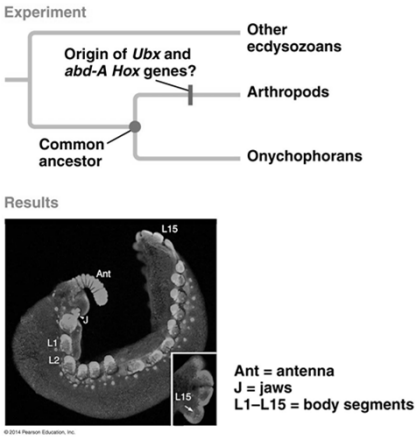
Arthropod Origins

- The arthropod body plan consists of a segmented body, hard exoskeleton, and jointed appendages, and dates to the Cambrian explosion (535–525 million years ago)
- Early arthropods show little variation from segment to segment



- Arthropod evolution is characterized by a decrease in the number of segments and an increase in appendage specialization
- These changes may have been caused by changes in Hox gene sequence or regulation



General Characteristics of Arthropods

- The diversity and success of arthropods are largely related to their segmentation, hard exoskeleton, and jointed appendages
  - Arthropod segmentation is more advanced than annelids
  - Different segments of the body, and associated appendages, are specialized for specific functions
  - Jointed appendages are specialized for walking, feeding, sensory reception, copulation and defense

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- As arthropods evolved the segments fused, and the appendages became more specialized
- The appendages of some living arthropods are modified for many different functions
- Arthropods show extensive cephalization
  - Sensory structures are clustered at the anterior end including eyes, olfactory receptors, and tactile receptors

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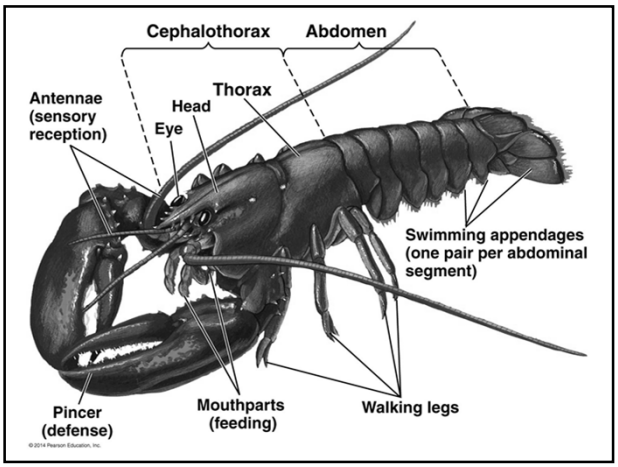

- The body of an arthropod is completely covered by the cuticle, an exoskeleton made of chitin
  - When an arthropod grows it molts its exoskeleton in a process called ecdysis
- Arthropods have an open circulatory system in which fluid called hemolymph is circulated into the spaces surrounding the tissues and organs
- A variety of organs specialized for gas exchange have evolved in arthropods

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- Molecular evidence now suggests that living arthropods consist of four major lineages that diverged early in the evolution of the phylum

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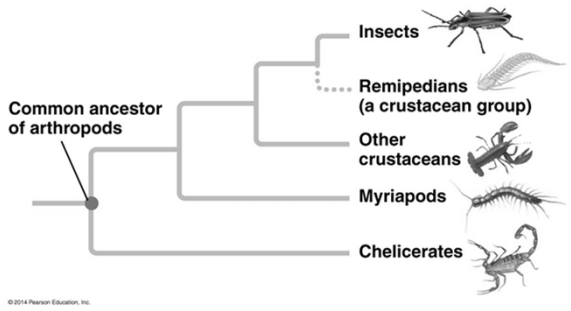

Cheliceriforms

- Cheliceriforms, subphylum Cheliceriformes ,are named for clawlike feeding appendages called chelicerae
  - This clade includes spiders, ticks, mites, scorpions, and horseshoe crabs
- Most of the marine cheliceriforms are extinct but some species survive today, including the horseshoe crabs

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- Most modern cheliceriforms are arachnids, a group that includes spiders, scorpions, ticks, and mites

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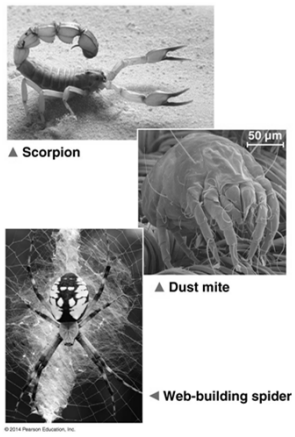
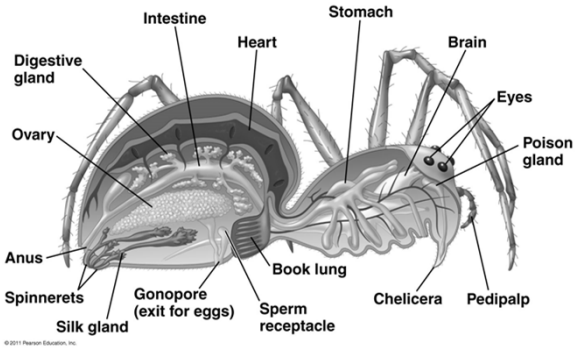


- Arachnids have an abdomen and a cephalothorax which has six pairs of appendages, the most anterior of which are the chelicerae
  - In spiders fang-like chelicerae (equipped with poison glands) are used to attack prey
  - Chelicerae and pedipalps macerate prey while digestive juices soften tissues
  - Gas exchange is by book lungs (stacked plates in internal chamber)

90



Myriapods

- Subphylum Myriapoda includes millipedes and centipedes
- Millipedes, class Diplopoda, have a large number of legs
  - Each trunk segment has two pairs of legs
  - Millipedes eat decaying leaves and other plant material
  - They probably amongst earliest land animals

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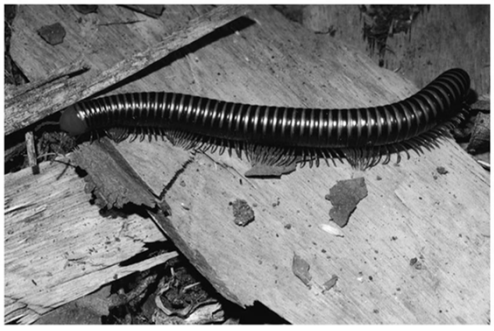

(a) Millipede

- Centipedes, class Chilopoda, are carnivores with jaw-like mandibles
  - Three pairs of appendages are modified as mouth parts (including mandibles)
  - Each trunk segment has one pair of walking legs
  - Poison claws on the anterior segment are used to paralyze prey and for defense

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(b) Centipede

Insects

- Subphylum Hexapoda, insects and their relatives, are more species-rich than all other forms of life combined
  - Insects live in almost every terrestrial habitat and in fresh water but only a few marine forms exist
- The internal anatomy of an insect includes several complex organ systems

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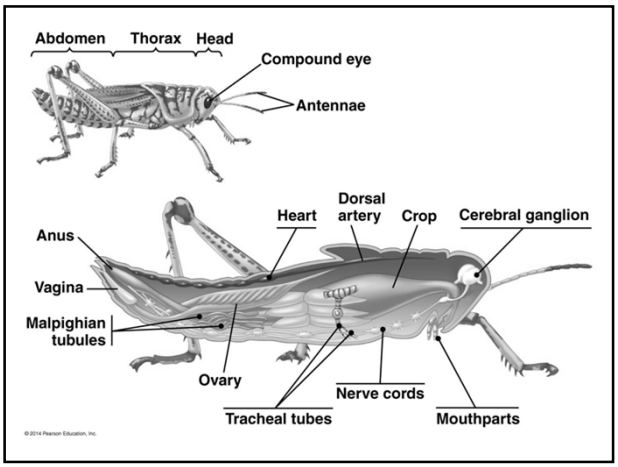

- Flight is obviously one key to the great success of insects
  - An animal that can fly can escape predators, find food, and disperse to new habitats much faster than organisms that can only crawl
- The origin of insect wings is uncertain
  - They may have first evolved to help absorb heat then developed for flight
  - An alternate views suggests wings first served for gliding, as gills, or as structures for swimming

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- Dragonflies were among the first insects to fly
  - They have two coordinated pairs of wings
- Modifications of this plan are found in groups that evolved later
  - Bees and wasps hook pairs together to act as one pair
  - Butterflies have overlapping anterior and posterior wings
  - Beetles have anterior wings modified to cover and protect posterior wings

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- Insects diversified several times following the evolution of flight, associated with adaptation to feeding on gymnosperms, and the expansion of angiosperms
- Insect and plant diversity declined during the Cretaceous extinction, but have been increasing in the 65 million years since

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- Many insects undergo metamorphosis during their development
  - In incomplete metamorphosis, the young, called nymphs resemble adults but are smaller and go through a series of molts until they reach full size

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- Insects with complete metamorphosis have larval stages specialized for eating and growing that are known by such names as maggot, grub, or caterpillar
  - The larval stage looks entirely different from the adult stage
- Metamorphosis from the larval stage to the adult stage occurs during a pupal stage

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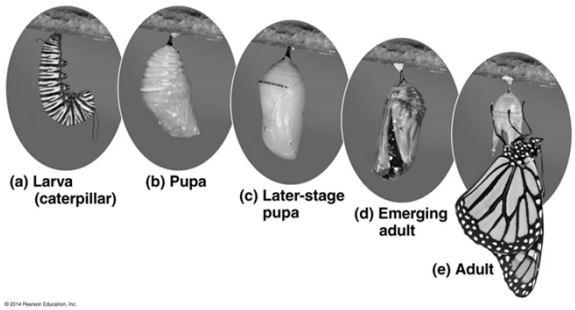

- Most insects have separate males and females and reproduce sexually
- Individuals find and recognize members of their own species by bright colors, sound, or odors
- Some insects are beneficial as pollinators, while others are harmful as carriers of diseases, or pests of crops
- Insects are classified into more than 30 orders

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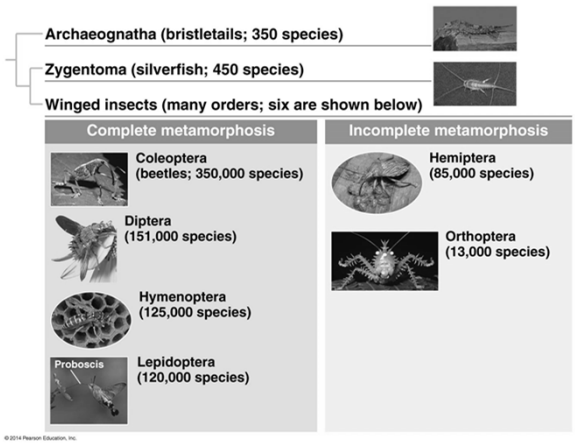

Crustaceans

- While arachnids and insects thrive on land crustaceans, for the most part, have remained in marine and freshwater environments
  - Crustaceans, subphylum Crustacea, typically have biramous, branched, appendages that are extensively specialized for feeding and locomotion
- Some characteristics of crustacean physiology include:
  - Gas exchange via thin areas of cuticle (small forms) or via gills (large forms)

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  - An open circulatory system with hemolymph
  - Nitrogenous waste excretion by diffusion via thin areas of cuticle
  - Regulation of the hemolymph salt balance by a specialized pair of antennal or maxillary glands
- Most crustaceans are dioecious
  - Some males (eg, lobsters) have special appendages for depositing sperm in female reproductive pore during copulation
  - Most have at least one free-swimming larval stage

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- Isopods are mostly small marine crustaceans but also includes sow bugs and pill bugs
  - Terrestrial forms live in moist soil and damp areas

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- Decapods are all relatively large crustaceans and include lobsters, crabs, crayfish, and shrimp

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(a) Ghost crab

- Planktonic crustaceans include many species of copepods which are among the most numerous of all animals

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(b) Krill

- Barnacles are a group of mostly sessile crustaceans whose cuticle is hardened into a shell

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(c) Barnacles

Deuterostomes

- Sea stars and other echinoderms, phylum Echinodermata, may seem to have little in common with phylum Chordata, which includes the vertebrates
- Chordates and echinoderms share characteristics of deuterostomes
  - Radial cleavage
  - Development of the coelom from the archenteron
  - Formation of the mouth at the end of the embryo opposite the blastopore

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Echinoderms

- Sea stars and most other echinoderms are slow-moving or sessile marine animals
- A thin, bumpy or spiny skin covers an endoskeleton of hard calcareous plates
- Unique to echinoderms is a water vascular system a network of hydraulic canals branching into tube feet that function in locomotion, feeding, and gas exchange

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- The radial anatomy of many echinoderms evolved secondarily from the bilateral symmetry of ancestors
- Males and females are usually separate, and sexual reproduction is external
- Living echinoderms are divided into six classes

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Sea Stars

- Sea stars, class Asteroidea have multiple arms radiating from a central disk
- The undersurfaces of the arms bear tube feet, each of which can act like a suction disk
  - Coordination of extension, attaching, contraction and release allow slow movement and attachment to prey
- Sea stars have regenerative abilities
  - One species can regenerate the entire body from single arm

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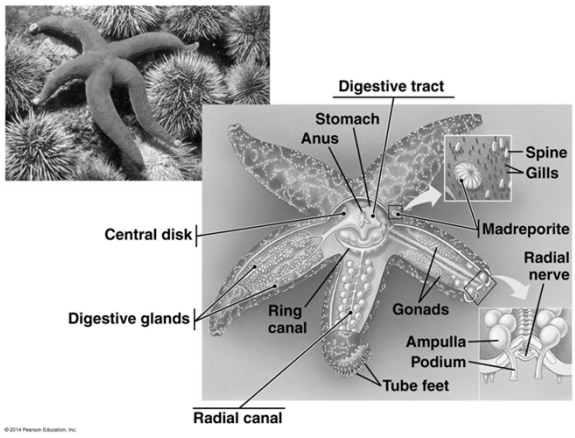

- Sea daisies were discovered in 1986 and only three species are known
  - These small disc-shaped marine animals live in deep water and feed on submerged wood (?)
- They do not posses arms
  - Tube feet located around disc margin and the water vascular system consists of two concentric ring canals

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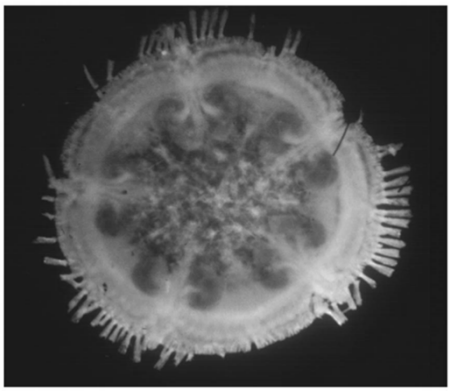

Brittle Stars

- Brittle stars (class Ophiuroidea) have a distinct central disk and long, flexible arms
- They differ from sea stars by the following:
  - have smaller central discs
  - longer, more flexible arms
  - no suckers on tube feet
  - locomotion by serpentine lashing of arms
  - varying feeding mechanisms including suspension feeding, predation, and scavenging

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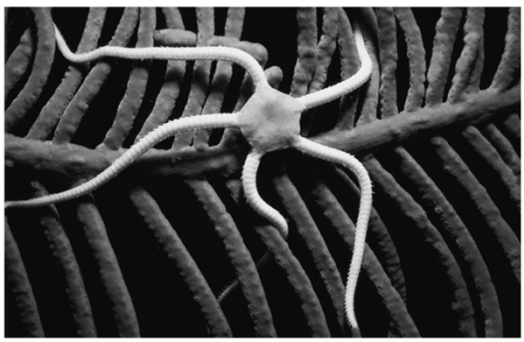

Sea Urchins and Sand Dollars

- Sea urchins and sand dollars (class Echinoidea) have no arms but they do have five rows of tube feet that function in movement
  - Sea urchins are spherical in shape, sand dollars are flattened in the oral-aboral axis
- They have a complex jaw-like apparatus around the mouth which is used for feeding on seaweeds and other food

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Sea Lilies and Feather Stars (class Crinoidea)

- Sea lilies live attached to the substrate by a stalk
- Feather stars crawl about using their long, flexible arms
- The evolution of these animals has been conservative
  - Extant species resemble fossilized species from the Ordovician (500mya)

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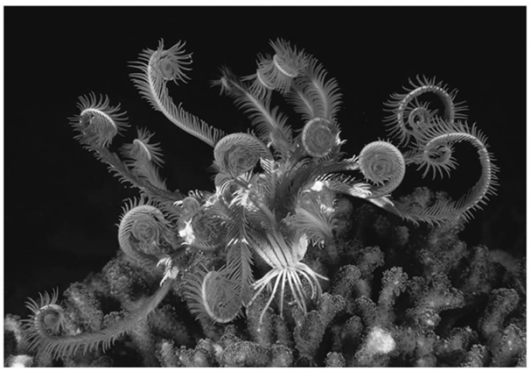

Sea Cucumbers

- Sea cucumbers (class Holothuroidea) upon first inspection do not look much like other echinoderms
  - They lack spines, and their endoskeleton is much reduced
  - They do posses five rows of tube feet which are part of the water vascular system
  - Some feet around the mouth have developed into feeding tentacles

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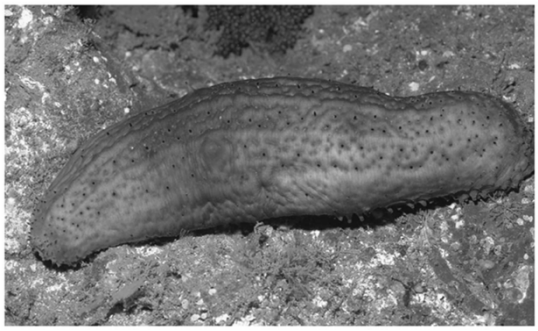

Chordates

- Phylum Chordata consists of two subphyla of invertebrates as well as the hagfishes and the vertebrates
  - Urochordata
  - Cephalochordata
  - Vertebrata
- Shares many features of embryonic development with echinoderms, but have evolved separately for at least 500 million years

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		Phylum	Description
Metazoa		Porifera (sponges)	Lack true tissues; have choanocytes (collar cells—flagellated cells that ingest bacteria and tiny food particles)
Eumetazoa		Cnidaria (hydras, jellies, sea anemones, corals)	Unique stinging structures (nematocysts) housed in specialized cells (cnidocytes); diploblastic; radially symmetrical; gastrovascular cavity (digestive compartment with a single opening)
Bilateria	Lophotrochozoa	Platyhelminthes (flatworms)	Dorsoventrally flattened acoelomates; gastrovascular cavity or no digestive tract
		Rotifera (rotifers)	Pseudocoelomates with alimentary canal (digestive tube with mouthand anus); jaws (trophi); head with ciliated crown
		Lophophorates: Ectoprocta, Brachiopoda	Coelomates with lophophores (feeding structures bearing ciliated tentacles)
		Mollusca (clams, snails, squids)	Coelomates with three main body parts (muscular foot, visceral mass, mantle); coelom reduced; most have hard shell made of calcium carbonate
		Annelida (segmented worms)	Coelomates with segmented body wall and internal organs (except digestive tract, which is unsegmented)
	Ecdysozoa	Nematoda (roundworms)	Cylindrical pseudocoelomates with tapered ends; no circulatory system; undergo ecdysis
		Arthropoda (spiders, centipedes, crustaceans, and insects)	Coelomates with segmented body, jointed appendages, and exoskeleton made of protein and chitin
	Deuterostomia	Echinodermata (sea stars, sea urchins)	Coelomates with bilaterally symmetrical larvae and five-part body organization as adults; unique water vascular system; endoskeleton
		Chordata (lancelets, tunicates, vertebrates)	Coelomates with notochord; dorsal, hollow nerve cord; pharyngeal slits; post-anal tail (see Chapter 34)

Selected Animal Phyla

	Phylum		Description
Metazoa, Eumetazoa, Bilateria, Ecdysozoa	Nematoda (roundworms)		Cylindrical, unsegmented pseudocoelomates with tapered ends; no circulatory system; undergo ecdysis
Metazoa, Eumetazoa, Bilateria, Ecdysozoa	Arthropoda (crustaceans, insics, spiders)		Coelomates with segmented body, jointed appendages, and exoskeleton made of protein and chitin
Metazoa, Eumetazoa, Bilateria, Deuterostomia	Echinodermata (sea stars, sea urchins)		Coelomates with bilaterally symmetrical larvae and five-part body organization as adults; unique water vascular system; endoskeleton
Metazoa, Eumetazoa, Bilateria, Deuterostomia	Chordata (lancelets, tunicates, vertebrates)		Coelomates with notochord; dorsal, hollow nerve cord; pharyngeal slits; post-anal tail (see Chapter 34)