**INVERTEBRATES**

About 95% of all living animals are invertebrates, animals without backbone.

The invertebrate-vertebrate dichotomy shows the bias we have since humans and most of the animals we are familiar with are vertebrates, animals with backbone. This division of the kingdom Animalia into vertebrates and invertebrates is artificial.

The **kingdom Animalia** is divided into two Subkingdoms.

Subkingdom **Parazoa** lacks of true tissues and indeterminate form.

Subkingdom **Eumetazoa** posses true tissues organized into organs and organ systems.

There are about 35 to 37 phyla in the kingdom Animalia. The number varies with different authors.

There are about 1.3 million described extant species of animals.

**PARAZOA**

The subkingdom Parazoa comprises two phyla, the Placozoa and the Porifera.

We will study the phylum Porifera. If you want information about the very interesting phylum Placozoa visit the following web sites:

<http://www.ucmp.berkeley.edu/phyla/placozoa/placozoa.html>

<http://www.ldeo.columbia.edu/edu/dees/ees/life/slides/phyla/placozoa.html>

**PHYLUM PORIFERA - sponges**

1. Multicellular; body a loose aggregation of cells.

2. Body with pores (**ostia**), canals, and chambers that serve for passage of water to the central cavity (**spongocoel**), and out of the open end, the **osculum**.

3. About 9,000 species have been identified; all are aquatic and mostly marine. About 100 species live in fresh water.

4. Symmetry radial or none.

5. Epidermis of flat **pinacocytes** and doughnut-shaped **porocytes**; most interior surfaces lined with flagellated collar cells (**choanocytes**) that create water currents; a gelatinous protein matrix called **mesohyl**, which contains **amoebocytes**, **collencytes** (secrete collagen), and skeletal elements (**spicules**).

*“The mobile cells in the center layer are called amoebocytes. These cells are able to move by use of pseudopodia. They are constantly moving, and their main function is to pick up food vacuoles from the choanocytes, digest the food inside them, and carry the nutrients to the cells that need them. However, they also function to carry oxygen to other cells, dispose of waste products, maintain the structure of the sponge, and even change into another cell type if they have to.”*

**The Bio-Web Group, Sidwell Friends School, Washington, D.C.** [**http://www.sidwell.edu/us/science/vlb5/Labs/Classification\_Lab/Eukarya/Animalia/Porifera/**](http://www.sidwell.edu/us/science/vlb5/Labs/Classification_Lab/Eukarya/Animalia/Porifera/)

6. Skeletal structure of calcareous (Class Calcarea) or siliceous crystalline spicules (Class Hexactinellida), or fibrillar collagen, a protein, and often combined with variously modified collagen (**spongin**) fibrils (Class Demospongiae).

7. No organs or true tissues; cells are relatively unspecialized and form a loose association but there is division of labor; digestion intracellular; excretion and respiration by diffusion. Cells can react to changes in the environment.

8. Reactions to stimuli apparently local and independent; nervous system probably absent.

9. All adults sessile and attached to substratum. Nearly all sponges are **suspension feeders**.

10. Asexual reproduction by buds or gemmules and sexual reproduction by eggs and sperm; most are **hermaphroditic**; gametes arise from amoebocytes or choanocytes; fertilization takes place in the mesohyl and the zygote develops into a free-swimming ciliated larvae.

References:

<http://www.ucmp.berkeley.edu/porifera/porifera.html>

<http://paleo.cortland.edu/tutorial/Protista/porifera.htm>

Myers, P. 2001. "Porifera" (On-line), Animal Diversity Web. Accessed January 10, 2005 at <http://animaldiversity.ummz.umich.edu/site/accounts/information/Porifera.html>

**EUMETAZOA**

***THE RADIATA***

These are animals that have radial symmetry. There are two phyla in this clade, Cnidaria and Ctenophora. We will study only the phylum Cnidaria.

**PHYLUM CNIDARIA – jelly fishes, corals, sea anemones.**

*Cnidos*: stinging nettle in Greek.

1. Entirely aquatic; some in fresh water but mostly marine. About 10,000 species.

2. Radial symmetry or biradial (radial and bilateral) symmetry around a longitudinal axis with oral and aboral ends; no definite head.

3. Two basic body forms: **polyp** and **medusa**. Some exist only as polyps, others only as medusa, and others pass from the medusa stage to a polyp stage in their life cycle.

4. Exoskeleton or endoskeleton have chitinous, calcareous, or protein components in some.

5. Body with two layers (**diploblastic**), epidermis and gastrodermis; with mesoglea; mesoglea with loose cells not organized as a tissue.

6. **Gastrovascular cavity or coelenteron** (often branched or divided with septa) with a single opening that serves as both mouth and anus; extensible tentacles usually encircling the mouth or oral region.

7. **Cnidocytes** (stinging cells) located in the epidermis and gastrodermis contain a capsule called **cnidae** with stinging organelles or **nematocysts**; nematocysts are thread like structures that are ejected forcibly on stimulation; cnidocytes are abundant on tentacles, where they may form batteries or rings. The term nematocyst is sometime used for the contents of the cnidocytes. Some cnidae have long threads that stick to or entangle small prey that bump into the tentacles.

8. **Nerve net** with symmetrical and asymmetrical synapses; some sensory organs; diffuse conduction.

9. **Muscular system** (epitheliomuscular type) is very simple and consists of an outer layer of longitudinal fibers at base of epidermis and an inner one of circular fibers at base of gastrodermis; modifications of this plan in anthozoans, such as separate bundles of independent fibers in the mesoglea.

10. Reproduction by asexual budding (in polyps) or sexual reproduction by gametes in all medusas and some polyps; sexual forms monoecious or dioecious; planula larva.

11. No excretory or respiratory systems.

12. No coelomic cavity.

**Class Hydrozoa** - Most hydrozoans are marine and colonial in form, and typically include both the medusa and polyp stage in their life cycle. Some, however, have no medusa stage, and some occur only as medusas and have no polyp stage. Examples: Hydra, Obelia. *See life cycle of Obelia, fig. 33.8 on page 645).*

**Class Scyphozoa** - Class Scyphozoa (jellyfishes) includes most of the larger "jellyfishes". A few, such as Cyanea, may attain a bell diameter exceeding 2 m and tentacles 60 to 70 m long, but most range from 2 cm to 40 cm in diameter. Their polyp stage is absent or greatly reduced, and the medusas of this class have no velum. Examples: Aurelia, Cyanea.

**Class Cubozoa** – Box-shaped medusas; with complex eyes on the fringes of the medusa; their tentacles are suspended on structures called **pedalia**; some like the sea wasp are extremely poisonous; predators found in tropical oceans. See a picture of a cubozoan here:

<http://bioweb.uwlax.edu/zoolab/Table_of_Contents/Lab-3a/Cubozoa/cubozoa.htm>

**Class Anthozoa** - Anthozoa means "flower animal," and anthozoans are indeed polyps with a flowery appearance. They do not have a medusa stage. All anthozoans are marine and are found all over the world, in various sizes and habitats. Examples: Sea anemones, corals, sea fans.

*“Cnidaria is thought to have one of the longest fossil histories of metazoan phyla with representatives in the Ediacaran fauna of the late Precambrian (Scrutton 1979). These earliest fossils are both medusoid and polypoid, and thought to represent all cnidarian classes (Scrutton 1979).*

*The four extant cnidarian classes are identifiable as early as the Ordovician (Robson 1985), but evolutionary relationships among them have been the subject of much debate (e.g. Brooks 1886, Hyman 1940, Jagersten 1955, Hand 1959, Pantin 1960, Werner 1973, Petersen 1979, Barnes 1987, Ax 1989).”*

<http://tolweb.org/tree?group=Cnidaria&contgroup=Animals>. Daphne G. Fautin, Division of Biological Sciences, University of Kansas, Lawrence, Kansas 66045 USA; Sandra L. Romano, Division of Science and Mathematics, University of the Virgin Islands, 2 John Brewers Bay, St. Thomas 00802 USVI. Page copyright © 1997 Daphne Fautin and Sandra Romano.

References:

<http://tolweb.org/tree?group=Cnidaria&contgroup=Animals>

<http://www.ucihs.uci.edu/biochem/steele/default.html>

<http://faculty.vassar.edu/mehaffey/academic/animalstructure/outlines/cnidaria.html>

Myers, P. 2001. "Cnidaria" (On-line), Animal Diversity Web. Accessed January 10, 2005 at <http://animaldiversity.ummz.umich.edu/site/accounts/information/Cnidaria.html>.

<http://biology.ucok.edu/AnimalBiology/Cnidaria/Cnidaria.ppt#256,2,Contents>

***THE BILATERIA***

These are animals with bilateral symmetry and triploblastic development.

Bilaterians evolved in the Precambrian times and diversified during the Cambrian explosion.

**PHYLUM PLATYHELMINTHES - flatworms**

There are about 20,000 species of flatworms living in marine, fresh-water and damp, terrestrial habitats. This group includes free-living and parasitic forms.

1. Three germ layers (**triploblastic**).
2. Bilateral symmetry; definite polarity of anterior and posterior ends.
3. Body flattened dorsoventrally in most; oral and genital apertures mostly on ventral surface.
4. Body with multiple reproductive units in one class (Cestoda).
5. Epidermis may be cellular or syncytial (ciliated in some).
6. Muscular system of mesodermal origin, in the form of a sheath of circular, longitudinal, and oblique layers beneath the epidermis or tegument.
7. No internal body space (**acoelomate**) other than digestive tube; spaces between organs filled with parenchyma.
8. Digestive system with only one opening (gastrovascular type), absent in some; extensively branched.
9. Nervous system consisting of a pair of anterior ganglia with longitudinal nerve cords connected by transverse nerves and located in the parenchyma in most forms
10. Simple sense organs, eyespots in some.
11. Excretory system of two lateral canals with branches bearing flame cells (protonephridia), lacking in some forms.
12. Respiratory, circulatory, and skeletal systems lacking.
13. Most forms hermaphroditic; reproductive system complex, usually with well-developed gonads, ducts, and accessory organs; internal fertilization; life cycle simple in free-swimming forms and those with single hosts; complicated life cycle often involving several hosts in many internal parasites.

**Class Turbellaria** - Turbellarians are mostly free-living worms than range in length from 5 mm or less to 50 cm, usually covered with ciliated epidermis, they are typically creeping worms that combine muscular with ciliary movement to achieve locomotion. The mouth is on the ventral side. They lack organs for gas exchange and circulation. Example: Dugesia. *Fig. 33.10, pg.647*.

**Classes Monogenea and Trematoda** - The monogeneans and trematodes are all parasitic flukes, and as adults they are almost all found as either external parasites of fish (monogeneans) or internal parasites of vertebrates (trematodes). The monogeneans have a single host while the trematodes have two hosts involved during their life cycle. Some zoologists consider them a single group, Trematoda. Examples: Clonorchis, Schistosoma.

See the life cycle of the fluke Schistosoma mansoni on page 675, fig 33.11.

**Class Cestoda** - The cestodes, or tapeworms, usually have long flat bodies made up of many reproductive units (**proglottids**) and have no digestive system. They also have a specialized structure called the **scolex** ("holdfast"), which is the organ by which they attach to their host. It is usually provided with suckers and often with hooks or spiny tentacles. Examples: Taenia

**PHYLUM ROTIFERA- rotifers**

1. Rotifera derive their name from their characteristic ciliated crown, or corona, which gives the impression of a rotating wheel when beating.
2. The body is usually divided into a head, trunk and foot. The head bears the corona, the trunk has a thickened cuticle with ridged plates and spines for defense and the foot often bears 1-4 projections called toes, which are used for attachment.
3. **Pseudocoelomate** animals. The pseudocoelom is filled with fluid that serves as a **hydrostatic skeleton**.
4. Rotifers are "cell constant": each member of a species is composed of the same number of cells.
5. Rotifers a **complete digestive tract** with mouth and anus.
6. Have a nervous system with a ganglion, nerves and an eyespot.
7. Excretory system consists of protonephridia with flame cells.
8. Some species consist only of females that produce more females from unfertilized eggs in what is called **parthenogenesis**. Other species produce two kinds of eggs, one kind develops, diploid, into females; the other kind of egg is haploid, and produced if the pond is drying; these egg develop into degenerate males that live long enough to produce sperms. The bdelloid rotifers are all females that reproduced parthenogenetically. Fertilization produces cysts that can survive periods of drought.

**PHYLA ECTOPROCTA, PHORONIDA AND BRACHIOPODA.**

These phyla did not fit well in neither coelomate group, protostomes nor deuterostomes, on the basis of embryological data. Molecular data, however, place them in the protostome branch.

These phyla are called the lophophorate phyla. Their distinctive characteristic is the structure called the **lophophore**.

1. The **lophophore** is a horseshoe-shaped or circular structure with ciliated tentacles around the mouth.
2. Lophophorates have a **true coelom**.
3. Their **complete digestive track** is U-shaped, and the anus lies outside the lophophore.
4. The lophophore is used to attract food particles to the mouth. They are **suspension feeders**.
5. The head is absent, an adaptation to sessile existence.

**Phylum Ectoprocta - byozoans**

Bryozoans are colonial and sessile animals surrounded by a calcareous exoskeleton with pores through which the lophophores can protrude.

There are about 5,000 species, mostly marine, and widespread. They are important reef builders.

**Phylum Phoronida – marine tube worms**

Phoronids are tube-dwelling marine worms. Some live buried in sand within tubes made of chitin. They extend the lophophore through an opening at the end of the tube to attract particles.

There are about 15 species only in two genera.

**Phylum Brachiopoda – Lampshells**

Brachiopods resemble clams but the shells are dorsal and ventral to the animal rather than lateral. They live attached to a hard substrate, bury or lie on the sand or mud, and open their shells enough to expose the lophophore to water currents. All brachiopods are marine animals. They evolved early in animal history. There are more than 30,000 species of fossil brachiopods from the Paleozoic and Mesozoic. They have changed little in 400 million years. There are about 300 extant species.

**PHYLUM NEMERTEA – proboscis or ribbon worms**

Members of the phylum Nemertea are commonly called the **ribbon worms**. There are approximately 900 known species, most of that are benthic marine animals, although there are a few freshwater and terrestrial species and some deep-water species.

1. They are **acoelomate**, flattened dorsoventrally and have circular, longitudinal, and dorsoventral muscles.
2. One defining characteristic of the nemerteans is the presence of an **eversible proboscis**.
3. Tube-within-a-tube body plan: outer body wall and inner digestive tract. **Complete digestive system: mouth and anus**.
4. **Closed circulatory system** with blood that travels through contractile vessels and may move in either direction. There is no heart and the pumping of blood is aided by the muscular contractions of the body associated with movement.

Nemerteans are extremely fragile. They can break up into fragments. These fragments have been shown to have a remarkable capacity for regeneration, and can rapidly produce whole new adult worms.

Nemerteans are considerably more advanced than platyhelminths in a number of respects.

1. Possession of an eversible proboscis.

2. Mouth and anus with connecting, unidirectional intestinal tract - complete

 digestive tract.

3. Blood vascular system.

4. Sensory apparatus including ciliated pits on the side of the head and simple eyes.

**PHYLUM MOLLUSCA – mollusks (clams, snails, squids, octopuses, etc.)**

Mollusks form the second largest phylum in the animal kingdom with about 50,000 extant species, and about 35,000 fossil species.

1. Bilateral symmetrical coelomate protostomes.
2. Coelom reduced to a small cavity around some organs; **hemocoel**, part of the circulatory system is the main body cavity.
3. Soft body usually covered with a shell.
4. Body divided into three regions: **mantle, foot and visceral mass**.
5. A thick epidermal layer of skin called the **mantle** covers the body; the mantle secretes the shell.
6. Digestive system well developed; **radula**, a rasp-like organ with teeth; absent in bivalves.
7. Open circulatory system except in many cephalopods; heart usually three-chambered, blood vessels, and sinuses present; respiratory pigments in blood or **hemolymph**.
* Hemolymph flows into a network of large spaces or sinuses where the tissues are bathed directly. This network makes up the hemocoel.
1. Gas exchange through gills, mantle, or body surface.
2. Nervous system consists of a pair of ganglia, with nerve cords; ganglia forming a nerve ring in gastropods and cephalopods.
3. Sensory organs present (touch, smell, taste, equilibrium, and vision in some); eyes

highly developed in cephalopods.

1. Sexes separate in most; fertilization external; many species pass through one or

Several larval stages.

**Class Polyplacophora** or chitons. Marine animals with segmented shells made of 8 plates; head reduced or absent; broad foot used in locomotion; radula.

**Class Gastropoda** includes snails, slugs and nudibranchs. Marine, freshwater and terrestrial animals with body and shell coiled in some species (**torsion**); **pulmonate** mantle in terrestrial species (pulmon: organ for gas exchange); well-developed head with tentacles and eyes; broad flat foot used in locomotion; radula.

**Class Bivalvia** includes clams, oysters and mussels. Marine and freshwater animals with a two-part shell hinged dorsally; a pair of gills; mantle forms siphons; lack head and radula; suspension feeders.

**Class Cephalopoda**, octopods, nautiluses and squids. Marine and predatory animals with the foot modified into tentacles, bearing suckers; tentacles surround the mouth of a large head; mouth with a horny beak; with or without radula; they are the only mollusks with closed circulatory system; eyes are very well developed; lack shell; confuse their enemies by changing colors and releasing "ink". Squids and octopods can learn to some degree.

**PHYLUM ANNELIDA – segmented worms**

There are about 15,000 species in the phylum. They may be marine, freshwater or terrestrial herbivores, carnivores, parasites, scavengers and suspension feeders.

1. Bilateral symmetry; body tubular and segmented (metamerism).
2. Coelom, body wall and many internal organs segmented by **septa**; well-developed muscles form the body wall.
3. **Setae** or **parapodia** present on each segment; absent on leeches.
4. Complete unsegmented digestive system with specialized parts: pharynx, esophagus, crop, gizzard and intestine.
5. Gas exchange through skin or gills.
6. Closed circulatory system; hemoglobin transports oxygen.
7. A pair of **metanephridia** in each segment.
8. Nervous system made of simple brain made of two **ganglia**, double ventral nerve cord and sense organs (touch, eyes); pair of ganglia and nerves repeated in each segment.
9. Reproduction sexual; hermaphroditic or separate sexes.

**Class Oligochaeta**. Terrestrial or freshwater worms characterized by having poorly developed head, few setae or chaetae per segment, hermaphroditic, and have a clitellum. E. g. earthworm.

**Class Polychaeta**. Polychaetes are characterized by having a well-developed head with eyes and antennae; paired appendages (**parapodia**) with chaetae on most segments; sexes separate. Mostly marine animals; about 10,000 species.

**Class Hirudinae**. Mostly freshwater blood-sucking parasites, also predators and scavengers; some species adapted to humid terrestrial habitats; body flattened with reduced coelom and segmentation; lack chaetae and parapodia; have a definite number of segments and an anterior and posterior sucker for attachment. E.g. leeches.

**PROTOSTOMIA: ECDYSOZOA**

This clade has been created based on molecular data. They all shed their exoskeleton at a certain point in their life cycle. This shedding of the exoskeleton is called **ecdysis**.

**PHYLUM NEMATODA – nematodes, roundworms, hookworms, pinworms, etc.**

A group of worms widely distributed in the soil, fresh and salt-water environments; scavengers, carnivores and parasites. About 90,000 species. They play an important role in decomposition and the recycling of nutrients in the soil.

1. Body bilaterally symmetrical, cylindrical in shape and unsegmented.
2. Body covered with a secreted, flexible, nonliving **cuticle**, which is shed periodically as the animal grows.
3. Fluid in **pseudocoelom** forms a hydrostatic skeleton.
4. Complete digestive system.
5. Excretory system consists of specialized cells and/or canal system; flame cell protonephridia lacking.
6. Circulatory system lacking. Nutrients are distributed through the fluid in the pseudocoelom.
7. Sexual reproduction; sexes separate.

Example: Ascaris, Trichinella (cause of trichinosis)

**PHYLUM ARTHROPODA – arthropods (shrimps, lobster, insects, spiders, scorpions,**

 **centipedes, millipedes, etc.)**

The largest and most diverse phylum with an estimated number of over a billion species found in all habitats. About one million species have been described.

Soft-bodied relatives of the arthropods, as well as trace fossils that were made by some arthropod-like organisms, appear in the Vendian (650-550 mya). However, arthropods underwent rapid evolution in the Cambrian Period (550-505 mya); Cambrian localities like the world-famous Burgess Shale in British Columbia are rich in unusual arthropods, many of which are not obviously related to the traditional classes of living arthropods.

Arthropods have two unusual Hox genes, both of which influence body segmentation. These genes are also present in the phylum Onychophora. Changes in the sequence and regulation of the existing Hox genes are responsible for the diversity of body plan in arthropods.

1. Bilateral symmetry.
2. Body segmented into **head, thorax and abdomen**; in some head and thorax fuse into a **cephalothorax**.
3. Coelom small and filled with fluid and internal organs.
4. **Jointed appendages** that function in locomotion, feeding or copulatory organs.
5. **Exoskeleton** secreted by the epidermis and made of protein, chitin, lipids and minerals; periodic molting (**ecdysis**) to allow growth. The exoskeleton or cuticle can be thick and hard or paper thin and flexible.
6. Respiratory system varied: marine forms use **gills**; terrestrial species have a system of branching tubes called **tracheae** or plate-like structures called **book lungs**.
7. Nervous system consists of a brain, double ventral nerve cord with many ganglia; sense organs well developed. Insects and crustaceans have compound eyes. **Cephalization** is well developed and most sensory organs are found in the head.
8. Muscular system well developed; muscles for rapid motion.
9. **Circulatory system open** with a dorsal tubular heart that pumps the **hemolymph**. The term blood is used for the fluid in a closed circulatory system.
10. Excretory system varied in the different subgroups. **Malpighian tubules** in insects.
11. Reproduction sexual and sexes separate.

**SUBPHYLUM CHELICERATA**

* Six pairs of appendages; first pair of appendages, the chelicerae, are used to manipulate food (pincers or fangs); pedipalps used in sensing; four pairs of walking legs; two part body: cephalothorax and abdomen; lack mandibles and antennae; simple eyes. Classes Merostomata and Arachnida.
* Spiders, scorpions, ticks, mites, horseshoe crabs.

**SUBPHYLUM CRUSTACEA**

* There are about 32,000 species of **Crustaceans**. They have a cephalothorax covered with a carapace, two pairs of biramous antennae, one pair of biramous legs per segment, and mandibles and maxillae. Antennal glands located on the head remove metabolic wastes. Statocysts help in maintaining balance.
* Isopods, crabs, lobsters, shrimps.

**SUBPHYLUM MYRIAPODA**

* Mandibles present; single pair of antennae; uniramous appendages. Classes Insecta, Chilopoda and Diplopoda.
* Myriapods

Centipedes belong to the class **Chilopoda**. There are about 3,000 species of centipedes. They have a head and segmented body, one pair of legs per segment, one pair of uniramous antennae, and mandibles and maxillae.

7,500 species of millipedes form the class **Diplopoda**. They have a head and segmented body, two pairs of legs per segment, a pair of uniramous antennae, mandibles and maxillae.

* Insects

The Class **Insecta** is the most successful group of animals. There are about 750,000 described species grouped into 26 orders. Insects appeared in the middle Devonian about 385 mya. Their body is divided into head, thorax and abdomen, have three pairs of legs, one pair of uniramous antennae, have **tracheal tubes** for gas exchange, open circulatory system and hemolymph, excretory organs called **Malpighian tubules**, a pair of ventral nerve cords, a cerebral ganglion, and undergo metamorphosis.

* Metamorphosis may be **complete** (egg, larva, pupa, adult) or **incomplete** (several nymphs that resemble the adult).
* Insecta are extremely successful due to their adaptations: exoskeleton, sense organs, segmentation, ability to fly, reproductive strategies, mechanisms of defense, etc.
* **Entomology** is the study of insects.

**DEUTEROSTOMES**

Echinoderms and chordates are...

1. Deuterostomes.
2. Radial embryonic cleavage pattern.
3. Indeterminate cleavage: fate of cells is fixed later in development than in protostomes.
4. Mesoderm develops from a pair of pouches that pocket out of the primitive gut: enterocoely.
5. Cavity in mesodermal pockets becomes the coelom.
6. Skeleton of mesodermal origin.

The clade Deuterostomia is also supported by molecular biology.

**PHYLUM ECHINODERMATA – sea stars, sea urchins, sea cucumbers, feather stars.**

1. Coelom well developed, filled with fluid that transports materials.
2. **Larva bilaterally symmetrical**; adult with **radial symmetry** and usually **pentamerous**; complex metamorphosis.
3. Head absent; mouth facing downward.
4. **Endoskeleton** of made of CaCO3 plates and bearing spines; covered with a thin ciliated epidermis.
5. **Water vascular system** consisting of canals filled with seawater through an opening called the **madreporite**; the madreporite is not central but on one side of the center; the water vascular system is derived from the coelom.
6. Free moving animals. Locomotion by **tube fee**t connected to the water vascular system, or by moving the spines or arms.
7. Gas exchange through a variety of structures, e.g. gills, respiratory trees.
8. Excretory system absent; excretion by diffusion.
9. Digestive system complete.

10. Circulatory system very reduced and function uncertain. It may or may not be

 homologous to the circulatory system of other phyla.

1. Nervous and sensory systems are poorly developed; **brain absent**; nerve ring around

the mouth with radiating nerves.

1. Reproduction sexual; sexes separate; external fertilization; a few species

 hermaphroditic.

Echinoderms are carnivorous, bottom dwellers of the sea. They are found at all depths. About 7,000 extant and 13,000 extinct species make the phylum.

**Class Crinoidea** - They dominated the Paleozoic fossil record of echinoderms and shallow marine habitats until the Permo-Triassic extinction, when they suffered a near complete extinction, about 250 mya.

* Body formed by a disc with a leathery skin containing calcareous plates; mouth faces up. Five flexible arms branch form many more arms and lateral pinnules giving a feathery appearance; tube feet on the arms, coated with mucus to trap plankton. Suspension feeders. E.g. Feather stars and sea lilies.

**Class Asteroidea** - Sea stars typically have five arms (though they may have more), which merge gradually with the central disc. Skin gills carry on gas exchange; tiny pincer-like pedicellariae keep the skin free of debris. Mouth facing downward. On the aboral surface can be found the madreporite, a disc sealing the water vascular system and used to equalize the pressure. The female may release as many as 2,500,000 eggs at a time. E. g. starfish.

**Class Ophiuroidea** - Pentamerous (have five arms); arms slender and sharply set off from the distinct central disc; lack pedicellariae; tube feet have no suckers, and not used in locomotion; tube feet may have a sensory function to detect food; ophiuroids use their entire arms for movement. The madreporite is located on the oral surface; anus is absent and undigested food is expelled from the mouth. E.g. Brittle stars

**Class Echinoidea** - Echinoids lack arms and have a compact body encased in a flat shell called **test**. Their pentaradial structure is evident in the arrangement of the ambulacral areas; tube feet and spines used in locomotion. Mouth ringed by complex, jaw-like structure. Examples: Sea urchins, sand dollars

**Class Holothuroidea** - Holothurians are elongated; their body is flexible and soft. They have become secondarily bilateral; their tube feet are well developed along only one ambulacral groove; endoskeleton is reduced to microscopic plates. Practice evisceration as a means of defense. Example: Sea cucumbers.

The class Concentricycloidea is an asteroid –Class Asteroidea – according to molecular data. See below.

**Class Concentricycloidea** - These are small (less than 1 cm in diameter) disk-shaped echinoderms have a concentric vascular ring. Just discovered in 1986, attached to and in crevices in wood. At >1000m off New Zealand and later at about 2000m in the Bahamas. Like echinoids and sea cucumbers but wit no arms. They have a big coelom, with a system with tube feet that have ampullae, and have a calcareous endoskeleton of ossicles. Tube feet in just one row in a circular arrangement along the periphery of the animal. One species has no gut... it absorbs nutrients presumably through the membrane surrounding their body. In the other species, there is a mouth and stomach and no anus. Where they fit is not yet clear. They are called sea daisies.

They live in submerged wood rich in bacteria. Recent cladistic studies have been made using nucleotide sequence in an attempt to understand the relationship among different echinoderm classes.

This Class is dubious taxonomic status and it may be transferred to one of the above after further investigation. See the quotation below:

From the web site: <http://www.ncbi.nlm.nih.gov/CBBresearch/Seminar/1998Spring/07291100>

SEMINAR: Wednesday, July 29, 1998, 11:00 am

Lister Hill Center (NIH BLdg 38A), 8th floor conference room

“As pointed out by Smith (1984, 1988), relationships among echinoderm classes are confused due largely to arbitrary assignment of aberrant forms to high taxonomic rank. Notable among these is Xyloplax. I tested the validity of the 'Class Concentricycloidea' with cladistic analyses of nucleotide sequences and morphology from many echinoderm and hemichordate lineages. The sensitivity of results to various alignment parameters was assayed with tests of taxonomic and character congruence between data partitions. Xyloplax is consistently placed among asteroids. This result is stable over a wide range of analysis parameters and demonstrates that Xyloplax is a recent asteroid rather than a relict stem lineage of echinoderm. Hence, the rank of Class is an inappropriate representation of the evolutionary history of the concentricycloids.”

The relationship of Xyloplax among echinoderms.

Daniel Janies, American Museum of Natural History, New York

**PHYLUM CHORDATA**

The chordates and the echinoderms share an ancient ancestry but both groups diverged over half a billion years. One group did not come from the other.

Chordates will be studied in the next chapter.

Related sites:

<http://www.earthlife.net/inverts/an-phyla.html>

<http://www.yale.edu/ynhti/curriculum/units/1995/5/95.05.08.x.html>

<http://home.entouch.net/dmd/cambevol.htm>

<http://www.manandmollusc.net/taxonomy.html>