Spring 2003

Biology 204 Laboratory 5. Animalia 2- Invertebrates and Vertebrates

We will continue our review of the kingdom Animalia. In this lab we will concentrate on the "higher" animals.

Objectives

1. Understand the distinctive characteristics shared by organisms in the following phyla: Mollusca, Annelida, Nematoda, Arthropoda, Echinodermata, and Chordata.
2. Understand the distinctive characteristics shared by organisms in the following classes: *Mollusca*: Polyplacophora, Gastropoda, Bivalvia, Cephalopoda; *Annelida*: Polychaeta and Oligochaeta; *Arthropoda*: Arachnida, Insecta, Crustacea; *Echinodermata*: Asteroidea, Holothuroidea, Echinoidea.
3. Understand the distinctive characteristics shared by chordates in the following subphyla and classes: *Urochordata, Cephalochordata, Vertebrata:* Myxini, Cephalaspidomorphi, Chondrichthyes, Actinopterygii, Amphibia, Testudines, Lepidosauria, Aves, Mammalia.
4. Recognize how each taxon (phylum, subphylum and class) feeds and deals with living in water or land.
5. Be able to identify an organism on display into its proper phylum and, if appropriate, subphylum and class.

Key Terms

lophophore	enterocoely
segmentation	spiral, determinant cleavage
metamorphosis	radial, indeterminate cleavage
exoskeleton	trochophore larvae
endoskeleton	cuticle
acoelomate	ecdysis
pseudocoelomate	notochord
coelomate	cephalization
schizocoely	pharyngeal gill slits

Key Themes

1. Phylogeny of the animal phyla has changed considerably in the last few years. Classification used to be based on body plans, but molecular data have caused us to rearrange the protostomes.
2. Animals can still be differentiated by body tissues, body cavities, embryological development and larval type.

Samples (refer to the chalkboard for updates)

prepared slides: earthworm (92) *Amphioxus* (93)	representative nematodes
representative molluscs (four classes)	representative arthropods (three classes)
representative annelids (two classes)	representative echinoderms (three classes)
representative chordates (three subphyla and nine classes)	

What to do

Study, draw and describe the specimens. Relate what you see to what you have read in the background information. For each specimen, try to identify most of the structures underlined in the background information; also describe how the animals move their body and body parts. Our survey will be taxonomic and the phyla displayed are arranged in order of evolutionary development. Make sure to study several organisms of each phyla and class plus the prepared slide. Most importantly, enjoy the animals; try to learn as much as possible and develop questions as you observe and describe.

Kingdom Animalia

Subkingdom Eumetazoa- Animals with true tissues. These members of this main subkingdom of the animal kingdom (but also all plants and many fungi) have really figured out what being multicellular can do for an

organism. The first animals that you study will be relatively simple examples, but their tissues already show a great deal of specialization.

Branch Bilateria- animals with **bilateral symmetry** (top, bottom, head, and tail) and varying degress of **cephalization** (concentration of nervous tissue at the anterior end). These animals also have a third germ layer, the **mesoderm**, during embryonic development and are thus **triploblastic**.

Branch Protostomia - animals with **spiral, determinate cleavage** during embryonic development. The coelom forms by **schizocoely** and the **blastopore** becomes the mouth of the adult.

Branch Lophotrochozoa - animals that have **trochophore larvae** and some have **lophophores** (crown of rentacles used for feeding).

Phylum Mollusca ("soft"): molluscs.

Class Polyplacophora ("many-plates bearer"). Marine. Oval shaped, shell divided into eight dorsal plates (but body is not segmented). Foot used for locomotion and attachment to substratum; head is reduced. They graze on algae by rasping with the radula. Chitons.

>> Observe the prepared and living specimens.

Class Gastropoda ("stomach foot"). Most marine, some freshwater or terrestrial. Characterized by **torsion**, the visceral mass of the embryo rotates so that the anus and mantle cavity are placed above the head in the adult. Most are protected by single shells; the formation of a coiled shell is an independent process to that of torsion. Foot used for locomotion and attachment; head is distinctive, with eyes at the tips of tentacles. They graze on algae, some species use the radula to penetrate prey. Internal fertilization and the lining of the mantle cavity, functioning as a lung, allow snails to colonize land. Snails, slugs, limpets, sea hares, abalone.

>> Observe the prepared and living specimens. Observe a crawling snail through a glass fingerbowl. How do gastropods move?

Class Bivalvia ("two valves"). Marine and freshwater. Shells divided in two halves hinged at the mid-dorsal line (thus valves are lateral) and protect the soft body. Foot is hatchet-shaped and used for digging and anchoring. There is no distinct head and the radula has been lost. Most are suspension-feeders and use their gills to trap food particles. Sedentary, but a few can swim by clapping their shells. Clams, mussels, scallops, oysters.

>> Observe the prepared and living specimens. Observe the dissected clam or mussel. What are the two functions of the gills?

Class Cephalopoda ("head foot"). Marine. Shell is external (chambered nautiluses), reduced and internal (squids) or missing (many octopuses). Foot has been modified into arms (tentacles), a muscular siphon, which is used for locomotion, and part of the head. Squids swim through jet propulsion of water, whereas octopuses scurry about on the sea floor. Fast-moving carnivores that capture their prey with tentacles, bite it with beaklike jaws and bring it to the mouth with the tongue-like action of the radula. The only mollusks with a closed circulatory system. Have a well-developed nervous system and a complex brain, traits essential in fast-moving predators. Sense organs are well-developed. Squids, octopuses, chambered nautiluses.

>> Observe the prepared specimens.

General information about Molluscs

True tissues, bilateral symmetry, triploblastic embryos, and coelom. Over 150,000 species in eight classes; most marine, but several in freshwater and some on land. Length: <1 mm to 21 m.

Body: soft but protected in most species by a hard shell made of calcium carbonate. The body has three main parts: a **foot**, usually used for movement, a **visceral mass**, containing most of the internal organs; and a

mantle, a fold of tissue that drapes over the visceral mass and secretes the shell (if present). In many mollusks the mantle extends to produce a water-filled chamber, the **mantle cavity**, which houses the anus and **gills** (portions of the mantle that increase surface area for gas exchange, making it more efficient).

Feeding: grazers that feed on algae or carnivores that capture prey. Most use a strap like rasping organ called a **radula** to scrape food. Mouth, dorsal, ventral, anterior, posterior. bivalves use their gills to filter-feed.

Muscle/nerves: well-developed muscles to move the animal or anchor the body. Nervous system developed at various levels, reaching its peak complexity in cephalopods.

Reproduction: most have separate sexes, but many snails are hermaphrodites. Many marine mollusks go through a life cycle that includes ciliated larva called the **trochophore**, followed in most marine snails and in bivalves by a second free-swimming stage, the **veliger**.

Evolutionary notes: the coelom gives a new body design, which allows the development of complex tissues and organs, novel body architectures and body sizes larger than those found in acoelomates. The shell and mantle cavity protect the organism and provide efficient respiration, helping mollusks diversify into fast predators and burrowing and terrestrial forms.

Phylum Annelida ("little rings"): segmented worms.

Class Polychaeta ("many bristles"). Most marine. Well-developed head; each segment has usually fleshy, paddlelike flaps (**parapodia**) bearing many setae. Tube-dwelling and free-living.

>> Observe the prepared and living specimens.

Class Oligochaeta ("few bristles"). Terrestrial and freshwater. Reduced head; no parapodia, a few setae present. Its reproductive system and the use of skin as a respiratory organ have assisted in the exploitation of terrestrial environments. Earthworms and relatives.

>> Observe the prepared and living specimens. Compare the movement of polychaetes and oligochaetes. Observe the slide of the earthworm (#92). Identify the digestive tract, the outer body wall, and the coelom. Are oligochaetes pseudocoelomates or true coelomates?

General Information about Annelids
True tissues, bilateral symmetry, triploblastic embryos, and coelom. About 15,000 species in three classes; marine, freshwater and damp soil. Length: <1 mm to over 3 m.

Body: body wall and internal organs are segmented (except the digestive tract), resembling a series of fused rings. Internally, these segments are divided by partitions called **septa**. Most groups have **setae**, bristles of chitin that help anchor the worms during locomotion.

Feeding: polychaetes are filter feeders or carnivores; oligochaetes eat detritus, aerating and improving soil texture. Both have a closed circulatory system. Mouth, anus, ventral, dorsal.

Muscle/nerves: circular muscles around each segment contract to provide movement. The front segments have been modified to contain sense organs and a well-developed brain.

Reproduction: most polychaetes have separate sexes, life cycle includes a trochophore larvae; oligochaetes are hermaphrodites, fertilized eggs develop into young worms inside the adult.

Evolutionary notes: having a body built from repeated units (segments) allows a more precise control of the development and function of individual segments or groups of segments.

Branch Protostomia - animals with **spiral, determinate cleavage** during embryonic development. The coelom forms by **schizocoely** and the **blastopore** becomes the mouth of the adult.

Branch Ecdysozoa - animals that secrete **exoskeletons** (external skeletons).

Phylum Nematoda ("thread form"): roundworms.

>> Observe the prepared and living specimens. How do these worms move compared to the annelids and the nemerteans?

General information about Nematodes
True tissues, bilateral symmetry, triploblastic embryos and pseudocoelom. About 90,000 species known in two classes. Found in most aquatic habitats, wet soils and inside plants and animals. Length: <1 mm to over 1 m.

Body: cylindrical, not segmented. The posterior end has a fine tip whereas the anterior end has a blunt tip. A tough exoskeleton called a **cuticle** covers the body; as the worm grows, it periodically sheds its old cuticle (molting) and secretes a new, larger one. Dorsal, ventral.

Feeding: some eat animals, others eat algae and fungi, many eat detritus and are important in nutrient cycling, many are parasites of plants and animals. Mouth is often equipped with piercing organs called **stylets.** Have a complete digestive tract but no circulatory system.

Muscle/nerves: muscles are longitudinal and their contraction produces a thrashing motion. There are hair-like sensory organs near the mouth.

Reproduction: mostly sexual, most have separate sexes.

Evolutionary notes: the pseudocoelom serves as a hydrostatic skeleton against which the muscles can work, making movement more efficient than in acoelomates.

Phylum Arthropoda ("joint foot"): arthropods.

Class Arachnida. Mostly terrestrial. Have a **cephalothorax** (head and thorax as one region) with six pairs of appendages: **chelicerae** (a pair of clawlike feeding appendages, the foremost ones in the body), **pedipalps** (a pair of appendages usually functioning in sensing or feeding) and four pairs of walking legs. Spiders are carnivores that use their chelicerae to inject poison into and **masticate** (chew) their prey; they spill digestive juices and suck up the liquid meal. Many spiders have the unique adaptation of catching flying insects by stringing webs of **silk**, a protein produced as a liquid by special abdominal glands. Scorpions are nocturnal carnivores and their pedipalps have been modified as pincers for defense and capture of food; the tip of the tail bears a poisonous stinger. Ticks and mites are parasites in vertebrates and invertebrates.

>> Observe the prepared and living specimens.

Class Insecta. Have the largest number of species of any life form. Mostly terrestrial, also freshwater and aerial, rare in the sea. Body divided into head, thorax and abdomen. Possess jawlike structures called **mandibles**. Antennae present. Most with one or two pairs of wings, which are extensions of the cuticle, and three pairs of legs. During development many undergo **metamorphosis**, either **incomplete** (young resemble adults, but are smaller and have different body proportions) or **complete** (have larval stages specialized for eating and growing and look different from the adult stage, which is specialized for dispersal and reproduction). Herbivores, carnivores, scavengers, detritus eaters, parasites. Beetles, lice, flies, mosquitoes, ants, bees, wasps, termites, butterflies, moths, crickets, dragonflies, fleas, mantids.

>> Observe the prepared and living specimens. What are some advantages to having a larval stage?

Class Crustacea. Mostly marine. Multiple appendages that are extensively specialized. The only arthropods with two pairs of antennae present. Three or more pairs of appendages have been modified as

mouthparts, including the hard mandibles. Three or more pairs of legs. Filter-feeders, plankton eaters, carnivorous, detritus eaters, parasites, scavengers. Crabs, lobsters, crayfish, shrimp, isopods, barnacles, copepods.

>> Observe the prepared and living specimens. What are the advantages and disadvantages of an exoskeleton?

General Information about Arthropods
True tissues, bilateral symmetry, triploblastic embryos, coelom and **ecdysis** (molt). Characterized by segmentation, hard **exoskeleton** (external skeleton) and jointed appendages. Over 1,000,000 species, most of them insects. Arthropods are the most diverse, widely distributed and abundant of all animal phyla. Length: 0.1 mm to 1.2 m.

Body: completely covered by the **cuticle**, an exoskeleton constructed from layers of protein and chitin. The cuticle is relatively impermeable to water and is strong enough to protect the animal and to provide points of attachment for the muscles that move the appendages. Arthropods molt their exoskeleton, that is shed the old one and secrete a new one.

Feeding: See descriptions for each class.

Muscle/nerves: well-developed muscles and sensory organs such as eyes, **olfactory receptors** (for smell) and antennae for touch and smell. Extensive **cephalization** (concentration of sensory equipment in the anterior end of the body). Many species have **compound eyes** (composed of many independent visual units), while some have **simple eyes** or **ocelli** (composed of single lenses).

Reproduction: Usually sexual, with separate sexes. Fertilization tends to be internal in terrestrial species and external in aquatic ones, which go through a larval stage.

Evolutionary notes: segmentation allowed groups of body segments and their appendages to specialize into a variety of functions resulting in an efficient body plan by the division of labor among segments and appendages and a great diversification of forms. The strength and relatively impermeability to water of the cuticle allowed many groups to move onto land by solving the problem of water loss and structural support. Flight has been a key to the success of insects, allowing them to escape predators, find food and mates, and disperse to new habitats. These three characteristics have made of arthropods in general and insects in particular the most successful animal form.

Branch Bilateria- animals with **bilateral symmetry** (top, bottom, head, and tail) and varying degress of **cephalization** (concentration of nervous tissue at the anterior end). These animals also have a third germ layer, the **mesoderm**, during embryonic development and are thus **triploblastic**.

Branch Deuterostomia - animals with **radial, indeterminate cleavage** during embryonic development. The coelom forms by **enterocoely** and the **blastopore** becomes the anus of the adult.

Phylum Echinodermata ("spiny skin"): echinoderms.

Class Holothuroidea. Elongated in the oral-aboral axis. Possess five rows of tube feet, some of which have developed into tentacles around the mouth. Lack spines, the hard endoskeleton is reduced to widely separated microscopic plates. When irritated eject a portion of their intestines. Some are hermaphroditic. Suspension- or detritus-feeders. Sea cucumbers.

>> Observe the prepared and living specimens. How do echinoderms move?

Class Echinoidea. Skeletal elements flattened and sutured into a solid case called **test**, with five rows of tube feet underneath. The mouth is found in the center of the oral surface and has five jawlike structures called **Aristotle's lantern** to scrape algae and gather detritus. The dominant grazers of kelp and other algae,

can also subsist on animal matter. Well-developed spines, a mechanical defense that can orient towards potential threats and pedicellaria. In some species pedicellaria also have a poison gland. Sea urchins (spherical), sand dollars (flattened).

>> Observe the prepared and living specimens. Observe the sea urchin and the sand dollar under a dissecting microscope.

Class Asteroidea. Body composed of arms projecting from a central disc. The madreporite is to the side of the center and the mouth is found in the center of the oral surface. Most are carnivores, eating even fish captured by pedicellaria, and evert their stomach, which either engulfs prey or digests it outside. Everted stomach is inserted through tiny openings between the imperfectly sealed edges of the valves of mussels or clams. Regeneration possible when at least 1/5 of central disc is attached to an arm. Eye spots at tip of arms to detect dark and light. They also detect prey through chemical stimuli. Sea stars.

>> Observe the prepared and living specimens. How are the body plans of these three echinoderm classes related to each other?

General Information about Echinoderms
True tissues, bilateral symmetry (larvae), triploblastic embryos, coelom and deuterostomic development. Sessile or slow-moving animals. About 7,000 species, all marine, in six classes. Length: 1-2 mm to 1 m.

Body: **pentamerous radial symmetry** in adults: the body can be divided into five parts arranged around a central axis. Only group with a **water-vascular system**, a unique system of fluid-filled tubes that begins in an opening called **madreporite** and terminates in blind-ending **tube feet**. Tube feet are used for locomotion, food gathering, and gas exchange. Possess an **endoskeleton** (internal skeleton) composed of movable or fixed plates called **ossicles** and elements that project outwards in the form of **spines** or **tubercles**. Many possess **pedicellaria**, thin, flexible stalks manipulated by muscles and with three jaws apiece that offer protection against predators and larvae attempting to settle on them (that's why they are not covered by algae or barnacles).

Feeding: See descriptions for each class.

Muscle/nerves: See descriptions for each class.

Reproduction: Mostly sexual, with separate sexes and external fertilization. Some species brood the fertilized eggs. Larvae is bilateral, differs from the trochophore larvae of mollusks and annelids and may take several months to finish development. Many are able to regenerate lost parts.

Evolutionary notes: first appearance of deuterostome development and endoskeleton. The endoskeleton is functionally similar to the exoskeleton of arthropods: a hard shell that encases the body, with muscles attached to its inner surface. These types of skeleton limit the body size that animals can reach because they become very heavy and cumbersome since they need to grow as the body grows in order to encase it. Echinoderms used to be classified with the Radiata due to the pentamerous symmetry of the adults (the larvae are bilateral).

Phylum Chordata: chordates.

General Information about Chordates
True tissues, bilateral symmetry, triploblastic embryos, coelom, segmentation, jointed appendages and deuterostomic development. Length: <1 mm to 30 m.

Characterized by four structures that appear at some point during their lifetime, often only during embryonic development:
-**Notochord**. Longitudinal, flexible rod between the digestive tube and the nerve cord. In most vertebrates it remains as a remnant (e.g. gelatinous material between the disks of the vertebral column).
-**Dorsal, hollow nerve cord**. In vertebrates develops into the central nervous system: brain and spinal cord.

-**Pharyngeal slits**. The region of the digestive tube posterior to the mouth is the **pharyn**x, which opens to the outside through several pairs of slits and allows water to exit without continuing through the digestive tube. The slits function as suspension-feeding devices in invertebrate chordates and have been modified for gas exchange in sharks, fishes and other aquatic vertebrates, jaw support, hearing and other functions.
-**Muscular, postanal tail**. The tail extends beyond the anus and provides much of the propulsive force in many aquatic species.

Muscles are arranged in segmented blocks. Most chordates have an internal skeleton that differs from the endoskeleton of echinoderms, instead of being a hard shell encasing the body, the skeleton is truly internal and jointed.

Subphylum Urochordata: tunicates or sea squirts.
Most are sessile marine animals, some are colonial. Water enters through an incurrent siphon, passes through the pharyngeal slits into a chamber called **atrium** and exits through an excurrent siphon or **atriopore**. Filter-feeders that trap food with a mucous net. The animal is encased in a **tunic** made of celluloselike carbohydrate. Adults scarcely resemble a chordate, yet larvae presents all four chordate characteristics.

>> Observe the prepared and living specimens. Is the notochord found in the adult? If not, at what stage is it found?

Subphylum Cephalochordata: lancelets.
Resemble an idealized chordate, adults possess all four chordate traits. Small, burrowing animals that live along sea coasts. Filter feeders that trap with mucus food particles drawn into the mouth by beating cilia, the water exits through the pharyngeal slits. Muscles are serially arranged like rows of chevron (<<<<<<) along the sides of the notochord and their contraction produces side-to-side movements that thrust the body forward. This serial musculature is evidence of the segmentation found in chordates. The mouth is surrounded by sensory tentacles. They frequently swim to new locations, displaying in a very simple form the swimming mechanism of fishes. Nerve cord, tail.

>> Observe the slide of *Amphioxus* (#93). Identify all four of the chordate traits.

Subphylum Vertebrata: vertebrates.
Many of the characteristic features of vertebrates are associated with large size and an active lifestyle:
-**Vertebral column**. Series of bones that enclose a protects the dorsal nerve cord. Not found in Myxini.
-**Head**. Distinct and well-differentiated head, with **cranium** (skull) and brain.
-**Neural crest**. Unique group of embryonic cells that participate in the development of various structures.
-**Endoskeleton**. Made of bone or more flexible cartilage, specialized tissues containing fibers of collagen compacted together; bone also contains crystals of calcium phosphate.
-**High degree of cephalization**. Presence of cranium, elaboration of brain and presence of paired sensory organs on head (eyes, ears, nose, etc.).

>> Observe the prepared and living specimens.

Class Myxini. All marine. Mostly bottom-dwelling scavengers. Slime glands along the sides secrete a slimy substance used to repel other scavengers and for protection against predators. Cartilaginous skeleton. No vertebrate column, no paired appendages, no jaws. Mostly blind, well-developed sense of smell. Hagfishes. Head, slime glands, tentacles, ventral, dorsal, anterior, posterior, mouth.

Class Cephalaspidomorphi. Marine and freshwater environments. Clamp their round mouth onto the flank of a live fish, using a rasping tongue to penetrate the skin of the prey and ingest their blood. Cartilaginous skeleton, vertebrate column. No paired appendages, no jaws. Lampreys. Head, mouth, horny teeth, eye, nostril, external gill slits, tail, dorsal fins, muscle segments, ventral, dorsal, anterior, posterior.

Class Chondrichthyes. Marine and freshwater environments. Cartilaginous skeleton, vertebrate column, skin covered by tooth-like scales. Most species have strengthened parts of their skeleton and have bony teeth. Sharks have streamlined bodies and well-developed jaws and fins; most are carnivores that

swallow prey whole or use their powerful jaws and teeth to tear flesh from animals, some are filter-feeders. Sharp black and white vision and well-developed senses of smell and electric fields in the head and of water pressure along the flanks (**lateral line system**). Most rays are flattened bottom-dwellers that crush invertebrates with their jaws, some live in open water and filter food. Sharks, rays, mantas, chimaeras. Mouth, eye, nostril, external gill slits, tail, ventral, dorsal, anterior, posterior.

Class Actinopterygii. Marine and freshwater environments. Ossified skeleton, vertebrate column, skin often covered by flattened, bony scales. Glands in the skin secrete a mucus that reduces drag during swimming. Well-developed lateral line system, jaws and fins, which are mainly supported by long flexible rays. A protective flap called the operculum covers the gills. Ray-finned fishes: tuna, herring, sardines, rockfishes, etc. Mouth, eye, nostril, tail, ventral, dorsal, anterior, posterior.

Class Amphibia. Aquatic and terrestrial environments. Ossified skeleton and vertebrate column. Characterized by moist skin, legs (secondarily lost in some species) and lungs (usually). Still tied to water for reproduction and are most abundant in damp habitats. Most are carnivores and many go through a metamorphosis. Skin glands secrete distasteful or poisonous mucus as a protection against predators. Frogs, toads, salamanders, newts and caecilians. Mouth, jaws, eye, nostril, tail, legs, ventral, dorsal, anterior, posterior.

Class Testudines. Terrestrial, marine and freshwater environments. Ossified skeleton, vertebrate column, legs. Characterized by a hard shell, to which vertebrae and ribs are fused. Development of **amniote egg** (embryo forms four extraembryonic membranes) with a shell that prevents desiccation. They have a sharp, horny beak without teeth, most are carnivorous or eat plant or algae. Turtles, sea turtles, tortoises. Mouth, jaws, eye, nostril, tail, legs, ventral, dorsal, anterior, posterior.

Class Lepidosauria. Terrestrial, some in marine and freshwater environments. Ossified skeleton, vertebrate column, legs (lost in snakes). Amniote egg with a shell that prevents desiccation. Most are carnivores with acute chemical (odor through the flicking tongue), ground vibration and heat sensors. They also have loose articulated jaws that enable them to swallow large prey, some inject poison into their prey. Tuataras, lizards and snakes. Mouth, jaws, eye, tongue, teeth, nostril, tail, legs, scales, ventral, dorsal, anterior, posterior.

Class Aves. Mostly in terrestrial environments, some in marine and freshwater environments. Most species move by flying. Ossified skeleton, vertebrate column, legs and wings. Characterized by a skin covered with feathers and a light and hollow skeleton adapted for flying. Amniote egg with a shell that prevents desiccation. Mouth developed into a beak. Carnivores, plant-eaters, filter-feeders. Kiwis, penguins, chickens, hawks, parrots, gulls, juncos, canaries, etc.

Class Mammalia. Mostly terrestrial, some in marine and freshwater environments. Ossified skeleton, vertebrate column, legs (lost in some). Characterized by a skin covered with hair (reduced or absent in some species) and mammary glands in the females to provide milk to the young. Amniote egg, but the embryo does not develop a shell. Carnivores, plant-eaters, filter-feeders. Humans, dogs, bats, rats, sloths, shrews, opossums, koalas, etc. Mouth, jaws, eye, teeth, nostril, tail, legs, ventral, dorsal, anterior, posterior.

Evolutionary notes: the notochord allowed the attachment of muscles and allowed early chordates to swing their backs from side to side, swimming through water. In vertebrates, the ability to attach muscles to a truly internal, jointed and strong but not brittle skeleton that grows with the body has permitted rapid, versatile movement (active lifestyle) and large body sizes.