GEORGIA HIGHLANDS COLLEGE

# General Zoology-Biol 2154

## Laboratory Manual

**GHC updated**

**Fall 2015**

# Microscopy

Microscopes are one of the most important tools scientists have in their arsenal. In this course we will look at many organisms that are too small to see in detail with the naked eye or even see at all. The microscope will help us define the structures that make each group of organisms unique. By looking at these characteristics we can make inferences on where this organism lives, how it gets it energy and nutrients, and how it might reproduce. These are all important characteristics in Zoology.

For this lab your instructor will provide various live organisms as well as prepared slides for you to observe. Practice making observations with the naked eye, the dissecting scope, and the compound scope.

**Amoeba**

Describe what the Amoeba looks like:

Does it move? If so, how?

Is there any indication of how it feeds? If yes, how? If no hypothesize on how it might get nutrients.

**Paramecium**

What does a paramecium look like?

Does it move? If so how?

Any indication of how it feeds? If yes, how? If not hypothesize how it might get nutrients.

**Hydra**

What does the hydra look like?

Does it move? If so how?

Any indication of how it feeds? If yes, how? If not hypothesize how it might get nutrients.

**Daphnia**

What does the hydra look like?

Does it move? If so how?

Any indication of how it feeds? If yes, how? If not hypothesize how it might get nutrients.

Important things to remember:

- Based on what you saw how would you describe each organism's method of gathering food?
- What organism was single celled and what was multi-cellular?
- Were all the organisms observed today animals? Which ones were not?
- Based on the descriptions you made which organisms are more closely related to each other?

# CLASSIFICATION AND EVOLUTION

Caminalcules are imaginary animals invented by the evolutionary biologist Joseph Camin. They make ideal organisms for introducing students to two related topics: taxonomic classification and evolution. In this lab exercise the students first classify 14 "living"species into genera, families, etc. Then they construct an evolutionary tree of the Caminalcules using an additional 42 "fossil" species. This illustrates how modern classification schemes attempt to reflect evolutionary history. In the process of doing this exercise the students are also introduced to concepts such as convergent evolution and vestigial structures.



This lab has been modified with premission from Robert P. Gendron at Indiana University of Pennsylvania:

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*Note that in my lab I use only a subset of all the 77 Caminalcules. To use the entire set would increase the time needed to complete the lab without appreciably increasing its educational value. Thus, the phylogenetic tree that is reproduced here is a “pruned” version of the original; I digitally removed those branches that are not represented by my subset of Caminalcules. If you want the entire set of Caminalcules and the complete phylogenetic tree you can scan in the pictures from the original source (Sokal, R.R. 1983. A phylogenetic analysis of the Caminalcules. I. The data base. Systematic Zoology 323:159-184).

# CLASSIFICATION AND EVOLUTION

Humans classify almost everything, including each other. This habit can be quite useful. For example, when talking about a car someone might describe it as a 4-door sedan with a fuel injected V-8 engine. A knowledgeable listener who has not seen the car will still have a good idea of what it is like because of certain characteristics it shares with other familiar cars. Humans have been classifying plants and animals for a lot longer than they have been classifying cars, but the principle is much the same. As an example, biologists classify all organisms with a backbone as "vertebrates." In this case the backbone is a characteristic that defines the group. If, in addition to a backbone, an organism has gills and fins it is a fish, a subcategory of the vertebrates. This fish can be further assigned to smaller and smaller categories down to the level of the species. The classification of organisms in this way aids the biologist by bringing order to what would otherwise be a bewildering diversity of species. (There are probably several million species - of which about one million have been named and classified.) The field devoted to the classification of organisms is called **taxonomy** [Gk. taxis, arrange, put in order + nomos, law].

The modern taxonomic system was devised by **Carolus Linnaeus** (1707-1778). It is a **hierarchical** system since organisms are grouped into ever more inclusive categories from species up to kingdom. Figure 1 illustrates how four species are classified using this taxonomic system. Note that it is standard practice to *italicize* the genus name and specific epithet.

| | | | | |
|---|---|---|---|---|
| KINGDOM | Animalia | | | Plantae |
| PHYLUM | Chordata | | Arthropoda | Angiospermophyta |
| CLASS | Mammalia | | Insecta | Monocotyledoneae |
| ORDER | Primate | Carnivora | Hymenoptera | Liliales |
| FAMILY | Hominidae | Canidae | Apidae | Liliaceae |
| GENUS | *Homo* | *Canis* | *Apis* | *Alium* |
| SPECIES | *sapiens* | *lupus* | *mellifera* | *sativum* |
| | (human) | (wolf) | (honeybee) | (garlic) |

Figure 1

As a consequence of Darwin's work it is now recognized that taxonomic classifications are actually **reflections of evolutionary history**. For example, Linnaeus put humans and wolves in the class Mammalia within the phylum Chordata because they share certain characteristics (e.g. backbone, hair, homeothermy, etc.). We now know that this similarity is not a coincidence; both species inherited these traits from the same **common ancestor**. In general, the greater the resemblance between two species, the more recently they diverged from a common ancestor. Thus when we say that the human and wolf are more closely related to each other than either is to the honeybee we mean that they share a common ancestor that is not shared with the honeybee.

Another way of showing the evolutionary relationship between organisms is in the form of a **phylogenetic tree** (Gk. phylon, stock, tribe + genus, birth, origin):

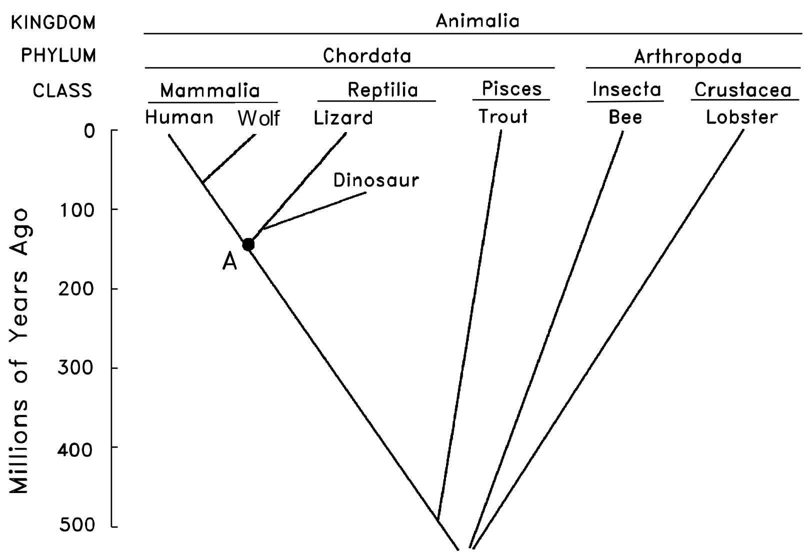



Figure 2

The vertical axis in this figure represents time. The point at which two lines separate indicates when a particular lineage split. For example, we see that mammals diverged from reptiles about 150 million years ago. The **most recent common ancestor** shared by mammals and reptiles is indicated by the point labeled A. The horizontal axis represents, in a general way, the amount of divergence that has occurred between different groups; the greater the distance, the more different their appearance. Note that because they share a fairly recent ancestor, species within the same taxonomic group (e.g. the class Mammalia) tend to be closer to each other at the top of the tree than they are to members of other groups.

There are, however, pitfalls with the approach of creating groups based on characteristics. For example, some species resemble each other because they independently evolved similar structures in response to similar environments or ways of life, not because they share a recent common ancestor. This is called **convergent evolution** because distantly related species seem to converge in appearance (become more similar). Examples of convergent evolution include the wings of bats, birds and insects, or the streamlined shape of whales and fish. At first glance it might appear that whales are a type of fish. Upon further examination it becomes apparent that this resemblance is superficial, resulting from the fact that whales and fish have adapted to the same environment. The presence of hair, the ability to lactate and homeothermy clearly demonstrate that whales are mammals. Thus, the taxonomist must take into account a whole suite of characteristics, not just a single one.

The fossil record can also be helpful for constructing phylogenetic trees. For example, bears were once thought to be a distinct group within the order Carnivora. Recently discovered fossils, however, show that they actually diverged from the Canidae (wolves, etc.) fairly recently. The use of fossils is not without its problems, however. The most notable of these is that the fossil record is incomplete. This is more of a problem for some organisms than others. For example, organisms with shells or bony skeletons are more likely to be preserved than those without hard body parts.

**The Classification and Evolution of Artificial Organisms**

In this lab you will develop a taxonomic classification and phylogenetic tree for a group of imaginary organisms called **Caminalcules** after the taxonomist Joseph Camin who devised them. At the back of this lab are pictures of the 14 "living" and 42 "fossil" species that you will use. Take a look at the pictures and note the variety of appendages, shell shape, color pattern, etc. Each species is identified by a number rather than a name. For fossil Caminalcules there is also a number in parentheses indicating the geological age of each specimen in millions of years. Most of the fossil Caminalcules are extinct, but you will notice that a few are still living (e.g. species #24 is found among the living forms but there is also a 2 million year old fossil of #24 in our collection).

**Exercise 1: The Taxonomic Classification of Living Caminalcules**

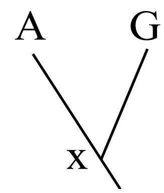
Carefully examine the fourteen <u>living</u> species and note the many similarities and differences between them. On a sheet of notebook paper create a hierarchical classification of these species, using the format in Figure 3. Instead of using letters (A, B, ...), as in this example, use the number of each Caminalcule species. Keep in mind that Figure 3 is just a hypothetical example. Your classification may look quite different than this one.

<table>
<tr><td colspan="12">PHYLUM CAMINALCULA</td></tr>
<tr><td colspan="7">CLASS 1</td><td colspan="5">CLASS 2</td></tr>
<tr><td colspan="7">ORDER 1</td><td colspan="3">ORDER 2</td><td colspan="2">ORDER 3</td></tr>
<tr><td colspan="5">FAMILY 1</td><td colspan="2">FAMILY 2</td><td colspan="3">FAMILY 3</td><td colspan="2">FAMILY 3</td></tr>
<tr><td colspan="2">GENUS 1</td><td colspan="2">GENUS 2</td><td>GENUS 3</td><td colspan="2">GENUS 4</td><td colspan="3">GENUS 5</td><td colspan="2">GENUS 6</td></tr>
<tr><td>A</td><td>G</td><td>H</td><td>D</td><td>B</td><td>J</td><td>L</td><td>E</td><td>K</td><td>C</td><td>F</td><td>I</td></tr>
</table>

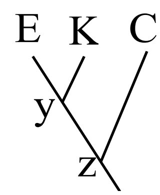
Figure 3

The first step in this exercise is to decide which species belong in the same genus. Species within the same genus share characteristics not found in any other genera (plural of genus). The Caminalcules numbered 19 and 20 are a good example; they are clearly more similar to each other than either is to any of the other living species so we would put them together in their own genus. Use the same procedure to combine the genera into families. Again, the different genera within a family should be more similar to each other than they are to genera in other families. Families can then be combined into orders, orders into classes and so on. Depending on how you organize the species, you may only get up to the level of order or class. You do not necessarily have to get up to the level of Kingdom or Phylum.

**Exercise 2. The Comparative Approach to Phylogenetic Analysis**




Construct a phylogenetic tree based only on your examination of the 14 living species. This tree should reflect your taxonomic classification. For example, let us say you have put species A and G into the same genus because you think they evolved from a common ancestor (*x*). Their part of the tree would look like the diagram on the right.




When there are three or more species in a genus you must decide which two of the species share a common ancestor not shared by the other(s). This diagram indicates that species E and K are more closely related to each other than either is to C. We hypothesize that E and K have a common ancestor (y) that is not shared by C. Similarly, two genera that more closely resemble each other than they do other genera presumably share a common ancestor. Thus, even in the absence of a fossil record it is possible to develop a phylogenetic tree. We can even infer what a common ancestor like y might have looked like.

**Exercise 3. The Phylogeny of Caminalcules**

Using a large sheet of paper, construct a phylogenetic tree for the Caminalcules. Use a meter stick to draw 20 equally spaced horizontal line on the paper. Each line will be used to indicate an interval of one million years. Label each line so that the one at the bottom of the paper represents an age of 19 million years and the top line represents the present (0 years).

Cut out all the Caminalcules (including the living species). Put them in piles according to their age (the number in parentheses). Beginning with the oldest fossils, arrange the Caminalcules according to their evolutionary relationship. Figure 4 shows how to get started.

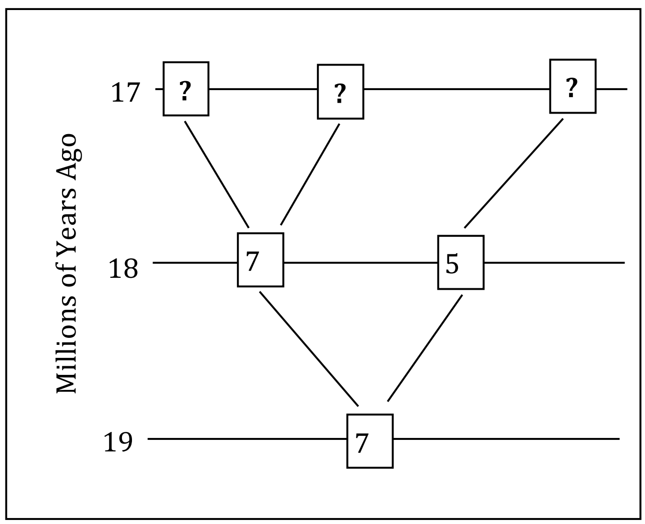
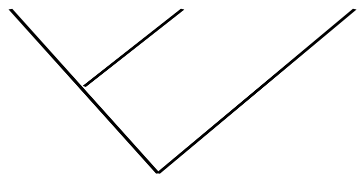



Figure 4

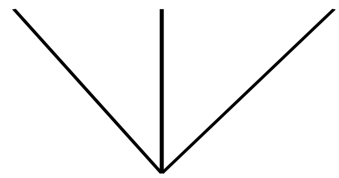
**Hints, Suggestions and Warnings**

a. Draw lines faintly in pencil to indicate the path of evolution. You may change your mind as you continue

b. Branching should involve only two lines at a time:



Like this



Not this

c. Some living forms are <u>also</u> found in the fossil record.

d. There are gaps in the fossil record for some lineages.

e. The Caminalcules were numbered at random; the numbers provide no clues to evolutionary relationships.

f. There is only one correct phylogenetic tree in this exercise. This is because of the way that Joseph Camin derived his imaginary animals. He started with the most primitive form (#73) and gradually modified it using a process that mimics evolution in real organisms. **After you complete your phylogeny compare it with Camin's original (posted afer lab on D2L) and turn in next class with the answers to the problems below for a quiz grade.**

**Problems**

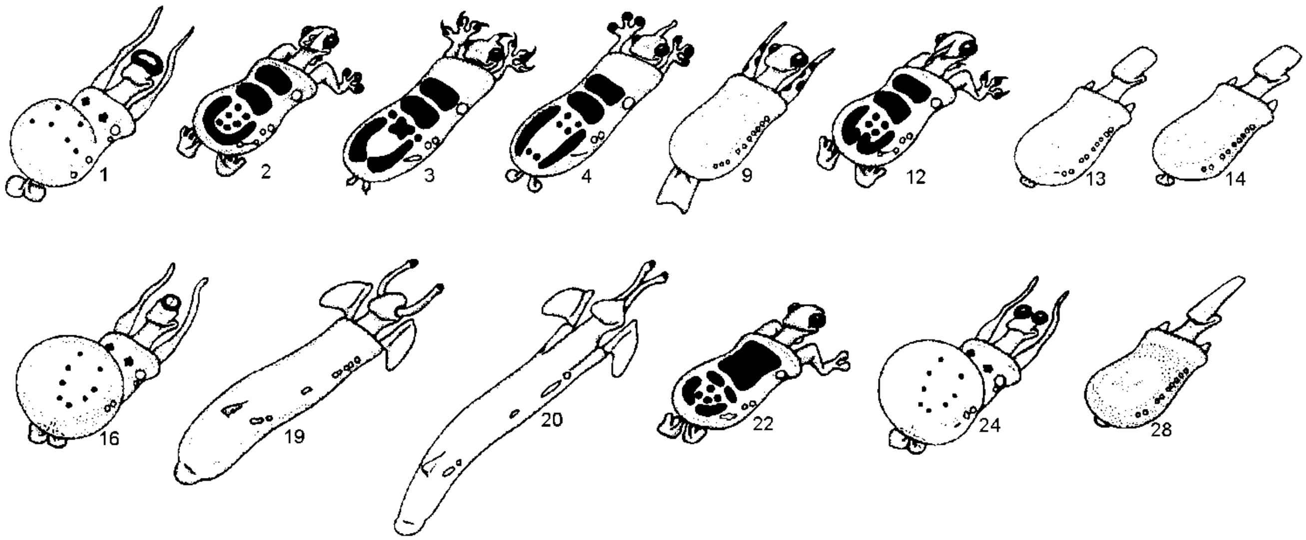
1. You will notice that some **lineages** (e.g. the descendants of species) branched many times and are represented by many living species. Discuss the ecological conditions that you think might result in the rapid diversification of some lineages (A real world example would be the diversification of the mammals at the beginning of the Cenozoic, right after the dinosaurs went extinct.)

2. Some lineages changed very little over time. A good example of this would be “living fossils” like the horseshoe crab or cockroach. Again, discuss the ecological conditions that might result in this sort of long-term evolutionary stasis.

3. Find two additional examples of **convergent evolution** among the Caminalcules. This means finding cases where two or more species have a similar characteristic that evolved independently in each **lineage**. The wings of bats, birds and bees is an example of convergence since the three groups did not inherit the characteristic from their **common ancestor**.

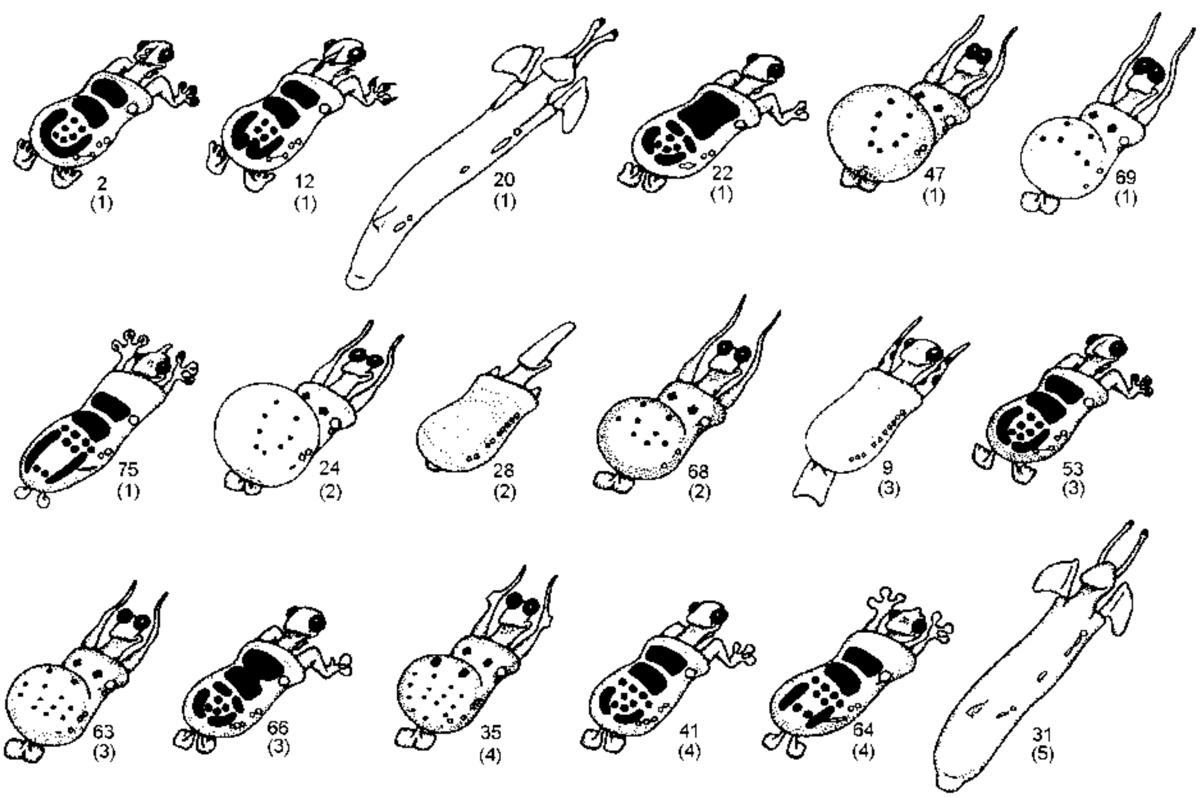
4. List two additional real-world examples of convergent evolution (ones that we have not already talked about in class) and discuss what might have caused the convergence.

**LIVING CAMINALCULES**

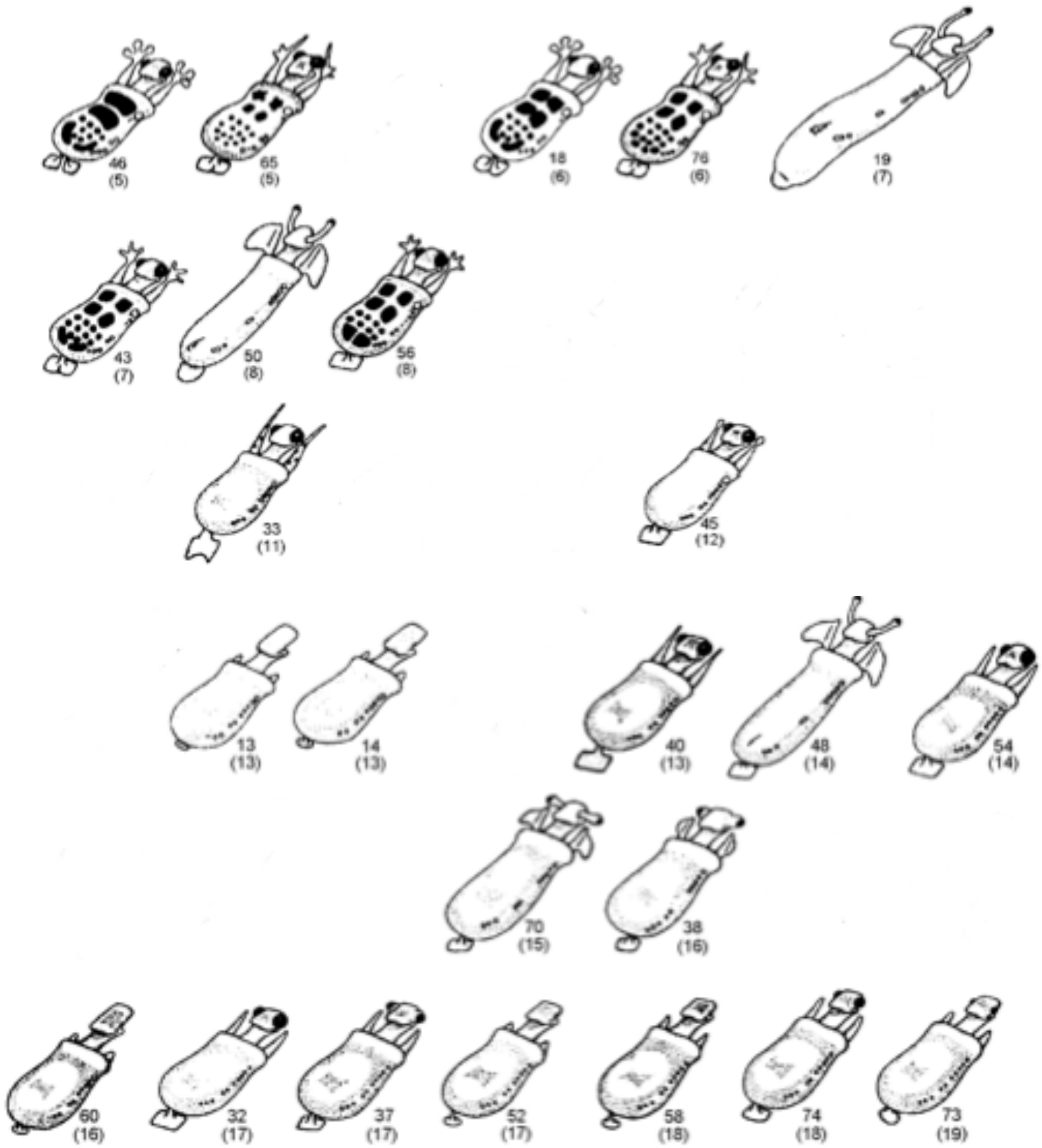



**FOSSIL CAMINALCULES**

(numbers in parentheses indicate age in millions of years)



**FOSSILS** (continued)



# Natural selection

Ancient Greek, Romans and Chinese all had philosophies which formed the basis for evolution. In the 1700's geologist began to notice that there was a pattern in fossils within rock strata, which led many to begin looking at the fossil record comparatively and seeing changes in organisms over time. By the 1800's evolution was becoming well studied and solidified in the scientific community; however the mechanism of how it worked was heavily debated.

In the early part of the 1800's a well-known French biologist named Jean-Baptiste Lamarck came up with the first full mechanism for how evolution worked. He stated that all organisms evolved based on acquired characteristics in a progression from simple to complex forms. However innovative Lamarck was, his theory had many flaws, but remained the most complete answer to the mechanism of evolution at the time. In 1859 a man named **Charles Darwin** published his now world famous book *On the Origin of Species*. In his book he proposes a new mechanism for evolution called natural selection, which is widely accepted amongst the scientific community as the main mechanism for evolution.

**Natural selection** is defined as a difference, on average, between the survival or fecundity of individuals with certain phenotypes compared with individuals with other phenotypes. What this means is an organism that has an adaptation that allows it to survive to reproduce more will be more likely to pass on that adaptation than another of the same species without that adaptation.

In nature we see rapid evolution by natural selection in predator and prey populations. This is because there is heavy pressure for the prey to escape or avoid predation (by camouflage, change in behavior, change in size etc…) and heavy pressure for the predator to continue to predate on this ever changing prey. In this experiment we will be simulating a predator population that has multiple methods for gathering prey and also a varied prey population with different levels of camouflage and sizes.

## Procedure

Each group will have 2 of each feeding types: Spoons, probes, Tweezers, Scoop, Scissors. Divide these up amongst your group members so that each feeding type is used at least once. There will also need to be one person designated as the time keeper.

### Habitat set up

On each bench spread out your cup of gravel evenly in the habitat area. Then place your cup of 100 beans of each type in the habitat as well.

### Predation

For one minute the predators (you) will collect the bean bunnies with your feeding mechanism **and only your feeding mechanism (no hands)!** After one minute count and record the total of each bean type you "ate" for each feeding mechanism and record this on the provided answer sheet.

**Mating time!**

For the remaining beans we assume everyone mates equally. Use the sheet provided to calculate how many of each bean to add back to your table for generation 2 (3, 4, and 5). This should always reach 400, our **carrying capacity** (the total number of individuals an ecosystem can contain based on available resources).

For the predators we assume consumption of less than 25% of the total beans consumed is insufficient to sustain life (those mechanisms go extinct). When we loose predators in nature we open up space for existing predators to take over (as seen in existing wolf and coyote populations). Use the attached sheet to redistribute feeding mechanisms.

Continue this for 4 generations.

| Prey | A | B | C | D | E<br>begining poulation in next generation | F<br>To be added back to habitat |
|---|---|---|---|---|---|---|
| Example | eginning bunnies | % of poulation | emaining after predation | % left | Iultiply Colum D with 400 | Subtract C from E |
| black | 100 | 0.25 | 50 | 0.28 | 112 | 62 |
| red | 100 | 0.25 | 12 | 0.6 | 24 | 12 |
| large white | 100 | 0.25 | 19 | 0.11 | 44 | 25 |
| small white | 100 | 0.25 | 99 | 0.55 | 220 | 121 |
| Totals | 400 | 100 | 180 | 100 | 400 | 220 |
| Generation 1 | | | | | | |
| black | | | | | | |
| red | | | | | | |
| large white | | | | | | |
| small white | | | | | | |
| Totals | 400 | 100 | | 100 | 400 | |
| Generation 2 | | | | | | |
| black | | | | | | |
| red | | | | | | |
| large white | | | | | | |
| small white | | | | | | |
| Totals | 400 | 100 | | 100 | 400 | |
| Generation 3 | | | | | | |
| black | | | | | | |
| red | | | | | | |
| large white | | | | | | |
| small white | | | | | | |
| Totals | 400 | 100 | | 100 | 400 | |
| Generation 4 | | | | | | |
| black | | | | | | |
| red | | | | | | |
| large white | | | | | | |
| small white | | | | | | |
| Totals | 400 | 100 | | 100 | 400 | |

# Intro to invertebrates

INTRODUCTION

When surveying the animal kingdom, we find an incredible amount of diversity in structure and function. Though there are over a million described species on earth, almost all of these species are invertebrates. Invertebrates are animals that lack a backbone. We can then subdivide the invertebrates based on a few characteristics such as symmetry, tissue development, and larvae development (figure 1).

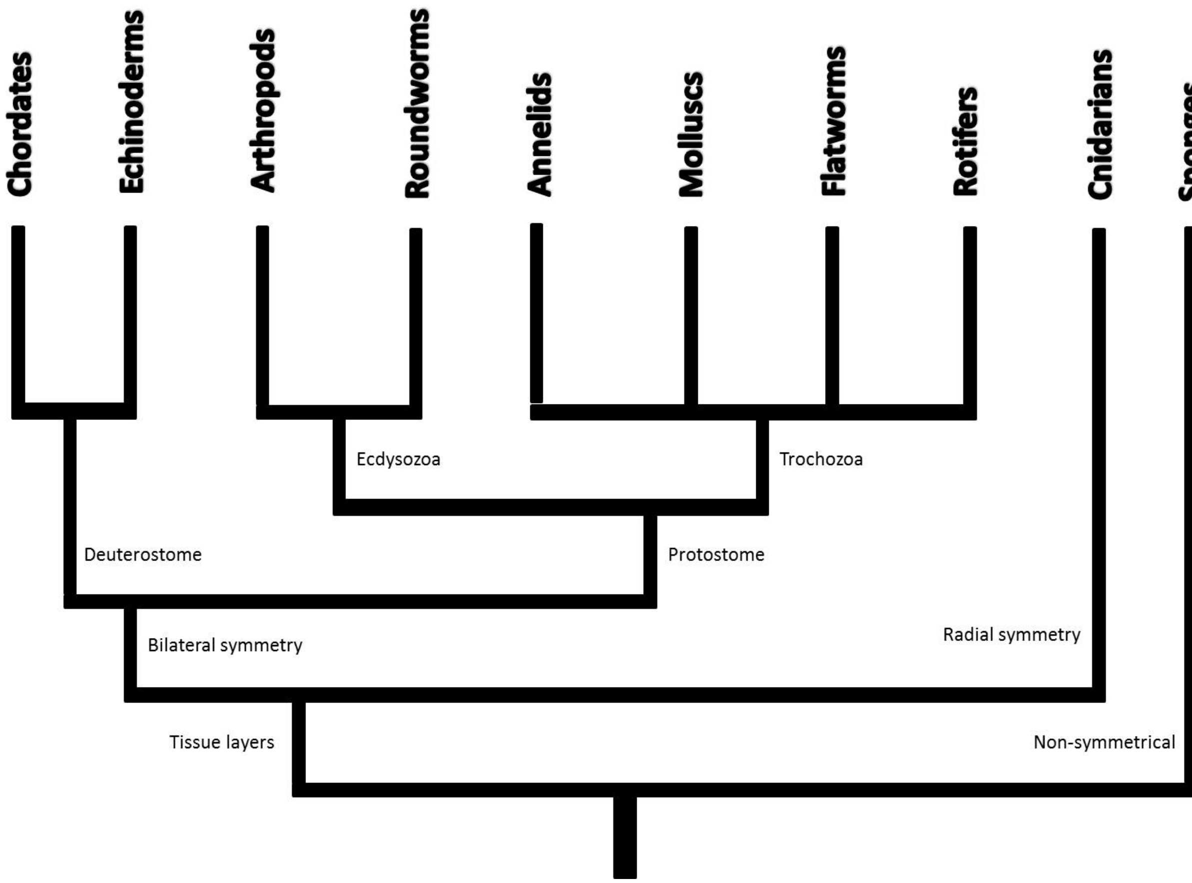



Figure 1: Evolutionary tree of animals

The first feature of interest in grouping is symmetry. Asymmetry means the animal, no matter what way its divided, will be identical (ex. Sponges). Radial symmetry, as in Cnidarians, means no matter what way we slice the animal longitudinally the two halves will be identical. The other phyla have bilateral symmetry, meaning these animals have a defined right and left half. These bilateral organisms are further divided based on the first opening in embryonic development being the mouth (protostomes) or Anus (deuterostomes). Of our protostomes we then divide them into Ecdysozoa or Trochozoa. Ecdysozoa have a shedable exoskeleton, and trochozoans have a larval form that is free swimming. These characteristics help us divide the highly diverse species on earth into distinct related groups.

The organisms below are all similar to each other because they are all non-coelomates. Coelomates have a body cavity that has been completely lined by the mesoderm which allows for growth of complex organs.

SPONGES

Sponges are in the phylum Porifera, they are asymmetrical, sessile (immotile), and reproduce sexually or asexually. Observe the sponges in class. Look for the following structures:

- Osculum
- Sponge wall
- Pores
- Spicule (not observable but is what makes a sponge hold it shape)

CNIDARIANS

Cnidarians are in the phylum Cnidaria, and they are radial symmetrical. Some Cnidarians undergo polymorphism, which means they have more than one life stage. Polyps are a sessile stage with the mouth pointing upward, while medusa's are fee moving with its mouth pointing downward. Both the polyps and medusa stage have tentacles that surround the mouth in order to aid in the capture of prey. In the tentacles there are specialized structures called **nematocyst** that, when triggered, fire a spine into the prey (in many cases also injecting venom) that captures the prey to be inserted into the gastrovascular cavity. The gastrovascular cavity is an opening that serves as both mouth and anus.

Observe the available Cnidarians (preserved or alive) and look for the gastrovascular cavity, the tenticles. Your instructor should show you nematocysts on the projector.

FLATWORMS

Flat worms are in the phylum Platyhelminthes, are bilaterally symmetrical, and has all three germ layers (ectoderm, mesoderm, and endoderm). Flat worms can be free-living or parasitic. The free living types are called planarians. Planarians are hermaphroditic, which means they have both male and female sex organs. Even though they are hermaphroditic, they still practice cross-fertilization (they don't fertilize themselves).

If available, look at the live planarians; notice the eye spots on the top of the head. These eye spots are not like the eyes that you and I have, they only detect the presence or absence of light. Now place a ground up piece of meat on a glass upside down over a full beaker with the planarian in it. Observe the planarians for extension of their pharynx. The pharynx is part of the digestive system that extends out of the mouth to ingest its food. Look at a prepared slide and observe the nervous system and excretory system.

Other flatworms are available to observe in lab as well. One is a liver fluke, these are found in the livers of mammals and feed on blood or bile. This can cause anemia, cirrhosis, and improper or inability to digest fats. Flukes are found in freshwater and can infect improperly treated water or aquatic plants. There is also Tapeworms available. These organisms are found in pork and can be ingested by humans. The scolex (head) of the tape worm is specialized to aide in the attachment of the tapeworm to the intestines where it can feed off nutrients that would normally be absorbed by the human.

ROTIFERS

Rotifers are in the phylum Rotifera; they are bilaterally symmetrical, have a pseudocoelom (a body cavity partially lined with a mesoderm), and a complete gastrointestinal tract from mouth to anus. Look at a live rotifer under the microscope (you may need to add a drop of "proto slow" to slow there movements down). Of the live rotifers look to see if you can identify the:

- Corona around the mouth
- Eye spots
- Stomach
- Anus
- Trophi (jaws)

ROUNDWORMS

Roundworms are in the phylum Nematoda; they have bilateral symmetry, pseudocoelom, and a complete digestive tract. Most roundworms are parasitic and take their nutrients from both plants and animals. Human consumption of undercooked foods is a common pathway to an infection of roundworms. Ascaris is a tropical intestinal parasite that when ingested burrows through the intestinal wall and makes its way to the lungs. Unlike the pervious phylum's, Ascaris has both a male and female form. You can observe both forums in the preserved specimens. Another common parasitic nematode is Trichinella. Trichinella comes from undercooked pork, and when ingested it burrows into the muscles causing cysts and major muscle aches. Observe the Trichinella cysts in the prepared slides.

THINK ABOUT WHAT YOU SAW

- The vast majority of animal species on earth are invertebrate.
- Characteristics important to grouping animals into phylum were ______________, ________________, __________________, ________________.
- The first opening during development is an important characteristic that separates phylum of animals, humans fall into which group _______________.
- How do the organisms observed today acquire nutrients?
- How does the organisms observed today reproduce?
- How does the symmetry of all the organisms observed today differ?
- What advantage does evolving mobility provide?
- Many of the organisms observed are parasitic, why would a parasite not want to kill its host species?
- Be able to identify what phylum each observed animal is in and general defining characteristics.

# Coelomates

INTRODUCTION

All animals more complex than sponges have primary germ layers that develop into all other organs and structures in the body. The three primary germ layers are ectoderm, endoderm, and mesoderm. The last of these layers to develop is the mesoderm. The mesoderm forms, among other things, the lining of the body cavity.

Coelomates have a body cavity that has been completely lined by the mesoderm. There are many advantages to having a coelom: the digestive system and body wall can move independently, internal organs have room to become more complex, coelomic fluid assist in respiration, circulation, excretion, and serve as a hydrostatic skeleton.

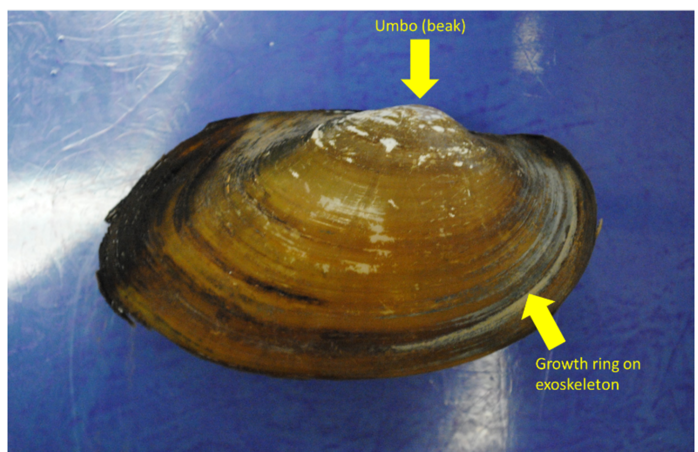
MOLLUSCS

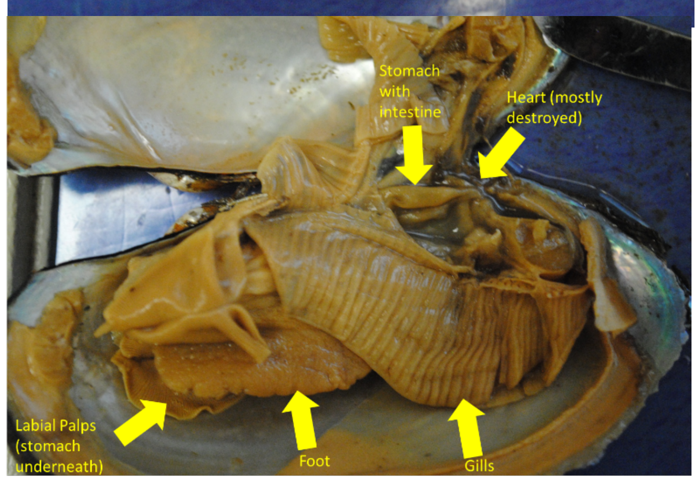
Molluscs are in the phylum Mollusca. Molluscs come in many varieties including the bivalve (clam), chitons (flattened grazing marine invert.), gastropods (snails), and cephalopods (squids). All these groups share three characteristics: They have a muscular foot specialized for locomotion, visceral mass that includes the internal organs, and have a thin tissue that encloses the visceral mass called a mantle.

Examine the clam, be able to identify:

External
- Hinge
- Umbo
- Growth ring
- Exoskeleton

Internal
- Heart
- Kidney
- Gills
- Foot
- Stomach
- Intestine
- Labial palps



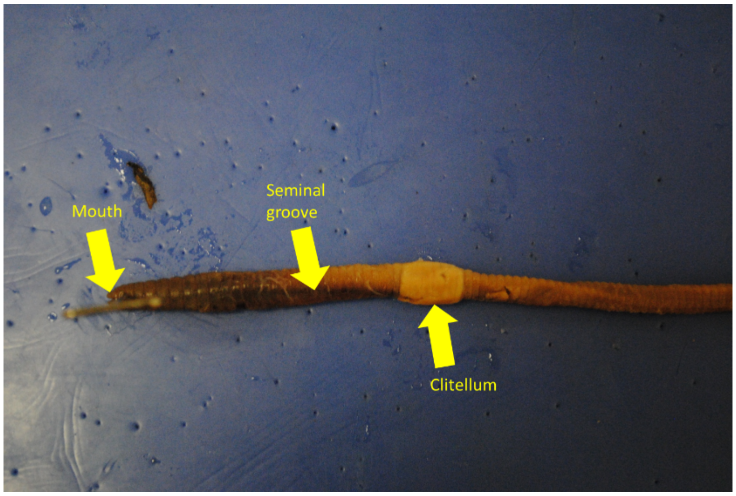
ANNELIDS

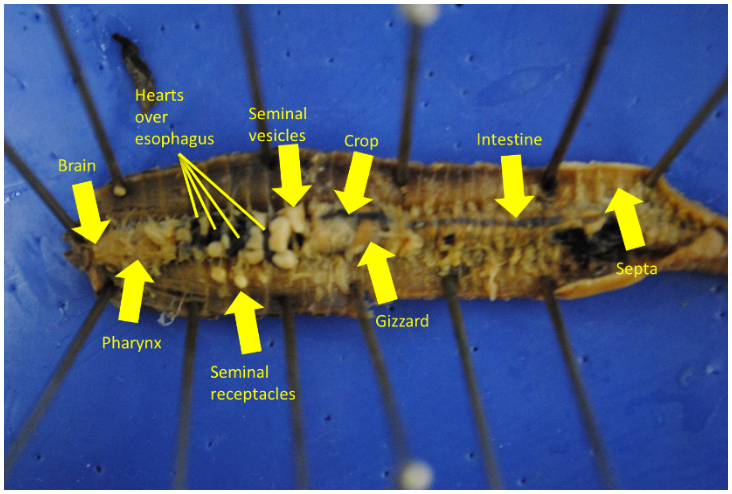
Annelids are in the phylum Annelida. These are considered segmented worms because the body is divided into regions called **somites**. Among the annelids are a group called oligochaetes. They share all the characteristics of Annelids except they have few bristles called setae on their body. The most well-known of the oligochaetes is the earthworm.

Examine the earth worm, be able to identify:

External
- Anus
- Clitellum
- Mouth
- Seminal groove

Internal
- Brain
- Pharynx
- Heart's
- Esophagus
- Seminal receptacles
- Seminal vesicles
- Crop
- Gizzard
- Intestine.
- Septa
- Dorsal blood vessel



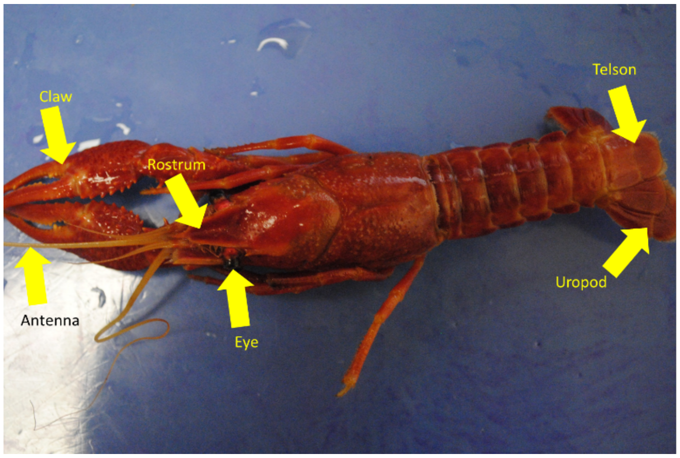



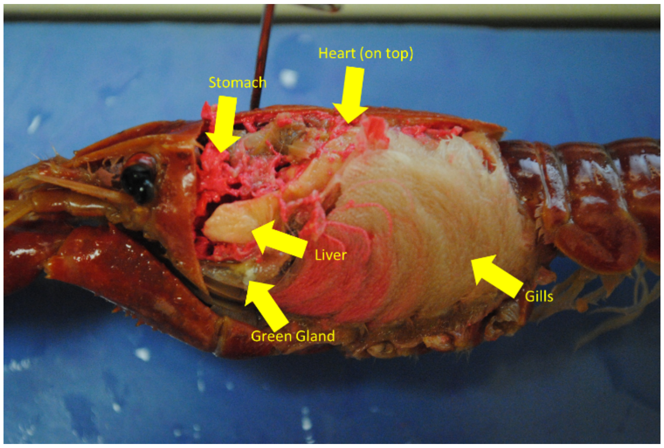
ARTHROPODS

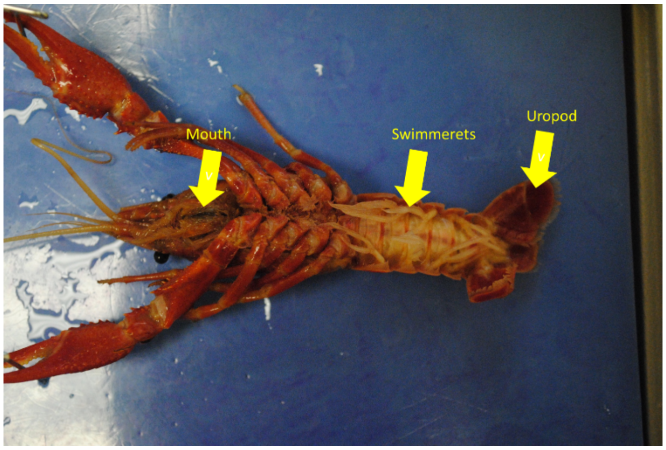
Arthropods are in the phylum Arthropoda. Arthropoda includes insects, arachnids, and crustaceans. They all share the same characteristics of a segmented body, exoskeleton, and jointed appendages. Insects are the most common of the arthropods; they contain three body regions, and three legs. Arachnids have four pair of legs, no antennae, and a fused head and thorax called a cephalothorax. Crustaceans have three to five pairs of legs and two pairs of antennae.
Examine the crayfish, you should be able to identify:

External
- Eye
- Claw
- Rostrum
- Antenna
- Mouth
- Uropod
- Telson
- Swimmerets
- Male or female

Internal
- Stomach
- Digestive gland (liver)
- Gills
- Heart
- Green gland
- Brain



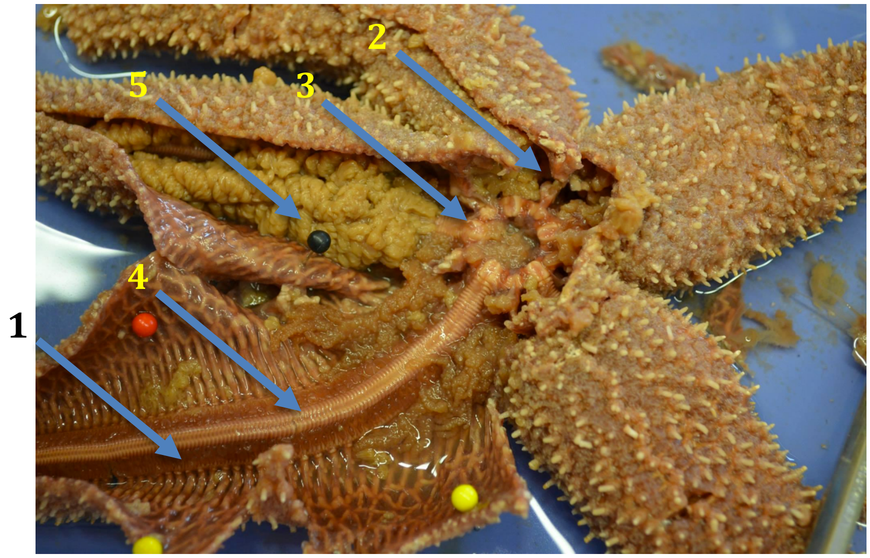



ECINODERMS

Echinoderms are in the phylum Ecinodermata. These includes starfish, sand dollars, brittle stars, sea urchins, and sea cucumbers. They are grouped because of their calcium endoskeleton, water vascular system, pedicellariae (small pincers used to clean skin or grab prey), and pentaradial symmetry. Examine the starfish in lab and identify the following:

External
- Eye spots on arms
- Central disk
- Mouth
- Ambulacral groove
- Tube feet inside

Internal
- stomach
- ampulla (1)
- stone canal (2)
- ring canal (3)
- radial canal (4)
- hepatic caeca (5)




THINK ABOUT WHAT YOU SAW
- Describe the circulatory systems observed today.
- How did respiration differ among organisms?
- How did digestion systems differ among organisms?

# Intro to chordates

**Chordates**

Chordates have a coelom and are a major branch of bilaterally symmetrical animals. We have looked at the major groups of the protostomes (molluscs, annelids, arthropods, etc…), now we will switch to looking at deuterostomes. Chordates are defined as having a notochord, pharyngeal slits, endostyle/ thyroid gland, dorsal hollow nerve cord, and post anal tail. The evolution of each of these structures has allowed for increased mobility, respiration, acquisition of nutrients, and reproduction. There are many organisms that display many but not all of these traits. One such group is the hemichordates. Hemichordates display half the characteristics of a chordates and half the characteristics of echinoderms (starfish, sea urchins, sea dollars, etc…). Chordates evolved early in the Cambrian period (about 530 million years ago), however the first real chordates most likely never left fossils because they did not evolve hard teeth and bones until later in the evolutionary timeline. Through half a billion years of evolution the basic body plan for vertebrates evolved leading to modern vertebrates.

**Vertebrates**

Vertebrates are true chordates possessing, at some point in their life, all five characteristics of chordates. Beyond these characteristics vertebrates also have a vertebral column and a true cranium.

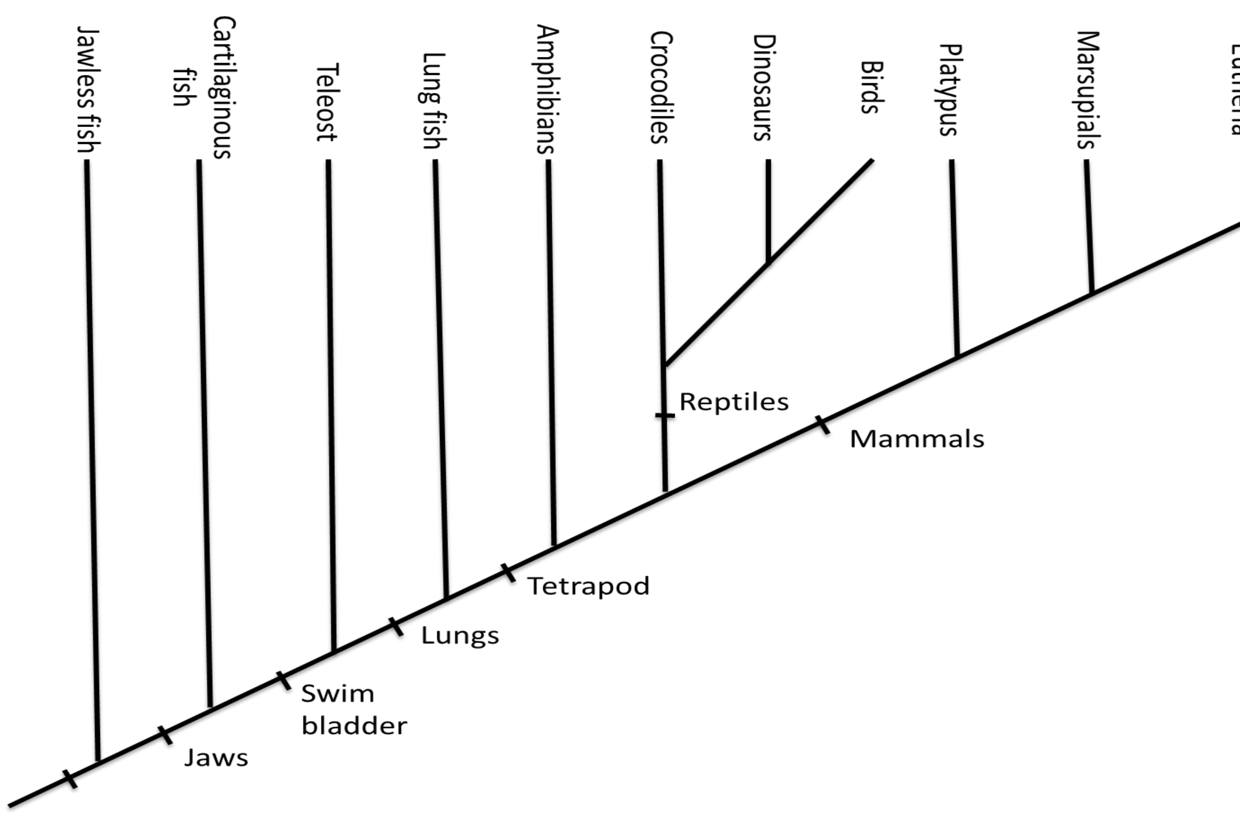



Figure 1: phylogenetic tree of vertebrates

Early vertebrates were all jawless fish, called agnathans. These fish were thought to be filter feeders using there large pharynx's to suck in organic particles. Living decedents of these agnathans are lamprey and hagfish. Quickly (relatively from a geological stand point ~ 50 million years) after the rise of vertebrates the first jawed fish (gnathostome) evolved. This gave fish a more efficient way to capture food. With more efficient ways to capture food other characteristics began to develop. Fish became more mobile to capture food, they began fighting gravity and moving off the sea floor, and occupying different habitats. One early adaptation to aide in movement was the loss of calcification of cartilage into bone. This group of fishes still exists in sharks, skates, rays, and ratfish. However other adaptations were taking place leading to modern teleost (bony) fish with their swim bladders. By the late Devonian period (~350 million years ago) the seas were thriving with many types of fish competing with each other. This new pressure started a chain of events that drove evolution into the development of limbs and lungs that allowed movement onto land where predators were fewer and competition for resources was greatly reduced.

Be able to identify the following structures from each provided critter:

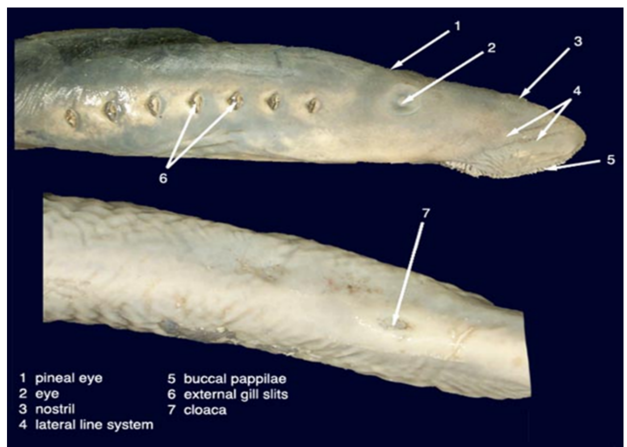
**Lamprey**

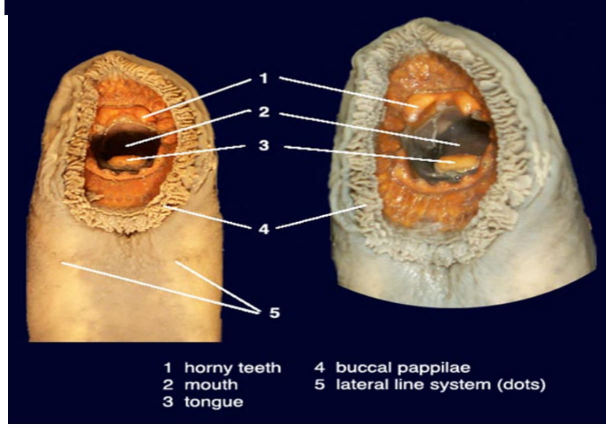
External

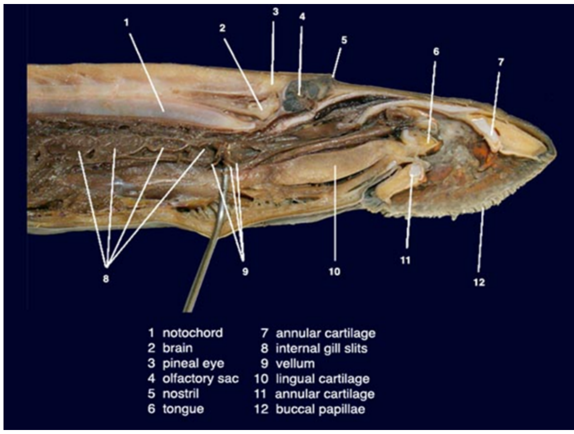
- Pineal eye
- Eye
- Nostril
- Lateral line
- Buccal papillae
- External gill slits
- Cloaca
- Horny teeth
- Tongue
- Buccal papillae

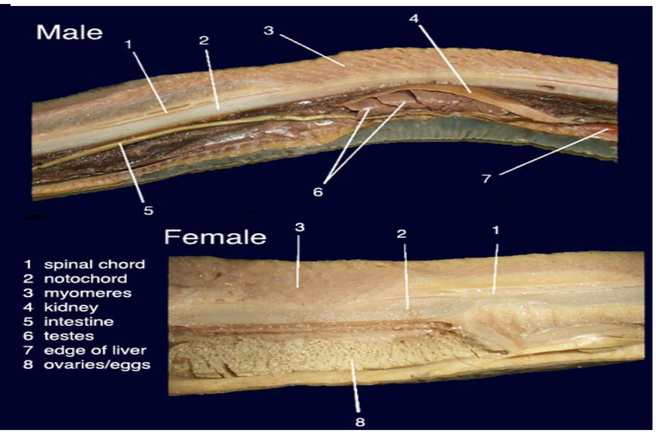
Internal

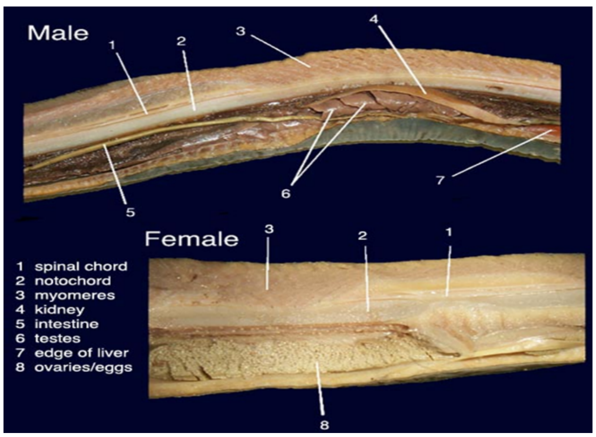
- Notochord
- Brain
- Internal gill slits
- Gonads
- Liver
- Heart
- Intestines






**Shark**

External

- Rostrum
- Ampullae of lorenzini
- Lateral line
- Gills
- Spiracles
- Male or female?

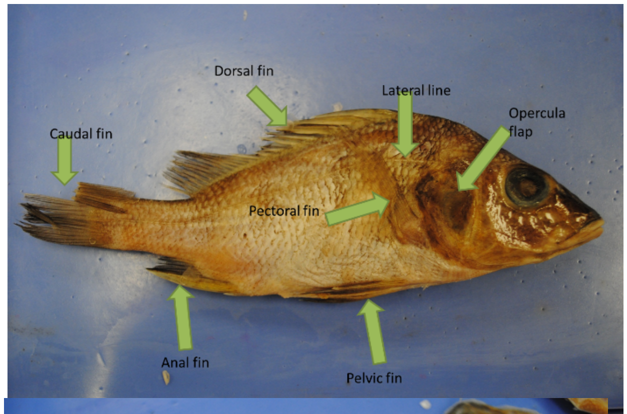
Internal

- Stomach
- Intestines
- Esophagus
- Liver
- Spleen
- Atrium
- Ventricle

**Bony Fish**

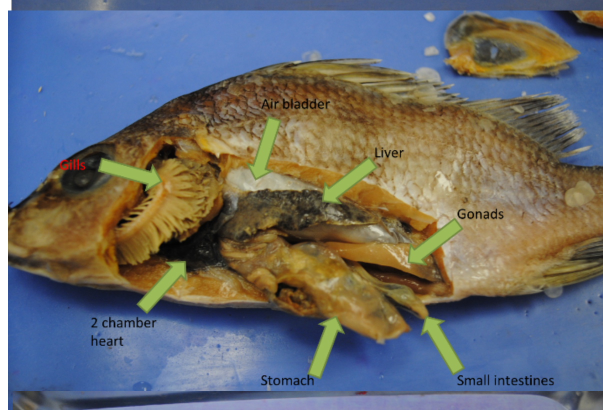
External

- Caudal fin
- Dorsal fin
- Anal fin
- Anus
- Pelvic fin
- Pectoral fin
- Gills
- Opercula flap
- Lateral line




Internal

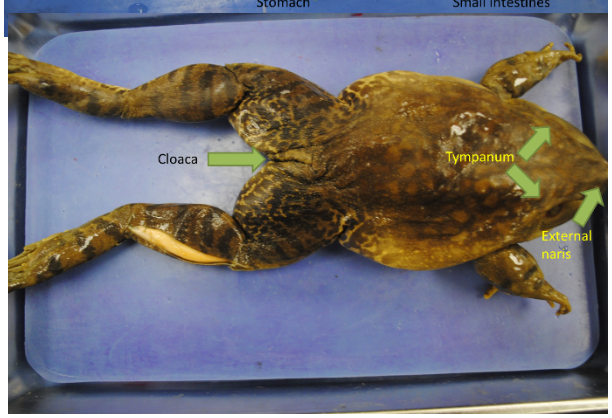
- Stomach
- Liver
- Air bladder
- Intestine
- Is it male or female?
- Heart
    - Dissect heart-how many chambers?




**Frog**

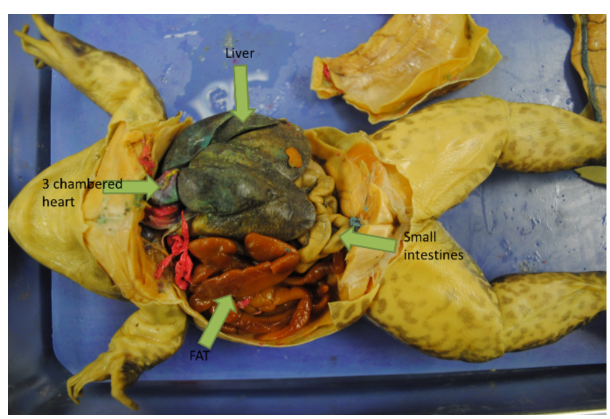
External

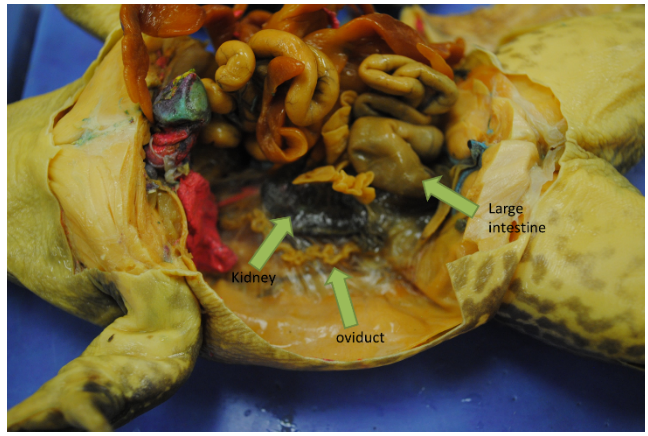
- Tympanum
- External naris
- Cloaca
- Internal nares (inside mouth)
- Vomerine teeth (inside mouth)
- Maxillary teeth (inside mouth)




Internal

- Stomach
- Liver
- Gallbladder (under liver)
- Lung
- Intestine (both)
- Pancreas (behind/ under stomach)
- Male or female? (and associated structures)
- Kidney
- Spleen
- Heart
    - Dissect heart-how many chambers?




THINK ABOUT WHAT YOU SAW:
-How did the digestive system change from invertebrates to vertebrates?
- How did the digestive system change from aquatic to terrestrial?
- Could you find a kidney in the fish?
- Was there a large intestine in the fish?
- How did the cardiovascular system change from the invertebrates to the vertebrates?
- How did it change from aquatic to terrestrial?
- How did respiration change from aquatic to terrestrial?
- How do bony fish and frogs reproduce?
- What were the main differences between lamprey, sharks, and boney fish?

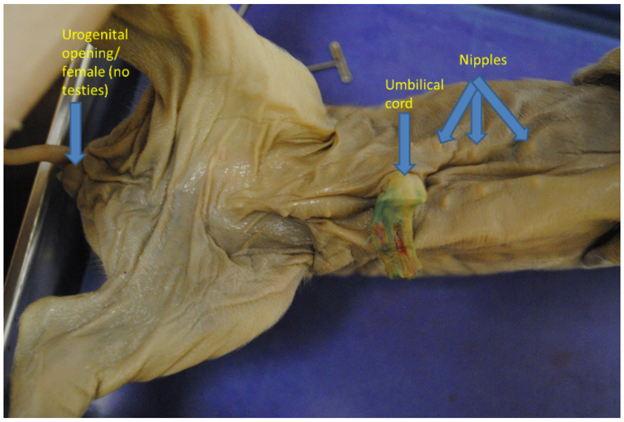
# Vertebrates cont…

At the end of the Devonian period (~360 million years ago), vertebrates first started walking on land. The first tetrapod's were transitional forms between aquatic and terrestrial likely spending most of their lives in shallow waters venturing on land to predate on insects or to lay eggs. These organisms lead to modern day amphibians. Once tetrapod's ventured onto land many adaptations had to take place to accommodate the new and different environment on land.

Locomotion vastly changes from an aquatic habitat to a terrestrial one. This is displayed in the pattern of bones in the limbs. The general development of these bones in tetrapods is: one bone (ex. Humerus), two bones (ex. Radius/ulna), many bones (wrist), and hand. Breathing becomes very different in air rather than water. Development of lungs also changes the circulatory system greatly. In fish and amphibians reproduction takes place in water and eggs have a ready access to water. When organisms moved onto land other reproductive measures had to adapt. This creates two major splits in the vertebrate tree, the reptiles, that have hardened eggs to hold in moisture, and mammals, whom retain their offspring internally.

Be able to identify the following structures:

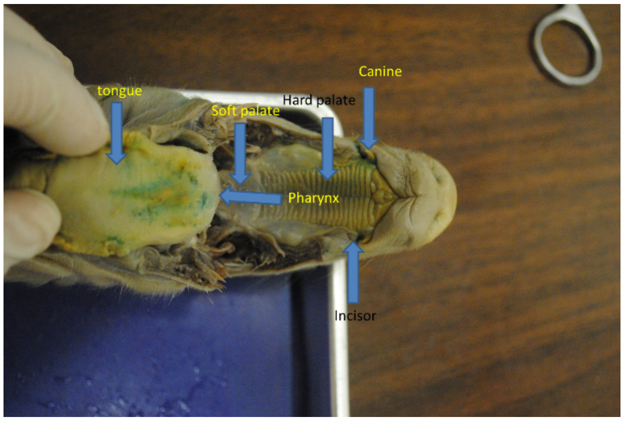
Mammal anatomy



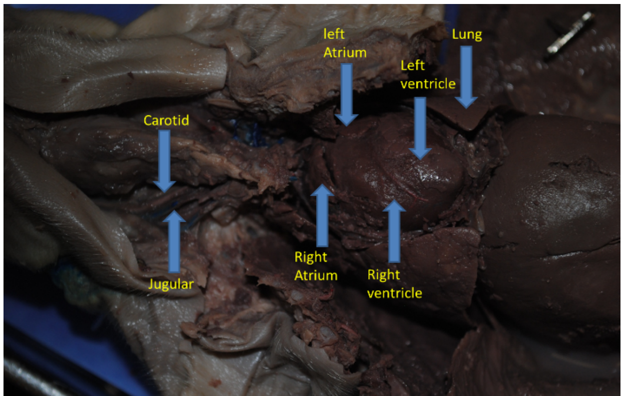

External:
- Male or female?
- Anus
- Umbilical cord
- Nipples
- Urogenital opening

Internal

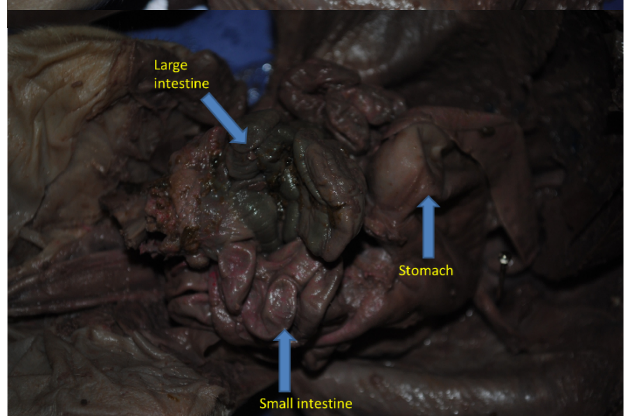
- Hard palate
- Soft palate
- Incisor
- Canine
- Epiglottis
- Tongue
- Pharynx
- Esophagus
- Trachea
- Thyroid
- Heart (atrium, ventricles)
- Lungs
- Diaphragm
- Liver
- Gallbladder
- Stomach
- Spleen
- Pancreas
- Small intestine



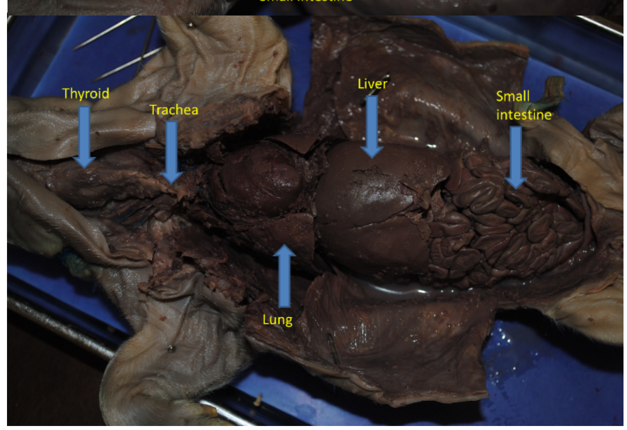
- Large intestine
- Urinary bladder
- Carotid artery
- Kidney
- Vena cava
- Aorta
- Iliac artery
- Male or female? (and associated structures)





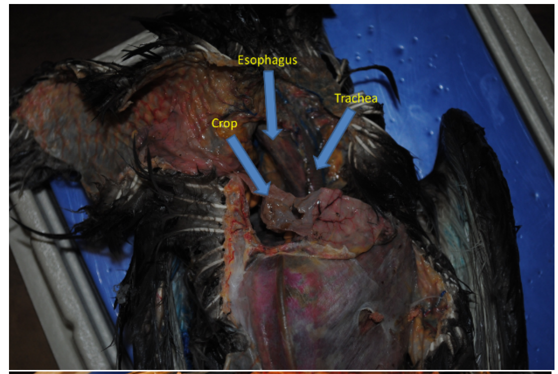



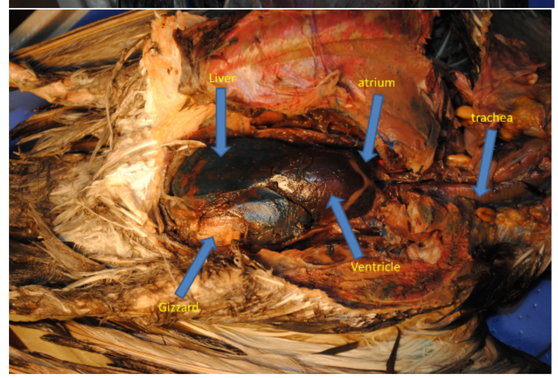


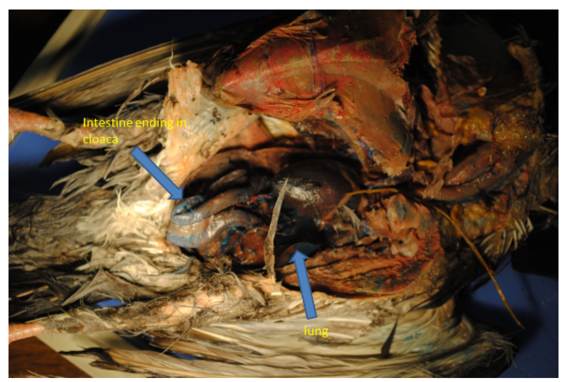


Pigeon

- Trachea
- Esophagus
- Crop
- Gizzard
- Small intestines
- Air sac
- Lung
- Liver
- Kidney
- Cloaca
- Heart (atrium, ventricles)




Think about what you saw:

- What were the main differences between the bird and pig?
- Why does the bird need a more efficient respiratory system?
- What is the difference in all the vertebrates cardiovascular systems?
- What's the difference between an anus and cloaca?