The goals of this lab are:
1. to learn the proper steps in the operation of a compound light microscope
2. to become comfortable with the operation of the compound microscope
3. to learn how to measure objects with the microscope
4. to learn the parts of the microscope & terminology used in microscopy
5. to learn how to make a wet mount
6. to learn how to use a dissecting microscope
7. to know all the terms in this handout that are in bold face type

Materials:
1. Prepared slides:
   • Letter e
   • crossed threads
   • Animal: columnar epithelium epithelium
   • Plant: Spirogyra; Elodea c.s.
2. Samples for wet mounts:
   • Animal: human cheek cells
   • Plant: Elodea leaf; onion
   • Pond water and/or cultures of ciliates
3. Insects for viewing with dissecting scopes

Procedure:
1. We will work together as a class to learn how to use the microscope and to gain an understanding of the following:
   • Magnification
   • Resolution
   • Field of View
   • Depth of Field
   • Working Distance
   • measurement of field diameter & objects
2. You will practice using commercially prepared slides
3. You will make wet mounts.
4. You will practice using the dissecting microscopes.

Readings: Sadava 8th ed., pp. 70-72
INTRODUCTION
The microscope we use in this lab is a light microscope. It uses a light bulb to illuminate the microscope slide. It is also called a compound microscope because two lens systems are used to produce the image that your eye sees.

The compound microscope is one of the principal tools of the biological laboratory. As a biology student you must learn proper use of the microscope. Proper use of the instrument demands practice. A little extra time now will pay off later when you are asked to do much more difficult microscopy.

A microscope is really only a sophisticated arrangement of magnifying lenses, constructed to see small objects. The compound microscope consists of a light source, three glass lens systems, plus the human eye. The lenses focus light. The important parts of the microscope are:

1. **light source**
2. **condensing lens system** to collect and focus light from the source onto the specimen
3. **objective lens system** to form and magnify the image of the specimen
4. **ocular lens** to enlarge the image made by the objective lens and to project this image onto the retina of the eye or to photographic film. The ocular produces no new detail. The detail you see is produced by the objective lens.

Light is reflected upward through the opening in the stage, passes through the specimen on the slide, and then into the body tube of the scope, ultimately forming an image on the retina of the user's eye. The quality of the light determines the quality of the image so it is important to learn how to adjust the light. The microscope has two mechanisms for this purpose: the **iris diaphragm** controls the amount of light entering the microscope and the **condenser** focuses the light.

**Resolution** (or **resolving power**) is the ability to see two objects that are close together as two separate objects rather than one blurred object. The human eye, unaided by optical devices, can resolve about 0.2 mm. By means of the light microscope, objects as small as 0.0002 mm or 0.2 micrometers (a **micrometer** is 0.0001 meter) can be seen and resolved. This represents a 1000X improvement in resolution beyond that of the naked eye.

RULES FOR HANDLING THE MICROSCOPE
A **compound microscope** is a delicate and expensive precision instrument. Treat it with care!

1. Always carry the microscope upright with two hands: one hand on the arm and one hand under the base.
2. Only use lens paper to clean the lenses. Any other type of paper may scratch the glass lenses, produce lint, or transfer oil from your fingers to the lens. Never touch the lenses with your fingers. You can distinguish between dirt on the ocular and dirt on the objective by rotating the ocular while looking through the microscope. If the dirt is on the ocular, the dirt will rotate with the lens.
3. Never touch the lens to water. Always use a square, plastic **coverslip** when making a wet mount.
4. When you are finished with the microscope, put the 4X objective lens in place and raise the stage as high as it will go. Wrap the electrical cord loosely around your hand and drape the coil over the tube of the microscope. **Do not wrap the cord around the base** because this will damage the condenser lens, diaphragm, and the cord. Put the dust cover back on. Return the scope to cabinet.
PROCEDURE FOR LOOKING AT A SLIDE.
Always use this procedure when you look at a new microscope slide:
1. turn the 4X objective lens into place
2. put the slide into the holder on the stage center the object to be seen over the opening in the stage
3. Use the coarse adjustment knob to move the stage as close to the lens as it will go (a brake will prevent the slide from actually hitting the lens)
4. While looking through the ocular, use the coarse adjustment knob to move the stage away from the objective lens until the image is in focus.
5. Adjust the iris diaphragm for the proper amount of light
6. To increase magnification, slowly turn the 10X objective lens into place.
7. Use the fine focus knob to bring it into proper focus.
   This microscope is parfocal. Parfocal means that when the image is in focus with one objective lens, it will be almost in focus at the next higher magnification. You should only need to make slight adjustments to bring it into perfect focus.
8. Adjust the iris diaphragm for the proper amount of light.
9. To increase magnification further, slowly turn the 40X objective into place.
   Note: We sometimes use or make slides that have a thick specimen mounted on them. This may prevent you from using a higher power objective. You should watch from the side as you move the objectives into place to avoid hitting the lens on the specimen. This may damage the lens.
10. Use only the fine focus knob to focus.
11. Do not use the 100X objective.

Generally, you will need the 10X objective when viewing a tissue and the 40X objective when viewing individual cells. As you become more experienced, you will learn which magnification is most appropriate for that which you want to see.

You should adjust the amount of light entering your specimen in order to form the best image possible. You will probably need to increase the amount of light as you increase magnification and decrease the amount of light as you decrease magnification. If the field is dark or the image very grainy, then increase the amount of light. If the image appears "washed out", reduce the amount of light reaching the specimen.

STUDENT WORK:
A. Learn the parts of the compound microscope.
   Use the wall chart to learn these parts of a compound microscope and their function:
   1. ocular lens  2. objective lenses  3. rotating nosepiece  4. base  5. arm  6. tube  7. stage  8. condenser  9. iris diaphragm  10. coarse focus knob  11. fine focus knob  12. microdrive

B. Learn to calculate magnification.
   Total magnification is calculated by multiplying the magnification of the objective lens by the magnification of the ocular. Why does it work this way? A microscope requires two sets of magnifiers. On low power (10X), for example, the objective forms a primary image inside the tube...
that is 10X larger than the viewed object. The ocular (10X) then magnifies the primary image another 10 times. Thus, the image that finally reaches your eye has been enlarged to 100X the size of the object.

> Calculate the Total Magnification for each objective lens (4X, 10X, and 40X) for a microscope with a 10X ocular lens. Record in the table.

<table>
<thead>
<tr>
<th>Ocular Magnification</th>
<th>Objective Magnification</th>
<th>Total Magnification</th>
<th>Diameter of Field (mm)</th>
<th>Working Distance (mm)</th>
<th>Depth of Field (Number of threads in focus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10X</td>
<td>4X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10X</td>
<td>10X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10X</td>
<td>40X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. The following procedure shows you how to use the microscope and introduces you to some related concepts and terminology.

1. Take the letter “e” slide from the slide folder.
2. Hold the slide upright (so that you can read the normal “e” that is beneath the coverslip) and place it on the stage so that the “e” is upright when viewed with the naked eye. Hold it in place with the clip on the microdrive.
3. Turn the 4X objective into place. Use the coarse focus knob to focus on the “e”.
4. Adjust the lighting with the iris diaphragm. Note any change in the image.
5. Observe the space between the objective lens and the microscope slide. This is the Working Distance. An object must be at this specific distance from the objective lens in order for its image to be in focus. Use a plastic ruler to measure this distance. Record in the table.
6. Draw the image of the “e” that you see in the appropriate space below. Show its size relative to the size of the field. The field is the area of the microscope slide that is visible through the microscope.
   > Compare the image of the “e” to the printed “e” on the slide. How do they differ?
7. Use the stage microdrive to move the slide to the right and then left. Use the stage microdrive to move the slide away from you and then closer to you
   > Compare the movement of the image to the movement of the slide. Do they move in the same direction?
   > What general conclusion can you draw from your observations of the image and its movement?
8. Re-center the “e” in the field. Focus. Adjust the light.
9. Slowly turn the 10X objective lens into position. Take your eyes away from the ocular lens and look at the microscope from the side as you do this.
10. Focus carefully. The lenses are parfocal so little adjustment is needed.
11. Adjust the light. Note any change in the image.
12. Measure the Working Distance. Record in the table.
13. Draw the image that you see.
   ⇒ How does it compare to the first image that you drew? Is it bigger? Does it fill a larger portion of the field? Are the lines thicker?
14. Re-center the “e” in the field. Focus. Adjust the light.
15. Slowly turn the 40X objective lens into position. Take your eyes away from the ocular lens and look at the microscope from the side as you do this.
16. Note the tiny Working Distance. Make an estimate of this distance and record in the table.
17. Focus using the fine focus knob.
18. Adjust the light.
   ⇒ Do you have to increase or decrease the light level?
19. Draw the image that you see.
   ⇒ How much of the “e” can be seen when using the 4X, 10X, and 40X objectives?
   ⇒ How is the image of the “e” different from the actual “e” mounted on the slide? List the ways that the image differs from the object on the slide. Base your answer on your observations.
20. Let’s look at how light levels change with magnification.
   • Turn the 10X objective lens back into place. Does the field get brighter or darker?
   • Adjust the light so that the letter “e” is visible but it is as dark as possible.
   • Turn the 40X objective lens back into place. Does the field get brighter or darker?
   ⇒ How does the requirement for light change as total magnification increases?

D. Learn about Depth of Field.

Depth of field refers to the thickness of the specimen that is in focus at any one time. The depth of field is a constant value for each of the objectives lens. Each objective lens has a different depth of field.

1. Obtain the “crossed threads” slide. Using the 4X objective focus at the point where the three threads cross over each other.
   ⇒ How many threads are in focus at any one instant? Record in the table.
2. Turn the 10X objective into place. Slowly focus up and down.
   ⇒ How many threads are in focus at any one instant? Record in the table.
   Notice that when one point or thread is in focus, the others above and below are blurred.
3. Increase the magnification by changing to the 40X objective.
   ⇒ How many threads are in focus at any one instant? Record in the table.
   Can you distinguish one whole thread clearly under high power?
   ⇒ Can you determine the order of the threads on the slide? Focus up and down keeping track of the order in which threads come into focus.
   Notice that if you focus on the bottom thread, the top thread cannot be seen.
E. Measure the diameter of the microscope field.

   The **Field** is the circle of light that you see through the ocular. It is the portion of the microscope slide that you can see at one moment. It is useful to know the diameter of field because you can then estimate the size of objects you are viewing. Let’s measure the diameter of this field.

   1. Lay a clear plastic ruler on the stage and measure the **diameter of field** at 40X and 100X total magnification. Record the values in the table to the nearest 0.1 mm.

      **Note:** When you make this measurement, you must take the thickness of the ruler markings into account. The distance from the left edge of one mark to the left edge of the next mark is 1 mm.

   2. You cannot measure this directly when the total magnification is 400X. You can calculate it since you know the field diameter at 40X (you measured it) and you know that the field diameter at 400X is 1/10 of the field diameter at 40X (the image is 10 times larger, so only 1/10 as much can be seen).

F. What have you learned about the microscope from these procedures? Use the data that you recorded in the table to summarize the trends that you observed. Answer the following questions.

   - As you go from 4X to 10X to 40X, how does depth of field change?
   - Based on your observations, at which magnification (4X or 40X) will the depth of field and the field diameter be largest?
   - As you increase magnification, what happens to the working distance?
   - At which magnification will you be able to see the largest part of your specimen?

<table>
<thead>
<tr>
<th>Size of the image</th>
<th>Diameter of Field (mm)</th>
<th>Working Distance (mm)</th>
<th>Depth of Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>As you increase magnification from 4X to 40X, what is the effect on each of these variables?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**THREE TIPS FOR USING THE MICROSCOPE:**

1. Be sure to adjust the light for each slide and for each magnification so that there is good contrast and the **image** is crisp. The amount of light blocked by the tissue on a slide varies considerably as a result of variation in tissue thickness and the amount of stain.

2. As you learned when studying diameter of field, the diameter of field decreases as you go from low power (scanner) to high power. To avoid “losing” the object when you change objective lenses always center the object **before** changing objective lenses.

3. You have learned that depth of field decreases as you go from low power to high power. As a result, an object that is in focus at low power may not be in focus at high power and you will not be able to see it. To avoid this, you must carefully focus **before** changing objective lenses to the higher power.

   **If you lose the object as you increase magnification, it may be the result of improper lighting; or you did not center it in the field; or you did not focus carefully. How do you find the object again? Change back to a lower power, then adjust the light, re-center the object, and focus carefully. This adjustment should allow you to find it with the higher power lens.**
INTRODUCTION TO CELLS

One of the most important ideas in biology is the cell theory: all living things are composed of one or more cells. This establishes the cell as the basic unit of life and the basic building block of all living things. The cell is the simplest and smallest thing that can be said to be alive (i.e., possesses all the characteristics of life). Cells are complicated and are the topic of BIO 112.

Only a small number of cellular structures are visible with the light microscope. An electron microscope is needed to see most of these cellular components. In this section, you will look at those cell parts that are visible with the light microscope.

There are two basic types of cells. Prokaryotic cells are only found in bacteria (Kingdom Monera). The cells of the other four kingdoms are called eukaryotic cells. Prokaryotic cells are approximately 1000X smaller in volume than eukaryotic cells and lack many cell structures, including the nucleus, which are found in a eukaryotic cell. We will study only eukaryotic cells in this lab.

A large spherical structure can be seen in most eukaryotic cells. This is the nucleus. The nucleus is the control center of the cell. Within the nucleus, although not visible with the light microscope, are a specific number of long molecules of DNA. These DNA molecules store information that is used to run the cell’s metabolism. Often one or two darker staining areas may be seen within the nucleus. These are nucleoli (singular = nucleolus). The nucleoli produce ribosomes, cell structures where all cellular proteins are produced.

The rest of the cell is called the cytoplasm. The cytoplasm is composed of structures called organelles and the surrounding fluid which is called cytosol. The cytosol is a watery liquid with many dissolved and suspended substances. Many chemical reactions occur in the cytosol. The rest of the cytoplasm is composed of gelatinous structures called organelles. There are numerous kinds of organelles. Each has a specific structure and function. Few organelles are visible with the light microscope. In some plant cells chloroplasts, the site of photosynthesis, are visible. Their green color is due to chlorophyll, a pigment that captures solar energy.

The plasma membrane is a thin sheet of material that forms the outer surface of every cell. The plasma membrane surrounds all the parts of the cell and serves as the boundary between the cell and its environment. It also plays an active role in the entry and exit of material from the cell.

Plant cells are surrounded by a non-living cell wall. The cell wall is outside of the plasma membrane and is not a part of the living cell. The cell wall is mainly made of cellulose that is secreted from the cell’s interior and builds up as a protective covering on the outside of the living cell. Plant cells are covered by a plasma membrane, but the membrane is so close to the cell wall that it cannot be seen with the compound microscope. Animal cells do not have a cell wall.

LOOKING AT CELLS WITH THE COMPOUND MICROSCOPE.

Almost all cells are too small to be seen with the naked eye so you must use the compound microscope to see them. In this course you will look at prepared slides that are obtained commercially and wet mounts which you will make. Wet Mounts are temporary slides made from a fresh specimen. The specimen must be thin so that light can pass through it.

Procedure for making a wet mount:
1. Place your specimen in the center of a slide.
2. Add a drop of water (or a saline [salt] solution) to cover the specimen.
3. Cover the specimen with a small plastic **coverslip** to prevent water from touching the objective lens. Use the following procedure to avoid trapping air bubbles beneath the cover slip. Holding the cover slip at a 30° angle to the slide, touch one edge to the left end of the slide. Drag the cover slip to the right until it contacts the drop of water. The water will flow beneath the coverslip. Then slowly lower the cover slip and release it.

![Diagram of covering specimen with coverslip](image)

**STUDENT WORK**

Practice looking for cells in these commercially prepared slides before trying to make your own wet mounts.

1. “Columnar Epithelium”. This slide has slice through the intestines of a rat. You will be able to see a variety of different cell types here. The nucleus of the cells will be darkly stained.

2. “Spirogyra”. This slide has strands of green algae.

Make wet mounts of the following specimens.

1. Typical animal cell
   Lightly scrape the inside lining of your cheek with a toothpick. This will scrape off some of the epithelial cells of your cheek lining. Make a wet mount of these cells and examine them with the microscope. After you have seen the cells in their natural state, gently lift the cover slip and add a small drop of **methylene blue**. This stain will improve the contrast within the cells. Examine the cells again. Note the nucleus, cytoplasm, and plasma membrane. Draw the cell.

   ****DISPOSE OF THE SLIDE, TOOTHPICK, CELLS, COVERSILP, ETC. IN THE BIOHAZARD CONTAINER.****

2. Typical plant cell
   Make a wet mount of a leaf from the aquatic plant **Elodea**. Note the cell wall, chloroplasts, and central vacuole of each cell. Draw one of the leaf cells. See the prepared slide of **Elodea** leaf XS that is on the demo microscope (side bench). How many cell layers are found in the leaf?

3. Break a wedge of onion, peel off a thin strip, and make a wet mount. This tissue is very thin and does not have much color. In order to see it, you will have to reduce the amount of light by adjusting the iris diaphragm on the microscope. Note the nucleus, cytoplasm, and cell wall of each cell. Why can’t the plasma membrane (which is present) be seen? Why are there no chloroplasts? Draw a cell.

4. Make a wet mount of the plankton sample from the campus pond. **Plankton** are aquatic organisms that float in the water and drift with the current. Some of these organisms move very quickly. You can slow them down by adding a drop of Protoslo to the water before placing the coverslip. What can you find? Use the **Pond Life** guidebook to identify them.
Objectives:
1. to observe the variety of life
2. to learn the modern classification system used by biologists
3. to learn the characteristics of the kingdoms and their major phyla
4. to learn to use a dichotomous key
5. to be able to write a dichotomous key
6. to be able to recognize certain organisms as representative of their phylum or class.

Materials:
A wide variety of preserved specimens that represent each of the major groups of organisms will be available for your study. The specimens will be arranged by taxonomic group. See the list attached to the end of this lab.

Procedures:
You will be introduced to the basics of macro-evolution and classification of organisms (taxonomy). We will review a simple outline of the phylogenetic tree, i.e. evolutionary tree, as a way to organize our thinking about the origins of the major taxonomic groups.

You will systematically study the characteristics of each taxonomic group and examine specimens of each. You will learn the evolutionary relationships between the groups.

You will learn to use a dichotomous key and you will write your own dichotomous key for the kingdoms and for the major plant taxonomic groups.

Readings:
The textbook does not use the traditional classification scheme that we are using in this course. They follow a different approach that is based strictly on evolutionary relationships. As a result, their coverage of the Protista and the invertebrates looks quite different from what you will find in our notes. When you read about any particular organism or low order taxon we will be in agreement, but the names used for describing the higher order taxa will be different.

The Syllabus lists page numbers in the text that have relevant information about each group. In many cases there will be only one or two paragraphs or a figure that is of value. Focus on using this handout and refer to the text for pictures and explanations of terms.

I would suggest that as you work your way through the descriptions of the various organisms, you should look them up in the text and find pictures. Write down the figure number in your handout so that you can easily flip to that picture when studying.

The Photographic Atlas will be very useful. It uses the same classification scheme that is used in this handout and it has very good pictures.
Introduction
Biology is the science of life. Biologists study life. It is believed that life developed on earth 3.1-3.8 billion years ago. This is based upon the first appearance of fossils. The current biological hypothesis to explain the origin of life on earth will be covered in BIO 112. The first living organisms are believed to have been extremely primitive cells with little internal structure and a primitive metabolism. They were much simpler than the simplest modern bacteria. However, from these first unicellular species all living species have evolved. All species are related. Some species are closely related and others are distantly related, but all species are related because they have evolved from common ancestors.

How many kinds of life (species) share the planet with us? Researchers, especially in the tropics, discover new species every day.

The number of species currently alive is unknown. Different researchers estimate the number of existing species as between eight and twenty million species. Less than two million species have actually been named. Still, two million species is a lot.

How can a biologist possibly know about two million types of life? The classification system allows biologists to know at least a small amount about each of the two million species. Classification acts as a filing system for information. Classification also acts as hypotheses as to the course life’s evolution has taken.

The modern classification system is a descendant of a system devised by Linnaeus (1707-1778). The system of Linnaeus was solely based upon structural similarities between species, while the modern system is based upon phylogeny (the evolutionary relationships; the evolutionary history) of a species. Species that are grouped together are believed to have evolved from a common ancestral species sometime in the past.

In the classification system a species is grouped with other similar species. The members of each kingdom are arranged in a hierarchy of groupings. The major groups are called phyla (singular = phylum). From these one works down through smaller and smaller levels (taxa). There may be as many as 34 taxa used in the classification of a specific species. The most basic taxa (singular = taxon) of the classification system are listed below. Each level represents a certain degree of similarity (often this similarity is not obvious). As one proceeds from domain (the largest grouping) down to species (the smallest grouping), the species within each taxon have more and more characteristics in common.

domain
  kingdom - a group of related phyla
  phylum (plural = phyla) - a group of related classes. It is called a division in Botany.
  class - a group of related orders
  order - a group of related families
  family - a group of related genera
  genus (plural = genera) - a group of related species
  species - a kind of living organism
    = all organisms who can potentially reproduce together under natural conditions and produce fertile offspring
The classification system is also used to give each species a scientific name that is used worldwide. The scientific name of a species is the name of the genus in which it is classified followed by its own specific name. For example, the human species is called sapiens and is grouped with other species in the genus Homo. Hence, the scientific name of humankind is Homo sapiens. The name of the genus is capitalized, but the species name is not capitalized. Both names are underlined or italicized. The system of giving two names to a species is called binomial nomenclature and was originated by Linnaeus.

Until recently, the kingdom was the largest taxon in the classification system. How many kingdoms exist? At one time all life was classified as plant or animal: two kingdoms. However, biologists came to recognize that many species cannot be neatly classified as either plant or animal. This led to changes in taxonomic groupings of organisms. We will use a five kingdom system of classification which was devised by Robert Whittaker in 1969. Other researchers have used as many as eight kingdoms. The entire taxonomic system is subject to revision as scientists learn more about organisms. Recent discoveries have caused most biologists to accept a modified version of Whittaker’s scheme in which one kingdom is split apart and four kingdoms are grouped together. A new taxon called a domain was created to account for these changes.

There will continue to be changes in the classification scheme as scientists learn more about the evolution of life. While the classification system attempts to accurately describe evolutionary relationships it must also be practical enough to be useful to biologists. You will learn some of the major groups of organisms as they have been traditionally described. Newer classification methods will break apart some of these groups, merge others, and rearrange the evolutionary tree, but most biologists will continue to recognize these traditional groups for years to come.

Modern biologists can analyze the chemical structure of DNA. Researchers can now compare the chemical structure of the genes of different species. Similarity of gene structure is probably the best evidence of phylogeny. As more genes are studied areas of classification are being revised to reflect the new data. Classification is still a very active area of research. Today as conservationists attempt to preserve earth’s biodiversity from extinction, there is a growing need for taxonomists to identify the species that exist here with us.
# Summary of the major features of each of the five kingdoms

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Kingdom Monera</th>
<th>Kingdom Protista</th>
<th>Kingdom Plantae</th>
<th>Kingdom Fungi</th>
<th>Kingdom Animalia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cells Types</td>
<td>Prokaryotic</td>
<td>Eukaryotic</td>
<td>Eukaryotic</td>
<td>Eukaryotic</td>
<td>Eukaryotic</td>
</tr>
<tr>
<td>Number of Cells</td>
<td>Unicellular or Colonial</td>
<td>Unicellular or Colonial</td>
<td>Multicellular</td>
<td>Multicellular</td>
<td>Multicellular</td>
</tr>
<tr>
<td>Type of Nutrition</td>
<td>Autotrophic or Heterotrophic</td>
<td>Autotrophic or Heterotrophic</td>
<td>Autotrophic (Photosynthesis)</td>
<td>Heterotrophic (saprophytic)</td>
<td>Heterotrophic (ingestion)</td>
</tr>
<tr>
<td>Cell Wall</td>
<td>Cell Wall</td>
<td>Cell Wall or No Cell Wall</td>
<td>Cell Wall (Cellulose)</td>
<td>Cell Wall (Chitin)</td>
<td>No Cell Wall</td>
</tr>
<tr>
<td>Examples</td>
<td>Bacteria &amp; Blue-Green Bacteria</td>
<td>Protozoans &amp; some algae*</td>
<td>Seaweeds, some algae*, mosses, vascular plants</td>
<td>Mushrooms, molds</td>
<td>Humans, fish, insects</td>
</tr>
</tbody>
</table>

### Definition of Terms used in the table:

**Cell Types:**

**Prokaryotic** = the cell type found only in bacteria. It is 1000x smaller in volume than the eukaryotic cell and lacks many of the structures (such as the nucleus) found in the eukaryotic cell. It also differs in its chemistry and has a simpler metabolism.

**Eukaryotic** = the “typical” cell of all organisms except bacteria. It contains internal structures such as the nucleus.

**Number of Cells:**

**Unicellular** – an organism that consists of 1 cell.

**Multicellular** – an organism that consists of many cells that function together as a unit. Individual cells are specialized to carry out specific tasks required for the organism’s survival. Individual cells do not survive on their own.

**Colony** = a group of cells which live together. Theoretically, each cell could survive as well on its own as it does as a member of the colony.

**Type of Nutrition:**

**Autotrophic** = an organism that makes its own food

**Heterotrophic** = an organism that does not make its own food. It must consume other organisms. It can do so by either ingesting them or by decomposing their dead remains (such organisms are called Saprophytes).

**Cell Wall:** A **Cell Wall** is a non-living covering of a cell that is secreted by the cell. It is external to the cell’s living plasma membrane. The chemical composition of the cell wall varies by kingdom.

**Algae:** The general term for simple autotrophic organisms. It is not a taxonomic category. The term algae may be used to refer to Monerans (such as blue-green bacteria), Protists such as dinoflagellates, or primitive aquatic Plants such as Spirogyra.

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*Algae: The general term for simple autotrophic organisms. It is not a taxonomic category. The term algae may be used to refer to Monerans (such as blue-green bacteria), Protists such as dinoflagellates, or primitive aquatic Plants such as Spirogyra.*
THE CLASSIFICATION SYSTEM*

* You are responsible for knowing the characteristics of the underlined taxa and representative examples. You do not have to memorize the numbers of species within each of these groups.

**DOMAIN EU BACTERIA - KINGDOM MONERA (or Eubacteria or Bacteria)**
Unicellular and colonial organisms that have a prokaryotic cell structure. Some species are autotrophic, and others are heterotrophic. They have a cell wall, but it is chemically different from the cell walls of the other kingdoms. 3000 species

The monerans are the **bacteria** (including the **blue-green bacteria**). These cells are approximately 1000X smaller in volume than a eukaryotic cell and lack many of the internal structures, including the nucleus, which are found in eukaryotic cells.

Some species make their own food by a variety of methods (including photosynthesis). Other species must find food. These heterotrophs normally feed upon dead organic matter. Bacteria play an important role in decomposition (rotting) that allows for the nutrients of dead organisms to be recycled and reused. Some disease-causing bacteria enter the bodies of other organisms and feed on their tissues.

Bacterial cells have three basic shapes: spherical (coccus); rod-shaped (bacillus); spiral-shaped (spirilus). The cells may be single or attached to each other in chains of two or more cells. The blue-green bacteria that are on display in this lab are chains of cells. Adjust the microscope’s fine focus to see the individual cells in the chain.

Many types of bacteria can be grown as cultures in a Petri dish. Reproduction is rapid so a single bacterium can produce very large numbers after just a few days. The mass of these cells that results from this growth is called a **colony**. The colony of each species will have a characteristic appearance.

**DOMAIN ARCHAEA (or Archaebacteria) – KINGDOM ARCHAEA**
The Archaebacteria are prokaryotic cells. Archaebacteria live in extremely harsh environments and may represent the closest descendents of the first life forms on earth.

The Archaea were grouped together with the bacteria in the Kingdom Monera until just a few years ago when scientists began to study their biochemistry. The differences between the Archaebacteria and Eubacteria have been found to be so great that biologists have re-organized the entire classification scheme so that the two groups are each placed into a classification level higher than a kingdom called a **domain** (domain Archaea and domain Eubacteria). A third domain called the Eukarya includes the other four kingdoms (Protista, Plantae, Fungi, and Animalia) which have been grouped together because they have eukaryotic cells.

**DOMAIN EUKARYA - KINGDOM PROTISTA**
The kingdom protista includes unicellular and colonial organisms that have a eukaryotic cell structure. Some species are autotrophic and some are heterotrophic. Some have a cell wall and some do not. Some protists are autotrophic and make their food by means of photosynthesis. These plant-like protists are classified in a number of phyla based upon their photosynthetic pigments, the manner in which they store extra food, and the chemicals of their cell wall. They are commonly referred to as “algae”. Some protists move and catch food to eat. These animal-like protists are called **protozoans** and are classified in a number of different phyla. Other protists are saprophytes. 41,000 species.
Some common examples on display are amoeba, paramecium, euglena, diatoms, and dinoflagellates. In this course, we will study the amoeba and paramecium as representative protists.

**DOMAIN EUKARYA - KINGDOM PLANTAE**

Plants are multicellular organisms with a eukaryotic cell structure. Plants are autotrophic and their cells are surrounded by a non-living cell wall that is mainly made of cellulose. 260,000 species.

The plant kingdom is divided into many phyla. As a matter of convenience, biologists commonly refer to groups of plant phyla that have similar body structures or reproductive adaptations by informal (i.e. not true taxonomic groups) group names. The headings that follow (Algae, Primitive Land Plants, Vascular Plants) are examples of this.

**Algae**

The simplest plants are algae. They have simple structure and little specialization of cells. Most algae live in water and have bodies that are filamentous or very flat and thin. The largest algae are the seaweeds. The types of pigments used in photosynthesis are one factor used in algal classification; hence, the color of the alga is often included in the name of the phylum. A number of phyla of algae are on display.

Some examples of algae are:

- Phylum Chlorophyta (the **green algae**) - found in fresh water, salt water, and wet places on land
- Phylum Rhodophyta (the **red algae**) - the seaweeds which grow to the greatest depth in the ocean
- Phylum Phaeophyta (the **brown algae**) - usually found in the ocean. Includes huge seaweeds called **kelp**.

**Primitive Land Plants (a.k.a. Non-Vascular Plants or Non-Tracheophytes or Thallophytes)**

The simplest land plants are small and live in moist environments. The most important example is the **mosses** (Phylum Bryophyta). The liverworts and hornworts are less well-known examples.

Algae and mosses are always small or thin since they do not have the ability to transport materials throughout the plant body. Their cells must get nutrients directly from the environment by diffusion. The term **thallus** is used to describe the bodies of algae, seaweeds, and mosses. A thallus is an unspecialized plant body that does not have vascular tissue. Vascular tissues consist of tubes that can transport water and other materials. Plants that have vascular tissue (the Vascular Plants) can become large because they can move water from one part of the body to another part, for example, from their roots to their leaves.

**Vascular Plants or Tracheophytes**

The most successful land plants are **tracheophytes (the vascular plants)**. Tracheophytes have vascular tissue, i.e. bundles of small tubes for the transport of various materials throughout the plant body. There are two types of transporting tissue: **Xylem** - for the transport of water and minerals, and **Phloem** - mainly used to transport sugar. Tracheophytes are the only plants with true roots, stems, and leaves. True roots, stems, and leaves must contain vascular tissue.
There are many phyla of tracheophytes which inhabit a variety of environments. They can be grouped by their reproductive adaptations as follows:

**Vascular Seedless Plants**
This group includes **Ferns**, horsetails, club moss. These plants require water for reproduction and do not make seeds.

**Vascular Seed Plants**
This group includes all the plant phyla that produce seeds. These plants produce pollen and do not require water for reproduction. These are the most successful plants on land.

There are 2 major groups of vascular seed plants:

**Phylum Gymnospermae** = Gymnosperms produce seeds but they do not have flowers.
There are only 4 phyla including the **Conifers** (produce seeds inside cones - they are often “evergreen”, e.g., pines, firs, etc.), cycads, and ginkgo.

**Phylum Angiospermae** = Angiosperms (a.k.a. Phylum Anthophyta) = the **flowering plants**
Angiosperms reproduce using flowers. The flowers are pollinated by wind, insects, birds, etc. After fertilization, a part of the flower develops into a fruit within which the seeds develop. We will discuss the reproduction in this phylum in a later lab.
These are the dominant land plants of earth. They are the largest plants and have the largest number of species.

There are two classes of angiosperms:

**Monocots** - 50,000 species
Monocots include the grasses. Since cereal grains (rice, corn, wheat, etc.) are grasses, the monocots are extremely important sources of human food. Monocots have three easily observed characteristics. They have one cotyledon inside of their seed (covered in Lab 3), narrow leaves with parallel veins, and flower parts in multiples of three.

**Dicots** - 225,000 species
The dicots are the commonest and most successful of the land plants. They include such common plants as daisy, rose, maple and oak trees, peas, beans, etc. Dicots are characterized by seeds with two cotyledons, broad leaves with netted venation, and flowers whose parts are found in multiples of four or five. A dicot will be the “typical” plant that is studied in this course.

**DOMAIN EUKARYA - KINGDOM FUNGI**
Fungi are multi-cellular organisms with a eukaryotic cell structure. Fungi are heterotrophic and their cells are surrounded by a non-living cell wall. 72,000 species.
Fungi have bodies composed of microscopic branching filaments called **hyphae**. Hyphae are usually colorless but collectively may appear white and cottony. The entire body made of hyphae is called a **mycelium**. The mycelium grows through the substrate from which it takes its food and is usually hidden within the substrate. Like the bacteria, the fungi are important in the decomposition process. There are several phyla of fungi, but we will only mention a few species by their common names: mushrooms, puffballs, rusts, smuts, bread mold, cheese molds, leaf molds, yeast, and mildew.

A large amount of research is currently being done on types of fungi called mycorrhizae that form symbiotic relationships with the roots of trees. They help tree roots absorb nutrients from the soil.
**DOMAIN EUKARYA - KINGDOM ANIMALIA**

Animals are multicellular organisms with a eukaryotic cell structure. Animals are heterotrophic and their cells do not have a cell wall. 1,500,000 species. There are approximately 30 phyla of animals. Animals are classified into their phylum based upon a number of characteristics such as body symmetry, body segmentation, type of skeletal, circulatory, and digestive system. Certain structures may be unique to some groups. These are described below:

**Symmetry** = the arrangement of body parts around the main axis of the body so that the two halves will be nearly identical. There are two types of symmetry:
- **Bilateral** – when there is symmetry between the 2 sides of a plane - only one cut (from head to tail) will produce two almost identical halves
- **Radial** – when there is symmetry around an axis (line) - many different cuts could produce almost equal halves

**Body Segmentation** – The body of many organisms is made of multiple repeating units which are very similar to each other in structure. Segmentation may or may not be obvious by looking at the animal from the outside. Segmentation is only obvious in the immature stages of some organisms.

**Skeletal systems** – provide support for the body:
- **Hydrostatic** - a stiffening of the body due to internal fluid pressure
- **Exoskeleton** - a hard skeleton on the outside of the body
- **Endoskeleton** - a hard skeleton inside the body

**Digestive systems** – sac or tube where food breaks down into small particles that can enter the blood:
- **Incomplete** - One opening serves as mouth and anus; a.k.a. “2-way gut”
- **Complete** - Two openings - a separate mouth and anus; a.k.a. “1-way gut”

**Circulatory systems** – distribute nutrients to all parts of the body and removes waste products. Not found in the simplest phyla (Cnidaria, Platyhelminthes, or Nematoda). There are two types:
- **Closed** - the blood is always inside blood vessels
- **Open** - the blood is seldom inside blood vessels; instead it fills the body cavity

**The major animal phyla**

There are about thirty animal phyla. The phyla that are described below are either large phyla or are the phyla which we will be studying this semester. The same characteristics are listed for each phylum. An arrow (→) indicates the characteristics that are noteworthy or most definitive of the phylum. If a characteristic is unique to that group, it will be indicated with an asterisk (*).

**PHYLUM CNIDARIA** - 10,000 species

→ radial symmetry
→ no segmentation
→ incomplete digestive system
→ hydrostatic skeleton
→ a circle of tentacles surrounds the mouth
→ the only animals that have a cell structure called a nematoecyst* for stinging or holding prey
→ EX: coral, hydra, jellyfish, sea anemone
→ The Hydra will be studied as a representative species of this phylum
**PHYLUM PLATYHELMINTHES** = the flatworms - 10,000 species
- bilateral symmetry
- no segmentation
- incomplete digestive system
- hydrostatic skeleton
- body flattened from top to bottom (= dorsoventral flattening)
- EX: planaria, flukes, tapeworms
- The *Planaria* will be studied as a representative species of this phylum

**PHYLUM NEMATODA** = the round worms
- Bilateral symmetry
- No segmentation
- Complete digestive system
- Hydrostatic skeleton
- Body is round in cross section
- EX: *Ascaris*, hookworms, *Caenorhabditis elegans*

**PHYLUM ANNELIDA** = the segmented worms - 8800 species.
- bilateral symmetry
- segmentation - the body is composed of many nearly identical segments
- complete digestive system
- hydrostatic skeleton
- closed circulatory system
- EX: earthworm, clam worm, blood worm, leech
- The earthworm will be studied as a representative species of this phylum.

**PHYLUM MOLLUSCA** - the mollusks - 70,000 species (second largest animal phylum)
- bilateral symmetry
- no segmentation in adults
- complete digestive system
- hydrostatic skeleton
- open circulatory system
- soft body with ventral (belly surface) muscular foot* used for movement
- a protective shell made of calcium carbonate usually covers the soft body. The shell does support the body somewhat, but is not the actual skeletal system
- EX: snails, slugs, clams, scallops, oysters, octopus, squid

**PHYLUM ARTHROPODA** - the arthropods - 1,000,000 species (the largest animal phylum)
- bilateral symmetry
- segmentation
- segments are usually fused into larger body regions (e.g., some of the 20 segments of an insect have fused together into three body regions: head, thorax, and abdomen)
- many pairs of jointed appendages (1 or 2 per segment) - arthropod means “jointed leg”
- complete digestive system
- exoskeleton
- open circulatory system
- EX: insects, spiders, ticks, scorpions, crustaceans (lobsters, crabs, etc.), centipedes, millipedes.
- The grasshopper will be studied as a representative species of this phylum
**PHYLUM ECHINODERMATA** - the “spiny-skinned” animals - 5400 species
  → radial symmetry in adults (the body is usually subdivided into five parts)
  → no segmentation
  → complete digestive system
  → endoskeleton made of calcified plates
  → open circulatory system
  → water vascular system & tube feet* to move and feed
  → rough skin made of calcified plates with spines
  → EX: starfish, sea urchin, sea cucumber, sea lily, sand dollar

**PHYLUM CHORDATA** - the **chordates**
  → bilateral symmetry
  → modified segmentation - segmentation is easily seen in the embryo but becomes somewhat hidden in the adult
  → complete digestive system
  → endoskeleton
  → closed circulatory system
  → chordates have three unique characteristics*:
    → dorsal (along the back) **notochord** = hard supporting rod of the skeleton
    → dorsal **nerve cord**
    → **pharyngeal gill slits** - openings from inside the pharynx to the environment. Gill slits were originally used for filter feeding. In fish, they contain gills which are respiratory organs.
  → EX: fish, birds, snakes, humans

**The Vertebrate Classes:**
The Chordata are subdivided into three subphyla, but almost all species of chordate are within the **Subphylum Vertebrata**, the **vertebrates**. In the Vertebrata, the notochord is replaced during development by a new rod made of many pieces which is called the **vertebral column** or backbone.

There are seven classes of vertebrates including:

**3 CLASSES OF FISH**
1. **Jawless fish** (e.g., lamprey) - 50 species
2. **Cartilaginous fish** = fish with a skeleton of cartilage (sharks, rays) - 800 species
3. **Bony fish** = fish with a skeleton of bone - 18,000 species

**CLASS AMPHIBIA** - the **amphibians** - 3,100 species
  → three chambered heart
  → aquatic larvae with gills
  → adults with lungs
  → moist glandular skin
  → no teeth, claws, or scales
  → EX: salamanders, frogs, toads

**CLASS REPTILIA** - the **reptiles** - 6,500 species
  → three chambered heart
  → dry skin covered with scales
  → usually possess claws and teeth
— EX: lizards, snakes, crocodiles, turtles

  Turtles are reptiles and have an endoskeleton. The shell of a turtle is made of scales produced by the skin. The inner scales become bony and attach to the endoskeleton.

**CLASS AVES** - the **birds** - 8,600 species

— four chambered heart
— warm blooded
— skin covered with feathers
— forelimbs adapted as wings
— hollow bones - reduces the bird’s weight so that flying is easier

**CLASS MAMMALIA** - the **mammals** - 4,100 species

— four chambered heart
— warm blooded
— skin covered with hair
— modified sweat glands called mammary glands to produce milk
— EX: kangaroo, mouse, bat, dog, cow, humans
— Humans and the fetal pig will be studied as representative species of this class.

**DICHOTOMOUS KEY**

When you find an organism that you do not know, it is probably not a new species. It probably has already been studied and named, but, you do not know its name. A **key**, like the one below, is a logical series of questions or statements that can be used to identify an organism that you do not know. The key identifies species that have already been named by biologists. It is not used to name a new species. Identification keys use any characteristic that lets us distinguish between two groups; these characteristics may be very different from the characteristics used to classify the groups. When biologists create a key, they try to use characteristics that are easily seen by the user. In contrast, the goal of taxonomic classification is to select characteristics that accurately reflect the natural evolutionary changes that have occurred among organisms.

A key can be very general and only identify phylum or class, or it can be highly specific and identify the actual species. The two keys on the next page are short, simple keys to the Animals. The first key only identifies the phylum of the animal. The second key identifies the classes of vertebrates.

A **dichotomous key** is made up of a series of **paired** statements, e.g., 1a and 1b on the next page, which describe characteristics of organisms. You decide which statement best describes your unknown organism; this narrows the list of possible organisms and leads you to a new pair of statements which are more specific. This process continues until you arrive at the name of your organism. For example, starting at “1” in the following “Key to the Major Animal Phyla”, read both statements of the pair and select the one that seems to best describe the unknown animal. If your animal has radial symmetry, then you will go to 2, but if your animal has bilateral symmetry, you will go to 3. If your animal has radial symmetry and you go to 2, then you are given statements that let you distinguish between Cnidaria and Echinodermata. On the other hand, if your animal has bilateral symmetry and you go to 3, then you are given statements that further narrow the possible list of organisms, and then you are directed to another pair of statements. This continues until the name of the organism is determined.

The following organisms are on the side table so that you can practice using this key:

  Leech, jellyfish, liver fluke, sea urchin, alligator
A KEY TO THE MAJOR ANIMAL PHYLA

1 A  the animal has radial symmetry...........................................2
    B  the animal has bilateral symmetry...................................3

2 A  soft cylindrical body; mouth surrounded by tentacles...........Phylum Cnidaria
    B  rough body divided into five regions (may have 5 arms)........Phylum Echinodermata

3 A  soft body; not segmented...................................................4
    B  body segmented although may be hidden (has repeated parts).6

4 A  flattened body (dorsoventral flattening)..............................Phylum Platyhelminthes
    B  body not flattened dorsoventrally.................................5

5 A  body wormlike, round in cross-section...............................Phylum Nematoda
    B  soft body; not wormlike; external shell..........................Phylum Mollusca

6 A  body soft; wormlike; appendages, if present, not jointed......Phylum Annelida
    B  body with paired, jointed appendages.............................7

7 A  exoskeleton of chitin......................................................Phylum Arthropoda
    B  endoskeleton of bone or cartilage.................................Phylum Chordata

                        (Go to the Chordate key.)

A KEY TO THE CHORDATES (Subphylum Vertebrata)

1 A  has a backbone............................................................ 2  Subphylum Vertebrata
    B  no backbone present.................................................. other types of Chordata

2 A  round mouth with teeth; no lower jaw..............................Class Agnatha (jawless fish)
    B  lower jaw present......................................................3

3 A  body fishlike; no legs.....................................................4
    B  body not fishlike; legs usually present...........................5

4 A  skeleton of bone; scaly skin; symmetric tail......................Class Osteichthyes (bony fish)
    B  skeleton of cartilage; rough skin; asymmetric tail...............Class Chondrichthyes (cartilaginous fish)

5 A  body covered with scales or feathers..............................6
    B  body smooth or covered with hair......................................7

6 A  body covered with scales.............................................Class Reptilia
    B  body covered with feathers...........................................Class Aves

7 A  body covered with hair..................................................Class Mammalia
    B  body smooth; skin is moist...........................................Class Amphibia
Side Table 1:

Kingdom Monera
1. bacteria types: demo slide of coccus, bacillus & spirillus shapes
2. petri dishes of bacteria: *E. coli*; *S. marcescens*; *M. luteus*
3. Blue-Green Bacteria:
   - *Oscillatoria* - herbarium mount // *Anabena* - slide // *Lyngbya* – slide

Student Bench 1:

Kingdom Protista
1. Amoeba: *Amoeba proteus* - slide
2. Ciliates: *Paramecium* - slide
3. Flagellates: *Euglena* - living, make wet mount
4. *Volvox* - living, make wet mount
5. Dinoflagellates - slide
6. Diatoms - slide

Kingdom Plantae
1. Red Algae (Ph. Rhodophyta): *Polysiphonia* - herbarium mount & culture dish
2. Brown Algae (Ph. Phaeophyta): *Fucus* - herbarium mount & culture dish

Student Bench 2:

Kingdom Plantae
1. Moss - living
2. Ferns with sori - living or Riker mount
3. Gymnosperm: evergreen branch with cone
4. Monocot: iris, lily or spiderplant
5. Dicot: geranium, impatiens or begonia
6. Monocot & Dicot: Riker mount

Kingdom Fungi
1. puff ball
2. bracket fungus
3. mushroom - culture dish & plasticized
4. Bread mold *Rhizopus* - slant culture in tube
### Student Bench 3

**Kingdom Animalia**

1. Ph. Cnidaria: Sea anemone - culture dish
2. Ph. Platyhelminthes: *Planaria* - living for making wet mounts
3. Ph. Nematoda: Enterobius
4. Ph. Mollusca: Assorted types
5. Ph. Annelida: Earthworm - culture dish
6. Ph. Annelida: *Nereis* (clamworm) - culture dish
7. Ph. Arthropoda: Assorted types
8. Ph. Echinodermata: Starfish, sand dollar, sea urchins
9. Ph. Chordata: Chick development in plastic mount - look for notochord
10. Ph. Chordata, Jawless Fish: Lamprey - preserved - look for gill slits
11. Ph. Chordata, Cartilaginous Fish: Dogfish shark - preserved - look for post-anal tail
12. Ph. Chordata, Bony Fish: Perch - preserved white pan

### Side Table 2:

**Kingdom Animalia - The 4 Vertebrate Classes**

1. Ph. Chordata, Class Reptilia: anoles - living
2. Ph. Chordata, Class Amphibia: newts - living
3. Ph. Chordata, Class Aves: robin - stuffed
4. Ph. Chordata, Class Mammalia: fox - stuffed

### Back Table:

**Unknowns** Use the Dichotomous Key to identify these.

1.
2.
3.
4.
Learning Objectives:
1. know all the terms that are in **boldface**
2. be able to describe the difference between haploid and diploid cells and their location
3. be able to describe the function of mitosis and meiosis and where each takes place
4. be able to describe/draw the basic events in early embryonic development of simple animals
5. be able to recognize the early stages of sea urchin embryonic development
6. be able to describe/draw the parts of an angiosperm seedling and explain their functions
7. be able to describe the growth and development of angiosperm seedlings
8. be able to explain how seedling development occurs in monocots and dicots. You should be able to recognize a monocot or dicot from the appearance of the seedling.
9. know what a tetrazolium test is. What is it used for?

Materials:
1. Prepared slide: starfish development
2. depression slides, slides, coverslips for making wet mounts of embryos
3. male and female sea urchins
4. models of frog and sea urchin development
5. flower model
6. corn & bean seedlings 5, 7, 11 & 14 days old
7. corn & bean seeds prepared for dissection
8. corn & bean seeds prepared for dissection, then boiled
9. tetrazolium – reagent used to reveal mitochondrial activity
10. video of animal development

Procedures:
You will fertilize sea urchin eggs and follow their early embryonic events. You will look at prepared slides and learn to recognize the early stages of development. You will see a video of early embryonic development in animals and look at models of development in frog.

You will dissect open seeds and observe the differences in the developmental patterns of monocot and dicot seedlings.

Readings:
The textbook coverage is divided among several sections. Consult the Syllabus for page numbers. The diagrams should be helpful. The Photographic Atlas has excellent photographs of sea star development. It also has diagrams of the seed.

Exam 1 is next week.
Overview of Embryonic Development
The Monerans and Protists are unicellular organisms. Plants and animals are multicellular organisms, but they begin life as a single cell called the zygote. Where does the zygote come from? Plants and animals reproduce sexually (actually, almost all organisms reproduce sexually). In sexual reproduction, two gametes (i.e. egg and sperm cells that are made by the parents), fuse together during fertilization to become a single cell, the zygote. This is the first cell of a new individual.

The zygote is the cell from which all other cells of the organism are produced. The cell reproduces by the process of mitotic cell division. This type of cell division produces cells that are genetically the same as the original cell. Thus, all cells of a plant or animal are genetically the same as the zygote and one another. During embryonic development, the cells (although genetically identical) will become specialized for different functions such as secretion or contraction. Specialization of cell function leads to the formation of tissues and organs. One organ is the gonad which will produce the gametes that are needed for sexual reproduction.

This lab describes the early events in the development of a complex organism from the zygote.

Background on Genes and DNA
The chemical events that take place inside a cell are controlled by the cell’s genes. You can think of the genes as being instructions to guide the cell’s activities. When a cell reproduces, it passes a copy of the genes to each of its daughter cells.

Genes are small regions of a type of molecule called DNA. The genes of most cells are found on 2 or more DNA molecules. For example, in fruit flies, all of the thousands of different genes are located on just four DNA molecules. These four DNA molecules are a “complete set” of genetic information that can control the cell.

Cells may have one or two “complete sets” of DNA. A cell that contains one complete set of genetic information is described as haploid (= 1N). A cell that contains two complete sets of genetic information is described as diploid (= 2N). Gametes are always haploid; but the cells that make up the bodies of most plants and animals are diploid. When two gametes (1N) fuse together at fertilization (1N+1N) they produce a zygote that is 2N. Consider the fruit fly. The fruit fly’s gametes contain 1 set of 4 DNA molecules. When a fruit fly egg is fertilized by a sperm cell, the zygote that forms is diploid (2 x 4 DNA molecules). When the zygote divides, each of its daughter cells will be diploid.

Types of Cell Division
Cells reproduce by dividing into two cells (daughter cells). Each cell receives half the cytoplasm of the original cell plus a copy of the DNA molecules that are in the cell. The process is complex and ensures that the DNA is properly distributed between the two daughter cells. If the cells do not receive the proper amount of DNA they will not be able to function. This process will be studied in detail in BIO 112.

There are two types of cell division which differ in how the DNA is distributed to the daughter cells during cell division. (More precisely, these terms refer to the way in which the nucleus divides):
1. **mitosis** - one cell divides once to produce two daughter cells which are genetically the same as one another and the maternal (original) cell.
This type of division is how some protists reproduce and how development (starting with the zygote), growth, and tissue repair occur in plants and animals.

2. **meiosis** - one diploid (2N) cell divides to produce daughter cells that are haploid (1N). Each daughter cell contains only one complete set of DNA, i.e. half the amount of DNA as in the original cell. Meiosis involves a sequence of 2 cell divisions that produces 4 haploid cells.

This type of division is used only by cells in the **gonads** of sexually reproducing organisms. Meiosis is used to produce the haploid **gametes** (eggs in females and sperm in males). Meiosis produces daughter cells that are genetically different from each other and genetically different from the maternal cell. This increases variation in the offspring.

**ANIMAL DEVELOPMENT**

Understand the processes involved in the early development of an animal:

**Gametogenesis** produces gametes by meiosis. The process is slightly different in males and females.

In males, meiosis results in four small cells. Following meiosis, the sperm cells, usually develop a tail-like flagellum that lets the sperm swim. In females, meiosis results in the formation of only 1 large egg. The egg has most of the cytoplasm that was present in the original mother cell.

**Fertilization** produces a zygote. In most organisms, the sperm cell must swim through a fluid to reach the egg. The sperm cell binds to the surface of the egg cell and the sperm’s genetic material enters the nucleus of the egg. The cell is now a Zygote. The zygote is 2N.

**Cleavage Divisions**: The zygote will undergo mitosis to produce 2 identical cells of equal size. Each of these cells will then divide producing an embryo with 4 identical cells. Again, all the cells will divide in synchrony to produce 8 cells. These synchronous divisions are referred to as **cleavage divisions**. These cleavage divisions do not have any period of growth in-between so the size of the embryo does not increase. The cells of the embryo form a solid mass known as the **morula stage**.

**Blastula** formation: The cells in the morula continue to divide, and they migrate away from the center to form a single layer of cells around a fluid-fill space called the **blastocoel**. This hollow ball of cells is the **blastula stage**.

Up until this stage, all the cells have behaved nearly identically. Now the cells will begin to respond to differences in their environment and the process of **differentiation** (specialization) begins.

**Gastrulation**: The cells in one region of the blastula start to migrate inward (invaginate) into the blastocoel. The cavity that is formed is called the **archenteron** and the opening from the outside into the archenteron is called the **blastopore**. The embryo at this time is called the **gastrula**. As the gastrula continues to invaginate, it produces a tube that eventually reaches the opposite end of the embryo and breaks through to the outside to form a pore.

A **tissue** is a group of cells, similar in structure and function, which work together. Gastrulation produces an embryo composed of three tissue layers that develop into the organ systems of the animal:

- **Ectoderm** = the cells on the outer surface → skin and nervous system
- **Endoderm** = cells the form the archenteron → digestive and respiratory systems
- **Mesoderm** = cells located between the endoderm & ectoderm → skeletal, muscular, circulatory, urinary & reproductive systems

An animal that develops from these three tissue layers is said to be **triploblastic**. Most animals are triploblastic. This is a gross over-simplification of the actual development of these organ systems.
STUDENT WORK

1. We will fertilize sea urchin eggs to follow the early stages of development:
   a. make a wet mount of sea urchin sperm on a flat slide
   b. make a wet mount of sea urchin eggs - use a depression slide so you don’t crush the eggs.
   c. lift the cover slip and add sperm to the eggs - use a depression slide
      Watch for the formation of a fertilization membrane
   d. periodically make a slide from the stock sample of fertilized eggs to see if cleavage is occurring

   >>>>> DO NOT THROW AWAY THE DEPRESSION SLIDES. WASH THEM AND RETURN THEM TO THE BASKET <<<<<<

2. Look at the prepared slides of starfish development. You should be able to find all stages from the zygote to the gastrula. Draw these stages.

3. Look at the models of embryonic development in frog and sea urchin. Be able to explain the sequence of events.

NOTE: In the introductory lecture, only the simplest type of animal development was discussed. This is found in the starfish and sea urchin (Phylum Echinodermata) or amphioxus (Phylum Chordata). These organisms have only a small amount of yolk in their eggs. Yolk slows the process of cell division and changes this basic developmental pattern. The greater the amount of yolk in the egg, the more changed the developmental pattern will be from this simplest type.

PLANT DEVELOPMENT

The eggs of angiosperms are fertilized within the ovule. The ovule is located inside the ovary of the flower. The ovule contains the zygote and a nutritive tissue called the endosperm. The ovule, zygote and endosperm develop into a seed. These terms will be described further in the plant reproduction lab.

A seed consists of three parts:
1. a tough seed coat surrounding the seed. The seed coat provides protection.

2. stored food to nourish the young plant until it can produce leaves and begin to carry out photosynthesis. Following fertilization, a nutritive tissue called endosperm is formed inside the ovule. Its cells fill with starch. In monocot seeds, this tissue remains as a portion of the seed (see the corn seed). In dicot seeds, the endosperm is digested by the embryo, and the starch is stored within special seed leaves called cotyledons (see the bean seed).

3. an embryo sporophyte plant. It is composed of three parts:
   a. special seed leaves called cotyledons. A monocot has one cotyledon that slowly digests and absorbs the endosperm. A dicot has two cotyledons that are large due to the food that is stored inside. The dicot cotyledons get smaller as the stored food is used during early growth. Cotyledons are not regular leaves for photosynthesis. They are special leaves that the embryo uses to store or digest food.
   b. Hypocotyls - the portion of the embryo which is below the point of attachment of the cotyledon. The tip of the hypocotyl is the radicle that becomes the growing root tip. The hypocotyl develops into the root system. Sometimes, it also becomes the lower portion of the stem (see the bean seedlings on display).
c. **Epicotyl** - the portion of the embryo which is above the point of attachment of the cotyledon. The epicotyl develops into the stem and leaf system. The tip of the epicotyl is the **plumule** that has the first true leaves attached. These small leaves can be seen in the bean seed.

**Fruit** Seeds are contained within the ovary of the flower. The ovary, and perhaps other flower parts, develops into a fruit. Fruits protect seeds and help in seed dispersal. Fruit does not supply food to the seeds. The food for the embryo is solely derived from the endosperm.

When a seed is mature, the water is removed from its tissue and it becomes dormant (its metabolic activity stops). The seeds of most plants can remain dormant for long periods of time. This provides a way for plants to survive unfavorable conditions. The seed will **germinate** (its metabolic activity resumes) and produce a new plant if held under the proper conditions. The nutrients for development of the new plant come from the endosperm (or cotyledons) inside the seed. A young plant is called a **seedling** until it has begun photosynthesis and no longer uses food stored within the seed.

The pattern of seedling development is different in monocots and dicots. In monocots, the hypocotyl grows down into the soil and the epicotyl grows straight up to the soil surface. In dicots, the tip of the hypocotyl grows down into the soil anchoring the seedling. Further growth of the hypocotyl in the region located immediately beneath the cotyledons causes the hypocotyl to bend and push above the soil surface. As it leaves the soil, the bent stem pulls the seed above the soil surface. Growth by the epicotyl leads to further growth of the stem and production of true leaves that start photosynthesis. The cotyledons, which supplied energy for development of the seedling, shrivel and fall from the stem.

**STUDENT WORK**

1. See the demonstration of bean fruit.

2. Use the dissection microscopes to observe bean and corn seeds. These seeds were soaked in water for 24 hours so that you can dissect them. Cut open the seeds using a razor or scalpel. Use the diagrams on the table to help identify the parts that were described above. Draw both seeds and label the parts.

3. See the demonstration of 1-14 day old corn and bean seedlings.
   - Note that the hypocotyl grows first to anchor the seedling in the soil.
   - Later, the epicotyl will grow. Note how the corn seedling’s **coleoptile** and the bean seedling’s **hypocotyl arch** each protects the delicate epicotyl.
   - Compare the growth of the bean seedling to the corn seedling. Where are the cotyledons located during growth? What is happening to the bean cotyledons as the plants grow? Why is this occurring? You should be able to describe the differences in the growth of corn and bean seedlings.

4. See the **tetrazolium test** demonstration on living and dead seeds. Tetrazolium is colorless, but it becomes pink in the presence of living mitochondria (i.e., living cells). The tetrazolium test can be used to determine the percentage of seeds in a package that are still alive. We will look at bean seeds and corn seeds that have been treated by either (1) soaking in water for several days to start germination or (2) boiling to kill the embryo. The seeds will be cut open and treated with tetrazolium.
Learning Objectives:
1. to understand what is meant by autotrophic nutrition
2. to understand root structure and function in angiosperms
3. know the difference in arrangement of structures in the monocot and dicot roots
4. to understand leaf structure and function in angiosperms
5. be able to describe the structure of the angiosperm leaf
6. be able to distinguish between monocot and dicot leaves
7. to describe and recognize adaptations in leaf structure of plants from different habitats
8. know all terms in **boldface** print.

**Autotrophs** (autotrophic organisms) are organisms that have the ability to produce their own food from inorganic raw materials. They are able to survive in a totally inorganic environment because they can produce every organic compound that they require from small inorganic compounds that they obtain from the environment. **Organic compounds** are large, carbon-based molecules such as carbohydrates, lipids, proteins, and nucleic acids which are produced by organisms. **Inorganic substances** are all the minerals and small compounds such as water and carbon dioxide.

There are a number of different kinds of autotrophic nutrition. However, the most common type is photosynthesis. We will only study how photosynthesis occurs in plants. The general equation for photosynthesis is:

\[
6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2
\]

The equation means that solar energy, captured by chlorophyll molecules in the chloroplast, is used to combine carbon dioxide (CO\(_2\)) and water (H\(_2\)O), two inorganic compounds, and form a sugar called glucose (C\(_6\)H\(_{12}\)O\(_6\)). Oxygen atoms are released as oxygen gas (O\(_2\)), a waste product. Glucose is the main energy source for the plant and also serves as a raw material from which all the other required organic compounds of the plant can be produced. The general equation is a very simplified version of the actual events that occur in the process.

Plants must obtain certain inorganic nutrients from the environment in order for photosynthesis to take place. A **nutrient** is any chemical substance required for metabolism. In plants, these nutrients include carbon dioxide and water, the raw materials of photosynthesis. Plants also require many **minerals** for their metabolism. These minerals serve as raw materials for the production of other compounds. For example, magnesium is a necessary part of the chlorophyll molecule; calcium is required for the construction of cell walls. Some plant nutrients are required in large quantities. These **macronutrients** include Carbon (obtained from CO\(_2\)), Hydrogen (obtained from H\(_2\)O), Nitrogen (from NO\(_3\)-), Sulfur (SO\(_4^{2-}\)), magnesium (Mg\(^{2+}\)), and calcium (Ca\(^{2+}\)). **Micronutrients** are nutrients required in very small quantities. They include Fe\(^{2+}\), Cl\(^{-}\), B, Mn\(^{2+}\), Zn\(^{2+}\), Cu\(^{2+}\), and Mo.

How do plants acquire their nutrients? Terrestrial vascular plants absorb water and minerals from the soil by the root system. Carbon dioxide is obtained by diffusion from the air through openings in the leaves (and green stems) called **stomata** (singular = stoma).

**Roots:**
Roots serve (1) to anchor the plant in the soil (2) as an area where extra sugar can be stored in the form of starch, and (3) to absorb water and minerals from the soil.
Root systems are commonly described as fibrous or taproot systems. In a **fibrous root system** the roots are all of similar size. In contrast, a **taproot system** has a single large root with smaller roots that branch from it.

**Root structure – longitudinal organization**
The tip of the root can be divided into 4 zones. Starting at the tip, the zones are: (1) the **root cap** (2) **division** (3) **elongation** (4) **maturation (differentiation)**. The division zone contains cells that are actively dividing to produce root growth. As new cells form in the division zone, those that are closer to the plant body will swell and increase in length. This forces the tip of the root deeper into the soil. Those cells in the division zone that are closer to the root tip protect the tip of the root as it is pushed into the soil; most of these cells will die. The cells that are in the elongation zone will begin to differentiate or become specialized for specific functions (vascular, storage, absorption). These cells form the maturation zone and it can be recognized by the presence of root hairs (to be described in the next section).

**Root Structure – cross sectional organization**
There are three regions that develop from the . Starting at the outside and moving to the center:

1. **Epidermis** = 1 layer of cells that forms the outer boundary of the root.
   - **Root hairs** = threadlike projections of the cells that increase the surface area of the root.
   - Function – absorb water and dissolved minerals
2. **Cortex**
   - Multiple layers of cells that store water and nutrients
   - **Endodermis** = 1 layer of cells that forms the inner boundary of the cortex
   - **Casparian Strip** = waxy material that forms a water-tight seal between cells of the endodermis
3. **Stele = Vascular Cylinder**
   - Contains vascular tissues:
     - **Xylem** – large diameter, thick walled tubes - carry water and minerals up into the plant
     - **Phloem** – small diameter, thin walled tubes - carry water and sugar up and down between the root and plant body.
   - **Pericycle** = 1 layer of cells next to the endodermis. Grows lateral roots.

Monocots and Dicots differ in the relative size and arrangement of the vascular cylinder. See Figure 34.16 in the textbook.

- **Dicots**: Dicots have a small vascular cylinder. The xylem forms an X or star-like pattern. The phloem is located in the spaces between xylem.
- **Monocots**: Monocots have a large vascular cylinder. The xylem and phloem form alternating bundles just inside the endodermis. The central part of the cortex is filled with large, thin-walled cells called **pith**.

**Leaves**
The function of the leaf is to carry out photosynthesis. It must have a large surface area to collect sunlight. It must have openings so that CO$_2$ can enter the leaf and O$_2$ can escape from the leaf.

**Leaf Structure – gross structure**
Monocot and Dicot leaves are differ in structure:

- **Dicots**: The **blade** is the flat part of the leaf. The blade is joined to the plant stem by the stalk-like **petiole**. Vascular tissue travels through the petiole into the blade. The **veins** in the blade consist of
vascular tissue. The veins form a central rib that forms branches that enter all parts of the leaf. The thick cell walls of vascular tissue provide support for the leaf.

**Monocots:** The leaf grows from the stem without a petiole. Veins run parallel to each other within the leaf.

**Leaf Structure – cross section**

The **epidermis** is a single (sometimes 2) layer of cells that forms the upper and lower surfaces of the leaf. The cells of the epidermis are close together. The outer surface of the leaf is coated with a layer of waxy **cuticle**. The cuticle reduces water loss from the leaf. **Stomata** (stoma, singular) are small openings in the epidermis that allow gases (O₂, CO₂, and H₂O) to cross the epidermis. A pair of cells called **guard cells** encircles each stoma. Guard cells can change shape which causes the stoma to open or close. The space between the upper and lower epidermis contains two types of tissue: vascular tissue and mesophyll tissue. The vascular tissue consists of xylem and phloem. The mesophyll cells contain lots of chloroplasts so they are the site of photosynthesis. Mesophyll cells form one or two layers of cells lying next to the upper epidermis that are called **palisade mesophyll cells**. Other mesophyll cells called **spongy mesophyll cells** fill the space next to the lower epidermis. Spaces between the spongy mesophyll cell allow movement of gases within the leaf.

**Leaf Adaptations**

Plant leaves have become adapted to many environments which vary in the temperature, the amount of light, and the amount of water. Leaves may show modifications of the location of their stomata, the amount of cuticle, addition of hairs, or size of the leaf. Plants may be classified by the environment in which they grow and their adaptations to those conditions. **Mesophytes** are plants adapted for moderate environments. **Xerophytes** are adapted for arid habitats. **Hydrophytes** are adapted for life in water.

**Student Work:**

1. See the demonstration of **taproot** and **fibrous root systems**. Draw and describe each type. What are **adventitious roots**?

2. Look at the LS of the root. Identify the **Root Cap**, an irregular mass of cells forming the tip of the root. Identify the **Apical Meristem region** where cell division is occurring. Identify the **Elongation region** where cells increase in length. Identify the **Differentiation (a.k.a. maturation) region** where the root hairs are located and specific tissues develop.

3. Look at the XS of the buttercup (**Ranunculus**) root. **Ranunculus** is a dicot. Draw the slide. Know the arrangement and function of each tissue layer. Know **Epidermis, Cortex, Endodermis, Vascular Cylinder (a.k.a. Stele), Pericycle, Xylem and Phloem**.

4. Look at the XS of the corn (**Zea mays**) root. Corn is a monocot. Draw the slide. Identify the tissues (including **Pith**). Know **Epidermis, Cortex, Endodermis, Vascular Cylinder, Pericycle, Xylem Phloem**, and **Pith**.

   ⇒ Compare the arrangement of the tissues in the monocot root with the dicot root. You should be able to recognize each.
5. Look at the demo slide of the growth of a **lateral root**. Note that the root begins at the **pericycle**, a meristematic tissue. **Meristematic tissue** is plant tissue that is capable of cell division (mitosis). Hence, it is an area of growth.

6. Make a wet mount of a radish seedling and look at the root tip with the stereoscopic microscope. Note the numerous **root hairs** that greatly increase the absorptive surface of the root. Each root hair is an extension of a single epidermal cell.

Only the green parts of a plant carry out photosynthesis. Leaves are the most common site of photosynthesis, but green stems also play a role. The water and minerals absorbed by the roots are transported to the leaves through the **xylem**, one of the vascular tissues.

7. Make a thin slice of the celery stalk (the petiole of a leaf). It has absorbed and transported some of the colored water in which it is immersed. Note that the colored water is only located in discrete circular areas. This is the **xylem** and is located within the veins.

8. Examine the gross structure of a monocot and dicot leaf. Be able to recognize them. Know **Petiole, Blade, and Veins**.

9. Look at the XS of **Ligustrum** leaf. Know the arrangement and function of each tissue layer. Pay special attention to the guard cells and stomata. Draw the slide. Know the following: **Cuticle, Epidermis, Pallisade Mesophyll, Spongy Mesophyll, Vein, Stomata, Guard Cell**.

10. Look at the XS of leaves from plants adapted to each habitat and see the living plants on display.
   a. **Ligustrum** is a mesophyte.
   b. **Nerium** (= oleander) is a xerophyte.
   c. **Potamogeton** (= water lily) is a hydrophyte.

   How does the structure of Nerium and Potamogeton leaves differ from that of *Ligustrum*?
   - How are the stomata different from those of *Ligustrum*?
     - Look at their location & shape.
     - Compare their density on the leaf surfaces
   - Compare the tissues of the three leaves tissue layer by tissue layer. Take notes about the appearance of each layer in each of the three leaves.
     - Compare the upper epidermis to the lower epidermis
     - Compare the amount of cuticle
     - Compare organization of the mesophyll cells.
   - Think about the ecological value of these adaptations in the habitat of each of these three plants.
LEARNING OBJECTIVES:
1. to know the meaning of heterotrophic nutrition
2. to know the process of digestion and what each step accomplishes
3. to learn the structure and function of representative protozoan and animal digestive systems
   ⇔ be able to describe and draw the parts of each
   ⇔ be able to describe the advantages and disadvantages of each

A heterotroph is an organism that cannot manufacture for itself every organic nutrient that it requires from inorganic raw materials. It must obtain certain specific organic nutrients from the environment. Besides organic nutrients, certain inorganic nutrients (such as water and minerals) are also needed. These nutrients enter the organism in food.

A heterotroph requires food for the same two reasons as an autotroph:
   1. as a source of energy (calories)
   2. as a source of raw materials from which to produce the various chemicals of its body

For most animals, food is in the form of large, bulky items. This food is larger than a cell; yet, it is the cells of the body that need these nutrients. Before it can be used by a cell, food must be processed into a form which can be absorbed. This job of food processing is the work of the animal’s digestive system.

Food processing generally proceeds as a logical series of steps:
   1. ingestion - the food is brought into the system
   2. mechanical breakdown - the food is physically torn into smaller pieces to increase the surface area upon which the digestive enzymes will work
   3. chemical breakdown - hydrolytic (digestive) enzymes break down chemicals too large for cells to absorb into smaller chemicals which can be absorbed
      Digestion is the mechanical and chemical breakdown of food into particles that are small enough to enter a cell.
   4. absorption - the useful chemicals produced by digestion are taken into the body
   5. elimination - indigestable and unabsorbed material is removed from the body

A sixth job, food storage, allows the organism to ingest large amounts of food at one time, and then the food is slowly processed during the time between meals as the animal engages in other activities. Storage can occur after ingestion (as in earthworms) or after mechanical breakdown (as in mammals).

In animals there are two main types of digestive systems:
   1. incomplete digestive system (2-way) - a digestive system with only one opening to the environment through which food enters and wastes leave. This opening is called a mouth.
   2. complete digestive system (1-way) - a digestive system with two openings to the environment: a mouth through which food enters and an anus through which wastes are eliminated.

Only animals with a complete digestive system have evolved specialized organs for digestion. Why?
**Student Work**

We will observe food processing in the following organisms:

1. **Paramecium** - Kingdom Protista
   a. Observe a wet mount of living *Paramecium*. If they are swimming too rapidly, add a drop of Protoslo to slow them down.
   b. Feed the *Paramecium* by adding a small drop of dyed yeast suspension observe the formation and movement of **food vacuoles**.
   c. Observe the plastic model of *Paramecium*.

2. **Hydra** - Phylum Cnidaria
   a. Transfer a single *Hydra* to a small Petri dish or Syracuse dish that contains enough water to cover the *Hydra*. Observe the *Hydra* using the dissecting microscope.
      - Add a water flea (*Daphnia* - Phylum Arthropoda) to the dish with the *Hydra* and observe the *Hydra* feed. Describe the process. What structures does it use?
      - Return the living *hydra* to its container.
   b. Observe the demo slides of *Hydra* LS and XS
      - Note the **gastrovascular cavity** which fills the entire interior of the animal.
      - Note that the body wall is only two cell layers thick. Embryonic development in Cnidarians does not have a three-layered gastrula stage. Cnidarians develop from a two-layered larva and are said to be diploblastic. In contrast, all the higher animals are triploblastic.
   c. Observe the plastic model of *hydra*.
   d. Watch the film loop of a feeding *hydra*.

3. **Planaria** - Phylum Platyhelminthes
   a. Observe the demo slide of *Planaria*. The digestive system (**gastrovascular cavity**) is stained for easy observation. How much of the interior is filled by the gastrovascular cavity? Describe the shape of the gastrovascular cavity. Why is it this size and shape?
   b. Observe the digestive system in the plastic model of the planaria

4. **Earthworm** - Phylum Annelida
   a. Dissect the earthworm digestive system
   b. Locate the **mouth**, **pharynx**, **esophagus**, **crop**, **gizzard**, and **intestine**. What is the function of each structure?
   c. Observe the demo slide of earthworm XS
      - Note the **typhlosole**, a dorsal fold of the inner surface of the small intestine, which increases the internal surface area for greater digestion and absorption.

5. **Fetal pig** - Phylum Chordata, Subphylum Vertebrata, Class Mammalia
   a. Know the difference between **frontal**, **sagittal**, and **transverse sections**
   b. Know the following anatomical terms:
      1. **anterior** - front surface
      2. **posterior** - rear surface
      3. **superior** – above or farther from the ground
      4. **inferior** – below or closer to the ground
      5. **dorsal** - back surface (with vertebral column) of the animal
6. **ventral** - belly surface of the animal
7. **cranial** - near the head end of the animal
8. **caudal** - near the tail end of the animal
9. **medial** - nearer to the midline of the animal
10. **lateral** - farther from the midline or toward the side of the animal

c. Observe the external anatomy of the fetal pig. You should know how to determine the gender. Is your pig male or female?

d. Dissect the digestive system of the fetal pig
   ⇒ Open the ventral side of the animal. Locate the **diaphragm** (a sheet of muscle used in breathing) that separates **thoracic cavity** from the **abdominopelvic cavity**.
   ⇒ Identify the structures in the list below and know the function of each. You should know the path that food follows as it passes through this system.

   **oral cavity:**
   - hard palate
   - soft palate
   - esophagus
   - nasal pharynx - the part of the pharynx that is superior to the palate
   - oropharynx - the part of the pharynx that is inferior to the palate
   - glottis - opening into the larynx
   - epiglottis of larynx – cartilage covering the glottis

   **neck area:**
   - larynx = voice box - not part of the digestive system
   - trachea = windpipe - not part of the digestive system
   - esophagus
   - thyroid gland - not part of the digestive system
   - thymus gland - not part of the digestive system

   **abdominal cavity:**
   - stomach
   - small intestine
   - liver
   - gall bladder
   - pancreas
   - large intestine (spiral colon)
   - caecum (cecum) – part of the large intestine
   - anus
   - spleen – not part of the digestive system

e. Observe the demo slide of the mammalian small intestine
   Note the finger-like **villi** (singular = villus) inside the lumen. What is the function of the villi? What structure in another organism observed in this lab has the same function?
Learning Objectives - Gas Exchange:
1. know why gas exchange occurs in all organisms
2. know why the gas exchange needs of plants are different in the night and day.
3. know the structure of leaves and the role of each structure in gas exchange
4. know the role of stomata and guard cells in gas exchange and protection against water loss.
5. recognize the lenticel
6. understand the Potameter experimental results
7. know all terms in bold face type

Learning Objectives – Transport:
1. to learn the external structure of stems
2. to learn the internal structure of stems
3. be able to distinguish between the monocot and dicot stems seen in XS.
4. to observe the forces which are involved in transport within xylem and explain them
5. to understand the pattern of growth in a woody stem that produces annual rings
6. understand and interpret the experiments
7. know all terms in bold face type

Cellular respiration is a process that occurs in the cells of all organisms (all the organisms of all five kingdoms) at all times. This process is a series of chemical reactions that break down large organic molecules (mainly glucose) and release the energy that is stored within. The released energy is then stored within the chemical bonds of a molecule called ATP (adenosine triphosphate). ATP is used as the direct source of energy by all cells. This energy source (ATP) is used by the cell for movement and the synthesis of new chemicals that are used for repair, growth, reproduction, etc. The term metabolism refers to all the chemical reactions in the cell. Many of these reactions require ATP.

Most organisms use aerobic cellular respiration, the most efficient form of cellular respiration. This process requires oxygen gas ($O_2$) which must be obtained from the outside environment. A very simplified general equation for aerobic cellular respiration is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36ATP \text{ (stored energy)}$$

Glucose is broken down into carbon dioxide ($CO_2$) and water ($H_2O$). The energy that is released from glucose is then stored in the chemical bonds of ATP where it is available for use in the cell’s metabolism. Note that the process produces carbon dioxide, a gaseous waste product, which must be excreted from the cell and the organism.

Since both plants and animals use aerobic cellular respiration, both plants and animals require the uptake of oxygen from the environment and the excretion of carbon dioxide into the environment.

Gas exchange between organisms and the environment occurs by diffusion. This is a slow process that only works over very thin and moist surfaces. Single celled organisms and small aquatic organisms can exchange gases directly across the cell membrane. However, larger organisms require specialized structures for gas exchange. Because diffusion is slow, the gas exchange surfaces are usually large and very thin. Land plants and animals must protect their gas exchange surfaces from dessication (drying out).
GAS EXCHANGE IN PLANTS
Plants are autotrophic and carry out photosynthesis \((6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2)\). Carbon dioxide is a raw material needed from the environment so that photosynthesis can occur. Oxygen is a waste product of photosynthesis and must be removed from the plant.

These same two gases (carbon dioxide and oxygen) are involved in aerobic cellular respiration, but their roles as nutrient and waste product are reversed.

Aerobic cellular respiration occurs at all times, but photosynthesis occurs only in sunlight. During daylight hours, the plant is carrying out both aerobic cellular respiration and photosynthesis. At night, photosynthesis stops and the plant is only carrying out aerobic cellular respiration.

During the day, photosynthesis produces more oxygen than the plant needs for aerobic cellular respiration so that the plant does not need an outside source of oxygen for its cells and even releases extra oxygen into the environment as a waste product. However, the daytime plant does need an outside source of carbon dioxide for photosynthesis since aerobic cellular respiration does not produce sufficient carbon dioxide waste to supply the plant’s needs for photosynthesis.

At night, when photosynthesis stops, so does oxygen production. At night, plants require an external source of oxygen and produce carbon dioxide as a waste product.

In summary, during the day a plant requires CO\(_2\) and produces O\(_2\) while at night it requires O\(_2\) and produces CO\(_2\). Be sure that you understand why this change occurs and that you can explain it.

**Student Work**
1. The leaf is the primary structure for gas exchange occurs in plants. Review the structure of leaves as studied in Lab #4. The leaf epidermis is covered by a waxy cuticle. The leaf epidermis encloses the mesophyll tissue. Extensive air spaces surround the spongy mesophyll and allow movement of gases to and from the stomata. The stomata provide openings between the the leaf interior and the atmosphere. How is a large surface area created for gas exchange? How does the leaf protect against dessication?

When stomata are open for gas exchange, there will always be some water loss. Plants need to be able to control this loss of water. Each stoma is bordered by two guard cells; these guard cells can open or close the stomata. When water enters guard cells by osmosis, they become swollen and the stoma is open. When water exits guard cells, they shrink and close the space between them. This closes the stoma and prevents most water loss. Low water levels in a leave will cause the stomata to close.

You can observe the opening and closing of stomata.
- Peel a thin piece of the lower epidermis from a living leaf of *Ruellia* or other plant and make a wet mount in distilled water. Why do we use the lower epidermis?
- Observe the stomata. Are they open or closed? Note that the cell walls bordering the stoma are very thick so that the guard cells take on a kidney-shape when they become swollen. The stoma is the space between these two kidney-shaped cells. Draw the guard cells and stomata.
- Replace the distilled water with 5% salt solution. This solution is composed of 95% water and 5% salt. Observe the guard cells and stomata. What has happened? Why?
2. **Transpiration** is the evaporation of water from the above-ground parts of a plant. Most transpiration occurs through open stomata. Plants open or close their stomata to allow gas exchange and to regulate water loss. Stomata are generally open during the day but closed at night or during a drought. Can you explain why this pattern of stomatal opening and closing makes sense?

The rate of transpiration depends upon whether the stomata are open or closed and also upon the environment. Any environmental factor that increases evaporation will tend to increase transpiration. Why? How do you expect increased temperature, increased humidity, or increased wind will affect the rate of transpiration?

A **potameter** is a device to measure the rate of transpiration. We will use a potameter to study several different environmental conditions: “normal”, wind, and humidity.

- Set up the potameter as you are instructed.
- Each table will simulate a different environmental condition.
  - Normal = plant on the table top
  - Wind = hair dryer fan directed towards plant (no heat)
  - Humidity = plastic bag placed over the leaf
- Make a reading of the changing water level every 10 minutes.
- Class results will be pooled on the chalkboard.

3. Green stems have stomata that operate like those in a leaf. Woody stems have specialized air spaces through the waxy bark to allow for gas exchange. These gas exchange structures are called **lenticels**. Which gas is required by the cells of a woody stem? Why?

- Look at the woody stems on the tables; use the stereomicroscope. Note the lenticels. Are all lenticels the same in appearance?
- Look at the demo slide of a lenticel. Note the loose packing of the parenchyma cells. Draw this slide.

**INTERNAL TRANSPORT IN PLANTS**

The root system of plants absorbs water and minerals from the soil. Stomata and lenticels are specialized gas exchange structures that bring in nutrient gases and let waste gases escape.

These specialized areas for nutrient intake are only small areas of the total organism. However, the nutrients that are absorbed are needed by all the cells of the organism. Most of these cells are far away from the nutrient intake regions.

For the cells to receive the nutrients they need, the nutrients must be transported from these intake regions to the individual cells. This is the main job of the internal transport system. In tracheophytes (vascular plants), the internal transport system is made of two types of vascular tissue: xylem and phloem.

**Xylem** transports water and minerals upward from the roots. At maturity, a functional xylem cell is dead. All that remains of the cell is its cell wall that is connected to the cell walls of other dead cells to
form non-living tubes for transport. The largest and most efficient xylem cells are called vessel cells that stack up into transporting tubes called vessels.

**Phloem** mainly transports sugar from the leaves (the site of most photosynthesis) or from sugar-storing tissues in the roots and stems to all other areas of the plant. Phloem can transport either upward or downward. The phloem cells that transport sugar are called sieve elements, and they stack up in columns called sieve tubes. Sieve elements are living cells, but they lack a nucleus. **Plasmodesmata** connect the cytoplasm of adjacent cells. Smaller companion cells are next to the sieve elements. Companion cells do have a nucleus, and it is believed that the nucleus of the companion cell controls the metabolism of a number of adjacent sieve elements. The companion cells do not transport sugar.

**Student Work**

1. Gross structure of stems
   a. observe the woody stems on the table. Identify the terminal bud, lateral buds, bud scars, leaf scars, nodes, and internodes.
   b. observe the demo section of woody stem. Note the heartwood and sapwood.

2. Microscopic anatomy of stems
   a. observe a slide of monocot stem (Zea) XS. Identify the epidermis, pith, vascular bundles, xylem, vessel cells, phloem, sieve elements, and companion cells. Draw the slide.
   b. observe a slide of a herbaceous (non-woody) dicot stem (Trifolium) XS. A young woody dicot stem would also have this tissue structure. Identify the epidermis, cortex, pith, vascular bundles, xylem, and phloem. Draw the slide.
      ⇒ Compare/contrast the organization of the structures in the monocot with those in the dicot stem. You should be able to recognize each.
   c. observe a slide of a 2-year old woody dicot stem (Tilia) XS. Identify the cork, cork cambium, cortex, phloem, vascular cambium, xylem rings, springwood and summerwood, and pith. Draw the slide.
      ⇒ Describe the process of growth that leads to formation of annual rings in the woody stem.

3. Observe the demonstrations showing root pressure and guttation. What conditions are required for guttation to occur?

4. Observe the demonstrations showing:
   a. the cohesion of water molecules
   b. the capillary action of water
      In which glass tube does water rise the highest? Why?
   c. transpiration
      The combined action of these forces explains water/mineral transport in xylem as proposed by the cohesion or transpiration pull hypothesis (also called TATC = transpiration-adhesion-tension-cohesion theory).
SLIDES
1. bacterial smear - typical monerans
2. amoeba - typical protist
3. paramecium - typical protist
4. euglena - typical protist
5. hydra - body wall of two cell layers
6. planaria - stained gastrovascular cavity
7. cheek cell (squamous epithelium) - typical animal cell
8. starfish development – various stages
9. dicot root XS – *Ranunculus*
10. monocot root XS – *Zea mays*
11. mesophyte leaf - *Ligustrum*
12. hydrophyte leaf - *Potamogeton*
13. xerophyte leaf - *Nerium*
14. monocot stem XS - *Zea*
15. herbaceous dicot stem XS - *Trifolium*
16. woody dicot stem XS - *Tilia*
17. lenticel
18. earthworm XS - see typhlosole and thin skin
19. mammalian small intestine XS - see villi

OTHER:
- Microscope parts
- Flower model
- Bean seed and sprouts dissection
- *Paramecium* model
- *Hydra* model
- *Planaria* model
- potameter and other transport demonstrations
- fetal pig - digestive system
  - lab 5 lists the organs for which you are responsible
- plant woody stem with lenticels
- living plants representative of monocots, dicots, gymnosperms, ferns, mosses
- preserved animal specimens representative of the major animal phyla and the major chordate classes
- earthworm dissection

Written Test 2 will follow the Practical Exam.
Test 2 will cover labs 4, 5, and 6: autotrophic nutrition
  - heterotrophic nutrition
  - gas exchange and internal transport in plants
Learning Objectives:
1. to know the reasons why gas exchange is required
2. to understand the characteristics of any gas exchange surface
3. to know the structure of respiratory systems in representative animals
   1. to know the structure of the mammalian heart
   2. to know the route blood follows as it travels through the mammalian heart
   3. to know the structural differences between arteries and veins
4. to know the major arteries and veins of the fetal pig and the organs that each serves

Materials:
Slides in student folders:
- insect trachea
- insect spiracle
Demo Slides:
- Nereis xs
- Earthworm xs
  - Artery & Vein xs
Preserved specimens:
- Earthworm
- Nereis - in Lucite block
- Crayfish
- Perch
- Grasshopper
- Freeze-dried Swine Lung
- Sheep hearts for dissection
Models:
- heart

Procedures:
You will observe the respiratory structures of a variety of organisms. You will dissect a preserved sheep heart. You will dissect the fetal pig and identify the major arteries and veins.
GAS EXCHANGE IN ANIMALS
Animals perform aerobic cellular respiration. Thus, they require oxygen from the environment and produce carbon dioxide as a waste. Why does an animal not need carbon dioxide as does a plant?

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} \]

Exchange of gases between the animal and its environment is the result of diffusion across cell membranes. These surfaces must remain moist. Diffusion is a slow process, so gas exchange surfaces must be thin and have a large surface area.

Some organisms which are small and live in moist environments may exchange gases directly across their outer surface or skin. But most organisms must have specialized gas exchange structures. The gas exchange surfaces are thin, moist tissues with very large surface areas. They usually have a rich blood supply for transport of the gases to the body. Land animals usually have structures to protect the gas exchange surfaces from dessication.

Most animal gas exchange surfaces can be placed into two informal categories:
1. evaginated gas exchange surface - a thin flap of the body wall extends outward for gas exchange. This is only found in water living animals. Why?
2. invaginated gas exchange surface - the gas exchange surface is within the body but connected by passages to the outside environment. This is the usual respiratory system for a terrestrial animal. Why?

STUDENT WORK: Examples of respiratory structures
1. Earthworm - Phylum Annelida
   Earthworms are able to exchange gases directly through their moist skin. This skin is very thin and contains numerous blood vessels. The reddish color of earthworms is due to this rich blood supply in the skin.
   • Observe the demo slide of earthworm XS and note the thin skin.

2. Gills - an evaginated gas exchange surface
   a. Nereis, the clam worm (Phylum Annelida) has paired parapodia on each segment. They serve as gills.
      • Observe the preserved specimen of Nereis.
      • Observe the demo slide of Nereis parapodia. Note that they are very thin.
   b. Crayfish (Phylum Arthropoda) has gills beneath its carapace.
      • Observe the demonstration of crayfish gills. Note their feathery appearance. This feathery nature greatly increases their surface area. What is the value of gills having increased surface area?
   c. Bony fish have gills located beneath a flap called the operculum.
      • Observe the gills of the preserved fish.
      • Look at the live fish in the aquarium. How does a fish breathe?

3. Tracheal system of insects - an invaginated gas exchange surface
   Openings, called spiracles, on the outside of the insect lead into tubes (tracheae) that extend throughout the body carrying oxygen to the individual cells.
   • Observe the spiracles of the preserved grasshopper.
   • Observe the slide of a spiracle. This particular type of spiracle has two valves that permit the spiracle to be opened and closed. Draw the slide.
• Observe the slide of tracheae. Draw the slide.

4. **Lungs** - an invaginated gas exchange surface
   • Observe the freeze-dried pig lung.
   • Dissect the respiratory system of the fetal pig.
     - Identify the following parts: nasal cavity, nasal pharynx, oropharynx, larynx (with glottis & epiglottis), trachea, thoracic cavity, lungs, and diaphragm.
   • Scrape away some of the left lung tissue to expose the bronchial tree

**INTERNAL TRANSPORT IN ANIMALS**

Digestive and respiratory systems bring food nutrients and oxygen into the organism. However, these nutrients are needed by all the individual cells throughout the body. The absorptive surfaces of these organ systems are far away from most cells of the body. As in plants, these nutrients must be transported from their site of entry into the body to cells throughout the body.

In animals the, or it may just be the fluids that surround the cells. Some animals have an open circulatory system in which the fluids that surround the cells circulate through the body. Movement of the fluid is caused by a muscular vessel (heart) that collects the fluid and then contracts so the fluid squirts out over the tissues. This produces some circulation of tissue fluids across the various organs.

Larger animals have a closed circulatory system. In these systems, the blood (a liquid tissue) is always contained inside vessels. The vessels form a continuous system that extends throughout the animal. As the blood flows within the vessels, it makes a 1-way circuit through the body. This allows for efficient transport of materials throughout the body. The blood vessels will pass next to surfaces in the digestive system where nutrients are absorbed and transferred to the blood. Then the blood passes each cell of the body so that the cells can receive nutrients from the blood. Chemical wastes (carbon dioxide and ammonia) that are produced by the cells enter the blood. These wastes are carried to specialized organs (such as the lungs and kidneys) which remove them from the body. Besides transporting nutrients, the circulatory system of an animal also transports hormones. In birds and mammals the circulatory system also serves to evenly distribute heat throughout the body.

A muscular pump called a heart is needed to make the blood flow through the blood vessels. The heart is essentially a blood vessel with very thick muscular walls. When the heart muscle contracts, it creates pressure that forces the blood into the blood vessels. Blood vessels that carry blood away from the heart are called Arteries. The arteries carry the blood to the tissues. The blood vessels at the tissues are called capillaries. The capillaries are the smallest blood vessels. It is in the microscopic capillaries that food and oxygen diffuse into the cells of the body and where cellular waste products diffuse from the cells into the blood. The blood vessels that carry the blood back toward the heart are called veins.

The three types of blood vessels differ in the structure of their walls. Arteries have relatively thick walls that can resist the outward push of the blood pressure. Capillaries are only one cell layer thick. The cells are very thin which lets materials move easily between the blood and the tissues. The veins have thinner walls than arteries because there is very little blood pressure in the veins. Veins also have cup-shaped flaps of tissue along their inner surface that function as valves. The valves prevent the blood from flowing backwards in the vein.
The blood vessels in adult mammals and birds form two circuits

The hearts of mammals and birds can be thought of as two pumps that lie side-by-side. Each pump pushes blood into one of two circuits. The **pulmonary circuit** consists of the blood vessels that lead from the right side of the heart to the lungs and back to the left side of the heart. This circuit allows for exchange of oxygen and carbon dioxide between the blood and the lungs. The **systemic circuit** consists of the blood vessels that lead from the left side of the heart out to the tissues of the body then back to the right side of the heart. This circuit includes the digestive organs where nutrients are obtained and the kidneys where ammonia is removed.

**Structure of the heart**

The heart is a muscular organ with hollow spaces (heart chambers) that fill with blood. Contraction of the muscle surrounding each chamber creates pressure (blood pressure) that forces the blood out of the chamber. As noted above, the heart contains two pumps lying side-by-side (the right and left sides of the heart). Each pump is made of two chambers. The first chamber is the thin-walled **atrium** which receives the blood from a vein. Blood leaves the atrium by passing through the **atrio-ventricular valve** (flaps of connective tissue) into the second chamber. The second chamber is the thick-walled **ventricle**. It pumps the blood through the **semi-lunar valve** into an artery. The valves prevent the blood from flowing backward into the chamber.

Vein → Atrium → Atrio-Ventricular Valve → Ventricle → Semi-Lunar Valve → Artery

The chambers and valves on each side of the heart have specific names.

Vena Cava → Right Atrium → Tricuspid Valve → Right Ventricle → Pulmonary Semi-Lunar Valve → Pulmonary Artery → Lungs

Pulmonary Vein → Left Atrium → Bicuspid Valve → Left Ventricle → Aortic Semi-Lunar Valve → Aorta → Tissues of the body

**Fetal Circulation**

The mammalian fetus cannot use its lungs. It must exchange gases (oxygen and carbon dioxide) with the blood of the mother. This exchange takes place in the **placenta**. The placenta is located in the uterus. The fetus must also obtain nutrients and eliminate wastes at the placenta. Blood vessels in the umbilical cord link the fetus to the placenta. The umbilical cord contains 3 vessels: the **umbilical vein** carries oxygen rich blood from the placenta; two **umbilical arteries** carry blood to the placenta.

How does the fetus avoid sending blood to the lungs? There are two changes in the fetus that let the blood by-pass the lungs: (1) the **Foramen Ovale** is a hole in the wall between the right and left atri which permits blood flow from the right atrium to the left atrium, (2) the **Ductus Arteriosus** is a short vessel that joins the pulmonary artery to the aorta.

The blood supply to the viscera follows a different pattern from other parts of the body.

Several arteries carry blood to the walls of the viscera. Their capillaries pick up nutrients from the viscera. The veins that carry blood away from the viscera do not connect directly to the vena cava. Rather they drain into a vessel called the **hepatic portal vein**. The hepatic portal vein carries the blood into the liver where it divides into smaller vessels and finally forms capillaries (liver sinusoids). The liver cells remove nutrients from the blood and filter out bacteria that may have entered the blood from the intestines. The blood vessels then come together to forma a single hepatic vein which returns the blood to the vena cava.

Arteries → capillaries → veins → hepatic portal vein → liver capillaries → hepatic vein
STUDENT WORK

1. Observe the demo slide of an artery and vein in cross section. Note that the artery has a thick wall and small lumen while the vein has a thinner wall and larger lumen.

2. Dissect the sheep heart. Be able to identify the
   a. four chambers: **right & left atria, right & left ventricles**
      *Note differences in the thickness of the atria and the right and left ventricles*
   b. four valves: **Atrio-Ventricular = Tricuspid and Bicuspid (aka mitral) Valves**
      **Semi-Lunar = Pulmonary and Aortic Semi-Lunar Valves**
      *Note the structural differences between the A-V and S-L valves*
   c. blood vessels: **cranial vena cava, caudal vena cava, pulmonary veins,**
      **pulmonary artery, and aorta**
      *Note the differences in the thickness of the walls of the arteries and veins*

3. Dissect the circulatory system of the fetal pig. Be able to identify the vessels in the following list. Know the area of the body that each artery or vein serves, i.e. does it carry blood to (or from) the liver or to the right foreleg or to the head or to the ……

<table>
<thead>
<tr>
<th>ARTERIES</th>
<th>VEINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>brachiocephalic artery</td>
<td>jugular vein</td>
</tr>
<tr>
<td>carotid artery</td>
<td>subclavian vein</td>
</tr>
<tr>
<td>subclavian artery</td>
<td>anterior vena cava</td>
</tr>
<tr>
<td>pulmonary artery</td>
<td>posterior vena cava</td>
</tr>
<tr>
<td>aorta</td>
<td></td>
</tr>
<tr>
<td>ductus arteriosus</td>
<td>hepatic portal vein</td>
</tr>
<tr>
<td>coeliac (celiac) artery</td>
<td>renal vein</td>
</tr>
<tr>
<td>cranial mesenteric artery</td>
<td></td>
</tr>
<tr>
<td>renal artery</td>
<td></td>
</tr>
<tr>
<td>gonadal artery</td>
<td></td>
</tr>
<tr>
<td>(testicular a. or ovarian a.)</td>
<td></td>
</tr>
<tr>
<td>iliac artery</td>
<td>iliac vein</td>
</tr>
<tr>
<td>umbilical artery</td>
<td>umbilical vein</td>
</tr>
</tbody>
</table>
Learning Objectives:
1. to understand the role of mitosis and meiosis
2. to understand the concept of a life cycle
3. to understand alternation of generations
4. to be able to compare and contrast the moss and flowering plant life cycle
5. to understand non-sexual reproduction in plants

Materials:
Slides in student folders:
- Moss Antheridia
- Moss Archegonium
- Moss Capsule
- *Lilium* Anther
- *Lilium* Ovary

Demo Slides:
- Pollen grains
- Pollen tube growth

Specimens:
- *Rhizopus* culture (dissecting microscope)
- Preserved mount of moss reproductive stages
- Living flowers for dissection
- Vegetative propagation examples:
  - Fern
  - Onion
  - Potato
  - Carrot
  - Kalanchoe
  - Coleus
  - Spider plant

Models:
- Flowers

Video:
- Angiosperms: Flowering Plants, part 2
- Film loop of pollen tube growth

Materials for stimulating pollen tube growth: paint brush, 20% sucrose, slides, and cover slips

Procedures:
We will review the basics of plant life cycles and reproduction. Then you will study the reproductive structures in molds, moss, and flowering plants. You will also see examples of vegetative propagation. Film.
Introduction
One of the characteristics of life is reproduction. All cells and organisms age and die. Without reproduction, life would continue for only a single generation. New individuals need to be produced.

Reproduction can also increase the numerical size of a population and allow it to expand into new habitats. Sexual reproduction also adds genetic variation to a population. It is genetic variability that is the raw material of natural selection.

Reproduction of an organism always involves the production of new cells. Review the information about mitosis and meiosis given in Lab 3. What is the difference between a diploid (2N) and a haploid (N) cell or organism? An understanding of this material is essential to today’s lab.

There are two types of reproduction:
1. non-sexual reproduction is uniparental - only a single individual is involved
   a. one or more cells of the parent separate from the parent. These cells have the ability to grow into a complete new individual. Since these are merely detached parental cells, they are genetically the same as the parent.
   b. all cell divisions are mitosis. Since mitosis produces daughter cells that are genetically the same as the maternal cell, the offspring are genetically the same as the parent.
   c. non-sexual reproduction introduces little genetic variation into a population. The only genetic variation comes from mutation.

2. sexual reproduction is biparental - generally, two different individuals are involved
   a. two specialized cells (gametes) fuse together to form a zygote. Sometimes the two gametes look the same (isogamy), but it is more common for the gametes to differ in size and appearance (sperm and egg).
   b. meiosis must occur somewhere in the organism’s life cycle to prevent the doubling of DNA. Meiosis occurs at different places in the life cycles of organisms in the different kingdoms.
      - animals: gametic meiosis - meiosis produces the gametes
      - plants: sporangial meiosis - meiosis is used to produce spores
      - fungi: zygotic meiosis - after fertilization the zygote undergoes meiosis
   c. sexual reproduction introduces large amounts of genetic variation. Genetic variation is produced by meiosis, random fertilization, and mutation.

Both types of reproduction have advantages. Non-sexual reproduction is an easy way to produce large numbers of new individuals. However, there will be little genetic variation among individuals. Sexual reproduction produces much genetic variability, and each individual is genetically unique. Some species utilize non-sexual reproduction during mild seasons, e.g., summer; but they switch to sexual reproduction if environmental conditions become harsh. What is the advantage of this strategy?

Plants have a life cycle named alternation of generations that involves both non-sexual and sexual reproduction. Thus, plants receive the benefits of each type of reproduction.
Non-Sexual Reproduction in Fungi and Plants

Two types of plant non-sexual reproduction are discussed and exhibited:

1. **Sporulation** - making and releasing spores
   A spore is a single cell which, if it lands in a favorable habitat, has the ability to grow into a complete new individual. In plants, spores are produced by meiosis (meiospores), but in other kingdoms, spores can be produced by mitosis (mitospores). Because a spore is only a single cell, it is light-weight and can be carried great distances by the wind. Sporulation can be an important means of dispersal to a species. Spores often have a tough capsule which enables the cell to withstand harsh conditions.

   Sporulation in mosses and flowering plants will be discussed later in the lab.

   A small sample of the black bread mold (*Rhizopus*, Kingdom Fungi) is on display as an example of sporulation, *Rhizopus* is a common mold that will grow on starchy foods. The thallus is called a mycelium and is haploid. The mycelium is composed of numerous branching threads called hyphae. Some of the hyphae end as swollen black spots. These black spots are sporangia, structures in which spores are produced by mitosis.

   ➞ Look at the living mold with the stereoscopic microscope
   ➞ Look at the demonstration slide of *Rhizopus* with the compound microscope. Observe the hyphae and sporangia.

   Each mature sporangium houses a large number of black spores. The wall of the sporangium will burst open, and the spores will be scattered by the wind. If a spore lands in a favorable habitat, it will grow into a new mycelium.

2. **Vegetative Propagation** - a portion of a plant detaches and grows into a complete new plant. In many plants almost any reasonably large part will grow into a new organism under proper conditions. By using vegetative propagation, human growers can produce huge numbers of a popular genotype or phenotype.

   ➞ Examine the following examples of vegetative propagation.
   a. leaves (*Bryophyllum*, Kalanchoe, African violet)
   b. stems (*Coleus*, *Begonia*, geranium, *Forsythia*, privet, willow)
   c. specialized stems
      1. runners - horizontally growing stems which will root at nodes to produce new plants (spider plant, strawberry)
      2. tubers - short, fleshy underground stems with minute scale leaves (buds or “eyes”) (potato, dahlia)
      3. bulbs - short, thick underground stems with roots and overlapping scale-leaves covering a bud (onion, garlic, tulip, lily, hyacinth)
   d. roots (beet, carrot, sweet potato)
The Plant Life Cycle
A life cycle refers to the life of an individual from its beginning as a zygote through its development and growth until a new generation is produced by fertilization.

In plants, the life cycle is called **alternation of generations**. This is because each plant species, has two types of plants: (1) a sexually reproducing **gametophyte** that produces gametes by mitosis, and (2) a non-sexual **sporophyte** that produces spores by meiosis (a process known as **sporulation**). The plants alternate between these two types during each life cycle.

Gametophytes produce gametes that unite to form zygotes. The zygote develops into a sporophyte (if you look back at Lab 3, you will see that there is an embryo sporophyte inside an angiosperm seed). Sporophytes produce spores by meiosis. These spores will grow into gametophytes.

A summary of the general life cycle of a plant is drawn below.

```
mitosis
→ → → sporophyte (2N) →
↑
zygote (2N) →
↑
gametes (1N)

meiosis
↓
spore (1N)
↓
mitosis
↓
gametophyte (1N) ←
mitosis
↓
```

In the primitive aquatic plants, alternation of generations produced sporophytes and gametophytes of equal size and appearance. However, in the land plants, one generation has become dominant, i.e., one generation is much larger in size and is more prominent than the other.

We will take a look at two phyla of land plants: the Bryophyta (mosses) and the angiosperms (flowering plants). In the bryophytes, the gametophyte generation is the dominant stage. In flowering plants, the sporophyte generation is the dominant plant form.

**THE LIFE CYCLE OF MOSSES (Phylum Bryophyta)**
The green moss plants that we see growing in moist places are the gametophytes, the sexual (gamete-producing) plants. The sporophyte plant is only present during the reproductive season and grows as a parasite from the top of the female gametophyte.

**The Gametophyte Generation**
The green gametophytes look like vascular plants in that they are composed of leaf-like, stem-like, and root-like structures. In botany, for something to be a leaf, stem, or root it must contain vascular tissue. Since bryophytes do not contain vascular tissue, their structures have different names. Without vascular tissues, mosses must be small so that their root-like and leaf-like structures are close to one another.

During the reproductive season the gametophytes develop sexual organs at the top of the plant. The male produces antheridia (singular = **antheridium**) which are structures that produce swimming sperm. The group of antheridia forms a star-shaped enlargement, called the antheridial head, at the top of the plant. This can be seen with the naked eye. The female produces bottle-shaped archegonia
(singular = **archegonium**) at the top of the plant. This archegonial head is not visible to the naked eye. Each archegonium produces one internal egg at its center.

**The Sporophyte Generation**
Biflagellate sperm are released from the antheridia of the male gametophyte and must swim through the external environment to the egg that is located at the top of the female gametophyte. The sperm usually swim in the morning dew or during rain.

Sperm swim down the neck of the archegonium and fertilize the egg that is inside. This forms the zygote, the first cell of the sporophyte generation.

The 2N (diploid) zygote grows by mitosis from the top of the female gametophyte. The sporophyte grows as a stalk that attaches itself to cells of its mother with root-like structures. The sporophyte absorbs nutrients from the female gametophyte and is a true parasite.

A **capsule** develops at the top of the sporophyte’s stalk. Inside the capsule is the **sporangium**, a spore-producing organ. Within the sporangium, spore mother cells undergo meiosis to produce 1N (haploid) spores. The capsule contains either a lid or pores. When mature, the lid falls off or the pores open, and the spores are released from the sporangium into the outside environment.

Wind blows the spores, and they may travel great distances. If a spore lands in a suitable environment, it will grow by mitosis into a new male or female gametophyte. Since the 1N (haploid) spore develops into the gametophyte by mitosis, the gametophyte will also be haploid.

**Summary of Moss Life Cycle**

\[
\begin{array}{c}
\text{Zygote (2N)} \\
\uparrow \text{fertilization} \\
\uparrow \text{mitosis} \\
\text{egg (1N)} \\
\uparrow \text{mitosis} \\
\text{sperm (1N)} \\
\uparrow \text{mitosis} \\
\text{Male Gametophyte (1N)} \\
\leftarrow \\
\text{Female Gametophyte (1N)} \\
\end{array}
\rightarrow \rightarrow \rightarrow \text{Sporophyte (2N)} \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \text{Spore (1N)} \downarrow \downarrow \downarrow \downarrow \downarrow \downarrow \downarrow \downarrow \downarrow \downarrow
\]

**STUDENT WORK**

✧ Observe the preserved moss plants in the black display box. It shows **male gametophyte, female gametophyte**, and **sporophyte plants**. Note the swollen top on the male gametophyte. This is the **Antheridial head** that contains the male sexual organs.

✧ Examine the slide of **Moss Antheridia** = male’s antheridial head.
  - Note the numerous antheridia. The numerous dots inside each antheridium are the nuclei of tiny sperm cells.

✧ Examine the slide **Moss Archegonia** = female’s archegonium.
  - Look for the bottle-shaped archegonia set amid sterile hairs. Few of the archegonia will be sectioned exactly in half and their appearance may vary. The hollow space inside each archegonium marks the location of the egg.

✧ Examine the slide of **Moss Capsule**. Note the sporangium containing spores and the location of the lid (or pores).
LIFE CYCLE DIAGRAM OF A MOSS
LIFE CYCLE OF FLOWERING PLANTS
The gymnosperm and angiosperm plants that you see in a garden or forest are the sporophyte (non-sexual) form of the plant. In the angiosperms, the sporophyte reproduces by producing spores in sporangia that are located within an organ called a flower.

In evolutionary terms, a flower can be considered a very short branch with whorls of highly modified leaves. These modified structures have different appearances and functions.

The stalk of a flower is called the peduncle. The tip of the peduncle is often a swollen receptacle to which the other flower parts attach. Recall that monocot flower parts will be in multiples of three, but dicot flower parts will be in multiples of 4 or 5.

The lowest circle of flower parts is the sepals. They are often green in color and protect the bud until it is ready to open. Sometimes they are colored like the petals and help the petals in their function. Collectively, the sepals are called the calyx.

The petals are interior to the sepals. Often they are large and brightly colored to attract insect or other animal (birds, bats, etc.) pollinators. In wind pollinated flowers the petals are often small and green. Collectively, the petals are called the corolla.

The stamens are interior to the petals. Stamens are, the male part of the flower. Each stamen is composed of a stalk-like filament that ends as a swollen upper chamber, the anther. The anther contains sporangia that produce the male spores (pollen grains). The male spores will grow into the small male gametophytes.

At the center of the flower is the pistil. The pistil is the female spore-producing structure. The pistil is bottle-shaped and is composed of a sticky upper stigma, a long neck-like style, and a swollen base called the ovary that contains the sporangia that produce the female spores. These female spores grow into small female gametophytes within the ovary.

Examine the flower model and locate the listed parts.
Dissect the living flower and locate the listed parts.

- Is this flower a monocot or dicot?
- Make a transverse cut through the ovary of the pistil. Note the three compartments containing ovules (described below).

The Angiosperm Gametophyte Generation develops inside the flower
The herb, shrub, or tree that you see is the sporophyte generation. Plants (but not fungi) produce their spores by meiosis. The anther (in the stamen) and the ovary (in the pistil) produce male and female spores. These spores will grow into the microscopic gametophyte generation.

The anther contains four chambers called sporangia (a.k.a. pollen sacs). The sporangia contain spore mother cells that undergo meiosis to form male spores (1N). The spores undergo mitosis and form pollen grains (1N). The pollen grain is the male gametophyte. Thousands of pollen grains will be produced in the stamens of one flower. The pollen grain has a tough capsule and is resistant to dry conditions. The pollen grain will be transferred to the female gametophyte in a process called pollination.
The ovary of the pistil contains chambers called **ovules**. Within each ovule (there may be hundreds of ovules in one ovary) a spore mother cell undergoes meiosis to produce four female spores (1N). Three of the spores die leaving only one living female spore in the ovule. The female spore undergoes mitosis three times to become a seven-celled organism within the ovule. This seven-celled structure is the female gametophyte (1N). Three small cells are located at each end of the female gametophyte; the seventh cell is a large central cell that contains two nuclei called **polar nuclei**. One of the small end cells is an **egg** ready to be fertilized.

- Look at the *Lilium Anther* slide. Look for the spores inside the pollen sacs.
- Look at the *Lilium Ovary* slide. Look for the female spores inside the ovules.

How does the plant deliver sperm to the egg? It involves 3 steps.

1. **Pollination**: Mature pollen grains are released from the anther and must travel to the pistil of a flower. This transfer of pollen from one flower to another is called pollination. Sometimes pollen is blown by the wind, but it is more efficient for the pollen to be transported by birds, bees, or other insects. Flowers often produce sugary **nectar** that attracts animals. When feeding on the nectar, pollen sticks to the body of the animal and is transported to a different flower. The pollen grain lands on the sticky stigma of the pistil.

   - See the demo slides of pollen.

2. **Growth of the Pollen Tube**: The sugar on the stigma simulates the pollen to develop a long **pollen tube** that grows down through the pistil’s style to the ovary. Within the tip of the pollen tube is a nucleus that directs the growth of the pollen tube. Higher up in the pollen grain is another nucleus that divides by mitosis into two **sperm nuclei**. These two nuclei will serve as sperm. This organism with three nuclei is the mature male gametophyte (1N). The pollen tube grows until it enters an ovule (location of the female gametophyte). The two sperm nuclei travel inside the pollen tube to the ovule. Since the sperm never leave the body of the male gametophyte, no water is required to deliver the sperm to the egg.

   - See the demo slides of pollen tubes.
   - See film loop of pollen tube growth.
   - Follow the procedure for stimulating pollen tube growth

3. **Double Fertilization**: Both sperm nuclei are used at fertilization.

   One sperm nucleus fuses with the egg cell within the female gametophyte to produce a zygote (2N). The zygote divides by mitosis into an embryo sporophyte plant.

   The second sperm nucleus enters the large central cell and fuses with the two polar nuclei to produce a triploid cell (3N) (1N + 1N + 1N = 3N). This cell undergoes mitosis to produce a triploid tissue called **endosperm** that serves as a food source for the embryo plant.

   The walls of the ovule become a protective covering (the **seed coat**) around the embryo and endosperm. This is a **seed**, composed of embryo, stored food, and a seed coat. The seed is located within a fruit that develops from the ovary of the pistil and perhaps other flower parts. Fruits do not feed the embryo plant within the seed. Fruits serve to disperse the seeds to environments away from competition with the parent plants. Fruits can be dry (e.g. dandelion) or fleshy (e.g. cherry). The fleshy fruits attract animals that eat the fruit, but they do not digest the seeds. The seeds pass through the digestive tract of the animal and are deposited a distance away from the parent.
Questions for review:

1. In mosses, which generation is dominant?

2. In angiosperms (and all tracheophytes), which generation is dominant?

3. What is the difference between a gamete and a spore? What is the fate of each?

4. If $2N = 24$ in a certain plant species, how many chromosomes will be in the:
   a. sporophyte
   b. gametophyte
   c. gamete
   d. spore
   e. zygote

5. Where is the sporophyte of a moss located? Describe its appearance.

6. Where is the gametophyte of a flowering plant located?

7. What do you think is the advantage of a life cycle like alternation of generations?

8. What factors make the angiosperms much more successful land plants compared to the mosses?
Learning Objectives:
1. to understand the general animal life cycle and be able to explain it
2. to be able to explain the fundamental differences between plant and animal life cycles
3. to know examples of the different forms of non-sexual reproduction used by various animals
4. to know examples of the different forms of sexual reproduction used by various animals
5. to learn the structure of the mammalian reproductive system - male and female – and be able to identify them in the fetal pig
6. to learn to identify the organs of the urinary system in the fetal pig

Materials:
Student slides:
• Paramecium in fission
• Paramecium in conjugation
• Obelia medusa
• Obelia hydroid colony
• Testis c.s.
• Ovary c.s.
Demo slides:
• Aurelia strobila = a type of jellyfish
• Hydra ovary (dissecting microscope)
• Hydra spermary (dissecting microscope)
• Hydra budding (dissecting microscope)
• Sperm smears from frog, rat, human
Models:
• Paramecium
• Hydra
• Planaria
Preserved specimens:
• Earthworm (dissecting microscope)
• Earthworm cocoons
• Pig Uterus

Procedures:
You will learn about the life cycles and reproductive strategies of a variety of animals through lecture and study of representative invertebrate specimens. You will also learn the anatomy of the mammalian reproductive system and dissect the reproductive system of the pig. You will be briefly introduced to the events in the formation of the egg.
Introduction
All animal species reproduce sexually. However, some animal species also have the ability to reproduce non-sexually at times. Non-sexual reproduction can be a very efficient way of producing large numbers of individuals for dispersal or making large numbers of individuals with successful genotypes during times of favorable environmental conditions when genetic variability is less important. However, all of these species also practice sexual reproduction to increase the genetic variability in the species.

Non-sexual reproduction in protists and animals:
1. **Binary Fission** - Paramecia can reproduce by binary fission. This means that the organism divides into two by mitosis. Binary fission produces two genetically identical cells.
   ⇒ Observe the slide of *Paramecium* binary fission (Kingdom Protista). Only a few examples of fission will be visible on the slide. Note that a *transverse* furrow divides the two cells.

2. **Fission** - in some species (e.g., the simplest flatworms) the body fragments into pieces. Each piece then by mitosis regenerates the body parts it is missing.

3. **Budding** - tissue from the parent’s body (produced by mitosis and genetically the same as the parent) grows into a miniature organism which is then released into the environment as a separate individual.
   ⇒ Observe the model and demo slide of *Hydra Budding*. Note that the gastrovascular cavity of the parent and the *bud* are continuous. Food digested by the parent nourishes the bud until it separates from the parent and now must capture its own food.

   In a coral reef, each coral organism (polyp) buds off new individuals that remain connected together as a colony of interconnected organisms that can share food.

   Hydra also use sexual reproduction. They have gonads (ovaries and spermaries) to produce gametes. The gametes are released into the water.
   ⇒ Observe the demo slide of the *Hydra ovary*.
   ⇒ Observe the demo slide of the *Hydra spermary*.

4. **Parthenogenesis** - in some species an unfertilized haploid or diploid egg can develop into a new haploid individual without being fertilized. This occurs in rotifers, aphids, wasps, ants, etc.

Sexual reproduction in Protists and Animals
All animal species reproduce sexually and have a relatively similar life cycle. All stages in the animal life cycle are diploid except for the gametes (sperm and eggs). Animals have *gametic meiosis* i.e. the gametes (N) are produced by meiosis. Fertilization causes the organisms to become diploid again. Fertilization may take place outside the body of the female (*external fertilization*) or it may occur inside the body of the mother (*internal fertilization*).
⇒ Contrast the animal life cycle with the life cycle in plants.

We will study a few examples of animal reproduction that show slight variations in the life cycle or that will illustrate a general point. We will study:
   1. **conjugation** - a different method of producing genetic recombination in protists
2. a life cycle which has an alternation of sexual and non-sexual individuals
3. hermaphroditism
4. the mammalian reproductive system

**Conjugation in Paramecium** (Kingdom Protista):
Paramecia can reproduce non-sexually by binary fission (described above), but binary fission produces no genetic change in the population. Paramecia can also reproduce by conjugation. **Conjugation** is sometimes described as primitive sexual reproduction. It produces genetic variability, one purpose of sexual reproduction, but the number of individuals is not increased.

In conjugation, two individuals fuse together side-by-side. The plasma membrane between the two cells breaks down so that their cytoplasm is connected. A series of nuclear divisions, including both mitosis and meiosis, produces two nuclei in each cell. Then the two cells exchange one of their two nuclei. Each cell now has two nuclei: one is its own and one is from its partner. The two nuclei fuse together to produce a new nucleus that is genetically different from the original nucleus. The plasma membrane re-forms, and the two cells separate.

There are still only two paramecia, but each is genetically different from the original organism. After separating the two paramecia will divide by binary fission to produce numerous copies of this new combination of genes.

⇒ Observe the slide of *Paramecium conjugation*. Only a few examples of conjugation will be seen on the slide. Notice that a **longitudinal** furrow divides the two cells.

**Obelia life cycle** (Phylum Cnidaria):
Primitive cnidarians have a very unusual life cycle that alternates between sexual and non-sexual individuals. Hydra is too advanced a cnidarian to have this primitive life cycle, so that we will need to observe a simpler animal named *Obelia*.

*Obelia* are salt-water animals which live on the ocean floor as a colony of non-sexual individuals. Each individual is called a polyp. **Polyp** is the term used to describe a stage in the Cnidarian life cycle which is sessile and looks like a Hydra. The colony is called a **hydroid colony** because the individuals resemble a hydra. Each polyp is a separate organism, but the individuals are connected together and have a common digestive system. The hydroid colony grows larger by budding new polyps.

Most polyps are **feeding polyps** with tentacles, but a few are **reproductive polyps** which have a different shape. The reproductive polyps, by budding, produce a different type of individual called a medusa. The **medusa** is the stage of the Cnidarian life cycle that can swim.

The medusa is the sexual stage of the life cycle. The medusa looks like a very small jellyfish with a ring of tentacles around the margin of the bell. It will develop four gonads for sexual reproduction. Sexes are separate (i.e., medusae are either male or female). Sperm and eggs are released into the water and external fertilization occurs in the ocean water. The embryo develops into a planula larva.

The medusa can swim and the larva can float in the plankton for a period of time. This helps to disperse the species into new environments. After a time, the larva will settle down to the ocean bottom and attach to a hard surface. Then it will develop into the first nutritive polyp of a new hydroid colony that will grow larger by budding off new polyps.
The primitive cnidarian life cycle resembles plant alternation of generations in that a sexual and non-sexual stage alternate; however, it is a typical animal life cycle because all stages of the life cycle are diploid except for the gametes.

\[
\begin{array}{c}
\text{polyp (2N)} \\
\text{zygote (2N)} \\
\text{gametes (N)} \\
\text{meiosis} \\
\text{medusa (2N)} \\
\end{array}
\]

→ budding (mitosis) →

⇒ Compare Obelia’s life cycle to the plant life cycle. How much of the plant life cycle is haploid?
⇒ Observe the slide of Obelia hydroid colony. Note the feeding and reproductive polyps.
Note the small medusae forming on the reproductive polyps.
⇒ Observe the slide of Obelia medusa.
⇒ Observe the demo slide Aurelia strobila. Aurelia is a different species of jellyfish. Strobilation is a different way to produce medusa buds.

Reproduction in earthworms: Hermaphrodites
Sexual reproduction introduces genetic variability, and all animals reproduce sexually. In some species of animal, the individuals are hermaphrodites. Each individual hermaphrodite produces both sperm and eggs; thus, the individual is neither male nor female.

Plants that produce both male and female spores on the same individual are called **monoecious**.
Plants that produce male and female spores on different individual plants are called **dioecious**.

Self-fertilization using an organism’s own sperm and eggs would produce much less genetic variation and, somewhat, defeat the purpose of sexual reproduction. (Gametes in animals and spores in plants are produced by meiosis. Because of the manner in which meiosis occurs [covered in BIO 112], gametes or spores from one individual are genetically different from one another; although they are more similar than would be gametes or spores from two different individuals.)

Usually there exists some mechanism to prevent self-fertilization in hermaphrodites. An organism might spend a portion of his/her life as one sex and then later in life transform into the opposite sex. Other organisms may be hermaphroditic but never produce sperm and eggs at the same time.
Earthworms are hermaphrodites who do produce viable sperm and eggs at the same time. However, they must exchange sperm with another worm.

Earthworms have a complete male and a complete female reproductive system.

**Male reproductive system:**
- two pairs of testes - segments 10 and 11
- three pairs of seminal vesicles to store and mature its own sperm - segments 10-12
- two sperm ducts which lead to external openings - segments 14 & 15

**Female reproductive system:**
- one pair of ovaries - segment 13
- one pair of egg sacs to store eggs - segment 14
- one pair of oviducts leading to external openings - segment 14
- two pairs of seminal receptacles to store sperm from another worm - segments 9 & 10

Worms have **mutual copulation** during which two worms exchange sperm over a period of two or more hours. Later, after the worms have separated, each worm will fertilize its own eggs with the sperm it received from the other worm. Thus, genetic recombination is assured since two parents produce the zygote.

Two worms will move together and overlap the first third of their bodies with their heads in opposite directions. Using their **clitellum** (the swollen area covering the segments which are located approximately one third of the way down the body from the head) to secrete mucus the two worms will attachment themselves together by a belt of mucus. While attached together, each worm will transfer sperm to the seminal receptacles of the other worm. Then, they separate and go their own way.

Later each worm separately will use its clitellum to produce another belt of mucus. It will slide the band of mucus toward its head. As the band of mucus passes segment 14, the worm will place its own eggs into the band. As the band passes segments 9 and 10, the worm will add the other worm’s sperm to the mucus. Fertilization occurs within the mucus band.

After the mucus band slips off the worm’s head, the mucus hardens into a cocoon in which the young worms develop. A series of cocoons will be produced over a period of time.

⇒ Observe the earthworm cocoons on the side lab bench.
⇒ Observe the earthworm life cycle on the wall charts.

**The mammalian reproductive system:** Phylum Chordata, Subphylum Vertebrata, Class Mammalia

Reproductive systems of mammals include the gonads and structures for copulation and, in females, a uterus for support of the developing embryo. The gonads of the mammal produce the gamete and the sex hormones. The sex hormones affect the development of each gender’s secondary sex characteristics. These can include differences in body structure and behavior. The sex hormones also regulate the process of gamete formation and, in females, preparation of the uterus for the embryo. Each gender also has structures for

*NOTE: You are responsible for knowing the anatomy of both the male and female reproductive systems. You will need to work with another student who has a pig of the opposite sex.*

⇒ **Locate and know the following structures in the male fetal pig:**
  - **Scrotum** - external sac which houses the testes. It regulates the temperature of the sperm.
  - **Testes** - the pair of male gonads that produce sperm and male sex hormones
  - **Epididymis** - a long coiled tube on the surface of each testis. Sperm is stored here until ejaculation.
  - **Vas Deferens** - a long muscular tube from each epididymis that travels up from the scrotum into the pelvic cavity they carry sperm during ejaculation
  - **Inguinal Canal** - the opening between the pelvic cavity and scrotum. The **spermatic cord** (containing the vas deferens, blood vessels, lymphatic vessels & nerves) passes through it.
  - **Urethra** - the tube of the urinary system which runs from the urinary bladder to the tip of the **Penis**. It is the final tube through which sperm are ejaculated. Thus, the urethra is an organ of both the urinary system and the reproductive system in males. The urethra is not a part of the
female reproductive system. In female mammals the urinary and reproductive systems are
totally separate.
• Three pairs of glands are associated with the vas deferens and urethra: seminal vesicles,
prostate gland, and Cowper’s (bulbourethral) glands. Collectively these glands produce a fluid
called seminal fluid.
• **Seminal Fluid:**
  • rinses acid urine from the urethra
  • activates sperm to begin swimming
  • is a medium in which the sperm swim
  • contains fructose for the sperm’s cellular respiration
  • being alkaline (basic), it neutralizes the acidity of vaginal secretions
• urinary system structures:
  2 kidneys, 2 ureters, 1 urinary bladder, 1 urethra

⇒ **Locate and know the following in the female fetal pig:**
• **Ovary** - the female gonad which produces eggs and female sex hormones
• **Oviducts** - extremely small tubes on the surface of each ovary. Fertilization will occur here.
• **Uterus** - where gestation occurs. Female pigs produce a litter of piglets. So that there is space
  for the many fetuses, female pigs have a Y-shaped uterus which is composed of two lateral
  horns which extend from a single medial body. The uterus connects to the vagina.
• **Vagina** - female copulatory organ and part of the birth canal
• **Urogenital Sinus** - a chamber formed by the fusion of the vagina and urethra. It opens to the
  exterior of the body near to the anus.
• urinary system structures:
  2 kidneys, 2 ureters, 1 urinary bladder, 1 urethra

⇒ **Examine the microscope slide of a Mammalian Testis (XS) under low power.**
   Note that the slide shows numerous tubes that are cut in cross-section. Each tube is called a
   **seminiferous tubule.** It is in the seminiferous tubules where sperm are produced by meiosis.
   **Spermatogenesis** produces four haploid (1N) sperm from each diploid mother cell. You should be
   able to see the hair-like tails (flagella) of many sperm in the lumen of each tubule. Are you able to
   see the heads of the sperm under high power? Thin layers of connective tissue bind the tubules
together. Observe the dark-staining cells scattered between the seminiferous tubules. These are
   **interstitial cells.** The interstitial cells produce androgens, the male sex hormones. Testosterone is
   the principle androgen produced.

⇒ **Observe the demo slides of Sperm from a variety of species.**
   A sperm is composed of a **head** (location of the DNA), **midpiece** (which contains mitochondria),
   and **flagellum** (for movement). Note their small size and that the appearance of sperm varies in
different taxa.

⇒ **Examine the microscope slide of a mammalian ovary under low power.**
   Observe the outer layer of the ovary. Note the numerous small circular structures. Each is a
   **follicle** composed of an oocyte (a diploid cell which will produce an egg) surrounded by one or
   more layers of epithelial cells. The cells in the follicle will go through a sequence of changes
called the **ovarian cycle.** During the ovarian cycle the epithelial cells multiply and secrete
increasing amounts of **estrogens** (including estradiol) and **progesterone,** the female sex hormones.
These hormone coordinate changes in the uterus which prepare it to receive and nourish the
embryo (the uterine cycle). At the same time, the oocyte undergoes **Oogenesis** to produce the egg (ovum). The diploid oocyte divides by meiosis to produce one large haploid egg cell and three small haploid polar bodies which have very little cytoplasm. As the follicles mature they grow larger and the number of epithelial layers increases. You will see follicles in different stages of maturity. Somewhere on the slide you should see one or more large fluid-filled follicles containing a large egg ready for release from the ovary (ovulation). This is a mature follicle, a **Graafian (or Vesicular) follicle**. The egg will enter the oviducts and be carried down to the uterus.

⇒ Use the wall charts or models that depict the Ovarian Cycle in humans to better understand these events.
Learning Objectives:
1. to understand the necessity for osmoregulation and excretion
2. to know how plants solve the problem of osmoregulation
3. to know examples of the different forms of osmoregulatory and excretory systems used by protists and various animals
4. to know the structures that are visible in the adult pig’s kidney
5. to dissect and learn the structures of the mammalian urinary system
6. to know the parts of the nephron and the basic process of urine formation.

Materials:
Student slides:
• Kidney – look for Bowman’s capsule and kidney tubules
Demo slides:
• Grasshopper Malpighian tubules
• Earthworm Nephridium
Models:
• Paramecium
• Planaria
• Honeybee
• Nephron
• Human kidney
Preserved specimens:
• Earthworm (dissecting scope)
• Pig kidneys – whole and sagital sections
Videotape – Work of the Kidney
Wall charts – Paramecium & earthworm reproduction

Procedures:
You will learn about the need for osmoregulation and excretion in animals and the strategies that various animals use. You will learn about the mechanism of urine formation in mammals. You will also learn the anatomy of the mammalian urinary system and dissect the urinary system of the pig.
**Introduction**

Cells carry out a wide variety of chemical reactions. Some of these chemical reactions are used to synthesize or repair cell parts; others involve the breakdown of molecules to produce energy that powers cell activities. Nutrients must be brought into the cell to supply materials for the chemical reactions. Many of the chemical reactions produce waste products which must be removed from the cell. For example, carbon dioxide is a waste product of cell respiration and ammonia is produced when amino acids are metabolized. If these wastes are not removed, the cell will die. The process of eliminating these metabolic wastes is called **excretion**.

Another job that all cells must accomplish is to maintain their correct osmotic concentration (correct concentration of osmotic particles and correct concentration of water). If the cell’s osmotic concentration is incorrect, the cell’s enzymes will not function properly. Thus, for any cell to work correctly, it needs to control (regulate) its osmotic concentration. **Osmoregulation** is the regulation of osmotic concentration by an organism.

A **hypotonic solution** has a lower concentration of osmotic particles (and a higher concentration of water) than the cytoplasm of a cell. When a cell is placed in fresh water (hypotonic), water will diffuse into the cell (water flows down its concentration gradient); and the cell will become swollen. The plasma membrane of the cell will stretch as the cell swells. However, there is a limit to how much the plasma membrane can stretch before it tears and the cell dies. If a cell is to survive in a hypotonic environment, it must stop the entry of water before it bursts and dies.

Fresh water plants and terrestrial plant roots live in a hypotonic solution but are able to passively osmoregulate by using their **cell walls**. The cell wall is a rigid structure outside of the plasma membrane. It does not stretch and prevents the plant cell from becoming so swollen that it would burst.

Animal cells and many protists do not have cell walls so they must use other methods to osmoregulate. Unlike plants, these methods are active processes that require the use of cellular energy supplied by ATP.

**Amoeba** and **Paramecium** (Kingdom Protista) are cells that also survive in fresh water, a hypotonic solution. These organisms possess cell organelles called **contractile vacuoles** that accumulate the water that is constantly diffusing into the cell. When the contractile vacuoles reach a certain size, they squeeze shut squirting the water back out of the organism.

**Planaria** also lives in fresh water. It possesses a **flame cell system** to osmoregulate. A flame cell system is made of tubes that open to the outside of the body. Water diffusing into the worm accumulates inside the tubes. The innermost ends of the tubes are dead-ends. The cell at the dead-end is called a flame cell which has cilia that move to create a current in the tube. This current causes the water to flow out of the system into the environment.

Large animals do not have each cell osmoregulate itself. It is more efficient to use a specialized organ to osmoregulate the blood. Since the blood flows past the cells in the body, the cells merely have to remain the same as the blood. Any excess water or solute in the blood will be removed by the specialized organ. In other words, the osmoregulatory system directly osmoregulates the blood and indirectly osmoregulates the cells of the animal.
The osmoregulatory system in many animals has evolved a second function: the excretion of nitrogenous wastes. **Nitrogenous wastes** are cellular metabolic wastes that contain nitrogen atoms. They result from the breakdown of proteins and nucleic acids. Examples include ammonia, urea, and uric acid. The removal of metabolic wastes from the body is called **excretion**. Many, animals use their osmoregulatory system as a way to dilute and excrete these nitrogenous wastes.

Note that feces are a different type of waste product. Feces are undigested, unabsorbed food: material that has never entered a cell of the body. The removal of feces is called elimination.

Thus, animals may use a single organ system for osmoregulation and excretion of nitrogenous metabolic wastes, two unrelated functions. Sometimes this system is used almost exclusively for osmoregulation (e.g. flame cell system). Sometimes the system is used almost exclusively for excretion (e.g. the Malpighian tubules of insects). Sometimes the system is equally important in accomplishing both jobs (e.g. the nephridium of the earthworm and the mammalian kidney).

**Student Work:**

1. **Protist contractile vacuoles**
   - Observe the contractile vacuoles in the *Paramecium* slide.
   - Observe the contractile vacuoles in the plastic models of *Amoeba* and *Paramecium*.

2. **Planarian flame cell system**
   - Observe the flame cell system in the plastic *Planaria* model.
   - Note the parallel tubes that extend nearly the length of the animal. Each tube opens to the outside. The Flame cells are located in branches of these tubes.

3. **Insect Malpighian tubules**
   Malpighian tubules branch from the gut tube of the insect. The tubules are bathed by the tissue fluids in the abdomen. Tissue fluids including uric acid enter the tubules and flow towards the gut. Almost all water is removed as the material travel down the tube and through the gut. The uric acid leaves the body in the feces.
   - Observe the slide of Grasshopper Malpighian tubules.
   - Observe the Malpighian tubules of the plastic bee model.

4. **Earthworm nephridia**
   Each segment in the earthworm contains a pair of nephridia. Each nephridium is a tube that has a funnel-shaped opening at one end called the nephrostome. The tube passes through the septum into the next body segment, where it opens to the outside at the nephridiopore. Blood vessels come into close contact with the nephridium. Tissue fluids enter the nephrostome. As they flow through the nephridium, most materials are reabsorbed by the blood. Wastes exit through the nephridiopore.
   - Observe the nephridia tubules in the earthworm model.
   - Observe the nephridia in the slide of the earthworm c.s.

5. **Mammalian urinary system**
   - Dissect the urinary system of your fetal pig.
   Identify the **kidneys, ureters, urinary bladder**, and **urethra**. The kidneys perform excretory and osmoregulatory functions. They produce urine. Urine is a mixture of water, salts, and
nitrogenous waste that are removed from the blood. Urine flows through the ureters into the urinary bladder. The urinary bladder is a muscular sac that stores the urine until it leaves the body through the urethra.

- Note the Renal Arteries and Veins where blood enters and leaves the kidneys.

⇒ Observe the frontal section of a pig kidney.
Identify the **cortex**, **medulla**, and **pelvis**. These three regions are obvious in frontal section. The outermost region is the cortex, deep to that is medulla, and deepest is the pelvis. The cortex and medulla contain approximately one million nephrons, which filter the blood and produce urine. Note the small spherical **renal corpuscles** in the cortex and the parallel striations in the medulla. The urine that forms in the nephron drains into the pelvis. The pelvis is a hollow space where the urine collects before entering the ureter. The pelvis has been injected with yellow latex.

⇒ Observe the model of the **nephron**.
The nephron is the functional unit of the kidney. The nephron is made of a **kidney tubule** and associated blood capillaries. Fluid leaves the blood and enters the kidney tubule by filtration. As the filtrate travels down the tubule, water, salts, and nutrients are reabsorbed into the capillaries. Some water, salts, and nitrogenous waste remains in the tubule; this is the urine. The blood vessels that leave the nephron carry away blood that has fewer nitrogenous wastes and is at the correct osmotic concentration.

- Look for the **renal corpuscle**. It is a spherical structure formed by a ball of blood capillaries (the **glomerulus**) enclosed by the **Bowman’s capsule**, the bowl-shaped end of the kidney tubule. This is where the fluids leave the blood and enter the kidney tubule.
- Look for the **Loop of Henle**. The kidney tubule extends far into the medulla and makes a hairpin turn before returning to the cortex. Because thousands of these loops extend into the medulla, the medulla has striate (striped) appearance.
- Note the **capillaries** that wrap around the kidney tubule. This is where materials are reabsorbed back into the blood.

⇒ Observe the microscope slide of the **mammalian kidney c.s.**
- Look for the Bowman’s capsule and kidney tubules.

In vertebrates, the urinary and reproductive systems develop from the same tissues of the embryo. Even in the adult, there can be close relationships between the two systems. In vertebrates, organs of the urinary system are often also used by the reproductive system. For example, in male frogs, sperm from the testes travels through the kidney and into the ureters. The ureters carry the sperm to the cloaca. A **cloaca** is a common chamber that receives the products of more than one organ system. In frogs the digestive, urinary, and reproductive systems all open into the cloaca, which is inside the body. The products of these systems leave the cloaca to the outside environment through a single opening. The products of only one organ system will be within the cloaca at any one time. A cloaca is found in sharks, fish, amphibians, reptiles, birds, and primitive mammals (monotremes = egg-laying mammals e.g. platypus).
Learning Objectives:
1. to understand the necessity for coordinating systems in animals
2. to know the relative advantages of the endocrine and nervous systems
3. to know the basic organization of earthworm and insect nervous systems.
4. to know the major structures of the neuron and their function
5. to know the structure of a reflex arc and how it operates
6. to know the organization of the human nervous system
7. to identify the major structures of the brain and spinal cord
8. to know the functions of major brain regions
9. to be able to distinguish between the functions of the somatic and autonomic divisions
10. to identify the structures of the eye and know their functions
11. to identify the structures of the ear and know their functions

Materials:
Student slides:
- Spinal cord smear = Multipolar Neurons = Neurons
Demo slides:
- Grasshopper nervous system
- Earthworm nervous system
- Nerve c.s.
Models:
- Neuron
- Spinal cord c.s.
- Vertebral column
- Human brain
- Ear
- Eye
Preserved specimens:
- Sheep brain
- Sheep eye
- Slice of human brain in plastimount
Wall charts – Central Nervous system; Eye; and Ear
Percussion hammer for testing patellar reflex

Procedures:
You will learn about the structure of the neuron and the organization of animal nervous systems. You will dissect the sheep brain and eye.
Plants and animals are composed of many cells. Each cell has a function. Yet, it is essential that each of the individual cells co-operates as part of a single organism. Coordination of all cells is needed in order for the organism to function correctly. To coordinate their activities, the different regions of the body need to communicate.

The organism also must be able to respond to changes in its external environmental (stimuli). To do this, an organism must have sensory receptors that can detect changes in the environment and communicate this information to effector organs, structures that are able to produce a response.

Multicellular organisms have evolved two types of coordination systems which allow enable cells to cooperate with each other and to respond to changes in the internal or external environment.

One type of coordination system is the endocrine system. The endocrine system produces chemicals, called hormones, which travel through the internal transport system to all areas of the organism. Hormones act as chemical messages that change the metabolism of specific target cells throughout the organism. The effects of hormones are slow to develop. Both plants and animals produce hormones.

The second type of coordination system is the nervous system. The nervous system allows rapid communication between all parts of the body. Because animals possess rapidly reacting muscle cells, they require a fast coordination system. The nervous system makes this possible. Only animals have a nervous system.

1. The mammalian nervous system is composed of many kinds of cells. However, only one kind of cell carries information. This cell is called a neuron. Different neurons have different shapes but function in the same manner. They produce electrical impulses called action potentials that the neuron uses to communicate information. The action potentials can travel from one end of the cell to the opposite end. Neurons can have extremely long, thin processes (millimeters to centimeters in length) that can carry action potentials (information) efficiently over long distances.

Neurons are complex cells that have three specialized regions. The neuron cell body (aka soma) is a sac-like region that contains the cell nucleus. Dendrites are branched processes that extend from the cell body. There may be one or more dendrites; the number depends upon the type of neuron. The function of dendrites is to receive information from the environment or from other neurons and then communicate it to the cell body. Each neuron has a single axon which is an un-branched, threadlike process that carries information away from the cell body. The function of axons is to create action potentials, conduct the action potentials over long distances, and then communicate with the dendrites of other neurons. Many axons are enclosed by multiple layers of a fatty coating called the myelin sheath which is formed by Schwann cells. The myelin sheath increases the speed at which action potentials travel along the axon.

- Observe the slide of nervous tissue (ox smear) and identify a neuron cell body.
- Observe the plastic model of a motor neuron. Identify the cell body, dendrites, axon, Schwann cell, and myelin sheath.

2. Neurons line up end-to-end to form pathways which carry information through the body. The neurons in a pathway do not touch one another but are separated by a small space, the synaptic cleft. This region, where two adjacent neurons in a path come near each other but do not touch, is called a synapse. Transmission of information across the synaptic cleft occurs by the diffusion of
chemicals called **neurotransmitters**. Acetylcholine (ACh) and norepinephrine (NE) are two of the many kinds of neurotransmitter.

3. Pathways of neurons can be simple, involving only a few neurons; however, most pathways are extremely complex involving millions or more neurons. The simplest pathway in the nervous system is a **reflex arc**. A reflex arc is a genetically inherited pathway that connects a specific receptor directly to a specific effector. A reflex arc usually contains one of each of the following structures:
   a. **Receptor** - a structure capable of detecting change in the external or internal environment
   b. **Sensory (afferent) neuron** - carries information to the CNS
   c. **Association neuron (interneuron)** - any neuron between a sensory neuron and a motor neuron. The brain is mainly composed of association neurons.
   d. **motor (efferent) neuron** - carries information away from the CNS
   e. **effector** - a structure which is capable of producing a response. The response produced by a reflex arc is called a **reflex**. Muscles and glands are the effector organs.

   ⇒ **Know these 5 structures (in the correct order) and the function of each.**
   Find the location of the afferent, association, and efferent neurons on the slide of the spinal cord c.s. and in the model of the spinal cord c.s.

   All pathways in the NS use the same five types of units as seen in the reflex arc. The main difference between a simple pathway like a reflex arc and a complex path such as solving math problems is the number of association neurons that are involved.

4. The earthworm and insect nervous systems have a **ventral** nerve cord. Association neurons form clusters (=ganglia). Small ganglia may be found in each segment or there may be a few larger ganglia. The brain is a very large ganglion in the head.

   ⇒ See the demo slide of the **Earthworm nervous system**
   ⇒ See the demo slide of the **Grasshopper nervous system**

5. The mammalian nervous system - by structure:
   a. **Peripheral Nervous System (PNS)** is composed of twelve pairs of cranial nerves and 31 pairs of spinal nerves. **Nerves** are bundles of axons that carry sensory and motor information into and out of the brain and spinal cord.

   ⇒ Observe the demo slide of a **Nerve c.s.** Note that each axon is surrounded by a myelin sheath (it looks clear) and that the axons are bound together by connective tissue.

   b. **Central Nervous System (CNS)** is composed of the brain and spinal cord. The entire CNS is covered by three membranes called **meninges**.

   1. **spinal cord** - the part of the CNS that extends down through the vertebral column.
      * The spinal cord receives sensory information from sensory receptors throughout the body. The sensory (afferent) cells send their axons into the spinal cord via the **dorsal roots**. They synapse on interneurons that are located in the **gray matter**. The interneurons send axons into the **white matter** where they ascend to the brain.
      * Gray matter = parts of the CNS where neuron cell bodies are concentrated together. A related term is **nucleus** or **ganglion** which is a cluster of cell bodies which have extensive connections with each other and perform a specific function. The term ganglion is usually used when describing clusters of cell bodies located in the PNS.
White matter = parts of the CNS where myelinated axons run parallel to each other. A related term is nerve tract which is a bundle of axons that are traveling to the same location.

- The brain sends motor (efferent) signals via axons that descend in the white matter of the spinal cord. These axons synapse on motor neurons that are located in the gray matter. The motor neurons send their axons out of the spinal cord via the ventral roots.

- The ventral and dorsal roots meet just outside the spinal cord to form the spinal nerves. Spinal nerves exit between each vertebra.

⇒ Study the models of the spinal cord. Know the location and function of the following: gray matter, white matter, central canal, and the dorsal and ventral roots of the spinal nerves.

2. Brain

⇒ Know the location and function of the following structures in both the sheep brain and plastic human brain model:
   a. Brainstem - expansion of the spinal cord. It consists of the following structures:
      - Midbrain – contains nuclei that control orienting movements of the head and eyes
      - Pons - “bridge” of white matter that connects the right and left cerebellum
      - Medulla Oblongata - The medulla contains vital centers for heart beat rate, blood pressure, and breathing. Other centers of the medulla control vomiting, coughing, sneezing, hiccupping, and swallowing.

   b. Thalamus - gray matter arranged as nuclei
      All sensory inputs, except olfaction, synapse here on its way to the cerebral cortex. The thalamus sorts out sensory information and sends it to the correct area of the cerebral cortex.

   c. Cerebrum - 60% of human brain weight
      - Cerebral Cortex - the thin (2-4mm) outer layer of the cerebrum
         The cerebral cortex is 40% of human brain weight. It is composed of gray matter (neuron cell bodies), and it is the site of all conscious activity: perception of sensation, control of skeletal muscles, all thought, memory, emotion, etc. The cerebral cortex is folded into worm-like ridges to increase surface area. Each ridge is called a Gyrus. The gyri are separated by grooves, each of which is called a sulcus. Deep sulci are called fissures. Fissures divide the cerebrum into left and right hemispheres and each hemisphere into four lobes.
         - The interior of the cerebrum is mainly composed of white matter (neuronal axons). The axons connect various part of the CNS. They may lead in or out of the cerebrum, connect areas of the same hemisphere, or cross from one hemisphere to the other. A structure which connects the axons of one hemisphere to the other hemisphere is called a commissure. The largest commissure is the corpus callosum.

   d. Cerebellum - second largest brain region
      The cerebellum receives sensory input from proprioceptors (cells that measure body position) in the muscles, joints, and ears. It also receives inputs from the cerebral cortex. It plans muscle use and coordinates muscle activity. It also controls balance and posture.
e. **Hypothalamus** - mainly concerned with aspects of homeostasis
   The hypothalamus controls the regulation of body temperature, hunger, thirst, water balance, sleeping and waking, etc. It is also a major control center of the ANS and the endocrine system. The **pituitary gland**, the “master gland” of the endocrine system, hangs from the hypothalamus.

6. The mammalian nervous system – Functional divisions
   a. **Somatic Nervous System**
      Carries (1) sensory information from the skin and skeletal muscles and (2) motor instructions to the skeletal muscles
   b. **Autonomic Nervous System**
      The ANS controls the secretion of many glands and the contraction of cardiac muscle and smooth muscle (located in the walls of many internal organs). It has 2 divisions that have opposing (push-pull) effects on each organ; one stimulates the organ, the other inhibits it. Together, they cause each organ to work at the appropriate level to meet the needs of the body.
      1. **Sympathetic division = S-ANS** – prepares the body for activity. It starts the “fight-or-flight” response to emergency
      2. **Parasympathetic division = P-ANS** – prepares the body for restful conditions.
         When the body is active, the S-ANS signals to the effector organs are greater than those of the P-ANS. In contrast, when the body is resting, the P-ANS signals to the effector organs will be greater than those of the S-ANS.

7. **Receptors** - specialized neurons located within the sensory organs of the body
   These cells are sensitive to different types of stimuli. When stimulated, they produce a nerve impulse which travels to a specific area of the cerebral cortex where the impulses are translated as some mode of perception. The cerebral cortex produces all conscious sensation.

   a. **Mammalian eye**
      ⇨ Dissect the sheep eye. Know the following structures:
         sclera, cornea, choroid, iris, pupil, ciliary body, lens, retina, aqueous humor, vitreous humor
      ⇨ See the demo slide of Retina c.s. Identify the cells of the retina.

   b. **Mammalian ear**
      ⇨ See the plastic model. Know the following structures:
         pinna, external auditory canal, tympanic membrane, ear ossicles, cochlea
      ⇨ See the demo slide of the Organ of Corti. Identify the hair cells.
Learning Objectives:
1. understand the functions of the skeletal system
2. know the three types of skeletal systems and the organisms that use them
3. know the structure of bone and cartilage and be able to recognize the tissue
4. know the bones of the human that are listed here
5. know the role of the pectoral and pelvic girdles
6. know the structure of the three types of muscle tissue and be able to recognize them
7. know how skeletal muscle is controlled and recognize the neuromuscular junction

Materials:
Student slides:
- Hyaline Cartilage
- Compact Bone
- Skeletal Muscle Teased
- Smooth Muscle = c.s. through the intestine
- Intercalated Disk - Cardiac Muscle
Demo slides:
- Hydra c.s. & I.s.
- Planaria
- Earthworm c.s.
- Neuromuscular (Myoneural) Junction = Motor End-Plate
- Muscle c.s. – skeletal muscle
Models:
- Hydra
- Planaria
- Motor end plate
Preserved specimens:
- Arthropoda
- Skeletons of fish, *Necturus*, frog, cat, bat, snake, human
- Riker mount of sectioned mammal bone
- Sectioned bone
Videos:
- Muscle Contraction
- Muscle
Kymograph of muscle contraction

Procedures:
We will learn about the structures used by animals for support and movement. We will see examples of different types of skeletal systems. We will look at muscle tissue and its organization in skeletal muscle.
Introduction
Movement (at least internal movement) is one of the characteristics of life. Although many species do not move on their own, all five kingdoms have species that exhibit movement in response to stimuli. This lab will only consider the movement of animals. Animals move through their environment by using the combined activity of their skeletal and muscular systems. In contrast, the movements of their internal organs and blood are produced by muscle tissue alone.

The skeletal system may benefit the animal in several ways. It provides support for the soft parts of the animal against the pull of gravity. It may protect some or all of the internal organs. It may provide a hard structure to which the muscles attach. For example, in vertebrates the bones serve as a system of levers that can be moved in relation to one another by the muscular system.

Muscle cells are characterized by the ability to contract (shorten). As these cells contract, they shorten and exert a force that pulls against other body parts such as bone or skin. Muscle cells cannot lengthen and exert a force to push against body parts. When a muscle is relaxed (not contracting), it can be stretched back to its original length by an outside force such as contraction of a different muscle, gravity, or hydrostatic pressure. Groups of muscle cells act to pull body parts closer together or to produce the squeezing movements of internal organs.

In mammals, the muscular system is composed of three types of muscle tissues. Skeletal muscle tissue forms the muscles which are multi-cellular organs that move the skeleton. Smooth muscle tissue is found in the walls of many internal organs and causes movements of these organs. Cardiac muscle tissue forms the walls of the heart chambers. Their contraction causes pumping of the blood by the heart.

SKELETAL SYSTEMS
1. There are three general types of skeletal system. Each has advantages and disadvantages.
   - **Hydrostatic skeletons** are found in soft-bodied organisms such as the cnidaria, annelids, nematodes, sea cucumbers, and octopus. The hydrostatic skeleton consists of a fluid filled cavity enclosed by an elastic body wall that contains muscle tissue. Contraction of the muscle produces hydrostatic pressure in the fluid. The muscle is arranged in 2 layers so that the muscle cells in each layer are oriented at right angles to each other. The animal can control contraction of the two layers. It may contract both to compress the fluid. Or, it may contract the layers in sequence to elongate or shorten the body cavity.

   ⇒ Examine the examples of hydrostatic skeletons.
   - *Hydra*: model and demo slides of *Hydra c.s.* and *Hydra l.s.*
   - *Planaria*: model and demo slide of the *Planaria*
   - *Annelida*: demo slide of the *earthworm c.s.*
     Note the arrangement of *circular* and *longitudinal* muscles in the earthworm *XS*. Identify each muscle layer. These muscles act upon the hydrostatic skeleton to produce movement of the worm.

   - **Exoskeletons** are found in arthropods and molluscs as well as several other invertebrate phyla. The exoskeleton is a hard external shell that serves as both skin and skeleton. We will discuss the arthropod exoskeleton here. The arthropod exoskeleton is made of *chitin*. The chitin forms tough, hard plates that enclose each segment of the animal. Softer, more flexible chitin forms the joints between each segment. The exoskeleton protects the internal organs. Muscles are attached
to the inside of the skeleton. They extend across the joints so that contraction causes the joint to bend. The exoskeleton is very efficient for small animals, but as the size of the animal increases, the weight of the skeleton relative to the rest of its body increases. This limits the potential size of the animal. Exoskeletons have another disadvantage; they cannot grow to match growth of the body. The animal must molt in order to grow. During a molt, the exoskeleton splits open and the animal leaves its exoskeleton. It uses hydrostatic pressure to expand the soft body, and then it reforms the exoskeleton around its new larger body. During the time of the molt, the animal is exposed to predators.

⇒ Examine the display of the insect exoskeleton

**Endoskeletons** are found in the vertebrates. The endoskeleton is made of rods of cartilage or bone that are joined together by connective tissue (ligaments and cartilage). Muscles are located on the external surface of the skeleton. Muscles attach via tendons to the bones on either side of a joint. Endoskeletons are strong and relatively light weight even in large animals. They can grow as the animal grows so molting is not necessary. Skeletons that are made of bone also store calcium.

⇒ Examine the examples of the vertebrate endoskeletons: Fish, Necturus (an amphibian), frog, snake, bat & human
⇒ What are the advantages & disadvantages of each of the 3 types of skeletal system?

2. The skeleton of sharks is made of a tissue named cartilage. The skeletal system in the fetal mammal is also made from cartilage. As fetal development continues, the cartilage is replaced by bone.

Cartilage is a connective tissue made from cells that are named chondrocytes. Chondrocytes secrete collagen fibers and other glue-like materials. These materials (the extracellular matrix) fill the spaces between the cells and make up most of the mass of cartilage. The chondrocytes sit in cavities that are called lacunae.

⇒ Observe the slide of hyaline cartilage. Identify the chondrocytes, lacunae, and matrix. Draw the slide.

3. Each bone in the mammalian skeleton is composed of an outer covering of layered compact bone which gives the bone its strength. Inside, the bone is criss-crossed by delicate bars and plates of bone. This region is called spongy bone and reduces the overall weight of the bone.

⇒ Examine the sectioned bones that show compact and spongy bone. Note the appearance of the two types of bone.

4. Compact bone is made of many cylindrical structures called Haversian Systems or Osteons. Each Haversian system is made of 3-5 sheets of osteocytes (bone cells) that form concentric rings around a Haversian canal. Each ring of cells is called a lamella. The cells secrete collagen fibers and matrix material. Calcium salts then crystallize in the matrix to make it become rigid. The cells are located inside small cavities called lacunae. The Haversian canals contain blood vessels which supply the osteocytes. Numerous small pores called canaliculi extend between lacunae and provide a path for diffusion between cells.
Look at the slide of the Haversian systems of compact bone. Identify the Haversian canal, lacunae (where the osteocytes had lived), lamellae, and canaliculi.

5. Mammalian skeletal system. The skeleton has two major components. The axial skeleton is composed of the vertebral column, skull and ribs. It forms the body of the animal. The appendicular skeleton consists of the bones in the appendages. The appendages are the arms and legs and the girdles. The girdles are the bones that connect the arms and legs to the axial skeleton.

Know the following bones of the human skeleton:

<table>
<thead>
<tr>
<th>Axial skeleton = the central axis of the body</th>
<th>Appendicular skeleton = the appendages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>Pectoral Girdle</td>
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<tr>
<td>mandible</td>
<td>Clavicle</td>
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<tr>
<td>maxilla</td>
<td>scapula</td>
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<tr>
<td>Vertebral Column (backbone)</td>
<td>Arms</td>
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<tr>
<td>vertebrae</td>
<td>humerus</td>
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<tr>
<td>intervertebral disc (cartilage)</td>
<td>ulna</td>
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<td>sacrum</td>
<td>radius</td>
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<td>coccyx</td>
<td>carpals</td>
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<tr>
<td>Rib Cage</td>
<td>metacarpals</td>
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<tr>
<td>ribs</td>
<td>phalanges</td>
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<tr>
<td>sternum</td>
<td>Pelvic Girdle</td>
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<td></td>
<td>Legs</td>
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<td>femur</td>
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<td>metatarsals</td>
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<td>Phalanges</td>
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</tbody>
</table>

MUSCULAR SYSTEM
1. Muscle tissue structure. The three types of muscle tissue differ in their appearance. You should be able to recognize each by description or its appearance under the microscope.
   a. **Skeletal muscle** is made of large cylindrical cells (aka fibers) that are approximately the length of the entire muscle. Each cell is multi-nucleate (contains many nuclei) and striate (thin stripes are visible in the cell). The striations are due to the arrangement of protein fibers in the cell.
   b. **Cardiac muscle** cells are small, branched, striate, uni-nucleate (1 nucleus), and striate. Cells are joined end-to-end. The junction between the cell ends is called the intercalated disk. Intercalated disks stain darker than the rest of the cell.
   c. **Smooth muscle** cells are small, tapered at each end, uni-nucleate, and non-striate. Cells are usually arranged into two layers oriented at right angle to each other (as in the small intestine).

Observe the slides of the three muscle tissues. Draw each slide. What are the characteristics and functions of each type of muscle cell/tissue? What clues will you use to recognize each?
   a. **Skeletal muscle** – teased
   b. **Smooth muscle** (this may be a c.s. through the intestine or else teased smooth muscle)
   c. **Cardiac muscle** (intercalated disks).
2. Muscles are organs composed of many skeletal muscle cells, connective tissue fibers, blood vessels and nerves. Each skeletal muscle cell is enclosed by a sheath of connective tissue. The connective tissues from all the cells in the muscle fuse together to form a tendon. The tendon connects the muscle to bone.

⇒ Observe the demo slide Muscle c.s. You will be able to see the individual muscle cell with thin sheets of connective tissue around them. Thicker layers of connective tissue are wrapped around groups of muscle cells.

3. How does the body control muscle tissue?

Smooth and cardiac muscle tissue are controlled by the autonomic nervous system and the endocrine system.

Skeletal muscle is controlled by the somatic nervous system (not by the endocrine system). Each skeletal muscle cell is controlled by a motorneuron which tells it when to contract. The axon of a motorneuron enters a muscle then branches. Each branch ends on a single muscle cell at the neuromuscular junction. The axon does not actually touch the muscle cell membrane. There is a small space between them. The neuron releases acetylcholine, a neurotransmitter, into the space. The ACh diffuses across the small distance to the muscle cell and causes contraction. Each neuron stimulates a number of muscle cells. The muscle cells which are stimulated by the same neuron all contract at the same time. A neuron and all the muscle cells that it controls, is called a motor unit.

⇒ Observe the demo slide of a neuromuscular junction (NMJ). Notice that one axon forms several branches. Each branch ends at a neuromuscular junction. The NMJ will look like a small button.

4. When a motorneuron signals the muscle cell to contract, the muscle cell contracts with full force for a fraction of a second. The pulse of force that it produces is called a twitch. The twitch size will always be the same. If the motorneuron sends many signals to the muscle cell at a rapid rate, then the force of contraction produced by all of the twitches is summed until a higher maximum force is reached. This process of increasing force at higher rates of stimulation is called summation. The maximum force of contraction that the muscle cell can produce is called tetanus. The muscle cell cannot continue to produce this full force of contraction for very long. It runs out of fuel and becomes fatigued. It cannot contract.

A force gauge can measure the force produced by a muscle. Changes in the force over time can be plotted on a paper chart recorder.

⇒ See the kymograph (one type of recorder) demo illustrating graphs of muscle physiology.

Identify the following:

- Twitch
- Summation
- tetanus and fatigue

The brain normally stimulates a motorneuron at a rate that is high enough to make it reach tetanus. How, then, does the body control the force that the muscle produces? The nervous system controls the force that a muscle produces by varying the number of motor units that it activates. It can “recruit” more motor units when it needs to increase the force.
Written Test 4 will be given in lab 14 (unless an earlier lab was cancelled due to weather problems). The exam will cover labs 11, 12, and 13: animal urinary and systems, mammalian nervous system, and muscular and skeletal systems. Time remaining after the test will be used to review for the Practical Exam.

The final practical exam covers labs 8-13:

**Slides:**
1. insect tracheae
2. insect spiracle
3. antheridial head – moss
4. archegonial head - moss
5. moss capsule (*Polytrichum*)
6. angiosperm anther (*Lilium*)
7. angiosperm ovary (*Lilium*)
8. paramecium binary fission
9. paramecium conjugation
10. hydroid colony - *Obelia*
11. medusa - *Obelia*
12. testis c.s.
13. ovary c.s. (maturing follicle)
14. neuron
15. hyaline cartilage
16. bone
17. skeletal muscle
18. smooth muscle c.s. & l.s.
19. intercalated disk (cardiac muscle)
20. earthworm c.s
21. kidney l.s.
22. neuromuscular (myoneural) junction

**Fetal Pig:**
- respiratory system
- circulatory system
- urinary system
- reproductive system

**Other:**
- flower anatomy – models & plants
- sheep heart
- sheep eye
- sheep brain
- human brain model
- neuron models
- human skeleton
- ear model

<end>