BIOLOGY II LABORATORY MANUAL

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Licensing

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

1: Safety and Viruses

1.1: Lab Safety Contract

Read over and sign the Laboratory Safety Contract. This document goes over essential practices for lab safety.

1.2: Viruses Lab

Learning Objectives

At the conclusion of the lab, the student should be able to:

- Understand the properties of a virus
- Explain how viruses are spread through a population by sharing bodily fluids

A **virus** is not considered a living organism as it only contains DNA surrounded by a protein coat. However, viruses are serious infectious agents causes conditions such as AIDS, chicken pox, and herpes. Viruses must have a live host cell to reproduce. The virus takes over the protein building machinery of the cell to create new viruses to spread the infection. Viruses can infect many different types of organisms, both prokaryotic and eukaryotic.
One way a virus can be spread through a population is by sharing bodily fluids such as saliva, blood, or semen. We will demonstrate how quickly a virus can spread through today's simulation activity.

Sharing Bodily Fluids

During this lab you will share "bodily fluids" with other students in the lab to simulate the spread of an infectious disease through a population.

Procedure

1. Obtain a numbered vial of solution and a plastic pipet from your instructor.
2. Record your student name and vial number on the class data sheet.
3. Share bodily fluids with another person in lab. Use the plastic pipet to withdraw solution from your vial and place 5 drops of your solution in another classmate's vial. Your classmate will also share fluids with you in the same way. Return the cap to the vial and invert to mix.
4. Record the name of the person you shared bodily fluids with in the table below.
5. Exchange bodily fluids with another person following the directions above. Record the name of the person with whom you exchanged fluids.
6. Exchange fluids with another student (different than the first two) and record his/her name below. You should complete three total fluid exchanges.

My vial #:_____

Record of Bodily Fluid Exchanges

Exchange 1: _____
Exchange 2: _____
Exchange 3: _____

Your lab instructor will add a drop of the test reagent to determine if you are infected with the disease. If your sample turns pink then you are infected. If it turns yellow you are not infected. If you are positive for the disease you may have originally had the disease or you may have contracted the disease in lab today from sharing bodily fluids.

- Are you infected?
- Is it possible to determine if you were originally infected or did you contract the disease from someone during today's lab?

As a class you will fill in Table 1 below. Include each person's name. If your test result is positive put a plus sign (+) next to your name. If your result is negative put a negative sign (−) by your name. For those individuals that are positive, record whom they exchange fluids with and whether that person was positive or negative.

Questions

1. How many people in the class are infected?
2. Can you determine who was originally infected?
3. If you can, whom do you think was originally infected?

4. What do the class results show about the spread of disease through activities in which bodily fluids are shared?

Fill out a table similar to Table 1 for all members of your class. Be sure to add as many tables as there are students!

Table 1. Class results for bodily fluid exchange activity

Student's Name	Test result (+/−)	Exchange #1 (+/−)	Exchange #2 (+/−)	Exchange #3 (+/−)
1.				
2.				
3.				
4.				
5.				

After you've completed Table 1, discuss with your lab group how this experiment simulates a real life infection through a population and answer the following questions.

1. What are some ways that viruses are spread?
2. What are some diseases that are spread by contact with bodily fluids?
3. What are ways to prevent the spread of these diseases?

1.3: Viruses Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Sharing Bodily Fluids

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
Vials labeled 1-24	24	randomly choose 1 vial to be infected. This should be a number less than 10 in case there is a small # of students in the class. Let instructor know which vial is infected in advance
Plastic pipets		
Reagent		

1.4: Dolphin Case Study

Learning Objectives

After completing the activities, you should be able to:

- Define unusual mass stranding events
- Explain the difference between mass strandings and an unusual mass stranding event
- State one symptom of cetacean morbillivirus and explain in general how the virus is spread
- Explain in general how a virus can spread through a population of organisms
- Explain in general how a vaccine works
- State two different ways a vaccine can be created

Introduction

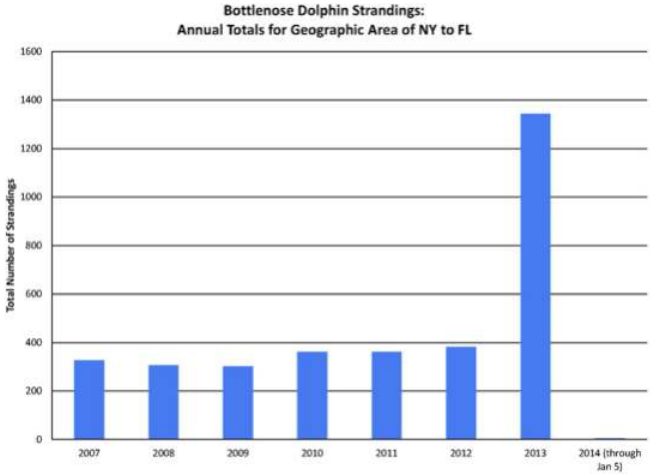
In July 2013, stranding teams (such as the Virginia Aquarium's Stranding Response team) from New York to North Carolina started noticing a large amount of dolphin strandings.

Some data that was collected on how many dolphins were being found dead or dying on the beaches:

- 430 from July to September
- 553 total from July to November
- 6 in one day in Virginia Beach

Using your computer and the Internet, research dolphin strandings. Here is one website to get you started: NOAA Strandings. Answer the questions below based on your research. Please put your answers in your own words. **Copying directly from a website is considered plagiarism.**

1. Give two examples of marine mammals that can strand themselves.
2. Give two specific reasons why marine mammals strand themselves.



Bottlenose Dolphin Strandings by State										
	NY	NJ	DE	MD	VA	NC	SC	GA	FL	Total
2007-2012 Average (July 1 - Jan 5)	4	5	3	3	27	25	23	9	46	**145**
2013-2014 (July 1 - Jan 5)	35	135	63	65	345	156	79	46	137	**1061**

Note: Data are dolphin strandings that have been confirmed and responded to by Stranding Network Members. Florida data is through Brevard County. Current UME Data are considered preliminary and may be subject to change as more information becomes available. From NOAA.gov data

3. Using the data above, how many dolphins were found a year on average in the Mid Atlantic states in the years 2007–2012?

4. How much larger were the number of strandings in 2013? Calculate how many times larger.
   These data lead researchers to believe that this event in 2013 would be classified as an Unusual Mortality Event (UME). Using your computer and the Internet, research UMEs. Here is one website to get you started: Marine Mammal Unusual Mortality Events (www.nmfs.noaa.gov/pr/health/mmume/). Answer the questions below based on your research. Please put your answers in your own words. Copying directly from a website is considered plagiarism.
5. Explain the difference between mass strandings, group strandings, and an unusual mass stranding event.
6. The dolphins that washed ashore exhibited skin lesions and weight loss that was abnormal for bottle nose dolphins.
   1. What kinds of data do you think would be useful in determining the cause of this UME event based on the condition of the dolphins? Name three things you think researchers should record about these dolphins.
   2. Some scientists remembered that there was a similar case in 1987–1988, as described in Morbilliviral Disease in Atlantic Bottlenose Dolphins and in Dophin Strandings.
7. What happened to bottlenose dolphins in 1987–1988?
8. Does this UME seem similar to that situation? Why or why not?
   In the 2013 strandings, dolphins were tested for cetacean morbillivirus, and approximately 85% of them were positive (NOAA.gov data). Using your computer and the Internet, research cetacean morbillivirus. Here is one website to get you started: Morbilliviris Infection. Answer the questions below based on your research. Please put your answers in your own words. Copying directly from a website is considered plagiarism.
9. What is cetacean morbillivirus? What symptoms does it cause?
10. How is cetacean morbillivirus spread?
    One of the things that researchers keep track of is the different populations of marine mammals. Scientists are able to track dolphins based on photo IDs and genetics. Different populations can have different coloration and caudal fins (tail fins). The populations of dolphins that have been monitored are shown on the next page.
    Researchers noticed that dolphins that were being found stranded were not only from coastal resident stocks of dolphins, but included migratory populations.
11. Thumbnail for the embedded element "How A Virus Changes The World (Nominated 2012 Webby Award)""title="How A Virus Changes The World (Nominated 2012 Webby Award)"src="/@api/deki/files/29087/hqdefault.jpg"/>
12. How long do dolphins live?
13. Would dolphins have immunity to this virus?
    Humans receive vaccines for many viruses like smallpox and measles. Using your computer and the Internet, research how a vaccine works. Use this website to get you started: How Vaccines Work. Answer the questions below based on your research. Please put your answers in your own words.
14. What substances from the immune system naturally fight against a virus?
15. How does a vaccine work?
16. List two different ways vaccines can be created.
17. Based on your research, do you think vaccination a possibility for cetacean morbillivirus? Discuss the practicality of vaccinating a mobile, wild population.

Data and information from NOAA Fisheries and Susan Barco, Virginia Aquarium Stranding Response Team.

1.5: Dolphin Case Study (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Dolphin Stranding Case Study

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
computers	1 per 2-3 students	can be laptops or tablets

CHAPTER OVERVIEW

2: Microbiology

2.1: Microbiology and Protista Lab

Learning Objectives

After completing this lab, you student should be able to:

- Describe the basic structures of a bacterial cell.
- State the three domains of life
- Name the shape of a given bacteria specimen
- State the domain of cyanobacteria
- Be able to identify the cyanobacteria examples viewed in lab
- State the domain of the protista
- Be able to identify the green algae examples viewed in lab and know if they are colonial or filamentous
- Be able to recognize the protista specimen viewed in lab
- Identify protista as photosynthetic or heterotrophic

Download a PDF of the lab to print.

Part 1: Prokaryotes

Procedure

1. Access the page “Reading: Prokaryotes.”
2. We will not be using any live bacteria specimens. Instead, watch this video about aseptic technique.This technique is important to avoid microorganism contamination.

Questions

1. Answer the questions below based on the video.
    1. What two tools are most commonly used to transfer bacteria?
    2. With the Bunsen burner, what color is the hottest flame?
    3. How are the inoculation tools sterilized?
    4. When transferring bacteria from a liquid culture to a Petri plate, why do you turn the plate while spreading the bacteria?
    5. When transferring bacteria from a Petri plate to a stab culture, how many times should you stab the needle?
    6. When transferring bacteria into a liquid tube do you flame the mouth of the tube before inoculation, after inoculation, or both?
2. Skip to the end of the lab activity where it says “Prepared slides of typical bacteria” and view the prepared slides of bacterial shapes available in the laboratory.
    1. Draw a picture of the coccus shaped bacteria.
    2. Draw a picture of the bacillus shaped bacteria.
    3. Draw a picture of the spirillum shaped bacteria.
3. View the prepared slides of cyanobacteria available in the laboratory. Although they are single celled note how they form colonies and attach to one another
    1. What is the function of the heterocycst in the *Anabaena?*
    2. If the *Oscillatoria* is moving, describe the movement quality below.
    3. Which cyanobacteria species form chains? Which cyanobacteria species form clumps?

Part 2: Protista

Procedure

1. Access the page “Reading: Protists.”
2. Watch this video.

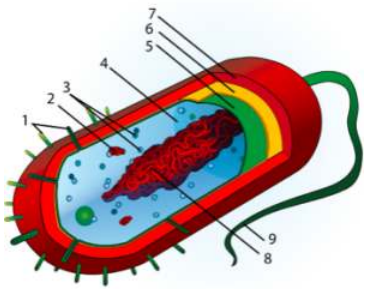
Questions

1. View the Euglenozoans specimens available.
    1. What color is the euglena?
    2. What structure does the euglena use to move?
    3. Can you see any internal chloroplasts?
    4. Can you see the red eyespot? It does not give the organism vision, rather allows it to sense the presence of light.
    5. *Trypanosoma sp*. cause African sleeping sickness. (This disease was discussed in the video.)
    6. What part of the human body does the *Trypanosoma* invade?
    7. What structure does the *Trypanosoma* use to move?
    8. How does the *Trypanosoma* avoid being killed by the white blood cells?
    9. Can African sleeping sickness cause death?
2. View the diatom specimens available.
    1. What material is found in the cell wall of the diatoms?
    2. Are the organisms single or multi cellular?
3. View the brown algae specimens available.
    1. What pigment does brown algae use for photosynthesis?
    2. Name and describe the characteristics of one brown algae specimen below.
4. View the dinoflagellate specimens available.
    1. What structure does the dinoflagellate use for movement? How many of these structures does it have?
    2. Are the organisms single or multi cellular?
5. View the ciliate specimens available.
    1. What structure does *Paramecium* use to move? Does it have only one or many of these structures?
    2. *Paramecium* contains two nucli, a macronucleus (large) and a micronucleus (small). Can you find both of them on your specimen?
    3. *Paramecium* also contains contractile vacuoles that help maintain water balance through osmosis. Can you locate any on your specimen?
6. View the red algae specimens available.
    1. What pigment does red algae use for photosynthesis?
    2. Name and describe the characteristics of one red algae specimen below.
7. View the green algae specimens available.
    1. What pigment does green algae use for photosynthesis?
    2. Name and describe the characteristics of one green algae specimen below.
8. View the Tubulinid specimens available.
    1. What structure does *Amoeba* use to move?
    2. Is the *Amoeba* single or multi celled?
    3. The *Amoeba* contains contractile vacuoles that help maintain water balance through osmosis. Can you locate any on your specimen?

Summary Questions

1. Answer the questions below to summarize the lab activity:
    1. What type of cell is considered more primitive or basic?
    2. State one difference between a prokaryotic and a eukaryotic cell.
    3. What two domains contain prokaryotic celled organisms?

4. Identify structures 1, 3, 4, 5, 6, 7, 8, and 9 on the generalized prokaryotic cell pictured below



5. Are the cyanobacteria autotrophic or heterotrophic?
6. Which cyanobacteria species secretes a gelatinous sheath?
7. Which protista are most similar to green plants? Why?
8. You viewed several protista that exhibited movement. Give an example of a protista that used each of the following movement structures:
    1. Flagella:
    2. Cilia:
    3. Pseudopod:
9. Give two examples of photosynthetic protista you viewed in lab and state what pigment each uses for photosynthesis.

2.2: Microbiology and Protista Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Part 1: Prokaryotes

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
bacteria types slide	1 per table	contains coccus, bacillus and spirilla shaped, can also be set up on side bench as demo
anabaena		live organisms are ideal but prepared slides will work
oscillatoria		live organisms are ideal but prepared slides will work
gloeocapsa		live organisms are ideal but prepared slides will work

Part 2: Protista

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
Trypanosoma slide	1 per table	
Dinoflagellate slide	1 per table	
mixed diatom slide	1 per table	
euglena slide	1 per table	
brown algae	variable	can be plastimounts or preserved specimens
paramecium slide	1 per table	live organisms can be used if available
red algae	variable	can be plastimounts or preserved specimens
green algae	variable	can be plastimounts or preserved specimens. Live organisms can be used like volvox and spirogyra
amoeba slide	1 per table	live organisms can be used if available

2.3: Reading- Prokaryotes

Introduction

Prokaryotes include the domains **Bacteria** and **Archaea**. All of the organisms that we study in this lab will be in the domain Bacteria.

This exercise is designed to familiarize students with some basic equipment and techniques used in the study of microorganisms. In addition, students will learn some basic techniques used in identifying prokaryotes and make and view microscope slides of some common prokaryotes.

Microbiology Laboratory Equipment

Sterilization

It is important that all instruments and media discussed below be sterile, that is, free of any living organisms. The use of sterile equipment, media, and techniques prevents unwanted microorganisms from contaminating your cultures.

Media

Culture media containing the necessary nutrients are used to grow microorganisms in a laboratory. Four kinds of commonly-used culture media are shown below.

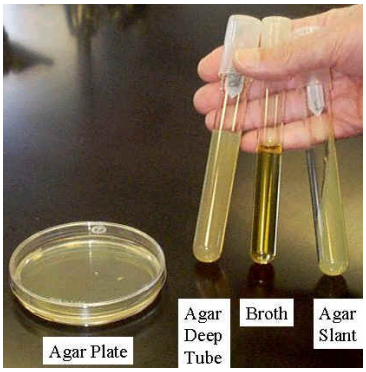


Figure 1. Common culture media

Broth

Broth is a liquid that contains nutrients for bacteria to grow. It is kept in glass tubes and capped with a metal or plastic sleeve.

Agar

Agar is solid or semisolid. It liquefies at 100º C and solidifies at 40º C.

Agar plates are Petri dishes that contain agar for growing microorganisms. They have a large surface area and are useful for isolating and studying microorganisms. After they are inoculated, they are incubated in an inverted position. This prevents condensation from dripping from the cover onto the agar.

Agar slants are useful for maintaining cultures. Microorganisms grow on the surface of agar plates and slants.

Transfer Instruments

Subculturing refers to transferring microorganisms from one medium to another. For example, bacteria growing in broth may be transferred to an agar plate.

Wire loops are used to transfer microorganisms from liquid media to liquid or solid media.

Figure 2. Wire loop

Pipettes are used to transfer liquids. A mechanical device must be used with pipettes to create a vacuum.

Incubation

Bacterial cells on the agar or in the broth will reproduce rapidly if other environmental conditions such as temperature are favorable. A single cell on the agar will shortly produce a **colony** of cells that is easily visible to the naked eye. Such a colony is a **pure culture** because it is a single species.

An **incubator** is a chamber that maintains a constant temperature. After microorganisms are transferred to broth or agar, they are placed in an incubator (incubated) for a period of time while the cells reproduce.

Refrigerators are useful for maintaining stock cultures for long periods of time because microorganisms grow (reproduce) very slowly at low temperatures. They can also be used to store subcultures after they have been incubated.

Culture Transfer Techniques

Figure 3. Bacti-cinerator

The procedure discussed below can be used to transfer microorganisms from a tube of broth to another culture tube.

Figure 4. Bunsen burner

Microorganisms are often transferred from one medium to another with a wire loop. Before the loop is used to remove a sample of microorganisms, it must first be sterilized. A bacti-cinerator or bunsen burner can be used to heat the loop. Figure 3 shows a bacti-cinerator. Figure 4 shows a bunsen burner being used to sterilize the loop. The wire should be heated in a bacti-cinerator or a bunsen burner flame until it glows red. The loop should be cooled in the air for 10 to 20 sec. Care should be taken not to put it down in order to avoid contamination.

Hold the source tube and also the tube to be inoculated in one hand as shown in figure 5. The loop is held in the other hand.

The two tubes are uncapped by using the hand that holds the loop. The likelihood of contamination can be minimized by keeping the caps in your hand as shown below.

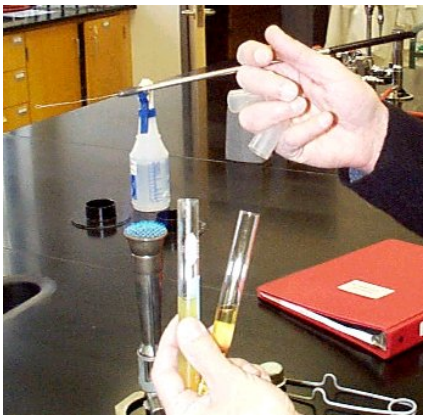


Figure 5. Uncapping test tubes

Pass the mouths of the tubes through the flame. Skip this step if you are using a bacti-cinerator.

Figure 6. Sterilize tubes

Remove a sample from a broth culture by using a sterile wire loop.

Figure 7. Transfer sample

Touch the colony to be subcultured with the wire but do not break the surface of the agar.

Figure 8. Transfer is completed

Reflame the mouths of the tubes and replace the caps.

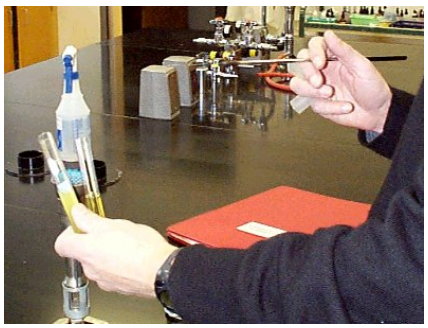


Figure 9. Reflaming tubes

Sterilize the loop in the flame or the bacti-cinerator before putting it down.

Notes on Transferring Samples

- **Transferring to broth—**Put the loop in the broth and then swirl it.
- **Agar slant or plate—**When inoculating an agar slant or plate, draw the loop very lightly over the surface while being careful not to break the surface. A straight or a zig-zag motion can be used.

Laboratory Procedure

1. Transfer *S. marcescens*: from **broth** to a sterile **agar slant** using a wire loop.
2. Transfer *S. marcescens*: from **broth** to a sterile **broth** using a wire loop.
3. Transfer *S. marcescens*: from a **slant** to a sterile **slant**.
4. Transfer *S.marcescens*: from a broth to an agar plate.

Put your name on each tube or plate and place them in a 37 degree incubator for 48 hours.

Sampling the Environment

The procedure below will demonstrate that bacteria are commonly found throughout our environment.

Use a cotton swab to sample bacteria on a surface such as a desktop, the floor, or a stair handrail. After rubbing the swab on the surface, rub it lightly on the surface of an agar plate.

Your instructor will place the plates in an incubator for 48 hours. They can be examined during the next lab period.

Staining

Procaryotes are typically stained to make them easier for viewing. We will use a basic staining procedure called **gram staining**. This staining method separates bacteria into two groups based on the thickness of their cell wall. Gram positive bacteria have a thick cell wall and will appear dark purple after a gram stain. Gram negative bacteria have a thinner cell wall and will appear lighter in color.

Preparing a Smear

The gram staining technique involves making a **smear** of bacteria on a slide and then adding the stain.

Use a wire loop to take a sample *Staphlococcus epidermidis* from a slant and place it on the center of a slide. Take a sample of *Escherichia coli* from a slant and place it on the center of a second slide.

Use a wire loop to add a very small amount of distilled water to the sample and use a wire loop to spread the culture evenly over an area the size of a dime or smaller. Be careful not to use too much water so that it will not take too long to dry.

Allow the slides to air-dry. If you used too much water, it can be spread over the surface of the slide so that it dries faster.

After the slides are air dried, the bacteria must be fixed (attached) to the surface of the slides so that they do not wash off during the staining process. The bacteria can be fixed by holding the slide above the opening of the bacti-cinerator for about 30 seconds. If a bunsen burner is used, pass the slide over the flame two or three times. A continuous, nonstop motion should be used as the slide passes over the flame. Each pass should take approximately 1 second.

Gram Staining

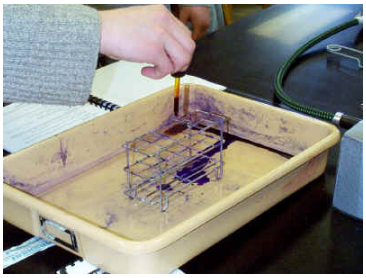


Figure 10. Gram Staining

1. Place a wire test tube rack in a plastic tray and place the slides on the test tube rack as shown in figure 10.
2. Flood the slides with crystal violet for 1 minute. This should be done over the sink or a tray to prevent stain from spilling on the laboratory bench top.
3. Wash the slides with tap water.
4. Flood the slides with Gram's iodine (a mordant) for 1 minute.
5. Wash again with tap water.
6. Flood the slides with 95% ethyl alcohol. This decolorizes bacteria that have thin cell walls.
7. Wash with tap water.
8. Counterstain with safranin for 45 seconds.
9. Wash with tap water.
10. Blot dry. The slide is ready for viewing; cover slips are not necessary. View the slide using high power. You may wish to also view the slide using the oil immersion lens.
    1. Draw and describe each slide. Note the gram positive cocci (*Staphlococcus epidermidis*) and the gram negative bacilli (*Escherichia coli*).
    2. Observe and draw a prepared slide of typical spirilla.
11. After you are finished with the slides, clean the immersion oil from the microscope lens.

Shape

The shape of a cell is used to help classify bacteria. Round cells are called **cocci** (sing. coccus), rod-shaped cells are **bacilli** (bacillus), and rigid, spiral-shaped cells are **spirilla** (spirillum). Flexible, spiral-shaped bacteria are **spirochetes**.

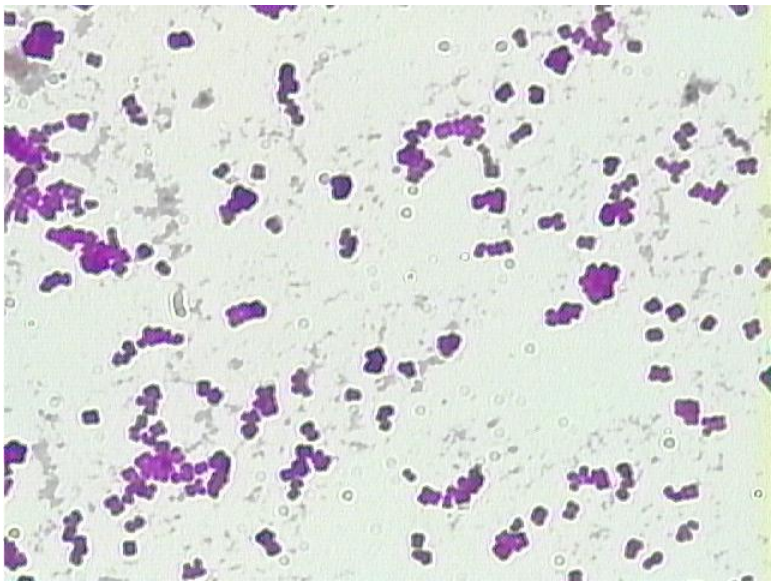


Figure 11. Cocci x 400

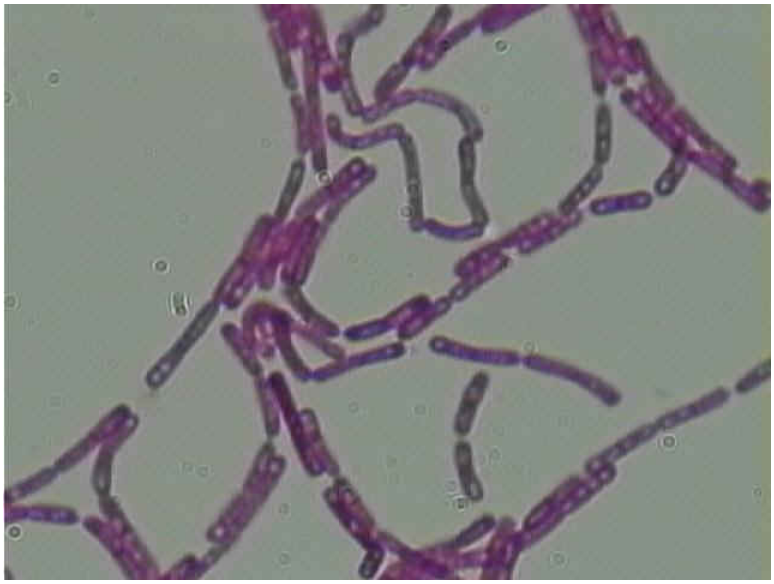


Figure 12. Bacilli X 1000.

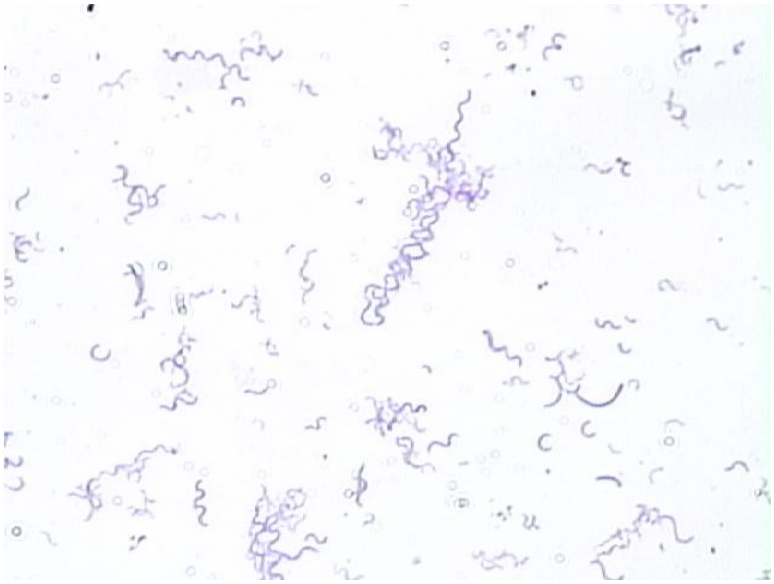


Figure 13. Spirilla X 400

Cyanobacteria

Cyanobacteria (sometimes called blue-green algae) are gram-negative bacteria that can photosynthesize and some can fix atmospheric nitrogen. The only organisms capable of fixing nitrogen are bacteria, and this is primarily done by the cyanobacteria. The fixation of nitrogen by cyanobacteria may have allowed plants to invade the land during the Paleozoic.

Like plants, cyanobacteria have the photosynthetic pigment chlorophyll A and they use water as an electron donor during photosynthesis. When water molecules are split, oxygen is liberated. This process resulted in oxygen accumulating in the earth's early atmosphere.

Unicellular, filamentous, and colonial species of cyanobacteria are common.Gloeocapsa is a unicellular cyanobacteria. The gelatinous material surrounding each cell causes the cells to stick together. Some Cyanobacteria form symbiotic associations with fungi forming structures called lichens.

Procedure

Observe and draw live *Oscillatoria* and *Anabaena*. If live organisms are not available, use prepared slides. Live organisms can be viewed by placing a small amount of the organism on a slide in a drop of water and then covering it with a cover slip. Be sure to indicate the magnification used in your drawing.

Contributors and Attributions

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2.4: Reading- Protists

The goal of this exercise is to learn about the protists. We will study major groups and for most of the groups, we will study representative genera.

Procedure

For each specimen:

1. Read the information thoroughly.
2. Create notes. Your notes will be most helpful if they include a drawing, a description, and significant information such as life cycle, commercial value, ecological significance, and unusual characteristics.

Euglenozoans

Kinetoplastids

Kinetoplastids are flagellated and unicellular. They have a dark staining region of mitochondria called a kinetoplast.

Some kinetoplastids are **symbiotic** (close) relationships with other organisms. Trypanosomes are Kinetoplastids that cause African sleeping sickness. They are transmitted to their human hosts by the bite of a tsetse fly. *Trypanosoma* causes African sleeping sickness.

Euglena

Euglena are unicellular. Many Euglenids feed by phagocytosis. Many species of Euglenids are photosynthetic but can become heterotrophic when sunlight is unavailable (mixotrophs).

Euglena use flagella for moving. The outer covering called a **pellicle**, is flexible and assists in moving. Some have an eyespot with a photoreceptor is capable of detecting the presence of light. Reproduction is asexual.

Diatoms

Diatoms are the most numerous unicellular algae in the oceans and as such are an important source of food and oxygen. They are also important in freshwater environments. They capture 20 to 25% of solar energy captured by living organisms. The cell walls of diatoms contain silica (a component of glass) and are formed in 2 halves like a pillbox. Their remains form diatomaceous earth. It is used for filtering agents, and abrasives such as scouring powders. Diatoms are a major component of phytoplankton in freshwater and marine environments.

Brown Algae

Brown algae are autotrophs (photosynthetic). Their characteristic brown color is due to carotenoid pigments. They are multicellular and range in size from small to very large. Some are 50 m to 100 m long. They are often found along rocky shores in temperate climates. The body (*thallus*) contains *holdfasts* for attachment, *blades*, and a stem-like structure that holds the blades is called a *stipe*. Many species have floats that function in floatation. Some have gas-filled floats. Mucilaginous (slimy) material in the cell walls retards drying in exposed individuals when the tide goes out. Most **species** have a life cycle with **alternation of generations**.

Fucus

Fucus is a common “seaweed” found along the rocky coast. Some species of *Fucus* have **diploid adults**.

Figure 1. Gametes are produced in the receptacles.

Macrocystis and Nereocystis

Macrocystis and nereocystis are deep-water kelps.

Sargassam

Sargassam sometimes breaks off to form floating masses. Other marine organisms congregate around these masses.

Laminaria

Laminaria is a brown alga that is usually found attached just below the intertidal zone. It has a life cycle with alternation of generations.

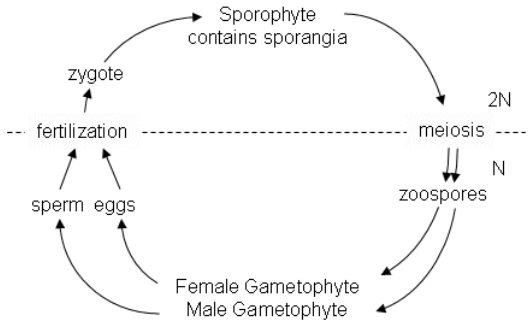


Figure 2. Alternation of Generations

Dinoflagellates

Protective **cellulose** plates cover dinoflagellates and two **flagella** enable them to move. One of the flagella lies in a transverse groove that causes cell to spin as it moves.

Most are found in marine or freshwater environments and many are photosynthetic. They are important components of **phytoplankton** and thus are important in **aquatic food chains**. This group also includes many heterotrophic and many mixotrophic species.

Some species are responsible for red tides that kill fish and shellfish (Gymnodinium, Gonyaulax, Pfiesteria). Some live as **symbiants** within some invertebrates. For example, some corals grow faster with dinoflagellates living within their cells. Some species are capable of bioluminescence (they produce light).

Both sexual and asexual reproduction occur. Sexual reproduction produces cysts which are resistant to unfavorable environmental conditions. Cysts are dormant and become active when environmental conditions improve.

Ciliates

The genus *Vorticella* belongs in this group.

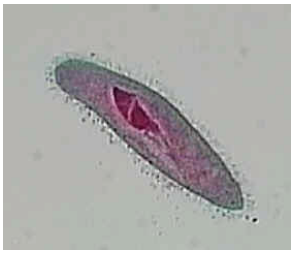


Figure 3. *Paramecium caudatum* X 100

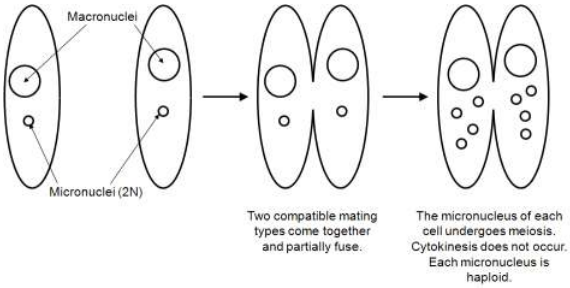
The **pellicle** (outer covering) of paramecium is covered with hundreds of **cilia**. They have numerous organelles including a gullet (oral groove) and an anal pore. Ciliates have a large macronucleus and a smaller micronucleus.

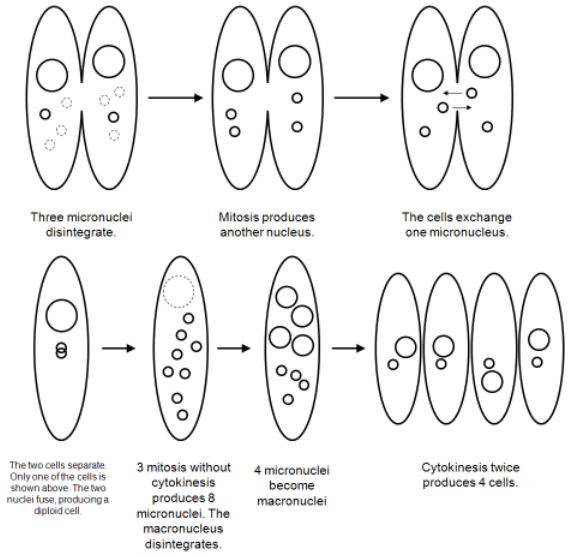
The micronucleus is involved in sexual and asexual reproduction. Other nuclear activities are handled by the macronucleus. The macronucleus is **polyploid** (approximately 860 N in Paramecium aurelia) and the micronucleus is **diploid**.

Figure 4. Paramecium X 200

During reproduction, the macronucleus disintegrates. Later, a micronucleus will develop into a macronucleus. Most reproduction is asexual (mitosis). Sexual reproduction is by **conjugation**.

The micronucleus will divide by meiosis; 3 of the 4 resulting nuclei will disintegrate as will the macronucleus. The remaining haploid nucleus will divide by mitosis producing an individual with two haploid nuclei. Two conjugating individuals will each exchange one of the nuclei. The two haploid nuclei will then fuse producing a diploid nucleus.





Red Algae

Red algae are mostly multicellular and are found mainly in warmer, tropical oceans. Their red color is due to an accessory **photosynthetic pigment** called phycoerythrin. The accessory pigments of red algae are able to absorb blue and green light. This allows some species to survive in deep waters where blue and green light predominates.

Some species are **filamentous** but most have a complex pattern of branching. Some coralline forms deposit calcium carbonate in their cell walls, which contributes to the development of coral reefs.

Green Algae

Four common forms of green algae are single-celled, **colonial**, **filamentous**, and **multicellular**. Green algae are thought to be ancestors of the first plants. Both kinds of organisms have the following characteristics in common:

1. They have a **cell wall** that contains **cellulose**.
2. They have **chlorophyll** a and b.
3. They store their food as **starch** inside the **chloroplast**.

Most species are freshwater but there are many marine species. Some live in damp soil.

Chlamydomonas

Chlamydomonas is a single-celled organism with two **flagella**. Although this organism is a single cell, the life cycle is similar to that with **haploid adults**.

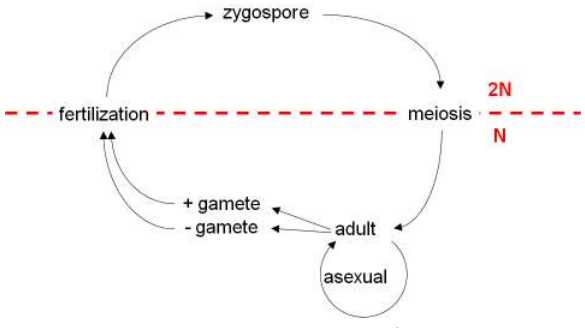


Figure 5. Chlamydomonas' life cycle

It reproduces asexually (by mitosis) when conditions are favorable. **Sexual reproduction** occurs when conditions become unfavorable. The **zygote** forms a thick-walled zygospore that is resistant to environmental extremes and divides by meiosis when

environmental conditions become favorable.

Most **species** of Chlamydomonas are isogamous (both gametes are the same size; they are isogametes), some are oogamous (gametes are two sizes; the larger gametes are eggs, the smaller ones are sperm).

Volvox

Volvox is a colonial green algae. The cells are arranged in a gelatinous sphere with two flagella directed to the outside. They divide asexually to produce a daughter colony.

Some cells are specialized to produce sperm and eggs for sexual reproduction. Specialization of cells as seen in the reproductive cells is a characteristic of multicellular organisms. Volvox is considered to be a colony because it appears to be intermediate between a group of individual cells and a multicellular organism.

Spirogyra

Spirogyra is a **filamentous** form. It has a ribbonlike spiral-shaped chloroplast. The *life cycle has haploid adults*.

Sexual reproduction occurs by **conjugation**. Conjugation refers to the process where gametes are transferred from one individual to another by a connection between the two.

The zygote is resistant and overwinters. In the spring, it divides by meiosis to produce haploid filaments.

Ulva

Ulva is multicellular with a leaflike body that is two cells thick but up to one meter long. The life cycle is alternation of generations. Both the haploid and the diploid generations look alike (**isomorphic**).

Tubulinids

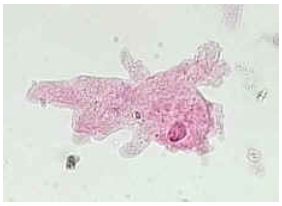


Figure 7. *Amoeba proteus* X 100

Tubulinids move by **cytoplasmic** extensions called **pseudopodia**. They feed by **phagocytizing** (engulfing) their prey. Tubulinids are found in soil, marine, and freshwater environments. *Amoeba proteus* (figure 7) is found in freshwater.

Amoeba movement and phagocytosis (video)

Contributors and Attributions

CHAPTER OVERVIEW

3: Fungi

3.1: Fungi Lab

Learning Objectives

- State the kingdom of mushrooms, yeast, and bread molds
- State the phylum of the bread mold
- State the phylum of the mushroom (club fungi)
- State the phylum of the yeast (sac fungi)
- State if spores are haploid or diploid
- Be able to identify a zygospore.
- Be able to identify hyphae
- Be able to identify the conidiospores and conidiphores of the ascomycota specimens
- Be able to identify the basiodcarp and basidospores and basidia of the mushroom.
- State what two organisms are involved in a symbiotic relationship to create a lichen.
- Give an example of a type of lichen.

Download a PDF of the lab to print.

Procedure

1. Access the page “Reading: Fungi.”
2. Watch this video:

Questions

1. Zygomycota (bread mold): View the prepared slides of the zygospores and sporangia.
    1. What kind of reproduction is used by the zygomycota?
    2. Is the zygospore diploid or haploid?
    3. Draw a picture of the zygospores you viewed under the microscope.
2. Ascomycota (sac fungi).
    1. We do not have a slide of the *Peziza*-please view the pictures on the website.
    2. *Aspergillus*: View the slides available of *Aspergillus*.
        1. Can you find any conidiospores?
        2. Are conidiospores used in sexual or asexual reproduction?
        3. Use the space below to draw a picture of the conidiospores as you viewed under the microscope.
    3. Yeast: create a wet mount slide of the yeast (as assisted by your instructor) to view under the microscope.
        1. Are yeast single or multi celled?
        2. Do yeast reproduce asexually or sexually?

3. Are you able to view budding, the asexual reproductive process of yeast? Review the Yeast Budding video to help visualize budding.
4. When yeast reproduces sexually, what is the name of the diploid cell that is formed?

3. We do not have a slide of the *Schizosaccharomyces octosporus*—please view the pictures on the website.
4. Skip over the Morels.
5. View the *Penicillium* slides only, no live specimens.
    1. Name the specialized stalks that the asexual spores attach to.
    2. Use the space below to draw a picture of the *Penicillium* specimen as you viewed it under the microscope.

Basidiomycota (club fungi)

1. View the mushroom specimens available in the lab. Do not dissect them. See if you can find the gills on the underside of the basidiocarp.
    1. Name the specific spores formed by the mushroom in the gills.
2. View the cross section slide of the *Coprinus*mushroom.
    1. Can you locate the basiodispores?
    2. Name the specific stalk that the basidiospores attach to.
    3. Use the space below to draw a picture of the *Coprinus* basidiospores and basidia as you viewed under the microscope.

Lichens

1. There may or may not be live specimens of the lichens to view in the classroom. If live specimens are present, please look at them. And, access this website to learn more.
    1. What type of lichen has the algae dispersed throughout?
    2. What type of lichen exhibits the fastest growth?
    3. What type of lichen grows in a circular pattern forming lobes?
2. View the lichen thallus slide under the microscope.
    1. What two organisms create the lichen?
    2. Use the space below to draw a picture of the lichen thallus as you viewed it under the microscope. On your picture try to label both the fungi and the algae.

Answer the questions below to summarize the lab activity:

1. What is the domain of the fungi?
2. How do fungi obtain energy?
3. What is the reproductive structure of the fungi? It’s not sperm and egg!
4. In the lab activity, which groups of fungi prefer to reproduce asexually? Which groups of fungi tend to exhibit sexual reproduction?
5. A lichen is a mutualisic relationship between what two organisms?

3.2: Fungi Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Fungi

Students will do this part in table teams (groups of 4).

Materials	Quantity	NotesDry
Rhizopus slides	1 per table	include sporangia and zygospores
Asergillus slides	1 per table	include conidia and coidiophores
Penicillium	1 per table	conidiophores only
Lichens	various	different forms (frutisoe, foliose, etc.) set up as demo on side bench
mushrooms	various	samples for students to view under dissecting microscope. Can be purchased at grocery store.
Coprinus slide	1 per table	cross section view
lichen thallus slide	1 per table	

Materials on side bench:

- Dry yeast packet (1 per class)
- 250 ml beaker
- sugar (sucrose)
- slides
- coverslips
- plastic pipets (~3)
- glass stir rod
- access to microwave or hot plate (heat for water)

To prepare yeast culture: heat 150 ml of water to 45C and dissolve 1 yeast packet. It's important the water is not too hot or the yeast will die. Add 1 teaspoon of sugar. Stir until yeast dissolved. Let sit for 5-10 minutes. If yeast is activated it will foam/bubble.

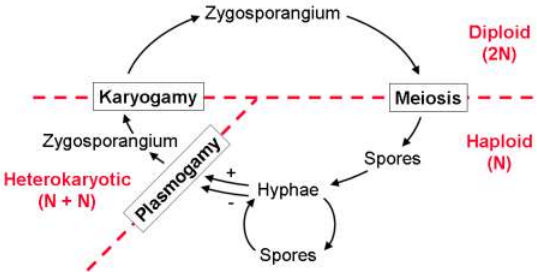
3.3: Reading- Fungi

Zygomycota

Fungi in the phylum Zygomycota are called zygomycetes. The zygomycetes are terrestrial. They are usually **saprotrophs** but there are some **parasites.** The hyphae are coenocytic (theyn lack septa). Septa are found only in the reproductive structures.

Reproduction in Zygomycota

Fusion of two hyphae leads to the formation of a **zygosporangium**, a thick-walled structure that is capable of surviving environmental extremes. Before karyogamy, the zygosporangium contains many haploid nuclei. after karyogamy, it contains many diploid nuclei.



Rhizopus (Bread Mold)

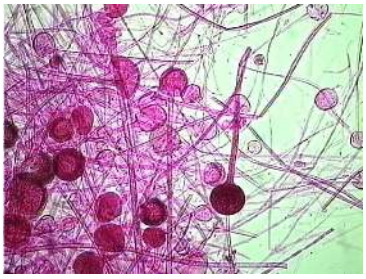


Figure 2. Rhizopus* sporangia

Asexual reproduction involves mycelia producing sporangia that produce haploid spores by mitosis. The spores produce new mycelia.

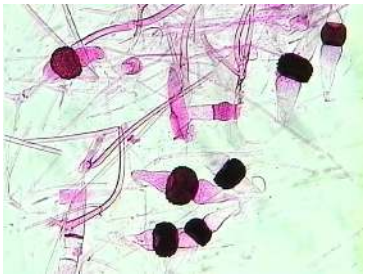


Figure 3. Rhizopus* zygotes

When environmental conditions deteriorate, sexual reproduction may occur. Hyphae from opposite mating types produce structures that contain several haploid nuclei. Fusion of two of these structures from opposite mating types results in a heterokaryotic **zygosporangium**. A thick wall develops that functions to protect the zygospore until environmental conditions become favorable. When conditions are favorable, nuclear fusion (karyogamy) occurs within the zygosporangium producing diploid nuclei. This is followed by meiosis. The zygosporangium then germinates to produce a sporangium which releases haploid spores.

Observe *Rhizopus* (bread mold) growing on a culture dish. Use a dissecting microscope to see details of the hyphae and sporangia. Is there any evidence of sexual reproduction?

Phylum: Ascomycota (Sac Fungi)

Examples: Yeasts, molds, morels, truffles

Figure 4. Morels (left) are sac fungi. Photo courtesy of Michael Lawliss.

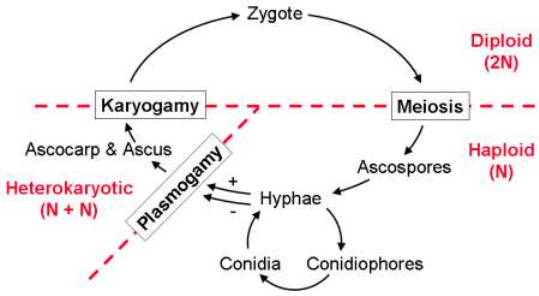
Ascomycetes are important in digesting resistant materials such as **cellulose** (found in plant cell walls), lignin (found in wood), and **collagen** (a connective tissue found in animals). This group also includes many important plant pathogens.

Many, perhaps half of the species of ascomycota form lichens—a symbiotic relationship between a fungus and a photosynthetic cell such as a green algae or a cyanobacteria. The fungal component of most lichens is an Ascomycete.

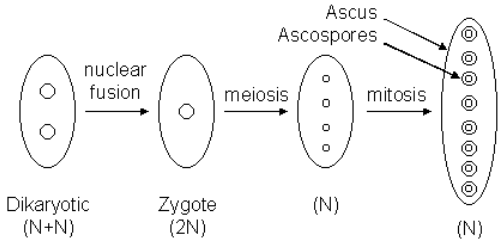
Reproduction in Sac Fungi

Sexual

Hyphae from opposite mating types fuse, forming a heterokaryotic structure which then produces dikaryotic hyphae. The fruiting body is called an **ascocarp**. It is composed of dikaryotic hyphae and haploid hyphae.



Dikaryotic hyphae within the ascocarp produces **asci** (singular: **ascus**), sacs that are walled off from the rest of the hyphae. Nuclear fusion within an ascus will produce a diploid zygote. The zygote will undergo meiosis, followed by mitosis to produce 8 haploid **ascospores**.



Asci with ascospores can be seen in figure 5.

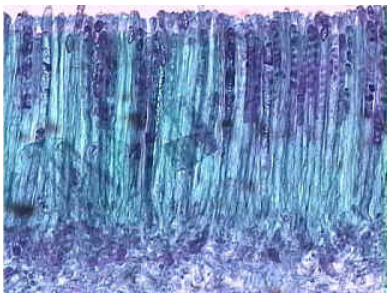


Figure 5. Peziza cross section X 200.

Asexual

Most reproduction is by asexual spores called **conidia**. Unlike the Zygomycetes which produce asexual spores within sporangia, conidia are produced on the ends of specialized hyphae called conidiophores.

Examples of Sac Fungi

Morels and truffles are gourmet delicacies. This group includes many important plant parasites such as Dutch elm disease, chestnut blight, leaf curl fungi, and *Claviceps*.

An ergot is the hard, purple-black fungus *Claviceps purpurea*. It contains toxic alkaloids, including LSD. When infected rye is made into bread, the toxins are ingested and cause vomiting, muscle pain, feeling hot or cold, hand and foot lesions, hysteria and hallucinations. Historians believe that those that accused their neighbors of witchcraft in Salem may have been suffering from ergotism. *Claviceps* is used to stimulate uterine contractions and to treat migraine headaches.

Peziza (Cup Fungi)

Observe preserved *Peziza* (cup fungus) using a dissecting microscope.

Observe a slide of *Peziza* at scanning, low, and high power magnification. Find an ascus and ascospores on the upper surface (inside the cup).

Aspergillus

Observe the conidiophores and **conidia** (asexual spores) of *Aspergillus*.

Yeast

Yeast are single-celled members of the sac fungi. Most reproduction is asexual; a small cell pinches off from a larger cell. This type of mitosis where a smaller individual grows from a larger individual is called *budding*.

Make a wet mount of live yeast and see if you can observe budding under high power. If you cannot see yeast budding, view a prepared slide of yeast budding under high power.

Yeast also reproduce sexually by forming an ascus and eight ascospores. View a slide of Schizosaccharomyces octosporus under high power or oil immersion and find an ascus with ascospores.

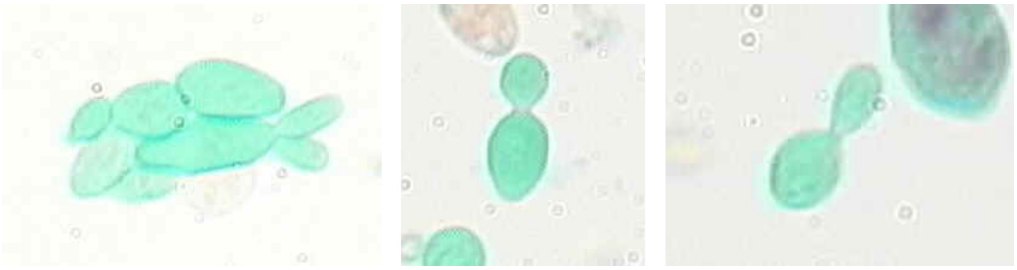


Figure 6. Yeast (Saccharomyces) budding X 1000.

During sexual reproduction, the fusion of two cells results in the formation of an ascus.

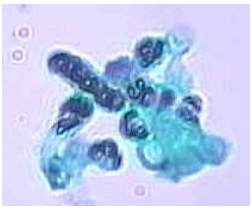


Figure 7. Schizosaccharomyces octosporus X 1000

The elongated cell in the upper left part of figure 7 contains ascospores.

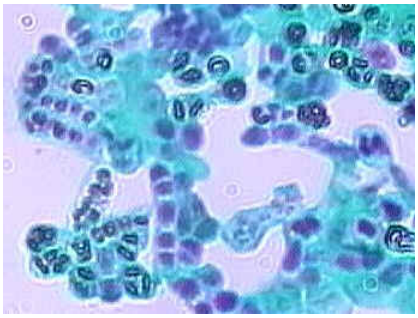


Figure 8. Schizosaccharomyces octosporus X 1000

Cells in the lower left part of the figure 8 contain ascospores.

Yeast is important in leavening bread by CO_2 production and in producing ethanol for alcoholic beverages.

Penicillium

Observe *Penicillium* growing on a culture dish.

Figure 9. Penicillium growing on an agar plate

Penicillium reproduces asexually. Observe a slide of *Penicillium***conidiophores** under high power. The spores are called **conidia**.

Figure 10. Penicillium Conidiophores and conidia X 400.

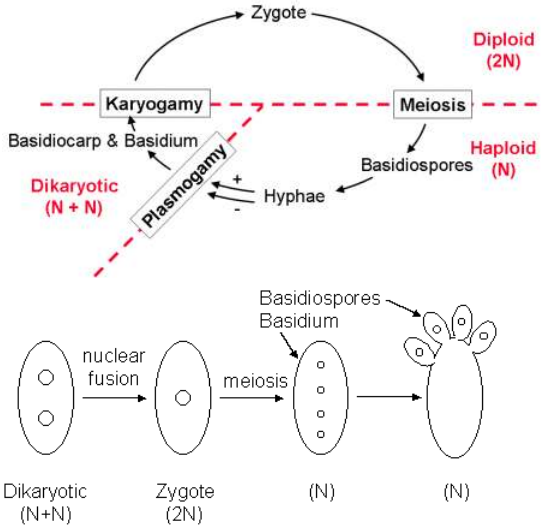
Phylum: Basidiomycota (Club Fungi)

Reproduction

Asexual reproduction in club fungi is rare. Their fruiting bodies are called **basidiocarps**. This is the visible *mushroom*.

Figure 11. Mushrooms showing gills

Spores, called **basidiospores** are produced on **basidia** within the basidiocarps. In mushrooms, the basidia are located along the gills on the underside of the cap. In figure 6, a portion of the cap of this mushroom has been broken away to reveal the gills.



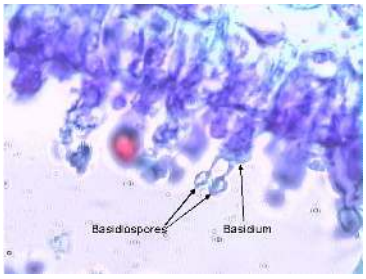


Figure 12. Basidia and basidiospores X 1000

In **ascomycota** (sac fungi), the **ascospores** were enclosed in an ascus. In basidiomycota, the basidiospores are not enclosed. Compare the diagrams of a basidium with basidiospores above with that of an ascus with ascospores seen earlier.

Basidiospores germinate to produce monokaryotic (haploid, one nucleus per cell) hyphae. Mushrooms are composed of dikaryotic hyphae which are formed when hyphae fuse. Dikaryotic nuclei within the basidium fuse to produce a zygote and meiosis then produces basidiospores.

Observe some representative club fungi on display including mushrooms, puffballs, and bracket fungi.

Bracket Fungi

Figure 13. Bracket fungi

Bracket Fungi and Lichens

Figure 14. Bracket fungi and lichens

Mushrooms

Figure 15. Mushrooms

Cut a mushroom to reveal the gills as shown in figure 16. Basidia and basidiospores form on the gills.

Figure 16. Mushroom cut to reveal the gills

View a cross section of the cap of a mushroom (*Coprinus*) showing the gills. Find a basidium and basidiospores.

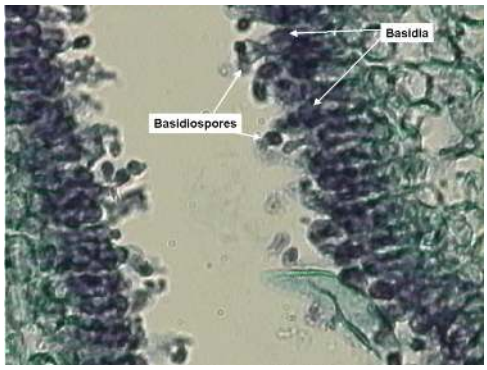


Figure 17. Coprinus X 400

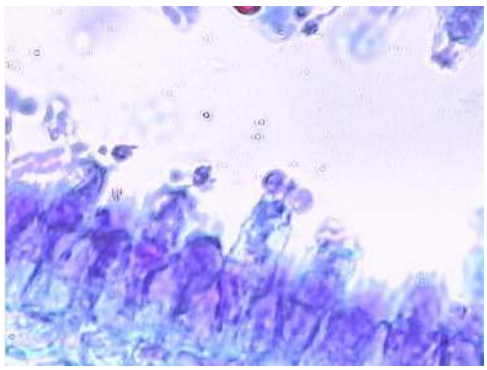


Figure 18. Coprinus X 1000 showing basidia and basidiospores

Symbiotic Associations of Fungi and Other Organisms

Lichens

Lichens are structures made up of two different species:

1. a fungus
2. either a cyanobacterium or a green algae

The photosynthetic cells are contained within the middle layer.

The photosynthetic cells provide photosynthesis for the lichen. It was thought that the relationship was mutualistic because the fungus prevented the algal cells from desiccation. Recent evidence indicates that the photosynthetic cells may grow faster when separated from the fungus. Perhaps the fungus is parasitizing the photosynthetic cells.

Reproduction is asexual. Fragments are produced that contain fungal hyphae and photosynthetic cells.

Lichens derive most of their water and minerals from rainwater and air. This allows them to survive on bare rock, tree trunks, inhospitable places.

Observe the lichens on display. Some lichens have a crust-like appearance (crustose). Others have a shrublike (fruticose) or leaflike (foliose) appearance.

Figure 19. Lichens growing on a rock

Figure 20. Lichens growing on a tree

Figure 21. Lichens growing on a tree

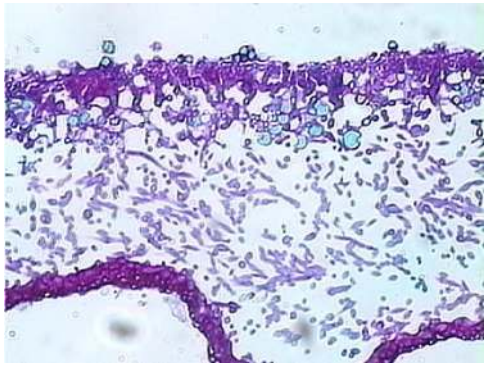


Figure 22. Lichen thallus (cross-section X 200)

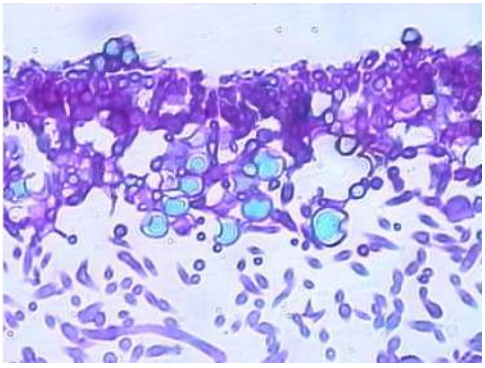


Figure 23. Lichen thallus X 400

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3.4: Case Study- Amphibian Die Off, Chytrid Fungi

Review this slideshow then answer the questions below.

Questions

1. What phylum of fungi is responsible for chytridiomycosis?
2. Why is this fungi successful at killing amphibians?
3. Why be concerned about the world's amphibian populations? What role do amphibians play in ecosystems?
4. How might Bd be spreading through the environment?
5. Propose a hypothesis that would explain why Bd is spreading like a new disease throughout the world.
6. Some scientists are attempting to prevent the extinction of amphibians by capturing amphibians in the wild, breeding them in chytrid free labs, then releasing some of the amphibians into the wild. Discuss how such a strategy could save some species of amphibians.
7. How else might we prevent the spread of Bd throughout the world?

CHAPTER OVERVIEW

4: Seedless Plants

4.1: Seedless Plant Lab

Learning Objectives

At the conclusion of the lab, the student should be able to:

- Explain what is meant by “alteration of generations”
- Explain the difference between the sporophyte and gametophyte generation in plants. State which generation is haploid and which is diploid
- Name the process that makes spores and state if spores are haploid or diploid
- Name the process that creates sperm and egg from spores and state if sperm and egg are haploid or diploid
- Name the phyla discussed in the lab and give an example of a plant from each
- Identify and know the function of the archegonium and the antheridum
- Identify the fern structures discussed
- Understand the basic moss and fern life cycle

Download a PDF of the lab to print.

Procedure

1. Access the page “Reading: Seedless Plants.”
2. Phylum Bryophyta (Mosses)
    1. View the live moss specimens available in the lab.
        1. Is the green “leaf like” tissue gametophyte or sporophyte?
        2. Is the stalk that emerges from the green “leaf like” tissue gametophyte or sporophyte?
    2. As indicated in #3 of the website use the space below to draw a simple life cycle of the moss. Include in the life cycle 2N, N, sporophyte, gametophyte, meiosis, spores, egg, sperm, antheridium, archigonium, fertilization. If you need help in constructing your life cycle picture check out this website.
    3. View the prepared slide of the archigonium and the antheridum (there should be a slide with both).
        1. Is the archegonium male or female?
        2. What cell is produced in the archegonium?
        3. Is this cell haploid or diploid?
        4. Is the antheridium male or female?
        5. What cell is produced in the antheridium?
        6. Is this cell haploid or diploid?
    4. View the prepared slide of the moss capsule.
        1. Is the capsule sporophyte or gametophyte tissue?
        2. What cell is produced in the capsule?
        3. Is this cell haploid or diploid?
        4. How are moss spores dispersed to new locations?
3. Skip the liverworts section (Phylum Hepatophyta)
4. Seedless Vascular Plants
5. Phylum Pterophyta (Ferns)
    1. As indicated in #1 of the website use the space below to draw a simple life cycle of the fern. Include in the life cycle 2N, N, sporophyte, gametophyte, meiosis, spores, egg, sperm, antheridium, archigonium, fertilization, sorus. If you need help in constructing your life cycle picture check out this website.
    2. Observe the preserved fern frond. Locate the sori on the underside.
        1. Is the frond sporophyte or gametophyte?
        2. What cell is produced in the sori?
        3. Is this cell diploid or haploid?

3. View the prepared slide of the fern prothallus under the microscope.
    1. What shape is the prothallus?
    2. Is the prothallus sporophyte or gametophyte?
    3. Can you find the archegonium and the antheridium?
    4. What cell is made in the archegonium?
    5. What cell is made in the antheridium?
6. Skip the horsetails
7. Skip the spikemosses and club mosses (Phylum Kycophyta)
8. Answer the review questions below.
    1. Is gametophyte tissue haploid or diploid?
    2. Is sporophyte tissue haploid or diploid?
    3. Is the moss life cycle gametophyte or sporophyte dominant?
    4. Is the fern life cycle gametophyte or sporophyte dominant?
    5. In the life cycle of the primitive plant, the process of meiosis produces what cell?
    6. Does the gametophyte or sporophyte generation produce spores?
    7. What process do spores undergo to create sperm and egg?
    8. State one reason why moss and fern are considered primitive plants.
    9. What is meant by the idea of “alteration of generations?”

4.2: Seedless Plant Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Seedless Plants

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
live moss speciman with gametophye and sporophyte tissue	1-2	put on side bench as demo, helpful to view under dissecting scope
moss antheridium slide	1 per table	
moss archigonium slide	1 per table	
moss capsule with spores slide	1 per table	
fern leaf with sori	1-2	put on side bench as demo, helpful to view under dissecting scope
fern prothallus slide	1 per table	should contain both antheridia and archegonia

4.3: Reading- Seedless Plants

Introduction

Plants (kingdom Plantae) are **autotrophs**; they make their own organic nutrients. The term “organic” refers to compounds that contain carbon. Organic nutrients such as sugars are made by photosynthesis.

Plants are adapted to living on land. For example, the above-ground parts of most plants are covered by a waxy layer called a cuticle to prevent water loss. **Aquatic plants are secondarily adapted to living in water.**

Some evidence that suggests that plants evolved from the green algae is:

- they both use chlorophyll a, chlorophyll b, and carotenoid pigments during photosynthesis.
- the primary food reserve of both is starch.
- they both have cellulose cell walls.

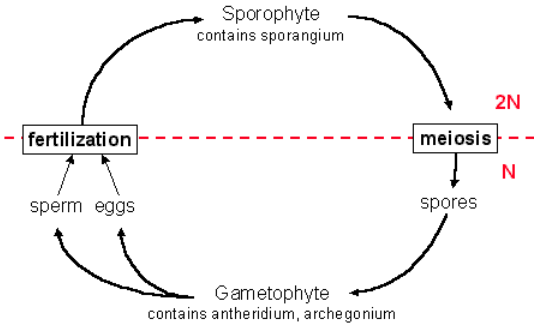
Genetic and morphological evidence indicates that plants evolved from a group of green algae called charophyceans. Many charophyceans inhabit shallow freshwater environments. Natural selection may have favored individuals capable of surviving occasional drying in these environments and this gave rise to land plants.

These traits occur in plants but not charophyceans. Some evolved independently in other algae.

- Apical meristems
- Alternation of generations
- Spores with protective walls
- Spores produced in sporangia
- Gametes are produced in multicellular structures called gametangia; Antheridia produce sperm; Archegonia produce eggs
- Multicellular dependent embryos
- Many have a cuticle that waterproofs and offers some protection

Alternation of Generations

The basic alternation of generations life cycle is illustrated below.



The diploid plant that produces spores is called a **sporophyte**. The haploid plant that produces gametes is called a **gametophyte**.

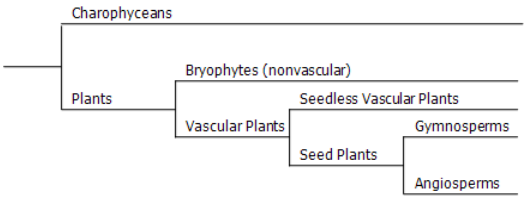
Some protists also have an alternation of generations life cycle but the structures that produce gametes in protists are usually single cells. Plants produce gametes in multicullar structures that have an outer protective layer. Sperm are produced in structures called **antheridia** (sing. antheridium), eggs are produced in **archegonia** (sing. archegonium),. As in protists and fungi, spores of plants are produced in**sporangia** (sing. sporangium).

A **dependent sporophyte** is a sporophyte that is small and grows attached to the gametophyte. It obtains nutrients from the gametophyte. An **independent sporophyte** grows separately from the gametophyte. Similarly, a **dependent gametophyte** is small and grows attached to the sporophyte while an **independent gametophyte** grows separately from the sporophyte.

The evolutionary trend in plants has been from plants with a dominant gametophyte and reduced, dependent sporophyte (ex. Mosses) to plants with a dominant, independent sporophyte and a reduced, dependent gametophyte (ex. Seed plants).

Classification

Evolutionary relationships among the plants are shown below.



We will study the following phyla of plants.

Characteristics	Classification
Bryophytes (no vascular tissue)	Liverworts (Phylum Hepatophyta) Mosses (Phylum Bryophyta) Hornworts (Phylum Anthocerophyta
Seedless vascular plants	Club mosses, Spike Mosses, Quillworts (Phylum Lycophyta)Horsetails, Whisk Ferns, Ferns (Phylum Pterophyta)
Gymnosperms (vascular, naked seeds)	Conifers (Phylum Coniferophyta) Cycads (Phylum Cycadophyta) Ginkgos (Phylum Ginkgophyta) Gnetophytes (Phylum Gnetophyta)
Angiosperms (vascular, protected seeds)	Flowering Plants (Phylum Anthophyta)Monocots Eudicots

Bryophytes

Phylum: Bryophyta (Mosses)

1. Observe different kinds of moss on display and note the body form of the gametophyte.

Figure 1. Moss growing on a rock.

2. Obtain live sporulating moss and identify the sporophyte and gametophyte generations.

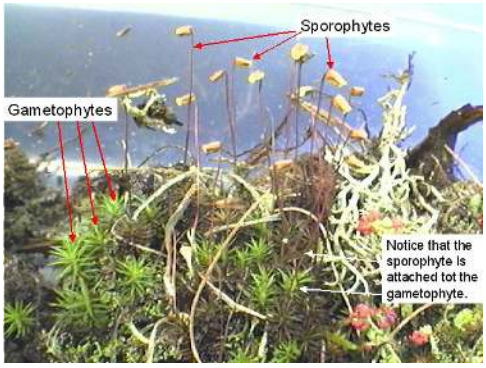


Figure 2. Moss gametophytes and sporophytes

3. Draw the life cycle of a typical bryophyte such as moss. Your drawing should contain the following terms:
    1. 2N
    2. N
    3. sporophyte
    4. sporangium
    5. meiosis
    6. spores
    7. protonema
    8. gametophyte
    9. antheridium
    10. sperm
    11. archegonium
    12. egg
    13. fertilization
4. Observe a slide showing the antheridial head of *Mnium* (a moss). Begin using the scanning (4X) objective and then switch to the low power objective (10X).
5. What is produced in this structure (the antheridium)?
6. Show where the antheridium occurs on the live moss plant. Indicate where this structure occurs in the life cycle diagram that you prepared (above).

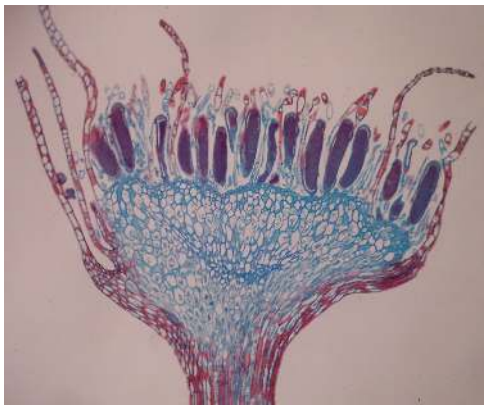


Figure 3. *Mnium* (a moss) antheridial head

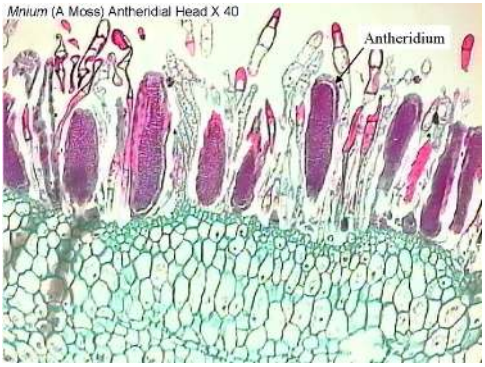


Figure 4. *Mnium* (a moss) antheridial head x40

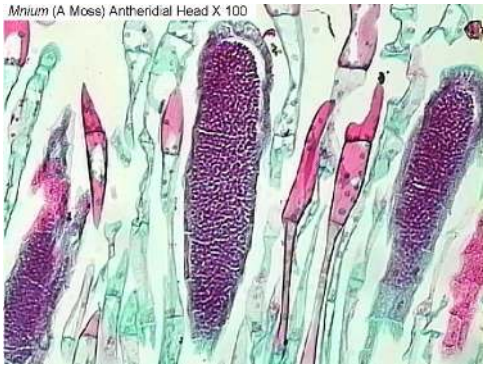


Figure 5. *Mnium* (a moss) antheridial head x100

7. Observe a slide showing the archegonial head of *Mnium* (a moss). Begin using the scanning (4X) objective and then switch to the low power objective (10X).
8. What is produced in this structure?
9. Show where the archegonium occurs on the live moss plant. Indicate where this structure occurs in the life cycle diagram that you prepared (above).

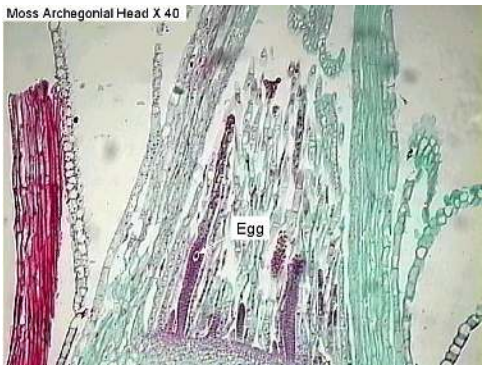


Figure 6. Moss archegonial head x 40

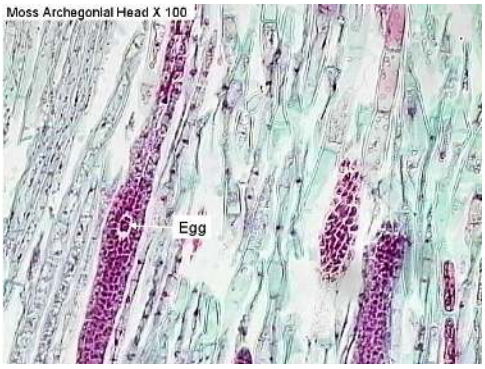


Figure 7. Moss archegonial head x 100

10. After the egg is fertilized, it grows and produces a sporophyte. A capsule containing a sporangium is found at the tip of the mature sporophyte. Refer back to figure 2 to view a sporophyte.
11. Use a dissecting microscope to view a longitudinal section (cut lengthwise).
12. What is produced within this structure (the capsule)?
13. Be sure that you can identify the sporophyte and the sporangium on the live moss plant. Indicate where these structures occur in the life cycle diagram that you prepared (above).

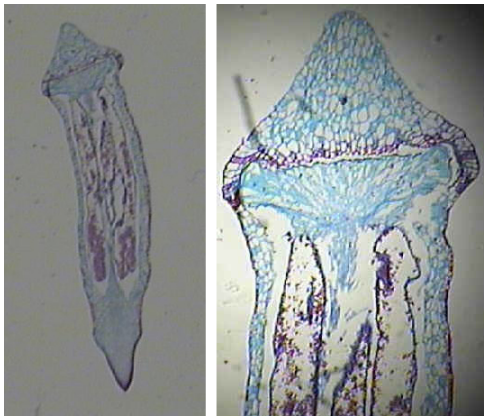


Figure 8. Moss capsule containing spores

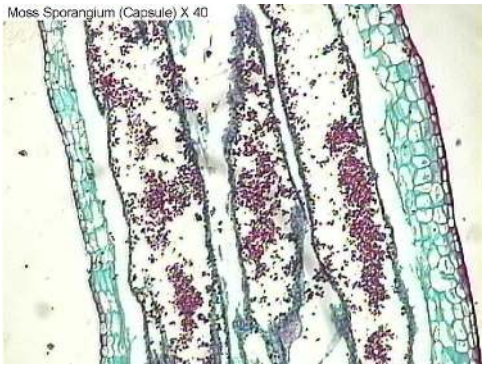


Figure 9. Moss capsule x40

14. How are moss spores dispersed to new locations?

Phylum: Hepatophyta (Liverworts)

Observe live *Marchantia* (a liverwort). Do the plants contain gemma cups? What is the function of gemma cups?

Figure 10. *Marchantia* (live)

Seedless Vascular Plants

Figure 11. Fern gametophyte

1. Draw the life cycle of a fern. Your drawing should contain the following terms:
    1. 2N
    2. N
    3. sporophyte
    4. sorus
    5. sporangium
    6. meiosis
    7. spores
    8. gametophyte
    9. antheridium
    10. sperm
    11. archegonium
    12. egg
    13. fertilization
2. Observe sori on the underside of a fern leaf. Are sporangia visible? Indicate where this structure occurs in the life cycle diagram that you prepared (above).

Figure 12. Fern showing sori on underside of leaf

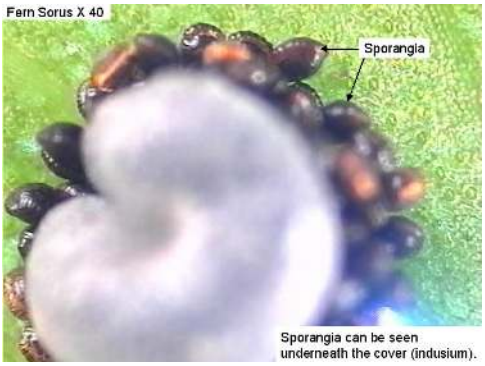


Figure 13. Fern sorus x40

3. View a slide of a fern gametophyte showing antheridia. What reproductive cells are produced by gametophytes? Indicate where the gametophyte occurs in the life cycle diagram that you prepared.

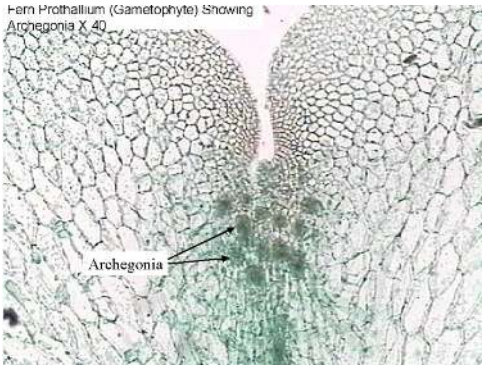


Figure 14. Fern prothallium (gametophyte)

Horsetails

Observe a live horsetail if available. Find the a **strobilus**. What reproductive structures are contained within the strobilus?

Figure 15. Horsetails

Figure 16. Horsetail showing strobilus

Phylum: Lycophyta

Members of this phylum have horizontal stems, upright stems, and small, spike-shaped leaves called **microphylls**.

Club Mosses

Observe a specimen of live club mosses such as *Lycopodium*. Find **rhizomes**. Identify **microphylls**. Do the specimens have any **strobili**? (Be sure to look up these words if you do not understand them.)

Figure 17. Club moss (*lycopodium*)

Spike Mosses

Observe a specimen of a spike moss such as *Selaginella*. Note the structure of the **microphylls**.

Figure 18. Spike moss (*selaginella*)

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CHAPTER OVERVIEW

5: Seed Plants

5.1: Seed Plants Lab

Learning Objectives

- Define the terms (meanings of the names) angiosperm and gymnosperm
- State what type of cells create eggs and what type of cells create sperm in gymnosperms and angiosperms
- Describe the general characteristics seed plants.
- Name the phyla discussed in the lab and give an example of a plant from each
- Recognize and identify plant specimens viewed in the lab, both slides and live samples
- Understand the basic gymnosperm and angiosperm life cycle
- Recognize the difference between a male and female pine cone
- Explain the seed plant alteration of generations including sporophyte and gametophyte structures
- Identify and know the function of the microscopes and the megaspores
- Identify the flower parts and which structures and male and female
- Explain and recognize the difference between a monocot and a eudicot flower
- Distinguish between the different types of fruits and give an example of each type

Download a PDF of the lab to print.

Procedure

1. Access the Seed plant lab.
2. Gymnosperms
    1. Name the four subgroups within gymnosperms.
    2. We will focus on conifers. Observe the conifer leaf samples available.
        1. How does the needle-like leaf benefit the conifer?
    3. Reproduction in Pines: As indicated on the website, draw a simple pine life cycle in the space on the next page. Be sure to include the terms egg, embryo, fertilization, megaspore, microscope, gametophyte, sporophyte, meiosis, mitosis, and pollen. Use this website to get you started.
    4. Observe the pine cones on display. Are pine cones haploid or diploid?
    5. Are male or female pine cones larger?
    6. View the slide of the pollen (male) pine cone cross section.
        1. Can you find the microscopes on the slide?
        2. Are microscopes haploid or diploid?
        3. What process do microscopes undergo to form pollen grains?
        4. Can you find pollen grains on the slide?
        5. Use the space on the next page to draw what you observed under the microscope.
    7. View the slide of the seed (female) pine cone cross section.
        1. Can you find the megaspores on the slide?
        2. Are megaspores haploid or diploid?
        3. What process do megaspores undergo to form the egg or ovule?
        4. Can you find the egg on the slide?
        5. Is the tissue surrounding the egg haploid or diploid?
        6. Once the egg is fertilized what structure will form?
        7. Use the space below to draw what you observed under the microscope.
    8. View the pine seeds on display
        1. Are the seeds haploid or diploid?
        2. How will the seeds be dispersed through the environment?
        3. What cell division process will the seeds undergo to create a new pine tree?
3. Angiosperms

1. As indicated on the website, draw a simple angiosperm life cycle in the space below. Be sure to include the terms egg, embryo, fertilization, megaspore, microscope, gametophyte, sporophyte, meiosis, mitosis, and pollen. Use this website to get you started: http://www.sumanasinc.com/webcontent/animations/content/angiosperm.html
2. Use the flower model to identify the different structures.
    1. Collectively, the male flower parts are called the _____.
    2. Collectively, the female flower parts are called the _____.
    3. Use the table below to describe the function of each flower part and if it is male, female, or neither.

Flower structure	Function	Male/Female/Neither
Anther		
Filament		
Stigma		
Style		
Ovary		
Petal		
Sepals		

3. Dissect the live flower. Start with the outside (sepals, petals) and work your way in. Identify each structure as you dissect the flower.
    1. How many petals does the flower have?
    2. Is the flower a monocot or a eudicot? What characteristic did you use to determine?
    3. Once you dissect the flower, dispose of the flower parts. You do not have to cut into the ovary or the anther as indicated on the website.
4. View the slide of the lily mature female gametophyte.
    1. Can you locate the egg?
    2. Is the egg haploid or diploid?
    3. What type of cell underwent mitosis to create the egg?
    4. Can you locate the polar nuclei?
    5. Is the ovary (tissue surrounding the egg) haploid or diploid?
    6. Use the space below to draw what you observed under the microscope.
5. View the slide of the lily anther cross section.
    1. Can you locate the pollen grains?
    2. Is the pollen haploid or diploid?
    3. What cell type underwent mitosis to create the pollen?
    4. Is the anther (tissue surrounding the pollen) haploid or diploid?
    5. Use the space below to draw what you observed under the microscope.
6. View the slide of the lily pollen grains.
    1. How many cells are held within a single pollen grain?
    2. Use the space below to draw what you observed under the microscope.
7. Skip the slide of germinated pollen. That slide is not available in the lab.
8. Skip the slide of the lily developing embryo. It is not available in the lab.
9. Skip the slide of the *Capsella* embryo, both early and mature embryo. These slides are not available in the lab.
10. Although there is not a live bean seed available, please view the preserved bean seed.
    1. Is the seed haploid or diploid?
    2. How many cotyledons does the bean seed have?

3. Is the bean a monocot or a eudicot?

11. Although there is not a live corn seed available, please view the preserved corn seed.
    1. How many cotyledons does the corn seed have?
    2. Is the corn a monocot or a eudicot?
    3. What is the function of the endosperm tissue?
12. Skip over the recently germinated bean and corn plants.
13. Fruits. There will be several fruit examples available in the lab. They may be different than the ones described on the website. Use the table below to discuss the fruits you view.

Name of fruit	Simple, Aggregate, or Multiple	Dry or fleshy

Review Questions

Answer the review questions below.

1. What does gymnosperm mean?
2. What group of gymnosperm plants is the largest?
3. What type of spore is used for male reproduction in seed plants?
4. Through mitosis, the male spore develops into what structure?
5. What type of spore is used for female reproduction in seed plants?
6. Through mitosis, the female spore develops into what structure?
7. What does angiosperm mean?
8. What structures of the flower are female?
9. What structures of the flower are male?
10. What is the function of the petals of the flower?
11. The process of _____ occurs in the flower anther to create haploid _____ followed by mitosis to create _____.
12. The process of _____ occurs in the flower ovary to create the haploid _____ followed by mitosis to create the _____ and the n+n _____.
13. State one difference between monocots and eudicots.
14. Explain how angiosperms undergo a double fertilization.
15. What part of the flower develops into a fruit?
16. How is a simple fruit different from a complex fruit?
17. Give an example of a fleshy fruit
18. Give an example of a dry fruit.

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5.2: Seed Plants Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Seed Plants

Conifers

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
pine seeds	various	on side bench as demo
pine cone	various	both pollen and seed cone examples on side bench as demo
pine pollen cone cross section slide	1 per table	
pine seed cone cross section slide	1 per table	
flower model	1 per table	
live flower	1 per table	for dissection, Alstroemeria works well
lily gametophyte slide	1 per table	
lily anther cross section slide	1 per table	
lily pollen grain slide	1 per table	
corn seed model	2-3 per class	demo on side bench
bean seed model	2-3 per class	demo on side bench
fruit examples	various	examples include apples, beans, raspberries, walnuts, acorns. Try to have several simple and multiple fruits, both fruity and dry

5.3: Reading- Seed Plants

Gymnosperms

The four phyla of gymnosperms are cycads, ginkgo, gnetophytes, and conifers.

Gymnosperms have naked seeds. The seeds of angiosperms are contained within a fruit.

Gymnosperm Diversity

We will examine conifers in some detail during this lab class but will use photographs on the Internet to study the other three divisions. Click on the links below to view photographs of them.

Cycads

Cycads re cone-bearing palmlike plants found mainly in tropical and subtropical regions today. They were very numerous in the Mesozoic Era.

Ginkgo

There is only one species of Ginkgo left. It survived due to Chinese planting them along roadsides. Click here for information and photographs.

Gnetophytes

Welwitschia and Ephedra (information and photographs)

Conifers

Conifers are the largest group of gymnosperms. They include evergreen trees such as pine, cedar, spruce, fir, and redwood trees. Examine the leaves of pine on display.

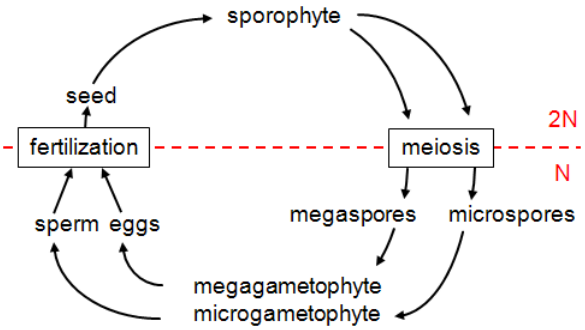
The leaves of conifers are needle-like and are adapted for dry conditions such as hot summers or freezing winters. Needles lose water slower than broad, flat leaves and therefore do not need to be shed during seasons when water is scarce, so most conifers are evergreen.

Reproduction in Pine

Life Cycle of Seed Plants

Seed plants are *heterosporous*—they have two different spore sizes: megaspores and microspores.

The generalized life cycle of plants has been modified (below) to illustrate plants which have separate male and female gametophytes (*megagametophyte* and *microgametophyte*) produced by different sized spores (*megaspores* and *microspores*).



The evolutionary trend from nonvascular plants to seedless vascular plants to seed plants has been a reduction in the size of the gametophyte. In seed plants, the gametophyte is usually microscopic and is retained within the tissues of the sporophyte.

The megasporangium is surrounded by layers of sporophyte tissue called the *integument*. The integument and structures within (megasporangium, megaspore) are the *ovule*.

Microspores germinate within the sporophyte tissue and become pollen grains. The microgametophyte is contained within the tough, protective coat of the pollen grain.

The entire microgametophyte (pollen grain) is transferred to the vicinity of the megagametophyte by a process of pollination. Wind or animals usually accomplish this transfer.

When pollen reaches the female gametophyte, it produces an elongate structure (pollen tube) that grows to the egg cell. Sperm are transferred directly through this tube to the egg. The advantage of this process is that sperm do not have to swim long distances as they do in seedless plants.

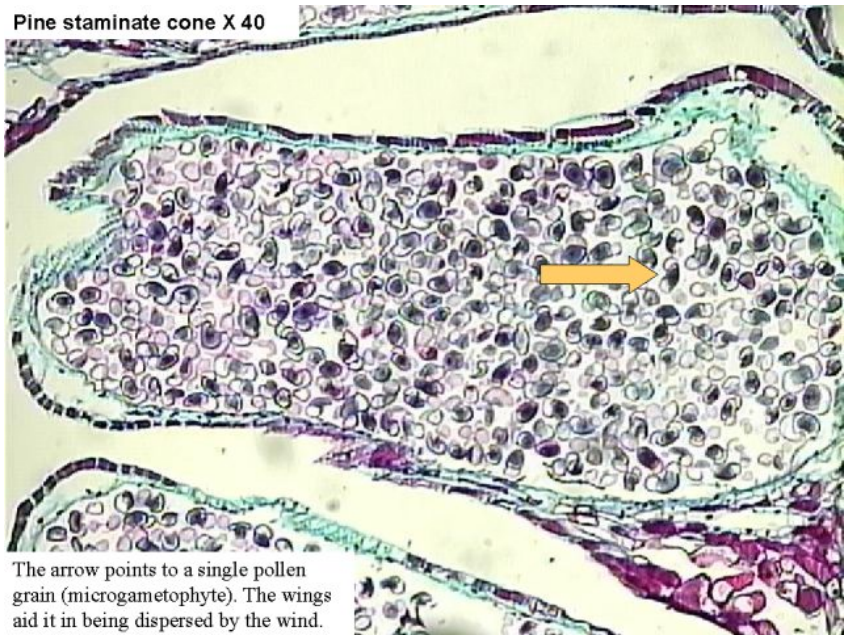
Seeds

Seeds contain the sporophyte embryo, food for the embryo, and a protective coat.

The embryo within the seed is dormant; it can survive for long periods without additional food or water. When conditions become favorable, the embryo resumes growth as the seed germinates.

1. Draw the life cycle of pine and include the following terms: eggs, embryo, fertilization, megagametophyte, megasporangium, megaspore, meiosis, microgametophyte, microsporangium, microspores, and zygote.
2. Observe the pine pollen cones on display. Is this structure haploid or diploid?

3. View a slide showing a section (l.s.) of a pine pollen cone. Identify the microsporangium. Identify the microgametophytes. What is another name for microgametophyte?

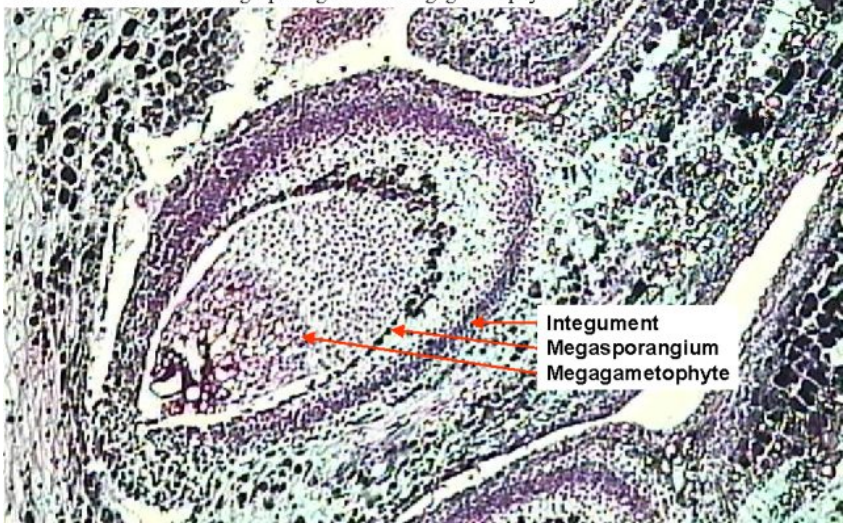


4. View a pine seed cone on display. Are there any seeds within the cone?

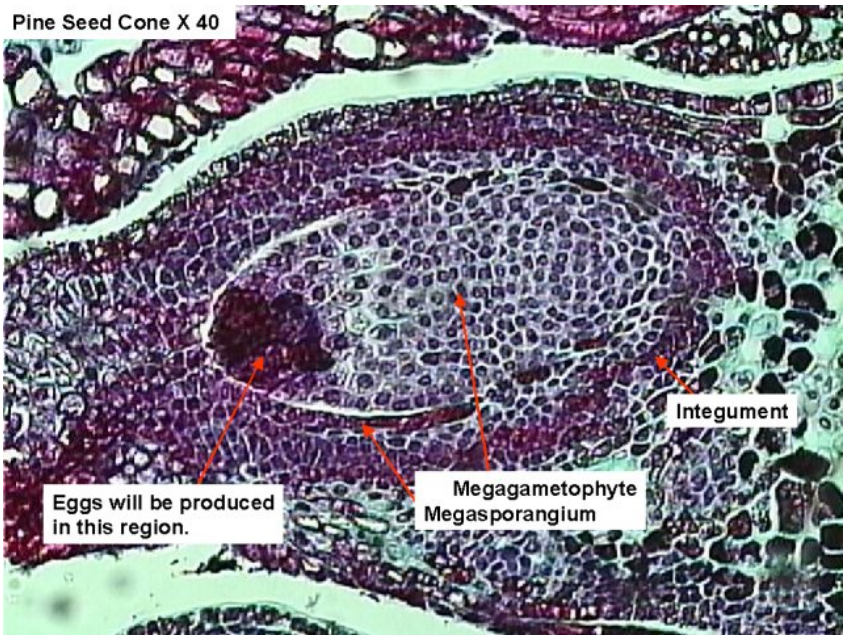
5. View a slide showing a longitudinal section of a pine seed cone. Identify the integument, ovule, megasporangium, and megagametophyte. Which of these structures is part of the sporophyte? Which are haploid? Which are diploid?

Pine seed (ovulate) cone
X 40

The structure within the integument is the ovule. It will become the seed. It contains the megasporangium and megagametophyte.



Pine Seed Cone X 40



6. View the pine seeds on display. From your drawing of the life cycle of pine, identify the structures that are part of the seed.

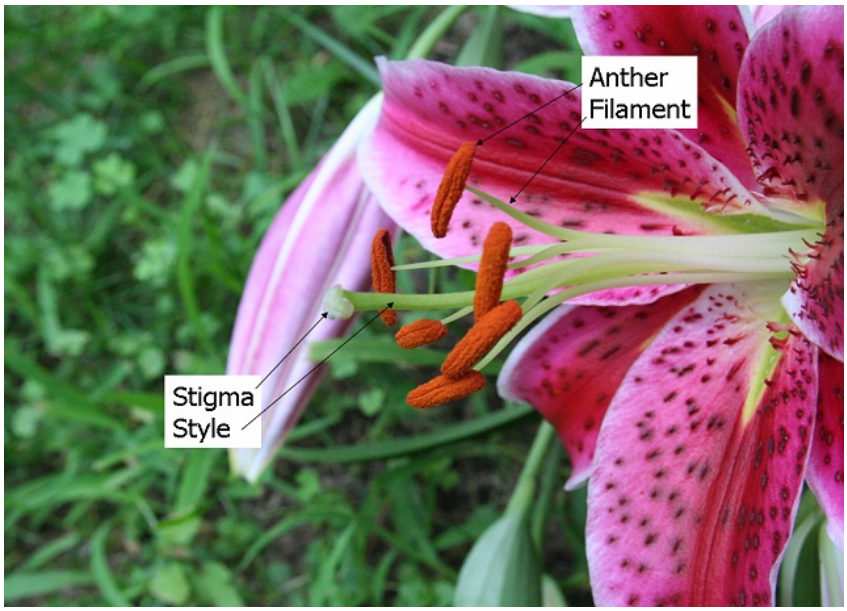
Pine seeds

Angiosperms

Create another diagram of the life cycle of seed plants that includes the following terms: eggs, embryo, fertilization, megagametophyte, megasporangium, megaspore, meiosis, microgametophyte, microsporangium, microspores, and zygote. This diagram will be used as a reference when viewing the reproductive structures of angiosperms.

Flower Parts

1. Obtain a monocot flower such as lily and identify the following structures: anther, filament, stamen, stigma, style, ovary, pistil, petals, sepals. State the function of each of these structures.

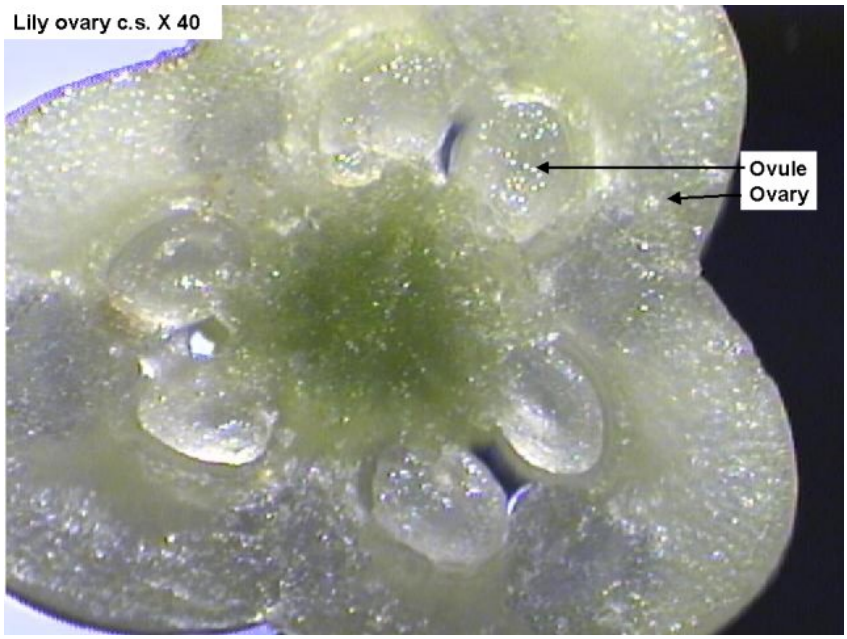


2. Remove the petals, stamens and pistil.

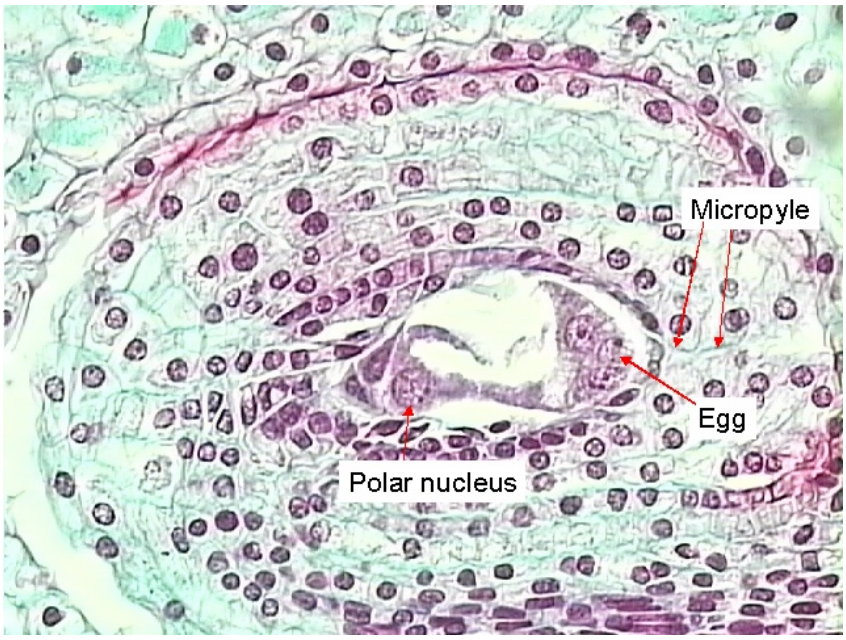
3. How many petals are present? How many sepals? Is lily a monocot or a eudicot? List three characteristics that can be used to distinguish between monocots and eudicots.

Within the Ovary

1. Use a scalpel to cut a thin cross section slice from the ovary. This can be done by cutting across the ovary and then slicing a thin section next to the first cut. Use a dissecting microscope to determine the number of carpels within the ovary. Identify the ovules. Which structures on the life cycle diagram are found within the ovules?



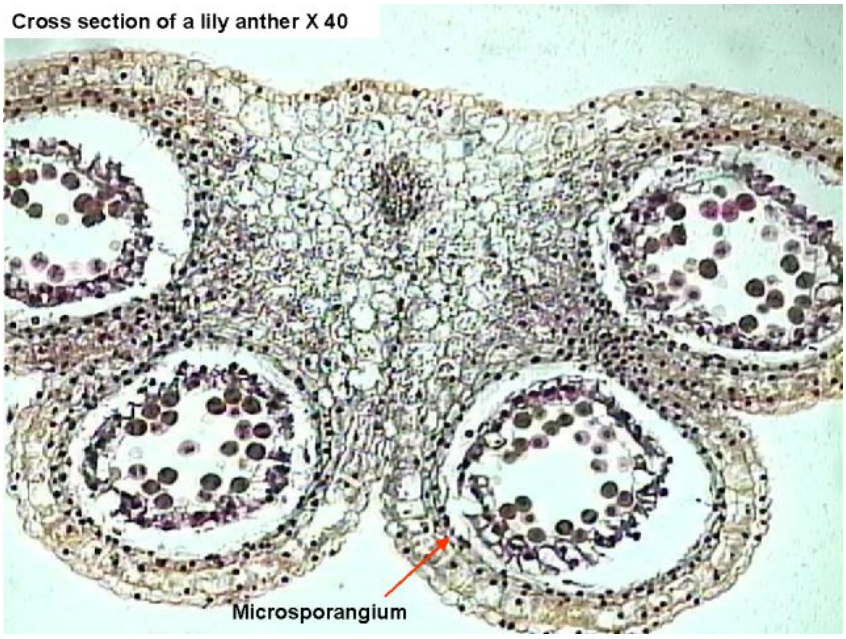
2. View a prepared slide of a lily mature female gametophyte. Identify the megagametophyte, Find the megagametophyte on the life cycle diagram. Try to find an egg and polar nuclei.



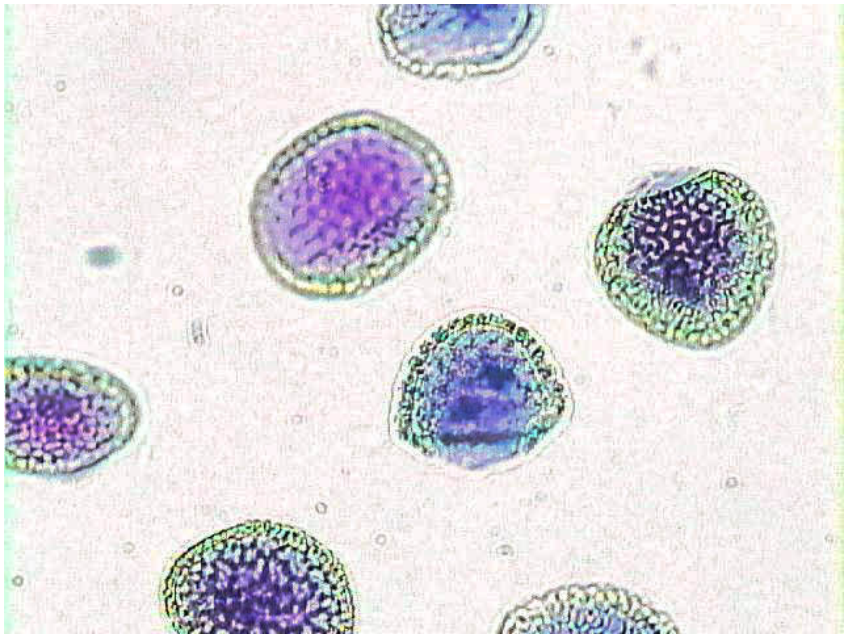
The photograph below shows a megaspore mother cell. It will divide by meiosis to produce megaspores.

Within the Anther

1. Use a scalpel to cut a thin cross-section of a lily anther and view it under a dissecting microscope. Identify the microsporangium. Are pollen grains visible? What structures on the life cycle diagram are contained within the anther? Meiosis occurs within the anther to produce microspores. Microspores undergo mitosis to produce microgametophytes (pollen grains).
2. If you were unable to get a good view of a lily anther in the dissection above, view a prepared slide of a lily anther c.s. and identify the microsporangium and pollen grains. Find where these two structures are located on your life cycle diagram.



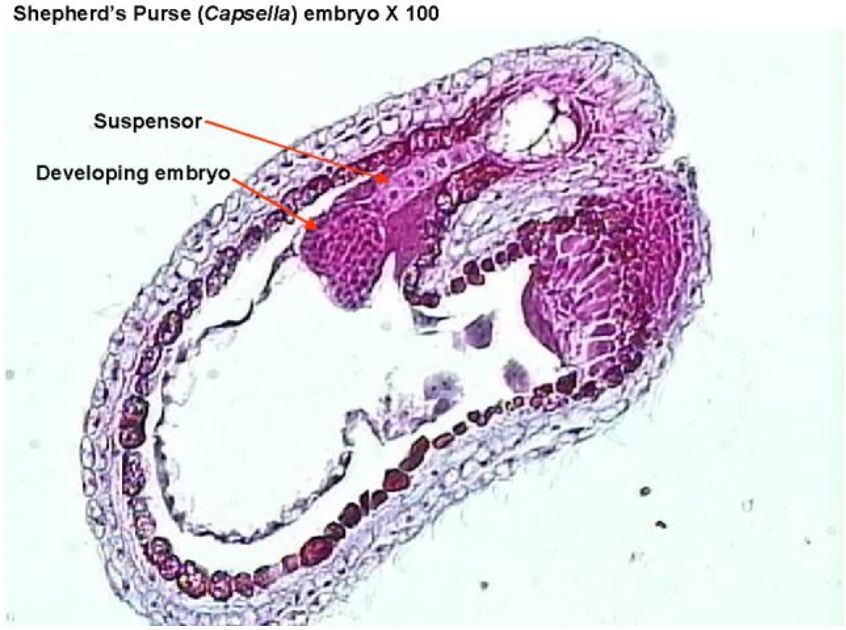
3. View a slide of lily pollen. identify the two nuclei.



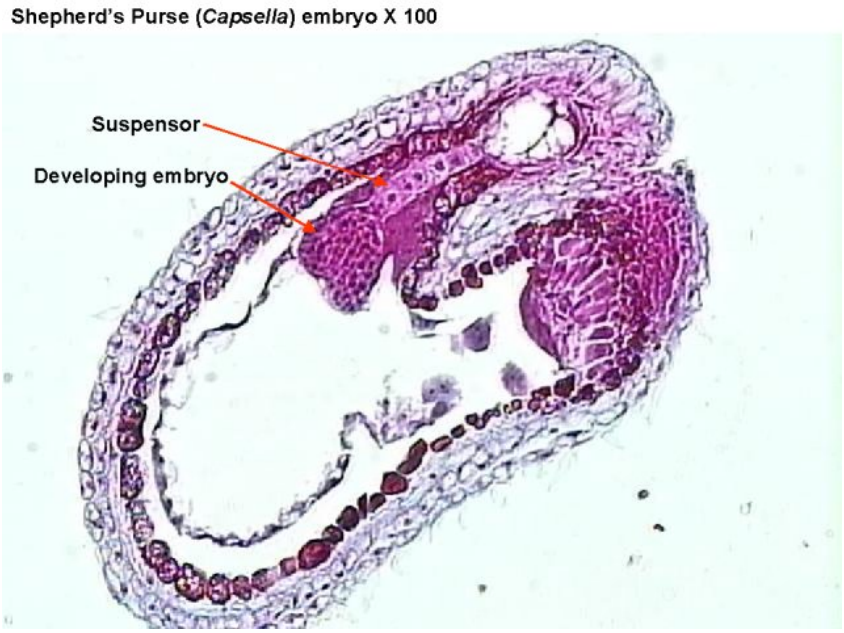
4. View slides of germinated pollen. Note the three nuclei within the pollen tubes. One is a tube nucleus. It directs the growth of the pollen tube. The other two are sperm.

After Fertilization: Embryonic Development

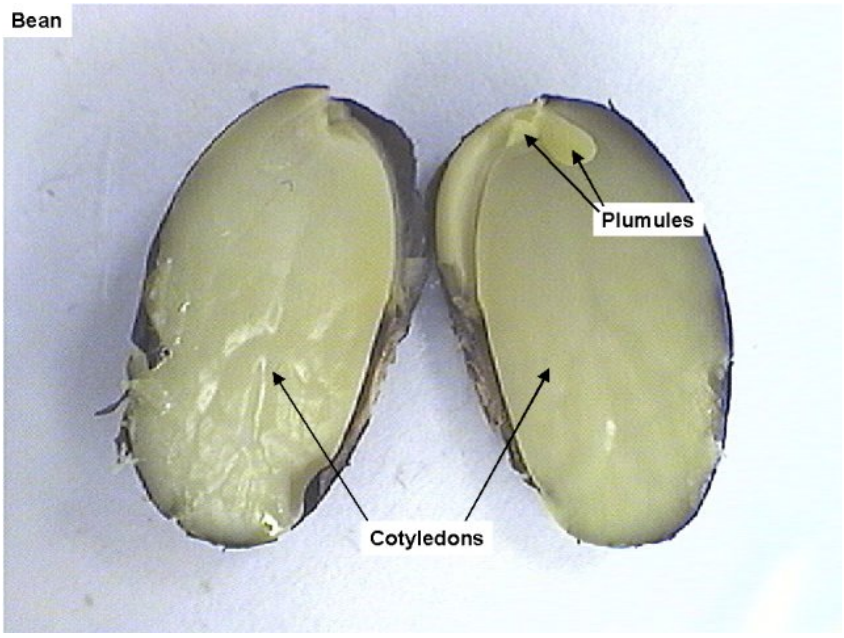
1. View a slide of a *Capsella* early embryo. Identify the suspensor and cotyledons. Is *Capsella* a monocot or a eudicot?



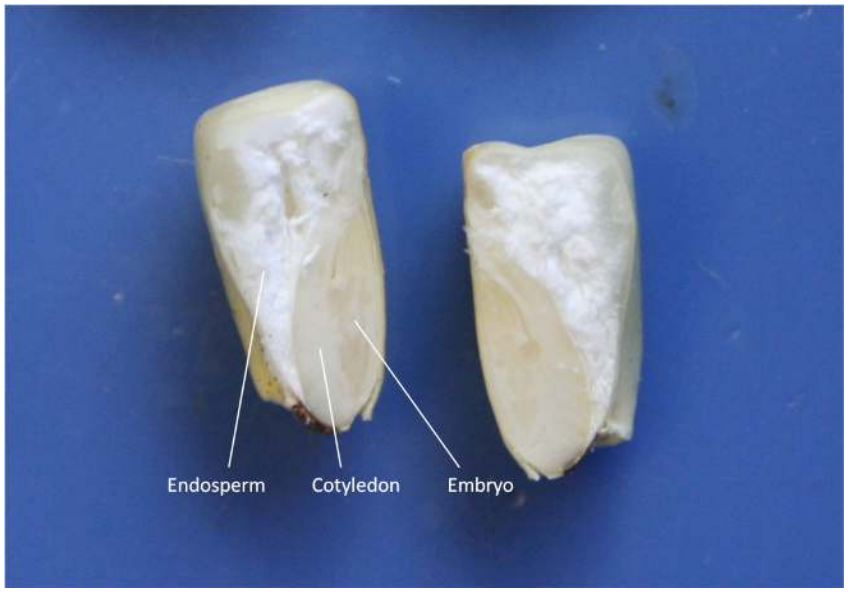
2. View a slide of a *Capsella* mature embryo. Identify the cotyledons, the tip of the growing root (root apical meristem) and the tip of the growing shoot (shoot apical meristem).



3. Obtain a bean seed that has been soaking in water. Cut the seed in half so that each cotyledon is visible and examine it using a dissecting microscope. Identify the embryo.



4. Obtain a corn that has been soaking in water and cut it lengthwise. Use a dissecting microscope to identify the embryo, the cotyledon, and the endosperm.



5. Observe beans and corn on display that have been recently germinated. Identify the cotyledons on the beans. Can you see cotyledons on the corn? Can you identify the coleoptile?

Bean (left) is a eudicot. Notice that the two cotyledons are still attached just below the leaves. Corn (right) is a monocot. The coleoptile is a protective leaf that wraps around the shoot of a germinating monocot seed.

Fruits

Angiosperms are distinguished from Gymnosperms in that the seeds are enclosed in a covering called the fruit.

Observe peas. Peas are seeds contained within a pod (fruit).

Observe the sliced tomato. It is produced from several fused carpels. Can you see the carpels? How many are there?

Observe a strawberry or a blackberry. These fruits are formed from a single flower that contained many pistals.

Observe a pineapple. This fruit is produced by the fusion of many flowers. Can you see each individual fruit?

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CHAPTER OVERVIEW

6: Plant Organization

6.1: Plant Organization Lab

Learning Objectives

At the conclusion of the lab, the student should be able to:

- List and give the major function of the three main types of plant tissues
- Identify a monocot verses a eudicot plant by observing either root, stem, leaf, or flowers
- Name and describe the various components and tissues within the root, both monocot and eudicot
- Name and describe the various components and tissues within the stem, both monocot and eudicot
- Name the describe the various components and tissues within the leaf, both monocot and eudicot
- Identify various examples of stem diversity
- Distinguish between simple and compound leaves

Download a PDF of the lab to print.

Angiosperms, or flowering plants are incredibly diverse. This group of plants contains between 250,000 and 400,000 different species. Although flowering plants are diverse in size, shape, color, and habitat, all angiosperms have the following four structures: the root, the stem, the leaf, and the flower. Each structures in comprised of one or more different types of tissues. In this lab activity we will learn more about angiosperm structures and tissues.

Angiosperm Tissues

Flowering plants contain three main types of tissues in the roots, stems, and leaves. Each tissue has a specific function as described below:

1. **Dermal tissue:** protects the outside of the plant.
2. **Ground tissue:** used for photosynthesis and storage. An internal plant tissue.
3. **Vascular tissue:** used for transport of water and sugars. *Xylem*transports water and *phloem* transports sugars.

Unlike animals, angiosperms increase in size their entire life because of **meristematic tissue**. Meristematic tissue continues to divide and create new cells through photosynthesis increasing the height and width of flowering plants. Plants have two types of meristems, as described below:

1. **Apical meristem**: located at the tip of the shoot and the tip of the root. The apical meristem lengthens up and down. It is responsible for *primary growth.*
2. **Lateral meristem**: located at branches to increase plant girth. It is responsible for *secondary growth.*

Angiosperm Body Plan

View the representative plants on display in the lab. Notice that the plants have aboveground and below-ground portions. The **shoot system** is aboveground. What components of the plan comprise the shoot system?

The **root system** is below ground. State two functions of plant roots.

Angiosperms are divided into two different groups, **monocots** and **eudicots.** These groups differ based on tissue organization in the seed, root, stem, leaf and flowers. For example, monocots have leaf veins that form a parallel patter and flower parts in multiples of threes. Eudicots have leaf veins in a net pattern and flower parts in multiples of fours or fives.

Using this information, identify the live plants on display as either monocots or eudicots using a table similar to the one below.

Monocots	Eudicots

Root

There are two main root arrangements. Most monocots have a **fibrous root** system where all of the roots are about the same size. Many eudicots have a **taproot** system with one very large main root and smaller roots branching off. A carrot is an example of a taproot.

View the monocot and eudicot roots models on display and the cross section slides of the monocot and eudicot root. Identify the following structures:

- Root cap
- Root hairs
- Zone of cell division
- Zone of elongation
- Zone of maturation
- Xylem
- Cortex
- Endodermis
- Pith
- Pericycle
- Epidermis
- Phloem

Questions

1. Draw and label the cross section of the monocot and eudicot root slides.
2. Why is the root cap necessary?
3. How does the arrangement of xylem and phloem differ in the monocot verses the eudicot root?

Stem

The stem provides aboveground support for flowers and leaves. Some stems are **herbaceous** or nonwoody while others are **woody**. Herbaceous stems increase in length via the apical meristem but they do not increase in girth through secondary growth.

View the cross section slides of the eudicot herbaceous stem and the monocot herbaceous stem. Identify the following tissues in both slides and notice that they have different arrangements of the xylem and phloem.

- Cortex
- Xylem
- Phloem
- Pith
- Epidermis

Questions

1. In the eudicot stem, which vascular tissue is more external, the xylem or the phloem?
2. The vascular bundles in a monocot herbaceous stem are said to have a scattered arrangement. Explain why in your own words.
3. Draw and label the cross section of the monocot and eudicot stem slides.

Many plants have modified stems to assist with food storage or for vegetative reproduction. Some examples include:

1. **Rhizome**: horizontal underground stem
2. **Corm**: underground fleshy stem, used for storage
3. **Stolon**: underground horizontal stem
4. **Runner**: aboveground horizontal stem
5. **Tuber**: underground storage stem
6. **Bulb**: underground storage stem with fleshy leaves

View the stems on display and identify which ones below to the categories described above. You may see more than one example of some and no examples of others.

Leaf

The main function of the leaf is photosynthesis. Therefore, it contains many chloroplasts and is thin to facilitate gas and water transport. View the leaf model and the leaf cross section slide. Make sure you can identify the following components:

- Epidermis (upper and lower)
- Cuticle
- Spongy Mesophyll
- Palisade Mesophyll
- Xylem
- Phloem
- Stomata (stoma singular)
- Guard Cells

Question

1. Draw and label the leaf with all of the components listed above.

The main, flat portion of the leaf is called the **blade** and it attaches to the stem via the **petiole** stalk. There are two main arrangements for the leaf blade. Leaves can either be simple or compound. A **simple leaf** has a single blade. A **compound leaf** has a blade divded into leaflets. All of the leaflets share the same **auxiliary bud** which is the source of new growth. The auxiliary bud is located at the base of the petiole.

There are two arrangements of compound leaves. **Palmately compound leaves** have all leaflets attached at the same point at the end of the petiole. **Pinnately compound leaves** have leaflets attached at intervals along the peitole.

View the preserved leaf specimens. Choose six to identify as simple or compound. If the leaf is compound, state if it is palmately or pinnately compound. Record your findings in a table similar to the one below.

Name of Leaf	Simple or Compound	Palmate or Pinnate

Questions

1. What cellular division process occurs in the apical meristem region?
2. The plant has two apical meristems. Identify the location of both.
3. If a plant had parallel leaf veins would you identify it as a monocot or a eudicot?
4. The tissue responsible for water transport is _____ and the tissue responsible for sugar transport is_____.
5. You look at a stem cross section and notice there is a ring of vascular bundles. Would you identify it as monocot or eudicot?

6. A potato is an example of what type of modified stem?
7. What is the function of the root hairs?
8. Vascular bundles contain what two tissues?
9. Are fibrous roots more common in eudicots or monocots?
10. State one structure that is part of the plant shoot system.

6.2: Plant Organization Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Angiosperm Tissues

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
root cross section slides	1 per table	monocot and eudicot
stem cross section slides	1 per table	monocot and eudicot

Angiosperm Body Plan

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
live stem examples	various	some options include ginger root for rhizome, potato for tuber, carrot for tap root, onion for bulb, set up as demo on side bench
leaf examples	various	try to have several monocot, several eudicot, and both simple and compound leaves, set up as demo on side bench
leaf model	1 per table	
live plant specimens	various	try to have several monocot and eudicot, set up on side bench as demo
root model	2-3 per class	

CHAPTER OVERVIEW

7: Invertebrate I

7.1: Invertebrate Lab I

Learning Objectives

- State the phyla of the organisms discussed in the lab activities
- Use the characteristics of symmetry, coelom, embryo tissue layers, and patterns of development to differentiate between the different invertebrate groups
- Recognize and identify the sponge specimens viewed in the lab
- Explain the purpose of the different sponge cells
- Recognize and identify the cnidaria specimens viewed in lab and if the specimens are polyp or medusa form
- Recognize and identify the nematoda examples viewed in the lab
- Recognize and identify the arthropoda examples viewed in the lab

Download a PDF of the lab to print.

Sponges

Procedure

Access the page “Reading: Sponges.”

Questions

1. The preserved sponge specimens will be on display, but may differ from the ones directly mentioned in the lab handout. Please make observations on the available specimens and fill in the chart below.

Name of Specimen	Physical Description	Sponge Structures Visible (osculum, other spores, spicules)

    1. What type of symmetry is displayed in the sponge specimens?
2. View the *Grantia* slides. There will not be slides available of the spicules but view the pictures in the lab materials.
    1. What is the function of spicules?
    2. Do sponges contain true tissues?
    3. Can you find any collar cells in the slide?
    4. What is the function of the collar cells?
    5. Can you find any epidermal cells in the sponge slide?
    6. What is the function of the epidermal cells?

Cnidarians

Procedure

1. Access the page: “Reading: Cnidarians.”
2. View the hydra specimens (live and slides).
3. Watch these videos:

Questions

1. Does the hydra illustrate the polyp or the medusa stage?
2. How many germ layers does the hydra contain?
3. What type of symmetry is seen in the hydra?

4. Can you find the hydra tentacles? How many tentacles does your hydra specimen contain?
5. Name the stinging cells present on the tentacles that are unique to cnidarians.
6. Explain the movement of the hydra if live specimens are available. If they are not, review the video on hydra movement.
7. If there are live hydra specimens do not add the vinegar as indicated on the lab website. Vinegar causes them to expel the cnidocytes. Review the nematocysts video, which shows a jellyfish discharging the nematocyst cells.
8. View the preserved cnidarian specimens will be on display. They may differ from the ones directly mentioned in the lab website but there should be some medusa cnidarians as well as corals and sea anemones. Please make observations on the available specimens. And fill in the chart below.

Name of Specimen	Physical Description	Polyp or Medusa Stage?

Roundworms (phylum nematoda)

Procedure

Access the page “Reading: Roundworms”

Watch this video:

Questions

1. We will not be dissecting the *Ascaris* as indicated in the website. Instead view the preserved slide.
    1. What type of symmetry is seen in the roundworm?
    2. Does it exhibit cephalization?
    3. *Ascaris* is a parasite that swims constantly in human intestines. What structure protects the nematode from being digested?
2. View the *Trichinella*slide. *Trichinella* is also a parasite. It can infect humans as well as other mammals like pigs, bears, and rodents. If untreated, it can lead to death.
    1. What mammal tissue does this roundworm infect?
    2. Draw a picture of the *Trichinella* as viewed under the microscope.
3. If there are live vinegar eel specimens available, view them. If there are no live specimens available, review the vinegar eels video.
    1. Describe the movement of the vinegar eels.
    2. Do they have a complete or incomplete digestive system?

Arthropods

Procedure

Access the page “Reading: Arthropods.”

Questions

1. View the preserved arthropod specimens available. There will be at least one example of each lineage group discussed on the website but not all of the specimens may be available. Use the table below to organize your observations.

Name of Specimen	Lineage	Exoskeleton?	Jointed Appendages?	Specialized Segments

2. What type of symmetry is displayed in the arthropods?
3. Do the arthropods exhibit cephalization?

Crayfish Dissection

Procedure

Complete the crayfish dissection using the directions available on the lab website.

Questions

1. Make sure you can identify the following external structures: antenna, chiliped, cephalothorax, abdomen, and walking legs
2. Do you have a male or female crayfish?
3. How many swimmerets does your crayfish have?
4. How many rows of gills does the crayfish have?
5. Where do the gills attach?
6. Can you find the stomach and the digestive glands?
7. What does the stomach attach to directly?
8. Try to locate the green glands. What is the function of this structure?

Review Questions

Answer the review questions below. The phyla we viewed today were the porifera, the cnidaria, the nematoda and the arthropoda.

1. Which phyla exhibited bilateral symmetry?
2. Which phyla had no true tissues?
3. Which phyla contained parasitic organisms?
4. Which phyla were coelomates?
5. Which phyla exhibited cephaliziation?
6. Which phyla that you viewed today contained specialized appendages?
7. Which phyla exhibited radial symmetry?
8. Which phyla were pseudocoelomates?
9. Which phyla had a complete digestive system?
10. Which phyla were multicellular?
11. Which phyla were asymmetrical?
12. Which phyla were acoelomates?

7.2: Invertebrate Lab I (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Sponges

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
sponge preserved specimens	various	on side bench as demo
grantia slide	1 per table	

Cnidarians

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
hydra slide	1 per table	
hydra live specimens	1 container per class	view under dissecting scope as demo on side bench
cnidaria preserved specimens	various	on side bench as demo
hydra model	1-2 per class	on side bench as demo

Roundworms (phylum nematoda)

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
Ascaris slide	1 per table	
Trichinella slide	1 per table	
live vinegar eels	1 vial per class	view under dissecting scope as demo on side bench

Arthropods

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
arthropod preserved specimens	various	on side bench as demo, helpful to have representatives from different subgroups

Crayfish Dissection

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
dissection kit	1 per table	should include scalpel, scissors, forceps, dissection needles, dissection pins
dissection tray	1 per table	
crayfish	1 per table	
gloves	1 pair per student	latex and non latex options in various sizes
goggles	1 pair per student	
lab coat	1 per student	
dissection waste container	1 per class	dissection waste should not go in regular trash

7.3: Reading- Sponges

There are two phyla of sponges: *Calcarea* and *Silicea*.

Preserved Specimens

Examine preserved sponges on display. Identify the osculum. Can you see pores? Some of these specimens are shown below.

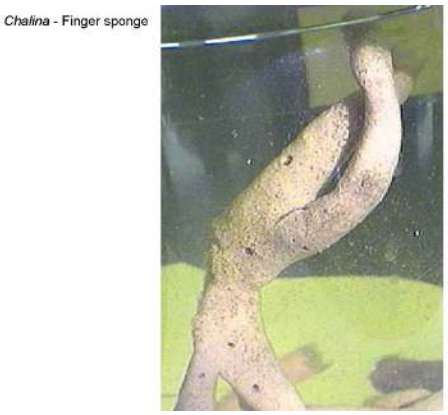

Figure 1. *Chalina*

Figure 2. *Spongila*

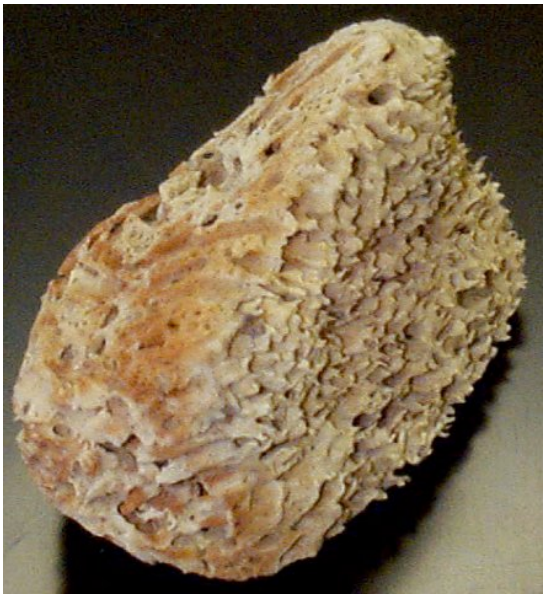

Figure 3. Commercial Sponge

Structure of Sponges

The photographs below are of *Grantia*. The body of this species is highly folded producing many chambers. In the last two photographs, the living cells have been removed to reveal the spicules.

Examine the following prepared slides: *Grantia* c.s.and *Grantia* l.s. Find collar cells, epidermal cells, and pores. What is the function of the collar cells? What is the function of the pores?

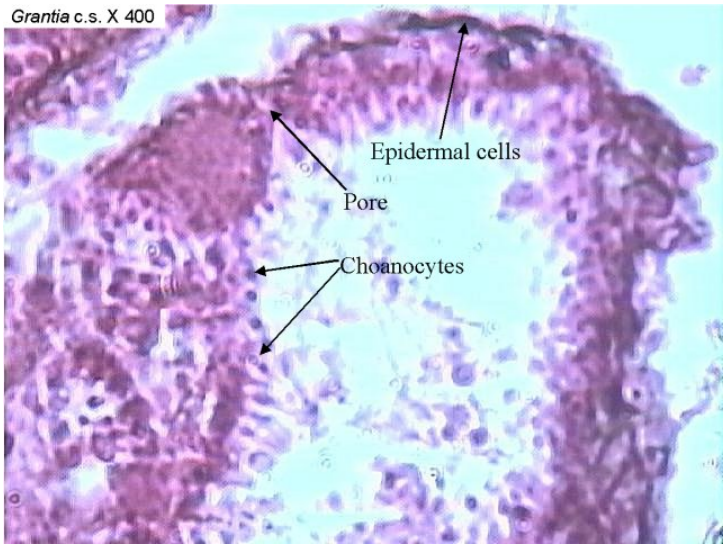

Figure 4. Grantia c.s. X 400

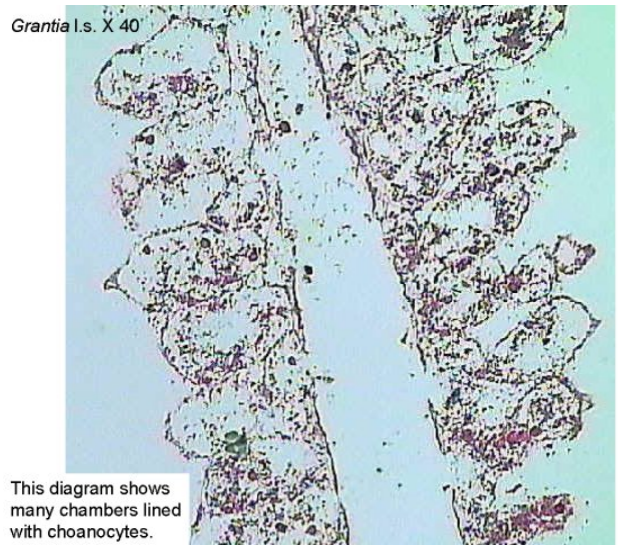

Figure 5. Grantia l.s. X 40

Examine a slide of Grantia spicules. What is the function of the spicules?

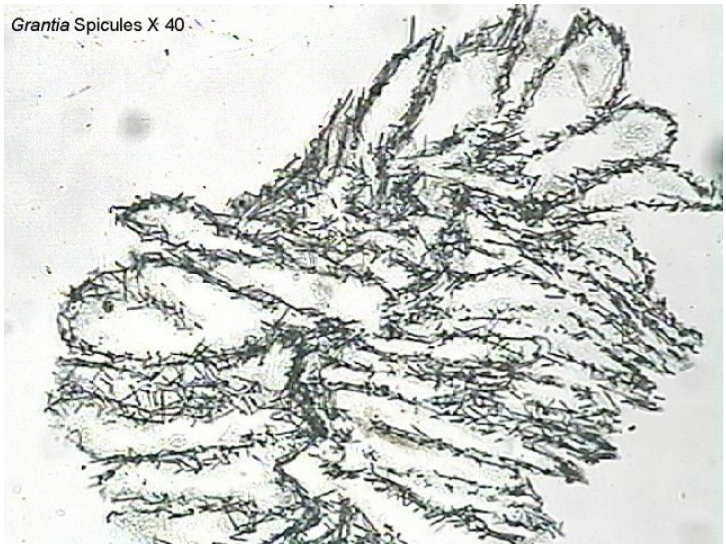

Figure 6. *Grantia* spicules X 40

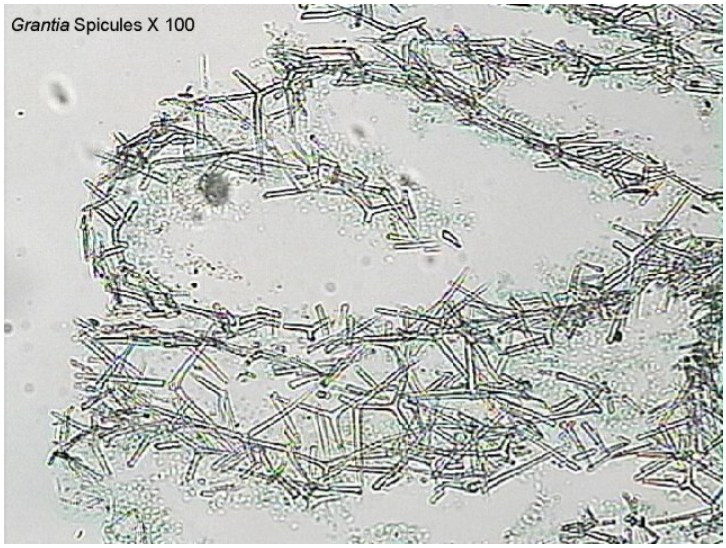

Figure 7. *Grantia* spicules X 100

Spicules are needle-like structures composed of either calcium carbonate or silica and offer support and protection.

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7.4: Reading- Cnidarians

This laboratory exercise covers the following animals. You should learn this classification scheme and be able to classify the animals into these categories.

- Phylum: Cnidaria
  - Class: Hydrozoa (Hydra and relatives)
  - Class: Anthozoa (Sea Anemones and Corals)
  - Class: Scyphozoa (Jellyfishes)

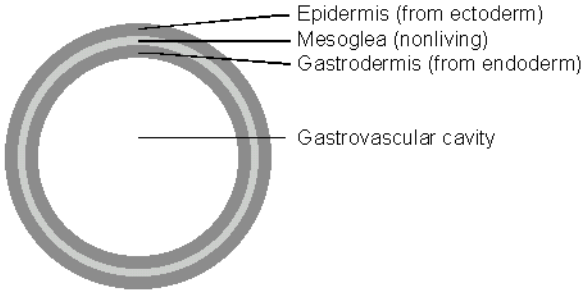
Some examples of Cnidarians are hydra, jellyfishes, corals, sea anemones, and Portuguese man-of-wars.

Characteristics

Radial Symmetry

The body parts of a radially symmetrical animal are arranged around a central axis so that each part extends from the center. The animal can be cut along the axis in more than one plane to produce identical halves. Animals that exhibit radial symmetry tend to be **sessile** (immobile). Radial symmetry allows them to reach out in all directions.

Cnidarians have two tissue layers. The outer layer is the **epidermis**. It is formed from ectoderm. The inner layer, the **gastrodermis**, secretes digestive juices into the inner space called the **gastrovascular cavity**. The gastrodermis is formed from endoderm.



Cnidarians do not have mesoderm and therefore do not have organs.

A nonliving gelatinous material called **mesoglea** separates the two tissue layers. A nerve net is located between the epidermis and mesoglea. The body contains long structures called **tentacles** that can be moved to capture prey. The tentacles contain stinging cells called **cnidocytes** and within each one is a capsule called a nematocyst, which discharges to either trap or sting the prey. Contractile (muscle-like) fibers are found in both the epidermis and the gastrodermis. Their movements are not complex because they do not have a brain.

Cnidarians have a **hydrostatic skeleton**. The contractile fibers act against the fluid-filled gastrovascular cavity. The movements are like a balloon; the animal can be short and thick or long and thin. Cnidarians have a saclike gut and extracellular digestion.

Two body forms are found among the Cnidarians, a **polyp** and a **medusa**. A polyp is attached and has the tentacles and mouth directed upward. A medusa is free-floating and has the mouth and tentacles on the ventral surface. It resembles an upside-down polyp. Some species have both a polyp and a medusa in their life cycle, others have one or the other form dominant.

Hydrozoa

Hydra

1. Use a dropper to place a live *Hydra* on a slide. Examine the *Hydra* using a dissection microscope.

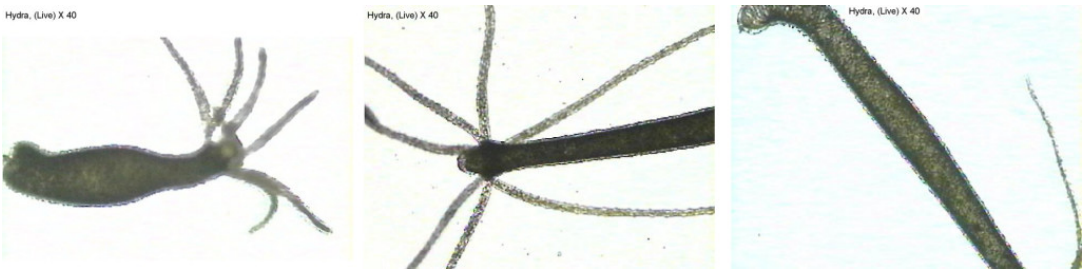


Figure 1. *Hydra* (live)

2. *Hydra* reproduce both sexually and asexually by budding. Try to find a live *Hydra* with buds. If you cannot find a live *Hydra* budding, look for budding in a prepared slide of *Hydra*.

Figure 2, *Hydra* budding. This is a form of asexual reproduction.

3. Add a drop of vinegar to the slide containing *Hydra*. Describe what happened to the cnidocytes.

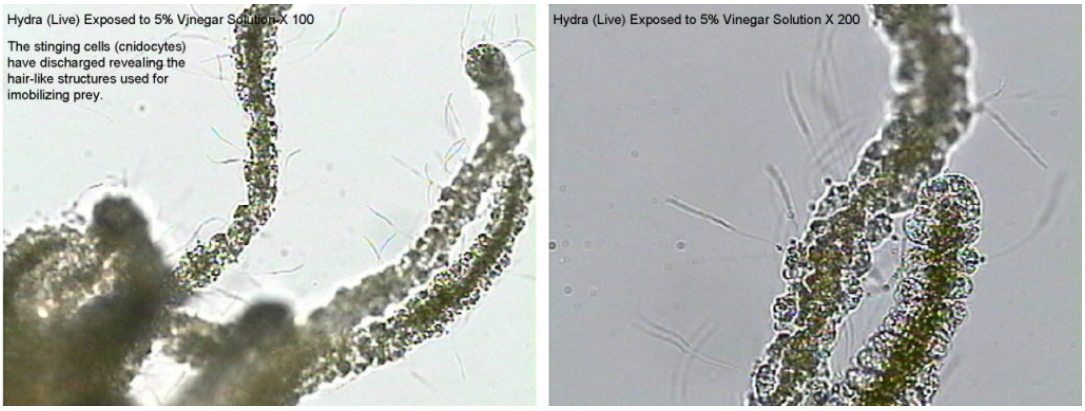


Figure 3. Left: *Hydra* (Live) Exposed to 5% Vinegar Solution X 100. Right: *Hydra* (Live) Exposed to 5% Vinegar Solution X 200

4. Examine microscope slides of hydra l.s. and hydra c.s. Look for the presence of two tissue layers. Identify stinging cells (Cnidocytes) in a slide of the whole animal.

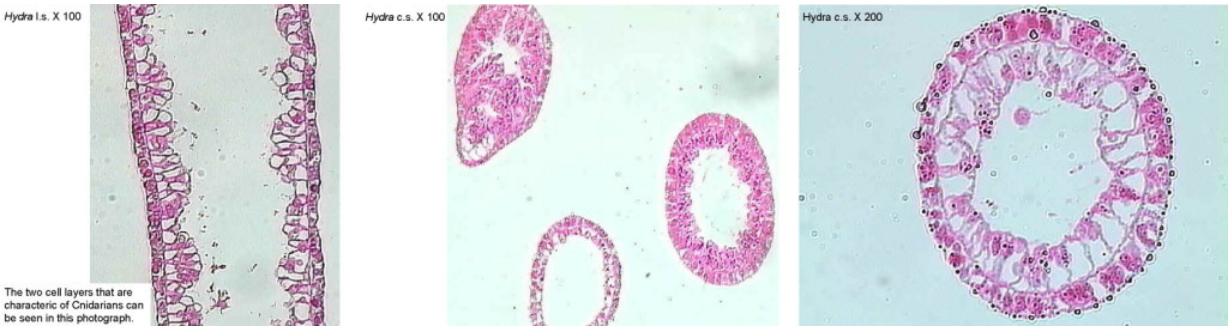


Figure 4. Left: Hydra l.s. X 100. Middle: Hydra c.s. X 100. Right: Hydra c.s. X 200

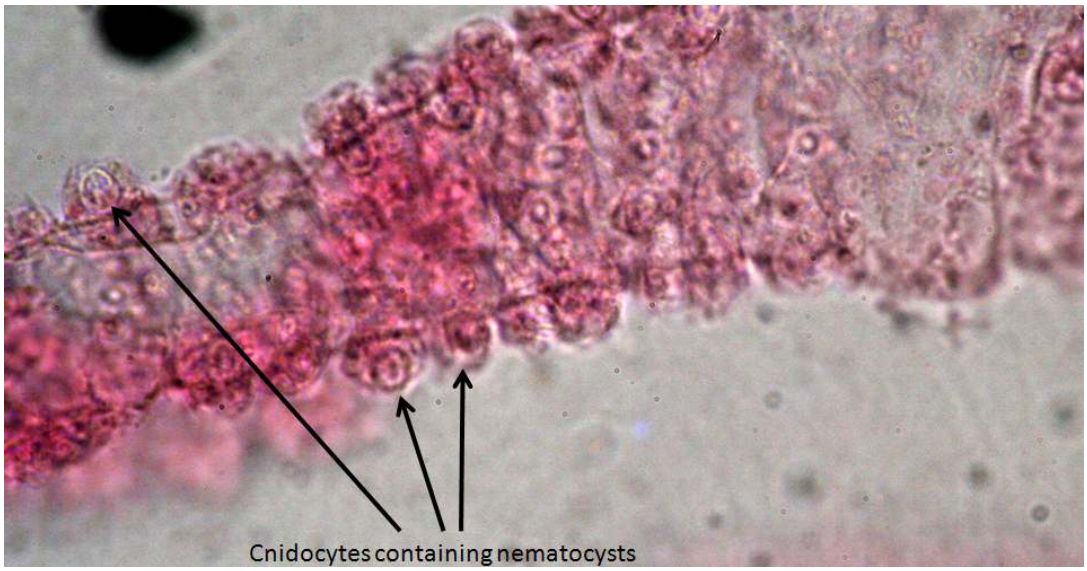


Figure 5. Portion of a Hydra tentacle showing cnidocytes

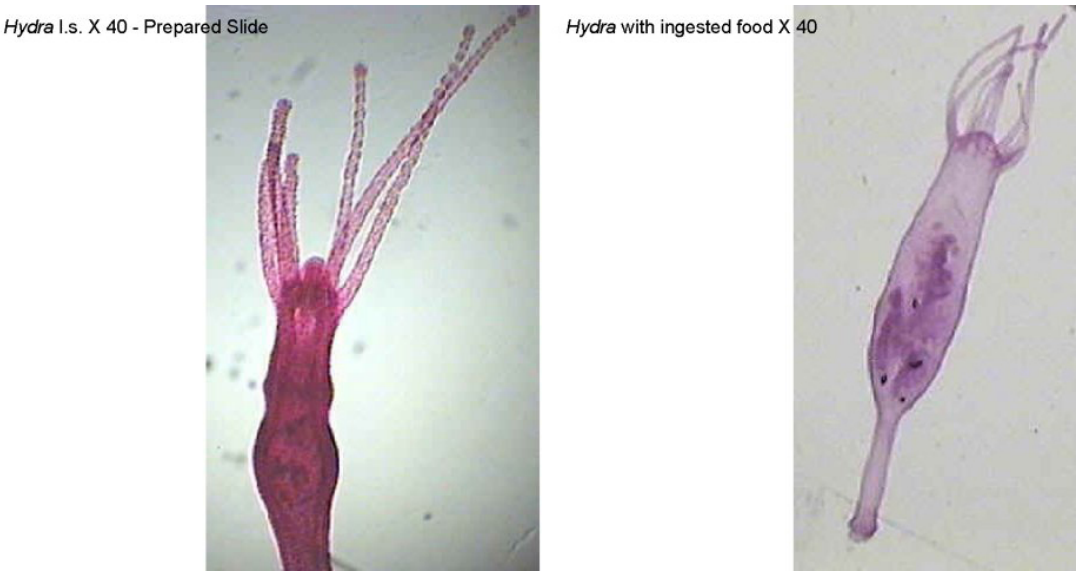


Figure 5. Left: Hydra l.s. X 40. Right: Hydra l.s. with ingested food X 40

Other Hydrozoans

Examine preserved specimens of *Gonionemius*, *Polyorchis*, and *Physalia*.

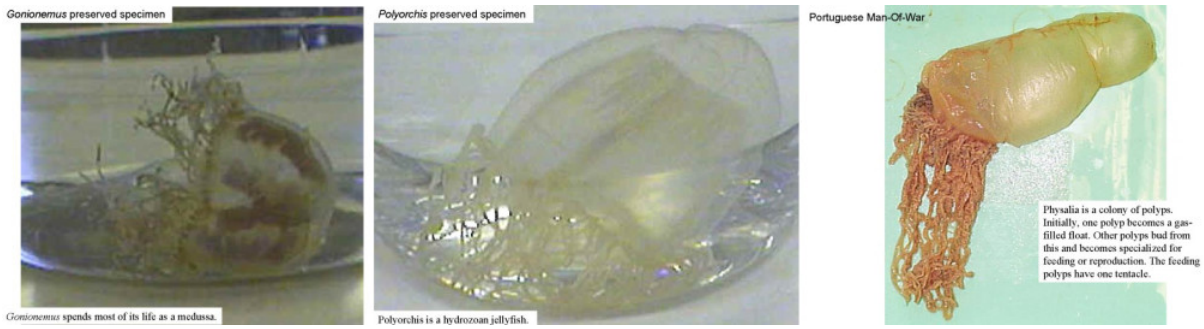


Figure 6. Left: *Gonionemus*, preserved. Middle: *Polyorchis*, preserved. Right: Portuguese Man-Of-War

Sea Anemones and Coral (Class Anthozoa)

Examine a sea anemone and coral.

Figure 7. Sea anemone, preserved

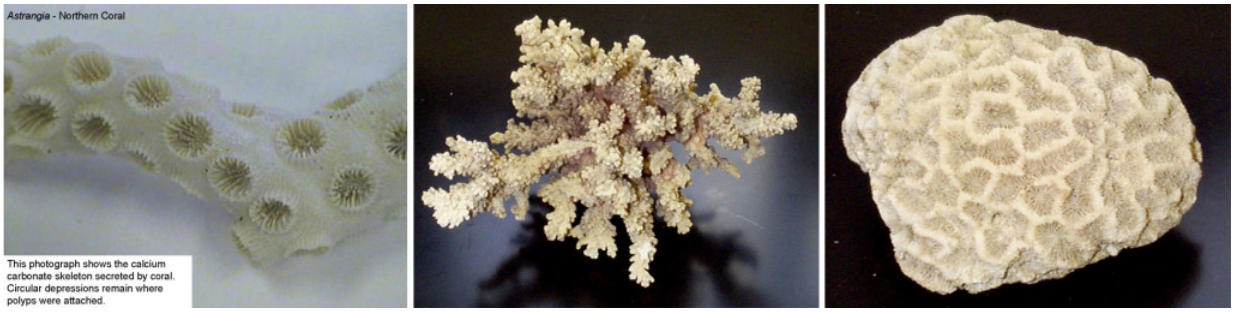


Figure 8. Left: *Astrangia* (Northern Coral) Skeleton. Middle: Coral Skeleton. Right: Coral Skeleton.

Jellyfish (Class Schyphozoa)

Examine preserved jellyfish on display.

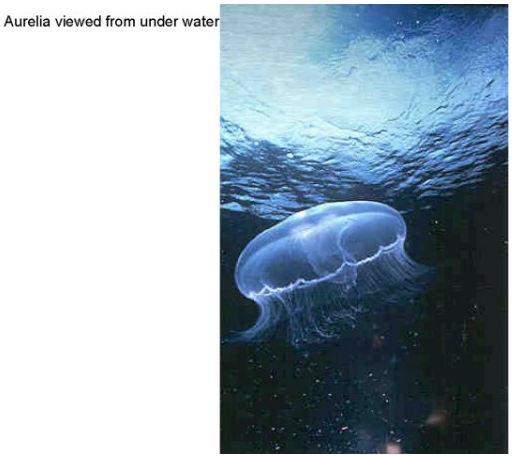


Figure 9. *Aurelia*

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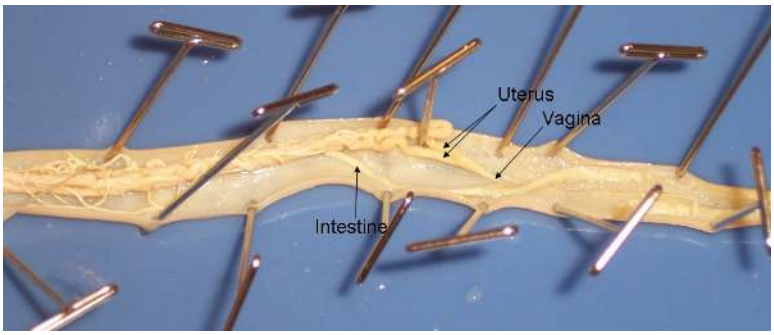
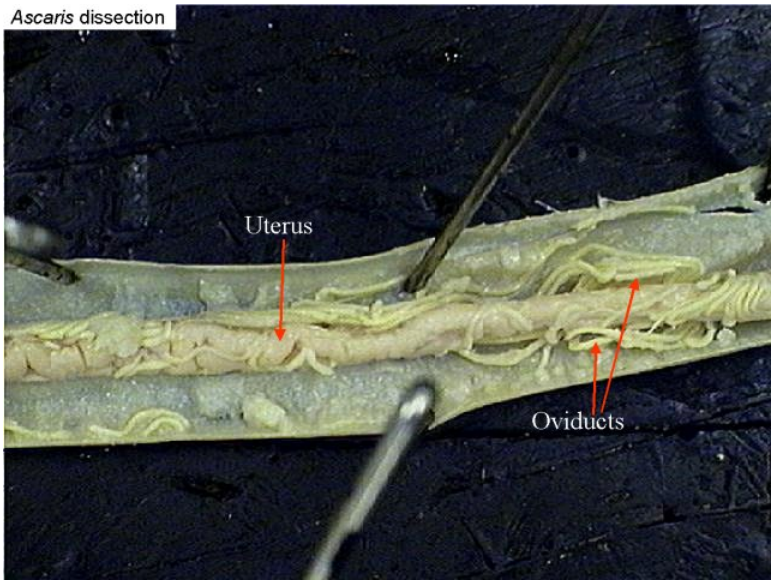
7.5: Reading- Roundworms

Ascaris Dissection

Procedure

1. Obtain a female *Ascaris* and place it on a dissecting pan. The posterior end is curved in males and straight in females.
2. Make a shallow longitudinal cut the length of the worm and pin it open as illustrated below.
3. Identify the gut, ovary, oviduct, uterus, and vagina.





Trichinella

View a prepared slide of *Trichinella* in the muscle tissue of a host organism.

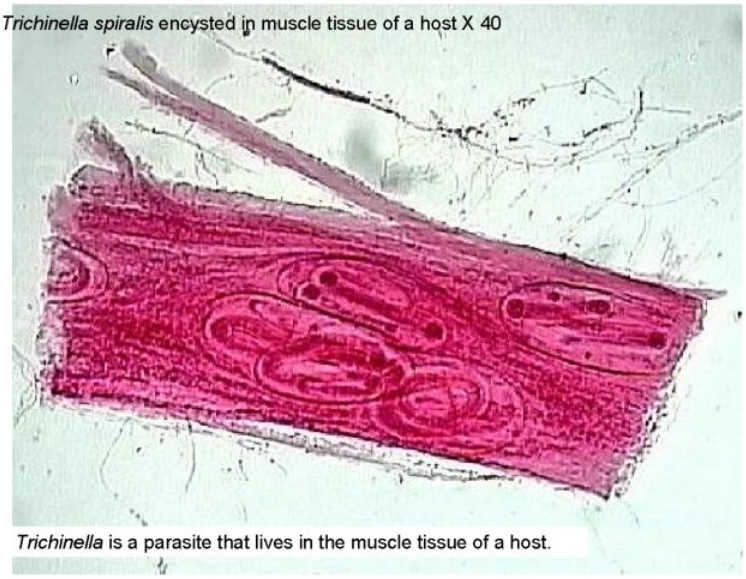


Figure 1. *Trichinella spiralis* encysted in muscle tissue of a host X 40

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7.6: Reading- Arthropods

Three clades of arthropods are listed below.

- Chelicerates
  - Arachnids—(Spiders, Scorpions, Harvestmen, Ticks and Mites)
  - Horseshoe Crabs
- Myriapods
  - Millipedes
  - Centipedes
- Pancrustaceans
  - Crustaceans
    - Decpods
    - Isopods
    - Krill
    - Copepods
    - Barnacle
  - Insects

Arthropods have an exoskeleton that cannot enlarge as the animal grows. As a result, it must be shed from time to time to allow growth. The exoskeleton from a tarantula (an arachnid) is on display.

Life Cycle

The young of some arthropods look like the adults. The change from young to adult that these species undergo is called **incomplete metamorphosis**.

In many species, the **egg** hatches to produce a **larva** (pl. larvae) that does not look like the **adult**. At some point in the maturation process, the larva will produce a **pupa** (pl. pupae). In this phase its tissues will become reorganized into the adult form. This type of development is called **complete metamorphosis**.

Observe a culture of fruit flies (*Drosophila*) and observe the eggs, larvae, pupae, and adults.

Chelicerates

The first pair of appendages of the members of this phylum are pincerlike or fanglike mouthparts called chelicerae. Observe these mouthparts in the tarantula on display.

Arachnids (Spiders, Scorpions, Harvestmen, Ticks, Mites)

Figure 1. Left: Scorpion. Middle: Tick X 40. Right: Mite X 40.

Horseshoe Crabs

Figure 2. Left: Horseshoe crab dorsal surface. Right: Horseshoe crab ventral surface

Crustaceans—Lobsters and Relatives

Decapods

Figure 3. Crab

Crayfish Dissection

Obtain a crayfish and identify the structures shown in the photograph below. You should familiarize yourself with the names of the external structures shown in the photograph below.

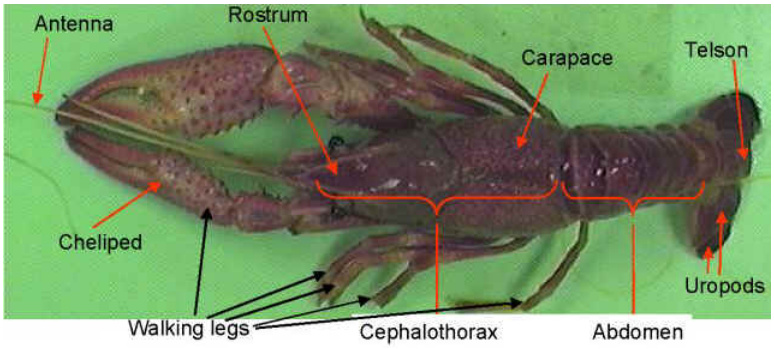

Figure 4

The photographs below show the ventral surface of male and female crayfish. Click on the photographs to view them. Identify the sex of your crayfish. Find somebody in class that has the opposite sex and view the ventral surface of their crayfish. Notice that

crayfish have five pairs of swimmerets. In males, the anterior two pairs are large and less flexible than those of females. They are used to transfer sperm to the female.

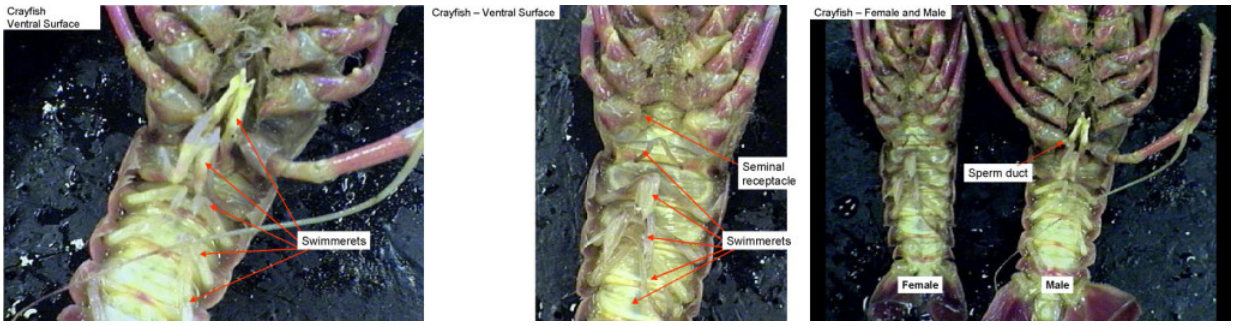

Figure 5

Find the seminal receptacles located between the third and fourth walking legs. These structures function to receive sperm from the male during mating.

Observe the sperm duct in males located at the base of the fifth walking leg.

Begin your dissection by cutting along the midline of the carapace from the posterior edge to an area just behind the two eyes (see the photographs below). Next, cut laterally just behind the eye until you reach the ventral edge. Carefully remove the piece of carapace that you have cut to expose the gills underneath. As you peel this piece of carapace away, it may be necessary to reach underneath with the point of a scissors or needle to brush away and detach any tissue from the interior of the animal that is attached to the carapace.

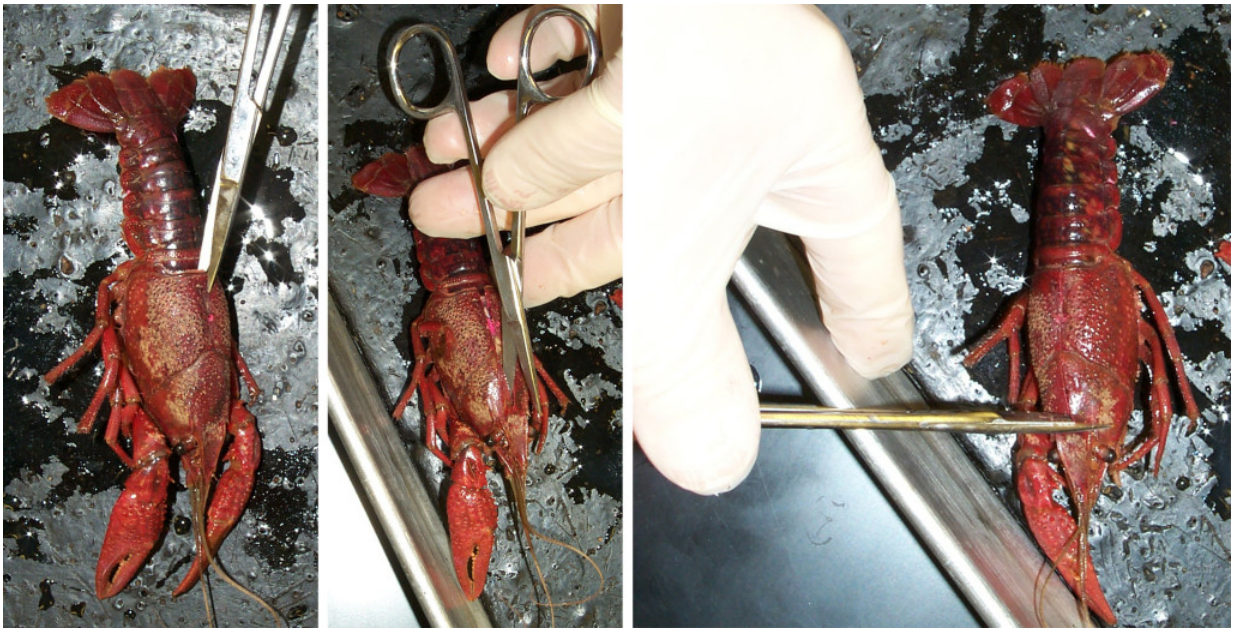

Figure 6

Your crayfish should look like the first photograph below. Next, remove the carapace on the other side.

Using a needle, carefully separate the first row of gills and notice that there is another row underneath. Remove one of the legs and observe how the gills are attached to the walking legs.

The first two photographs below show the gills on the left side of a crayfish. The third photograph is a crayfish with the entire carapace removed. The first row of gills on each side has been moved aside to expose a row underneath it.

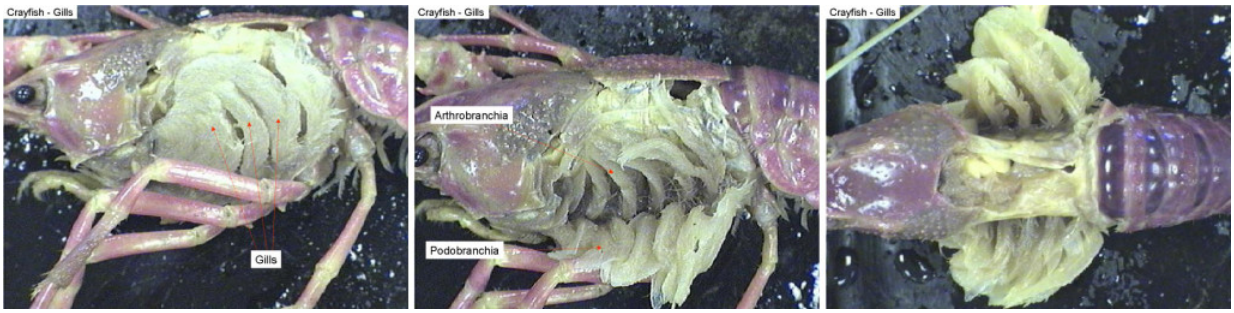

Figure 7.

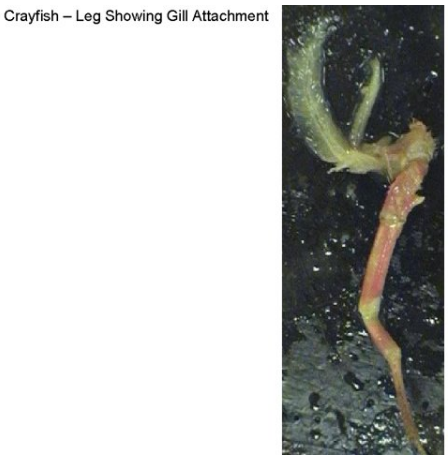

Figure 8. Crayfish leg showing gill attachment

Brush all of the gills to the side and then carefully cut the membrane (epidermis) that covers the internal organs.

The heart is a small diamond-shaped structure located below where the posterior edge of the carapace was. It may be difficult to see the blood vessels attached to the heart. Openings (ostia) in the side of the heart should be visible. These allow blood to enter the circulatory system.

Large white digestive glands can be seen on each side of the stomach. They produce digestive enzymes.

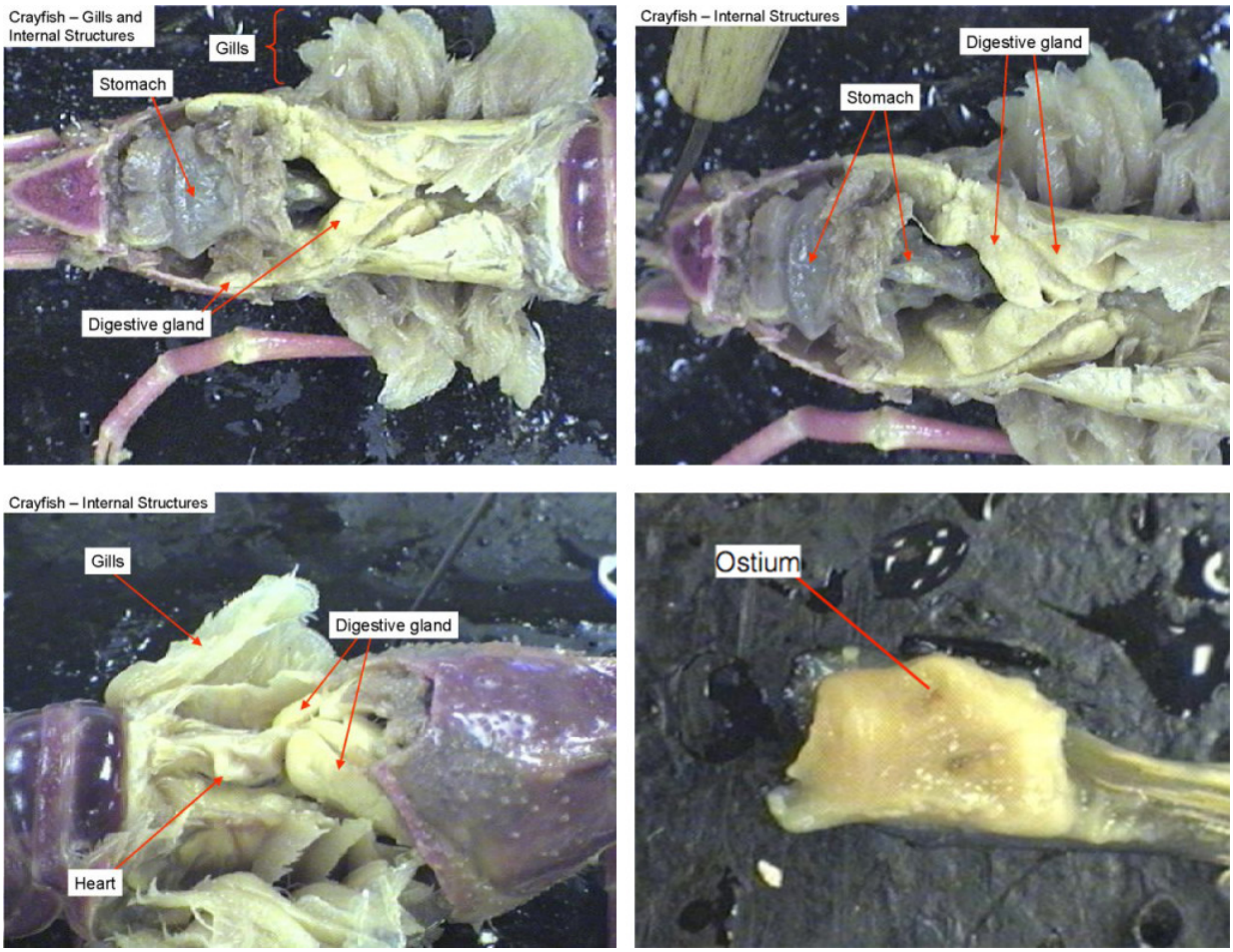

Figure 9.

Remove the digestive glands and then carefully remove the stomach. Notice how the stomach is attached to the mouth. Cut open the stomach and observe the tooth-like structures at the anterior end for grinding food. This is called the gastric mill.

The green glands are positioned ventrally near the anterior end of the body cavity. They are spherical and will appear to be embedded within the surface. Their function is excretion. Find the openings for the green glands on the outer surface near the base of each antenna.

Find the brain near the anterior end and the two ventral nerve cords attached to the brain.

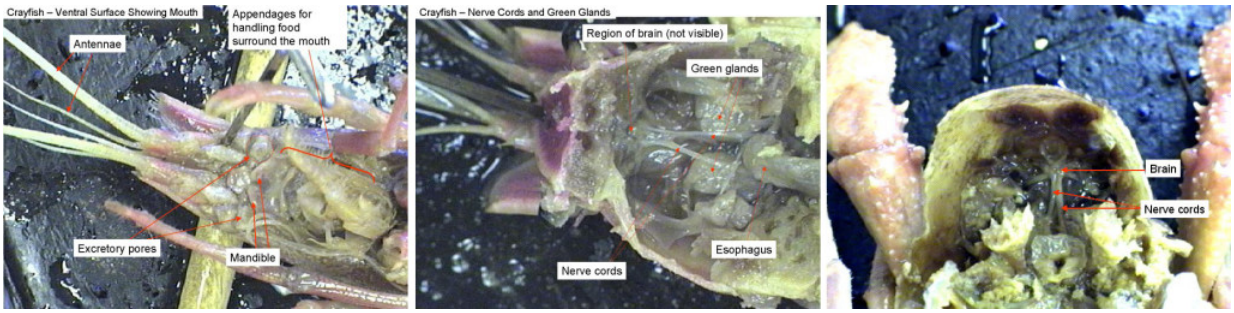

Figure 10. Left: Crayfish ventral surface. Middle: Crayfish viewed from above. The stomach has been removed revealing the nerve cords and green glands underneath. Right: Crayfish viewed from above looking into the head region. The stomach has been removed. The brain can be seen.

Copepods and Krill

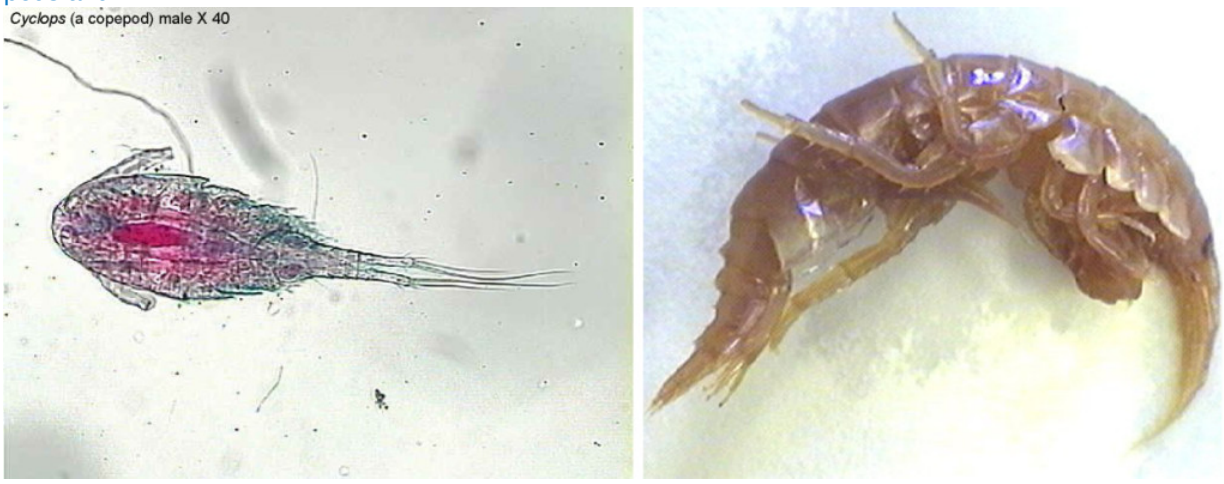

Figure 11. Left: A copepod (Cyclops, male). Right: Krill (Gammarus).

Barnacles

Figure 12. Left: Balanus—a barnacle. Right: A stalked barnacle

Isopods

Figure 13

Myriopods

Millipedes

Figure 14

Centipedes

Figure 15. A centipede

Insects

Figure 16. Fly life history showing complete metamorphosis

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CHAPTER OVERVIEW

8: Invertebrate II

8.1: Invertebrate Lab II

Learning Objectives

- State the phyla of the organisms discussed in the lab activities
- Use the characteristics of symmetry, coelom, embryo tissue layers, and patterns of development to differentiate between the different invertebrate groups
- Recognize and identify the platehelminthes specimens viewed in the lab
- Describe the lifecycle of the tapeworm, *Taenia pisiformes*
- Recognize the planeria structures eyespot, flame cell, pharynx, scolex
- Recognize and identify the mollusca specimens viewed in lab
- Identify identify foot, visceral, mantle, exoskeleton and radula
- Recognize and identify the annelidia examples viewed in the lab
- Identify setae and clitellum
- Design and perform a set of experiments to evaluate whether female bean beetles (*Callosobruchus maculatus*) discriminate between suitable species of beans.
- Perform a chi square analysis and determine if the results from the bean beetle experiment are statistically significant by using the degrees of freedom and the p value

Download a PDF of the lab to print.

Flatworms (phylum platyhelminthes)

Procedure

Access the Flatworms Lab.

Questions

1. Observe the live planaria, if present, under the dissecting. If there are no live specimens, review the planarian video.
    1. What type of symmetry does the planaria display?
    2. Does the planaria exhibit cephalization?
    3. Can you locate the planaria eyespots? What do the eyespots sense?
2. View the large planaria model. Make sure you can identify the pharynx, the eyespots, and the flame cells.
    1. Does the planaria have a complete or incomplete digestive system?
    2. What is the function of the flame cell?
    3. Are planaria hermaphrodites?
    4. Scientists say planaria have ladder like organs. Why?

Liver Flukes

View the preserved liver fluke specimens. Liver flukes are an example of a parasitic flatworm. Access this website to learn more about the liver fluke life cycle.

Questions

1. Where does the adult liver fluke live?
2. When the liver fluke egg hatches, what organism does it infect first?
3. Can humans become infected?

View the preserved tapeworm and the slides of the tapeworm scolex (head) and proglottids (reproductive bodies). This is another example of a parasitic flatworm. Access this website to learn more about the tapeworm life cycle.

Questions

1. What structures are located on the scolex to help the tapeworm attach to the host?
2. Are tapeworms hermaphrodites?
3. Name two livestock that can be infected by tapeworms.
4. If a human is infected, where does the tapeworm live?

Mollusks

Process

Access the Mollusks Lab.

The preserved mollusca specimens will be on display, but may differ from the ones directly mentioned in the lab handout. Please make observations on the available specimens and fill in the chart below.

Name of Specimen	Physical Description	Gastropod, chiton, bi-valve or cephalopod

Dissect a clam following the directions on the website. Make sure you can identify the mantle, the foot, the gills, and the visceral mass.

Questions

1. What is the function of the foot?
2. What is the function of the gills?
3. What does the mantle secrete for the clam?
4. What is contained within the visceral mass?

Squid Dissection

Dissect a squid following the procedure below

External Anatomy

1. Place the squid in the dissection pan with the **mantle** (major body part) facing away from you and the **tentacles** and **arms** towards you.
2. Turn the squid so that the **siphon** faces you. It is located between the eyes. By expelling water through the siphon the squid can effectively move through the water.
3. Notice the **chromatophores** on the mantle. They allow the squid to change color and blend into the environment.
4. At the pointed tip of the mantle there are two **fins** that help stabilize and propel the squid
5. Notice the **eyes** on either side-they are well developed and allow the squid to have excellent vision
6. Distinguish between the tentacles and the arms. The tentacles are longer and are used to pass food to the arms.
7. Count the number of arms. How many are there?
8. Notice the **suction cups** on both the tentacles and the arms. How does the distribution of the suction cups differ between these two structures?
9. Pull back the arms and locate the **beak** or mouth in the middle.

Internal Anatomy

1. Use a pair of scissors and starting at the bottom of the mantle above the siphon cut one long incision up to the tip of the mantle. Be careful to lift up with the scissors while cutting to avoid cutting the internal organs.
2. Spread the mantle open and try to indentify the following internal structures
    1. Feathery gills
    2. Heart, located at the base of each gill. Squid actually have three hearts!
    3. Liver, probably yellowish in color and long in shape running down the middle

4. Ink sack, which looks like a small silver fish. If you find it, cut it out at both ends and you can extract some of the ink and try to write with it!
5. The pen, which is all that remains of the shell. To try and find the pen, lift the head of the squid and place it down over the organs. You should notice a pointy area along the midline of the body, the tip of the pen. If you grasp the tip and pull the pen will release from the mantle. It resembles a transparent feather.

Annelidia

Process

Access the page “Reading: Annelidia.”

Skip the earthworm dissection indicated on the lab website. Rather, view the earthworm model. Make sure you can identify the setae and the clitellum.

Questions

1. What type of symmetry does the earthworm display?
2. Does the earthworm exhibit cephalization?
3. Does the earthworm exhibit segmentation?

The preserved annelida specimens will be on display, but may differ from the ones directly mentioned in the lab handout. Please make observations on the available specimens and fill in the table below.

Name of Specimen	Physical Description	Leech, Earthworm, or Marine Worm

Review Questions

Answer the review questions below. The phyla we viewed today were the platyhelminthes, mollusca, and annelida.

1. Which phyla exhibited bilateral symmetry?
2. Which phyla contained parasitic organisms?
3. Which phyla were coelomates?
4. Which phyla exhibited cephaliziation?
5. Which phyla that you viewed today contained specialized appendages?
6. Which phyla were aceolomates?
7. Which phyla had an incomplete digestive system?
8. Which phyla contained a shell?
9. Which phyla contained hermaphrodite organisms?

8.2: Invertebrate Lab II (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Flatworms (phylum platyhelminthes)

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
live planaria	1 vial can be shared by all lab sections	set up on side bench under dissection microscope as a demo
flatworm model	1 per bench	
planaria slides	1 per bench	can alternatively be set as a demo
Taneia slides	1 per bench	can alternatively be set as a demo

Liver Flukes

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
live flukes	1 vial can be shared by all sections	set up on side bench under dissection microscope as a demo
fluke slides	1 per bench	can alternatively be set as a demo

Mollusks

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
mollusk examples (preserved)	various	set up on side bench as a demo including squid, octopus, chitin, clams, snails, etc.

Squid Dissection

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
dissection kit	1 per bench	should include scalpel, scissors, forceps, dissection needles, dissection pins
dissection tray	1 per bench	
squid	1 per bench	
gloves	1 pair per student	latex and non latex options in various sizes
lab coat	1 per student	
goggles	1 pair per student	
dissection waste container	1 per class	dissection waste should not go in regular trash

Clam Dissection

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
dissection kit	1 per bench	
dissection tray	1 per bench	
clam	1 per bench	
gloves	1 pair per student	latex and non latex options in various sizes
lab coat	1 per student	
goggles	1 pair per student	
dissection waste container	1 per class	dissection waste should not go in regular trash

Annelidia

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
earthworm model	1 per table	
preserved annelid examples	various	examples include earthworms, leeches, polychete worms

8.3: Reading- Flatworms

This laboratory exercise covers the following animals. You should learn this classification scheme and be able to classify the animals into these categories.

- Phylum: Platyhelminthes (Flatworms)
  - Class: Turbellaria (planarians)
  - Class: Trematoda (Flukes)
  - Class: Cestoda (Tapeworms)

Characteristics

Flatworms are flattened and have bilateral symmetry.

They are **triploblastic** (have 3 embryonic tissue layers: ectoderm, mesoderm, and endoderm) and therefore have organ-level of organization. There is no body cavity, so they are acoelomate.

Flatworms have a **gastrovascularcavity** with one opening (a sac-like gut).

Free-living Species

Example: *Dugesia*—a freshwater planarian

Planarians have a branching sac-like gut (one opening).

The main function of the excretory system is for water regulation. It consists of two structures called **protonephridia**. Each protonephridium contains **flame cells** that move excess water into tubes that open to the outside.

Planarians have a head region with sense organs. The nervous system of *Dugesia* is somewhat more complex than the nerve net of Cnidarians. It consists of a brain and nerve cords arranged in a ladder-like configuration.

Planarians have **ocelli** (eyespots) allow the presence and intensity of light to be determined. These structures are covered but have an opening to one side and forward. They can tell the direction of light because shadows fall on some of the receptor cells while others are illuminated. They move away from light.

Planarians are **hermaphroditic**, that is, they contain both male and female sex organs. They can reproduce asexually simply by pinching in half; each half grows a new half.

Movement is accomplished by the use of cilia and also by muscular contractions.

Trematodes

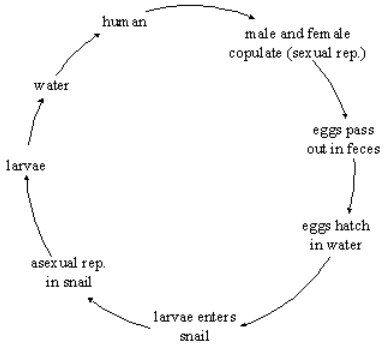
Members of this group are primarily parasites (feed on a host species).

Parasitic forms lack cephalization.

The reproductive cycle typically involves two host species, a **primary host** and a **secondary (or intermediate) host**. Adults live in the primary host and larvae develop in the secondary host. The life cycle often alternates between sexual and asexual reproduction.

Liver flukes are found in vertebrate livers.

Nearly half of people in the tropics have blood flukes. **Schistosomiasis** is a blood fluke that afflicts 200 million people in the world. The secondary host is a snail.



Planarians

1. Place a living planarian on a watch glass and observe its movements under a dissecting microscope. Look for the eyespots, auricles, gastrovascular cavity, and pharynx.
2. Planarians cannot see images but they can tell the direction of light with their eyespots. Cover 1/2 of the watch glass with aluminum foil. Does the planarian favor the light area or the dark area?
3. View a slide of a preserved planarian and note the eyespots, auricles, gastrovascular cavity, and pharynx.

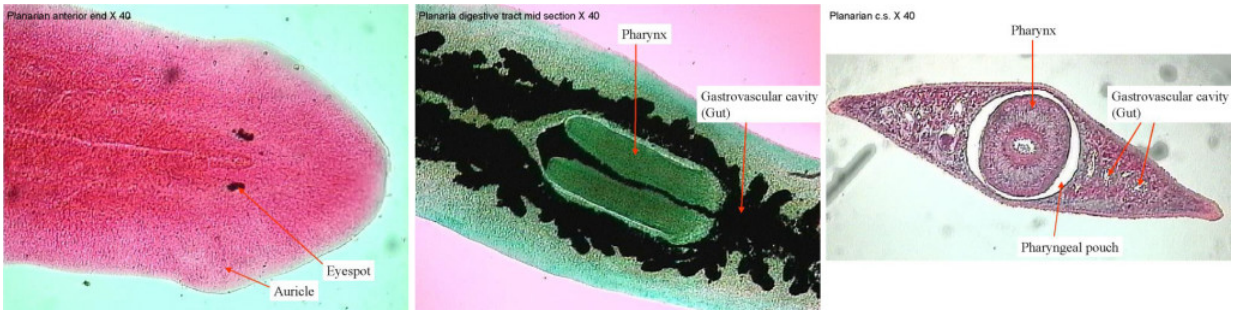


Figure 1. Left: Planarian anterior end X 40. Middle: Planarian digestive tract mid section X 40. Right: Planarian c.s. X 40.

Liver Flukes

Observe either a preserved liver fluke or a slide of a liver fluke using a dissecting microscope.

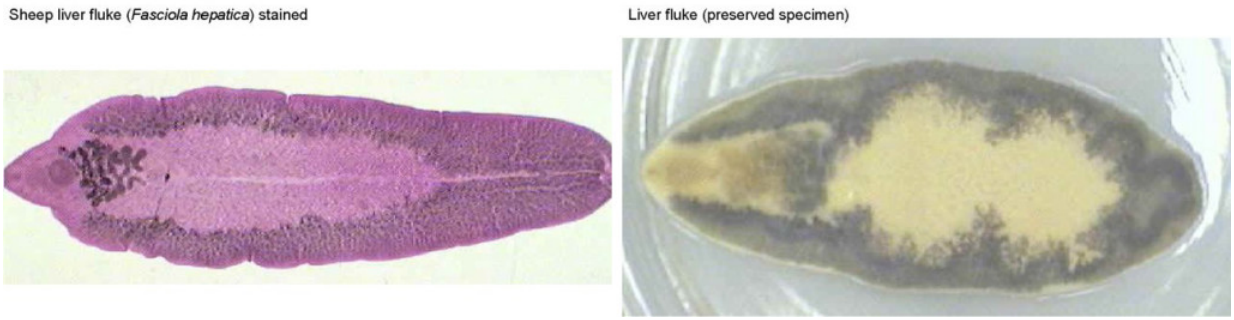


Figure 2. Left: Sheep liver fluke (Fasciola hepatica) stained. Right: Liver fluke (preserved)

Tapeworms

1. View a preserved tapeworm (Taenia).
2. View slides of Taenia. Locate the scolex. View a gravid (filled with eggs) proglottid.

Tapeworms live in the intestines of vertebrates.

They may reach 10 m in length (>30 feet). They have no digestive or nervous tissue. Attachment to the intestinal wall is by a **scolex**, a structure that contains hooks and suckers.

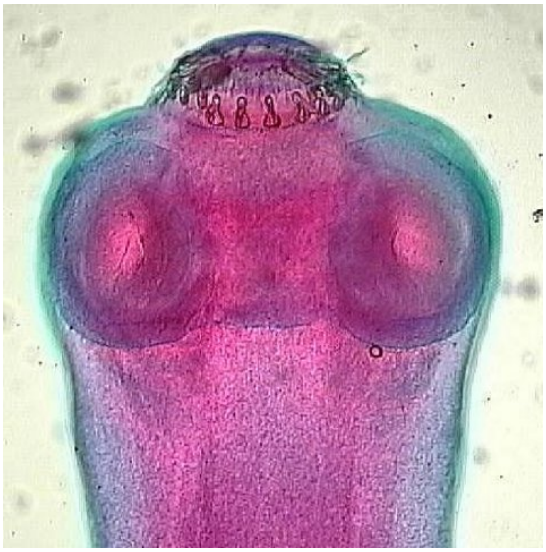


Figure 3. *Taenia* scolex X 40

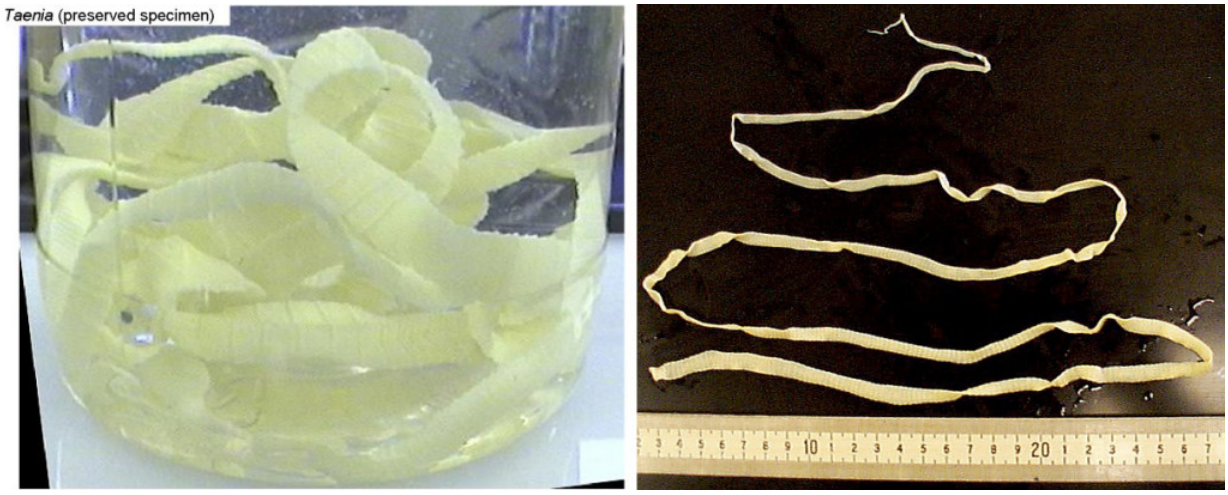


Figure 4. *Taenia* (preserved)

The segments (**proglottids**) each contain male and female reproductive organs. Eggs are fertilized from sperm, which often come from other proglottids of the same individual. After fertilization, other organs within the proglottid disintegrate and the proglottid becomes filled with eggs.

The intermediate hosts are usually pigs or cattle. They can become infected by drinking water contaminated with human feces.

Tapeworms can be passed to humans in undercooked meat, especially pork.

The photographs below show the scolex and proglottids at increasing distances from the scolex. Those segments closest to the scolex (on the left) are the smallest. Those furthest away (on the right) become filled with zygotes, break away, and pass out with the feces.

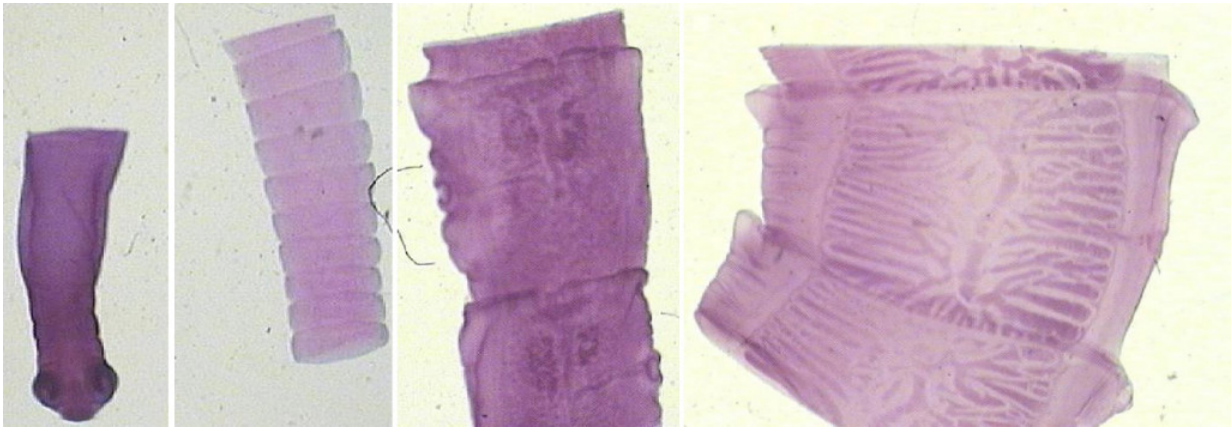


Figure 5. Left: *Taenia pisiformis* anterior end. Middle: *Taenia pisiformis* mid region. Right: *Taenia pisiformis* posterior end

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8.4: Reading- Mollusks

This laboratory exercise covers the following animals. You should learn this classification scheme and be able to classify the animals into these categories.

- Phylum: Mollusca (Mollusks)
  - Class: Polyplacophora (Chitons)
  - Class: Gastropoda (snails)
  - Class: Bivalvia (Clams)
  - Class: Cephalopoda (Nautilus, Squid, Octopus)

All mollusks have a **visceral mass**, a **mantle**, and a **foot**. The visceral mass contains the digestive, excretory, and reproductive organs. The mantle is a covering. It may secrete a shell. The foot is muscular and is used for locomotion, attachment, and/or food capture.

The mantle and foot can be seen in the figure 1. The visceral mass is underneath the gill.

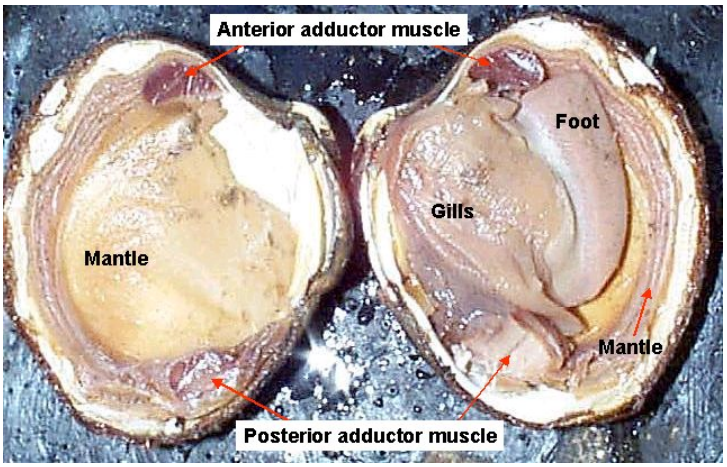

Figure 1.

There may be a **radula**, a structure that resembles a tongue but contains hard plates and is often used for scraping food. The coelom is reduced and limited to the region near the heart.

Most mollusks have an **open circulatory system** but cephalopods (squids, octopus) have a **closed circulatory system**. The blood pigment of mollusks is hemocyanin, not hemoglobin. The heart of a clam can be seen in the photograph below. Bivalves have three pairs of ganglia but do not have a brain.

Most mollusks have separate sexes but most snails (gastropods) are hermaphrodites. Some marine mollusks have a ciliated larval form called a **trochophore**.

Chitons (Class: Polyplacophora)

Chitons have a dorsal shell composed of 8 plates. A ventral foot is used for locomotion and for attachment to rocks. It pulls itself close to rocks for protection. Observe the chiton on display.

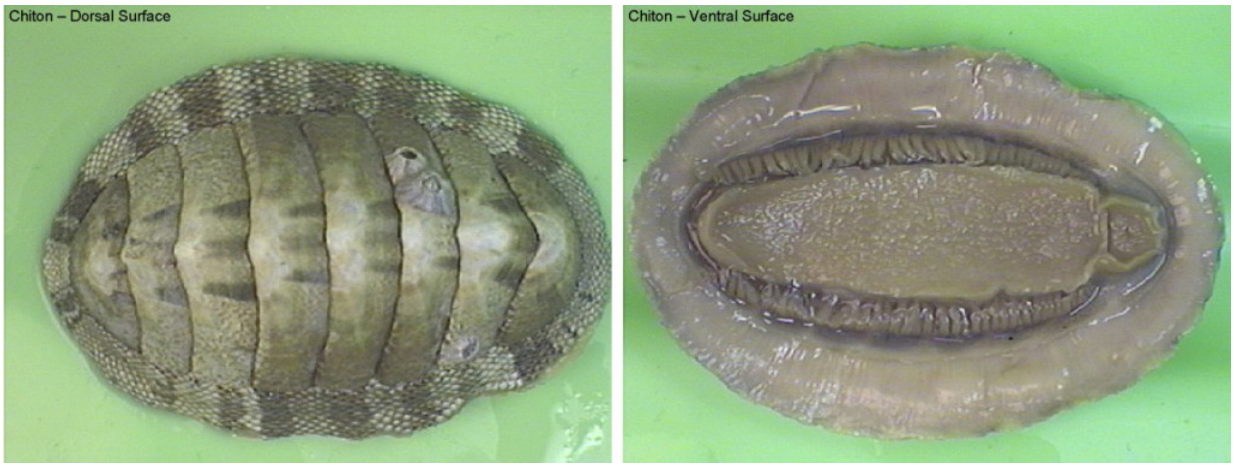

Figure 2. Left: chiton, dorsal surface. Right: ventral surface

Snails—Class Gastropoda

Gastropods have an elongated, flattened foot and usually a head and shell although nudibranchs (sea slugs) and terrestrial slugs lack a shell.

Most are marine but there are also numerous freshwater and terrestrial species. Herbivorous gastropods use a radula to scrape food from surfaces. Carnivores may use a radula to bore a hole through surfaces such as bivalve (clam) shells. Some gastropods such as the slug (below) do not have a shell.

The larvae undergo **torsion** during development. It is a twisting that positions the visceral mass so that the anus is above the head. It is due to one side of the visceral mass growing faster than the other. The advantage (or function) of torsion is uncertain but it may be to balance the animal or it may be to allow the head to be withdrawn into the shell first when predators approach.

Observe the snails and slugs on display.

Figure 3. A slug. Slugs do not have shells.

Gas Exchange (Respiration)

Some gastropod species are terrestrial and have lungs for gas exchange, others are aquatic and use gills.

The space near the entrance to the shell that is bound by the mantle is the **mantle cavity**. Aquatic gastropods have gills located in the mantle cavity. The mantle of terrestrial gastropods functions as a lung.

Bivalves—Clams and relatives (Class: Bivalvia)

Bivalves have two shells (valves) held closed by powerful muscles. The shell is produced by the underlying mantle; it grows along the outer margins. They use their foot for burrowing. Mussels use their foot for the production of threads for attachment.

The gills are large because they are used for filter-feeding as well as respiration. Food is trapped by mucus on the gills and moved by cilia. Water enters and exits through siphons.

Obtain a preserved clam for dissection and place it on a dissecting tray. Remove one of the **valves** (shells) by inserting a scalpel and cutting the adductor muscles on each side of the hinge. See the diagram below for the location of the **adductor muscles**.

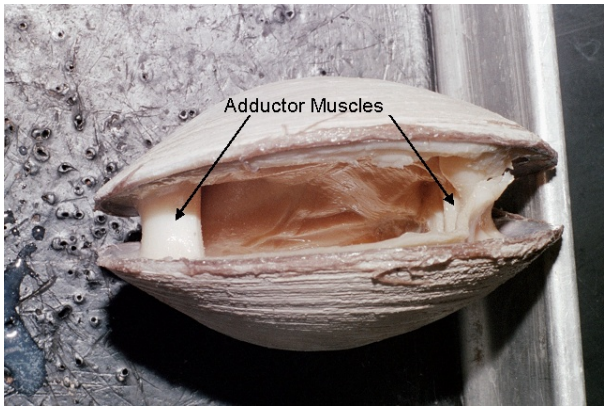

Figure 4. Adductor muscles of a clam.

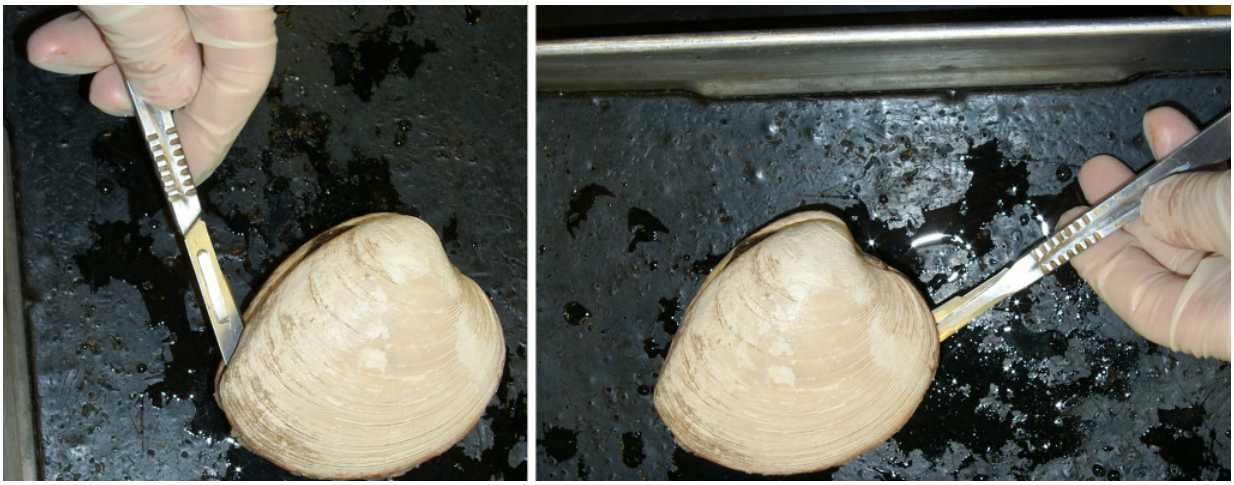

Figure 5. The anterior and posterior adductor muscles being cut so that the valves can be pulled apart.

The **mantle** is a membrane that surrounds the internal structures and is characteristic of all mollusks. The portion of the mantle from the exposed surface may have remained attached to the valve that was removed or it may be covering the internal structures. Find the mantle and if necessary, remove it to expose the internal structures of the clam.

Identify the foot, visceral mass, gills, and labial palps. The gills are large because they are used for filter-feeding as well as respiration. Food is trapped by mucus on the gills and moved by cilia to the mouth. Cilia on the labial palps also direct food and mucus to the mouth.

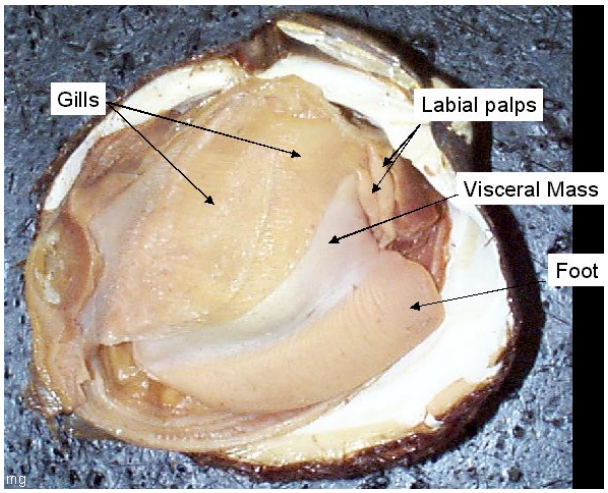

Figure 6.

The heart can be found in the area dorsal to and slightly posterior to the visceral mass. The coelom of bivalves is reduced and limited to the area surrounding the heart. Because the coelom is reduced, it is difficult to see the digestive organs. Cut through the visceral mass and identify the intestine.

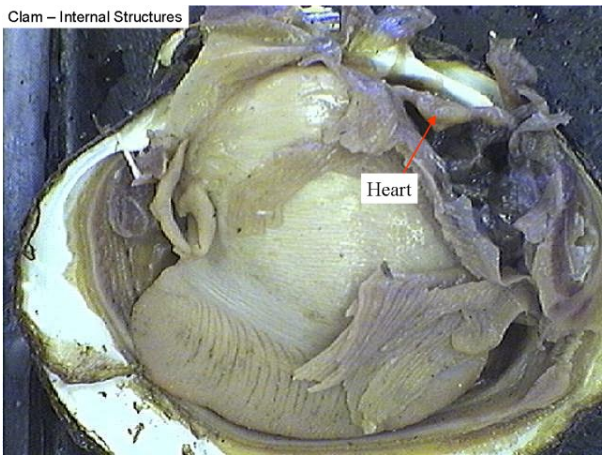

Figure 7.

In the photograph below, the foot and visceral mass have been lifted so that the mouth can be seen. Notice the labial palps on either side of the mouth.

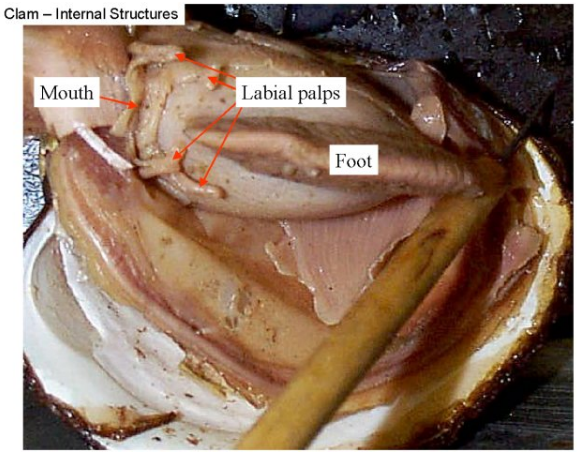

Figure 8.

Squid, Octopus, Nautilus, and Relatives (Class: Cephalopoda)

Cephalopods are predators and live in a marine environment. A closed circulatory system allows them to move rapidly in pursuit of prey. They move by jet propulsion; water in the mantle cavity is squirted rapidly through a siphon. The foot has evolved into tentacles around head. Cephalopods have a powerful beak-like structure to tear apart prey. The sense organs of cephalopods are well developed.

Mollusks are the simplest animals with eyes. Some mollusks have ***lenses*** and therefore are capable of forming clear images. The camera-type eyes of some cephalopods (squid, octopus) are capable of focusing and forming clear images. Cephalopods are fast-moving predators and well-developed camera-type eyes help them catch prey.

Well-developed brains (especially in octopuses) give them a high learning capacity. Cephalopods can hide from enemies by releasing a dark colored fluid from ink sacs.

Shells

The shell of a nautilus encloses the animal. A squid's shell is small and internal. Octopuses do not have shells. Examine representative cephalopods on display.

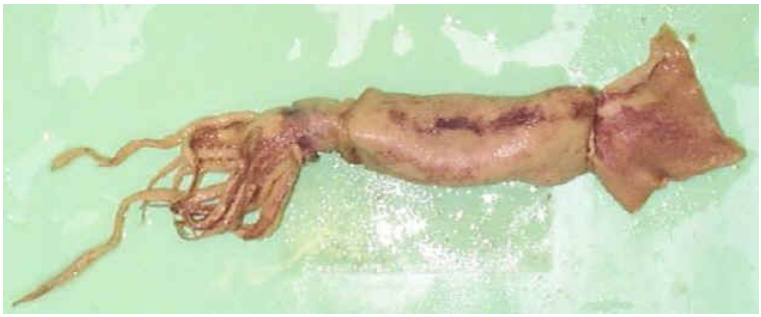

Figure 9. A Squid

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8.5: Reading - Annelids

This laboratory exercise covers the following animals. You should learn this classification scheme and be able to classify the animals into these categories.

- Phylum: Annelida (Annelids)
  - Class: Oligochaeta (Earthworms, Leeches)
  - Class: Polychaeta (Marine Annelids)

Oligochaeta (Earthworms, Leeches)

Earthworms

Segmentation

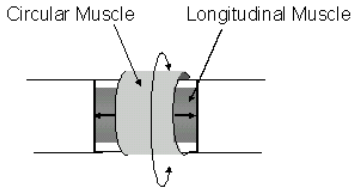
Segmented animals have repeating units. This has led to specialization of parts over evolutionary time because the different segments could become specialized for different purposes. Notice the variety of specialized structures near the anterior end of the clam worm in the photograph below.

Molecular data suggests that segmentation evolved independently in the annelids, the arthropods, and the chordates because ancestors to each of these three groups were not segmented.

Segmented Worms (Phylum Annelida)

Annelids are bilateral, coelomate protostomes. The coelom is partitioned by **septa** (crosswalls).

The fluid-filled coelom acts as a **hydrostatic skeleton**. When the **circular muscles** that surround each segment contract, the segment becomes thinner and longer. When the **longitudinal muscles** that extend from one end of the segment to the other contract, the segment becomes shorter but thicker.



Because muscles can only contract and cannot lengthen, other muscles are used to lengthen them. In annelids, when circular muscles contract to lengthen the segment, the longitudinal muscles are lengthened. When the longitudinal muscles contract to make the segment shorter and thicker, the circular muscles become lengthened.

Setae are bristles on the skin that anchor or help move the animal. Movement occurs when waves of contraction of longitudinal muscles cause a “bulge” to progress from the anterior end to the posterior end.

Annelids exhibit specialization of the digestive tract. Some of these structures are the pharynx, crop, gizzard, intestine, and accessory glands. Annelids have a **closed** circulatory system.

A pair of cerebral ganglia function as a simple brain. A ventral nerve cord extends the length of the animal and connects to a pair of fused ganglia (mass of nervous tissue) in each segment. The ganglia within each segment function to coordinate muscle contractions.

Examine the exterior of an earthworm and find the ventral surface. Place the worm in a dissecting pan with the ventral surface down. Identify the clitellum. This structure produces mucous needed for reproduction. Find rows of setae along either side of the ventral surface. These help provide traction as the animal moves through the soil.

Find the dorsal blood vessel. This structure should be visible through the body wall and will appear slightly darker than the rest of the body. It extends the length of the animal. With a scalpel, make a shallow cut along the dorsal surface beginning at a point approximately half way between the clitellum (see photograph below) and the posterior end and ending at the anterior end. Try to

avoid cutting the dorsal blood vessel by keeping your cut to one side of the vessel. Try to cut only the body wall but not the internal structures.

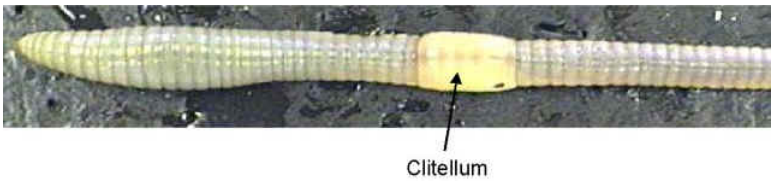


Figure 1.

The septa between each segment will prevent you from spreading the walls open to view the interior structures. Use a needle or scalpel to carefully cut the septa while spreading the body open. Pins can be used to hold the body open.

Find the structures shown in the photographs below. Be sure that you understand the function of each of these structures.

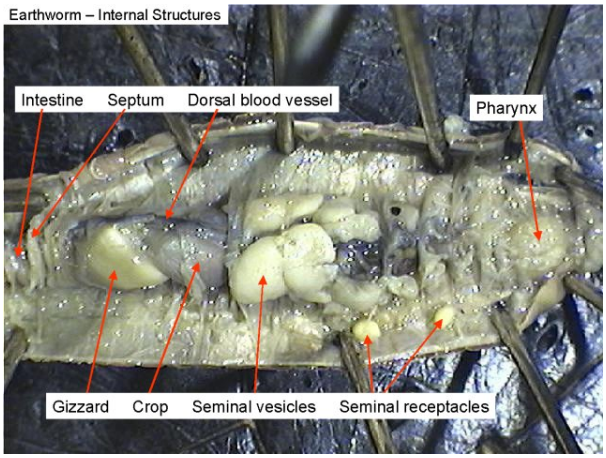


Figure 2. The anterior end of this earthworm is on the right.

Figure 3. Left: The anterior end of the worm. Middle: The brain. Right: The mid-section

Use a needle to cut the septa in the region of the intestine and roll it aside to expose the nerve cord underneath.

Examine a labeled earthworm composite. This slide shows three different cross sections. The cross-section on the right side of the slide is from the intestinal region.

Identify the intestine, typhlosole, coelom, nephridium, longitudinal muscles, circular muscles, and dorsal blood vessel. Are any setae present in the cross section?

Leeches

Most leeches are freshwater predators or parasites. Parasites have oral and posterior suckers used to attach to the host. Bloodsucking leeches produce hirudin, a powerful anticoagulant, in their saliva.

When surgeons reattach severed human fingers, they occasionally use laboratory-raised leeches during the patient's recovery. The leeches remove blood from the tissues around the reattachment sites, release anesthetics and anticoagulants, and thereby relieve pressure and decrease pain. Removal of fluids from the area by the leech enables fresh fluids to move into the area.

Figure 4. Leech

Marine Annelids (class: Polychaeta)

The largest class of annelids is polychaeta. Polychaetes have **parapodia**, fleshy, paddlelike lobes on each segment. Parapodia function in locomotion and gas exchange. Setae are located on the parapodia.

Feeding

Many Polychaetes are predators. **Tubeworms** are sessile filter feeders that live in tubes constructed from sediment from the ocean floor. Cilia on their tentacles create water currents that enable them to filter food from the water.

Figure 5. Left: Clam worm (Nereis). Right: Clam worm (Nereis) anterior end

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8.6: Natal Bean Discrimination by Bean Beetles

Adapted from C. Beck and L. Blumer by Staci Forgey, TCC Biology Faculty

Objective

Design and perform a set of experiments to evaluate whether female bean beetles (*Callosobruchus maculatus*) discriminate between suitable species of beans.

Introduction

Bean beetles, *Callosobruchus maculatus*, are herbivorous pest insects that are found in Africa and Asia. Females lay their eggs on the surface of beans. Eggs are layed singly, and hatch into larvae (maggots) several days later. The larva then burrows into the bean and will form a pupa 21–30 days after the egg was deposited. They mature 24–36 hours after emergence from the pupa and do not need to feed.

Adults typically live for 1–2 weeks. Mating and oviposition occur during this time period. Females will choose the best substrate (bean) to lay their offspring on, since the larvae cannot move. By choosing a substrate for oviposition, the female chooses the food resource available to her offspring (Brown and Downhower 1988). This is a critical choice for the female, as it influences the growth, survival and future reproductive success of her offspring (Mitchell, 1975, Wasserman and Futuyma, 1981). Females can lay eggs on a wide range of bean species, but very few bean species will result in normal development and the successful emergence of adults. Some species of beans are toxic to larvae (Janzen 1977).

Materials

In class, you will be provided with live cultures of bean beetles containing adults that have been raised on mung beans (*Vigna radiata*).

Female beetles are easily identified in the live cultures because they have two dark stripes on the posterior of the abdomen, whereas the posterior abdomen of males is uniformly light in color.

You will also have access to petri dishes and several types of beans.

Experimental Design

Since the oviposition choices of females influences the survival and future success of their offspring, females may be very sensitive to the species and condition of the beans on which they are depositing eggs.

Each group should design a set of experiments to address whether female bean beetles discriminate between suitable species of beans. We will re-visit the experiment next week and collect our data set. We will choose one experiment to perform as a class.

As a group, list several ways we might examine female bean choice for oviposition. We will pick one experiment from the class to perform. Write your ideas below.

****Stop here. We will go over ideas for our experiment as a class and choose one to perform****

Outline the agreed on experiment using the criteria below.

1. Formulate a hypothesis for this week's experiment. Be specific!
2. We will re-visit the experiment in a week to collect data on the number of eggs laid. Formulate a hypothesis for this experiment.
3. Identify the independent variable(s).
4. Identify the dependent variable(s).
5. What variables will you keep standard?
6. What is your control?
7. Design data collection tables for both of your experiments on a separate sheet of paper.

For this data, it is most useful to perform a Chi Square analysis. Chi Square statistical test evaluate whether this is a significant difference between groups of data. The null hypothesis (H_0) is the hypothesis that states that there is no difference between the groups of data. The alternative hypothesis, (H_a) is the hypothesis you outlined above.

1. Restate your H_0 hypothesis.
2. H_a hypothesis.
3. If the null hypothesis is correct, what would we expect to see?
4. If our alternative hypothesis is correct, what would we expect to see?

To do this statistical test, we need to calculate observed and expected values for the bean species and for our control. Our expected values are based on our null hypothesis (that there is no difference).

For example, if we had 40 eggs and four different treatment groups, we would expect there to be 10 eggs on each group.

Treatment	Observed number of eggs	Expected number of eggs
Mung beans	5	10
Pinto beans	25	10
Chick peas	10	10
Control	0	10

Fill in the data table below with our observed (what we actually found) and expected values.

Treatment	Observed number of eggs	Expected number of eggs

To calculate the chi-square value, or χ^2, we simply add the square differences, divided by the expected, of all the observed and expected. In mathematical terms:

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \tag{8.6.1}$$

So for our example from the previous sample table, the first $\frac{(O-E)^2}{E}$ would be $\frac{(5-10)^2}{10}=2.5$

We would then add to this value all of the other $\frac{(O-E)^2}{E}$ in the table and then add to get the χ^2 value.

Treatment	Observed number of eggs	Expected number of eggs	Observed-Expected	(Observed-Expected)^2	(Observed-Expected)^2/Expected

Compute the χ^2 value for your data by adding all of the (Observed-Expected)2/Expected values.

In order to find something to compare this number with, we need to calculate the degrees of freedom, or the number of different comparisons that can be made within the table. The degrees of freedom are the number of columns (M) minus one times the number of rows (N) minus one.

Degrees of freedom = (M − 1)(N − 1)

A	B
C	D

How many ways can this two by two table be broken into individual comparisons? Hint: Use the formula above.

Calculate the degrees of freedom in your experiment.

Now we can compare against the Chi distribution for the likelihood that our data is generated by chance. Remember, we are looking at the column labeled 0.05 for our p value. This means that at this level, we are 95% sure our results are real. The Chi distribution table gives us a critical value to compare our test value to.

- If test > critical value @ p level, **reject** null hypothesis
- If test < critical value @ alpha level, **fail to reject** null hypothesis

Compare to the Chi-distribution table. Did your results come about by chance?

DF/P	0.995	.990	0.975	.950	.900	.750	.500	.250	.100	.050	.025	.010	.005
1	0.00004	.00016	0.001	0.004	0.016	0.102	0.455	1.323	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.0506	0.103	0.211	0.575	1.386	2.773	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.351	0.584	1.213	2.366	4.108	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	1.923	3.357	5.385	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	2.675	4.351	6.626	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	3.455	5.348	7.841	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	4.255	6.346	9.037	12.017	14.067	16.013	18.475	20.278
8	1.344	1.647	2.180	2.733	3.490	5.071	7.344	10.219	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	5.899	8.343	11.389	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	6.737	9.342	12.549	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	7.584	10.341	13.701	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	8.438	11.340	14.845	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	9.299	12.340	15.984	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	10.165	13.339	14.114	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	11.037	14.339	18.245	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	11.912	15.339	19.369	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	12.792	16.338	20.489	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	13.675	17.338	21.605	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.657	14.562	18.338	22.18	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	15.452	19.337	23.848	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	16.344	20.337	24.935	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	17.240	21.337	26.039	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	18.137	22.337	27.141	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	19.037	23.337	28.241	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	19.939	24.337	29.339	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	20.843	25.336	30.435	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	21.749	26.336	31.528	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	22.657	27.336	32.620	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	23.567	28.336	33.711	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	24.478	29.336	34.800	40.256	43.773	46.979	50.892	53.672

We will now use this data and information to do a lab write up.

Lab Report Template

The report should be typed and single spaced. See grading rubric for clarity on formatting.

Title Page

- Should include Title (a brief, concise, yet descriptive title), your name, lab instructor's name, and lab section.
  - Note: this is a separate sheet

Body of Report

Identify the different sections of the body of the report with headings.

The report should begin with a brief paragraph (complete sentences) that includes a statement of the problem and your hypothesis. This should be under the heading of Introduction.

- Statement of the problem:
  - What question are you trying to answer?
  - Include any preliminary observations or background information about the subject (in this case the bean beetles) such as reproductive cycle, life span etc. Be sure to cite any sources.
- Hypothesis:
  - Write a possible explanation/prediction for the problem/question you are asking.
  - Make sure this possible explanation/prediction is a complete sentence and not a question.
  - Make sure the statement is testable. In other words, can you perform an experiment that will either support or refute your prediction. If you cannot not think of a way to test your prediction, then it is not testable.

Next heading should be **Materials**:

- Make a list (this does not need to be in paragraph form) of ALL items used in the experiment and their quantities. Of the materials used, **identify which are dependent and independent variables, constants (standardized variable) and control group (you will lose points if you do not identify ALL dependent and independent variables, constants and controls)**.

Next heading should be **Procedure** :

- Write a paragraph (complete sentences) which explains what you did in the experiment.
- Your procedure should be written so that anyone else could repeat the experiment. For instance, what beetle did you use? How was your petri dish set up? What beans did you use? That means that **even some of the most obvious steps need to be stated** so there is no ambiguity.
- **When designing the procedure, be sure to include replicating the experiment to ensure data is reproducible and valid.**

Next heading should be **Results** :

- Write a paragraph (complete sentences) describing the results and observations of your experiment. Here you will compare results for controls and variables and not simply list the numbers.
- This section also includes data tables, graphs or charts to illustrate the results of you experiment. **Be sure to include calculated averages of *t*.**
- All tables, graphs and charts should be labeled appropriately (a title, labels for *x* & *y* axis, legend etc.) so the reader will be able to understand.

Next heading should be **Conclusions** :

- Write a paragraph restating your hypothesis and whether you accept or reject your hypothesis
- In this paragraph, **explain** why you accepted or rejected your hypothesis **using data from the experiment**. Include a brief summary of the data—averages, highest, lowest, etc., to help the reader understand your results and why you have come to particular conclusions.
- Discuss your thoughts about the possible reasons for your results (for example, if you chose salt water as a variable, give a possible reason why salt water, in particular, may have generated your results).

- Discuss possible errors that could have occurred in the collection of the data (experimental errors) and describe how these errors may have impacted the data.

External Helps

These websites have helpful hints related to scientific writing that will help you with your lab report:

- The Writing Center: Scientific Reports
- Writing a Biology Lab Report

How to write citations:

- APA Citation Style

The following rubric will be used to grade these reports:

	Excellent 5 points	Satisfactory 2.5 points	Unsatisfactory 0 points
Title Page	Contains title, student name, instructor name and section	Missing either instructor name or section	No title page
Formatting: typed, spacing	Typed and single spaced	Typed, but not single spaced	Not typed
Grammar and Spelling	No errors; contains complete sentences and no misspellings	A few minor errors in grammar and spelling	Several major errors in grammar and spelling
Formatting: headings	Each section has a heading as described in template	Some sections lack headings	No headings
Hypothesis	Predictions are clearly stated and written as a testable statement	Predictions/expected outcomes are not clearly stated	Not written as a testable statement
Materials	All equipment and materials described; identify variables, controls and constants	Materials incompletely described	No identification of variables, controls and constants
Procedure	Clear step-by step description	Description missing details making it difficult for another scientist to repeat experiment	Description missing so much detail it would be impossible to repeat
Results	Clearly written description of results comparing controls and variables	Results are presented but no comparison between controls and variables are made	No written description of results
Data tables, graphs or charts	Easy to interpret, clear labels, all data, including calculated averages, included	Disorganized (not easy to understand, missing labels) but **all** data included	Disorganized and or data clearly missing
Conclusion	Clearly explains acceptance or rejection of hypothesis using data to support conclusion; identifies sources of error	Accepts or rejects hypothesis but does not use data to explain why; or does not identify sources of error	Does not explain conclusion and does not identify sources of error
			Total _____out of 50 points

Literature Cited

Brown, L. and J.F. Downhower. 1988. Analyses in Behavioral Ecology: A Manual for Lab and Field. Sinauer Associates, 194 pages.

Janzen, D.H. 1977. How southern cowpea weevil larvae (Bruchidae *Callosobruchus maculatus*) die on non-host seeds. Ecology 58:921–927.

Mitchell, R. 1975. The evolution of oviposition tactics in the bean weevil, *Callosobruchus maculatus* F. Ecology 56:696–702.

Wasserman, S.S. and D.J. Futuyma. 1981. Evolution of host plant utilization in laboratory populations of the southern cowpea weevil, *Callosobruchus maculatus* Fabricius (Coleoptera: Bruchidae). Evolution 35:605–617.

8.7: Natal Bean Discrimination by Bean Beetles (Instructor Materials Preparation)*

Lab Materials

This is the prep for *one section* of 24 students.

Bean Beetles

Side bench: containers of assorted beans: garbanzo bean, black beans, mung beans, baby lima beans, split green peas, black eyed peas

To share between students: cultures of bean beetles, male and female adults. Bean beetles can be purchased from Carolina Biological. Information for care of bean beetles to maintain your own culture can be found here: http://beanbeetles.org/handbook/

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
large Petri dish (experimental chamber)	1 per table	
soft forceps	1-2 per table	
small paint brush	1-2 per table	
hand held lens	1-2 per table	

CHAPTER OVERVIEW

9: Deuterostomes

9.1: Deuterostome Lab

Learning Objectives

- State the phyla of the organisms discussed in the lab activities
- Use the characteristics of symmetry, coelom, embryo tissue layers, and patterns of development to differentiate between the different organisms
- Describe the general characteristics of echinoderms
- Identify and locate external and internal structures of a starfish
- State the common characteristics of all chordates
- Be able to identify the chordate characteristics on a model or picture
- Identify and locate external and internal structures of a frog

Download a PDF of the lab to print.

Echinoderms

Procedure

Access the page “Reading: Echinoderms.”

Questions

1. Skip viewing the slide of the different developmental phases of the sea stars
2. Dissect the starfish following the directions on the website. Remember the oral end (with mouth) is actually on the underside of the starfish.
    1. On the oral side make sure you find the **mouth**.
    2. Also on the oral side in the center region of each leg look for the **tube feet**. Tube feet are used for locomotion powered by the water vascular system. How many rows of tube feet does your starfish have?
    3. Try to differentiate between the **spines** and the **skin gills**. The spines are longer are used for protection. The skin gills are smaller and used for gas exchange.
    4. Find the **sieve plate/madreporite** on the aboral side. This is the water entrance point for the water vascular system used for movement.
    5. The starfish has plates located underneath the skin for protection and support. What material comprises these plates?
    6. The starfish has a two part stomach, the upper **pyloric stomach** and the lower **cardiac stomach.** Can you differentiate between the two stomachs on your specimen?
    7. In the starfish arms you should find both **digestive glands** and **gonads.** The digestive glands are brown and typically on top of the off white gonads. Make sure you can identify both structures.
3. The preserved echinoderm specimens will be on display, but may differ from the ones directly mentioned in the lab handout. Please make observations on the available specimens and fill in the chart below.

Name of Specimen	Physical Description

Chordates

Procedure

Access the page “Reading: Chordates.”

Questions

1. There are two groups of invertebrate chordates, the cephalochordates and the urochordates. We don’t have any urochordate examples in the lab.
    1. View the lancelet slide. The lancelet is an example of a cephalochordate. It contains all four chordate characteristics. List the four chordate characteristics below.
    2. View the lancelet model. Make sure you can identify all four chordate characteristics on the model.

Dissection

Our vertebrate chordate example of today’s lab is the **frog**. Dissect a frog following the procedure below.

1. External anatomy
    1. Place the frog in the dissection pan legs down.
    2. Identify the eyes, covered by a **nicitating membrane**, the **external nares** (nostrils), and the **tympanum** located behind each eye.
        1. What is the function of the tympanum?
    3. Examine the front and back limbs. How many phalanges are on the hindfeet? The forefeet? Which pair of limbs is the longest? How does this assist the frog in its movement?
2. Mouth
    1. Turn the frog over and open the mouth as wide as you can. You can cut the hinges of the jaw if necessary. Identify the following structures:
        1. Two **vomerine teeth** located in the middle of the roof of the mouth
        2. **Maxillary teeth** (smaller) located on the sides of the upper jaw
        3. **Tongue**
        4. **Pharynx** (located behind the tongue)
        5. **Esophagus**, the opening leading to the stomach
        6. **Glottis**, slit where air passes through to enter the **trachea**, which leads to the lungs
        7. **Eustacian tubes** (2) openings that lead to the ears. They are located in the angle of the jaw.
3. Body Dissection
    1. Place the frog belly side up in the dissecting tray. You can pin down the limbs if necessary.
    2. Lift up the skin with forceps midway between the hind legs of the frog. Use scissors to cut the skin along the midline of the frog starting between the hind legs and ending at the neck. Be careful not too cut too deeply.
    3. Cut the skin horizontally above the hind legs and below the front legs creating skin flaps.
    4. Pick up a skin flap with forceps and use a scalpel to separate the skin from the muscle below.
    5. Pin the skin flaps to the dissection tray.
    6. Repeat the same procedure to cut through the muscles. Create one long incision along the midline of the frog from between the hind legs to the neck. Be careful not to cut too deeply and damage the internal organs. When you reach the area just below the front legs of the frog, turn your scissors sideways to cut through the chest bones and avoid damaging the heart and lungs . Then make horizontal incisions above the rear legs and between the front legs. Use forceps and a scalpel to separate the muscle from the tissue below. Then pin the muscle to the dissection tray.
4. Internal Organs
    1. The most prominent organ is the **liver**, dark brown in color, and taking up most of the abdominal cavity
    2. Identify the **lungs**, two small pouches on opposite sides of the frog midline. They may be partially hidden by the liver.
    3. Lift up the liver and underneath locate the **gallbladder.**
    4. Identify the **heart** covered by the protective **pericardium**. Frogs have a three chambered heart with two atria and one ventricle. Try to locate these different areas of the frog heart.

1. How is it a disadvantage to have a 3 chambered heart?

5. The **stomach** is a j-shaped organ located underneath the left lobe of the liver. It connects to the **esophagus** bringing food from the mouth and the **small intestine** used for nutrient absorption.
6. The small intestine connect to the **large intestine** which carry any undigested material to the **cloaca**. Frogs have one opening to the outside environment and the cloaca receives materials from the intestine, the urinary system and the reproductive system.
7. Find the **pancreas**, a yellow ribbon located between the stomach and the small intestine.
8. Locate the **spleen**, shaped similarly to a pea and located near the stomach.
9. You will be able to see the yellow, finger like, **fat bodies**, which the frog uses to store fat.
10. The **kidneys** of the frog are long and narrow and located along the back body wall.
11. Try to find the **mesonephric ducts**, thin white tubes that carry urine from the kidney to the cloaca.
12. If your frog is female, the abdominal cavity will be filled with black and white eggs. The eggs are stored in the **ovaries.**
13. If you have a male frog, locate the **testes**. The testes are shaped like a bean and located at the top of the kidneys. They are yellow/tan in color.
    1. Do you have a male or female frog?

Review Questions

Answer the review questions below. The phyla we viewed today were the echinodermata and the chordata.

1. Which phyla observed today were deuterostomes?
2. Which phyla exhibited cephalization?
3. Which phyla were coelomates?
4. What does the name “echinodermata” mean?
5. What type of symmetry does the echinoderm larva display?
6. Give an example of an echinoderm example other than a starfish.
7. What unique system does the starfish use for movement?
8. Give an example of a chordate that is not a vertebrate.
9. State the four common characteristics shared by all chordates.
10. Name the two types of teeth found in frogs.
11. Frogs have small lungs that are inefficient. What other structure do frogs use for gas exchange?
12. Frogs have one opening to the outside environment, the cloaca. What three areas transfer material outside through the cloaca?

9.2: Deuterostome Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Echinoderms

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
starfish model	1 per table	
example echinoderm organisms (preserved)	various	these are put on the side bench and can include sea stars, sea fans, sea urchins, sea cucumbers

Chordates

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
lancelet slides	1 per table	can also be set out on side bench as a demo
lancelet model	1 per table	
frog model	1 per table	

Dissection

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
dissection kit	1 per table	should include scalpel, scissors, forceps, dissection needles, dissection pins
dissection tray	1 per table	
waste disposal container	1 per class	dissected organisms should not go in regular trash
gloves	1 pair per student	latex and nonlatex (for allergies) in various sizes
lab coat	1 per student	
goggles	1 pair per student	
preserved starfish	1 per table	
preserved frog	1 per table	

9.3: Reading- Echinoderms

Phylum: Echinodermata

Reading

Echinoderms are coelomate, and deuterostomes. Echinoderms include sea stars (starfishes), sea urchins, sand dollars, sea cucumbers, and sea lilies. There are 6,000 species of echinoderms; they are all marine. Although echinoderm adults have radial symmetry, they evolved from ancestors that were bilaterally symmetrical. They have free-swimming, bilateral larvae that metamorphose (change as they mature) into adults with radial symmetry.

Figure **9.3.1**: Restorations of early Deuterostomes and their modern counterparts. (CC BY-SA 4.0; Nobu Tamura via Wikipedia)

The adult body usually has five-part organization. They possess an internal skeleton (**endoskeleton**) composed of calcium carbonate plates just beneath the surface of the skin. The plates often bear spines that protrude through the skin. Echinoderms have numerous **tube feet** underneath each arm. The tube feet are connected to a system of pipes referred to as the **water vascular system**. Water enters the system by a sieve plate on the **aboral** surface. Each tube foot has a fleshy bulb or **ampulla** attached so that the entire structure looks like an medicine dropper or pipette. When muscles surrounding the ampulla contract, fluid inside the bulb moves down into the tube foot, extending it.

Large digestive glands produce enzymes necessary for digestion. Sexes are separate and gametes are shed into the water. The gonads are large due to the necessity of releasing large numbers of gametes into the marine environment. Coelomic fluid circulates substances and carries amoeboid cells that clean up particulate wastes. Gas exchange is done with numerous tiny gills that extend from the surface of the skin.

The nervous system consists of a central nerve ring with nerve branches extending into the arms. They do not have a brain.

Identify the blastopore. What structure in the adult does this give rise to? Notice that the embryo shows bilateral symmetry yet the adult is radial. The ancestral echinoderms were bilateral and bilateral symmetry is maintained in the larval stage.

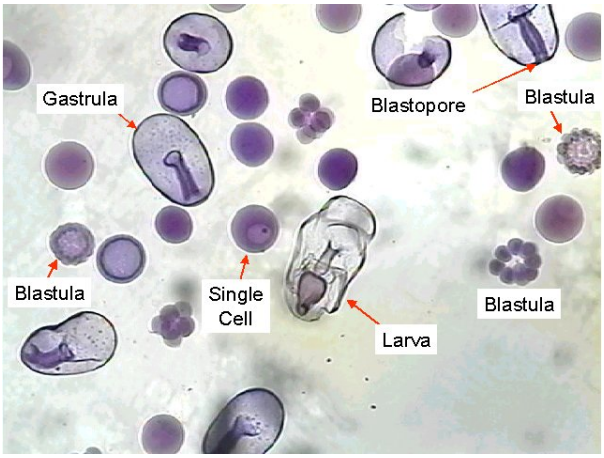

Figure **9.3.2**: Development (various stages)

Sea Star (Class Asteroidea)

Sea stars and their relatives are composed of a central disk, usually with five or a multiple of five arms (rays) extending outward. They feed on bivalves (clams) by pulling apart the shell and lowering their stomach into the mollusk, releasing enzymes and digesting the mollusk, then absorbing the digested material into the body of the starfish, where digestive glands in each arm continue the process of food breakdown.

Obtain a preserved sea star for dissection. Identify the oral and aboral surfaces. On the aboral surface, find the sieve plate (madreoporite), a structure that allows water to enter the water vascular system. Notice the spines that protrude from the skin. The word “echinoderm” means spiny-skinned.”

On the oral surface, identify the tube feet and mouth.

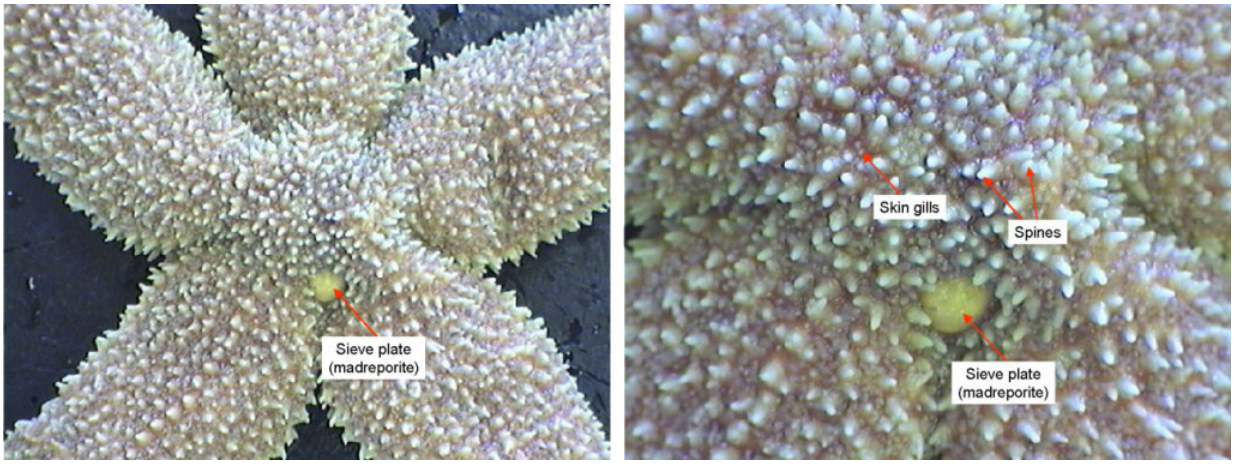

Figure **9.3.2**: Left: Aboral surface. Right: Close-up of the skin of a sea star.

Examine the oral surface of a sea star under a dissecting microscope and observe the spines. Most of the fleshy projections are **skin gills** and are used to absorb oxygen. Claw-like projections called pedicellariae function to capture small animals and protect the skin gills. A sieve plate (madreporite) located on the aboral surface allows water to enter the water vascular system.

To examine the internal structures, you will remove the skin from the aboral surface (see the diagram below). With scissors or a scalpel, cut along the side of one **arm** the entire length of the arm from the tip of the arm to the point where the arm attaches to the central disk. As you cut you will notice that there is a layer of **calcium carbonate plates** just below the surface of the skin. It will be necessary to cut through these plates.

Figure **9.3.3**

Cut around the tip and then cut along the opposite side of the arm. When you reach the base of the arm, continue cutting to the next arm and repeat this cutting procedure for this arm and the rest of the arms.

Figure **9.3.4**

At this point, you have cut the animal's skin into two halves, an upper surface and a lower surface.

Carefully, peel the skin back from the tip of one arm. It will be necessary to use a dissecting needle or a blunt probe to help you lift the skin while keeping the internal structures from being lifted away and damaged. Repeat this procedure for the remaining 4 arms. Use extra care to peel the skin away from the central disk of the animal. If your initial cuts along the sides of the arms were not sufficient, you may need to cut the side as you peel the skin back.

The stomach of the animal has two parts. The upper part is called the **pyloric stomach** and the lower part is called the **cardiac stomach**. When feeding, it extends the cardiac stomach out through the mouth and into the shell of a bivalve mollusk. It secretes digestive enzymes into the mantle cavity of the bivalve. The enzymes digest the bivalve's tissue. Digestion is completed within the pyloric stomach and the digestive glands in the arms (discussed below).

Identify the stomach and try to discern the cardiac and pyloric portions.

The **digestive gland** is the soft, brown material that fills most of the space in the arms. Remove or lift the digestive gland from one of the arms. The **gonads** are lighter in color and located underneath the digestive gland. They may be much smaller than the digestive gland. The size of the gonads depends on the stage of the reproductive cycle of the animal and may not be evident in some animals.

Observe the rows of **ampullae** along each side of the **ambulacral ridge**. The muscle surrounding these bulb-like structures can contract and extend the **tube feet** underneath.

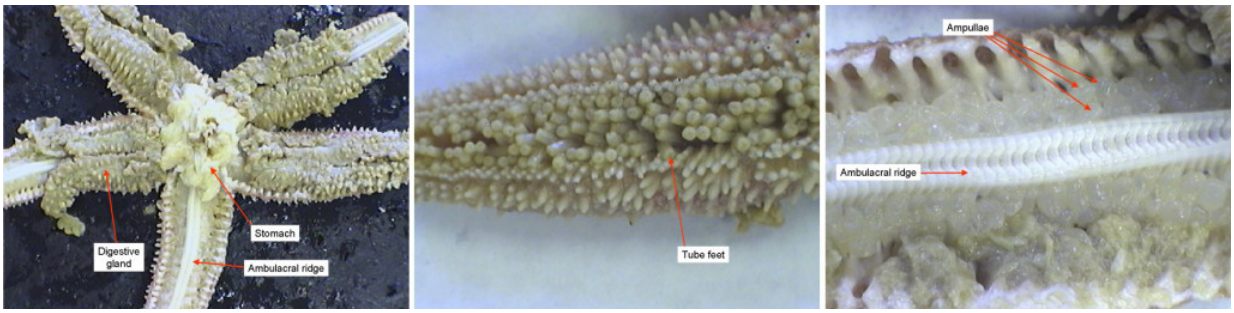

Figure **9.3.5**: Left: Internal structures. Middle: Tube feet. Right: Ampullae.

Other Echinoderms

- Sea Urchins, Sand Dollars—Class Echinoidea
- Brittle Stars—Class Ophiuroidea
- Sea Cucumbers—Class Holothuroidea
- Sea Lilies—Class Crinoidea

Examine a slide showing different stages of development in sea stars. Find the following stages: single cell, blastula, gastrula, and a later embryonic stage. Name and describe the type of cleavage exhibited by deuterostome embryos.

Figure **9.3.6**: Sea Urchin (Preserved) Oral Surface

Figure **9.3.7**: Sea Urchin Shell, Oral Surface

Figure 9.3.8: Sea Urchin Shell, Aboral Surface

Sea Cucumber, Preserved

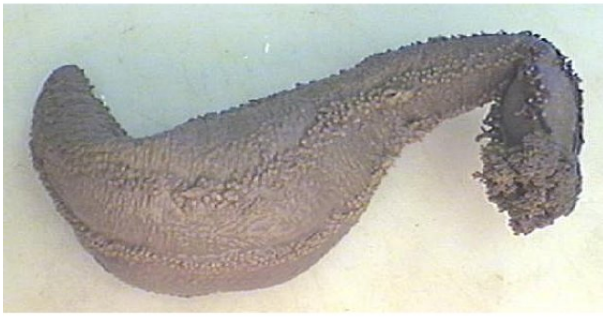

Figure 9.3.9: Sea Cucumber, Preserved

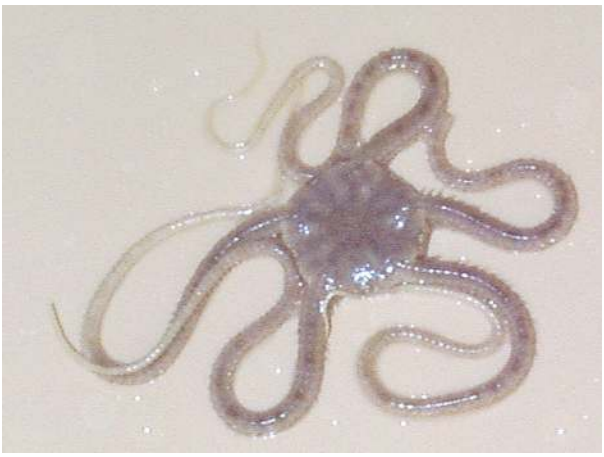

Figure 9.3.10: Brittle Star—aboral surface

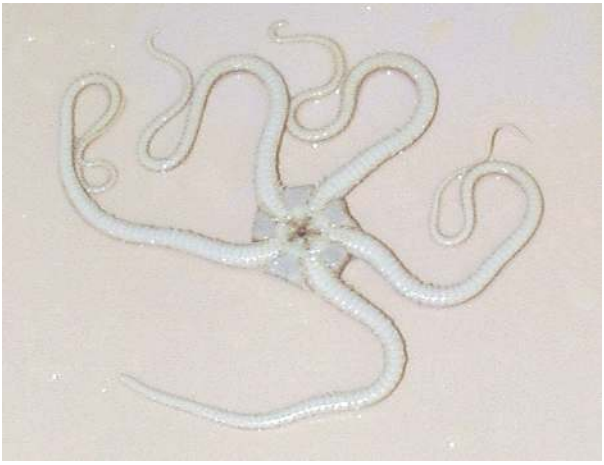

Figure **9.3.11**: Brittle Star—oral surface

Contributors and Attributions

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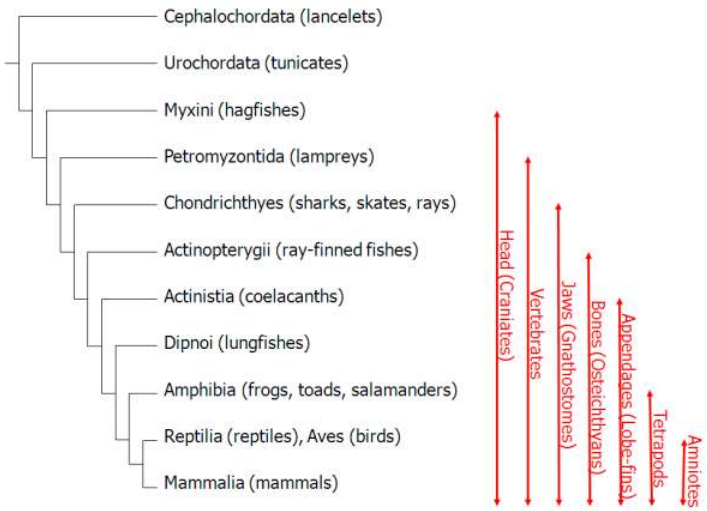
9.4: Reading- Chordates

Chordates

The diagram below shows evolutionary relationships among the major clades of chordates but avoids classification into subphylum and classes. For example, the close relationship between Myxini and the rest of the vertebrates can be seen even though there is uncertainty in the classification of Myxini.



Chordates exhibit bilateral symmetry. Chordates have the following characteristics at some point in their life history:

1. a dorsal, hollow nerve cord.
2. a dorsal supporting rod called a **notochord**. This is replaced by a vertebral column in vertebrates.
3. pharyngeal clefts (pouches). These develop into openings to the exterior (gill slits) in some chordates. Gill slits functioned as a mechanism for filter-feeding in primitive vertebrates. The gills of fish function in gas exchange.
4. a postanal tail. In most other kinds of animals, the digestive tract extends the entire length of the animal.

Subphylum Urochordata (Tunicates)

Larvae

The larvae of tunicates resemble the ancestral chordate. It has chordate characteristics and looks like a tadpole. The free-swimming larva develops into a sessile, filter-feeding adult.

Adult

The adult has a thick-walled body sac and an incurrent siphon and an excurrent siphon. Gill slits are the only chordate feature retained by the adult form. In some tunicates, the adult form may have been lost. These animals retained the larval form as adults.

Subphylum Cephalochordata (Lancelets)

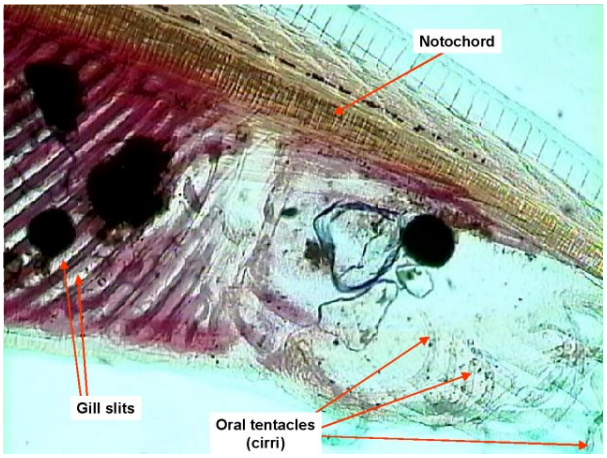
Examine a slide of a lancelet using a dissecting microscope.

Although this animal is not a vertebrate, it has all three of the chordate characteristics. Identify the **notochord**, **nerve chord**, and **pharyngeal gill slits**.

Notice the segmented pattern of the muscles, also a chordate characteristic.

When feeding, water enters the mouth and moves into the **pharynx**, a chamber posterior to the mouth. The gill slits are openings in the wall of the pharynx and function to allow water to pass out of the pharynx while filtering particles out of the water. The particles move into the gut for digestion. After passing through the gill slits, water exits via the atriopore.

Examine a preserved lancelet and observe the segmented pattern of muscles and the atriopore located on the ventral surface posterior to the pharynx.



Craniates

Craniates are chordates with a head. The head contains sensory organs because it is in front of the animal as it moves through the environment.

The evolution of a head with well-developed sensory organs and a corresponding large brain enabled these animals to be active and to feed by predation or other means that required an active animal.

Hagfishes (Class Myxini)

Hagfishes have a cartilaginous skull but do not have jaws. They do not have vertebrae; their notochord provides the support necessary for their muscles to produce movement.

Subphylum Vertebrata (Vertebrates)

The notochord of vertebrates is generally replaced by a vertebral column composed of numerous small bones called vertebrae that are joined together to form a flexible supporting structure. In most vertebrates, the vertebrae surround the spinal cord.

The vertebral column allows the body to flex and provides attachment sites for muscles. In addition, it surrounds and protects the nerve cord.

They exhibit extreme cephalization and possess complex sense organs (ex: eyes, ears).

Lampreys (Class: Petromyzontida)

Lampreys do not have jaws. Most species of lampreys are parasites. They attach to host fish and feed on the blood of the host.

The larvae are filter feeders that live in freshwater streams. As they mature, they move downstream to the ocean (or lakes) and begin a parasitic life style.

The skeleton is cartilage and the notocord persists in the adult.

Gnathostomes

Gnathostomes are vertebrates with jaws. The evolution of jaws promoted the switch from filter-feeding to predation and thus promoted an active life style. Jaws evolved from the forward gill supports in fish.

The appearance of jaws transformed the worlds ecology due to improved predation and herbivory. As a result, complex food chains evolved.

Filter feeding (gill slits) became less important with the evolution of jaws because jaws allowed the animal to chew larger food items and to capture prey. Gills became more important in gas exchange.

Aquatic gnathostomes have a lateral line system. This system is composed of a line of sensory organs on each side of the body. It is able to detect vibrations in the water.

Cartilaginous Fish (Class: Chondrichthyes)

Chondrichthyes include the sharks, and rays. The cartilage skeleton of sharks is partially hardened with calcium. This type of skeleton is strong and is more flexible and lighter than a bony skeleton. The bodies of cartilaginous fish are covered with small toothlike scales. Their teeth are larger versions of these scales.

They do not have a swim bladder but the oil-storing capacity of their livers improves their buoyancy. The shape of the head and caudal fin also lift the animal as it swims. Sharks must swim to keep from sinking.

Some sharks are fast-swimming predators; others are filter feeders.

Reproduction

Fertilization is internal. The pelvic fin is used to transfer sperm to the female.

Some species are **oviparous**—they lay eggs that hatch outside the mother's body; some are **ovoviviparous**—the eggs are retained within the body and young are born alive; and a few are **viviparous**—they receive some nourishment via a placenta that develops from the yolk sac of the egg.

The reproductive, digestive and excretory system exit the body through a common opening called a **cloaca**.

Osteichthyans

Osteichthyans have an ossified (bony) skeleton. The skeleton is hardened with calcium phosphate.

Characteristics of Aquatic Osteichthyans (Bony Fish)

The gills are covered by an operculum so that the gill chamber is enclosed and protected. A swim bladder and is used for buoyancy. It evolved from lungs. The gas content, and thus buoyancy, can be regulated by transfer to and from the blood.

Bony fish have broad, flat scales. The skin contains mucous secreting glands that reduce friction as the fish swims through the water. A lateral line system detects vibrations in the water. Most species are oviparous. Bony fish are the largest group of

vertebrates. Approximately 49,000 species have been identified.

Ray-finned Fishs (Class Actinopterygii)

The fins are supported by spinelike rays. In ray-finned fishes, the lungs gave rise to the swim bladder which gives the fish buoyancy.

Lobe-fins

Lobe-finned fish have fins located on fleshy appendages. This group includes coelacanths (class Actinistia), Lungfishes (class Dipnoi) and tetrapods. Coelacanths were thought to have been extinct for 75 million years until one was captured in 1938 off the southeastern coast of Africa. The first vertebrate animals to develop lungs were fish. The lungs developed from a sac-like pocket of tissue that formed in the pharynx.

Lungfishes are a group of lobe-finned fish that inhabit stagnant fresh water ponds that dry up. Their lungs allow them to gulp oxygen from the air when it has been depleted from the water. Their lobe fins enable them to walk under water. The ancestors of lungfish gave rise to amphibians.

Contributors and Attributions

CHAPTER OVERVIEW

10: Cardiovascular/Respiratory System and Pig Dissection

10.1: Fetal Pig Dissection Lab

Learning Objectives

- Learn about the anatomy of the pig as an example of a vertebrate mammal
- Identify structures on the pig and know their functions
- Identify structures that are a part of the digestive system, respiratory system, circulatory system, reproductive system, and excretory system
- Compare pig anatomy to human anatomy

Download a PDF of the lab to print.

Procedure

Access the page “Reading: Fetal Pig Dissection.” The pig may or may not be injected with dye. Follow the steps in the handout to view the external pig anatomy.

Questions

1. Based on the external anatomy is your pig male or female? How can you tell?
2. Can you locate any hair on your pig, a common characteristic of mammals? Where is there the most hair?

Follow the steps in the handout to cut open the pig beginning with the mouth. Make sure you can locate the following structures in the mouth region:

- Glottis
- Epiglottis
- Hard and soft palate
- Pharynx
- Trachea

Question

1. What do the hard and soft palate separate?

Cut into the neck region. Make sure you can locate the following structures:

1. Trachea
2. Thymus
3. Thyroid
4. Esophagus

Question

1. Is the trachea in front of or behind the esophagus?

Cut into the thoracic cavity beneath the rib cage. Make sure you can locate the following structures:

1. Heart
2. Lungs
3. Bronchi
4. Diaphragm

Questions

1. How many chambers does the pig heart have?
2. How does the size of the pig lungs compare to the size of the frog lungs you dissected previously?
3. What role does the diaphragm play in respiration?
4. What cavity contains the lungs?
5. What cavity contains the heart?

Focus next on the abdominal cavity. First look at the digestive system organs. Make sure you can locate the following organs:

1. Stomach
2. Spleen
3. Liver
4. Gallbladder
5. Small intestine
6. Large intestine
7. Pancreas

Questions

1. What is the function of the liver?
2. What is the function of the gallbladder?
3. What type of digestion occurs in the stomach?
4. Name the three sections of the small intestines in order.
5. Name one process that occurs in the large intestine.
6. Which digestive organs located in the abdominal cavity are considered to be accessory organs?

Also in the abdominal cavity you will find the excretory system organs. Make sure you can locate:

- Kidneys
- Bladder

Finally in the abdominal cavity are the reproductive organs. If you have a female pig look at another group's male pig and vice versa. You should be able to find:

- Testes (male)
- Uterus with horn (female)
- Ovary (female)

The arteries and veins are challenging to identify, especially if the pig is not injected with dye. Arteries carry blood away from the heart. Veins return blood to the heart. Try to identify the following:

1. Aorta
2. Pulmonary artery
3. Coronary arteries
4. Jugular vein
5. Carotid artery
6. Renal artery
7. Renal vein

Questions

1. Where does the renal vein transport blood?
2. Where does the pulmonary artery transport blood?

View the human torso model on your bench. Locate the same organs you found above on the fetal pig.

Questions

1. List three similarities between the pig internal anatomy and human internal anatomy.
2. List three differences between the pig internal anatomy and human internal anatomy.

10.2: Fetal Pig Dissection Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Pig Dissection

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
preserved pig	1 per table	helpful to have a few male and a few female pigs
dissection kit	1 per table	should include scalpel, scissors, forceps, dissection needles, dissection pins
dissection tray	1 per table	
gloves	1 pair per student	latex and non latex options in various sizes
lab coat	1 per student	
goggles	1 pair per student	
dissection waste container	1 per class	dissection waste should not go in regular trash

10.3: Reading- Fetal Pig Dissection

The fetal pig that you will dissect has been injected with a colored latex (rubber) compound. The arteries have been filled with red latex and the veins with blue. An incision was made on the side of the neck to enable the injections. The incision can be seen in the first photograph below.

Several different pig dissections were used to obtain the photographs below. As a result, a structure shown in one photograph may look different than the same structure shown in another photograph.

Click on any of the photographs to view enlargements. Links to high-resolution, unlabeled photographs are also provided for many of the photographs.

Orientation

The following words will be used to help identify the location of structures.

- **Anterior** refers to the head end. If a structure is anterior to another, then it is closer to the head.
- **Posterior** refers to the tail end.
- **Dorsal** refers to the back side. The pig in figure 1 is lying on its dorsal side.
- **Ventral** is the belly side. It is opposite the dorsal side. The pig in figure 1 below has its ventral side up.

External Structures

Obtain a fetal pig and identify the structures listed in figure 1. Use figures 1–4 below to identify its sex.

Use your pig and also a pig of the opposite sex to identify the structures in the photographs below. The word “urogenital” refers to an opening that serves both the urinary (excretory) and the reproductive systems.

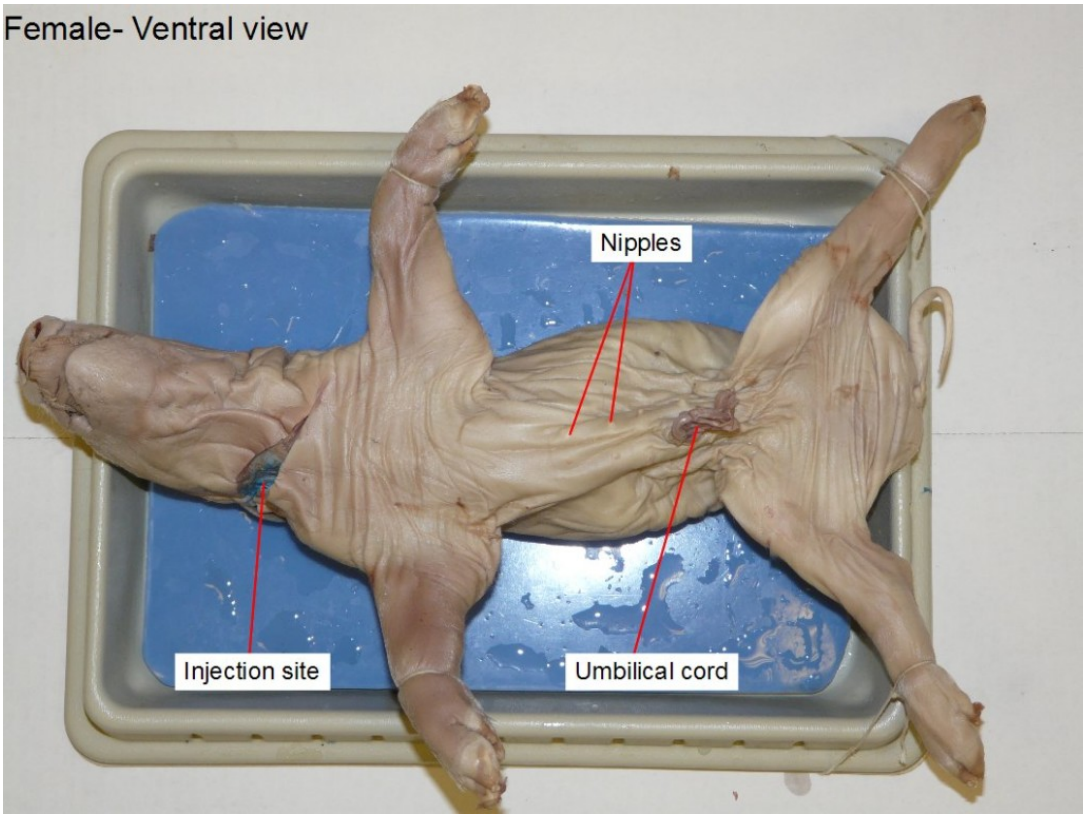


Figure 1. Female: injection site, nipples, umbilical cord

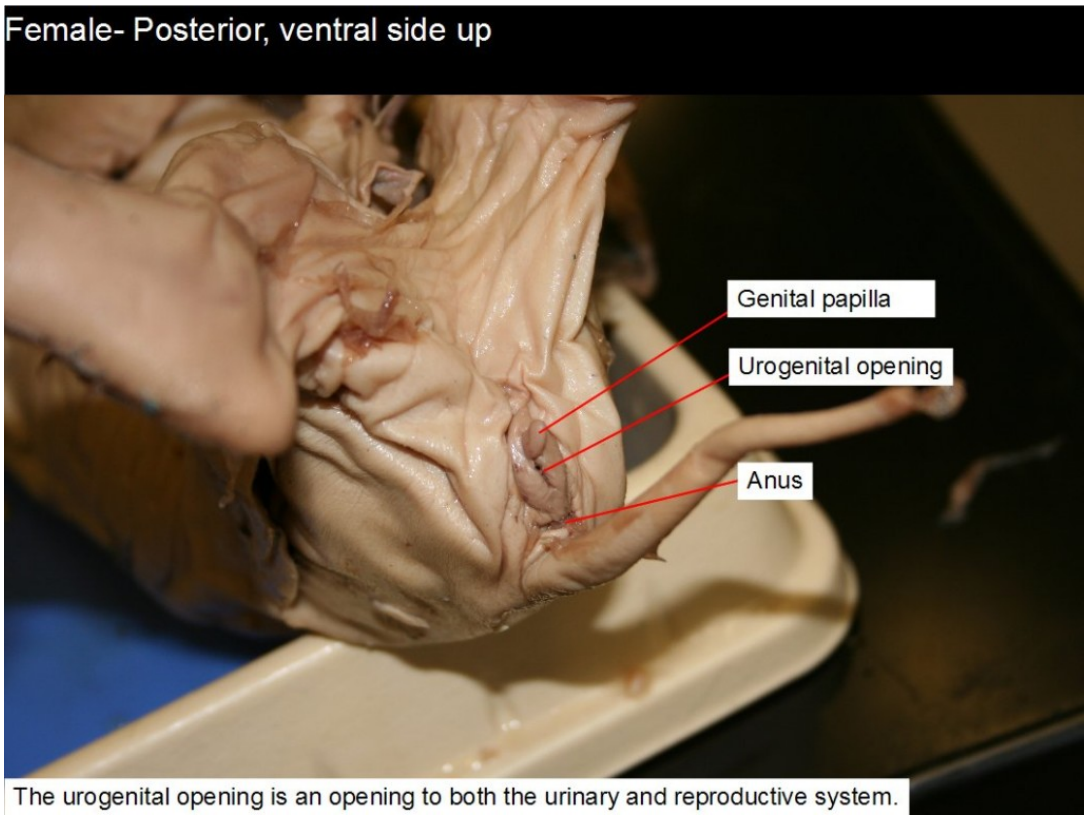


Figure 2. Female: genital papilla, urogenital opening, anus

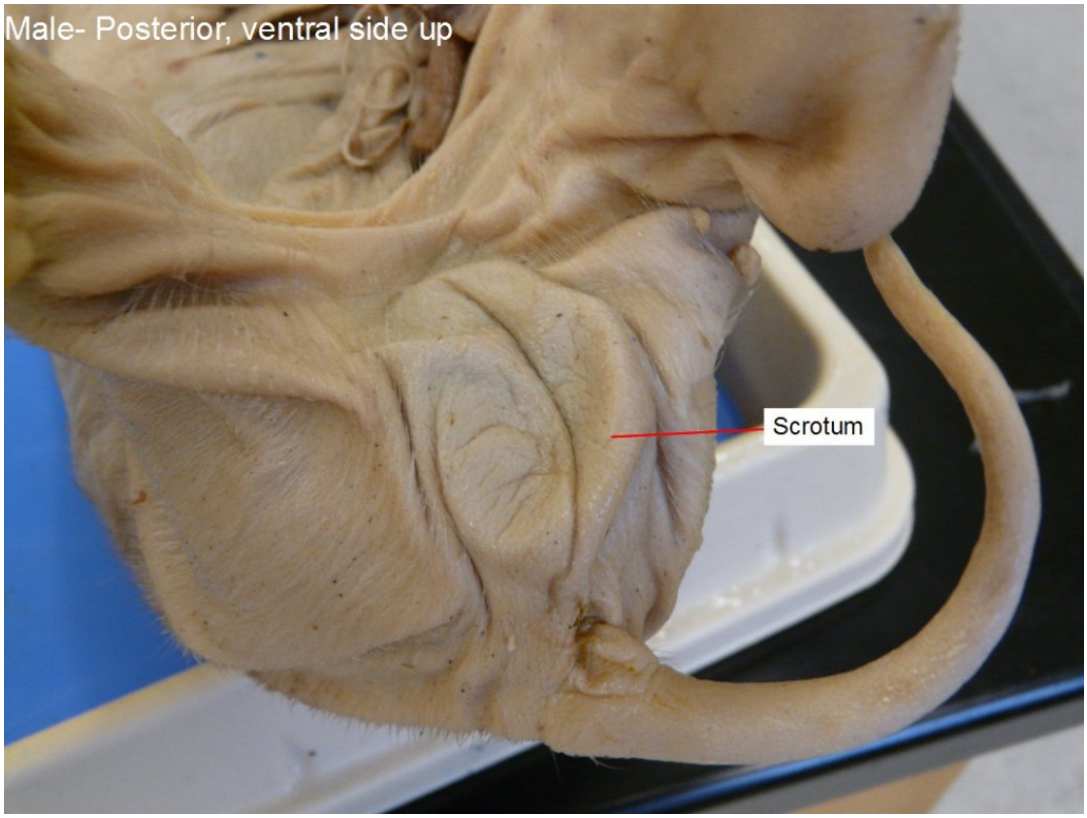


Figure 3. Male: scrotum

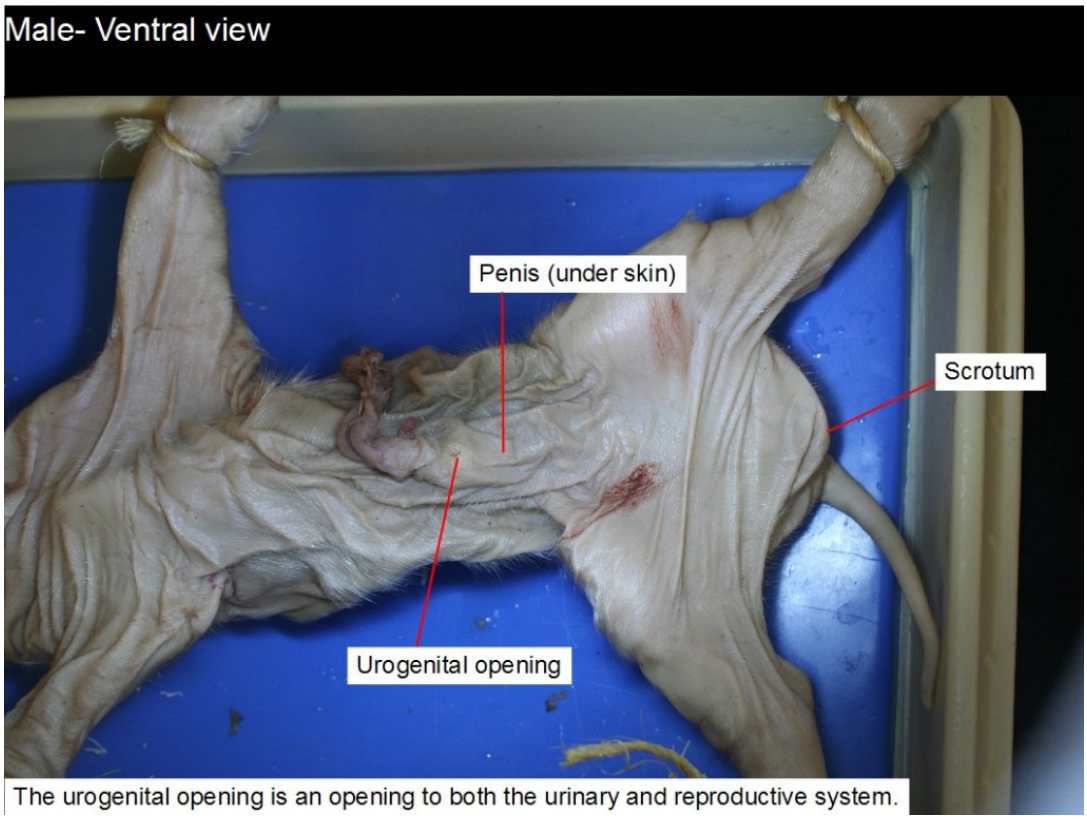


Figure 4. Male: urogenital opening, penis, anus

Preparation and Initial Cuts

Tie one front leg of the animal with a string that passes underneath the dissecting pan to the other leg. Repeat this with the back leg.

The first step is to tie the pig to the dissecting pan so that it remains in place for easy viewing. A string tied to one front leg of the animal passes underneath the dissecting pan to the other leg. A string passing under the pan also holds the two back legs in place.

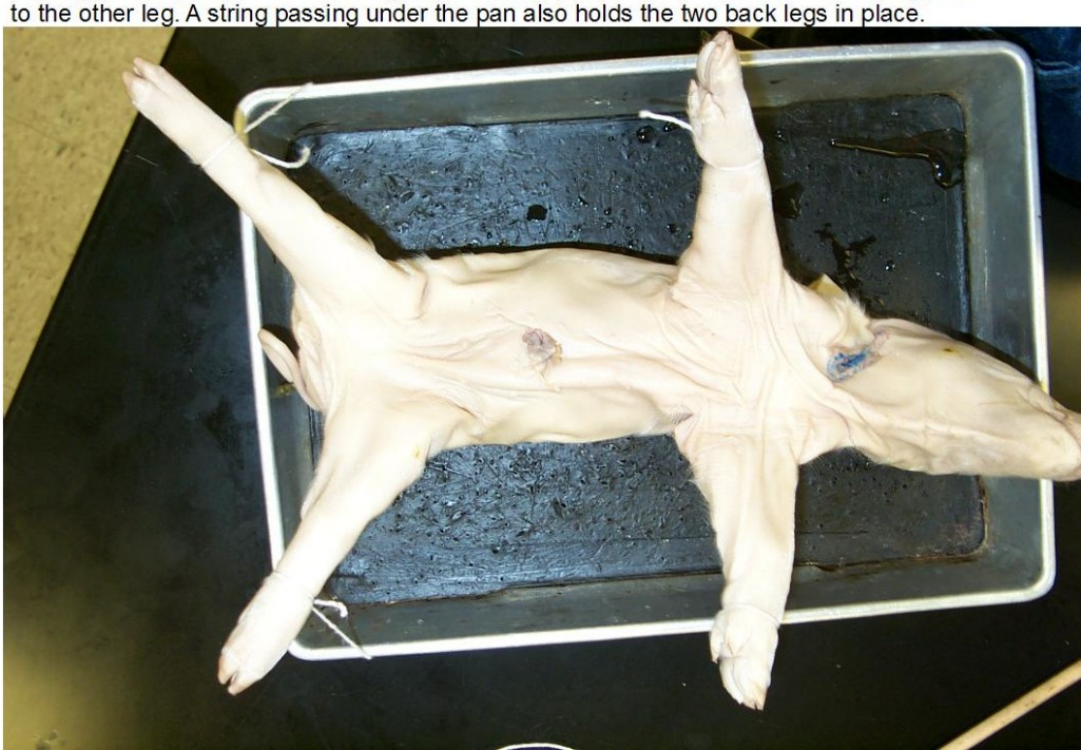


Figure 5.

Insert one blade of scissors through the body wall on one side of the umbilical cord and cut posteriorly to the base of the leg as shown in figure 6. Continue cutting from the anterior end of this cut so that it resembles an upside-down U. Your finished cut will be anterior to the navel and along each side of the navel. The flap of body wall that contains the navel can be folded posteriorly to reveal the internal organs of the abdomen.

One blade of the scissors is inserted through the body wall on one side of the umbilical cord and a cut is made posteriorly to the base of the leg.

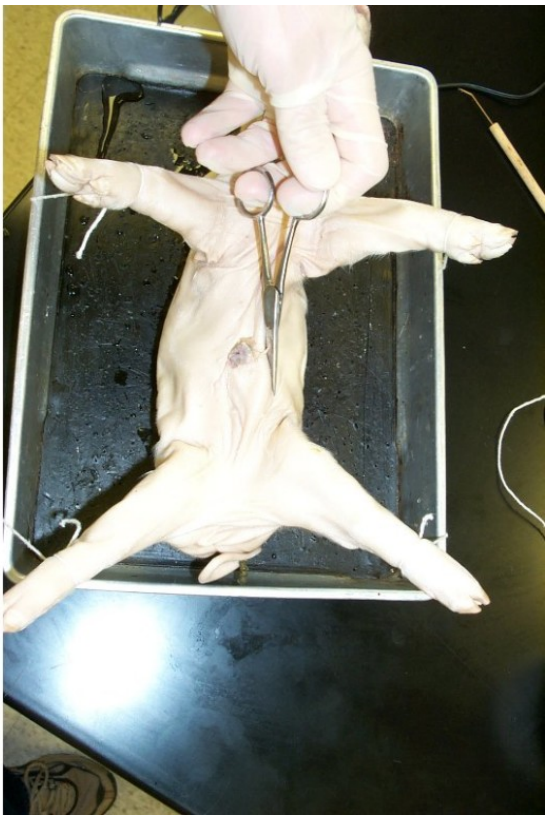


Figure 6.

The cut is extended from the anterior end around the navel and then posterior again so that it resembles an upside-down U.

The finished cut is anterior to the navel and extends in a posterior direction on each side of the navel.

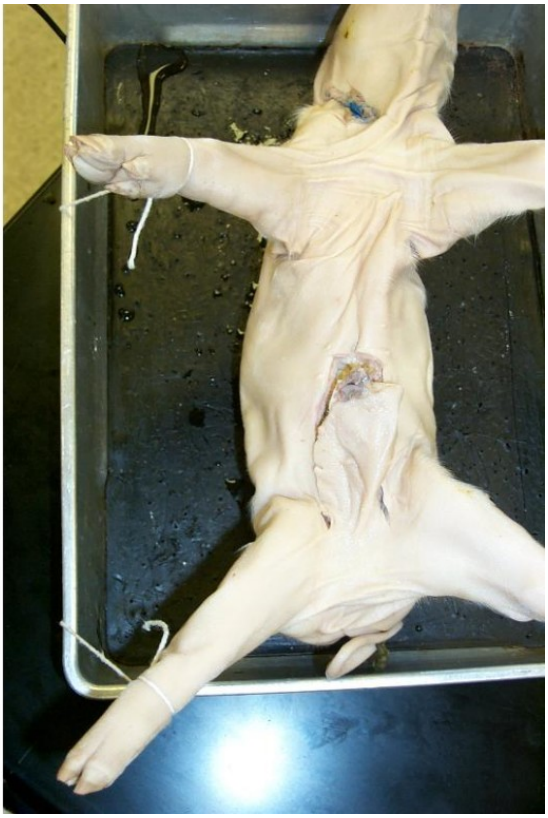


Figure 7.

The flap of body wall that contains the navel can be folded posteriorly to reveal the internal organs of the abdomen.

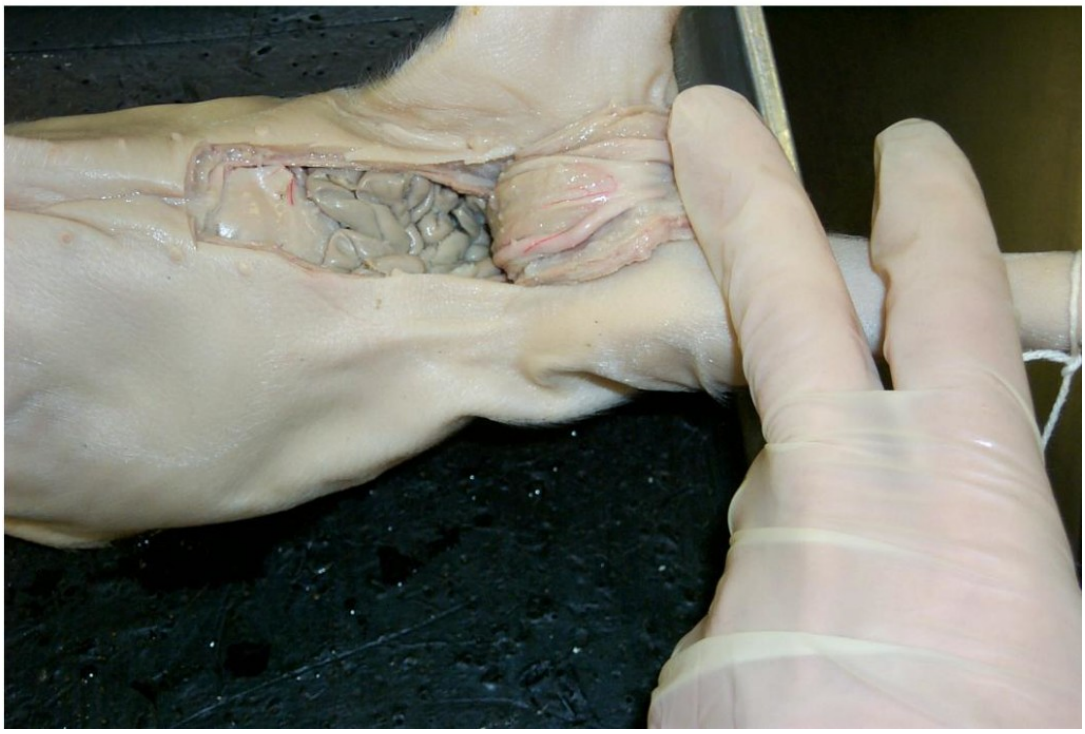


Figure 8.

Extend a single cut along the midline of the ventral surface of the animal to about 2 cm. from the chin. Cut completely through the body wall in the abdominal area but keep the cut shallow in the neck region.

A single cut is extended along the midline of the ventral surface of the animal to about 2 cm. from the chin. In the abdominal area, this cut is completely through the body wall but in the neck area, care must be taken to keep it shallow so that the underlying glands are not destroyed.

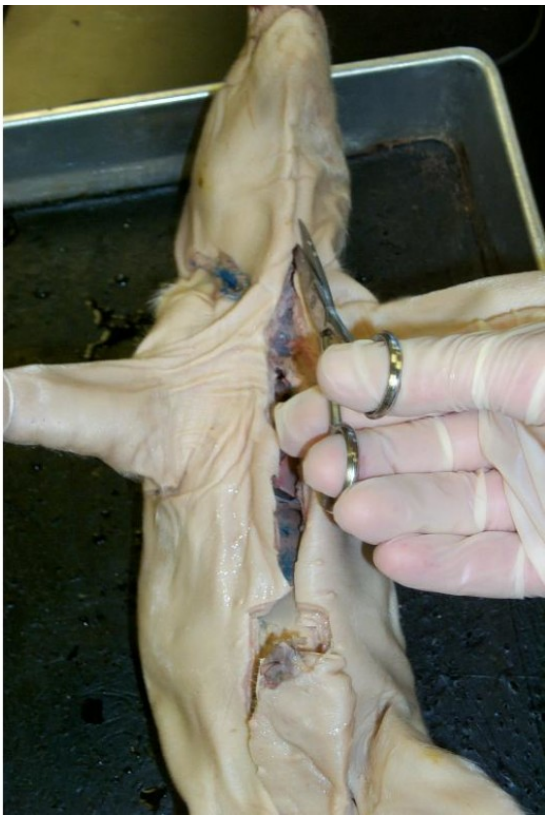


Figure 9.

A cut is made on the side of the animal from the point just posterior to the diaphragm dorsally. A similar cut is made on the other side. These two cuts will enable you to spread open the abdominal cavity.

A cut is made on the side of the animal from the point just posterior to the diaphragm dorsally. A similar cut is made on the other side. These two cuts will enable you to spread open the abdominal cavity.

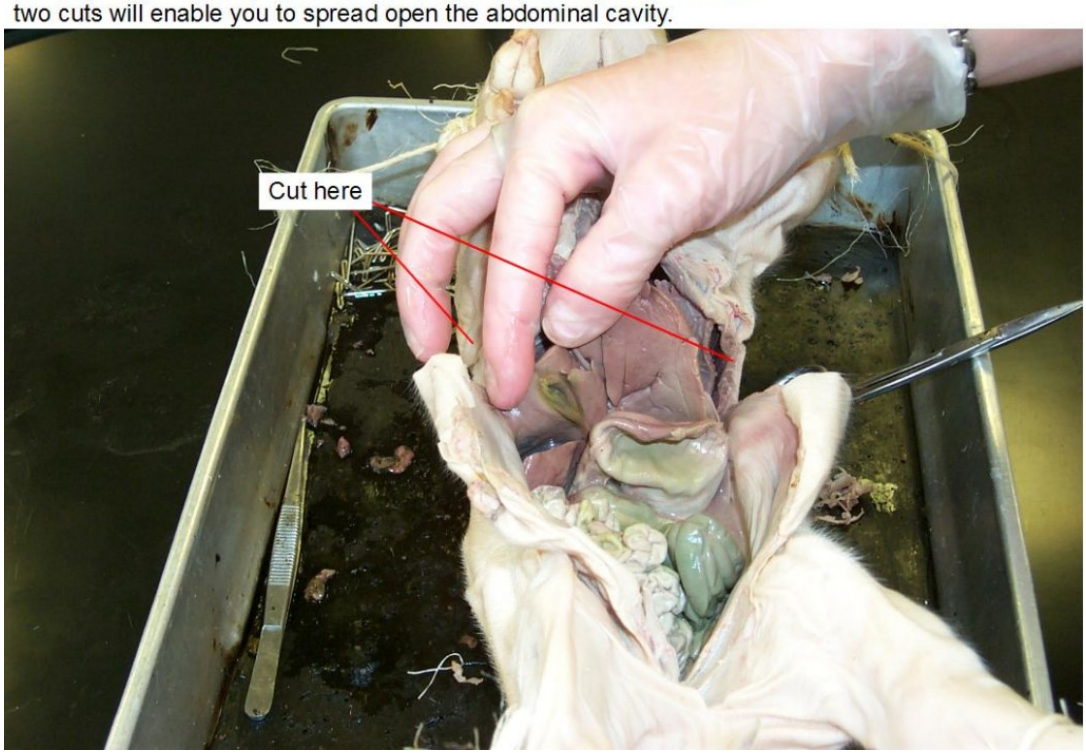


Figure 10.

Mouth and Neck Region

Use a scalpel to cut the sides of the mouth so that the bottom jaw can be opened for easier viewing (see figure 11). You will need to cut through the musculature and the joint that holds the lower jaw to the skull.

A scalpel is used to cut the sides of the mouth so that the bottom jaw can be opened for easier viewing. It is necessary to cut through the musculature and the joint that holds the lower jaw to the skull.

Figure 11.

Open the jaw wide enough so that the **glottis** and **epiglottis** are exposed. The epiglottis projects up through the soft palate into a region called the **nasopharynx**. The **hard palate** and **soft palate** separate the nasal and oral cavities. When breathing, air passes through the nasal passages to the **pharynx**. The pharynx is the space in the posterior portion of the mouth that both food and air pass through. From the pharynx, it passes through the glottis to the **trachea**.

The jaw is opened wide enough so that the glottis and epiglottis are exposed. The epiglottis projects up through the soft palate into a region called the nasopharynx. The hard palate and soft palate separate the nasal and oral cavities. When breathing, air passes through the nasal passages to the pharynx. The pharynx is the space in the posterior portion of the mouth that both food and air pass through. From the pharynx, it passes through the glottis to the trachea.

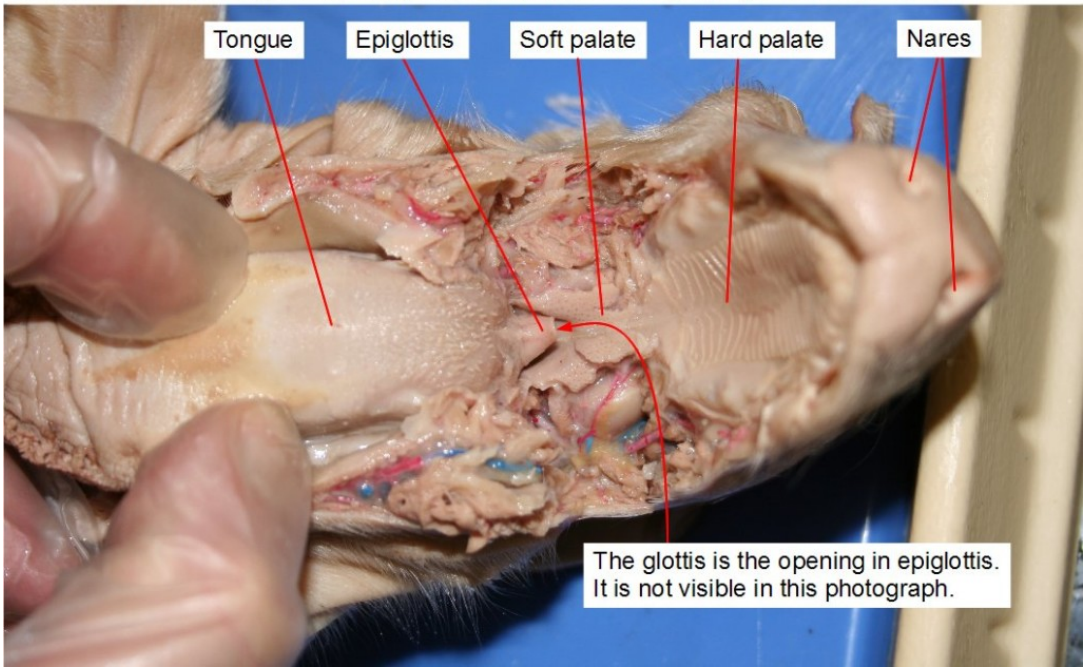


Figure 12. Hard palate, soft palate, glottis, epiglottis, and tongue.

Carefully, peel the skin away from the incision in the neck region using a blunt probe (a needle or the point of scissors will do if a blunt probe is not available). Use the probe to peel away muscle tissue until the thymus gland on each side of the trachea is exposed.

Use a probe to separate the two lobes of the thymus gland and to further separate the musculature over the trachea. The thyroid gland is darker and lies between the posterior ends of the two lobes of the thymus gland.

The skin is carefully peeled away from the incision in the neck region using either a blunt probe, a needle, or the point of scissors. The muscle tissue around the thymus gland is also peeled away until the thymus gland on each side of the trachea is exposed.

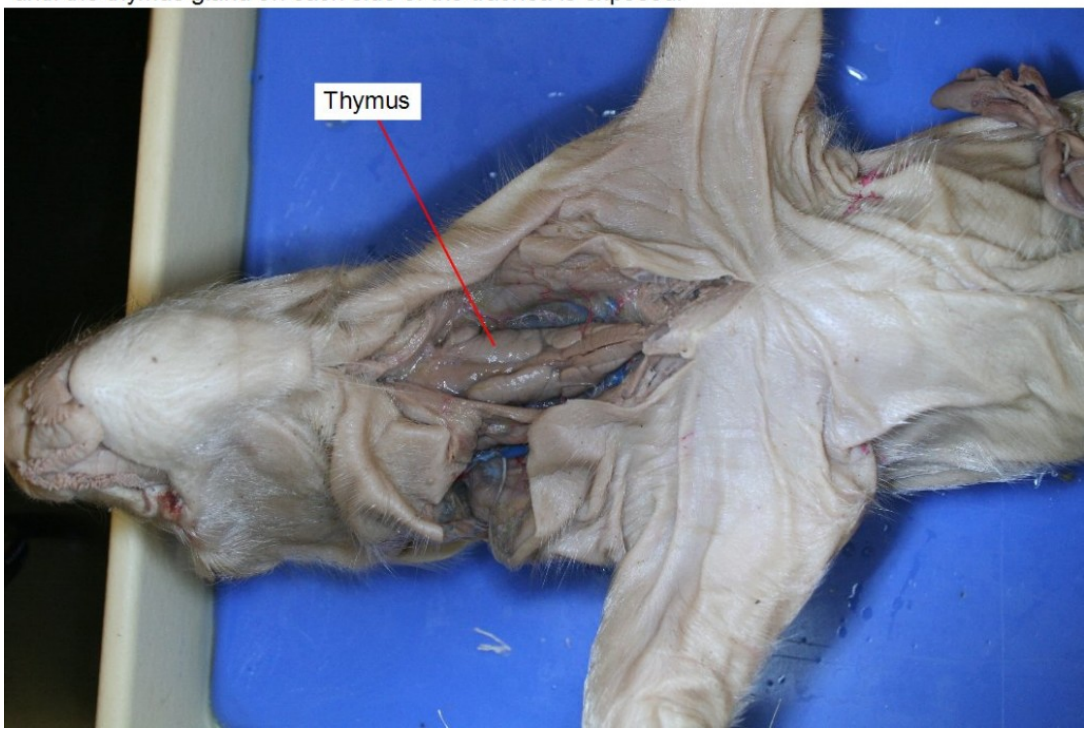


Figure 13. Thymus

A blunt probe is used to separate the two lobes of the thymus gland and to further separate the musculature over the trachea. The thyroid gland is darker and lies between the posterior ends of the two lobes of the thymus gland.

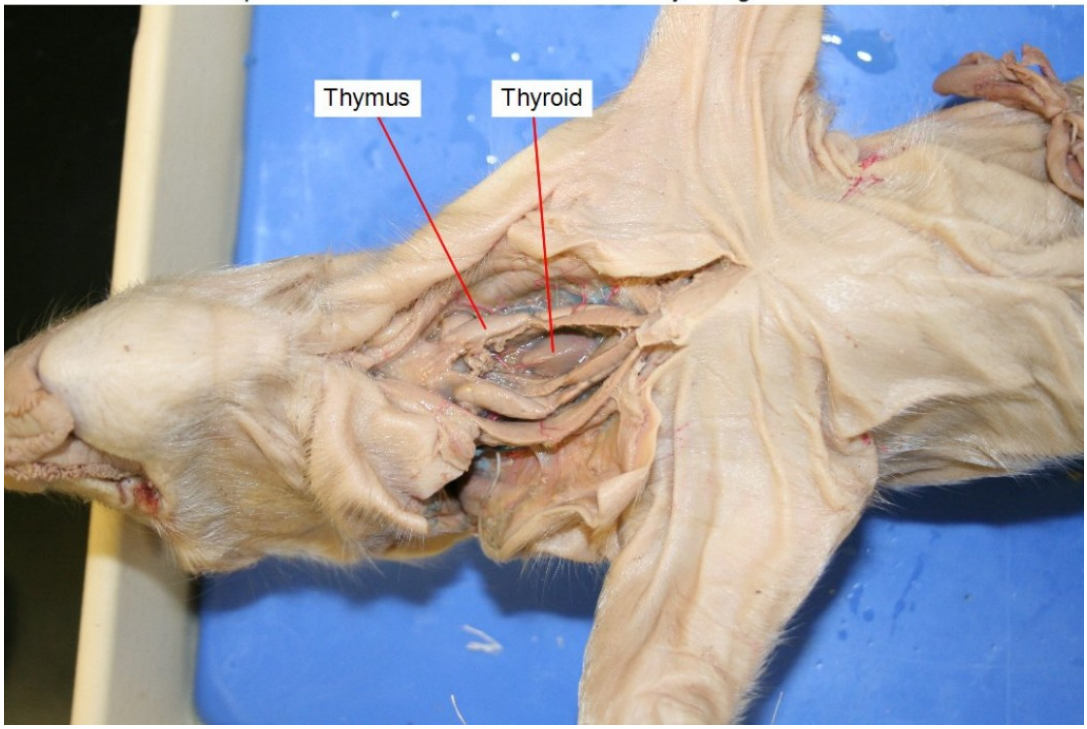


Figure 14. The surrounding tissues have been separated to reveal the thyroid gland.

Continue separating the tissue with a probe until the **trachea** and **esophagus** are exposed. The esophagus is dorsal to the trachea. The large hard structure attached to the trachea is the **larynx**. It contains the vocal chords.

In the photograph below, the heart and blood vessels of the neck region have been removed so that the trachea can be seen more clearly. You should not remove these structures yet because you will need to identify the blood vessels later in the dissection.

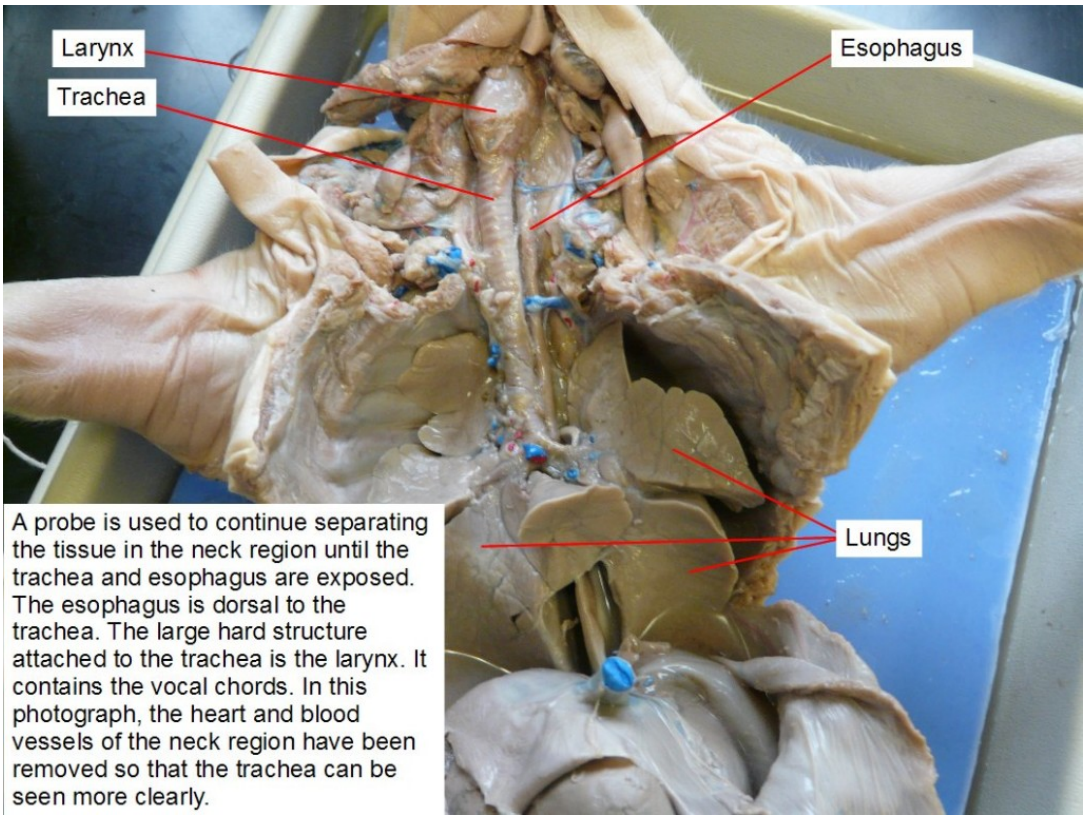


Figure 15. Esophagus, larynx, trachea, bronchus, and lungs.

Respiratory System

Observe how the **diaphragm** attaches to the body wall and separates the abdominal cavity from the lung (pleural) and heart (pericardial) cavities (figure 16 and 18 below). Contraction of the diaphragm forces air into the lungs.

You have already seen the nasopharynx, hard palate, soft palate, epiglottis, glottis, trachea, and larynx. Follow the trachea to where it branches into two **bronchi** and observe that each bronchus leads to a **lung**. The left lung contains three lobes and the right lung contains four. Each lung is located in a body cavity called a **pleural cavity**.

The diaphragm attaches to the body wall and separates the abdominal cavity from the lung (pleural) and heart (pericardial) cavities. Contraction of the diaphragm forces air into the lungs.

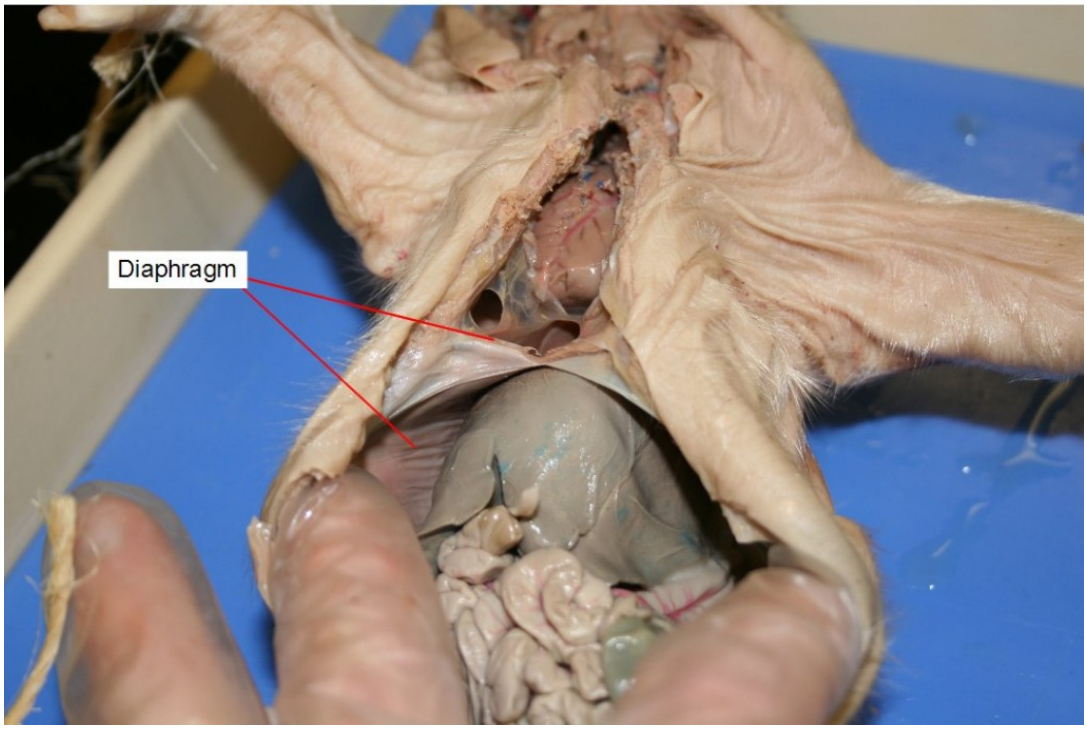


Figure 16. Diaphragm.

In this photograph, the diaphragm has been cut so that the body wall can be spread open to reveal the lungs.

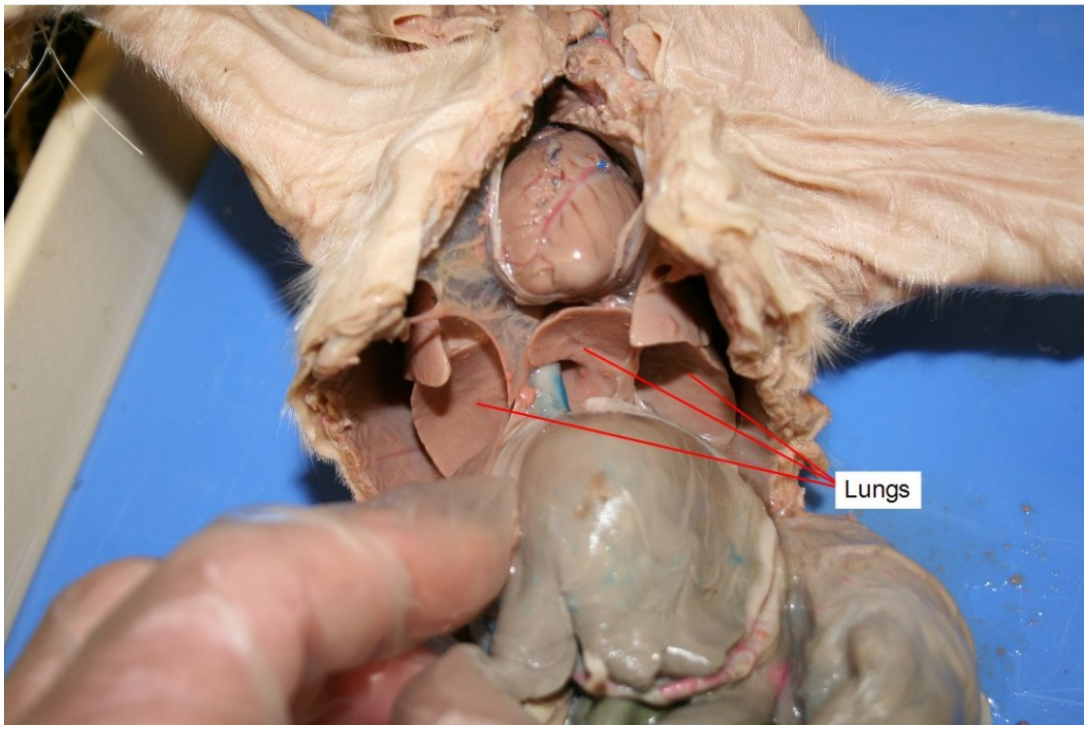
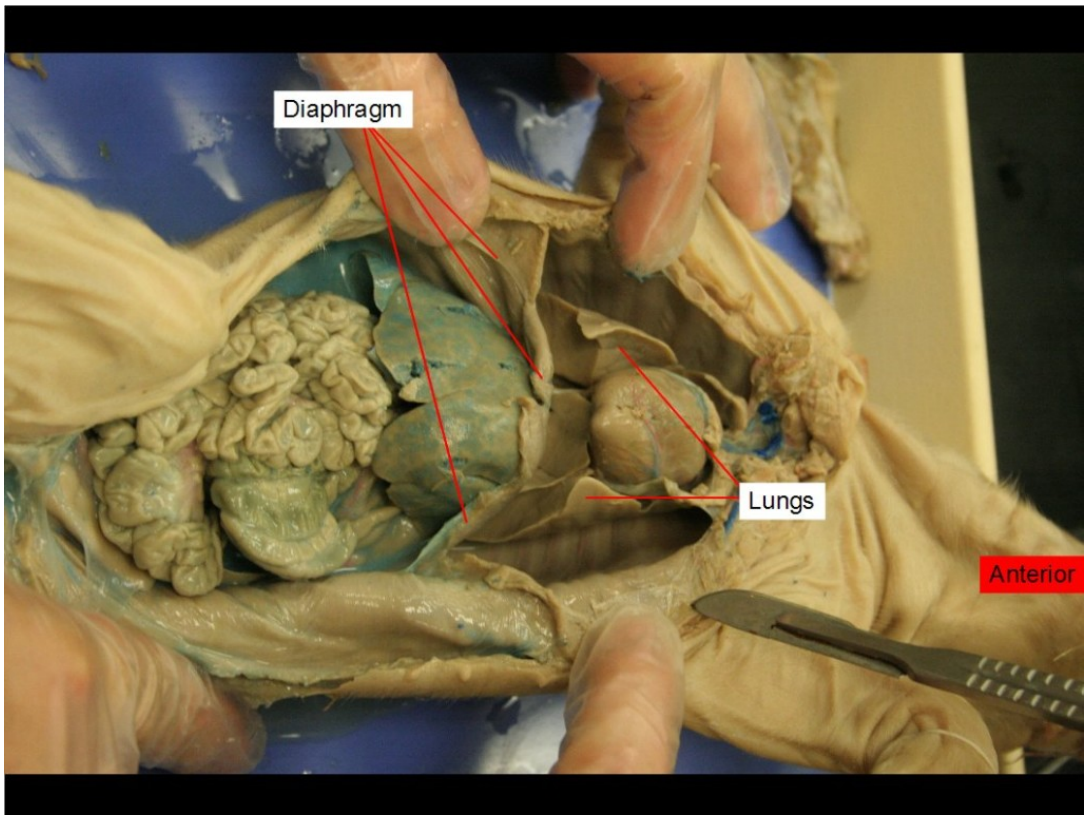


Figure 17. Lungs



18. Lungs, diaphragm.

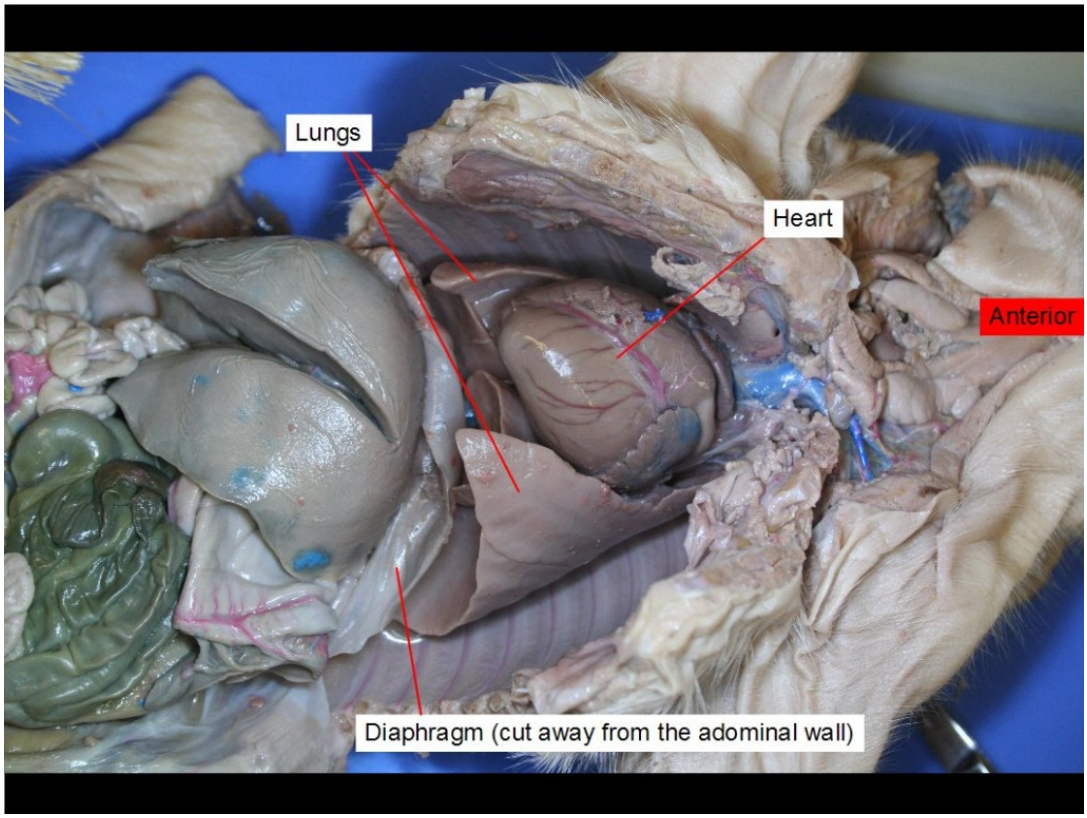


Figure 19. Lungs, diaphragm (cut)

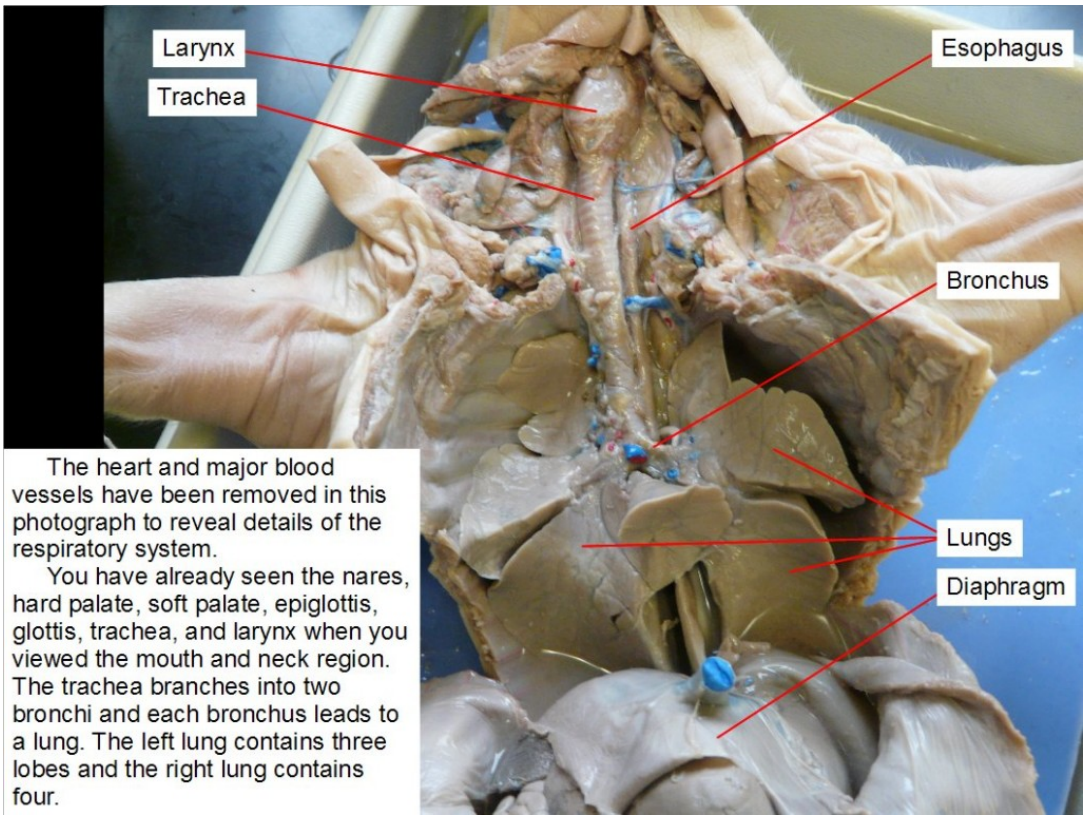


Figure 20. Esophagus, larynx, trachea, bronchus, and lung.

Digestive System

You have already seen how the **esophagus** leads from the **pharynx** through the neck region. Using a probe, trace follow the esophagus to the **stomach**. Identify the **small intestine** and **large intestine**. Find the posterior part of the large intestine called the **rectum** and observe that it leads to the **anus**. Locate the **cecum**, a blind pouch where the small intestine joins the large intestine.

Identify the **liver**. Lift the right lobe and find the **gallbladder**. This structure stores bile produced by the liver. Find the **bile duct** that leads to the small intestine. The **pancreas** is located dorsal and posterior to the stomach. It extends along the length of the stomach from the left side of the body (your right) to the point where the stomach joins the small intestine. Lift the stomach and identify this light-colored organ.

The **spleen** is an elongate, flattened, brownish organ that extends along the posterior part of the stomach ventral to (above) the pancreas.

The cecum is a blind pouch where the small intestine joins the large intestine. It houses bacteria used to digest plant materials such as cellulose. The cecum is large in herbivores but much of it has been lost during evolution in humans. The appendix in humans is the evolutionary remains of a larger cecum in human ancestors.

Food passes through the esophagus to the stomach, small intestine, and large intestine. The first part of the small intestine is the duodenum. Secretions released from the pancreas and gall bladder empty into the duodenum. In this photograph, the liver has been lifted to show the gall bladder attached underneath.

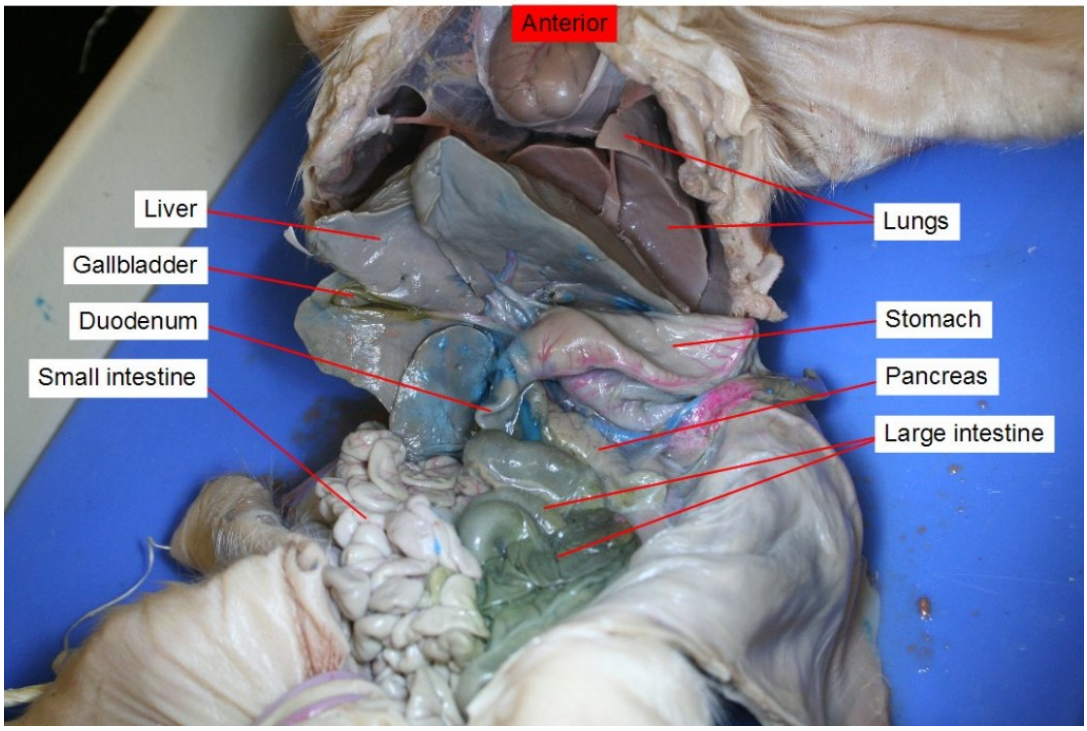


Figure 21. Duodenum, gallbladder, liver, lungs, large intestine, pancreas, small intestine, stomach. The liver has been lifted to reveal the gallbladder.

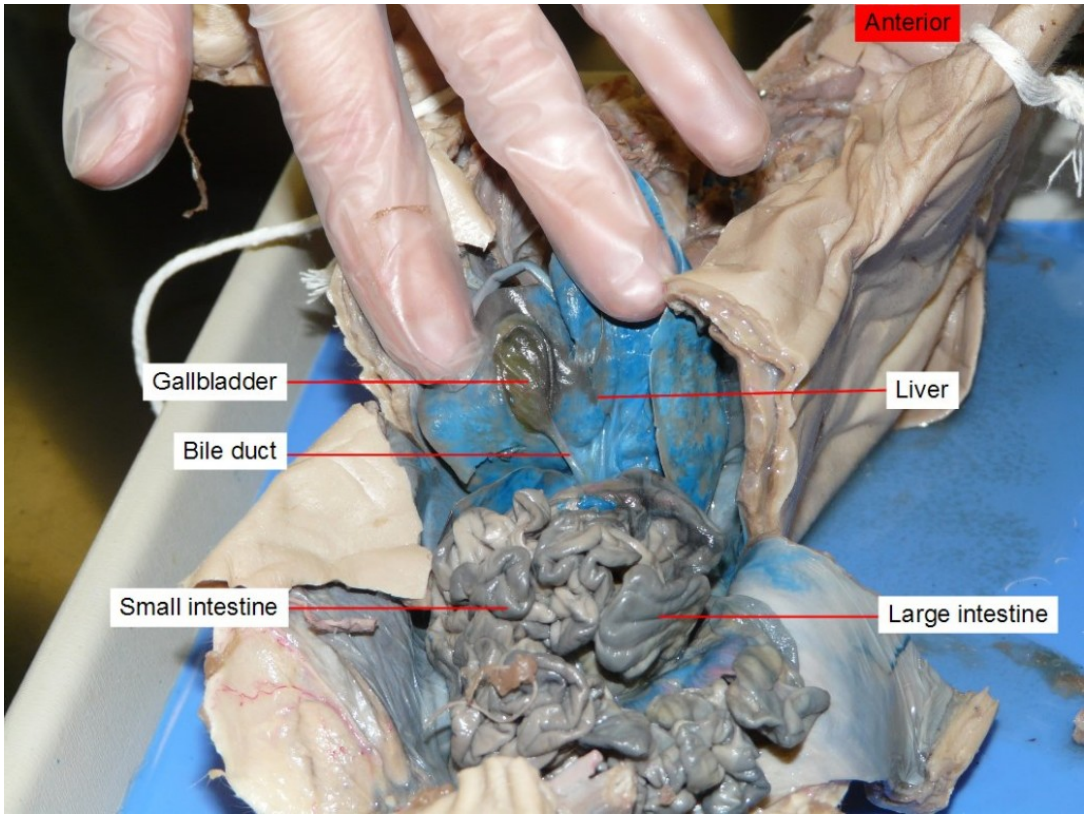


Figure 22. bile duct, gallbladder, large intestine, liver, and small intestine. The liver has been lifted to reveal the gallbladder.

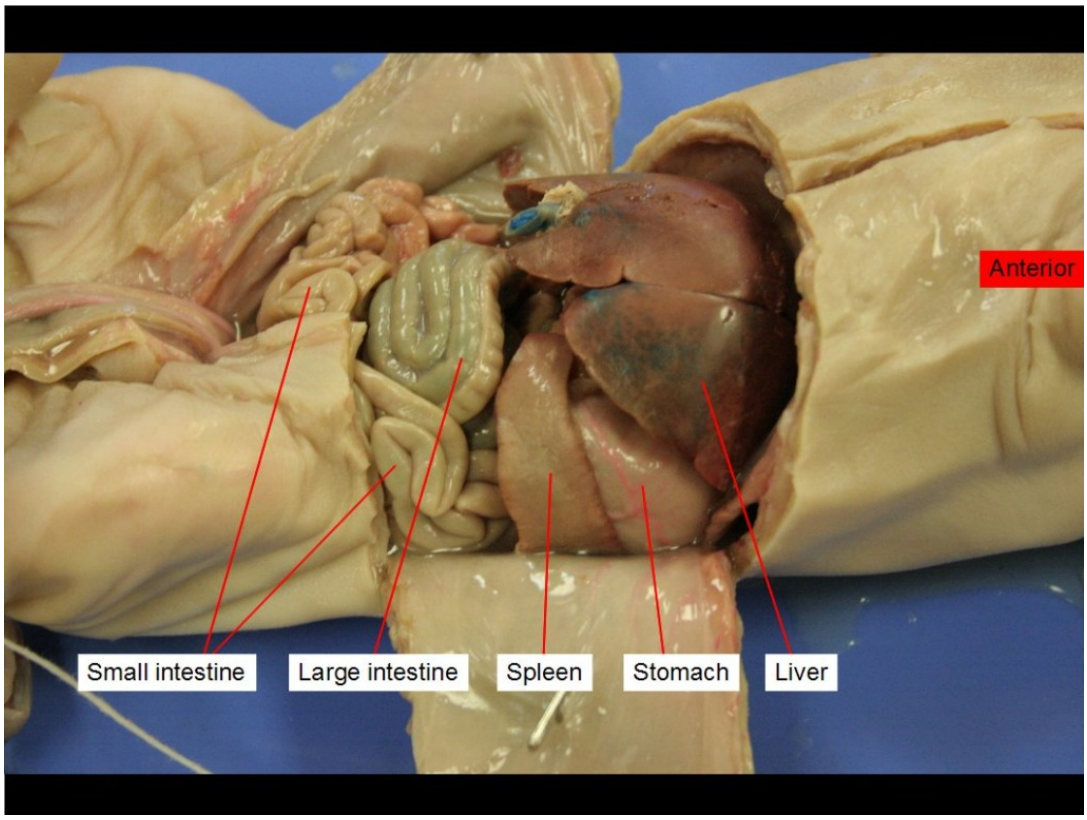


Figure 23. Large intestine, liver, small intestine, spleen, and stomach.

The stomach and spleen have been moved to the right to show the pancreas underneath. See the previous photograph to view these structures before they were moved.

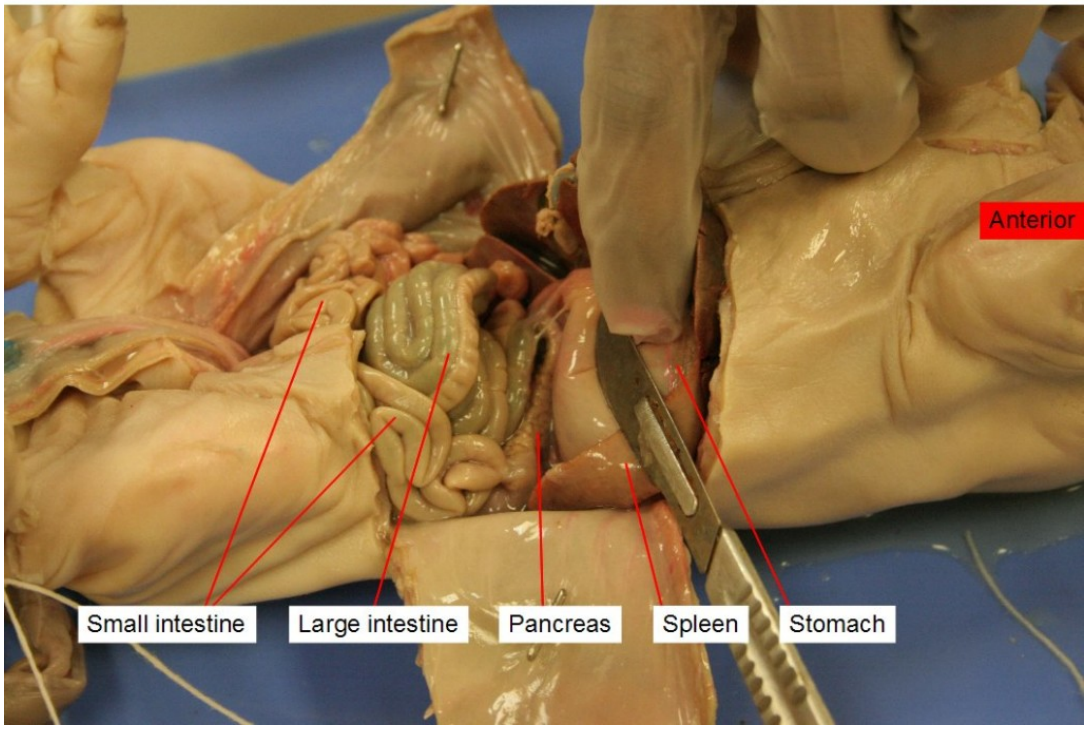


Figure 24. small intestine, large intestine, pancreas, spleen, stomach – The spleen has been moved aside to reveal the pancreas.

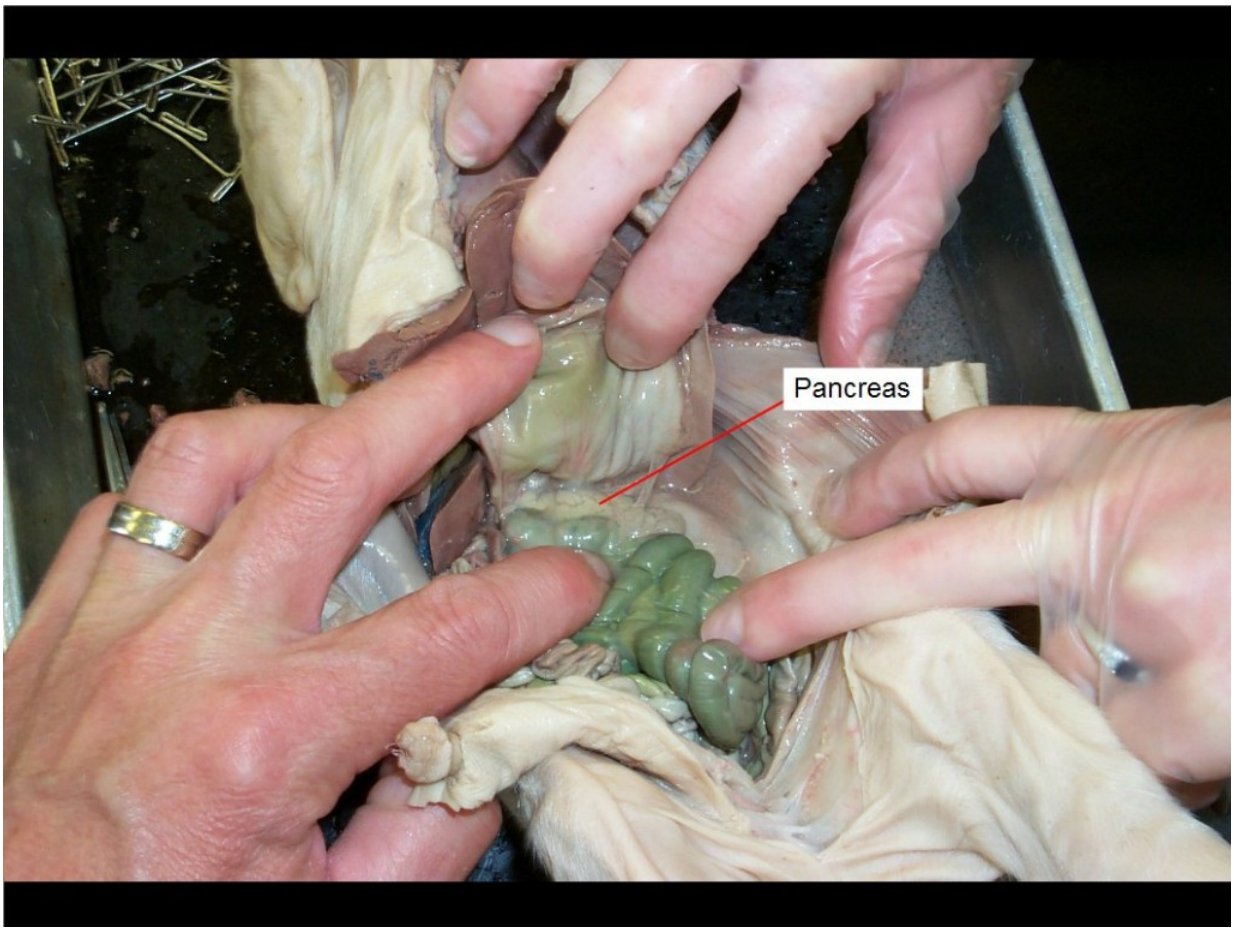


Figure 25. The stomach and liver are lifted to show the pancreas.

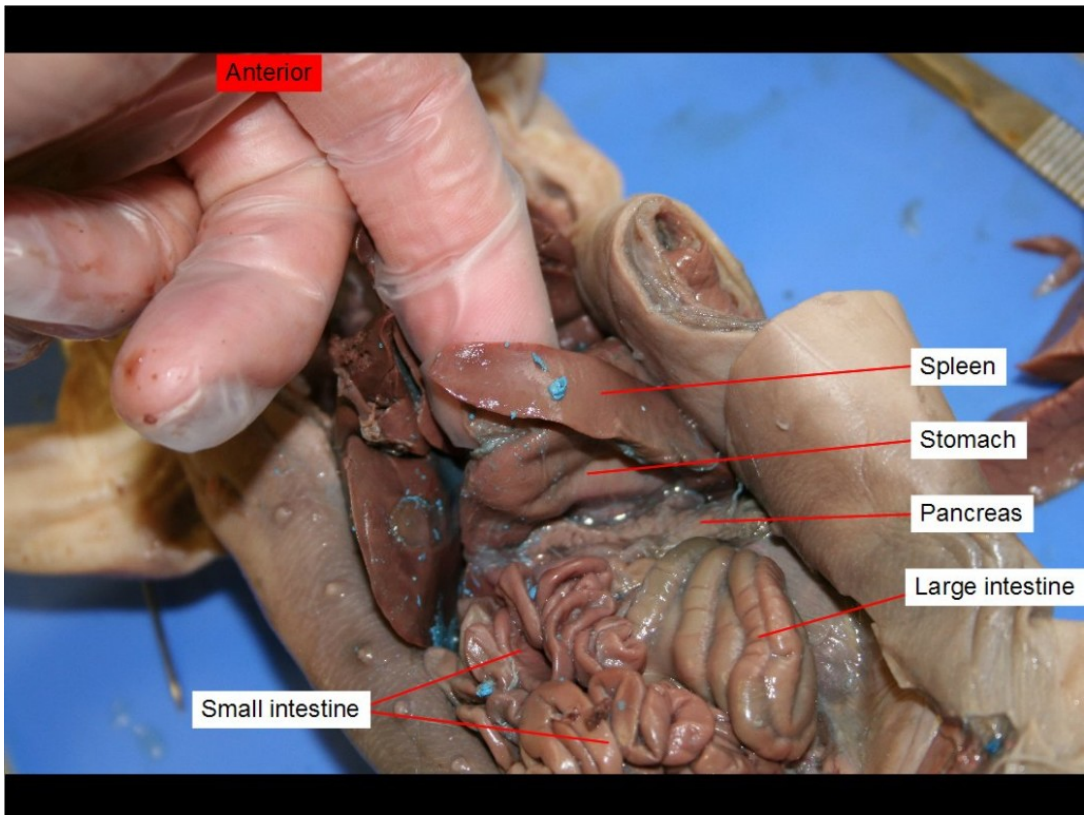


Figure 26. Large intestine, pancreas, small intestine, spleen, and stomach.

The cecum is a blind pouch where the small intestine joins the large intestine. It houses bacteria used to digest plant materials such as cellulose. The cecum is large in herbivores but much of it has been lost during evolution in humans. The appendix in humans is the evolutionary remains of a larger cecum in human ancestors.

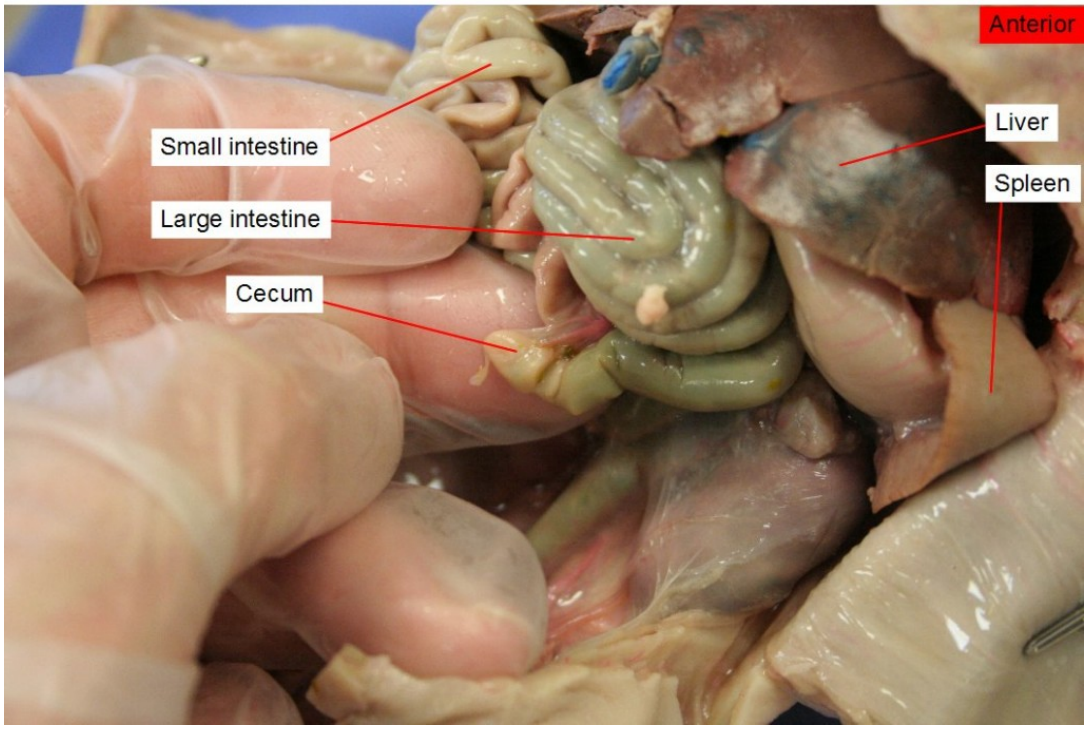


Figure 27. cecum, large intestine, liver, small intestine, spleen. The cecum is found at the point where the small intestine joins the large intestine.

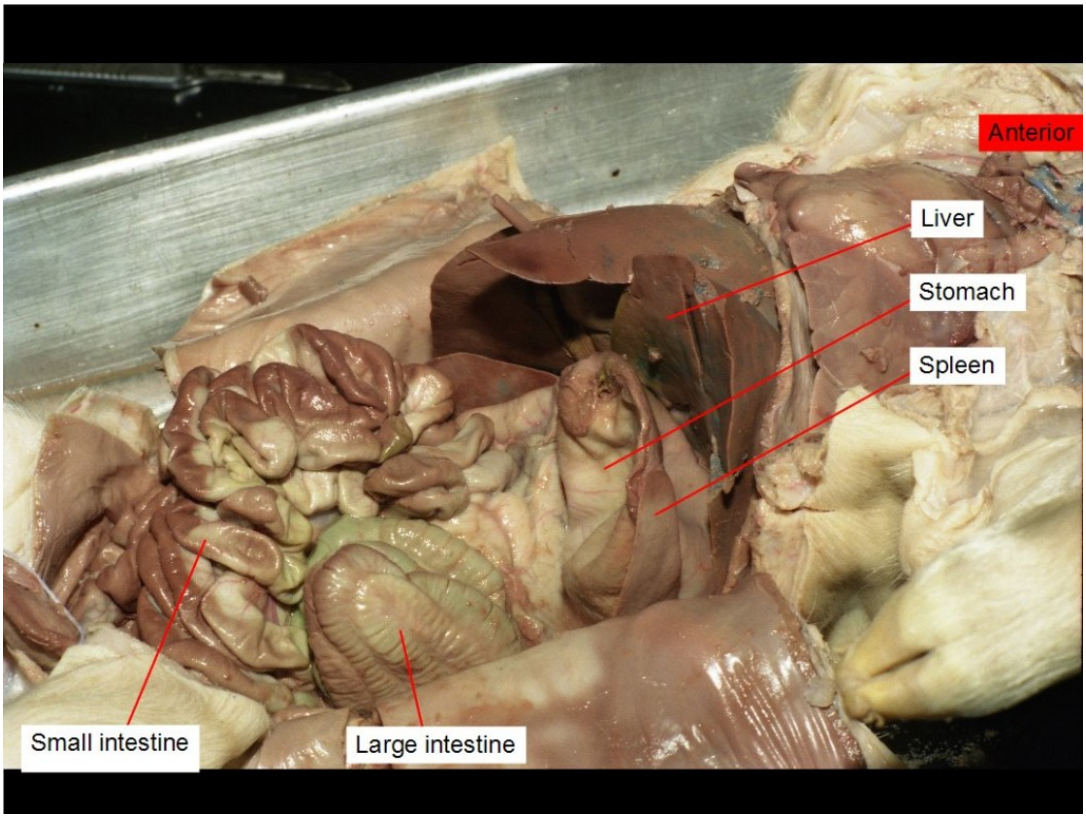


Figure 28. Large intestine, liver, small intestine, spleen, and stomach.

Circulatory System

Figures 29 and 30 summarize the circulatory system of a mammal.

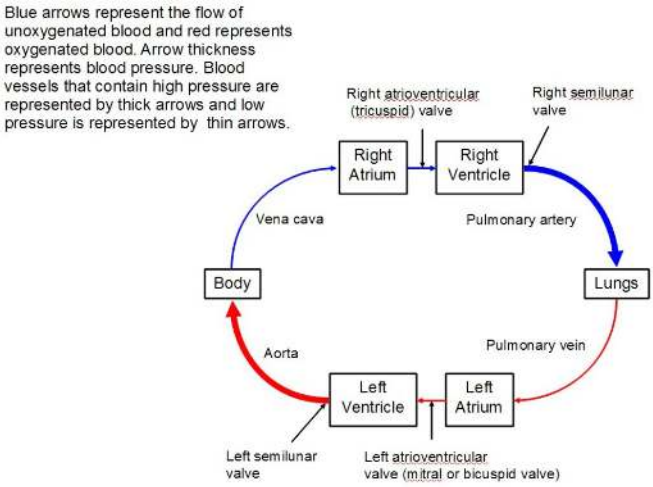


Figure 29. Circulatory system

This diagram is similar to the one on the previous page except that the two ventricles are next to each other. This more accurately reflects the structure of the heart.

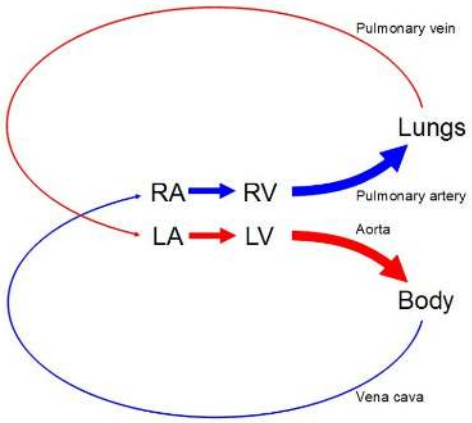


Figure 30. Circulatory system

The drawing below shows some of the major arteries that carry blood to the body. Blood vessels that branch from the aorta carry blood to most of the body.

The pulmonary artery is capable of delivering a large amount of blood to the lungs but the lungs are not needed to oxygenate the blood of a fetus, so most of the blood is diverted to the aorta. This diagram shows that the ductus arteriosus connects the pulmonary artery to the aorta and diverts blood that would otherwise go to the lungs.

Shortly after birth, the ductus arteriosus closes and blood in the pulmonary artery goes to the lungs instead of the body.

Blood passes from the left ventricle through the aortic arch and aorta to the body. The first branch of the aorta is the brachiocephalic artery. The second branch is the left subclavian artery which goes to the left front leg. The right subvclavian carries blood to the right front leg and the carotids carry blood to the head.

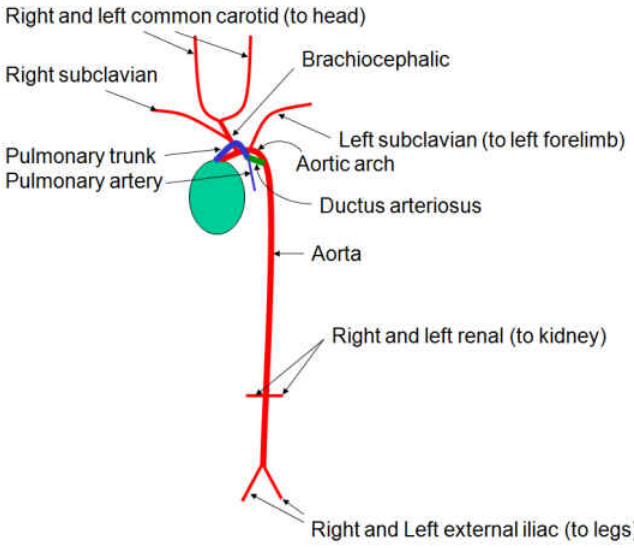


Figure 31. Major arteries

The pericardium is a membrane that surrounds the heart and lines the pericardial cavity. It contains a lubricating fluid and isolates the heart from body movements such as the expansion and contraction of the nearby pleural (lung) cavity.

To view details of the aortic arch, ductus arteriosus, and pulmonary artery, it will be helpful to remove the left lung. With the left lung removed, the heart can be pushed to the right side to reveal the aorta and other blood vessels shown in figures 33–42.

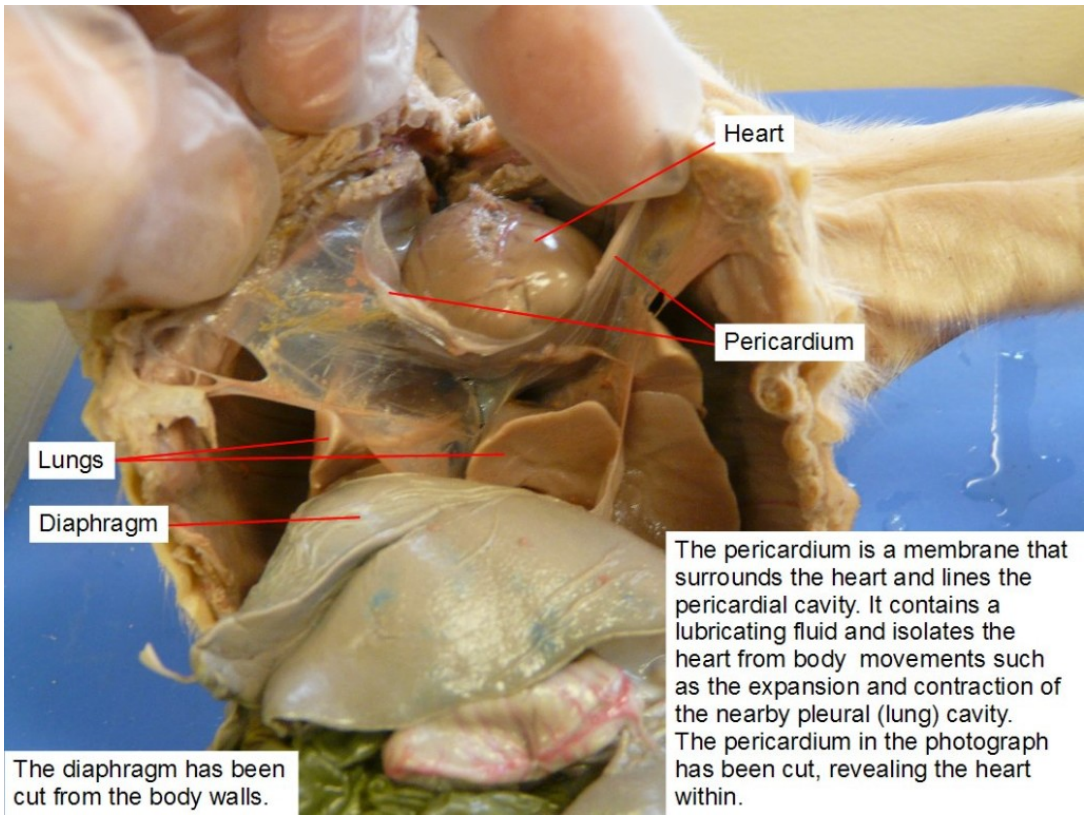


Figure 32. Diaphragm, heart, lungs, and pericardium

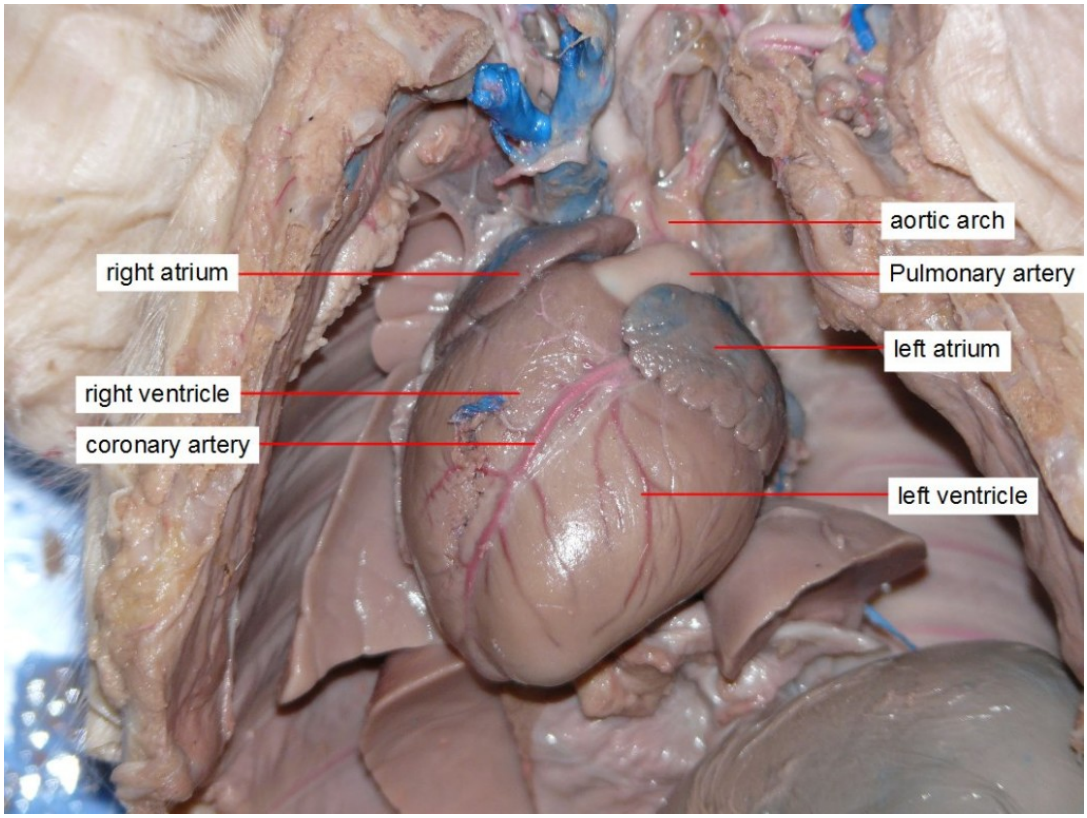


Figure 33. Aortic arch, coronary artery, left atrium, left ventricle, pulmonary artery, right atrium, right ventricle.

Blood passes from the left ventricle through the aortic arch and aorta to the body. The first branch of the aorta is the brachiocephalic artery. The second branch is the left subclavian artery which goes to the left front leg.

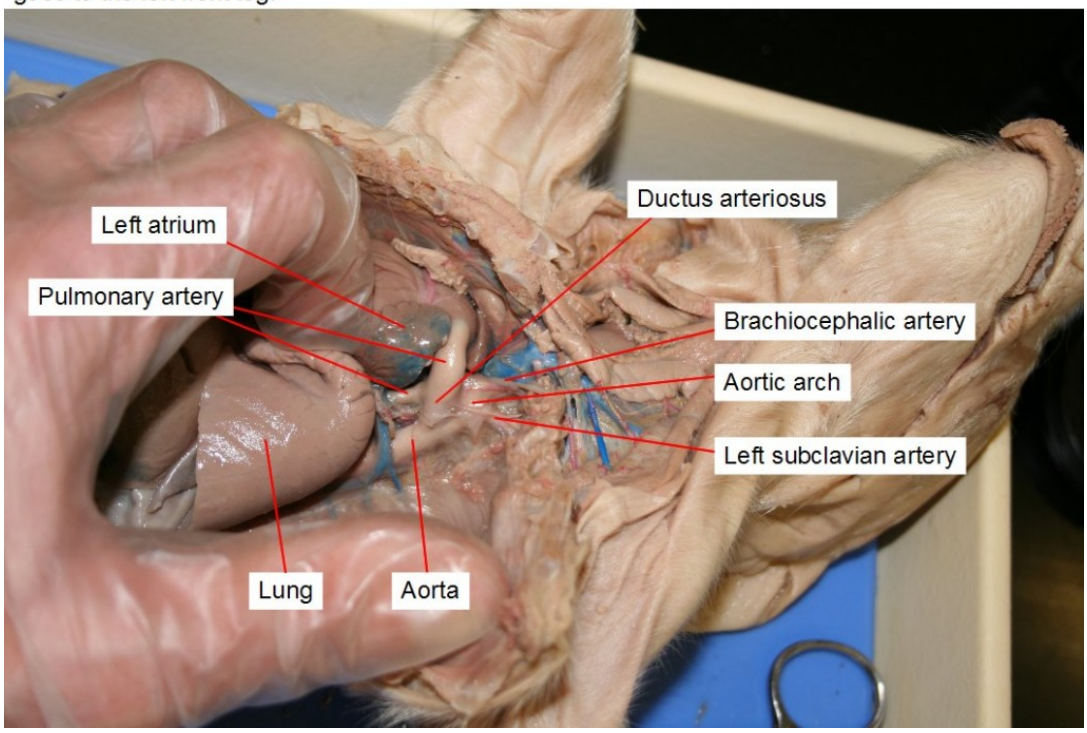


Figure 34. Aorta, aortic arch, left atrium, brachiocephalic artery, ductus arteriosus, lung, pulmonary artery, pulmonary trunk, left subclavian artery,

The first branch of the aorta is the brachiocephalic artery. The second branch is the left subclavian artery which goes to the left front leg. The right subvclavian carries blood to the right front leg and the carotids carry blood to the head.

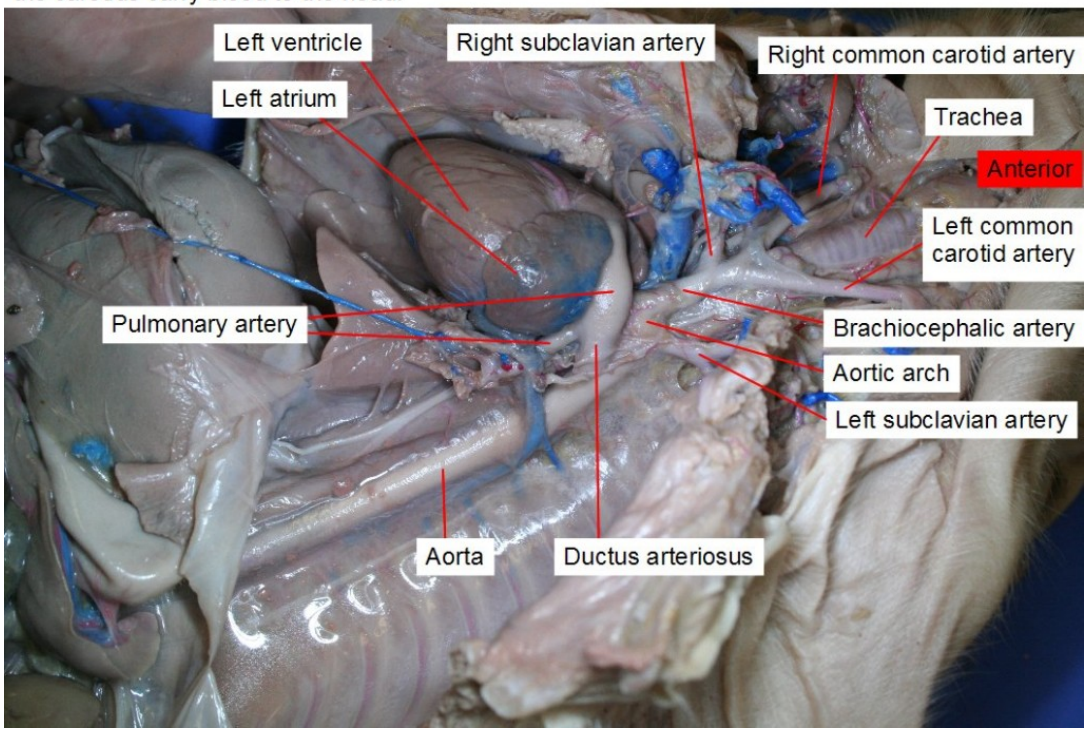


Figure 35. Aorta, aortic arch, left atrium, brachiocephalic artery, left common carotid artery, right common carotid artery, ductus arterious, pulmonary artery, pulmonary trunk, left subclavian artery, right subclavian artery, trachea, left ventricle

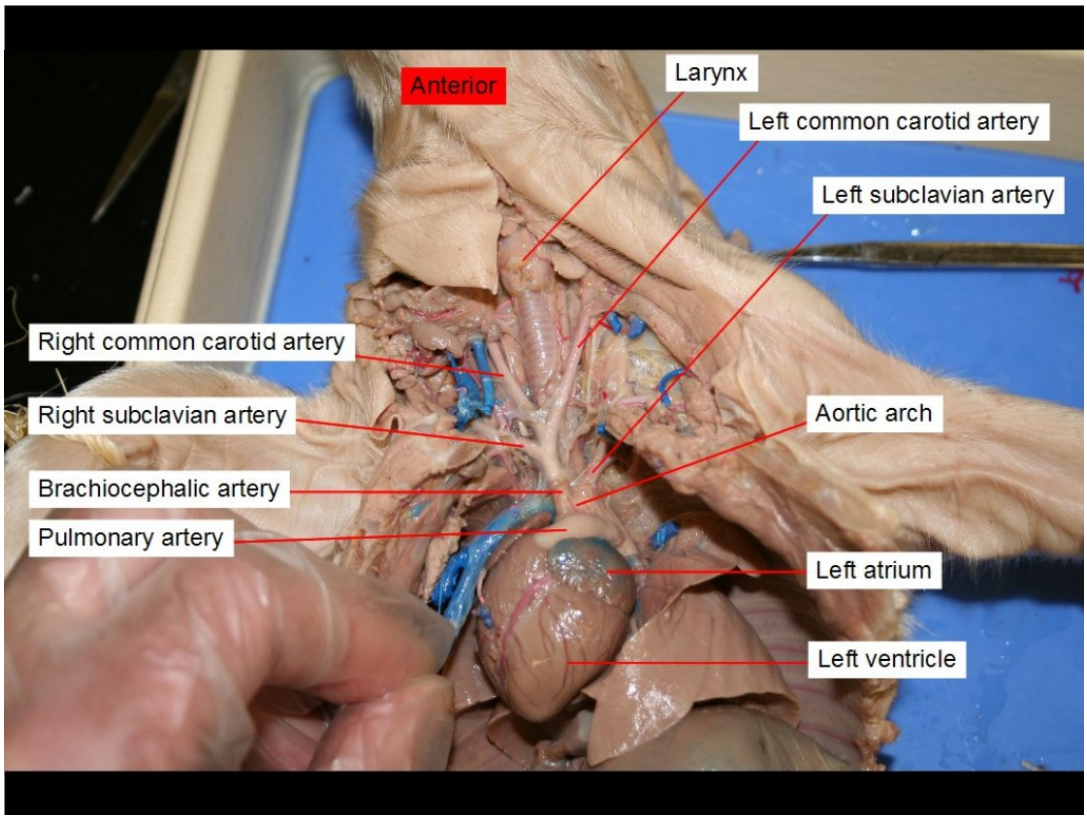


Figure 36. Aortic arch, left atrium, brachiocephalic artery, left common carotid artery, right common carotid artery, larynx, pulmonary trunk, left subclavian artery, right subclavian artery, left ventricle.

The anterior vena cava receives blood from the anterior part of the body and carries it to the right atrium.

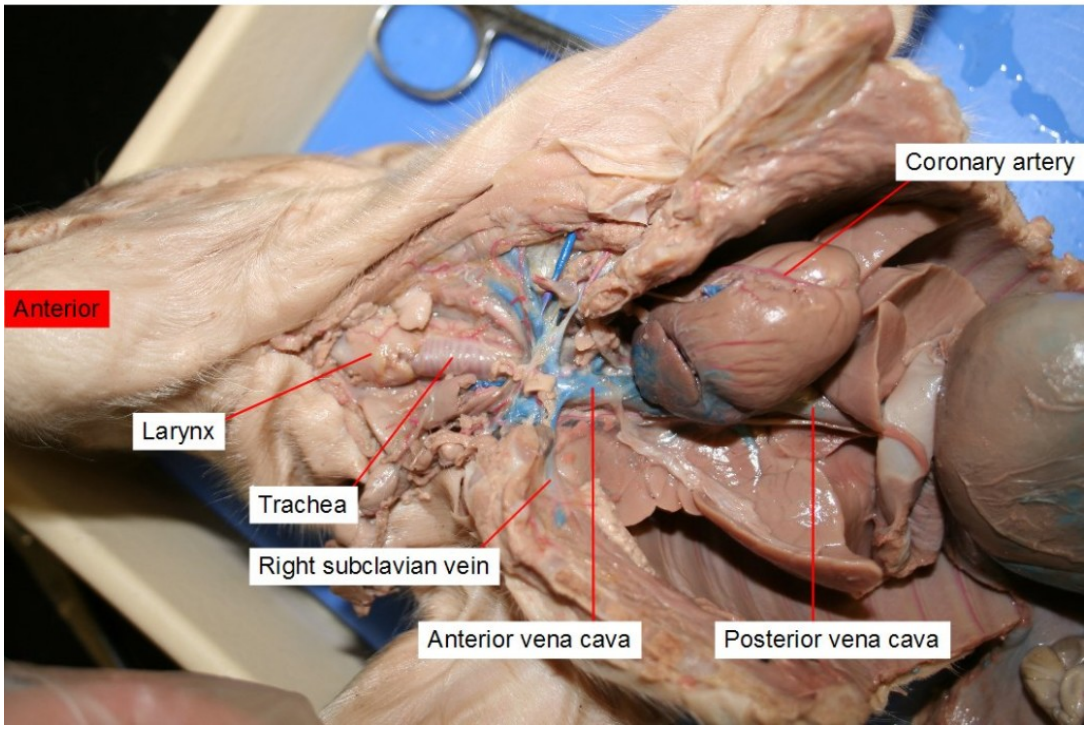


Figure 37. Anterior vena cava, coronary artery, larynx, posterior vena cava, right subclavian vein, trachea.

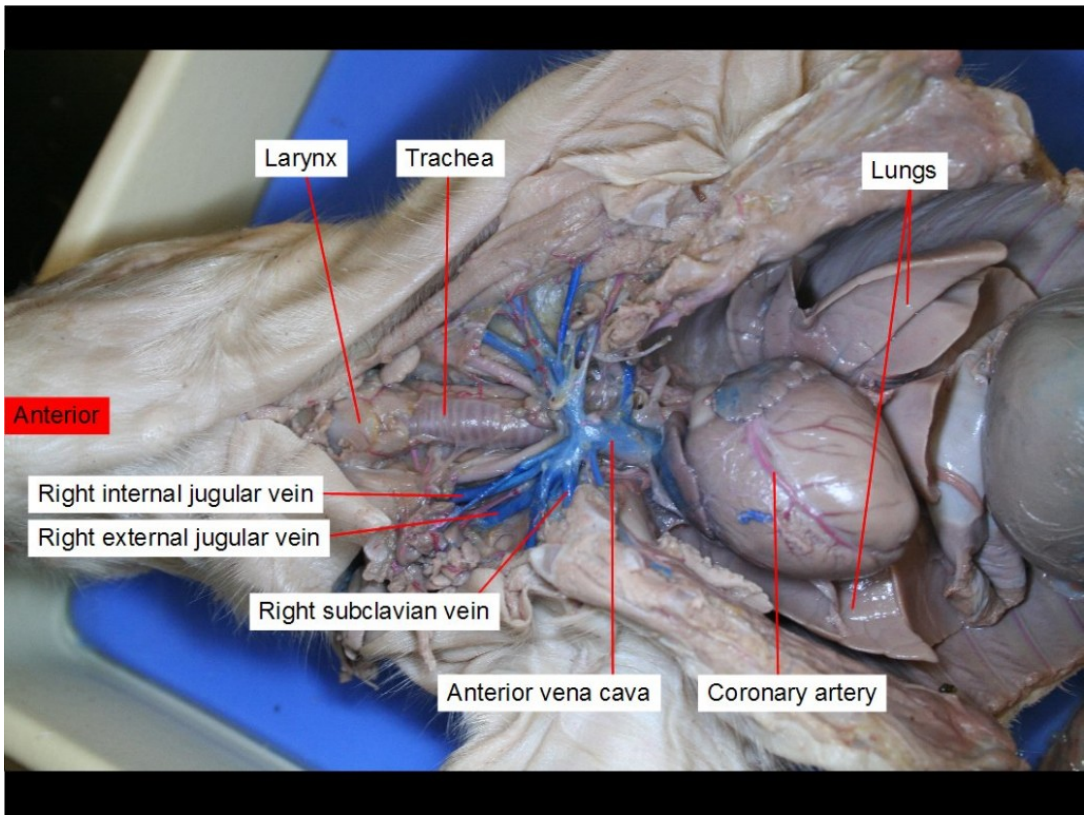


Figure 38. Anterior vena cava, coronary artery, right external jugular vein, right internal jugular vein, larynx, lungs, right subclavian vein, trachea

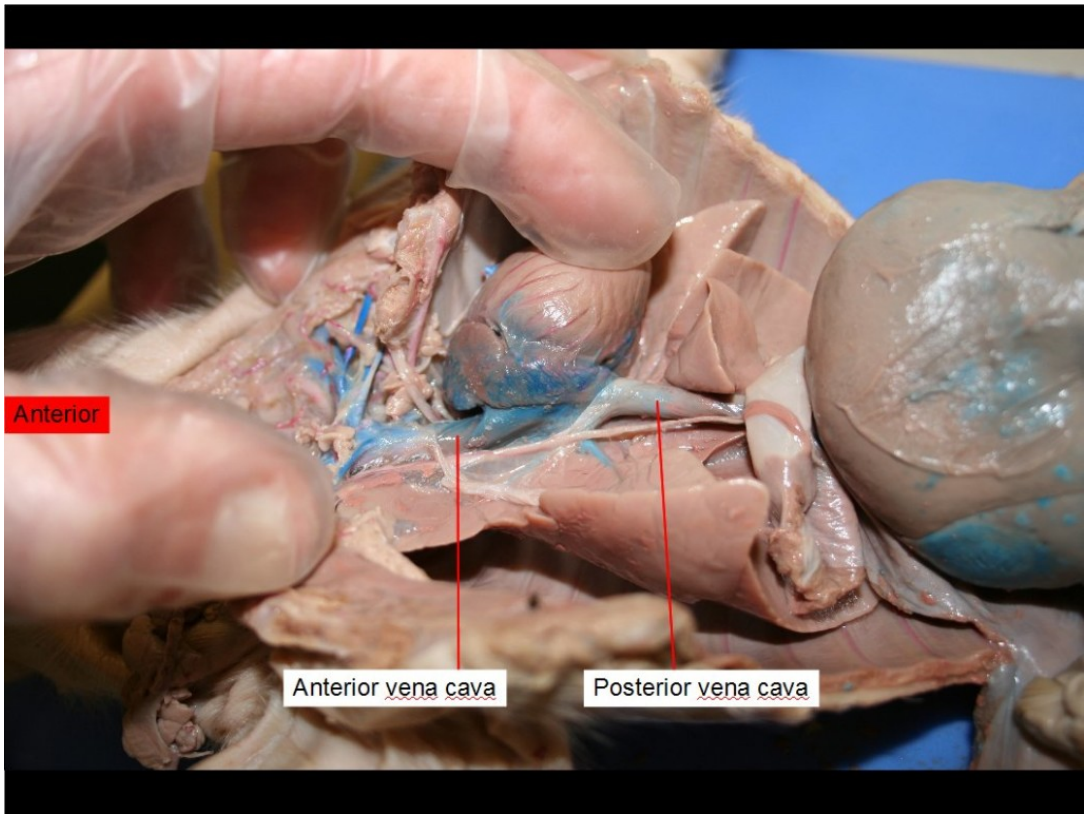


Figure 39. Anterior vena cava, posterior vena cava.

The posterior vena cava receives blood from the posterior portion of the body and carries it to the right atrium.

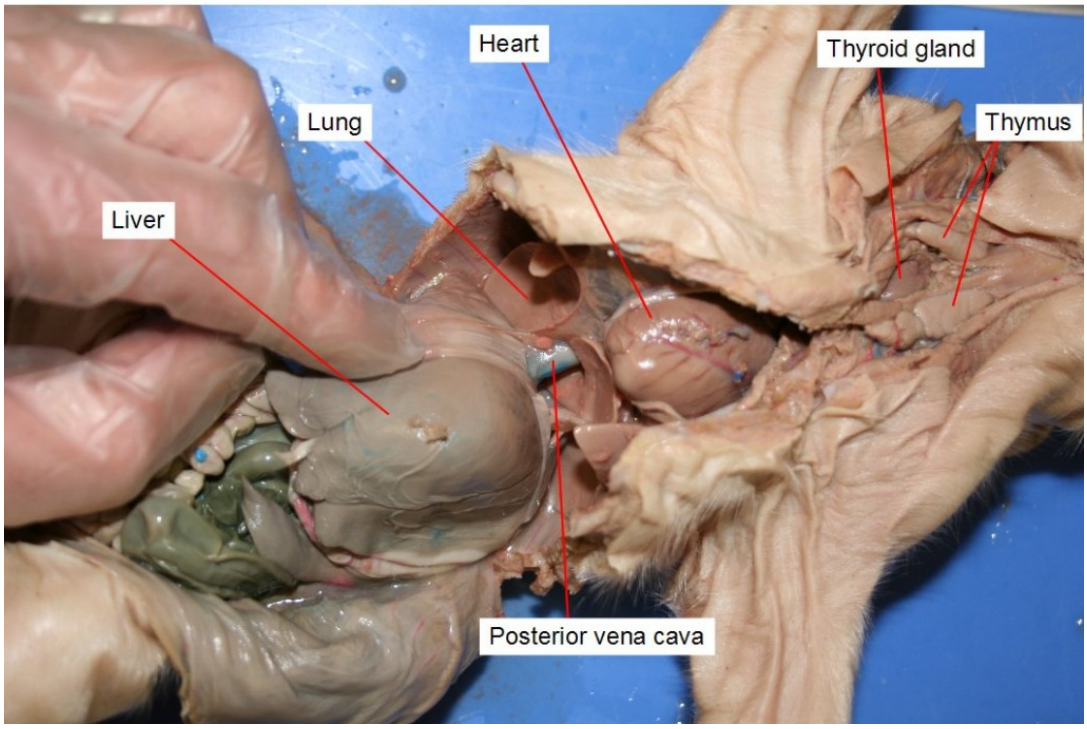


Figure 40. Heart, liver, lung, posterior vena cava, thymus, thyroid

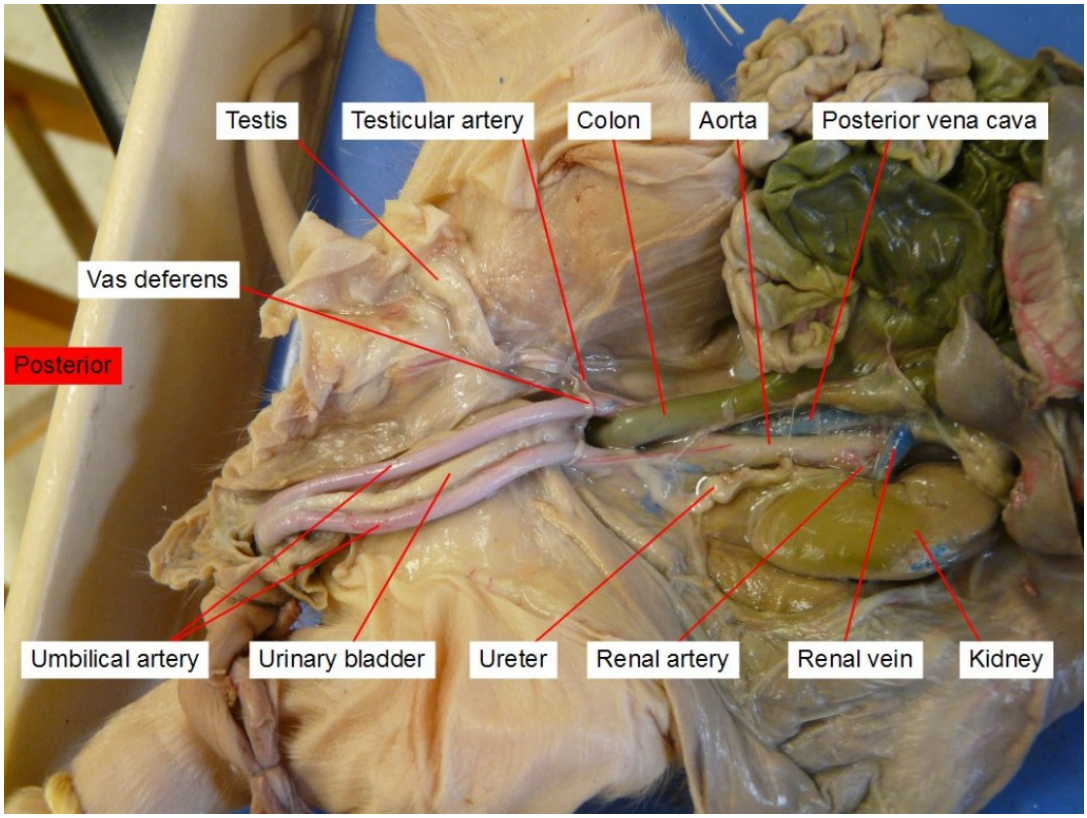


Figure 41. Aorta, colon, kidney, posterior vena cava, renal artery, renal vein, testicular artery, testis, umbilical artery, ureter, urinary bladder, vas deferens. The renal artery passes blood from the aorta to the kidney. The renal vein returns blood from the kidney to the posterior vena cava.

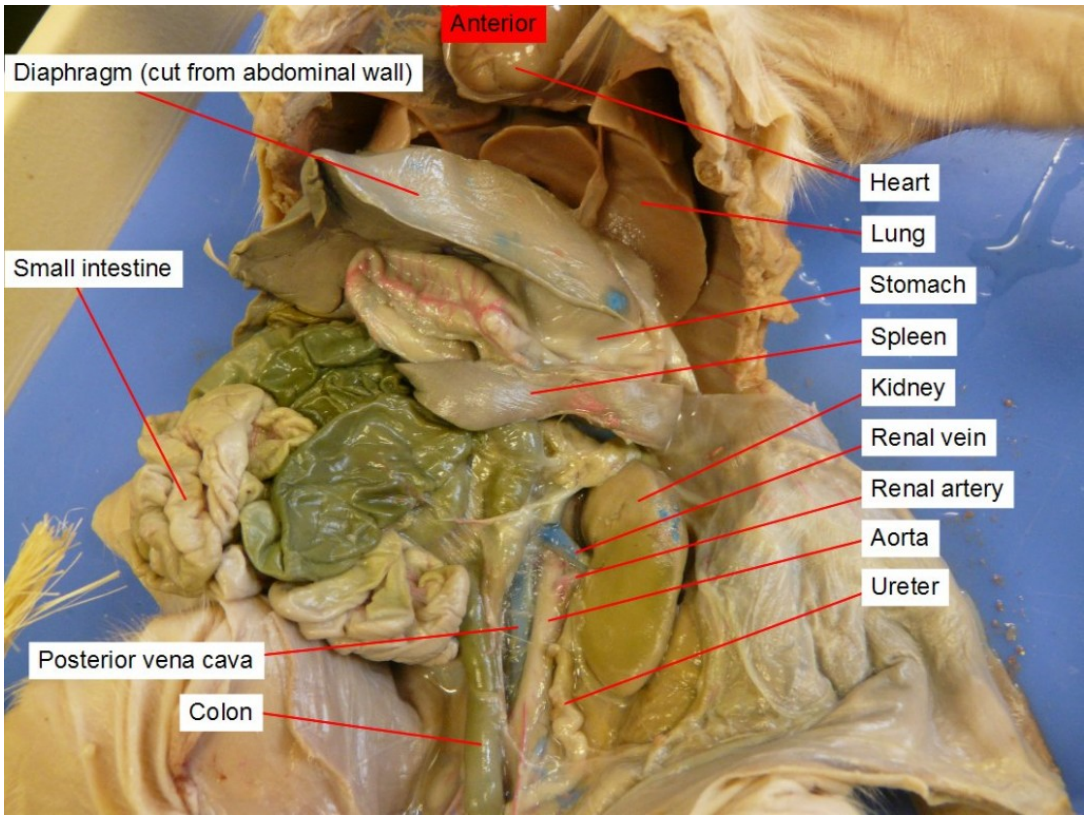


Figure 42. Aorta, colon (large intestine), diaphragm, heart, kidney, lung, renal artery, posterior vena cava, renal vein, small intestine, spleen, stomach, ureter.

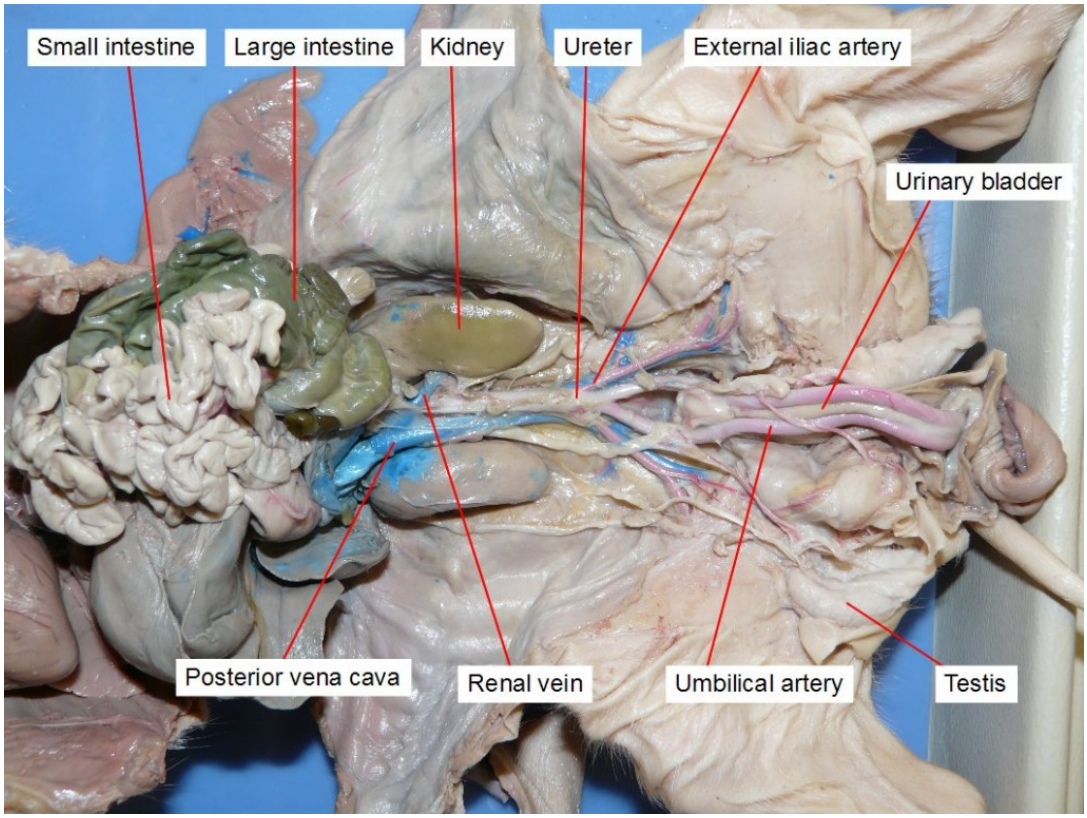


Figure 43. External iliac artery, kidney, large intestine, posterior vena cava, renal vein, small intestine, testis, umbilical artery, ureter, urinary bladder.

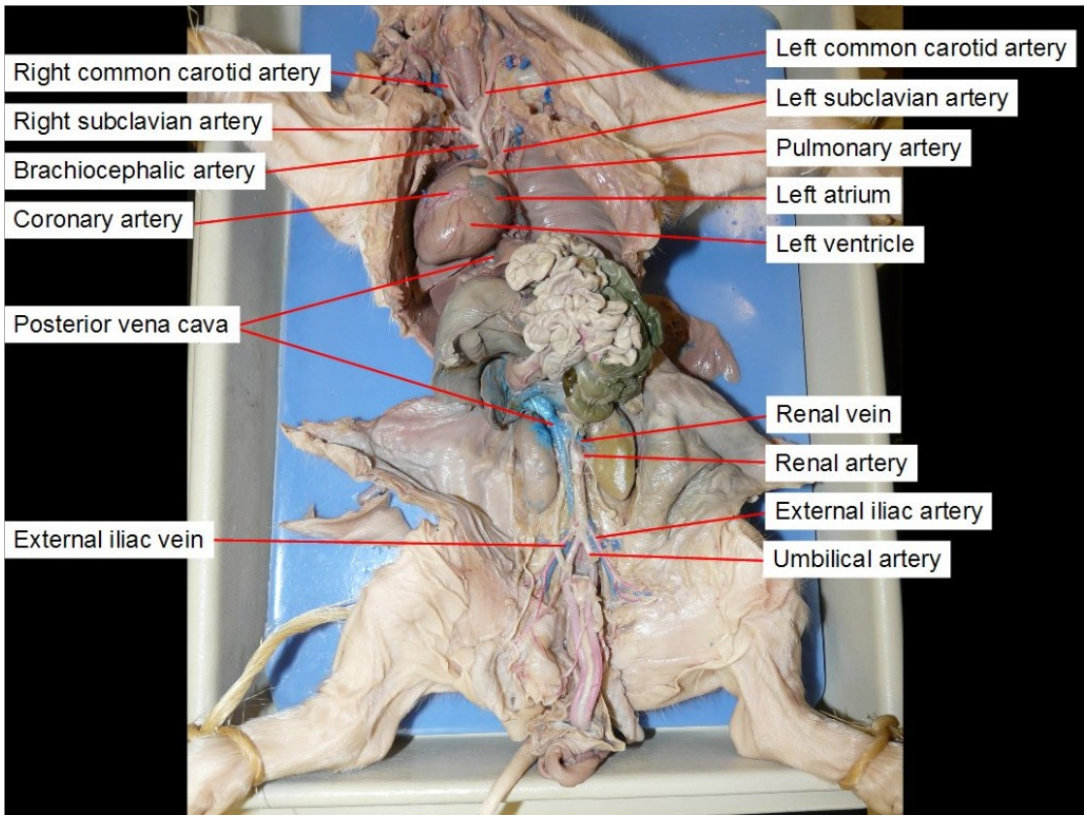


Figure 44. Left atrium, brachiocephalic artery, left common carotid artery, right common carotid artery, coronary artery, external iliac artery, external iliac vein, posterior vena cava, pulmonary trunk, renal artery, renal vein, left subclavian artery, right subclavian artery, umbilical artery, left ventricle.

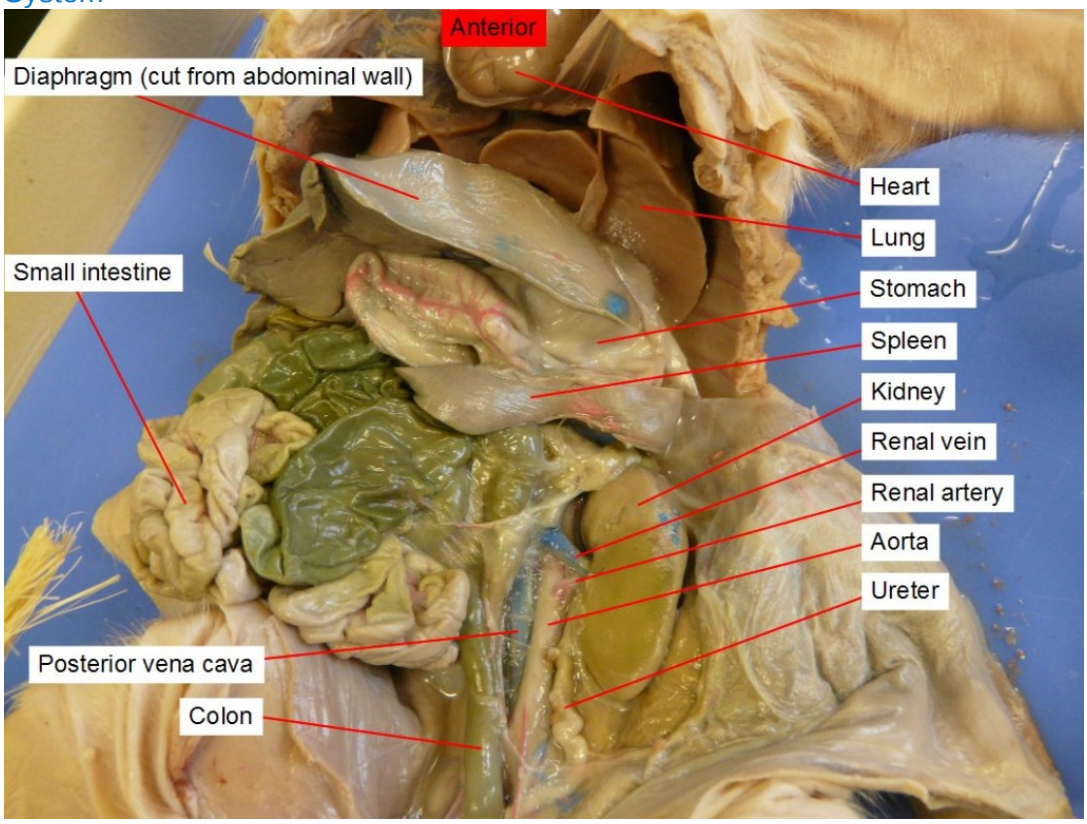


Figure 45. Aorta, colon (large intestine), diaphragm, heart, kidney, lung, renal artery, posterior vena cava, renal vein, small intestine, spleen, stomach, ureter.

Blood from the aorta passes through the renal artery and then to the kidney. The kidneys remove wastes and return blood via the renal vein to the posterior vena cava.

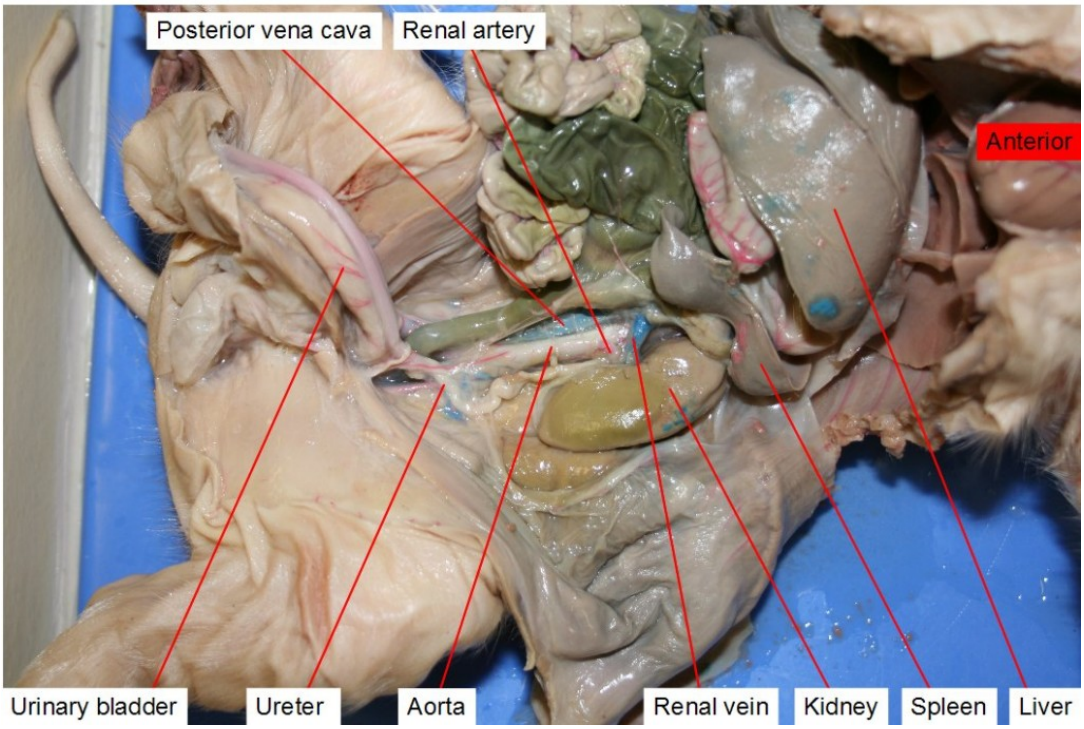


Figure 46. Aorta, kidney, liver, posterior vena cava, renal artery, renal vein, spleen, ureter, urinary bladder.

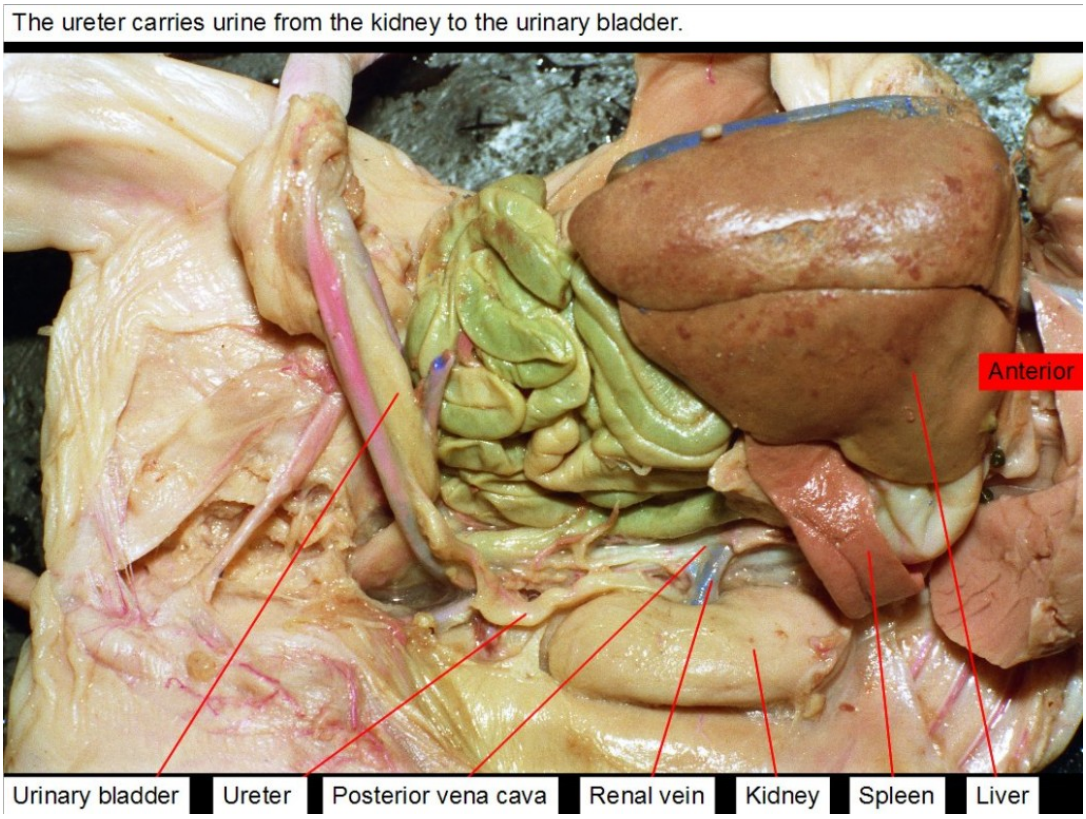


Figure 47. Kidney, liver, posterior vena cava, renal vein, spleen, ureter, urinary bladder

Reproductive System (Female)

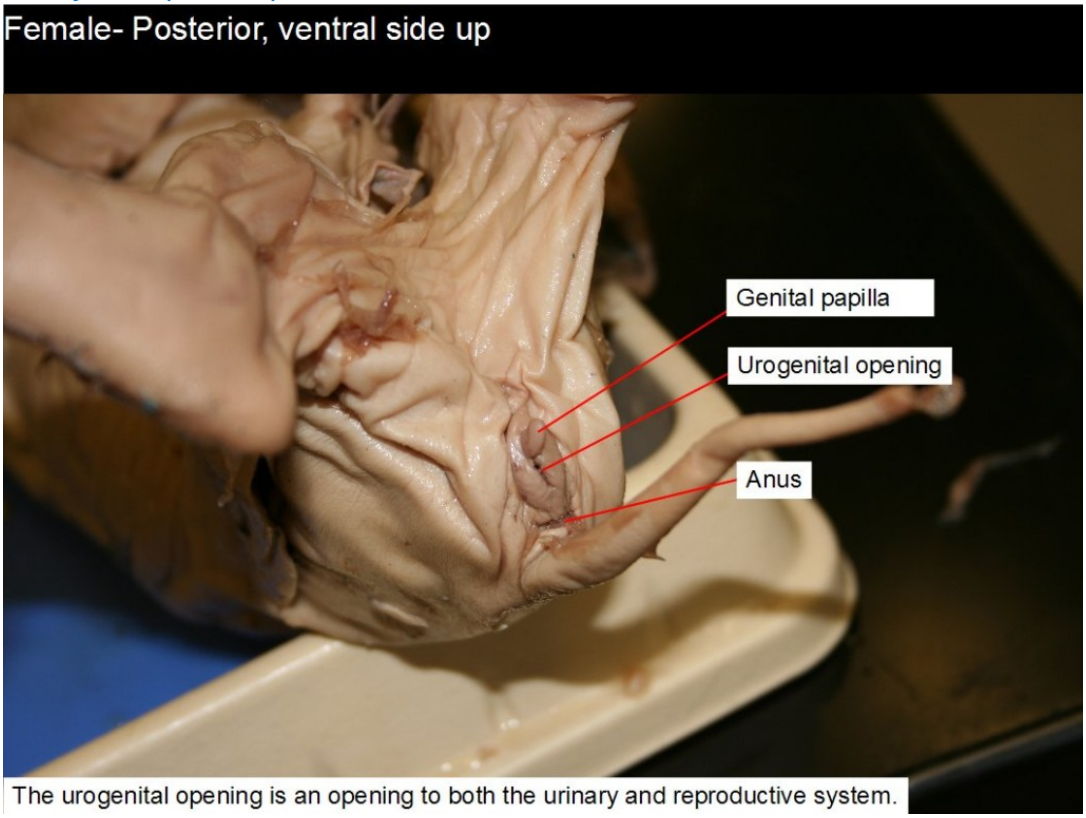


Figure 48. Urogenital papilla, anus

The uterus of a pig is different than that of a human in that the upper part of the pig uterus is divided into two uterine horns. Near the ovaries, the uterine horns become oviducts.

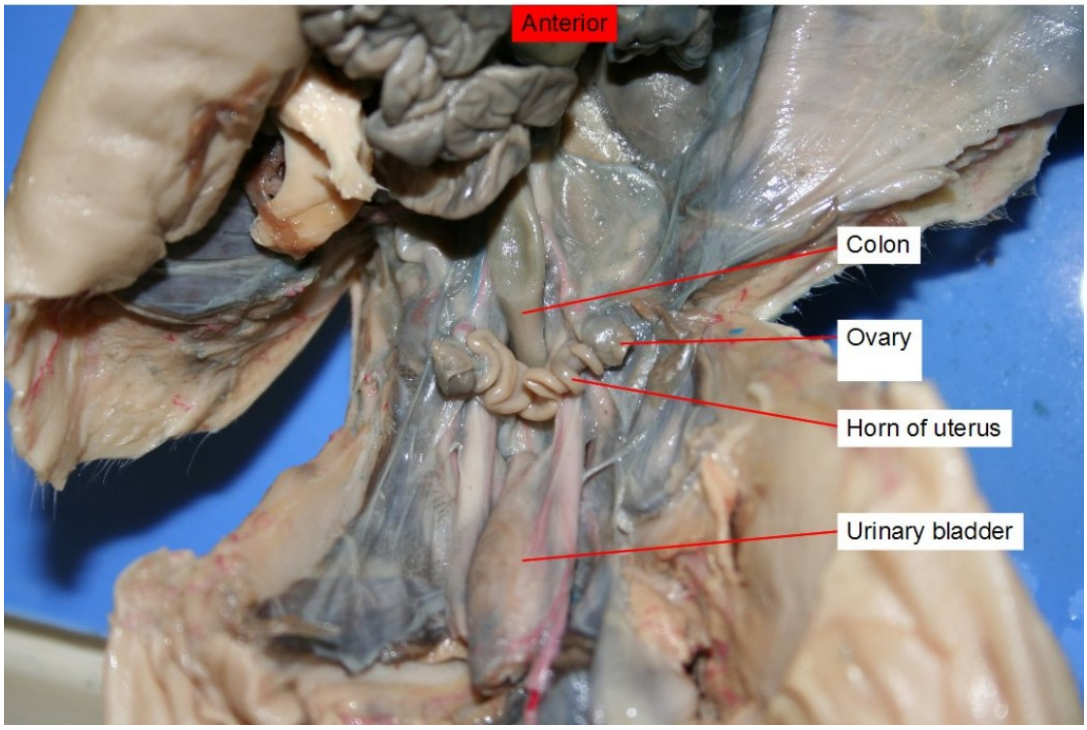


Figure 49. Colon, horn of uterus, ovary, urinary bladder

The urethra (carries urine from the bladder) merges with the vagina to form a common duct called the urogenital sinus.

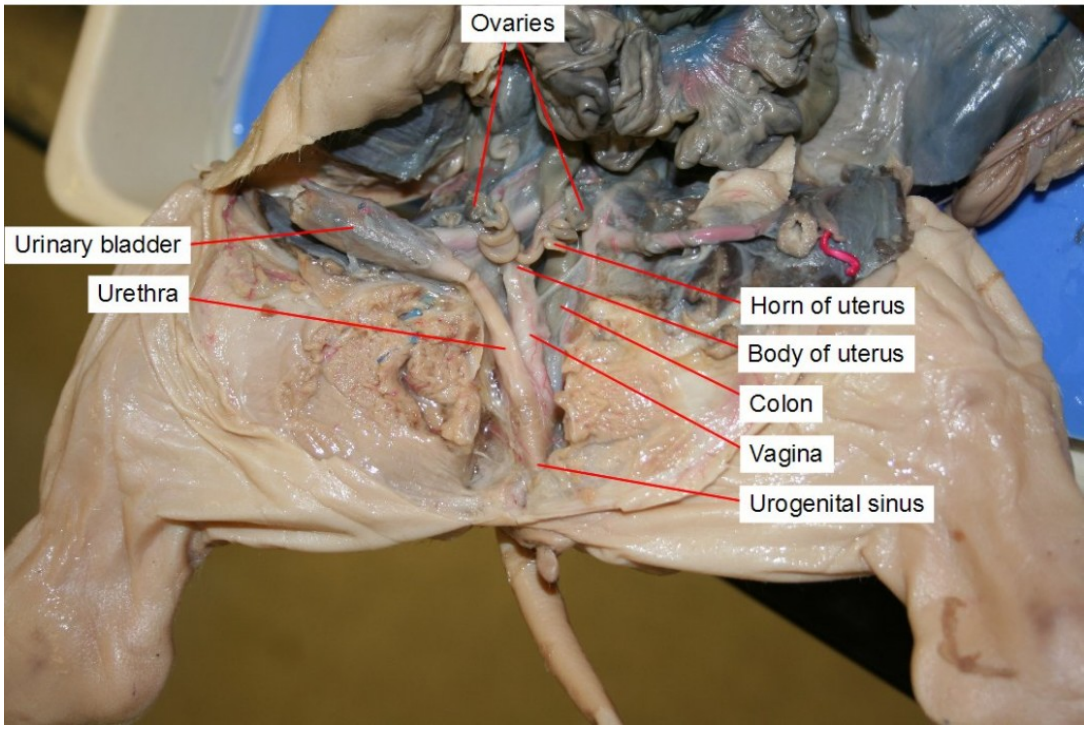


Figure 50. Colon, body of uterus, horn of uterus, ovaries, urethra, urinary bladder, urogenital sinus

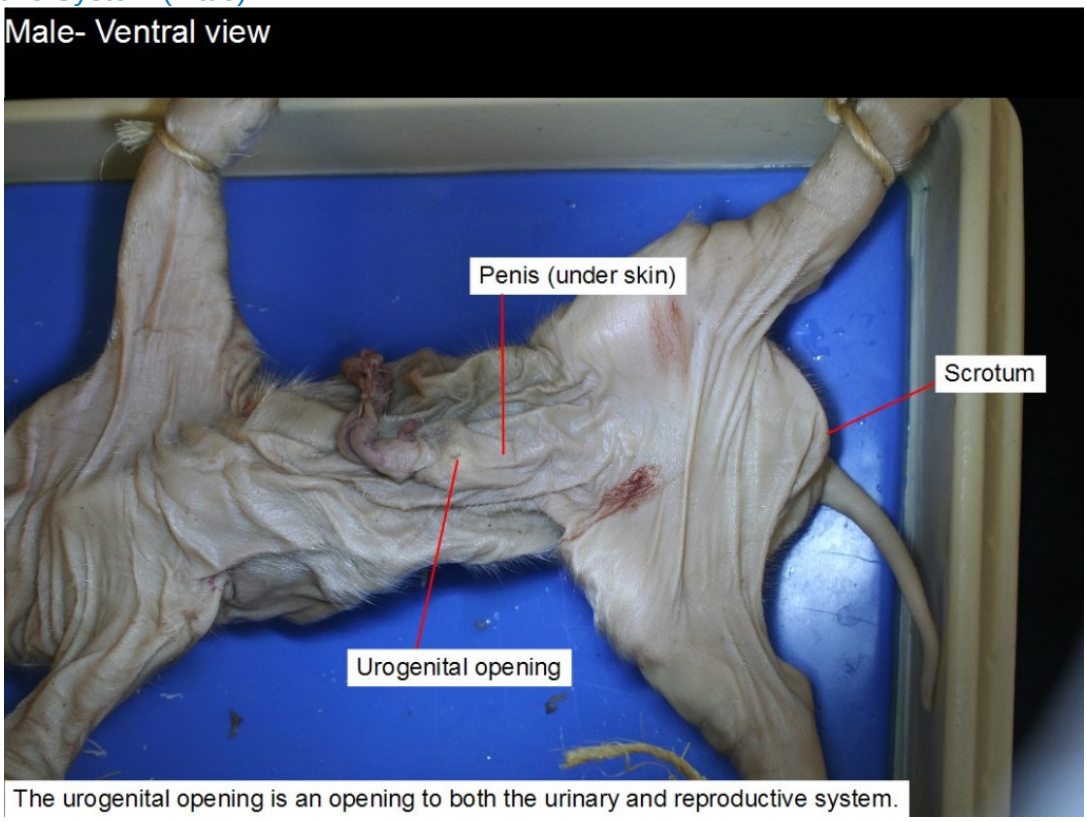


Figure 51. Penis, scrotum, urogenital opening

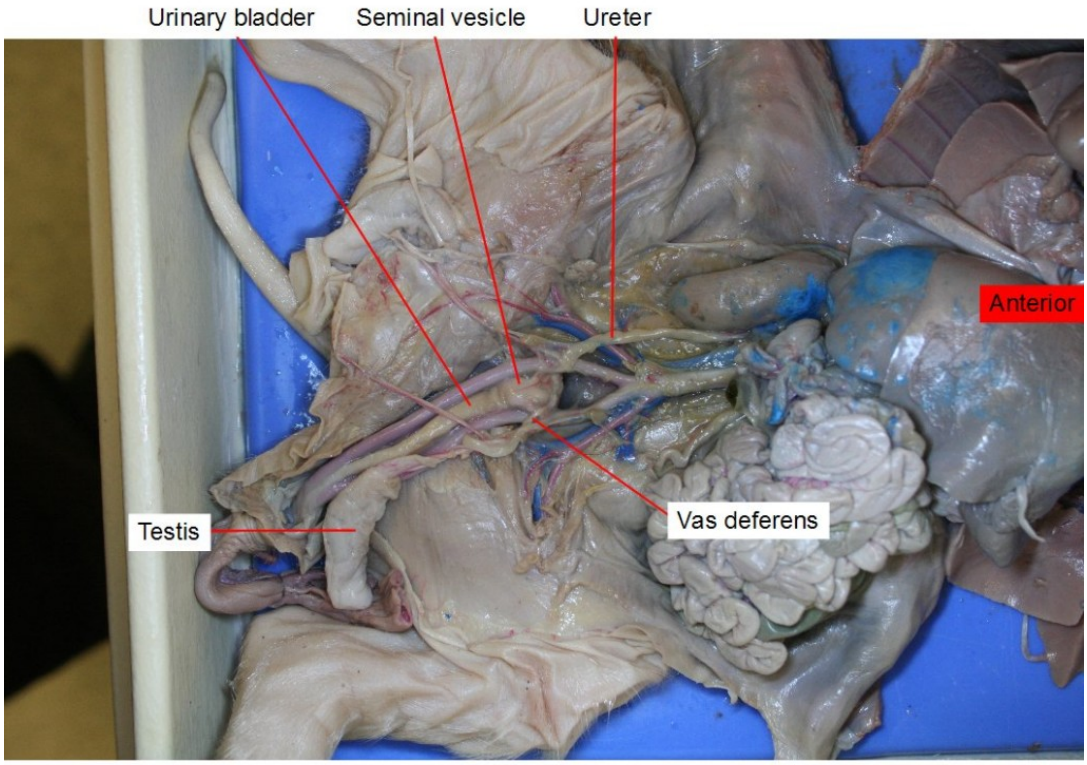


Figure 52. Seminal vesicle, testis, ureter, urinary bladder, vas deferens

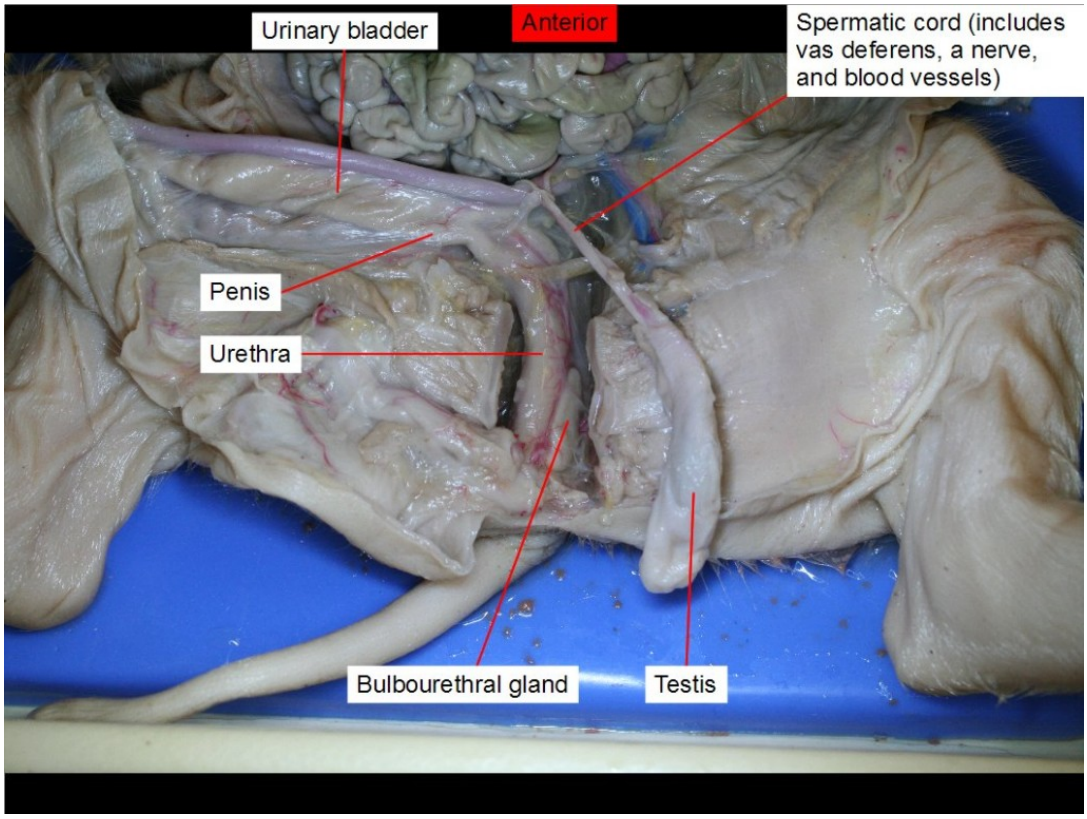


Figure 53. Bulbourethral gland, spermatic cord, testis, urethra, urinary bladder, vas deferens

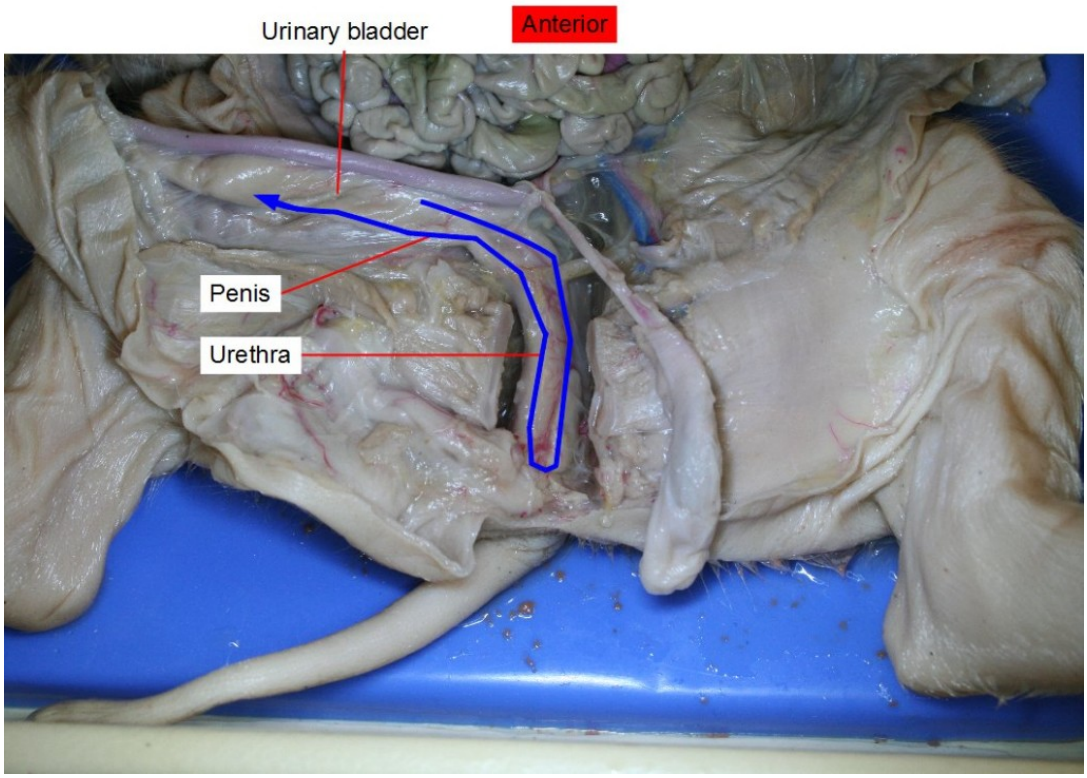


Figure 54. Path of urine flow

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10.4: Cardiovascular and Respiratory Systems Lab

Learning Objectives

- State the parts of the cardiovascular and respiratory systems and give the functions of each part.
- Identify the parts of the cardiovascular and respiratory systems on the human torso model and other models.
- Explain how the respiratory and cardiovascular systems are interrelated.
- Describe the path of the blood through the heart
- Test the effects of various factors on heart rate and breathing rates
- Measure various respiratory volumes using a spirometer.
- Define the following terms:

nostrils	trachea	spirometer	nasopharynx
bronchi	pleura	pharynx	larynx
forced vital capacity	epiglottis	lung	vital capacity
diaphragm	glottis	forced expiratory volume	intercostal muscles
aorta	brachial artery and vein	superior vena cava	ventricle
hepatic artery and vein	inferior vena cava	atrium	renal artery and vein
iliac artery and vein	pulmonary artery and vein	jugular vein	systole
diastole	coronary artery and vein	carotid artery systole	

Download a PDF of the lab to print.

Activity I: Identifying Structures

Find the following structures on the human torso model and other models.

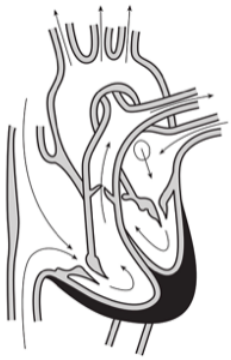
- Nostrils
- Trachea
- Nasal cavity
- Oral cavity
- Bronchi
- Diaphragm
- Pharynx
- Pleura
- Larynx
- Lung
- Epiglottis
- Intercostal muscles
- Glottis
- Iliac artery and vein
- Carotid arteries
- Jugular veins
- Right and left ventricle
- Right and left atria
- Pulmonary artery and vein
- Brachial artery and vein

- Coronary artery and vein
- Renal artery and vein
- Hepatic artery and vein
- Femoral artery and vein
- Superior and inferior vena cava

Use the chart on the next page to help organize your understanding of the different arteries and veins. For each one listed, state where the blood is traveling to and from.

Artery or Vein	Where blood is traveling to and from
Pulmonary Artery	
Pulmonary Vein	
Coronary Artery	
Coronary Vein	
Hepatic Artery	
Hepatic Vein	
Iliac Artery	
Iliac Vein	
Jugular Vein	
Carotid Artery	
Brachial Artery	
Brachial Vein	
Femoral Artery	
Femoral Vein	
Renal Artery	
Renal Vein	

Use the heart picture below and label the different atria and ventricles. Also include the aorta, superior vena cava and inferior vena cava.



Activity II: Respiratory Volumes and Lung Capacities

Spirometry is the classic pulmonary function test. A **spirometer** is an instrument used to measure how much air and how quickly air is expelled after a deep inhalation. The measurements can be used to calculate how efficiently and how quickly the lungs can be filled upon inspiration and emptied during expiration. The most common measurements obtained from a spirometer are listed in the table below.

Abbreviation	Measurement	Description
VC	Vital Capacity	Maximal amount of air exhaled steadily from full inspiration to maximal expiration
FVC	Forced vital capacity	The total amount of air that you blow out in one breath
FEV1	Forced expiratory volume in one second	The amount of air you can blow out in one second. An individual with normal lungs and airways can blow out most of the air from the lungs in the first second
FER	Forced expiratory ratio (FEV1/FVC)x100	Percentage of the FVC expelled in the first second of a forced expiration
PEF	Peak expiratory flow	Peak expiratory flow in liters per minute

The spirometer we will use measures peak expiratory flow, a useful indicator of lung function to assess conditions such as asthma. Peak flow is achieved by blowing out as fast as possible after taking in as much air as possible.

Directions to Operate Spirometer

1. For best results, stand. If you are unable to stand, sit in a straight and upright position.
2. Move the peak indicator (red internal piece) to the start position (all the way on the left).
3. Hold the spirometer in your hand with your thumb and forefinger on the grips and the mouthpiece facing toward you. Avoid blocking the vent holes as much as possible and do not allow the fingers to interfere with the red peak indicator.
4. Take as deep a breath as possible filing your lungs completely with air
5. Place your mouth on the mouthpiece, past your teeth, and form a tight seal with your lips. Place your tongue below the mouthpiece to make sure it is not blocking the opening at any time.
6. Blow out as hard and fast as you can. The red indicator will move indicating your peak flow.
7. Do not reset the peak indicator. Repeat steps 4-6 two more times for a total of three. The indicator will automatically point to the best of the three efforts.
8. Record your results in the table on the next page.
9. Clean off the spirometer using a paper towel and rubbing alcohol.
10. Have your partner complete the same process.

	PEF
My value	
My partner	

Results

Comparing Your Results to Expected Values

Use the normal predicted average peak expiratory flow tables in the spirometer box and any additional handouts provided by your instructor to compare your readings to expected values based on an individuals gender, age, ethnicity, and height.

How does your average PEF compare with the value for a person your age and height?

What do These Values Mean in the Real World?

Individuals suffering from **obstructive pulmonary disease** (narrowed airways) have a low FEV1 but a normal FVC. Since the airways are narrowed less air can be blown out in one second. Individuals with obstructive lung disease also have a FER less than 70% of the predicted value. **Asthma** is one condition which causes narrowing of the airways. Spirometry is used to diagnose asthma and asses the efficiency of treatments.

Individuals can also suffer from **restrictive pulmonary disease**. These individuals have a normal FEV1 since the airways are unobstructed but a lower FVC. The lower FVC is caused by various conditions that affect the lung tissue or the capacity of the lungs to expand.

There are some conditions that involve both lung obstruction and restriction, such as **cystic fibrous**. Individuals with cystic fibrous secrete excess mucus which narrows the airways and damages the lung tissue.

Activity III: Investigation

How do different everyday activities affect your circulation and respiration? You and a partner will work together to come up with and implement a procedure to test the following question:

How does body position (laying down verses sitting verses standing) affect your heart rate and your breathing?

In the space below, write a hypothesis and null hypothesis for the question.

Hypothesis:

Null Hypothesis:

You have the following tools available to test these questions:

1. Spirometer
2. Measuring pulse
3. Measuring breathing rate

You need to determine how you can test both respiration and circulation. Some points to consider:

- How long your experiment should run?
- How many trials you should do
- How often should you take measurements?
- How could you create a control?

Use the space below to write out a procedure to test each question. Make sure that your instructor approves your procedures before you begin your experiments.

Procedure for Question 1:

Now begin your experiments. Use the space below to record your results. Feel free to make your own tables to organize your data.

Use your results to answer the following questions:

1. How did your heart rate change with body position? When was it the lowest? Highest?
2. How did your breathing rate change with body position? When was it the lowest? Highest?
3. Why might your heart and breathing rate differ from your partner?

As modified from Piedmont Virginia Community College's Biology 102 Circulatory and Respiratory Systems Lab

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10.5: Cardiovascular and Respiratory Systems Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Activity I: Identifying Structures

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
human torso model	1 per table	
heart model	1 per table	

Activity II: Respiratory Volumes and Lung Capacities

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
spirometer	1-2 per table	
alcohol preps	4 per table	to clean spirometers in between student use
lung capacity value tables	1-2 per table	for students to compare their values

Activity III: Investigation

Students will do this part in table teams (groups of 4). They will use the same materials as in part II of the lab activity.

CHAPTER OVERVIEW

11: Homeostasis

11.1: Homeostasis Lab

Learning Objectives

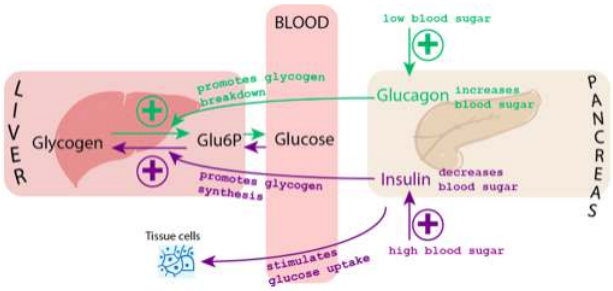
- Describe the anatomy of the liver including the path of blood flow from the intestines, through the liver, and to the heart
- Compare glucose levels in different veins and arteries before and after eating
- Describe the anatomy of the kidneys and a nephron including circulation of the blood
- Explain the three steps of urine formation and where each stem occurs in the nephron
- Predict whether substances will be found in the filtrate or the urine after kidney function
- Explain how the kidneys and the liver contribute to homeostasis

Download a PDF of the lab to print.

Homeostasis describes the dynamic balance of the body's internal environment and the effort to maintain a constant, stable inside. There are many body components that contribute to homeostasis. This lab activity will focus on the liver and the kidneys.

Part I: Liver

The liver is an organ within the digestive system and is responsible for maintaining sugar levels in the blood as part of homeostasis. After a large meal, the liver converts extra glucose into **glycogen**, a polysaccharide that stores glucose. A hormone called **insulin** is produced by the pancreas stimulates glycogen production. When levels of glucose in the blood drop, the liver breaks down glycogen back into glucose for the blood to circulate throughout the body. A hormone called **glucagon** produced by the pancreas stimulates this process. All cells of the body require glucose for cellular respiration to make energy.



The liver receives blood from the small intestines through the **hepatic portal vein**. After a large meal, the hepatic vein would transport glucose rich blood from the small intestines to the liver. Blood leaves the liver and returns to the heart through the **hepatic vein**. We will conduct a simulation to learn more about the liver's role in maintaining blood glucose levels in relationship to homeostasis.

The table below describes the blood serums you will test:

Serum	Location
A	Mesenteric artery (takes blood from aorta to small intestine)
B	Hepatic portal vein (transports blood between intestines and liver)
C	Hepatic vein (takes blood form liver to heart)

We will use a test called the **Benedict's test**to determine the amount of glucose in each location. The benedicts test ranges in color from blue (no glucose) to orange/red (lots of glucose). Follow the directions below.

Procedure

Glucose levels after eating:

1. Fill the large beaker ½ full with tap water. Place the beaker on top of the hot plate. Turn the hot plate on to create a hot water bath.

2. Label three test tubes A1, B1, and C1 with a wax pencil
3. Use the small plastic ruler to mark on the test tube at 1 cm and 2 cm.
4. Fill test tube A1 to the 1 cm mark with serum A1 and to the 2 cm mark with Benedict's reagent.
5. Fill test tube B1 to the 1 cm mark with serum B1 and to the 2 cm mark with Benedict's reagent.
6. Fill test tube C1 to the 1 cm mark with serum C1 and to the 2 cm mark with Benedict's reagent.
7. Place all three test tubes into the hot water bath at the same time.
8. Heat the tubes for 5 minutes. Observe and record any color changes.
9. Record your results in the table below. Remember that blue indicates no glucose and red/orange indicates the most glucose. A green color signifies some glucose.

Results

Table 1 Glucose levels after eating

Test tubes in order of color change	Source of the serum

Questions

1. Which blood vessel, the mesentery artery, the hepatic portal vein, or the hepatic vein contains the most glucose after eating?
2. Explain why the hepatic portal vein contains more glucose than the hepatic vein after eating.

Procedure

Glucose levels before eating:

1. Keep your hot water bath from the first procedure
2. Label three test tubes A2, B2, and C2 with a wax pencil
3. Use the small plastic ruler to mark on the test tube at 1 cm and 2 cm.
4. Fill test tube A2 to the 1 cm mark with serum A2 and to the 2 cm mark with Benedict's reagent.
5. Fill test tube B2 to the 1 cm mark with serum B2 and to the 2 cm mark with Benedict's reagent.
6. Fill test tube C2 to the 1 cm mark with serum C2 and to the 2 cm mark with Benedict's reagent.
7. Place all three test tubes into the hot water bath at the same time.
8. Heat the tubes for 5 minutes. Observe and record any color changes.
9. Record your results in the table below. Remember that blue indicates no glucose and red/organge indicates the most glucose. A green color signifies some glucose.

Results

Table 2: Glucose levels before eating

Test tubes in order of color change	Source of the serum

Questions

1. Which blood vessel, the mesentery artery, the hepatic portal vein, or the hepatic vein contains the most glucose before eating?
2. Explain why the hepatic portal vein contains less glucose than the hepatic vein before eating.

Once you have recorded your results, please clean up the materials. Make sure to:

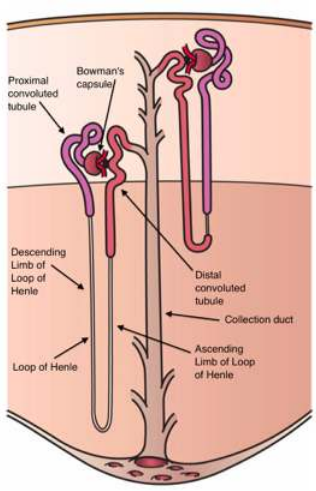
- Turn off and unplug the hot water bath
- Dump the contents of the test tubes down the sink
- Wash out the test tubes and place them in the test tube rack to dry

Part II: Kidneys

The kidneys are part of the urinary system. As they produce urine to release nitrogenous wastes from the body the kidneys also maintain homeostasis through pH balance and water-salt balance in **osmoregulation**. These bean shaped organs are located along the dorsal wall of the abdominal cavity.

Observe the kidney models available in the lab. Locate the outer renal cortex tissue and the more internal renal medulla. The renal pelvis is the area that collects the urine. Find the renal artery and the renal vein.

The functioning unit of the kidney is called the **nephron.** Part of the nephron is located in the cortex and part in the medulla. Use the picture below and the models in the lab to identify the following components of the nephron.



- Glomerulus
- Bowman’s capsule
- Proximal tubule
- Distal tubule
- Loop of Henle (descending limb and ascending limb)
- Collecting duct
- Peritubular capillaries

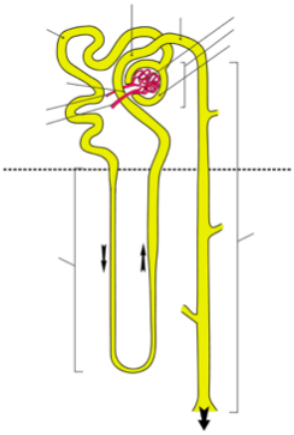
Questions

1. Which parts of the nephron are located in the renal cortex?
2. Which components of the nephron are located in the medulla?

Urine production in the kidney involves four main steps:

1. **Filtration**: molecules move out of the glomerulus into Bowman’s capsule. Large molecules like proteins and blood cells are too big to be filtered and remain in the blood.
2. **Reabsorption**: glucose and amino acids move from the proximal tubule back into the blood stream through peritubular capillaries.
3. **Secretion**: Substances like histamines, H+, and ammonia get secreted into the nephron from the peritubular capillaries
4. **Water reabsorption**: both the Loop of Henle and the collecting duct reabsorb water to maintain the blood volume

Label the parts of the nephron on the diagram below and indicate where the different urine production steps occur.



Focus on Filtration

Blood entering the glomerulus contains cells, proteins, glucose, amino acids, salts, urea, and water. Fill in the table below indicating which molecules will leave the glomerulus and enter the Bowman's capsule. Write yes or no for each and state why based on size (small or big).

Substance	Enter Bowman's Capsule?	Why?
Cells		
Proteins		
Glucose		
Amino acids		
Salts		
Urea		
Water		

Focus on Reabsorption

When the filtrate enters the proximal tubule it contains the following molecules: glucose, water, urea, amino acids, and salts. Water and salts are passively reabsorbed to maintain blood volume and pH as part of homeostasis.

Questions

1. What would happen to the blood volume over time if water were not reabsorbed?
2. How would this lack of water reabsorption affect blood pressure?
3. Fill in the table below indicating which molecules will be reabsorbed into the blood.

Substance	Reabsorbed?	Why?
Glucose		
Amino acids		
Salts		
Urea		
Water		

Kidneys are also important in **osmoregulation** , maintaing an internal salt/water balance. The kidney can produce large amounts of dilute urine or small amounts of concentrated urine depending on the needs of the body. The pituitary glad produces antidiuretic hormone (ADH) which controls the concentration of urine output. ADH specifically acts on the collecting duct making it more or less permeable to water.

The table below has several different events that would impact osmoregulation. Fill in the chart with either “increase” or “decrease” to explain how the kidney would help maintain homeostasis.

Event	Change in blood concentration	ADH output	Water Reabsorption	Type of Urine produced
Dehydration due to sunbathing in the afternoon and forgetting your water bottle				Scant, concentrated
Drinking large amounts of water throughout the day				Copious, dilute
Going to the move theater and eating a large bucket of salty popcorn without water to wash it down				Scant, concentrated

Kidneys also play a role in pH balance.

Questions

1. If the blood is more basic than normal, what pH do you think the urine will be?
2. If the blood is more acidic than normal, what pH do you think the urine will be?

11.2: Homeostasis Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Part I: Liver

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
human torso models	1 per bench	
liver models	1 per bench	
Benedicts reagent	1 bottle per bench	
test tubes	6 per bench	
goggles	1 pair per student	
gloves	1 pair per student	latex and non latex options in various sizes
Solution A1	1 bottle per bench	keep refrigerated
Solution B1	1 bottle per bench	keep refrigerated
Solution C1	1 bottle per bench	keep refrigerated
Solution A2	1 bottle per bench	keep refrigerated
Solution B2	1 bottle per bench	keep refrigerated
Solution C2	1 bottle per bench	keep refrigerated
hot plate	1 per bench	
goggles	1 pair per student	

Recipe for Solution A1 (0.25% glucose): Dissolve 1.25g glucose/500ml DI water

Recipe for Solution A2 (0.25% glucose): Dissolve 1.25g glucose/500ml DI water

Recipe for Solution B1 (3% glucose): Dissolve 15g glucose/500ml DI water

Recipe for Solution B2 (0% glucose): 500 ml DI water

Recipe for Solution C1 (0.5% glucose): Dissolve 2.5g glucose/500ml DI water

Recipe for Solution C2 (0.5% glucose): Dissolve 2.5g glucose/500ml DI water

Part II: Kidneys

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
Kidney model	1 per bench	
nephron model	3 per class	

CHAPTER OVERVIEW

12: Food Choice

12.1: Food Choice Lab

Adapted by Staci Forgey, Tidewater Community College biology faculty, with permission from Niagara University's Dr. William Edwards Food Choice Lab.

Learning Objective

By the end of this section, you will be able to:

Identify the basic tenets of Ecology and how they apply to population success.

Foraging is the act of an animal searching for food. An animal's choice of food should reflect energetic considerations such as maximizing net energy gain per unit time or net gain per cost expended in foraging. Animals want the most energy return for their caloric investment. They seek out food sources that will give them the most energy reward for the least amount of energy expended. We will be examining the foraging behavior of birds in our quad.

Question

1. What factors might influence seed selection in the birds we will be watching? Name three factors and their effects.

Given these factors, we will now form hypotheses and predictions that we will test by observing birds in the courtyard area. After, we will perform a Chi-Square statistical test on our data, and revise our hypotheses and thought processes to fit the new data.

Many birds will visit our feeders and collect seeds. Our feeders are stocked with three types of seeds. The Feathered Friend black oil seed is very soft hulled. The Lyric Sunflower gray striped sunflower seeds are large and thick hulled. Gray safflower seeds are also small and soft hulled.

Question

1. Look at the three seed types. Feel them and try to break them open. Note the differences you observe between the seed types.

The table below summarizes measurements for the 3 types of seeds. This shows the average kernel (food part of the seed), hull (outside covering of the seed) and entire seed weight. The kernel/hull ratio for each seed type, and the average caloric (energy) content of the seeds. Use these values and your observations to make predictions about optimal foraging behavior for various bird types that visit the feeders.

Table 1: Mass and caloric content of sunflower seed components.

Seed (mg)	Kernel (mg)	Hull (mg)	Entire seed (mg)	Kernel/Hull	Cal/g	Cal/seed
Black oil	28.8 ± 3.8	12.2 ± 1.6	41.0 ± 0.5	2.37 ± 0.3	5400 ± 240	150
Safflower	26.8 ± 3.9	10.4 ± 3.3	38.3 ± 6.9	2.603 ± 0.1	6200 ± 240	161
Striped	61.7 ± 4.7	59.1 ± 2.7	120.8 ± 6.0	1.045 ± 0.1	5600 ± 240	350

Now, take a look at the birds that are commonly found in our area during this time period. You will have a list of birds on your lab bench.

Your lab group will propose two experimental hypotheses about avian seed choice and discuss these with your instructor. Provide a rationale for your testable hypotheses. Clearly state each of your ideas in the form of an "If . . . then . . ." hypothesis. If your hypothesis is correct, which type of seed do you expect the birds to choose? Why?

Questions

1. Clearly state a testable hypothesis explaining why birds will choose or not choose the different seeds.
2. Would this hypothesis change with different birds? Why or Why not?
3. What is the alternative(s) to your hypothesis? (i.e., if you are wrong)
4. If your hypothesis is right, what would you predict the birds will do at the feeders?
5. If your alternative is right, what would you predict?

Check in with your instructor before continuing after this point!

In order to test your hypothesis, we need to think a bit about experimental design. Variables are important to consider because they will help us evaluate our hypothesis. For example, if we were interested in the height at which giraffes eat their food from, we might propose a hypothesis that giraffes will eat food from high areas in a tree. Each time the giraffe ate, the height at which the food was taken from would need to be recorded. This gives us two variables: the height at which the mouthful of vegetation came from and the mouthful height. This height is measurable. We will look at what is called "categorical" data. Each of our data points will fit into a category. We will have a bird taking a seed (making a food choice), and the type of seed chosen.

Questions

1. What is the independent variable (what we are manipulating)?
2. What is the dependent variable (what we are measuring)?
3. Design a data table to record the species of bird and type of seed each bird selects during our lab time. You can use hash marks to record visits. We will be visiting our feeders for a 20 minute time span.

Discuss your data sheet with your instructor before you begin collecting data!

When we return, you'll need to transfer the data from your table into the following table as totals.

Bird Type	Safflower	Striped Sunflower	Black Oil
TOTALS			

Bird Observation

Stay well away from the feeders at all times and keep as quiet as possible. One noisy or clumsy move can scare all the birds away, leaving you without any data!

Question

1. Describe the behavior of the birds with the seeds.
2. How long does it take an individual bird (record the species of bird and the type of seed eaten) to eat a seed and return to the feeder for another? Use your binoculars to follow individual birds and record the time from when a bird takes a seed to when it returns for another. Do the birds do anything unusual with the seeds?
3. Compare and contrast the seed handling behavior of the birds visiting the feeders. How do the different birds crack each of the seeds? Do they have difficulty opening any of them?

Statistical Analysis

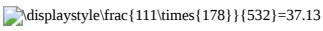
Using your feeder choice data, perform a chi-square Goodness of Fit test to determine if the birds show a preference for any given seed.

A Chi-Square test involves testing the probability that your categorical data differs from random enough to have confidence that the data does not come from chance alone. Typically, we accept that significance is 0.05 (called alpha). This means that there is only a 1 in 20 chance of the data arising from chance alone. When doing a chi-square, we typically call the boring hypothesis (that all the birds would randomly select seeds and your hypothesis is wrong) the "null" hypothesis, abbreviated H_O. The hypothesis where the

data support your idea is called the alternate hypothesis, abbreviated H_a. Note: this is a different type of hypothesis, used to fit specifically into statistical tests. This may not match perfectly with your description of hypotheses above. A chi-square also doesn't tell you exactly where the differences causing significant deviation from the expected. You would need more involved statistics for that. We will visually pick out our differences in data.

First, transfer your choice data into a table like the following table. We will calculate the expected values from the data.

Add the data for each bird horizontally, then for each seed vertically. The total row and total column should now be filled. These represent how many birds and seeds by type were actually eaten and recorded. Now we will calculate the expected values based on how these would be distributed by random chance. We will take the total for each species, multiply it by the total number of seeds for that seed type, and divide by the total number of seeds

For example, 

Put the answer into the table. This is how many safflower seeds would be expected to be eaten by the chickadees through chance alone. Complete your own table.

SAMPLE TABLE				
	Safflower	Striped	Black Oil	Total
Black-capped chickadee	13	23	75	111
(Expected)	37.13			
Tufted titmouse	21	32	23	76
(Expected)				
House finch	45	23	43	111
(Expected)				
American goldfinch	0	0	0	0
(Expected)				
Nuthatches	0	0	0	0
(Expected)				
Junco	76	32	32	140
(Expected)				
House sparrows	23	27	44	94
(Expected)				
TOTALS	178	137	217	532

Bird Type	Safflower	Striped	Black Oil	Total
(Expected)				
(Expected)				
(Expected)				
(Expected)				
(Expected)				
(Expected)				
(Expected)				
(Expected)				
TOTALS				

To calculate the chi-square value, or $\displaystyle\chi^2$, we simply add the square differences, divided by the expected, of all the observed and expected. In mathematical terms:

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \tag{12.1.1}$$

So for our example from the previous sample table, the first $\displaystyle\frac{(O-E)^2}{E}$ would be

$$\frac{(13-37.13)^2}{37.13} = 15.7 \tag{12.1.2}$$

We would then add to this value all of the other $\displaystyle\frac{(O-E)^2}{E}$ in the table to get the $\displaystyle\chi^2$ value.

Question

1. Compute the $\displaystyle\chi^2$ value for your data. (Use an extra sheet of paper if necessary)

In order to find something to compare this number with, we need to calculate the degrees of freedom, or the number of different comparisons that can be made within the table. The degrees of freedom are the number of columns (M) minus one times the number of rows (N) minus one. Degrees of freedom = (M–1) (N–1)

Questions

1. How many ways can this two by two table be broken into individual comparisons? Hint: Use the formula above.

A	**B**
C	**D**

2. Calculate the degrees of freedom in your experiment.

Now we can compare against the Chi distribution for the likelihood that our data is generated by chance. Remember, we want a 0.05 or less value to say that it's not chance, but our hypothesis that's causing the choices.

Questions

1. Compare to the Chi-distribution table at the end of the lab with your instructor's assistance. What is the p value or probability that your data came out by chance? Is this less than 0.05? Did your results come about by chance?
2. Describe and summarize what you observed in the field. Are some parameters more difficult to measure than others? If so, why? Which predictions did your data support? Interpret you results as they relate to your hypotheses and discuss your interpretation.
3. How could you re design your experiment to better measure energy gains, handling time, and energetic costs of foraging, and thus more accurately test the predictions of optimal foraging theory? Think of other hypotheses regarding seed choice by birds? Propose a follow up study that would allow you to test a related idea about avian foraging behavior. Make clear the ways in which your proposed study is an extension of or improvement upon the study on which you report here.

Chi Square Distribution Table:

DF/P	0.995	.990	0.975	.950	.900	.750	.500	.250	.100	.050	.025	.010	.005
1	0.00004	.00016	0.001	0.004	0.016	0.102	0.455	1.323	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.0506	0.103	0.211	0.575	1.386	2.773	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.351	0.584	1.213	2.366	4.108	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	1.923	3.357	5.385	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	2.675	4.351	6.626	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	3.455	5.348	7.841	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	4.255	6.346	9.037	12.017	14.067	16.013	18.475	20.278
8	1.344	1.647	2.180	2.733	3.490	5.071	7.344	10.219	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	5.899	8.343	11.389	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	6.737	9.342	12.549	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	7.584	10.341	13.701	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	8.438	11.340	14.845	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	9.299	12.340	15.984	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	10.165	13.339	14.114	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	11.037	14.339	18.245	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	11.912	15.339	19.369	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	12.792	16.338	20.489	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	13.675	17.338	21.605	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.657	14.562	18.338	22.18	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	15.452	19.337	23.848	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	16.344	20.337	24.935	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	17.240	21.337	26.039	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	18.137	22.337	27.141	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	19.037	23.337	28.241	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	19.939	24.337	29.339	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	20.843	25.336	30.435	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	21.749	26.336	31.528	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	22.657	27.336	32.620	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	23.567	28.336	33.711	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	24.478	29.336	34.800	40.256	43.773	46.979	50.892	53.672

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12.2: Food Choice Lab (Instructor Materials Preparation)*

Lab Materials

This is the prep for *one section* of 24 students.

One week in advance fill three separate bird feeders, one with black oil seeds, one with sunflower seeds, and one with safflower seeds. Place the bird feeders in the same tree in close proximity to one another. Leave feeders until experiment begins.

Bird Observation

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
metal clipboards	1 per pair of students	
binoculars	1 per pair of students	
bird book or identification key for local birds	1 per pair of students	
Black oil, sunflower, and safflower seed samples in Petri dishes	1 sample of each seed type per table	

Statistical Analysis

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
calculators	1 per pair of students	

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CHAPTER OVERVIEW

13: Succession Lab

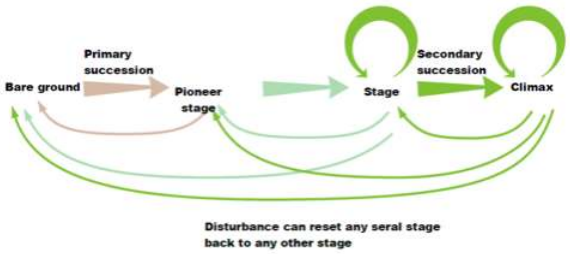
13.1: Community Ecology Lab

Learning Objectives

- Describe the processes of primary succession and secondary succession
- Explain what makes a community and an ecosystem different
- Describe the differences between abiotic and biotic factors
- Explain why disturbances play an important role in the progression of succession
- Define a climax community
- Describe why most areas will not make it to a climax community
- Describe the plant communities present after glacial succession and how they change the environment
- Explain the stages of succession of milk
- Describe how pH changes as milk goes through successional stages
- Explain the difference between gram negative and positive bacteria
- Draw and describe the shapes of bacteria
- Formulate a hypothesis based on background data

Ecological Succession of Bacteria in Milk

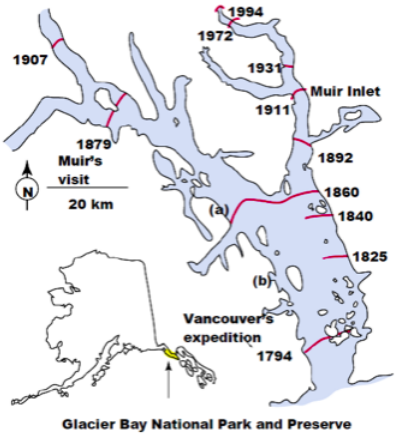
The communities within ecosystems develop over time, from very simple species assemblages, to complex, rich ecosystems. In this process, called succession, each *succeeding* species facilitates changes in environment which allow new species to come into the ecosystem. As the community becomes more and more complex, the biodiversity of the ecosystem also increases. Both biotic and abiotic processes can reset the succession process. That is, events cause by both the community itself, and outside events can return the community to an earlier succession state. The gradual changes in the community are both orderly and predictable in many ecosystems. The peak or most complex, advanced community that can develop in any abiotic environment is called the climax community. The picture below describes the developing communities as a series of steps, each of which can be driven against the succession process by disturbances:



Question

1. What types of events could “reset” a succession process? Name at least one biotic and one abiotic disturbance.

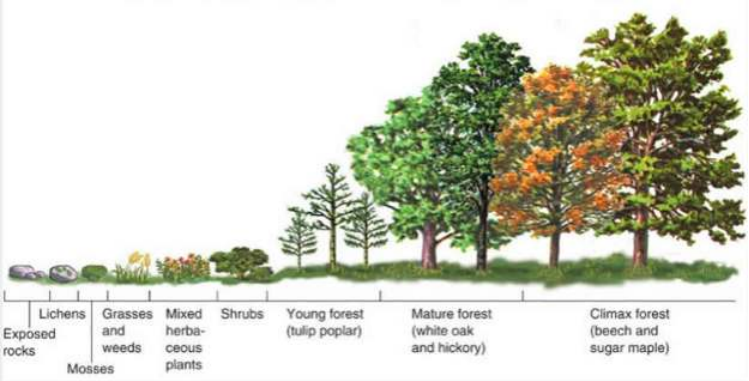
One example of a severe disturbance, reducing the land to bare ground, is the passage of a glacier. Though glaciers have not covered this part of North America for ten thousand years, there are parts of the continent that are even now becoming uncovered by receding glaciers. One area is the pacific northwest. From Juneau to Glacier Bay, many glaciers which have previously fallen directly into the ocean are now leaving bare soil which has not been exposed for more than fifty thousand years. Because the glaciers retreat very slowly, we can watch communities change across time in a single snap shot. Take the glaciers of Glacier Bay National Park, midway between Juneau and Anchorage, Alaska. The glaciers there have been retreating since the explorer Vancouver’s first expedition in 1794. Since then, the retreat has covered over 100 km, including new coastline, meadows and mountains:



Glacier Bay National Park and Preserve

Question

1. Explain how this retreat will result in different communities along the glacier's retreat, though in similar environments. Hint: what is the difference between exposed soil at point A and point B.



As the glacier retreats, it leaves nutrient poor soil which can only support simple plants such as liverworts, lichens, and other primitive plants. As they photosynthesize and die, we see them enter the decomposer pathway and increase the quality of the soil for later plants. However, this slow glacier retreat is a unique situation. To set up an experiment to test our understanding of succession would require hundreds of years, longer than a scientists lifetime. However, some organisms and communities proceed at a much faster rate, within your own refrigerators. The process of milk decomposition from a community of bacteria can test the same processes and theories in a much more reasonable time frame. This substitution of a simpler and faster community for experimental purposes is called a 'model' system.

Milk is a highly nutritious food containing carbohydrates (lactose, or milk sugar), proteins (casein, or curd), and lipids (butterfat). This high level of nutrition makes milk an excellent medium for the growth of bacteria. Pasteurizing milk does not sterilize it (sterilizing kills *all* bacteria) but merely destroys pathogenic bacteria, leaving many bacteria that can multiply and these bacteria will begin to grow and bring about milk spoilage. Biologists have discovered that as milk ages, changing conditions in the milk bring about a predictable, orderly succession of microorganism communities.

In this laboratory exercise, you will observe successional patterns in several types of milk. You will record changes in the environmental conditions of the types of milk as they age. These changes are a result of changes in the bacterial communities. Here are some of the major bacteria found at various stages.

Stages of Milk Succession

1. *Psuedomonas* and *Achromobacter* (gram-negative rods) digest butterfat and give milk a putrid smell
2. *Lactobacillus* (gram-positive rod) and *Streptococcus* (gram-positive coccus) ferment lactose to lactic acid and acetic acid.
3. Acidity sours milk and converts casein to curd.

4. Yeast (fungi) thrive in acidic conditions and metabolize the acids into non-acidic compounds.
5. *Bacillus* metabolize proteins into ammonia products and raise the milk's pH. Spoiled milk odor is very noticeable at this stage.

Questions

1. What are some advantages to using bacteria as opposed to plants in this experiment?
2. What factors might speed or delay a successional process? Apply your example to succession in milk.

Locate the milk samples available in the lab. Take a look at the samples and form two conditions you would like to study. Develop a short design for studying the first condition, state the dependent and independent variable, control and experimental group, the hypothesis and any variables which have been controlled. Then develop a short design for studying the second condition, state the dependent and independent variable, control and experimental group, the hypothesis and any variables which have been controlled.

Just as in any of our experiments, you must use effective scientific method**.** Develop hypotheses (at least 2—one with different milk types and one with either temperature or time as an independent variable) that you can test in the process of the milk community succession.

We will be performing a gram stain on our milk samples. Remember from our microbiology section that bacteria can be either gram negative (pink) or gram positive (purple). We will also look at these bacteria under a microscope to identify their shapes. Recall that bacteria can be cocci, bacilli, or spirillum.

Questions

1. What hypotheses are you testing? List both here.
2. What information led you to ask these hypotheses?
3. Make predictions about your hypotheses. i.e. How will you know if the data supports or refutes your hypotheses?
4. Be sure to identify the variables you will *test*, and those you will *control* for each experiment.
5. Prepare a table for data collection. You will be recording the pH, smell, consistency, and bacteria shapes and colors present in your milk samples.

On each lab bench are several small beakers. You will obtain a sample of the milk samples you need for your experimental design and test the pH, color, consistency, smell and other characteristics of each sample. For each milk sample:

1. Using the Vernier, take the pH of each flask. Record your results.
2. Record the color, odor (sour, putrid), and consistency (coagulation slight, moderate, chunky) for the milk in each flask.
3. Perform Gram Staining as outlined below. **Note: We will be using chemicals and open flames. Exercise caution when performing this portion of the lab.**

Materials

- Microscope slide
- Bunsen burner and tubing
- Crystal violet (primary stain)
- Iodine solution/Gram's Iodine (mordant that fixes crystal violet to cell wall)
- Decolorizer (e.g. ethanol)
- Safranin (secondary stain)
- Water (preferably in a squirt bottle)

Procedure

1. Make a slide with your milk sample to be stained. Heat fix the sample to the slide by carefully passing the slide with a drop or small piece of sample on it through a Bunsen burner three times.
2. Add the primary stain (crystal violet) to the sample/slide and let sit for 15 seconds. Rinse slide with a gentle stream of water for a maximum of 5 seconds to remove unbound crystal violet.
3. Add Gram's iodine for 15 seconds – this is an agent that fixes the crystal violet to the bacterial cell wall.
4. Rinse sample/slide with acetone or alcohol for ~3 seconds and **rinse with a gentle stream of water**. The alcohol will decolorize the sample if it is Gram negative, removing the crystal violet. However, **if the alcohol remains on the sample for too long, it may also decolorize Gram positive cells**.

5. Add the secondary stain, safranin, to the slide and incubate for 15 seconds. Wash with a gentle stream of water for a maximum of 5 seconds. If the bacteria is Gram positive, it will retain the primary stain (crystal violet) and not take the secondary stain (safranin), causing it to look violet/purple under a microscope. If the bacteria is Gram negative, it will lose the primary stain and take the secondary stain, causing it to appear red when viewed under a microscope.

Questions

1. Describe the changing sequence of organisms and corresponding environmental changes during succession in the milk samples. Which bacteria are in each of your milk samples?
2. Describe the changing sequence of organisms and corresponding environmental changes during succession in chocolate milk. Do the results of your investigation match your hypothesis?
3. Compare succession in one or more types milk. Propose reasons for differences.
4. Propose another experiment to test the environmental factors and/or organisms changing in your proposed scenario for milk succession.
5. How could you improve your test of the hypotheses? Be specific!
6. Identify what happened to the pH of the milk as time passed.
7. Infer what the change in pH means about the populations of microorganisms in the milk.

13.2: Community Ecology Lab (Instructor Materials Preparation)*

Lab Materials

This is the prep for *one section* of 24 students.

Ecological Succession of Bacteria in Milk

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
clean microscope slides	1 box	
coverslips	1 box	
Bunsen Burner	1 per table	
tubing for Bunsen Burners	1 per table	
wire loop	1 per table	
50 ml beaker	3 per table	
pH probe	1 per table	can use pH paper as an alternative
compound light microscope	1-2 per table	
clothespins	2 per table	to hold slides for gram staining procedure
gram staining kit	1 per table	includes Safranin, Crystal violet, Iodine and ethanol
Bunsen striker	1 per table	
squirt bottle of DI water	1 per table	

Side bench for students to share: empty milk containers with nutritional information: whole milk, 2%, 1%, skim, chocolate, whole buttermilk and reduce fat buttermilk

Side bench for students to share: 1L beaker of 10% bleach solution (to disinfect slides are staining)

1 week prior to lab purchase the following:

- Whole milk: 1 gallon (red tape)
- 2% milk: 1/2 gallon (white tape)
- 1% milk: 1/2 gallon (green tape)
- Skim milk: 1/2 gallon (blue tape)
- Chocolate milk; 1/2 gallon (brown tape)
- Whole buttermilk: 1/2 gallon (yellow tape)
- Reduced fat buttermilk: 1/2 gallon (orange tape)

Milk set up:

1. Label seven 300 ml clear bottles with colors listed above.
2. Pour 100 ml of each milk type intwo their respective bottles
3. Place bottles on a cart in the prep area until the first lab
4. Repeat steps 1-3 each day until the last day of the lab
5. At the end of the two week there should be a total of 70 labeld bottles

Milk in incubator (should be set at 37 C)

1. Obtain one 300 ml clear glass bottl

2. Pour 100 ml of whole milk into the bottl and place in the incubator (whole milk is the only type to go in the incubator)
3. Repeat steps 1-2 each day until the last day of this lab
4. At the end of the two week period there should be a total of 10 labeled bottles

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CHAPTER OVERVIEW

14: Ecosystem Lab

14.1: Ecosystem and Eutrophication Lab

Learning Objectives

- Define eutrophication and explain how human behaviors lead to eutrophication.
- Explain how algae blooms are detrimental to aquatic ecosystems.
- Explain how zooplankton might impact algae blooms caused by cultural eutrophication.
- Predict the effects of changes in an aquatic ecosystem using a computer model

Download a PDF of the lab to print.

An **ecosystem** is defined as an association of life and the physical environment. Ecosystems take into account both living organisms and the nonliving components like water, soil, light, etc. Ecosystems can be either terrestrial (dessert, forest, grassland) or aquatic (coral reef, pond, estuary).

Within ecosystems scientists study **energy transformations**. Energy typically enters the ecosystem from the sun, is transferred to photosynthetic organisms (primary producers) and then to organisms that need to eat others for energy, the consumers or heterotrophs. An ecosystem will typically have several levels of consumers. The transfer of energy from organism to organism can be illustrated through **trophic levels.** A trophic level includes all organisms the same number of transfer steps away from the energy input into an ecosystem. A simple trophic level diagram for a forest ecosystem is illustrated below. Notice the photosynthetic organisms like plants are on the first trophic level, one step away from the energy source. The squirrel is a primary consumer (eating plants directly) but on the second tropic level two steps away from the primary energy source. At each step along the pathway some energy is lost as heat. Therefore at higher tropic levels there are fewer organisms (as noted by the pyramid shape) and most ecosystems support no more than four or five total trophic levels.

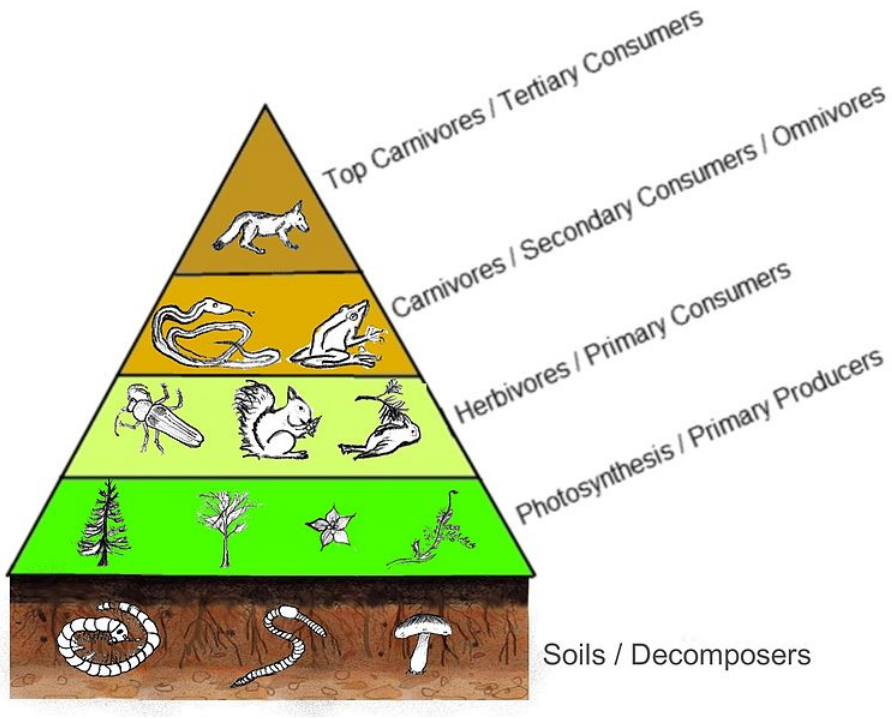

Figure **14.1.1**: Thompsma. **Located at**: https://commons.wikimedia.org/wiki/File:Trophiclevels.jpg. **License**: *CC BY-SA: Attribution-ShareAlike*

Ecosystems are changing due to human behaviors. Humans negatively impact natural ecosystems through activities such as deforestation, hunting, and pollution. Today's lab focuses on the impact of **eutrophication** on aquatic ecosystems. Through eutrophication bodies of water acquire extremely high concentrations of nutrients. The source of these nutrients can be natural or artificial. Humans cause cultural eutrophication through behaviors like run off from agricultural fields, wastewater from sewage

treatment plants, and excel detergents running into bodies of water. The excess nutrients fuel photosynthesis causing an increased growth in algae, a photosynthetic primary producer protist, and an algae bloom. During the bloom the algae cover the surface of the water. When the algae die, decomposers in the ecosystem break down the protists using up the oxygen available in the aquatic environment through respiration. As oxygen levels decrease (hypoxia), fish die, and the balance of the ecosystem is destroyed.

In an effort to understand ecosystems and human impact on ecosystems scientists often use models. Modeling of ecosystems serves two main functions. First, the model represents scientist's best understanding of the relationships/functions that define the ecosystem. Second, models allow scientists to investigate questions that would be impossible to pursue in reality.

Ecosystem models fall into two categories, analytical models and simulation models. Analytical models use math to explain simple linear relationships. Simulation models, more widely used, are used to illustrate complex non linear relationships in ecosystems. Since the natural ecosystem has numerous interactions between living and non living components ecosystem models must simplify this real world situation. Models incorporate only the most important components or group similar components in an effort to effectively represent the ecosystem in a straightforward fashion.

Silver Springs

This lab will utilize the Silver Spring model, an analytical model, developed by H. T. Odum in 1957. Silver Springs is a real aquatic ecosystem located in central Florida. Odum developed his model to illustrate energy flow through the different trophic levels. The main organisms in Sliver Sping organized by trophic level are:

- *First trophic level*: Eelgrass and algae are the main photosynthetic organisms.
- *Second trophic level*: Invertebrates, turtles, and fish are the herbivores.
- *Third tropic level*: Both fish and invertebrates are carnivores and prey upon the herbivores.
- *Fourth tropic level*: The top carnivores consist of gar and bass, which eat the other fish species at lower trophic levels.
- *Decomposers*: Bacteria and crayfish are the main decomposers.

The Silver Springs model is on Blackboard as an Excel file. The general model structure is pictured on the next page. Odum's model contains five state variables representing energy inputs into the four tropic levels and the decomposers. Flux rates describe the addition/removal of energy to/from the various parts of the system and the rate of transfer of energy between the components of the system. In the Excel file you can change the initial values **(X)** of any or all of the state variables and coefficients **(P)**, and control the length of time simulated. Following a simulation "run" you will be easily able to view graphs of the state variables or community respiration versus time. To change the initial values, simply type over the current value and press return. Use the model to investigate the scenarios below:

We will use the model in two different scenarios in today's lab, to understand eutrophication and to determine the impact of bread on the ecosystem.

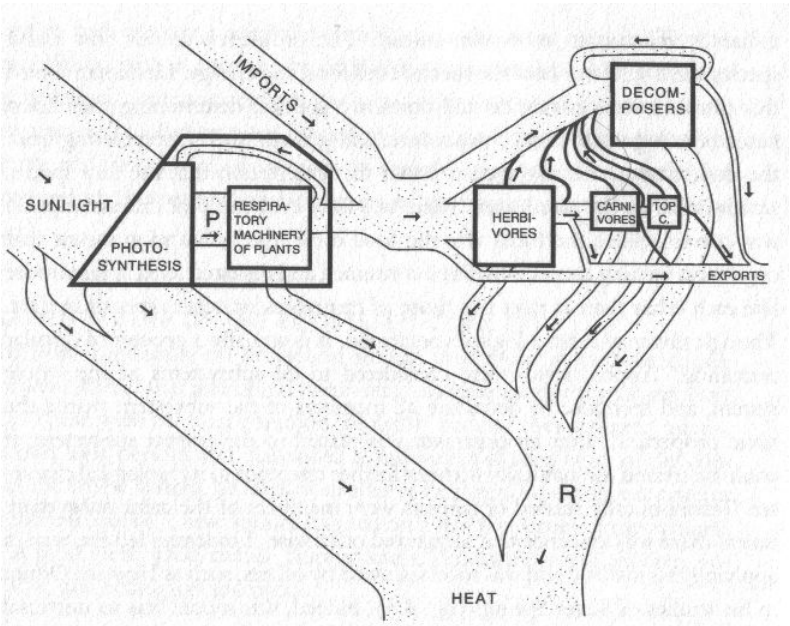

Figure **14.1.1**: Odum's Silver Spring Model. Sholto Maud. **Provided by**: Wikipedia. **Located at**: https://commons.wikimedia.org/wiki/File:Silver_Spring_Model.jpg. **License**: *Public Domain: No Known Copyright*

Activity I

To understand more about eutrophication, you will conduct a laboratory experiment (Part 1) and use the Silver Springs computer model (Part 2)

Part 1

One potential way to decrease cultural eutrophication is by having higher trophic level organisms consume the algae. We will investigate this possibility using *Daphnia*, a zooplankton that feeds on green algae, and an alga species called *Chorella*. Although the information we gain from this activity is useful, it is an over simplification as to what might really occur in the aquatic environment.

We will use a **colorimeter** to measure the algae population. A colorimeter measures absorbance, the amount of light that is absorbed by a solution rather than the amount of light that can pass through. As the algae population increases (number of algae cells), the absorbance will also increase. It is a direct relationship.

Procedure

1. Obtain two cuvettes and a transfer pipette.
2. Fill one cuvette with distilled water. This cuvette is the blank
3. Place the blank into the colorimeter and zero it. This provides a baseline measure for the experiment. Save the blank cuvette for later use.
4. Using the disposable pipette, fill the second cuvette with the *Chorella* algae. Use the pipette to try and disperse the algae evenly throughout the cuvette.
5. Add 10 *daphnia* to the cuvette and immediately measure the absorbance using the colorimeter. Record your reading in the table below.
6. Remove the cuvette from the colorimeter and allow it to sit, undisturbed for 30 minutes.
7. After 30 minutes, place the blank cuvette (with distilled water) back into the colorimeter. Use the blank to re-zero the machine.
8. Remove the blank cuvette and put the algae/*Daphnia* cuvette into the colorimeter. Measure the absorbance and record your reading in the table below.

Table 1: Colorimeter data of *Daphnia* feeding on *Chorella*	
	Absorbance value
Before feeding (time zero)	

Questions

1. How did the absorbance change from time 0 to time 30 minutes? Did the absorbance increase, decrease, or stay the same?
2. What does the absorbance value change tell you about the concentration of the *Chorella*? Did it increase, decrease, or stay the same?
3. What does the absorbance value chance tell you about the behavior of the *Daphnia*? Did they consume *Chorella?* How do you know?
4. In a real aquatic ecosystem, do you think zooplankton could decrease the impact of cultural eutrophication and algae blooms? Explain why or why not.

Part 2

Now that you have observed trophic interactions and cultural eutrophication in a lab experiment, apply that knowledge to the computer model. Use the model to analyze the sensitivity of the Silver Springs ecosystem to cultural eutrophication. Remember that alga is a photosynthetic producer on the first trophic level. The *Daphnia* would be one of the herbivores in the environment on the second trophic level. Change the levels in the model to simulate a eutrophication situation. View the graphs to see how the different trophic level populations change through the simulation.

Questions

Based on your findings with the model, answer the following questions:

1. What is the maximum number of producers the ecosystem can support before higher trophic levels begin to decline?
2. What happens to community respiration in the simulated algae bloom? Does it increase, decrease, or stay the same?
3. What happens to the decomposer population in the simulated algae bloom? Does it increase, decrease, or stay the same? Why?
4. Which group of carnivores (which trophic level) is more greatly impacted by the algae bloom? Why do you think this is the case?

Activity II

Eutrophication is not the only way that human activities affect aquatic ecosystems. Tourism in the Silver Spring area has grown lately as a result of more of vacationers visiting Central Florida. When visiting Silver Spring, tourists enjoy feeding the ducks. But, the ducks are gaining weight and becoming dependent on the tourists as a food source disrupting the normal food chain in the environment. Some environmental organizations have voiced displeasure regarding the dependence of ducks on bread handouts from visitors to the lake. Is it feasible to stop feeding the ducks or have they become too reliant on the tourists and the bread handouts?

Task

Use the model to analyze the sensitivity of long-term duck populations to an increase or decrease in bread input. There is a separate variable for bread and the ducks would be on the second trophic level as herbivores. View the graphs to see how the different trophic level populations change through the simulation.

Questions

Based on your findings with the model, answer the following questions:

1. Is an elimination of bread feasible? Why or why not?
2. How would the system respond to increasing levels of tourism, assuming bread levels also increased? What trophic levels are most impacted by increased levels of bread?
3. What is the role of bread in the system, and how does its presence or absence impact the ecology of Silver Springs?

4. What would be your suggestion to the managing board of Silver Springs? Should they completely eliminate the tourists feeding the ducks? Why or why not?

14.2: Ecosystem and Eutrophication Lab (Instructor Materials Preparation)

Lab Materials

This is the prep for *one section* of 24 students.

Activity I

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
colorimeter	1 per bench	
cuvettes	2 per bench	
live *Daphnia*	1-2 vials can be shared by all lab sections	
Chorella algae	1-2 vials can be shared by all lab sections	

Activity II

Students will do this part in table teams (groups of 4).

Materials	Quantity	Notes
laptop computers	1 per pair of students	

CHAPTER OVERVIEW

15: Sample Lab Report

15.1: Sample Lab Report- Sugar Size and Diffusion Through a Mock-Cell Membrane

BIO 101L

Instructor: L. Hauser

Introduction

Diffusion is the process in which a substance moves from an area of high concentration to an area of lower concentration. It is important for membranes to be semi-permeable. If membranes were universally permeable, they would not legitimately serve their purpose as membranes; certain substances need to be kept out of a cell, and others kept in. If membranes were not at all permeable, there would be no interface between the cell and its environment – effectively starving the cell. Membranes, being selectively permeable, allow in nutrients and other necessary substances, and also provide for the purging of cell waste.

This experiment investigates the permeability of cell membranes to various types of sugars: polysaccharides, disaccharides, and polysaccharides. Dialysis tubing is used to simulate a cell membrane; it is permeable to small molecules and water, but not to larger molecules.

Given the generally larger size of polysaccharides, it is hypothesized that starch will not pass through the dialysis tubing, and that iodine will pass through the membrane due to the small size of its molecules. Based on the trouble that some people have digesting lactose, it is predicted that it is a polysaccharide or disaccharide and will yield diffusion results similar to starch.

Methods

I) Permeability of cell model to starch

The 100ml graduated cylinder was used to measure out 50ml of tap water; the water was poured into a 250ml beaker. One teaspoon of corn starch was added to the beaker and stirred with a spoon. A 50ml beaker was filled with 50ml of tap water. A piece of dialysis tubing was placed into the beaker of water until it became soft and pliable. The tubing was then extracted from the beaker; one end was tied closed with dental floss, using a double-knot. The other end of the dialysis tubing was opened; a pipette was used to fill the dialysis tubing with the starch solution. Another piece of dental floss was used to tie the end of the dialysis tubing closed. A second 250ml beaker was filled halfway with tap water. Another pipette was used to add 15 drops of iodine to the beaker; the solution was mixed with a spoon. The filled dialysis tube was placed into the 250ml beaker so that the cornstarch mixture was submerged in the iodine water mixture. After 15 minutes had passed, results were observed and recorded.

II) Permeability of cell model to lactose

Part I: Determining the type of sugar being tested

The 100ml graduated cylinder was used to measure out 100ml of tap water; the water was poured into a 250ml beaker. Two teaspoons of the lactose was added to the water, and the solution was stirred with a spoon for thorough mixing. 50ml of the resultant solution was measured out using the 100ml graduated cylinder, and was reserved for Part II.

Twenty drops of Benedict's reagent were placed in a clean, empty test tube. Twenty drops of the lactose solution were added to the same test tube, and the solution was heated in a boiling water bath for 2 minutes. The results were then interpreted.

Twenty drops of Barfoed's reagent were placed in a clean, empty test tube. Twenty drops of lactose solution were added to the same test tube. The resultant solution was headed in a boiling water bath for 3.5 minutes. The results were then interpreted.

Part II: Permeability of cell model

This method is based on the premise of the unknown sugar being a disaccharide.

A 50ml beaker was filled with 50 ml tap water. A piece of dialysis tubing was placed in the beaker of water and left to soak until it became soft and pliable. The dialysis tubing was then removed from the beaker, and one end tied closed with a double-knotted piece of dental floss. The other end of the dialysis tubing was opened. The tubing was filled with lactose solution (set aside from Part I); a pipette was used to transfer the solution from the graduated cylinder to the tubing. A second piece of dental floss was used to tie the other end of the dialysis tubing closed. A second 250ml beaker was filled halfway full with tap water.

15 drops of iodine were added to the tap water in the beaker. The resulting solution was swirled with a spoon to mix it; the colors of the baggie solution and the beaker solution were noted. The dialysis tubing baggie was placed in the 250ml beaker so that the lactose solution was submerged in the beaker solution, and left to sit undisturbed for 15 minutes. The color of the baggie solution was noted.

The baggie was removed from the beaker and samples of the beaker solution were transferred to separate, appropriately marked test tubes. 20 drops of Bendict's reagent were added to one test tube, and the tube heated for 2 minutes. The color of the resulting solution was noted. 20 drops of Barfoed's reagent were added to the second test tube, and the tube heated for 3.5 minutes. The color of the resulting solution was noted.

Results

Table 1: Starch experiment results

	Solution in baggie	Solution in Beaker
Starting color	Murky white	Clear yellow
Color after 15 minutes	Dark purple	yellow

In the starch experiment as seen in Table 1, the starch solution inside of the dialysis baggie was initially a murky white color. The solution in the beaker, external to the baggie was a clear yellow color. After 15 minutes of submersion in the beaker solution, the baggie had turned a dark purple color. The beaker solution remained clear and yellow.

In Part I of the lactose experiment, the lactose solution was initially a dark brown color. Benedict's reagent is pale blue in color. Lactose, mixed and heated with the Benedict's reagent, yielded a solution of a murky yellow-brown color. Barfoed's reagent, like Benedict's reagent, is pale blue in color. Lactose, mixed and heated with the Barfoed's reagent, yielded a pale blue solution.

Table 2: Lactose experiment results

	Solution in baggie	Solution in Beaker
Starting color	brown	yellow
Color after 15 minutes	yellow	(? Not given)

In Part II of the lactose experiment, as seen in Table 2, the lactose solution inside of the dialysis baggie was initially dark brown in coloration. The iodine and water solution in the beaker was a clear yellow color. A Benedict's test on the beaker solution after the experiment yielded a dark brown liquid; a Barfoed's test on the beaker solution after the experiment resulted in a clear blue liquid.

Discussion

Permeability of cell model to starch

The starch solution inside of the dialysis baggie went from a murky white color to dark purple; iodine from the beaker solution must have diffused into the dialysis baggie, reacting with the starch solution and producing the "positive" dark-purple result, confirming the presence of a polysaccharide inside of the baggie. The beaker solution remained a clear yellow color throughout the experiment; it can hence be inferred that no polysaccharide was present in the beaker solution at the end of the experiment, and in turn, that no starch diffused out of the baggie and into the beaker solution during the 15-minute soaking.

The experimental hypothesis for this section was correct; starch was unable to diffuse through the cell model, however, iodine was able to diffuse through the cell model. The discrepancy in permeability is due to the difference in the sizes of iodine and starch molecules.

Permeability of cell model to lactose

The Benedict's test control on lactose yielded a solution that was a murky yellow-brown color; this indicated the presence of a mono- or di- saccharide. The Barfoed's test control on lactose yielded a solution that was pale blue in color, without any red precipitate; this indicates that no monosaccharaides were present, and in turn, that lactose is a disaccharide. The solution inside of

the dialysis tubing changed color in the course of the experiment; this implies that iodine diffused into the dialysis tubing and reacted with the lactose solution. The resulting clear yellow color indicates that there were no polysaccharides present inside of the dialysis tubing.

A negative Benedict's test is of blue coloration; a test on the beaker solution after the experiment is a very dark red-orange-brown color that looks similar to the original lactose in the tubing. A Barfoed's test on the post-experiment beaker solution was a clear light blue; no monosaccharaides diffused out into the beaker solution, but this result was irrelevant. The Benedict's test revealed that lactose was able to diffuse out of the dialysis baggie, into the beaker solution. If the cell model is reliable, it appears that lactose is able to diffuse in and out of cells.

The experimental hypothesis for this section appears to have been wrong; the cell model was permeable to lactose.

Overall, the cell model has demonstrated impermeability to large molecules such as polysaccharides, and permeability to smaller molecules such as disaccharides and iodine molecules. Since the model was permeable to a disaccharide, it would be reasonable to infer that the model will be permeable to monosaccharaides, as they are even smaller in size than disaccharides. Further testing with a variety of disaccharides should be done, to determine whether lactose is unique or whether the cell model is permeable to all disaccharides.

15.2: Rubric

The following rubric will be used to grade the lab reports:

	Excellent 5 points	Satisfactory 2.5 points	Unsatisfactory 0 points
Title Page	Contains title, student name, instructor name and section	Missing either instructor name or section	No title page
Formatting: typed, spacing	Typed and single spaced	Typed, but not single spaced	Not typed
Grammar and Spelling	No errors; contains complete sentences and no misspellings	A few minor errors in grammar and spelling	Several major errors in grammar and spelling
Formatting: headings	Each section has a heading as described in template	Some sections lack headings	No headings
Hypothesis	Predictions are clearly stated and written as a testable statement	Predictions/expected outcomes are not clearly stated	Not written as a testable statement
Materials	All equipment and materials described; identify variables, controls and constants	Materials incompletely described	No identification of variables, controls and constants
Procedure	Clear step-by step description	Description missing details making it difficult for another scientist to repeat experiment	Description missing so much detail it would be impossible to repeat
Results	Clearly written description of results comparing controls and variables	Results are presented but no comparison between controls and variables are made	No written description of results
Data tables, graphs or charts	Easy to interpret, clear labels, all data, including calculated averages, included	Disorganized (not easy to understand, missing labels) but **all** data included	Disorganized and or data clearly missing
Conclusion	Clearly explains acceptance or rejection of hypothesis using data to support conclusion; identifies sources of error	Accepts or rejects hypothesis but does not use data to explain why; or does not identify sources of error	Does not explain conclusion and does not identify sources of error
			Total _____out of 50 points

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