

PRINCIPLES OF BIOLOGY II (LAB MANUAL) [BIS 151]



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Principles of Biology II (Lab Manual) [BIS
151]

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CHAPTER OVERVIEW

0: BIS 151 Lab Manual

Introduction

The laboratory component of this course is designed to complement and expand on the material presented in lecture. Recall that our lecture topics include units on evolution and natural selection, plant and animal anatomy and physiology, ecology, as well as four units devoted to organismal diversity. As such, most of the labs that we will be completing together will focus on organismal diversity, providing us with the opportunity to look more closely at the remarkable variety of life forms that inhabit our planet. Here you will explore representatives from all the major groups of organisms from unicellular protists to complex vertebrates. In doing so, you will gain a deeper understanding of how structure and function reflect evolutionary history and key adaptations acquired by each group of organisms. Essential to these labs is careful observation of specimens.

Accurate and well-organized lab notes are also a vital part of scientific study. Record your observations and data in your lab manual as you make them. Each laboratory exercise in this course will culminate in a written report designed to help you synthesize what you have observed and learned. Your lab reports are more than summaries of observations and results, they are opportunities to analyze your data, interpret your findings, and connect them to the biological concepts discussed in lecture. By comparing your observations across different groups of organisms, you will begin to recognize patterns that illustrate key principles such as structure and function, adaptation, and ecological interaction.

A major goal of these reports is to help you think like a biologist. You will be expected to apply the knowledge gained from both lab and lecture to evaluate evolutionary relationships among organisms and to identify the key adaptations that enable each group to survive and reproduce in its environment. Through this process, you will deepen your understanding of the unity and diversity of life. Each lab report will include application style questions that will help you in your reflection of the content.

[0.1: The Role of Observation in Biology](#)

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0.1: The Role of Observation in Biology

Observation is one of the most fundamental skills in biology and one that can be developed through careful, detailed examination. Effective observations take time and should include subjective, descriptive insights (**qualitative data**) as well as objective, measurable information (**quantitative data**). Alongside your observations, drawings or labeled sketches are also required. These visual representations can help you capture patterns and proportions that written notes might miss.

Many organisms will be examined at both the macroscopic and microscopic scale. For example, you might first observe the overall structure of a mushroom (**macroscopic**) and then examine the details of its reproductive structures under a microscope (**microscopic**). Microscopic observation reveals fine details, such as cell shape and arrangement, that often cannot be seen otherwise. Integrating both perspectives helps you build a more complete understanding of form and function of the specimen you are observing. When working with microscopes, be sure to note the magnification level used when making your observations.

As you further develop your observational skills in this class, you will learn to go beyond simply recognizing what you see and will learn to evaluate specimens based on multiple factors. Your goal is to capture a clear and comprehensive record of what you see so that another person can visualize the organism from your descriptions. There may be specific characteristics that you are asked to pay attention to for specific groups of organisms. There may also be specific terminology that should be used to describe specific groups of organisms. However, the following can be used as a guideline to help you start thinking about what kinds of information should be included in your observations:

- **Size and Dimensions:** Estimate the overall size or provide actual measurements when possible. It is also important to note relative proportions of structures (e.g., body segments, appendages, leaf length to width) when applicable.
- **Color:** Record natural coloration and any patterns or variations (e.g., bands, spots, iridescence). Keep in mind that many preserved microscope specimens will be stained for increased visibility and, thus, the coloration observed may be artificial.
- **Texture:** Describe the surface characteristics (e.g. smooth, rough, scaly, slimy, fuzzy) as a way of conveying information about the texture of a specimen or its parts. Texture can be a distinguishing trait for many organisms.
- **Shape and Structure:** Note overall form (e.g. circular, ovular, rectangular) and symmetry (e.g., radial, bilateral, irregular). Identify major body regions or parts and describe how they are arranged.
- **Distinctive Characteristics:** Highlight any unique or diagnostic features that help classify the specimen.

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0.2: Overview of Microscopy

Microscopy allows us to observe structures too small to be seen with the naked eye, opening a window into the intricate details of cells and microorganisms. By using lenses to magnify and focus light, microscopes help biologists study the form and function of living systems at the microscopic level. Understanding how to properly handle, focus, and care for a microscope is essential for obtaining clear, accurate observations and maintaining the instrument's quality for future use.

In this biology class we will be making use of two different microscopes to aid in our observations. Below you will find a guide for how to properly recognize the different components of each microscope as well as the best practices for use and care of these microscopes. We will be using a combination of these scopes throughout the semester so please use these guidelines as needed.

Compound Light Microscopes

The compound light microscope allows you to observe specimens at high magnifications using transmitted light. Review the components of the microscope described below and use the steps that follow to ensure accurate observations and to protect the microscope and slides.

Parts of the Compound Light Microscope

- **Ocular lenses (eyepieces):** Our microscopes are binocular which means that there are two ocular lenses for you to look into. The specific microscopes that we have in the classroom are butterfly binocular lenses which means that you can adjust the distance between each of the lenses (similar to how a butterfly flaps its wings) to better match the distance between your eyes. Each has a magnification of 10x.
- **Objective lenses:** Four lenses mounted on the rotating nosepiece —
 - **4x (scanning power):** This lens should always be the first that you use to “scan” the slide from a relatively low magnification until you see the area of the slide that you wish to focus in on.
 - **10x (low power):** This lens will allow you to see larger microscopic animals and plants structures and can also be used as a step as you make your way to using the 40x/high power lens.
 - **40x (high power):** This lens should be used when examining details of a specimen or some of the larger unicellular organisms we will observe.
 - **100x (oil immersion):** This lens is used only with immersion oil for the observation of fine details as well as prokaryotes such as bacteria which tend to be much smaller than most eukaryotes. When using the oil immersion lens, you should go directly from 4x to the 100x without bringing the 10x or 40x lens near the oil that you have placed on the slide.
 - These lenses are *parfocal*, meaning once the specimen is focused under one objective, only minor adjustments are needed when switching to a higher power.
- **Stage:** The flat platform that holds the slide in place.
- **Stage clip:** This has a lever that you can use to secure your slide so it doesn't move. You will notice that there are two notches inside this clip—one that accommodates the traditional glass slides and a smaller, notch that accommodates deep-welled slides.
- **Stage adjustment knobs:** These knobs can be found hanging from the right side of the stage and function to move the slide left/right and forward/backward for precise positioning.
- **Coarse focus knob:** This is the larger of the two knobs which moves the stage up and down quickly to bring the specimen into general focus.
- **Fine focus knob:** This knob is used to make small adjustments to sharpen the image once the specimen is visible.
- **Iris diaphragm:** This is a small lever that can be found just underneath the stage and it controls the amount of light passing through the specimen. Adjust to improve contrast and clarity.
- **Light source:** Provides illumination from below the stage.

Using the Compound Light Microscope

1. Set Up the Microscope

- Obtain a microscope from the microscope cabinet using care to place a hand under the base as well as the arm of the microscope to carefully carry the microscope to your workstation.
 - Place the microscope on the lab bench, plug it in and turn on the light source.
2. **Start with the Scanning Power Objective (4x)**
- Rotate the nosepiece until the 4x objective lens clicks into place.
 - Always start and end with this lens to protect the microscope and slides.
3. **Place the Slide on the Stage**
- Open the stage clip and insert the slide so that the specimen is centered over the light source.
 - Use the stage adjustment knobs to position the specimen precisely.
4. **Focus on the Specimen**
- While looking from the side of the stage, use the coarse focus knob to raise the stage until the objective lens is just above the slide.
 - Then look through the ocular lenses and slowly adjust the stage with the coarse focus knob until the image comes into view.
 - Use the fine focus knob to sharpen the image.
 - You may need to adjust the amount of light reaching the slide to get a clear view of your specimen. Too much light can wash out details; too little light can make the image dim. You can do this by adjusting the level of light coming from the light source as well as the iris diaphragm to control brightness and contrast.
5. **Increase Magnification**
- Center the specimen in view before switching to a higher-power lens.
 - Rotate the nosepiece to click the next objective into place (you will rotate clockwise bring first the 10x and then 40x into position).
 - Use only the fine focus knob to adjust clarity — never the coarse focus knob on high power as this may cause the lens to collide with the slide. Remember, the microscope is *parfocal*, so only minor adjustments should be necessary.
6. **Using the Oil Immersion Lens (100x) (if applicable)**
- Focus the specimen first using the scanning power/4x objective lens.
 - Add a drop of immersion oil directly on the cover slip.
 - Rotate the 100x objective lens into place so it touches the oil.
 - Use the fine focus knob to sharpen the image.
 - When finished, clean the lens and slide with lens paper only.
7. **After Use**
- Return the objective to the 4x scanning lens.
 - Lower the stage, remove your slide, and turn off the light.
 - Unplug the microscope and wrap the cord and return the microscope to the proper location in the microscope cabinet.

Dissecting Microscopes/Stereo Microscopes

The dissecting microscope is used to view larger, opaque specimens in three dimensions using reflected and/or transmitted light. It provides lower magnification but greater depth of field.

Parts of the Dissecting Microscopes/Stereo Microscopes

- **Ocular lenses (eyepieces):** Our microscopes are binocular which means that there are two ocular lenses for you to look into. The eyepieces are connected by a moveable slider allowing you to move them closer together or farther apart to adjust to the distance between your eyes. Each has a magnification of 10x.
- **Zoom knob:** Adjusts magnification continuously as you rotate the knob. Our microscopes can zoom in for a maximum of 10x magnification.
- **Focus knob:** This knob is used to sharpen the image and bring the specimen into focus.
- **Stage plate:** This is the platform where you will place the specimen. Often, we will use petri dishes or a similar container to hold the specimens that we are observing with the dissecting microscopes. The platforms for our microscopes have a plate

which can be removed and replaced. There is a clear plate and a black plate depending on what you want to observe and whether you want illumination from below.

- **Upper light (incident light):** Illuminates specimens from above.
- **Lower light (transmitted light):** Illuminates specimens from below.

Using the Dissecting Microscopes/Stereo Microscopes

1. Set Up the Microscope

- Obtain a microscope from the microscope cabinet using care to place a hand under the base as well as the arm of the microscope to carefully carry the microscope to your workstation.
- Turn on the appropriate light source: The upper light is often used for solid, opaque specimens while the lower light is typically used for transparent or thin specimens; both lights can be used together for best illumination. Note that there is one master power switch as well as two separate switches for each of the light sources. The master power switch must be turned on prior to turning on either of the light sources.

2. Place the Specimen on the Stage Plate

- Position the specimen in the center of the stage plate.

3. Adjust Magnification and Focus

- Look through the ocular lenses and use the zoom knob to select the desired magnification. Start at low magnification to locate features, then zoom in for closer inspection.
- Use the focus knob to bring the image into clear view.
- Adjust lighting as needed for the best contrast and detail by moving the dial for the light source(s) you are using.

4. After Use

- Turn off the lights and unplug the microscope.
- Remove any specimens and clean the stage.
- Wrap the cord and return the microscope to the proper location in the microscope cabinet.

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0.3: Lab Safety Guidelines

The science laboratory is an exciting and rewarding place to explore and learn, but it must be approached with care, maturity, and respect. Each student is responsible for maintaining a safe environment for themselves and others. Staying alert, prepared, and cautious at all times will help prevent accidents and ensure productive lab experiences. Review and follow the safety rules below before beginning any laboratory activity.

General Safety Guidelines

- Always wear safety goggles or glasses when working with heat and chemicals glassware. Goggles may be worn over prescription glasses.
- Wear rubber or latex gloves when handling chemicals.
- Tie back long hair and remove loose jewelry.
- Ensure you only perform experiments authorized by your professor.
- Never work alone. No student may work in the laboratory without the professor present.
- Know the locations and proper use of safety equipment, including the exits, safety shower, eyewash station, and fire extinguisher.

Pre-Lab Preparation

- Prepare for the experiment by reading and understanding all directions before starting.
- Clean the lab table surface with soap and water (or other cleaner) and dry it with a paper towel.
- Wash your hands before beginning the experiment.

During Lab Work

General Conduct

- Conduct yourself in a responsible manner—no running, pushing, horseplay, or practical jokes.
- Do not eat, drink, or chew gum in the laboratory. Never use laboratory glassware as food or beverage containers.
- Keep work areas clean and tidy. Only your lab manual, writing utensil, and lab equipment/supplies should be on your lab bench. All personal items (bags, phones, jackets, etc.) should remain at lecture tables.
- Observe good housekeeping practices and stay alert to your surroundings at all times.
- Follow all professor instructions carefully and ask questions if unsure.

Accidents and Injuries

- Report any accident, spill, or injury to the professor immediately, regardless of severity.
- If a chemical splashes in your eye(s) or on your skin, flush immediately with running water from the eyewash station or sink.
- Report all fires to your professor and evacuate safely after turning off electrical equipment (if safe to do so). Do not attempt to extinguish a fire yourself.

Handling Chemicals

- Treat all chemicals as dangerous. Only smell a chemical when instructed, using the proper wafting technique.
- Check chemical labels twice before using.
- Never taste or touch chemicals.
- Keep hands away from your face, eyes, and mouth while working with chemicals.
- Never remove chemicals or materials from the laboratory.
- Always add acid slowly to water while stirring carefully.
- Take only the chemicals you need and never return unused chemicals to stock bottles. Dispose of all chemicals as instructed.

Handling Glassware and Equipment

- Always grasp electrical plugs by the plug—not the cord—and make sure hands are dry before handling electrical equipment.
- Report any damaged equipment (frayed cords, exposed wires, loose parts) immediately.
- Inspect glassware before each use; do not use chipped, cracked, or dirty glassware. Avoid sudden temperature changes to prevent shattering.

- Never handle broken glass. Instead, notify your professor for cleanup.

Post-Lab Procedures

- Cleanup is your responsibility.
- Dispose of all used and unused materials as instructed in lab manual and/or as directed by your professor.
- Clean the lab table surface with soap and water (or other cleaner) and dry it with a paper towel.
- Wash your hands thoroughly with soap and water after each experiment.
- No student may leave until all areas and equipment are cleaned, dried, and replaced properly.

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0.4: Lab Safety Assignment

True or False (Write T for true or F for false)

1. ___ Safety goggles must be worn anytime you work with heat, chemicals, or glassware.
 2. ___ You should tie back long hair and remove loose jewelry before beginning lab work.
 3. ___ It is acceptable to work alone in the lab if you are familiar with the procedures.
 4. ___ Reading the lab directions before beginning is part of proper pre-lab preparation.
 5. ___ You should wash your hands before starting the experiment.
 6. ___ Eating, drinking, and chewing gum are prohibited in the laboratory.
 7. ___ All personal items like phones and bags should remain off the lab bench.
 8. ___ All accidents, no matter how minor, must be reported to the professor immediately.
 9. ___ If a chemical splashes in your eye, you should flush with water immediately.
 10. ___ Students should attempt to extinguish small fires themselves before notifying the professor.
 11. ___ Chemicals should always be treated as dangerous, and the wafting technique should be used when smelling a substance.
 12. ___ You should never return unused chemicals to stock bottles.
 13. ___ You should always add acid slowly to water while stirring.
 14. ___ Broken glass should be cleaned up by students using gloves.
 15. ___ After the experiment, you must clean the lab table and wash your hands thoroughly.
-

Multiple Choice (Circle the best answer)

16. Which of the following is *not* part of proper lab attire?
 - A. Safety goggles
 - B. Loose bracelets
 - C. Gloves when handling chemicals
 - D. Tied-back long hair
17. Before starting any lab activity, students should:
 - A. Begin the experiment to save time
 - B. Read and understand all lab directions
 - C. Ask a friend to explain the procedure
 - D. Skip preparation and wait for instructions later
18. Where should personal items (bags, phones, jackets) be kept during lab?
 - A. On the lab bench
 - B. Under the sink
 - C. At lecture tables
 - D. On top of chemical storage shelves
19. If a student spills a chemical, the first action should be to:
 - A. Wipe it up quickly without telling anyone
 - B. Ask other students what to do
 - C. Report it to the professor immediately
 - D. Ignore it and continue working
20. Which of the following is allowed in the laboratory?
 - A. Chewing gum
 - B. Drinking water
 - C. Using glassware for food
 - D. None of the above
21. When smelling a chemical, you should:
 - A. Put your nose directly above the container

- B. Waft the fumes toward your nose if instructed
 - C. Ask another student to smell it first
 - D. Never smell chemicals under any circumstance
22. What should you do if glassware is cracked or chipped?
- A. Use it carefully
 - B. Use it only for cold liquids
 - C. Continue using it until it breaks
 - D. Do not use it and report it to the professor
23. To safely unplug electrical equipment, you should:
- A. Pull the cord firmly
 - B. Pull the plug, not the cord
 - C. Turn off the lights first
 - D. Unplug it with wet hands
24. After completing the experiment, students must:
- A. Leave immediately if their part is done
 - B. Clean and dry all equipment and work areas
 - C. Leave materials for the next class to clean
 - D. Only wash hands if chemicals were used
25. What should students do with unused chemicals?
- A. Pour them back into the stock bottle
 - B. Dump all unused chemicals down the sink
 - C. Dispose of them only as instructed
 - D. Store them in their backpack for later use

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CHAPTER OVERVIEW

1: Galapagos Island Lab

[1.1: Introduction](#)

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1.1: Introduction

Learning Objectives

- Demonstrate the process of natural selection using a simulation of birds with different beak types and access to different food types.
- Identify the impacts of factors like gene flow, genetic drift, and bottleneck effect on the process of evolution.

Evolution is described as the changing of organisms over time as they adapt to their environment. The process of evolution is illustrated in all living organisms, but much focus is put on a few key examples such as those described by Charles Darwin. Darwin observed in his journey of the Galapagos Islands that finches living on different islands had different beaks but that all the island species resembled the finch species he had observed on the mainland of South America. He also observed that the environment on each of the islands was quite different from the mainland as well as one another; in particular, the type of food available to the finches was different on each island. He developed a hypothesis that the finches had all been similar at one time and that they likely inhabited the coast of South America, but that they then evolved as they adapted to the conditions of a particular island after migrating from the mainland giving rise to different species. The original parent population would have had to exhibit some variations in their beaks. It is this variation that led to the selection for beak types based on which beak type was most well suited to obtaining the food sources of a particular island. Thus, birds with those beaks which were most well suited would have a higher chance of survival and reproduction and would become more predominant on that island; a mechanism we know as **natural selection**.

In this activity, individuals will be assigned a particular beak type and a particular island to illustrate the process of natural selection and evolution. The idea being that the various beak types will adapt to the food sources available on each island. In this simulation, the beaks will be demonstrated by various utensils, and the food will be demonstrated by various small objects. In addition, we will investigate some of the agents of evolutionary change and their profound impact on evolution. Such agents include mutations, climate change, gene flow, genetic drift, and the bottleneck effect.

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1.2: Procedure

1. Collect the appropriate “beak” and join the group members on the island to which you are assigned. Identify the appropriate data table based on the island to which you are assigned. Record the number of each beak type in your group for your island (see Table 1 below). If there is a specific beak type that is not present on your island enter a 0 in that column.

Table 1

Beak #	Beak Type
1	Tweezers
2	Salad Tongs
3	Clips
4	Stapler Remover
5	Mutation

2. Work with your group members to set up your island using the supplies provided. The fabric will serve as the “substrate” for your island and the various small objects will serve as your “food”. Be sure to record the types of food items in Data Table 1 for your specific island. All members of your group should record these food items in the same order. Note that each island will begin with 4 different food types, though there are 5 slots for food types on your data table. An extra slot is provided in case a new food type is introduced during the simulation.
3. Use your beaks to forage with your group members for 10 seconds trying to collect as many “food” items as possible. Wait until your instructor announces that time has begun and listen to your instructor to signal that time is up.
4. After foraging, count the number of food items your group collected and record *the total amount of food eaten* as well as *the amounts of each type of food* in Data Table 2 for your specific island. This represents the foraging behavior for one “season”.
5. The team with the highest total amount of food gains one team member. The new team member will take on the same “beak” structure as the group member who was most successful at foraging food in that “season”.
6. The team with the least amount of food loses a team member. The team member that is lost is the one that was the least successful at foraging food in that “season”.
7. The team member who is lost by the least successful island will become the member which is added to the most successful island.
8. If you are one of the individuals that moves from one island to a new one, you should begin recording data for the island which you enter starting at the season in which you enter that island. For example, if you begin on Island Floreana but then at the end of season 4 you move to Island Genovesa, begin recording data in the table for Island Genovesa starting in season 5.
9. Repeat steps 2-5 for a total of 5 “seasons.”
10. At the end of 5 seasons, each team picks a card from the “events” pile and follows the directions on the card. Once you have considered the outcome of your “event”, a typical foraging “season” will be carried out as described above in steps 2-5 for two additional “seasons”. Be sure to record a brief description of the event selected in Data Table 3 for your specific island.
11. At the end of the activity, select one member of your group to share your island’s data with the class. You will need to record the data for each island to complete your report for this lab activity.

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1.3: Data

Island Pinta

Data Table 1

Food Items Available
1:
2:
3:
4:
5:

Data Table 2

Season	# of Each Beak Type at Beginning of Season					Total Individuals	# of Each Type of Food Item Collected					Total Food Items
	1	2	3	4	5		1	2	3	4	5	
1												
2												
3												
4												
5												
6												
7												
8												

Data Table 3

Season	Event
5	
6	
7	

Island Isabela

Data Table 1

Food Items Available	
1:	
2:	
3:	
4:	
5:	

Data Table 2

Season	# of Each Beak Type at Beginning of Season					Total Individuals	# of Each Type of Food Item Collected					Total Food Items
	1	2	3	4	5		1	2	3	4	5	
1												
2												
3												
4												
5												
6												
7												
8												

Data Table 3

Season	Event
5	
6	
7	

Island Floreana

Data Table 1

Food Items Available	
1:	
2:	
3:	
4:	
5:	

Data Table 2

Season	# of Each Beak Type at Beginning of Season					Total Individuals	# of Each Type of Food Item Collected					Total Food Items
	1	2	3	4	5		1	2	3	4	5	
1												
2												
3												
4												
5												
6												
7												
8												

Data Table 3

Season	Event
5	
6	
7	

Island Genovesa

Data Table 1

Food Items Available
1:
2:
3:
4:
5:

Data Table 2

Season	# of Each Beak Type at Beginning of Season					Total Individuals	# of Each Type of Food Item Collected					Total Food Items
	1	2	3	4	5		1	2	3	4	5	
1												
2												
3												
4												
5												
6												
7												
8												

Data Table 3

Season	Event
5	
6	
7	

Island Baltra

Data Table 1

Food Items Available
1:
2:
3:
4:
5:

Data Table 2

Season	# of Each Beak Type at Beginning of Season					Total Individuals	# of Each Type of Food Item Collected					Total Food Items
	1	2	3	4	5		1	2	3	4	5	
1												
2												
3												
4												
5												
6												
7												
8												

Data Table 3

Season	Event
5	
6	
7	

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1.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your data tables for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explains how this activity demonstrated natural selection and the process of evolution. Provide specific examples from the activity to support your conclusions and be sure to address each of the following in your discussion:

1. **Explain how this activity models natural selection.** Which beak type was most successful on your island? What type(s) of food did it collect most efficiently? Was there a type of food that was unattainable to certain beak types? Were there any beak types that were consistently unsuccessful? What might this indicate about their ability to survive in that environment?
2. **Identify one example of adaptation that was illustrated by this simulation.** Did the total population on your island increase, decrease, or remain stable over the course of the simulation? What factors contributed to this trend? Compare the success of your island to at least one other island. What factors might explain the differences observed between the islands?
3. **Describe how the events encountered in seasons 5-7 impacted your population.** Be detailed here as you explain what the event was and how it impacted your population, both in the short term as well as over the course of the seasons that followed (if applicable).
4. **Examine how do your observations from this activity relate to the course material.** How does this simulation help explain the diversity of finch species Darwin observed on the Galapagos Islands? In what ways is this activity a simplified model of evolution, and what real-world factors are not represented here?

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CHAPTER OVERVIEW

2: Fossils and Radioactive Dating Lab

[2.1: Introduction](#)

[2.2: Procedure](#)

[2.3: Data](#)

[2.4: Data Analysis and Discussion](#)

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2.1: Introduction

Learning Objectives

- Examine the characteristics of various types of fossils and evaluate their relatedness.
- Evaluate the use of radioactive decay to calculate absolute age of rocks.

Evidence in support of evolution must show the process of change that occurs over time while still demonstrating that evolving populations share common features with their closest relatives. Some of the best evidence in support of evolution is supplied by the fossil remains of organisms which help to provide a record of living things from the distant past. **Fossils** are commonly found in sedimentary rocks of the earth's crust which are deposited as layers of sediment in the seabed or along rivers. When these rocks are later uplifted to form dry land, the fossils within them can be revealed.

The process of fossilization can occur in many ways and can be used to preserve not only the physical parts of the animal but also to preserve things that the animal has left behind. For example, **trace fossils** are something left behind like footprints or droppings while a **body fossil**, is the preserved remains of a living thing. There are also **chemical fossils** which are organic molecules preserved in rock. Such fossils can provide chemical clues of past life. Most often, we see fossils that represent hard part preservation, which would preserve things like shells or bones. While soft body parts such as muscles or flesh are less commonly fossilized there are some examples of soft body part preservation in the fossil record. In some instances, the best fossil evidence we have for an extinct organism is a mold or a cast. A **mold** is best described as an impression or imprint, typically pressed into sedimentary rock to create a pattern of the organism's body. A **cast** is formed when that mold is later filled in with sediment or other minerals, creating a replica of the original organism. By examining the characteristics of different fossil specimens, you can draw conclusions about the relatedness of the organisms.

The relative position of a fossil within the layers of sediment can provide clues for the age of that fossil; this is known as the **relative age**. The basis for this form of dating is the idea that those fossils buried deep within the layers of sediment would be much older than those in the more superficial layers. An alternative, and more accurate form of dating relies on the use of radioisotopes. This is known as radioactive dating, and it is based on the idea that certain isotopes are so unstable that they decay over time (from what is known as the parent isotope form to a more stable daughter isotope). Using radioactive dating, we can determine the **absolute age** of these fossils based on the levels of parent and daughter isotopes present in the sample as each isotope is known to decay at a specific rate known as its half-life. The *half-life* is a measure of how long it takes for half of the parent isotope molecules to decay into the daughter isotope. Thus, if the half-life of a Carbon-14 isotope is 5,730 years and we retrieve a sample with only ¼ of the original parent isotope remaining, we know that 2 half-lives have passed and that the fossil is ~11,460 years old. The dating of fossils is important as it can be used to create a timeline of events that depict the history of life on Earth.

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2.2: Procedure

Part I. Fossil Observations

1. Obtain the collection of fossils provided on your lab bench. From the collection, select 4 of the fossils for your investigation. Using the key provided, record the specimen name/type.
2. Next, determine if the fossil is a BODY, TRACE, MOLD or CAST fossil for each of your selected specimens and record that below.
3. Draw, color, and label the fossil with as many details as you can see. Take your time with these sketches and use a pencil so that you can adjust your drawing as you go. There are small handheld magnifying glasses that you can use to get an idea of the fine details that may be present in the sample you have selected. I realize that this is a biology class and not an art class, but you will be graded based on the time and care evident in your sketches. Colored pencils will be provided for you to add additional detail to each of your sketches.
4. Provide a detailed description of each fossil you have selected. Again, the key here is to take your time and notice the various features of the fossil to include in your description. Think of things like the overall shape, dimensions, color, texture, and any interesting features of your fossil should be included in your description. Use the rulers provided to take measurements and pay attention to patterns and numbers of features to collect quantitative data to go along with your qualitative descriptions.
5. You will use your textbook and the internet to obtain additional information about each specimen (e.g., the type of organism from which the fossil was collected, the time period that organism inhabited the Earth, whether the organism represented is of an extinct or extant species, the distribution and relative abundance of the organism type that the fossil represents, any important ecological roles of that organism etc.).

Be sure to put this additional information into your own words and provide a citation for each of the sources that you use.

Part II. Radioactive Dating

1. Place 50 beads (or other two-sided objects such as coins) into a container all with the same side facing up. These will represent the parent isotopes.
2. Shake the cup gently for 2-3 seconds, then pour the beads/coins onto the table.
3. Remove and count all the beads that land with the opposite side facing up. These represent the atoms that have decayed into the daughter isotope.
4. Record the number of daughter beads and parent beads in data table 2.1 for Trial 1.
5. Return only the remaining parent beads to the container and repeat steps 2-4. Do this until you end up with 0 parent isotopes remaining.

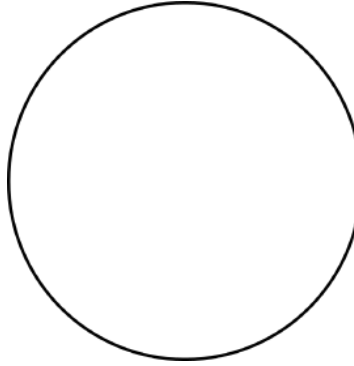
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2.3: Data

Part I Fossil Observations

Specimen 1: _____

1. Type of Fossil (body, trace, or mold): _____
2. Sketch:

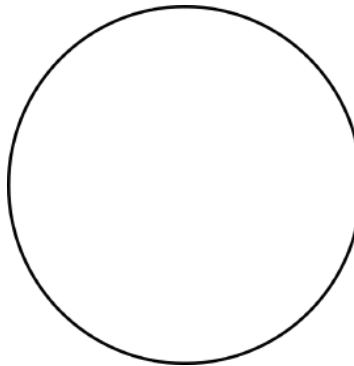


3. Description:

4. Additional Information:

Specimen 2: _____

1. Type of Fossil (body, trace, or mold): _____
2. Sketch:



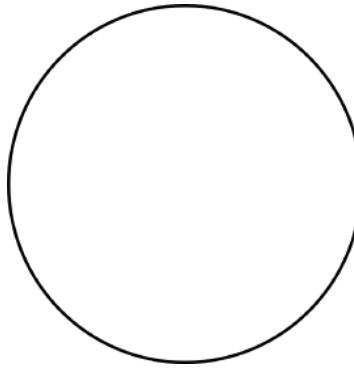
3. Description:

4. Additional Information:

Specimen 3: _____

1. Type of Fossil (body, trace, or mold): _____

2. Sketch:



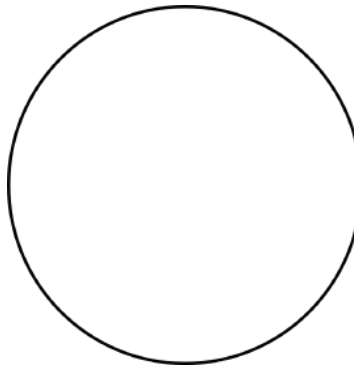
3. Description:

4. Additional Information:

Specimen 4: _____

1. Type of Fossil (body, trace, or mold): _____

2. Sketch:



3. Description:

4. Additional Information:

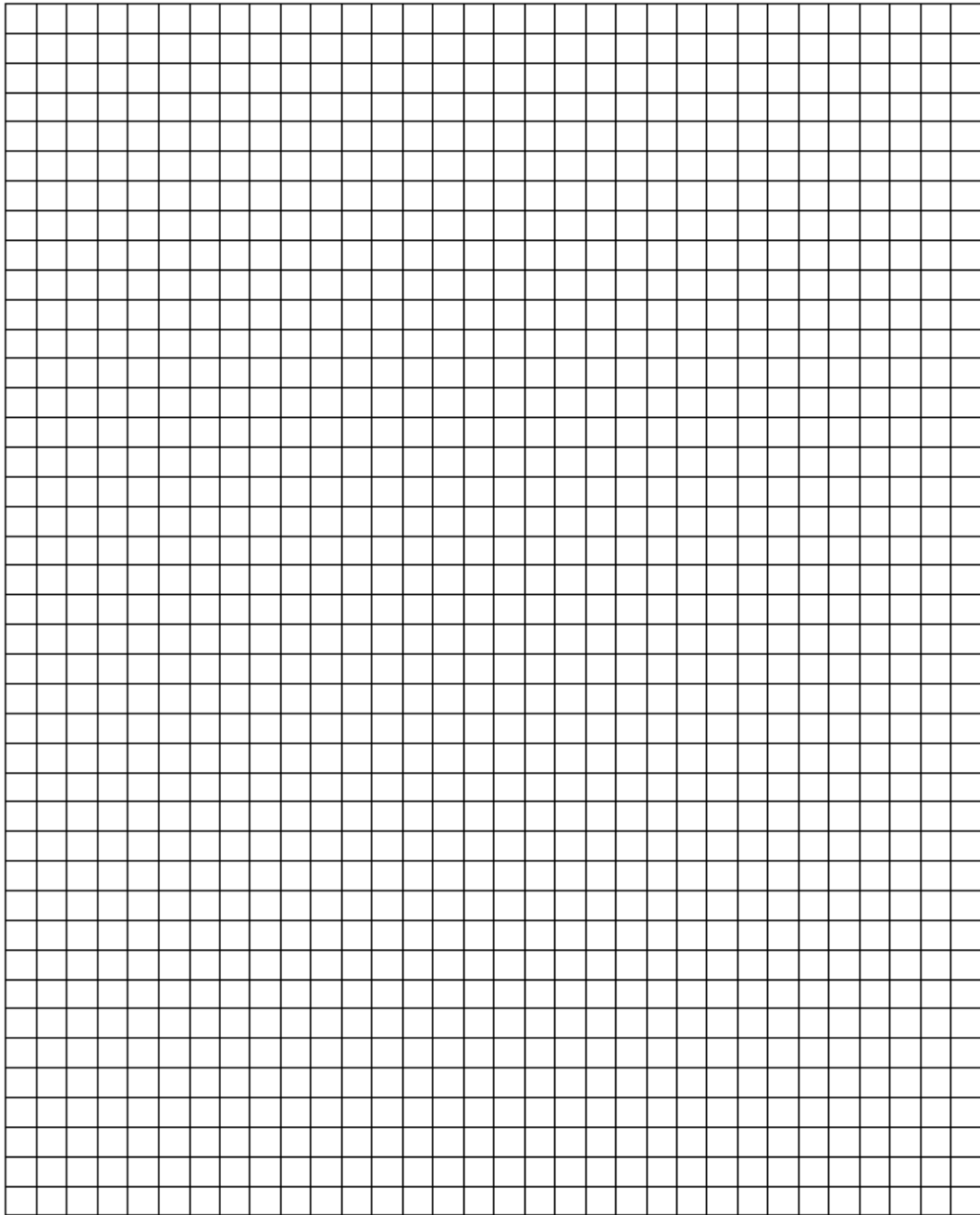
Part II Radioactive Dating

Data Table 2.1

Trial	# of Parent Isotopes Remaining	# of Daughter Isotopes Formed	% of Parent Isotopes Remaining	% of Daughter Isotopes Formed
0	50	0	100	0
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Figure 1

Draw a graph of the % of parent atoms remaining versus the number of trials performed.



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2.4: Data Analysis and Discussion

Instructions

Your discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your fossil observations, data table 1, and the graph (figure 1) for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explains how this activity demonstrates the importance of fossils as evidence for evolution. You will also evaluate the data you collected for the radioactive decay simulation. Be sure to address each of the following in your discussion:

1. **Recognize fossils as evidence for evolution.** Describe how fossils have influenced our understanding of the history of life on Earth. What are some of the advantages of using fossils to understand life's history? What are the major disadvantages?
2. **Identify evolutionary relationships between organisms.** Based on the data you collected for each fossil specimen, which species appear most closely related? Explain your reasoning. Construct a simple cladogram showing the relative relatedness of the specimens you observed.
3. **Demonstrate the process of radioactive dating.** Describe the trend you observe in your graph. Use the graph to determine the half-life of your isotope (HINT: see how many trials have passed to get to 50% of the parent isotope remaining). How does this simulation demonstrate the concept of half-life and radioactive dating?

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CHAPTER OVERVIEW

3: Bacteria Lab

[3.1: Introduction](#)

[3.2: Procedure](#)

[3.3: Data](#)

[3.4: Data Analysis and Discussion](#)

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3.1: Introduction

Learning Objectives

- Practice inoculating, growing and properly disposing of bacterial cultures.
- Observe the ubiquitous nature of bacteria.
- Practice aseptic techniques in preparing bacterial cultures.
- Familiarize yourself with various features of bacterial colonies and the basic cell shapes of bacteria.

Bacteria represent a diverse collection of organisms which can live in nearly every habitat on the Earth. They are an important group of organisms that have significant impacts on our environment, including playing important roles in nutrient cycling. We encounter bacteria daily in just about everything we interact with. Bacteria have been found to inhabit nearly every niche of our planet, and their microscopic size often makes it difficult to detect their presence. To provide us with insight into the ubiquitous nature of bacteria you will be collecting samples from your surroundings to evaluate their bacterial content. We will also be using our microscopes to get a closer look at the cellular structures and features commonly found in bacteria.

Different bacterial species can be differentiated by a variety of characteristics including the growth pattern they take when growing as **colonies** on nutrient agar as well as their microscopic features. *Bacterial colonies* are described based on several factors including form or shape, color, size, margin, elevation, and texture. The **form** of a bacterial colony reflects the general shape and can be classified using terms such as *circular, irregular, filamentous or rhizoid*. The **elevation** is a description of the side view and can be classified as *flat, raised, convex, umbonate or crateriform*. The **margin** is the edge of the colony growth. Several margin types are commonly observed including *entire, undulate, filiform, curled, lobate, etc.* **Size** of colonies can be influenced by the amount of competition on the agar plate and can be measured with a ruler as the diameter of the colony. Very small colonies are referred to as being *punctiform*. Some colonies will grow in a spreading manner and may even cover the entire plate or an entire region of the plate in what is referred to as a bacterial lawn. The **texture** is often observed on the surface of the colony. Common surface textures include *smooth, creamy (glistening), waxy (dull), and veined*. When examining the **color** of the colony it is also important to take note of the **optical characteristics** as well. For example, does the colony appear *opaque, cloudy, translucent, iridescent*. You will evaluate the colonies grown from the cultures that you collect based on these traits. (See Figure 3.1 below for reference of these patterns).

We will also be examining bacterial samples under the microscope to become more familiar with the diverse *bacterial cell shapes* including the primary shapes which are: *coccus* (round), *bacillus* (rod-shaped) and *spirillum* (spiral). Additional common bacterial cells shapes include a shorter rod known as a coccobacillus and a curved rod known as a vibrio.

Figure 3.1: Illustration of various characteristics of colony morphology

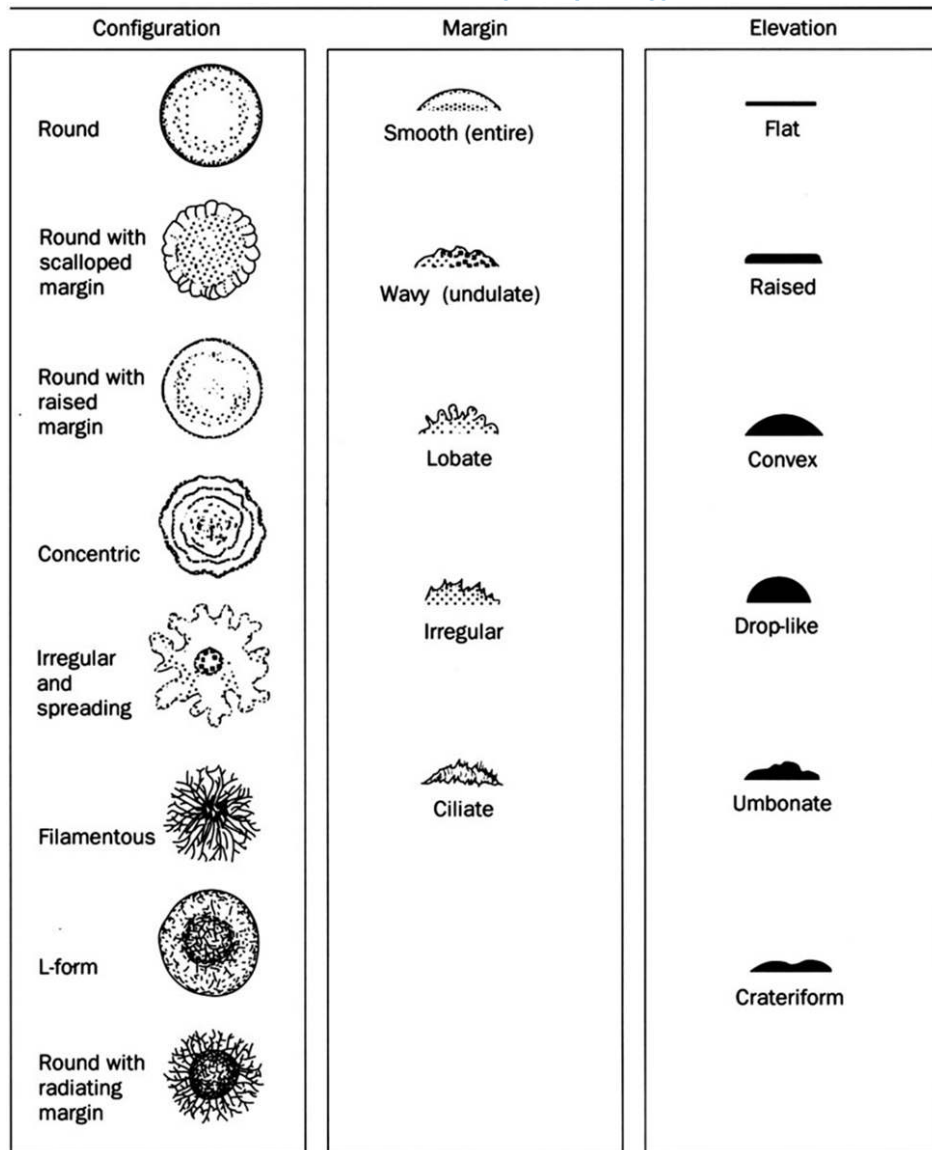


Figure 3.1.1: "Manual Of Rice Seed Health Testing_p34" by IRRRI Images is licensed under CC BY-NC-SA 2.0.

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3.2: Procedure

Part I. Bacterial Cultures and Colony Morphology

Obtain 2 nutrient agar plates and four sterile swabs. Use a sharpie marker to label the outside of the bottom of the plates (where the agar is located) with your name and the date and draw a line to divide the agar plate in half.

Identify 4 locations (e.g., kitchen sponge, cell phone, bottom of shoe, dogs' mouth, etc.) that you would like to swab. Use a sterile swab and moisten with water prior to rubbing that swab gently across the surface of choice. Next, gently rub that swab onto one half of the agar plate to transfer the bacteria. Make sure you label the bottom of the petri dish to reflect the location you have swabbed. If you are swabbing a location that is already moist-such as the mouth of your pet cat-there is no need to pre-moisten the swab prior to collecting the sample.

Place the agar plates into a Ziploc bag but do not completely seal the bag. Place plates in a safe location that will not be disturbed until the next class period. Discard the swab.

You will bring the inoculated agar plates to the next class period and will place them in the incubator. This will provide an opportunity for any bacteria present in your sample to grow. You may see colonies begin to form prior to incubation as well.

During the following class period, you will remove your agar plates from the incubator and observe the growth patterns. You will select one of your plates to sketch and describe the using the space provided below. Be sure to include the various features of your colonies such as their form, elevation, margin, size, texture, and optical characteristics in your descriptions (see illustration and descriptions of these colony characteristics in Figure 1).

Once you have finished your observations, set the plate aside to be used for microscopic observations as described below.

Part II. Microscopic Observations

Prepare and Observe Slide from Environmental Sample

1. Identify a single colony from your agar plate that you would like to view microscopically.
2. Obtain a clean glass microscope slide and add your initials with a sharpie to one end. Next, add a small drop of water to the center of the slide.
3. Using a sterile loop, collect a small sample from a colony of your choice by gently touching the end of the sterile loop to that colony. After collecting your sample, return the lid to the plate.
4. Carefully use the loop to spread the sample back and forth in the drop of water you previously placed in the center of the glass slide. You will want to move the loop back and forth across most of the slide to spread out the cells in your sample as evenly as possible.
5. Set the slide on the slide warmer to "fix" the bacterial cells to the slide in preparation for staining. Depending on how much water you initially added to your slide, this can take anywhere from a few to more than 15 minutes.

Note

While you are waiting for this step, you should move on to view the Bacterial Types slide as described below.

6. Once your slide is completely dry, you will transfer the slide to a staining tray. Use the tweezers provided to carefully transfer the slide as it will be hot.
7. Next, you will apply a drop of methylene blue stain to the smear, allowing the excess stain to run into the staining tray. After a moment, rinse the slide for 2-3 seconds with the bottles of distilled water by gently applying water to the entire slide.
8. Tap off the excess water and use the blotting paper provided to gently blot dry. Take care not to wipe the slide when drying or you may remove the cells. Rather than rubbing the slide with the blotting paper, you will simply place your slide in between the pages of the booklet and press gently.
9. Place a small drop of immersion oil onto the region of the slide you wish to view (no cover slip is needed for this slide). Use the 4x (scanning power lens) to locate the specific region under the microscope where the bacterial cells are located.
10. Next, position the 100x objective lens into place using the rotating nosepiece.

 Caution

Please note that you should never use the 10x or 40x lens while you have oil on the slide as getting oil onto these lenses can ruin them so you will want to turn the nosepiece in a counterclockwise direction to move directly from the 4x to the 100x lens. DO NOT MOVE THE 10X OR 40X LENS INTO PLACE WHEN THERE IS OIL ON THE SLIDE!

11. Provide a sketch and a detailed description of notable features for your specimen in data table 3.1 using the 100x objective lens.
12. Once you have viewed your slide, please place it in the used slide container provided.
13. You should also use a kim-wipe to remove the oil from the 100x objective lens. It is important to understand that you should never use anything other than a kim-wipe when cleaning the lenses of a microscope as these other materials can scratch the surface of the lens.

 Caution

ONLY USE LENS CLEANING WIPES WHEN CLEANING THE MICROSCOPE LENS.

Observe Slide of Bacterial Types

1. Obtain a slide of mixed bacteria. Locate the three different regions of the slide which include bacteria of different types.
2. Place a small drop of immersion oil onto the region of the slide you wish to view. Use the 4x (scanning power lens) to locate the specific region under the microscope where the bacterial cells are located.
3. Next, position the 100x objective lens into place using the rotating nosepiece.

 Caution

Please note that you should never use the 10x or 40x lens while you have oil on the slide as getting oil onto these lenses can ruin them so you will want to turn the nosepiece in a counterclockwise direction to move directly from the 4x to the 100x lens. DO NOT MOVE THE 10X OR 40X LENS INTO PLACE WHEN THERE IS OIL ON THE SLIDE!

4. Provide a sketch and a detailed description of notable features for each of these specimens in data table 3.1 using the 100x objective lens.
5. Repeat steps 2-4 for the remaining 2 regions of the slide where the different bacterial samples are located, being careful to never bring the 10x or 40x lens near the immersion oil.
6. Once you have viewed all 3 regions of the mixed bacteria slide remove the slide from the stage and use a kim-wipe to remove the oil from the slide prior to returning the slides to the slide box.
7. You should also use a kim-wipe to remove the oil from the 100x objective lens.

 Caution

It is important to understand that you should never use anything other than a LENS CLEANING WIPE when cleaning the lenses of a microscope as other materials can scratch the surface of the lens.

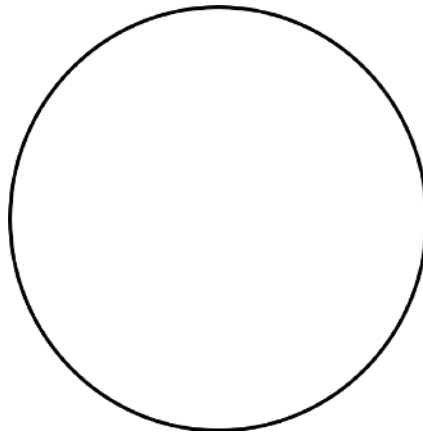
8. Before returning the microscope to the microscope cabinet, return the 4x lens into position and wrap the power cord using the Velcro power cord band. When placing the microscope inside the cabinet be sure to match the number on the microscope with the number on the shelf.

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3.3: Data

Part I. Bacterial Cultures and Colony Morphology

Nutrient Agar Plate Sketch



Nutrient Agar Plate Description

- It is not necessary to describe every single colony, especially if there are dozens of different types; in that case describe the more common colony types observed on your agar plate:

Part II. Microscopic Observations

Data Table 3.1

Shape	Magnification Observed	Sketch	Key Characteristics
Coccus			
Bacillus			
Spirillum			
Environmental Sample			

Note

***All observations should be made with the 100x lens/1000x total magnification.**

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3.4: Data Analysis and Discussion

Instructions

Your discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your observations of your bacterial samples for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explains how this activity allowed you to explore the ubiquity of prokaryotes. You will also take a closer look at the ecology of prokaryotes. Be sure to address each of the following in your discussion:

1. **Explore bacterial diversity.** Based on your agar plate results, what evidence did you observe that supports the idea that bacteria are *ubiquitous* (found everywhere)? Which sample location showed the most bacterial growth? Which had the least? Propose possible explanations for these differences. Which sample location showed the most diversity of bacterial growth? Which had the least diversity? Propose possible explanations for these differences. What was the most surprising result from your bacterial sampling?
2. **Discuss the ecological significance of bacteria.** Identify at least two beneficial and two harmful roles of bacteria in the environment or in relation to humans. How might bacterial diversity contribute to the stability of ecosystems?

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CHAPTER OVERVIEW

4: Pond Water and Protist Diversity Lab

[4.1: Introduction](#)

[4.2: Procedure](#)

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4.1: Introduction

Learning Objectives

- Observe and identify microorganisms, especially protists, within a sample of pond water.
- Identify distinguishable features of several common protists

Protists were around long before the appearance of multicellular eukaryotes such as plants and animals. Fossilized protists have been found in rocks dated around 2.1 billion years old. Rather than being classified into a single group due to their similarities, protists are classified as such because they are eukaryotic, and they do not belong to any other group of eukaryotes (i.e. plants, animals and fungi). Thus, if there is one thing to take away from our investigation of protists, it should be that this is a very diverse group. This is especially evident when examining the structure and organization of protists as well as their ecological roles.

The classification of protists is changing as our understanding of this group grows. Often protists are classified based on their primary mechanisms of movement (e.g., ciliates, flagellates). Other means of classification focus on their means of metabolism (e.g., whether they are autotrophic or heterotrophic). Protists are also often described as being *animal-like* (lack cell walls, exhibit movement and are heterotrophic), *plant-like* (contain cell walls, are non-motile and autotrophic) or *fungus-like* (contain cell walls, have motile and non-motile stages and are saprophytic). The phylogeny of protists is probably best understood by using molecular evidence which places protists among each of the clades or supergroups of eukaryotes.

An investigation into the microscopic life of a pond can reveal a great deal about the diverse organisms that thrive in these freshwater habitats. In a single drop of pond water hundreds of organisms can be observed, including many protists. These protists represent a vital component of aquatic ecosystems and can be seen carrying out many life processes including movement, phagocytosis, ciliary action, cell excretion, and a variety of responses to stimuli. For this lab, we will use a Pond Identification Sheet and a Protist Field Guide to aid in our identification of these organisms. In addition to the live specimens from the pond water, we will examine preserved specimens of several common protists to become more familiar with some of their distinct features.

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4.2: Procedure

Part I: Prepared Slides

1. Select four specimens from the prepared slides provided (e.g., *Amoeba*, *Paramecium*, *Foraminifera*, *Spirostomum*, *Vorticella*, *Trichomonas*, *Radiolaria*, etc.).
2. Observe each of the selected slides. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided.
3. Using outside resources such as your textbook and the internet, provide some additional information regarding each of the specimens observed (e.g., ecological or clinical significance, habitat, distribution, interesting behaviors or features, etc.).

Part II: Pond Water Samples

1. Obtain a sample of pond water and prepare a wet mount using both a traditional glass slide as well as a deep-welled slide to view in the microscope.
2. To prepare a wet mount using a traditional glass slide simply place a drop of the pond water in the middle of the slide, place a cover slip over the sample. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens)-when possible. Provide a sketch and description of your observations in the space provided.
3. Once you are done viewing the slide, you can discard the used slide in the container provided.
4. To prepare the deep well slide for your observations, first remove the circular cover slip, and add 3-4 drops of pond water. You may also want to add 1-2 drops of Proto-Slo to your slide to slow down fast-moving organisms for better viewing. Replace the cover slip, making sure that it clicks into place prior to viewing with the 10x objective lens. An important thing to note is that it is often difficult to observe the deep well slide using anything higher than the 10x objective lens.
5. Once you are done viewing the slide, you should remove the cover slip and rinse both the coverslip as well as the slide. Set aside to dry before returning to the tray of clean deep-well slides.

Note

- You may also want to add a drop of Proto-Slo to the slide prior to adding the cover slip to slow down fast-moving organisms for better viewing. You may have difficulty viewing specimens that do not have natural pigmentation as they tend to get “washed out” by the light of the microscope; adjust the level of your lamp as well as the iris diaphragm accordingly.
- Try to observe samples from the water column as well as the sediment on the bottom of the container to get a diverse mix of organisms to view.
- You may need to prepare a few different slides before you feel like you have gotten a good mix of pond water creatures to view.

6. Use the Pond Identification Sheet and Protist Field Guide to identify four different organisms (**at least 3 must be protists!!**). Provide sketches and detailed observations of these organisms below. Observations should be made using the 40x objective lens when possible. The Classification of the organism should reflect the general type of organism (e.g., protist, animal, plant, bacteria).

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4.3: Data

Part I: Prepared Slides

Specimen 1

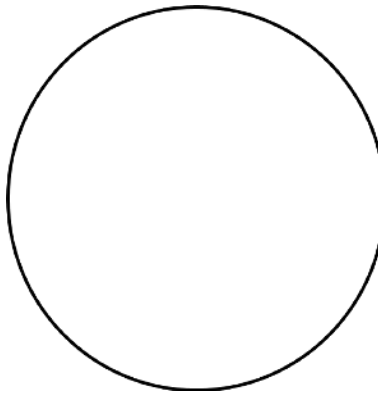
(a) Name: _____

(b) Total Magnification: _____

(c) Description:

(d) Additional Information:

(e) Sketch



Specimen 2

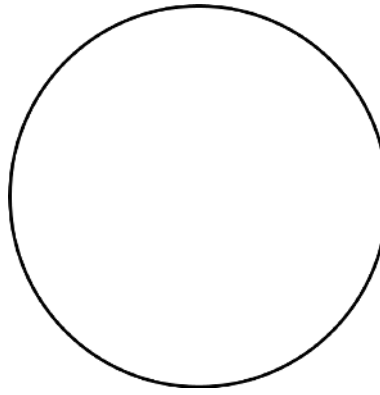
(a) Name: _____

(b) Total Magnification: _____

(c) Description:

(d) Additional Information:

(e) Sketch



Specimen 3

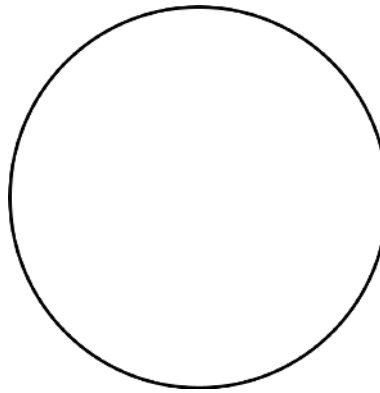
(a) Name: _____

(b) Total Magnification: _____

(c) Description:

(d) Additional Information:

(e) Sketch



Specimen 4

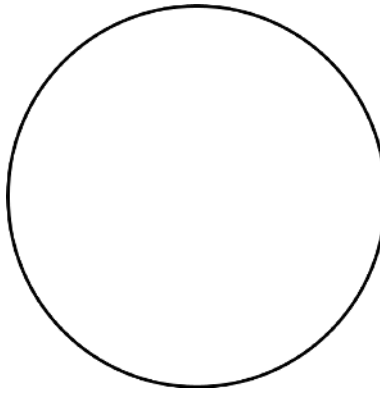
(a) Name: _____

(b) Total Magnification: _____

(c) Description:

(d) Additional Information:

(e) Sketch



Part II: Pond Water Samples

Organism 1

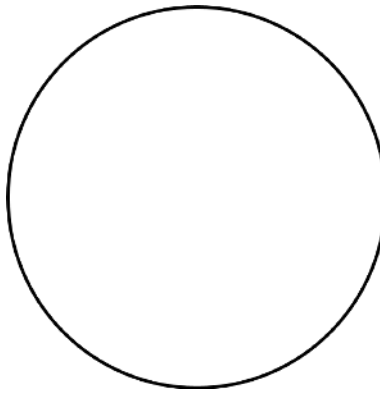
(a) Name: _____

(b) Total Magnification: _____

(c) Classification: _____

(d) Observations (color, size, shape, movement, feeding, etc.):

(e) Sketch



Organism 2

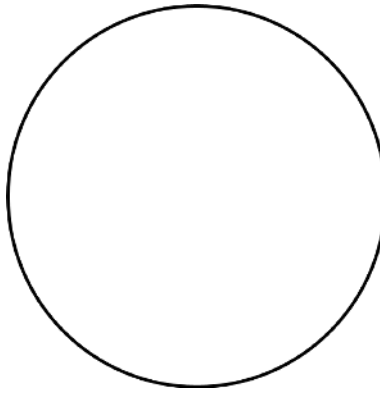
(a) Name _____

(b) Total Magnification: _____

(c) Classification: _____

(d) Observations (color, size, shape, movement, feeding, etc.):

(e) Sketch



Organism 3

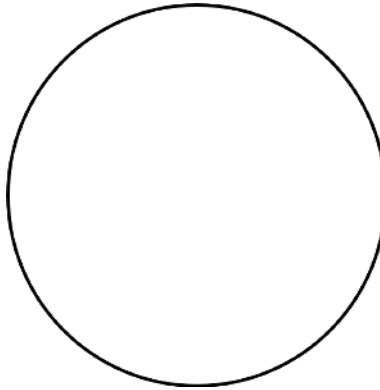
(a) Name _____

(b) Total Magnification: _____

(c) Classification: _____

(d) Observations (color, size, shape, movement, feeding, etc.):

(e) Sketch



Organism 4

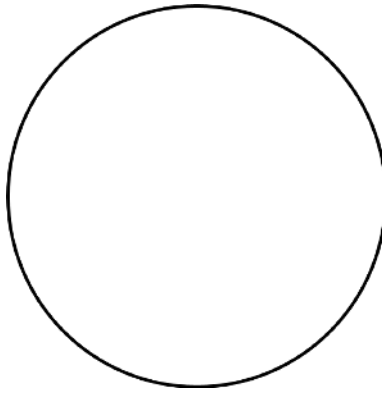
(a) Name _____

(b) Total Magnification: _____

(c) Classification: _____

(d) Observations (color, size, shape, movement, feeding, etc.):

(e) Sketch



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4.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the diversity, ecology and evolutionary significance of protists that you examined. Provide specific examples from the activity to support your conclusions. Be sure to address each of the following in your discussion:

1. **Observe the diversity of protists.** Compare the movement of different protists you observed (e.g., *Amoeba*, *Euglena*, *Paramecium*). What structures are used for locomotion, and how do they differ? What other significant characteristics and/or behaviors were observed among the specimens you examined. How did this lab change your perception of microscopic life in common aquatic environments?
2. **Examine the ecological roles of protists.** What ecological roles do protists play in aquatic ecosystems? How might environmental factors such as light, temperature, or nutrient availability affect the diversity of protists in your pond sample?
3. **Recognize the evolutionary significance of protists.** How does the diversity of protist form and function that you observed in this lab support the idea that protists are a paraphyletic group (not all descending from a single common ancestor)? Why are protists considered as the bridge to the evolutionary gap between prokaryotes and multicellular eukaryotes?

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CHAPTER OVERVIEW

5: Fungal Diversity Lab

[5.1: Introduction](#)

[5.2: Procedure](#)

[5.3: Data](#)

[5.4: Data Analysis and Discussion](#)

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5.1: Introduction

Learning Objectives

- Observe the ubiquity of fungi in the environment.
- Describe the microscopic structures of fungi by examining samples of molds, mushrooms and yeast.

Fungi are a diverse and important group of eukaryotes. As saprobes they play a critical role in decomposing dead organic matter and returning essential nutrients to our environment. Most fungi do this by excreting enzymes into their environment to break down organic material and then subsequently absorb the breakdown products of those nutrients across their cell walls and cell membranes. Many fungi also form important symbiotic relationships with other organisms such as the case with mycorrhizae and lichens. In the case of **mycorrhizae**, fungal organisms associate with the roots of plants forming a mutualistic relationship. The nature of this relationship is that the fungi function as extensions to the root systems, increasing the surface area of nutrient and water absorption. In return, the plants deliver some of their photosynthetic products back to the fungus. Similarly, **lichens** are an example of mutualism between a fungal organism and a unicellular photosynthetic organism such as an algae or cyanobacteria. The role of the fungi in this relationship is to help to support and anchor the photosynthetic partner while receiving organic nutrients from that partner in return. We will observe samples of both symbiotic relationships as part of this lab.

There are approximately 1.5 million fungal species dispersed into seven major groups including: *Basidiomycota*, *Ascomycota*, *Blastocladiomycota*, *Neocallismastigamycota*, *Chytridiomycota*, *Glomerulomycotina*, and *Zygomycota*. Each of these groups has distinguishing characteristics such as their methods of reproduction, habitat or structural features that allow us to differentiate between them. You will be observing specimens selected from the most prominent of these groups of fungi including Basidiomycota, Ascomycota and Zygomycota. A combination of live and prepared specimens will be available for you to gain familiarity with the distinguishing features of each group.

Fungi have a variety of different means of reproduction but often rely on the dissemination of spores to disperse organisms to new locations. These spores are easily airborne and are, therefore, prevalent in the air that we breathe. Thus, in addition to your observations of the various types of fungi, you will perform an experiment to evaluate the prevalence of fungi in your environment. You will do this using an assay known as the **Settle Plate Method**. This method requires that you leave plates exposed to the environment for a period to collect any fungal spores that might be present. After several days of incubation, the growth on these plates will help you to determine how many fungal organisms were able to settle onto the plate during the period of exposure.

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5.2: Procedure

Part I: Fungal Ecology

Mycorrhizae

1. Obtain a prepared slide of ectotrophic (ectomycorrhiza) mycorrhiza. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Look for the fungal hyphae wrapped around the pine root. Be sure to label both the fungi and the plant root.
2. Obtain a prepared slide of endotrophic mycorrhiza (arbuscular mycorrhizae). View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Look for the fungal hyphae tightly coiled within the plant cells of the root. Be sure to label both the fungi and the plant root.

Lichens

1. Obtain a prepared slide of lichen. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Look for the fungal hyphae surrounding the large algal cells. Be sure to label both the fungi and the algae.

Part II: Fungal Diversity

Zygomycota

1. Obtain a prepared slide of *Rhizopus* fungi. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Note that there are two regions of the slide, one which contains zygospores and one that contains the sporangia. Provide a sketch and description of your observations in the space provided. Be sure to label both types of spores as well as the hyphae. Indicate whether the hyphae is septate or coenocytic.

Basidiomycota

1. Obtain a mushroom, dissecting tray and dissecting kit. Examine the different components of the mushroom, locating the stem, cap and gills. Draw a diagram of your mushroom in the space provided, making sure to label each of these structures. If the gills are not visible, remove the tissue protecting them (this is called a veil) gently with your forceps. Be careful not to touch the gills with the forceps.
2. Grasp the cap firmly with one hand and the stem with the other hand. Gently wiggle and/or twist the stem until it breaks away from the cap. Pinch the stem between your fingers until it breaks into two or more long pieces. Use your tweezers to gently pull small pieces of the stem apart. The thin, hair-like filaments you will see where you split the stem are the hyphae. Prepare a slide of the hyphae by placing the small stem fragment on a glass slide and adding a drop of water and a cover slip. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to note whether the hyphae you observe is septate or coenocytic.
3. Place the stem pieces on a corner of your paper towel and turn your attention to the cap. Look at the underside of the cap to study the gills. Each gill is lined with thousands of small structures called basidia. Using your forceps, gently remove one gill from the cap. You will get better results if you GENTLY grasp the gill near where it attaches to the cap. Try to avoid touching the free edge, the one along the bottom of the gill, with your forceps. The basidia you want to see under the microscope are fragile and easily damaged if you are not careful. Place the gill on a microscope slide. Add a drop of water and a coverslip and then place your slide on the microscope and examine the gill using the 10x lens. Look at the edge of the gill that was not attached to the mushroom and look for the little finger-like projections. Switch the microscope to the high power/40x objective lens. Look at the finger-like projections under high power. These are the basidia. If your mushroom is mature the basidia may

have spores attached to them. Provide a sketch and description of your observations in the space provided. Be sure to label the gills, basidia and spores.

Ascomycota

1. Prepare a wet mount of *yeast* by adding a drop of the liquid yeast culture to a slide and adding a coverslip. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Scan the slide to look for examples of budding, if present sketch and label the parent and daughter cell.

Note

Alternatively, if you are provided with an agar culture of yeast, you should add a drop of water to a clean slide. Using a sterile loop, you can then collect a small sample of yeast by gently touching the loop to the growth on the agar plate. Gently swirl the loop into the drop of water to disperse the yeast. Lastly, add a cover slip.

2. Obtain a slide of *Sordaria* fungi. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to label both the ascus and the ascospores.
3. Obtain a slide of *Penicillium* fungi. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to label both the conidiophores and the conidia.

Part II: Settle Plate Method

1. Obtain 3 Sabouraud or potato dextrose agar plates. Label the bottom of the plates (not the lid) with your group/group members name and the date. You want to label the plastic dish, not the agar itself. Additionally, one plate will be labeled “classroom”, one will be labeled “hallway” and the other will be labeled as “outside”.
2. Place these plates in their respective locations with the lids removed and the agar exposed for a total of 30 minutes.
3. At the end of the 30 minutes, replace the lids and bring the plates to the classroom for incubation. You will observe the growth patterns of the plates in the lab next week.
4. After the plates have incubated for a week, sketch and describe the observed growth patterns on each plate below. First, examine the plates by simply looking at them with your unaided eyes. You can also use the dissecting microscope/stereoscope to observe the growth patterns on each plate. Remember to use both the zoom knob (to change the magnification) and the focus knob to get a clear image of what you are seeing.

Caution

- Often, you will find moisture or condensation inside the lid which may make it difficult to clearly see some regions of the plate. It may be tempting to open the plate and remove this moisture. However, the lids will be sealed with tape, be sure to leave the tape intact and **never remove the lid during your observations**, doing so will release mold spores into the air.
- Once you have completed your observations, the used fungal plates should be placed in the biohazard container for proper disposal.

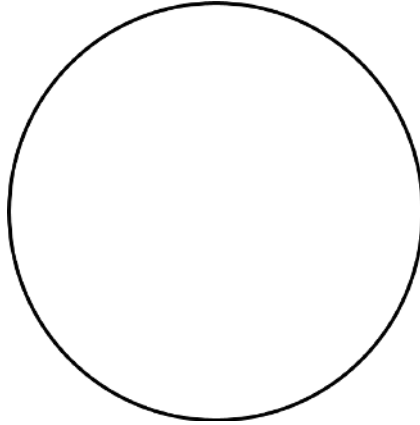
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5.3: Data

Part I: Fungal Ecology

Ectotrophic (ectomycorrhiza) Mycorrhiza

(a) Sketch

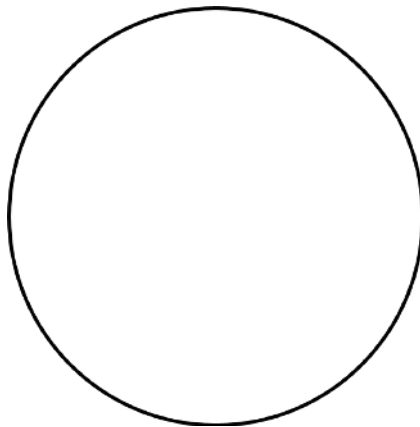


(b) Total Magnification: _____

(c) Observations:

Endotrophic (arbuscular) Mycorrhiza

(a) Sketch

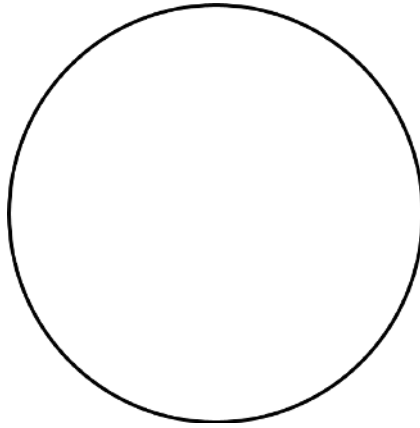


(b) Total Magnification: _____

(c) Observations:

Lichens

(a) Sketch



(b) Total Magnification: _____

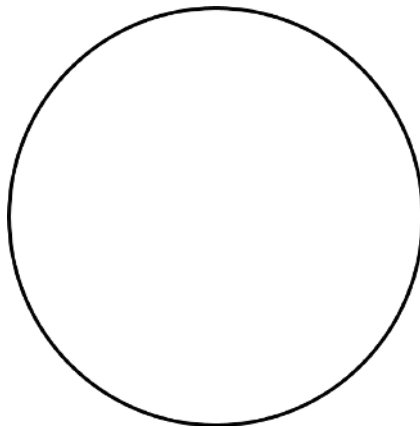
(c) Observations:

Part II: Fungal Diversity

Zygomycota

Rhizopus spp. (label hyphae, sporangiophores and zygosporangia)

(a) Sketch



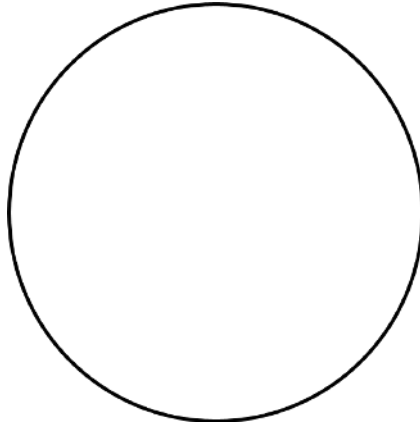
(b) Total Magnification: _____

(c) Observations:

Basidiomycota

Mushroom (label cap, stem and gills)

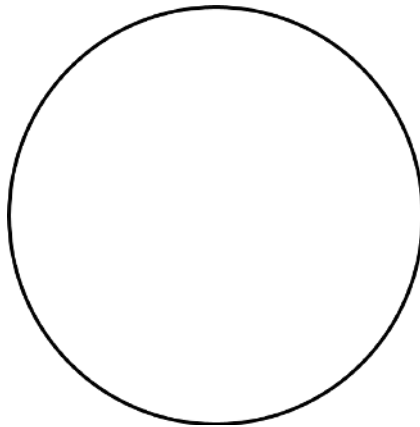
(a) Sketch



(b) Observations:

Mushroom stem hyphae (septate or coenocytic)

(a) Sketch

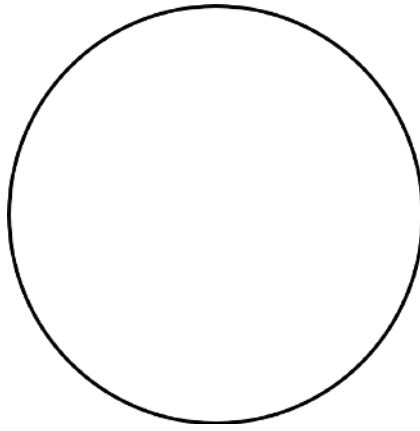


(b) Total Magnification: _____

(c) Observations:

Mushroom gill (label gill, basidia, basidiospores)

(a) Sketch



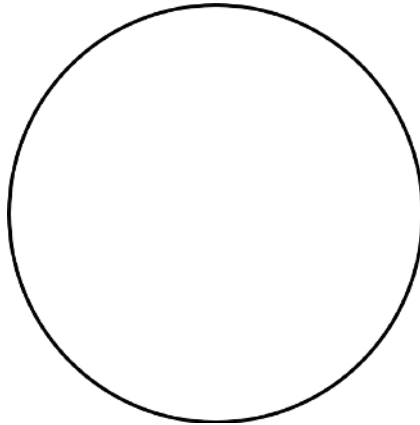
(b) Total Magnification: _____

(c) Observations:

Ascomycota

Yeast

(a) Sketch

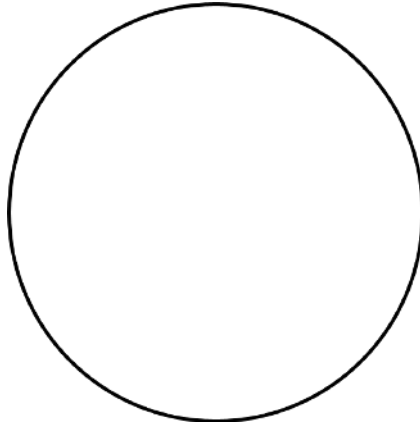


(b) Total Magnification: _____

(c) Observations:

Sordaria (label ascus and ascospores)

(a) Sketch

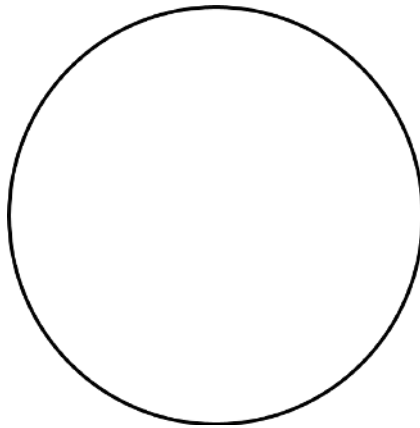


(b) Total Magnification: _____

(c) Observations:

Pencilium (label conidiophores and conidia)

(a) Sketch



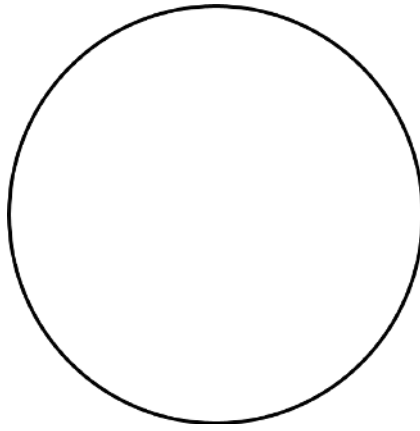
(b) Total Magnification: _____

(c) Observations:

Part III: Settle Plate Method

Classroom

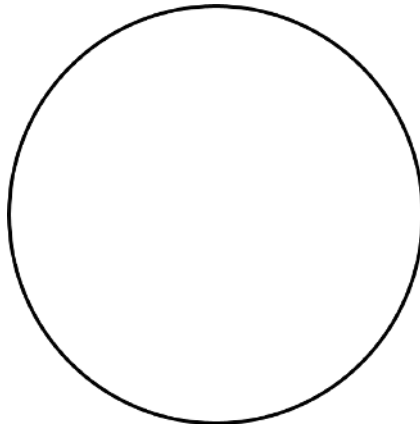
(a) Sketch



(b) Observations:

Hallway

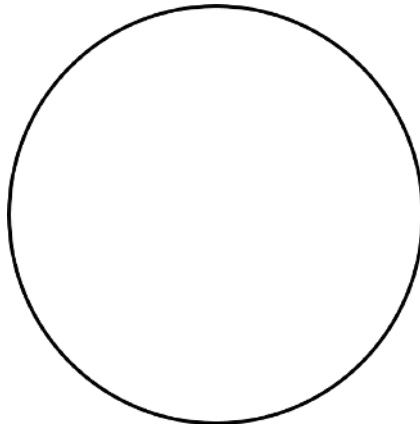
(a) Sketch



(b) Observations:

Outdoor

(a) Sketch



(b) Observations:

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5.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your fungal observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the diversity and significance of fungi. Provide specific examples from the activity to support your conclusions. Be sure to address each of the following in your discussion:

1. **Examine the mutualistic relationships between fungi and photosynthetic organisms.** Compare and contrast ectotrophic (ectomycorrhizae) and endotrophic (arbuscular) mycorrhizae based on your microscopic observations. How does each type of mycorrhizal association benefit both the fungus and the plant? Why are mycorrhizal relationships particularly important in nutrient-poor soils? Identify the partners in the lichen symbiosis. How does each organism benefit from the relationship? Lichens are often used as biological indicators. What does their presence or absence tell us about environmental quality?
2. **Explore fungal diversity.** Why is the coenocytic (non-septate) nature of Zygomycota hyphae advantageous or disadvantageous? Why might having septate hyphae provide advantages for fungi belonging to Basidiomycota or Ascomycota? How does yeast reproduce? How does this differ from the reproductive structures observed in *Sordaria* and *Penicillium*?
3. **Evaluate the prevalence of fungi in the environment.** Compare the amount and diversity of fungal growth on your classroom, hallway, and outdoor plates. What environmental factors might explain the differences? How does the Settle Plate Method demonstrate the ubiquity of fungal spores in our environment?

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CHAPTER OVERVIEW

6: Nonvascular and Seedless Vascular Plant Diversity Lab

[6.1: Introduction](#)

[6.2: Procedure](#)

[6.3: Data](#)

[6.4: Data Analysis and Discussion](#)

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6.1: Introduction

Learning Objectives

- Identify distinctive features of specimens representing the major groups of plants.
- Recognize the characteristics and adaptations plants have made for life on land.
- Examine a collection of bryophytes and identify the distinctive features of these organisms.
- Examine the narrow, unbranched leaves of a lycophyll.
- Examine the leaflet and sori patterns of ferns.

In our last unit we learned about green algae which are believed to be the ancestor to plants because of their similarities in cell wall composition, photosynthetic pigments, and life cycles. Ancestral land plants acquired adaptations giving rise to the diversity of plants that we see today. One unifying feature of all land plants is their mechanism for reproduction which is commonly referred to as the “alternation of generations” or **haplodiplontic life cycle**. This is because plants essentially alternate between a multicellular haploid (gametophyte) and a multicellular diploid (sporophyte) stage. A mature sporophyte will produce spores via meiosis. These haploid spores will then fuse to form the diploid zygote, which develops into the gametophyte. You will have a chance to observe these different stages as well as the spores that plants produce during this lab activity.

Plants are generally organized into different groups based on whether they have vascular tissue, where the nonvascular plants are known as Bryophytes and those with vascular tissue are known as Tracheophytes. **Bryophytes**, which include mosses and liverworts, are the most primitive of plants. They are typically found in areas where water is relatively accessible since they lack a vascular system. This lack of a vascular system also prevents these organisms from growing more than a few inches tall. Bryophytes rely on spores for dispersal and are thus considered a seedless plant. **Tracheophytes** are believed to have evolved ~420 million years ago. The presence of a vascular system allowed these plants to grow taller and further away from water.

One such group of tracheophytes, known as seedless *vascular plants*, includes Lycophytes and Pterophytes. The lycophytes are a relatively small group of vascular plants commonly known as the club mosses. Their key feature is the presence of narrow leaves with a single bundle of vascular tissue running down the center; these leaves are known as lycophylls. The larger of these two groups, the **Pterophytes**, includes ferns, whisk ferns and horsetails. Of these plants, ferns are the most widely recognized and are characterized by their leaf-like fronds and spore producing structures (known as sori) which are located on the underside of these fronds. Like bryophytes, seedless vascular plants rely on spores for reproduction. In this lab, you will examine the lycophylls of a common lycophyte as well as the fronds and sori of various ferns.

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6.2: Procedure

Part I: Bryophytes

1. Obtain a small sample of moss and place it in a petri dish. Observe the features of the moss using the dissecting microscope. Draw a diagram of the plant labeling the leaf-like structures (phyllids), root-like structures (rhizoids) and stem-like structures (caulids) in the space provided below. If evident, distinguish the sporophyte from the gametophyte in your sketch.
 2. Obtain a small sample of liverwort and place it in a petri dish. Observe the features of the moss using the dissecting microscope. Draw a diagram of the plant labeling the leaf-like structures (phyllids), root-like structures (rhizoids) and stem-like structures (caulids) in the space provided below. If evident, distinguish the sporophyte from the gametophyte in your sketch. Note the different shapes and structures of the antheridia and archegonia that represent the male and female gametophyte, respectively.
-

Part II: Lycophytes

1. Obtain a small sample of lycopodium and place it in a petri dish. Observe the features of the moss using the dissecting microscope. Draw a diagram of the plant focusing on the narrow, unbranched leaves (lycophylls). Be sure to label the leaves and stems in your sketch.
-

Part III: Pterophytes

1. Obtain a sample of fern. In the space below, draw a fern leaflet, precisely showing the arrangement of sori on the underside of each leaflet.
 2. Turn the fern leaflet over to get a closer look at the sori. First, examine the sorus under a dissecting microscope. Notice the cluster of rounded "sporangia". The spores are produced inside the sporangia, and some of these should be visible. Using forceps or a scalpel (this will be demonstrated by your instructor), carefully remove some of the sporangia and mount them in a drop of water on a microscope slide with a cover slip. Place the microscope slide on your compound light microscope and draw a sporangium as it appears under the 10x objective lens.
-

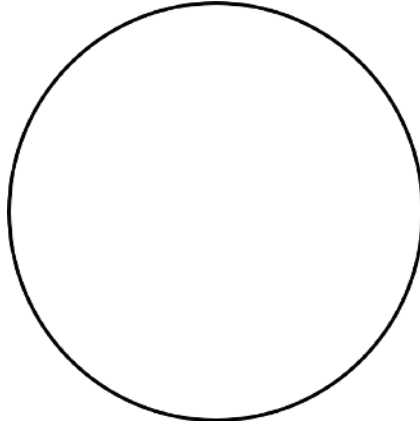
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6.3: Data

Part I: Bryophytes

Moss: label the phyllids, rhizoids, and caulids; distinguish between gametophyte and sporophyte

(a) Sketch

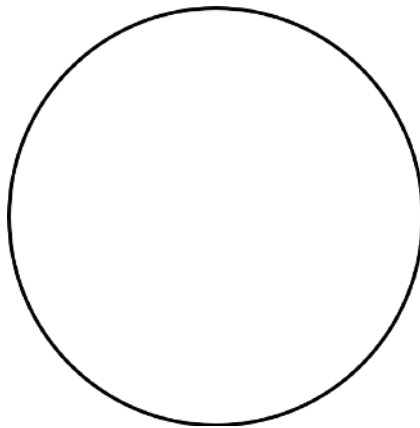


(b) Total Magnification: _____

(c) Observations:

Liverwort: label the phyllids, rhizoids, and caulids; distinguish between gametophyte and sporophyte

(a) Sketch



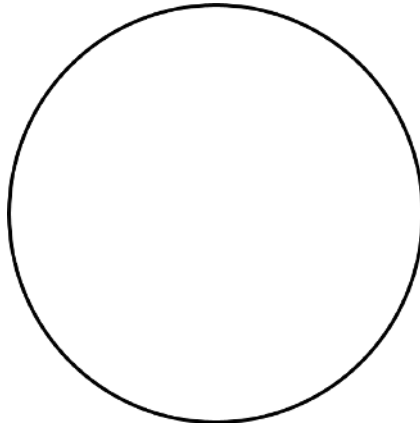
(b) Total Magnification: _____

(c) Observations:

Part II: Lycophytes

Lycopodium: label the stems and lycophylls

(a) Sketch



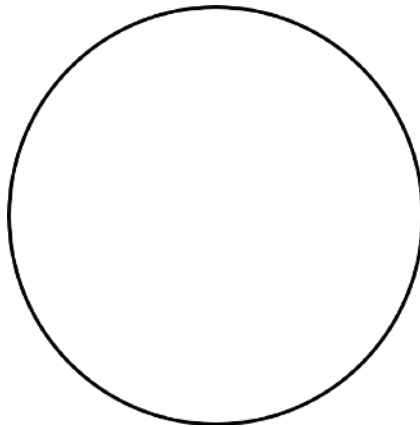
(b) Total Magnification: _____

(c) Observations:

Part III: Pterophytes

Fern leaf (label leaflets and sori)

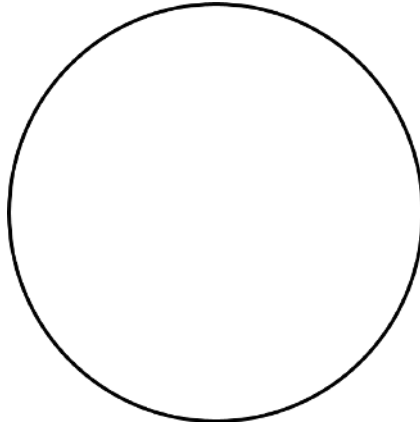
(a) Sketch



b) Observations:

Sori (label sporangia and spores)

a) Sketch



b) Total Magnification: _____

c) Observations:

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6.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your plant observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the adaptations and diversity of nonvascular and seedless vascular plants. Provide specific examples from the activity to support your conclusions. Be sure to address each of the following in your discussion:

1. **Observe bryophyte characteristics and diversity.** What structural differences and similarities did you observe between the moss and liverwort samples? How can you distinguish between the gametophyte and sporophyte generations? Which stage appears to be dominant in bryophytes? How do the structures you observed (rhizoids, caulids, and phyllids) perform similar functions to the roots, stems, and leaves of vascular plants?
2. **Recognize the lycophylls of lycophytes.** How do the leaves of lycophytes (lycophylls) differ from those of mosses and ferns? What evolutionary advantage does the presence of vascular tissue provide to lycophytes compared to bryophytes?
3. **Examine fern characteristics and reproduction.** Where are the sori located on the fern frond, and what is their function? Describe how the mechanism used for the dispersal of spores in ferns from these sori may explain why ferns are the most successful of the groups of seedless plants.
4. **Evaluate the adaptations of land plants.** Looking across all three groups you examined (bryophytes, lycophytes, and pterophytes), summarize the evolutionary trend you see in plant complexity and adaptation to terrestrial life.

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CHAPTER OVERVIEW

7: Seed Plant Diversity Lab

[7.1: Introduction](#)

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7.1: Introduction

Learning Objectives

- Identify distinctive features of specimens representing the major groups of plants.
- Recognize the characteristics and adaptations plants have made for life on land.
- Examine the different characteristics of a seed.
- Differentiate the features of conifers including their needle-like leaves as well as their cones.
- Perform a flower dissection and distinguish the reproductive structures of flowering plants.

In our last lab, we examined plant diversity by observing nonvascular plants as well as seedless vascular plants. Now we will turn our attention to our *seed producing plants* which include two major groups: Gymnosperms and Angiosperms. Of course, the unifying trait of these two groups of plants is the production of **seeds** as part of their reproduction. The introduction of which offered a significant evolutionary advantage to these plants. As we take a closer look at these seeds we can understand why. The seed itself includes a dormant state of the plant embryo encased within an outer protective layer known as the seed coat or integument. This protective outer layer allows the embryo to survive harsh conditions such as cold temperatures and lack of moisture; conditions which would typically kill a living plant. Another trait of these seeds is to contain an endosperm which functions as the nutrient source for the developing embryo that will support the initial stages of growth after seed germination. In this lab we will examine these characteristics by looking at a cross section of a seed under the microscope.

Gymnosperms are often referred to as the “naked-seed” plants and include the conifers, cycads, gnetophytes and ginkgo plants. Rather than enclosing their seeds within an embryo as the angiosperms do, the seeds of gymnosperms will develop on the surface of scales or leaves, which are often modified to form **cones** (as is the case in conifers). Conifers are the most abundant of this group and are often characterized by their evergreen needle-like leaves which allow them to survive colder, drier climates. Pollen grains of conifers are produced in the male cones which are found lower branches on the tree. Female cones are larger and have woody scales, each of which contains the ovules of the plant for reproduction. In this lab, you will have the opportunity to observe pollen grains and cones of common conifers.

Two hallmark characteristics of the last group of plants, the **angiosperms**, include flowers and fruit. Angiosperms, which are often referred to as the flowering plants, developed flowers to attract pollinators. Flowers can do this using their bright colors, unique shapes and aromas which draw certain insects and animals to them. Flowers have four main components: sepals, petals, stamen, and carpels. These structures are organized in a whorl, or circular pattern, to form the flower. **Petals** come in many shapes and colors and are the part of the flower that attracts the pollinators. **Sepals** are located outside the petals to protect the bud. Inside the petals are the reproductive organs known as the stamen and carpels. The **stamen** is the male reproductive part which consists of a pollen producing structure (known as the **anther**) which is held by a **filament**. The **carpel** is the female reproductive structure. The **stigma**, which is sticky, feathery or hairy to bind pollen is located on the top of the carpel. The middle supporting structure is known as the **style** and the large base is the **ovary**. The ovary contains the ovules where the eggs are produced. The term angiosperm means “container seed” because once the egg is fertilized it becomes the seed which is protected by a fleshy fruit that develops from the ovary tissue that surrounds the seed. To familiarize yourself with these features, you will perform two flower dissections.

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7.2: Procedure

Part I: Seeds

1. Obtain a prepared slide of a persimmon seed and observe under the microscope using the low power/10x objective lens. Provide a sketch of your observations in the space provided. Be sure to label the seed coat/integument, embryo and endosperm in your sketch.
-

Part II: Gymnosperms

1. Examine the assortment of female cones on display in the lab. Select a single cone and provide a sketch of that cone in the space provided; be sure to label or describe any notable features.
 2. Examine the assortment of male cones on display in the lab. Select a single cone and examine the pollen grains found within. Place a drop of water on a microscope slide and then add pollen using tweezers or swirl the anther in the droplet to release some pollen and add a coverslip. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. If male pinecones are not available for this purpose, use the prepared slide of male pine pollen instead and provide a sketch of that pollen grain below. Note the pair of airbladders that aid in movement of the pollen grain in your sketch. Label both the pollen grain and the air bladders in your sketch.
 3. Obtain a pine seedling and observe the thin, needle-like evergreen leaves present. Provide a sketch of the seedling in the space provided. Label the needle-like leaves in your sketch.
-

Part III: Angiosperms

1. Obtain a flower and perform a flower dissection.
 2. Locate the outermost layer of flower parts. These are the sepals. Carefully remove the sepals. Provide a sketch and detailed description of the sepals in data table 7.1. If possible, count the number of sepals and record that with your description as well. Note that for some flowers the sepals resemble petals while others have leaf-like sepals.
 3. Identify the petals. These form the next layer of flower parts. Carefully remove each petal. Provide a sketch and detailed description of the petals in data table 7.1. If possible, count the number of petals and record that with your description as well.
 4. Now locate the stamen. These male flower parts should now be exposed. Provide a sketch and detailed description of the stamen in in data table 7.1. Label the parts of the stamen (i.e., the anther and the filament) on the sketch.
 5. Now locate the carpel. This female flower part should be what remains. Observe the components of the carpel including the stigma and the style. Next, use a scalpel to slice lengthwise through the ovary at the base of the carpel to reveal the ovules inside. You can use the dissecting scope or magnifying glass to get a closer look at the eggs inside these ovules. Provide a sketch and detailed description of the carpel in in data table 7.1. Labels the parts of the carpel (i.e., the ovary, style, and stigma) on the sketch.
 6. Repeat steps 1-4 using a different flower for comparison. Record your sketches and observations of this flower in data table 7.2.
-

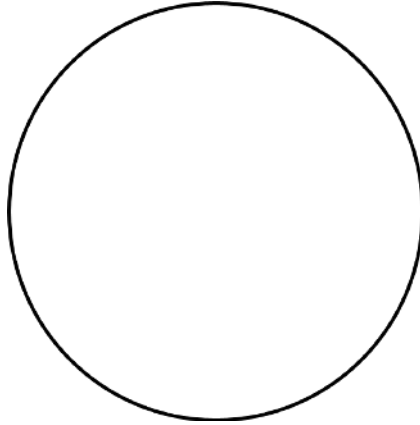
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7.3: Data

Part I: Seeds

Persimmon seed (label the seed coat/integument, embryo and endosperm)

(a) Sketch



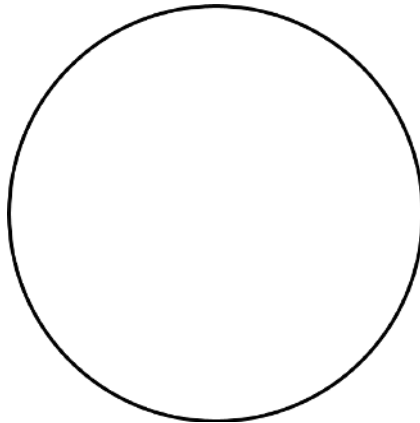
(b) Total Magnification: _____

(c) Observations:

Part II: Gymnosperms

Female cone

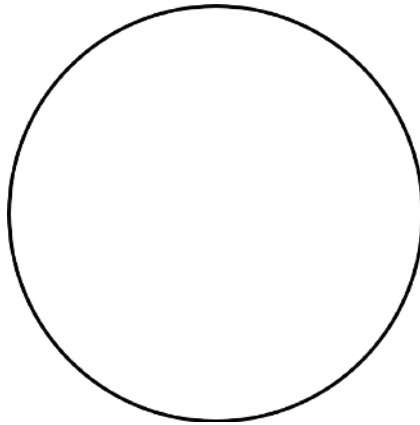
(a) Sketch



(b) Observations:

Pine pollen (label pollen grain and air bladders)

(a) Sketch



(b) Total Magnification: _____

(c) Observations:

Part III: Angiosperms

Flower: _____

Table 7.1

Flower Part	Sketch	Description
Sepal		
Petal		
Stamen (Label the anther and filament)		
Carpel (Label the stigma, style, ovary)		

Flower: _____

Table 7.2

Flower Part	Sketch	Description
Sepal		
Petal		
Stamen (Label the anther and filament)		
Carpel (Label the stigma, style, ovary)		

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7.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your plant observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the adaptations and diversity of vascular seed plants. Provide specific examples from the activity to support your conclusions. Be sure to address each of the following in your discussion:

1. **Characteristics and advantages of seeds.** What structures were visible in your seed cross section? Describe the function of each labeled part (seed coat, embryo, and endosperm). How does the presence of a seed provide an evolutionary advantage compared to spore-based reproduction in non-seed plants (HINT: How do the features of a seed contribute to the plant's ability to survive and disperse?).
2. **Characteristics of gymnosperms.** Why are gymnosperms commonly referred to as "naked-seed" plants? How does their method of seed production differ from that of angiosperms?
3. **Characteristics of angiosperms.** Compare the number and arrangement of sepals, petals, stamens, and carpels in the two flowers you dissected. What patterns or differences did you notice? How do the flower's color, shape, and structure relate to the type of pollinator it might attract?
4. **Evaluate the adaptations of land plants.** Looking across nonvascular, seedless vascular, gymnosperm, and angiosperm plants, summarize the major evolutionary trends in plant reproduction and structural complexity.

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CHAPTER OVERVIEW

8: Invertebrate Animal Diversity I Lab

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8.1: Introduction

Learning Objectives

- Study the body plans and anatomical structures of various animals.
- Observe evolutionary patterns and structural differences across the animal kingdom.

Although all animals share key characteristics including being multicellular, obtaining food through ingestion, demonstrating active movement, and carrying out sexual reproduction, they are remarkably diverse in their form and habitat. This lab begins our closer examination of animal diversity with some of the simplest animals: sponges, cnidarians and flatworms.

Sponges represent a group of aquatic animals that belong to the **Phylum Porifera**. They are the most basal of animals, lacking some of the key attributes found in all other animals. Specifically sponges are asymmetrical and lack true body tissues while all other animals have some form of body symmetry and their cells organized into distinct tissues. They do, however, have two layers of cells that create the basic body structure. The outer layer is comprised of cells known as **pinacocytes** and on the inside is a layer of cells known as choanocytes (which are similar to their protist ancestor, the choanoflagellates). In between these two layers of cells is a gelatinous material known as the **mesohyl**. Sponges are aptly named as they contain several small pores or openings lining the outside of their body, known as **ostia** (singular is ostium). It is through these pores that water enters the sponge body. As filter feeders, the sponges use a current created by the inner layer of **choanocytes aka collar cells**. The force created by the flagella of these choanocytes is used to pull water *in* through the ostia and *out* a large opening at the top of the animal, known as the **osculum**. As the water moves through the animal, the choanocytes engulf bacteria, algae and other plankton as a source of food.

Cnidarians (Phylum Cnidaria), which include animals such as sea jellies, anemones, and hydras, also represent an important stage of animal evolution. Cnidarians have **radial symmetry** and two key layers of tissues, but their bodies are still relatively simple. On the outer surface they have a tissue layer known as the **epidermis** and lining the digestive cavity they have the **gastrodermis**. In between these tissue layers is a gelatinous material known as the **mesoglea**. Perhaps the most interesting and notable feature of cnidarians is their **tentacles** and the cnidocytes which often line those tentacles. These **cnidocytes** (also known as **nematocytes**) produce harpoon-like structures known as **nematocysts** that can be used to capture prey and ward off predators.

Flatworms belong to the Phylum Platyhelminthes and are the only of the animals that we will observe in this particular lab that are considered bilaterians. A bilaterian is an animal which possesses **bilateral symmetry** characterized by the body being composed of 2 similar halves. The vast majority of animals alive today are bilaterians, owing in part to the advantage of cephalization which accompanies this form of body symmetry. **Cephalization** is described as having a collection of sensory structures in the anterior region of an animal. This allows for better perception and coordination of movement within the animals' environment. Another trait we associate with all bilaterians is that they are triploblastic which means that their embryos have all 3 germ layers. This, in part, is what contributes to the increased complexity seen in these animals. The flatworms that we will examine for this lab are known as planarians. **Planarians** exhibit both bilateral symmetry and cephalization. This is evidenced by a quick examination of their body structure which shows that you could draw an imaginary line right down the center of the animal and divide it into relatively equal left and right halves. You should also be able to easily observe the presence of projections from the anterior region, known as the **auricles**, which can collect chemical stimuli as well as information about physical disturbances in their environment. In addition, planarians have two **eyespot**s in the anterior region which can detect light stimuli (allowing them to detect light from dark).

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8.2: Procedure

Part I: Phylum Porifera (Sponges)

Observe Preserved Sponge Specimen

1. Obtain a preserved specimen of the grantia sponge. Using the tweezers from a dissecting kit to collect a single sponge and place it in a petri dish. Next, using the dissecting microscope, view the specimen. You should use the tweezers and any other tools from the dissecting kit to move and manipulate the sponge, allowing you to see the ostia and osculum. Note the texture, shape, size and appearance of the overall body as well.
2. Record your observations and sketch the specimen in the space provided. Label the ostia and osculum on your sketch. Dispose of dissected animals in the classroom trash.
3. Clean dissecting trays and dissecting materials, leaving them to dry next to the classroom sink.

Observe Prepared Slides of Sponge

1. Obtain a prepared slide of the grantia sponge. This slide contains both a cross section and a longitudinal section of the sponge. Observe both sections of the slide using the low power/10 objective lens. Note the layers of cells that form the animals' body as well as the hollow body cavity in the center.
 2. Using your sketch, trace the path of water through the sponges' body (this should be done on the sketch of the longitudinal section for the best perspective).
-

Part II: Phylum Cnidaria

Observe Live Specimen of Hydra

1. Handle the hydra with care. Obtain a live specimen from the jar of mixed hydra using a transfer pipette. Place the hydra into a deep well slide.
2. Next, using the compound microscope view the specimen using the 10x objective lens. From this level of magnification, sketch the overall body structure of the hydra being sure to label the tentacles. Record your observations of the animals behavior including any movement or feeding behavior.

Observe Prepared Slides of Hydra

1. Obtain a prepared slide of the *longitudinal section* of a hydra. Observe using the low power/10 objective lens. Note the overall body structure which includes the outer layer (epidermis) and inner layer (gastrodermis) of tissue. Provide a sketch being sure to label these structures in the space provided.
 2. Obtain a prepared slide of the *cross section* of a hydra. Observe using the low power/10 objective lens. Note the overall body structure which includes the outer layer (epidermis) and inner layer (gastrodermis) of tissue. Provide a sketch being sure to label these structures in the space provided.
-

Part III: Phylum Platyhelminthes

1. Handle the planarians with care. Obtain a live specimen of planaria by gently sucking them into a plastic pipette and gently expelling them into a petri dish containing spring water.
 2. Next, using the dissecting microscope, view the specimen. You may need to continuously move the petri dish as the planarian moves to continue your observations. Take note of the movement, behavior and features of the planaria for a few minutes.
 3. Record your observations and sketch the planaria in the space provided. Label the eyespots and auricles as well as the anterior and posterior ends.
-

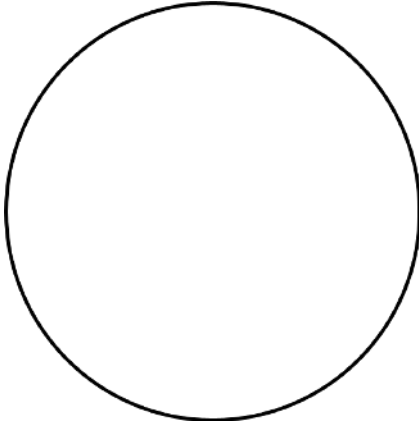
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8.3: Data

Part I: Phylum Porifera (Sponges)

Preserved Sponge Specimen

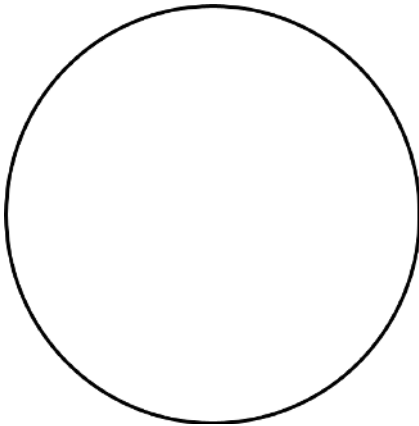
(a) Sketch (label ostia and osculum)



(b) Observations (color, size, shape, distinct features, etc.):

Prepared Slides of Sponge

(a) Sketch (trace the path of water through the sponges' body)



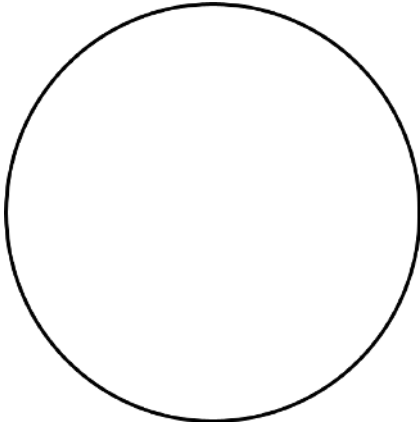
(b) Total Magnification: _____

(c) Observations:

Part II: Phylum Cnidaria

Live Hydra Specimen

(a) Sketch (label tentacles)

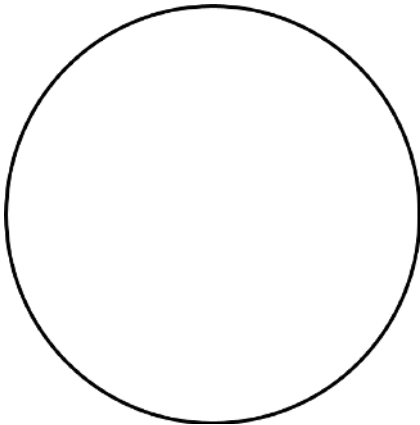


(b) Total Magnification: _____

(c) Observations (color, shape, movement, behavior, etc.):

Prepared Slide of Hydra

(a) Sketch (label the epidermis and gastrodermis)



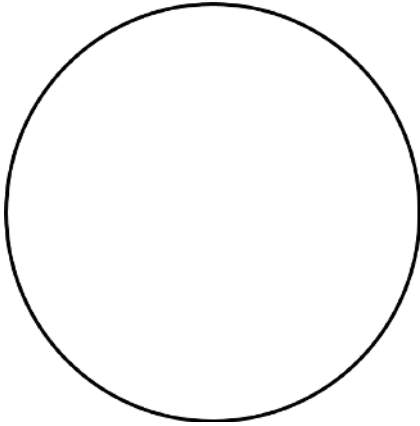
(b) Total Magnification: _____

(c) Observations:

Part III: Phylum Platyhelminthes

Live Planaria Specimen

(a) Sketch (label auricles, eyespots and the anterior and posterior regions)



(b) Total Magnification: _____

(c) Observations (color, shape, movement, behavior, etc.):

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8.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the characteristics and evolutionary significance of the animals observed during this lab. Be sure to address each of the following in your discussion:

1. **Examine the body plan of sponges.** Discuss how the sponge body plan represents an evolutionary transition between unicellular protists and more complex multicellular animals.
2. **Examine the body plan of cnidarians.** Compare the organization of tissues in cnidarians with those in sponges. What new level of complexity is introduced in cnidarians?
3. **Examine the body plan of flatworms.** What evidence of cephalization did you observe in the planarian? How might this contribute to its behavior and interaction with the environment?
4. **Evaluate the evolutionary relationships between these different animals.** Across these three groups, what trends do you see in the development of tissues, organs, and organ systems? (HINT: Based on your observations, describe the overall trend in body organization and complexity from Porifera → Cnidaria → Platyhelminthes.).

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CHAPTER OVERVIEW

9: Invertebrate Diversity II Lab

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9.1: Introduction

Learning Objectives

- Study the body plans and anatomical structures of various animals.
- Observe evolutionary patterns and structural differences across the animal kingdom.

One of the key transitions in the evolutionary history of animals was the introduction of a true body cavity in which specialized organs and organ systems could be housed. Animals that exhibit such body cavities are known as **coelomates**. We will examine 4 specimens, each of which represent an important group of animals (mollusks, annelids, arthropods and echinoderms), all of which are coelomates. We will also examine the role of segmentation and in the transition towards more complex animal body plans.

Phylum Mollusca is a large and diverse group of bilaterians which includes familiar animals such as the octopus, garden snail and clam. Mollusks have several key characteristics, many of which can be observed in the mussel that we will examine as part of this lab. This includes a collection of organs concentrated into what is known as the **visceral mass**. This visceral mass is surrounded by a thick epidermal sheet known as the **mantle**. It is this mantle that is responsible for secreting the hard protective **shell** that many mollusks possess. In the case of the mussel, it has two shells and is known as a bivalve. Upon opening the shell of such an animal, you should also be able to observe the **muscular foot** which is used primarily for movement (note that in certain mollusks such as the cephalopods, the muscular foot is divided into distinct tentacles).

Organisms belonging to **Phylum Annelida** are most well noted for their highly **segmented** bodies. Often these animals are commonly referred to as segmented worms as a result. Their elongated bodies are often divided into hundreds of segments by internal walls known as **septa**. The annelid we will be using for this lab is the common earthworm. Though the body plan of the earthworm is relatively simple, you will be able to observe some of the complex organs and organ systems inside. You may also get the chance to observe another key trait of annelids-**chaetae aka setae**. These are small, bristle-like structures that the animal uses to grab ahold of substrate while it is moving. These chaetae, along with circular bands of muscles are responsible for the changing stripe pattern that you notice when watching an earthworm inch along the ground.

The group of animals that contributes most significantly to animal diversity belong to **Phylum Arthropoda**. With over 1 million species of arthropods identified, it can be difficult to identify a specimen that illustrates all of the key traits of arthropods. For this lab, we will use crayfish. This is an aquatic vertebrate, so it will have **gills** rather than the trachea and spiracles of most arthropods. However, the hard external skeleton, or **exoskeleton**, that is characteristic of arthropods will be evident. Also evident, will be the segmented body which is organized into functional regions known as **tagmata**. The **jointed appendages** for which these animals are named will also be clearly visible; be sure to note the appendages that have been specialized into antennae and mouthparts.

For our final animal observation, we will examine a sea star which is an iconic echinoderm. Animals belonging to **Phylum Echinodermata** are unlike any other animals on the planet with their unique pentaradial symmetry and **water-vascular system**. The **pentaradial symmetry** is what gives rise to the star-shaped pattern of a sea star; with its 5 arms projecting from one central body mass. It is important to note, that although these animals exhibit pentaradial symmetry as adults, they are still considered bilaterians as their juvenile stages have bilateral symmetry. As you examine the anterior portion of the sea star you will clearly see the **madreporite** which is a sieve-like structure used for drawing water into the water-vascular system. As you open the animal's body you will cut through the small bones (ossicles) that form the echinoderm **endoskeleton**. Inside you should see other elements of the water vascular system including the **ring canal** as well as the **radial canals** that branch into each arm. Upon closer inspection of the posterior of the animal you should also be able to see the **tube feet** that are connected to each of these radial canals. This network of tube-like structures functions to bring water into the **ampullae** associated with each of the tube feet. These ampullae are lined with muscles, that, when they contract, will force water into the tube feet so that they can be used for grabbing ahold of substrate for movement or prey for feeding.

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9.2: Procedure

Each pair of students will be assigned either the mussel and the crayfish OR the earthworm and the sea star. As each group will be assigned different specimens to dissect, you will follow the specific dissection instructions according to those assignments. Once the dissections are complete, all students will have the opportunity to view the other groups' specimens so that they may complete their sketches and observations of all 4 organisms for this lab report.

Part I: Mollusca

Dissect Preserved Mussel Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a mussel from the specimens provided. Also obtain a complete mussel dissection guide which includes images that you can reference to help you with your dissection.
2. Place the mussel in the dissecting tray with the hinge (dorsal side) up. Identify anterior/posterior openings by the longer/shorter ends: the anterior end is usually toward the siphons. Create a sketch of the external surface of the mussel. Be sure to measure the dimensions of the shell and record that in the space provided.
3. Stabilize the mussel in the tray with the dorsal hinge toward you. Insert the tip of a blunt probe or small flat screwdriver into the posterior shell gape (the wider opening at the back where the siphons are). Do not force but instead work gently to pry the valves slightly apart. Gently slide the scalpel along the opening to sever the adductor muscles where they attach to the shell. Cut close to the muscle rather than through the tissue, if possible, to preserve internal contents. Once both adductor muscles are severed, gently open the mussel like a book.
4. Gently separate the mantle lobes at the posterior end to reveal the mantle cavity and gills. Note any incurrent/excurrent siphonal openings.
5. Gently lift a gill plate with forceps. Note the gills are often in pairs folded in a fan-like arrangement.
6. Carefully separate the mantle from the visceral mass using the probe from your dissecting tray, taking care to loosen the tissue. You may need to cut small connective tissues to lift the visceral mass slightly.
7. Find the muscular foot, which is usually located in the anterior region. Gently tease it free from surrounding tissue to observe muscle fibers.

Observe the Dissected Mussel

Carefully observe the dissected mussel, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 9.1.

1. *Shell*: hard, protective outer coat; in this case there are 2 similar shells enclosing the entire animal.
2. *Mantle*: tissue lining the shell; surrounds the visceral mass and produces shell material.
3. *Visceral mass*: central soft region encased within the mantle; contains digestive, reproductive and excretory organs such as nephridia.
4. *Gills aka ctenidia*: plate-like structures with many folds, located on either side of the visceral mass; used for respiration and filter feeding.
5. *Muscular Foot*: large, muscular organ used for burrowing; very fibrous.

Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed).
2. Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp! Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part II: Phylum Annelida

Dissect Preserved Earthworm Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and an earthworm from the specimens provided. Also obtain a complete earthworm dissection guide which includes images that you can reference to help you with your dissection.
2. Place the worm in dissecting tray on a paper towel and blot excess preservative. Measure total length and note approximate number of visible segments. Create a sketch of the animal and record this information in the space provided.
3. Distinguish the anterior (head) vs. posterior (tail) ends. The anterior end is typically more tapered and contains the mouth; the posterior end is blunter. Locate and note the clitellum present in the anterior third of the animal's body; this is a thickened band used for reproduction. Add this structure to your sketch if you have not done so already and take note of its segmental position.
4. Examine individual segments with a magnifying glass or by placing them under dissecting microscope. Note the positions of chaetae/setae and the tiny pores of nephridia if visible.
5. Place the worm dorsal (belly) side up in the dissection tray. Gently stretch the worm straight (do not overextend) and insert pins through the body wall at several segments near each end and one or two along the mid-body to stabilize. Pin at an angle to secure the specimen.
6. Make note of the dorsal midline. Carefully, make an incision along this midline. To do this, use scissors or a scalpel to make a small transverse nick at the posterior pinned end (careful not to cut deep). Next, with the scissors, carefully cut along the dorsal midline from posterior toward anterior through the dorsal body wall only, cutting segment by segment. Keep the blade shallow and controlled — you want to open the coelom without severing internal organs. Stop just before getting to the anterior/head region to avoid cutting into the pharynx.
7. Gently fold back and pin the two dorsal body flaps (cut edges) to expose the internal cavity. Place pins in alternate segments to hold flaps open without tearing tissue.

Observe the Dissected Earthworm Specimen

Carefully observe the dissected earthworm, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 9.2.

1. *Pharynx* (segments ~1–6): just posterior to the mouth find the muscular pharynx — thick, muscular chamber used to ingest soil. It may be pale, rounded. Gently move aside mantle tissue to view.
2. *Esophagus* (segments ~7–9): a short tube posterior to the pharynx. Several muscular aortic arches/hearts encircle the esophagus near the anterior region. They can be distinguished as small, rounded muscular structures.
3. *Crop* (food storage; variable segments): posterior to the esophagus; a thin-walled storage chamber. It appears as an expanded region of the gut.
4. *Gizzard* (muscular grinding organ): posterior to the crop; thicker muscular wall used to grind soil and food. Palpate gently with probe to appreciate thickness.
5. *Intestine*: follows the gizzard; a tube-like structure that runs the remainder of the body.
6. *Nephridia* (excretory tubules): found in most segments in pairs; look for thin, coiled tubular structures along the body wall/near septa. You will need to place the specimen under the dissecting microscope to view effectively.
7. *Septa*: internal septa separate segments and the body wall.
8. *Chaetae*: bristle-like structures; located on the underside and sides of each body segment, except for the first and last ones. You will need to place the specimen under the dissecting microscope to view effectively.



Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part III: Phylum Arthropoda

Dissect Preserved Crayfish Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a crayfish from the specimens provided. Also obtain a complete crayfish dissection guide which includes images that you can reference to help you with your dissection.
2. Place the crayfish dorsal side up in dissecting tray on a paper towel and blot excess preservative. Measure body length and observe external features. Create a sketch of the animal and record this information in the space provided.
3. Distinguish the anterior (head) vs. posterior (tail) ends. The anterior end is where you will find several sensory structures such as the eyes and mouthparts. Locate and note the carapace which is a thickened region that covers the cephalothorax. Stretch gently and pin the legs and tail to secure the specimen. Use pins at both the anterior and posterior end of the animal to stabilize.
4. Locate the seam of the dorsal carapace. Using small scissors or a scalpel, make a shallow cut through the carapace. Be cautious, making sure to cut only the shell, not the underlying tissue.
5. Carefully lift and remove the dorsal carapace to reveal the internal cephalothorax cavity. Set the removed piece aside. Pin the tissue back if needed to hold the cavity open.
6. Identify the gills (paired comb-like structures) and carefully remove them with forceps and transfer them to a dish containing saline. Observe the gills under the dissecting microscope.
7. The heart sits dorsally within the pericardial sinus, just posterior to the gastric region, often faintly muscular and may be visible as a triangular structure.
8. Turn the specimen ventral side up (carefully unpin and re-pin with ventral side facing up). Pin legs laterally so abdomen is flat.
9. Make a mid-ventral incision along the abdomen between the walking legs and continue along the rest of the body: using fine scissors, cut through the exoskeleton on the ventral abdomen along the midline down to but not through the intestine. Cut segment by segment. Be careful, cutting too deep may sever the gut.
10. Trace the intestine from the cephalothorax through the abdomen to the anus.
11. Locate and identify the ventral nerve cord which consists of two nerve cords fused into a double chain of ganglia running ventrally along the midline. The paired segmental ganglia may be visible as whitish nodules.

Observe Preserved Crayfish Specimen

Carefully observe the dissected crayfish, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 9.3.

1. *Exoskeleton*: hard, outer covering that surrounds the entire animal's body.
2. *Carapace*: dorsal, anterior part of exoskeleton observed as a thickened band in the cephalothorax region.
3. *Tagmata*: note the cephalothorax (a fused head and thorax) and the abdomen (the segmented tail) that represent the functional regions of the animal's body.
4. *Jointed appendages*: these are the paired appendages that include:
 - Short, sensory structures (*antennules*) and long, sensory structures (*antennae*) in the anterior most region.
 - Mouthparts (*mandible*, *maxilla* and *maxillipeds*) near the mouth.
 - Walking legs with claws (*chelipeds*) and similar sized walking legs (*pereiopods*) attached laterally to the cephalothorax region.
 - *Uropods* and *telson* forming the outside and inside of the tail fan, respectively.
5. *Gills*: Feather, like structures located just underneath the carapace in the cephalothorax region.

 Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part IV: Phylum Echinodermata

Dissect Preserved Sea Star Specimen

1. Follow the instructions outlined below to carefully complete the dissection of your specimen:
2. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a sea star from the specimens provided. Also obtain a complete sea star dissection guide which includes images that you can reference to help you with your dissection.
3. Place the sea star dorsal side up in dissecting tray on a paper towel and blot excess preservative. Measure overall diameter from arm tip to opposite arm tip and observe external features including the madreporite. Create a sketch of the animal and record this information in the space provided.
4. Turn the specimen ventral side up and observe the oral surface with the mouth at the center and the groove running down each arm.
5. Using small scissors or a scalpel, make a shallow incision in one arm along the center of the groove from about mid-arm toward the disc at the center of the animal. Be sure to keep the cut shallow so that you do not disturb the internal organs.
6. Gently use forceps or a blunt probe to separate the cut edges and expose the internal cavity of the arm. Pin the edges open laterally to hold the incision and reveal internal structures. If you are observing a mature specimen, you will find prominent gonads throughout each arm. If present, remove the gonads to reveal the underlying structures.
7. Examine the arm under the dissecting scope to observe the tube feet (podia) and the calcified plates (ossicles) of the endoskeleton.
8. Make a short incision at the edge of the central disc (near the mouth) to extend exposure into the central disk. Be cautious around the mouth and ring canal. Take note of the ring canal and its attachment to the radial canals in each arm as well as to the stone canal which leads to the madreporite. You may need to observe using the dissecting microscope for a clearer view of internal features.

Observe Preserved Sea Star Specimen

Carefully observe the dissected sea star, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 9.4.

1. *Madreporite*: sieve-like plate found on the dorsal side near the center of the animal's body.
2. *Stone canal*: small, tube-like structure which connects the madreporite to the ring canal.
3. *Ring canal*: circular, tube-like structure found in the center of the animal's body.
4. *Radial canals*: narrow, tube-like structures that extend throughout each of the animal's arms.
5. *Ampullae*: muscular bulb-like structures which connect the tube feet to the radial canals.
6. *Tube feet/podia*: small, sucker-like structures which are attached to the radial canals and extend through the groove of each arm.
7. *Endoskeleton*: small overlapping bony plates known as ossicles which create the internal structure of the animal's body.

 Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

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9.3: Data

Part I: Phylum Mollusca

o Label shell, mantle, visceral mass, gills and muscular foot

Data Table 9.1: Preserved Mussel Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part II: Phylum Annelida

o Label pharynx, esophagus, crop, gizzard, intestine, nephridia, septa, and chaetae

Data Table 9.2: Preserved Earthworm Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part III: Phylum Arthropoda

o Label exoskeleton, tagmata, carapace, gills, jointed appendages (antennules, antennae, chelipeds, peripods, mouthparts), uropods and telson

Data Table 9.3: Preserved Crayfish Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part IV: Phylum Echinodermata

o Label madreporite, stone canal, ring canal, radial canal, gonads (if present), ampullae and tube feet

Data Table 9.4: Preserved Sea Star Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

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9.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the characteristics and evolutionary significance of the animals observed during this lab. Be sure to address each of the following in your discussion:

1. **Examine the body plan of mollusks.** The mussel's visceral mass houses several organ systems in a compact space. Discuss one advantage and one limitation of having organs concentrated in a visceral mass.
2. **Examine the body plan of annelids.** Describe how segmentation is evidenced in the earthworm's external and internal anatomy. What are the advantages of segmentation?
3. **Examine the body plan of arthropods.** Identify three distinct adaptations of the crayfish that reflect its active, mobile, and often predatory lifestyle. For each adaptation, explain the functional advantage. The crayfish exoskeleton requires periodic molting for growth. Discuss the advantages and disadvantages of having an exoskeleton compared to an internal skeleton/endoskeleton.
4. **Examine the body plan of echinoderms.** Describe the unique water-vascular system of the sea star (madreporite → stone canal → ring canal → radial canals → ampullae → tube feet). How does this system enable locomotion and feeding?
5. **Evaluate the evolutionary relationships between these different animals.** Arrange the four phyla examined (Mollusca, Annelida, Arthropoda, Echinodermata) along a short continuum describing increasing organ/system complexity and justify your ordering with two anatomical observations from the lab.

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CHAPTER OVERVIEW

10: Vertebrate Diversity Lab

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10.1: Introduction

Learning Objectives

- Study the body plans and anatomical structures of various animals.
- Observe evolutionary patterns and structural differences across the animal kingdom.

In our previous labs covering animal diversity, we explored invertebrates (animals which lack a backbone or vertebral column). In those investigations, we were able to trace the evolutionary innovations that led to increasing body complexity and specialization in the animal kingdom. In this lab, we turn our attention to the **vertebrates**, a group of animals belonging to **Phylum Chordata**, **Subphylum Vertebrata**. This group also represents a major evolutionary leap in structural and functional organization. There are 3 subphyla within Subphylum Vertebrata, all of which share several key characteristics. This includes having a flexible rod-like structure that establishes the midline of the animal (**notochord**), a tract of nervous tissue that runs along the back of the animal (**dorsal nerve cord**), a set of openings that lead to the pharynx (**pharyngeal slits**) and a **postanal tail**. In many vertebrates, these features are replaced prior to maturity (e.g. the notochord and dorsal nerve cord which develop into the vertebral column and the brain and spinal cord, respectively).

There are also characteristics that are unique to vertebrates themselves and as we more closely examine these traits, we can begin to appreciate the importance of these traits and the complexity of these animals. The name *Vertebrata* is a reflection of the presence of a **vertebral column**, or **backbone**, which is one of the most evident features of animals in this group. Like their echinoderm relatives, vertebrates also possess an internal skeleton, or **endoskeleton**, made of bone or cartilage. In addition, they have a highly developed head region with many distinct sensory structures as well as a highly organized body plan with many specialized organs and organ systems compartmentalized into a variety of body cavities. These features have allowed vertebrates to adapt to a wide variety of habitats, from deep oceans to terrestrial environments.

Vertebrates represent several classes of animals which are organized into 5 common groups: fishes, amphibians, reptiles, birds and mammals.

Fishes are an important group of vertebrates for a variety of reasons. They represent the oldest extant group of vertebrates and contribute most significantly to overall vertebrate diversity with over 35,000 currently recognized species and hundreds more being discovered every year. Fishes are aquatic vertebrates with streamlined bodies that are covered in protective **scales**, **fins** for movement, **gills** which allow for effective gas exchange in water, and specialized sensory structures (known as the **lateral line system**) which runs along the length of the animals' body and is used to collect important information about movement in the surrounding water. This lateral line system is key for helping with navigation, finding prey and social interactions. While there are several classes of fish, the largest group is known as the **ray-finned fishes**. Such fishes are known for having pectoral fins that contain narrow bones that run along the length of the fin to effectively move water to create the force needed for swimming. While ray-finned fishes account for nearly 99% of fish species, another group, known as the **lobe-finned fishes**, are important for their evolutionary significance. It is these fish, with their central core of bones and fleshy lobe at the center of their pectoral fins that are the ancestors of land vertebrates. These lobe fins would be potentially useful for supporting a body on land.

Amphibians are believed to be the direct descendants of these lobe-finned fish. As we examine fossil evidence of the transitional forms of this evolutionary path, we see the gradual growth of legs from fins as well as the development of **lungs** and **larger muscles** to support movement on land. We also see evidence of the aquatic ancestry of amphibians in the reliance that they have on water for laying their eggs and keeping their skin moist. Although amphibians do have developed lungs, they are not able to keep up with all the respiratory needs of the animal which is why they use **cutaneous respiration** to exchange gases across their skin.

The transition of vertebrates becoming more independent from aquatic habitats is first observed in **reptiles**. With their **dry, scaly skin**, more **developed lungs** and **double loop circulation** (where the path of blood has a dedicated circuit that runs from the heart to the lungs and back) they are better able to avoid dehydration in a terrestrial landscape. However, perhaps the most significant adaptation first observed in this group is the introduction of a watertight egg known as the **amniotic egg**.

These amniotic eggs are a trait which reptiles passed on to their bird and mammal descendants. Of course, each of these groups has their own adaptations as well. For example, **birds** have a **porous skeleton** that is well adapted to flight, forelimbs that are covered in **feathers** creating **wings** for capturing and moving air during flight. They do still have **scaly skin**, like their reptile ancestors, on

their legs and feet. While it is the presence of hair and mammary glands that are distinctive characteristics of **mammals**. The **hair** of mammals plays a variety of roles including temperature regulation, collecting sensory information and allowing for things like camouflage. The structure for which mammals are named, **mammary glands**, provide nourishment for their developing young which reflects a general trend in these animals of providing high degrees of parental care to their offspring.

During this lab, you will examine specimens that represent several of these vertebrate groups.

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10.2: Procedure

Each pair of students will be assigned to one of the following vertebrates to dissect: perch, frog, snake or rat. As each group will be assigned a different specimen to dissect, you will follow the specific dissection instructions according to those assignments. Once the dissections are complete, all students will have the opportunity to view the other groups' specimens so that they may complete their sketches and observations of all 4 organisms for this lab report.

Part I: Fishes

Dissect Preserved Perch Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a perch from the specimens provided. Also obtain a complete mussel dissection guide which includes images that you can reference to help you with your dissection.
2. Place the perch in dissecting tray on a paper towel and blot excess preservative. Measure total length and note the external features including the scales, fins and operculum. Create a sketch of the exterior of the animal and record this information in the space provided.
3. Place the perch in your dissecting tray with the right side up and examine using a magnifying glass. You should be able to make out the lateral line system (as faint lines running down each side of the animal).
4. Locate the operculum which is just posterior to the mouth. Gently lift the operculum using forceps to reveal the gills beneath. Note the feather-like appearance of the gill structures to appreciate the amount of surface area available for gas exchange.
5. Use dissecting pins to secure the fins and tail gently. Starting just behind the pectoral fin, make a shallow cut through the body wall along the ventral surface (belly).
6. Extend the incision posteriorly toward the anus. Then make a second incision upward behind the operculum, forming a flap. Carefully lift and pin the flap back to expose the internal cavity. Note the position of major organs such as the heart, liver, stomach, and intestines. Just inferior to the vertebral column, you will the swim bladder. Be careful not to puncture the membrane of the swim bladder as it will deflate. Create a sketch of the internal structures of the animal and record this information in the space provided.

Note

If you happen to be dissecting a gravid female, you may find that the ovaries, containing thousands of eggs, occupy a large portion of the abdominal cavity. If this is the case, carefully remove the ovaries to better see remaining structures.

Observe the Dissected Perch

Carefully observe the dissected perch, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 10.1.

1. *Operculum*: hard, plate-like structure covering the gills.
2. *Gills*: feather-like structures used for gas exchange; located just posterior to the mouth.
3. *Scales*: thin, overlapping plates that cover the body surface.
4. *Fins*: appendages, often paired and used for movement.
 - Dorsal fins are the two that run along the back.
 - The tail fin, also known as the caudal fin.
 - The anal fin which is ventrally located and posterior to the anus.
 - The paired pelvic fins are also ventrally located on the side near the head
5. Just behind the gills are a pair of pectoral fins
6. *Lateral line system*: canals that run along the length of the body; appear as faint lines.
7. *Swim bladder*: shiny, air-filled sac with thin membrane found in the dorsal regio just inferior to the vertebral column.

Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part II: Amphibians

Dissect Preserved Frog Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a frog from the specimens provided. Also obtain a complete earthworm dissection guide which includes images that you can reference to help you with your dissection.
2. Place the frog in a dissecting tray on a paper towel and blot excess preservative. Place the frog on its dorsal side (back) in the dissecting tray so that the ventral side (belly) faces up.
3. Measure total length and note the external features including the smooth skin, distinct head region and legs. Create a sketch of the exterior of the animal and record this information in the space provided.
4. Use dissecting pins to secure the legs and arms to the tray at an angle, spreading them slightly.
5. Using small scissors, make a shallow incision through the skin of the abdomen starting just above the cloaca and extending up to the lower jaw. Next, make two lateral cuts near the forelimbs to create a skin flap. Use forceps to gently lift and pin back the skin to expose the muscles underneath.
- 6.
7. Make a similar incision through the muscular wall of the abdomen being careful not to damage the underlying organs. Extend the cut upward and outward near each forelimb to create flaps. Pin back the muscle layers to fully open the body cavity. Note the position of major organs such as the heart, liver, stomach, and intestines. Create a sketch of the internal structures of the animal and record this information in the space provided.

Observe the Dissected Frog Specimen

Carefully observe the dissected frog, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 10.2.

1. *External nares (nostrils)*: small openings above the mouth, used for breathing air.
2. *Tympanic membranes*: circular patches of skin behind the eyes, used for hearing.
3. *Forelimbs and hind limbs*: adapted for more effective movement such as swimming and jumping.
4. *Webbed toes*: provides for effective movement in water.
5. *Cloacal opening*: the single posterior opening for the digestive, reproductive, and excretory systems.
6. *Heart*: small, triangular organ located in the center of the thoracic/chest region.
7. *Lungs*: spongy sacs located on either side of the heart.
8. *Digestive tract*: extends from the mouth to the anus and includes an esophagus, stomach and intestines.
9. *Kidneys*: flat, dark bean-shaped organs located along the dorsal wall.
10. *Urinary bladder*: thin-walled sac located in the pelvic cavity.
11. *Reproductive organs*: in females, yellowish lobed ovaries and oviducts; in males, paired testes near the kidneys.

Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed).
2. Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp! Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part III: Reptiles

Dissect Preserved Snake Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a snake from the specimens provided. Also obtain a complete crayfish dissection guide which includes images that you can reference to help you with your dissection.
2. Place the snake in a dissecting tray on a paper towel and blot excess preservative. Place the animal dorsal side down (belly up) in the dissecting tray. Measure total length and note the external features including the scales, elongated body, as well as the head and tail region. Create a sketch of the exterior of the animal and record this information in the space provided.
3. Secure the specimen with dissecting pins along the body at several points (head, midbody, and tail) to keep it stable. Starting just beneath the head, make a shallow incision through the ventral body wall along the midline using scissors or a scalpel. Carefully continue this cut posteriorly toward the cloaca, stopping before the tail. Avoid cutting too deeply as this can damage underlying organs.
4. Use forceps to gently lift the body wall and pin it open on both sides to reveal the coelomic cavity. Note the position of major organs such as the heart, liver, stomach, and intestines. These can be difficult to distinguish as the organs are elongated to fit the snake's narrow body shape. Create a sketch of the internal structures of the animal and record this information in the space provided.

Observe Preserved Snake Specimen

Carefully observe the dissected snake, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 10.3.

1. *External nares (nostrils)*: small openings above the mouth, used for breathing air.
2. *Scales*: large, rectangular scales running along the body that provide a protective outer layer (those on the belly also aid in locomotion).
3. *Cloacal opening*: the single posterior opening for the digestive, reproductive, and excretory systems.
4. *Tail*: region posterior to the cloaca.
5. *Mouth*: opening in head region which contains a forked tongue used for sensing chemicals as well as a Jacobson's organ (vomeronasal organ) located inside the roof of the mouth and used for detecting scent particles.
6. *Heart*: small, triangular organ located just posterior to the head.
7. *Lungs*: most snakes have one functional right lung (long and tubular) and a reduced or absent left lung.
8. *Digestive tract*: extends from the mouth to the anus and includes an esophagus, stomach and intestines.
9. *Kidneys*: long, dark organs located toward the posterior end of the body cavity.
10. *Reproductive organs*: paired reproductive organs located anterior to the kidneys (testes in males, ovaries in females).

 Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

Part IV: Mammals

Dissect Preserved Rat Specimen

Follow the instructions outlined below to carefully complete the dissection of your specimen:

1. Wear gloves and eye protection. Obtain a dissecting tray, dissecting kit, dissecting pins, and a rat from the specimens provided. Also obtain a complete sea star dissection guide which includes images that you can reference to help you with your dissection.
2. Place the rat in dissecting tray on a paper towel and blot excess preservative. Place the animal dorsal side down (belly up) in the dissecting tray. Measure total length and note the external features including the head, trunk, tail and the fur that covers most of the body. Create a sketch of the exterior of the animal and record this information in the space provided.
3. Secure the specimen with dissecting pins along the body at several points (head, arms, legs, and tail) to keep it stable. Using scissors, make a midline incision through the skin beginning just below the jaw and extending to the anus. Make two lateral cuts near the hind limbs to create flaps of skin. Use forceps to gently separate the skin from the underlying muscles. Pin back the skin flaps to fully expose the muscular body wall.
4. Make a second incision through the muscle layer following the same pattern. Be sure to cut shallowly to avoid damaging underlying organs. Carefully pin back the muscle flaps to reveal the coelomic cavity and internal organs. Note the position of major organs such as the heart, liver, stomach, and intestines. Create a sketch of the internal structures of the animal and record this information in the space provided.

Observe Preserved Rat Specimen

Carefully observe the dissected rat, being sure to note and label the characteristics below. Record your sketches and observations in Data Table 10.4.

1. *External nares (nostrils)*: small openings above the mouth, used for breathing air.
2. *Fur*: hair covering the surface of the animal, note the color and texture.
3. *Ears (pinnae)*: external flaps for hearing.
4. *Tail*: long extension that is located posterior to the anus, covered in scaly skin.
5. *Mouth*: includes upper and lower *incisors* (specialized teeth) used for gnawing and surrounded by *vibrissae* (whiskers) which are sensory hairs used for detecting objects.
6. *Mammary glands*: visible on the ventral surface (particularly in females); arranged in 6 pairs along the ventral body wall from the chest area to the groin.
7. *Digestive tract*: extends from the mouth to the anus and includes an esophagus, stomach and intestines.
8. *Anus*: external opening of the digestive tract. Located anterior to the tail.
9. *Urogenital opening*: near the base of the tail; note the differences between male and female specimens.
10. *Heart*: small, triangular organ located in the center of the thoracic/chest region.
11. *Lungs*: spongy sacs located on either side of the heart.
12. *Kidneys*: flat, dark bean-shaped organs located along the dorsal wall.
13. *Urinary bladder*: thin-walled sac located in the pelvic cavity.
14. *Reproductive organs*: testes within the scrotal sac (males); ovaries, oviducts, and uterus (females).

 Clean-Up

Use the following instructions to clean up the dissected specimen, only after other groups have had a chance to observe the specimen:

1. Carefully unpin and remove specimen pieces. Dispose of biological waste per instructions (biohazard bag or classroom trash as directed). Rinse and disinfect dissecting instruments making sure they are dry prior to returning to the dissecting kit. Use caution as these tools can be sharp!
2. Also rinse your dissecting tray, leaving it to air dry next to the sink. Next, clean the lab bench of your workspace. Wash hands thoroughly after removing gloves.

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10.3: Data

Part I: Fishes

o Label scales, operculum, gills, fins, lateral line system, swim bladder

Data Table 10.1: Preserved Perch Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part II: Amphibians

o Label nostrils, tympanic membranes, forelimbs and hind limbs, heart, lungs, digestive tract, kidneys and reproductive structures

Data Table 10.2: Preserved Frog Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part III: Reptiles

o Label nostrils, scales, tail, lungs, digestive tract, kidneys and reproductive structures

Data Table 10.3: Preserved Snake Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

Part IV: Mammals

o Label nostrils, fur, ears, tail, mammary glands, heart, lungs, digestive tract, kidneys and reproductive structures

Data Table 10.4: Preserved Rat Specimen

Sketch (Exterior Features)	Sketch (Internal Structures)	Observations/Descriptions

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10.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the characteristics and evolutionary significance of the animals observed during this lab. Be sure to address each of the following in your discussion:

1. **Examine the body plan of fishes.** What are the main structural adaptations of the perch that allow it to live successfully in an aquatic environment?
2. **Examine the body plan of amphibians.** Frogs have both lungs and moist skin for respiration. How does this dual respiratory system benefit them?
3. **Examine the body plan of reptiles.** Snakes show many adaptations for terrestrial life despite lacking limbs. What body structures help them move and hunt effectively?
4. **Evaluate the evolutionary relationships between these different animals.** Compare the body symmetry, skeletal support, and mode of locomotion among the four vertebrates dissected (perch, frog, snake, and rat). How do these features reflect their adaptations to aquatic or terrestrial habitats? Discuss how the transition from aquatic to terrestrial life is reflected in the anatomy of the frog, snake, and rat. Which features provide evidence of this evolutionary progression?

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CHAPTER OVERVIEW

11: Plant Form Lab

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11.1: Introduction

Learning Objectives

- Recognize the characteristics and adaptations plants have made for life on land.
- Identify some of the key features of a vascular plant.

Plants have developed a wide variety of adaptations that enable them to thrive in terrestrial habitats. One key adaptation is the **waxy cuticle**, a protective outer layer that prevents water loss. However, because this watertight barrier is also impermeable to gases, plants evolved **stomata** which are small pores that can open and close to allow for gas exchange while still maintaining the integrity of the cuticle. Another major evolutionary hurdle for terrestrial life was **reproduction outside of water**. Many land plants overcame this challenge by enclosing sperm within **pollen grains** and protecting developing offspring inside **seeds**. The vast majority of land plants alive today are considered seed plants, a testament to the role that seeds play in allowing the plant embryo to remain dormant until environmental conditions are favorable for growth.

To support photosynthesis and nutrient transport, most plants also evolved **vascular tissue**, which enables the movement of water, minerals, and sugars throughout the organism and provides the structural support necessary for plants to grow tall. This structural support allows for the development of extensive **shoot systems**, which serve as scaffolding for photosynthetic structures such as leaves and **root systems**, which play critical roles in anchoring the plant and providing a means for nutrient absorption. Closer examination of these shoot and root systems can be helpful in distinguishing various types of plants. For example, inspection of a plant's shoot system will reveal different **leaf venation patterns** and **phyllotaxy (leaf arrangement)**. Leaves with veins that run parallel throughout the blade are said to have **parallel venation**, while those forming a branching network exhibit **reticulate venation**. Leaf arrangement can include **opposite patterns** where the leaves grow in pairs on either side of the stem at the same node or **alternate patterns** in which the leaves grow singly at each node, alternating sides along the stem. With **whorled patterns** leaves grow in a circular pattern from a single node. Some additional morphological features used in plant identification can be observed in the root system. For example, plants with **taproot systems** feature a single large root with smaller lateral branches, whereas **fibrous root systems** consist of many roots of similar size forming a dense network.

At the heart of plant growth are regions of undifferentiated cells called **apical meristems**, from which all plant tissues originate. The root apical meristem and shoot apical meristem together produce the plant's **primary body**. These primary plant tissues arise from the upward and downward growth of the plant. The **root apical meristem** includes four main regions: the **root cap**, which protects the growing tip and secretes mucigel to ease movement through the soil; the **zone of cell division**, where mitosis actively occurs; the **zone of elongation**, where cells increase in size; and the **zone of maturation**, where cells differentiate into specialized types. The **shoot apical meristem** is organized into distinct functional regions. The **central zone** contains slowly dividing stem cells that preserve the meristem's structure, while the **peripheral zone** contains rapidly dividing cells that contribute to the formation of leaves and stem tissues. Beneath these, the **rib meristem** generates cells that develop into the internal tissues of the stem. Together, these regions coordinate cell division and differentiation, enabling upward growth and the formation of new shoots, leaves, and flowers.

In this lab, you will explore a variety of plant specimens. Through direct observation and microscopy, you'll identify the structures that enable plants to grow, adapt, and survive in terrestrial environments and will gain a better understanding of plant form and function.

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11.2: Procedure

Part I: Plant Adaptations

Observations of the Epidermis and Cuticle

1. Obtain a leaf from the *Kalanchoe* (flaming Katy) plant (or similar succulent).
2. Gently and slowly tear the leaf back in a diagonal direction to separate the epidermis from the rest of the leaf. Your instructor will provide a demonstration of how to do this.
3. Use a pair of forceps to transfer a piece of the epidermis to a microscope slide. Add a drop of water to the specimen and cover with a coverslip.
4. View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to label the cells of the epidermis, the cuticle, as well as the stomata and the guard cells.

Note

Look for a thin, transparent, waxy layer over the epidermal cells; this is the cuticle. You will also be able to see small pores in the epidermis; these are the stomata. Note the two elongated cells flanking either side of the stomata; these are the guard cells.

Observing Differences in Stomatal Density

1. Obtain a leaf sample from the *Tradescantia* Wandering Jew plant.
2. Place the leaf between your finger and thumb, with the top side of the leaf facing up. Gently, and slowly, tear the leaf back in a diagonal direction with your other hand to separate the upper epidermis from the rest of the leaf (this is known as the epidermal peel technique). Your instructor will provide a demonstration of how to do this.
3. Use a pair of forceps to transfer a piece of the lower epidermis to a microscope slide. Add a drop of water to the specimen and cover with a coverslip.
4. View the slide with the 40x objective lens. Count the number of stomata in your field of view (FOV). Record this information in data table 11.1.
5. Repeat these observations for a total of 3 random, non-overlapping fields. Record this information in data table 11.1.
6. Calculate the mean of the 3 counts. Record this as the mean stomatal density of the upper epidermis in data table 11.1.
7. Repeats steps 1-6 with a piece of the lower epidermis. To obtain a sample of the lower epidermis, be sure to hold the leaf with bottom side facing up while performing the epidermal peel. Record this as the mean stomatal density of the lower epidermis in data table 11.1.
8. Obtain a graticule slide with a marked set of gridlines. You will use this to determine the actual size of your FOV.
9. View the slide with the 40x objective lens. Count the number of grid marks that it takes to go from one side of the FOV to the other. Record this information in the space provided as the field of view diameter (FOV_{diameter}). Note that each grid mark is equivalent to 0.01 mm.
10. Calculate the area of the FOV using the following equation:

Equation

$$Area = \pi \times (FOV_{\text{diameter}}/2)^2$$

Note that this is simply the equation for calculating the area of a circle using the measurement of the radius (r), which is exactly half of the diameter (i.e. $Area = \pi r^2$).

11. Record this information as the area of the field of view in data table 11.1.
12. Next, calculate the mean stomatal density for both the upper and lower epidermis by dividing the number of stomata by the area of the FOV. Record this information as the mean stomatal density in data table 11.1.

Part II: Vascular Plant Structure

Leaf Venation Patterns

1. Obtain a blade of grass and observe the pattern of veins present using the dissecting microscope. Provide a sketch and a description of your observations in the data table provided. Be sure to include the overall structure and shape of the leaf as well as the pattern of veins present.
2. Obtain a maple leaf and directly observe the pattern of veins present. Provide a sketch and description of your observations in the data table provided. Be sure to include the overall structure and shape of the leaf as well as the pattern of veins present.

Phyllotaxy

1. Obtain 3 stem samples representing each of the three forms of phyllotaxy: opposite (such as basil, maple, dogwood or viburnum), alternate (such as mustard, sunflower, oak or poplar) and whorled (such as whorled milkweed, Joe-Pye weed, burning bush or oleander). Provide a sketch and description of your observations for each specimen in data table 11.2. Be sure to include the arrangements of the leaves observed.
 2. You will also be taking measurements of the internode length (distance between nodes) for each of these specimens. To do this, you will measure the distance between one node and the next. Measure internode length (mm) for three successive internodes per stem and calculate mean internode length. Record this as the mean internodal distance in data table 11.2.
-

Part III: Plant Meristems

Root Apical Meristem

1. Obtain a prepared slide of *Allium*/onion root tip (root apical meristem). View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to label the root cap, zone of cell division, zone of maturation and zone of elongation.

Shoot Apical Meristem

2. Obtain a prepared slide of the *Coleus* stem tip (shoot apical meristem). View the slide first at low power (with the 10x objective lens) before increasing the magnification to high power (with the 40x objective lens). Provide a sketch and description of your observations in the space provided. Be sure to label the central zone, peripheral zone and rib meristem.
-

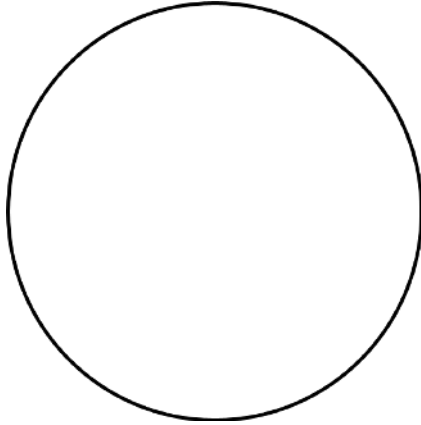
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11.3: Data

Part I: Plant Adaptations

Epidermis and Cuticle

(a) Sketch (label the epidermis, cuticle, stomata and guard cells)



(b) Total Magnification: _____

(c) Observations:

Stomatal Density

Data Table 11.1

Layer of Epidermis	Number of Stomata			Area of Microscope Field of View/FOV (mm^2)	Stomatal Density (# of stomata/ mm^2)
-----	Region 1	Region 2	Region 3		-----
Upper Epidermis				N/A	
Lower Epidermis				N/A	

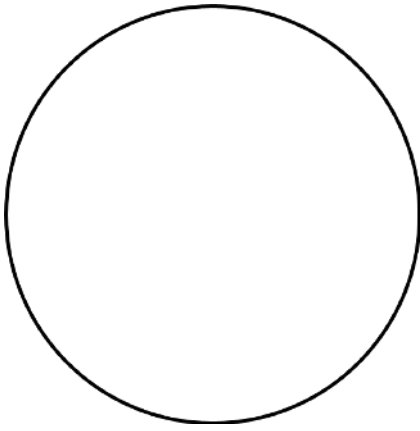
? Exercise

FOV_{diameter}: _____

Part II: Vascular Plant Structure

Blade of Grass

(a) Sketch

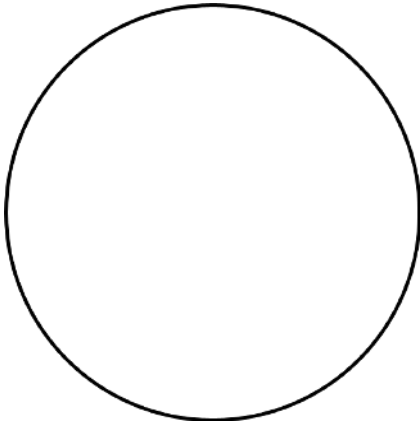


(b) Total Magnification: _____

(c) Observations:

Maple Leaf

(a) Sketch



(b) Observations:

Phyllotaxy

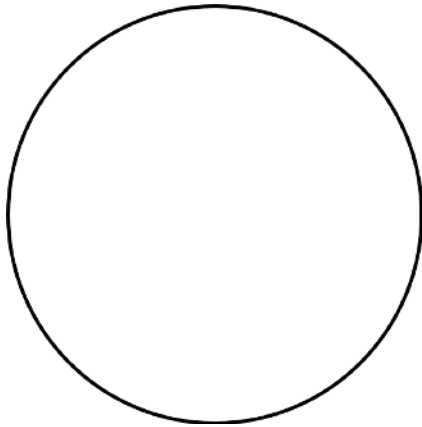
Data Table 11.2

Specimen	Form of Phyllotaxy	Internodal Distance (cm)			Mean Internodal Distance (cm)
		Node 1	Node 2	Node 3	

Part III: Plant Meristems

Allium Root Tip

(a) Sketch (label the root cap, zone of cell division, zone of maturation and zone of elongation)

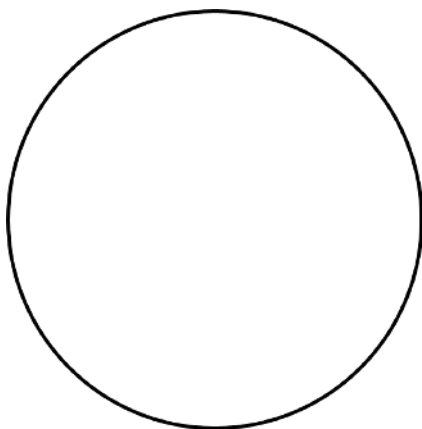


(b) Total Magnification: _____

(c) Observations:

Coleus Shoot Tip

(a) Sketch (label the central zone, peripheral zone and rib meristem)



(b) Total Magnification: _____

(c) Observations:

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11.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your plant observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores the adaptations and diversity of vascular seed plants. Provide specific examples from the activity to support your conclusions. Be sure to address each of the following in your discussion:

1. **Evaluate plant adaptations.** Compare the number of stomata between the upper and lower epidermis. Which surface had the higher stomatal density, and why might this difference exist? How might stomatal density differ between plants living in arid (dry) environments and those living in humid environments? Explain your reasoning.
2. **Examine vascular plant structure.** How might venation patterns influence the mechanical strength or photosynthetic efficiency of a leaf? What did you notice about the relationship between phyllotaxy and internode length? How might variations in internode distance influence plant form and competition for light?
3. **Observe regions of plant growth.** Compare the structure and function of the shoot apical meristem and root apical meristem. How do their cellular organization and growth patterns reflect their different roles in plant development?

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CHAPTER OVERVIEW

12: Homeostasis Lab

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12.1: Introduction

Learning Objectives

- Describe the process of negative feedback and explain its role in homeostasis.
- Compare and contrast the methods used by ectotherms and endotherms for maintaining body temperature.

Homeostasis is the process by which living organisms maintain stable internal conditions despite changes in their external environment. This stability is essential for proper cellular function and overall survival. To achieve homeostasis, the body relies on **sensory receptors** that detect changes, or *stimuli*, in the internal or external environment, such as fluctuations in temperature, blood pressure, or pH. These receptors send information to a **control center** (often the brain or a specific gland), which processes the data and determines the necessary action to restore balance. The control center then sends signals to **effectors**, such as muscles or glands, which carry out the appropriate response to counteract the disturbance. Most homeostatic regulation occurs through **negative feedback loops**, in which the response reverses or reduces the original change, bringing the system back toward its normal set point. Once the organism returns to the set point, the response that was initiated will be shut down (hence the term negative feedback).

The ability to maintain homeostasis is no small feat considering some of the significant environmental challenges that organisms can face that would threaten such a steady state. Consider, for example, that the average body temperature of a polar bear is 37°C (like humans) and that their surroundings can drop well into the -30°s. There are several physical and behavioral adaptations that allow for this including having insulating layers of blubber and fur, having a high metabolic rate, and exhibiting behavioral changes such as seeking shelter or basking in the sun. Also consider that the body temperature of polar bears will be close to the same regardless of whether they are sunbathing on the ice or actively chasing down their prey. To maintain such a stable body temperature in the face of such different physiological needs, there are several mechanisms at play.

Like humans, polar bears are **endotherms** and, as such, the mechanisms used for regulating body temperature (also known as **thermoregulation**) relies on internal processes. In humans, this includes changes to the individuals blood vessels, muscular activity and metabolic rate. For example, when faced with cold temperatures, superficial blood vessels undergo **vasoconstriction** (narrowing of the blood vessels) to divert heat away from extremities and towards the core where visceral organs are located. Another reaction to the cold is to increase metabolism to generate heat from metabolic processes (this is known as **thermogenesis**). The involuntary muscular contractions that we know as **shivering** can also generate body heat to help keep someone warm when faced with a cold environment. In contrast, when our bodies need to release heat to avoid becoming too hot, they can use sweat to carry away the hottest water molecules in our bodily fluids so that it can cool our body surface (this process is also known as **evaporative cooling**). In the opposite effect of vasoconstriction, blood vessels near the surface of our skin can expand, known as **vasodilation**, to bring heat to the surface of our skin to be released as well.

In this lab, we will evaluate some of these physiological responses that our body has to changes in temperature.

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12.2: Procedure

1. Identify one member of your group to serve as the subject for this experiment. Obtain a baseline measurement of heart rate as the subject is sitting quietly. Measure heart rate by placing your index and middle fingers on your wrist or the side of your neck and count the beats for 15 seconds, then multiply by four to get your beats per minute. Record this as the resting heart rate in table 12. 1.
 2. Obtain a baseline measurement of skin temperature. Measure skin temperature at the back of your subject's hand using the infrared thermometer; alternatively, you can use a probe thermometer held between the thumb and forefinger. Record this as the initial temperature in table 12. 1.
 3. Apply a cold stimulus to your subject by having them place their hands in a container of cold water for a total of 1 minute.
 4. Immediately after removing your hand from the container, take a skin temperature, core temperature, and heart rate reading. Record this as the post-stimulus skin temperature in data table 12. 1. Also record the subjective sensations and physical observations you experienced from the exposure to this stimulus.
 5. Repeat the measurements of skin temperature, core temperature, and heart rate every 2 minutes, for a total of 8 minutes. Record this information in data table 12.1.
 6. Apply a heat stimulus to your subject by having them place their hands in a container of warm water (~40°C) for a total of 1 minute.
 7. Immediately after removing your hand from the container, take a skin temperature, core temperature, and heart rate reading. Record this as the post-stimulus skin temperature in data table 12. 2. Also record the subjective sensations and physical observations you experienced from the exposure to this stimulus.
 8. Repeat the measurements of skin temperature, core temperature and heart rate every 2 minutes, for a total of 8 minutes. Record this information in data table 12.2.
 9. Plot the data for time vs skin temperature *and* time vs core temperature in Figure 1. This means that you will have 2 separate lines on this same graph.
 10. Plot the data for time vs heart rate in Figure 2.
-

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12.3: Data

Data Table 12.1

Time	Skin Temperature (°C)	Core Temperature (°C)	Heart Rate (bpm)
0 min (Baseline)			
2 min			
4 min			
6 min			
8 min			

Description of observations and sensations after cold stimulation:

Data Table 12.2

Time	Skin Temperature (°C)	Core Temperature (°C)	Heart Rate (bpm)
0 min (Baseline)			
2 min			
4 min			
6 min			
8 min			

Description of observations and sensations after heat stimulation:

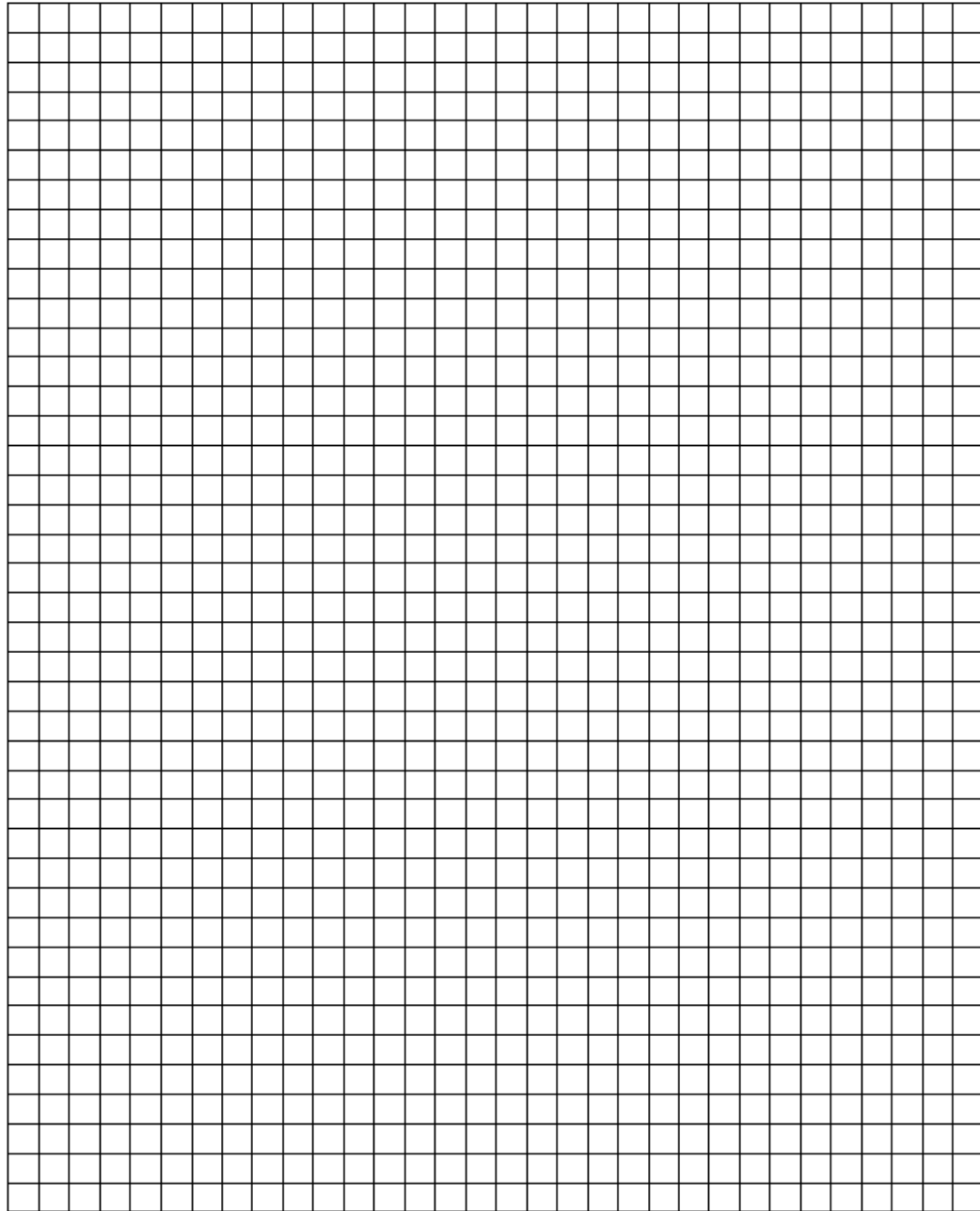


Figure 1: Time (min) vs Skin Temperature and Core Body Temperature

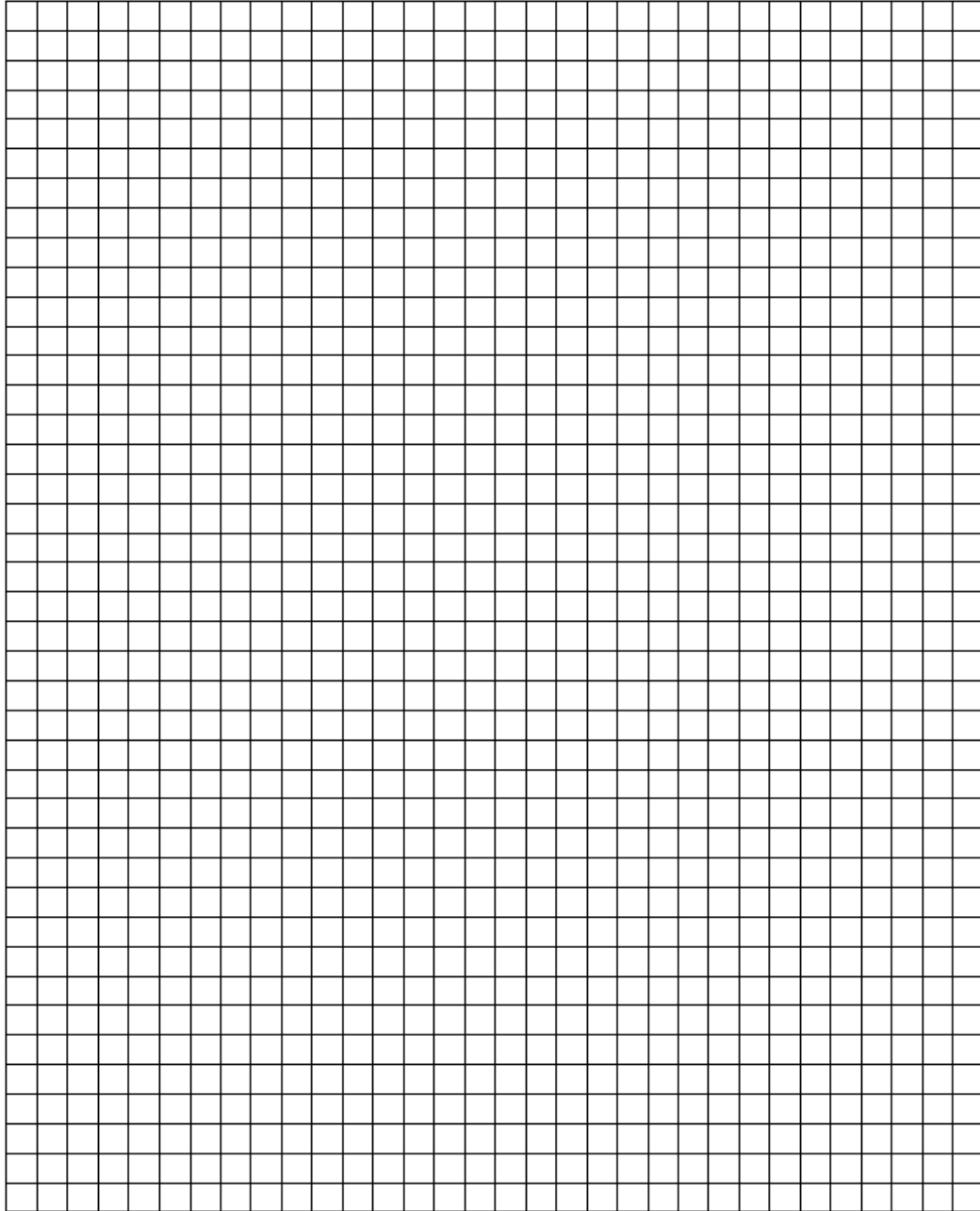


Figure 2: Time (min) vs Heart Rate

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12.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores how the concepts of homeostasis and feedback mechanisms were illustrated in this lab. Be sure to address each of the following in your discussion:

1. **Evaluate the data and analyze the trends observed.** Compare how skin temperature, core temperature, and heart rate changed over time following both cold and warm water exposure. What overall trends do you notice, and how do these trends illustrate the body's attempt to maintain homeostasis through negative feedback mechanisms?
2. **Explain the physiological mechanisms at play.** Describe the specific physiological responses (e.g., vasoconstriction, vasodilation, shivering, sweating) that occurred during each temperature treatment. How did these responses help stabilize internal body conditions?
3. **Reflect on the experiment.** Why did skin temperature change more rapidly than core temperature in your data? What does this tell you about how the body prioritizes different regions during thermal stress? Would repeated exposure to the same stimulus change the response? Why or why not?

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CHAPTER OVERVIEW

13: Population and Community Ecology Lab

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[13.4: Data Analysis and Discussion](#)

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13.1: Introduction

Learning Objectives

- Observe how different populations interact with one another.
- Identify predator-prey relationships and competition amongst different species

Organisms interact with physical elements (abiotic factors) and other organisms (biotic factors) as they go about their lives. These factors make up an ecosystem, the organizational level that encompasses all living and nonliving things in a particular area. Depending on where the organism lives, changes in the environment vary in intensity. Species adapt to the characteristics of their habitat. Some adaptations result in the formation of relationships with other organisms. Organisms are not limited to one type of relationship or interaction with other populations. Organisms also form partnerships within their own species to aid in individual and population survival in an area.

Within a population, individuals of the same species may compete for habitat, food, and mates. Usually, these resources are limited and only some individuals will be successful enough to get them. The struggle to obtain a limited resource, undertaken by members of the same species, is called **intraspecific competition**. Sometimes organisms of different species share the same space or search for the same food. This is termed **interspecific competition**. In this case, less successful organisms might die or be forced to use different resources. Another type of interspecific interaction is known as **predation**. In a *predator-prey* relationship, one species (**predator**) feed on another species (**prey**).

When organisms live in close proximity to one another they often form what are referred to as **symbiotic relationships**. Symbiosis can come in one of three forms: **mutualism** occurs as both partners benefit from the relationship, **commensalism** occurs as one partner benefits while the other is unaffected, and finally **parasitism** which results in one partner profiting while the other is harmed. The costs and benefits may change as organisms evolve. In some cases, individuals possessing the physiology or behavior best suited to the symbiotic relationship will live longer and be more likely to pass on their genes. The nature of symbiotic relationships are fine-tuned by natural selection.

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13.2: Procedure

Background Information

1. Navigate to the [Virtual Biology Lab: An Inquiry-Based Learning Environment Barnacle Competition Study Simulation](#) page.
2. From the home page click on the “Background Information” link. Read through all 3 pages of the background and answer questions #1-4 of your lab report prior to proceeding with the simulation.

Note

You will see navigation arrows at the bottom of each “page”. Use these to navigate forward and backwards within the simulation.

3. Return to the home page.

Note

You will see a house icon on the upper right-hand corner of the screen. You can use this to navigate back to the home page.

4. After returning to the home page, click on the “Tutorial” link to get an overview of how the simulation works. There is a total of 8 pages of instructions in the tutorial, be sure to read through them all carefully before moving on.

Note

Advance through the different pages of the tutorial by clicking the “Next” button in the middle of the screen.

5. Return to the home page using the house icon on the upper right-hand corner of the screen.

Part I: Experiment with Preset Values

6. Click on the “Run Experiments” link. Locate the data table in the middle of the screen. Note the preset Values for each of the following should match what is shown below.

Preset Data Values for the Experiment

Variable	Value
Sea Level (m)	0
Tide Change (m)	3
<i>Balanus</i> (Larvae/mL)	2.5
<i>Chthamalus</i> (Larvae/mL)	2.5
<i>Thais</i> Density	3

7. Next, click the “To Data” arrow in the center of the screen to begin the simulation.
8. After 10 days of observation, pause the simulation and record these values in [the first table in the Data section](#).

Part II: Experiment with Increased Sea Level and Balanus Larvae Values

9. Once you have recorded your data, click the “To Design” link in the center of the page to go back and re-set the values for the next experiment. Using the up and down arrows on the controls, raise the Sea Level to 1 m to simulate sea level rise due to climate change. Also, increase the *Balanus* larvae to 3.5. Note the Values for each of the variables should now match what is shown below.

Adjusted Data Values with Sea Level Rise and Adjusted Balanus Population

Variable	Value
Sea Level (m)	1
Tide Change (m)	3
<i>Balanus</i> (Larvae/mL)	3.5
<i>Chthamalus</i> (Larvae/mL)	2.5
<i>Thais</i> Density	3

10. Next, click the “To Data” arrow in the center of the screen to begin the simulation.

11. After 10 days of observation, pause the simulation and record these values in data table 13.2.

Part III: Experiment with Your Desired Values

12. For the final part of the experiment, use the controls to manipulate the variables and set them to a value of your choice. Record these values in data table 13.3.

13. As with parts 1 and 2 of the lab, once you have set the values, click the “To Data” arrow in the center of the screen to begin the simulation.

14. After 10 days of observation, pause the simulation and record these values in data table 13.4.

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13.3: Data

Part I: Experiment with Preset Values

Data Table 13.3.1

Measurement	<i>Balanus</i>	<i>Chthalmus a</i>
Local Abundance		
Mean Elevation on Rock		
Std. Deviation Elevation		

Part II: Experiment with Increased Sea Level and Balanus Larvae Values

Data Table 13.3.2

Measurement	<i>Balanus</i>	<i>Chthalmus</i>
Local Abundance		
Mean Elevation on Rock		
Std. Deviation Elevation		

Part III: Experiment with Your Desired Values

Data Table 13.3.3

Variable	Value
Sea Level (m)	
Tide Change (m)	
<i>Balanus</i> (Larvae/mL)	
<i>Chthamalus</i> (Larvae/mL)	
<i>Thais</i> Density	

Data Table 13.3.4

Measurement	<i>Balanus</i>	<i>Chthalmus</i>
Local Abundance		
Mean Elevation on Rock		
Std. Deviation Elevation		

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13.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores how the concepts of ecological niche and species interactions, such as competition and predation, were illustrated in this lab. Be sure to address each of the following in your discussion:

1. **Evaluate important background information for the simulation.** What causes Earth's tides? Write 4 facts you think might be important to know about barnacles to understand this simulation. Describe the relationship between the two species of barnacles and the snail species. Be sure to include the concepts of predation, competition, fundamental niche, realized niche.
2. **Examine interspecies competition and predation.** When larva levels are equal (2.5 for both species) to begin the experiment, what did you observe about the placement and population size of both species after 10 days? During this simulation, you should have noticed a pattern between populations of *Belanus* and *Chthamalus*. Describe this trend and give a possible ecological reason for this to occur. Compare and contrast your observations from the first simulation with the second one. Describe the results of your chosen simulation.

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CHAPTER OVERVIEW

14: Ecosystems and Biodiversity Lab

[14.1: Introduction](#)

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14.1: Introduction

Learning Objectives

- Observe how different populations interact with one another.
- Identify predator-prey relationships and competition amongst different species.
- Evaluate patterns of population growth; generate and compare J and S shaped population curves.
- Examine the relationship between logistic and exponential growth and carrying capacity.

Illinois was once home to an estimated 22 million acres of prairies, covering much of the northern part of the state. **Prairies** are a unique ecosystem consisting of a mixture of grasses and forbs. **Grasses** are easily recognized by their narrow leaves and soft stems and are the dominant plant in prairie habitats. Many prairie grasses are considered tallgrasses which can reach 2-3 meters in height. The state's official prairie grass is known as the big bluestem. **Forbs** also have soft stems but broad leaves and include many wildflowers such as blazing stars, goldenrods, asters and coneflowers. Many prairie plants have deep root systems which can extend 3.5 meters into the soil which anchors them against strong winds and allows them to access water deep underground. The root network formed by prairie plants is very important for the prevention of soil erosion. Prairie plants are also adapted to fires as they form underground buds that can regrow following a fire. Fire is an important part of these ecosystems as it helps to spread prairie plants and can open space for prairie plants to grow. Prairie plants have also evolved close relationships with many animals, providing food and habitat for a number of animals including several pollinators. One other key feature of prairie ecosystems is the lack of woody plants. Trees and shrubs are generally sparse because the combination of frequent fires, grazing pressure, and deep, nutrient-rich soils favors herbaceous plants instead. Fire regularly removes young woody seedlings before they can establish, while the dense root mats of prairie grasses make it difficult for shrubs and trees to compete for space, water, and nutrients. As a result, prairies remain open, sun-filled landscapes dominated by grasses and forbs rather than forests or shrublands.

Today, approximately only 1% of this unique prairie ecosystem in Illinois remains, largely due to the expansion of agriculture. Two other major ecological pressures on Illinois prairies are (1) woody encroachment (especially *Juniperus virginiana*, eastern red cedar), which alters fire regimes and light/water availability, and (2) shifting herbivore pressure (for example, high densities of white-tailed deer that browse vegetation, and changes in small-mammal communities such as meadow or prairie voles). White-tailed deer influence plant composition by selective browsing and can reduce forb abundance and alter succession dynamics when abundant. Meadow voles and other small prairie mammals affect seed predation/dispersal and soil structure. These ground-level herbivores/soil engineers are also prey for many predators and help sustain bird and carnivore populations. The impacts of these changing community dynamics has led to changes in plant species richness and structure. As a result, this has impacted community stability and ecosystem function.

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14.2: Procedure

Use the example data below to analyze how herbivore populations, woody encroachment, and small mammal activity could influence plant species richness and community stability in Illinois prairie remnants.

Part I: Prairie Population Ecology

Examine the following data tables to investigate population and community ecology in Illinois prairie grasslands. Use this data to plot the relative population densities of each species: white-tailed deer, prairie voles and big bluestem grass.

We will be using the same unit for measuring dimension for each of the different species being examined here (km^2) to provide accurate and consistent comparisons (note that the bluegrass is measured in kg rather than # of individuals). Due to the vast differences in relative population densities of these species, you will be using logarithmic graph paper for these populations' growth curves. When such vast differences in population density exist, the graph becomes skewed as those populations with high densities will dominate the scale, while those populations with relatively low densities will appear as very small values close to the x-axis. Applying a log transformation to the density axis (y-axis) you will compress the large values and expand the small values, allowing both high and low densities to be comparable on the same graph.

Table 14. 1 — Population Densities of White-Tailed Deer (Individuals/ km^2)

Year	Deer Population (Individuals/ km^2)
2000	12
2001	15
2002	18
2003	22
2004	28
2005	35
2006	41
2007	45
2008	48
2009	51
2010	54
2011	52
2012	47
2013	44
2014	46
2015	49
2016	50
2017	53
2018	55
2019	58
2020	60

Table 14. 2 — Population Densities of Meadow Voles (Individuals / km²)

Year	Vole Population
2000	500
2001	700
2002	1400
2003	2200
2004	1600
2005	900
2006	600
2007	1200
2008	2000
2009	2800
2010	2500
2011	1800
2012	1000
2013	800
2014	1400
2015	2600
2016	3300
2017	2100
2018	1700
2019	900
2020	600

Table 14.3 — Big Bluestem Biomass (kg / km²)

Year	Biomass
2000	210000
2001	215000
2002	220000
2003	240000
2004	260000
2005	280000
2006	300000
2007	310000
2008	315000
2009	290000
2010	270000
2011	250000
2012	200000
2013	230000
2014	250000
2015	275000
2016	295000
2017	310000
2018	325000
2019	340000
2020	350000

Part II: Community Ecology & Diversity

A survey of three 1-ha prairie plots with differing management histories (e.g. burning and woody removal) can help us to better understand the community dynamics at play in this ecosystem. The table below provides information on the prevalence of *Juniperus* encroachment and the varying presence of white-tailed deer, prairie voles and overall plant species richness as an outcome of different management strategies. Use the information provided to evaluate the impacts on community ecology and biodiversity.

Table 14. 4 — Species Richness and Habitat Variables

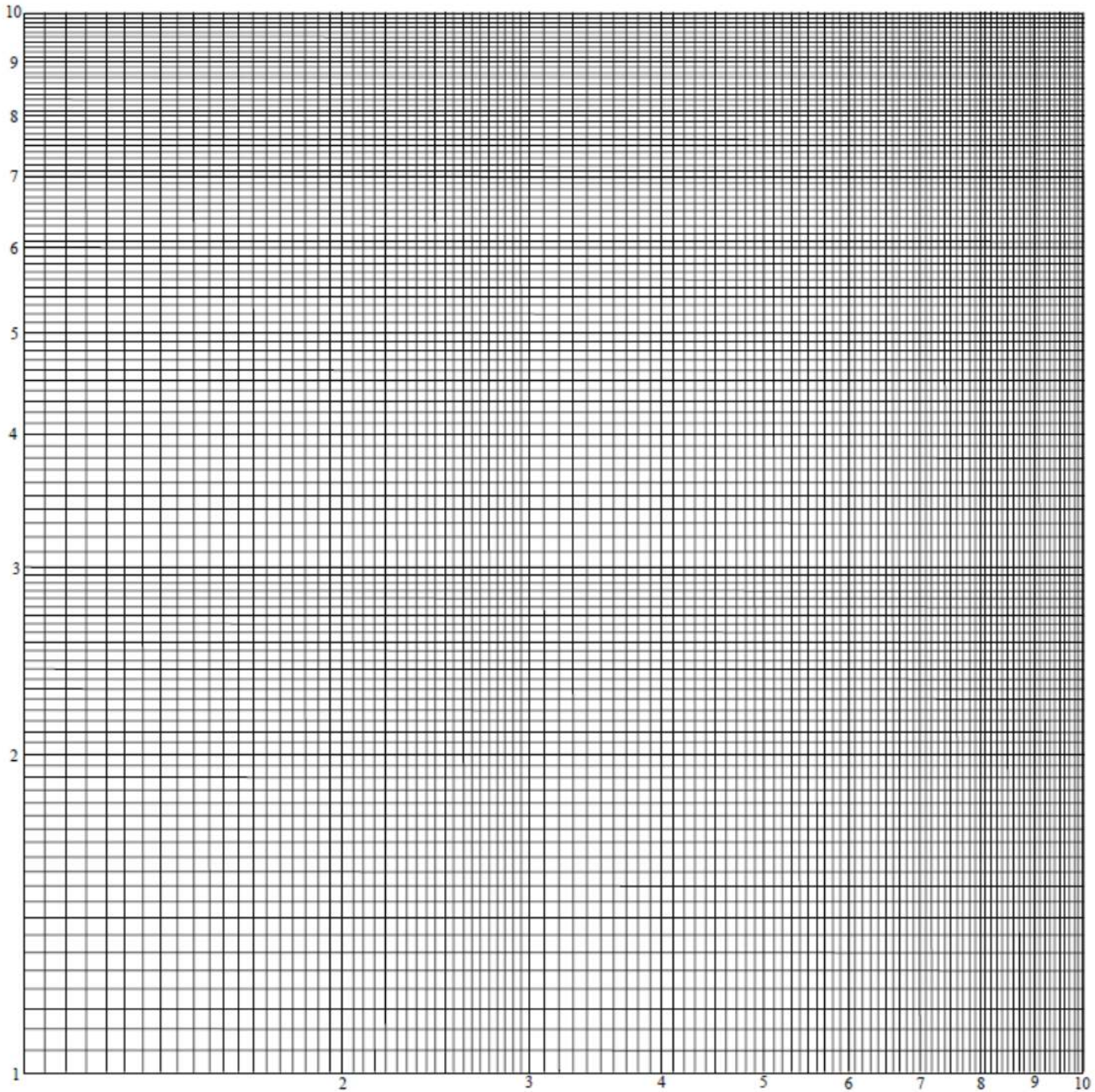
Plot	Deer Present	Voles Present	Shrub Density (<i>Juniperus</i> / m ²)	Plant Species Richness	Management Notes
A	Yes	Yes	0.6	34	Annual fire + woody removal
B	Yes	No	1.9	20	Fire every 4–5 years
C	No	No	3.0	12	No fire for 20+ years

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14.3: Data

Part I: Prairie Population Ecology

Plot the population densities of the white-tailed deer, prairie voles and big bluestem grasses using the grid below (Year on the x-axis, Population Density on the y-axis). Label each population curve according to the species it represents.



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14.4: Data Analysis and Discussion

Instructions

Discussion should be typed (double spaced, size 12 font and standard 1" margins). There are no specific length requirements for this discussion but be sure to address all the components in the prompt below. You will submit this discussion along with your sketches and observations for your completed lab report.

Prompt/Questions to Address

Write a discussion for this experiment which explores community dynamics of an ecosystem. Use ecological reasoning (population and community ecology, competition, disturbance, keystone roles) to answer the questions below:

1. **Describe the patterns you observe for deer, voles and big bluestem from 2000-2020.** What ecological interactions or landscape changes might explain these trends? (Hint: consider browsing pressure, habitat fragmentation, woody encroachment and predator dynamics). What kind of interspecific relationship best describes the indirect interaction between deer and prairie voles (e.g., competition, facilitation)? How could deer density affect plant species richness and small mammal habitat indirectly? Describe at least two ways the invasion of *Juniperus virginiana* (eastern red cedar) may alter energy flow, nutrient cycling, and trophic structure in an Illinois prairie.
2. **Evaluate the impacts of varying management strategies on prairie ecosystems.** Describe the trend in plant species richness across plots A → C. How is richness related to shrub density and animal presence? Which plot would you call the most stable in terms of long-term plant community and why? Consider resilience to invasion, maintenance of native forbs, and likelihood of trophic cascades.

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