

BIO 4A+4B LAB INSTRUCTOR RESOURCES MANUAL



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BIO instructors manual

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About the Book



An Open Educational Resource Initiative at Evergreen Valley College

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<add names, and what each worked on>

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CHAPTER OVERVIEW

1: Microscopy Part I

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1.1: Instructor Guidelines

Purpose

In this lab, students will be introduced to the lab safety guidelines, rules, and protocols created by the Biology Department at Evergreen Valley College. Students will also learn to name and identify the parts of a compound light microscope. Students will view prepared slides of *Amoeba* and *Paramecium*, and create labeled sketches of these organisms at various total magnifications in order to demonstrate their ability to focus a specimen using the compound light microscope.

Tasks

As the the first lab of the semester, course-related administrative tasks will also need to be completed. These include the following:

- Adding students to the lab in order of their waitlist position
- Reviewing the course syllabus, schedule, and requirements/expectations
- Reviewing the lab safety guidelines and important reference points in and out of the classroom (i.e., emergency phone, first aid kit, fire extinguishers and blankets, emergency exits, evacuation meeting areas, etc.)
- Biology kits (located in the top drawer next to each student; identify and check contents)
- Microscopes (located in the cabinets next to each student; review proper handling and storage)

These tasks should be completed prior to the introduction of the prepared slides/organisms and demonstration/explanation of proper microscope use.

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1.2: Formative/Summative Questions

Formative Questions

Parts of the Compound Light Microscope

Figure 1.2.1: Side and front view of Olympus CX43 microscope, from user manual.

I tried to leave a comment here and the pics of the microscope disappeared.

Instructions: Identify & label the following parts of your microscope onto the image above, and fill-in-the blanks below.

- Binocular head, Oculars: _____x
- Arm
- Revolving nosepiece
- Objective lenses: _____x, _____x, _____x, _____x
- Mechanical stage and X/Y knobs
- Stage/slide clips
- Condenser Turret _____, _____, _____, _____
- Iris diaphragm and how to adjust it
- Coarse adjustment knob & fine adjustment knob
- Light source; illuminator
- Base
- Dimmer; light intensity
- Power switch & power cord
- Total magnification calculation =

Specimens Viewed Under the Compound Light Microscope

View both *Paramecium* and *Amoeba* slides under the 4x, 10x, and 40x objectives, and **sketch and label** each organism in the space below.

Organism:

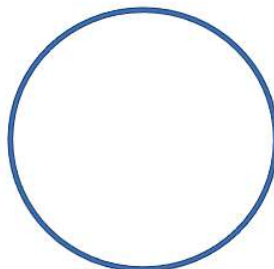
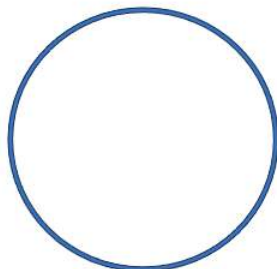
Objective:

Total magnification:

Organism:

Objective:

Total magnification:



Summative Questions

oper Use of the Compound Light Microscope

1. Describe the steps needed to focus a specimen on your slide at 100x total magnification.

Answer: Students should know to start with the 4x objective lens. Center specimen and use the coarse adjustment knob to focus before going to 10x objective lens.

2. A student has focused a specimen at 100x total magnification and plans to view the specimen at 400x total magnification next. Why is the coarse adjustment knob not necessary when focusing the slide at 400x total magnification?

Answer: Movements with the coarse adjustment knob are too "big." Smaller movements with the fine adjustment knob are needed to focus at 400x total magnification.

3. Describe the steps necessary to store your microscope away properly after use.

Answer:

1. Turn off power.
2. Remove slide.
3. Rotate 4x objective lens into place.
4. Lower and center stage.
5. Wipe lenses with lens paper.
6. Wrap cord.
7. Cover with dust cover.
8. Place in appropriate cabinet.

Lab Safety Guidelines

1. State the location of the classroom emergency phone, emergency exits, and fire extinguisher.

Answer: variable. Identify before class starts.

2. What are the proper safety protocols to complete at the beginning and end of each lab?

Answer: Variable. Protocols include washing hands before and after lab. Wipe down desk/counter surfaces before and after lab.

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1.3: Pull Sheets/Materials

Item	How Many	Location
Biol4A kits	28	Student drawers, top row
Paramecium slides	15+	Room S-123 box A, tray 10 and 12
Amoeba proteus slides	15+	Room S-123 box A, tray 7
Coverslips	1 box	(purchase, if needed)
Plain microscope slides	1 box	(purchase, if needed)
Kimwipes	1 box	(purchase, if needed)
Extra clear 6" rulers	6	(purchase, if needed)
Extra lens paper packets	10	(purchase, if needed)

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CHAPTER OVERVIEW

2: Measurement and Equipment

[2.1: Instructor Guidelines](#)

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2.1: Instructor Guidelines

Purpose

The purpose of this lab is to review the general chemistry concepts students will need for the majors biology series. Students will practice using pipettes, micropipettes, graduated cylinders, and volumetric flasks for measuring volumes. Students will also practice using a laboratory scale to measure mass, calculate and prepare solutions of differing concentrations, and compare and contrast accurate versus precise measurements. Students will also be introduced to the hand refractometer in order to determine the relationship between specific gravity and the concentration of a saline solution.

Tasks

Students will need to turn in their signed biosafety sheets (if applicable) before beginning the lab.

For each lab, we separate our class into 6 groups of students (2 groups per bench). There should be no more than 5 students in each group, so all students will be able to participate. All of the items on our lab pull sheets should account for 6 groups per section. If you have fewer or more groups, please let our lab techs know so they can modify the lists and materials accordingly.

Instructors should begin the lab by providing a brief introduction to the next lab and any homework associated with or due during the next lab. In our context, the next lab will cover pH and buffers, so students will need to be able to calculate pH, pOH, $[H^+]$, and $[OH^-]$ prior to beginning that lab. Remind students to bring a scientific calculator for the next lab on pH and buffers (we'll also have a few extras available to them in lab – ask the Lab Tech for them, if needed).

Then, introduce students to today's lab on measurement. Review each section of the Lab 2: Measurement and Equipment for students, reviewing the materials around the room and how to use them properly. They may need a more detailed intro to micropipettes, the hand refractometer, and a review of vocabulary terms: precision vs. accuracy, but the rest of the lab should be a review of their pre-requisite chemistry course, so instructors can cover these materials briefly and walk around the room and help students as needed once they begin the lab.

Please have students rinse and replace all glassware for the next lab section to use. For the final lab section (afternoon or night lab / the last lab of the day), please have students rinse and place used materials on a cart for the lab tech so that they can set up for the next course the following morning.

For this lab only, we may have students pour the red solution (water + food coloring) back into the beakers for the next class to use. This is done to help out our lab techs prepare fewer materials. Students should note that this is a rare exception and that we generally do not pour any reagents back into the original container.

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2.2: Formative/Summative Questions

A. Formative Questions

1. Why does the formation of the meniscus differ in the plastic graduated cylinder compared to the glass graduated cylinder?

Answer: In a glass cylinder water molecules have an affinity for adhering to glass (cohesion.) Water molecules have an affinity for other water molecules in a plastic cylinder (plastic is non-polar.) In either case, you measure the volume of the liquid at the center of the liquid level.

2. What is the purpose of the first stop on the micropipette? The second stop?

Answer: First stop aspirates the sample. Second stop dispenses the volume. Check me here please

3. Is it best to measure your sample volume by looking at the measurements from above the sample, at eye level, or below your sample?

Answer: Eye level

4. Which graduated cylinder would be best to measure 9 mL of a sample: 10 mL or 100 mL?

Answer: 10mL

5. Compare and contrast accuracy and precision.

Answer: Accuracy is closest to true value. Precision is degree of repeatability.

6. What is the specific gravity of water? Explain.

Answer: Specific gravity (SG) is the density of a liquid compared to the density of water. Density is mass (solute)/volume (solution.) The density of water is ~1g/1ml, or 1.000. Since there are two solutions being compared, specific gravity does not have units.

B. Summative Questions

1. How do plastic and graduated cylinders differ? Which is more precise? Accurate?

Answers: I'm seeing a lot of answers for this, depending on various factors. What do you all want to convey here?

2. What is the purpose of the micropipette? How do the volumes measured using a micropipette differ from those measured using a Pasteur pipette?

Answer: Micropipettes measure small volumes (1 μL to 100 μL .) Pasteur pipettes are disposable, measure larger volumes, and can be less accurate.

3. How do volumetric and Erlenmeyer flasks differ? Which is more precise? Accurate?

Answer: Volumetric flask (narrow neck) is more accurate and precise.

4. What is the equation used to calculate the molarity of a solution, if given the mass and volume of the solute?

Answer: Grams of solute = [molecular weight (grams)] $\times$ [volume (liters)] $\times$ [desired molarity].

5. What are the steps necessary to prepare a series of serial dilutions, where each dilution is 1/10 the concentration of the previous solution?

Answer: Add 1-part of the stock solution, to 9-parts water/solvent.

6. What is the purpose of a hand refractometer?

Answer: Measures the specific gravity of a solution.

7. What is specific gravity and how does s.g. vary as a solution increases in concentration?

Answer: A measure of the density of a solution over the density of water. As a solution increases in concentration (mass of solutes/mL solution,) the specific gravity increases.

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2.3: Pull Sheets/Materials

Item	How Many
Balances (digital)	6 (2 per table, one at each end)
Weighing papers	15 sheets
Propipettes (green pipette aides)	6
10 mL pipette	15
1 mL pipette	15
*Beakers containing 150 mL of red-dye (food coloring) solution in each	7
Food coloring (red or another bright/intense color)	enough for 36 drops (2 lab sections)
Funnels	2
100 mL graduated cylinder - glass	7
100 mL graduated cylinder - plastic	7
10 mL graduated cylinder	7
Parafilm	1 box
Scissors (to cut Parafilm)	1 (place next to Parafilm box)
p20 micropipettes	7
p200 micropipettes	7
Tips for micropipettes - 20 and 200 microliter sizes	6 boxes of each size (2 boxes per lab bench)
100 mL volumetric flask	7
125 mL Erlenmeyer flask	7
container of NaCl/table salt (at least 200 grams)	1
100 mL beaker	7
150 mL beaker	7
Pasteur pipettes (disposable)	15
Glass stirring rods	7
Hand refractometers	at least 3 (6 if available)
Kimwipes	3 boxes (place next to refractometers)
DI water in wash bottles	6
Test tubes	30
Test tube racks	6
Glassware soak basins	2 (in/by steel sink)

***To prepare this solution:**

- Beaker with 150 ml of red-dye solution
 - Use tap water with a few drops of red food coloring (any other high contrast color is okay as well if red is not available)

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CHAPTER OVERVIEW

3: Scientific Investigation

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3.1: Instructor Guidelines

Purpose

Students are introduced to the vocabulary terms and basic steps of the scientific method during this lab. Students will be able to identify and explain the relationship and differences between the dependent, independent, and controlled variables of an experiment. By the end of the lab, students should also be able to formulate a hypothesis and prediction, use the scientific method to design an experiment to test their hypothesis, and evaluate and present their data.

Tasks

Use the introduction provided in the lab manual to review the vocabulary terms with students, including the following: observation, question, hypothesis, prediction, experiment, independent variable, dependent variable, controlled variables, experimental group, control group, replication, and findings/results. Then, as a class, come up with an observation and apply the vocabulary terms for practice.

Students will begin the lab by completing Exercises A, B, and C in smaller groups (pairs or groups of 3s). Exercise D works best when the class comes up with a single hypothesis and prediction together. Complete D1 through D5 as a class. This can be completed using the projector or lab board. (Sample hypothesis: Athletes have lower resting heart rates than nonathletes.)

Students will then take their own heart rates using their radial or carotid vessels. Students will do this for 15 seconds, 10 times. Multiply these values by 4 to find the second row of values (in beats per minute).

Once students are done, copy the Athlete vs. Nonathlete table onto the board. Athletes may be defined as those who exercise for 30 minutes or more, 3 or more times each week. Students will record their average BPM in the column they belong to. Students will calculate the average BPM for each group and determine if the findings support or refute the hypothesis. Students will also decide if a bar or line graph works best to present this data.

Explain why athletes generally have lower resting heart rates than nonathletes using the equation: $CO = HR \times SV$ (cardiac output = heart rate x stroke volume)

Cardiac output (mL / min) is the volume of blood that leaves the heart per minute. Heart rate is the number of beats per minute (beats / min). Stroke volume is the volume of blood that leaves the heart (ventricles) per beat (mL / beat). Two individuals that are the same height/weight will have the same CO. However, athletes have lower resting heart rates because they generally have greater stroke volumes.

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3.2: Formative/Summative Questions

Formative Questions

1. Define the following terms:

1. Hypothesis
2. Prediction
3. Dependent variable
4. Independent variable
5. Controlled variable
6. Experimental group
7. Control group

Answer: Definitions are self explanatory. Students should understand the difference between a question/prediction/hypothesis/theory. Emphasize the differentiation between control group and controlled variables. Experiments will have at least 2 hypotheses- the null and alternate hypotheses. Experiments can have more, depending on the number of variables. There are multiple control variables.

1. What is the purpose of reporting your scientific work?

Answer: Peer reviewed data allows researchers to collaborate and verify data. Collaboration of data leads to scientific theories.

1. When graphing data, which variable goes on the x-axis? The y-axis?

Answer: Independent variable on x-axis. Dependent variable on y-axis.

1. Why do athletes have lower resting heart rates than non-athletes?

Answer: Refer to the equation $CO = HR \times SV$ (cardiac output = heart rate x stroke volume.) Cardiac output (mL / min) is the volume of blood that leaves the heart per minute. Heart rate is the number of beats per minute (beats / min). Stroke volume is the volume of blood that leaves the heart (ventricles) per beat (mL / beat). Two individuals that are the same height/weight will have the same CO. However, athletes have lower resting heart rates because they generally have greater stroke volumes.

Summative Questions

1. Design a scientific experiment and apply the terms related to the scientific method (listed above) to each component of your experiment.

Answer: This is an open-ended question. Students should focus on the difference between question/prediction/hypothesis. Students should have at least two hypotheses. Have them identify all of the control variables, not just one or two.

1. What is the process and reason behind peer review?

Answer: Allows for verification of results. Researchers submit materials and methods, and statistical analyses of their raw data. Others can repeat the experiment.

1. What parts of an experiment should be reported? Explain.

Answer: Raw data is not reported. Materials, methods, and statistical analyses (of raw data) are presented in a way such that others can understand and repeat the experiment.

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3.3: Pull Sheets/Materials

Item	How Many?
Calculators	28
Stop watch / timers (to count 15 sec intervals)	10 (28 if available)
Saturated phenolphthalein indicator in dropper bottle	2-3 bottles (need 10 drops per lab section)
Straws	24 (for 2 lab sections)
100 mL 0.01N NaOH (with labeled 5 mL pipette and plunger)	1
250 mL beaker	6
150 mL beaker	6
Distilled water	1 gallon (or 2-3 smaller containers that are easy to pour; need 1500 mL for 2 lab sections)

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CHAPTER OVERVIEW

4: Ph and Buffers

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4.1: Instructor Guidelines

Purpose

Students will conduct experiments and calculations related to acids, bases, and buffers in order to review the general chemistry concepts required in this course. Students will be preparing pH indicator solutions using anthocyanins extracted from red cabbage as a standard or reference for pH values. They will also compare pH values of various common household solutions using their self-created standards, and compare these values to those derived using pH paper and a pH meter. Finally, students will also test unknown solutions for the presence of buffers.

Tasks

We recommend assigning students a pre-lab homework assignment before completing this lab, so that students have a chance to review their ability to calculate pH, pOH, $[H^+]$ and $[OH^-]$ before starting this lab. If so, students should turn in their homework at the start of the lab. Additionally, for each lab, students should receive their previous lab assignment/report so that the answers, common errors, etc. can be reviewed together as a class.

Students should view the relevant online lecture before starting lab, but you may want to provide a quick review of pH and buffers just in case. Remind all students to wear exercise-appropriate shoes, clothing, gloves, and goggles during this lab.

Introduce today's lab and the lab materials around the lab room. Students will need a calculator today. They can sign one out if they need to—make sure they return it before leaving. Students should wear gloves and goggles for today. They can use cotton balls and alcohol to clean off the goggles before and after wear.

Students will need to save their standards (pH indicators made with cabbage extract) for the entire lab today.

For exercises B and C, assign each group one solution to test (there will be some duplicates).

Please have students rinse and replace all glassware for the next lab section to use. For the last lab of the day, please have students rinse and place used materials on a cart for the lab tech.

I also try to have them rinse some of the test tubes and set them on the side to dry upside down for the next class, if needed. Since we use so many of them during today's lab, there may not be enough to distribute between all of the biology classes.

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4.2: Formative/Summative Questions

Formative Questions

1. Describe the color of the standard pH indicators (anthocyanins) when acidic, neutral, and basic.

Answer: Red at low pH (acidic,) purple at neutral pH (7,) yellow/green at high pH (basic.)

2. Is there a difference in the pH measured using the cabbage extract compared to pH paper? Which is more accurate and why?

Answer: I am not sure what you want to convey here. As far as I'm aware, vegetable sources of anthocyanin are just as reliable (if not more) as pre-made pH strips.

3. Name 5 household chemicals we tested in lab today and describe their pH range.

Answer: Variable, depending on which solutions you choose.

4. What should we drink while taking aspirin? Explain.

Answer: Aspirin is acidic (pH 2-3) so something with a pH higher than that to buffer the stomach. What direction are we going here? How much info do you want to share about meds and stomach pH?

5. What is the purpose of a buffer?

Answer: Buffers resist a change in pH. They absorb excess H^+ or OH^- ions.

Summative Questions

1. Given a solution's $[H^+]$, how do you determine $[OH^-]$? pH? pOH?

Answer: $pH = -\log [H^+]$, $pOH = -\log [OH^-]$, $pOH = 14 - pH$, $pH = 14 - pOH$. insert a conversion diagram for this question?

1. Describe the best uses for congo red and phenolphthalein.

Answer: Phenothalein is--- not sure what you are looking for for this question.

1. What is the approximate pH of the stomach? The blood? Why is there variation in the pH of our different organs or body systems?

Answer: Stomach chyme is ~ pH 2. Blood is pH 7.35 to 7.45. Low pH in the stomach helps to chemically digest various molecules and to kill pathogens that may have been ingested. Blood pH is closer to neutral, the optimal pH for many important enzymes. The variability of pH within organs and body systems helps prevent pathogens from infecting the body. Pathogens are killed with low pH at points of entry.

1. How might the pH of different medicines impact your likelihood to get food poisoning?

Answer: Student answers might vary. Medicines that raise the pH of the stomach will allow pathogens to survive, and infect at the small intestines.

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4.3: Pull Sheets/Materials

Item	How Many?
Calculators	28
Gloves (one box of each size: S, M, L)	1 set per lab bench
Goggles (with alcohol pads for cleaning)	28 (56 alcohol prep pads)
Prepared solutions within Erlenmeyer flasks: each with its own labeled pipette): pH 2, 4, 5, 7, 8, 10, & 12	see below (please attach to pipette aids) 100 mL of each pH
pH 7	will need an additional 1200 mL (as unknown soln D)
pH 2 and 6	will need an additional 50 mL each (as unknowns A and B)
test tubes	160
test tube racks	12
masking tape	2 rolls
wax pencils or sharpies	6
*500 mL of red cabbage-extract indicator	1
with 1 mL labeled pipettes (cabbage extract)	2 (please attach to pipette aids)
with 5 mL labeled pipettes (cabbage extract)	2 (please attach to pipette aids)
Parafilm	1 box
Scissors (to cut Parafilm)	1
*Unknown Solution A (HCl pH 2)	50 mL
*Unknown Solution B (HCl pH 6)	50 mL
each unknown with a 5 mL labeled pipette	2 (1 for A, 1 for B - please attach to pipette aids)
Apple juice	250 mL (with 2 or 5 mL labeled pipette + aid)
7-Up or Sprite	250 mL (with 2 or 5 mL labeled pipette + aid)
Ivory liquid solution	250 mL (with 2 or 5 mL labeled pipette + aid)
Tide solution	250 mL (with 2 or 5 mL labeled pipette + aid)
Maalox	250 mL (with 2 or 5 mL labeled pipette + aid)
White wine	40 mL (with 2 or 5 mL labeled pipette + aid)
Aspirin solution	40 mL (with 2 or 5 mL labeled pipette + aid)
Coffee	40 mL (with 2 or 5 mL labeled pipette + aid)
Milk of magnesia	40 mL (with 2 or 5 mL labeled pipette + aid)
Sodium bicarbonate solution	40 mL (with 2 or 5 mL labeled pipette + aid)
Drano solution	40 mL (with 2 or 5 mL labeled pipette + aid)
Cascade solution	40 mL (with 2 or 5 mL labeled pipette + aid)

Extra resting solution for pH meters	1 bottle at instructor's desk
pH meters - please calibrate each one to pH 7	6 (2 per lab bench; keep in resting solution)
At each pH meter:	6 sets: Please place each set near one pH meter
Magnetic stir plates (hot plate with stir function)	6 (1 at each pH meter)
pH paper strips	6 (1 at each pH meter)
Glass stirring rods	6 (1 at each pH meter)
Forceps	6 (1 at each pH meter)
Distilled water in squirt bottles; empty waste jar	6; 6 (1 of each at each pH meter)
50 mL beakers - unlabeled	6 (1 at each pH meter)
100 mL beakers - unlabeled	12 (2 next to each pH meter)
Stir bar and magnetic wand	6 of each (1 at each pH meter)
2 mL pipette (or 5 mL) with aid - labeled "HCl"	6 (1 at each pH meter)
2 mL pipette (or 5 mL) with aid - labeled "NaOH"	6 (1 at each pH meter)
20 mL 0.1 N HCl (purchase already prepared)	6 in small Erlenmeyer flasks (1 at each pH meter)
20 mL 0.1 N NaOH (purchase already prepared)	6 in small Erlenmeyer flasks (1 at each pH meter)
*200 mL Unknown Solution C (distilled water) - please label as "Solution C"	6 in flask or beaker (1 at each pH meter)
*200 mL Unknown Solution D (pH 7 buffer) - please label as "Solution D"	6 in flask or beaker (1 at each pH meter)
Congo red in glass dropper bottle (>50 mL each)	6 (1 at each pH meter)
Phenolphthalein in glass dropper bottle (>50 mL each)	6 (1 at each pH meter)
Glassware soak basins	2 (in steel sink)
Congo red waste container	1 (place in hood)

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CHAPTER OVERVIEW

5: Organic Macromolecules

[5.1: Instructor Guidelines](#)

[5.2: Formative/Summative Questions](#)

[5.3: Pull Sheets/Materials](#)

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5.1: Instructor Guidelines

Purpose

The purpose of this lab is to review and identify the structure and characteristics of the biological macromolecules. Some students may have experience with this lab from their organic chemistry courses. In this lab, students will utilize a variety of tests and reagents to test for the presence of carbohydrates, lipids, proteins, and amino acids in various common household substances. Nucleic acids will be introduced in lecture, but not identified during this lab, as we will focus on these macromolecules in a later component (and future labs) of this course. By the end of this lab, students should be able to recognize, identify, and describe three of the four biological macromolecules.

Tasks

Introduce the lab topics and materials and remind students of the hazardous materials:

- Benedict's reagent, Sudan IV, Biuret reagent should have designated waste containers in the hood for disposal

Students will need to wear gloves and goggles for the toxic materials, including ninhydrin.

Some common student questions/errors:

- For Benedict's test, if they overheat the potato slice, they will see + instead of –
- Students will likely need help with defining their dependent and independent variables
- The unknown exercise is optional. This is a long lab and completing the additional unknown exercise may take students more than 3 hours of total lab time.
- Please see the pull sheets for the unknowns in Exercise D (optional exercise)
 - I assign each group 2 unknowns to test for Exercise D. If they are organized, they can do these at the same time as the rest of the lab (or we can remind them).
- This lab is also supply/solution heavy. Remind students to let you know if they mess up and need to repeat any test. I've had students not tell me in the past, and we ran out of solution for the next lab section. I may tell students to get the data from another group, if necessary. We can check with our lab techs to see if they have extra.

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5.2: Formative/Summative Questions

Formative Questions

1. What causes Benedict's reagent to turn from blue to orange after boiling?

Answer: Terminal aldehyde or internal ketone (double-bonded oxygen) portion of a monosaccharide react with the Cu^{2+} portion of Benedict's solution to produce Cu^+ . Heat is required to break the bond within the monosaccharide.

1. What are the contents of Lugol's reagent?

Answer: Key ingredients of Lugol's solution is potassium iodide.

1. Create a hypothesis for an experiment testing for the presence of starch. What are the dependent and independent variables?

Answer: Hypotheses can vary. Something like, "If starch is present, then the iodine in the Lugol's reagent will react, and show a blue/black color."

Independent variable: type of carbohydrate.

Dependent variable: color change of Lugol's reagent (blue-black indicates polysaccharide.)

1. Why might potatoes test positive for reducing sugars?

Answer: potato contains both starch and a reducing sugar (glucose.)

Summative Questions

1. Name the reagent used to detect each of the following: 1. reducing sugars, 2. starch, 3. lipids, 4. proteins, and 5. amino acids.

Answer:

- 1 Benedict's reagent.
- 2 Lugol's reagent.
- 3 Sudan IV reagent.
- 4 Biuret's reagent.
- 5 Ninhydrin reagent.

1. For the reagents above, describe their appearance if the test is negative, and if the test is positive.

Answer:

- 1 Blue (- for reducing sugars,) orange/red (+ for reducing sugars).
- 2 Yellow/tan (- for starch,) Brown (some starch,) Black (+ for starch.)
- 3 Red globs/lipid layer (+ for lipids,) uniform red (- for lipids.)
- 4 Dark purple (+ for many peptide bonds,) light purple (+ for some peptide bonds,) blue (- for peptide bonds.)
- 5 Purple violet (+ for amino acid,) yellow (+ for proline,) clear (- for amino acid.)

1. Name 2-3 common household foods/items that contain each of the following: carbohydrates, lipids, proteins, amino acids.

Answer: This is a long list. Feel free to come up with any you prefer.

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5.3: Pull Sheets/Materials

Item	How many?
Gloves (small, medium, large)	1 of each size per lab bench
Goggles and alcohol prep pads to clean	28; 56 prep pads
Test tube racks (yellow, double row)	24
Test tubes (#16)	300
Pipette aids	18
2 mL pipettes	24
1 mL pipettes	8
2" x 2" brown paper squares (unglazed; paper towel is fine)	18
Filter paper (Whatman #1, 15 cm, square or round)	18
Red-bulb long droppers	5
Black, short droppers	4
Pasteur pipettes, disposable	24
Hot plates	6 (2 per lab bench)
Boiling beaker with rocks (~600 mL)	6 (1 next to each hot plate)
Test tube tongs	6 (1 next to each hot plate)
DI water in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
2% potato starch in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
6% glucose in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
6% maltose in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
6% sucrose in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Onion juice in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Whole milk in labeled flask (for Exercise A) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Small potato (for Exercise A; fresh, on cutting board with small knife; old potatoes do not work)	1
DI water in labeled flask (for Exercise B) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Vegetable oil in labeled flask (for Exercise B) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL

Onion juice in labeled flask (for Exercise B) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Cola (regular) in labeled flask (for Exercise B) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Hamburger juice (grease from cooking ground beef) in labeled flask (for Exercise B) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
DI water in labeled flask (for Exercise C) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
6% egg albumin in labeled flask (for Exercise C) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Potato starch in labeled flask (for Exercise C) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Glucose in labeled flask (for Exercise C) with 2mL (or 5mL) labeled pipette+aid attached)	70 mL
Amino acid solution in labeled flask (for Exercise C) with 2mL (or 5mL) labeled pipette+aid attached) - L-methionine or any other amino acid (other than Proline)	70 mL
"Unknown Solution A" in labeled flask (for Exercise C) labeled dropper (amino acid Proline)	70 mL
"Unknown Solution B" in labeled flask (for Exercise C) labeled dropper (distilled water)	70 mL
"Unknown Solution C" in labeled flask (for Exercise C) labeled dropper (amino acid Methionine)	70 mL
"Unknown Solution D" in labeled flask (for Exercise C) labeled dropper (amino acid Alanine)	70 mL
10 mL ninhydrin	Dropper bottle (not aerosol)
450 mL Benedict's reagent in flask with labeled 2mL (or 5mL) pipette+aid	OR 6 dropper bottles with ~75 mL in each (30 drops = 2 mL)
70 mL Lugol's solution	6 dropper bottles
70 mL Sudan IV	6 dropper bottles
400 mL Biuret reagent in flask with labeled 2mL (or 5mL) pipette+aid	OR 6 dropper bottles with ~75 mL in each
Soak basin for glassware	2 (1 per lab section) - in steel sink
Separate labeled toxic waste containers for: Benedict's, Sudan IV, Biuret reagents	place in hood

Optional Unknown Experiments:

If completing the unknown experiment, you will need 70 mL of the following, each in its own flask labeled as "Unknown #," as well as labeled pipettes attached to pipette aides for each solution:

1. Karo syrup

2. Whole milk (keep cold; else will curdle)
3. Table sugar (dissolved in water)
4. Egg albumin
5. Proline
6. Onion
7. Potato starch
8. Vegetable oil

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CHAPTER OVERVIEW

6: Microscopy Part II

[6.1: Instructor Guidelines](#)

[6.2: Formative/Summative Questions](#)

[6.3: Pull Sheets/Materials](#)

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6.1: Instructor Guidelines

Purpose

In this lab, students will be introduced to microscopy and related procedures, including light microscopes, electron microscopes, staining, dark-field microscopy, and phase-contrast microscopy. Students will learn to identify the purpose of each microscopy type, measure organisms using the ocular micrometer, and demonstrate their ability to view organisms under oil immersion and proper use of the phase-contrast settings.

Tasks

Students will complete the following exercises during this lab:

- View a prepared slide of *Amoeba proteus* using light microscopy and use the ocular micrometer to measure the organism under 40x, 100x, and 400x total magnification.
- View and measure a bacterium under the oil immersion lens.
- View live specimens using phase-contrast microscopy.
- Complete the post-lab report and submit to the instructor before leaving the lab.

The instructor should conduct a brief review of the proper use of the microscope and the types of microscopy before the lab begins. Remind students not to use the coarse adjustment knob when viewing specimens under 400x and 1000x total magnification.

Students will also need an introduction to the purpose and proper technique related to the use of the oil immersion lens and the ocular micrometer. The position of the micrometer is usually fixed on the microscope and found under the right ocular lens; the pointer should be found in the left ocular lens. Remind students the differences between lens paper and kimwipes. Students will need to use lens paper to remove oil from the 100x (and usually 40x as well) objective lenses. Students will also need a review of the phase-contrast settings for the microscopes in our laboratory. The proper settings are listed on each of the objective lenses--students simply match the setting listed on the objective lens with the phase-contrast setting found on the condenser turret.

Although most experiments in this course are conducted in groups. This laboratory should be completed individually in order to allow students to maximize their time working with the microscope. Encourage students to discuss potential answers to each of the lab questions with one another.

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6.2: Formative/Summative Questions

Section 1: Questions

Formative Questions

1. How do you determine total magnification?
2. Describe how to use the ocular micrometer under 40x, 100x, 400x, and 1000x total magnifications.
3. Why is immersion oil necessary when viewing specimens under 1000x total magnification?

Summative Questions

1. Compare and contrast light microscopy and phase-contrast microscopy.
2. How do the marks on the ocular micrometer change as magnification increases? Why?
3. When would a scientist choose to use an electron microscope instead of a light microscope?

Section 2: Rubric / Answers

Formative Questions

1. How do you determine total magnification?
 1. $\text{ocular lens magnification} \times \text{objective lens magnification} = \text{total magnification}$
2. Describe how to use the ocular micrometer under 40x, 100x, 400x, and 1000x total magnifications.
 1. The distance between each line varies as the total magnification changes. At 40x total magnification, the distance from one line of the ocular micrometer to the next is 25 micrometers. For 100x, 400x, and 1000x total magnifications, the distances are 10, 2.5, and 1 micrometer(s), respectively.
3. Why is immersion oil necessary when viewing specimens under 1000x total magnification?
 1. The refraction of light is such that some of the light rays are bent too much and do not pass through the objective lens. This creates a blurry image. Adding immersion oil decreases the refraction such that all light rays will be able to enter the objective lens, creating a clear image of the specimen.

Summative Questions

1. Compare and contrast light microscopy and phase-contrast microscopy.
 1. Light microscopy uses visible light to detect and magnify very small objects and enlarge them. Lenses are used to focus light on the specimen, magnifying it to produce an image. In phase-contrast microscopy, special lenses create phase shifts in light passing through a transparent specimen that translate to brightness changes in the image. These shifts reveal differences in density in various regions of the specimen, visible as brightness variations.
2. How do the marks on the ocular micrometer change as magnification increases? Why?
 1. The marks represent smaller absolute distances as the resolution increases. See Formative Question 2.
3. When would a scientist choose to use an electron microscope instead of a light microscope?
 1. Electron microscopes are often necessary to view specimens or samples that are smaller than 1 micrometer in diameter, such as organelles or viruses.

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6.3: Pull Sheets/Materials

Item	How many?
<i>Amoeba proteus</i> prepared slides	28 slides (1 rack)
Three types bacteria slides (or equivalent)	28 slides (1 rack)
Immersion oil	6-8 bottles per lab section
Extra lens paper packets	6 packets
Kim wipes	2-3 boxes
Pond water sample with dropper	1 per lab section
Hay infusion sample with dropper	1 per lab section
Extra microscope slides	1 box
Extra cover slips	2 boxes

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CHAPTER OVERVIEW

7: Eukaryotic Cells

[7.1: Instructor Guidelines](#)

[7.2: Formative/Summative Questions](#)

[7.3: Pull Sheets/Materials](#)

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7.1: Instructor Guidelines

Purpose

In this lab, students will review and use the microscope skills they acquired from the previous lab to view various prokaryotic and eukaryotic specimens. By the end of the lab session, students should be able to distinguish prokaryotic and eukaryotic cells through the observation of their cellular differences under the microscope. This lab includes student preparation of wet mounts of *Oscillatoria*, students' human cheek cells, onion cells, and *Elodea*.

Tasks

Students will complete the following exercises during this lab:

- View and identify the three common shapes of bacterial cells.
- Prepare a wet mount of *Oscillatoria* and infer cell type and characteristics based on cell structures.
- Prepare a wet mount of their own cheek cells, onion cells, and *Elodea* and identify major cell structures.
- Compare and contrast prokaryotic and eukaryotic cells and determine cell function based on cell structure.

The lab instructor should conduct a brief review of major differences between prokaryotic and eukaryotic cells, including cell structure, organelles, and examples of each. Students may need a brief reminder of how and when to use the oil immersion lens.

Demonstrate the preparation of a wet mount and how to properly clean or dispose of the materials after each procedure. Used toothpicks, slides, and coverslips from the cheek cell wet mount should be disposed of in a beaker (or similar container) containing alcohol or bleach. Forceps, dissecting needles, slides, and coverslips are available in the biology kits next to each student's seat (usually in the top drawer closest to the student).

Optional: have students review proper use of the ocular micrometer by include measurements (l x w) with each of their drawings (i.e., measuring individual cells).

Although most experiments in this course are conducted in groups. This laboratory should be completed individually in order to allow students to maximize their time working with the microscope. Encourage students to discuss potential answers to each of the lab questions with one another.

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7.2: Formative/Summative Questions

Formative Questions

1. Why are nuclei not visible within *Oscillatoria*?
2. How do the photosynthesizing structures of prokaryotic cells differ from eukaryotic cells?
3. Which objective lenses should be used when viewing bacteria? When viewing plant or animal cells?

Summative Questions

1. How do the photosynthesizing structures of prokaryotic cells differ from eukaryotic cells?
2. What is the purpose of adding methylene blue to a wet mount?
3. What cellular structures should be visible under the microscope for prokaryotic cell versus eukaryotic cell? Animal cell versus plant cell?

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7.3: Pull Sheets/Materials

Item	How many?
Three types bacteria slides (or equivalent)	28 slides (1 rack)
Immersion oil	6-8 bottles per lab section
Extra lens paper packets	6 packets
Kim wipes	2-3 boxes
<i>Oscillatoria</i> sample with dropper	1 per lab section
<i>Elodea</i> sample with dropper and forceps	1 per lab section
Sterile (or new) toothpicks	35 per lab section
Beaker with alcohol or bleach for used toothpicks	1 per lab section
Container with bleach for used slides & coverslips (cheek cell samples)	1 per lab section
Methylene blue	6 bottles per lab section
Onion	1 per lab section
Knife and cutting board (to cut onion)	1 per lab section
Extra box of microscope slides	1 box
Extra cover slips	2 boxes

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CHAPTER OVERVIEW

8: Bacteriology (Prokaryotic Cells)

[8.1: Instructor Guidelines](#)

[8.2: Formative/Summative Questions](#)

[8.3: Pull Sheets/Materials](#)

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8.1: Instructor Guidelines

Purpose

Students will continue using the microscope during this lab. Students will be introduced to bacteria, including cultures, subcultures, aseptic technique, the streak plate, and colonial morphology. Students will also be introduced to bacterial cellular morphology, simple staining, and differential staining.

Tasks

Students will complete the following exercises during this lab:

- Identifying colonial morphological characteristics of the following bacteria on plates: Micrococcus, Serratia, Bacillus, and Escherichia.
- Designing an experiment testing a hypothesis regarding microbes in the environment.
- Identifying cellular characteristics of three common types of bacteria.
- Performing a Gram stain on the following bacteria: Micrococcus, Serratia, Bacillus, and Escherichia.

The lab instructor should conduct a brief introduction to aseptic technique and the proper handling of microbes on plates, tubes, and microscope slides. Students will need an introduction on how to handle and label Petri dishes, transfer microbes from test tubes to microscope slides using the inoculation loop, and the basics of heat-fixing and staining bacterial cells.

Students should wear gloves and goggles during this lab. Lab coats will also be provided for students during this lab. Students will also need an introduction to proper use of the staining tray and rack and where to dispose of the stains, gloves, and microbes upon completion of the lab.

Optional: during Exercise D, students may also wish to perform a Gram stain of their own plaque. Plaque may be collected by using a toothpick to collect plaque (and epithelial cells) from the gumline. Students will be able to compare and contrast the size and morphology of epithelial cells with bacteria from their mouths. A greater percentage of bacilli, spiral, or filamentous bacteria may indicate plaque that has been there for a longer period of time.

Students generally take longer to complete this lab, so each group of students should divide tasks amongst group members in order to complete the lab on time. Encourage students to view all experimental procedures and results together rather than copying data or answers from one another.

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8.2: Formative/Summative Questions

Formative Questions

1. List and describe the purpose of each step of the Gram stain.
2. What is the purpose of identifying colony characteristics?
3. Why is aseptic technique important when culturing or subculturing microbes?

Summative Questions

1. How does colony morphology differ from cellular morphology?
2. What is the purpose and significance of the Gram stain?
3. What would a student observe if they skipped the alcohol step during the Gram stain? Why?

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8.3: Pull Sheets/Materials

Item	How many?
Lab coats (borrow boxes from physiology)	28
Goggles (large ones for people with glasses)	28
Bacteria “3 types” microscope slides (cocci, bacilli, spirilla)	28
Poster - Bacteria Morphological Types	1
Bacterium model	1
Kimwipes	2 boxes
Bacterial cleaning solutions (Wavicide)	6 bottles
Paper towel rolls	6
Plain microscope slides	2 boxes
Clean or sterile toothpicks	1 container
Dropper bottle of DI water	6
DI wash bottles	6
Lens paper packets	6
Immersion oil	6 dropper bottles
Test tube racks (yellow ones)	12
Inoculating loops	12
Bunsen burners	6
Striker lighters	6
Wax pencils	6
Staining trays and racks	12
Bibulous paper	12
Clothespin	12
Solutions for Gram staining in boxes - Gram's crystal violet -Gram's iodine solution -95% ethanol -Safranin stain	6-12 staining boxes
Beaker with 10% bleach for used toothpicks	1
Large autoclave waste bag for used gloves	1 per lab section
Soak container for used slides	1
Waste container for used Gram stain (in hood)	1
Gloves (s, m, l) for handling bacteria	1 box of each

*Quadrant streak plate of <i>Micrococcus luteus</i>	3 (1 per lab table) parafilm to keep closed
*Quadrant streak plate of <i>Serratia marcescens</i> (Grown at 25C for red color)	3 (1 per lab table) parafilm to keep closed
*Quadrant streak plate of <i>Bacillus</i>	3 (1 per lab table) parafilm to keep closed
*Quadrant streak plate of <i>E. coli</i>	3 (1 per lab table) parafilm to keep closed
*Slant culture of <i>Micrococcus luteus</i>	6 (3 per lab section)
*Slant culture of <i>Serratia marcescens</i> (Grown at 25 for red color)	6 (3 per lab section)
*Slant culture of <i>Bacillus</i>	6 (3 per lab section)
*Slant culture of <i>E. coli</i>	6 (3 per lab section)
Sterile TSA agar plates	14 per lab section
Sterile cotton swabs	28 per lab section
3 mL sterile water in 16mm test tube	14 per lab section

- All of these cultures should be available from our microbiology tech (also used for Biol74)

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CHAPTER OVERVIEW

9: Diffusion and Osmosis

[9.1: Instructor Guidelines](#)

[9.2: Formative/Summative Questions](#)

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9.1: Instructor Guidelines

Purpose

Students are introduced to diffusion and osmosis during this lab. Students will observe effects of molecular weight on diffusion rate through agar and a dialysis membrane, the impact of tonicity on water movement, and observe osmosis in red blood cells and *Elodea*.

Tasks

Students will complete the following exercises during this lab:

- Compare diffusion rates of methylene blue and potassium permanganate on an agar plate.
- Observe and measure diffusion rates across a dialysis membrane.
- Observe the effects of osmosis on plant and animal cells, including potato tuber, red blood cells, and *Elodea*.

Lab instructors should provide students with an introduction to diffusion and osmosis, including the effects of hypertonic, isotonic, and hypotonic solutions on plant cells versus animal cells.

This will be a longer lab that will require students to cooperate and divide the work amongst group members in order to finish on time. Some experiments require a longer experimental time (i.e. Part 1, Experiment 1 takes up to 80 minutes), so students should begin these experiments first.

When working with the dialysis membrane, students will need to be reminded to rinse each of their filled dialysis membranes with water before placing into each cup.

Students will need to be careful when working with the potato borers in Part 2, Experiment 1. If borers are not available, have students use knives to cut potatoes into small rectangles similar to french fries. These will need to fit into the test tubes and be equivalent in size.

In Part 2, Experiment 2, when working with the red blood cells, students should make one slide at a time. These slides dry out quickly and students will be unable to view the cell shape once the cells or slides are dry.

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9.2: Formative/Summative Questions

Formative Questions

1. Describe or define osmosis.
2. What factors impact the diffusion rate of a molecule? How or why?
3. Does diffusion rate equal 0 at equilibrium? Explain.

Summative Questions

1. How does a plant or animal cell change in a hypertonic solution? Hypotonic solution? Isotonic solution?
2. How does osmosis differ in animal versus plant cells? Why?
3. How does the dialysis membrane compare with a cell membrane? In what ways are they similar? Different?

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9.3: Pull Sheets/Materials

Item	How many?
Gloves (s, m, l)	1 box of each
Biol4A kits (already in drawers next to each student's seat)	28
Mueller-Hinton agar plates	7 per lab section
Disposable straws	6 per lab section
Methylene blue with dropper	6 bottles
Potassium permanganate with dropper	6 bottles
Pasteur pipettes, disposable	6 per lab section
Disposable cups (at least 400mL size)	30 per lab section
Electronic balance	6 (2 per lab bench)
Weighing boats, large (or aluminum foil)	6 per lab section
15 cm strips of moist dialysis tubing (soaking in water)	30 per lab section
Dialysis tubing clips (to seal ends); or rubber bands/equivalent	60 per lab section
dI H ₂ O	500 mL per lab section
15% Sucrose solution with 10 mL pipette	70 mL per lab section
30% Sucrose solution with 10 mL pipette	1000 mL per lab section
30% Glucose solution with 5 mL pipette	40 mL per lab section
15% Starch solution with 5 mL pipette	40 mL per lab section
Iodine solution (or Gram's iodine) with 1 mL pipette	10 mL per lab section
10 mL graduated cylinder	6
100 mL graduated cylinder	6
wax pencil or sharpie	6
Tape for labeling glassware	1 roll with scissors
Glucose test strips	12 per lab section
Potato (fresh) with 1 knife and cutting board; please remove skin	3 per lab section
cork borer	6
Test tubes	20
Test tube racks	6
Petri dish with lid	18
10% NaCl solution with disposable pipette	100 mL per lab section
0.9% NaCl solution with disposable pipette	100 mL per lab section
Plain microscope slides	2 boxes
Coverslips	2 boxes
Dropper bottles with ox or sheep blood	3 bottles

Item	How many?
Test tube rack with 10 drops of ox or sheep blood in each of 3 tubes, labeled: - 15 mL dI water - 15 mL 10% NaCl - 15 mL 0.9% NaCl	1 demo for both sections
Newspaper page or magazine page with small text	3
Live Elodea	need 20 leaves per lab section
Soak container for used slides	1
Soak container for used coverslips	1

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CHAPTER OVERVIEW

10: Enzymes

[10.1: Instructor Guidelines](#)

[10.2: Formative/Summative Questions](#)

[10.3: Pull Sheets/Materials](#)

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10.1: Instructor Guidelines

Purpose

Students are introduced to enzymes and the catalyst catalase (from potatoes) during this lab. Students will observe the effects of catalase with and without its substrate. Students will also have the opportunity to test their own hypotheses regarding catalase activity related to the following factors: temperature, pH, and concentration.

Tasks

Students will complete the following exercises during this lab:

- Compare catalase activity with and without substrate through observation of the formation of the chemical product.
- Design their own hypotheses and predictions related to catalase activity and one of the following: temperature, pH, or concentration.
- Observe the outcomes of their experiment, and analyze and communicate their results through a written laboratory report and/or an oral presentation.

Lab instructors should provide students with an introduction to enzymes, including their composition and structure (active site, allosteric site), as well as factors influencing their activity. Although not included in the laboratory experiment, please also review the concepts of competitive and noncompetitive inhibition with students.

Students will work in their usual groups for Part 1 (catalase activity with and without the hydrogen peroxide substrate). For Part 2 (design your own experiment), I recommend having students complete experiments in duplicate. For example, since there are three lab benches in the room, and two groups per bench. Each group from the same bench can perform the same experiment and compare their final results. This will allow us to have two groups for each variable (2 groups testing temperature, 2 groups testing pH, and 2 groups testing enzyme concentration).

Have students design their experiment and show you their hypothesis and prediction BEFORE beginning their experiments. Edit and suggest revisions as you see fit. Students are likely to choose cold, room temp, and hot/boiling variables for the temperature factor; acidic, neutral, and basic variables for the pH factor; and concentrations of 1, 1/10, and 1/100 (created through a serial dilution) for the enzyme concentration factor.

Instructors can decide whether students will communicate their findings through a written laboratory report or oral presentation. Before students begin either experiment, review their results and have each of the groups (testing the same factor) compare their results with one another. Students should describe potential confounding factors that may have affected their results. If completing an oral presentation, this can be completed at the start of the next laboratory session. Assign each group to present a specific portion of their experiment (and give them a heads up that you may ask questions related to any part of the experiment). A post-presentation lab quiz may be helpful to ensure students pay attention to all of the presentations.

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10.2: Formative/Summative Questions

Formative Questions

1. How do enzymes speed up reactions?
2. List and describe at least 3 environmental factors that influence enzyme activity?
3. What is the difference between a catalyst and catalase?

Summative Questions

1. How does temperature affect enzyme activity? What happens to the enzyme at cold temperatures? Hot temperatures?
2. How does pH affect enzyme activity? Consider the pH differences of human saliva versus the stomach. How does this influence enzymes located in each body region?
3. How does enzyme concentration affect enzyme activity? How does this compare with changing the substrate concentration?
4. Compare and contrast competitive and noncompetitive inhibition. Which one can be overcome by increasing the substrate concentration? Why?

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10.3: Pull Sheets/Materials

Item	How many?
Gloves (s, m, l)	1 box of each
Goggles	28
Biol4A kits (already in drawers next to each student's seat)	28
Test tubes	48
Test tube racks	6
Catalase (from potatoes or similar)	45 mL per lab section
Hydrogen peroxide	20 mL per lab section
dI H ₂ O	80 mL per lab section
hot plates	2
beakers 500mL	4
Ice	1 bucket
Concentrated HCl solution	2 dropper bottles
Concentrated NaOH solution	2 dropper bottles
12" rulers	6
Wax pencils	6
Thermometers	4
10 mL pipette tips	6
Pipette aides	6
Tape	3 rolls
Sharpies	6
Disposable Pasteur pipettes	20 per lab section
small beakers (10 mL or larger)	12
10 mL graduated cylinders	6

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CHAPTER OVERVIEW

11: Spectrophotometry

[11.1: Instructor Guidelines](#)

[11.2: Formative/Summative Questions](#)

[11.3: Pull Sheets/Materials](#)

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11.1: Instructor Guidelines

Purpose

Students are introduced to spectrophotometry during this lab. Students will learn how to use the spectrophotometer to determine the specific dyes present in different colored candies (Skittles). The purpose of this introductory lab is to prepare students for more advanced use of the spectrophotometer in future labs.

Tasks

Students will complete the following during this lab:

- Extract federally approved food dye from each color of Skittles candy (original flavors, red packaging).
- Blank and use the spectrophotometer to measure absorbance for each dye.
- Use the derived absorbance values to determine which dye(s) are present in each of the colored candies.

Lab instructors should provide students with an introduction to spectrophotometry and the absorbance spectrum (x-axis vs. y-axis). Review the relationship between absorbance and transmittance, as well as the range of wavelengths found in the visible spectrum. Students may not know that red light has a longer wavelength (lower energy) than violet light (higher energy). Provide students with examples of how to calculate absorbance if given percentage transmittance, and vice versa.

We will be using newer spectrophotometers compared to the image found in the student introduction (Chapter 11.1, Figure 2). The spectrophotometers students will be working with are the ThermoFisher Spectronic 200 models. Please introduce students to this instrument and show students where to place cuvettes, how to blank the spectrophotometer, and how to measure absorbance for each sample.

Remind students to make sure the light from the spectrophotometer does not pass through the frosted side of the cuvettes. Students can use Kimwipes wipe the clear side of each cuvette before each reading.

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11.2: Formative/Summative Questions

Formative Questions

1. Which wavelengths of light fall within the range of the visible spectrum?
2. How does red light compare with blue light in terms of wavelength and energy?
3. What is the relationship between absorbance and percent transmittance?

Summative Questions

1. How can an absorbance spectrum be used to determine the presence or absence of an unknown molecule?
2. Would a greater concentration of the same molecule change the absorbance spectrum? Why or why not? Explain.
3. Examine your experimental findings. Does the absorbance of red dye fall within the range of wavelengths for red light on the visible spectrum? Why or why not? Explain.
4. If a plant appears primarily green in color, which wavelength(s) of light are most likely absorbed by this plant?

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11.3: Pull Sheets/Materials

Item	How many?
Test tubes	30 per lab section
Skittles (original flavor): each lab group needs 4 candies of the same color: -red, orange, yellow, green, purple	24 candy pieces of each color per lab section
dI H ₂ O - with 2-5 mL pipettes and pipette aides	120 mL per lab section
Disposable Pasteur pipettes	30 per lab section
Microcentrifuge tubes	30 per lab section
Microcentrifuge	1 (2 if available)
Cuvettes	36 per lab section
Spectronic 200 spectrophotometer	6 (2 per lab bench)

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CHAPTER OVERVIEW

12: Cellular Respiration and Fermentation

[12.1: Instructor Guidelines](#)

[12.2: Formative/Summative Questions](#)

[12.3: Pull Sheets/Materials](#)

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12.1: Instructor Guidelines

Purpose

Students are introduced to aerobic cellular respiration and fermentation during this lab. Cellular respiration will be monitored through the presence of carbon dioxide in solution and subsequent changes in pH, as well as redox reactions. Fermentation levels will be monitored through the production of CO₂ gas. Students will learn how to use pH indicators and saccharometers to measure CO₂ production.

Tasks

Students will complete the following during this lab:

- Investigate cellular respiration in dormant versus germinating seeds through the production of CO₂ (acid) and subsequent change in pH.
- Use methylene blue and microscopy to detect the presence or absence of redox reactions that occur during aerobic cellular respiration.
- Use saccharometers to measure CO₂ levels produced through alcoholic fermentation in yeast.

Lab instructors should provide students with an introduction to cellular respiration and fermentation. Although the material is also covered in the lecture and course textbook, these two topics tend to be some of the most challenging for all biology students. Instructors may want to provide students with a brief overview of glycolysis, the Krebs cycle, and the electron transport chain for aerobic cellular respiration. Students may not know that some bacteria undergo anaerobic respiration with a final electron acceptor that is not oxygen. Remind students that fermentation is different from anaerobic cellular respiration.

Exercise A requires preparation of the pea plant seeds at least two days prior to the experiment, which may be completed by the students or the laboratory technicians. Additionally, the lab manual asks students to record color changes after 24 hours. This is not possible for our students, so instructors may ask a colleague or the lab technicians to take a picture of the samples after 24 hours if desired. According to our previous results, there are no differences between the three tubes after 2 hours vs. after 24 hours.

In Exercise B, remind students that the yeast cells should be viewed under 400x or 1000x (oil immersion) total magnification.

There are a total of four exercises listed for this lab (Exercises A-D), but currently, our laboratory supplies are insufficient and we only have enough materials and saccharometers to complete Exercises A-C. In Exercise C, each group of students should be assigned two conditions to test (see Table 3 in the lab manual for Exercise 12):

1. Sacch 1 (no yeast) and Sacch 3 (less yeast), or
2. Sacch 2 (no glucose) and Sacch 4 (more yeast).

Students will need to be introduced to the saccharometers and how to properly fill each with the yeast/glucose mixture, especially Procedure Step 5 of Exercise C. Once each saccharometer has been properly filled, they should be taped to the tray or lab benchtop in order to prevent shattering of the glass should they fall over.

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12.2: Formative/Summative Questions

Formative Questions

1. Do dormant peas or germinating peas exhibit greater rates of cellular respiration? Explain.
2. What additional variables or factors impacting the respiration rate of pea seeds could we have tested during this lab?
3. Does methylene blue act as an oxidizing agent or reducing agent in Exercise B?
4. What is the relationship between the concentration of yeast and fermentation rate?

Summative Questions

1. How can pH changes be used to detect the presence or absence of cellular respiration in pea plants?
2. Is glucose oxidized or reduced when examining the overall chemical equation of aerobic cellular respiration?
3. What are the substrates, intermediates, and products in the chemical equation for alcoholic fermentation in yeast?
4. What is the purpose of a saccharometer? How is it used to measure fermentation rate?

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12.3: Pull Sheets/Materials

Item	How many?
Microscope slides	1 box
Coverslips	1 box
Electronic balance	6 (2 at each lab bench)
Spatula	6 (1 next to each balance)
Weighing papers	12 (6 per lab section)
Saccharometers	12 (students will rinse and replace after each lab)
Red food coloring	2 dropper bottles
distilled or dI water	200 mL (100 mL per lab section)
10% glucose solution	150 mL (75 mL per lab section)
Pipette tips with pipette aides attached for the following: • 5 mL labeled for dI H₂O • 10 mL labeled for dI H₂O • 5 mL labeled for glucose • 10 mL labeled for glucose	1 of each listed
20 mL test tubes (or small Erlenmeyer flasks)	12 (students will rinse and replace after each lab)
Extra 6" rulers	6
Large plastic trays (to tape saccharometers onto/to catch ferment overflow)	6

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CHAPTER OVERVIEW

13: Photosynthesis

[13.1: Instructor Guidelines](#)

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13.1: Instructor Guidelines

Purpose

Students are introduced to photosynthesis during this lab. Students will extract plant pigments and separate these pigments using paper chromatography. The spectrophotometer will be used again in this lab to allow students to identify the plant pigments present in various plant leaves (e.g., Coleus). Students will also monitor the rate of photosynthesis through oxygen production, and observe and compare the quantity of stomata found on the upper versus lower parts of a leaf.

Tasks

Students will complete the following during this lab:

- Use acetone to extract plant pigments from spinach (or equivalent) and then separate these pigments based on polarity.
- Use paper chromatography and retention factor (R_f) calculations to identify the relative polarities of major plant pigments.
- Use the spectrophotometer to identify common pigments present in plant leaves.
- Investigate the impact of CO₂ availability on the rate of photosynthesis.
- Identify and determine differences in stomata in the upper versus lower portions of a leaf.

Lab instructors should provide students with an introduction photosynthesis and contrast photosynthesis with cellular respiration. The examination of the overall chemical equations for each is important for students to understand the relationship between humans (and other animals) and plants.

Students should wear gloves and goggles when working with acetone and the chromatography solvent. Remind students that these solutions require special waste containers that will be found in the biological safety cabinet.

Students will need guidance on how to use the chromatography paper. Remind students to use the glass capillary tube to overlay the plant pigment on the pencil line several times, allowing the pigment to completely dry each time before applying the next later. Students should apply at least three layers, although five layers appears to generate the best results. Students can tape or staple the edges of the chromatography paper together to generate the tube that will be placed in the jars of solvent. Students should stand next to the solvent jars and check their papers frequently in order to ensure the solvent front does not to end of the chromatography paper.

Four bands of plant pigment should appear once the experiment has been completed:

- Lowest band (most polar): chlorophyll b (appears yellow-green)
- Chlorophyll a (appears grass green)
- Xanthophyll (appears light yellow)
- Highest band (least polar): carotene (appears dark/golden yellow)

In Exercise 2, students may need to dilute their plant pigment solution with more ethanol if distinct peaks do not appear in their absorbance spectrum. Using 1 gram of leaf tissue (as opposed to 4g as stated in the original manual) may be sufficient for dark-colored leaves.

In Exercise 3, students may need to perform the vacuum syringe step (see Exercise C Step 6) several times in order to remove the gas from the plant leaf disks. This step is critical to get optimal results for this experiment.

In Exercise 4, students should be able to view the stomata under 100x total magnification. We recommend having the instructor or student(s) take a picture of their samples (upper and lower leaf) through the microscope ocular lens in order to compare the two and discuss their findings with their peers.

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13.2: Formative/Summative Questions

Formative Questions

1. Why is acetone used for plant pigment extraction?
2. Which plant pigments are more attracted to the chromatography paper? The petroleum-ether acetone solvent?
3. In the spectrophotometry experiment, absorbance values equal to or greater than 1.0 are too high. How might you adjust your leaf extract to improve your absorbance data if your absorbance values are too high?
4. What is the purpose of the sodium bicarbonate solution in the leaf disks (rate of photosynthesis) experiment?
5. What are stomata?

Summative Questions

1. What is the purpose of paper chromatography?
2. How is the retention factor (R_f value) calculated?
3. How can an absorbance spectrum be used to determine the presence or absence of a specific plant pigment?
4. Why do the leaf disks exposed to sodium bicarbonate float? Explain using your knowledge of the chemical equation for photosynthesis.
5. Are there more stomata on the upper or lower surface of the leaf? Explain.

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13.3: Pull Sheets/Materials

Item	How many?
Gloves (s, m, l)	1 box of each
Spinach leaves: • Dark, green, fresh leaves are best • Each lab section needs approx. 25g leaves	2 bundles (1 / lab section) or at least 80 leaves (40 / lab section)
Electronic balance	6 - 2 per lab bench
Weighing boats for balance	1 at each balance
Clean quartz sand (to grind spinach) • 0.4g per "pinch" • 24 pinches (12 pinches/lab section)	10 grams (5 g / lab section)
Mortar and pestle	6 per lab section
Acetone (keep in hood)	80 mL (40 mL / lab section)
Test tubes	24 (12 / lab section)
Test tube racks	6
Chromatography papers (11 cm square or similar)	12 (6 / lab section)
Glass capillary tubes	12 (6 / lab section)
Grass or spinach soaking in acetone (for student demo)	1
Extra 6" rulers	6
Pencils	6
Handheld UV light	1 (2 preferred)
<u>With each stored in 1 L glass jar with lid:</u> • *petroleum ether-acetone solution	6 (placed in safety hood)
Special waste container for acetone/chlorophyll extract	1 (placed in safety hood)
3 different potted plants with flat leaves • Best if 3 plants have leaves of different colors	each plant should have 14 leaves
95% ethanol	250 mL (125 mL / lab section)
Spectrophotometers	6 – 2 per lab bench
Plastic cuvettes	24 (12 / lab section)
Pasteur pipettes	36 (18 / lab section)
10 or 20 mL plastic graduated cylinders	6 (rinse/replace between lab sections)
Clear plastic cups (to hold at least 300mL)	24 (12/lab section)
Index cards	24 (12/lab section)
Plastic petri dishes	12 (rinse/replace between lab sections)
Water with 0.3%-0.5 sodium bicarbonate (NaHCO ₃) or baking soda	1000 mL (500 mL/lab section)

100 mL beaker	6 (rinse/replace between lab sections)
Dilute detergent (5mL dishwashing detergent+250mL water) • Aliquote into microcentrifuge tubes, label “DD”	at least 12 microcentrifuge tubes (6 per lab section)
Hole puncher (or straws)	6 (or 12 straws for both lab sections)
10 mL syringes without needles	12 (rinse/replace between lab sections)
Stopwatches	6
Desk lamps	6 preferred (3 is okay)
Bottle of clear nail polish	6 preferred (3 is okay)
Clear packing tape	6 rolls
Microscope slides	1 box

***Preparation for the Petroleum ether-acetone solution:** Use 9 parts petroleum ether and 1 part acetone; volume should be less than 1” in height from bottom of each jar.

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CHAPTER OVERVIEW

14: Mitosis

[14.1: Instructor Guidelines](#)

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14.1: Instructor Guidelines

Purpose

Students are introduced to mitosis and simulate the stages of mitosis using pop beads during this lab. The exercise is complemented by prepared slides of whitefish blastula and onion root tip cells to emphasize the mitotic differences between plant and animal cells; elongated chromosomes and the cell plate are especially distinct in the onion root cells.

Tasks

Students will complete the following during this lab:

- Use pop beads to create two pairs of homologous chromosomes, with sister chromatids attached using magnetic centromeres.
- Use white chalk and additional materials (such as plastic straws) to simulate centrioles and kinetochore/nonkinetochore microtubules.
- Compare and contrast mitosis in animal versus plant cells.

Lab instructors should provide students with an introduction to the cell cycle and the stages of mitosis. A pre-lab reading quiz is recommended for this lab to ensure students have read the lab manual and have a general understanding of the stages of mitosis prior to coming to class.

Students may need help identify the stages of mitosis in the whitefish blastula and onion root cell slides. If sufficient time and materials are provided, we recommend setting up different microscope stations around the room, with one mitotic stage and cell type visible under each microscope. These may be labeled or unlabeled if instructors plan to use this as a mini-review or practice quiz.

Exercise 4 requires the use of a laptop or device with internet access. The instructor may wish to lead this exercise using the classroom computer, or have students complete this exercise in groups. Please note that the images on the provided website may be slow to load, so instructors may want to complete this activity beforehand and provide the number of cells in each stage for students to analyze.

Remind students to clean the chalk from the bench tops by wiping the chalk dust off of the desks toward the seats/floor and not into the sinks, as this clogs the lab sinks.

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14.2: Formative/Summative Questions

Formative Questions

1. What is the purpose of mitosis? In which cell types does mitosis occur?
2. Describe the stages of the cell cycle.
3. What is the difference between kinetochore and nonkinetochore microtubules?

Summative Questions

1. List and describe the phases of mitosis.
2. Compare and contrast mitosis in plant versus animal cells.
3. Which mitotic structures are absent in plant cells?
4. How does the number and ploidy of the daughter cells compare with the parent cell?

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14.3: Pull Sheets/Materials

Item	How many?
pop beads of one color	200 (yellow)
pop beads of a different color	200 (red)
small plastic cylinders (to represent centrioles) • can use plastic straws cut into 1-1.5" pieces	30
magnetic centromeres	30
Onion root tip microscope slides	28 slides
Whitefish blastula	28 slides

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CHAPTER OVERVIEW

15: Meiosis

[15.1: Instructor Guidelines](#)

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15.1: Instructor Guidelines

Purpose

This lab will be very similar to the previous lab on mitosis. Students are introduced to meiosis and simulate the stages of meiosis using pop beads during this lab. Microscope slides, however, are not available for this lab.

Tasks

Students will complete the following during this lab:

- Use pop beads to create one pair of homologous chromosomes, with sister chromatids attached using magnetic centromeres.
- Use pop beads to create one X and one Y chromosome, with sister chromatids attached using magnetic centromeres.
- Use white chalk and additional materials (such as plastic straws) to simulate centrioles and kinetochore/nonkinetochore microtubules.
- Compare and contrast mitosis and meiosis.

Lab instructors should provide students with an introduction to the cell cycle and the stages of meiosis. A pre-lab reading quiz is also recommended for this lab to ensure students have read the lab manual and have a general understanding of the stages of meiosis prior to coming to class.

Students tend to have a difficult time understanding the concept of homologous chromosomes. Make sure students include the B and b allele labels on their beads when simulating the stages of meiosis. Students should include the allele labels on each of the sister chromatids.

Introduce students to crossing over in prophase I and independent assortment of chromosomes during metaphase I. Students may want to take pictures of their pop beads at each of the meiotic stages. Ask students to compare and contrast mitosis and meiosis using the pop beads before leaving lab.

We have found that "testing" students at the end of lab by walking around the room to each group and asking individual students to use their pop beads to simulate specific meiotic stages helps to promote engagement and understanding of the material.

Remind students to clean the chalk from the bench tops by wiping the chalk dust off of the desks toward the seats/floor and not into the sinks, as this clogs the lab sinks.

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15.2: Formative/Summative Questions

Formative Questions

1. What is the purpose of meiosis? In which cell types does meiosis occur?
2. How does interphase of meiosis I compare with interphase of meiosis II?
3. Meiosis is absent in which organisms?

Summative Questions

1. List and describe the phases of meiosis I and meiosis II.
2. Compare and contrast mitosis and meiosis.
3. How does the number and ploidy of the daughter cells after meiosis I compare with the original parent cell?
4. How does the number and ploidy of the daughter cells after meiosis II compare with the original parent cell?

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15.3: Pull Sheets/Materials

Item	How many?
pop beads of one color	200 (yellow)
pop beads of a different color	200 (red)
small plastic cylinders (to represent centrioles) • can use plastic straws cut into 1-1.5" pieces	30
magnetic centromeres	50 (note increase in number from mitosis lab setup)
Ultra fine point sharpies (to label alleles)	at least 6
Dispensers of colored tape (for allele labels)	at least 3

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CHAPTER OVERVIEW

16: Genetics

[16.1: Instructor Guidelines](#)

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16.1: Instructor Guidelines

Purpose

This lab provides a basic introduction to Mendelian genetics for students. In Part 1, students are introduced to genetics vocabulary terms, including heterozygous, homozygous, dominant, and recessive. Practice problems integrating Punnett squares allow students to compare typical inheritance patterns with incomplete dominance and codominance. Students will also be able to compare the genotypic and phenotypic ratios seen in monohybrid versus dihybrid crosses.

Tasks

Students will complete the following during this lab:

- Investigate patterns of Mendelian genetics using Punnett squares and alleles representing the following:
 - Typical inheritance patterns
 - Incomplete dominance
 - Codominance
- Compare and contrast the genotypic and phenotypic ratios of monohybrid vs. dihybrid crosses.
- Use phenotypic traits to derive potential genotypes and relative frequencies in the classroom population.

Lab instructors should provide students with an introduction to Mendelian genetics and the related vocabulary terms. Going over at least one practice problem of each type as a class will help provide a guide for students to complete the remaining problems.

In your introduction to the lab, provide students with sample images of the physical traits (e.g. tongue rolling, widow's peak, etc.) as many students will be unfamiliar with these terms. Once the percentages of dominant and recessive phenotypes for the class are calculated, students will be able to see that dominant alleles are not always more common (both in the class and in the general population).

In Part 2, the dihybrid cross, students generally have a difficult time understanding how to create gametes when two characters are involved. Remind students that each gamete must have at least one allele for each character. For instance, an AaBb parent could form the following gametes: AB, Ab, aB, or ab. Here, students often make the mistake of creating gametes such as the following: AA, BB, Aa, etc. Creating connections between meiosis and the gametic alleles may be helpful.

Finally, encourage students to recognize (memorize) major genotypic or phenotypic patterns. Recognizing the 1:2:1 genotypic and 3:1 phenotypic ratio in the progeny for a monohybrid cross and the 9:3:3:1 phenotypic ratio in the progeny for a dihybrid cross will be helpful as students progress to more challenging genetics problems.

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16.2: Formative/Summative Questions

Formative Questions

1. Why are the genotypes of organisms represented by two alleles for each character (i.e., Aa)?
2. Which cell type(s) are represented by a single allele for each character?
3. How does complete dominance differ from incomplete dominance and codominance?

Summative Questions

1. Compare and contrast genotype and phenotype.
2. How do the genotypic and phenotypic ratios of monohybrid cross compare with those of a dihybrid cross?
3. Are dominant alleles more common in the population compared to recessive alleles? Explain.

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16.3: Pull Sheets/Materials

This laboratory is primarily a "dry" lab. However, students will need PTC tasting paper. Control tasting paper is also recommended (1 of each per student).

The following test strips from Carolina may be helpful:

- **Item #:** 974896 - [PTC Tasting Paper \(Pack of 100, \\$3.38 as of May 2024\)](#)
- **Item #:** 974895 - [Control Tasting Paper \(Pack of 100, \\$3.32 as of May 2024\)](#)

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CHAPTER OVERVIEW

17: DNA and Chromosomes

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17.1: Instructor Guidelines

Purpose

Students are introduced to the central dogma of molecular biology in this lab. Students will practice transcribing DNA sequences into mRNA and tRNA and use the genetic code to determine the corresponding amino acids.

Tasks

Students will complete the following during this lab:

- Compare and contrast DNA, mRNA, tRNA, and amino acids.
- Compare and contrast transcription and translation.
- Synthesize a short protein from a given DNA template.
- Apply their understanding of gene expression to quickly transcribe and/or translate a given sequence to generate an amino acid.

Lab instructors should provide students with an introduction to gene expression. Students will need a brief review of the structure of DNA vs. mRNA. Then, introduce the steps required to transcribe DNA into mRNA and translate mRNA into protein. Introduce the genetic code and the three axes that can be used to quickly find a codon, the start and stop codons in the genetic code, and the redundancy seen in the genetic code.

Pre-lab preparation may be necessary for Part 3 of this exercise, Protein Synthesis Bingo. Instructors should prepare various sequences (DNA, mRNA, and tRNA) in advance to cover the 20 amino acids. Additionally, we suggest using the link provided for the printable version and preparing several copies of this handout at the start of this lab or in the lab preceding this class. Students can take work in pairs and cut out the amino acids to tape to the card randomly. Once completed, each student can copy the three letter and one letter amino acid codes from the shared handout to their own lab handout.

Students may need guidance for the start of the bingo activity. we recommend providing at least one example of each sequence (one DNA, one mRNA, and one tRNA), and its corresponding codon and amino acid before allowing students to transcribe and translate the sequences on their own.

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17.2: Formative/Summative Questions

Formative Questions

1. Which amino acid would be derived from the DNA sequence CGA?
2. Codons are located on which type(s) of molecule?
3. Although each RNA codon codes for only one amino acid, one amino acid may be encoded by multiple codons. Why?

Summative Questions

1. What is the central dogma of molecular biology?
2. How does the structure of DNA differ from that of mRNA? tRNA? Amino acids?
3. Compare and contrast transcription and translation.

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17.3: Pull Sheets/Materials

This laboratory is primarily a "dry" lab (handouts only), where students will practice transcribing mRNA from DNA sequences, and then translating mRNA into amino acid chains.

- 6 rolls of adhesive (Scotch) tape will be needed for students to create their bingo cards for each lab section

Part 4 of the student lab manual describes a DNA extraction lab from wheat germ, but we are currently skipping part this since we will be integrating a separate DNA extraction lab experiment created by Carolina which uses students' own human cheek cells:

- **Item #:** 211138 - Carolina DNA Necklace Kits (\$72.75 per kit as of May 2024) - 2 kits are needed (1 for each lab section)

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CHAPTER OVERVIEW

18: Recombinant DNA and Bacterial Transformation

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18.1: Instructor Guidelines

Purpose

Students are introduced to recombinant DNA technology and bacterial transformation during this lab. This is a 2-day lab, as students will transform bacteria on day one and view and analyze their results during the following lab session. Students will transform competent *E. coli* cells with the pAMP plasmid to generate ampicillin-resistant bacteria.

Tasks

Students will complete the following during this lab:

- Optimize the conditions for bacterial transformation by altering the salt concentration and heat shocking bacterial cells.
- Perform bacterial transformation by introducing the pAMP into competent *E. coli*.
- Compare and contrast growth patterns of *E. coli* with and without pAMP on LB plates and LB + ampicillin plates.
- Determine the transformation efficiency of *E. coli* based on the number of colonies on the LB + amp plates (second lab).
- Simulate a restriction enzyme digest and create a recombinant plasmid using a paper replica of an *E. coli* plasmid and a segment of DNA from the human chromosome (second lab).

Lab instructors should provide students with an introduction recombinant DNA technology and bacterial transformation. Students will need a review of the structure of a bacterial cell, the structure and function of plasmids, and how plating can be used to select for successfully transformed bacteria. A pre-lab reading quiz is suggested to ensure students have read the lab manual and are prepared to work with the biohazardous materials.

Students will need a review of proper use of the micropipette, including the appropriate volumes for each type of micropipette, how to set the volume, how to attach and remove the disposable tips, and the procedures necessary to obtain and dispense the solution of interest (e.g., first stop, second stop, and location of the tip within the microcentrifuge tube).

Students will also need a brief introduction of proper plating and labeling of the Petri dishes. Remind students to include labels on the base of each plate, not the lid. Students may need to use the microcentrifuge to spin down their samples periodically. When heat shocking the samples, students should keep the lid of the water bath closed to maintain a constant temperature. Also remind students not to flame the spreader if plastic disposable spreaders are provided instead of metal spreaders (Exercise 18.2.1.1, Step 11).

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18.2: Formative/Summative Questions

Formative Questions

1. How is plasmid DNA different from the bacterial chromosome?
2. What are competent bacteria? How can competency be artificially generated if necessary?
3. How does pAMP allow bacteria to survive in the presence of ampicillin?
4. What are restriction enzymes? Restriction sites?

Summative Questions

1. Define bacterial transformation.
2. On which of the four plates will only the antibiotic-resistant bacteria grow? Explain.
3. Calculate the transformation efficiency (TE; expressed as the number of antibiotic-resistant colonies per microgram of pAMP) for your bacteria. How does your TE compare with the average for our class?
4. Describe the steps required to create a recombinant plasmid.

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18.3: Pull Sheets/Materials

DAY 1

LIVE MATERIAL

Escherichia coli - MM294 - 2 slants (or plates)

- Carolina #21-1530
- Give to Micro tech when they arrive. They will need to make a total of 12 *E. coli* streak plates for this lab (we need 6 streak plates per section)
- *Note: this is not the same E. coli we use in Biol74 – this MM294 strain takes up plasmids more readily*

Plasmid pAmp – need 2

- Carolina #21-1430
- (if we have enough \$, can we order 1 extra to account for student pipetting errors? – if not, that is okay – cost is \$188/tube)

EQUIPMENT

Item	How many?
Gloves (s, m, l)	1 box of each
Goggles	30
Inoculating loops	6 (prefer 12 if available)
Spreading rods	6 (prefer 12 if available)
Bunsen burners	6
Strikers for Bunsen burners	6
Eppendorf tube racks	6
Plastic beakers for ethanol	6
Ice buckets OR Dyna Chill™ lab coolers (frozen before lab)	7 (6 for students, 1 for instructor plasmids)
Hot water bath – set to 42°C with trays in water bath to hold microcentrifuge tubes	1
P20 micropipettes (0-20ul)	6
P100 micropipette s (measure to 100ul)	6
P200 micropipettes (measure to 200ul)	6
Sterile micropipette tips (fit to micropipettes above)	6 boxes of each type
Sterile microcentrifuge tubes	40
Large waste beakers or jars Each labeled “Used Eppendorf Tubes & Pipette Tips”	3 (one per bench)

CHEMICALS & SOLUTIONS

Item	How many?
2.0 ml 0.05 M CaCl ₂ – in 250 µl Eppendorf tubes At least 250uL 0.05 M CaCl ₂ in each Eppendorf tube x 28 Eppendorf tubes (14 per section)	8 - <i>keep cold & sterile</i>
95% Ethanol - <i>keep cold</i>	200 ml in 2 Erlenmeyer flasks
2.0 ml Luria broth – in 250 µl Eppendorf tubes At least 250uL Luria broth in each Eppendorf tube x 28 Eppendorf tubes (14 per section)	8 - <i>keep cold & sterile</i>
LB/Amp agar plates Carolina #21-6621 (ready to pour, give to micro tech)	need 28 plates across 2 lab sections
LB agar plates (micro tech may be able to make)	need 28 plates across 2 lab sections
Spray cleaner or wavicide	3 bottles
Paper towels	3 rolls (or use those available in the lab room)

Note: After lab: Incubate inoculated Petri dishes at 37° C for 24 hours; then move to 5° C cooler.

DAY 2

Item	How many?
Spray cleaner or wavicide	3 bottles
‘Scotch’ (clear) tape or glue sticks (make sure they are fresh)	15

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CHAPTER OVERVIEW

19: Molecular Biology

[19.1: Instructor Guidelines](#)

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19.1: Instructor Guidelines

Purpose

Students are introduced to restriction enzymes and gel electrophoresis during this molecular biology lab. This is a 2-day lab, as students will run the gel during day one and view their results during the following lab. Students will use three different restriction enzymes to digest lambda DNA, and then separate their fragments using gel electrophoresis. Students will also create a standard curve using the HindIII digest and use this curve to determine the sizes of the unknown fragments generated by the EcoRI and PstI digests.

Tasks

Students will complete the following during this lab:

- Use three restriction endonucleases, PstI, EcoRI, and HindIII, to digest lambda bacteriophage DNA.
- Cast an agarose gel with DNA wells, set up an electrophoresis chamber, and load DNA samples into the gel.
- Stain and destain an agarose gel in order to identify DNA fragments.
- Create and use a standard curve to identify the sizes of unknown DNA fragments.

Day one of this lab is a long, intensive 3-hour lab that may require the instructor or lab technician to take additional time to stain or destain the gels after the lab in order to have the gels ready to view and analyze during the following lab. Although a pre-lab reading quiz is recommended, waiting until the middle of the lab session (e.g. during incubation or while the gels are solidifying) to complete the quiz may work best to ensure all of the steps can be completed during the lab period.

All of the students in each group should practice using the micropipettors several times before beginning the experiment. All students should also practice loading the practice gels with the practice loading buffer solution.

The restriction enzymes should be kept at the instructor's desk so that the instructor can ensure the proper volumes are added to each microcentrifuge tube. Casting trays will need to be taped on the top and bottom edges to prevent the agarose from leaking. Remind students that the height of the agarose should be just below the edge of the comb teeth to create proper wells for loading.

Once the agarose has set, flooding the wells with dI water will help students remove the combs without breaking the wells.

Once the power supplies have been turned on, ask students to check for small bubbles to ensure the chamber is working properly. Remind students to check their gels 5 minutes after starting to ensure the bands are running in the correct direction. During this time, each group of students should prepare a plastic Tupperware storage container (or equivalent) by labeling the lid with tape, and pouring enough methylene blue into the box to cover their gel. Gels will be transferred into the storage container to be stored in the refrigerator overnight. 24-hours later, the gels should be destained by removing the methylene blue and replacing with dI water for 24- hours. If more than 48-hours will pass before the next lab session, gels should be removed from the dI water, wrapped in plastic wrap to prevent drying, and stored in the storage container in the refrigerator.

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19.2: Formative/Summative Questions

Formative Questions

1. Why are three different restriction enzymes used in this lab?
2. If HindIII cuts lambda DNA at six different restriction sites and generates six fragments of DNA, is lambda DNA a circular or linear molecule?
3. Which restriction digest acts as the ladder for our gels? Explain.

Summative Questions

1. What is the purpose and function of restriction endonucleases?
2. What is the purpose of DNA gel electrophoresis?
3. How can known DNA fragment sizes be used to create a standard curve?

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19.3: Pull Sheets/Materials

The following DNA sample and restriction endonucleases will need to be ordered and arrive/stored prior to the start of this lab:

- **lambda DNA (bacteriophage lambda, 48,502bp)** **200uL (100uL/section)**
 - Thermofisher Catalog # SD 0011 (or equivalent)
 - <https://www.thermofisher.com/order/catalog/product/SD0011>
 - \$154 for one (*one should be enough for both lab sections*)
 - Note: volumes are based on 0.3 ug/uL concentration

- **Pst I enzyme – keep on ice** **12uL (6uL/section)**
 - Need 6uL per section
 - <https://www.thermofisher.com/order/catalog/product/ER0611>
 - \$28.98 for one (*one should be enough for both lab sections*)
 - Should come with buffer (need 30 uL of buffer /section)

- **Eco RI enzyme - keep on ice** **12uL (6uL/section)**
 - Need 6uL per section
 - <https://www.thermofisher.com/order/catalog/product/ER0271>
 - \$47.38 for one (*one should be enough for both lab sections*)
 - Should come with buffer (need 30 uL of buffer /section)

- **Hind III enzyme – keep on ice** **12uL (6uL/section)**
 - Need 6uL per section
 - <https://www.thermofisher.com/order/catalog/product/ER0501>
 - \$39.09 for one (*one should be enough for both lab sections*)
 - Should come with buffer (need 30 uL of buffer /section)

PREPARED MATERIALS:

Item	How many?
Gloves (s, m, l)	1 box of each
Electrophoresis chambers and power boxes models with dials/scales to adjust voltage	6
Electrophoresis trays and combs	6
Pans or trays (clean) To hold electrophoresis chambers	6
Ice bucket with ice	2
Extra Microcentrifuge (one is already in the lab room, need 2 total)	1
P-20 micropipettes	12
Micropipette tips for P-20	6 boxes
P-2 micropipettes	12
Micropipette tips for P-2	6 boxes
Plastic cling wrap	1 roll
Sharpie™ pens	6
Large beaker or jar labeled – “Used Pipette Tips and DNA Vials”	3 (1 per bench)
Waste container for methylene blue stain (keep in safety cabinet/hood)	1
Microtubes for practice	14 (7 per lab section)
Microtube racks	6
Water bath set to 55-60°C (for agarose)	1
Water bath set to 37°C (for enzyme digest)	1
7x7 plastic (Tupperware) boxes with lids for staining	12 (6/section)
Practice gels covered with water in Petri dishes	14 (7/section)
Agarose gel solution in flask (keep in 55°C water bath)	14 (7/section)
1X TAE solution - Divided into 2-3 flasks that students can pour (or enough for 7 gels and afternoon lab can reuse the morning lab solution)	enough for 14 groups in total
Practice solution – Colored Glycerin Water 1 mL in each microtube	14 total microtubes
0.025% Methylene Blue Staining Solution	enough for 14 gels
Microtubes with gel loading dye At least 15uL per microtube	14 microtubes

Do not dilute loading dye (keep it as it comes, 6x)	
4 color-coded microtubes (keep empty, students will fill) Labeled: L, P, E and H (different color for each tube)	12 of each color (6 of each per lab section)

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CHAPTER OVERVIEW

20: Scientific Method

[20.1: Instructor Guidelines](#)

[20.2: Formative/Summative Questions](#)

[20.3: Pull Sheets/Materials](#)

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20.1: Instructor Guidelines

This lab is designed as the first lab in the second semester of a introductory biology majors series. Students should have some experience with the scientific method. The lab reminds students of the scientific method framework, and has them practice using the framework with paper and lab-based examples.

There are paper-based examples students can work through if you don't have the supplies needed, or if there are issues with shipping or husbandry of termites. The paper-based examples may also be assigned as pre-labs or as homework, allowing students to focus on the in-class animal behavior experiment.

Future labs focus on evolution and biodiversity, so an introduction to taxonomy is included in this lab. This may be used in the first lab if time permits, as an at-home assignment, or with another lab.

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20.2: Formative/Summative Questions

Formative Questions

1. What is a hypothesis?
2. Define the word theory

Summative Questions

1. What are the parts or stages of the scientific method?
2. What is a positive control group?
3. What is a negative control group?
4. What is a dichotomous key, and how is it useful?

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20.3: Pull Sheets/Materials

Materials needed for termite experiment (for 25 students).

- 25 paint small paint brushes (pipe cleaners will also work)
- 25 small plastic holding cups
- 50 pieces of blank white paper (copier paper is fine)
- 6 black ink pens (like BIC, not gel)
- Various other writing implements (at least 4 of the same brand of each, give students many options)
 - Crayons
 - Markers
 - Pencils
 - Gel pens
- 6 protractors
- Live termites (can be purchased from Carolina or another biological supply)

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CHAPTER OVERVIEW

21: Evolution and Natural Selection

[21.1: Instructor Guidelines](#)

[21.2: Formative/Summative Questions](#)

[21.3: Pull Sheets/Materials](#)

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21.1: Instructor Guidelines

This lab is designed to introduce students to the concept of evolution via natural selection and begin to work with phylogenies (relatedness of organisms).

Students are expected to having some familiarity with genetics, and basic concepts like genes, alleles, genotype, and phenotype. A brief review of these key concepts can be helpful before talking about evolution and natural selection on certain traits.

Students should consider both selection on the predators and prey in their populations.

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21.2: Formative/Summative Questions

Formative Questions

1. What do you think of when you hear the word evolution?
2. What does "survival of the fittest" mean? How does this relate to evolution and natural selection?

Summative Questions

1. Define and give an example of convergent evolution
2. Define divergent evolution
3. Is natural selection the only mechanism of evolution? Why or why not?
4. What types of information can be used to create cladograms and understand relatedness of organisms?

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21.3: Pull Sheets/Materials

Materials needed for bean simulation (for 25 students)

- 4 different types of beans (at least 400-500 of each - a one pound bag of each should be enough)
- Plastic knives, forks, and spoons (20 ea)
- Chopsticks (20 sets)
- Forceps (20)
- 50 small paper cups
- 6 different table cloths of varying colors (camouflage)
- 4 plastic (0.5 L) containers (to count out collected beans)

Materials needed for phylogeny activity

- 6 small bags containing various metal items (paper clips, pins, screws, nails, washers, etc.). Recommend 10-12 different items in bag. You may want to include "outgroups", things like rubber bands or small plastic items.
- Activity can also be done with various shapes of pasta or candy.

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CHAPTER OVERVIEW

22: Microscopy Part III

[22.1: Instructor Guidelines](#)

[22.2: Formative/Summative Questions](#)

[22.3: Pull Sheets/Materials](#)

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22.1: Instructor Guidelines

This lab is designed to introduce the organismal study of bacteria and introduce key concepts in ecology (community interactions, succession). It is expected that students have experience with microscopy, including oil immersion, and gram staining bacteria. At Evergreen Valley College this lab is done in the second semester of the biology majors series, with the first semester being general and cell biology. If this lab is done in the first semester of a biology series or in a stand-alone biology course students will need prior labs on basic compound microscopy, use of oil immersion, gram staining bacteria, and safety training when working with bacteria.

The experimental setup requires 8 days of incubation of bacteria, which can be done by laboratory technicians or instructors. Those setting up the experiment should get whole plain milk and whole chocolate milk, then put the milks out on the counter in flasks (room temperature incubation) for 8 days, 4 days, 2 days, 1 day, and 0 days. Bacteria should be plated, and incubated for 24 hours at 37 degrees from each of these milk conditions, for a total of 10 plates. In the experiment, students will take data from the milk flasks and create and stain bacterial slides from the plates.

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22.2: Formative/Summative Questions

Formative Questions

1. What is an ecological community?
2. What organisms might you expect to find in milk left at room temperature?
3. Using chocolate milk and plain whole milk, come up with a hypothesis for what will happen if those milks are left out at room temperature. Will there be a difference in organisms seen in the two milk conditions? Will this change over time?

Summative Questions

1. What is an ecological community?
2. Define biological succession
3. What information can be gained from doing a gram stain?
4. Are bacteria the only organisms we might find in milk left at room temperature? Why or why not?
5. What do you think would happen if we left the milk for longer? 10 days? 12 days?
6. Why did you take pH in the different milk conditions? What do changes in pH indicate about presence or absence of certain organisms?

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22.3: Pull Sheets/Materials

Note: This lab requires bacteria to be grown and prepared ahead of time. Begin experimental setup 9 days before the lab.

Pre-lab setup:

- 100mL flasks of plain and chocolate milk aged 0 (refrigerated and then kept on ice), 1, 4, and 8 days
- TGY agar plates with milk growth for each milk type

Materials needed for students in lab (25 students per lab).

- Colored pencils
- Prepared slides of gram stain negative and gram stain positive bacteria (for comparison)
- Gramstaining(3-6“sets”)
 - Crystal violet
 - Iodine
 - Safranin
 - 95% Ethanol
 - Immersion oil
 - Water droppers
- Wax pencils (6-12)
- Placemats/Staining matstopreventstainingthelabbenches
- Microscope slides (100)
- Clothespinstoholdslides(30)
- Staining tray(6)
- Bunsen burner and tubing (6)
- Bunsen burner lighter(6)
- DI water bottle (6)
- Protective Equipment: Goggles, gloves, lab coats
- Hazardous material container for gloves and toothpicks
- Hazardous material container for the gram stain
- pH paper (6 tubes)
- Transfer pipets
- Nutritional Info for milk

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CHAPTER OVERVIEW

23: Protist Diversity

[23.1: Instructor Guidelines](#)

[23.2: Formative/Summative Questions](#)

[23.3: Pull Sheets/Materials](#)

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23.1: Instructor Guidelines

This lab is designed to help students understand eukaryotic origins and evolution, and introduce students to the diversity of protists. The phylogeny of eukaryotes is updated often, so we use this as an example for students that phylogenies are hypotheses. We use the [Openstax Biology 2e](#) textbook for the lecture portion of the course, so use this eukaryotic phylogeny for consistency.

This lab will greatly depend on what the institution has access to. Prepared slides are good for understanding diversity, while live specimens and pond water are exciting for students and teach new microscopy skills.

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23.2: Formative/Summative Questions

Formative Questions

1. Based on the tree of life, was there a single origin of eukaryotes (organisms with nucleated cells) or multiple?
2. Are all organisms known as "protists" singled-celled organisms? How do they obtain their food?
3. If you were shown an algal species that produced large amounts of carotenoids, what would you infer about the ecology of this organism? Explain your reasoning.
4. What regions of the spectrum of light do chlorophylls absorb? Which part do they reflect?

Summative Questions

1. What is a protist?
2. Are protists a monophyletic group? Why or why not?
3. What are the current supergroups within Domain Eukarya, and why are they grouped the way they are?
4. How many times did multicellularity evolve in eukaryotes?

Contributors and Attributions

- [Maria Morrow](#) ([College of the Redwoods](#))

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23.3: Pull Sheets/Materials

Materials for protist diversity lab

- Pond water
- Pond water identification book
- Pond water posters
- Microscope slides and coverslips (4 of each/student)
- 2-3 water droppers to transfer pond water to microscope slide Methyl cellulose dropper to slow organisms
- Live specimens
 - Amoeba
 - Paramecium
 - Euglena
- Bleach bath for slides
- Macro Specimens
 - Brown Algae (Phaeophyta)
 - Red Algae (Rhodophyta)
 - Green Algae (Charophyta)
- Prepared slides (locations at EVC in parentheses)
 - Trypanosoma gambiense blood smear, rat (Micro C - 25)
 - Euglena (Bot B - 4)
 - Diatom Stew (Micro A - 24)
 - Paramecium caudatum (Bio 1-1 - 10)
 - Dinoflagellates (Bio 1-6 - 13)
 - Radiolarians
 - Plasmodium vivax (blood smear) (Bio 1-1 - 4)
 - Foraminifera (Bio 1-1 - 3)
 - Amoeba proteus (Bio 1-1 - 1)
 - Chlamydomonas (Bot A - 9)
 - Spirogyra vegetative (Micro A - 19)
 - Ulva (Bot-A - 24)

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CHAPTER OVERVIEW

24: Fungal Diversity

[24.1: Instructor Guidelines](#)

[24.2: Formative/Summative Questions](#)

[24.3: Pull Sheets/Materials](#)

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24.1: Instructor Guidelines

Objectives: Introduce students to the diversity of fungi, help students get to know major groups, help students understand fungal life cycles and position of fungi in the tree of life.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of major groups (zygomycota, ascomycota, basidiomycota).

Ensure students to exercise caution and to not open or breathe in molds or other organisms/specimens of concern.

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24.2: Formative/Summative Questions

Formative Questions

1. What is a fungus? What traits do you associate with being fungal?
2. Which group of organisms do you think fungi are most closely related to? Explain your reasoning.
3. What does the term symbiosis mean to you? How do you think this is different from the term mutualism?
4. What is the function of a mushroom? Do all fungi make mushrooms?

Summative Questions

1. How would you classify a heterotrophic eukaryote with a filamentous thallus? What traits would you need to make your determination?
2. Fungal hyphae are much smaller in diameter than plant roots. How would this influence the ability of a mycorrhizal fungus to acquire water and nutrients from the soil, in comparison to the plant?
3. Compare and contrast yeast and conidia.
4. What classifies something as a mold?
5. Where do you most often see molds and how might this relate to the reproductive strategy of these organisms?
6. Describe what is happening in the *Rhizopus* life cycle diagram below. Label important structures and note where fertilization and meiosis are occurring. Choose a different color to represent haploid and diploid tissues.

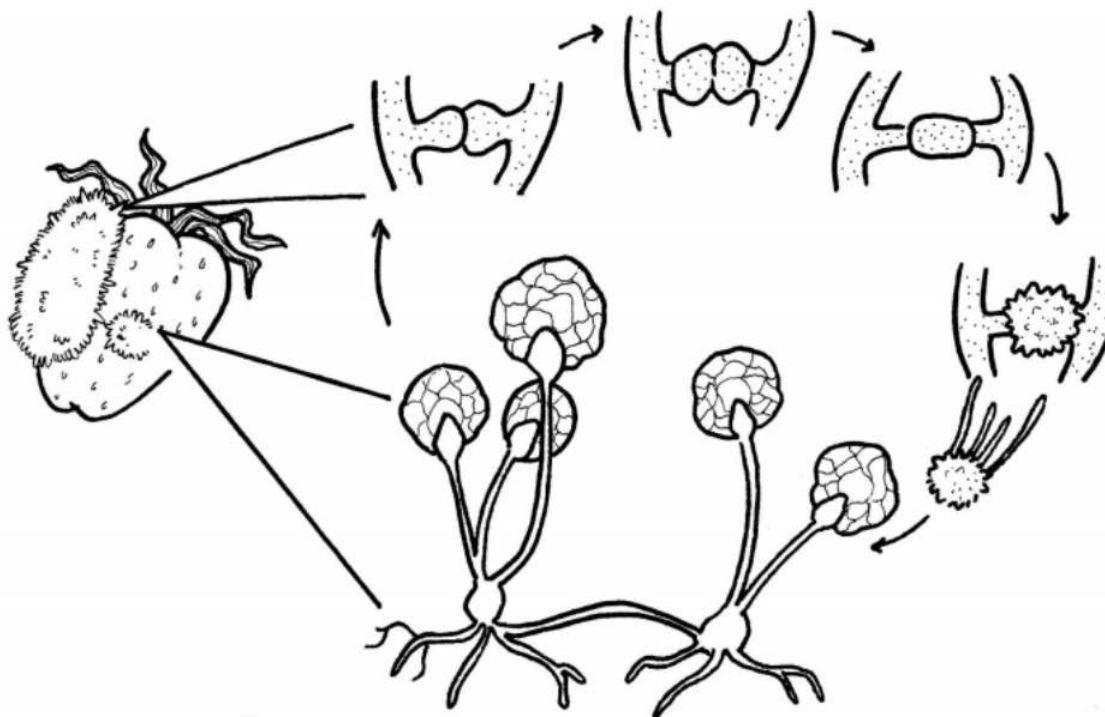


Figure 24.2.1: *Rhizopus* life cycle diagram

7. What determines whether a fungus is considered microfungi or macrofungi?
8. How would you differentiate between an ascomycete and basidiomycete? Which features would be most helpful in making this determination?
9. Fungi can form many different types of symbiotic relationships with plants. Compare and contrast parasitic and mutualistic symbioses.
10. What is a lichen? How would you classify this in the tree of life and why?

11. How do lichens obtain food? Are they autotrophic or heterotrophic? Explain your reasoning.
12. Label the structures present in the diagram on the next page and identify the group of fungi that each of these is from. Choose a different color to represent haploid, diploid, and dikaryotic tissues.

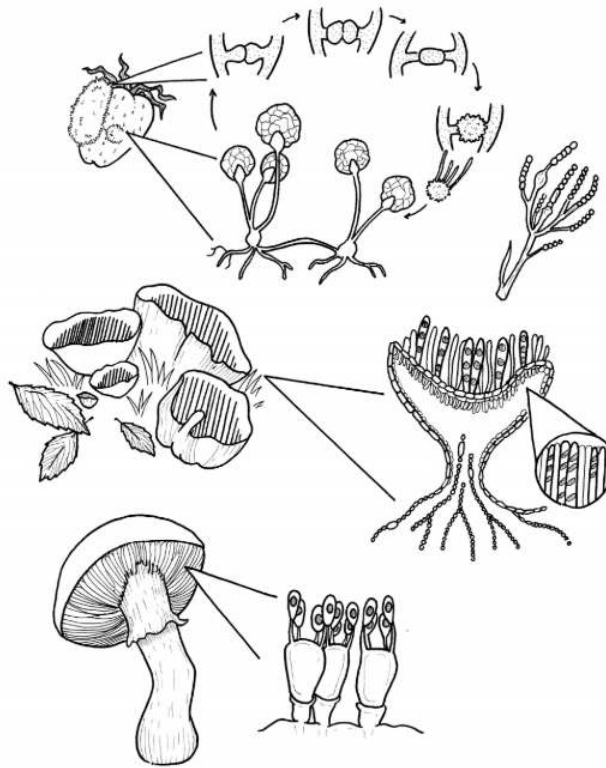


Figure 24.2.1: Fruiting structures of Kingdom Fungi

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24.3: Pull Sheets/Materials

These labs require student access to compound microscopes and dissecting microscopes.

Materials needed (for 25 students)

- Zygotc Fungi (Phylum Zygomycota)
 - *Rhizopus* Prepared slides
 - *Rhizopus* zygosporc (sexual Spore) (EVC Location: Micro-C - 12)
 - *Rhizopus* sporangiosporc (asexual spores) (EVC Location: Micro-B - 5)
 - Live specimens - Culture plates *Rhizopus*
- Sac Fungi (Phylum Ascomycota)
 - *Peziza* and *Penicillium* Prepared slides
 - *Peziza apothecium* (disc-shaped fruiting body) (EVC Location: Micro-B - 10)
 - *Penicillium* mycelium conidiophores (EVC Location: Micro-B - 8)
 - Live specimens - Culture plates *Penicillium*
- Club Fungi (Phylum Basidiomycota)
 - *Coprinus*, Puffball, edible mushrooms
 - Models/Preserved Specimens
 - Nest fungi
 - Puffball
 - Shelf/bracket fungi
 - Model of edible mushroom
 - Prepared slides
 - *Coprinus* entire pileus (EVC Location: Micro-B - 11)
 - Live specimens Edible mushroom for dissection
- Lichen
 - Models/Preserved Specimens Lichens

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CHAPTER OVERVIEW

25: Plant Diversity

[25.1: Instructor Guidelines](#)

[25.2: Formative/Summative Questions](#)

[25.3: Pull Sheets/Materials](#)

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25.1: Instructor Guidelines

This lab is designed to take place over two 3-hour lab periods, with one lab period devoted to seedless plants and one devoted to seed plants. The lab manual and instructor guidelines are formatted in this way to support two lab periods.

Seedless plant lab

Objectives: Introduce students to the diversity of seedless plants, help students get to know major groups, help students understand adaptations of early plants and features assisting in the transition to land.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of major groups (mosses, liverworts, hornworts, club mosses, ferns, horsetails, whisk ferns).

Seed plant lab

Objectives: Introduce students to the diversity of seed plants, help students get to know major groups, help students understand the importance of seeds, and how life cycles and features (like fruits and flowers) have made these groups so successful and diverse today.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of major groups (gymnosperms and angiosperms).

Send students on a campus scavenger hunt and list gymnosperms and angiosperms found. Have students download the [Seek by iNaturalist](#) app on their phone (group students if not all have devices). This app can be used for the outdoor campus identification for this and future labs.

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25.2: Formative/Summative Questions

Seedless Plants

Formative Questions

1. What new environmental stressors would an alga need to adapt to if it were to try to move onto land?
2. Choose one of the stressors you mentioned above. Try to come up with a few ways that you could modify the alga to be adapted to that stressor (changes in specialized cells, changes in tissue composition and types of biomolecules present, changes in organ structure, etc...). Explain how these modifications would help the alga adapt to those conditions. Drawings or diagrams may help.
3. When bryophytes evolved on land, they didn't have to compete with other plants. What were the major selective pressures for the bryophytes?
4. If seedless vascular plants evolved after bryophytes began to colonize terrestrial surfaces, this would indicate a new major selective pressure: competition. What features might enable a fern to outcompete a moss?

Summative Questions

1. Describe three adaptations that bryophytes have specifically for life on land.
2. Explain why bryophytes tend to be so small in stature and are often found growing close to a surface.
3. How would you tell the difference between a leafy liverwort and moss? Describe at least two things you could look for.
4. Describe three adaptations that seedless vascular plants (SVPs) have that allow them to compete with bryophytes.
5. Commonly called spike mosses and club mosses, lycophytes aren't truly mosses at all. How could you distinguish between a moss and a lycophyte?
6. Compare and contrast the role of the gametophyte in bryophytes and SVPs.
7. What are the advantages to having a branching sporophyte?
8. Compare the life cycles of a moss and a fern - how is the alternation of generations seen in each organism?

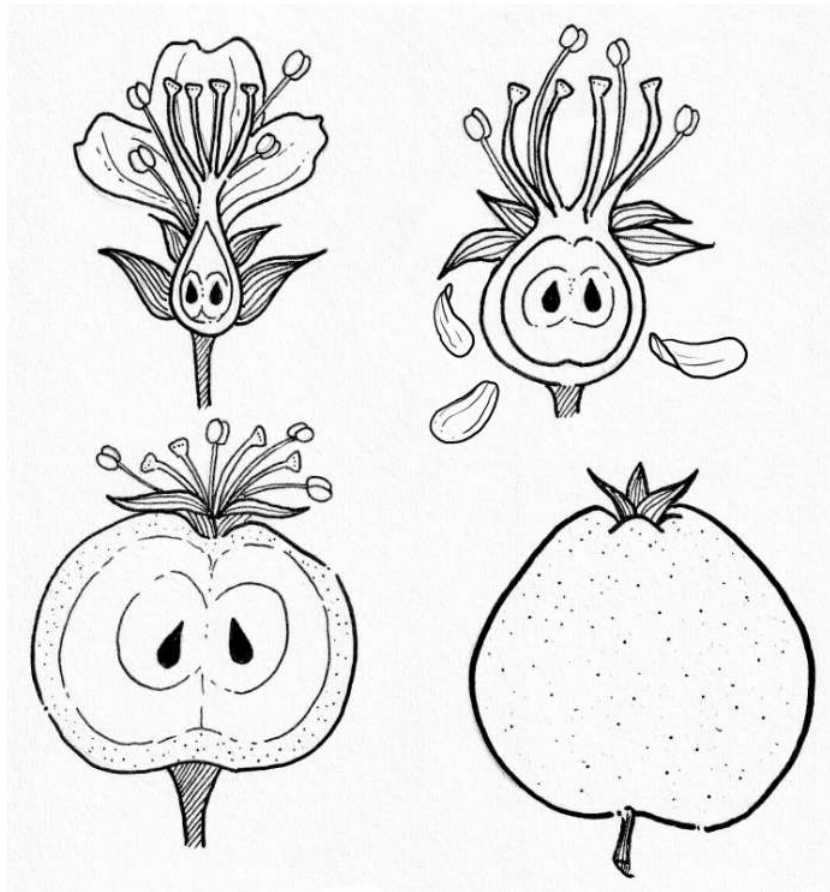
Seed Plants

Formative Questions

1. When you think of plants adapted to dry conditions, what comes to mind? What features do these plants have?
2. Would a snowy environment be considered a dry environment for a plant? Why or why not?
3. When you think of a flower, what characteristics come to mind?
4. How might those characteristics relate to the function of a flower?
5. When you think of a fruit, what characteristics come to mind?
6. How might those characteristics relate to the function of a fruit?

Summative Questions

1. What is pollen?
2. Why was pollen an important adaptation for gymnosperms, considering the changing global conditions?
3. What adaptations do gymnosperms share that allowed them to compete with SVPs?
4. Describe the advantages provided by the adaptations you listed in the previous question and relate them to changes in global climate.
5. How would you differentiate a fern and a cycad?
6. In what climate(s) would you be most likely to find gymnosperms? Explain your answer.
7. How could the coevolution of angiosperms and pollinators explain the vast radiation in species that angiosperms experienced?
8. How does the structure of a vessel element relate to the ability of angiosperms to compete with gymnosperms?
9. Where does meiosis occur in the flower?
10. What is the function of a fruit?
11. How could you distinguish between a fruit and a vegetable at the grocery store?
12. In the diagram below, an apple blossom is developing into a fruit. Label all of the parts of fruit and flower anatomy that you can see. What type of fruit is this?



13.

Figure 25.2.1: Copy and Paste Caption here

14. What food sources does the embryo have before it opens its first leaves in the sunlight?

15. Oaks and alders are both angiosperms that grow into trees. Oaks produce nuts with large seeds, while alders produce tiny samaras. In a year in the life of a black oak, it might grow 50 cm and produce 6500 nuts. In that same year, a red alder might grow 1-2 meters and produce around 5 million samaras. What are the tradeoffs between these two very different strategies? How might they relate to the different life histories of oaks and alders?

16. Contributors and Attributions

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25.3: Pull Sheets/Materials

These labs require student access to compound microscopes and dissecting microscopes.

Materials needed for seedless plant lab (for 25 students)

Bryophytes (seedless, nonvascular plants)

- Models/Preserved Specimens: Mosses (Bryophyta), liverworts (Hepatophyta), hornworts (Anthocerophyta) collection (EVC location: S115, UGC 4)
- *Marchantia*: Model and key of *Marchantia* (liverwort) life cycle
- Moss life cycle poster
- Prepared slides
 - *Mnium* (moss) antheridia (EVC location: Bot-C - 18)
 - *Mnium* archegonia head (EVC location: Bot-C - 19)
 - *Mnium* sporophyte (EVC location: Bot-C - 20)
- Live specimens
 - Female and male liverwort, Genus *Marchantia*
 - Fruiting and vegetative moss, Genus *Mnium*

Seedless vascular plants

- Fern life cycle poster
- Preserved specimens
 - Club moss (Lycophyta > *Selaginella* (spike moss) or *Lycopodium* (club moss))
 - Horsetails (Monilophyta > *Equisetum*)
 - Whisk Ferns (Monilophyta > *Psilotum*)
- Prepared slides
 - *Selaginella* strobilus (EVC location: Bot-C - 23)
 - Fern Prothallus anth and arch (EVC location: Bot-D - 4)
 - Fern Prothallus sporophyte (EVC location: Bot-D - 5)
- Live specimens
 - Club moss (Lycophyta > *Selaginella* (spike moss) or *Lycopodium* (club moss))
 - Horsetails (Monilophyta > *Equisetum*)
 - Whisk Ferns (Monilophyta > *Psilotum*)

Materials needed for seed plant lab (for 25 students)

Gymnosperms

- Pine life cycle poster
- Preserved Specimens
 - Cycad (Cycadophyta)
 - Ginkgo (Ginkgophyta)
 - Mormon tea (Gnetophyta > *Ephedra*)
 - Pine or spruce; Juniper, hemlock, fir (Coniferophyta)
- Models/Prepared specimens
 - Pine (ovulate cone and staminate cone) (EVC location: EVCS-115. UGC 4)

- Riker mounts: common gymnosperms (EVC location: S-115, LGC 2)
- Male and female pine cone
- Prepared slides
 - Pinus w.m. of pollen (EVC location: Bot-D - 16)
 - Pinus female cone l.s., for ovule (EVC location: Bot D - 17)
- Live specimens
 - Pollen/Staminate cones and ovulate cones

Angiosperms

- Models/Prepared Specimens
 - Apple blossom flower model (EVC location: S-115, GC 4)
 - Dicotyledonous and monocotyledon flower models (EVC location: S-115, UGC 3)
 - Riker mounts: flower types and inflorescences (EVC location: S-115, LGC 2)
 - Pollination type display
- Prepared Slides
 - *Lilium* anthers mature pollen (EVC location: Bot-F - 9)
 - *Lilium* ovary (EVC location: Bot-F - 11)
- Live specimens
 - Live flowers (At least 4 different types, complete flower with male and female parts) - *try not to get all lilies as some students may be allergic*
- For flower anatomy
 - Razor blades (12)
 - Plastic petri dishes

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CHAPTER OVERVIEW

26: Animal Diversity

[26.1: Instructor Guidelines](#)

[26.2: Formative/Summative Questions](#)

[26.3: Pull Sheets/Materials](#)

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26.1: Instructor Guidelines

Objectives: Introduce students to the diversity of animals, help students get to know major groups, discuss evolution of animals and position the kingdom in the tree of life.

Major animal groups are represented in this lab, with a discussion of phylogeny and evolution of animals. Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of major groups (porifera, cnidaria, lophotrochozoa, ecdysozoa, deuterostomia (echinodermata and chordata)).

Crayfish dissection can be done with the animal tissues lab (chapter 29) if time is of concern. Students can be advised that they will get much more exposure to chordata (vertebrata) in the dissections in chapter 30.

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26.2: Formative/Summative Questions

Formative Questions

1. What is an animal?
2. What is heterotrophy? Describe this, and give an example of another organismal group that exhibits this
3. What is the most basal group of animals in evolutionary terms?

Summative Questions

1. How is a coelom different than a digestive tract?
2. What are the different types of body symmetry seen in animals? Which animal groups exhibit each type?
3. What differentiates lophotrochozoa, ecdysozoa, and deuterostomia?
4. What is the most basal group of animals in evolutionary terms?
5. What group is the sister taxa to animals, and why is this thought to be true?
6. What are the common characteristics of chordata?

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26.3: Pull Sheets/Materials

This lab requires access to dissection and compound microscopes.

Materials needed for animal diversity lab (for 25 students)

Major animal groups are represented in this lab, with a discussion of phylogeny and evolution of animals. You may use representatives for each phylum available to you at your institution.

Phylum Porifera

Sponges/*Scypha* Models

Sponge

Biosmounts: *Porifera* Preserved Specimens

Scypha

Dry large sponge

Dry Venus Flower Basket (Glass sponge) Riker mounts: Finger sponge

Phylum Cnidaria

Preserved Specimens

Riker mounts: Fan coral

Biosmounts: Coral collection, Coelenterate (jellyfish, coral, sea anemone etc) Models

Hydra

Aurelia (jellyfish) Sea anemone

Prepared slides

Hydra (Bio 1-1 - 17) cross section, not useful *Hydra* plain budding (Bio 1-1 - 16)

Live specimens

Hydra

Lophotrochozoa

Phylum Platyhelminthes

Preserved Specimens

Tapeworms Models

Planaria

Prepared slides

Planaria (Bio 1-1 - 23)

Planaria plain and digestive tract (Bio 1-1 - 23) *Taenia pisiformis* (Bio 1-1 - 24)

Clonorchis sinensis (Bio 1-2 - 1)

Live specimens

Planaria

Empty petri dish and small pieces of liver

Phylum Mollusca

Preserved Specimens

Preserved octopus in jar

Dissected squid mount

Biosmounts: Mollusks (squid, oyster, scallop, limpet)

Models

Mussel

Phylum Annelida - Clamworms/*Nereis*, Earthworms/*Lumbricus terrestris* (18.5) Preserved Specimens

Preserved mount of *Lumbricus* (Earthworms) - dissected?, Leech, Tubeworm, Polychaete (bristleworm)

Biosmounts: Annelids

Models

Segmented worm

Phylum Nematoda - Roundworms/*Ascaris* (19.1) Preserved Specimens

Female and male *Ascaris* Roundworm biosmount (Hall GC 6) Prepared slides

Trichinella spiralis (parasitic nematode) encysted (Bio 1-2 - 4) *Ascaris lumbricoides* (Bio 1-2 - 3)

Phylum Arthropoda (19.2)

Gooseneck barnacles in jar

Grasshoppers in jar Riker mounts

Centipede and Millipede

Tarantula

Biosmount of arthropoda (Crayfish, Shrimp, Barnacles, Crab) Prepared slides

Flea (Bio 1-5 - 8) Louse Hog (Bio 1-5 - 6)

Phylum Echinodermata - Sea Star (19.3)

Preserved Specimens

Dry specimens of Sea Stars (Two)

Box trays: Echinoderms, Sea Stars

Riker mount containing Sand Dollar, Sea Star, Sea Urchin and Sea Cucumber, Brittle Star, Feather Star

Phylum Chordata (19.4)

Set of chordates (Hall GC 4) Preserved Specimens

Sea Tunicates (Sea Squirts)

Amphioxus (Lancelet) Prepared slides

Tunicate larvae (Bio 1-5 - 12)

3-4 Vertebrate mounts (birds, mammals)

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CHAPTER OVERVIEW

27: Plant Anatomy and Transport

[27.1: Instructor Guidelines](#)

[27.2: Formative/Summative Questions](#)

[27.3: Pull Sheets/Materials](#)

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27.1: Instructor Guidelines

Objectives: Introduce students to basic plant anatomy and physiology. Discuss specialization of cells, creation of tissues and organs in plants. Discuss modifications and adaptations of plant organs.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of plant tissues and organ identification.

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27.2: Formative/Summative Questions

Formative Questions

1. Can unicellular organisms have tissues? Explain your answer.
2. Why would a nucleus be required for an organism to be multicellular? What does this organelle allow cells to do?
3. What is the function of a root?
4. How does its structure contribute to that function?
5. What is the function of a stem?
6. How does its structure contribute to that function?
7. What is the function of a leaf?
8. How does its structure contribute to that function?
9. What part of a plant do you think the following things you'd get at the grocery store are:
 - Onion
 - Potato
 - Ginger
 - Lettuce
 - Broccoli
10. What do you think are the most important selection pressures on plants?
11. Which of these do you think is the most important for determining plant anatomy and morphology? Explain your reasoning.

Summative Questions

1. What are the three main cell types in a plant?
2. What are the three main tissue types in a plant, and what is a specific example of each?
3. What is the function of the xylem tissue and which specialized cells are involved in this function? Was this a simple or complex tissue in the specimens you viewed?
4. What is the function of the phloem tissue and how do the specialized cells in this tissue contribute to this function? Was this a simple or complex tissue in the specimens you viewed?
5. One of the characteristics of living things is a hierarchical (nested) organizational structure. Organize the following terms into a nested structure: specialized cell, organ, organism, tissue, organelle.
6. Open stomata result in water loss through transpiration. Why don't plants just close their stomata to prevent water loss?
7. How does the diameter of a conducting cell in the xylem influence the ability of the plant to take up water?
8. What type of environmental conditions might select for a netted root system or a taproot system? Explain your answer.
9. Why would a plant evolve to produce roots from stem tissue? What benefits does this provide the plant?
10. What is the function of meristematic tissue? In what parts of a plant would you see meristematic tissue?
11. Categorize the plant modifications described above as an adaptation in response to the following stressors. Briefly state how each modification helps the plant deal with the particular stressor.
 - a. Water availability:
 - b. Access to sunlight:
 - c. Nutrient availability:
 - d. Defense against herbivory
12. How do you differentiate between a stem and a root? What about a stem and a leaf? Consider both macroscopic and microscopic options.

Contributors and Attributions

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27.3: Pull Sheets/Materials

This lab requires access to dissection and compound microscopes.

Materials needed for plant anatomy and transport lab (for 25 students)

You may use substitute plants or slides as available at your institution.

Plant Morphology

Living bean or geranium plant - 1/table (6) or 1/pair (14) Squirt bottle of water - 1/table (6)

Plant Primary Growth

Prepared slides

Coleus stem tip (BOT-E - 12) - needs to be long section

Cell Structure of Primary Tissues

Prepared slides

Monocot and dicot stems (BOT-F - 19) Lilium stem (BOT-E - 11)

Lilium root (BOT-D - 25)

Lilium leaf epidermis (BOT-F - 4)

Celery stalks (2-3)

Pears (2)

Razor blades or scalpels

Slides and coverslips for wet mounts

Toluidine blue

Root system demonstration

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CHAPTER OVERVIEW

28: Plant Growth

[28.1: Instructor Guidelines](#)

[28.2: Formative/Summative Questions](#)

[28.3: Pull Sheets/Materials](#)

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28.1: Instructor Guidelines

Objectives: Focus on plant physiology, with demonstrations and experiments concerning plant growth. Student design and execute their own experiments on seed germination and plant growth.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. Additional longer-term project can be done using Wisconsin Fast Plants, which data can be used for students to write a formal lab report.

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28.2: Formative/Summative Questions

Formative Questions

1. What are some factors that limit how tall a plant can grow?
2. What are some factors that limit where a plant can grow?

Summative Questions

1. How is the production of secondary meristems different in the shoot and the root?
2. What are the tradeoffs (costs and benefits) to secondary growth?
3. What is the function of a lenticel?
4. Would roots in secondary growth need lenticels? Why or why not?
5. What is the function of a xylem ray?
6. How could you distinguish phloem fibers from other phloem cells? What cell type are phloem fibers?
7. What type of questions could you answer with dendrochronology if you didn't have a living reference specimen to connect the cores to the current date?
8. Girdling is a process used to slowly kill a tree and/or to create a standing dead tree (a snag). Both the outer and inner bark of the tree is removed all the way around a section of the trunk. Often, this also removes or damages the vascular cambium. Explain why girdling would kill the tree.

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28.3: Pull Sheets/Materials

This lab requires access to dissection and compound microscopes.

Materials needed for plant growth lab (for 25 students)

Factors Influencing Seed Germination (21.1) - need a couple days to prepare demos

Demo: Germinating bean seeds (at least 12) for students to observe

Demo: Germinating *Brassica rapa* seeds (at least 12) for students to observe

Radish seeds (not sure what size bags come in - 50? 100?)

As many other varieties of seeds as can be found

Empty petri dishes (at least 20/section)

Filter paper (at least 20/section)

Different pH solutions (3, 7, 11)

Different colored cellophane sheets (at least 3 types)

Foil

Coffee grounds

10% NaCl (100 mL) or NaCl (so students can make their own various salinity solutions) Detergent - dishwashing and laundry

dH₂O

Serological pipets - 5 and 10 mL (30 of each)

Transfer pipets

Depression well slides (6)

Plant Growth Regulators: Auxin (21.2) - need at least 10 days - 2 weeks to prepare demos

Demo: Coleus plant placed on its side Demo: Coleus plant in unilateral light Demo: Coleus plant in upright position

Plant Growth Regulators: Gibberellins (21.3) - need at least 4 weeks to prepare demos

Demo: 4 pots (2 with tall corn seedlings and 2 with dwarf corn seedlings, each type of corn seedling will have 2 treatments: water and gibberellin)

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CHAPTER OVERVIEW

29: Animal Tissues

[29.1: Instructor Guidelines](#)

[29.2: Formative/Summative Questions](#)

[29.3: Pull Sheets/Materials](#)

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29.1: Instructor Guidelines

Objectives: Introduce students to major animal tissue types. Discuss specialization of cells, creation of tissues and organs in animals.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting college. If lab is modified, ensure adequate representation of animal tissues. Crayfish dissection from chapter 26 may be performed during this lab to discuss tissues in situ.

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29.2: Formative/Summative Questions

Formative Questions

1. What tissues are found in animals?
2. Thinking about a cross-section through the knee of an animal, what tissues or cell types would you expect to find there?

Summative Questions

1. What are the four major tissue types found in animals and what are their functions?
2. How does epithelial tissue structure contribute to its function?
3. How does muscle tissue structure contribute to its function?
4. How does nervous tissue structure contribute to its function?
5. How does blood tissue structure contribute to its function?
6. How does bone tissue structure contribute to its function?

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29.3: Pull Sheets/Materials

Prepared slides

Simple squamous epithelium

Simple cuboidal epithelium (A&P-1 - 9)

Simple columnar epithelium (A&P-1 - 7)

Stratified squamous epithelium

Areolar (loose) connective tissue (A&P-2 - 13)

Adipose tissue (A&P-2 - 7)

Bone human ground (and) Bone mammal compact (A&P-2 - 10)

Hyaline cartilage (A&P-2 - 12)

Blood human Wright (A&P-2 - 5)

Muscle composite (A&P-2 - 9) ??? Is the right slide? - I want the 3 muscle types slides.

Nervous tissue slide

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CHAPTER OVERVIEW

30: Comparative Animal Anatomy

[30.1: Instructor Guidelines](#)

[30.2: Formative/Summative Questions](#)

[30.3: Pull Sheets/Materials](#)

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30.1: Instructor Guidelines

This lab is designed to take place over two 3-hour lab periods, with one lab period devoted to comparison of invertebrate and vertebrate systems and one devoted to comparison across vertebrate systems. The lab manual and instructor guidelines are formatted in this way to support two lab periods.

Comparative Anatomy Lab I

Objectives: Introduce students to the animal anatomy and physiology, with a focus on form and function. Compare invertebrate and vertebrate systems.

At Evergreen Valley College we use squid and frogs as representative dissections for invertebrates and vertebrates.

How do animal bodies solve problems? All animals need to obtain oxygen, transport things within the body, obtain and digest food, move, protect their bodies, reproduce, and more. Shaped by evolutionary pressures, animals will have different anatomy to support the physiology (function) of their systems in their environment.

Pull sheets contain materials for a 25 student lab, with three of each animal dissected during the lab period. Students begin by drawing and labeling external anatomy of both the squid and the frog. Groups of 4-5 students are paired up with another group, such that one group of students dissects the squid, the other dissects the frog, and all students examine, draw, and label the internal anatomy of both the squid and the frog. Use of six total animals per class allows for contact and opportunity for all students, while being aware of budget limitations and maximal educational value of the use of animals.

Pull sheets include personal protective equipment (PPE) for students and appropriate disposal mechanisms for biohazardous material. Ensure dissections completed at your institution are using appropriate safety procedures and disposal adheres to local and federal guidelines.

Comparative Anatomy Lab II

Objectives: Compare body systems of animals across vertebrate taxa. Students dissect birds and mammals, and compare these dissections to their previous work on amphibians. Dissection comparison is enhanced by a comparison of vertebrate skeletal systems, with full skeletons and skull models on display.

Pull sheets contain specimens, models, slides, and posters in use at Evergreen Valley College. Lab may be modified depending on resources and availability of specimens at adopting institution.

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30.2: Formative/Summative Questions

Formative Questions

1. What is homeostasis?
2. What are the major processes an animal body needs to do?
3. What are some major differences between invertebrate and vertebrate anatomy?
4. How do animals that live in the water and on land breathe differently?
5. What are the functions of skin in an animal?
6. How has the vertebrate body form changed over evolutionary time?

Summative Questions

1. What is the form and function of sensory systems in the squid, the frog, the pigeon, and the rat?
2. What is a complete digestive tract?
3. How is the specialization of different parts of the digestive tract adaptive?
4. How do the kidneys and liver contribute to homeostasis?
5. Compare and contrast respiratory surfaces of the four animals dissected. Are they the same size? Different?
6. Explain how the respiratory and cardiovascular systems are interrelated.
7. Describe an open vs. closed circulatory system
8. How are invertebrate and vertebrate hearts different? Do all animals have the same number of chambers in the heart?
9. What is an advantage of a 4-chambered heart over a 3-chambered heart?

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30.3: Pull Sheets/Materials

Comparative Anatomy Lab I

- 3 preserved squids
- 3 preserved frogs
- PPE for students (disposable aprons, goggles, gloves)
- 6 Dissection trays
- 6 sets of dissection tools
- Disposal bucket for animal parts (check local and federal hazardous waste disposal protocols)

Comparative Anatomy Lab II

- 3 preserved pigeons
- 3 preserved rats
- PPE for students (disposable aprons, goggles, gloves)
- 6 Dissection trays
- 6 sets of dissection tools
- Disposal bucket for animal parts (check local and federal hazardous waste disposal protocols)
- Set of vertebrate skulls, skeletons, and brains

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CHAPTER OVERVIEW

31: Experimental Physiology

[31.1: Instructor Guidelines](#)

[31.2: Formative/Summative Questions](#)

[31.3: Pull Sheets/Materials](#)

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31.1: Instructor Guidelines

Objectives: Introduce students to experimentation in animal physiology. This lab focuses on hypothesis testing, experimental design, and physiology in situ.

Pull sheets contain materials for a class experiment on the effect of caffeine (and caffeine dosage) on daphnia heart rate. Students can use daphnia for other experiments as well (ethanol, sugars, pollutants, etc.).

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31.2: Formative/Summative Questions

Formative Questions

1. How is heart rate set in an animal?
2. What factors affect heart rate?
3. Why is a control group important in an experiment?

Summative Questions

1. Is heart rate variable within an animal or within a species? Why or why not?
2. What effect does caffeine have on heart rate in daphnia? Is this consistent with other studies on caffeine and heart rate in other animals?

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31.3: Pull Sheets/Materials

Per pair of students

Microscope

Concavity slides (1-2)

Plastic pipettes (2)

Small scissors

Daphnia (*Daphnia magna* preferred, *Daphnia pulex* is ok but will make counting heart rate more difficult)

Stopwatch

Daphnia anatomy diagram (laminated)

Thermometer

Ice

Spring water

Beakers (2)

Petri dishes (2)

Caffeine solution (.1 mg/L, 1 mg/L, 10 mg/L) – caffeine solutions must be prepared in spring water, not distilled or tap.

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CHAPTER OVERVIEW

32: Field Biology and Ecology

[32.1: Instructor Guidelines](#)

[32.2: Formative/Summative Questions](#)

[32.3: Pull Sheets/Materials](#)

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32.1: Instructor Guidelines

Objectives: Introduce students ecosystems and ecology, and how field biologists study these topics.

This lab is a series of paper-based exercises or exercises that can be done using your local campus or ecosystems. We recommend having students go outside and identify ecosystems and organisms on campus or nearby and bring that information back to lab. This information (accompanied by research) can help students complete the "Modeling a food web" exercise.

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32.2: Formative/Summative Questions

Formative Questions

1. What is an ecosystem?
2. Differentiate between biotic and abiotic components of an ecosystem.

Summative Questions

1. Why is a food web more accurate than a food chain?
2. What factors define terrestrial ecosystems?
3. What factors define marine ecosystems?

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32.3: Pull Sheets/Materials

Materials for this lab are paper, pens and/or markers, computers for research, and any field biology materials your institution has (quadrats, line transects, binoculars, trail cameras, etc). As a primarily outdoor and paper-based lab instructors can use the local campus and resources at their disposal.

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CHAPTER OVERVIEW

33: Animal Behavior

[33.1: Instructor Guidelines](#)

[33.2: Formative/Summative Questions](#)

[33.3: Pull Sheets/Materials](#)

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33.1: Instructor Guidelines

Objectives: Introduce students to the study of animal behavior through controlled lab experiments and observations in nature.

The lab portion of this chapter uses bean beetles or pill bugs (roly-polys). Pill bugs can often be gathered by the instructor or lab technician, or ordered live from a biological supply company.

For the observation portion (ethology), at EVC we visit the pond on campus at watch waterbirds or turtles. Adjust outdoor animal observations for your local campus environment. We recommend scheduling this lab during a time students could easily be outside and view animals. If going outside or animal observations are not available on campus we recommend use wildlife cameras for students to observe wildlife. Some options include:

[African River Wildlife](#)

[National Park Service Webcams](#)

[The Wildlife Trust Wildlife Webcams](#)

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33.2: Formative/Summative Questions

Formative Questions

- 1.
- 2.

Summative Questions

1. What do "proximate" and "ultimate" mean in terms of animal behavior?
- 2.

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33.3: Pull Sheets/Materials

Live Pill Bugs

Paper towels

Water squirt bottles

Plastic petri dishes

Bird observations on campus do not require materials. Binoculars and field guides can be provided if the institution has them.

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CHAPTER OVERVIEW

34: Museum Science

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34.1: Instructor Guidelines

Objective: This chapter is designed for students to complete a course-based undergraduate research experience (CURE) in ecology. Students will complete a group research project using digitized natural history museum collections. At EVC we have worked within the framework of one of the research projects designed by the [Biological Collections in Ecology and Evolution Network \(BCEENET\)](#). Instructions and full project materials are available through BCEENET (hosted on QUBES) and are integrated on Canvas.

At EVC we take 8 or 9 three-hour class periods to scaffold and work on the project.

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34.2: Formative/Summative Questions

As a semester-long research project there are not specific formative/summative questions. The summative assessment is a research poster that students present at an on-campus symposium at the end of the semester.

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34.3: Pull Sheets/Materials

All teaching materials for this and other BCEENET CUREs are [hosted on QUBES](#). Students will need a laptop to work in the databases and mapping software required for the project. Tablets, phones, and chromebooks cannot host the software required for mapping with [QGIS](#).

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