❖ Teacher Notes ❖
for
The Apprentice's Companion
for
General Biology

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Teacher Notes for The Apprentice's Companion for General Biology

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Contents

Activity 1 Making Observations

We encourage you to give this activity as much time as you can afford. Students can also continue their observations and sketches outside of regular class hours, or the entire activity can be performed at home over a more extended period of time. As mentioned at the end of the activity, we highly recommend reading Samuel Scudder's famous essay, "In the Laboratory with Agassiz."

Activity 2 The Cycle of Scientific Enterprise

Students should have already covered Section 1.1 in *General Biology*. Begin this activity by reviewing the stages in the Cycle of Scientific Enterprise. Discuss what makes a good hypothesis and how to design a good experiment. It is expected that students in this course are already familiar with the steps in the Scientific Method, which are essentially a protocol for conducting a valid experiment. You may want to review the steps:

1. State the problem.
2. Research the problem.
3. Form a hypothesis.
4. Conduct an experiment.
5. Collect data.
6. Analyze the data.
7. Form a conclusion.
8. Repeat the work.

Encourage students to be creative and make thorough observations. Help them as they work to design their experiment using the questions provided in *The Apprentice's Companion*. This is meant to be a rather open-ended experiment to encourage the students to think independently and creatively. However, some students will struggle with the lack of explicit instruction. As instructor, you may choose to give your students more specific guidance. Below are three different examples of hypotheses and brief explanations of experiments that students could perform to test the hypotheses. The photos at the right suggest how this experiment might be conducted.

Hypothesis & Experiment 1

Brand X is best because it is the strongest.

Soak a paper towel in water and wring out any extra water. Stretch the paper towel over the beaker, and allow it to cling to the sides. Place one penny on the paper towel. Keep adding pennies one at a time, counting as you go, until the paper towel breaks. Record the final number of pennies that the wet paper towel holds prior to breaking and record it. Repeat the experiment at least three times with each separate brand of paper towels.

Variable: number of pennies or mass of pennies

Constant: amount of water in paper towel, dimensions of paper towels, size of beakers.

Hypothesis & Experiment 2

Brand X is best because it is the most absorbent.

This could be tested in one of two ways. 1) Fill a beaker or graduated cylinder with set amount of water, say 100 mL. Place the paper towel into the water un-

til it is completely saturated, then remove it from the beaker, allowing the excess to drip out, but do not wring. Measure the amount of water remaining in the beaker. Take the difference between the initial volume of water and the final volume of water. Record the value. Repeat the experiment at least three times with each separate brand of paper towels. 2) Soak a paper towel in water, squeeze out all of the water into an empty beaker and measure the amount of water that was contained in the paper towel. Record the value. Repeat the experiment at least three times with each separate brand of paper towels.

Variable: volume of water

Constant: method of absorbing water, dimensions of paper towel

Hypothesis & Experiment 3

Brand X is best because it has the most favorable combination of high absorbency and low cost.

Absorbency could be tested in one of two ways. 1) Fill a beaker or graduated cylinder with set amount of water, say 100 mL. Place the paper towel into the water until it is completely saturated, then remove it from the beaker, allowing the excess to drip out, but do not wring. Measure the amount of water remaining in the beaker. Take the difference between the initial volume of water and the final volume of water. Record the value. Repeat the experiment at least three times with each separate brand of paper towels. 2) Soak a paper towel in water, squeeze out all of the water into an empty beaker and measure the amount of water that was contained in the paper towel. Record the value. Repeat the experiment at least three times with each separate brand of paper towels.

We assume that cost and absorbency are of equal significance. Also, lower cost is better, so we use the reciprocal of cost to obtain a cost figure where higher is better. Compute the combined performance of each towel brand as:

$0.5 \times$ (amount of water absorbed) + $0.5 \times$ (1/cost)

Variable: volume of water, cost

Constant: method of absorbing water, dimensions of paper towel

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Activity 3 Introduction to Microscopes

Begin this lab activity by helping the students to become familiar with their microscopes. Consider playing a game with the students or class to help them learn the different parts of the microscope.

If a student reports "losing" the letter when they go to a higher magnification, it is probably because 1) the letter was not centered in the field of view, or 2) they have focused in on an open space in the printed letter. This can be corrected by centering the black text in the field of view prior to moving to a higher magnification. You may also be able to slightly move the slide to one side or the other and find the letter again.

Activity 4 Making Solutions

This lab activity can be done by the students, or it can be completed by the instructor or a lab assistant. If you have the students make the solutions, you may want to have each team make their own set of solutions. Alternatively, you can divide up the work. Have all the students make the calculations, but then assign different student teams to make the different solutions. Regardless of how you choose to distribute the work, these solutions are needed to carry out Activity 5.

Below are tables listing the correct masses (or volumes) to make the solutions. This can be used to check your students' work before they begin their work. These values produce volumes in the range of 90–100 mL. If you need larger amounts for Activity 5, you can increase the amounts by doubling or tripling the values.

Note 1

Grocery-store salt containing sodium silicoaluminate does not completely dissolve at 5% and 10%, even after vigor-

Salt Solutions

concentration (g/g × 100%)	mass of solute (salt) (g)	mass of solvent (distilled water) (g)
10%	10.0	90.0
5%	5.0	95.0
2%	2.0	98.0
1%	1.0	99.0
0%	0.0	100.0

Sugar Solutions

concentration (g/g × 100%)	mass of solute (salt) (g)	mass of solvent (distilled water) (g)
10%	10.0	90.0
5%	5.0	95.0
2%	2.0	98.0
1%	1.0	99.0
(Only one 0% solution is required.)		

ous continuous stirring and heating for over 30 minutes. These same solutions with salt containing yellow prussiate of soda dissolve in less than 2 minutes with only slight heating and stirring.

Note 2

If you opt to use weighing paper or small pieces of parchment paper, instruct the students to fold the paper in half diagonally, and to crease the paper. The crease gives a nice pathway for gently transferring the solid to the beaker after weighing. Weigh trays may be cleaned, dried, and reused. If you are using cupcake liners or something similar for weighing the solutes, use a fresh one for each new measurement.

Activity 5 Melting Points of Two Solutions

In answering the initial questions, you want to get the point across that salt and sugar behave differently when they dissolve in water. The salt dissociates into its two ions, Na^+ and Cl^-, while the sugar molecules are simply separated out individually and surrounded by water molecules. This influences the impact of the solution concentration on the solvent melting point.

Students may struggle with the calculations and data analysis. Below are the completed tables, including the optional Challenge Data Analysis, so you can check their work.

Data Analysis for Salt Solutions

Salt Solutions

concentration (g/g × 100%)	mass of solute (salt) (g)	moles of solute (salt) (mol)	volume of solvent (water) (L)	molarity of salt solution (mol/L)	molarity of ions in salt solution (mol/L)
0%	0.0	0	0.1	0	0
1%	1.0	0.01711	0.099	0.173	0.346
2%	2.0	0.03422	0.098	0.349	0.698
5%	5.0	0.8556	0.095	0.901	1.80
10%	10.0	0.1711	0.090	1.90	3.80

Data Analysis of Sugar Solutions

Sugar Solutions

concentration (g/g × 100%)	mass of solute (sugar) (g)	moles of solute (sugar) (mol)	volume of solvent (water) (L)	molarity of sugar solution (mol/L)
0%	0.0	0	0.1	0
1%	1.0	0.002921	0.099	0.0295
2%	2.0	0.005843	0.098	0.0596
5%	5.0	0.01461	0.095	0.1538
10%	10.0	0.02921	0.090	0.325

Students may need assistance setting up their graphs, especially if this is the first time they have had to graph data. You may want to provide some assistance in helping students determine the scale to use on each axis. Make sure that they label each axis as well as the different data lines.

You should expect to see that the salt solution has a bigger impact on the melting point. The higher concentration of salt lowers the freezing point/melting point of the solution more dramatically. In the Challenge Data Analysis, the line using 2× the molar concentration of salt will more accurately reflect the trend in the salt data, since it represents the two ions in solution.

Activity 6 Properties of Water

Styrofoam bowls are acceptable, but may have some static electricity which could affect results

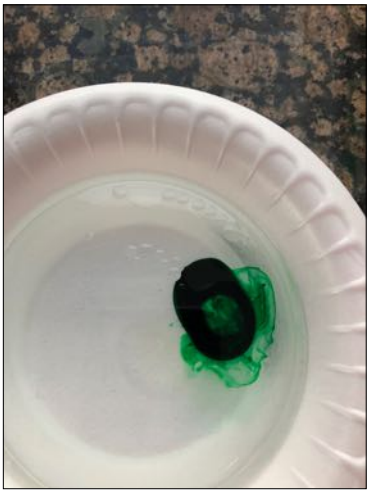
Part 1

Step 2

Students should see at least a portion of the food coloring immediately spread throughout the water because the dye is water soluble.

Step 3

The food coloring becomes "trapped" in the area where the oil is, and is unable to make much contact with the water, since oil (hydrophobic) and water do not mix. As the dye itself is hydrophilic, it tends to stick to itself and to avoid the oil around it.



Step 4

The dish soap allows the dye to start to mix with the water. Because the soap molecule has both a "water-loving" and a hydrophobic end, it allows the oil and water to start to mix. As this occurs, the dye can now begin to diffuse throughout the bowl, making contact with the water and the soap molecules.

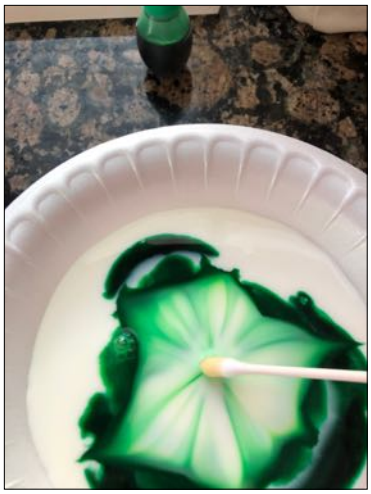
Step 5

Whole milk has a high concentration of fat. Fat molecules are hydrophobic, consisting of long hydrocarbon chains. When the dye enters the milk, the dye clumps together. As a hydrophilic molecule, the dye tends to avoid the hydrophobic milkfat.

Step 6

The dish soap immediately begins to diffuse through the milk, but because the hydrophobic milk is the solvent (instead of water), the dye never completely fills the bowl. Instead, the dye follows the small amount of dish soap, making fantastic, moving, swirling patterns.

Before dish soap (on cotton swab) makes contact.



The moment the cotton swab contacts the milk.

Pattern of dye moving away with the motion of the soap molecules.

Step 8

The paper clip should initially rest on top of the distilled water because the surface tension of the water is stronger than the gravitational pull of the earth on the paperclip. As soon as a drop of dish soap is added, the paperclip sinks to the bottom because the soap molecules serve to disrupt the hydrogen bonding of the water molecules, and thus break the surface tension.

Activity 7 Introduction to Cells

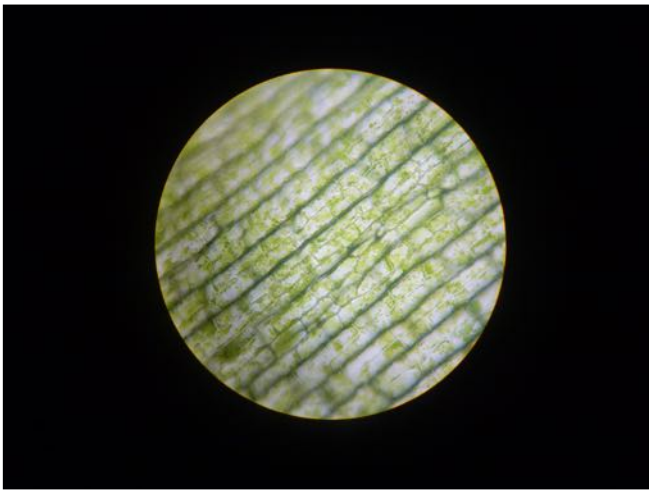
There are two sets of materials for this lab. You may purchase prepared slides of Elodea, epithelial tissue, and protozoans. These prepared slides are all available from Home Science Tools at reasonable cost. These are common slides and simplify some of the work on the student's part. Another option is to have the students prepare their own slides as described in the lab. This is more time consuming but provides more practice. If desired, the Protozoans could be saved until a later lab activity.

Below are some images to provide an idea of what students should see on their slides.

Observation of Plant Cells

Step 1

Elodea leaf living, not prepared:



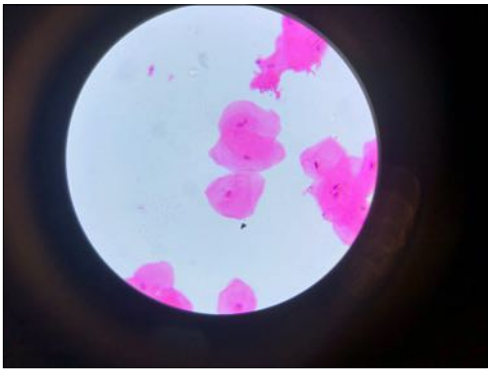
Steps 3 and 4

Students should mention that plant cells contain chloroplasts and vacuoles. Small green structures in the interior of the cells are the chloroplasts; large clear areas are vacuoles.

Observation of Animal Cells

Steps 1 and 2

Prepared slide of human epithelium (400×).



Steps 6 and 7

Eukaryotic cells have membrane-bound organelles, such as the nucleus, whereas prokaryotic cells do not. The darkly stained spots in the center of each cell are the nuclei.

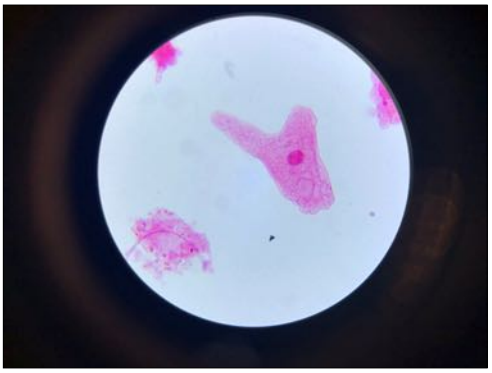
Steps 8 and 9

If bacteria are visible, they will be stained, and they will appear much smaller than the cell nucleus. If you have oil immersion capability (1000×), bacteria are easier to view.

Observation of Protozoans

Steps 1 and 2

Prepared slide of amoeba (400×).

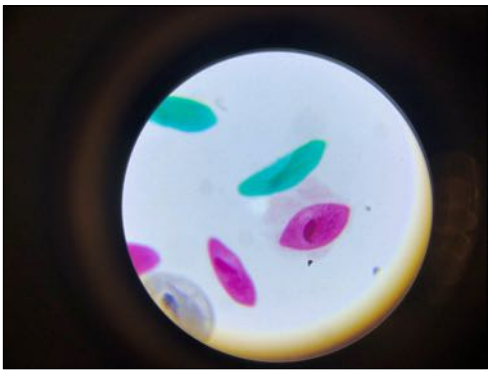


Steps 3 and 4

Amoeba use pseudopods. These are blob-like structures that protrude from the body of the cell. The Latin meaning of pseudopod is "false foot." As the organism constricts and changes shape, these structures produce motion through water.

Paramecia use cilia. These are small, hair-like projections surrounding the cell that beat to propel the organism. Because they are so small, these are much more difficult to observe on the microscope. However, a "blurry/fuzzy" edge may be seen around the membrane.

Prepared slide of paramecium.



Activity 8 Diffusion

Preparation of the Petri Dish

The materials list specifies pre-prepared nutrient agar, available from Home Science Tools. Remove the cap from the bottle, and microwave for 30 seconds. Gently swirl the bottle. Microwave for an additional 15 seconds, and swirl the bottle (using hot pads). Continue this pattern until the agar just boils. Pour just enough agar to cover the bottom of a petri dish and allow to settle for about 1 hour. Alternatively, you can purchase plates already prepared (Home Science Tools, BE-PPLATEN).

Regarding food coloring, we used McCormick brand containing red, yellow, green, and blue. Please check your dye ingredients against the molecular mass table included in the student portion, and make adjustments as necessary. Molecular masses for each ingredient can be found by a simple Internet search.

Guidance for Questions

Introduction questions: Diffusion is a type of passive transport (not requiring outside energy) where molecules move from areas of high concentration to areas of low concentration (down a concentration gradient).

According to the laws of diffusion, molecules with lower molecular mass diffuse faster through the medium. The agar becomes a solid matrix with certain size pores through which molecules can travel. Smaller molecules are less impaired from moving than larger ones.

Questions in Procedure Step 2

Because the cell wall has larger spaces and more hydrophilic molecules (carbohydrates), hydrophilic molecules (such as dye) should more easily travel through agar than through a cell membrane (whose interior consists of more tightly packed hydrophobic lipids. Small molecules (such as O_2 and CO_2) diffuse across the cell membrane.

Questions Section, Question 1

A concentration gradient is a difference in concentration between two areas. Hypotheses may vary. Students should answer that the dye should travel in all directions, expanding the area of the circle of dye, because the highest concentration of dye is in the well and the surrounding agar initially has a dye concentration of zero.

Notes about Results

Students should expect to see the red dye travel the farthest because of the lowest molecular mass of FD&C Red 40. The other colors may have similar distances. Students may see the colors lighten as the edge of the circle travels out in all directions. This is a visual way to explain the concept of a concentration gradient. As the dye begins to move, it is traveling from a region of 100% dye to 0% dye. As the dye diffuses outwards, its concentration lessens as it "mixes" with the agar, but still always travels outwards towards the region of zero concentration. The result is a gradual rise in concentrations, from the outer edge (lowest concentration) to the central well (highest concentration).

When making the graph, remind students that the independent variable is read on the horizontal axis and the dependent variable is read on the vertical axis. In this activity, time is the independent variable and the distance traveled is the dependent variable.

Activity 9 Osmosis

The eggs must be prepared four days before the day you plan to have your students do this lab activity. The shells are removed by soaking the eggs in vinegar for three days. Fill a glass or Tupperware pan with vinegar and gently place the fresh eggs into the vinegar (making sure that the eggs are submerged). Allow it to sit at room temperature overnight. On the second day carefully remove the vinegar and replace it with fresh vinegar. You will use about 1 gallon of vinegar for a dozen eggs. On day three, gently rub the remaining shell off the eggs. Dispose of the vinegar and place the eggs in the 20% sucrose solution to soak overnight prior to the lab. This ensures that the 20% sucrose solution is an isotonic solution.

We recommend having each student in a group of four take responsibility for a single egg. For keeping track of time, students may have watches or cell phones. Alternatively, you could use a clock in the classroom and the teacher could instruct students when it is time to weigh the eggs. Ideally, each group has its own scale. We recommend having the students weigh the eggs in the same order they did the first time to try and keep the 15 minute interval fairly consistent within the group.

Making Solutions

For one dozen eggs, you will need about 500 mL of 10% sucrose and 40% sucrose solutions. To make a 10% sucrose solution, add 50 g of sucrose (sugar) to 450mL of distilled water. To make a 40% sucrose solution, add 300 g of sucrose to 450mL of distilled water. Dissolution of such a large quantity of sugar requires some time. It may be useful to stir it while heating it, but do not allow the solution to boil.

Make about 2.5 L of 20% sucrose solution because you will be using this to soak the de-shelled eggs. You may need more, depending on the size of container in which you are soaking the eggs. Dissolve 550 g of sucrose in 2.20 L of

distilled water. Set aside 500 mL of 20% solution to be used on the day of the activity.

Store these solutions in jars with lid or another similar airtight container.

Clean Up

Once the activity is finished, the eggs can be sealed in plastic bags and disposed of in the regular trash. You may want to take them to an outside trash can so they do not begin to smell.

Activity 10 Calorimetry

This experiment involves the use of walnuts or peanuts. Due to the prevalence of food allergies, check with students' medical records or parents ahead of time about the suitability of this food item, and make substitutions as necessary.

You may wish to look at the references for variations on the calorimeter apparatus. Note: Both these procedures recommend using a cork as a stand for holding the food. We do not recommend this strategy as the cork itself is flammable. However, a cork wrapped in aluminum foil would be a great alternative.

- https://www.flinnsci.com/api/library/Download/f9560a5fc7ef4a6b8f4598fea30626eb
- Science Buddies Staff. "Burning Calories: How Much Energy is Stored in Different Types of Food?" Science Buddies, 23 June 2020, https://www.sciencebuddies.org/science-fair-projects/project-ideas/FoodSci_p012/cooking-food-science/food-calorimeter. Accessed 25 July 2020.

As mentioned in The Apprentice's Companion, the preferred method for supporting the soda can is with a ring stand and burner ring. The alternative is to use a large-sized steel vegetable can. The image below shows a closer view of how the bottom of the can may be cut (using tin snips) to provide openings for air flow and food placement. The folded pie tin under the steel can may be adjusted to that the steel can is stable and at the correct height for air flow around the flame.

Questions

1. The purpose of cellular respiration is to convert the chemical potential energy found in foods into usable cellular

energy in the form of ATP.

2. The law of conservation of energy is *energy can neither be created nor destroyed, only changed in form*. In cellular respiration, chemical potential energy stored in the chemical bonds of food molecules is converted into chemical potential energy of other molecules (with loss of heat at each step), into an electrochemical gradient that drives the phosphorylation of ATP.
3. Glucose + O_2 + ADP + $P_i \rightarrow CO_2 + H_2O$ + ATP

Analysis

1. Applying the law of conservation of energy to the experiment: The chemical potential energy of food is converted into heat (that flows into the water and surroundings) as well as electromagnetic radiation (flame).
2. The experimental procedure is the same as cellular respiration because the general chemical reaction is food + $O_2 \rightarrow CO_2 + H_2O$ + energy. The experimental procedure is different because this transformation happens in an uncontrolled way with a flame and heat produced. In the cell, this overall chemical reaction happens as a series of tightly controlled enzymatic reactions that serve to harness the energy into the usable form of ATP (and prevent the organism from catching fire).
3. Results: In general, chips and walnuts have a higher fat content, should burn for a longer time, and should raise the water temperature much more. Marshmallows largely contain carbohydrates and so should be less effective at raising the temperature of the water per gram.

Sample Calculation

Food Sample	Initial Water Temp, °C	Final Water Temp, °C	Temperature Difference, °C	Initial Mass of Foil + Food, g	Final Mass of Foil + Food, g	Mass of Burned Food, g	Calories per gram
marshmallow	25	26	1	2.5	2.38	0.12	

This calculation is based on $Q = cm\Delta T$, where Q is increase in thermal energy in the water (Cal), c is specific heat capacity of water, 0.001 Cal/g·°C, m is mass of water (g), and ΔT is the change in temperature (°C). The increase in thermal energy in the water is assumed to be equal to the energy released by the burning food. This energy quantity, Q, is then divided by the mass of the food (g) to determine the energy content in the food in Calories per gram.

Here, we use 100 g water since all trials added 100 mL water into the aluminum can, and the density of water is 1 g/mL. The specific heat capacity of water is 0.001 Cal/g·°C. The change in temperature and the mass of food that was burned are obtained from the data table.

$Q = cm\Delta T$ = (0.001 Cal/g°C)(100 g)(1°C) = 0.1 Cal

Cal/g = 0.1 Cal/0.12 g = 0.83 Cal/g

The nutrition label for the marshmallows indicates that the marshmallows contain 100 Calories per 30 grams, giving 100Cal/30g = 3.33 Cal/g

The Cal/g from the nutrition label is substantially higher than that measured in this experiment. This is because heat is lost to the surroundings rather than heating up the water.

Activity 11 Enzymes

For best results, make sure your potato and your hydrogen peroxide are as fresh as possible. A 3% hydrogen peroxide solution is available at many drugstores and grocery stores.

To save time, you can prepare potato cubes ahead of time. Since this is a qualitative lab, the size can be approximate, but 1 cm^3 is a good target to shoot for. If you need to save further time, you can soak a set of potato cubes in hot water (>80°C) and another set in vinegar for your class ahead of time. Quantities of hot water and vinegar need only

to allow the potato cube to be comfortably immersed and do not need to be measured exactly.

Example Responses

Questions

1. An enzyme is a protein that serves as a catalyst, lowering the activation energy for a chemical reaction that occurs in a cell.

3. The surface area:volume ratio is important for accessibility. The more surface area there is, the more easily molecules can cross the plasma membrane. If there is a relatively large volume but low surface area, then it will be more difficult for molecules to reach the plasma membrane from the interior.

Expected Results

Trial	Observations	Notes
1 plain potato cube		Immediately starts bubbling, with the surface covered after 5 minutes. Catalase is able to convert hydrogen peroxide into oxygen gas and water.
2 pieces of 1/2-cut potato cube		Starts bubbling immediately, and covers surface with bubbles faster than control. After 5 minutes, there appear to be more bubbles than the control. The increased surface area of the potatoes makes the catalase much more accessible to the H_2O_2.
4 pieces of 1/4-cut potato cube		Starts bubbling immediately, and covers surface faster and thicker than both the control and the ½-cut potato pieces. After 5 minutes, the bubbles are more numerous and reach higher than the previous two samples. In four pieces, the available surface area is substantially more than the previous two samples, making the catalase reaction vigorous as much more catalase can reach the H_2O_2.
1 potato cube taken from hot water soak		It takes a couple minutes for bubbles to form, and after 5 minutes the number of bubbles is far less than the other samples. The bubbles do not cover the surface and congregate in one small corner. Elevated temperatures can denature a protein (cause it to lose its tertiary structure). Without its 3-D structure, an enzyme loses its function. The hot water must have deactivated many, but not all of the catalase enzyme molecules.

1 potato cube taken from vinegar soak		Bubbles do not form here, even after 5 minutes. Vinegar is acidic, and serves to denature the protein even more effectively than does the hot water. (Hydrogen ions from the acetic acid in the vinegar attach to amino acids in the enzyme that should be ionized, preventing them from forming the correct 3-D structure.)

Activity 12 Fermentation

To prepare the solutions, measure out 5 g of solute and dissolve it in 95 mL of distilled water. I used table sugar for the sucrose and corn starch for the starch solution. You could expand this activity by trying additional solutions (glucose, maltose, lactose, protein, etc.). Interestingly, yeast does not have the enzyme lactase and as a result cannot break down lactose even though it is a simple sugar. It will break down the other simple sugars. However, it will not break down proteins. I had some Sweet'N Low packets in my kitchen and included that in my test. The yeast were able to break down the Sweet'N Low quickly.

The distilled water tube should not have any fermentation since there is no sugar present. The starch solution also should not have much fermentation. The sucrose will have the most. I found that the very active tubes, as the air bubble increased, it started to push some of the solution out of the small tube and into the larger tube. This could obstruct the view of the level of the air bubble. However, by holding the tube up to the light, you can see where the air bubble ends and the yeast solution begins, in order to make a measurement. Below are some images of fermentation after about 20–30 minutes.

With very small tubes, active fermentation produced so much CO_2 pressure that it gradually pushed the inner tube out of the outer tube over the course of 30 minutes. If you opt for a 10 × 75 mm tube inside a 13 × 100 mm tube, then you may opt to have the students measure the distance from the mark to the top of the inner tube. (See pictures below)

0 min

5 min

10 min

15 min

20 min

30 min

Fermentation results (measuring from sharpie mark to top of inner test tube)

Time (min)	Distilled Water (cm)	5% Sucrose (cm)	5% Starch (cm)
0	0.6	0	0.6
5	0.6	2.5	0.6
10	0.6	3.8	0.6
15	0.6	5.4	0.6
20	0.6	7.2	0.6

Responses to Questions

1. Sugar solution should show most fermentation.
2. Starch is a polysaccharide and sucrose is a simple sugar, a disaccharide.
3. Yeast breaks down simple sugars. It cannot effectively breakdown starches.
4. Because fermentation requires enzymes, the lower temperature will result in a slower rate of fermentation. However, the high temperature would denature the enzyme, since it is a protein. This will render the enzyme dysfunctional and result in no fermentation. An extension of this lab activity would be to run the experiment at different temperatures and see which ones worked best.
5. Other factors could be the concentration of sugar in the solution, the amount of yeast, the type of yeast, the length of time, the presence/absence of activators or inhibitors.

Other Possible Test Tube Sizes

10 × 75 mm with 13 × 100 mm without lip (polystyrene)

https://www.homesciencetools.com/product/test-tubes-polystyrene-13-x-100-mm-12-pack/

18 × 150 mm with lip w/ 13 × 100 mm without lip purchased from Amazon

https://www.amazon.com/gp/product/B01BTCIZGI/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1

https://www.amazon.com/gp/product/B00CH3E36K/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&psc=1

Activity 13 Extracting DNA

Prepare the extraction buffer ahead of time. Measure out 2.0g of NaCl and dissolve it in 90 mL of distilled water. Add 1 mL of dish soap detergent. This solution can be stored at room temperature for up to a year.

Make sure students mash up and mix the fruit and extract thoroughly.

Look for 91% isopropyl alcohol at a pharmacy, typically under $3. Higher purities are available but cost far more. (The rubbing alcohol commonly sold in grocery stores is only 70% alcohol, and thus not acceptable.)

At least 1 hour before the activity, place the isopropyl alcohol into the freezer so that it is cold. Keep it cold either by storing it on ice or pulling it out right before it is needed for the extraction. The cold isopropyl alcohol is needed for the DNA to precipitate or come out of solution.

It is important for students to pour the alcohol down the side of the test tube/beaker SLOWLY. If you pour the alcohol directly into the fruit extract it will mix with the extract and the precipitation will not be as clear.

To clean up, the plastic bag, cheesecloth, fruit, and skewer can be disposed of in the trash. The fruit extract and DNA can be washed down the sink.

Results

The DNA is stringy and appears white and cloudy.

Selected Answers

Dish soap has a long hydrophobic end and a charged, hydrophilic end. Sodium chloride dissolves in water, dissociating into Na^+ and Cl^- ions. These molecules and ions disrupt the cell membranes of the strawberry's cells, causing the cellular contents to spill out.

When the solution is poured through the cheesecloth, solid chunks of undissolved debris are retained in the cheesecloth, while water-soluble, hydrophilic molecules flow through (proteins and DNA).

DNA is insoluble in cold isopropyl alcohol, so once it is added, the DNA precipitates out of solution, becoming a cloud of long, white, stringy molecules. It is important for the isopropyl alcohol to be cold so that the DNA has a better chance of precipitating. (This is more apparent if you think about it the other way around: heat generally helps molecules to dissolve in solution.)

Activity 14 Gene Expression

While this activity could be done entirely on paper by writing out the RNA transcript and the amino acid sequence with letters on paper, the goal is to allow students to have a hands-on experience to build these molecules. This helps to reinforce the concept by involving another (tactile) mode of learning. The use of the Lego bricks as amino acids adds a three-dimensional element that simulates the three-dimensional structure of a protein.

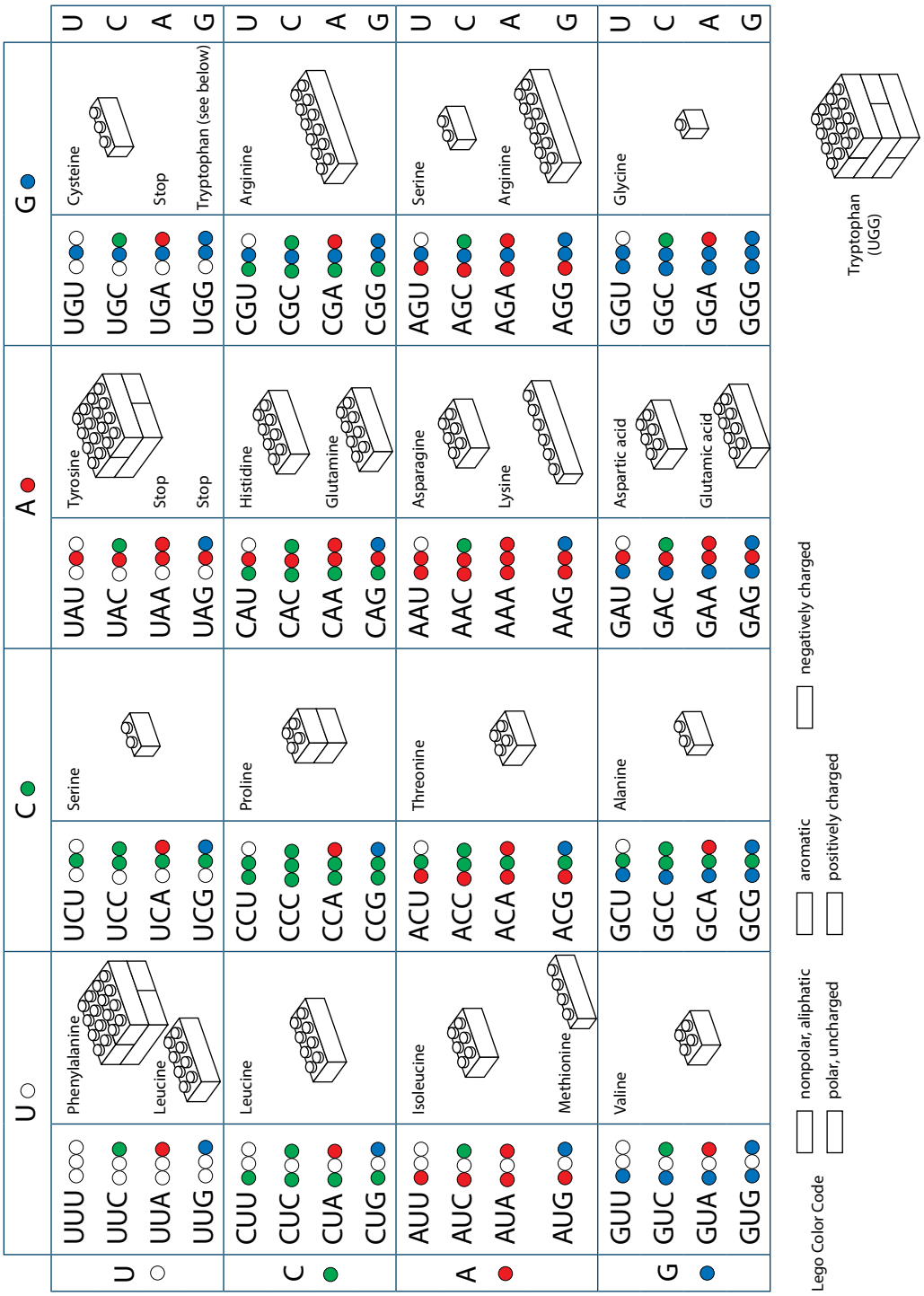
The pony bead colors assigned to each nucleotide are merely suggested and could be easily changed to the colors that are readily available. However, please note that in doing so the genetic code provided will not be exactly the same and may require you to modify it for the student.

The purpose of using five different colors of Lego bricks is to illustrate that different amino acids have different chemical properties: non-polar, neutral-polar, negatively charged, and positively charged, as indicated in the codon table shown in Figure 5.24 in *General Biology*. While most students will not go into this level of detail, it is an optional exercise introduced in the Extension Question. If you need to switch colors of Lego bricks you may do so, but we recommend maintaining five different colors in the groupings provided. The size and shapes of the different bricks are intended to give the students a relative idea of how small or bulky an amino acid is in comparison to others, loosely

based on its chemical make-up. However, they are not to scale. In assigning bricks, we have tried to use common shapes so that they are more readily available, but you may change out shapes if needed. If you need to change the color scheme, use the colorless codon table below by printing this page, coloring the shapes using your revised color scheme, and then distributing the revised table to your students. Note that in order to preserve the chemical properties, color groupings should be the same as those shown in the colored table in *The Apprentice's Companion*.

Note: If you are short on time, the whole of Task 4 could be done as an extension activity.

Below is a codon table with the Lego shapes uncolored, in case you need to use a different color scheme.

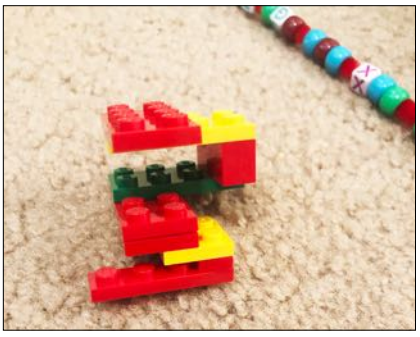


Sample results for Task 1, DNA

Sample results for Task 2, mRNA (square "letter" beads were used for uracil)

Sample results for Task 3 (note red pipe-cleaner gaps between each 3-bead "codon")

Attaching and adding structure to the resulting protein:



Students may want to know "how" they are to assemble the Lego bricks. They should assemble them in the order of the strand; however, the orientation of each Lego is not as important. This may provide an opportunity to talk a bit about the process of protein folding, since the amino acid string will fold up while it is being assembled due to the electrical attractions and repulsions among the various amino acids.

Sample Answers for Task 4

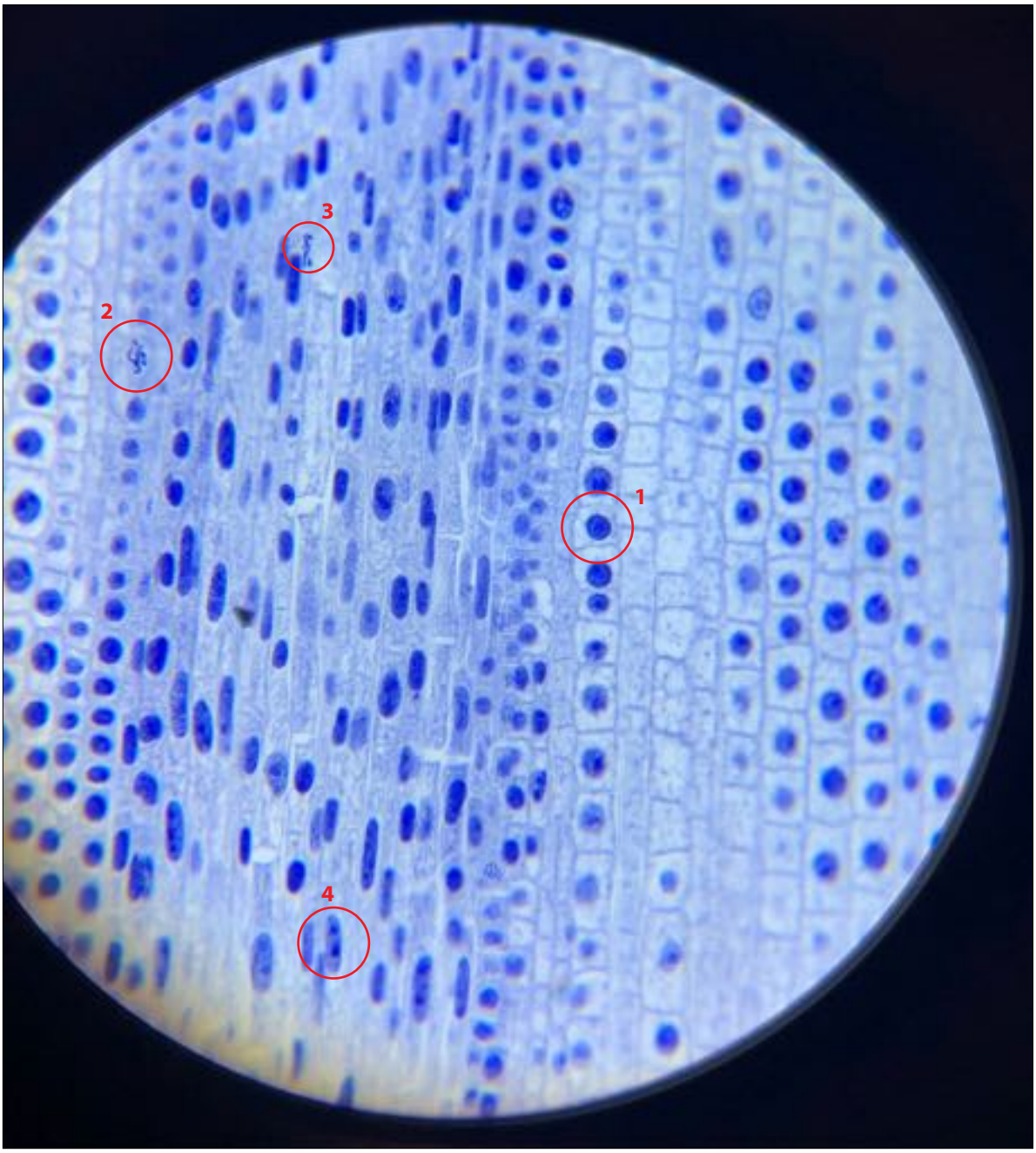
Yes, the substitution will cause a mutation in the protein. The original DNA sequence in question is 3′-CTC-5′, leading to an mRNA sequence of 5′-GAG-3′. With the substitution mutation, we now have DNA reading 3′-CAC-5′, leading to an mRNA codon of 5′-GUG-3′.

The original amino acid is therefore glutamate, which is large and negatively charged. In the mutant protein, the resulting amino acid is valine, which is a bit smaller, more branched, and non-polar. Since the chemical properties and size of the new amino acid are so different, it should dramatically alter the overall structure and function of the protein.

Activity 15 Observing Mitosis

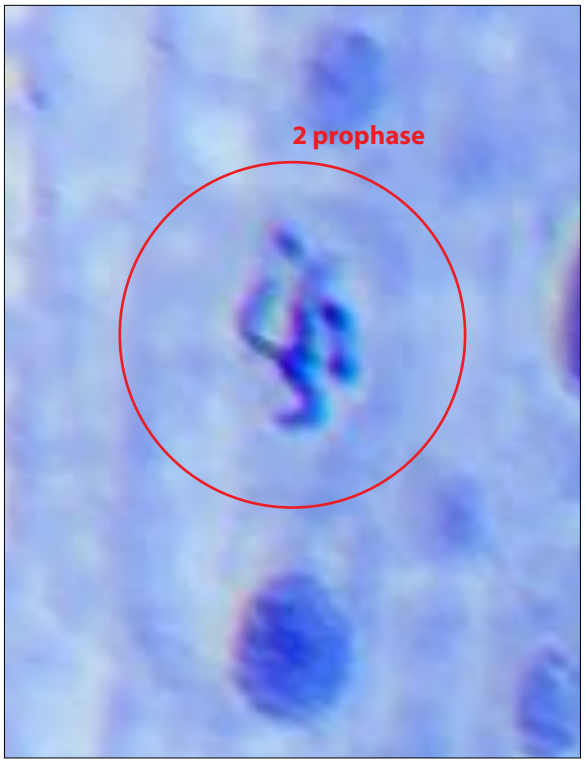
The designation "l.s" for the onion root slide in the Materials list means "longitudinal section" (rather than a cross-section.)

Students may initially struggle with identifying the cells in various stages of mitosis. Looking at the slide on the high-power magnification (40× objective), enables them to see the detail. The following images are provided as examples.



Closeups of these on next page.

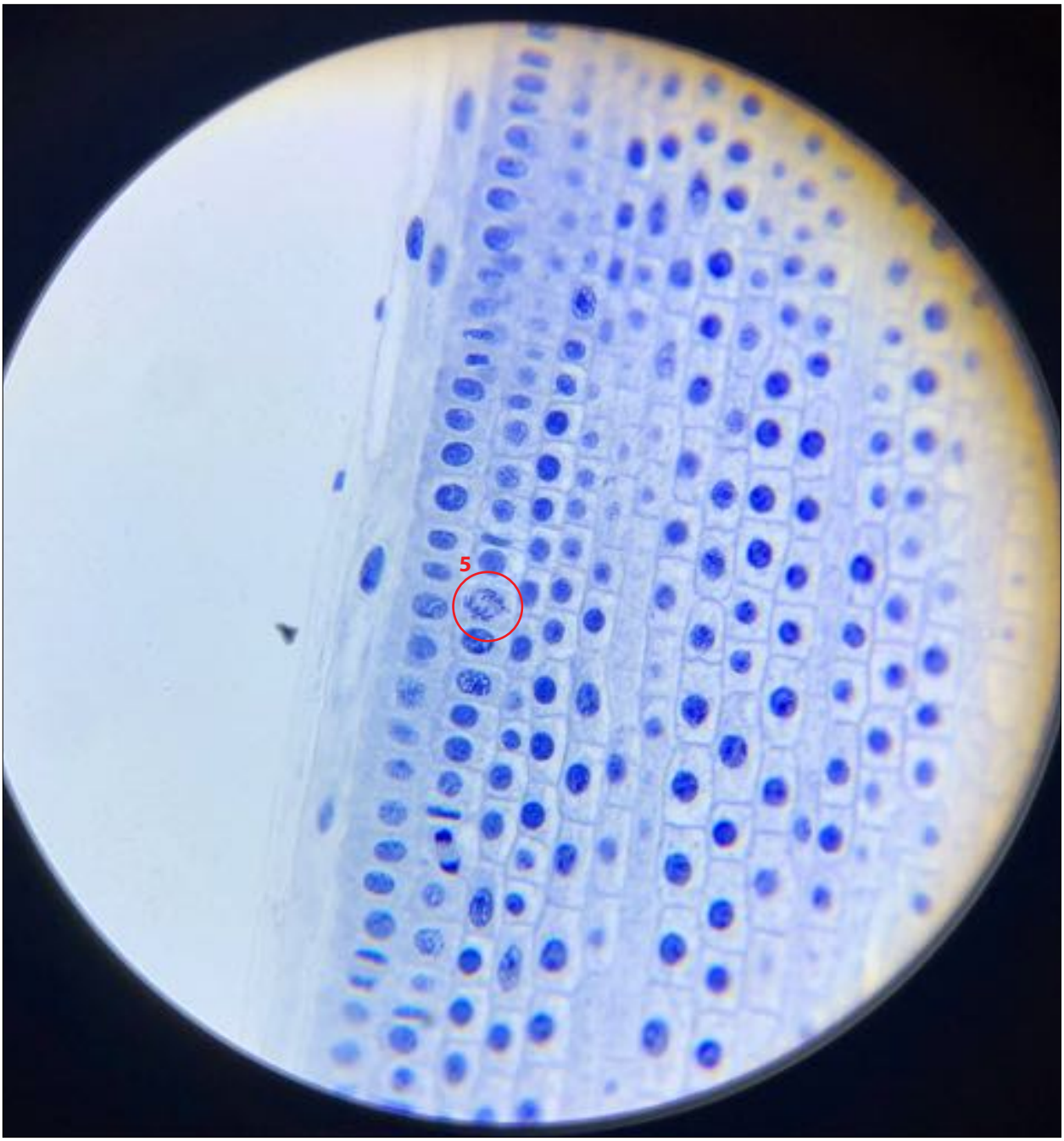
1 interphase, closeup of image on previous page



2 prophase, closeup of image on previous page

3 metaphase, closeup of image on previous page

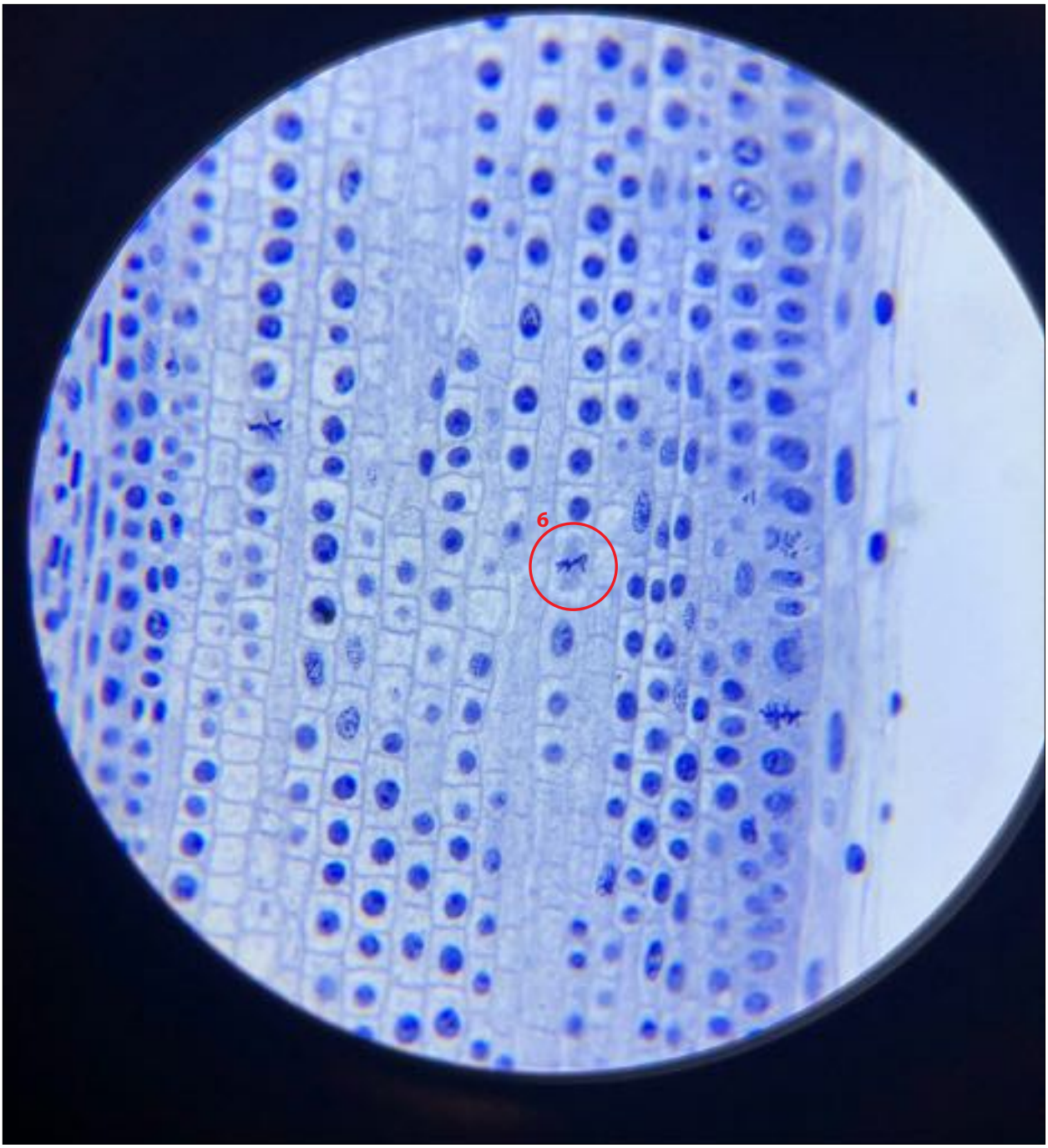
4 telophase, closeup of image on previous page



Closeup on following page.

5 anaphase, closeup of image on previous page

6 metaphase, closeup of image on next page

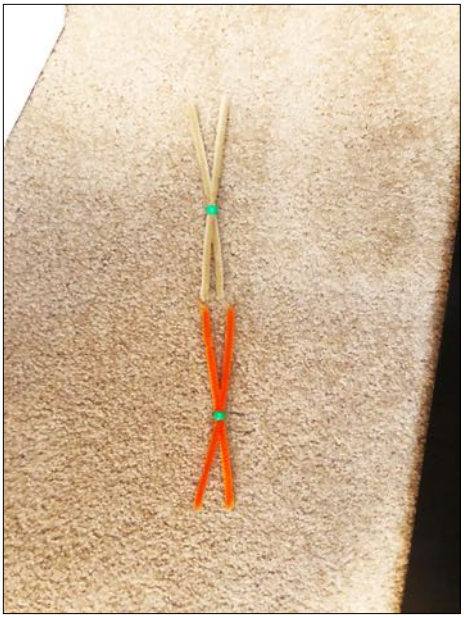


Closeup on previous page.

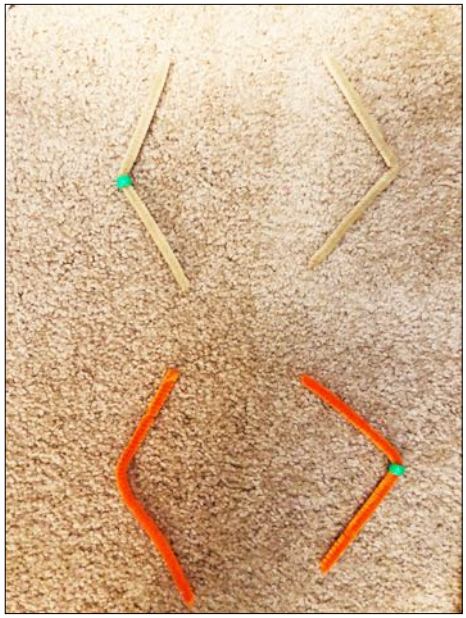
The pipe cleaner chromosomes are made in the following manner. Take a pipe cleaner and cut it in half. Insert both halves through the pony bead, joining them in the middle. The pony bead holds the pipe cleaners together and as like the centromere of the duplicated chromosome. The final chromosome looks like an 'X.' I like to use two different colors of pipe cleaners to make two duplicated chromosomes (one of each color, both cut in half). (Note, however, that the different colors don't represent anything other than the fact that these are two different duplicated chromosomes.) Examples are shown in the following five images.

interphase

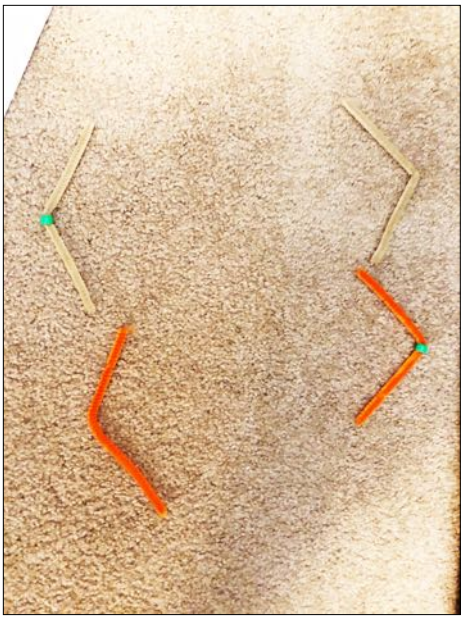
prophase



metaphase



anaphase



telophase

Answers to the Questions

a. two

b. duplicated

c. four

d. unduplicated

e. two

f. genetically identical

Activity 16 Looking at Meiosis

This lab activity could be combined with Activity #15 to help students compare the processes of mitosis and meiosis.

If you have a microscope with a 100× oil immersion lens capability (for achieving 1000× total magnification), this would be a great time to use it. However, this is not required.

If your students have access to a smartphone or another way to digitally image their observations, they may opt to take pictures at 40× (400× total) microscope magnification, and then enlarge their images digitally for easier viewing of the chromosomes.

Helpful Resources

Reference (for help identifying stages of meiosis on slides)

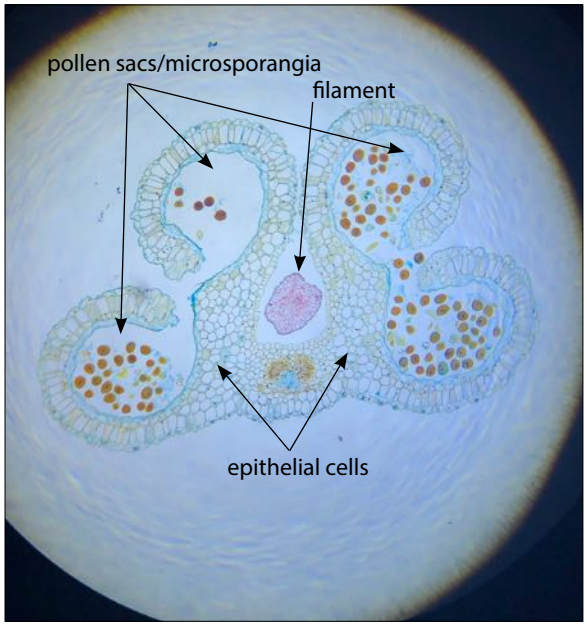
https://www.iasprr.org/old/iasprr-pix/lily/male.shtml

A set of lily anther prepared slides in various stages of meiosis is available from Amazon:

https://www.amazon.com/gp/product/B01CSURPZW/ref=ppx_yo_dt_b_asin_title_o03_s00?ie=UTF8&psc=1

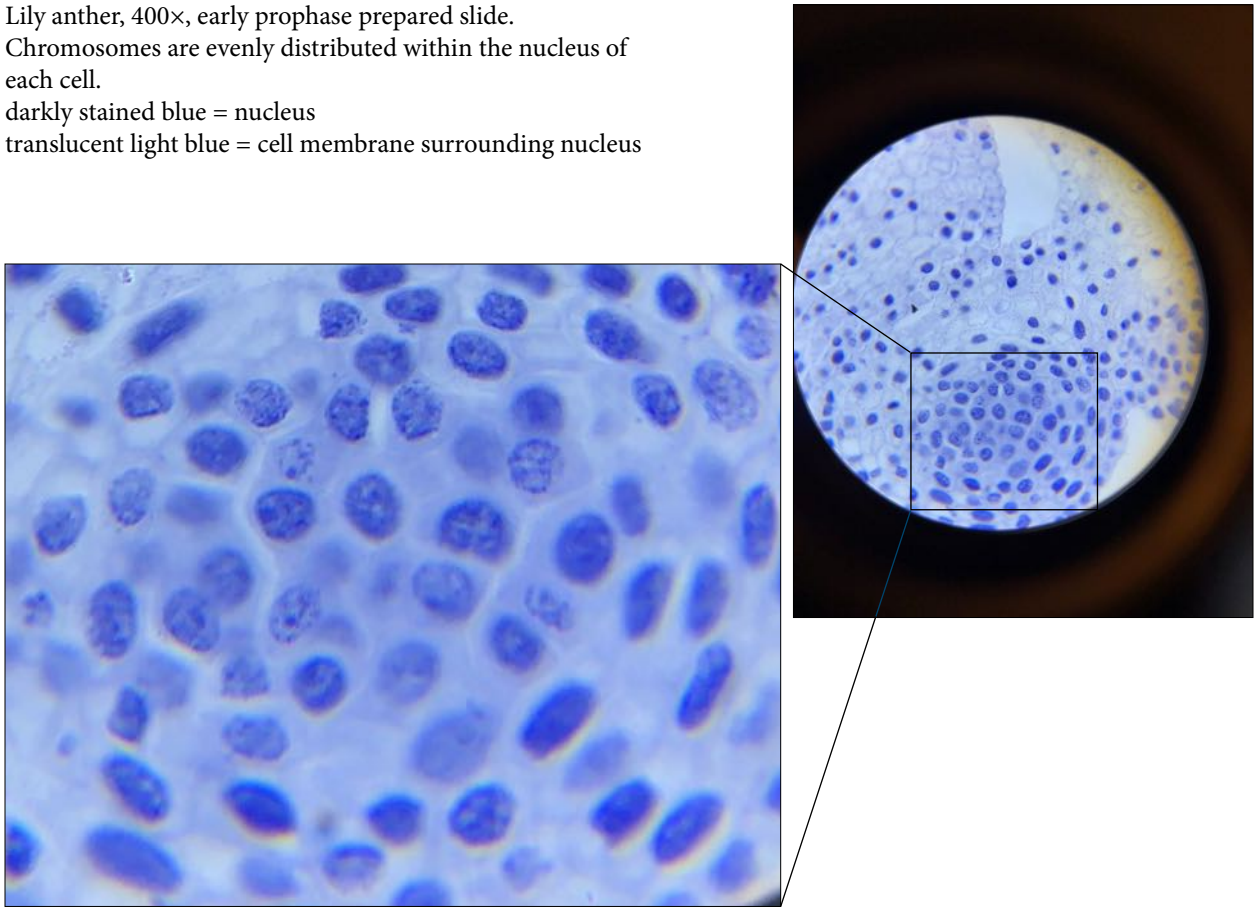
This product also contains prepared slides of the lily ovary, which are not required to complete this lab, but might be used to compare/contrast the female and male cells.

Below are some lily anther images and notes.

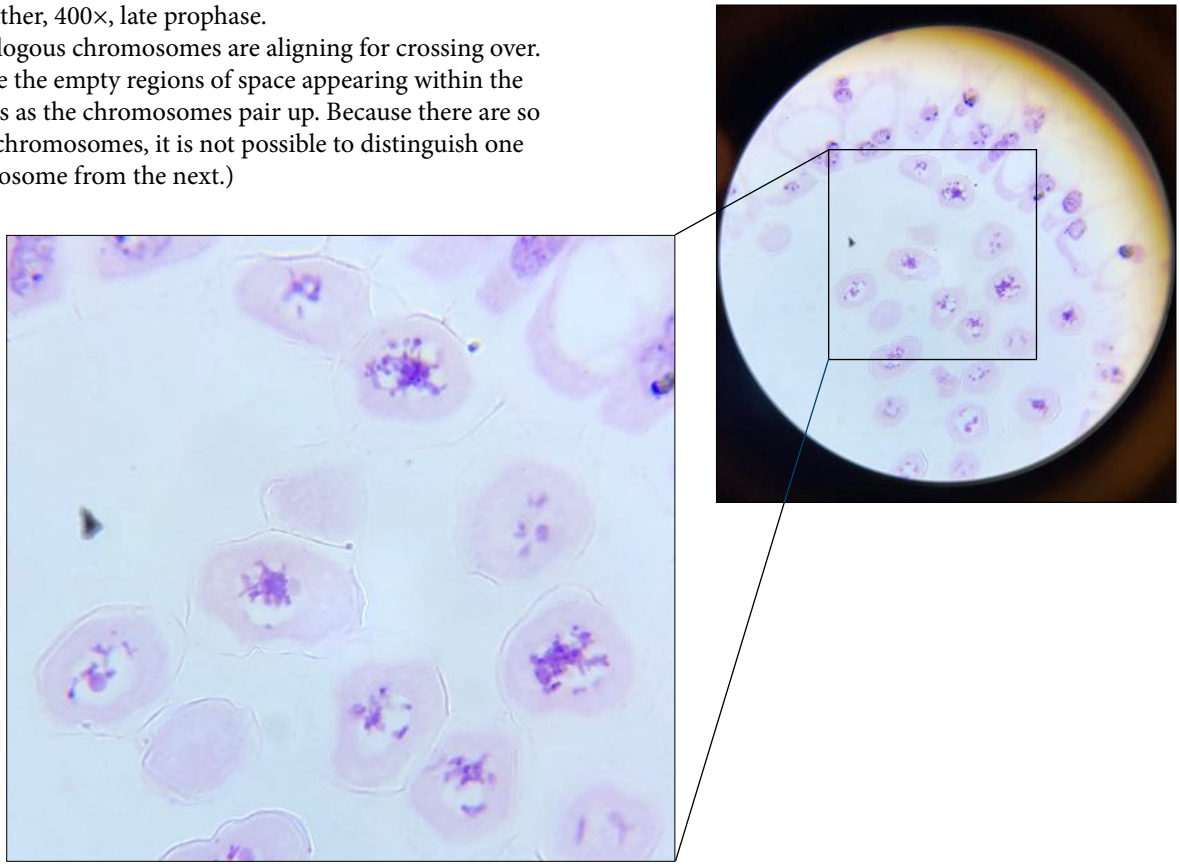


Lily anther at 40×. Yellow circles inside the pollen sacs are the pollen cells.

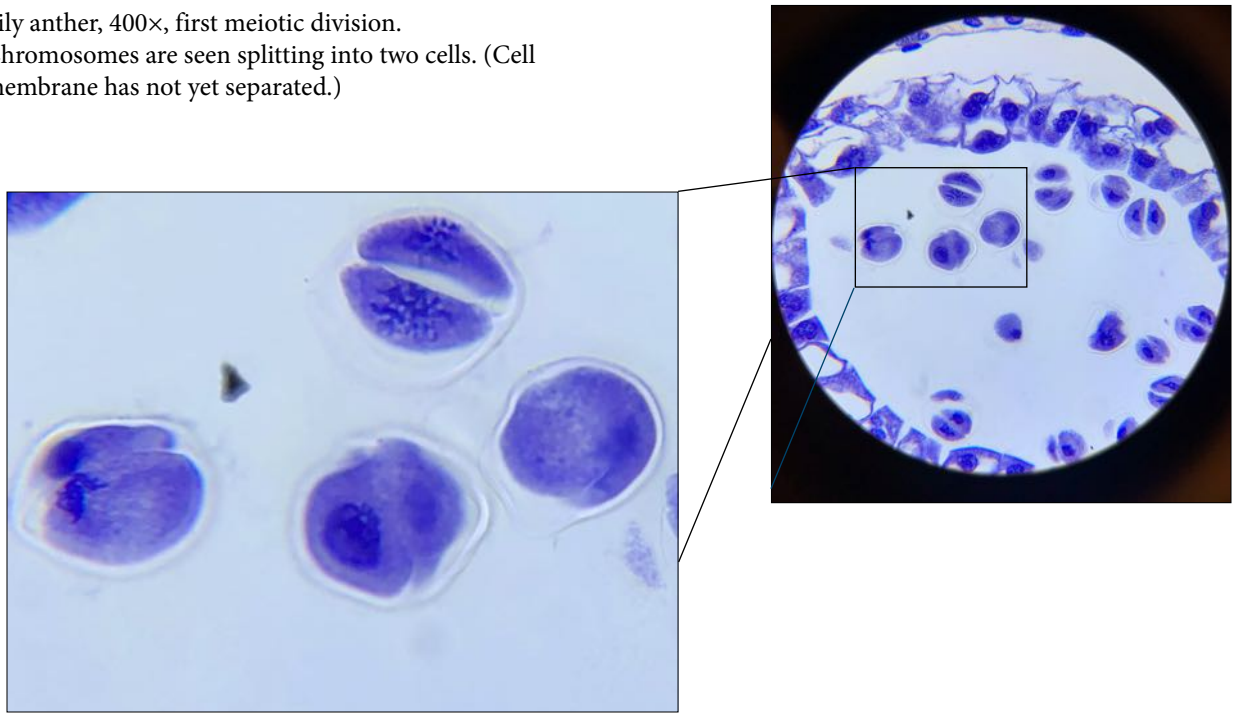
Lily anther, 400×, early prophase prepared slide.
Chromosomes are evenly distributed within the nucleus of each cell.
darkly stained blue = nucleus
translucent light blue = cell membrane surrounding nucleus



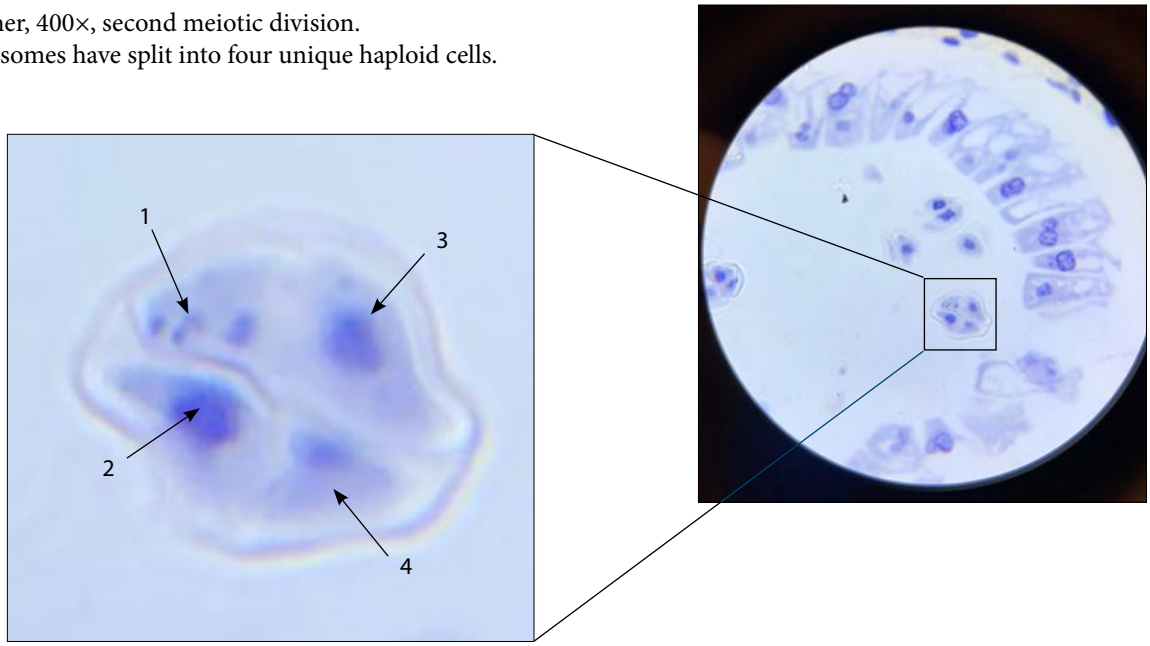
Lily anther, 400×, late prophase.
Homologous chromosomes are aligning for crossing over. (Notice the empty regions of space appearing within the nucleus as the chromosomes pair up. Because there are so many chromosomes, it is not possible to distinguish one chromosome from the next.)



Lily anther, 400×, first meiotic division.
Chromosomes are seen splitting into two cells. (Cell membrane has not yet separated.)



Lily anther, 400×, second meiotic division.
Chromosomes have split into four unique haploid cells.



Answers to the Questions

a. 2

b. duplicated

c. 4

d. unduplicated

e. 4

f. unique

Pipe-cleaner Models

The pipe cleaner chromosomes can be made in the following manner. Take a pipe cleaner and cut it in half. Insert both pipe cleaners through the 2 pony beads, joining them in the middle. The pony bead holds the pipe cleaners together and forms the centromere of the duplicated chromosome. The final chromosome looks like an 'X.' I like to use two different colors of pipe cleaners (2 of each color) to represent the homologous chromosomes.

Sample pipe-cleaner model. For extra accuracy, have the students model crossing over by cutting and reattaching a piece of pipe cleaner like so:

Occurs during prophase I.

Model without crossing over:

prophase I

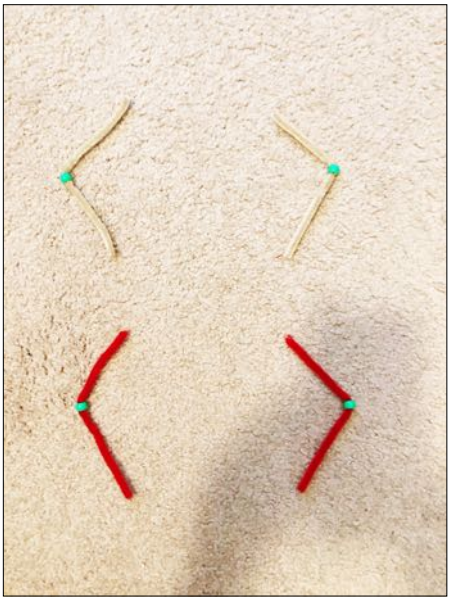
metaphase I

anaphase I

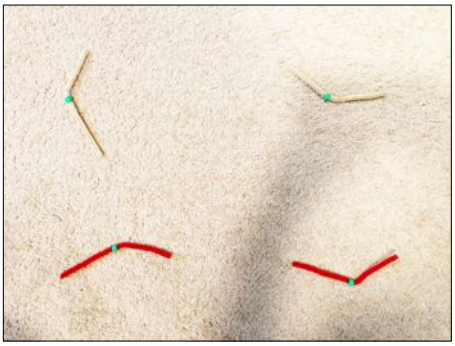
telophase/cytokinesis
Right and left are becoming two separate cells.

prophase II
Top and bottom are part of different cells.

metaphase II
Top and bottom are part of different cells.
Chromosomes are aligned across the center of each cell.



anaphase II
Top and bottom are part of different cells.



telophase II/cytokinesis
Four cells are now present, each with one unique pipe-cleaner chromosome.

Activity 17 Inheritance: Following Mendel

If you are running this for an entire class, you may want to purchase the "Corn Genetics Set" from Carolina Biology (#176321). If it is a small group of students, you could probably purchase one or two individual ears of corn. For those who for some reason can't get real ears of corn, you can make an artificial ear by wrapping a paper towel tube with a print of the image shown on the following page (drawn from an actual ear of corn). To make the kernel-counting task as lifelike as possible, trim the paper-towel tube to be the same length as the kernel image, 9.5 inches. (The width of the image has been scaled to fit exactly around a standard tube.) The photo below shows what this artificial ear can look like. The printable pattern is shown on the following page.

The dihybrid portion is optional as some teachers may choose not to emphasize the dihybrid crosses.

Answers to Questions

2. Monohybrid ratio should be about 3:1 (purple:yellow)

3. The numbers of kernels might slightly differ from other classmates', if the class is using different ears of corn. However, when these numbers are reduced into whole-number ratios, the ratios should all be 3:1.

4. Because both purple and yellow show up in the F_2 generation, with a ratio of 3:1, we can conclude that the F_1 generation cobs were heterozygous for these traits, and that purple is dominant over yellow.

5. Genotypes: Purple parent (PP); yellow parent (pp); F_1 (Pp). (Remember that the alleles should be represented by the same letter, so we indicate the yellow genotype as lowercase p).

		sperm from F_1 plant: P	sperm from F_1 plant: p
egg from F_1 plant	P	PP purple	Pp purple
	p	Pp purple	pp yellow

6.

Expected genotype ratio of PP:Pp:pp would be 1:2:1

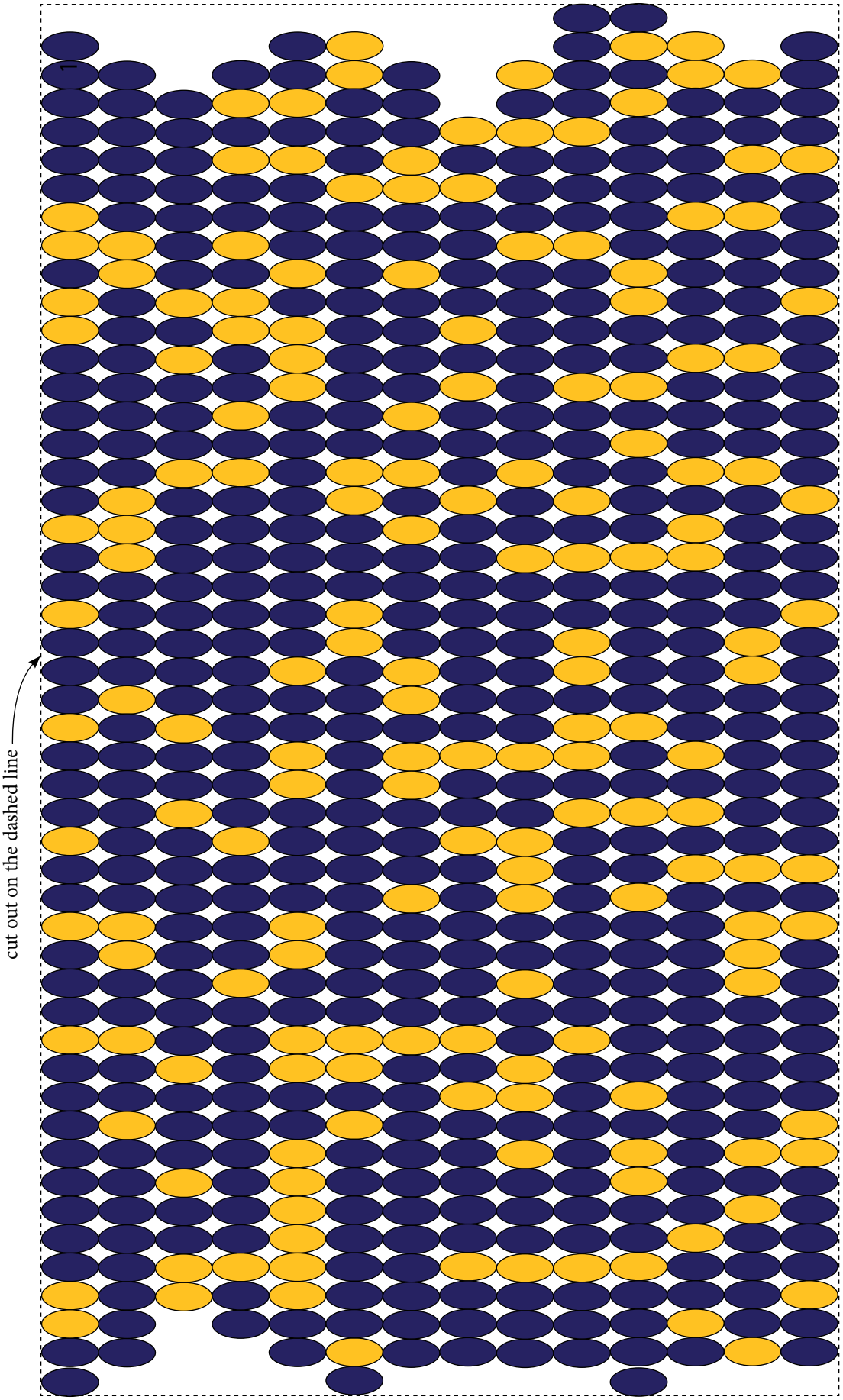
7. Yes, our observed phenotype ratio of purple:yellow, 3:1, matches the genotype ratio predicted by the Punnett Square. Both the PP and Pp genotypes produce a purple phenotype, so adding 2+1 gives us 3. Only the pp genotype gives us a yellow phenotype. Therefore, a 1:2:1 genotype ratio is equivalent to a 3:1 phenotype ratio.

Dihybrid cross genotypes:

1. Purple, starchy parent (PPSS); Yellow, sweet parent (ppss)

2. F_1 (PpSs)

3. 9/16 will be purple, starchy; 3/16 will be purple, sweet; 3/16 will be yellow, starchy; 1/16 will be yellow, sweet. Purple and starchy are the dominant traits.



Activity 18 Blood Typing

Scenario 1

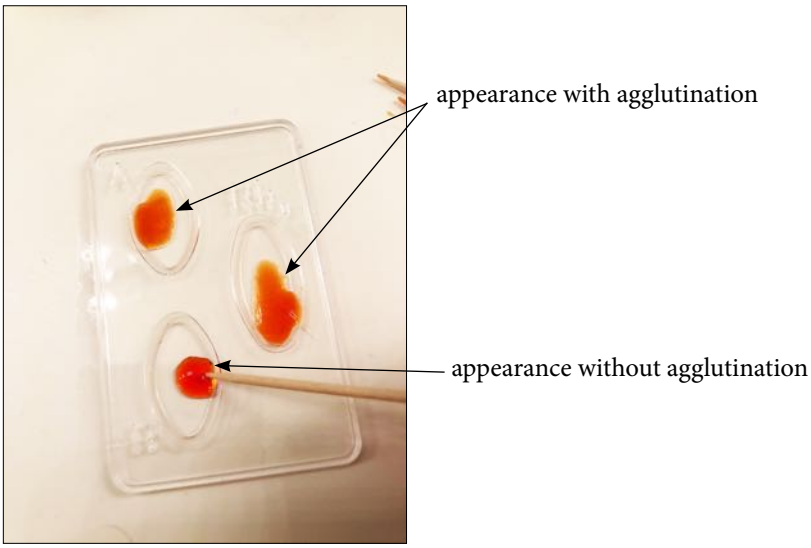
Punnett square:

Rh-positive father \ Rh-negative mother	r	r
R	Rr	Rr
R	Rr	Rr

The Rh-positive allele is dominant and present in every possible inheritance outcome from these two parents. Thus, the child has a 100% chance of having Rh-positive blood. Therefore, the mother should have the RhoGAM shot.

Sample #1	Anti-A Serum	Anti-B Serum	Anti-Rh Serum
Result (agglutination?)	+	–	+

Blood Type for Sample #1: A+



6. If agglutination occurs, it means the antigen is present in your sample. Based on your observations, what is the blood type of Sample #1?

   A+

7. Will this blood type in the baby cause the mother to need the RhoGAM shot? Why or why not?

   Yes. If the mother is Rh-negative but the baby is Rh-positive, then the mother will need the RhoGAM shot to protect future pregnancies.

Scenario 2

Sample #2	Anti-A Serum	Anti-B Serum	Anti-Rh Serum
Agglutination Results	–	+	–

Blood Type	B–

Sample #4	Anti-A Serum	Anti-B Serum	Anti-Rh Serum
Agglutination Results	–	–	–
Blood Type	O–		

8. Which donor blood sample will you recommend for the mother who has A– blood? Why?

   I would recommend Sample #4 (type O–). While both blood samples are Rh-negative just like the mother, Sample #2 displays the B antigen. This will cause an immune response from the mother whose blood cells have the A antigen but not the B antigen.

Scenario 3

Sample #3	Anti-A Serum	Anti-B Serum	Anti-Rh Serum
Agglutination Results	+	+	+
Blood Type	AB+		

Dihybrid Punnett square:

Mother's genotype: I^Birr

Father's genotype: I^AiRr

	I^Br	I^Br	ir	ir
I^AR	I^AI^BRr	I^AI^BRr	I^AiRr	I^AiRr
I^Ar	I^AI^Brr	I^AI^Brr	I^Airr	I^Airr
iR	I^BiRr	I^BiRr	$iiRr$	$iiRr$
ir	I^Birr	I^Birr	$iirr$	$iirr$

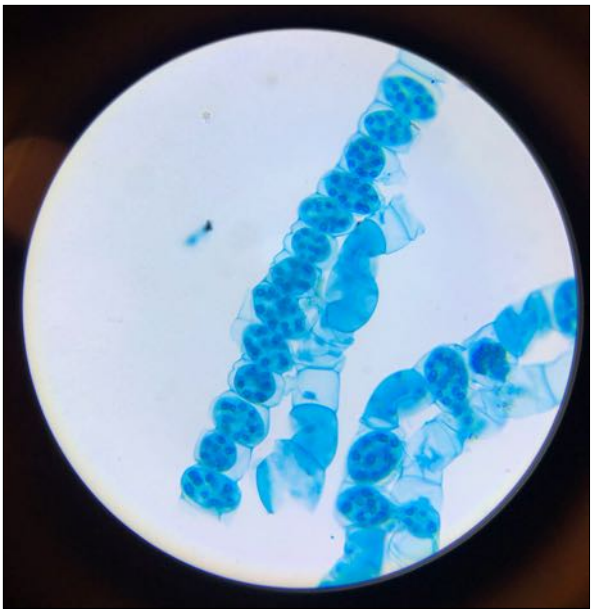
Probability calculation:

Phenotype of AB+ can have a genotype of I^AI^BRr or I^AI^BRR. There are two of the first of these outcomes and none of the second, out of 16 total possible outcomes. That gives a probability of 2/16 or 1/8 = 0.125 of the child having AB+ blood.

Activity 19 Microbes

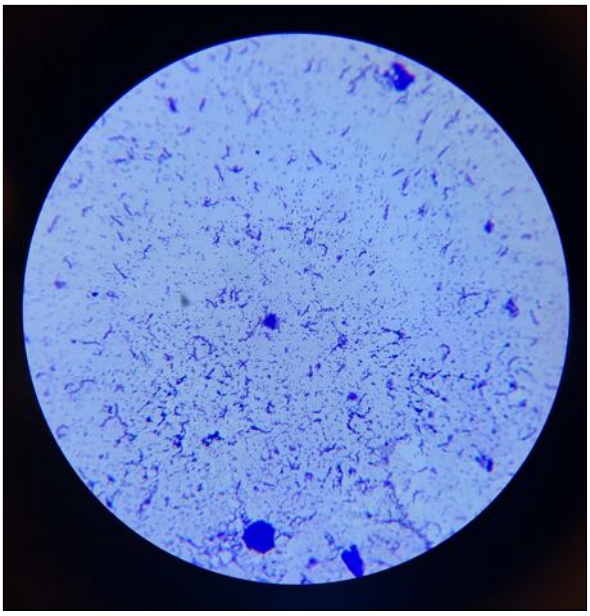
This activity pairs well with Activity 20, The Dichotomous Key. If you choose to pair these two activities, I recommend doing Activity 19 first because it enables students to look at the prepared slides of several of the protists before trying to identify them in a live culture.

The *Spirogyra* have photosynthetic pigments within their cells that allows them to perform photosynthesis. They are often found as algae in ponds and other freshwater environments.



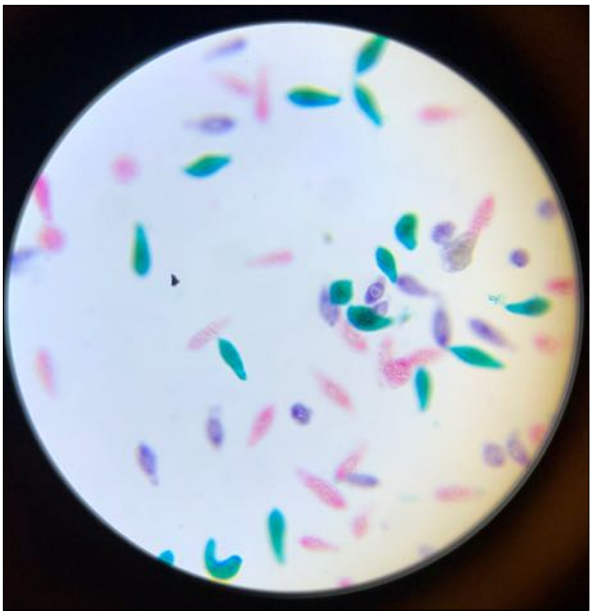
Spirogyra, 400×

The microbes in the smear of bacteria will be the most difficult for students to find as the bacteria are very small. They will probably look like small dots or lines on the slide. The three main shapes of bacteria are cocci (spherical), bacilli (rod or bar shaped), and spirilli (spiral or squiggly).



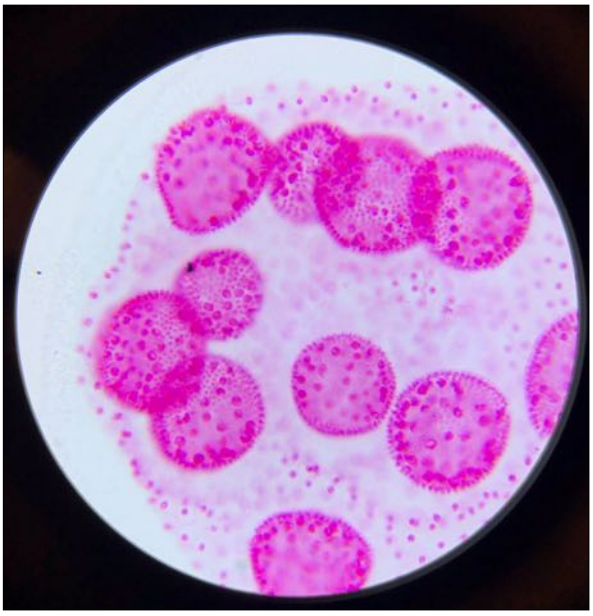
Bacteria, Three types, smear, 400×

Euglena contain chloroplasts and can carry out photosynthesis. In this way, they are plant-like protists. However, they are also capable of consuming food. Because they have characteristics of both autotrophs and heterotrophs, they are considered mixotrophs. *Euglena* have a single flagellum they use to propel themselves. These are usually not visible in the prepared slides.



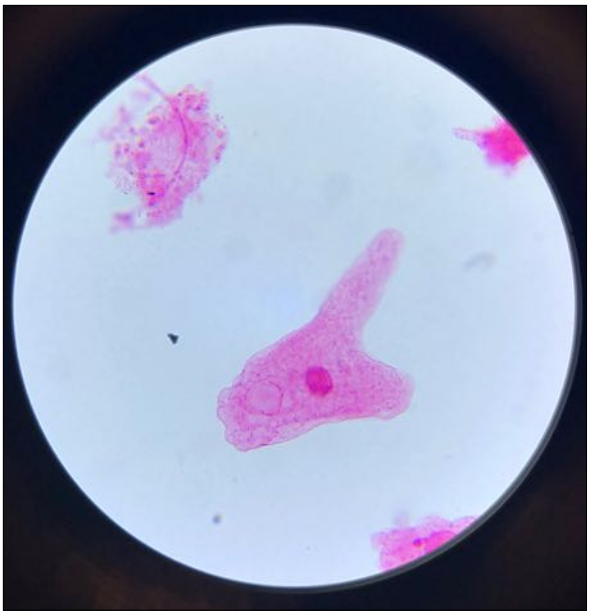
Euglena, 400×

Volvox is sometimes considered colonial and sometimes considered multicellular. I have gone with the colonial classification here. They are also plant-like protists often found in ponds. Each of the little cells on the surface of the sphere contains a flagellum that allows the *Volvox* to slowly float/spin through its environment.



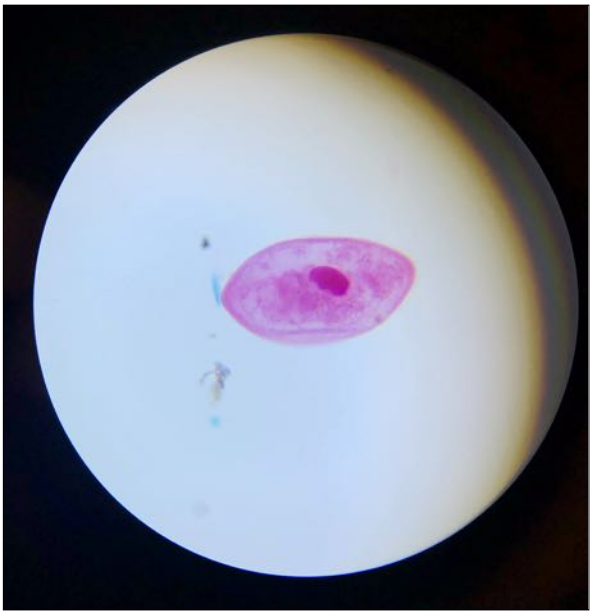
Volvox, 400×

Amoeba use pseudopods to move and ingest their food via phagocytosis. You may be able to see a food vacuole inside the cell as a result of this process. They are animal-like protists.



Amoeba, 400×

Paramecia use cilia-small hair-like projections surrounding the cell that beat to propel the organism. They are also animal-like protists.



Paramecium, 400×

Activity 20 Dichotomous Keys

When using the dichotomous key, sometimes students want to go down the list and start with something they can see. Remind students that they must always begin with the first item in the dichotomous key.

To make slides of living protists, you want to have students get a drop of pond water or from the live protist culture, Home Science Tools LD-PROTOZOA. Alternatively, you can order a dry protozoa culture kit from Home Science Tools (LM-PROTIST). Take the drop from the bottom where there is visible algae (the food on which protists feed).

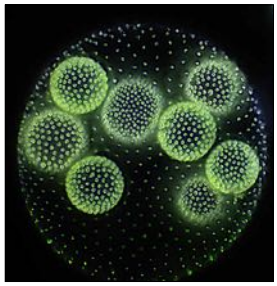
Amoeba tend to be found on the bottom of the jar but can get dislodged if it is shaken or moved too much. You will probably see more *Colpidium* than *Paramecium*. They are similar, but the *Colpidium* are smaller and more numerous.

To make a slide of the living protists, add the drop to a blank glass slide. Gently place a cover slip over the drop of water as described in Activity #3 for how to prepare a slide. View the slide under the microscope.

Student's may find that creating a dichotomous key of their own is more challenging than they initially anticipate. Use the suggested hints to help guide them. Remember that each item should only have two options, no more.

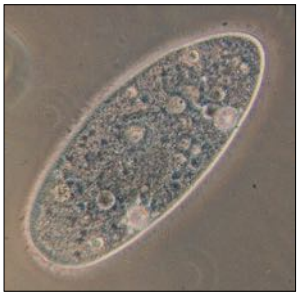
Answers to the Protist Key activity are shown below.

Blepharisma



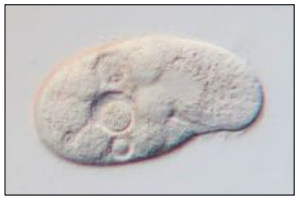
Volvox

Vorticella



Paramecium

Stentor



Colipidium

Amoeba

Euglena

Activity 21 Growing Bacteria

This experiment has much room for creativity. It's up to you to guide your students as to what types of surfaces you will test. You could also place sensitivity strips (available from Home Science Tools) to test different cleaning products for their ability to kill bacteria.

Make sure that you properly dispose of the Petri dishes when finished with this experiment and the next (Gram Staining—Activity #22). Cover the agar surface with either a bleach solution or 70% isopropanol (isopropyl alcohol), tape the Petri dish shut, enclose in a gallon size ziplock bag, and dispose in the regular trash.

Questions for Reflection

1. Why is it important that you collect your sample with a sterile swab?

Sterile swabs have been steamed at high temperature to kill any possible microorganisms. You should use sterile swabs so that the only bacteria you culture are those you obtained from swabbing your surface.

2. Why does the swabbing technique matter for isolating single colonies?

On any particular surface, there may be large numbers of different bacterial species present. Thus, your swab will have these many bacteria clumped together. If they are plated together, they will compete with one another for space and resources, and you may wind up with a rather complicated mess. By streaking via the repeating zig-zag patterns, you are essentially spreading fewer and fewer bacteria over a larger space—giving single bacteria room to grow. Any colony that you observe after a few days should thus have come from a single parent bacterial cell, and should have uniform properties.

Swab of toilet seat, observed after 3 days on benchtop. Notice the single colonies in the center and top left of the Petri dish, while the bottom left/right has more overgrown clumps. This is why it is important to swab so that your sample is "diluted" over the Petri dish.

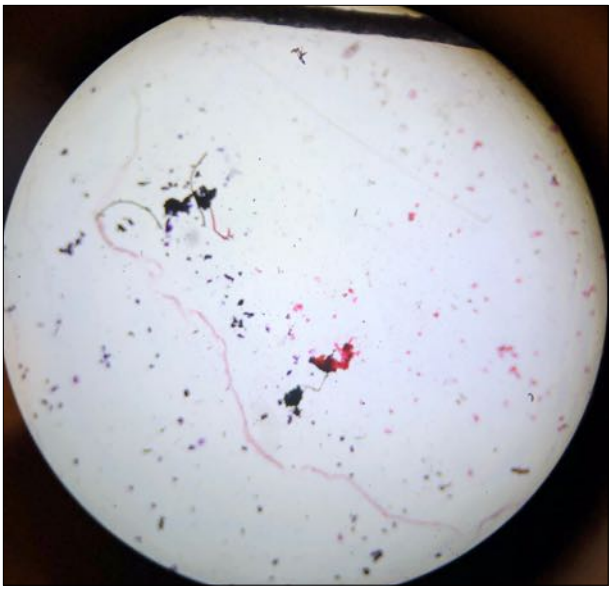
Swab from bathroom sink handle, after three days on benchtop. Notice how there are substantially fewer bacterial colonies than for the toilet seat. Also notice how the swabbing pattern is evident on the top of the Petri dish, where the most growth occurs. The next "dilution" of the swabbing pattern is visible on the upper right quadrant. The other portions of the Petri dish do not yet exhibit any growth because not enough time has passed for visible colonies to appear. These results show that the toilet seat had much more bacterial contamination than did the sink handle.

3. Why is it important to incubate your Petri dishes with the agar side up?

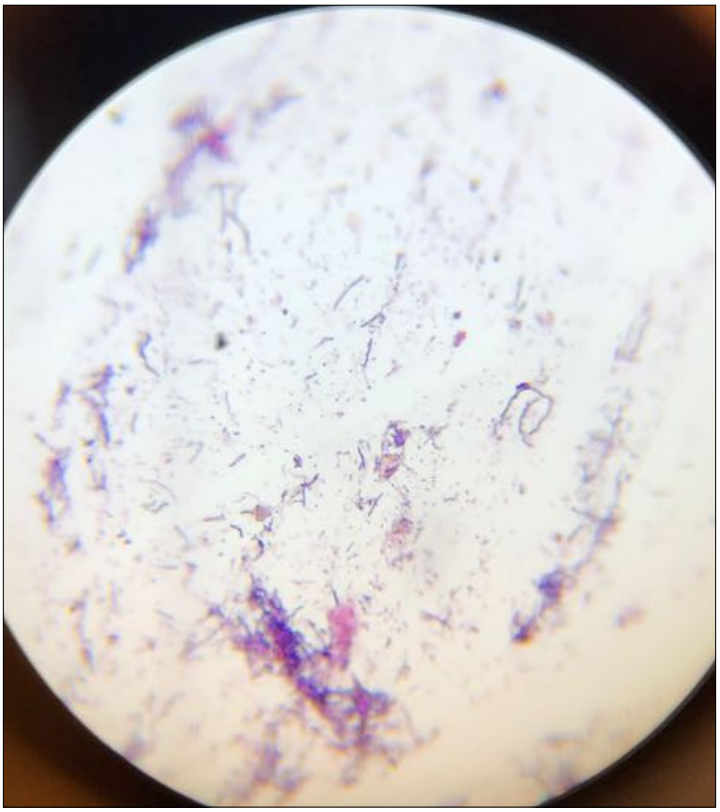
The answer has to do with condensation. Water from the agar will have the tendency to evaporate. If you keep the agar side down, the water will evaporate and condense at the top—but then pool up and fall back down on the agar. As a result, some colonies may have more moisture than others, and there may be mixing and contamination. By keeping the agar side up, the moisture in the agar stays uniformly distributed, keeping the colonies from cross-contaminating.

Activity 22 Gram Staining

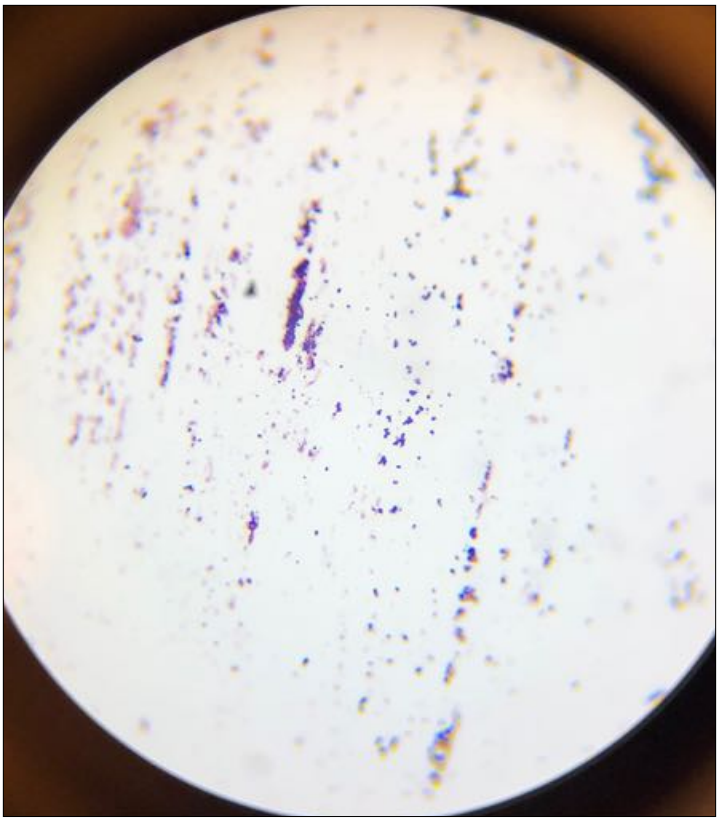
This activity is especially beneficial for development of careful technique. You may opt to perform only the Gram stain with teeth-bacteria, or to test also colonies from Activity #21.



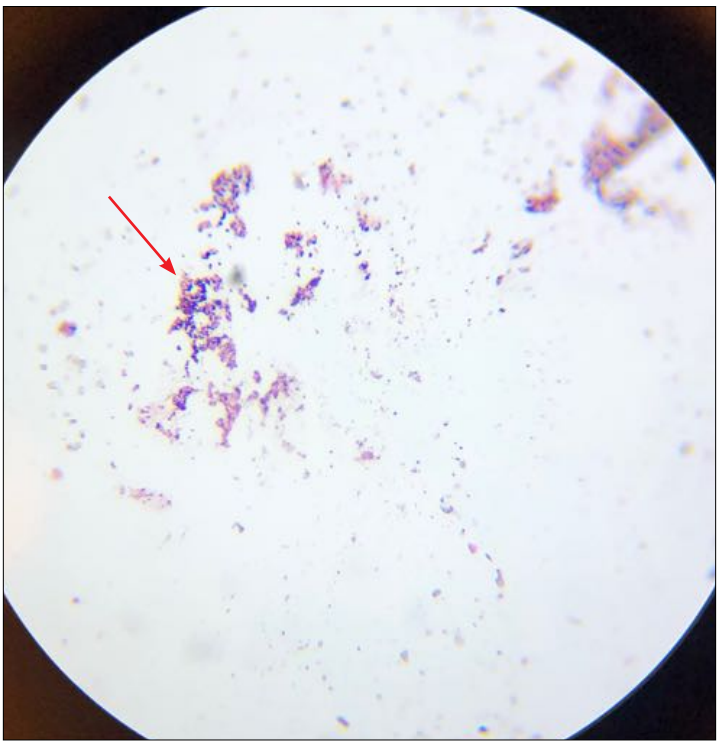
Gram stain of tooth bacteria, 40×. Notice the presence of both purple (left) and red-stained cells (right). The larger cells are eukaryotic, and zooming down to the very tiny cells reveals the types of bacteria present.



Gram stain of teeth bacteria, 400×. Notice that there are diverse species present (both cocci and rods).

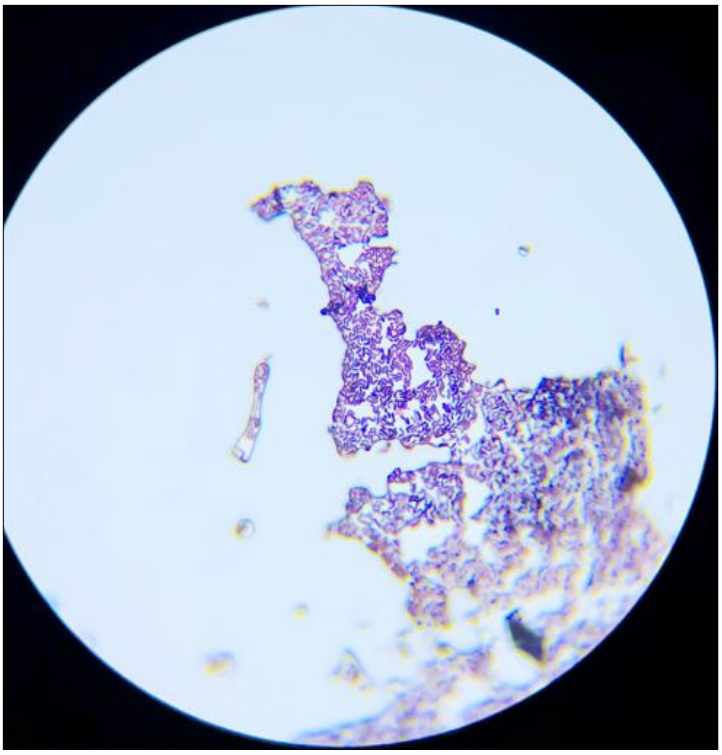


Gram Stain of single white-colored colony grown from the bathroom door handle, 400×. Bacteria are spherical and predominantly gram-positive (purple).



Gram stain of single white colony grown from bathroom sink handle, 400×. Gram-negative stain seems to predominate here, although there are some purple bacteria present (left of center). Either the colony merged with another from overgrowth (the Petri dish had been sitting over a week) or the ethanol step of the gram stain was not quite long enough.

#18: The colonies from the Petri dishes should look much more uniform. If they truly represent one colony, they should have a single type of bacteria present. In contrast, the teeth bacteria should contain many diverse species.



This photo shows a much better gram stain. The student swabbed the microwave button panel in the teacher's lounge, and gram stained a single colony. The resulting bacteria are uniform in nature—and are gram positive rods.

Activity 23 Introduction to Fungi

Abbreviations for prepared slides:

w.m. = whole mount

c.s = cross-section

l.s. = longitudinal section

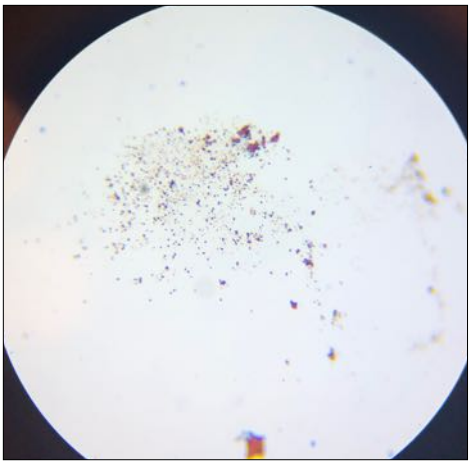
sec. = section

Part 1

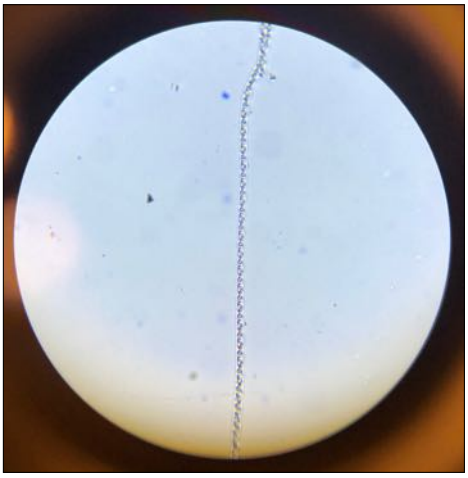
Field study: You may opt to skip the nature study step, and to obtain a water or soil sample yourself, ahead of time. Or, you may find that the nature study is a valuable part of connecting the students to their surroundings. The soil sample may be used immediately after collection.

You may find that your students are enthralled with what they see in their microscopic soil or water sample. If so, don't rush it. This may turn into a two-day lab.

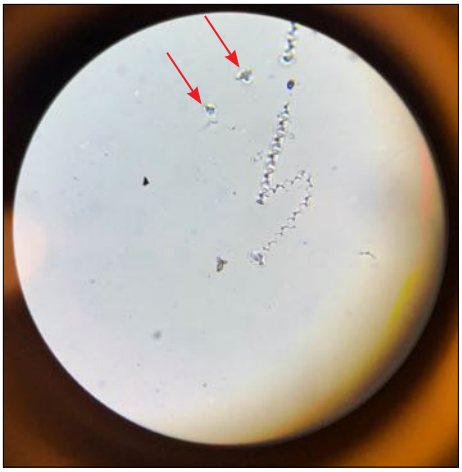
Here are some inhabitants of my Southern-California backyard soil, after a good rainfall in the winter.



Filtered backyard soil-water, 400×.



Filtered backyard soil-water, 400×.

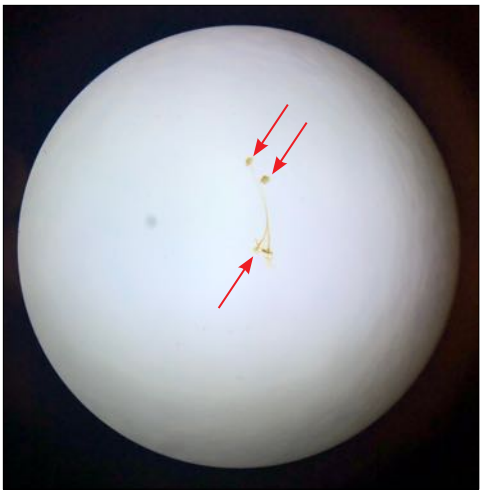


Filtered backyard soil-water, 400×. Center, top half, there are two unicellular organisms, with the lower one looking like it has a flagellum. Possibly a chytrid?

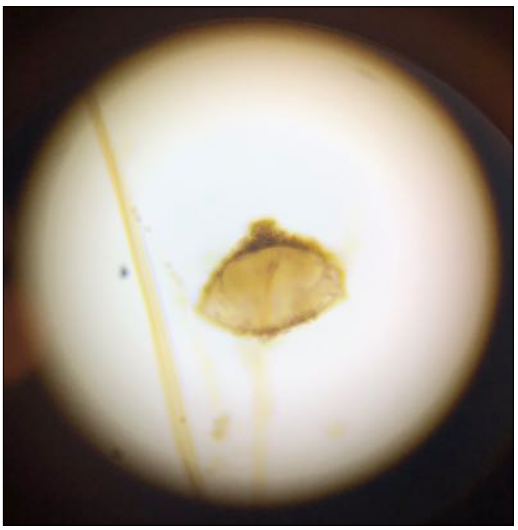
Part 2

The purpose of this study is to compare/contrast different features of fungal phyla. Instructors may opt to omit some of the prepared slides in order to focus on others.

1. Phylum Zygomycota



Rhizopus at 400×, mycelium.

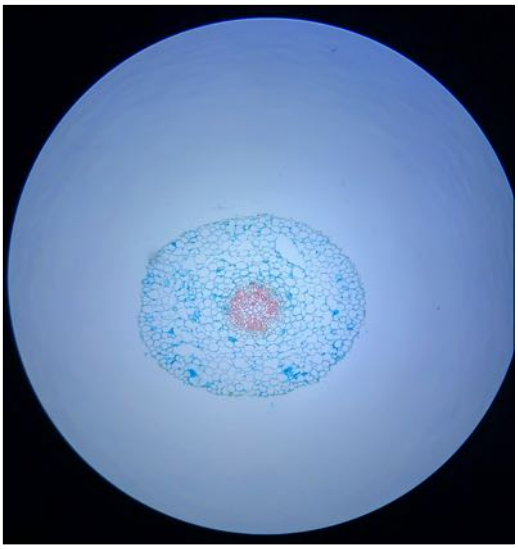


Rhizopus at 400×, sporangia.

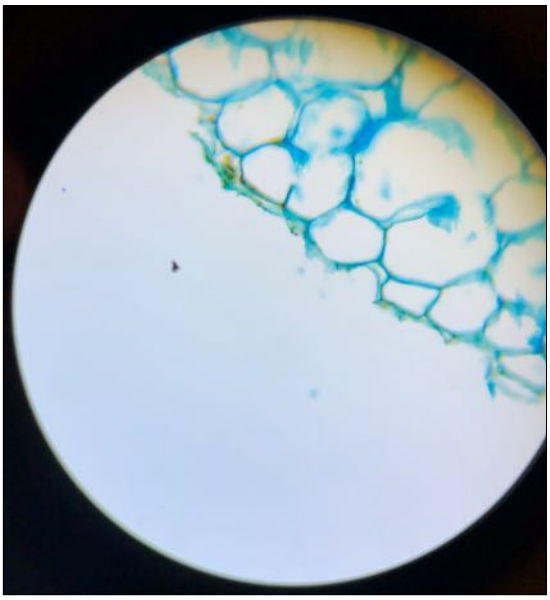
The sample is reproducing asexually—no suspensors or zygospores are visible. There is one sporangium per hyphae. The structure is not connecting two hyphae as would be the case for sexual reproduction.

2. Phylum Glomeromycota

Note: other slides showcasing various mycorrhizae are available from Carolina Biological Supply. We chose the *Ranunculus* slide here because is it more readily available from Home Science Tools.

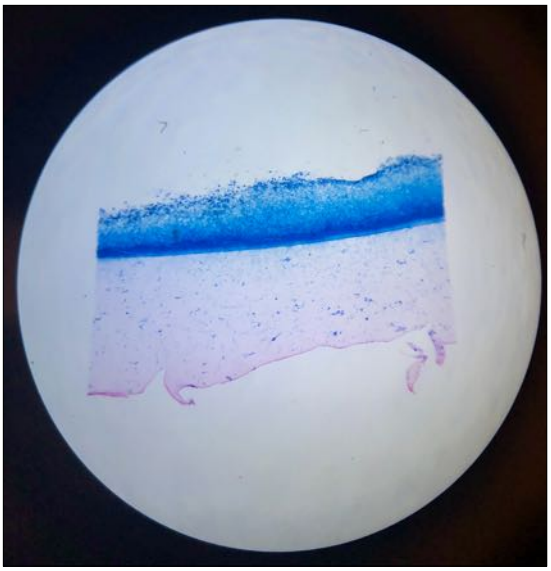


Ranunculus root cross-section, 40×.

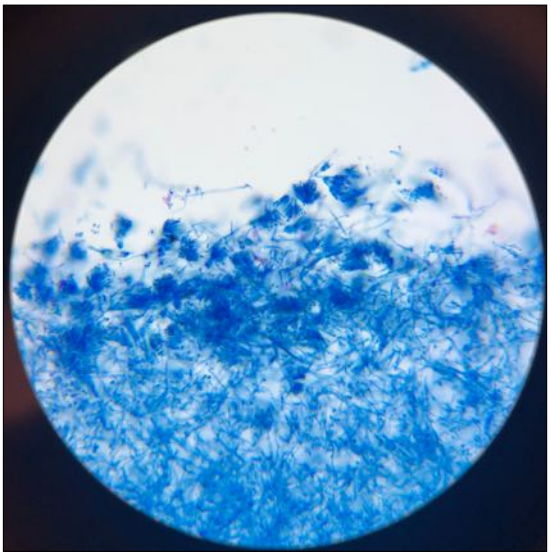


Ranunculus root cross-section, 400×, outer edge. Mycorrhizae are visible as the darker green/black structures at the edge of the root that are pushing their way into the cells.

3. Phylum Ascomycota

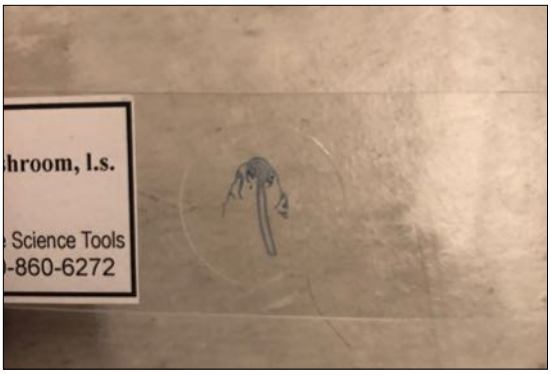


Penicillium, 40×.

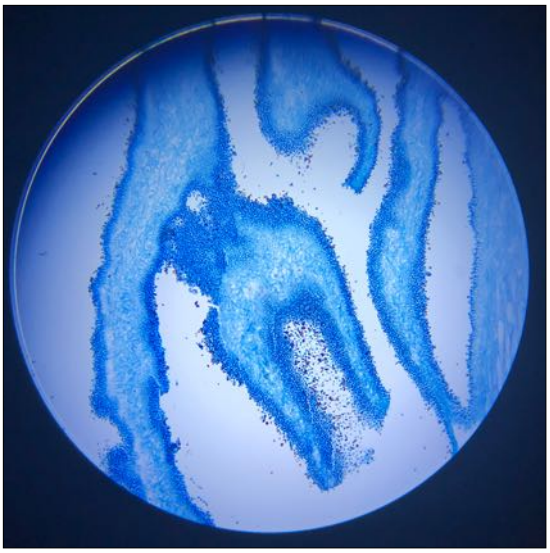


Penicillium, 400×. Conidia are visible at top. Note that each conidium has multiple asci (vertical structures with ascospores).

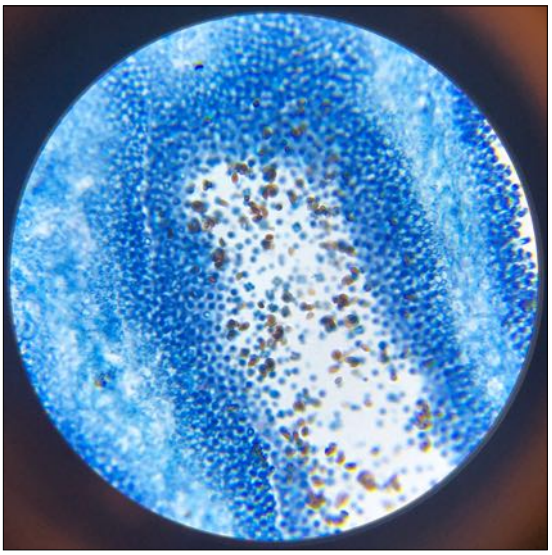
4. Phylum basidiomycota



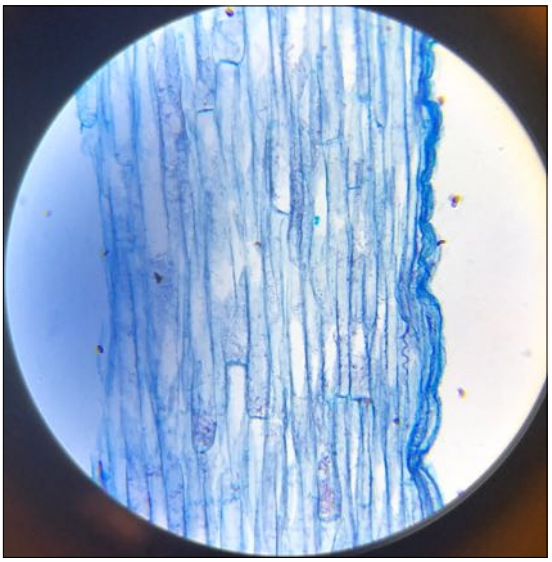
Mushroom slide, not magnified. (Longitudinal section). Mycelium is the long stem on the bottom. Fruiting body is the globular structure on the top.



Mushroom, fruiting body (protrusion), 100×.

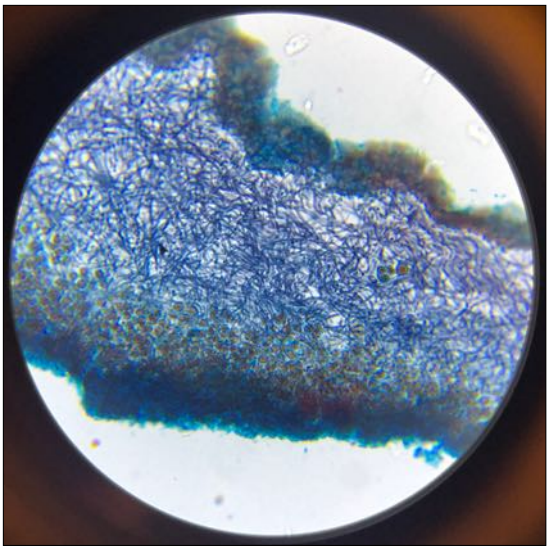


Mushroom fruiting body, (zoomed in from above image), 400×. Spores are shown in gold, center.



Mushroom mycelium, 400×. Septae are shown separating the long, vertical cells of the hyphae.

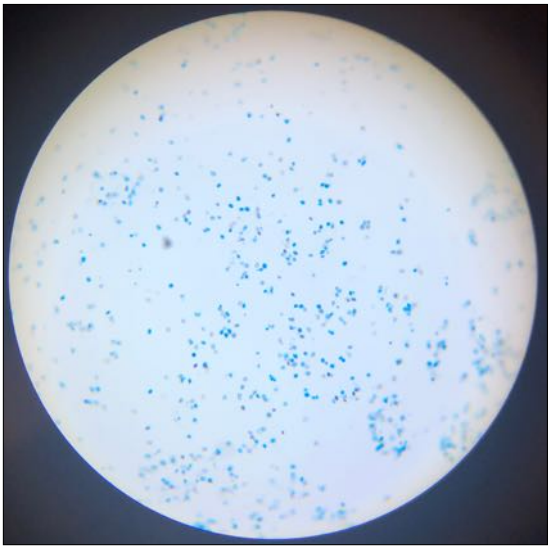
5. Lichen



Lichen 400×. Algal cells appear near the bottom in more gold color, surrounded by the blue hyphae of the fungus.

6. Unicellular fungi

The yeast are football-shaped, small, and unicellular. Yeast are ascomycota.



Yeast at 400×.

References

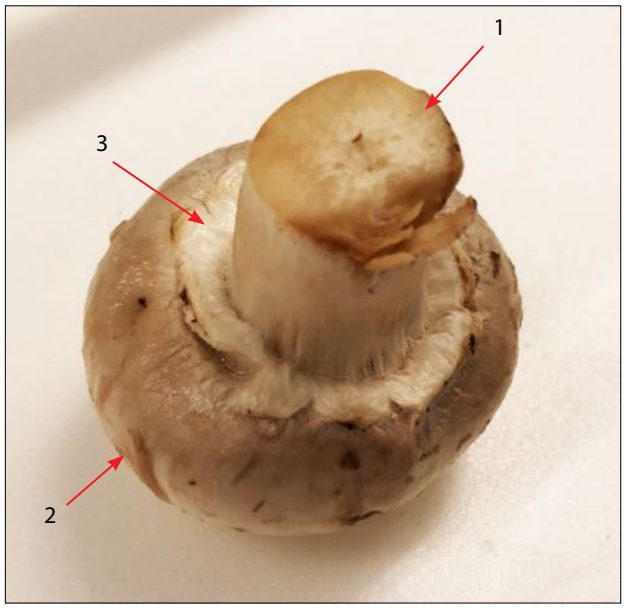
Procedure for chytrid isolation:

https://nsfpeet.as.ua.edu/isolation.htm

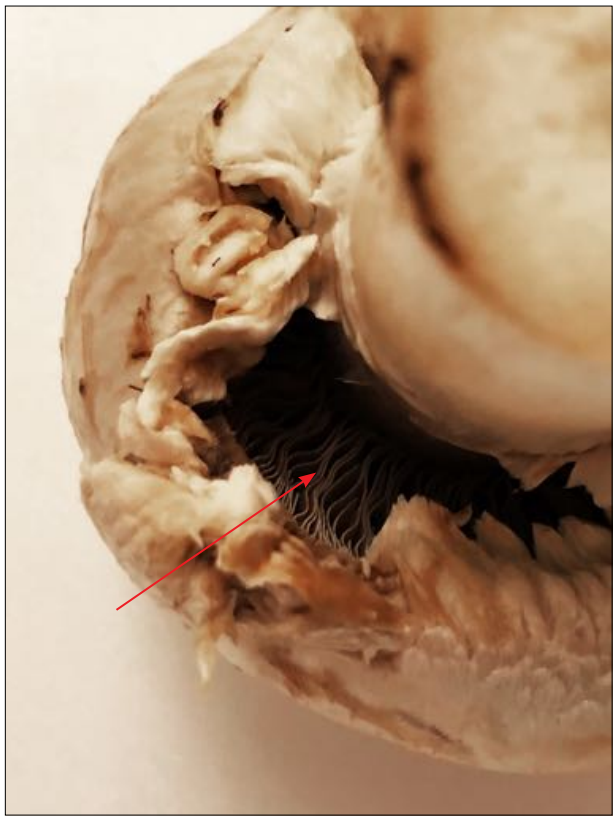
https://umaine.edu/chytrids/isolation-methods-for-chytrids/

Activity 24 Mushroom Dissection

Obtain a mushroom. Make a close examination of the mushroom and make a sketch of the entire organism in the space provided below. Label the following structures: cap, stalk, and gills. If you cannot see the gills, gently use some forceps to remove the thin tissue on the underside of the cap. This is known as the veil. It protects the gills. As you remove the veil, be careful not to damage the gills in the process.



1. Stalk
2. Cap
3. Veil (circled, surrounding stalk)

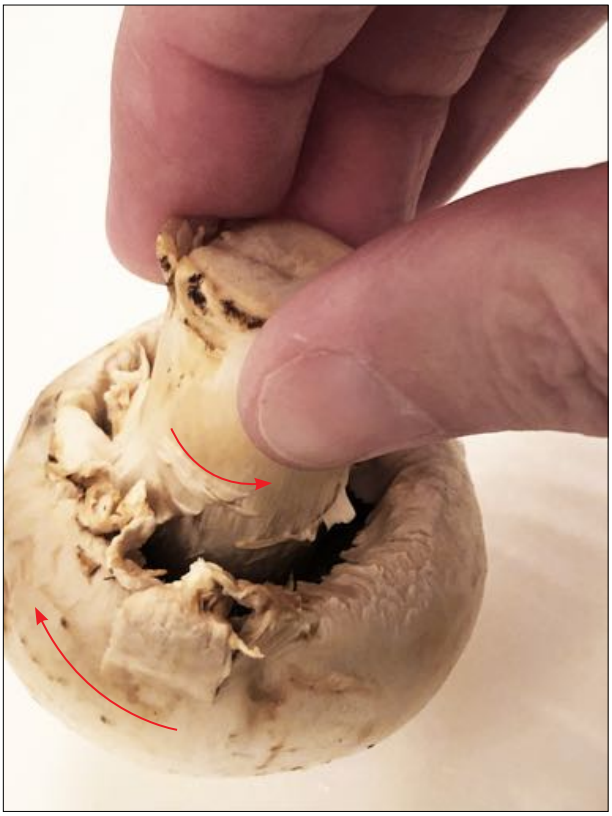


Mushroom after the veil is removed. The gills are visible underneath (indicated by arrow).

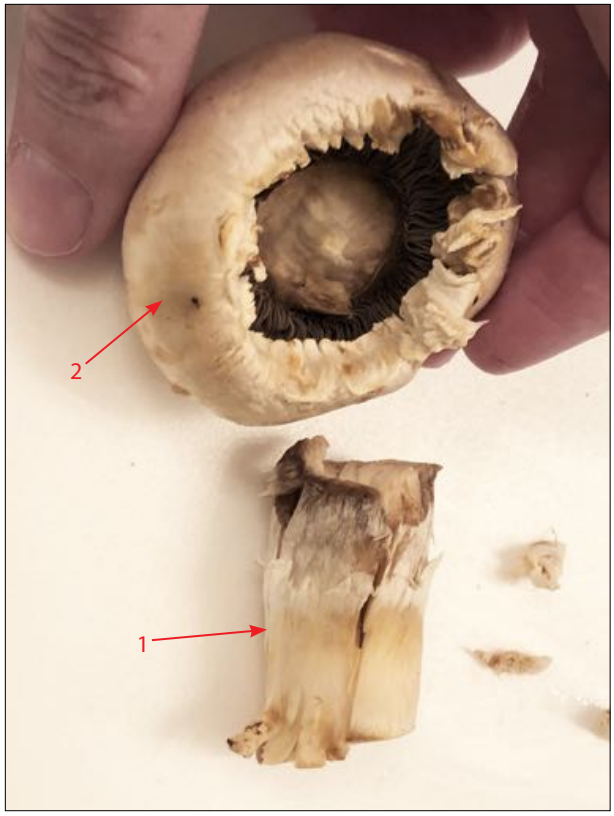
2. What do you notice about the structure of the gills? Are they designed to have high or low surface area? What do you think the purpose of the gills is, and in light of that purpose, how might the surface area of the gills contribute to that purpose?

   The gills are arranged in parallel but separate from one another such that they have very high surface area. The purpose of the gills is to disperse spores for the purpose of reproduction. Higher surface area allows for a much greater number of spores to be released, increasing the chances of reproductive success.

3. To remove the cap, firmly hold the cap with one hand. With the other hand, gently twist the stem until it breaks off. Pinch the stem between your fingers and gently pull the stem apart, much like string cheese, until you have several thin, hair-like strands. These are the hyphae. Use a magnifying glass to observe the hyphae. Include a sketch and description of them in the space provided below.



Twist the stalk off while holding on to the cap.

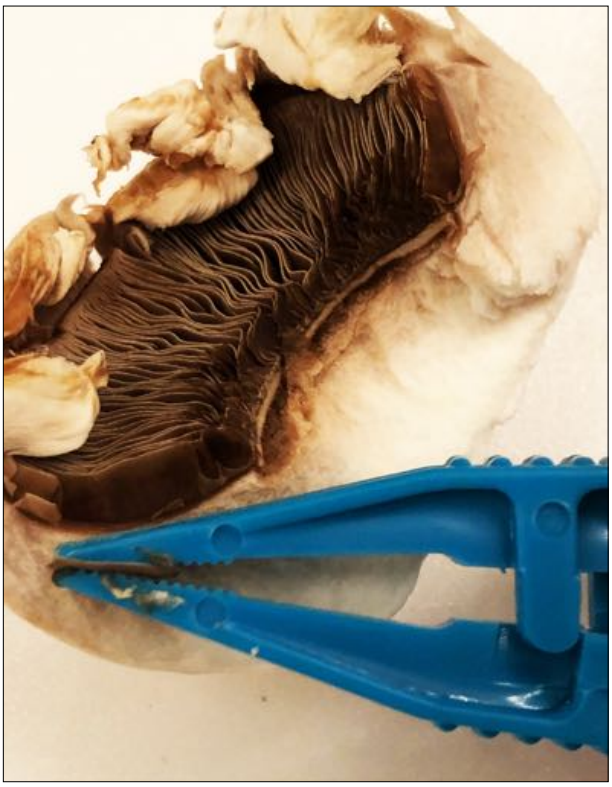


The stalk (1) is shown here, separated from the cap (2).

The interior of the stalk, with the string-like hyphae shown.

4. Take the cap and locate the gills on the underside of the cap. Use a pair of forceps to carefully remove one gill from the cap. To do so, *gently* grasp the gill at the base where it attaches to the cap. If you pull on the free edge you are likely to tear the gill. Put the gill on a glass slide. Add a drop of water and a cover slip. Look at the gill under the low power objective of the microscope. Focus on the free edge of the gill. Make a sketch of what you

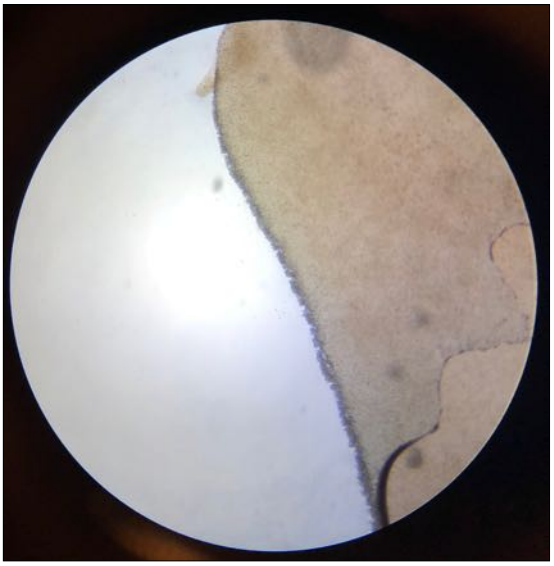
see in the circle provided.



The gill at the lower end is carefully removed with forceps.

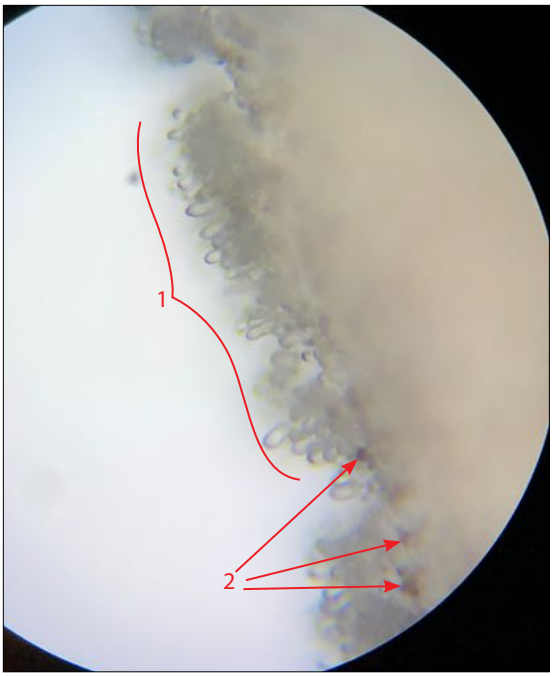
Gill is placed on slide with a drop of water.

Place coverslip over gill and water.



Edge of gill at low magnification.

b. Center in on the finger-like projections and turn to a higher objective. The projections are the basidia. A mature mushroom will have spores attached to the basidia. Make a labeled sketch of the basidia and spores.

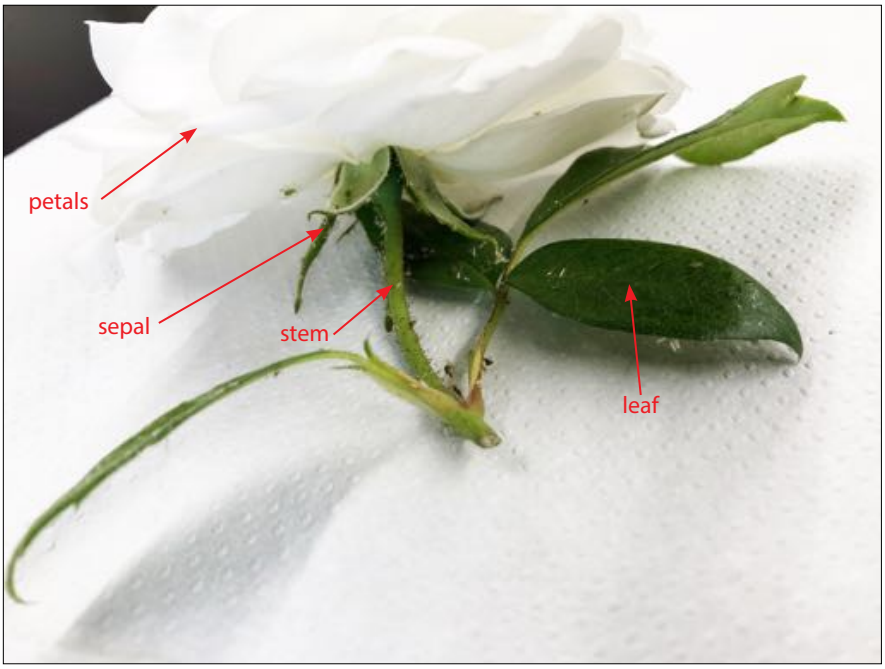


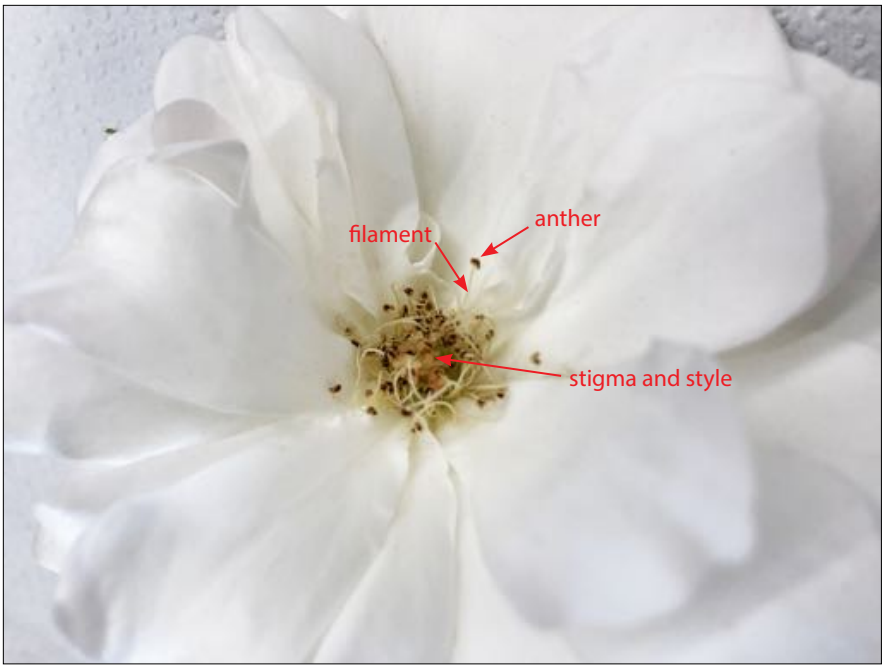
Edge of gill at 400× magnification.

1. Basidia
2. Spores

Activity 25 Introduction to Plants

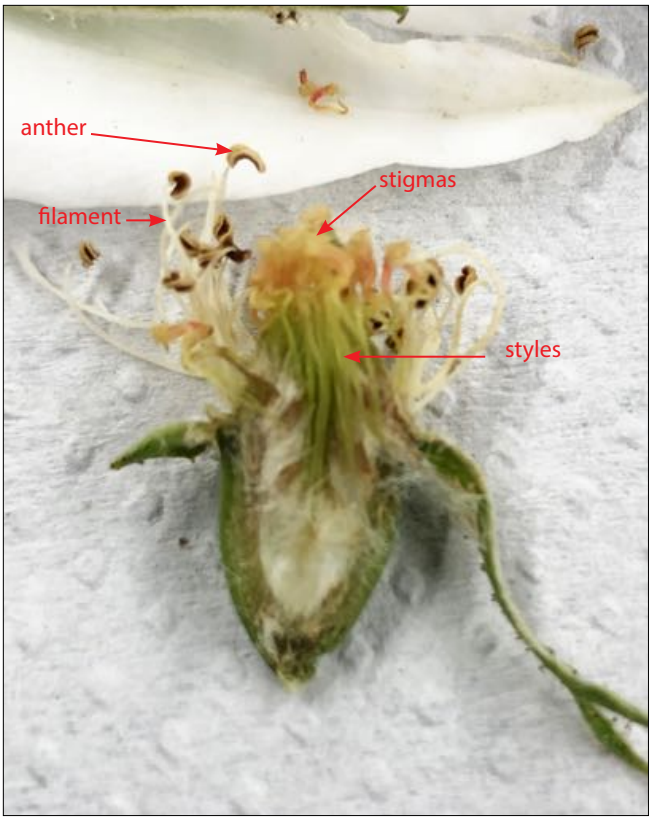
While you may choose to buy a flower from a grocery store, it might be more fun to obtain one from a natural source. Sample flower dissection results are shown below. Of course, these vary based on the types of flowers you obtain.





View of pistil with all petals removed.

Orientation for cutting open the receptacle.



Activity 26 Stomata

Students may struggle with coming up with hypotheses. You can help them by asking questions, or you can assign them a specific hypothesis to test.

Here are some tips to help:

- Very waxy leaves do not have stomata on the top of the leaves, so if students are only looking at one side of the leaf encourage them to use the bottom of the leaf.
- Different types of leaves have different sizes of stomata.
- If students are interested in looking at open versus closed stomata, try to have them use leaves freshly harvested.

Some ideas include:

- Compare the top and bottom of the same leaf—which side will have more? On which side will you find more open or closed stomata.
- Look at leaves in different conditions from the same plant. For example, compare a well-watered plant to one that has not been watered. Or compare a plant in the sun to one in the shade.
- Compare leaves from different plants.

It is *very* important that the fingernail polish be completely dry before trying to remove it with the tape. If it is not completely dry, you will not get a good imprint. Avoid places with a leaf vein.

This video provides some useful tips and ideas:

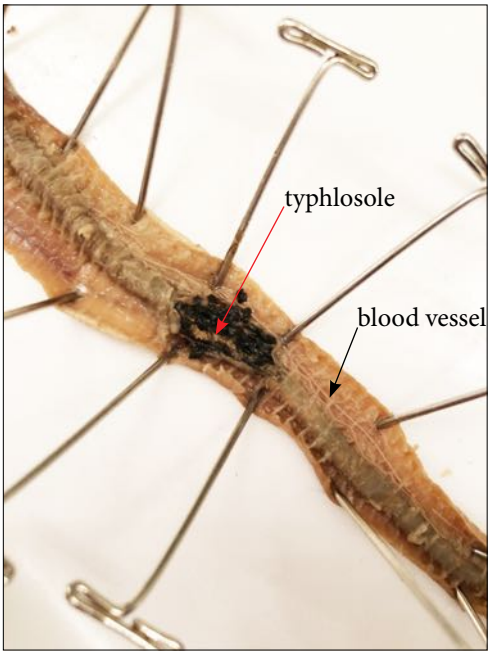
https://www.youtube.com/watch?v=5uv4lIWDECs

Activity 27 Animal Dissection 1

Answers to Questions

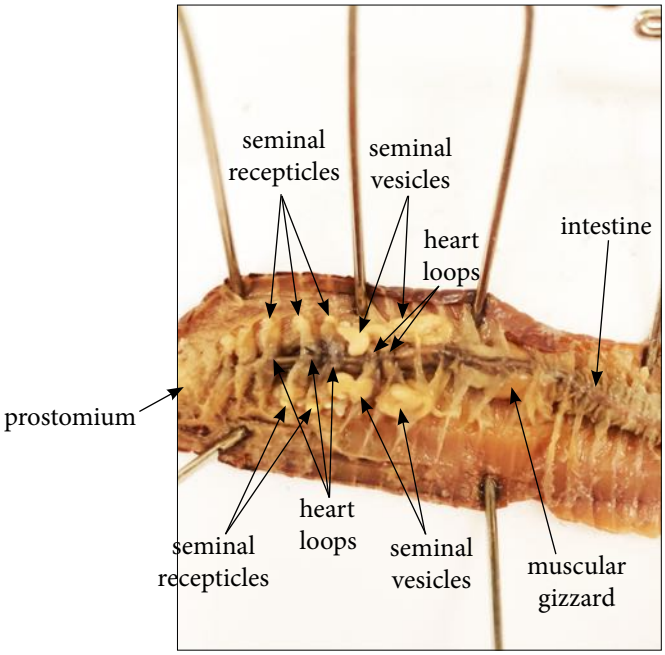
12. coelomate

15.



Note the typhlosole, another tube found inside the earthworm's intestine. This structure is consistent with the earthworm's classification as a coelomate. It serves to increase the surface area of the intestine.

Note the blood vessels running the length of the worm.



The heart loops (aortic arches) are in segments 7, 8, 9, 10, and 11.

For reference, see also https://upload.wikimedia.org/wikipedia/commons/8/8f/Earthworm_head.svg

17. bilateral

18. Yes, it has a "head" end that differs from the tail end.

19. annelida

20. multicellular, eukaryote

Reference: How to Dissect, 4th Ed. ,(1984) by William Berman. New York: Fireside.

Activity 28 Animal Dissection 2

The activity here is structured more as a comparative activity than a traditional one-at-a-time dissection. If you prefer to have your students become deeply familiar with the proper names of each part and spend considerable time with their dissections, Home Science Tools publishes inexpensive dissection guides for each specimen that may prove useful. There are also a number of guided dissection videos freely available on the Internet that you or your students may wish to study. *How to Dissect* by William Berman is another excellent resource.

Depending on your resources and time, you may wish to purchase a 9-specimen set for each group. Alternatively, you could buy one set for the class, assign each group to make the initial incisions on one or two specimens (for Activities 27–29), and then have the groups rotate to make their comparisons between specimens.

You may wish to frontload the students with knowledge about how each of the animals' systems work prior to the dissection. Alternatively, you may take a more exploratory route and have the students hypothesize the functions of each structure as they encounter them—discussing what they think the structure does and why.

You may or may not wish to cover some of Chapter 10 on human organ systems prior to doing these dissections.

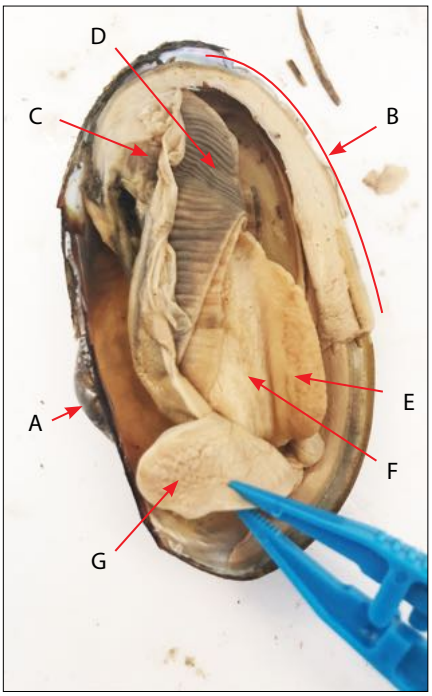
Notes On External Features Observations				
specimen	clam	starfish	crayfish	grasshopper
external features and functions	Two connected hard shells, with growth rings that allow the clam to increase in size without shedding the shell.	Spiny projections and a small circle on the dorsal side (sieve plate). The ventral side has small tube feet that extend down the center of each ray. There is a mouth in the center of the animal on the ventral side.	Many appendages (antennae, walking legs, swimmerets, and chelipeds—giant pincers used for defense, grabbing and cutting up prey.)	Has complex mouth parts, a compound eye, antennae. End of abdomen should determine whether the specimen is female (pointed and forked) or male (rounded).
symmetry	Bilateral (two halves of shells exhibit symmetry)	Pentaradial (5 rays extend from center)	Bilateral	Bilateral (there are paired appendages on some segments)
segmentation	No	No	Yes: has cephalothorax and abdomen (which exhibit further sub-segmentation).	Yes, it has a head, thorax and abdomen. The thorax and abdomen exhibit further sub-segments.
protection	protected by shell	spines offer protection from predators	hard exoskeleton and pincers	hopping legs and wings to help escape

Notes On Species				
specimen	clam	starfish	crayfish	grasshopper
respiratory system	gills	Water transport system carries oxygen throughout	gills	Spiracles (holes on the ventral side of the grasshopper that take air in, and subsequently expose every cell in the body with that air through an extensive system of air sacs).
locomotion	Siphon system for injecting and ejecting water, muscles (foot) for burrowing, adductors for opening/closing shells.	Tube feet on the rays of the starfish can cling to objects and pull the starfish via suction created by the water flow through the vascular system.	Appendages/muscular legs, uropod (strong tail that can propel it into the mud at the bottom of a lake for protection from predators)	Powerful muscular legs that propel the grasshopper over long distances; wings that allow for flight.
support (skeletal pr similar system)	Hard bivalve shell	Spiny projections over dorsal end of starfish.	Exoskeleton made of chitin (must molt its exoskeleton in order to grow)	Exoskeleton
transport nutrients and oxygen? (circulatory or similar system)	Open circulatory system (with heart that pumps blood openly throughout body cavity—rather like a pool pump)	Water (bloodless) system carries oxygen throughout. Water enters through sieve plate on dorsal side (slightly off center). Water is distributed through radial canals, can flow through entire body cavity, and then exits through openings in tube feet on the ventral end of each ray.	Has heart, arteries, and more open sinuses in place of veins (making the system partly open). The main purpose is to transport oxygen.	Open circulatory system with hearts, one blood vessel (dorsal aorta), and a haemocoel—continuous body cavity through which the blood flows. The blood does not carry oxygen, only nutrients.
digestive system	Filter feeder. Mouth with flaps (palps) that move food particles towards it. Curved intestine, one digestive gland, anus.	Has cardiac stomach that can invert and exit the mouth, excreting enzymes that digest prey externally (very handy for getting inside the shell of a clam!!) The clam then takes its stomach and partially digested material back inside. Rest of system is rather primitive because of external digestion.	Mouth, digestive organs, intestine and anus	Has a mouth, salivary glands, digestive organs, a stomach, large & small intestine, rectum and anus.

Notes On Species				
specimen	clam	starfish	crayfish	grasshopper
excretory system	Wastes expelled though siphon system.	Wastes expelled through vascular system and/or anus in digestive system.	Bladder and pore found under the mouth.	Tubules in the body cavity take in liquid wastes and transport them to the intestines for expulsion through the anus.
sensory & nervous system	Very simple.	Has eyespots at the end of each ray.	Has eyes, antennae, brain and motor/sensory neurons.	Has a two halves of brain (aka ganglia) that are connected by two nerve cords.
reproductive system	Gonad tissue surrounds intestine inside visceral mass. External fertilization. Cannot tell male vs female via the dissection.	Gonad tissue found in every ray. To determine the sex of the organism, obtain some gonad cells and smear them on a blank slide to examine under a microscope. Sperm cells will be smaller and have a flagellum. Egg cells will be larger and spherical.	Female holds eggs externally on swimmerets (appendages underneath the tail) for male to fertilize them (using his swimmerets). The fertilized eggs remain attached to the mother's swimmerets until they are developed enough to live independently.	Sexual dimorphism—female has an abdomen that is pointed and divided at the tip. Males have a rounded and non-divided tip. During mating, males deposit sperm into the female where she stores it until it is time to lay eggs (at this time fertilization takes place). The female deposits fertilized eggs into a burrow in the ground. Internal sexual anatomy is different for males and females.
Other notes of interest	The starfish preys upon clams and other molluscs. Water habitat.	Can be an invasive species. Can regenerate itself from body parts when cut off. Water habitat.	Water habitat. Can regenerate its legs if broken off.	Land habitat.

Reference: *How to Dissect*, 4th Ed (1986) by William Berman. New York: Fireside.

Clam internal anatomy:



Clam internal anatomy with one shell removed.

A: umbo

B: mantle (secretes shell)

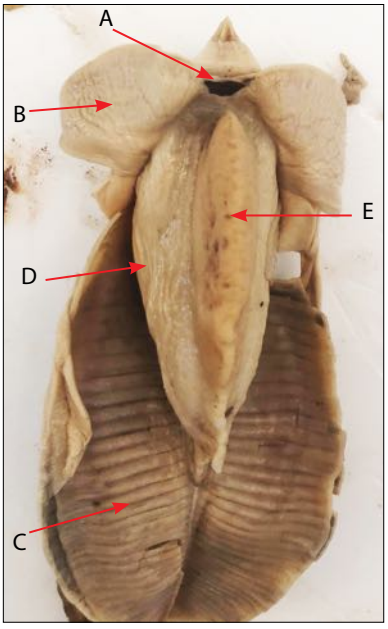
C: severed adductor muscle

D: gills

E: muscular foot

F: visceral mass (intestines found within)

G: palps (used to move food towards mouth, which is located underneath).



Top view of clam, with shells removed.

A: Mouth (the inhalant and exhalant siphons can be found on the opposite end of clam)

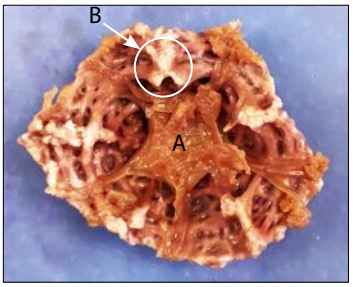
B: palp

C: gill

D: visceral mass

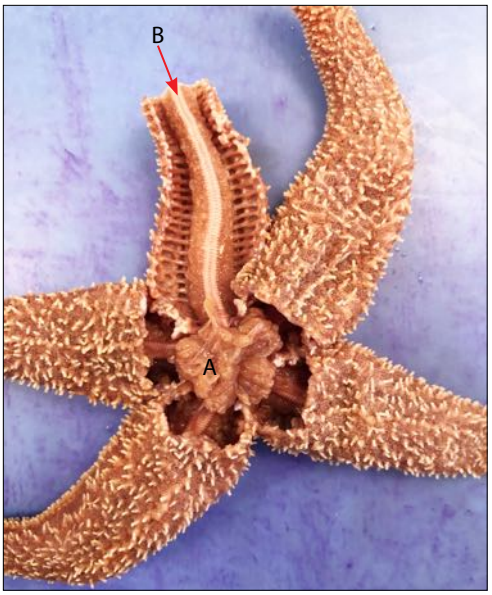
E: foot

Sea star internal anatomy:



Dorsal center of sea star removed (underside), showing part of (A) pyloric stomach gland (that secretes digestive enzymes).

(B) underside of sieve canal (aka madreporite) where water enters the canal system.

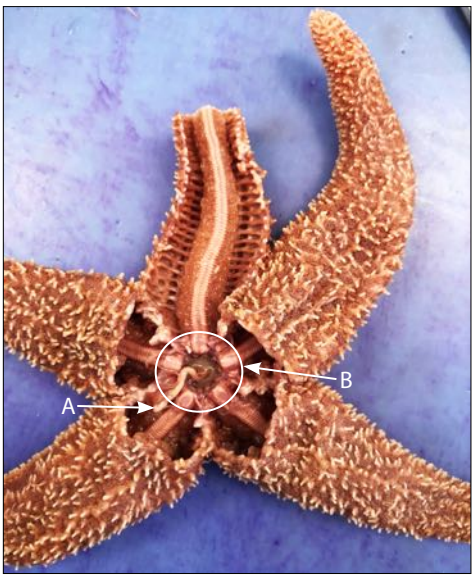


A: Pyloric stomach

B: Ambulacral ridge

Pyloric stomach moved aside.

Attachment to mouth and cardiac stomach (which everts to collect digested food) shown in the circle.



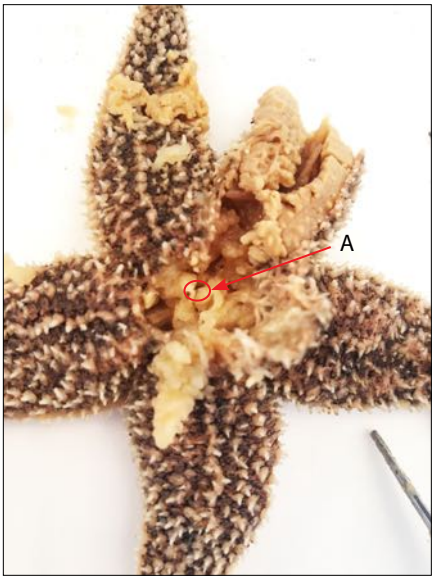
Pyloric stomach removed.

A: Stone canal

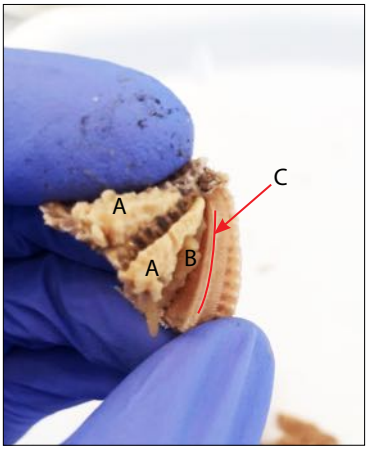
B: ring canal visible (underneath white outline).

A: (left side removed from place), digestive glands

B: gonads (this specimen was collected during breeding season is and is almost entirely filled with eggs/gonad tissue…note eggs even spilling out of the uncut ray on the left. Most specimens will not be so full.)



A: Stomach (visible after gonad cells removed).



Dissection of end of ray.

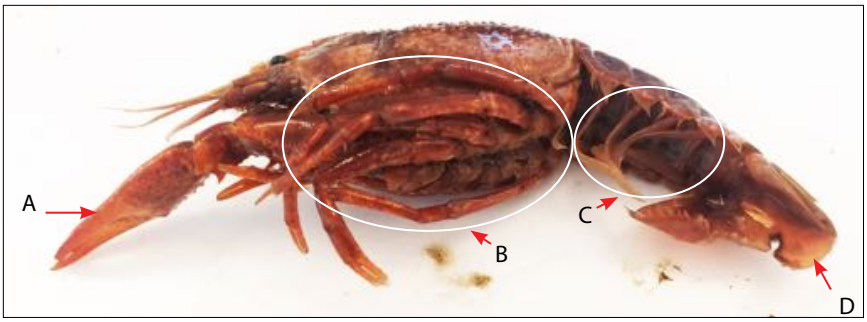
A: digestive glands

B: gonads

C: Ambulacral groove (tube feet can be found lining this groove on opposite external side of the ray)

Crayfish anatomy:

Excellent resource for additional detail: https://www.biologyjunction.com/crayfish_dissection.htm



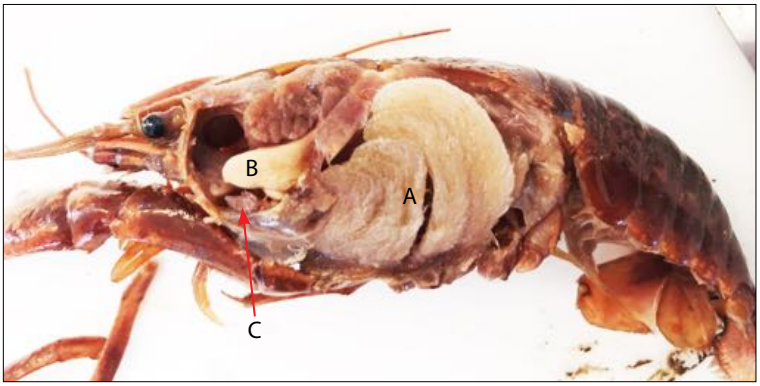
Crayfish external anatomy.

A: Cheliped

B: Walking Legs

C: Swimmerets

D: Uropod

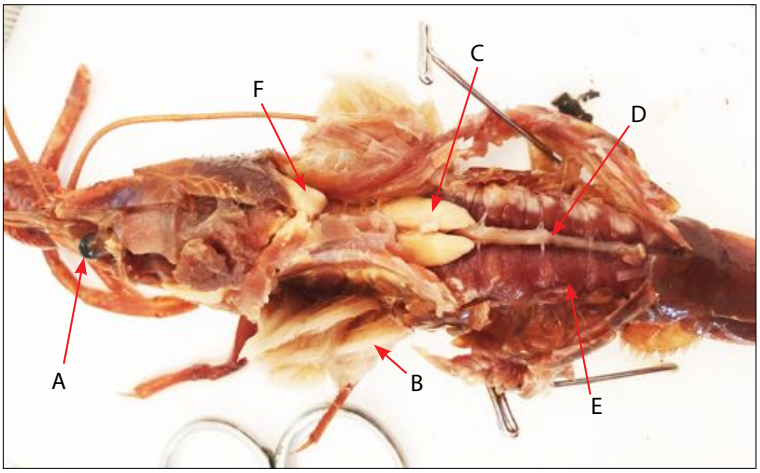


Internal anatomy, side view.

A: gills

B: digestive glands

C: green gland



Selected internal anatomy, top view.

A: eye

B: gills

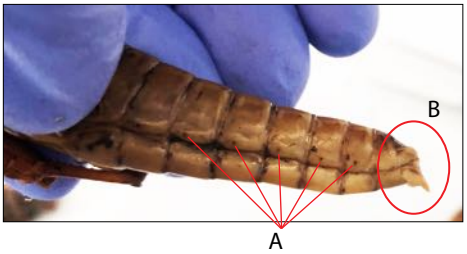
C: testis

D: intestine

E: muscle

F: digestive organ

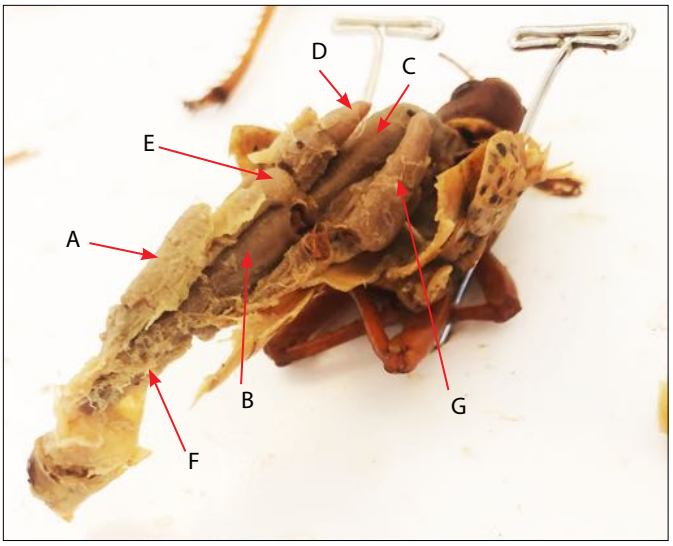
Grasshopper internal anatomy:



Grasshopper abdomen, external.

A: Dots show the spiracles, that the grasshopper uses to breathe.

B: The pointed abdomen indicates that the specimen is female.



Grasshopper internal anatomy, side view.

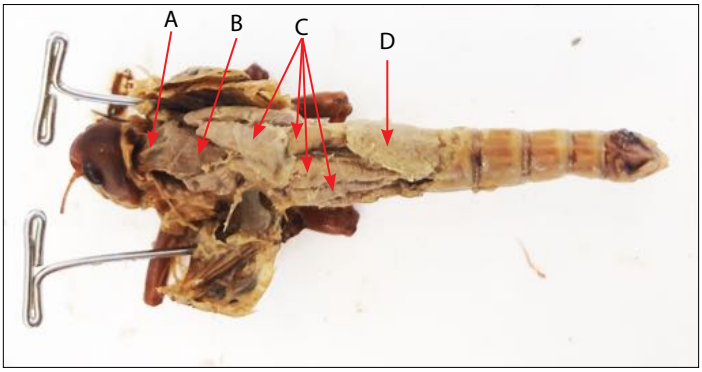
A: eggs/gonads

B: stomach

C: crop

E/D/G: Air sacs

F: Intestine



Grasshopper internal anatomy, top view

A: esophagus

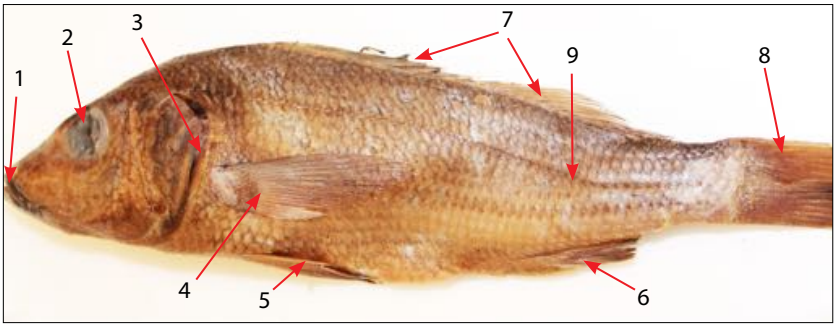
B: crop

C: air sacs

D: gonad

Activity 29 Animal Dissection 3

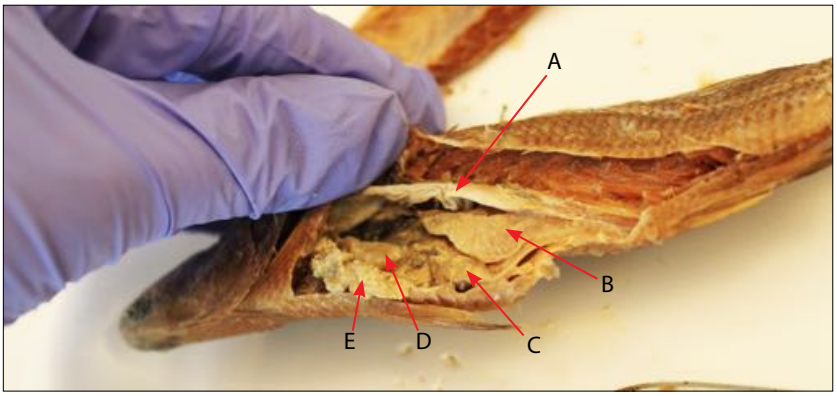
Perch



External anatomy of perch.

1. Mouth
2. Eye
3. Operculum/opening to gills
4. Pectoral fin
5. Pelvic fin
6. Anal fin
7. Dorsal fins
8. Caudal fin
9. Lateral line (for sensing pressure)

Operculum removed to expose gills of perch.

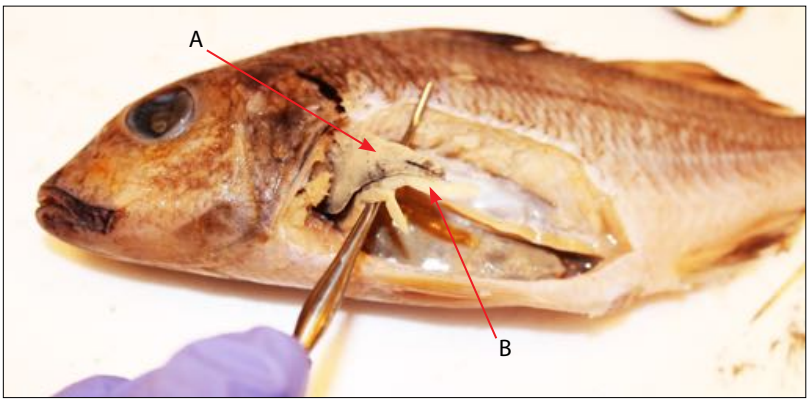


Internal anatomy of perch. (Female with prominent gonads)

A. Swim bladder

B. Intestine

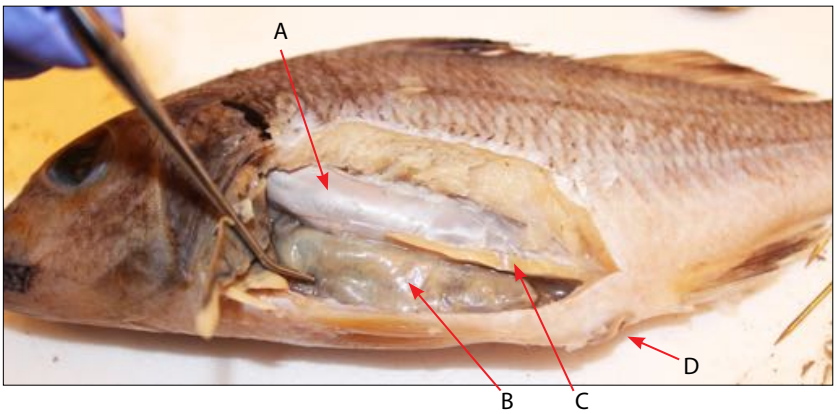
C/D/E eggs



Different specimen.

A: liver

B: fat pads



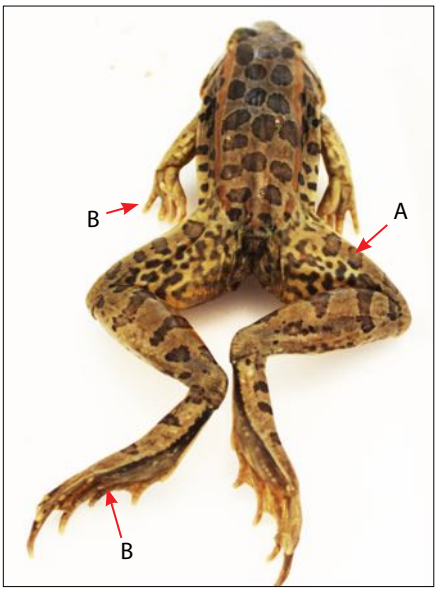
A: Swim bladder

B: Stomach

C: Gonad

D: Cloaca (anal/urogenital opening)

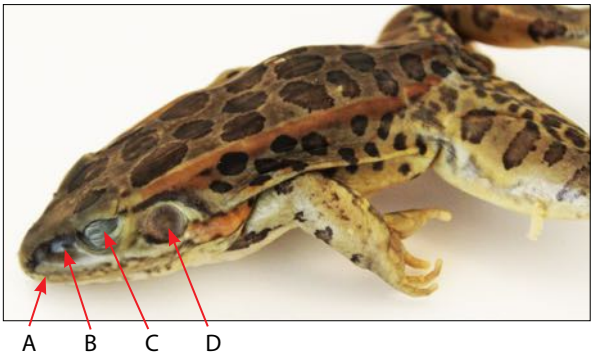
Frog



Dorsal external anatomy of frog

A: Muscular legs

B: Webbed digits

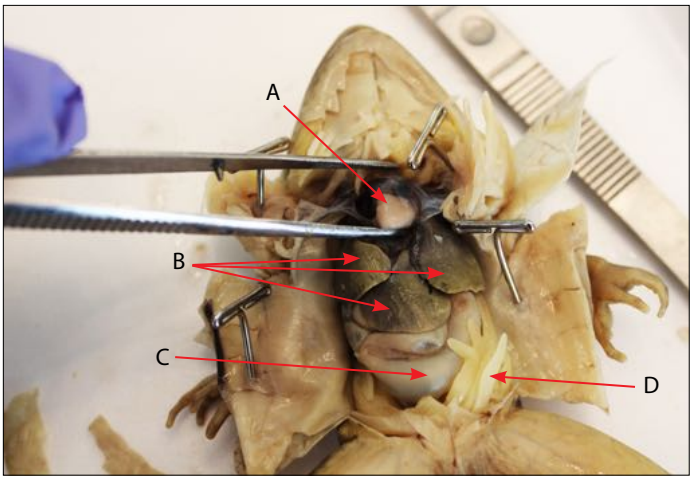


A: Mouth

B: Nare (nostril)

C: Eye

D: Tympanic membrane ("external eardrum")

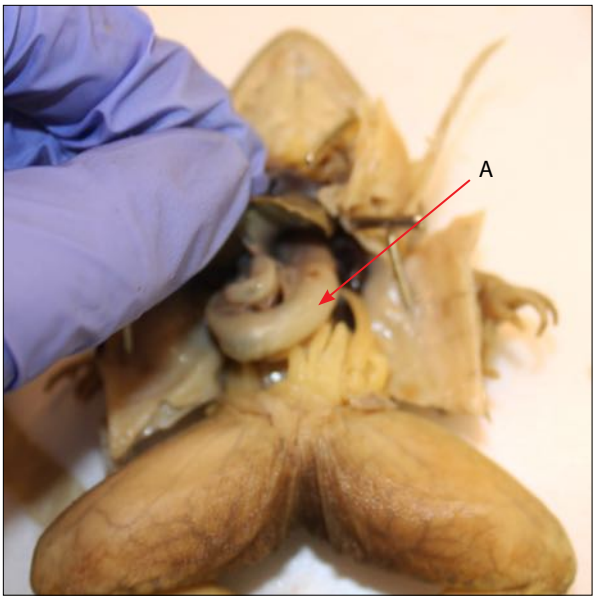


A: Heart

B: Liver (3 lobes)

C: Intestine

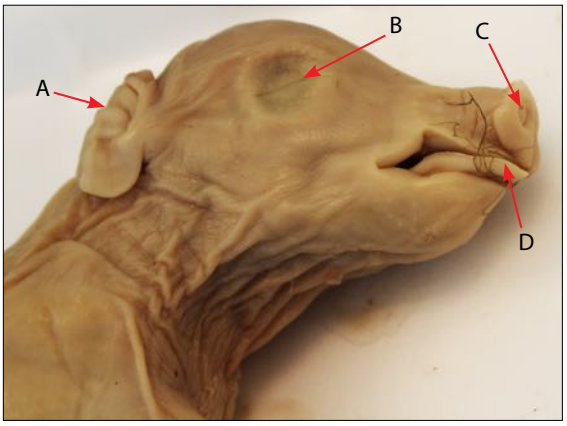
D: Fat pads



A. Stomach

Note: some female specimens may have body cavities filled with eggs.

Pig

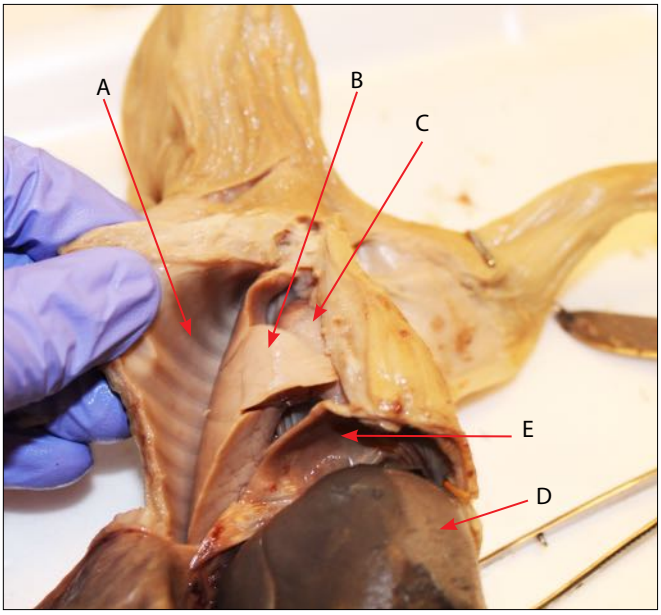


A: ear

B: eye

C: nose/nostril

D: tongue



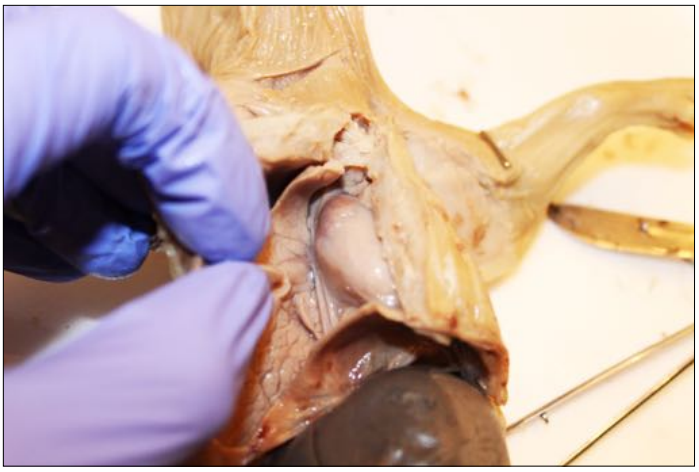
A: ribcage

B: lungs

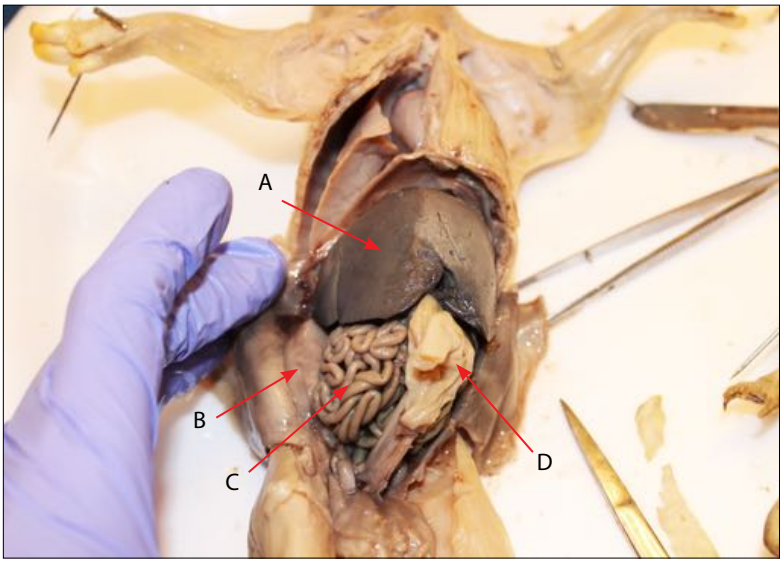
C: heart

D: liver

E: diaphragm (separates thoracic cavity from abdominal cavity)



Heart, surrounded by pericardial sac.

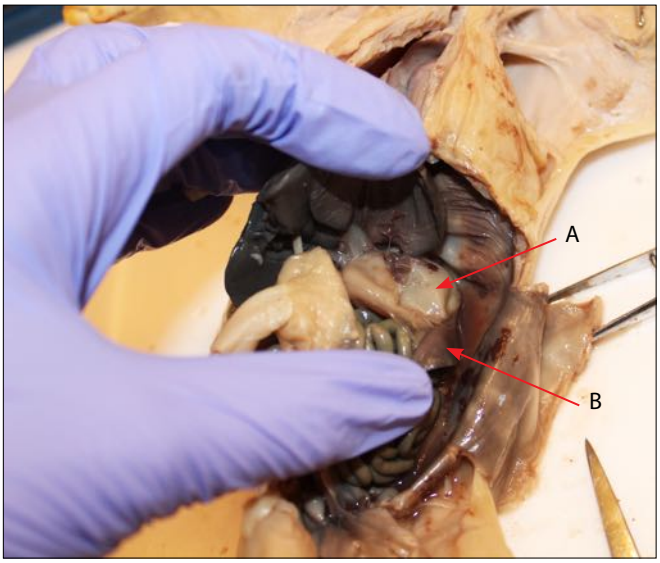


A: liver

B: kidney

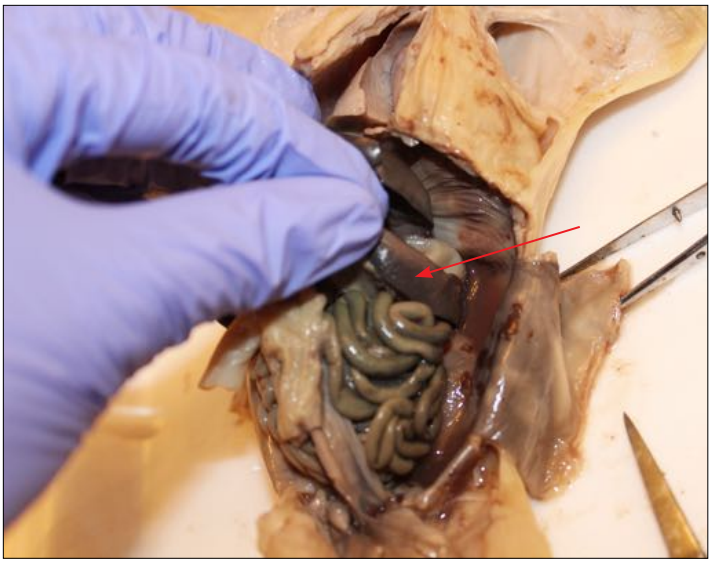
C: intestine

D: umbilicus

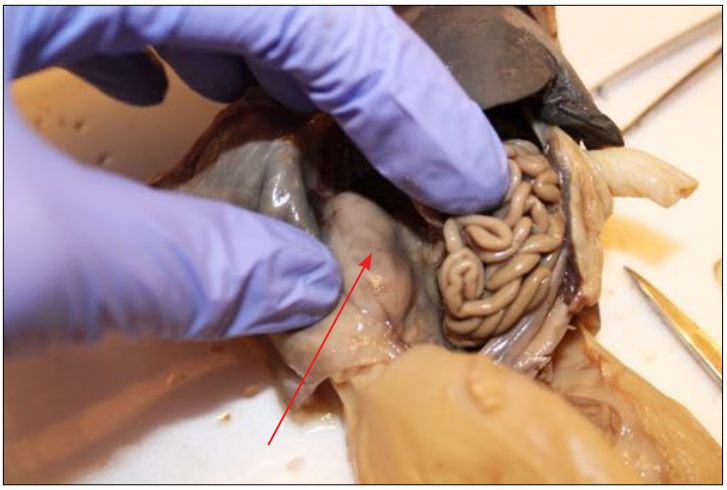


A: stomach (underneath liver)

B: pancreas



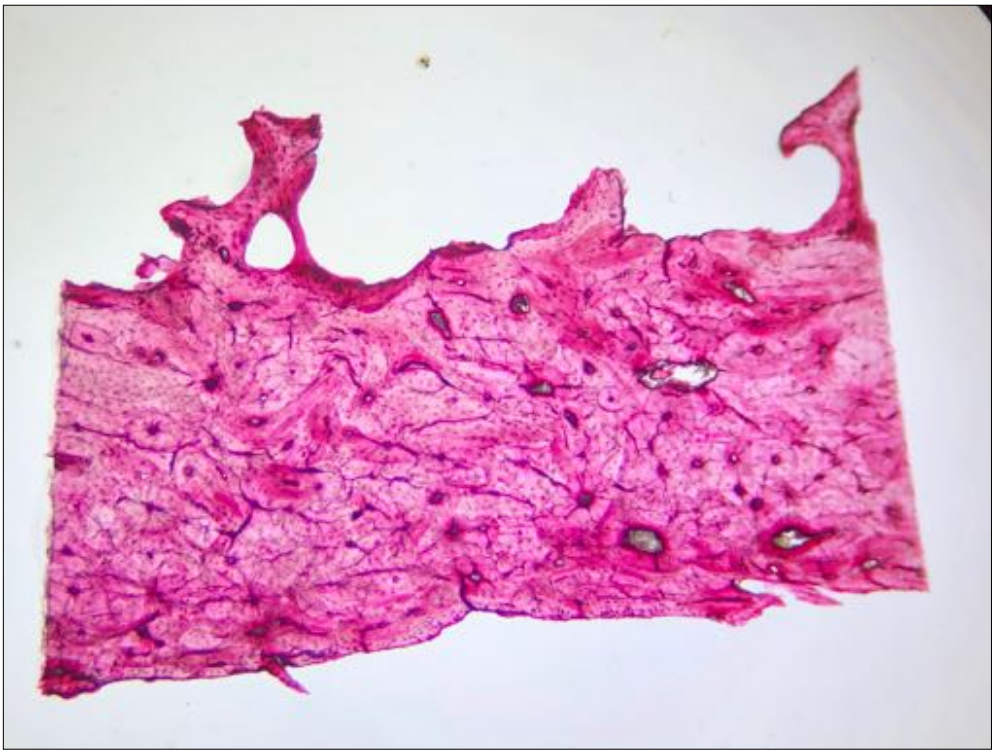
Better view of pancreas.



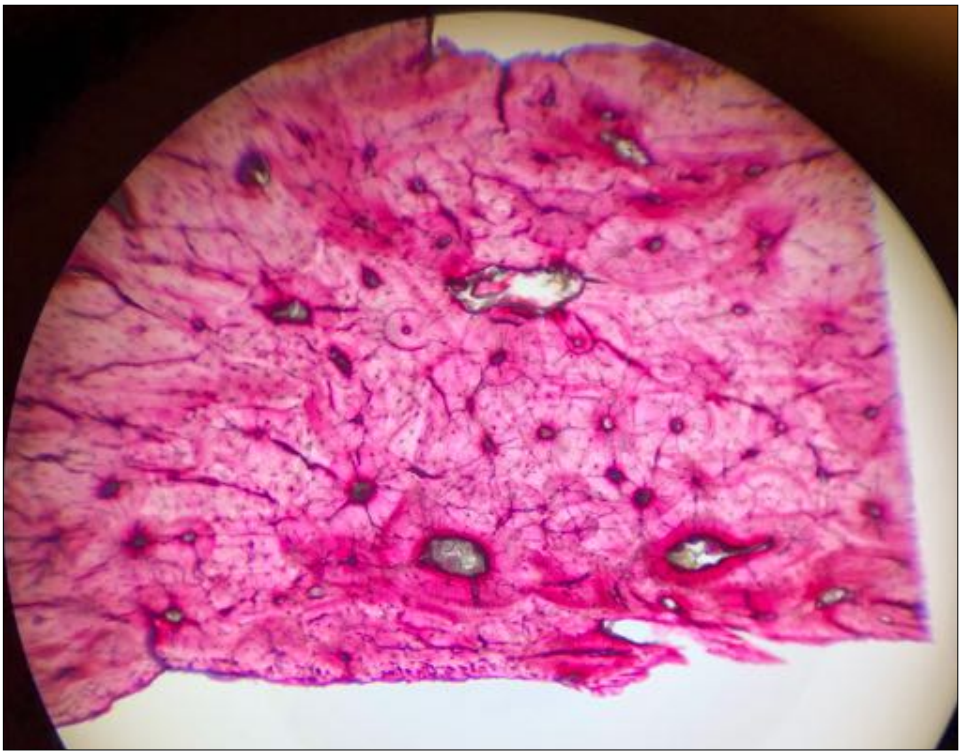
Direct view of kidney.

Activity 30 Bone and Muscle

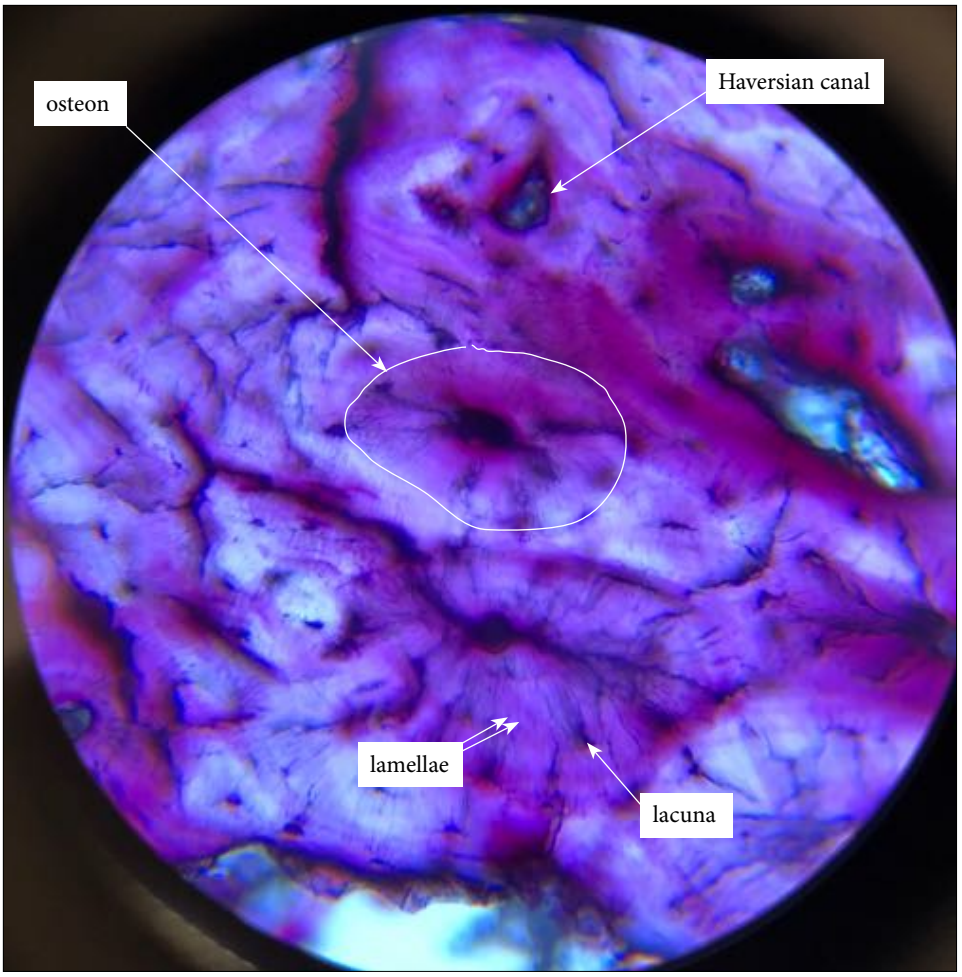
Below are some photos typical for this activity.



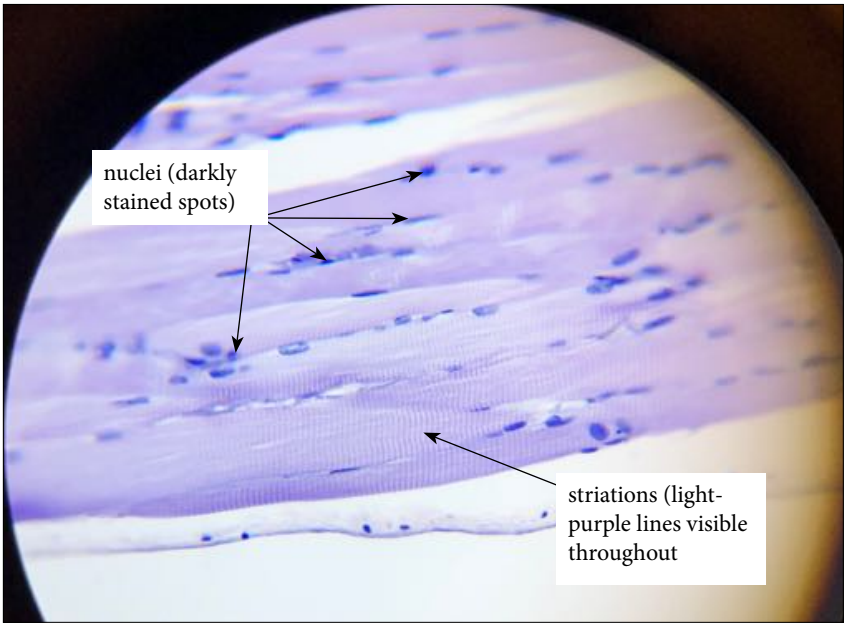
Human ground bone, 40×.



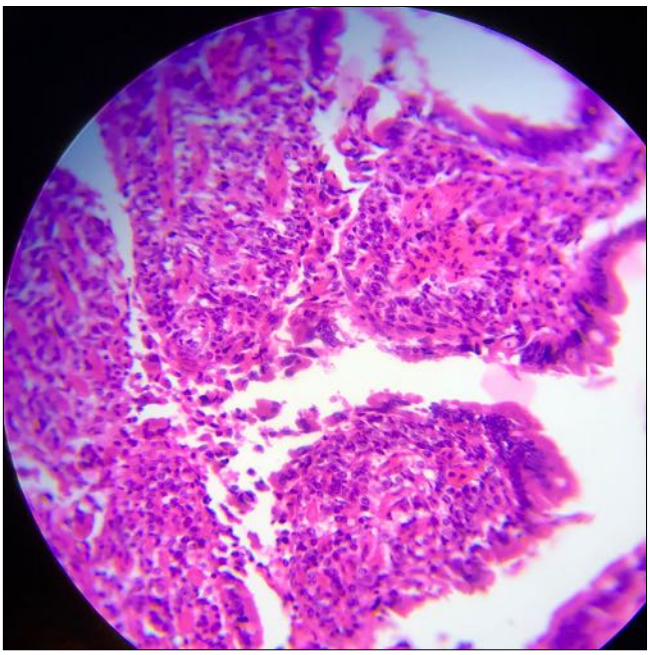
Human ground bone, 100×.



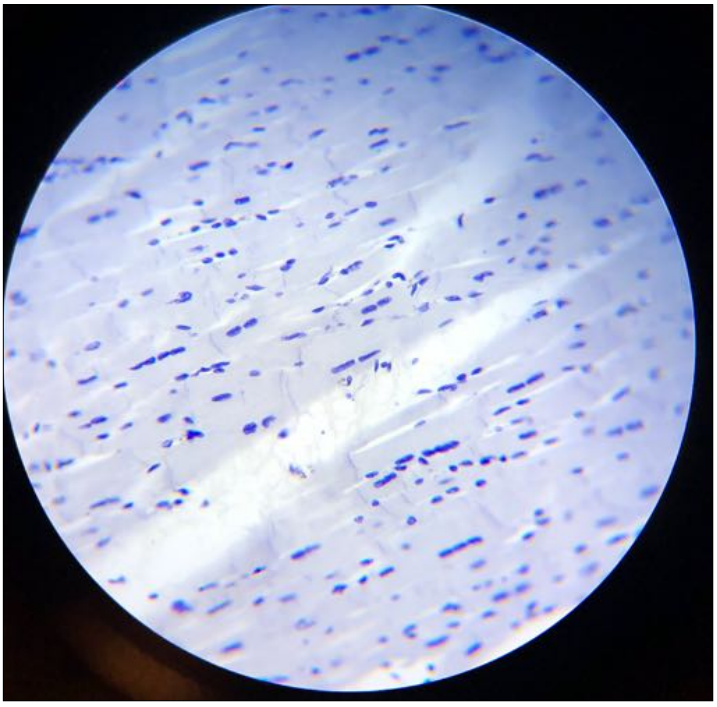
Human ground bone, 400×.



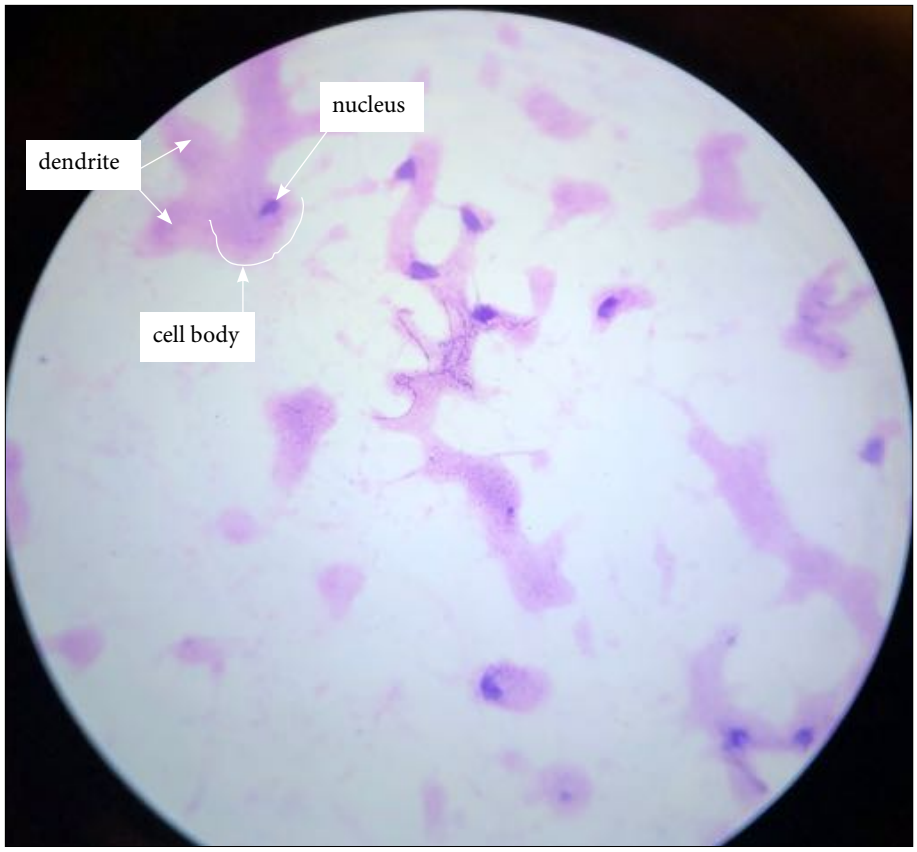
Striated muscle, 100×.



Smooth muscle, 400×. The darkly stained purple structures are nuclei. There should be one nucleus per cell.



Cardiac muscle, 400×. Cells are striated but branched. There is one (darkly stained) nucleus per cell.



Motor neuron, 40×.

Activity 31 Anatomy of the Heart

Note: Home Science Tools provides a sheep heart dissection kit which includes the dissecting tray, dissecting tools, and sheep heart needed for this lab. If you already have dissecting equipment, you can purchase the heart separately.

Dissecting guides are provided by Home Science Tools and are highly recommended. However, if you do not have them you can find many versions online. Below are three:

Heart Dissection Walk Through (biologycorner.com)
https://www.biologycorner.com/anatomy/circulatory/heart/heart_dissection.html

Heart Dissection : 8 Steps (with Pictures) - Instructables
https://www.instructables.com/Heart-Dissection/

Sheep Heart Dissection Lab for High School Science | HST (homesciencetools.com)
https://learning-center.homesciencetools.com/article/heart-dissection-project/

Using labeled wooden dowels is helpful for identifying and keeping track of the different blood vessels.

The cut described in this activity for opening the heart allows for the students to see the chambers more or less intact. However, you could also instruct the students to cut along the sides of the heart and around the apex to produce two halves.

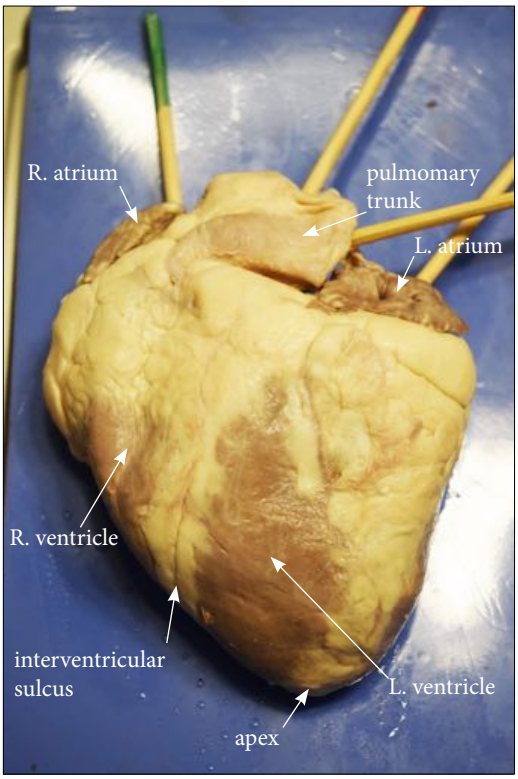
Responses for the first item in the review are:

vena cava ⟶ right atrium ⟶ tricuspid valve ⟶ right ventricle

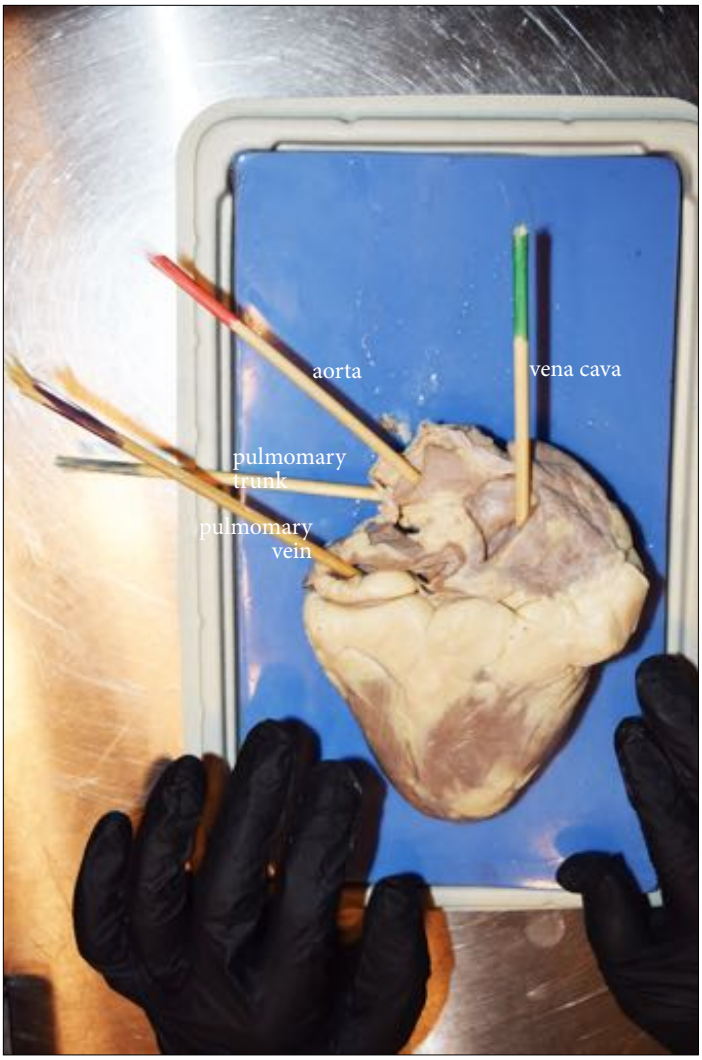
→ pulmonary valve → pulmonary artery → lungs

lungs → pulmonary vein → left atrium → mitral valve

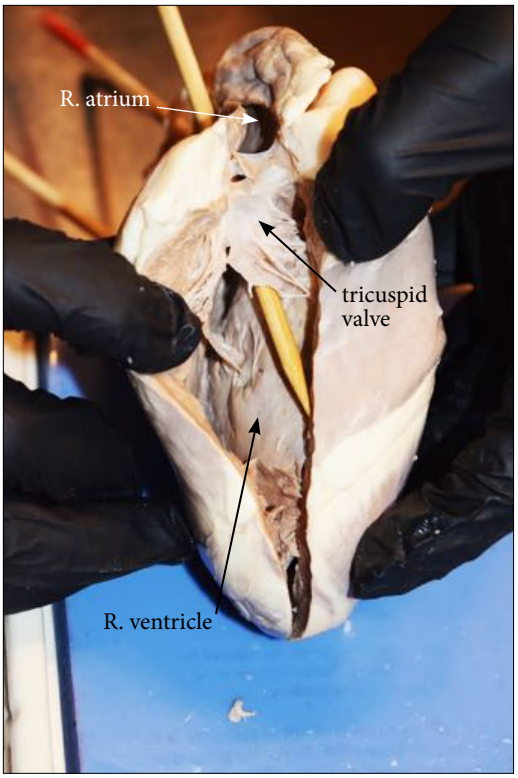
→ left ventricle → aortic valve → aorta



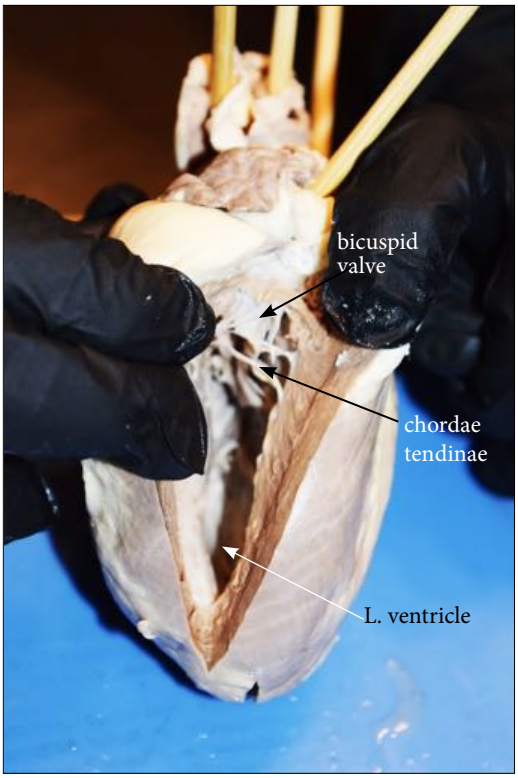
Ventral view of heart



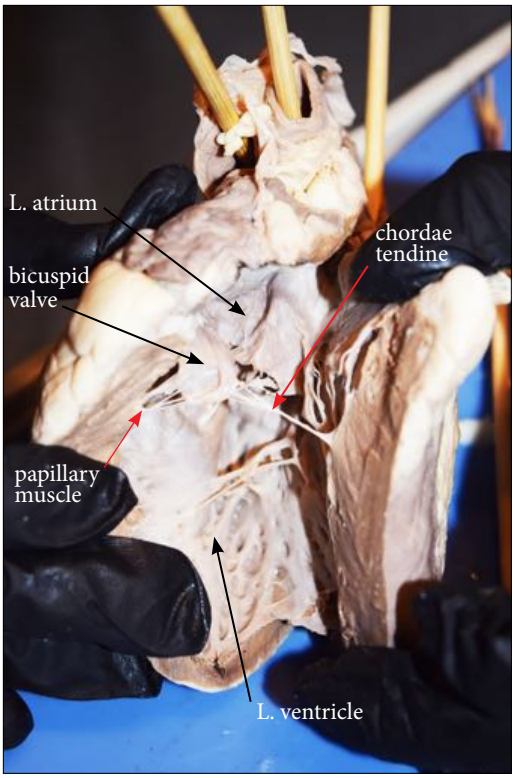
Dorsal view of heart w/ major blood vessels marked by wooden dowels.



Right side of heart cut open.



Left side of heart cut open.



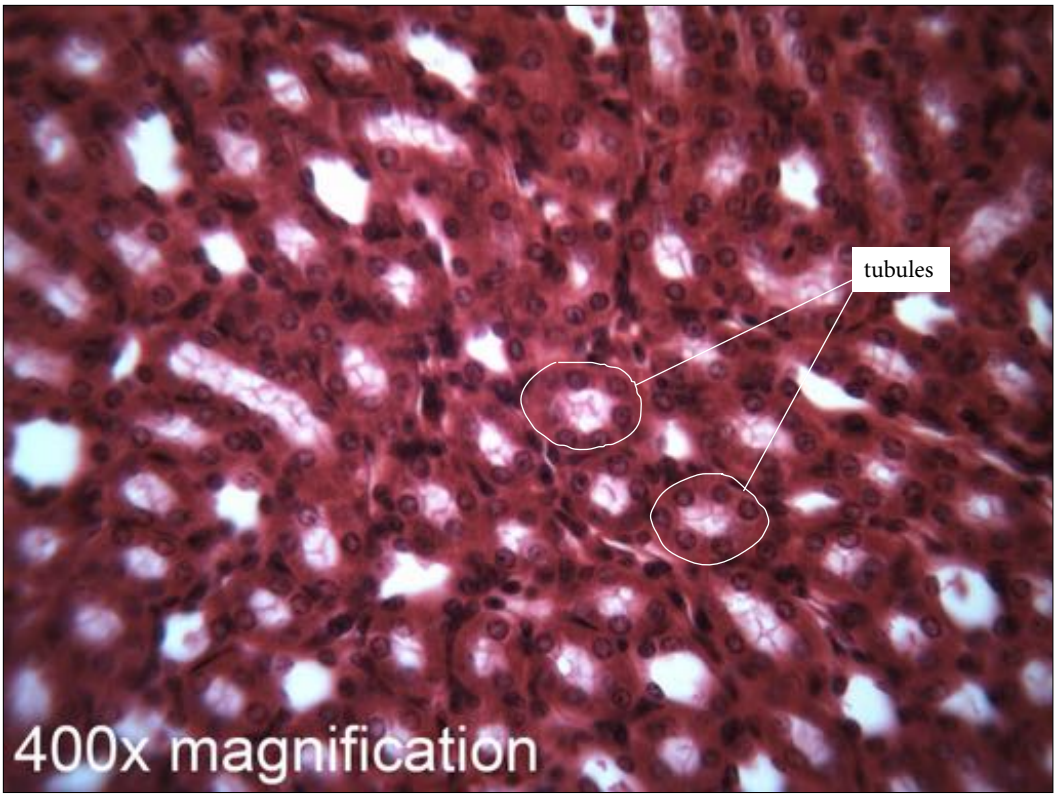
Activity 32 Heart Physiology

This is a relatively easy and fun lab activity to run. It may take some practice for the student's to find their pulse initially.

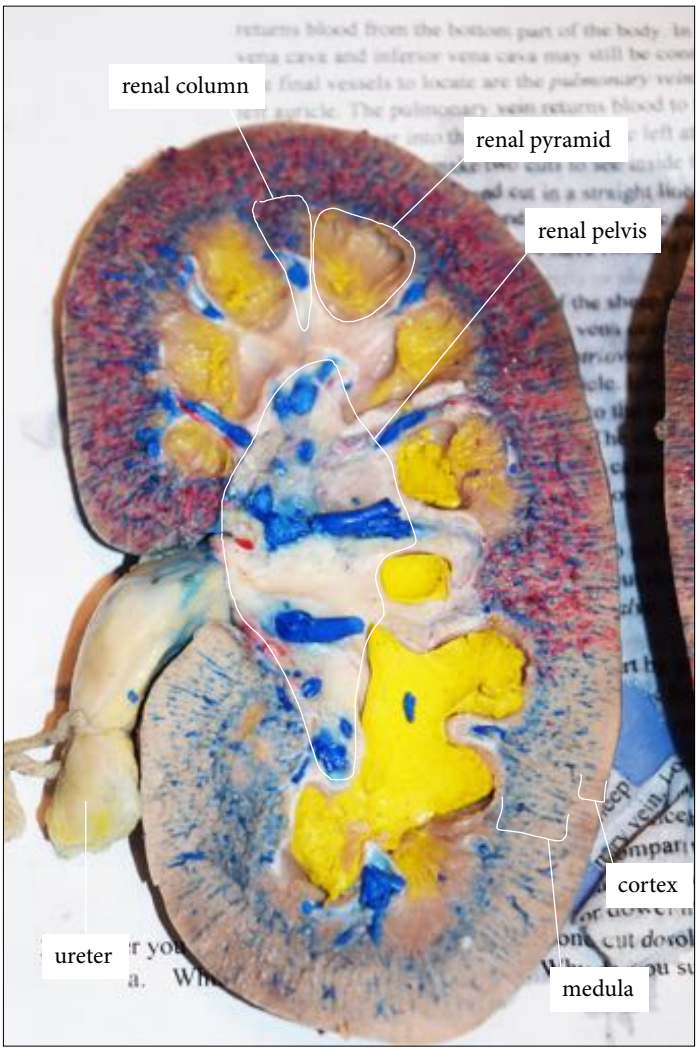
Students may struggle with developing a testable hypothesis. Help them by asking questions about what kinds of things may cause a change in heart rate. Some factors our students have tested in the past include caffeine intake, changes in emotion (fear), music, and standing on one's head. What you can and cannot do depends on how much time you have allotted. It does not need to be sophisticated. The idea is to have students practice working through the Cycle of Scientific Enterprise.

Activity 33 Kidneys

Belwo is an image of the slide from Home Science Tools. The circles are cross sections of tubules that run through the medulla. The tubules are surrounded by cells. The dark purples spheres are the nuclei of the cells. The cells are cuboidal or cube shaped cells.


tubules
400x magnification

Next is a photo of a dissected kidney.



The dissected kidney.

Activity 34 Plant Response to Pollutants

This activity is designed to be run concurrently with Activity 35 on soil testing. However, you may choose to do them separately if desired.

To pre-sprout the mung beans for the students, begin 36-48 hours before you begin the experiment. This is easily done by putting the beans in a bowl of water over night (~8 hours). Then rinse the beans and lay them out on a cookie sheet lined with a paper towel. Place a second paper towel over the top of the beans so they are sandwiched between the two layers. Lightly moisten the paper towels. You want to keep the paper towels moist, but do not want water to pool on the cookie sheet. Keep them on the cookie sheet for 24–36 hours at which point they will be ready to plant.

Other types of beans or legumes may also be used. Mung beans work well because they have a relatively short sprouting time. If you have access to a sprouting/growing mat, this may help speed up the process. However, you also need to keep an eye on the paper towels because they will dry out more quickly due to the extra warmth produced by the sprouting/growing mat.

Make 100 mL of each high-concentration pollutant solution using the formulas provided below, and then prepare the medium- and low-concentration solutions from the high-concentration solutions. (The medium-concentration salt

solution is prepared separately.) In the salt solutions, the designation "w/v" means the solution is a certain mass of solute (w) added to the certain volume of distilled water (v). (We know mass and weight are different, but this is the common notation used.) In the acid solution, the designation *M* refers to the molarity of the acid solution. A 0.01-*M* solution contains 0.01 moles of acid per liter of water.

Always remember the important safety precaution of always slowly adding concentrated acid to water, and never the other way around. Adding water to concentrated acid generates a lot of heat, which can lead to dangerous flash boiling and splashing of concentrated acid out of the container. Adding acid to water disperses the heat-generating acid in the water.

Road Salt Solution

To make the high-concentration salt solution (50%, w/v), measure 100.0 mL distilled water and add it to a 250-mL beaker. Then measure 50.0 g NaCl and add it to the water in the beaker. Stir until dissolved.

To make the medium-concentration salt solution (40%, w/v), measure 50.0 mL distilled water and add it to a 250-mL beaker. Then measure 20.0 g NaCl and add it to the water in the beaker. Stir until dissolved.

To make the low-concentration salt solution (33%, w/v), measure 50.0 mL of the high-concentration salt solution (50%, w/v) and add it to a clean 250-mL beaker. Measure out 25.0 mL distilled water and add it to the beaker.

Acid Rain (Sulfuric Acid) Solution

Wear gloves and safety goggles when working with this concentrated acidic solution.

To make 100 mL of the high-concentration solution (0.01 *M* H_2SO_4) from 0.1 *M* H_2SO_4, measure out 90.0 mL distilled water and pour it into a 250-mL Erlenmeyer flask. Measure 10.0 mL 0.1 *M* H_2SO_4 and SLOWLY add it to the distilled water, a few drops at a time, swirling the mixture between each addition of acid. (Again, always add the acid to the water. Do NOT add the water to the acid!)

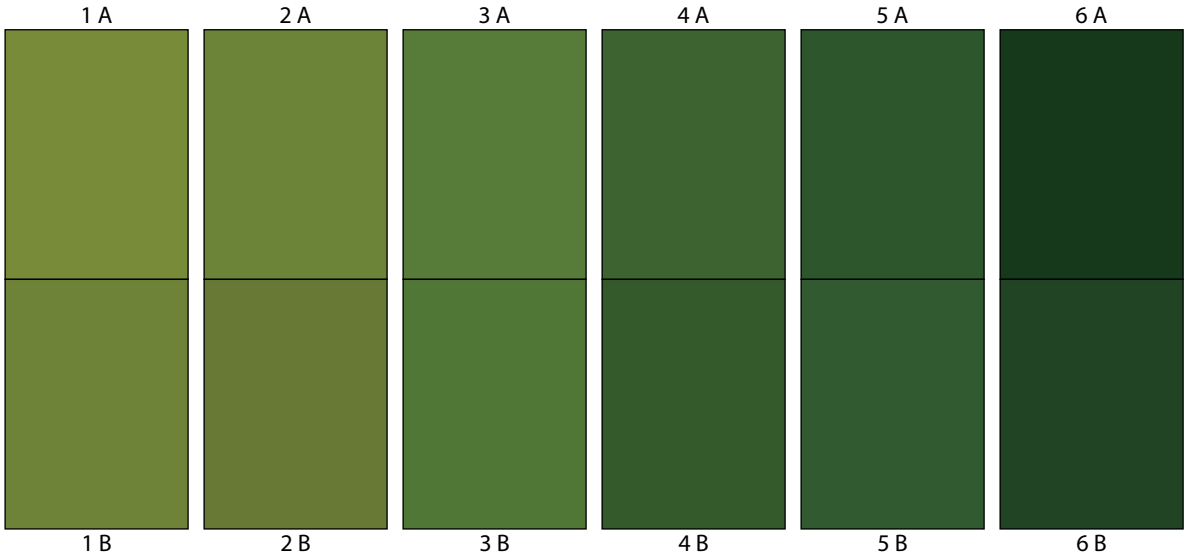
To make the medium-concentration acid (0.001 *M* H_2SO_4), measure 18.0 mL distilled water and add it to a clean 250-mL Erlenmeyer flask or beaker. Then measure out 2.0 mL 0.01 *M* H_2SO_4 and add it to the water, pouring the acid SLOWLY into the water while swirling.

To make the low-concentration acid (0.0001 *M* H_2SO_4), measure 18.0 mL distilled water and add it to a clean 250-mL Erlenmeyer flask or beaker. Then measure out 2.0 mL 0.001 *M* H_2SO_4 and add it to the water, pouring the acid SLOWLY into the water while swirling.

These recommendations may be scaled up if you wish to pre-measure enough solution for an entire class.

The variables listed in the table are recommendations. You may choose to do all of them or some of them. You may also add additional variables to measure.

To determine the leaf color, you may consider creating your own "leaf color chart" (LCC) using paint color chips. Leaf color charts are used in rice farming but are not easily obtained commercially. (To see such a chart, search under "nitrogen parameters leaf color chart," and select images.) The image below shows an example of an LCC.



To measure the leaf size, have students select a medium size leaf and trace it on a sheet of graph paper. Next estimate the total number of squares taken up by the leaf.

Students will likely need help producing the graphs. Depending on the data they have collected, you can have them make either a line graph or a bar graph as described above.

Activity 35 Soil Testing

Soil samples should come from a variety of environments, such as a dry, clay-like area of your front yard or school field; a well-watered, dark, rich soil that is supporting a thriving plant or tree; pure decomposed compost from the bottom of a compost bin; or bagged potting soil.

For soil samples, restaurant-style sauce containers with lids work well and can be purchased in bulk for a large class.

There are several types of soil testing kits available from Home Science Tools or your local garden shop. It should measure the following: pH, N (nitrogen), P (phosphorus), and K (potassium). The kit should tell you how many tests it supports. The least-specific but quickest tool is a three-pronged digital meter that measures soil moisture, pH, sun level, and a non-specific "nutrient level" that combines N, P, and K. This tool is not specific enough for a good soil-testing study, but it might be good to combine this tool with Activity #34 in order to quickly determine the soil condition of every plant on a regular basis. Look closely at the kit you plan to purchase. Some require re-using test tubes or the addition of multiple reagents, adding time to the students' procedures. Others provide a cartridge with attached color-coding chart, and these might save time (see materials list for specifics).

Activity 36 Calculating Populations

1b. $BR = 0.25$

1c. $DR = 0.13$

1d. $G = 0.12$

2a. $G_1 = 19.68$

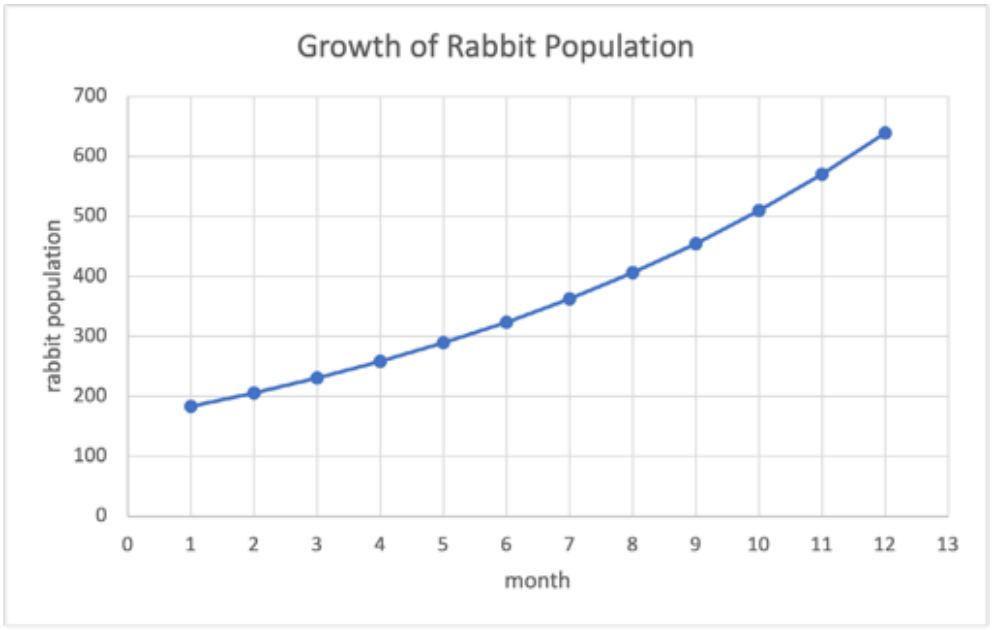
2b. $N_1 = 183.68$

2c. $G_2 = 22.04$; $N_2 = 205.72$

2d. See the table below for all the values.

		N_0	164
G_1	19.68	N_1	183.68
G_2	22.04	N_2	205.72
G_3	24.69	N_3	230.41
G_4	27.65	N_4	258.06
G_5	30.97	N_5	289.02
G_6	34.68	N_6	323.71
G_7	38.84	N_7	362.55
G_8	43.51	N_8	406.06
G_9	48.73	N_9	454.78
G_{10}	54.57	N_{10}	509.36
G_{11}	61.12	N_{11}	570.48
G_{12}	68.46	N_{12}	638.94

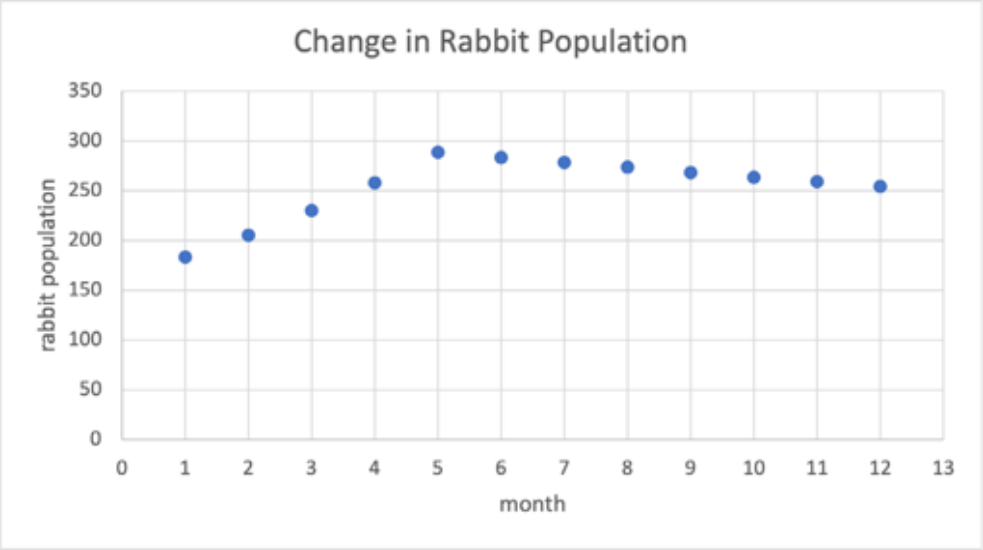
Graph sample created in excel.



In the Bonus Activity for #6, the new G value is $G = 0.27$. The modified table and graph are shown below.

		N_0	164
G_1	19.68	N_1	183.68
G_2	22.04	N_2	205.72
G_3	24.69	N_3	230.41
G_4	27.65	N_4	258.06
G_5	30.97	N_5	289.02
G_7	−5.20	N_7	283.82
G_8	−5.11	N_8	278.71

G_9	−5.02	N_9	273.70
G_{10}	−4.93	N_{10}	268.77
G_{11}	−4.84	N_{11}	263.93
G_{12}	−4.75	N_{12}	259.18



For the second activity use between 150 and 200 beans.

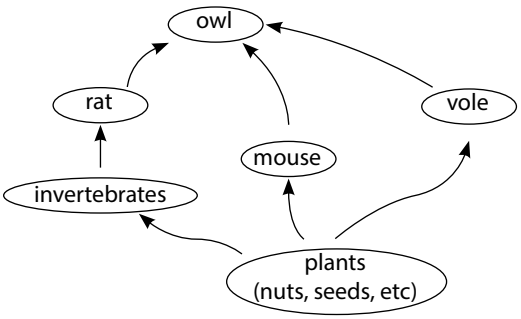
A variation of the second activity could involve giving every student group a bag with the same number of beans. Then, before having students count the beans, have the student groups share the information with the rest of the class and calculate a class average or estimation. Add a question about which analysis yielded the more accurate results, the individual group or the class average? Why is that the case?

Activity 37 Owl Pellet Dissection

Four sets of forceps per group will allow work to proceed at a faster rate.

The time spent on this activity can vary widely, as some students will be able to more quickly dissect the owl pellet, whereas others will pay painstaking attention to detail.

As an optional extension activity, you could assign more advanced students to create their own dichotomous key for identifying the rodent skulls.



Sample Food Web (Answers will vary, depending on what is observed in the owl pellet).

Example Energy Pyramid calculation:

Sample mass of owl pellet: 6 g

The owl pellet is regurgitated and not digested, so we don't count its mass. The result of 0.5% does not closely follow the 10% rule, but it is within the range of 0.1%–36% stated in the text.

types of skulls present	number of skulls present	average mass of individual prey (g) (see table above)	mass of prey eaten in this meal (g)	net mass digested (g) (subtract mass of owl pellet from the mass of prey)	total mass digested in owl lifetime (g) (assume 2 meals/day and a lifespan of 3 years)	owl mass as a percentage of total mass digested
rat	1	200	200 + 50 = 250 g	250 – 6 = 244 g	244 ·2·365·3 = 534,360 g	2600/534,360×100% = 0.5%
mouse	1	50				

Additional images of the rodent skeleton shown in *The Apprentice's Companion*:

Skull, front view.

Skull, top view.

Skull, bottom view.

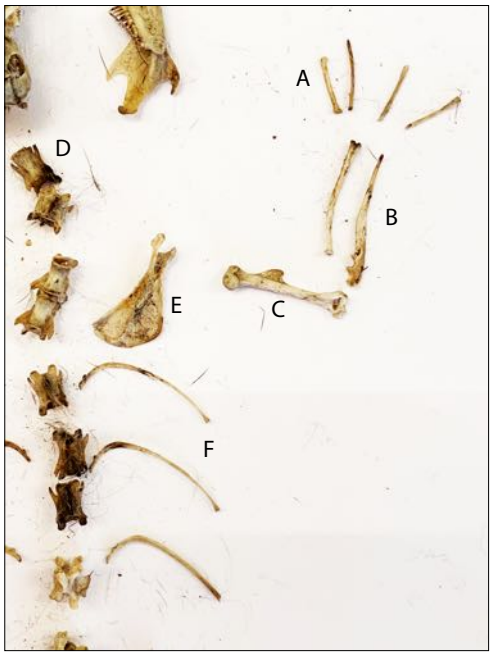
Jaws.

A: pelvic bone

B: femur

C: tibia/fibula

D: metatarsals



A: metacarpals
B: radius/ulna
C: humerus
D: vertebrae
E: scapula
F: ribs

Vertebrae.

References:

1. https://www.barnowltrust.org.uk/sitemap/galleries/pellet-analysis/

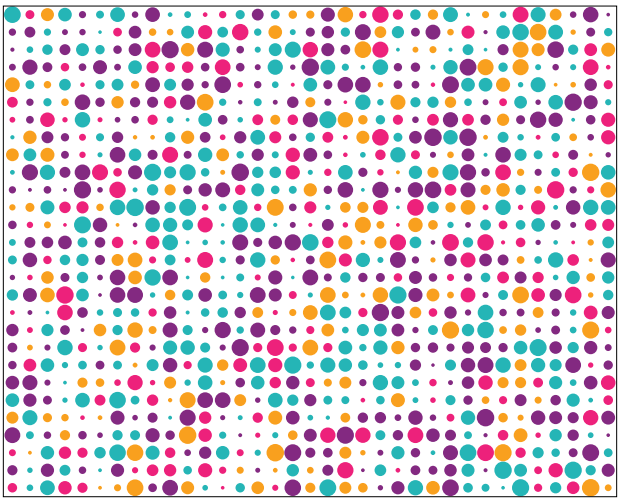
2. https://en.wikipedia.org/wiki/Barn-owl

3. https://teachingapscience.com/owl-pellet-dissection-trophic-levels-energy-loss/ (The extention activity is adapted from this source)

Activity 38 Natural Selection

When selecting fabric colors, first choose white or black as a neutral background. This is meant to work as a control such that all of the colors of M&M's stand out fairly equally. For a second fabric, try to select a solid color that matches one of the M&M's colors. The idea is that the same-colored M&M's will blend in and will be selected for survival more often. The third fabric should be a colored pattern. I used a small floral pattern shown below that contained blues and reds. This worked will to camouflage the blue and red M&M's.

Here are some other ideas:



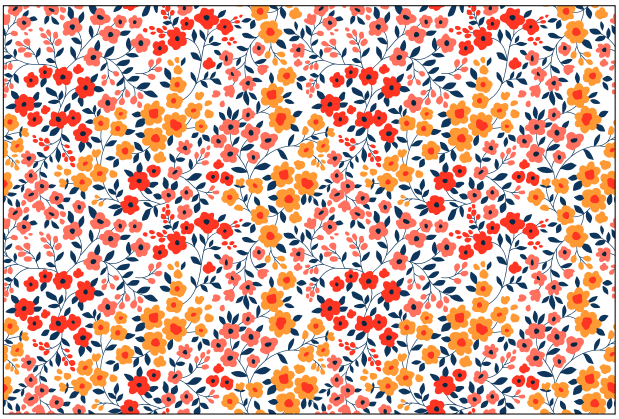


Image Credits for Teacher Notes

Activities 2, 6

Katie Rogstad

Activity 7

Eulodia leaf: Cloroplasti_Elodea.jpg via https://commons.wikimedia.org/wiki/File:Cloroplasti_Elodea.jpg. Author: Cimice50, licensed under CC-BY-SA 4.0.

Other images: Katie Rogstad

Activities 11, 12, 13

Katie Rogstad

Activity 10

John D. Mays

Activity 14

Codon table: John D. Mays

Photos: Katie Rogstad

Activities 15, 16, 18, 19

Katie Rogstad

Activity 20

Left to right, top to bottom: Mikrofoto.de-Blepharisma_japonicum_15.jpg via https://commons.wikimedia.org/wiki/File:Mikrofoto.de-Blepharisma_japonicum_15.jpg. Author: Frank Fox, licensed under CC-BY-SA 3.0 Germany. Mikrofoto.de-volvox-4.jpg via https://commons.wikimedia.org/wiki/File:Mikrofoto.de-volvox-4.jpg. Author: Frank Fox, licensed under CC-BY-SA 3.0 Germany. Vorticella_convallaria.jpg via https://commons.wikimedia.org/wiki/File:Vorticella_convallaria.jpg. Author: CG Ehrenberg, public domain. Paramecium.jpg via https://commons.wikimedia.org/wiki/File:Paramecium.jpg. Author: Barfooz at the English Wikipedia, licensed under CC-BY-SA 3.0. Stentor_roeseli_composite_image.jpg via https://commons.wikimedia.org/wiki/File:Stentor_roeseli_composite_image.jpg. Author: Protist Image Database, public domain. Colpidium_colpoda_-_160x_(9001031120).jpg via https://commons.wikimedia.org/wiki/File:Colpidium_colpoda_-_160x_(9001031120).jpg. Author: Picturepest, licensed under CC-BY-SA 2.0. Amoeba_(Amöbe)_01.jpg via https://commons.wikimedia.org/wiki/File:Amoeba_(Amöbe)_01.jpg. Author: Picturepest, licensed under CC-BA-SA 2.0. Euglena_-_400x_(8999902391).jpg via https://commons.wikimedia.org/wiki/File:Euglena_-_400x_(8999902391).jpg. Author: Picturepest, licensed under CC-BY-SA 2.0.

Activities 21, 22, 23, 24, 25, 27, 28, 29, 30

Katie Rogstad

Activities 31, 33

Heather Ayala

Activity 34

John D. Mays

Activity 36

Graphs: Heather Ayala

Activity 37

Katie Rogstad

Activity 38

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