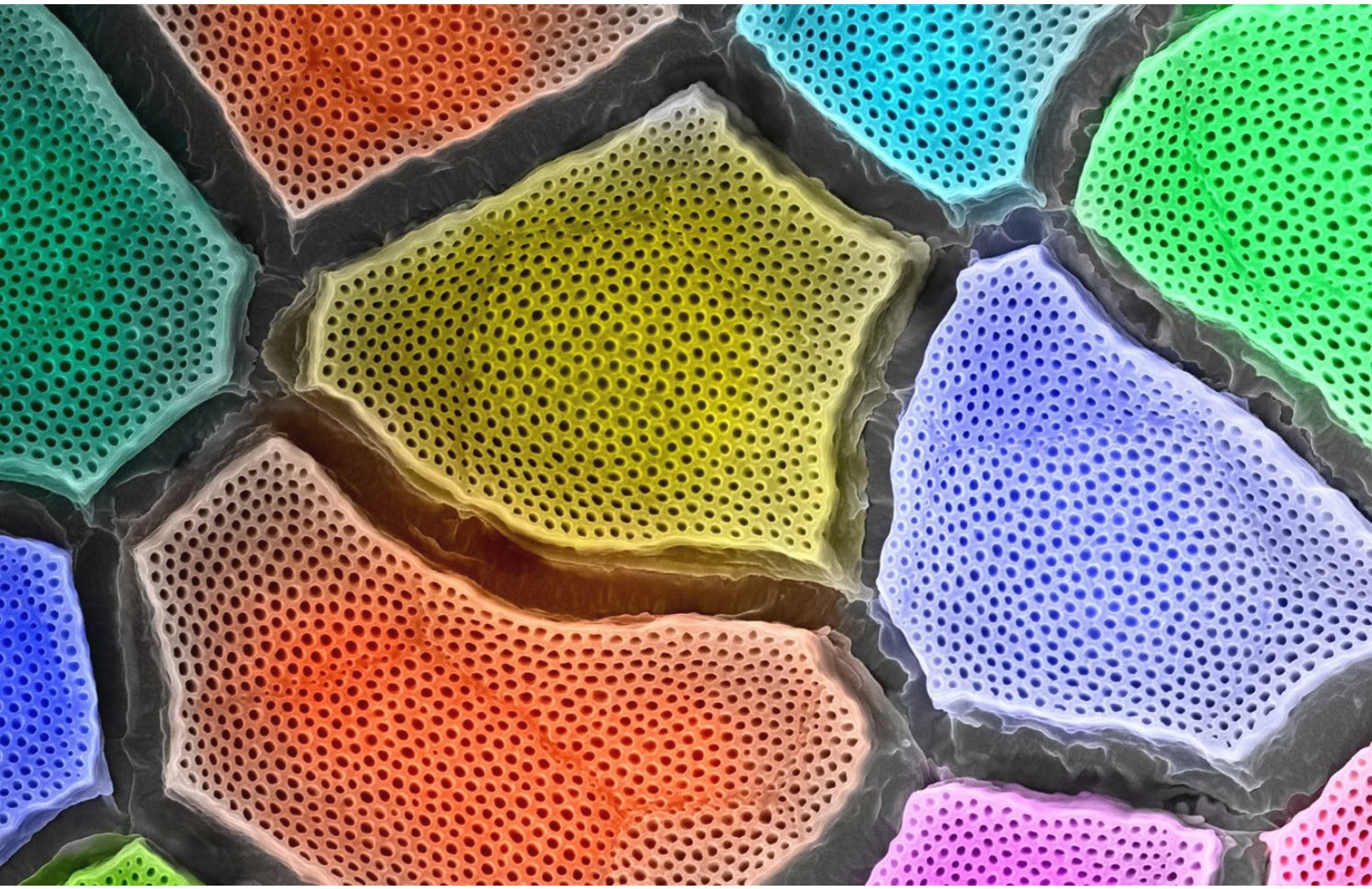
FUNDAMENTALS OF BIOLOGY LABORATORY MANUAL

Karen Marks. M.Sc

Valeria Hochman Adler, Ph.D



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INTRODUCTION

ABOUT THIS COURSE

Hello, citizen scientist! You may be wondering why you're being called a "citizen scientist" or what that even means. This is an introductory biology course, after all. You may be taking the class as a prerequisite for nursing or maybe you are fulfilling your general education units as you work towards a degree in another field. Regardless of what your long term educational and career goals are, it is important not only to develop a general understanding of science, but also to recognize that science is happening all around us and that science affects our lives whether we realize it or not. It is in our best interest to understand science so that we can make well-informed, good decisions for ourselves, those around us, and the world at large.

Enter the citizen scientist. A citizen scientist is just that -- a regular person without an extensive formal or professional background in science who not only understands the importance of science but also participates in the vast scientific work happening around the globe. While professional scientists may hold impressive degrees and conduct cutting-edge research, sometimes they need the help of everyday people -- our help.

What do you need to be a citizen scientist? Not much, really. You only need to understand the scientific process, have a basic understanding of core concepts, have an openness to scientific evidence, and an ability to tap into your curiosity.

We will begin our journey as citizen scientists in this course by developing a good foundation in the basics of biology. To accomplish this, we will take on the role of scientists and perform thoughtful, hands-on experiments in the hopes that we will develop a respect for the scientific process and better understand how life all around us works. And hopefully, this course will spur you to join the citizen science community going into the future too.

SAFETY IN THE LABORATORY

Science can be exciting and fun, but there are also many dangers in the laboratory. Many experiments require the use of harmful chemicals, flame, or sharp objects. While there's no need to fear these things, it's important to understand the dangers found in a lab classroom and what precautions we can take to prevent mishaps. You'll find that lab

classrooms have several basic safety rules that you must follow to keep everyone safe. To ensure that you fully understand these rules, you will sign a safety contract included in this manual. Only sign the safety contract after the instructor has reviewed the rules with the class and you have asked for clarification on anything you did not understand. If you violate these lab rules, you may be asked to leave the lab. Remember, we are all in charge of safety!

1. Do not eat or drink in the laboratory. Any food and drink should be sealed and/or stored in a location deemed appropriate by the instructor and/or campus safety protocol.
2. Dress in lab-appropriate attire. Lab-appropriate attire generally means closed toed shoes and pants (or equivalent) covering most of the leg. Keep long hair tied back and confine or remove loose jewelry. If a lab requires more strict attire policies, abide by those.
3. Keep items such as bags and backpacks under the table instead of in walking spaces and on table tops to reduce trip hazards and contamination.
4. Use protective gear when directed. Some labs may require skin or eye protection. If the instructor and/or protocol require the use of gloves or goggles, remember that it is <u>not</u> optional.
5. Inform your instructor if you have medical concerns or situations that may require special precautions, such as allergies, pregnancy, or immunosuppression.
6. Identify and follow special safety precautions. When special attention is needed, your lab manual will utilize special symbols to grab your attention.

The biohazard symbol indicates that a procedure may pose health concerns.

The caution symbol indicates that special attention to safety should be given and identifies hazards that may come from substances and/or procedures.

7. Dispose of materials in their appropriate receptacle. Some items may be washed down the drain or thrown in the regular trash, but other items may require collection for special disposal such as certain chemical waste products, biohazardous waste, and sharp instruments. If you don’t know where to dispose of something, always ask your instructor.

8. Report all spills, glass breakages, and accidents to the instructor. Do not attempt to clean any spillage, broken glass, or wounds yourself without direct instruction.
9. If a chemical or microorganism gets on your skin, wash the area immediately and thoroughly with mild soap and water.
10. Know the locations of safety equipment in the classroom. Safety equipment includes items like the telephone, emergency exits, fire extinguisher, fire blanket, eyewash station, emergency shower, first-aid kit, spill kit, and broken glass container.
11. Handle laboratory equipment with care. Many of the tools and models used in the lab are used by many classes and may not be easily replaced.
12. Pay special caution when using flame or heat. Never grab suspected or known hot objects with your hands and never leave a flame or hot plate unattended.
13. Report any unsafe actions or situations to the instructor, to include things like broken equipment, horseplay among students, or unauthorized guests.
14. Clean your workspace after completing your lab. This includes putting away equipment, sanitizing the table top, and disposing of any trash. Wash your hands before leaving the classroom.
15. Lastly, follow all other safety instructions given by the instructor that may not be covered in this form. Safety can be specific to the procedure being conducted and further safety measures may be required.

I, _____, fully understand and agree to adhere to the safety policies as explained in this safety contract. I understand that failure to adhere to these rules may result in me being asked to remedy the violation (when possible) or leave the lab classroom and that repeated violations may result in further penalties.

_____ _____

Signature Date

NAME:_____ LAB SECTION:_____

How Scientists Think

The Scientific Method

Introduction

Learning Objectives:

- Understand the scientific method as a logical process
- Develop hypotheses based on observation
- Design and conduct an experiment
- Analyze and interpret data from an experiment

The scientific method is a process used by scientists to identify a logical explanation for an observation through experimentation. Scientists first make an observation that spurs a question. From there, a scientist will formulate at least one hypothesis. After forming a hypothesis, they will design an experiment to put it to the test. After gathering information from the experiment, they will then analyze the data to draw a logical conclusion on whether or not the hypothesis was supported.

This process isn't exclusive to scientists though. Non-scientists use it regularly albeit without realizing it. Consider the following scenario: you get in your car but when you turn the key, the car doesn't start. What are some possible reasons the car failed to start? Maybe the alternator went out or maybe the battery is dead. Each possible reason is a hypothesis. Since the battery hypothesis is easier to test in this case, you start there. This is your experimental phase. Using a meter to measure the battery's voltage, you find that the battery is dead. You then replace the battery and try to start the car again. It starts up. Given the information you gained from this experiment, you conclude that the car failed to start originally due to a dead battery. Your evidence supports this hypothesis, leaving you to reject the alternator hypothesis.

For this lab, we will take a closer look at each step of the scientific method, putting our understanding into practice.

1.1 Developing a Hypothesis

A *hypothesis* is more than a random guess. It requires that you pay close attention to the observations you made and pull from previous knowledge to develop a probable explanation. In many cases, scientists formulate multiple hypotheses to cover many possible outcomes. Generally, scientists regularly use two types of hypotheses -- the null hypothesis and the alternate hypothesis. The *null hypothesis* states that there is no significant relationship between a variable being tested and the observed outcome. The *alternate hypothesis* states that there will be a significant relationship. Depending on the original observations or questions, there may be several alternate hypotheses.

Let's revisit our car example for developing hypotheses. We have already mentioned two possible hypotheses. Hypothesis A was that the car failed to start due to a faulty or dead battery. Hypothesis B was that the car failed to start due to a faulty alternator. In this case, our null hypothesis is that neither the battery or alternator have anything to do with the car failing to start.

Now it's your turn to practice developing hypotheses. Remember that your hypotheses do not need to be perfect or correct, they just need to be possible explanations for the given observations or questions.

Scenario 1: You spill a large amount of sauce on your shirt and want to remove the stains. In your laundry room you have two stain removers -- StainAction and BriteWhite. You want to know which stain remover will do a better job.

Null Hypothesis (H_0):

Alternate Hypothesis I:

Alternate Hypothesis II:

Scenario 2: Your friend tells you that a penny is more likely to land heads up. Being skeptical of your friend's statement, you decide to test if this statement is true.

Null Hypothesis (H_0):

Alternate Hypothesis I:

Alternate Hypothesis II:

1.2 Designing an Experiment

Experimental design is an extremely important part of the scientific process because the conclusions drawn can only be as good as the experiment itself. If the experimental setup is flawed in a significant way, it can impact the data collected and in turn lead to a faulty or incorrect conclusion.

A good experiment's appearance can vary depending on the hypotheses being tested, but most experiments have a few things in common. Most of the variables are kept the same, but one may be changed by the experimenters. By changing only one variable and keeping everything else the same, we can have more confidence in our conclusion. When many variables are changed together, it can be hard to tease apart which variable(s) led to the result.

Variable -- a part of an experiment that can change or be changed
- *Experimental variable* -- the variable that is purposefully being changed
- *Experimental group* -- the group that is exposed to the experimental variable

Control -- known variables that are purposefully kept constant or the same
- *Control Group* -- the group that will experience a known or expected outcome and can be used as a comparison tool for the experimental group
- *Positive Control* -- the group exposed to a treatment/variable that is expected to produce results
- *Negative Control* -- the group exposed to a treatment/variable that is ***not*** expected to produce results

Independent variable -- the variable that is changed by the experimenters (also called the experimental variable)

Dependent variable -- the outcome measured by the experimenters

A good experiment does not rely on a single test to support or reject a hypothesis. The reason being is that there will always be some variance in results and in some cases, random chance can lead to something very misleading. To limit the effects of variance and random chance, researchers and scientists will use replicates in their experiments. Replicates are identical runs of the same experiment. The more times an experiment is run, the more confident a researcher can be that their results are representative of the natural world. That being said, there are limitations on how many replicates one can use and so researchers must strike a balance to maximize the number of replicates while maintaining the feasibility of the experiment.

Another important aspect of experimental design is reproducibility. Studies should be designed and explained in a way so that another researcher could set up the same experiment and get similar results. When it's impossible to reproduce the experiment, it takes away from its validity. This means that it's very important to be clear, direct, and thorough when explaining the experiment's materials and setup.

For this exercise, you will design an experiment to test the hypotheses you created for Scenario 2 from Exercise 1.1. Use the worksheet below to determine the important components of your experiment. Then, write a step-by-step explanation on how you plan to conduct your experiment.

Table 1.1 Preparing for the Experiment

Independent Variable	
Dependent Variable	
Necessary Materials	
Number of Replicates	

In the space below, write a step-by-step guide for conducting your experiment. This will serve as your procedure for the next exercise so be very clear in your instructions!

1.3 Collecting and Analyzing Data

When conducting an experiment, researchers collect data -- the information gathered from the experiment. This information will serve as evidence and will help the experimenters draw proper conclusions about their hypotheses. While collecting data can be easy, drawing logical conclusions can be trickier. Scientists use statistical analysis to help differentiate a significant result from natural variance. While we will not dive deeply into the required statistics for determining significance, we should develop a basic understanding of data.

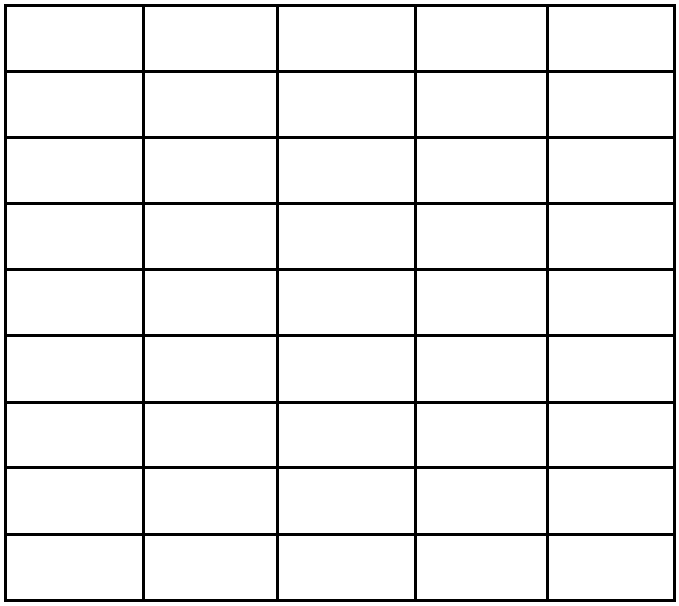
We will practice collecting and analyzing data by conducting the experiment developed in Exercise 1.2. In the space below, complete the table and graph to record and plot your data. (Make sure to include labels for items like x-axis, y-axis, title, etc.)

Table 1.2 Data Collection from Self-Designed Experiment

Result	**Data -- Tally Marks**	**Total Number**	**Percentage**
Heads			
Tails			

Graph 1.1

Title:_____



Now for a twist! You will conduct the same experiment again. However, this time you will follow a different group's procedure. Trade one of your group's handouts with another group. Follow their procedure exactly as written.

Write down the names of the group from the new procedure below.

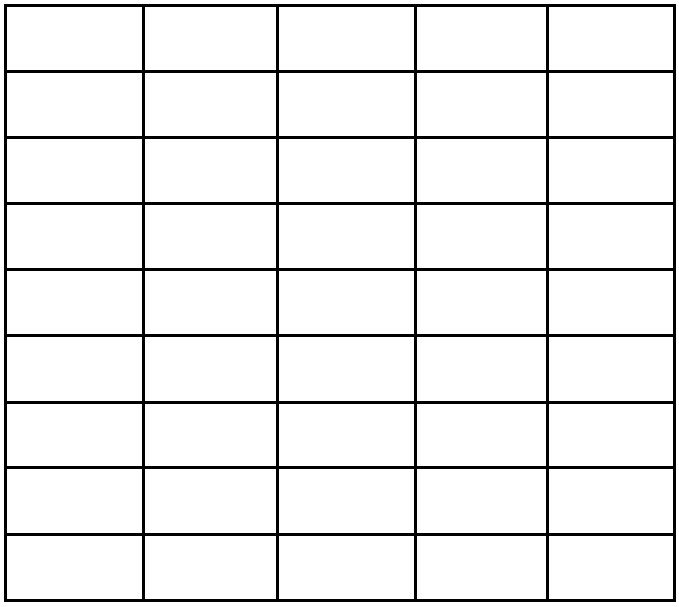
Complete the table and graph using the other group's procedure.

Table 1.3 Data Collection from a Different Procedure

Result	**Data -- Tally Marks**	**Total Number**	**Percentage**
Heads			
Tails			

Graph 1.2

Title:_____



What parts of the other group's procedure would you ask for clarification on?

How did your procedure and results differ from the other procedure and results?

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NAME:_____ LAB SECTION:_____

We Are What We Eat

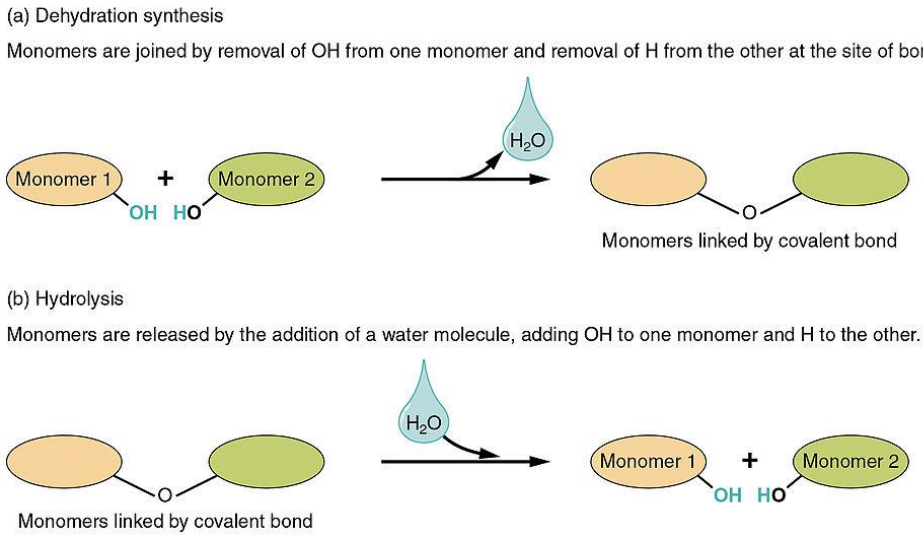
The Chemistry of Life

Introduction

Learning Objectives

- Understand the chemistry of biological molecules
- Describe the structure and function of the four classes of biological macromolecules
- Explain how to identify the presence or absence of biological molecules in food materials

As living systems we are bound by the rules of chemistry, with cells composed of atoms arranged in larger atomic structures called molecules. While there are many important molecules in living things, we will be looking at a few types in detail. We will look at water as well as the macromolecules. The macromolecules consist of four classes -- the carbohydrates, proteins, lipids, and nucleic acids. These molecules tend to be large and built of repeating components called “subunits” or “monomers.” These subunits can be strung together by a reaction called a dehydration synthesis reaction and broken apart by a hydrolysis reaction. Dehydration reactions remove water to link two subunits together, while a hydrolysis reaction adds in water to split two subunits apart.



Each class of macromolecules has unique properties such as their monomers, functions, and structure. Let's look at each class in detail.

Nucleic Acids

Nucleic acids are made of subunits called nucleotides. The nucleotides repeatedly link together in long chains to form molecules, like DNA and RNA. These molecules are used to store and utilize genetic information. Since all living things have large amounts of nucleic acids, we consume them in high amounts, so it is not something we typically look for in our food sources. Given the fact that nucleic acids are found in all living things, we will not be testing for nucleic acids and will instead revisit them in a later lab.

Carbohydrates

Carbohydrates serve as an important energy source for living things. The monomer for carbohydrates is called the monosaccharide (*mono*--, one; --*saccharide*, sweet/sugar.) These monosaccharides have a similar structure with a 1:2:1 ratio of carbon, hydrogen, and oxygen. Some common monosaccharides are glucose, galactose, and fructose. Monosaccharides can stand alone or also be linked together in twos, in which the molecule is called a disaccharide (*di*--, two; --*saccharide*, sugar.) Disaccharides include sugars like sucrose and lactose.

Some carbohydrates are more complex than the monosaccharides and disaccharides. These carbohydrates are called polysaccharides (*poly*--, many; --*saccharide*, sugar.) Given their much larger size, polysaccharides serve as structural molecules and as a way to store carbohydrates. In animals, carbohydrates are stored as glycogen and in plants they are stored as starch.

Proteins

Proteins are a large and diverse class of molecules. Proteins can serve many purposes in cells -- transport, defense, movement, structure, and signaling are just a few things that proteins can do within a cell. You may also notice that many proteins end in -in or -ase. The monomer for proteins is the amino acid, which is composed of an amino group (--NH_2), carboxyl group (--COOH), and a variable R group. There are 20 different R groups, meaning that there are 20 different amino acids.

Lipids

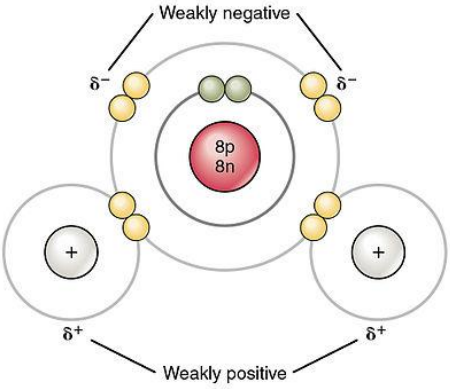
Lipids are also diverse in their structure and function but they all have two things in common -- they are mainly composed of carbon and hydrogen and they are all *hydrophobic*. Molecules that are hydrophobic do not dissolve in water, and instead repel water away. Some common lipids are triglycerides (fats and oils,) phospholipids, and sterols.

2.1 Water and Solvency

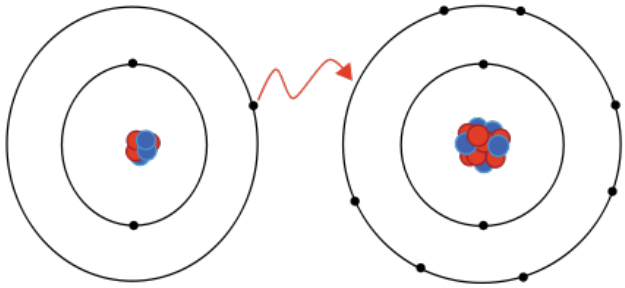
Water is one of the most important molecules to organisms. In fact, over half of the human body is water. Water has many properties that contribute to its ability to support all life. Let's review these properties.

1. Water is cohesive
2. Water is less dense as a solid
3. Water has a high heat capacity
4. Water is an excellent solvent

For this exercise, we will focus on the last of these properties. Water is an excellent *solvent* -- something that other substances can easily dissolve in. However, not everything can dissolve in water. The substances able to do so must meet one of two criteria; they must either have a *polar covalent* or an *ionic* bond. If a substance is *nonpolar*, then it won't readily dissolve in water.



A. *Polar Covalent Bond*



B. *Ionic Bond*

Before conducting the exercise, develop a hypothesis for each substance's solubility in water in the table here.

Table 2.1 Solvency Hypothesis

Substance Added	**Hypothesis**
Table Salt	
Acetone	
Vegetable Oil	

Materials:

- 3 test tubes
- Pinch of table salt
- Dropper bottle of acetone
- Dropper bottle of vegetable oil
- Permanent marker

Procedure:

1. Label each tube.
2. Fill three test tubes halfway with water.
3. In Tube 1, add a pinch of table salt. Swirl.
4. In Tube 2, add 5 drops of acetone. Swirl.
5. In Tube 3, add 5 drops of vegetable oil. Swirl.
6. Record whether the solute dissolved in the water.

Table 2.2 Solvency Results

Substance Added	**Observation**	**Hypothesis Supported? (Y/N)**
Tube 1: Table Salt		
Tube 2: Acetone		
Tube 3: Vegetable Oil		

Based on your results, what can you conclude about each substance's polarity?

2.2 Simple Carbohydrates: Benedict's Test

The monosaccharides and disaccharides are the simple carbohydrates. They are present in many of the foods we eat each day. We can test for the presence of simple carbohydrates such as glucose by using Benedict's reagent. When simple carbohydrates are present, the Benedict's reagent will change color from blue to orange-red when heated. We will be testing several substances for simple carbohydrates using this reagent.

Benedict's Reagent	**Negative Result**	**Positive Result**
	Blue	Green (low) to Red (high)

Table 2.3 Simple Carbs Hypotheses

Tube #	**Substance**	**Hypothesis**
1	Water	
2	Glucose	
3	Onion	
4	Potato	
5	Whole Milk	

Materials:

- 5 test tubes
- Dropper bottle of Benedict's reagent

- 1 mL of water
- 1 mL of 1% glucose solution
- 1 mL of onion juice
- 1 mL of potato juice
- 1 mL of whole milk

Procedure:

1. Label each tube.
2. Put 1 mL of the appropriate substance in each tube.
3. Add 5-7 drops of Benedict's reagent to each tube.
4. Place all tubes in a hot water bath for 10 minutes.
5. Carefully remove tubes from the water bath and let cool.
6. Record color observations of each tube.

Use caution when adding and removing tubes from the water bath. Use tongs to limit the risk of burns.

Table 2.4 Simple Carbs Results

Tube #	**Observation**	**Hypothesis Supported? (Y/N)**
1		
2		
3		
4		
5		

Using what you learned from the scientific method lab, which tube(s) served as controls in this experiment?

2.3 Complex Carbohydrates: Lugol's Iodine Test

Polysaccharides are complex carbohydrates. In order to test for the presence of polysaccharides, we can use Lugol's iodine. Lugol's iodine is normally an amber-orange color, but will turn black-blue in the presence of complex carbohydrates such as starch. We will be testing various substances for complex carbohydrates using this reagent.

Lugol's Iodine Reagent	**Negative Result**	**Positive Result**
	Amber/Golden	Blue-Black

Table 2.5 Complex Carbs Hypotheses

Tube #	**Substance**	**Hypothesis**
1	Water	
2	Starch	
3	Onion	
4	Potato	
5	Whole Milk	

Materials:

- 5 test tubes
- Dropper bottle of Lugol's Iodine reagent
- 1 mL of water
- 1 mL of 1% starch solution
- 1 mL of onion juice
- 1 mL of potato juice
- 1 mL of whole milk

Procedure:

1. Label each tube.
2. Put 1 mL of the appropriate substance in each tube.
3. Add 2-3 drops of Lugol's Iodine reagent to each tube.

4. Record color observations of each tube.

Table 2.6 Complex Carbs Results

Tube #	Observation	Hypothesis Supported? (Y/N)
1		
2		
3		
4		
5		

There was a difference in the results of the simple and complex carbohydrate tests for tubes 3 and 4. Why do you think a substance would test positive for one but not the other? *Hint: Think about the structure of both simple and complex carbohydrates.*

2.4 Proteins: Biuret Test

When the amino acids of a protein are linked together, they are linked by peptide bonds. These peptide bonds are unique to proteins and can be detected using Biuret reagent. Biuret reagent is normally a pale blue color but will turn into a light pink color in the presence of amino acids and a violet color in the presence of proteins such as albumin. We will be testing various substances for proteins using this reagent.

Biuret Reagent	**Negative Result**	**Positive Result**
	Blue	Pink/Purple

Table 2.7 Protein Hypotheses

Tube #	Substance	Hypothesis
1	Water	
2	Albumin	
3	Onion	
4	Potato	
5	Whole Milk	

Materials:

- 5 test tubes
- Dropper bottle of Biuret reagent
- 1 mL of water
- 1 mL of 1% albumin solution
- 1 mL of onion juice
- 1 mL of potato juice
- 1 mL of whole milk

Procedure:

1. Label each tube.
2. Put 1 mL of the appropriate substance in each tube.
3. Add 10 drops of Biuret reagent to each tube.
4. Record color observations of each tube.

Table 2.8 Protein Results

Tube #	Observation	Hypothesis Supported? (Y/N)
1		
2		
3		
4		
5		

Tubes 1 and 2 served as controls in this test. What is the importance of having both of these tubes serve as controls?

Clean-up for 2.1-2.4:

- All liquids from 2.1-2.4 are safe to go down the drain. Wash test tubes with soap and water.

2.5 Lipids: Bile Salts Test

Since lipids are so diverse in their structure, we will take a different approach to identifying lipids. Instead, we will identify lipids using bile salts. Bile salts are emulsifiers, meaning they help blend hydrophobic and hydrophilic substances, such as oil and water. When added to water, bile salts will disperse. When added to a lipid-containing substance, such as oil, the bile salts will form clumps around the lipids. We will be testing various substances for lipids using this substance.

Bile Salts Results	**Negative Result**	**Positive Result**
	Bile salts disperse	Bile salts form clumps

Table 2.9 Lipids Hypotheses

Tube #	**Substance**	**Hypothesis**
1	Water	
2	Vegetable Oil	
3	Onion	
4	Potato	
5	Whole Milk	

Materials:

- 5 test tubes
- Bile salts
- 1 mL of water
- 1 mL of vegetable oil
- 1 mL of onion juice
- 1 mL of potato juice
- 1 mL of whole milk

Procedure:

1. Label each tube.
2. Put 1 mL of the appropriate substance in each tube.
3. Add a small amount of bile salts to each tube and swirl gently.
4. Record solubility observations of each tube.

Table 2.10 Lipids Results

Tube #	**Observation**	**Hypothesis Supported? (Y/N)**
1		
2		
3		
4		
5		

Did any of your tubes contain lipids? Did this surprise you?

Further Thoughts

1. Look at tubes 3 - 5 for exercises 2.2, 2.3, 2.4, and 2.5. Which food source was highest in simple carbohydrates? Complex carbohydrates? Proteins? Lipids?

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NAME:_____ LAB SECTION:_____

On the Small Side

Introduction to Microscopy

Introduction

Learning Objectives:

- Identify the parts of a compound light microscope and describe their functions
- Use a microscope to make scientific observations
- Distinguish differences and similarities between prokaryotic and eukaryotic cells
- Create a model of the eukaryotic cell, including identification of organelles and their functions

In biology, many of the components we study are too small to observe without technology. In fact, the largest cell in the human body -- the human ovum -- is only 100 µm (0.1 mm) large. This is just barely large enough to see with the naked eye. Most other animal and plant cells and all bacterial cells need a microscope to view. In order to magnify cells, scientists rely on microscopes.

There are many different types of microscopes. Some of the more complicated ones such as scanning electron microscopes use beams of electrons to view the tiniest of objects such as organelles and proteins. While these microscopes allow you to see such miniscule objects, they are large, expensive, and require more training to use.

The ones we will use in this lab instead use visible light to magnify and view objects. While these microscopes are more limited, their smaller size and ease of use have many benefits. Light microscopes function using a series of lenses that bend light. With each additional lens, the microscope gains *resolution* -- the ability to distinguish detail. There are two types of light microscopes we will use in the lab: the stereoscope (or dissecting microscope) and the compound light microscope.

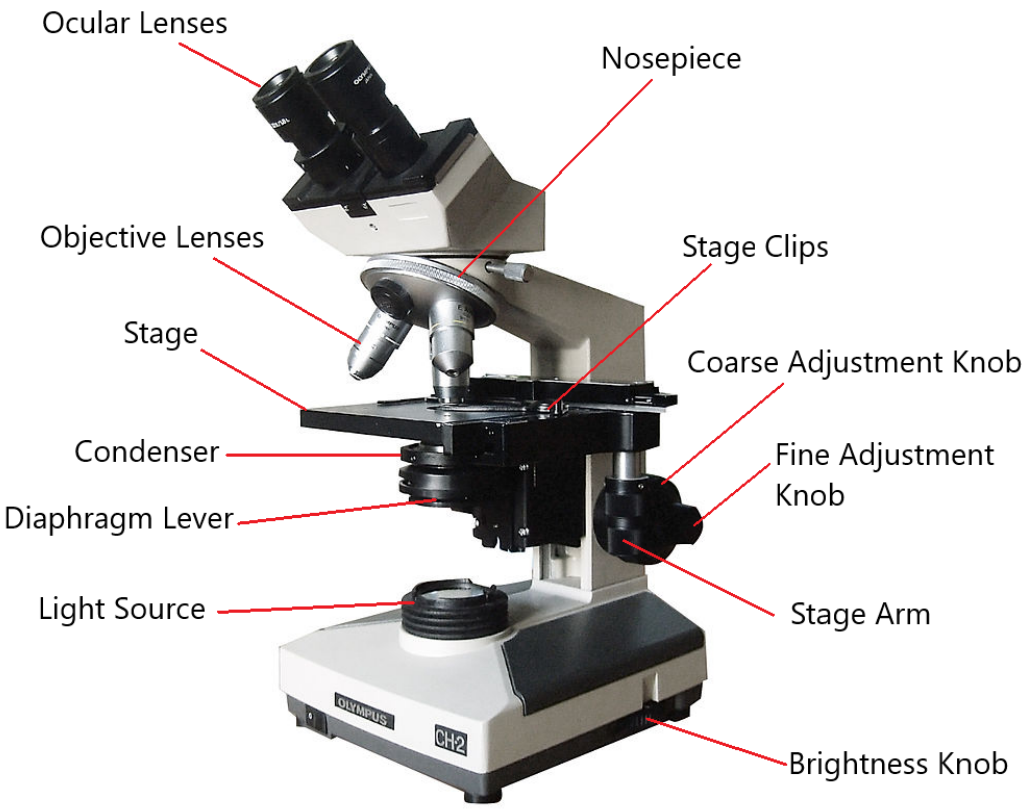
The stereoscope is a simple type of microscope that only uses one lens. This means that it has the weakest resolution, but is able to see objects in three dimensions. This microscope is best for viewing larger objects in greater detail. So, if you wanted to view

a flower’s stamens or a grasshopper’s face in detail, this microscope would be ideal for the job.

The compound light microscope is more complicated than the stereoscope. This microscope uses multiple lenses, giving it higher resolving power than the stereoscope. This microscope is better for viewing much smaller (and thinner) objects, such as cells. The tradeoff is that since the resolution is higher, objects cannot be seen in three dimensions as much like with the stereoscope. So, neither microscope is “better” than the other, as they each have benefits and drawbacks. The best microscope is the one that fits the job.

3.1 The Compound Light Microscope

The compound light microscope is the primary microscope we will be using in this course. It has many parts that contribute to its function and being familiar with each part will make using the microscope that much easier. Let’s take a look at each component of the microscope and its function.



Adapted by Karen Marks from Amada44, CC BY-SA 3.0, via Wikimedia Commons

Common Components of the Microscope

- **Ocular Lenses** -- Also called the eyepieces, these contain the first set of lenses. These generally magnify an object 10x. The ocular lenses also are adjustable to fit your face.
- **Objective Lenses** -- The second set of lenses on the microscope. The microscope will have several objectives, each with their own magnification. Magnifications can be 4x (scanning), 10x (low), 40x (high), and 100x (oil immersion.) NEVER use the oil immersion objective without oil. Microscopes are also *parfocal* -- meaning that the microscope will stay focused even if you change objectives.
- **Nosepiece** -- The structure that holds the objectives in place. When moving from one objective to the next, use the nosepiece to do so.

- **Stage** --This is where the microscope slide will be held.
- **Stage Clips** -- These hold the slide in place on the stage. Make sure that the slide is held in place properly. The stage clip should be adjacent to the slide, not on top or under it.
- **Stage Arm** -- This moves the stage forwards, backwards, left, and right so that you can center an object in view.
- **Condenser** -- This focuses the light on the slide and field of view.
- **Diaphragm Lever** -- This lever adjusts the condenser. You may need to use this when you change from one objective to another as the field of view shrinks.
- **Coarse Adjustment Knob** -- This knob raises and lowers the stage to bring an object into view. This knob should only be used when first looking for an object on the lower objectives. Do NOT use this knob when using the higher objectives.
- **Fine Adjustment Knob** -- This knob also raises and lowers the stage, but in smaller increments. This knob helps bring an image into focus after using the coarse adjustment knob.
- **Light Source** -- This is where the light bulb is housed.
- **Brightness Knob** -- This adjusts how bright the light source shines. You may need to adjust brightness as you change objectives.
- **Power Switch** -- This turns the microscope on and off.

Microscopes are not the most intuitive of tools. It's important that you know how to properly use, care for, and store the microscope. When microscopes are used or cared for incorrectly, damage can result. When microscopes are damaged, the repairs can be both costly and time consuming. Review these points on how to handle your microscope so that we can keep microscopes in the best working order.

Proper Care and Use of a Microscope

- ALWAYS carry the microscope with two hands -- one supporting the bottom and one on the arm.
- Always start on the lowest possible objective, such as scanning or low.
- NEVER use the oil immersion objective without immersion oil. You will damage the microscope and the oil is necessary to see anything with this objective.
- Use the coarse adjustment knob ONLY on lower objectives when first trying to find your image.

- Start with the stage in the lowest position, then move the stage up slowly using the coarse adjustment knob until your image is visible.
- Once the image is visible, use the fine adjustment knob to sharpen the image.
- Change the objective if necessary. Microscopes are *parfocal*, meaning they retain focus. So you will not need to refocus, but you may need to sharpen the image with the fine adjustment knob slightly.

Troubleshooting

- Is the objective locked into place?
- Is the objective the most appropriate one for the specimen (i.e., are you zoomed in too much or not enough?)
- Is the specimen on the slide centered in your field of view?
- Is the brightness level high enough?
- Have you moved the diaphragm lever to refocus light on the specimen?

Proper Clean-up and Storage

- Move the stage to its lowest position.
- Remove any slides from the stage and follow instructor directions on storage or disposal of slides.
- Turn the brightness knob down and move to the lowest objective.
- Turn off the microscope and wrap the cord up neatly.
- If oil was used, use appropriate materials to wipe oil away.
- Using two hands, carry the microscope to its storage location and cover with its dust cover.

Calculating the Total Magnification of the Microscope

Total magnification is the combined magnifying power of both the ocular and objective lenses. It can be calculated by multiplying the ocular and objective magnifications. The magnifications can be found directly on the eyepieces and objectives. (Hint: Look for a number followed by “x”).

Table 3.1 Total Magnification

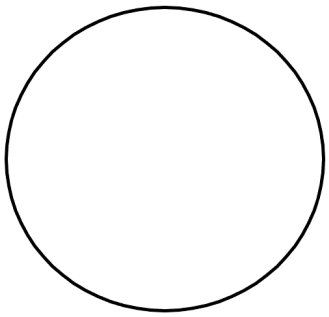
Objective Lens	**Eyepiece Magnification**		**Objective Magnification**		**Total Magnification**
Scanning		X		=	
Low		X		=	
High		X		=	

3.2 Looking at an Object Under the Microscope

Now that we've reviewed how to use a microscope, let's start putting it into practice. For our first slide, we will be looking at the letter "e".

Procedure:

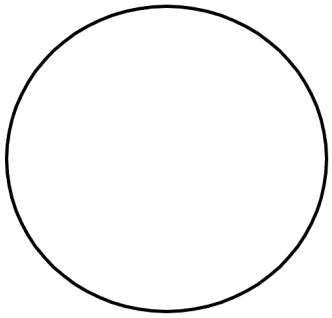
1. View the letter "e" slide under the microscope starting on the scanning objective. Make sure the "e" is right side up when viewed on the stage without the eyepieces. Draw what you see in the space provided.



Title:_____

Total Magnification:_____

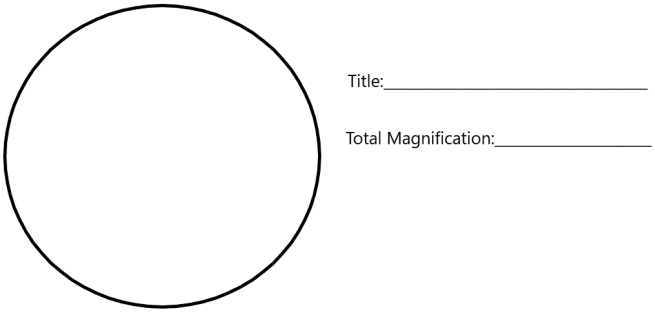
2. View the slide on the low objective and draw what you see.



Title:_____

Total Magnification:_____

3. View the slide on the high objective and draw what you see.



What do you notice about the appearance of the letter “e” when viewed with the naked eye versus with the microscope? Note ALL of the differences you see.

How did your field of view (the space visible when looking through the eyepieces) change as you moved from the lower objectives to the higher ones?

3.3 Depth of Field

While the field of view describes the two dimensional visible space, depth of field refers to the three dimensional space. The last exercise showed us how the field of view changes when we change objectives. Depth of field also changes in response to changes in the objectives. As you increase magnification (by moving to a higher objective), your depth of field will decrease. This means your ability to see an object in 3D will diminish as you increase magnification. You may need to use the fine adjustment knob to “move” through and view the different layers of the specimen.

We will put our understanding of depth of field into action by viewing the “threads” slide. This slide has three threads stacked on top of each other. Our goal is to determine which colored thread is on top, which is in the middle, and which is on the bottom.

Procedure:

1. View the “threads” slide on the scanning objective and with the stage in the lowest position.
2. Bring the threads into focus using the coarse and then fine adjustment knobs.
3. Move to the low objective. Use the fine adjustment knob to sharpen the image if necessary.
4. Using the fine adjustment knob, slowly move the stage down until all three threads are just barely out of focus.
5. Slowly move the stage up using the fine adjustment knob. The first thread to come into focus will be the top thread, the second will be the middle thread, and the last one to come into focus will be the bottom thread.

Table 3.2 Depth of Field Results

Position	**Thread Color**
Top Thread	
Middle Thread	
Bottom Thread	

3.4 Viewing Prepared Slides

In many biology classes, specimens are preserved onto slides and can be used over and over again. These preserved slides are professionally prepared and can have a variety of specimens on them -- from simple onion cells to thin slivers of a spinal cord. When looking at these slides, you should see a label identifying what the specimen is and how it was prepared. Slides can be prepared in a variety of ways including:

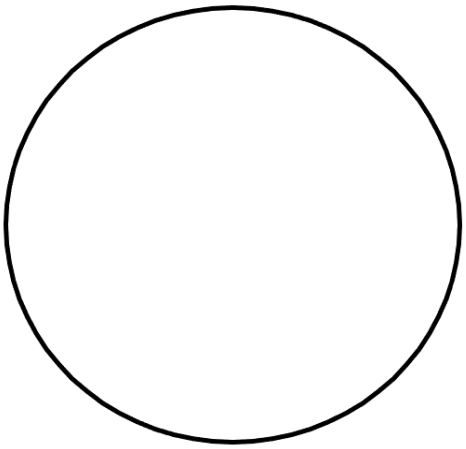
- *Whole mount (w.m.)* -- the entire specimen without cuts
- *Longitudinal section (l.s)* -- specimen is cut parallel to specimen’s length
- *Cross section (c.s.)* -- also called a *transverse section (t.s.)*, specimen is cut perpendicular to specimen’s length

When using prepared slides, use caution and common courtesy. Prepared slides can be fragile so keep them on the microscope when in use and in the slide box when done.

When sharing slide boxes, only take one slide to your desk at a time so that your labmates can access them too.

Now let's put our skills we gained in exercises 3.1, 3.2, and 3.3 in action. If you get stuck, look to these exercises and your instructor for help.

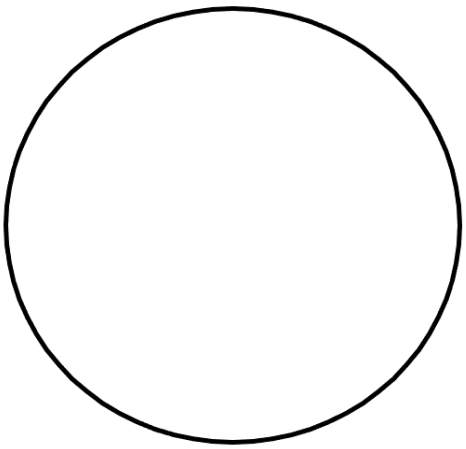
Prepared Slide #1 -- Onion Cells



Title:_____

Total Magnification:_____

Prepared Slide #2 -- Blood Smear



Title:_____

Total Magnification:_____

3.5 How to Make a Wet Mount

Not every slide can be prepared in advance. Sometimes we will need to make our own slides in class. To do so, we will make a wet mount -- a fresh slide containing our specimen of interest. When making a wet mount, there are several things we need to consider. We need to consider what type of tissue our specimen is and whether or not we need to stain it.

Staining is a process that uses a chemical to alter the color of the specimen. Since many cells appear nearly colorless, staining is a vital part of the wet mount process. Stains come in a variety of colors and different stains more readily attach to different parts of the cells. The cell type and components of interest will dictate which stain is most appropriate.

For this lab, we will make a wet mount using our own cheek cells.

Materials:

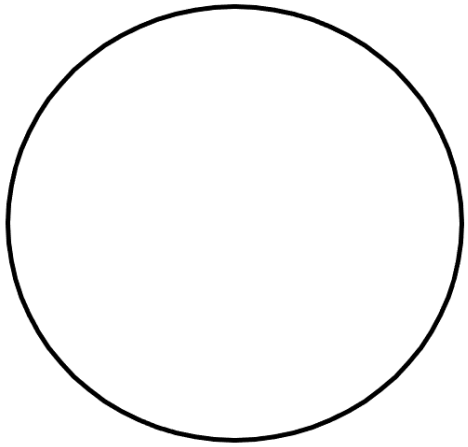
- Microscope slide with coverslip
- Clean toothpick
- Methylene blue stain
- Small piece of paper towel

Procedure:

1. Obtain a clean slide, cover slip, and toothpick.
2. Scrape the inside of your cheek with the toothpick vigorously but gently.
3. Smear the end of the toothpick along the middle of your slide.
4. Add 1 drop of methylene blue to the center of the slide.
5. Gently place the coverslip on top of the methylene blue droplet.
6. If excess stain is on the slide, use the paper towel to draw out the excess.
7. Observe the slide under the microscope using steps from previous exercises.

Wet mount slides should NEVER go into the regular trash. Make sure to follow in-class disposal instructions for wet mount slides.

In the space below, draw what you see under the microscope using the best fit objective.



Title:_____

Total Magnification:_____

Which objective did you find most useful for viewing the cheek cell slide in the most detail? Why did you find that objective to be the most helpful in viewing the cheek cells?

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NAME:_____ LAB SECTION:_____

Cell's Kitchen

Cells and Membranes

Introduction

Learning Objectives:

- Identify the fundamental characteristics of life
- Compare and contrast prokaryotic and eukaryotic cells
- Describe the organelles and their functions
- Apply understanding of diffusion and osmosis in an experimental setting
- Describe tonicity and solute concentration's effect on cells

In lecture, we defined life using several important characteristics. We also introduced *cell theory* -- the theory that the cell is the basic unit of life, that all living things are made of at least one cell, and that cell must come from preexisting cells. But what is a cell? What makes a cell, a cell?

Cells are membrane-bound biological units that contain DNA and have the ability to control their own metabolism and reproduction. This is important, as not all biological units are considered alive or cellular. Remember that in order to be considered alive, an organism must follow cell theory and ALL of these criteria:

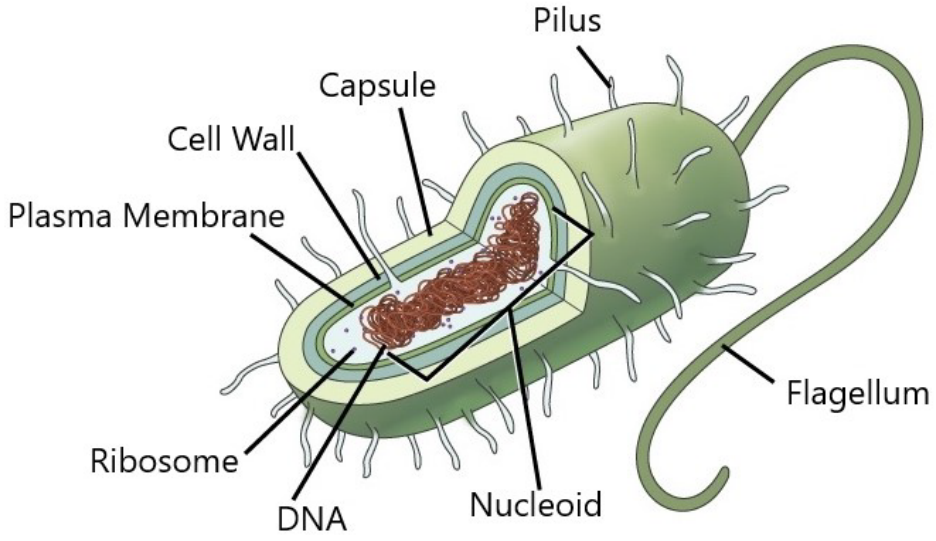
- Organization
- Reaction to stimuli
- Ability to reproduce
- Ability to regulate internal environment
- Uses energy
- Has an evolutionary history

When a biological entity does NOT meet all criteria, we do not consider it to be alive. One such entity is the virus, which generally only consists of a nucleic acid and protein coat. Viruses are not considered to be alive because they cannot regulate their own internal environment nor can they reproduce on their own. They require the invasion and takeover of a cell to reproduce since they do not have the machinery to produce more viruses. Without the cell, the virus is completely unable to replicate.

Cells can be categorized into one of two categories based on their structural make-up as well as how they regulate themselves. We will take a look at both categories -- the *prokaryotes* and *eukaryotes* -- before diving into one of universal cellular structures: the membrane.

4.1 Prokaryotic Cells

Prokaryotic cells are the simplest of cells and consist of the bacteria and archaea. They tend to be very small and do not have many of the structures seen in eukaryotic cells. Prokaryotic cells are *unicellular* (single-celled) with DNA found in a central region called the *nucleoid*. They also have *ribosomes* that produce all of the proteins required for the cell's daily functions, all of which is suspended in a gel-like fluid called *cytoplasm* and encapsulated by the *plasma membrane*. Let's take a look at a typical prokaryotic cell.



Modified by Karen Marks from CNX OpenStax, CC BY-SA 4.0, via Wikimedia Commons

DNA: serves as the genetic blueprint for a cell

Ribosome: produces proteins

Nucleoid: central region where DNA is found in prokaryotes

Flagellum: used for movement

Plasma Membrane: controls movement of materials in and out of the cell

Cell Wall: provides structure and protection to the cell

Capsule: used for attachment and protection

Pilus: used for attachment to surfaces as well as for DNA transfer

4.2 Eukaryotic Cells

Like the prokaryotes, eukaryotic cells also have DNA, a plasma membrane, cytoplasm, and ribosomes. But eukaryotic cells have much more than that. Eukaryotes may be unicellular, but can also be *multicellular* (many-celled) organisms. Eukaryotes include animals, plants, fungi, and protists. They also have *organelles* -- membrane-bound structures that carry out specific tasks in the cell. Let's look at a typical eukaryotic cell. Then, using your book, lectures, notes and other resources, fill in the table with each organelle's function.

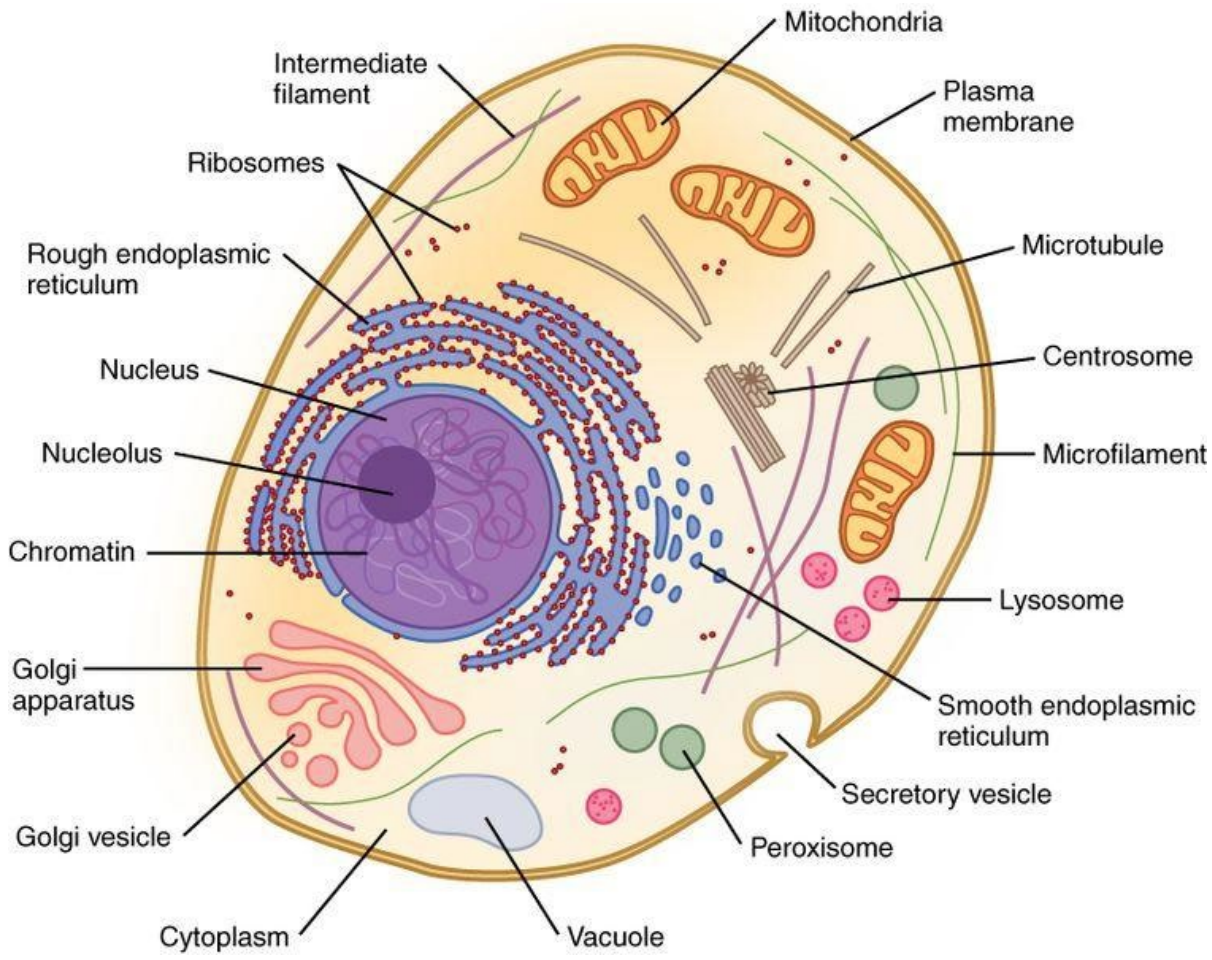


Table 4.1 The Organelles

Organelle	**Function**
Nucleus	
Ribosome	
Smooth ER	
Rough ER	
Golgi Apparatus	
Lysosome	
Peroxisome	
Mitochondrion	
Chloroplast	
Flagellum	
Cilia	
Cell Wall	
Centrioles	

Which organelle(s) are only found in plant cells? Which organelle(s) are only found in animal cells?

In the space below, draw the composite cell model available in class. Label the following structures:

☐ Nucleus ☐ Ribosome ☐ Rough ER ☐ Smooth ER
☐ Golgi Apparatus ☐ Mitochondria ☐ Lysosome
☐Peroxisome ☐ Centrioles ☐ Cytoplasm ☐ Plasma Membrane

Now that we've looked at both prokaryotes and eukaryotes, make a table or Venn Diagram comparing their similarities and differences.

4.3 Simple Diffusion

Diffusion is the movement of molecules from an area of high concentration to an area of a lower concentration until *equilibrium* is met. This movement is spontaneous, does not require the input of energy and can happen in a gas, liquid or semi-solid. There are many factors that affect how fast equilibrium will be reached, including the medium (gas versus liquid), size of the molecule, and temperature. For this exercise, we will look at temperature's effects on diffusion.

Hypothesis: Which temperature (warm or cold) do you think will see a faster rate of diffusion (if any?)

Materials:

- 1 bottle of food dye
- 2 medium sized beakers
- A stopwatch (your phone's timer is okay)
- Both warm (30° C) and ice water

Procedure:

1. Label each beaker as either warm or cold water.
2. Add 20 mL of warmed (30° C) water to the beaker labeled warm.
3. Add 20 mL of ice water (without any of the ice cubes) to the beaker labeled cold.
4. Add 2 drops of food dye to each beaker.
5. Immediately start the stopwatch (or phone).
6. Record the time when the dye appears to have evenly distributed throughout each beaker.

Table 4.2 Diffusion and Temperature Results

Beaker	Diffusion Time
Warm Water	
Cold Water	

Based on your results, what do you think would happen if a third beaker with hot (45° C) water was added to the experiment?

4.4 The Artificial Cell

Cells are very selective in what moves through their membrane as it is important that the cell maintain a well-regulated internal environment. This regulation is called *selective permeability*, which allows the cell to control the concentration of *solutes* (dissolved substances) on each side of the membrane. Things that affect a solute's ability to easily move through a membrane include the solute's size, charge, and polarity. When a solute is too large or has a charge, then it will need an alternate method to move through the membrane, such as a channel or carrier protein. These are special proteins that allow certain molecules to pass through the membrane. However, in our artificial cell these protein channels will be absent.

Materials:

- 1 pre cut strip of dialysis tubing
- 2 pieces of twine OR dialysis clips (when available)
- 1 large beaker filled ⅔ full with distilled water
- 1 dropper bottle of Lugol's iodine
- 1 dropper bottle of starch solution

Procedure:

1. Fill the beaker with distilled water and soak the dialysis tubing for several minutes until you can open the tubing with your fingers.
2. Tie off (or clip) one end of the dialysis tubing.
3. Add 2 mL starch solution to the inside of the tubing.
4. Add 1 mL distilled water to the inside of the tubing.
5. Tie off (or clip) the other end of the tubing and gently wash off any starch residue from the tubing in the sink. This is your artificial cell.
6. Weigh your artificial cell and record it as well as its color in the table below.
7. Place your cell in the beaker of distilled water.
8. Add 10 drops of Lugol's iodine to the beaker water. Record the water color.
9. Leave the beaker and cell alone for at least 15 minutes.
10. Reweigh the cell and record the new weight and any color changes.

Table 4.3 Hypotheses

Observation	**Hypothesis**
Weight Change	
Movement of Iodine	
Movement of Starch	

Table 4.4 Artificial Cell Results

Observation	Before	After
Cell's weight		
Cell's color		
Beaker water's color		

Which molecules moved across the membrane? Justify your answer using evidence from your results.

Which molecules were stopped by the membrane? Justify your answer using evidence from your results.

Clean-up for 4.3 and 4.4:

1. Dump all liquids down the sink, including liquid from the artificial cell.
2. All string and tubing should be thrown into the regular trash. Do NOT throw away dialysis clips if being used.

4.5 Osmosis and Tonicity

Water is also capable of moving through a membrane in a process called *osmosis*, usually in response to the concentration of solutes found inside and outside the cell. Generally, *water will move towards the higher solute concentration*, as that means the relative water concentration there is low.
The relative concentration of solutes on the outside of the cell is the solution's *tonicity*. There are three terms we can use to describe the tonicity of the cell's environment.

> *Isotonic*: The solute concentration outside the cell is equal to the solute concentration on the inside.
>
> *Hypotonic*: The solute concentration outside the cell is lower than the solute concentration on the inside.
>
> *Hypertonic*: The solute concentration outside the cell is higher than the solute concentration on the inside.

For this exercise, we will demonstrate how tonicity affects cells using pieces of potato. These potato pieces will be exposed to solutions of differing tonicity. In Table 4.5, write what you think will happen to the potato in each environment in terms of weight change.

Table 4.5 Hypotheses

Cell's Environment	**Hypothesis**
Isotonic	
Hypotonic	
Hypertonic	

Materials:

- Corer or knife with cutting board
- Potato
- Ruler
- Scale with weigh boat
- Permanent marker
- 3 test tubes
- DI water
- 0.9% saline solution
- 10% saline solution

Procedure:

1. Using a corer or knife, cut three pieces of potato approximately 5 cm long.
2. Record the original potato weights in the before column. (Hint: Make sure to "zero" out the weight of the weigh boat.)
3. Label and number three test tubes.
4. Place one potato piece in each tube.
5. Add water to tube 1, 0.9% saline to tube 2, and 10% salt solution to tube 3.
6. Leave potato pieces for 45 minutes.
7. Calculate the weight change (After weight - before weight) and % change.

Table 4.6 Tonicity Results

Environment	**Before Weight**	**After Weight**	**Weight Change (+/-)**	**% Weight Change** (Weight change/before weight x 100)
Isotonic				
Hypotonic				
Hypertonic				

Which environment caused the largest increase in potato weight? Why do you think the weight increased?

Which environment caused the largest decrease in potato weight? Why do you think the weight decreased?

Which environment saw little to no change in potato weight? Why do you think the weight stayed the same?

Clean-up:

- Pour all liquids down the drain and wash test tubes with soap and water.
- Solid potato pieces should go into the regular trash.

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NAME:_____ LAB SECTION:_____

Cells Need Energy

Cellular Respiration and Fermentation

Introduction

Learning Objectives:

- Describe the importance of ATP to cellular processes
- Identify the steps of cellular respiration
- Compare cellular respiration to fermentation in terms of ATP production

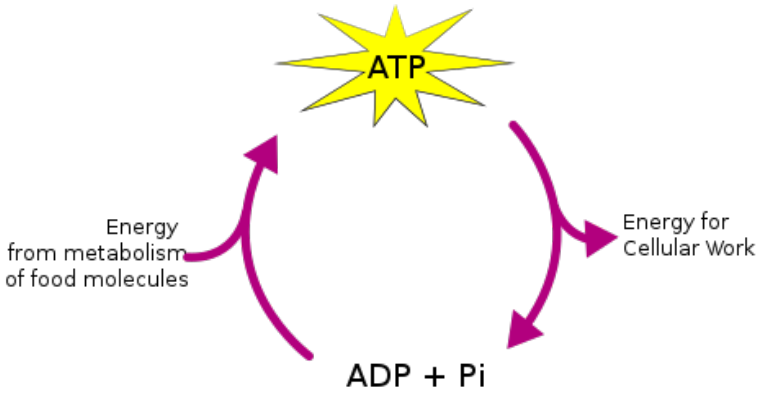
One of the characteristics shared among all living things is the requirement to use energy. *Energy* is the capacity to do work. Energy can take many forms like potential, kinetic, chemical, and heat energy. Energy is not lost or destroyed; it is simply transformed into another form. Not every form is useful to living systems though and so living things must convert energy into a more useful format or it may not be able to harness it.

ne of the most useful forms of energy for living things is chemical energy. Chemical energy is stored in the chemical bonds of a molecule. When that bond is broken, the chemical energy is released. Most living things bring in this energy through the food they consume, although some organisms (such as plants) are able to convert light energy into chemical energy. All organisms store energy in the form of chemical energy. For this lab, we will look at how cells harness the chemical energy found in the food we eat to power many of the important reactions that occur in our cells every day.

5.1 The ATP Cycle

One of the most biologically important molecules is *adenosine triphosphate* (or *ATP* for short). ATP is a short-lived, unstable molecule that stores large amounts of chemical energy in the bonds between the three phosphate groups. Because of this, cells utilize ATP to help “power” other chemical reactions. When a necessary chemical reaction needs an input of energy, a cell can utilize ATP by breaking one of the phosphate bonds. This releases all of the chemical energy stored in the phosphate bond, which the needed reaction can use.

ATP is also useful in that it is recyclable. When ATP is used, the last phosphate breaks off. The cell can use an enzyme called ATP synthase to reattach a phosphate back onto ADP (adenosine diphosphate) to reform ATP. For this exercise we will look at the cyclic nature of ATP.



Why do you think it is beneficial to recycle ATP instead of building brand new ATP molecules each time energy is needed?

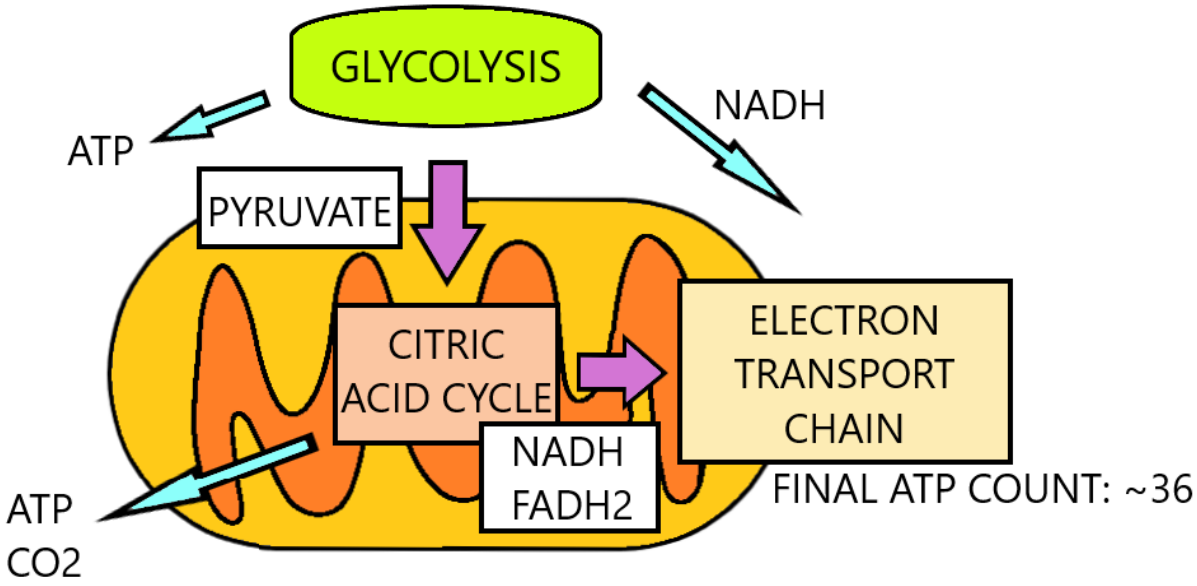
Both plants and animals use carbohydrates and lipids for long term energy storage. Considering the information in 5.1, why do plants and animals do this instead of storing energy in the form of ATP?

5.2 Cellular Respiration

There are many ways to rebuild and recycle ATP, but not all methods are created equal nor are they free. Cells must bring in energy in order to rebuild ATP. They do this by bringing in and using the chemical energy stored in molecules such as glucose.

Cellular respiration is one process used to rebuild ATP by using the chemical energy stored in glucose. Glucose will go through a series of chemical reactions to move high energy electrons and hydrogen ions. Cellular respiration is *aerobic*, meaning the final

electron acceptor is oxygen. This is why we rely on breathing in oxygen, as most of our ATP is produced by cellular respiration.
Cellular respiration is composed of three main stages: glycolysis, the citric acid cycle (or Krebs cycle), and the electron transport chain. Glycolysis occurs in the cytoplasm of the cell, while the citric acid cycle and electron transport chain both occur inside the mitochondria.



For this activity, we will assess your ability to undergo cellular respiration. Remember that cellular respiration will use oxygen and produce carbon dioxide. Carbon dioxide forms an acid called carbonic acid when mixed with water. This acid can be easily detected with a pH indicator such as bromothymol blue. You will be performing an experiment to view how physical activity changes the rate of cellular respiration.

First let's formulate a hypothesis. In the table below, rank each activity from fastest (1) to slowest (3) rate of respiration.

Table 5.1 Cellular Respiration Hypothesis

Activity	Rank (1 = fastest, 3 = slowest)
Rest	
Slow Walk	
Fast Walk	

For the following procedure, you and your lab partner will both complete the following procedure. You may want to have one participant go first, and then have the second participant go after.

Materials:

- 6 test tubes, labeled (3 per person)
- 1 transfer pipette
- Bromothymol blue (may substitute with phenol red)
- 2 drinking straws (1 per person, different colors)

Make sure you only use your own straw for this exercise to prevent the spread of germs. Do not inhale, aspirate, or drink the bromothymol blue.

Procedure:

1. Label your test tubes according to the activities listed in Table 5.2
2. Add 1 mL of bromothymol blue to each tube.
3. Sit or stand still at your table for 30 seconds.
4. Place the straw in your “Rest” tube and prepare a timer.
5. Record how long it takes for the bromothymol blue to turn yellow while gently blowing into the straw.
6. Walk for 30 seconds. (You may want to do this in the hallway.)
7. Repeat steps 4-5 with your tube labeled “Slow Walk”.
8. Walk outside, and walk at a faster than normal pace around the building.
9. Repeat steps 4-5 with your tube labeled “Fast Walk”.

Table 5.2 Cellular Respiration Data and Results

Name of Each Participant	Time (s)		
	Rest	Slow Walk	Fast Walk

Now, let's graph both your and your partner's data in the graph below. Make a line graph using the data from Table 5.2. Make sure to color code yours and your partner's data and label both the x and y axis.

Graph 5.1

Title:_____

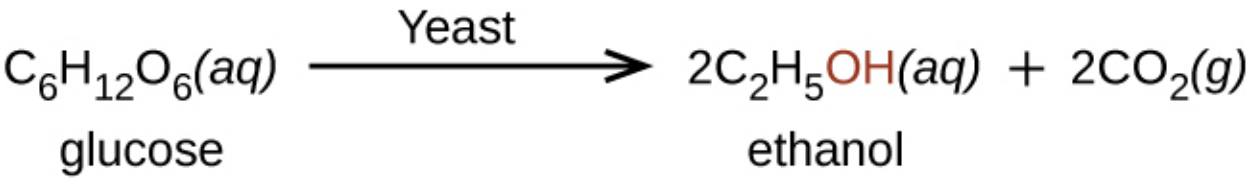
Name	Color

Was your hypothesis supported? If yes, how does your data support it? If not, justify your reasoning.

5.3 Fermentation and Substrate

Cellular respiration is not the only way to build ATP. Many organisms, such as eukaryotic yeast and many prokaryotes, use *fermentation* to produce ATP. As humans, we enjoy the benefits of this process and use it to make many food items like bread, kimchi, and beer.

Unlike cellular respiration, fermentation does not need oxygen as a final electron acceptor. Since oxygen is not required, fermentation is an *anaerobic* process. Instead of oxygen, fermentation uses organic molecules, such as acetaldehyde or pyruvate, as final electron acceptors. When pyruvate is used as the final electron acceptor, lactic acid is produced. When acetaldehyde is the final electron acceptor, ethanol is produced. Remember that regardless of the process, a fuel source, such as glucose, is required, otherwise the cell will not be able to use either cellular respiration or fermentation.



To measure fermentation, we will capture the CO_2 produced by yeast. We will place yeast in several environments with different substrates: some with varying levels of

glucose, one with artificial sweetener, and one with only water. First, let's develop a hypothesis for this exercise.

Table 5.3 Fermentation Hypothesis

Yeast Environment	**Fermentation? (High/Low/No)**
Glucose	
Fructose	
Artificial Sweetener	
Water	

Materials:

- 4 large test tubes or jars, labeled
- 8g baker's yeast
- Scale with weigh boat
- 4 small balloons
- Glucose
- Fructose
- Artificial Sweetener
- Distilled water
- String and ruler

Procedure:

1. Label the tubes according to Table 5.4.
2. Add 2g yeast to each tube.
3. Add 1 g glucose to Tube 1.
4. Add 1 g fructose to Tube 2.
5. Add 1 g artificial sweetener to Tube 3.
6. Add 100 mL water to tubes 1-4.
7. Shake the tubes.
8. Place a balloon over the top of each tube. Ensure it is secure.
9. Measure the diameter of each balloon and record it in Table 5.4.
10. Leave the tubes alone for 40 minutes, checking every 10 minutes.
11. After 40 minutes, measure the diameter of each balloon.

Table 5.4 Fermentation Data and Results

Yeast Environment	0 Minutes	10 Minutes	20 Minutes	30 Minutes	40 Minutes
Glucose					
Fructose					
Artificial Sweetener					
Water					

Graph your data from the table above.

Graph 5.2

Title:_____

What does it mean if the balloon inflated?

What gas do you think the bubbles are made of?

Which substrate had the highest rate of fermentation? How do you know?

5.4 Fermentation and Temperature

Now that we know substrate can impact rates of fermentation, now let's see if temperature can have an influence over fermentation too. We will create three identical tubes but place them in different environments.

Table 5.5 Fermentation Hypothesis

Yeast Environment	**Fermentation? (High/Low/No)**
Room Temperature	
Warm Water Bath	
Cold Water Bath	

Materials:

- 3 test tubes or jars, labeled
- 6g baker's yeast
- Scale with weigh boat
- 3 small balloons
- Glucose
- Distilled water
- Ice water bath

- Warm water bath
- String and ruler

Procedure:

1. Label the tubes according to Table 5.6.
2. Add 2g yeast to each tube.
3. Add 1g glucose to each tube.
4. Add 100 mL water to each tube.
5. Shake the tubes.
6. Place a balloon over the top of each tube. Ensure it is secure.
7. Measure the diameter of each balloon and record it in Table 5.6.
8. Place each tube in their respective environment and leave the tubes alone for 40 minutes, checking every 10 minutes.
9. After 40 minutes, measure the diameter of each balloon.

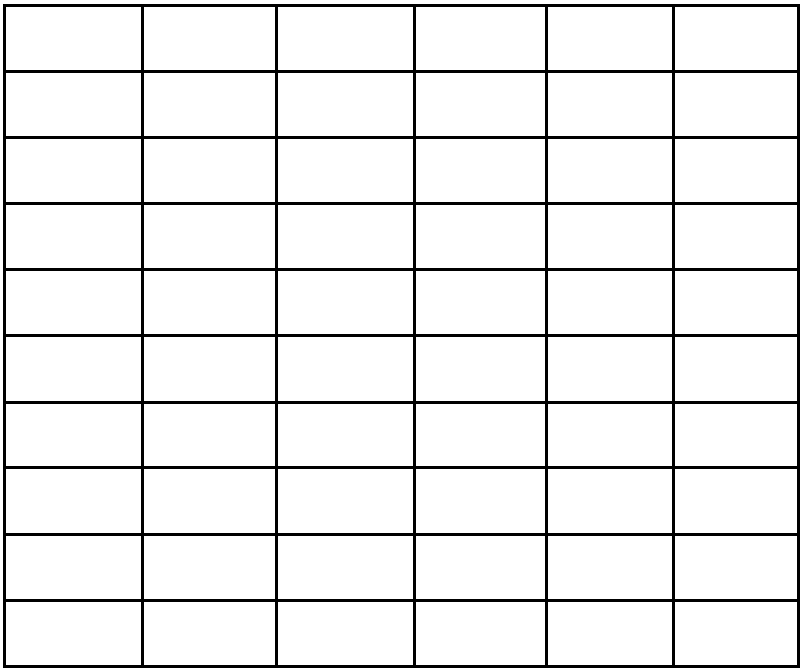
Table 5.6 Fermentation Data and Results

Yeast Environment	**0 Minutes**	**10 Minutes**	**20 Minutes**	**30 Minutes**	**40 Minutes**
Room Temperature					
Warm Water Bath					
Cold Water Bath					

Graph your data from the table above.

Graph 5.3

Title:_____



Which environment saw the highest rate of fermentation?

Clean-up for 5.2 and 5.3:

- All liquids are safe to wash down the drain. Wash all tubes with soap and water.
- Throw balloons, transfer pipettes, and straws in regular trash.

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NAME:_____ LAB SECTION:_____

Living on Sunshine

Photosynthesis

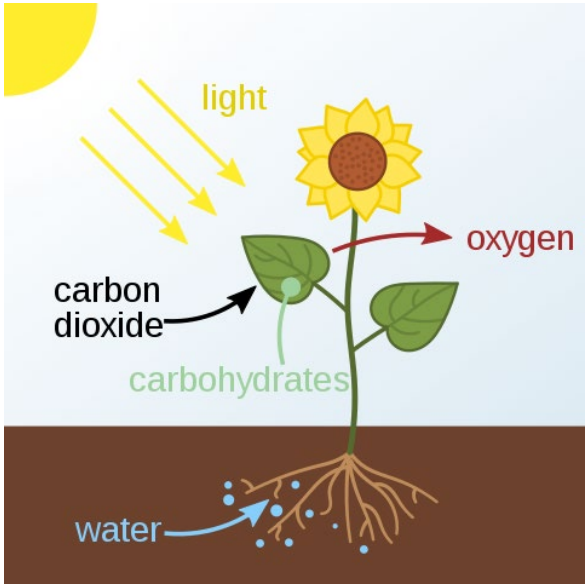
Introduction

Learning Objectives:

- Identify the steps of photosynthesis
- Describe the purpose of photosynthesis
- Explain various pigments' roles in photosynthesis

In the last lab, we learned about how all organisms use molecules like glucose to produce a much-needed energy-releasing molecule called ATP. While many organisms get glucose from the food they eat, some organisms can make their own using light energy from the sun and electrons from water. This process is called *photosynthesis*.

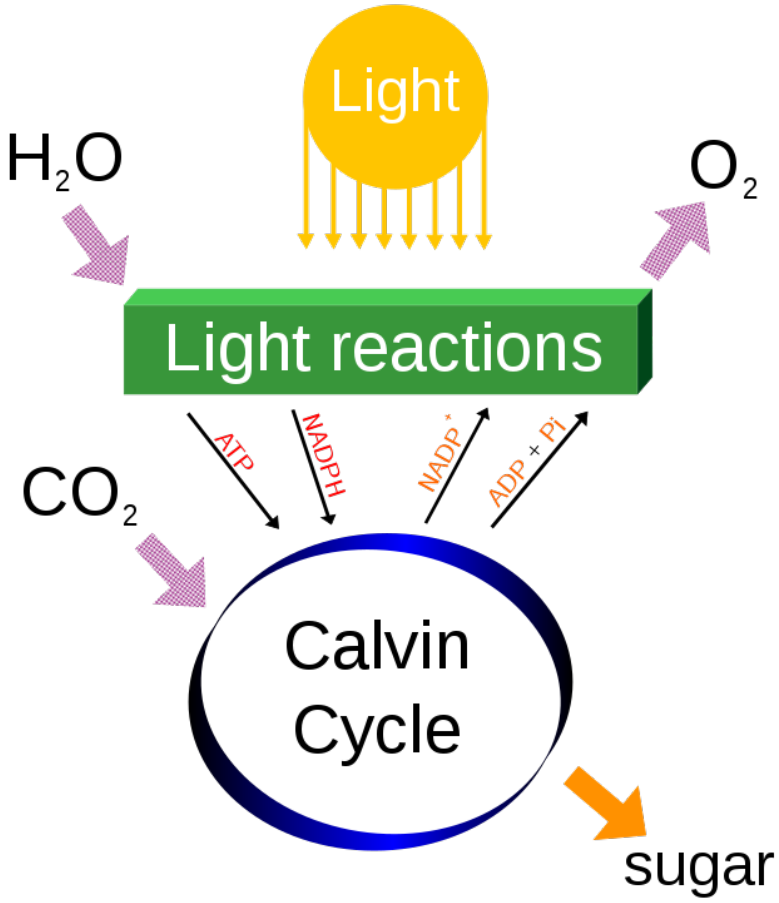
Photosynthesis is used by *autotrophs* -- organisms that make their own food source. Autotrophs can be bacteria, algae, or plants. For this lab, we will focus on photosynthesis occurring in plants.



6.1 The Process of Photosynthesis

Photosynthesis is composed of two main steps -- the *light dependent* and *light independent reactions*. The light dependent reaction is where energy from light is used to harvest electrons from water. Light is absorbed by chlorophyll in the form of photons. When chlorophyll absorbs a photon, one of its electrons gets knocked away. A water molecule is then split and one of its electrons replaces the one chlorophyll lost.

These electrons are then passed on to the light independent reaction. In the light independent reaction (also called the *Calvin cycle*), these electrons are used to "fix" carbon. Carbon dioxide is taken in through the leaves' stomata and brought into the chloroplast. Then, an enzyme called RuBisCO strips oxygen away and fixes the carbon to another molecule called RuBP. After cycling through the Calvin cycle, a three-carbon molecule called G3P is formed, with RuBP being recycled to be used again later.



Daniel Mayer (mav) - original imageVector version by Yerpo, CC BY-SA 4.0, via Wikimedia Commons

For this exercise, we will observe the consumption of CO_2 from photosynthesis. Carbon dioxide (CO_2) is taken in through the leaves of a plant to be used as a carbon source

when building carbohydrates. We will use phenol red to detect the use of CO_2. Phenol red appears red when in the presence of a neutral and basic pH, but becomes yellow when the pH becomes acidic. CO_2 becomes carbonic acid when in water, making the liquid slightly acidic. Prior to class, your instructor has added CO_2 to your phenol red, giving it a yellow color. If CO_2 is used up, the solution will become less acidic, turning the solution red.

Materials:

- 2 test tubes with a test tube rack
- 1 sprig of *Elodea*
- Phenol Red (with CO_2 already added)

Procedure:

1. Obtain 1 small branch of *Elodea*, approximately 2-3 cm long.
2. Place 1 branch of *Elodea* in Tube 1.
3. Add enough phenol red (now yellow from the added CO_2) to cover the *Elodea* in Tube 1.
4. Add the same amount of phenol red to Tube 2. (This tube should only have phenol red.)
5. Leave the test tubes in a sunny part of the room (such as a window sill) or outside in the sun for 45 minutes.
6. After 45 minutes, record the color in the space below.

Table 6.1

Tube	Color Before	Color After
With *Elodea*		
Without *Elodea*		

6.2 The Leaf Structure

Leaves are the main photosynthetic structure of the plant. Leaves increase the amount of surface area of the plant. With that increase of surface area, the plant has access to

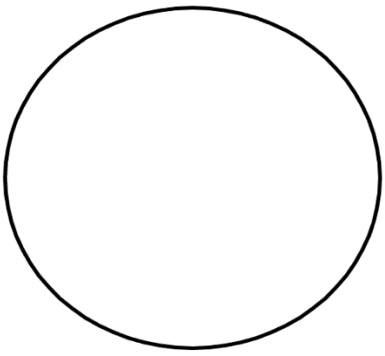
more light. Leaves also provide a place for carbon dioxide to enter and oxygen gas to exit the plant. On the underside of each leaf are many door-like structures called stomata. We can view an impression of these stomata under the microscope

Materials:

- 1 microscope slide
- 1 fresh leaf
- Clear nail polish
- Packing tape

Procedure:

1. Place a fresh leaf on the table with the underside of the leaf facing up.
2. Paint a thin layer of clear nail polish on the underside of the leaf.
3. Let the nail polish dry completely (about 5-10 minutes).
4. Take a short strip of packing tape and stick it to the leaf.
5. Pull the leaf off of the tape, revealing the impression of the leaf on the tape.
6. Stick the tape on the slide, with the impression centered on the slide.
7. View the slide under the microscope and draw what you see in the space below.



Title:_____

Total Magnification:_____

6.3 The Chloroplast

In plants, the organelle responsible for photosynthesis is the chloroplast. Since chloroplasts are responsible for harvesting light for photosynthesis, they are capable of moving within the plant cell to effectively harvest light. When light is weak or low, chloroplasts will move towards the brightest area. When light is too intense or strong, chloroplasts will move away. This may seem counterintuitive, but very intense light can cause damage to the chloroplasts. For this activity we will observe this movement of chloroplasts -- called photorelocation -- in *Elodea*.

Materials:

- Fresh *Elodea* leaves
- Microscope slide and coverslip
- Dropper bottle of distilled water
- Compound light microscope
- Lamp

Procedure:

1. Place one fresh *Elodea* leaf on a slide.
2. Add 1 drop of distilled water to the leaf on the slide and cover with the coverslip.
3. View the *Elodea* slide under the microscope using the high objective.
4. After viewing the *Elodea* under normal conditions, shine the lamp on one side of the slide.
5. Leave the lamp shining on one side of the slide for 10 minutes.
6. After 10 minutes, view the *Elodea* slide again.

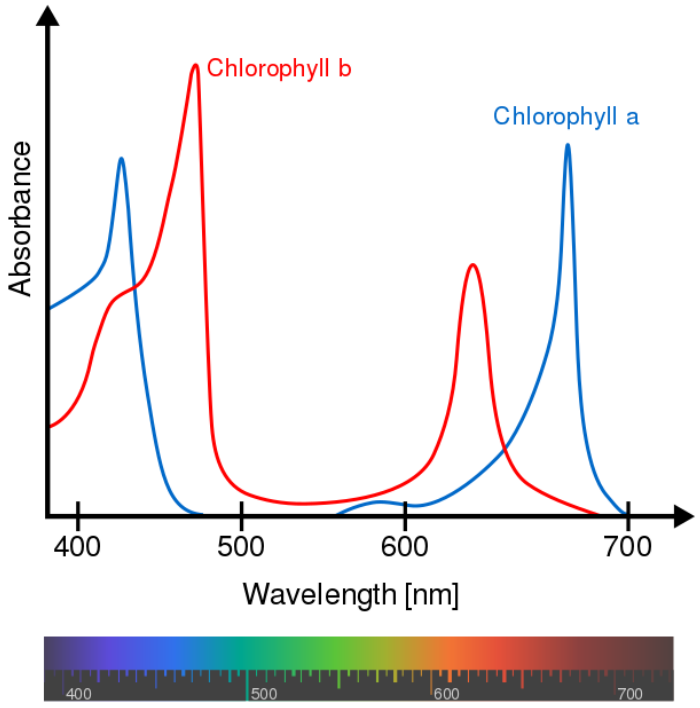
How were the chloroplasts dispersed in the *Elodea* cells before exposure to bright light?

How were the chloroplasts dispersed in the *Elodea* cells after exposure to bright light?

Wet mount slides should NEVER go into the regular trash. Make sure to follow in-class disposal instructions for wet mount slides.

6.4 Pigments and Photosynthesis

Within the chloroplasts are photosynthetic pigments. These pigments, such as *chlorophyll a* and *chlorophyll b*, help capture light energy for the plant. However, these pigments cannot just capture any wavelength of light. Chlorophylls are limited in which light wavelengths they are able to absorb. Any wavelength of light they cannot absorb is reflected. This is why plants appear green, as green wavelengths (500-600 nm) are reflected, while blue wavelengths (425-500 nm) and red wavelengths (600-700 nm) are readily absorbed.



Chlorophyll_ab_spectra2.PNG: Daniele Pugliesi derivative work: M0tty, CC BY-SA 3.0, via Wikimedia Commons

Chlorophylls are not the only pigments found in plants, however. Other pigments such as *carotenoids* (which appear yellow and orange) and *anthocyanins* (which take on shades of red and blue) may also be found alongside the chlorophylls. For this final exercise, we will discover which pigments are found within a spinach leaf.

Hypothesis: Based on the above information, which pigment(s) do you think you will see in a spinach leaf?

Materials:

- 2-3 fresh spinach leaves
- A pencil, paperclip, and coin
- A 10 cm length of chromatography paper
- Chromatography solvent or acetone
- A small beaker
- A metric ruler

Procedure:

1. Fold the chromatography paper in half lengthwise.
2. Measure 2 cm away from one edge and draw a point or line at the 2 cm measurement.
3. Place a spinach leaf on the point or line and use the coin to press the leaf into the paper.
4. Continue pressing, using fresh parts of the leaves until a solid line of spinach extract has been pressed into the paper. (See example image below.)
5. Obtain 10 mL of chromatography solvent (or acetone) from the instructor in the beaker.
6. Place the chromatography paper in the beaker with the spinach end closest to the solvent and the other end facing up. (See example image below.)
7. Use the paperclip to hold the paper to the beaker.
8. Let sit for 45 minutes. Check periodically to ensure that the solvent does not fully evaporate. If the solvent runs low, obtain more from your instructor.
9. After 45 minutes, record and draw your results.

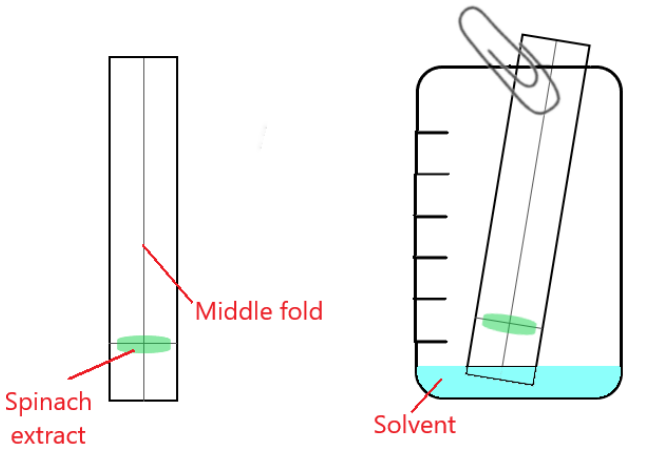


Table 6.1 Paper Chromatography Results

Pigment(s) Present (include color)	
Drawing of Chromatography Paper	

How do your results compare to your hypothesis?

Were there any pigments present that surprised you?

In the fall, leaves lose their green color and instead appear in shades of yellow, orange, and red. Based on your knowledge of plant pigments, which pigments disappeared from the leaves? Which ones are likely still present?

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NAME:_____ LAB SECTION:_____

Putting Genes to Work

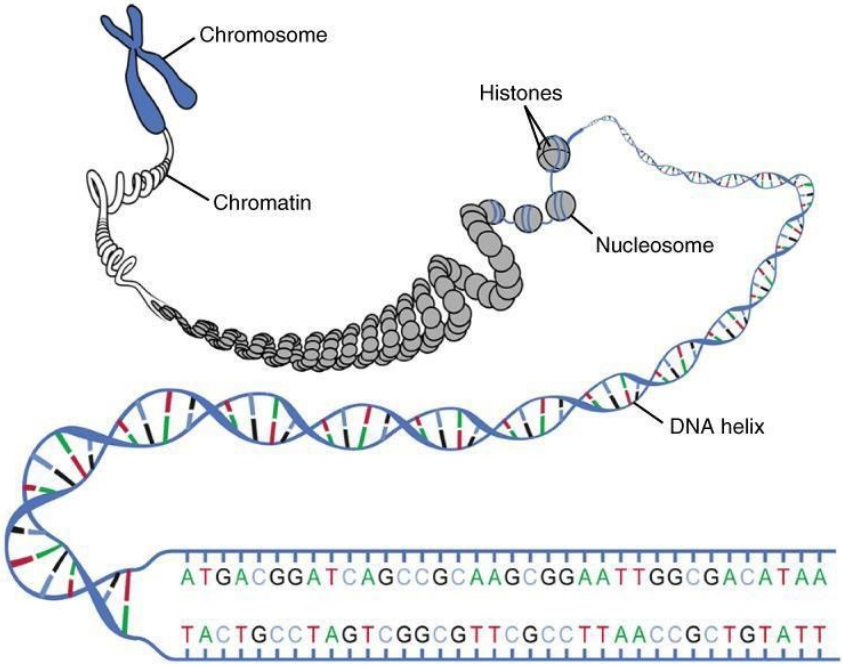
DNA and How Proteins are Made

Introduction

Learning Objectives:

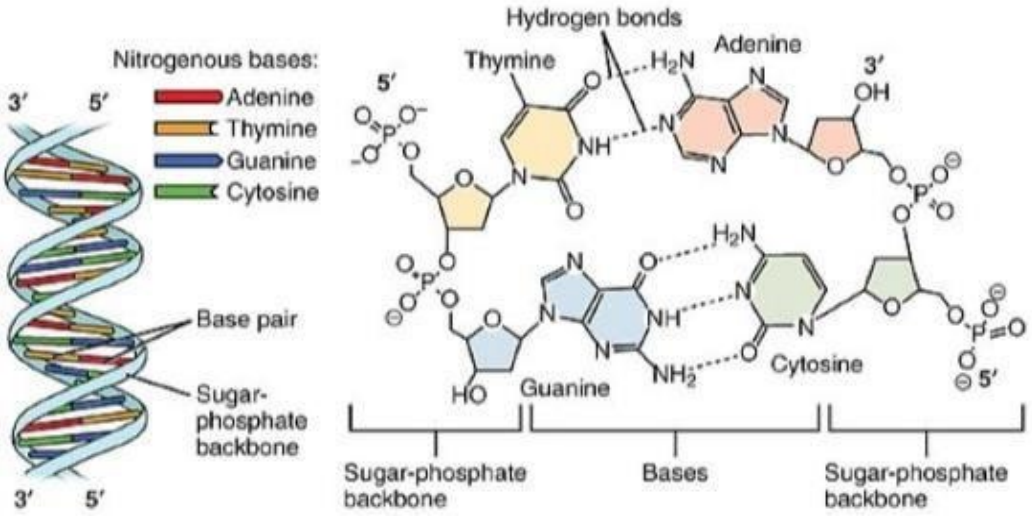
- Identify the structures of DNA and RNA
- Compare and contrast DNA and RNA
- Describe the processes of transcription and translation

Our cells are constantly doing work, day and night. All of this work is spearheaded by one molecule -- *Deoxyribonucleic Acid* (or *DNA* for short.) DNA is a massive molecule consisting of repeating nucleotides in a double helix shape. These repeating nucleotides can have one of four different bases: adenine, thymine, cytosine, or guanine. It's the unique combination of these four bases that allows DNA to encode all of the information for the cell.



7.1 The Structures of DNA and RNA

DNA's double helix shape is in part due to it having two nucleotide chains running parallel to each other, forming a ladder-like shape. The phosphate and deoxyribose sugars link together to form what are called the "backbones", while the bases extend outward, forming the "rungs." The two bases forming the rungs are not random though. Each base has only one other base that it can bond with: adenine and thymine always pair together while cytosine and guanine only pair with each other. This is called *complementary base pairing*. This gives us a predictable pattern so that knowing the bases from one side of the DNA molecule means you can easily figure out the other side. A close up of DNA's structure can be seen below.



Let's practice these complementary base pair rules. Complete the table using the appropriate base letter.

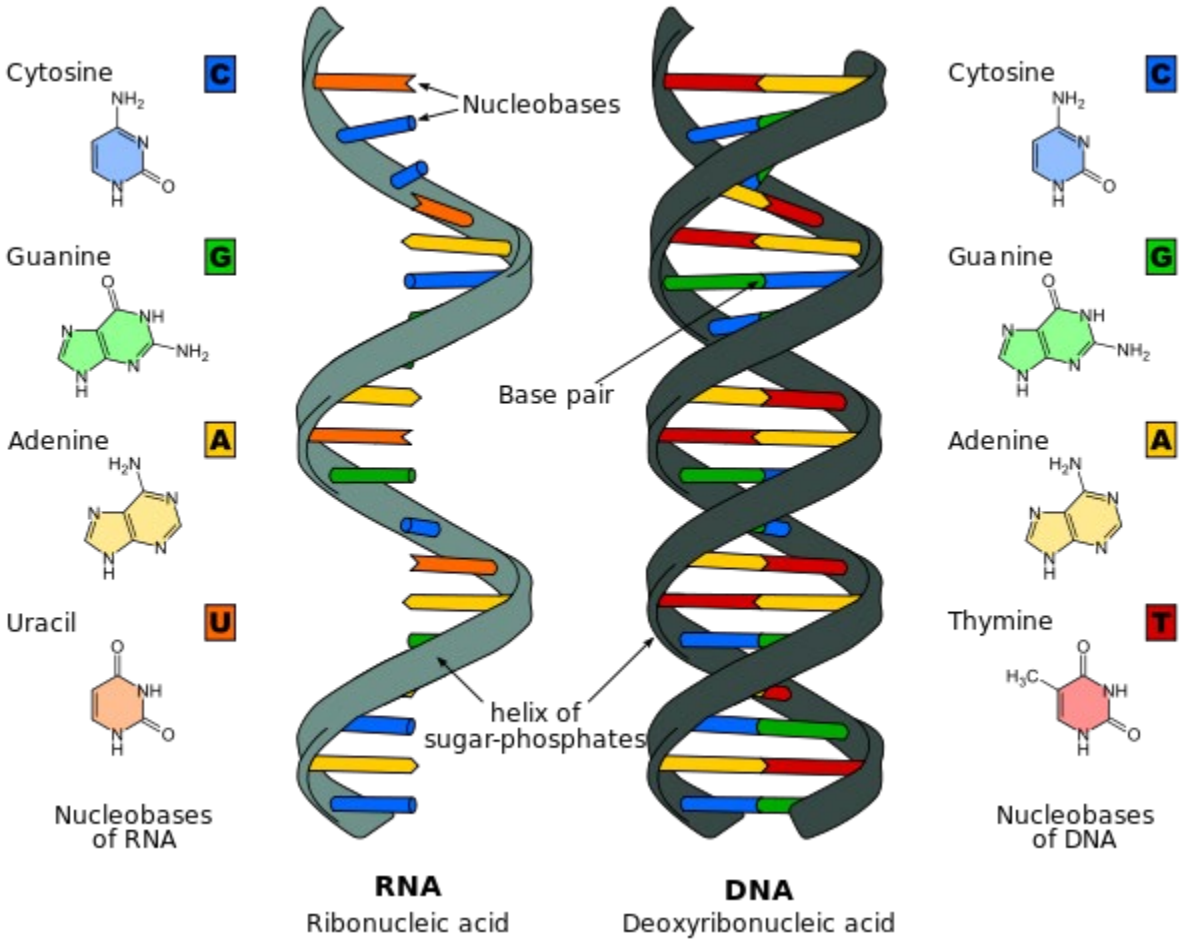
Table 7.1 Base Pairing Rules

STRAND #1	STRAND #2
	T
G	
A	
	G
T	
	C

DNA is not the only nucleotide important to the cell. *RNA* (ribonucleic acid) is also a necessary molecule, as it helps the cell read and use DNA's instructions. RNA has a similar structure with a few key differences: it is single stranded and DNA's thymine has been replaced with uracil. So, the base pair rules in RNA are A with U and C with G. There are three different types of RNA that we will look at in this class: rRNA, mRNA, and tRNA. Each RNA type can be seen in the table below. RNA compared to DNA is seen in the image below.

Table 7.2 Types of RNA

Type of RNA	Full RNA Name	Function
rRNA	Ribosomal RNA	Forms part of the ribosome
mRNA	Messenger RNA	Carries instructions from nucleus to ribosome
tRNA	Transfer RNA	Transfers amino acids in translation



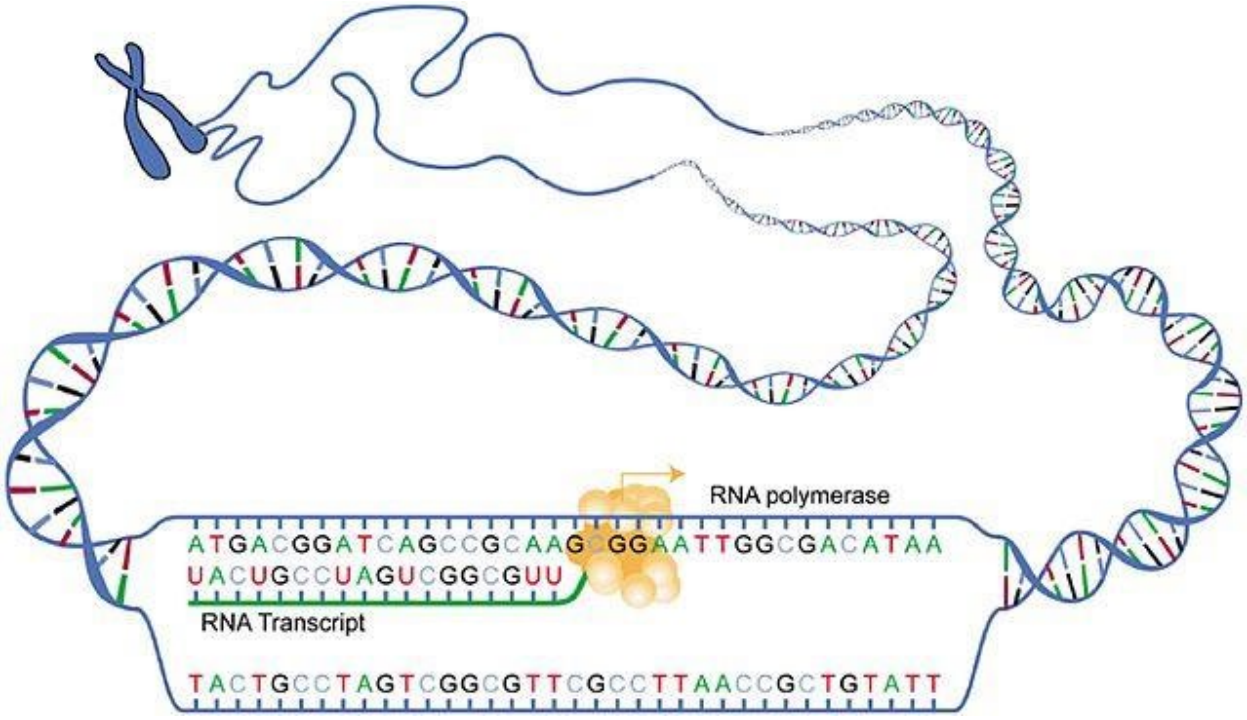
File:Difference DNA RNA-DE.svg: Sponk / *translation: Sponk, CC BY-SA 3.0, via Wikimedia Commons

7.2 Transcription and Translation

Transcription and translation put DNA to work. DNA contains many smaller segments called *genes* -- sections of DNA that code for a protein. These genes cannot directly produce these proteins however, and so the cell must create temporary copies of these segments to use elsewhere in the cell.

To *transcribe* quite literally means “to put into written or printed form.” This is a very close description as to what is happening in the cell. Since the DNA cannot directly make proteins, mechanisms are in place to read and transcribe DNA’s genes. Instead, mRNA is made by *RNA polymerase*, which reads the opened DNA strand. When RNA polymerase reads the DNA, it uses the complementary base pair rules to select the correct base for mRNA it’s building. Then, the mRNA molecule is released and leaves the nucleus.

RNA polymerase needs direction on where and when to start the transcription process. Since the cells do not need to use every gene all the time, it’s important that there is a way to regulate when genes are used. The *promoter* is a special section of DNA that comes before the gene and helps dictate if a gene should be used often, sometimes, or hardly ever.



OpenStax, CC BY 4.0, via Wikimedia Commons

Table 7.3 Transcription Roles

	Role in Transcription
Promoter	Regulates when a gene will go through transcription
RNA polymerase	“Reads” DNA and builds the mRNA strand
mRNA	Carries the information from the transcribed gene
DNA	Encodes information in the form of genes to be read and used

Translation puts the mRNA produced during transcription to work. The mRNA molecule leaves the nucleus and enters into the cytoplasm. We can describe translation in three steps.

Initiation: Once in the cytoplasm, a ribosome will grab onto the mRNA.

Elongation: The ribosome reads mRNA three bases at a time. These three bases are called a *codon* and dictate which amino acid is next in the sequence. This codon binds with the *anticodon* of tRNA in the ribosome, which brings the appropriate amino acid.

Termination: When a STOP codon is reached, it causes the ribosome to let go of the mRNA molecule and protein strand.

Now we will take RNA strands and translate it into a sentence. For this activity, transcribe the DNA strands below and identify the codons in the message. Then, look around the room for cards showcasing each codon (we will avoid using anticodons for simplicity.) The opposite side of the card will have a word that you will write down below. After you find all the anticodons, you should have a complete sentence for your answer.

1. DNA: T T T A G C C T A G C T A A A T T T C A G T G C

   mRNA:

   Protein:

2. DNA: T T T T G A G G C G C T G T G T T T G T C

   mRNA:

   Protein:

3. DNA: T T T C A G T T C C A A A A A T T T A G C C T T

   mRNA:

   Protein:

4. DNA: T T T G G T A A T G G G G T A C A G T T G

   mRNA:

   Protein:

5. DNA: T T T T T A A A G G G A G C T T G G G A G T T T T G C

   mRNA:

   Protein:

6. DNA: T A A G A T G T A A G C A A C C C T

   mRNA:

   Protein:

7. DNA: T A A A G G C C G A A C G T T

   mRNA:

   Protein:

8. DNA: C A G G A A T G T T A G C C A T C T

   mRNA:

   Protein:

9. DNA: T A A A G G A C C T C G

   mRNA:

   Protein:

10. DNA: T T T T G A G G C G C T C G C T T T C A G C G A

    mRNA:

    Protein:

11. DNA: T A A A G G A C C A A G T C C C G T

    mRNA:

    Protein:

12. DNA: T A A C G G G T A G G T A A T

    mRNA:

    Protein:

13. DNA: T T T A G C C T A T A T T T T T G A C T A

    mRNA:

    Protein:

14. DNA: T T T A A C A A T T A C T C A T T T T G C

    mRNA:

    Protein:

7.3 DNA Extraction

DNA may be stored away inside the nucleus of every cell, but that does not mean that it is inaccessible. We can access the DNA as long as we can get past the plasma membrane. Remember that the membrane is lipid-based, so chemicals that break down lipids are the best bet to releasing the DNA. For this exercise, we will extract DNA from wheat germ, although any living thing can be used, such as strawberries or your own saliva. In fact, this experiment can be replicated in your own kitchen!

What do you think DNA will look like when extracted?

Materials:

- 1 test tube
- 1 g wheat germ
- 1 dropper bottle of saline
- 1 dropper bottle of dish soap
- 1 stirring rod
- Ethanol, ice cold

Procedure:

1. Obtain a clean test tube.
2. Add 1 g of wheat germ to the tube.
3. Add enough saline to fully saturate and cover the wheat germ.
4. Add 3-5 drops of dish soap.
5. Slowly stir the contents of the tube with the stirring rod, carefully avoiding making bubbles, for at least 5 minutes.
6. Add 1 mL of ice-cold ethanol to the tube by tilting the tube at a 45° angle and slowly dripping the ethanol down the side of the tube. This will create a layer of ethanol floating over the top of your wheat germ slurry.
7. Set the tube aside for 3-5 minutes. The DNA will precipitate up into the ethanol.

Clean-up:

1. Dump the wheat germ solids in the trash.
2. Wash the tube in the sink and return to the test tube rack

When the DNA precipitated into the ethanol, how did it look?

Why do you think dish soap was added to extract the DNA? *Hint: Consider what cell structure serves as a barrier.*

Consider the fact that the procedure called for the ethanol to be poured so that it floated over the top of the wheat germ slurry. How do you think DNA's visibility would change if the ethanol mixed with the slurry?

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NAME:_____ LAB SECTION:_____

From One Cell Comes Many

Mitosis and Meiosis

Introduction

Learning Objectives:

- Describe the phases of the cell cycle
- Identify and explain each of the four phases of mitosis
- Describe the phases of meiosis and how it contributes to genetic diversity

Early in the semester we learned about cell theory. One of the components of cell theory is that cells must come from other cells. How does that happen though? There are actually several ways to replicate cells. Which process a cell uses depends on what type of organism the cell is and the reason why the cell is replicating.

One such method is *binary fission* -- a replication process used by simple organisms such as bacteria and archaea. In binary fission, the bacterium's single circular chromosome is replicated with each copy moving to opposite sides of the cell. Then proteins begin pinching the cell in the middle, a septum forms, and the cell splits into two. This process is both simple and fast, meaning bacteria can replicate very quickly.

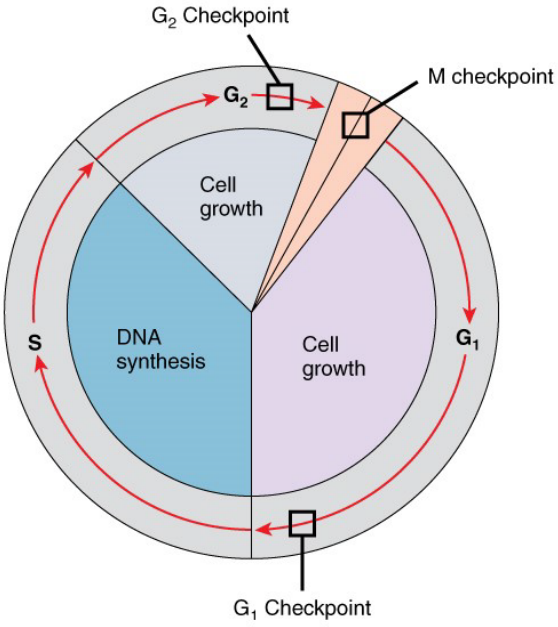
Another method is *mitosis*. This process is used by the more complex eukaryotic cells. In multicellular organisms like ourselves, mitosis is used for growth and repair. Consider how big you were when you were born. Are you the same size? Hopefully, no. But rather than your cells getting larger, your body has simply made more cells to create the growth you've experienced over the years. You've also probably experienced a few injuries before. But if you get a cut, it heals. This healing you see is because the cells that were killed and damaged by whatever cut your skin were replaced. Nearby healthy cells used mitosis to replace them.

The last method is *meiosis*. Meiosis is a special form of replication in that the cells produced are not identical, nor do they even have the same number of chromosomes as the original cell! This is because meiosis is only used by special cells that produce *gametes* -- sperm and eggs. These gametes are then used for sexual reproduction.

8.1 The Cell Cycle

In eukaryotic organisms like plants and animals, cell replication is a tightly regulated cycle. Cells must receive various signals and meet certain criteria before being able to divide. These checks and balances ensure that the cell has enough building material, that the DNA replicates correctly, and that the chromosomes are aligned properly to divide. This helps ensure that the organism is keeping up with normal rates of cell death and not wasting resources. When this system fails, things like cancer can result.

The cell cycle can be broken down into two main parts: *interphase* and the *mitotic phase*. Let's look at interphase first. In interphase, there are three distinct phases: G_1, S, and G_2. In the G_1 phase, the cell is running its daily activities and is gathering needed materials for the next steps. Then the cell enters the S phase. S phase is unique in that this is when a cell replicates its entire *genome* (the complete set of DNA) of the cell. After all of the DNA has been replicated, the cell then enters the G_2 phase. In the G_2 phase, the cell makes final preparations to divide.



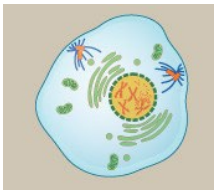
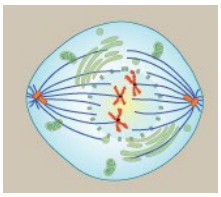
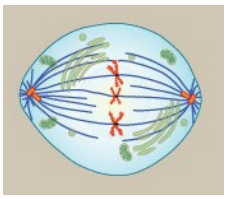
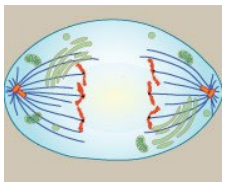
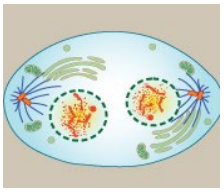
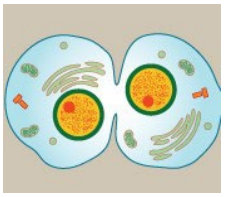
Modified by Karen Marks, from OpenStax, CC BY 4.0, via Wikimedia Commons

Looking at the figure above, do you think a cell spends more time in interphase or mitotic phase?

8.2 Mitosis in Plant and Animal Cells

Mitosis has five phases: *prophase*, *prometaphase*, *metaphase*, *anaphase*, and *telophase*. Once the cell has completed these phases, it will split in two via *cytokinesis*.

Table 8.1 Phases of Mitosis

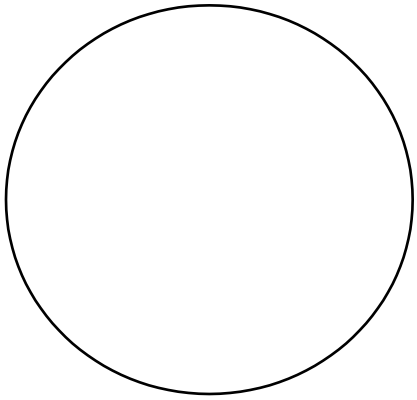
PHASE	DESCRIPTION	APPEARANCE
Prophase	• Chromosomes condense and become visible • Nuclear envelope disappears • Centrosomes move to opposite sides (poles)	
Prometaphase	• Kinetochores (attachment points) appear on chromosomes • Spindle fibers form and attach to chromosomes	
Metaphase	• Chromosomes line up at equator • Spindle fibers attach sister chromatids to opposite poles	
Anaphase	• Sister chromatids are pulled apart and towards opposite poles • The cell begins to elongate	
Telophase	• Chromosomes are on opposite poles • Nuclear envelope reforms around chromosomes • Spindle fibers break down	
Cytokinesis	• The cell splits into two • Forms a cleavage furrow (animals) or cell plate (plants)	

Modified by Karen Marks from OpenStax, CC BY 4.0, via Wikimedia Commons

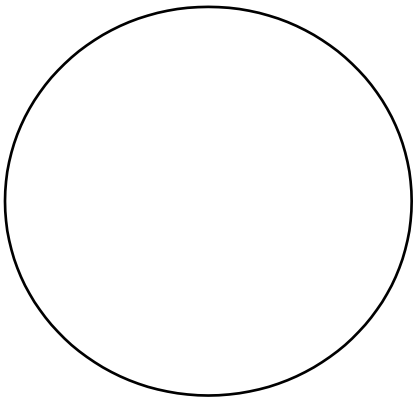
Now that we are familiar with the many phases of mitosis, let's identify them under the microscope. For this activity you will need your microscope, as well as a prepared fish blastula slide and an onion root tip slide. Find an example of each phase and then draw it in the provided space.

Fish Blastula

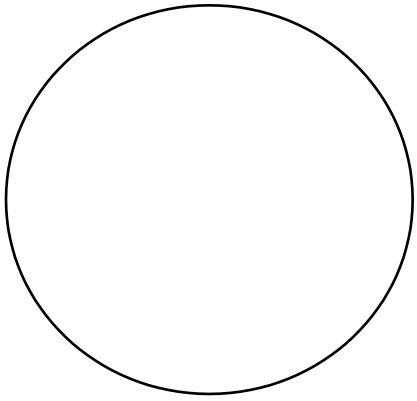
Prophase/Prometaphase



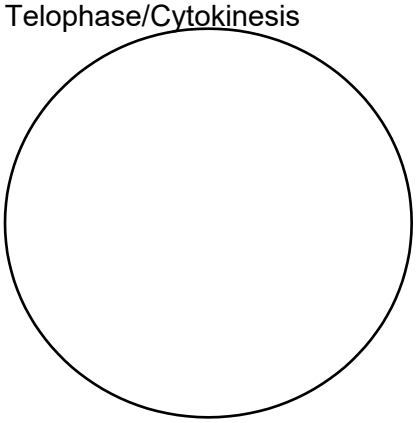
Anaphase



Metaphase



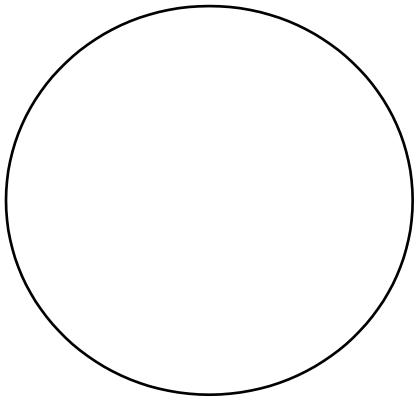
Telophase/Cytokinesis



Which phase was the easiest for you to find? Which was the hardest?

Onion Root Tip

Prophase/Prometaphase



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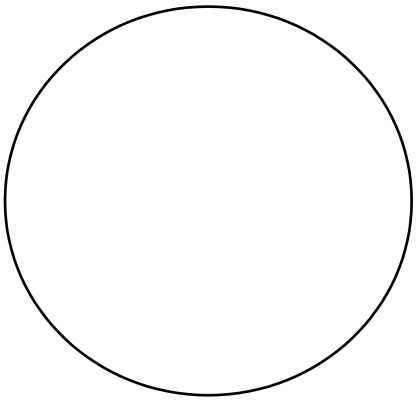
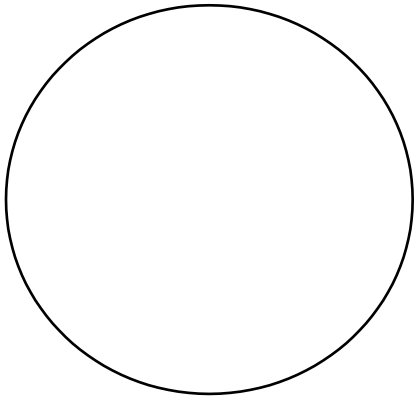
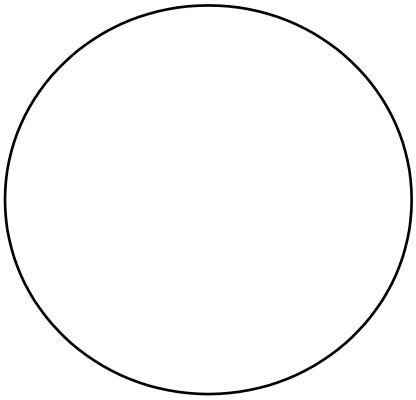


Metaphase



Telophase/Cytokinesis



Now that you've looked at large groups of cells on slides, do you think a cell spends more time in interphase or mitotic phase? Why?

8.3 Modeling Mitosis

Now that we've studied cells at the various stages of mitosis, it's your group's turn to model mitosis in the lab. For this exercise, your group will use chalk to draw each phase

of mitosis on the lab bench and then explain what happens during each phase to your instructor. In your explanations, you must follow these “rules”:

1. Everyone in the group must participate
2. You must use the proper terminology to explain something
3. You cannot read steps directly from a book or other resource
4. Be prepared *before* calling the instructor over

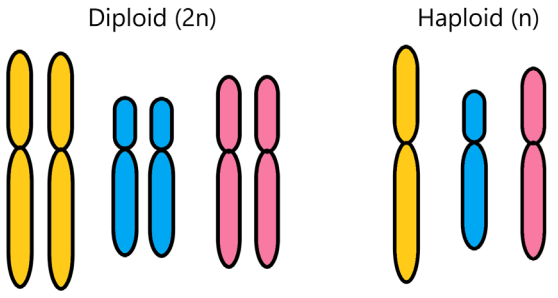
Group Members:

Verified complete:_____
(Instructor signature)

8.4 Meiosis

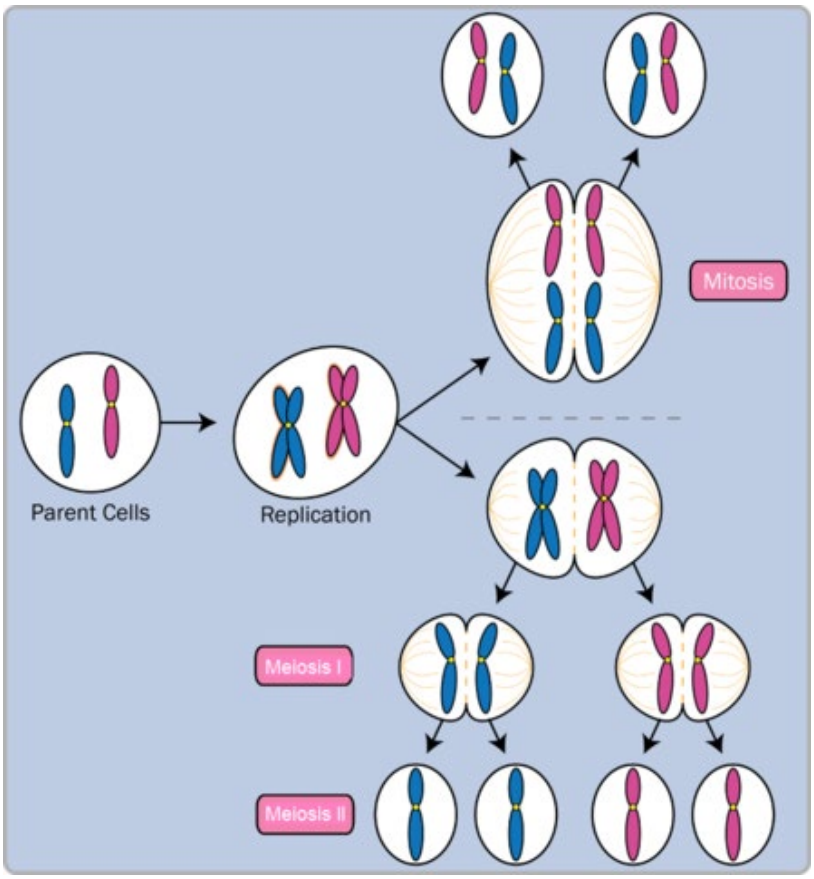
In meiosis, the goal is to create special reproductive cells called gametes. A gamete’s job is to fuse with another gamete in order to produce offspring. Since two gametes must come together, it is important that the number of chromosomes be reduced.

In a human cell, there are normally two sets of 23 chromosomes (46 total), with one set coming from the maternal side and the other set coming from the paternal side. When a cell uses mitosis, every chromosome is replicated and placed in a daughter cell. This means that the parent cell and daughter cells are all *diploid*, because they all have two sets of chromosomes. However, in meiosis, we must reduce from two sets to just one. This reduces the parent cell from diploid to *haploid* (one set) in the daughter cells.



To reduce the number of chromosomes, meiosis uses two divisions instead of one. The first division (called meiosis I) is responsible for dividing the *homologous pairs*. Homologous pairs are chromosomes that are the same size, have the same type of

genetic information, and have the same banding patterns. Each pair consists of one maternal and one paternal chromosome. The second division (called meiosis II) will then divide the replicated chromosomes.



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8.5 Modeling Crossing Over and Independent Assortment

One of the important features of sexual reproduction is the increase in *genetic diversity*. Genetic diversity means that the population has variety in the genome so that each individual is different from each other. There are several ways of increasing genetic diversity: crossing over, independent assortment, and sexual reproduction. We will take a closer look at crossing over and independent assortment.

Crossing Over:

In spaces provided, draw a pair of chromosomes undergoing crossing over. Make sure to color code the maternal and paternal chromosomes.

Independent Assortment:

For this activity, you and your partner will use popsicle sticks to simulate independent assortment.

Procedure:

1. Put both chromosomes labeled 1 in the paper bag. Shake the bag and select one.
2. Repeat this process for chromosomes 2.
3. Repeat this process for chromosomes 3.
4. Repeat this process for chromosomes 4.
5. Draw your chromosomes that you pulled in the space below.

Independent Assortment Results

How did your results compare to your partner's?

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NAME:_____ LAB SECTION:_____

The Traits We Have

Genetics and Patterns of Inheritance

Introduction

Learning Objectives:

- Define allele, genotype, phenotype, homozygous, and heterozygous
- Use a Punnett square to determine genotypic and phenotypic ratios
- Explain incomplete dominance, multiple alleles, and codominance
- Analyze pedigrees to determine patterns of inheritance

At this point in the semester, we have learned about DNA and how cells replicate. Now, we are going to take a step back and look at another angle -- how we get the traits we see in ourselves and each other. Our traits are determined (at least in part) by our *genes*. Genes are segments of DNA that encode instructions. As we learned in Lab 7, these instructions tell the cell how to make a protein. These proteins then contribute to how we look, behave, and function. We also learned about our chromosomes in lecture and in Lab 8 and that we have two of each chromosome, meaning we have two copies of every gene.

So, for every gene we have two copies. These copies are called *alleles*, and they don't have to be identical to each other. Alleles code for the same type of trait but they don't need to code for the same version. So for example, two alleles can both be responsible for eye color, but one allele codes for brown eyes while the other allele codes for blue.

Not all alleles are created equal, in that some alleles are able to dominate over others. These more prominent alleles are called dominant and are written using capital letters while the masked alleles are called recessive and shown using lower case letters. There are also alleles that create a blended appearance (*incomplete dominance*) as well as others that both show equally (*codominance.*)

9.1 Understanding Genotype and Phenotype

The unique pair of alleles an individual has for a gene is called a *genotype*. Genotypes can be described as *homozygous* (same alleles) or *heterozygous* (different alleles). When a genotype is homozygous, we can then further describe it based on whether the alleles are both dominant or both recessive. The genotype then leads to the physical result -- the *phenotype*. The phenotype is described using qualitative terms -- brown hair, blue eyes, tall, freckles, etc.

Sometimes more than one genotype will lead to the same phenotype. This is the case when a dominant allele is present. Dominant alleles “mask” recessive alleles so the dominant phenotype is seen for both homozygous dominant and heterozygous genotypes. Recessive phenotypes only show when both alleles are recessive.

Let’s get some practice understanding the relationship between genotype and phenotype.

Identify the genotype using the terms homozygous dominant, heterozygous, or homozygous recessive.

1. Tt _____
2. AA _____
3. pp _____
4. qq _____
5. Gg _____
6. RR _____

Identify the phenotype for each genotype using the given information.

Freckles are dominant to no freckles.

FF _____

Ff _____

ff _____

Tall plants are dominant to short plants.

TT _____

Tt _____

tt _____

Brown hair is dominant to blond hair.

BB _____

Bb _____

bb _____

Round peas are dominant to wrinkled peas.

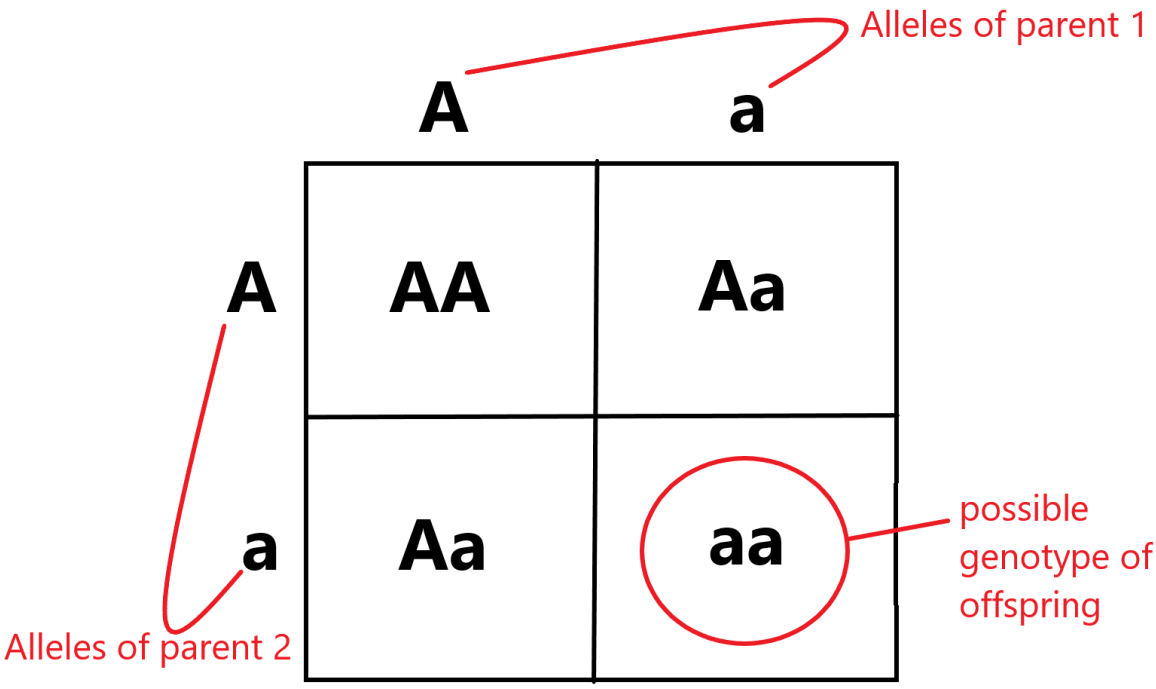
RR _____

Rr _____

rr _____

9.2 Using Punnett Squares

Now that we understand the relationship between genotype and phenotype, let's learn how we can use this information to make predictions. We can use the genotypes of the parents to predict their offspring's possible genotypes and phenotypes as well as their probabilities. The best way to chart these possible outcomes is to use the *Punnett square*.



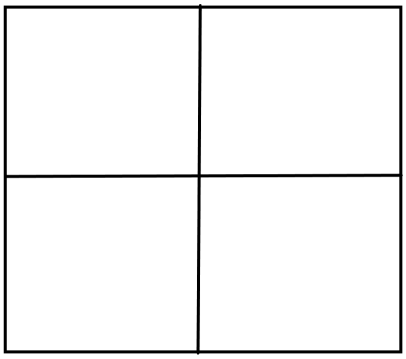
Punnett squares work by crossing the alleles of each parent to determine all of the possible genotypes for their offspring. We separate each parent's alleles to represent their possible gametes (sperm or egg) so that when we cross it with the other parent's gametes, each offspring receives one allele from each parent.

When we fill in the Punnett square, we can then determine the probability of each genotype and phenotype. Since a Punnett square has four outcomes, each outcome has a 1-in-4 chance of happening. However, this does not mean that if the parents have 4 offspring that each outcome will be represented. For this exercise, we will practice using Punnett squares to find genotypic and phenotypic frequencies. Then we will conduct an experiment to see how close real results come to expected outcomes.

Punnett Squares

Complete the following crosses using the provided space.

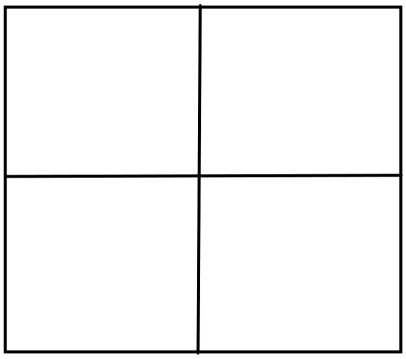
1. tt x tt



Genotypic Ratio: _____

Phenotypic Ratio :_____

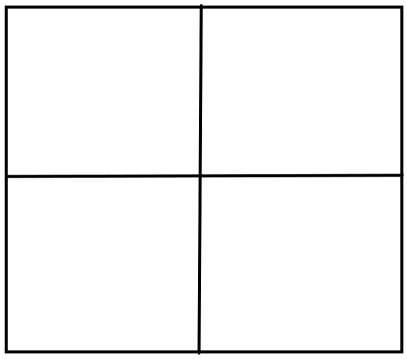
2. NN x nn



Genotypic Ratio: _____

Phenotypic Ratio :_____

3. Ee x ee



Genotypic Ratio: _____

Phenotypic Ratio :_____

Expected Outcomes versus Real Results

For this exercise, we will determine the expected outcomes for a specific cross and then test to see if the real results resemble these expected outcomes. Each parent will be represented by a coin. Since coins have a heads and tails side, this means both parents will be heterozygous, with heads being the dominant allele.

Using the information above, determine the genotype for each parent using the letter **R**.

Mother: **Father:**

What are the expected genotypic and phenotypic ratios for this cross?

Genotypic Ratio: _____ Phenotypic Ratio :_____

Now you will use the coins to determine real-world results. You will need two coins and a cup or small bag to complete this procedure.

Procedure:

1. Place the coins in the cup or bag and shake it briefly.
2. Pour the coins from the bag onto the table top and record the outcome below.
3. Repeat this for a total of 40 times.
4. Find the genotypic/phenotypic ratios by dividing the total by the lowest outcome.

Table 9.1 Real Results

Outcome	Tally	Genotypic Total	Genotypic Ratio	Phenotypic Total	Phenotypic Ratio
Heads/Heads					
Heads/Tails					
Tails/Tails					

How do your real genotypic and phenotypic ratios compare to the expected ones?

9.3 Codominance, Multiple Alleles, and Incomplete Dominance

In the previous exercises, we treated every trait the same -- that there were only two possible alleles for a trait, with one of those alleles being dominant and the other recessive. However, this is not always the case. Sometimes the heterozygotes show a third phenotype due to incomplete dominance or codominance and sometimes there are more than two alleles for a trait in a population.

Multiple Alleles and Codominance

Human blood types provide an excellent example of multiple alleles and codominance. In the human population, there are three possible alleles: I^A (type A), I^B (type B), and i (type O). I^A and I^B are both shown with capital letters because they are both dominant to i and the superscript A and B are used because I^A and I^B are codominant to each other. Since they are codominant, someone with the genotype I^AI^B would have type AB blood.

Using the information above, determine the blood type of each genotype below.

1. I^AI^A: _____
2. I^Bi: _____
3. I^AI^B: _____
4. ii: _____

Now let's apply this knowledge to the following scenario.

Julia grew up not knowing who her biological father is. Her mother, Mary, did not tell her before Mary passed away. Julia knows her own blood type, her mother's blood type, as well as the two possible fathers (Larry and David) and their blood types. The table below contains this information. You will then use this information to fill in the blanks of the table and ultimately help Julia figure out who her biological father is.

Table 9.2 Blood Type and Paternity

	Julia	**Mary**	**Larry**	**David**
Blood Type	Type O	Type O	Type AB	Type A
Possible Genotype(s)				
Are They the Father?				

Incomplete Dominance

Incomplete dominance occurs when neither allele can "mask" the other. Instead, the heterozygotes' alleles create a third phenotype that appears to be a blend of the two. So for example, if there is a straight hair allele and curly hair allele, then the heterozygote would have wavy hair as wavy hair would be "in between" straight and curly. Since neither allele is dominant, capital letters with superscripts are used to show each allele as seen in the table below.

Table 9.3 Incomplete Dominance Genotypes

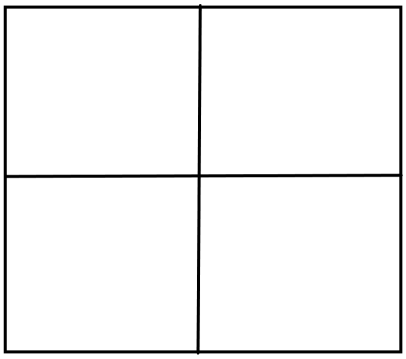
Homozygous (Straight)	**Heterozygous (Wavy)**	**Homozygous (Curly)**
H^SH^S	H^SH^C	H^CH^C

For this exercise on incomplete dominance, we will look at flower color. There are two alleles for flower color in this example: C^R, which encodes for red flowers, and C^W which encodes for white flowers. In the table below, fill in the blanks and then complete the Punnett squares for the given cross. Once you completed the Punnett squares, color in the squares with the correct phenotype/flower color.

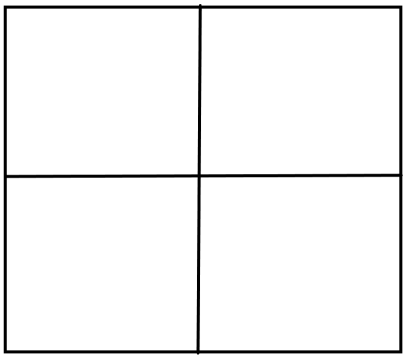
Table 9.4 Incomplete Dominance and Phenotype

Genotype	C^RC^R	C^RC^W	C^WC^W
Flower Color			

Cross: C^RC^R x C^WC^W



Cross: C^RC^W x C^RC^W



9.4 Gametes and Fertilization

Now that we've learned about genotypes, phenotypes, and various crosses, let's put this all together. We will be creating our own gametes, then combining them with a classmate's to see what the potential offspring would look like. Remember that some of these traits will use simple dominance, but some may demonstrate incomplete dominance.

In a designated place in the lab, there are bags of alleles for various physical traits. You will need to randomly grab TWO alleles for each trait. This determines your genotype, which you will record in the table below. Then, using the information written on the alleles and in the table, you will determine and record your phenotype as well.

Table 9.5 Your Alleles and Phenotype

Trait	Type	Your Allele 1	Your Allele 2	Your Phenotype
Hair Color	Incomplete Dominance			
Hair Texture	Incomplete Dominance			
Freckles	Simple Dominance			
Eye Color	Simple Dominance			
Eye Shape	Simple Dominance			
Nose Shape	Incomplete Dominance			
Face Shape	Incomplete Dominance			
Skin Color	Incomplete Dominance			
Cleft Chin	Simple Dominance			

Now you need to work with a partner. Record your partner's alleles and phenotype in the table below.

Table 9.6 Your Partner's Alleles and Phenotype

Trait	Type	Partner Allele 1	Partner Allele 2	Partner Phenotype
Hair Color	Incomplete Dominance			
Hair Texture	Incomplete Dominance			
Freckles	Simple Dominance			
Eye Color	Simple Dominance			
Eye Shape	Simple Dominance			
Nose Shape	Incomplete Dominance			
Face Shape	Incomplete Dominance			
Skin Color	Incomplete Dominance			
Cleft Chin	Simple Dominance			

Now that you have recorded this information, you and your partner will each need to create a gamete with your respective alleles. You can do so by having one person place their two alleles for the first trait in a paper bag, randomly removing one, and recording the allele in the table below. Each person should randomly select one allele per trait and record the allele in its appropriate box until the "Your Gamete" and "Partner Gamete" columns are filled in. Then, using the information on the allele sticks and information below, determine the offspring phenotype in the last column.

Table 9.7 Gametes and Offspring Phenotype

Trait	Type	Your Gamete Allele	Partner Gamete Allele	Resulting Offspring Phenotype
Hair Color	Incomplete Dominance			
Hair Texture	Incomplete Dominance			
Freckles	Simple Dominance			
Eye Color	Simple Dominance			
Eye Shape	Simple Dominance			
Nose Shape	Incomplete Dominance			
Face Shape	Incomplete Dominance			
Skin Color	Incomplete Dominance			
Cleft Chin	Simple Dominance			

Now, draw your, your partner's and the offspring's faces using the phenotypes.

Your Face (Table 9.5)	Partner's Face (Table 9.6)	Offspring's Face (Table 9.7)

What phenotypes do you share with the created offspring? Which phenotypes are different?

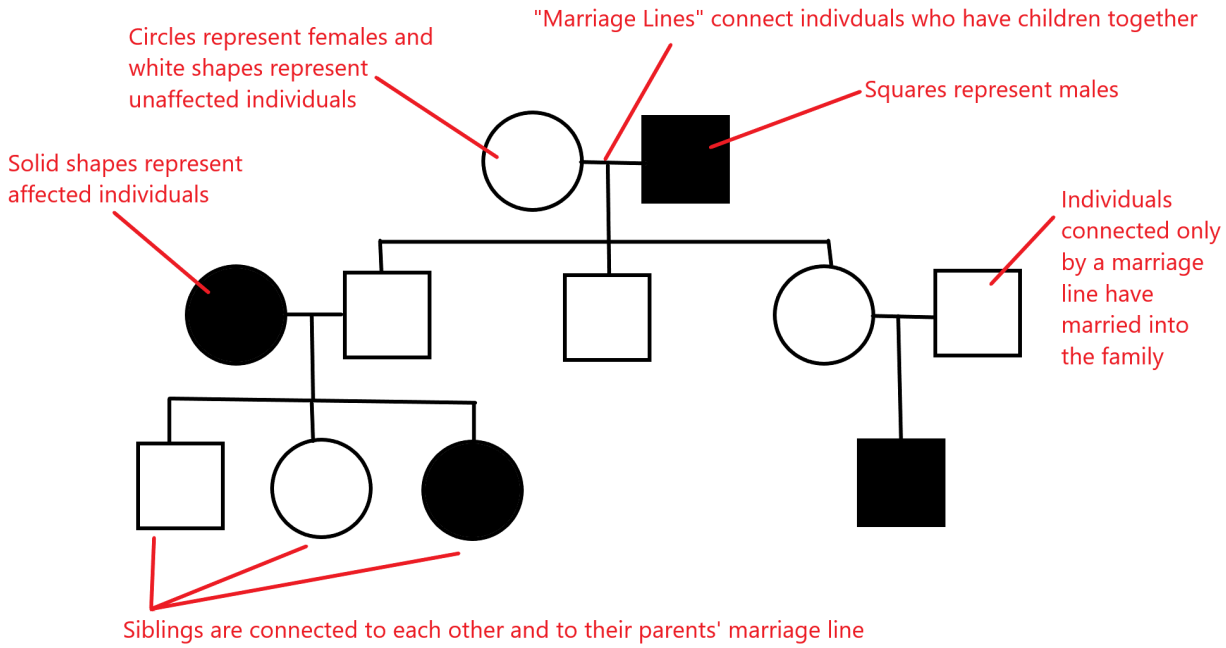
Did any similarities or differences surprise you? Why?

Did the offspring share more similarities with one “parent”? Why do you think that?

9.5 Using Pedigrees

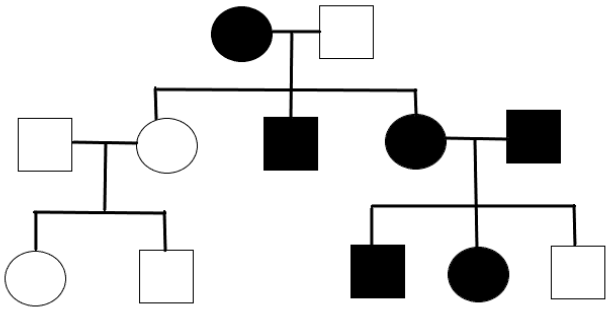
Pedigrees can be used to trace patterns of inheritance by looking at several generations of a family. They can be used to trace genetic diseases while giving family history and helping provide insight for future generations.

Many conditions are genetic but the pattern of inheritance may be different depending on which chromosome the gene is found on and whether or not the mutated allele is dominant or recessive. When a mutated allele is found on the autosomes, the condition affects males and females equally. But when the mutated allele is found on a sex chromosome (X or Y), then the condition tends to predominantly affect one sex (usually male).



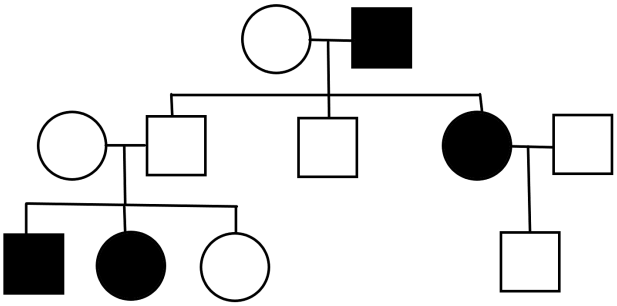
In the example pedigree seen above, we see that there are several affected individuals, as noted by the colored-in shapes. By analyzing the relationships and connections of affected individuals, we can determine if the pattern of inheritance is autosomal dominant, autosomal recessive, sex-linked dominant, or sex-linked recessive. In this particular example, the pattern of inheritance is autosomal recessive since males and females are equally affected and the affected male on the left has two healthy parents (the “skipped generation”.)

Now it’s your turn to practice determining patterns of inheritance using pedigrees.



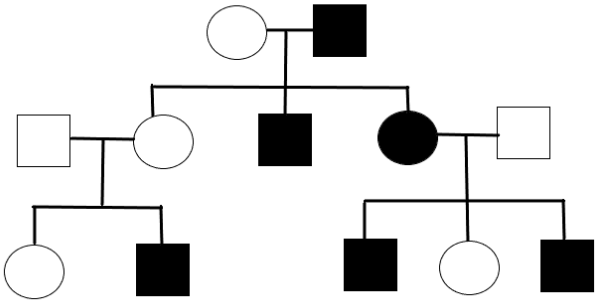
Is this autosomal or sex-linked?

Is this dominant or recessive?



Is this autosomal or sex-linked?

Is this dominant or recessive?



Is this autosomal or sex-linked?

Is this dominant or recessive?

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NAME:_____ LAB SECTION:_____

Sick of It

Epidemiology and Disease

Introduction

Learning Objectives:

- Define pathogen, infectious disease, and epidemiology
- Understand how diseases can spread in a population
- Describe what contact tracing is and why it is used
- Understand how vaccines can prevent the spread of disease
- Define herd immunity and describe how it protects populations at large

Mostly everyone remembers a time they felt ill. Whether it be a cold, the flu, or something else, people are vulnerable to infection from microorganisms like bacteria and viruses. These illness-causing microorganisms are called *pathogens* and the illnesses they cause are called *infectious diseases*.

Many pathogens can spread from one person to another, although they can vary in their methods of travel. Transmission can be *direct* or *indirect*. Direct transmission requires direct contact with the infected person, such as shaking hands, talking with an infected person, or sexual intercourse. Indirect transmission does not require this, as the infected person instead can contaminate a space via airborne particles or through infected surfaces such as a door handle.

Knowing how these diseases are spread is very useful when trying to avoid getting sick, but there are other things we can do to protect ourselves as well. This includes vaccinations and contact tracing, which we will discuss throughout this lab. When a population is aware of a pathogen and uses these tools to avoid getting and spreading illness, the health of the general public is protected better than if people are unaware and do not utilize these tools.

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Table 10.1 Types of Disease Transmission

Transmission Name	Definition
Airborne	Spread through very tiny particles in the air when a person coughs or sneezes, they can stay suspended in the air long after the ill person leaves.
Droplets	Spread through particles in the air when a person coughs or sneezes, but due to their size, they do not travel as far or stay suspended in the air as long.
Fecal-Oral	Microscopic amounts of feces from an infected person contaminate an uninfected person either directly (on the uninfected person's hands) or indirectly (via objects.)
Skin Contact	An infected person directly comes into contact with an uninfected person, such as through shaking hands, or indirectly by touching surfaces the contaminated person previously touched.
Bodily Fluids	Transmission requires bodily fluids of an infected person (such as saliva, breastmilk, blood, semen, or vaginal secretions) come into contact with an uninfected person. This can occur through kissing, breastfeeding, sexual contact, or needle sticks.

10.1 Spread of Disease in a Population without Vaccination

In today's world, we have the luxury of having *vaccines* against many diseases that previously would get many people sick and cause many long term health problems or even death. We don't see these diseases very often now because most people receive vaccines at a young age to protect us. Vaccines are injections that contain a weakened, dead, or piece of a pathogen intended to stimulate our immune system. Our immune

system then learns to recognize the pathogen to fight an infection later on. This provides us with *immunity* against that disease – long-term protection against that specific pathogen. The only other way to gain immunity is to become infected with that pathogen, which can have serious consequences. For this simulation, we will see how an infectious disease can spread when no one in a population has immunity.

First, develop a hypothesis about the spread of this infectious disease with a 0% vaccination rate.

Materials:

- Test tube, numbered
- Phenolphthalein

Procedure:

1. Pick up a test tube of sample liquid from your teacher. Note your test tube number:_____
2. Complete the first exchange when given the signal. Pour half the liquid from your test tube into a classmate's test tube; then pour the same amount, from the classmate's test tube, into your original test tube. Your test tube should now contain a mixture of the liquids from both test tubes. Record the other student's name and test tube number in Table 10.2.
3. Complete the second, third, and fourth exchanges when given the signal. For each exchange, record the student's name and test tube number in Table 10.2.
4. Wait for your teacher to add a diagnostic solution to your tube. Determine if you are infected as follows:

    - If the liquid turns pink, you are considered (+) positive for the virus (i.e., infected).

- If no color change is noted, you are considered (-) negative for the virus (i.e., not infected).

5. Ask your four exchange partners if they were positive or negative for the virus according to the diagnostic test results. Complete Table 10.2.
6. On the board, write your tube number, vaccination status, and results.
7. As a class, help identify the first two students infected. Hint: Start with those who are infected and work backward. For example, look at those who are infected and their first exchange partners. Figuring out when each person was infected will help eliminate individuals as the first infected. Include your contact tracing map in the space provided on the next page.

Table 10.2 Your Direct Contacts with 0% Vaccination Rate

Names	Tube Number	Infection Results
(Your Name)		
1st Partner		
2nd Partner		
3rd Partner		
4th Partner		

Table 10.3 Class Results for Infection

Infected Tube Numbers	Uninfected Tube Numbers

In the space below, create a contact tracing map, showing everyone's contacts and indicating who is positive and negative. You may work as a class on this section at your instructor's discretion.

10.2 Spread of Disease in a Population with a Low Vaccination Rate

Vaccines are one of the most successful public health tools in the modern era, and have saved millions of lives over the decades. Vaccines can protect an individual against severe illness and decrease the spread of an infectious disease in a population. While they are not perfect, research shows that vaccines are safe and effective tools against many diseases that used to cause widespread harm. That being said, to truly prevent widespread disease in a society, it requires most people to be vaccinated.

We will use the next exercises to see how vaccines and vaccination rates impact the spread of disease in a population, starting with a population with a low vaccination rate of 30%.

How do you think the spread of disease with a 30% vaccination rate will compare against the results from the 0% vaccination rate from the previous exercise?

Procedure:

1. Pick up a test tube of sample liquid from your teacher. Note your test tube number and vaccination status:_____

2. Complete the first exchange when given the signal. If you and the other person are both not vaccinated, pour half the liquid from your test tube into a classmate's test tube; then pour the same amount, from the classmate's test tube, into your original test tube. Your test tube should now contain a mixture of the liquids from both test tubes. If either person is vaccinated, do NOT exchange liquid and instead give a high five to each other. Record the other student's name and test tube number in Table 10.2.

3. Complete the second, third, and fourth exchanges following the rules above when given the signal. For each exchange, record the student's name and test tube number in Table 10.2.

4. Wait for your teacher to add a diagnostic solution to your tube. Determine if you are infected as follows:

    - If the liquid turns pink, you are considered (+) positive for the virus (i.e., infected).

    - If no color change is noted, you are considered (-) negative for the virus (i.e., not infected).

5. Ask your four exchange partners if they were positive or negative for the virus according to the diagnostic test results. Complete Table 10.2.

6. On the board, write your tube number, vaccination status, and results.

7. As a class, help identify the first two students infected. Hint: Start with those who are infected and work backward. For example, look at those who are infected and their first exchange partners. Figuring out when each person was infected will help eliminate individuals as the first infected. Include your contact tracing map in the space provided on the next page.

Table 10.2 Your Direct Contacts with 0% Vaccination Rate

Names	Tube Number	Vaccination Status	Infection Results
(Your Name)			
1st Partner			
2nd Partner			
3rd Partner			
4th Partner			

Table 10.3 Class Results for Infection

Infected Tube Numbers	Uninfected Tube Numbers

In the space below, create a contact tracing map, showing everyone's contacts and indicating who is positive and negative. You may work as a class on this section at your instructor's discretion.

10.3 Spread of Disease in a Population with a High Vaccination Rate

When most people in a population are vaccinated against a disease, we have reached *herd immunity*. Herd immunity is when so many people are vaccinated, that the disease has a very difficult time spreading, even among people who are vulnerable, such as the very young, the elderly, or people with weakened immune systems. The healthy, vaccinated people are able to protect these vulnerable populations because the rate of infection is so low.

Herd immunity is the hallmark accomplishment of the modern vaccine and is why there is so much focus on not just vaccinating individuals, but on vaccinating large populations in masse. For this last exercise, we will see how a high vaccination rate of 70% impacts the spread of disease.

How do you think the spread of disease with a 70% vaccination rate will compare against the results from the previous two exercises?

Procedure:

1. Pick up a test tube of sample liquid from your teacher. Note your test tube number and vaccination status:_____
2. Complete the first exchange when given the signal. If you and the other person are both not vaccinated, pour half the liquid from your test tube into a classmate's test tube; then pour the same amount, from the classmate's test tube, into your original test tube. Your test tube should now contain a mixture of the liquids from both test tubes. If either person is vaccinated, do NOT exchange liquid and instead give a high five to each other. Record the other student's name and test tube number in Table 10.2.
3. Complete the second, third, and fourth exchanges following the rules above when given the signal. For each exchange, record the student's name and test tube number in Table 10.2.

4. Wait for your teacher to add a diagnostic solution to your tube. Determine if you are infected as follows:

    - If the liquid turns pink, you are considered (+) positive for the virus (i.e., infected).

    - If no color change is noted, you are considered (-) negative for the virus (i.e., not infected).

5. Ask your four exchange partners if they were positive or negative for the virus according to the diagnostic test results. Complete Table 10.2.

6. On the board, write your tube number, vaccination status, and results.

7. As a class, help identify the first two students infected. Hint: Start with those who are infected and work backward. For example, look at those who are infected and their first exchange partners. Figuring out when each person was infected will help eliminate individuals as the first infected. Include your contact tracing map in the space provided on the next page.

Table 10.2 Your Direct Contacts with 0% Vaccination Rate

Names	Tube Number	Vaccination Status	Infection Results
(Your Name)			
1st Partner			
2nd Partner			
3rd Partner			
4th Partner			

Table 10.3 Class Results for Infection

Infected Tube Numbers	Uninfected Tube Numbers

In the space below, create a contact tracing map, showing everyone's contacts and indicating who is positive and negative. You may work as a class on this section at your instructor's discretion.

How did your results compare between the 0%, 30%, and 70% vaccination rate results?

Of these three results, which vaccination rate made it easiest to determine who was the index case?

What can you conclude about vaccines with these results?

Procedures modified by Karen Marks, based on Centers for Disease Control and Prevention (CDC). Science Ambassador Workshop—Spreading Sickness in Middle School. Atlanta, GA: U.S. Department of Health and Human Services, CDC; 2015. Available at http://www.cdc.gov/scienceambassador/lesson-plans/index.html

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NAME:_____ LAB SECTION:_____

Living Things Change

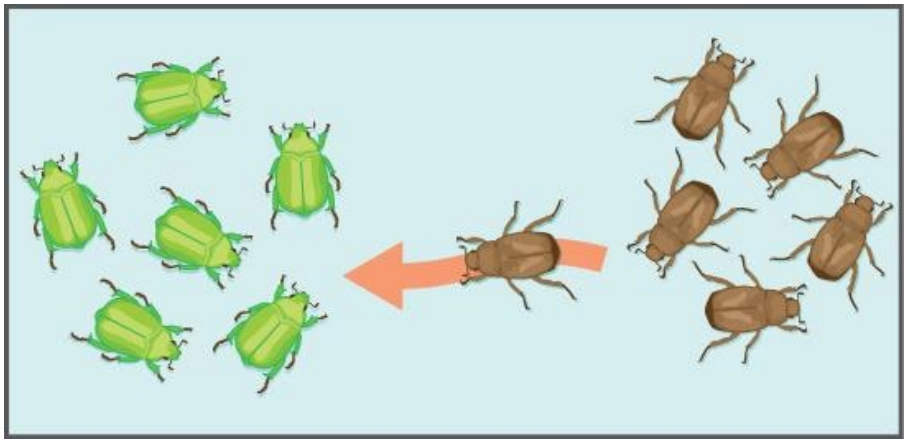
Mechanisms of Evolution

Introduction

Learning Objectives:

- Define evolution, microevolution, and macroevolution
- Model natural selection as a mechanism of evolution
- Model the bottleneck effect as a mechanism of evolution

When looking at the great diversity of life, there are clear differences between many species. Some organisms are photosynthetic, others have scales, some are capable of flying. Although these differences seem great, they are ultimately due to smaller, less noticeable changes that accumulate over time. This change over time is called *evolution*. There are several mechanisms that can lead to change, such as *natural selection*, *genetic drift*, and *gene flow*. Natural selection is a process where change is driven by selective pressures from the environment, genetic drift is a change in a population's allele frequency, and gene flow is the movement of alleles in or out of a population as seen in the image below. However, the ultimate driver of all change is *mutation* (random genetic changes), as all other mechanisms of change rely on having a varied genetic pool to work. For this lab we will model two of these mechanisms of evolution -- natural selection and the bottleneck effect.

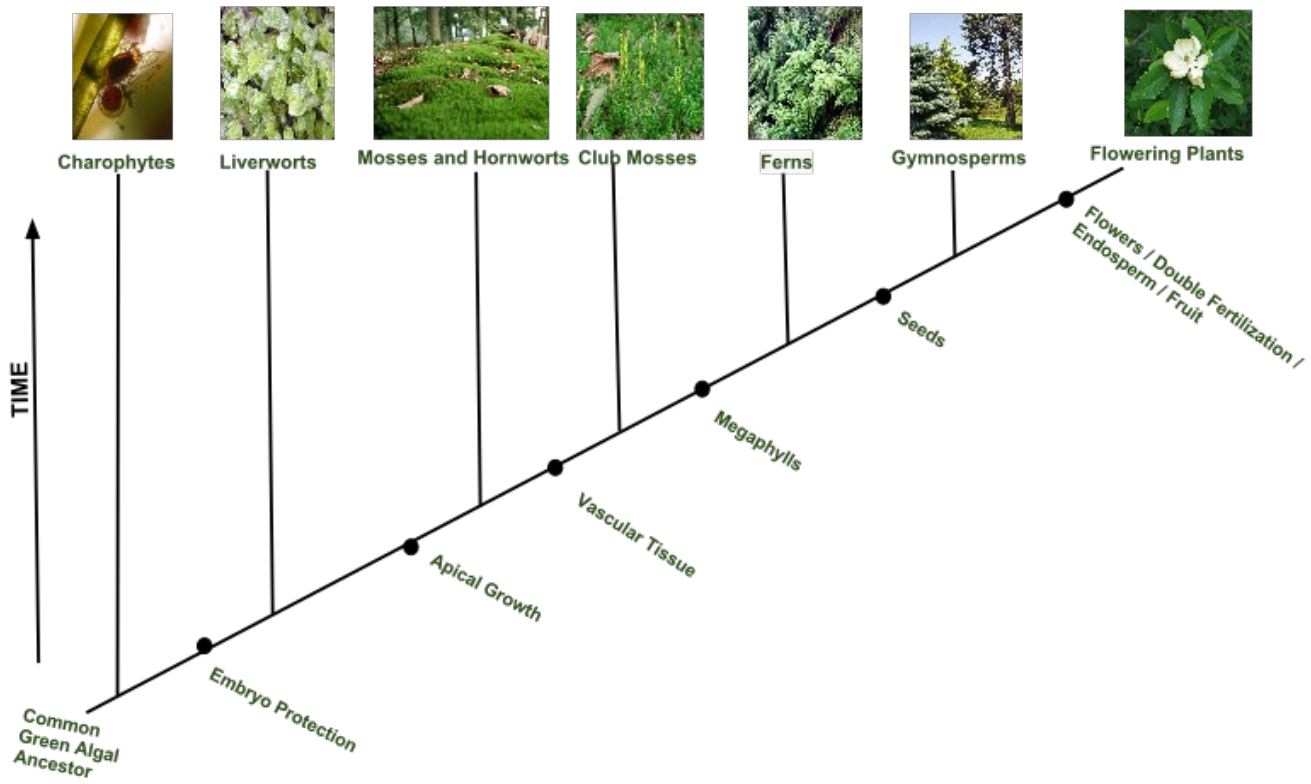


"Gene Flow" by OpenStax, Rice University, CC BY 4.0, via Wikimedia Commons

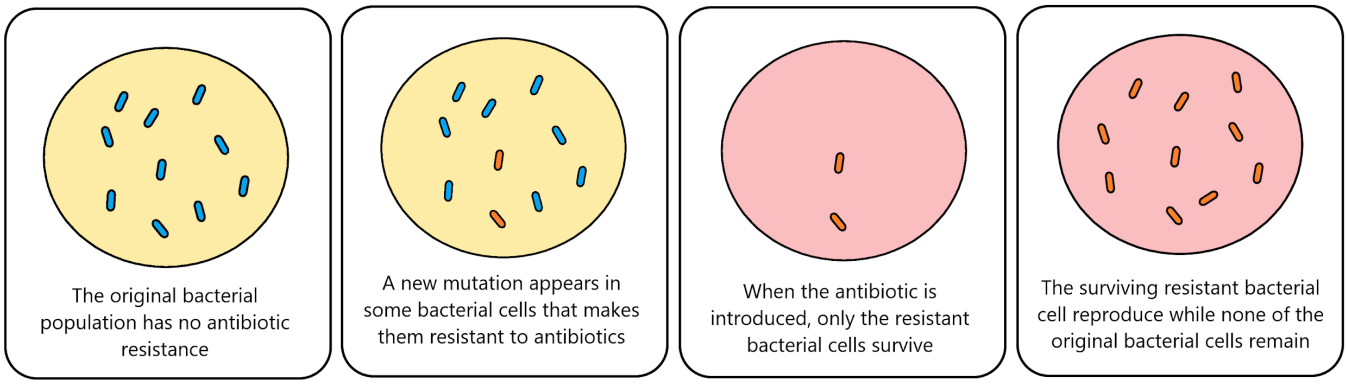
11.1 Evolution on the Large and Small Scale

When most people think of evolution, they often think of large, obvious changes such as the differences between a mouse and an elephant. The divergence seen between such drastically different organisms is due to *macroevolution* -- larger changes that have occurred over millennia. However, evolution does not always lead to such obvious differences. Evolution can also occur on a smaller scale. This smaller scale is called *microevolution* -- smaller changes that occur within a species over a few generations.

Macroevolution is seen when two species diverge, such as the divergence seen in early hominins and other primates. The image below demonstrates how macroevolution led to the *speciation* (development of new species) of the many plants we see today. The flowering plants seen on the right are more closely related to the gymnosperms and more distantly related to the mosses, liverworts, and charophytes.



Microevolution is seen when a population changes, such as a change in beak size in finches due to changes in food source. The population is still considered part of the same taxonomic group, but has accumulated some differences when compared to previous generations. The image below demonstrates the development of antibiotic resistance -- an example of microevolution that is impacting our ability to fight bacterial infections in modern medicine.



11.2 Modeling Natural Selection

Natural selection is a process where populations change in response to the environment. In order for natural selection to occur, a few points must be met first:

1. There must be variation in the population.
2. Traits must be inherited from one generation to the next.
3. Resources must be limited, leading to competition.

Virtually all natural populations meet these three criteria. A population will have individuals who may appear and behave slightly different and many of these differences are passed down genetically. Additionally, resources such as food and shelter are found in limited quantities so individuals need to compete for them. Because of the variation in traits, some individuals will thrive due to being better adapted to the environment while others will struggle. However, the traits that are considered good adaptations are highly dependent on the environment. A trait that is good for one environment may be weak in another.

For this exercise, we will analyze natural selection's influence on dot color in different environments.

Materials:

- 2 fabric backgrounds (you may need to trade with another group for the second)
- 10 paper dots in 10 different colors (100 total)
- Hole punch

Procedure:

1. Assign one person to moderate the activity and 2-3 people to be the “predators”.
2. Place the fabric background facing up on the table.
3. Randomly place 10 dots of each color on the background while the “predators” face away.
4. Have a predator turn around and grab 1 dot at a time, turning around between each pick, until 75 dots have been removed from the background. (You can save these dots to reuse later if needed.)
5. Note what color dots remain in the table below.
6. Replenish the dot population back to 100 total by adding 3 dots in the same color ratios. (So if your remaining dots are 10 red, 12 orange and 3 yellow, add an additional 30 red, 36 orange, and 9 yellow to this existing group.)
7. Repeat steps 4-6.

Hypothesis: What do you think will happen to the dot population in this background?

Color(s) you think will do well

Color(s) you think will do poorly

Color(s) you think may go extinct

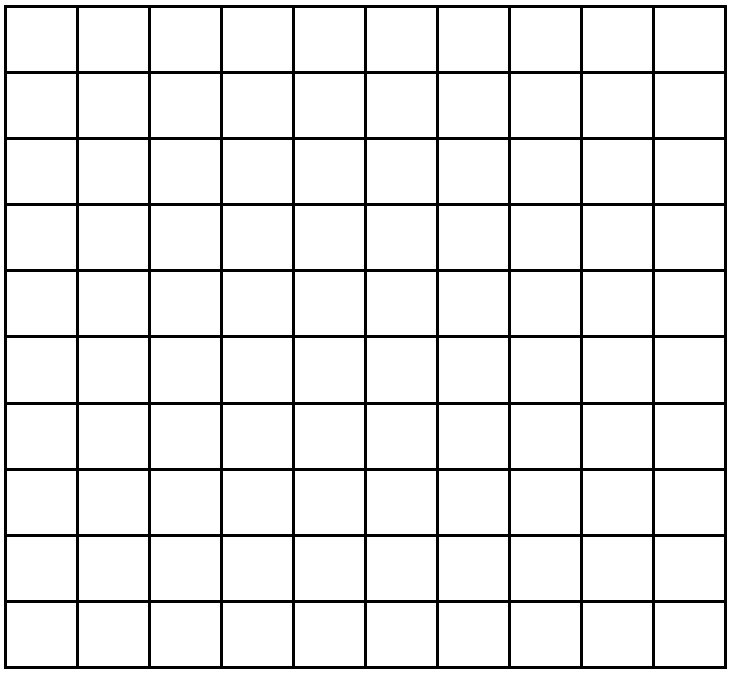
Table 11.1 Dot Survivors on First Background

Dot Color	Round 1	Round 2

Graph your final results using your data from Table 11.1. Make sure to label each axis.

Graph 11.1

Title:_____



Then, using **only** your survivors to bring the population back to 100, change the background to a new background. What do you think will happen to the dot population when a different background is showing?

Color(s) you think will do well

Color(s) you think will do poorly

Color(s) you think may go extinct

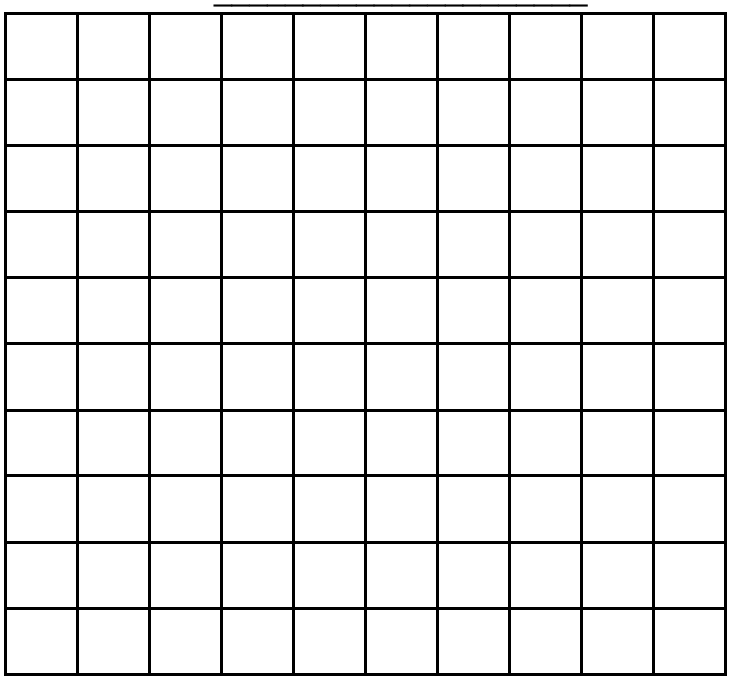
Table 11.2 Dot Survivors on Second Background

Dot Color	Round 1	Round 2

Graph your final results using your data from Table 11.2. Make sure to label each axis.

Graph 11.2

Title:_____

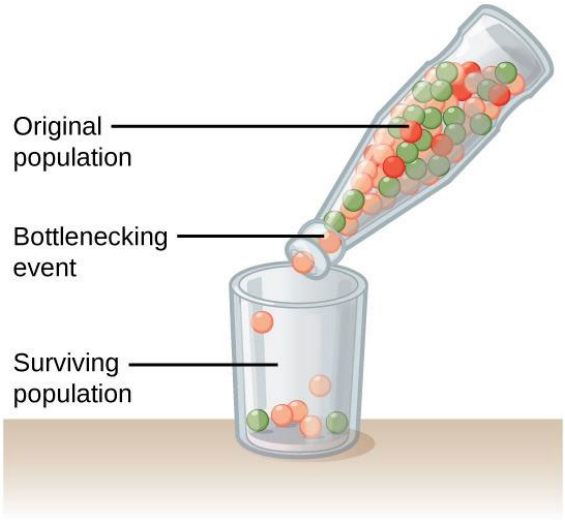


How did your results from the first background (Table 11.1, Graph 11.1) compare to your results from the second background (Table 11.2, Graph 11.2)?

Why did we not “revive” any dots that went extinct on the first background when we switched to the second?

11.3 Modeling the Bottleneck Effect

Not all change is due to environmental pressures. Sometimes random events can cause major changes to a population as well. Catastrophic events such as fires or floods can wipe out many individuals selected at random. This is called the *bottleneck effect*. Since who survives the event is random, the frequency of certain traits in the population can look very different after such an event occurs. In most cases, genetic diversity is lost, as the more common traits will survive (albeit maybe in different ratios) and the more rare traits lost entirely.



For this exercise we will model the bottleneck effect using popsicle sticks. Each popsicle stick will represent an individual and each color represents a different phenotype. Some of these phenotypes will be more common with others being more rare. A paper bag will be used to simulate the randomness of survival after a catastrophic event.

Hypothesis: Looking at the “materials” list, which color(s) do you think will most likely make it past the bottleneck? Which color(s) do you think are at risk of disappearing?

Materials:

- 15 red popsicle sticks
- 12 blue popsicle sticks
- 8 yellow popsicle sticks
- 4 green popsicle sticks
- 1 purple popsicle sticks
- 1 paper bag

Procedure:

1. Place all popsicle sticks in the bag.
2. Close the bag and shake it vigorously.
3. Remove 10 popsicle stick “survivors” from the bag without looking.
4. Record the colors pulled in Table 10.3.

Table 11.3 Bottleneck Effect Data

Stick Color	Starting #	Starting %	Ending #	Ending %
Red	15	37.5% (15/40)		
Blue	12			
Yellow	8			
Green	4			
Purple	1			

Which color(s) remained in the ten surviving popsicle sticks? Did any disappear completely? If so, which colors?

How did your results compare with your hypothesis?

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NAME:_____ LAB SECTION:_____

The Diversity of Life I

A Look at the Microbes

Introduction

Learning Objectives:

- Identify the key features of bacterial colonies
- Identify the key features of protists

While we readily recognize the larger living things around us, there is an entire world of organisms living on a microscopic scale. These tiny organisms are collectively called *microorganisms* and can belong to one of many different groups. Microorganisms can include bacteria, archaeans, and protists. Each of these different types of microorganisms has a unique way of living – they can be photosynthetic, parasitic, aerobic, anaerobic… The list goes on and on! In this lab we will explore microorganisms collected from the environment and view preserved specimens under the microscope.

12.1 Bacteria in the Environment

Bacteria are the most prolific living things on Earth. There are thousands of known bacterial species with many more still undiscovered. Bacteria are one of the two prokaryotic *domains* -- the largest categories for classifying living organisms. Some bacteria prefer environments that are oxygen-rich while others prefer oxygen-poor environments. Some are free-living while others can cause disease. Bacteria can vary in their cell and colony shapes as well. We have already reviewed the general structure of prokaryotic cells in Lab 4: Cell's Kitchen, but before getting started on this exercise, you may want to review 4.1 to refresh your memory.

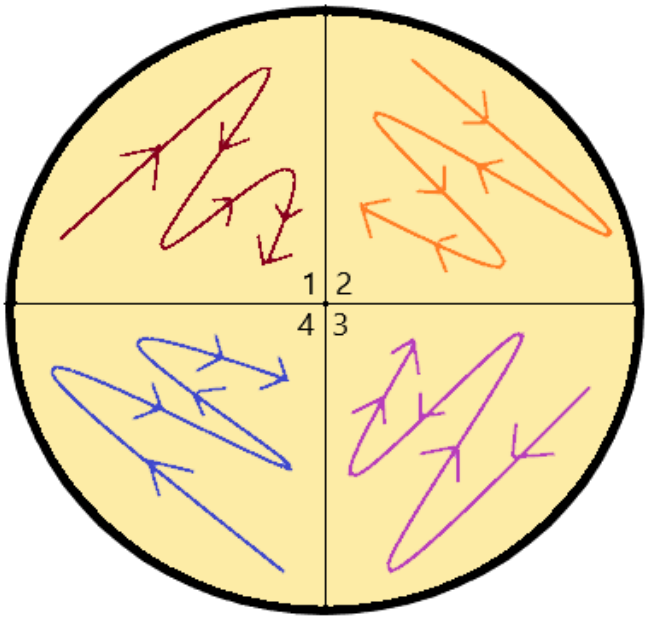
For this exercise, we will explore the microscopic world all around us by taking bacterial samples from everyday objects. These samples will then be streaked onto nutrient-containing plates and then left to incubate for several days. After allowing the plates to incubate, we will observe the plates for any growth.

Before getting started, let's look at proper techniques for collecting environmental bacterial samples and streaking plates.

When taking a sample, you will use a sterile swab. Keep the swab in the packet until you are ready to use it. When you are ready, remove the swab from its packaging. If you are swabbing a dry area, such as a table top, you will need to wet the swab with sterile water first. Make sure that if you use water, that you keep it covered and it is cool before using. If you use very hot water, the heat may kill any potential bacteria on your swab. If you are swabbing a wet area, you do not need to preemptively wet the swab. Then when you are ready to take a sample, simply roll the swab over the area.

For streaking plates, you will use a zig-zag pattern over the top of the gel, starting from the outer edge of the plate and working your way towards the middle. Since we will be taking four samples in this lab, your plate will be divided into fourths. Make sure not to overlap your samples. Below is an image demonstrating the nutrient plate set-up and streaking pattern.

When streaking your plate, it is important not to puncture or tear the gel on the bottom surface of the plate when rolling the swab over it. This gel is a nutrient-containing agar which will serve as a home and food source for any bacteria from your samples. While you want to make sure your swab comes into contact with the gel, you may not get clear results if you damage it.



Materials:

- 4 sterile cotton tipped swabs
- 1 nutrient agar plate
- Sterile water
- Permanent marker

Procedure:

1. Use a permanent marker to divide the bottom side of the agar plate into fourths.
2. Number each quadrant 1 through 4.
3. Along the bottom side's margin, write at least one lab partner's name. (Write small! You don't want to cover the entire bottom.)
4. Open one of the sterile swabs. If sampling a dry surface, wet the swab in the sterile water.
5. Roll the swab over the surface of the object being sampled.
6. Then, open the lid on the plate just enough to get the swab inside and roll the swab on the gel in the zig-zag pattern seen above on the first quadrant on the plate.
7. Repeat steps 3-6 for each sample, using a new swab each time.

When deciding on where to take your samples from, be creative as long as you do not enter any unauthorized areas or access someone's personal belongings without permission. Many students choose to sample areas they suspect are likely to be dirty such as cell phones and headphones, the inside of sink faucets, the bottoms of shoes, or the inside of toilets. These are just a few ideas to help you decide on where to sample. Once you've decided, write the sample area/object in the table on the next page.

Table 12.1 Sampled Areas and Objects

Sample #	Sampled Area/Object
1	
2	
3	
4	

Now that we've identified four areas to take samples from, let's hypothesize how much growth and how many different types of bacteria we will see for each sample.

Table 12.2 Hypotheses on Growth and Variety

Sample #	Amount of Growth (Low/Med/High)	# of Bacterial Species
1		
2		
3		
4		

After plating your samples, they must incubate until the next lab period. Make sure your name is on the plate and that the lid is taped shut. Then, give your plate to your instructor, who will then store it in the incubator.

All used swabs need to go into the biohazardous waste container. Other waste, such as swab wrappers, can go into the regular trash.

After your plate has incubated, you can now look for growth and how many bacterial species were on your sample. To determine how many different types of bacteria are on your plate, use **Appendix A** at the end of this manual. Appendix A will help you differentiate bacterial species based on shape, margin, color, and more.

Table 12.3 Results on Growth and Variety

Sample #	Amount of Growth (Low/Med/High)	# of Bacterial Species
1		
2		
3		
4		

How did your results compare to your hypotheses?

Were there any sample results that surprised you? Why did they surprise you?

All used agar plates must be disposed of in the biohazardous waste. Do **not** throw any used swabs or plates into the regular trash.

12.2 Protists

While bacteria are simple prokaryotes, protists are more complicated eukaryotic organisms. Protists are extremely diverse in their choice in nutrition, environment, and appearance. They may be unicellular or colonial. Many do not harm humans but some are responsible for diseases such as malaria and African sleeping sickness. Some are important nutrient recyclers and some are used to help treat our wastewater. In essence, the protists belong in a “junk drawer” in that they are so different from each other but are classified together as they do not belong to any other group.

Let’s introduce a few of the protist groups we will look at in this exercise. Below is a list of different types of protists and the organisms they are similar to.

Protozoa - single celled animal-like protists
Algae - plant-like protists
Slime molds - fungus-like protists

Protozoans

Protozoans are protists that are single-celled and *heterotrophic*, meaning that they consume other biological compounds. This can mean that they are predators, detritivores, or decomposers. Even though the protozoans are similar to animals, they do not meet all of the criteria to be part of Kingdom *Animalia*, hence their separation.

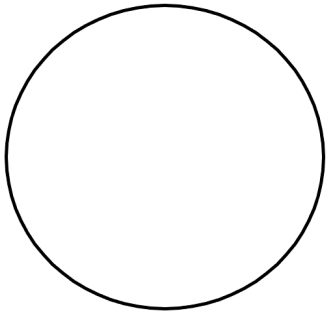
Protozoans can move around using structures such as cilia, flagella, or pseudopodia. Below is a table describing each of these methods of movement.

Table 12.4 Types of Locomotion in Protists

Structure	**How It Provides Movement**
Cilia	Many short cilia move together to move the protozoan. They can also be used to guide food in towards the cell.
Flagella	1-2 flagella move in a wave- or oar-like pattern to generate movement.
Pseudopodia	Parts of the cell protrude forward to allow the protozoan to “crawl” along the surface. These protrusions can also be used to engulf materials such as food particles.

Let’s look at a few preserved protozoans under the microscope.

Paramecium

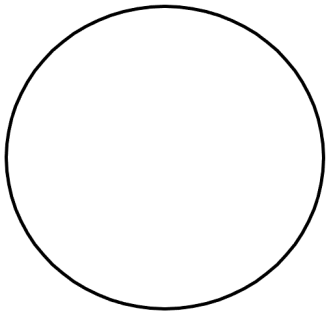


Title:_____

Total Magnification:_____

What mode of locomotion does the *Paramecium* specimen use?

Amoeba



Title:_____

Total Magnification:_____

What mode of locomotion does the *Paramecium* specimen use?

Algae

Algae are another type of protist. Algae may be unicellular, colonial, filamentous, or multicellular. Algae generally are aquatic and photosynthetic. Even though they are similar to plants, they do not meet the criteria of the Kingdom *Plantae*. When we classify

algae, we base that classification on two things – color and complexity. Below is a table explaining these classifications.

Table 12.5 Algal Color Classification

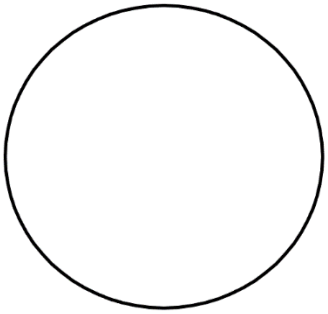
Green	Brown	Golden-Brown	Red

Table 12.6 Algal Complexity Classification

Unicellular	Algae lives on their own as a single cell
Colonial	Algae cells live together in a cluster, but individual cells can also live independently
Filamentous	Algae consists of long chain of cells, but individual cells can also live independently
Multicellular	Algae consists of cells that may be specialized and form structures such as a holdfast or blade

Now, let's observe several algae specimens. Some will require the use of a microscope while others are visible to the naked eye.

Chlamydomonas



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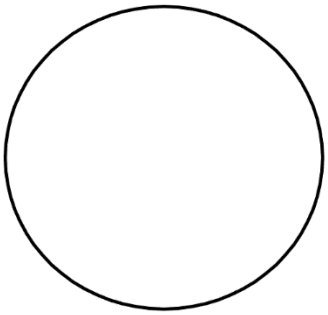
Total Magnification:_____

To which of the 4 color categories does *Chlamydomonas* belong?

To which of the 4 complexity categories does *Chlamydomonas* belong?

Spirogyra



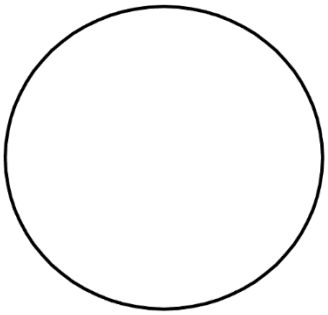
Title:_____

Total Magnification:_____

To which of the 4 color categories does *Spirogyra* belong?

To which of the 4 complexity categories does *Spirogyra* belong?

Ulva



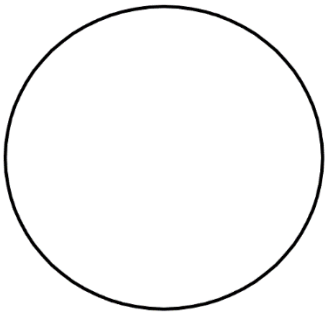
Title:_____

Total Magnification:_____

To which of the 4 color categories does *Ulva* belong?

To which of the 4 complexity categories does *Ulva* belong?

Diatoms



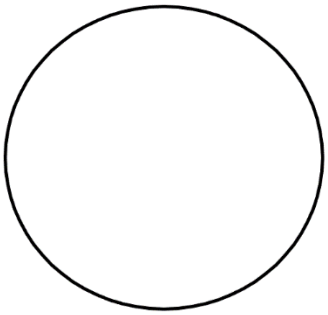
Title:_____

Total Magnification:_____

To which of the 4 color categories do diatoms belong?

To which of the 4 complexity categories do diatoms belong?

Red algae



Title:_____

Total Magnification:_____

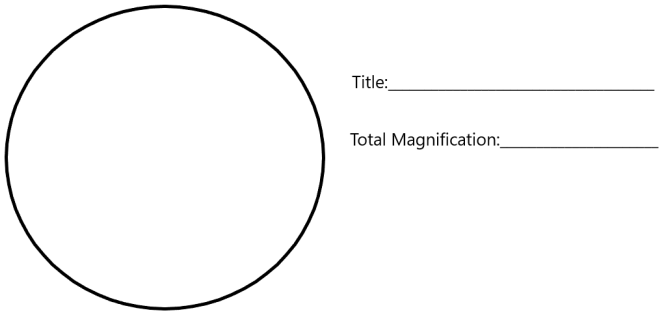
To which of the 4 color categories does *red algae* belong?

To which of the 4 complexity categories does *red algae* belong?

Euglenoids

Some protists still don't fit even into these categories! Our last microorganism is *Euglena*, which shows characteristics of both protozoans and algae. *Euglena* are freshwater protists that are able to photosynthesize like algae. They also have flagella and lack a cell wall like protozoans. They even have an eyespot to detect light.

Euglena



How does the eyespot help the *Euglena*? Hint: think about *Euglena's* capabilities.

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NAME:_____ LAB SECTION:_____

The Diversity of Life II

A Look at the Plants

Introduction

Learning Objectives:

- Identify the key features of plants
- Identify and categorize plants using a dichotomous key
- Identify the different parts of a flower and their functions

13.1 The Classification of Plants

Plants are a large, versatile, and varied group of organisms with over 300,000 known species on Earth. With so many different types of plants, we must organize them into groups that make sense. Plants can be classified based on their tissues, reproductive methods, and more. Let's take a look at some of the larger categories of plants and the characteristics that make each group unique.

The Bryophytes -- Nonvascular Plants

The bryophytes are nonvascular plants and the simplest of land plants.There are three groups within the bryophytes: the hornworts, the liverworts, and the mosses. Nonvascular plants do not have any specialized vascular tissue to conduct water through the plant, nor do they produce seeds. Instead, bryophytes absorb water via osmosis and produce water-dependent gametes. This means that most bryophytes must remain close to moisture otherwise they may quickly dry out.

Bryophytes also do not have true leaves, stems, or roots. Without these structures, the bryophytes are also stuck to being very small. Because of their simplicity, the bryophytes come across as the most “ancient” of the plants.

The Ferns -- Seedless Vascular Plants

In this group of plants, we now see vascular tissue -- xylem and phloem -- that help transport fluids around the plant. We also see true leaves, stems, and roots as well, meaning that these plants are no longer limited in size like their bryophyte cousins. These are the ferns -- a group of plants that includes true ferns, club mosses, and horsetails. Additionally, ferns reproduce using spores instead of swimming gametes, although these spores do still need a moist environment to function. These spores are formed in the sori, which are found on the underside of the fern’s fronds.

Petritap, CC BY-SA 3.0, via Wikimedia Commons

The Gymnosperms -- Seeded Plants

One of the greatest evolutionary leaps made by plants was the development of the seed. Compared to their seedless cousins, seed-bearing plants were able to conquer areas that were much warmer and drier. Seeds provide a protective and nourishing coating around the embryonic stage of the plant, meaning that the developing plantling

is not limited to moist, shady environments.

"Hikers Under a Giant Sequoia Tree" by Karen Marks, Reedley College is licensed under CC BY 4.0

The first plants to develop seeds were the gymnosperms. The gymnosperms are a very diverse group consisting of the conifers, gnetophytes, cycads, and ginkgophytes. These plants vary greatly in their physical appearance as well as where they grow, ranging from the warm tropics to the cold, high altitude mountains. Some of the largest organisms found on the planet belong to the gymnosperms. If you look closely at the image on the right, you'll see just how big they can be!

The Angiosperms -- Flowering Plants

The newest and most successful group of plants in modern day are the angiosperms. The angiosperms are the flower-producing plants and with over 260,000 different species, they now dominate the plant world.

Calimo, CC BY-SA 3.0, via Wikimedia Commons

Flowers are specialized structures originally modified from leaves. Their primary use is for reproduction, with the male and female reproductive organs found within. Many angiosperms rely on pollinators to help distribute the male gametes. Once the female gamete has been fertilized, a fruit begins to form around the developing seed. This fruit is used to reward animals who eat it and then (unknowingly) distribute the seeds through their feces.

13.2 Identifying Plants

Now that you have become familiar with all of the classifications of plants and their characteristics, we will put it into practice. Around the room are several plants and posters which have been identified with a letter. Using the dichotomous key found in **Appendix B**, identify each plant in the room.

Plant A

Does the plant have true roots, leaves, or stems? _____

How does the plant reproduce? _____

Does the plant flower? _____

What type of leaves does the plant produce? _____

Type of Plant: _____

Plant B

Does the plant have true roots, leaves, or stems? _____

How does the plant reproduce? _____

Does the plant flower? _____

What type of leaves does the plant produce? _____

Type of Plant: _____

Plant C

Does the plant have true roots, leaves, or stems? _____

How does the plant reproduce? _____

Does the plant flower? _____

What type of leaves does the plant produce? _____

Type of Plant: _____

Plant D

Does the plant have true roots, leaves, or stems? _____

How does the plant reproduce? _____

Does the plant flower? _____

What type of leaves does the plant produce? _____

Type of Plant: _____

Plant E

Does the plant have true roots, leaves, or stems? _____

How does the plant reproduce? _____

Does the plant flower? _____

What type of leaves does the plant produce? _____

Type of Plant: _____

13.3 Flower Dissection

In the previous exercise, we learned about the flower-producing plants – the angiosperms. Flowers serve as an important evolutionary development in plants and

have created situations where plants utilize the services of other organisms to help with pollen and seed dispersal. Generally, the pollinator must be “rewarded” to entice them to return to the flowers. This reward generally is given in the form of nectar which is a sweet, nutritious substance eaten by the pollinators. Other flowers rely on trickery to fool a pollinator into accidentally pollinating it. Many of these pollinators have developed a very special relationship with a single flower type or species. This development is called *coevolution* – where two species evolve in response to each other – and can lead to changes in both the pollinator and the plant. Below is a table discussing some of the additional ways plants try to attract certain pollinators.

Table 13.1 Pollinator Attraction Methods

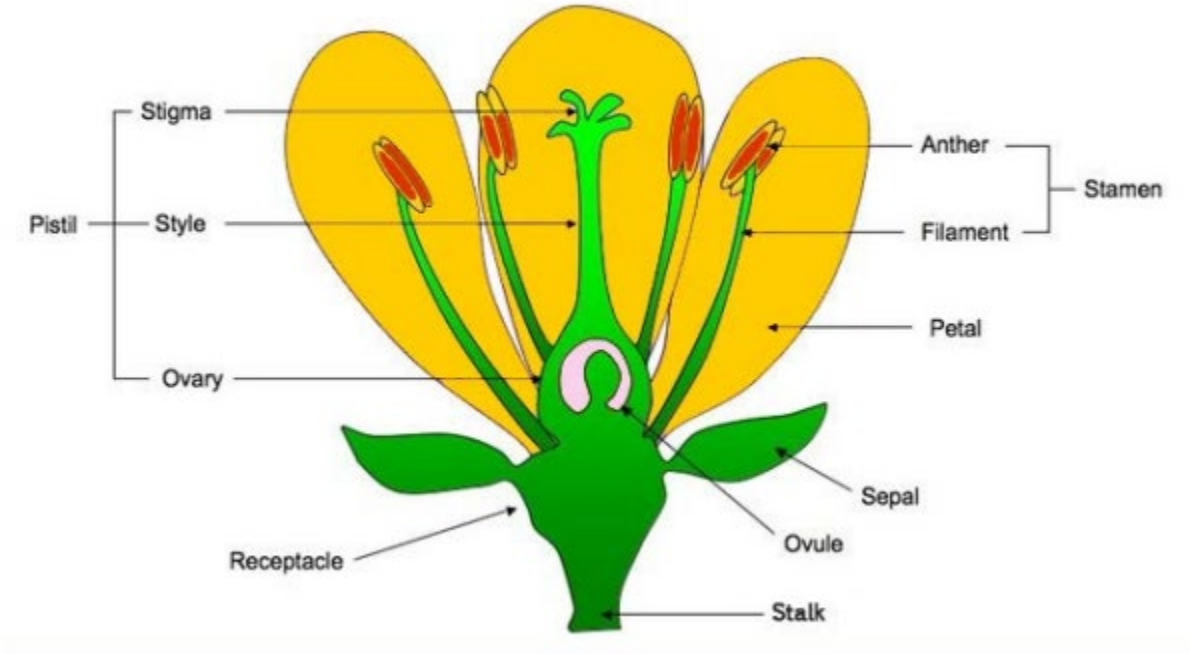
Flower Trait	Type of Pollinator it Attracts
Open during the day	Pollinators that are awake in the daytime
Open at night	Pollinators that are awake at night
Red or orange color	Birds who see reds easily
Yellow, blue, or UV color	Bees and butterflies who see these colors and UV light
White color	Bats who see the bright white flowers at night
Flowers smell sweet	Bees, butterflies and bats who have good sense of smell
Flowers smell rotten	Flies who are attracted to rotting meat
Tubular shaped flowers	Butterflies and hummingbirds who have long tongues
Large flowers	Bats and other large animals that are heavier than other pollinators

Some flowering plants bypass using animals as pollinators completely, using wind to carry pollen and small, light seeds. You’ve likely seen this before in the form of dandelions, who’s seeds take on a “puffball” appearance before being scattered by the wind (or a person who decided to blow on it!)

Now let’s get more familiar with the flowers by revealing their important structures through dissection. In the table and image below are some of the important parts seen in flowers. After we familiarize ourselves with these, we will dissect some flowers to see these structures in their various forms.

Table 13.2 Parts of a Flower

Flower Part	Purpose
Pistil	The female reproductive part that receives pollen and produces the ovule
Stamen	The male reproductive part that produces pollen for dispersal
Petal	Serves as the visual aid to attract pollinators
Sepal	Protects the flower while it is developing and opens to let the flower bloom
Ovule	Forms the seeds that develop after the flower is pollinated
Receptacle	A supportive structure to handle the weight of the flower and/or fruit



Now let’s examine the flowers. Before we dissect them, let’s examine their outer appearance. We will write down information about each flower in the table provided as well as create a drawing for each.

Table 13.3 Flower Dissection – Outer Examination

	Trait		**Drawing**
Flower #1	Color		
	Scent		
	Flower Shape		
	Flower Size		
	Potential Pollinator(s)		

	Trait		**Drawing**
Flower #2	Color		
	Scent		
	Flower Shape		
	Flower Size		
	Potential Pollinator(s)		

	Trait		**Drawing**
Flower #3	Color		
	Scent		
	Flower Shape		
	Flower Size		
	Potential Pollinator(s)		

After you have examined each flower's exterior, you are ready to dissect it. You should make one cut along the long axis of the flower, dividing it into mirror-image halves. Be sure the cut goes through the middle of the flower, bisecting the ovary and receptacle. Dissecting microscopes will be available in the lab to help you make clean and even cuts through the middle of the flower. If you find yourself having trouble, ask your instructor for help.

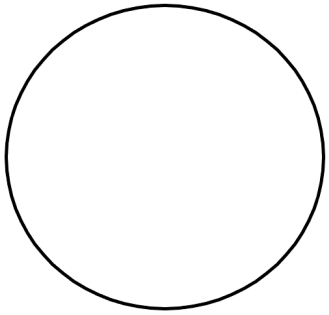
Use caution when using sharp objects such as scalpels to avoid cuts. If your blade is too dull, ask your instructor for a new one.

After you cut the flowers open, observe the inside structures that you couldn't see before. In the space below, draw each flower and include labels for the following:

- Anther (part of stamen)
- Stigma (part of pistil)
- Ovary (part of pistil)
- Petals
- Sepals
- Receptacle

Lastly, prepare a wet mount of the ovary and anther from your flower to observe ovules and pollen. Place a drop of water on a slide. Using a scalpel, slice a thin cross section of the ovary or anther and place the thin slice in the water on the slide. Apply a coverslip. Using a compound microscope, view the wet mount under 4x, 10x and 40x. Sketch what you see and make notes on the structure of each.

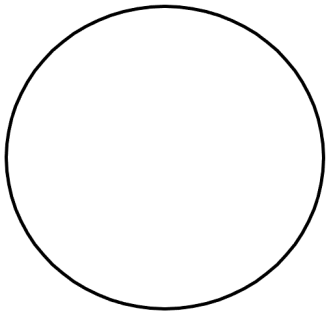
Flower #1



Title:_____

Total Magnification:_____

Flower #2



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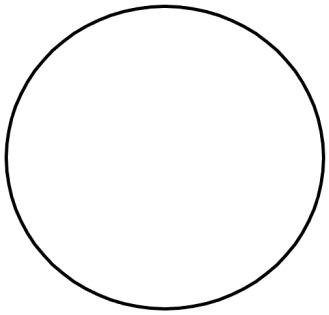
Flower #3



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The Diversity of Life III

A Look at the Animals

Introduction

Learning Objectives:

- Identify the key features of animals
- Identify and categorize animals using a dichotomous key

14.1 The Classification of Animals

All of life can be classified using *taxonomy* -- a systematic process of naming and categorizing living things. Categories can be very large and inclusive or very small and exclusive. Below is a table showing how humans are taxonomically categorized. Notice that the last two categories are italicized. These last two categories (genus and species) are used to identify a species in a shorter, easier to write format.

Table 14.1 Taxonomy of Humans

	Taxonomic Group	**Human Classification**
Largest	Domain	Eukarya
	Kingdom	Animalia
	Phylum	Chordata
	Class	Mammalia
	Order	Primate
Smallest	Family	Hominidae
	Genus	*Homo*
	Species	*sapiens*

14.2 Some of the Common Animal Phyla

All animals share a few key features; they are heterotrophs, they are mobile during at least one life stage, and they are composed of many eukaryotic cells. But each species has characteristics that distinguish it from the rest. Let's look at some of the different phyla and classes of animals and see what makes them unique.

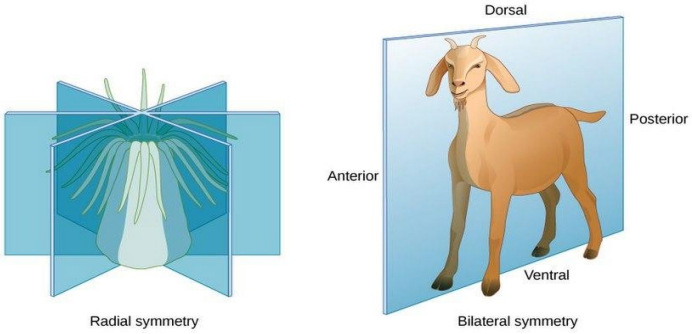
Phylum Porifera

Phylum *Porifera* is probably the last thing you think of when you think of animals -- the sponges. These aquatic animals are very simple, without the diversified tissues we see in other animals. Members of *Porifera* are filter feeders, drawing in water and filtering out particulate matter to eat. Another defining feature of the sponges is that they are asymmetrical. This is very different from other animals that show symmetry in their body shape.

Phylum Cnidaria

The members of Phylum *Cnidaria* are the jellies. Organisms like jellyfish and man-of-war are found in the *Cnidaria* phylum. These organisms have specialized cells called cnidocytes that contain toxins used to immobilize prey. Most cnidarians have two phases in life -- the immobile, stalk-shaped "polyp" phase, and the mobile, bell-shaped "medusa" phase. The polyp body shape shows bilateral symmetry while the medusa body shape shows radial symmetry.

Luis Miguel Bugallo Sánchez (Lmbuga), CC BY-SA 4.0, via Wikimedia Commons



Body Symmetry by CNX OpenStax, CC BY 4.0, via Wikimedia Commons.

Phylum Arthropoda

The arthropods are the largest group of animals, with about 85% of animals belonging to phylum *Arthropoda*. The arthropods have a segmented body with several pairs of jointed legs. Because *Arthropoda* is so expansive, it is broken into several subphyla: *Myriapoda* (millipedes and centipedes), *Hexapoda* (insects), *Chelicerata* (spiders and scorpions), and *Crustacea* (crabs, shrimps, lobsters, and isopods.) One common characteristic shared among all arthropods is a hard, chitin-based exoskeleton that must be *molted* (shed) in order to grow.

Hexapoda by Dick Belgers., CC BY 3.0, via Wikimedia Commons

Filo gèn', CC BY-SA 4.0, via Wikimedia Commons

Phylum Mollusca

Phylum *Mollusca* is another very diverse group of animals, containing several unique classes like *Gastropoda* (snails and slugs), *Cephalopoda* (squid and octopus), and *Bivalvia* (mussels, clams, and scallops.) This phylum has over 75,000 species, with most of these species being marine. All mollusks are soft-bodied with a muscular “foot.” Some mollusks have shells as well, which can be a single, cone or spiral shape or two hinged shells that close together.

Termininja, CC BY-SA 4.0, via Wikimedia Commons

Phylum Annelida

This phylum contains the segmented worms. Not all worms fall into *Annelida* (as the non segmented worms can be from phyla *Nematoda* or *Platyhelminthes*) but the ones that you are likely most familiar with do. The earthworm is probably the most famous of the annelids. Annelids have special hairlike projections called *chaetae* as well as two layers of muscle that can help the annelid move. Annelids also have very complete digestive systems, despite their simple appearance.

Aruna at ml.wikipedia, CC BY-SA 3.0, via Wikimedia Commons

Phylum Echinodermata

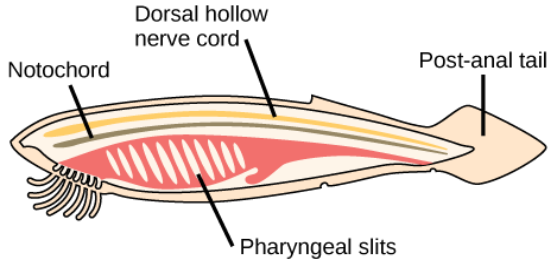
The echinoderms are a group of marine animals that have a tough, prickly exterior and include sea stars, sea urchins, and sea cucumbers. They also have a water vascular system which helps with circulating nutrients, gas exchange, and movement. To move, water is pumped in and out of special structures called tube feet. While these tube feet

are very slow, they are extremely powerful and can even be used to pry shelled animals open, like clams

.

Phylum Chordata

At this point, every animal we have analyzed has been an invertebrate -- animals without backbones. Phylum Chordata, however, is mostly composed of the vertebrates -- the animals that do have a backbone. While not every chordate has a backbone, all chordates have the following at some point in their life: a notochord, dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail. For this lab, we will focus on the vertebrates, as there are several unique vertebrate groups.



The fishes are a diverse group that can be classified as jawless (like lampreys) or jawed. Jawed fishes can be further classified by their skeleton. Some fishes use cartilage for their skeleton, like the sharks, skates, and rays, while most other fishes use bone.

Tiia Monto, CC BY-SA 3.0, via Wikimedia Commons

Class *Amphibia* begins our journey out of the water. Amphibians include frogs, toads, salamanders, and caecilians , all of which are found in moist areas, as their eggs are aquatic. Once hatched, most amphibians enjoy an aquatic larval stage before maturing into a land-dwelling adult.

Charles J. Sharp , CC BY-SA 4.0, via Wikimedia Commons

Class *Reptilia* is composed of the non-avian reptiles, such as snakes and lizards. Reptiles also lay eggs, however instead of a jelly-like material, reptilian eggs are covered with a hard shell, making them suitable for land. Adults also have a tough, scaly exterior. This scaly skin helps prevent water loss, allowing reptiles to live in some of the hottest and driest environments.

Pahcal123, CC BY-SA 4.0, via Wikimedia Commons

While birds are technically reptilian, they are morphologically different enough to form their own class: *Aves*. Birds have unique characteristics that set them apart from their lizard cousins, such as extra-lightweight bones and feathers. Birds also are

endothermic, also known as being “warm-blooded”, while their lizard cousins are “cold-blooded.”

Mathew Schwartz, CC BY 3.0, via Wikimedia Commons

The last, but certainly not least, class of the chordates we will examine is Class *Mammalia*. Mammals are unique in that they have hair and mammary glands. Their hair can perform a variety of functions such as providing warmth or sensory information. Meanwhile, their mammary glands produce milk that is used to nourish their young. While not every mammal gives live birth (with monotremes like the platypus laying eggs), all mammals produce milk as their offspring’s first food source.

Stephanb, CC BY-SA 3.0, via Wikimedia Common

If we look back at Table 12.1, we see that humans fall in Class *Mammalia*. Grouped with us in *Mammalia* are the Primates -- the lemurs, tarsiers, monkeys, apes, and humans. The primates are generally arboreal, meaning that they are adapted to living in trees. When looking at the primates, our closest relatives would be the chimpanzees and bonobos, both of which are African apes. Biologists have evidence that humans last shared a common ancestor with chimps about 6-7 million years ago.

Overall, there is great diversity in the animal kingdom. While some animals remind us of ourselves, like the chimpanzees and bonobos, others seem otherworldly, like the sponges. But regardless of their appearance or how closely related they are to us -- we are all united under the title of “animal.”

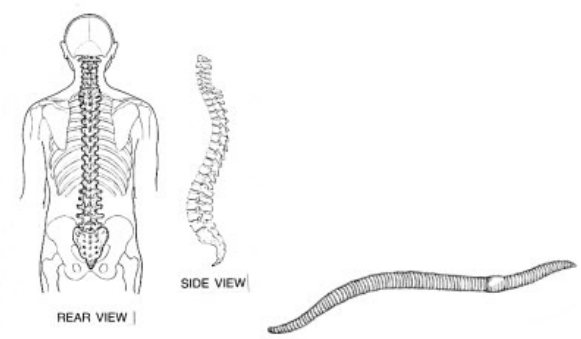
14.3 Determining Characteristics of Animals

Before we determine the classifications of animals, let’s get some practice with determining characteristics first.

Symmetry: We will start by practicing with animal symmetry. Remember that animals can show *bilateral* symmetry (only one plane of symmetry), *radial* symmetry (multiple planes of symmetry), or *asymmetry* (zero planes of symmetry).

1. Ascaris worm _____
2. Clam _____
3. Crayfish _____
4. Grasshopper _____
5. Sea Anemone _____
6. Fish _____
7. Frog _____
8. Sea Star _____
9. Earthworm _____

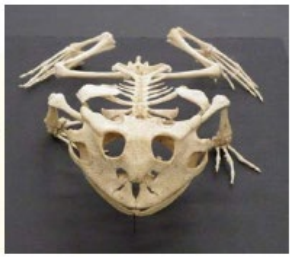
Segmentation: Some animals are segmented in that similar parts are repeated over and over in a linear order. The earthworm would be a classic example of segmentation with many segments that are very similar. Some animals demonstrate segments of varying size causing them to appear different. Often segments may be fused and in some cases evidence of segmentation is not visible on the external body but internal structures reveal that segmentation is present. Look at some of the skeletons of vertebrate animals that are provided. Using the 9 animals from above, determine whether they are segmented or not.



Segmented:_____
_____
_____

Non-Segmented: _____
_____
_____

Skeleton: Some animals possess a skeleton for support and locomotion. Some skeletons are internal like our own bone structure. Others have a skeleton that is external like a suit of armor that covers the outer body. There are also animals that have no skeleton at all. Note that a shell is not considered to be a skeleton.



1. Which of the 9 animals have no skeleton?

_____

2. Which have an internal skeleton?

_____

3. Which of them have an external skeleton?

_____

Paired Appendages: Paired appendages are structures that are paired because they are attached to the body on each side and are frequently used for locomotion. Each of these arthropods has different numbers of paired appendages. In the table on the next page, identify how many PAIRS of appendages each organism has.

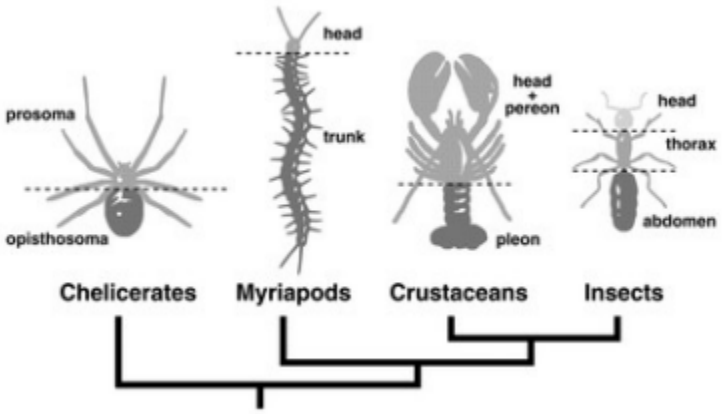


Table 14.2 Appendage Pairs of Different Organisms

Organism	Number of Appendages	Organism	Number of Appendages
Human		Frog	
Fish		Sea anemone	
Crayfish		Sea Star	
Grasshopper		Earthworm	
Bird			

14.4 Determining Classification of Known Animals

After learning about the characteristics of each animal, we will now classify each of the organisms from Activity 14.3. Use the dichotomous key in **Appendix C** to complete this exercise. Note that while some will stop at phylum, others you may need to key to class.

Table 14.3 Classification of Known Organisms

Organism	Classification
Human	
Fish	
Crayfish	
Grasshopper	
Bird	
Frog	
Sea anemone	
Sea Star	
Earthworm	

14.5 Determining Classification of Unknown Animals

Now that you have become familiar with all of the classifications of animals and their characteristics, we will put it into practice. Around the room are several animal specimens which have been identified with a letter. Using the dichotomous key found in **Appendix C**, identify each animal in the room. Make sure to include the taxonomic level (phylum, class, order, etc.)

Table 14.4 Unknown Animal Identification

Letter	Classification	Letter	Classification
A		**N**	
B		**O**	
C		**P**	
D		**Q**	
E		**R**	
F		**S**	
G		**T**	
H		**U**	
I		**V**	
J		**W**	
K		**X**	
L		**Y**	
M		**Z**	

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Come Together

Ecology and Biodiversity

Introduction

Learning Objectives:

- Define biodiversity, species richness, and conservation
- Understand the importance of biodiversity

One of the most beautiful things on our planet is the wide variety of plants, animals, fungi, and microbes inhabiting it. However, it's not just beautiful; it's also extremely important to have such diversity in life. When we look at a particular environment, there are many roles that need to be filled for it to stay healthy. Environments need species to capture sunlight and inorganic carbon from the atmosphere; they need species to consume excess *autotrophs*, they need various *carnivores* (meat-eaters) to prevent the overabundance of *herbivores* (plant-eaters), they need organisms to break down *detritus* (dead matter) into useable energy again. When this diversity drops, many of these roles go unfilled which leads to an unhealthy environment.

There are a number of ways to measure the health of an ecosystem including species richness and biodiversity. *Species richness* simply is the number of different species found in an environment. *Biodiversity* looks at both the number of different species as well as their relative abundance. Species richness gives us a quick snapshot of the ecosystem, while biodiversity gives a more detailed picture.

To understand the difference, let's look at the example in the table below. Notice how Forest #1 is dominated by species #3, while Forest #2's species are fairly evenly split.

Table 15.1 Species Richness vs Biodiversity

	Species #1	**Species #2**	**Species #3**	**Species #4**	**Species #5**
Forest #1	10%	5%	60%	20%	5%
Forest #2	20%	20%	20%	20%	20%

15.1A Analyzing Species Richness In a Natural Environment

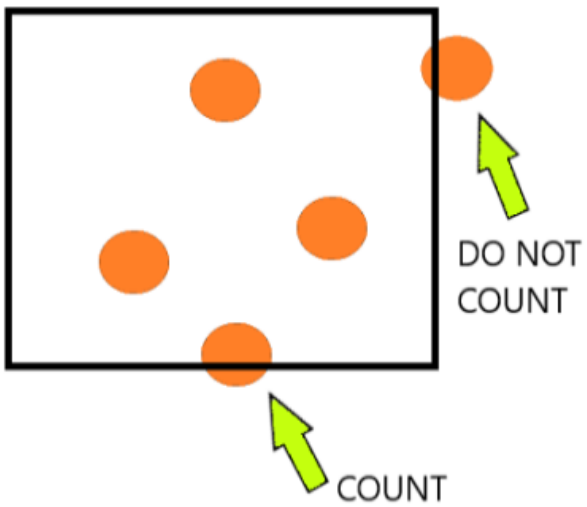
The environment around us is filled with many different species, even if we are not always aware of them. For this activity, we will analyze an area outside and identify as many different plants, animals, and fungi as possible. There are two ways to identify how many species are in a given area. One method is the *transect* method, where a researcher identifies every species found along a straight line. Another method uses *quadrats* -- where the researcher identifies everything with a square area. We will use the quadrat method for this activity.

Before we start, make note of the following information in the table below. Species composition may change based on the location, season, time of day, and weather conditions so noting this down is part of the process.

Table 15.2 Information on Environment

Location	Date/Time	Temperature	Weather Description

Now you can lay down your quadrat and begin looking closely for every type of organism you can find. When counting species within your quadrat, the organism must mostly be inside the quadrat. See the image below to ensure you follow this rule.



15.1B Analyzing Species Richness in a Water Sample

While the weather may not permit us to analyze life out in the open environment, we can look at water samples taken from water sources. While most bodies of water may seem unassuming at first, water is usually teeming with life. We will discover the biodiversity hidden within these ecosystems.

Before we start, make note of the following information in the table below. Species composition may change based on the location, season, time of day, and weather conditions so noting this down is part of the process. This information will be provided in class by the instructor.

Table 15.3 Information on Environment

Location	Date/Time	Temperature	Weather Description

Then, we will analyze our samples to find as many different species as possible. Make sure to not only find and describe as many different organisms as you can but also note how many of each species you see as well. You may see plant, animal, and fungus species in your sample. Since this is a water sample, you may need to also look at some of the water samples under the microscope to identify anything microscopic like protists. Remember that microbes do count!

15.2 Analyzing Species Richness Results

Now, in the table found on the next page, draw an example of each species, write a brief description and how many you see in your quadrat/sample. Try to be detailed in your drawings and descriptions, as you will want to be able to tell species apart. Include things like approximate size, colors, smells, patterns, and behaviors (if any) that you notice.

Your level of detail may depend on whether you are completing the outdoor or indoor version of this activity. Regardless of which form of the activity you are doing, remember that more detail is better than less.

If you need more space, use the Table 15.4 Extension found in **Appendix D** and turn it in with your lab.

Table 15.4 Quadrat/Sample Results

Species Drawing	Species Description	Number Seen

How many total different organisms did you find? Did this number surprise you?

What type of organism was the most abundant? Why do you think it was the most abundant?

15.3 Making a Native Seed Ball

One threat to greater biodiversity are *invasive species*. Invasive species are non-native species that outcompete the native species. This may not seem like an issue, but in most cases, an invasive species can affect multiple native species leading to an overall drop in diversity. The invasive species may grow faster than natives or have no predators to keep their numbers down. One example is the Burmese python that was introduced to Florida. The Burmese python was introduced to Florida by people who kept them as pets and then -- intentionally or not -- released them into the wild. These massive snakes quickly grew in numbers since they have no natural predators there and have the ability to kill large numbers of native animals for food.

Invasive species also have a large financial impact. Florida spends large amounts of money on controlling the python population, funding educational and advertising materials, spending on anti-invasive species legislation, and paying hunters to catch and kill pythons regularly.

One way to combat invasive species is to intentionally plant native species. For this activity, we will create “seed balls” containing the seeds of native plants. These seed balls can be planted in your garden or local area; just make sure to get permission first if you don’t own the land.

Materials:

- Compost
- Top soil
- Sand
- Regionally appropriate seeds

- A bowl of water

Procedure:

1. Add 3 tablespoons of soil to your bowl
2. Add 1 tablespoon of compost to your bowl
3. Add 1 tablespoon of sand to your bowl
4. Add ½ teaspoon of native seeds to your bowl and mix all components well.
5. Slowly add water while mixing until you achieve a cookie dough-like consistency.
6. Roll into balls; you should get about 8-10 balls out of this amount.
7. Let dry for 24 hours.

These seed balls contain native flowering plants. Besides the plants themselves, what other native organisms could benefit from these seed balls?

Why do you think the seed ball contains a variety of different seeds rather than just 1 or 2 types of seeds?

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NAME:_____ LAB SECTION:_____

Our Impact

Humans and the Planet

Introduction

Learning Objectives:

- Relate principles of population ecology to the study of the global human population
- Determine one's personal carbon footprint and describe actions that lower the carbon footprint
- Describe what e-waste is and its impact on the planet
- Reflect on personal and societal causes of increased carbon footprint and waste

As humans, we have a mass effect on the environment around us. Like any living thing, we use space and resources to survive. However, we humans tend to use an unfair amount of resources. We tear down wild ecosystems to cultivate land for food and living space, divert waterways to protect property and irrigate crops, and release pollutants into the air and water. While some damage is inevitable, many of us lead lifestyles that use up resources in a way that outpaces the Earth's ability to replenish them. We can calculate our individual impact on the planet by calculating our carbon footprint. Once we are aware of our carbon footprint, we can determine where in our lives we can cut down usage. Some examples include eating less meat, buying fewer materials (like clothing), and turning off lights and appliances when not needed.

While individuals can lessen their impact by creating less garbage and waste and using fewer resources like electricity, we also need to account for society's resource usage and creation of waste at large. Individuals are not the only ones who create waste! Companies, institutions, and governments also create waste. Since most companies are focused on making a profit in the shorter term, they may not be concerned about the long term impacts of waste creation, making them less sustainable. This is why there are many regulations placed on companies and institutions by governments – to protect resources for society for the long term. By placing regulations in place that encourage the use of renewable and/or sustainable resources and discourage the use of

nonrenewable, unsustainable ones, we can ensure a planet that remains livable for many, many years to come.

16.1 Determining Your Carbon Footprint

Your carbon footprint is a measure of greenhouse gasses produced by your regular activities. Activities like how you travel, what you eat, and the type of goods you buy all impact your carbon footprint. For this exercise, you will calculate your own carbon footprint. While we all want to show a “good” carbon footprint, it’s important that you answer the questions honestly. Your grade is not based on how “good” your footprint is; rather, it is based on what you notice about your footprint, what you learn from it, and what you decide to do to improve it.

For this exercise, we will use a carbon footprint calculator to find out our personal carbon footprints. Use the website Foot Print Calculator .You’ll also be putting some of the data you enter into the calculator into the spaces below.

How many times per week do you eat...

Meat (beef/lamb/pork:) _____ Dairy/cheese/eggs: _____

Poultry (chicken): _____ Fruits/Vegetables: _____

How many meals per week do you…

Cook at home: _____ Use local ingredients: _____

Buy pre-prepared: _____

How do you get around? (Circle all that you regularly use. Place a star next to the one you use the most.)

Walk/Bike	Motorcycle
Bus	Car (gasoline)
Electric Vehicle	Truck/SUV/Van (gas/diesel)

How many miles do you travel per week? _____

On a monthly basis, how much do you spend on goods such as…..

Clothing: _____ Electronics: _____

Household Goods: _____ Decor/Items for Home: _____

After using the footprint calculator, what is your personal Earth Overshoot Day?

How many Earths are required for support if everyone had the same lifestyle as you?

What are some **realistic** lifestyle changes you can make that would help lower your footprint?

16.2 e-Waste Today

When we imagine waste and pollution, we typically imagine garbage -- candy wrappers, Styrofoam containers, dirty water, etc. We probably don't imagine the cell phone in our pocket one day becoming waste. However, e-waste, or electronic waste, consists of unusable or outdated electronic products such as DVD players, cell phones, computers, and more.

e-Waste is a growing issue with no indication of slowing down. Valuable elements, such as gold, palladium, lithium, and cobalt are recyclable. However, mixed in with these more valuable materials, are elements such as lead, beryllium, and cadmium.When not properly recycled, these toxic components can leach into water supplies.

For this exercise, discuss the issue of e-waste with your group/class. You can use the resources listed in the reference section to assist in answering the questions.

How often do you throw out and/or replace electronic devices? What types of devices are they and how do you dispose of them?

What is the safest way to dispose of e-waste?

Many like to blame the consumer for e-waste problems. However, producers should also shoulder the blame for their contributions to this problem.
What do producers (like tech companies) do that creates more e-waste?

One of the current national arguments involving e-waste is the fight for the right to repair privately owned devices.

What does “right to repair” mean?

Why are many companies, like Apple and John Deere, so against this concept?

How does “right to repair” help alleviate the e-waste problem?

References

1. California recycle
2. The word has an E- waste Problem
3. What Can We Do About the Growing E-waste Problem?

16.3 Population Demography

In addition to how individuals live and how companies act, we must also take into consideration the population growth within different countries. How countries are structured and how they grow will change the amount and types of resources required for the population living there.

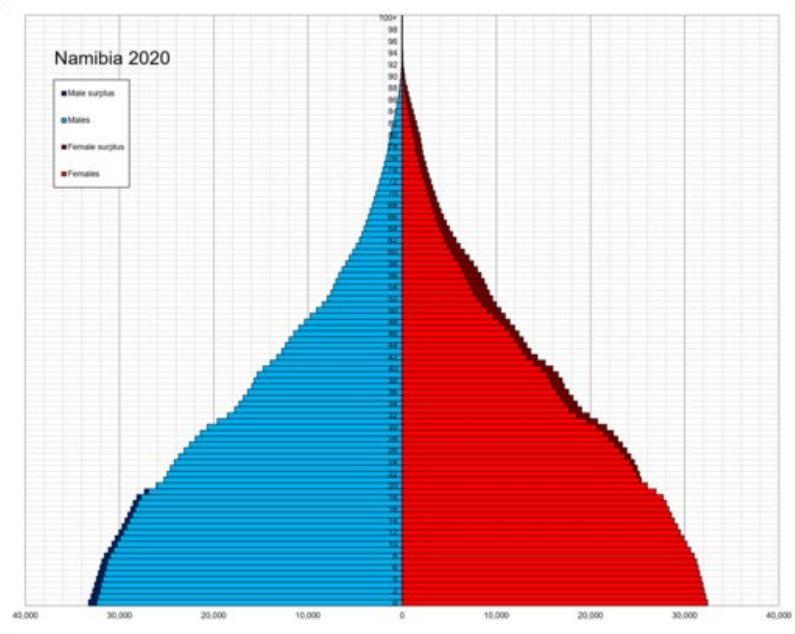
Countries generally fall into one of two categories – more developed and less developed. More developed countries (MDC) tend to have slower population growth, but use more resources per person. Less developed countries (LDC) tend to have faster population growth, but use fewer resources per person. See the table below for a more detailed comparison of the two categories of countries.

Table 16.1 Comparison of More and Less Developed Countries

	More Developed Countries	Less Developed Countries
Education	Access to education is generally available	Some groups may have a difficult time accessing education
Healthcare	Most people have access to regular medical care, including reproductive care	Medical care may be hard to obtain due to lack of infrastructure or healthcare professionals
Employment	Low unemployment and people enjoy a high standard of living	Higher unemployment or employment does not pay enough for a high standard of living
Growth Rate	Low birth rate, Low death rate	High birth rate, high death rate
Resource consumption	High resource consumption per capita	Low resource consumption per capita
Age Pyramid Shape	Box-like, most age groups are about even	Triangle-like, with very few elderly and many young people

Many countries transition from less developed to more developed. When this transition occurs, we usually see a pattern in that death rates will drop first since people have better access to healthcare and basic needs while the birth rate stays high because the effects of social changes, like better access to education, are not visible just yet. The birth rate drops later on as the country transitions into more developed.

We can see the evidence of where a country likely falls based on information such as the life expectancy, children birthed per woman, and by looking at the age distribution of the population as seen in an age pyramid. Below is an example of an age pyramid.



For this last exercise, we will use a simulation to see how population growth rates can change over time using real data to make predictions about the development of a country. Use the simulator link below to complete the activity.

Remember that growth rate is calculated by using the following:

Birth Rate – Death Rate + Immigration = Growth Rate

We will use the following UN simulation to complete this exercise:

Exercise 1: Compare Countries in the Present Day

Use the simulator to view the current population and details of the countries from the table below. Make sure you are using the UN simulator.

Table 16.2 Population Demographics in Present Day

Country	Life Expectancy	Children per Woman	Shape of Age Pyramid	Largest Age Group (estimated)
United States				
Nigeria				
Japan				

Based on the information you collected, which countries appear to be more developed? Which appear to be less developed?

Exercise 2: Compare Countries in 2060

Use the simulator to view the 2060 estimated population and details of the countries from the table below. Make sure you are using the UN simulator.

Table 16.3 Population Demographics in 2060

Country	Life Expectancy	Children per Woman	Shape of Age Pyramid	Largest Age Group (estimated)
United States				
Nigeria				
Japan				

Compare the information from tables 16.2 and 16.3. Which country(ies) saw the greatest changes in life expectancy and births per woman? Describe those changes and what that means for development.

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Appendices

Appendix A

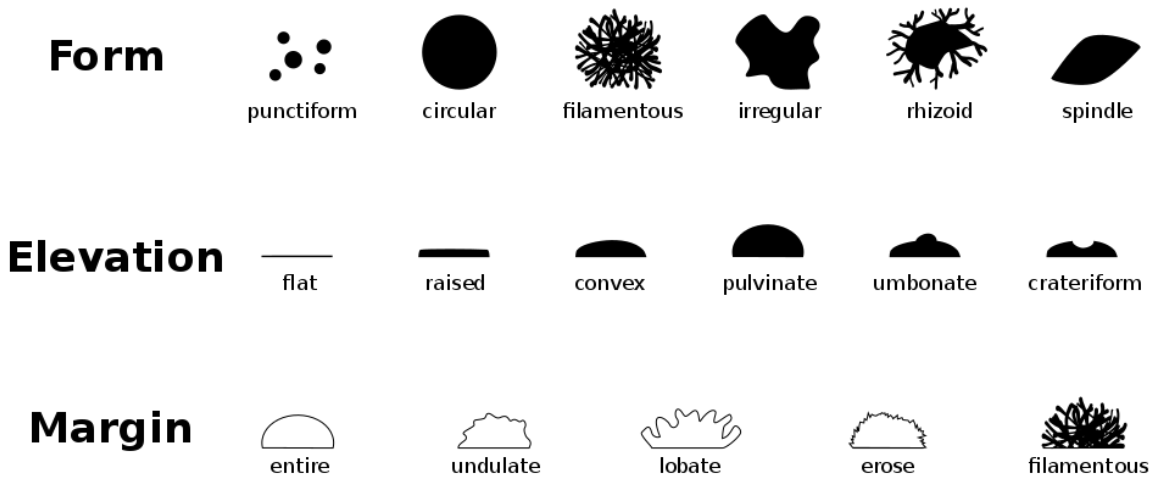
Bacterial Colony Shapes

Bacterial colonies can take on many shapes, elevations, and margins depending on the species. While you will not need to identify any particular species of bacteria in this class, you should be able to identify the various characteristics seen below.

Form: The overall shape of the colony

Elevation: The height of the colony

Margin: The shape of the colony's border



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In addition to form, elevation, and margin, you may also see different colors. Color is another indicator that you have different bacterial species. Bacteria can range from pale whites to deep reds and all colors in between.

Appendix B

Plant Dichotomous Key

Identify the organism using the following questions. Start at 1 and then move onto further questions based on your answers to the previous question.

1. Does the plant have true roots, leaves, or stems?

   No ……..…….……..… *Moss*

   Yes …….. Go to 2

2. How does the plant reproduce?

   Spores ……..…….. ……. *Fern*

   Seeds ……..... Go to 3

3. Does the plant flower?

   Does not produce flowers ……..…….. Go to 5

   Does produce flowers ……..……..……... Go to 4

4. What type of leaves does the plant produce?

   Long, thin leaves ……..……... *Monocot* (*Grass)*

   Broad leaves …….. *Dicot (Angiosperm)*

5. What shape are the leaves?

   Thin, needle-like ……... *Conifer (Gymnosperm)*

Appendix C

Animal Dichotomous Key

Identify the organism using the following questions. Start at 1, read all of the choices and then move onto further questions based on your choice.

Key to the Phyla of the Animals

1A Single cell or colony of cells without specialized body tissues……..……KINGDOM PROTISTA
1B Body composed of many cells
…… 2

2A Body usually without symmetry; small pores and large openings for water circulation
…….. PHYLUM PORIFERA
2B Body has either radial or bilateral symmetry
……..…… 3

3A Radial symmetry
……..…… 4
3B Bilateral symmetry
…….. 5

4A Soft body; body sac-like or bell-shaped with tentacles surrounding only one opening
…… PHYLUM CNIDARIA
4B Body with a hard, spiny, or leathery covering; internal skeleton; mouth and anus present
…… PHYLUM ECHINODERMATA

5A Body worm-like (soft-bodied, no skeleton)
……..…… 6
5B Body not worm-like
……..…… 9

6A Body nonsegmented
……..…….. 7
6B Body segmented
…… 8

7A Flattened body; digestive tract with one opening
……..……..…PHYLUM PLATYHELMINTHES
7B Round body; mouth and anus present
…….. PHYLUM NEMATODA

8A Body segments flat; tiny head; parasites of digestive tract
……..……... PHYLUM PLATYHELMINTHES
8B Body segments round, may have a head; body appears to have rings; no skeleton; may have fleshy protuberances, bristles or setae
……..……..……. PHYLUM ANNELIDA

9A Flattened or branched fleshy muscular foot; shell may be in overlapping plates, a spiral coil, or two hinged valves; shell may be internal or absent
……..…… PHYLUM MOLLUSCA
9B Jointed appendages which are sometimes absent as in snakes; no shell; skeleton internal or external
…….. 10

10A External chitinous skeleton; three or more pairs of externally jointed appendages
…… PHYLUM ARTHROPODA (GO TO KEY TO CLASS)
10B Internal skeleton of cartilage or bone; two pairs of jointed appendages usually present
……. PHYLUM CHORDATA (GO TO KEY TO CLASS)

Key to the Classes of Phylum Arthropoda

1A Antennae absent; usually four pairs of walking legs
…… CLASS ARACHNIDA
1B Antennae present
…… 2

2A Two pairs of antennae; at least five pairs of walking legs; gills for respiration…… CLASS CRUSTACEA
2B One pair of antennae
…… 3

3A Usually three pairs of walking legs; wings usually present
…… CLASS INSECTA
3B Many pairs of walking legs; wings absent; most body segments similar
…… 4

4A Majority of segments with one pair of legs
…… CLASS CHILOPODA
4B Majority of segments with two pairs of legs
…… CLASS DIPLOPODA

Key to the Classes of Phylum Chordata and Subphylum Vertebrata

1A Fins present; respiration by gills throughout life
…… 2
1B Fins absent; respiration by gills during early stages of development or not at all
…… 3

2A Skin leathery; open gill slits, cartilaginous skeleton
…… CLASS CHONDRICHTHYES
2B Skin with overlapping scales; bony skeleton; operculum
…… CLASS OSTEICHTHYES

3A Skin smooth and moist
…… CLASS AMPHIBIA
3B Skin covered with scales, hair or feathers
…… 4

4A Skin covered with scales and/or bony plates
…… CLASS REPTILIA
4B Skin covered with feathers or hair
…… 5

5A Skin covered with feathers
…… CLASS AVES
5B Skin covered wholly or partly with hair; mammary glands present
…… CLASS MAMMALIA

Appendix D

Table 15.4 Extension

Species Drawing	Species Description	Number Seen

Species Drawing	Species Description	Number Seen