

Lab Manual for Environmental Science

Biology 1117



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Chemical Hazardous Waste:

Rules for Safe Handling in the Classroom

Products we use every day can be harmful to humans and the environment depending on their quantity, concentration, or physical, chemical or infectious condition when improperly treated, stored, transported, or disposed of, or otherwise managed inappropriately. The Minnesota Pollution Control Agency regulates the generation, storage and disposal of hazardous waste.

You are responsible to properly handle the chemical waste you generate:

1. **Always** put the wastes in the designated and labeled hazardous waste containers. Your instructor will show you the proper location in the laboratory for each type of waste generated.
2. **Never** mix one type of waste with another.
3. **Never** dispose of hazardous waste using sinks, intentional evaporation, or as regular trash. They are harmful for the environment and against the law. All campus laboratories must abide by strict Minnesota Pollution Control Agency and federal Environmental Protection Agency waste disposal requirements. You may be held liable for violations of applicable laws.
4. **Immediately report** any spills to the instructor or lab assistant.
5. **Remember**, simply because a waste is not hazardous does not mean it may go into a dumpster or drain. Other regulations may apply. Ask you instructor.

Hazardous waste includes many types of materials. They are categorized by state and federal laws. The categories are referred to as “list”. Examples that may be found on campus or in a classroom include:

- Toxic chemical products or spill residues that are unused or unusable. Some types are defined as “acutely hazardous” because they can be fatal to humans, even in small doses (P List). Other wastes in the category, although harmful, are not as toxic as P-listed waste (U List).
- “Characteristic hazardous wastes” exhibit characteristics such as ignitability, corrosivity, reactivity or toxicity (waste containing hazardous contaminants above maximum allowable concentrations) or lethality.

Hazardous wastes may be generated in laboratory courses such as these:

- Biology Art
- Chemistry Clinical Laboratory Science

What hazardous waste will I come in contact with in my academic program?

Your instructor will discuss specific hazardous wastes you may encounter in your class. Each type of hazardous waste is separately stored in a special container designed for that waste. Your classroom has containers for types of wastes you will generate in academic program.

What happens to the waste after it is put in the labeled waste containers?

From the classroom, the hazardous wastes typically are transferred to a holding location that has been identified by the college. Eventually, an authorized and licensed waste disposal facility will dispose of the waste. Each waste is separately disposed of in a way that prevents it from polluting the air, water, and land.

Additional Resources

- Campus Environmental Health and Safety Officer is Tom McCluney, Heritage Hall 103
- Campus Lab and Chemical Hygiene Officer is Jodi Schmelz, Heritage Hall 315.
- Minnesota Pollution Control Agency: www.pca.state.mn.us/waste/index.html
- Hazardous Waste Compliance Guide: www.pca.state.mn.us/publications/w-hw5-25.pdf
- Minnesota State Colleges and Universities
- Hazardous Waste Management Plan and additional resources:
www.firecenter.mnscu.edu/ehs/environmental/documents/Appendix1toAnnexK.pdf

Name: _____

Working With Data Pre-Lab Assignment

1. List the 4 types of graphs you will be working with in the lab:
 - a.
 - b.
 - c.
 - d.
2. For today's lab activity, will you be drawing your graphs by hand or with computer software?
3. What is the difference between a table and a graph?

Working With Data

OBJECTIVES:

- Explain the criteria used to determine the appropriate type for graph for different data sets.
- Demonstration of ability to prepare various types of data illustrations.
- Interpret data sets to draw conclusions.

An important component of science is

INTRODUCTION:

s the collection, illustration, and interpretation of data. Data are usually displayed in the forms of tables and graphs. Both are important! **Tables** display all of the raw data collected in an experiment in an orderly way, while graphs summarize the data in a visual way. **Graphs** (pictures) are often easier to interpret than tables (a list of numbers).

Both tables and graphs show the relationship between two variables. **Variables** are things that can change during the course of the experiment. The **independent variable** (also known as the experimental variable and the X-variable) is the thing that is manipulated by the experimenter. It causes or creates a response. The **dependent variable** (also known as the Y-variable) is the response to the independent variable; in other words, it is the effect. One way to remember this is that the dependent variable “depends upon” the independent variable.

Tables, such as the one shown below, provide all the data collected in a particular experiment. Tables allow this data to be displayed in an orderly way. The independent variable (in this example, year) is shown in the left-hand column, while the dependent variable (population size) is shown in the right-hand column. There is also a descriptive title, so that readers know what kind of data they are looking at. When appropriate, measurement units (such as cm, L, mph, etc.) should be included.

Human Population
Growth

Year	Population Size
1	170,000,000
1800	1,000,000,000
1930	2,000,000,000
1960	3,000,000,000
1975	4,000,000,000
1987	5,000,000,000
1999	6,000,000,000
2011	7,000,000,000

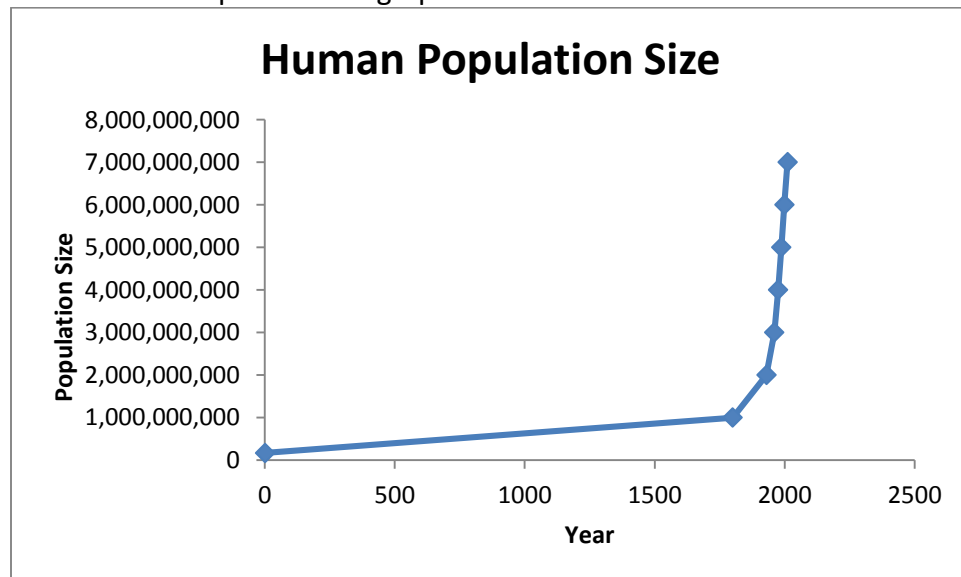
You should make it a habit to set up your data table before you start your experiments. Before your experiment you should know what your two variables are, as well as the values for your independent variable. Then you can fill in the values for the dependent variable as your experiment progresses.

There are many different types of graphs. For example, there are line graphs, bar graphs, pie charts, histograms, area graphs, scatterplots, etc. Not all graphs are appropriate for every data set! When illustrating your data it is essential to start by selecting the correct type of graph. The type of graph you should use depends primarily on the type of data you have. In this lab, we will focus on just the four types of graphs you are most likely to need to draw this semester. Keep in mind, though, that you may encounter other types of graphs in your textbook or lecture notes.

To decide what kind of graph to use for a particular data set, you need to begin by examining your independent variable. Your independent variable will either describe measurement data or categorical data. **Measurement data** consist of numbers (1995, 1996, 1997,...), while **categorical data** consist of discrete categories (fork, knife, or spoon). Your dependent variable will always be a number.

If your independent variable is a measurement, then you will either draw a line graph or a scatterplot. There are rules to follow to determine which one is appropriate. If the independent variable does not have repeats (for example, there is only one measurement taken per year), then you will draw a **line graph**. If, however, the independent variable does have repeats (for example, several measurements were taken each year), then you will instead draw a **scatterplot**.

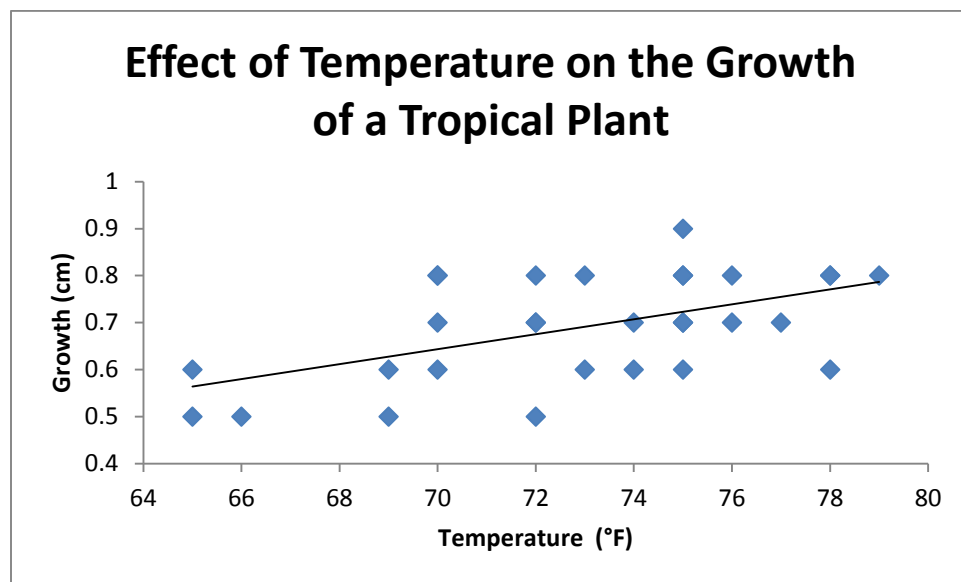
Here is an example of a line graph:



When drawing a line graph, you start by determining your x-axis and y-axis. The x-axis is the horizontal axis and is used to display the independent variable (this is why it is also known as the x-variable). The y-axis is the vertical axis and is used to display the dependent variable (y-variable). You then need to label each axis to indicate what variables are being studied, and include measurement units as appropriate. Next you need to mark off units along each axis, being careful to adjust the scale so that it is spaced out in a way that will be easy to read. Give your graph a descriptive title that lets the reader know what your experiment was about.

Now you are ready to plot your data! Plot each point by finding the correct value on your x-axis and then moving up until you reach the correct value on the y-axis, and then mark it with a dot. Once you are done marking all your data points, you draw a line connecting all the dots.

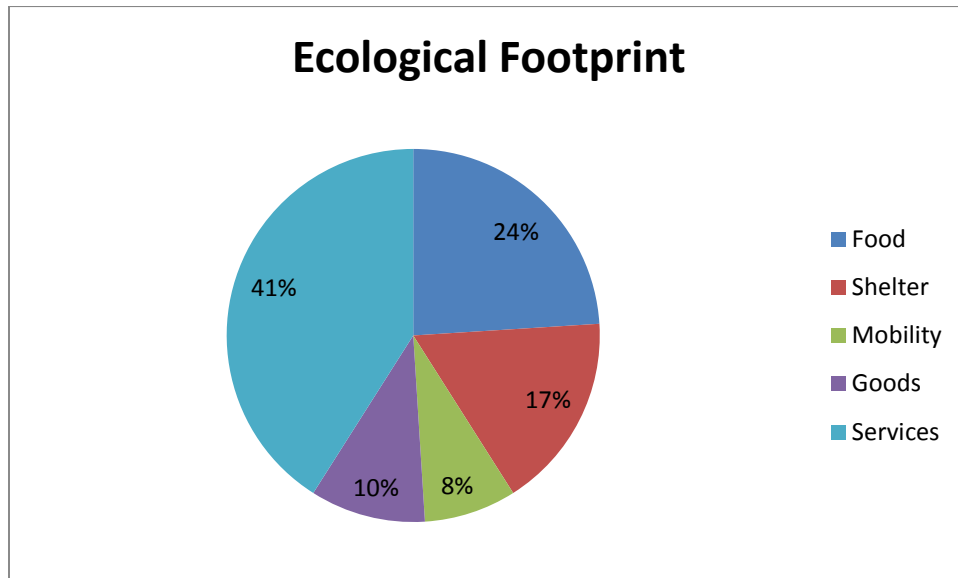
Now, here is an example of a scatterplot:



The steps to creating a scatterplot are almost identical to those of the line graph. However, here you cannot connect the dots with a line. Instead you can draw a **line of best fit** which passes through the center of the dots and shows the general trend of the graph.

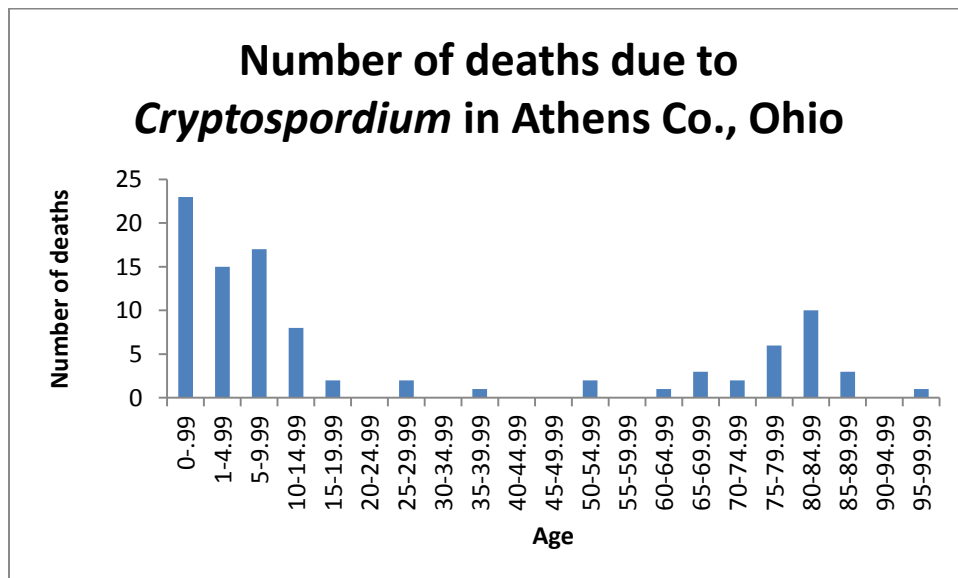
If your independent variable is a category, then you will either draw a pie chart or a bar graph. If your data can be displayed as parts of a whole or total, then you will draw a pie chart. Otherwise, you will draw a bar graph.

Here is an example of a pie chart:



One important thing to note about pie charts is that you do not set up your x-axis and y-axis as you do in other graph types. You do, however, need to include a **legend** that describes what each portion of the “pie” represents.

Finally, here is an example of a bar graph:



Sometimes you have to think very carefully about what kind of data you are working with. Here the independent variable (age) looks like numbers, so you might be tempted to make a line graph. However, the ages are grouped in to categories, so the bar graph is more appropriate.

When deciding on a graph type, you may find the flowchart on p. 206 in the Appendix to be helpful.

Once you've drawn your graph, you're still not done! Now you need to interpret your graph. In other words, you need to figure out what the data are telling you and what conclusions can be made. To start, you should state the relationship seen between the two variables. For example, in the line graph, we see that human population growth was slow from years 1 to 1800 and grew dramatically from 1800 to 2000. Next, draw conclusions (inferences) about the data. For example, we might infer that the Industrial Revolution in the 1800s led to a dramatic increase in human survival rates due to better sanitation and healthcare.

Sometimes in order to interpret the data, we need to extrapolate, or make projections. Perhaps I want to know what to expect the human population to look like in 2050. I can make a projection as to what it may look like by extending the line, following the trend, to the year 2050. This is known as **extrapolation**. It assumes that the current trend will continue, which may or may not occur. Typically, the extrapolation is shown as a dashed line.

Work with your group members to practice data interpretation using the graphs above.

1. Line graph (human population growth):

2. Scatterplot (effect of temperature on a tropical plant):

3. Pie chart (ecological footprint):

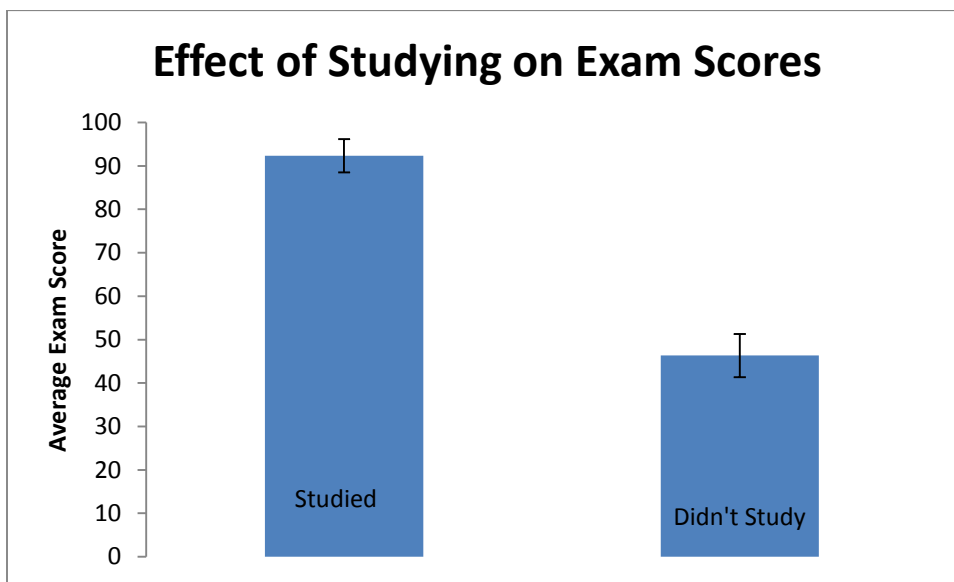
4. Bar graph (deaths due to *Cryptosporidium*):

Sometimes, we do not want to just graph all of our data points. It may be more informative to simply plot averages. Or we may need more information and include error bars. Therefore, we need to know a bit about descriptive statistics. It may be useful to determine the mean (average), range, standard deviation, and standard error of our data set.

To calculate the **mean** (average), simply add up all the numbers in the data set and divide by the total number of numbers. For example, if you had test scores of 93%, 98%, and 74%, what is your average test score? Add up 93, 98, and 74. Then divide that number by 3 (the total number of test scores).

Range refers to the lowest and highest values in the data set. In the example above, the range of test scores is 74%-98%.

Standard deviation refers to the average amount of variation from the mean in the data set. **Standard error** is a measurement that helps us determine how accurate our sample's mean is compared to the entire population's mean. Standard error is based on the standard deviation. Both standard deviation and standard error are typically calculated using spreadsheets or other computer programs. You will be provided with these spreadsheets when needed in future labs. Standard error is typically indicated as $\pm$ values (for example, 88.7 ± 7.3) or as error bars on a graph, as shown below.



ACTIVITY: Attached you will find data sets from various disciplines. For each data set, construct one illustration from the following types: bar, line, pie, and scatterplot. Divide up the 4 data sets so that each group member produces one graph using the provided graph paper. For this lab, you must draw your graphs by hand! Work with each other and use the information above to complete your graphs.

Don't forget to include a descriptive title for each graph, as well as appropriate axes labels, units, and legends as needed.

For each data set, you need to write a brief explanation as to why the graph type you chose was most appropriate. (For example, we chose to use a line graph because our independent variable was year, which is a measurement, and there was only one measurement taken each year).

Finally, for each data set, you must also interpret your graph. In other words, write a brief narrative of what the data is telling you. Describe any general trends or patterns you see, the relationship between the variables, and any outliers. You do not need to discuss every data point. Then draw some inferences about what the data means: what might have caused the relationship? what else may be true because of this relationship?

Feel free to ask your instructor for help and feedback as you work!

Data Set A - The Population of Juvenile Alligators in Lake Apopka After A Chemical Spill in 1980

Year	Number of Alligators, Size 30 to 120 Centimeters per Kilometer of Shoreline*
1980	23.5**
1981	12.0
1982	6.0
1983	3.0
1984	2.0
1985	2.0
1986	2.5
1987	2.5
1988	1.5
1989	0.5
1990	2.0
1991	4.0
1992	3.0

*Counts are adjusted for changes in water level.

** Chemical spill occurred just prior to the 1980 surveys

Source: Raven, Berg, Johnson, Environment, 1998.

Data Set B - The Cost of Regular-Grade Gasoline at the Pump From 1994-95

Country	Price per U.S. Gallon (\$)*
U.S.	1.24
Australia	1.74
Brazil	1.88
France	3.31
Germany	3.34
India	2.28
Japan	4.14
U.K.	2.86
Venezuela	0.18

Source: U.S. Bureau of the Census, 1996. Statistical Abstract of the U.S.: 1996, 116th ed., Washington, DC

*Price given in 1994 U.S. dollars

Data Set C - Major Gas Compositions of the Atmosphere*

Gas	Volume (%)
Nitrogen	78.000
Oxygen	21.000
Argon	00.930
Carbon Dioxide	00.035
Average atmosphere	100.00

*Percentages do not add up to 100 due to rounding, approximation, and ignoring water vapor and all minor and trace gases.

Data Set D - Relationship between Height and Weight

Subject	Height (inches)	Weight (lbs.)
A	67	125
B	69	173
C	65	122
D	70	172
E	69	152
F	72.5	180
G	68	115
H	70	180
I	62	103
J	62	115

Source: Biology 1115 lab, IHCC, 1999.

Name: _____

Scientific Method and Experimental Design Pre-Lab Assignment

1. Review the “Working with Data” lab. Use the information from that lab to define the following terms:
 - a. independent variable
 - b. dependent variable
 - c. graph
 - d. table
2. For today’s lab activity, what familiar object will you be working with?
3. What is a hypothesis?

Scientific Method and Experimental Design

OBJECTIVES:

- Understand how to use the scientific method in everyday life.
- Formulate hypotheses.
- Perform an experiment, analyze data, and draw conclusions based on experimental results.

INTRODUCTION:

Scientists study the world around them through a series of steps known as the **scientific method**. The series of steps are as follows:

- Observation
- Question
- Hypothesis
- Experiment
- Analysis
- Conclusion

Please note that different scientists and different textbooks may list this series of steps slightly differently than listed above.

The scientific method is a way of finding answers to questions. This is something that everyone does every day! For example, let's say that after class you head out to the parking lot to go home and discover that your car won't start. One of the first things you likely do is wonder about why your car won't start. Perhaps your battery is dead. Or there's an ignition problem. Or you're out of gas. Well, if you want to get home, you need to figure out which of these is the problem. So you try turning on your radio, check for a spark at the plug, or look at your gas gauge. You discover that your radio still works, there's an ignition spark, but your gas gauge reads "E". Now you know that you've run out of gas and need to put some in your car in order to get home. You've solved the problem. And you did it using the scientific method (even though you likely didn't realize it)!

- Observation—your car won't start
- Question—why won't it start?
- Hypothesis—dead battery, ignition problem, out of gas (you actually had 3 hypotheses in this case)
- Experiment—turn on radio, look for ignition spark, check gas gauge
- Analysis—radio works, ignition spark present, gas gauge reads "E"
- Conclusion—your car is out of gas

Let's work our way through the steps of the scientific method using another example.

Step 1: **Observation(s)**. I've noticed that after it rains in the summer, my lawn seems to grow a bit faster.

Step 2: **Question(s)**. What factors are affecting the growth of my lawn? Specifically, does the amount of water affect the growth of my lawn? Note that my specific question states my variables (go back to the previous lab if you need to review). Take a moment to underline the variables in my question, and determine which is the independent variable and which is the dependent variable.

"Does the amount of water affect the growth of my lawn?"

Independent variable:

Dependent variable:

Step 3: **Hypothesis (hypotheses)**. A hypothesis is sometimes described as an educated guess. It is your prediction as to what the answer to your question will be. Hypotheses are based upon previous knowledge and observations. There are multiple ways to write hypotheses. For this lab, we are going to write hypotheses as "if..., then...." statements, which will help ensure that our hypotheses include all the necessary information. The "if" part of the statement identifies the relationship you are studying. That is, it states your independent and dependent variables. For example, "If the amount of water is related to the growth of my lawn...". The "then" part of the statement is where you make your prediction as to what the relationship will be. For example, "then an increase in the amount of water will increase the growth of my lawn." Note that my prediction is very specific as to exactly what I think the relationship will be. Don't be vague in your hypotheses! Let's practice. For each of the following questions, write a hypothesis.

"Does chocolate affect the number of pimples acquired?"

"Does temperature affect the growth of bacteria?"

Step 4: **Experiment(s)**. The purpose of experiments is to test our hypotheses. To accurately test our hypotheses, we must think carefully about our **experimental design** before we start collecting our data. Some factors to consider include:

- control groups
- constants (controlled variables)
- group size
- quantitative vs. qualitative data
- repetition

Let's say that I test my hypothesis ("if the amount of water is related to the growth of my lawn, then an increase in the amount of water will increase the growth of my lawn") by simply watering my lawn with a sprinkler every day for a month, and after the month I conclude that my lawn grew faster. However, what if my neighbor's lawn grew just as fast even without extra water? I need to include a control group to my experimental design. A **control group** is a group that is not manipulated during the experiment and serves as a basis for comparison. The control group(s) is compared to the **experimental group(s)** which is manipulated during the experiment. In our example, my lawn that is getting extra water through the use of a sprinkler is the experimental group. A neighbor's lawn that is only getting water from rainfall is the control group.

We also need to consider other variables that might affect lawn growth. What if my lawn grew faster not because of extra water, but because it got more sunlight? In order to be able to draw a valid conclusion, we need to eliminate these other factors. These other factors need to remain the same throughout the experiment. These factors are referred as **constants** or **controlled variables**.

We already said that sunlight needs to be a constant (controlled variable). What other factors can you think of that should be kept constant in order to test our hypothesis? List at least 3.

- a.
- b.
- c.

There are a few other things we can do to increase the validity of our experiment. We should have a large group size. **Group size** refers to how many individuals are in our control group(s) and experimental group(s). By having large group size, we are able to reduce the impact of variations we forgot or are unable to keep constant. So instead of comparing just my lawn to my neighbor's lawn, I should compare several watered lawns to several unwatered lawns. We should measure quantitatively, not qualitatively. **Quantitative** data refers to numbers, whereas **qualitative** data consists of non-numerical data. Quantitative data is preferred as there is less **bias** with this type of data. Bias refers to a tendency or opinion, often based on preconceived ideas. Therefore we should measure the growth of our lawns with a ruler, as opposed to just saying that it looks longer (or greener). Please note that the metric system is used in science, so you should use the metric system whenever possible in this lab. Finally, we should repeat our

experiment. **Repetition** (also called **replication**) helps us ensure that our results are true.

Step 5: **Analysis (analyses)**. Once data has been collected, it needs to be analyzed. This can involve the use of statistics and generation of tables and graphs. Please refer to the “Working with Data” lab for more information.

Step 6: **Conclusion(s)**. Finally, we draw a conclusion about our hypotheses. Based on our data, we can either “accept” or “reject” our hypotheses. We can never “prove” a hypothesis, as other experiments and data may disprove it later. It is perfectly okay to reject a hypothesis. A rejected hypothesis is typically re-evaluated, and a revised hypothesis is tested.

ACTIVITY: Now that we've gone over the scientific method, it's time for you to practice it in small groups. We'll work with something we're already familiar with...paper airplanes!

Step 1: Observation

I've noticed that the design of paper airplanes affects the distance that they fly (observation).

Step 2 : Questions

What are some variables in the design of paper airplanes that might affect the distance flown?
List at least 3.

a.

b.

c.

These are independent variables. They cause a response. The dependent variable is the response. What is your dependent variable?

Step 3: Hypothesis

Select one of your independent variables to test. Write a hypothesis about the effect of your chosen variable on the dependent variable. Remember to use the *if....then...* format, and be specific in your prediction!

Step 4: Experiment

What is your control group?

What is your experimental group?

What are your constants (list at least 3)?

a.

b.

c.

Write out your experiment methods. In addition to a control group and constants, be sure to consider group size, type of data to collect, and repetition. Provide enough detail in your methods that I could replicate your test!

Step 5: Analysis

Provide both a table (raw data) and a graph of your results. Review the “Working with Data” lab if you’re not sure what type of graph to make. Also consider whether you might need to do some simple statistical analyses in order to present your data as simply as possible. Be sure to provide titles, label axes, units, etc. This should be a stand-alone document. I should be able to look at your results and understand your experiment without reading anything else in this document! Don’t forget to attach both your table and graph to your lab.

Step 6: Conclusion

Do you accept or reject your hypothesis? Why?

Why do you think you got the results that you did? Be detailed! Don’t just tell me (for example) that plane A flew further because it weighed more. Give me a reason as to why and how weight made a difference.

Name: _____

Range of Tolerance to Abiotic Factors Pre-Lab Assignment

1. Review the “Scientific Method and Experimental Design” lab. Use the information from that lab to define the following terms:

- a. control group
- b. experimental group
- c. constants (controlled variables)

2. What organism will you be working with in this lab? Read about it (use your textbook, the library, or a trustworthy website) and write a short paragraph about this organism. Focus your paragraph on information that might be useful to have in this lab.

3. Give an example of a biotic and an abiotic factor that you experience in your environment:

- a. biotic:
- b. abiotic:

Range of Tolerance to Abiotic Factors

OBJECTIVES:

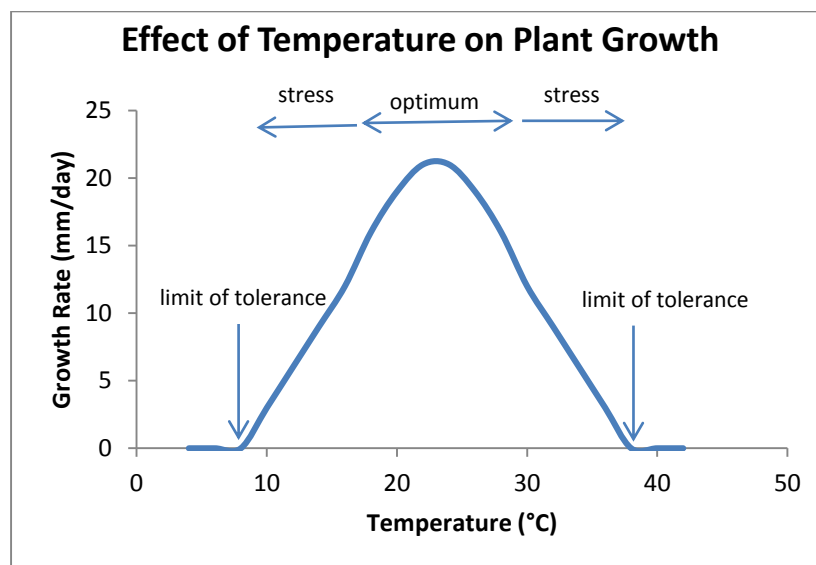
- Design and perform an environmental science experiment using the scientific method.
- Interpret data and draw conclusions.
- Understand the principles of limiting factors and range of tolerance.

INTRODUCTION:

Ecology is the field of biology devoted to study how organisms interact with each other and their surroundings. The surroundings, or environment, can be divided into two parts: the **biotic** (living) and **abiotic** (nonliving) components. Biotic refers to biological factors, while abiotic refers to chemical and physical factors. Both types of factors can affect an organism's survival, growth rate, and behavior.

In this lab, we will work with an organism known as *Daphnia*, or the water flea. *Daphnia* are small aquatic crustaceans commonly found in freshwater environments. *Daphnia*'s biotic (living) environment includes things like fish, bacteria, algae, and other *Daphnia*. Their abiotic (nonliving) environment includes things like temperature, pH, and salinity of the water.

We will focus on abiotic factors for this lab. The degree of the presence of an abiotic factor affects the ability of organisms to survive. Species have a **range of tolerance** to abiotic factors. They have an **optimal range** where all factors are available in right amounts. For example, in this graph below, the plant has the highest rate of growth at its optimal temperature range of 18-28 degrees Celsius.



Above or below that optimal range is a **zone of stress**—it is less than optimal but the organism can survive. You can see, for example, that in our picture, the plant is still growing when the temperature is 15 or 35 degrees Celsius, but the growth is much less than it is at 25 degrees Celsius. If conditions exceed those upper or lower limits (range of tolerance), the organism cannot survive. If it is much too cold (a frost perhaps) or too hot, our plant will die, as we see happening at 8 degrees Celsius and 38 degrees Celsius.

The factors, such as temperature (could also include things like water and food), that limit growth of an organism are called **limiting factors**. There is something called the law of limiting factors. This idea originally came from agriculture, but can also be applied to ecology. This law says that if any one factor (whether it be food, water, temperature, pH, or whatever!) is outside the optimal range, it will limit growth. In other words, one limiting factor (either too little or too much of it) can inhibit growth (or number of individuals, etc.).

ACTIVITY: In this lab you will use your knowledge of the scientific method, experimental design, and data illustration and interpretation to test a hypothesis to determine *Daphnia*'s range of tolerance to a certain abiotic factor. Please review the "Working with Data" and "Scientific Method and Experimental Design" labs as needed.

Some important considerations to keep in mind as you plan your experiment:

- *Daphnia* are extremely sensitive to chlorine in water. Use deionized water only (no regular tap water).
- Choose a range for your independent variable that will result in an effect (for example, too hot a temperature will kill your organisms, which may not be the effect you want to measure).
- A variety of materials will be available for you to use. While a few other materials may be available upon request, for the most part you will need to design your experiment using the provided materials only.
- Your experiment needs to work within the lab period; if you need more time, you will need to make arrangements to finish your experiment outside of our lab time. Keep in mind that if your experiment will take more than a day or two, you will need to aerate and feed your *Daphnia* to keep them alive.
- Give your organisms time to adjust to the environmental conditions; if you immediately measure you may get false results.
- Don't forget to repeat your experiment (a total of at least three or more trials is recommended).
- Ask your instructor if you need help!

1. Choose (circle one) which variable you want to investigate :
 - a. different temperatures
 - b. different salinities
 - c. different pHs
2. What is your independent variable? In other words, what factor will you be manipulating?
3. What is your dependent variable? In other words, what data will you be measuring? This is up to you...perhaps you want to measure heart rate, death rate, movement, or some other factor. Think carefully about what type of effect you think your chosen independent variable will actually have upon the *Daphnia*.
4. Write an appropriate hypothesis that predicts the relationship between your two variables.

5. Identify a control group for this experiment. Why did you choose it as a control group?

6. Identify your experimental group(s) for this experiment.

7. List at least three constants (controlled variables). Beside each, explain how you will keep them constant.
 - a.

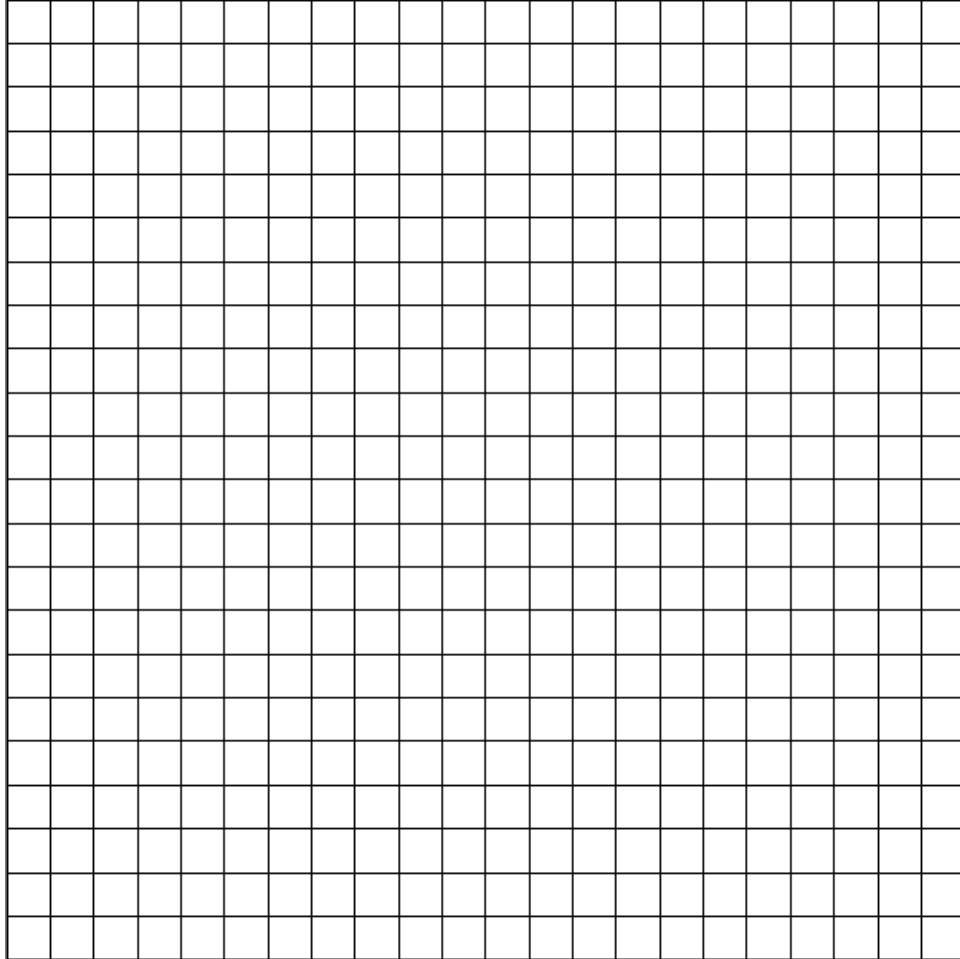
 - b.

 - c.

8. Write out the step-by-step procedure as you will perform it. Let your instructor approve it before you proceed! Use a separate sheet of paper if you need more space (just don't forget to attach it to the rest of your lab).

9. Design a table to organize your data. Remember that your table should include a descriptive title (which includes both variables and their relationship), labels, units, etc.

10. Prepare a graph of your data below. Remember that your graph should include a descriptive title (which includes both variables and their relationship), labels, units, etc.



11. Write a graph narrative. Describe patterns or trends in the data. Make sure you discuss important values in your graph (actual numbers), but don't tell me every number.

12. Based on your data, do your results agree or disagree with your hypothesis? Based on these results, do you accept or reject your hypothesis?

13. Explain why your results agreed or did not agree with your hypothesis. Justify your answer.

14. Write out two problems with your experiment. These may be problems with the set-up or design of the experiment, or may include how the experimental procedure was followed. Explain why each was considered a problem. Suggest a solution to each problem.

Name: _____

Analysis of a Wetland Ecosystem Pre-Lab Assignment

1. What kind of clothing and footwear should you wear for this lab?

2. Use your textbook, the internet, and library sources to answer the following questions.
 - a. Why are wetlands important?

 - b. What ecosystem functions do wetlands provide?

 - c. Why/how are wetlands being threatened?

3. List the sources of information you used to answer question #2.

Analysis of a Wetland Ecosystem

OBJECTIVES:

- Identify the local biotic and abiotic components that could influence quality of the wetland ecosystem
- Determine trophic (feeding) interactions within the wetland
- Assess the water quality of the wetland based on the invertebrate community

INTRODUCTION:

An **ecosystem** is a grouping of organisms (plants, animals and microbes) that occupy a defined unit of space and interact with each other and their environment.

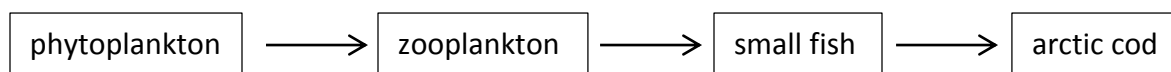
Ecosystems are described by their structure and the services they perform. The structure of an ecosystem is determined by the biotic (living) and abiotic (nonliving) components and the interactions of these components.

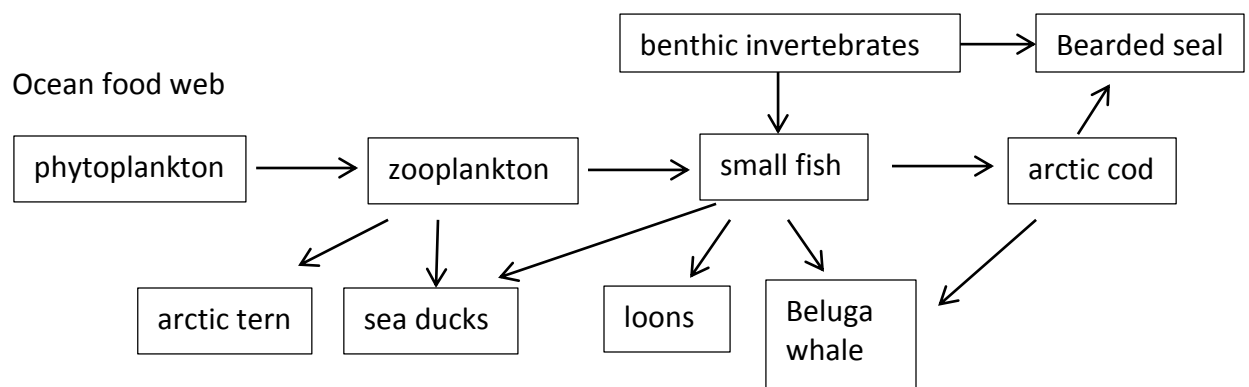
We often describe the biotic components of an ecosystem by describing their feeding relationships. We refer to this as **trophic structure** (the term trophic means feeding). There are different levels to trophic structure:

1. **Producers** (autotrophs) are organisms that get energy from sun or other abiotic material
2. **Consumers** (heterotrophs) are organisms that eat other organisms
 - a. **Primary consumers** (herbivores) feed directly on the producers
 - b. **Secondary consumers** (carnivores and omnivores) feed on the primary consumers
 - c. **Detritus feeders** eat dead plant and animal material and **decomposers** are things that we typically associate with rot

We can depict the relationships between trophic levels as **food chains** and **food webs**. As you can see in the examples below, food chains tend to be more simplistic and food webs are more realistic.

Ocean food chain





The **abiotic** components are the basic inorganic and organic compounds of the environment. It includes energy sources and matter. Almost all energy initially comes from the sun. Producers capture this energy and store it in the bonds formed between different atoms (matter). Energy flows through the ecosystems and is lost along the way as heat when bonds are broken, while matter is continually recycled.

ACTIVITY: In this laboratory, you will be asked to examine an ecosystem and identify as many components as possible. To aid you in identifying biotic organisms, simple keys to the plant and animal kingdom are provided. For this outdoor lab, you must follow all safety precautions and dress appropriately for field work. You need to wear sturdy, closed-toed shoes and long pants/skirt. Ecologists often work in adverse weather conditions, so be sure to wear clothes appropriate to the weather (jacket, raincoat, etc.) and that can get wet and dirty.

OUTDOOR PROCEDURE

Location: Small wetland just west of the fine arts building

Group equipment needed: This lab with clipboard, dip net, plankton net, three sample jars, waders (optional but encouraged).

Procedure:

1. Collect multiple dip net samples from one end of the wetland. Samples should be collected in the shallow, near-shore area not deeper than 3 feet. Use strong strokes to sweep the net through the water towards you about 3-5 times.
2. Evert all of the net contents into one of your sample jars.
3. Repeat steps 1-2 at the other end of the wetland.
4. Throw the plankton nets multiple times into areas without duckweed and put into your other sample jar.
5. Answer the questions below before returning to the lab.

Observations

1. Describe the wetland. This includes a drawing showing the shape and any other major items you want to emphasize such as storm water drainage pipes, aquatic plant beds, areas covered in duckweed, nearby parking lots, etc. What kind of landscape surrounds the wetland (forest, prairie, mowed areas, other wetlands, etc.)? Do you see any evidence of disturbances to this wetland or to the surrounding landscape? If so, what kinds of disturbances are they? Is this wetland is natural or dug by humans?

2. Look around the wetland. List some different sources of energy/matter that would naturally be available to this ecosystem.

3. List some different sources of matter/energy that are due to anthropogenic (human) influences (remember matter can be things like beer bottles and sand).

INDOOR PROCEDURE

1. Set up a dissecting scope with a Petri dish to hold the organisms.
2. Dump out your dip net sample into a sorting tray. Sort through your sample and separate (using forceps) the invertebrates from the duckweed and muck. Place the invertebrates into a Petri dish.
3. Pour some of the plankton sample into another Petri dish.
4. Get a copy of the yellow freshwater invertebrate key.
5. Using the scope and the key (pages 88-187 are the most useful) identify your specimens.
6. Once they are identified fill out the table below.
7. Complete the essay at the end of the lab.
8. Clean up your lab station as directed. Do NOT pour your samples down the sink drains!

The table on the next page can be filled out using the information available in the yellow key. Some of the organisms we typically find include:

- mosquito larvae
- phantom midges
- *Daphnia*
- copepods
- pygmy backswimmers
- springtails
- physid snails
- scuds/sideswimmers
- water boatmen
- backswimmers
- predaceous diving beetles
- water scavenging beetles

For the abundance column, please use your observations about how many you found in your samples (not what the key states about abundance throughout North America). After reading the key, please ask your instructor if you need help determining the trophic level or stress tolerance of an organism.

Common name	Abundance rare, common, very abundant, etc.	Trophic level producer, herbivore, carnivore/predator, decomposer	Stress tolerance very sensitive, facultative, etc.

Draw a food web based on the species you collected and other organisms that are likely present, such as turtles, frogs, ducks, bacteria, etc. There are not any fish in this wetland. Hint: the base of the food web should be duckweed, algae, and dead leaves (detritus).

Read pages 53-55 in the yellow key. Write a paragraph that makes a conclusion about the water quality of this wetland based on the abundance and stress tolerance of the organisms you found. Be sure to refer back to your data (the organisms) and the observations you made about natural and anthropogenic inputs. This wetland is obviously not without human impact; offer some suggestions on how the water quality could be improved.

Name: _____

Natural Selection in Peppered Moths Pre-Lab Assignment

1. Define the term “natural selection”.
2. What is “industrial melanism”?
3. What material are our peppered moths made out of?

Natural Selection in Peppered Moths

OBJECTIVES:

- Explain how natural selection causes populations to change
- Describe the importance of coloration in avoiding predation
- Relate changes in the environment to changes in populations of organisms

INTRODUCTION:

The ideas of natural selection and adaptation are among the most important ideas in biology. Natural selection is a key mechanism of **evolution**.

Natural selection is the gradual process by which heritable biological traits become either more or less common in a population as the result of the effect of inherited traits on the **differential reproductive success** of organisms interacting with their environment. In other words, natural selection refers to the fact that the fittest individuals are able to survive and have more offspring, passing their traits to their offspring. Individuals that are less fit have fewer offspring, so their traits are less represented in the next generation. **Fitness** refers to the ability to survive and reproduce.

Variation exists within all populations of organisms. Individuals with certain variants of a trait may survive and reproduce more than individuals with other, less successful, variants. Therefore the population evolves. Over time, this process can result in populations that specialize for particular ecological niches and may eventually result in the emergence of new species. In other words, natural selection is an important process (though not the only process) by which evolution takes place within a population of organisms.

Industrial melanism refers to the adaptation of a population in response to pollution. One famous example of industrial melanism occurred in a population of peppered moths in England during the Industrial Revolution (mid-to-late 19th century). Prior to the Industrial Revolution, the trunks of the trees were light grayish-green, due to the presence of lichens. Most of the peppered moths were light gray with dark spots. During the Industrial Revolution, the trunks of the trees turned dark, due to deposits of soot. During this same period, there was a shift in the variety of peppered moths, with the dark moths becoming more common.



ACTIVITY:

You will work in pairs to simulate the processes of natural selection and industrial melanism in peppered moths. One person will be the “predator” and the other person will arrange the “prey” (paper cut-outs) and track time.

1. Write a hypothesis predicting which variety of peppered moths will be most prevalent after natural selection acts upon the light colored background.
2. The predator should turn around while the prey are being placed on the background. Five (5) moths of each color (10 moths total) should be randomly placed on the background.
3. The predator will then have 6 seconds to remove the moths. Predators may only remove one moth at a time, using their thumb and forefinger as a “beak”.
4. Count the number of each color of moth remaining on the background. These are the survivors. Record these numbers in Table 1 as the Generation 1 survivors.
5. Each of the surviving moths now reproduces. Each moth has 2 offspring that are identical to their parent. Again, the predator should turn around while the prey (survivors and offspring) are being randomly placed on the background. (If any moths were bent in step 3, be sure to flatten them back out).
6. Repeat steps 3-5 for the second generation of moths and record the survivors in Table 1. Each survivor from the second generations also has two identical offspring.
7. Repeat the procedure for a third generation of moths and record the survivors in Table 1.
8. Complete Table 2, determining the ratio of light to dark moths, and the percentage of light and dark moths in each generation.
9. Write a hypothesis predicting which variety of peppered moths will be most prevalent after natural selection acts upon the dark colored background.
10. Repeat the procedure as described above, but using the dark background instead. Record your results in Tables 3 and 4.

11. Write a hypothesis predicting which variety of peppered moths will be most prevalent after natural selection acts upon the medium colored background.

12. Repeat the procedure as described above, but using the medium background instead. Record your results in Tables 5 and 6.

Table 1. Moth Survival on Light Background

Number of Moths	Light Variant	Dark Variant
Original Population	5	5
Generation 1 Survivors		
Generation 2 Survivors		
Generation 3 Survivors		

Table 2. Proportion of Moth Variations Across Generations on Light Background

Number of Moths at Start of Each Generation	Light Variant	Dark Variant	Ratio of Light: Dark Moths	% Light Moths	% Dark Moths
Generation 1	5	5	1:1	50%	50%
Generation 2					
Generation 3					

Table 3. Moth Survival on Dark Background

Number of Moths	Light Variant	Dark Variant
Original Population	5	5
Generation 1 Survivors		
Generation 2 Survivors		
Generation 3 Survivors		

Table 4. Proportion of Moth Variations Across Generations on Dark Background

Number of Moths at Start of Each Generation	Light Variant	Dark Variant	Ratio of Light: Dark Moths	% Light Moths	% Dark Moths
Generation 1	5	5	1:1	50%	50%
Generation 2					
Generation 3					

Table 5. Moth Survival on Medium Background

Number of Moths	Light Variant	Dark Variant
Original Population	5	5
Generation 1 Survivors		
Generation 2 Survivors		
Generation 3 Survivors		

Table 6. Proportion of Moth Variations Across Generations on Medium Background

Number of Moths at Start of Each Generation	Light Variant	Dark Variant	Ratio of Light: Dark Moths	% Light Moths	% Dark Moths
Generation 1	5	5	1:1	50%	50%
Generation 2					
Generation 3					

13. What can you conclude, based upon your experimental results, about how prey are selected by predators?
14. What moth coloration is best adapted for a light background? How do you know?
15. What moth coloration is best adapted for a dark background? How do you know?
16. What moth coloration is best adapted for a medium background? How do you know?
17. Are the light and dark colored moths from the same species or are they from different species? How can you tell?
18. Write a short paragraph explaining how this experiment is an example of evolution by means of natural selection.

19. What would need to happen in the environment (what changes would need to occur) in order for the moth population to shift from mostly dark variants back to mostly light variants?

There has been some controversy concerning the methodology used in the original studies of industrial melanism in peppered moths. However, better air pollution control methods in England have reduced the amount of soot on trees and lichens have grown back. As the hypothesis predicts, the light colored variation of peppered moths have also become more common.

Name: _____

Plant and Animal Adaptations Pre-Lab Assignment

1. What are the four major parts of natural selection? (Hint: you may find video #4: “How Does Evolution Really Work?” found at <http://www.pbs.org/wgbh/evolution/educators/teachstuds/svideos.html> to be a helpful resource).

2. Briefly explain how natural selection leads to evolutionary adaptations. Use your textbook, lecture notes, and the “Natural Selection in Peppered Moths” as references.

3. Why must you be careful when handling the specimens in this lab?

Plant and Animal Adaptations

OBJECTIVES:

- Appreciate the power of adaptation in the generation of biological diversity
- Understand how adaptation leads in increased survival and reproduction in a wide variety of organisms
- Use observations about organisms to make predictions

INTRODUCTION:

An **adaptation** is a heritable trait that replaces other variants by means of selection for greater **fitness** (reproductive success). In other words, adaptations are features that allow organisms to be better suited to the conditions of their environment, increasing their chances of survival and reproduction. Adaptations arise through the process of natural selection, and are found in all species.

Adaptations can take many forms. Plants and animals vary in coloration, for example, with some being very bright and others being very dull (or drab). Advertising coloration is used to get someone's attention. There is also deceptive coloration, which may be used to fool a predator or prey. There are two broad categories of deceptive coloration: camouflage and mimicry. Camouflage helps an organism blend in to its surroundings. Mimicry helps an organism look another organism. (There is sometimes a fine line between camouflage and mimicry).

Adaptations are not limited to coloration. Some other examples include variations in bone structures, skeleton types and teeth in animals, and the wide variety of seed types in plants. Anything that gives an organism a better chance of survival and reproduction can be considered to be an adaptation.

It should be pointed out that adaptations merely increase the likelihood of survival and reproduction. They do not mean that organisms are perfect, as natural selection can only "work" with the variations present in the population (it can only "edit" what already exists; it cannot create new features from scratch). Additionally, adaptations are often compromises. For example, the flexibility of your wrist allows you to do many things. However, it also means that this joint is more prone to sprains and strains.

As natural selection shapes and molds organisms to their environment, we see the evolution of adaptations and tremendous amounts of biological diversity.

ACTIVITY:

Work your way through the stations in any order. You are welcome (and encouraged) to pick up and move the specimens, but please handle them gently. These are real bones, skins, and seeds, and many of them are rather old and fragile. As you answer the questions, use your observations and previous knowledge to generate answers that would be considered reasonable. Be sure to write in complete sentences and fully explain and justify your answers.

Station 1: Coloration

1. Zebra stripes are an example of camouflage. What advantages do the stripes provide?
2. What are two different outcomes that mimicry can accomplish? In other words, what would you “want” to look like?
3. Some butterflies and fish have “eye spots” on their wings and fins. These are not true eyes; they just look like eyes. What is the advantage of these?
4. Many animals (some birds, fish, squirrels) have dark coloration on their backside and light coloration on their underside. What is the advantage of this coloration?
5. Why are the males of many birds brightly colored, while the females are not?
6. Why are some frogs in the tropics brightly colored (they stand out)?
7. What are the advantages of colored fruit and flowers?

Station 2: Mammal skulls and feeding

8. Describe the different shapes of teeth. What does each type of tooth seem to be good for (gnawing, ripping, eating insects, etc.)?

9. Teeth can be group into incisors, canines, premolars and molars. What are the most prominent types found in insectivores, rodents, carnivores and herbivores? Put the animals (skulls) into each group to help you with this question.

10. What is the difference in the jaw movements between herbivores and carnivores? How does this translate into how (and what) they eat?

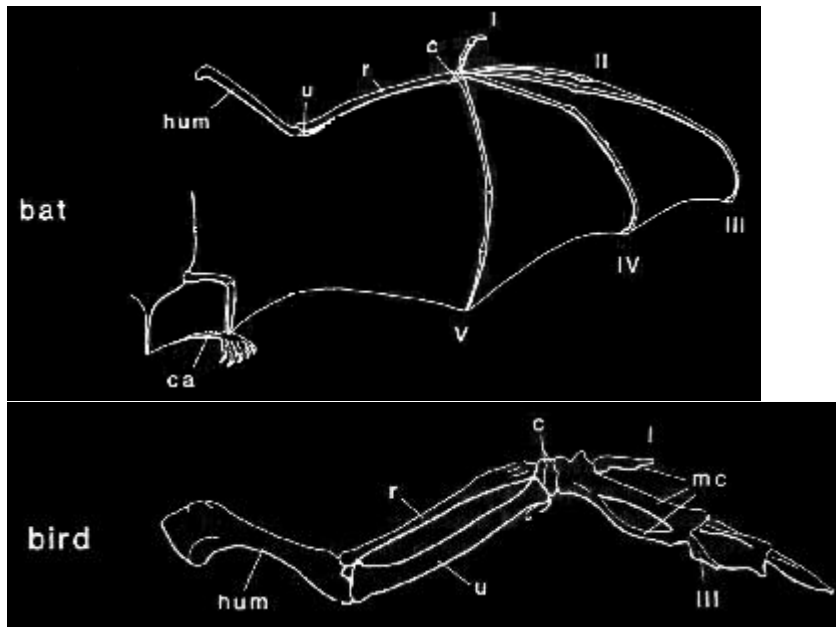
Station 3: Snakes

It is widely believed that snakes evolved from a burrowing lizard. After spending much time underground some started to re-emerge, giving rise to the snakes we have today.

11. What traits of snakes would indicate a life underground? What advantages do these traits provide?

Station 4: Birds and bats

Both birds and bats can fly, but they evolved the trait at different times.



12. Describe the differences in the anatomy (bone location) between a bird and bat wing. Describe the similarities. What is an adaptive advantage of flying?

Station 5: Horseshoe crabs

13. What are some advantages and disadvantages to having an exoskeleton? Look at the horseshoe crab specimens to help you answer.

Station 6: Plants

14. Describe the different types of dispersal adaptations from the specimens in lab.
15. Jack pine cones usually do not open unless they are broken by fire. What is the advantage of this?
16. Why would plants make seeds that are edible? Describe the differences in dispersal between a grape, orange, and oak.
17. Which will travel further, the burdock or the maple seed? What are advantages for traveling further? For staying near the parent?
18. What is the advantage of producing only a few seeds (equilibrial/K-selected species)? For producing many (opportunistic/r-selected species)?
19. Why is the coconut so big? Why does it have a strong husk?
20. Is a potato a seed? What are the advantages and disadvantages to producing plants this way?

Name: _____

Predator-Prey Relationships Pre-Lab Assignment

1. List the three organisms we will be studying in this lab. Which are predators and which are prey?
2. What steps should you take to avoid breaking the aquarium heaters?
3. What is an owl pellet?

Predator-Prey Relationships

OBJECTIVES:

- Analyze and construct a food web using owl pellets
- Generate hypotheses regarding predator-prey relationships
- Explore predator-prey relationships in terrestrial and aquatic ecosystems

INTRODUCTION:

Organisms interact with other organisms (biotic) and their surroundings (abiotic). Organisms interact with individuals of their own species; all of these individuals make up a population. Organisms may interact with other organism of other species. All of these organisms together make up a **community**. A community is a collection of different populations living together in the same area. The organisms that make up a community interact with each other in a variety of ways. These relationships include predator-prey, host-parasite, mutualisms, competitive, and commensal.

In this lab, we will focus on the community interaction of that between a **predator** and its **prey**. A predator (a snake, for example) eats prey (frogs, for example). A predator may have several different types of prey, and similarly prey may be eaten by several different predators. This is why, as we saw in the Analysis of a Wetland Ecosystem lab, food webs are generally quite complex!

ACTIVITY 1: OWL PELLETS

Owls are top level consumers in many terrestrial ecosystems. They prey on a wide variety of small animals, particularly rodents and small birds. Owls swallow their food whole, and parts (such as bones, fur, and feathers) that cannot be digested are regurgitated in the form of a pellet. Depending on the owl, one or two pellets may be produced per day.

In this activity, you will examine the contents of a pellet to determine how many prey an owl eats in a year and to construct a food web based on the organisms found in your pellet and those of your classmates.

1. Cover your lab bench with the white paper from the provided roll. This paper serves two purposes: 1) it makes clean-up easier and 2) it makes it easier for you to see and label your bones.
2. Wear gloves! Unwrap your pellet and examine it. Describe the outside of your pellet. Do you see any fur or feathers?
3. Use forceps and dissecting probes to carefully extract all of the bones from the pellet. If you are having trouble, try soaking your pellet in a beaker of water for about 20 minutes to soften it. When you are done soaking, carefully drain the pellet and water through a couple of layers of cheesecloth so that you don't lose any bones. As you work, try to keep the bones from different animals together and separate from other animals.
4. Use the provided keys to identify what species your bones represent. Start by examining and separating skulls (if you find two skulls that means your pellet contains two animals). If a skull has a beak, it must be a bird. If a skull has teeth, it must be a rodent. Then use the keys to try to determine which of the other bones belong to each skull.
5. Complete the table below. Then add your data to the class table on the board.

Owl Pellet Contents: Individual Data

Species	Number of Individuals

6. Use the class table on the board to complete the table below. Also record the number of pellets dissected by your class: _____

Owl Pellet Contents: Group Data

Species	Number of Individuals

7. Use the information in #6 to construct a food web. You should also use other knowledge you have about these species (for example, what do the prey eat?) to complete your food web. Refer to the Analysis of a Wetland Ecosystem lab if you need to review how to construct a food web.

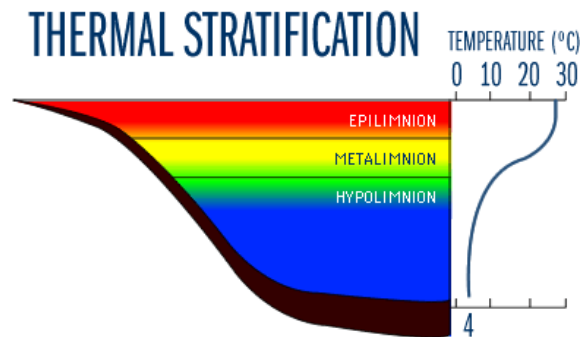
8. Based on the class data (#6), how many of each prey animal would you expect a single owl to consume in a year. Show your work!

9. If you were a farmer, how would you feel about the presence of owls on your property? Explain/defend your answer.

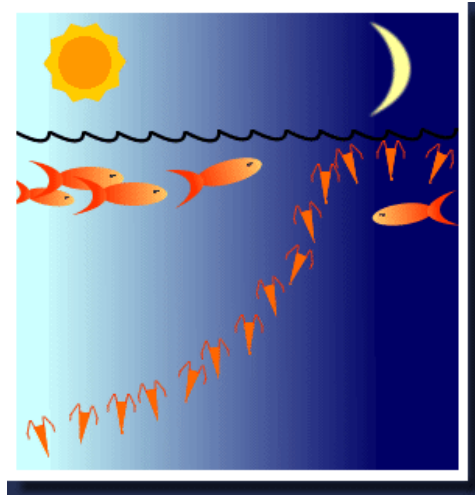
ACTIVITY 2: EFFECT OF TEMPERATURE ON PREDATOR-PREY INTERACTIONS

In this activity, we will look at the effect of a predator (*Chaoborus*, the phantom midge) on its prey (*Daphnia*, the water flea). We will specifically look at the effect temperature stratification, seen in many lakes, on the relationship between this predator and prey.

In many temperate lakes (such as those in Minnesota), there is **thermal stratification** in the summer months. Cold water is denser, so it sinks to the bottom of the lake, and warm water floats on top.



Daphnia feed on algae, which is found in the upper levels of the lake (where light is abundant for photosynthesis). *Daphnia* also grows more quickly in the warmer waters than in cold water. However, there is a trade-off to being in these upper waters. Visual predators (such as fish and *Chaoborus*) can see you! So *Daphnia* exhibit a behavior known as **diel vertical migration** (DVM).



They compromise if predators, such as fish, are present. *Daphnia* can detect pheromones (chemical “scents”) produced by fish. If fish are present, then during the day, we would expect *Daphnia* to remain in the cold and dark layers of the lake. At night, we would expect *Daphnia* to rise to the warm layers of the lake to feed. And then they would return to the bottom of the lake as morning approaches.

Part I: *Daphnia* only

Fill the graduated cylinder with distilled water (regular tap water contains chlorine, which will kill the organisms). Collect several *Daphnia* from the appropriate beaker, and add them to the cylinder. Then set the cylinder in bin filled with ice and water; this will help simulate the cold layers of the lake. Ideally, we would let this layer get to about 8-12 deg C. Set up the aquarium heater at the top of the cylinder; this will simulate the upper warm layer of the lake. Ideally, we want this layer at about 25 deg C. [Please be careful with the aquarium heaters, so they do not break. Plug the heaters in only when in water, and don't set a hot heater on a cold surface.] Wait for the temperature gradient to be established. While you wait, answer question #1. Then check the temperatures of your "lake's" layers and observe where the *Daphnia* are found. Complete questions 2 and 3. Then return your *Daphnia* to the appropriate beaker, and move on to Part II.

1. In this set-up, *Chaoborus* is not present. Write a hypothesis that predicts where the *Daphnia* will be found (which layer). Why do you predict the *Daphnia* will be found in this layer?

2. Draw a picture of your graduated cylinder. Indicate the temperatures (deg C) at the bottom, middle, and top of the cylinder. Use an "x" to make the location of each of your *Daphnia*.

3. Were the *Daphnia* in the layer you predicted them to be? If not, provide a possible explanation for their actual location.

Part II: *Chaoborus* only

Repeat the same procedure from Part I, only this time use *Chaoborus* instead of *Daphnia*. Then return your *Chaoborus* to the appropriate beaker, and move on to Part III.

4. Write a hypothesis that predicts where the *Chaoborus* will be found (which layer). Why do you predict the *Chaoborus* will be found in this layer?
5. Draw a picture of your graduated cylinder. Indicate the temperatures (deg C) at the bottom, middle, and top of the cylinder. Use an “o” to make the location of each of your *Chaoborus*.
6. Were the *Chaoborus* in the layer you predicted them to be? If not, provide a possible explanation for their actual location.

Part III: *Daphnia* and *Chaoborus* together

7. Write a hypothesis that predicts what the *Daphnia* will do if added to the cylinder that contains *Chaoborus*. Why is this a reasonable prediction?

8. Write a hypothesis that predicts what the *Chaoborus* will do if *Daphnia* added to the cylinder that contains *Chaoborus*. Why is this a reasonable prediction?

Remove the aquarium heater. [Please be careful, do not set a hot heater on a cold surface...it will likely break.] Add several *Daphnia* and several *Chaoborus* to the cylinder. Observe what happens (where each organism goes). Immediately after obtaining your results, separate the organisms and return them to the appropriate beaker. Do not allow the *Chaoborus* to eat the *Daphnia* "just for fun". Other students need to use these organisms this week. If you carelessly let the *Daphnia* get eaten after obtaining your results, you will be responsible for collecting and separating out more!

Clean up the rest of your supplies, and answer the following questions.

9. Draw a picture of your graduated cylinder. Indicate the temperatures (deg C) at the bottom, middle, and top of the cylinder. Use an "x" to make the location of each of your *Daphnia*. Use an "o" to make the location of each of your *Chaoborus*.

10. Why do each think each organism was found where it was?

Name: _____

Community Interactions: Goldenrod Galls Pre-Lab Assignment

1. You will be outside in winter for about a half hour during each of the two sessions. What kind of clothing and footwear should you wear for this lab?

2. Watch the first 14 minutes of the film “Goldenrod and Gallfly”. It is produced by the Abrahamson lab at Bucknell University. It can be accessed at:

http://www.facstaff.bucknell.edu/abrahmsn/solidago/gallfly_video.html

- a. What is a Goldenrod?
- b. What is a midgefly or gallfly?
- c. List 4 different animals that can attack the midgefly (gallfly) larva.
- d. What does the midge fly larva dig a tunnel?
- e. What time of year do the following events occur?
 - Adult midge fly lays its eggs:
 - Egg turns into larva:
 - Larva turns into a pupa and goes through metamorphosis:
 - Adult midge fly emerges:

Community Interactions: Goldenrod Galls

OBJECTIVES:

- Practice the scientific method, by creating with your own hypothesis, designing your own experiment, collecting data, graphing and summarizing your results.
- Understand community ecology concepts regarding species interactions, specifically those of parasitism and predation
- Understand the lifecycle of midge fly, wasps and beetle and how they relate to the goldenrod plant described in the exercise.

INTRODUCTION:

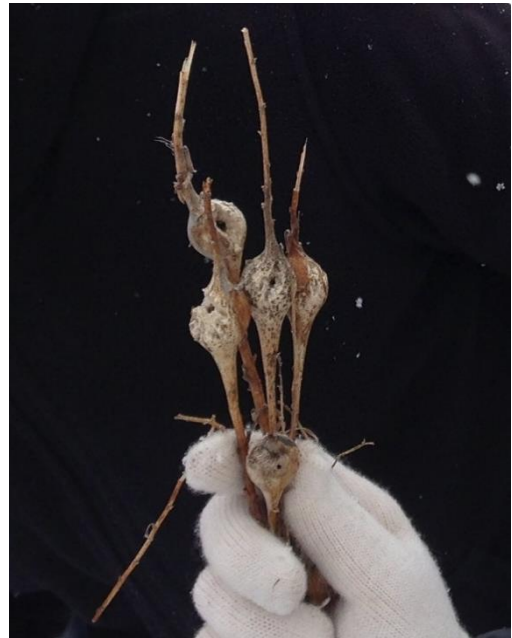
Our goldenrod gall lab is an exercise in making observations, forming a hypothesis, recording data, graphing, and summarizing and interpreting data. This model uses goldenrod galls as a study system to understand community ecological relationships between species, particularly relationships of parasitism and predation (+/-).

This is a two part lab. In the first lab, we will collect, measure, dissect and observe galls and their contents. Each lab group will then design their own experiment. During the second lab, students will carry out the experiments they designed.

RESOURCES:

Your instructor may show the first 14 minutes of the film “Goldenrod and Gallfly” or it may be part of your prelab. It is produced by the Abrahamson lab at Bucknell University. It can be accessed at:

http://www.facstaff.bucknell.edu/abrahmsn/solidago/gallfly_video.html



PLAYERS IN THE STORY OF THE GOLDENROD GALL:

Canadian Goldenrod (*Solidago Canadensis*)

Midge Fly (*Eurosta solidagnis*)

Wasp (*Eurytoma gigantea*)

Wasp (*Eurotoma obtusiventris*)

Beetle (*Modellistna convicta* or *Modellistna unicolor*)

Downy Woodpecker (*Picoides pubescens*)

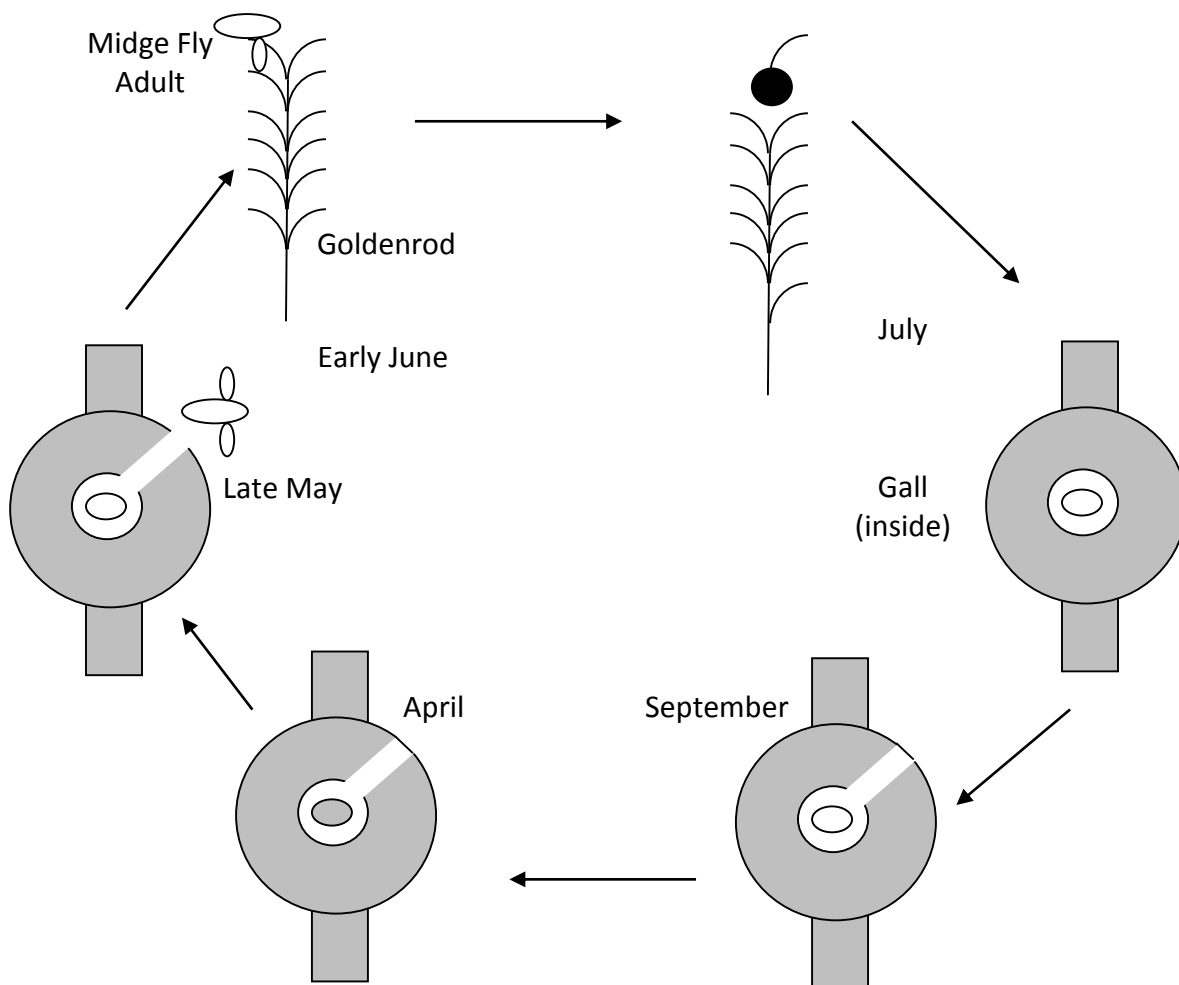
Black-capped Chickadee (*Poecile atricapillus*)

MIDGE FLY (GALL FLY) LIFECYCLE:

The lifecycle of many insects is similar to that of the familiar butterfly. An adult lays an **egg**, which hatches and becomes a **larva** (caterpillar in the case of butterflies), which forms a **pupa** (chrysalis in the case of butterflies), where the insect undergoes **metamorphosis** and **emerges** as an **adult**.

In the specific case of the midge fly, the adult female layer her egg on the goldenrod plant in late May or early June. Usually within a week, the egg hatches into a larva which eats some of the plant stem. The goldenrod plant responds by growing more plant tissue (a **gall**) around the larva. The larva eats away a small space within the gall, a **chamber**. In September, it tunnels a hole toward the outside of the gall, but not all the way through it. This tunnel will allow the insect to escape the gall as an adult in spring. In October and November, the larva enters diapause, or resting stage. Throughout winter, the larva is 4-6mm long, crème colored and barrel shaped. In April, it turns into a pupa, which has a hard, brown case. Metamorphosis occurs and the adult emerges from the pupa in May or June. It crawls up its pre-formed **exit tunnel** and cuts through the thin outer membrane to exit the gall. It then mates and begins the life cycle again.

Label the following diagram with it with information and dates from above to help you remember key points and terms.



MIDGE FLY LIFE CYCLE IS DISTURBED:

There are five other players that can disturb the midge fly lifecycle. They fit into two main categories, predators and parasites.

Predators:

Birds: Two species of attack the gall in order to eat the larva.

- **Downy woodpeckers** makes a small (3-8mm) tidy conical hole
- **Black-capped chickadees** makes a large irregular hole with bits of gall torn away.

Beetle:

- A **beetle** species (*Modellistena unicolor*) lays their eggs into the gall in July. The beetle tunnels around eating plant material. Sometimes it finds a midge fly larva, in which case it will eat it. Both beetle and midge fly could be found together. The beetle forms a pupa in May and emerges in June, using the midge fly's exit tunnel.

Parasites:

Wasps: Two wasp parasites can infect the midge larva.

- ***Eurytoma obtusiventris*** wasps lay their eggs *on* the midge fly egg or larva *before* the gall forms. The wasp larva actually hatches within the midge fly larva! The midge fly larva is then the host to the wasp parasite. The wasp larva causes the midge larva to pupate early, in the fall. The wasp larva develops within the fly pupa case. In this case, you would usually find a brown resinous substance inside the gall. The wasp pupates inside the fly pupa in May and emerges in June. The adult wasp gnaws its way out the exit tunnel that the fly larva made.
- ***Eurytoma gigantea*** wasps lay their eggs between June and August in full size galls near the host larva. The wasp larva hatches and eats the host and some of the gall tissue. 10% emerge right away in late summer. 90% of these wasps overwinter in the gall, pupate and emerges early the following summer.

QUESTIONS ABOUT DISTURBANCES TO THE MIDGE FLY CYCLE

1. In an undisturbed gall, when do each of the following occur:
Egg layed:
Larva hatched:
Pupa forms:
Adult emerges:
2. Which species predaes the midge larva and leaves a clean conical hole?
3. Which species predaes the midge larva and leaves a messy, chunky, larger hole?
4. Which species lays its egg into the gall and sometimes 'finds' and eats the midge larva?
5. Which species causes the midge fly to pupate early and then lives 'inside' the larvae?
6. Which species *could* leave a perfect exit hole by late summer of the first year?

PROCEDURE: GOLDENROD GALL COLLECTION AND DISSECTION PART I:

Once you have explored the lifecycle of the midge fly within the goldenrod gall, you will collect galls with your class. Each student will collect at least 10 galls. It is best to snap the goldenrod plant just above and below the gall so as not to bring in excess plant material. At Inver Hills, there are plentiful patches of goldenrod, many with galls in several places:

- On the hill directly west of Heritage Hall – visible from the HH220 lab windows
- Along the path from Heritage Hall toward the Community Garden and then along the path for a short ways to the right (North) when you reach the garden.
- The most plentiful area is on the hill that faces highway 52, just west of the Science Building, accessible from paths beginning just north of the Community Garden

When you return to lab, you will be identifying the outcome of the gall by using the dichotomous key below (Gall Content Key). First, observe the outside of the gall and characterize any holes. Then, open the gall along a vertical plane with a scissors or clippers. Be careful, because if you snap straight through, you could damage the gall inhabitant. Instead, cut slowly, and when you approach the center of the gall, stop using the scissors and pull it open manually. Continue following the Gall Content Key using information you find from the inside of the gall. For each of the galls, identify the outcome. This will be one of the nine options listed in the Gall Content Key. For each gall, list the steps you followed and the outcome:

Gall Number	Steps Followed in Gall Content Key	Outcome from Gall Content Key
Example Gall	1a to 3a to 5a to 6a to 7a	Eurosta solidaginis (midge fly) larva

When you find a larva inside the gall, you will need to use a dissecting microscope in order to complete the Gall Content Key and identify which kind of larva it is. Midge fly larva are the most common inhabitant, followed by wasps, followed by beetle. If you don't find all three types, be sure to look under the microscope of other students in the class. Your instructor may amplify some larva onto the screen using the camera in a dissecting microscope.

DESIGNING YOUR OWN STUDY:

Now that you have had the opportunity to perform a preliminary study on your goldenrod gall system, you and your group should make a unique hypothesis. You may have ideas of predation and parasitism rates based on a number of factors, such as distance to the nearest tree, distance off the ground, number of galls on the same plant, size of the gall, etc. Make your OWN hypothesis. Then, draw what you expect your graph to look like if your hypothesis is correct. Lastly, record what information you need to record while you collect galls in order to answer your question (distance to the nearest tree, distance off the ground, number of galls per goldenrod, etc). Your instructor needs to check your hypothesis, graph and information needs before you can continue.

Your Hypothesis:

What your graph will look like if the data supports your hypothesis (include title, axis labels, units, figure legend, etc):

Information required at collection:

PROCEDURE: GOLDENROD GALL COLLECTION AND DISSECTION PART II:

When you return to lab the second week, you will be ready to collect data for your own gall study. Before you head out to collect galls, find out what data the other members of the class needs (height from ground, distance to nearest tree, single/double gall, gall diameter, etc). We will be pooling class data for each study to increase sample size. You may need to take some data in the field before bringing the galls back. Make sure you get specific information about HOW they want the data collected, what units they are including etc. Find out what materials you need to collect all the data (measuring tape, ruler, calipers, etc) You will need to bring a permanent marker to write the gall number on each gall, so that you know which is which when you return. Each group should collect data about 15 galls. On the next page is the data sheet on which to record:

Gall Collection Data Sheet

Group Member Names (first and last): _____

Gall Number (write on gall)					Gall Outcome, using Gall Content Key

ANALYZING YOUR DATA

As each group finishes collecting their data, they will write their data on the board or on the class data sheet. Figure out which data you need to answer YOUR question. You may not need to use all the class data. Ask your instructor if you need help. Make a graph of your results using the graphing paper in the lab. Draw a proper graph (including all components) that shows your ACTUAL results. See the lab “Working With Data” for a reminder of what needs to go on a graph. Be sure to include your conclusion in the figure legend. Turn this in to your instructor.

Gall Content Key

1. Gall with hole.....Go to 2
- 1a. Gall with no hole.....Go to 3
2. Hole large (3-8mm) either conical or irregular.....Bird Attack – Got to 8
- 2a. Hole small (<2mm), and circular..... *Eurytoma gigantea* (wasp) emerged
3. Gall Empty.....Go to 4
- 3a. Gall with insect larva or pupa inside (larva may be tunneling).....Go to 5
4. Gall chamber contains frass.....killed by unknown insect
- 4a. Gall chamber brown, but without frass.....Early larval death
5. Brown pupal case (4mm) in chamber (see figures).....*Eurytoma obtusiventris* (wasp pupa)
- 5a. Cream colored larva; in chamber or tunneling in pith region.....Go to 6
6. Cylindrical larva; 4-5mm long, <1mm wide; three pairs of legs; hairs on posterior segments; galls show signs of tunneling through.....*Mordellistena convicta* or *Mordellistena unicolor* (beetle larva)
- 6a. Larva globular in shape; always in chamber.....Go to 7
7. Larva drop-shaped; distinct, white head capsule with darkened mandibles, brown spirals apparent under microscope; highly variable in size (2-5mm); gall chamber frequently contains brown frass.....*Eurytoma gigantea* (wasp) larva
- 7a. Larva ovoid; no distinct head capsule; mandibles modified to anteriorly directed mouth hooks; general appearance of a maggot; gall chamber lined with tightly pressed grey frass.....*Eurosta solidaginis* (midge fly) larva
8. Large irregular hole; bits of gall torn away to form hole.....Black-capped chickadee attack
- 8a. Small, tidy, conical hole.....Downy Woodpecker attack

From: Dr. Warren Abrahamson or Paul Heinrich; accessed Sept 12, 2011
<http://www.facstaff.bucknell.edu/abrahmsn/solidago/gallkeyintro.html>

Name: _____

Human Population Growth Pre-Lab Assignment

1. Define and draw exponential growth and logistic growth.
 - a. exponential growth

 - b. logistic growth

2. What is the demographic transition?

3. What is meant by density dependent and density independent controls?

Human Population Growth

OBJECTIVES:

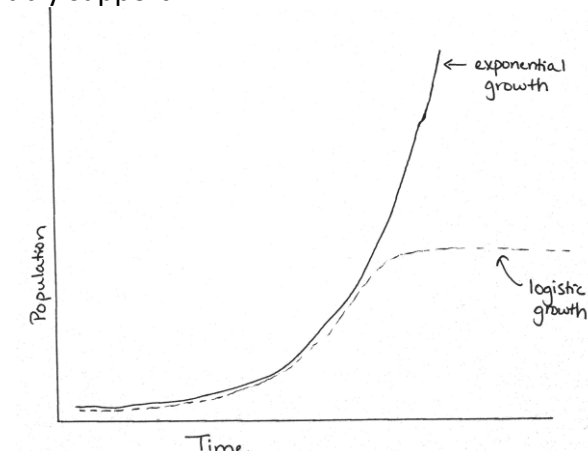
- Understand human population growth in various parts of the world
- Describe the various factors that affect population growth through the world
- Consider the impacts of population growth on natural resources

INTRODUCTION:

Growth curves are used to reflect how the various factors cause a population to grow or decline. There are two major types of growth curves: exponential and logistic.

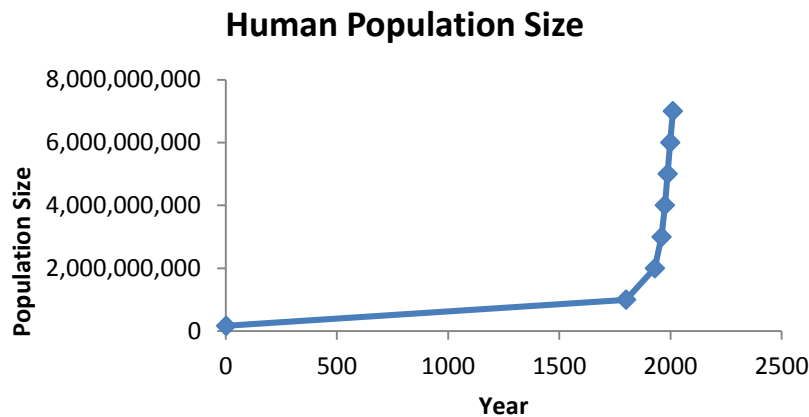
We'll consider **exponential growth** first. What does exponential mean? Well, let's say we start out with 10 and double it. Now we have 20. If we double it we have 40. Double that, and you get 80. Double 80, and you get 160. Double that, and you have 320. The population grows faster and faster as it gets bigger and bigger. Because it looks like the letter J, exponential growth is sometimes called J-curve growth. When a population is experiencing exponential growth, it is growing at its **biotic potential** (maximum reproductive rate). **Environmental resistance** (biotic and abiotic factors that can decrease a population's size) is NOT limiting growth.

Can a population grow exponentially forever? Of course not! Eventually it will run out of food, space, water, etc. For most populations, exponential growth is pretty unrealistic. In most populations, there is a balance between environmental resistance and biotic potential. This is **logistic growth**. It is also called the S-curve, based on its shape. At first biotic potential causes exponential growth (look at the two curves early on the left side...see how they have the same shape). But then environmental resistance kicks in. When deaths equal births, we are at population equilibrium. **Carrying capacity** is the maximum population of an organisms that a given habitat can sustainably support.



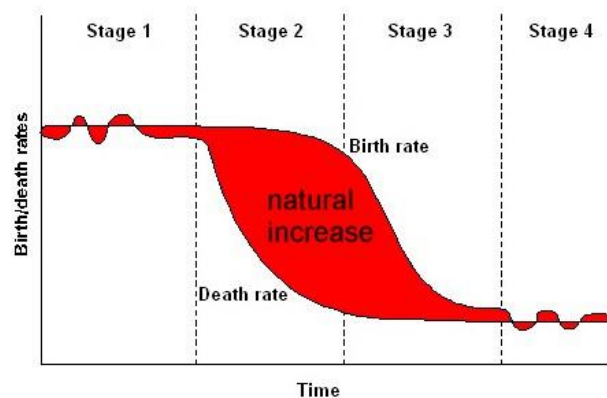
Factors that influence the size of a population can either be density-dependent or density-independent. **Density-dependent factors** are those that have a greater influence the greater the density of the population. **Density-independent factors** affect a population regardless of its size.

Let's look at the trend in world human population. As you can see in this graph, our population size did not explode until modern times (mid-1800s through the present). The current population is over 7 Billion people, and it continues to grow exponentially. The question is, when will humans reach carrying capacity?



We can examine patterns in population growth using several different tools. One is to study the **demographic transition**. The demographic transition is a model that shows how birth rates and death rates change in a society as it progresses from a pre-industrial to industrialized economic system. The wider the gap between birth and death rates, the faster the population is growing.

The Stages of the Demographic Transition.



ACTIVITY:

Work in groups of two or three. Use the information in the introduction, the website listed below, and your other knowledge on the subject to answer the questions below. Be sure to write your answers in coherent, grammatically correct full sentences.

Go to: http://www.prb.org/pdf14/2014-world-population-data-sheet_eng.pdf

1. Find the organization's website. Who is responsible for this publication? How is this group funded?

2. What is the most recent world population estimate?

From what source is this estimate?

3. What is meant by the **Rate of Natural Increase** (RNI)?
4. One property of exponential growth is that you can predict how long it will take for the population to double. The equation is:

$$\frac{70}{\% \text{ growth rate}} = \text{years to double population}$$

- a. What is the current growth rate for the world population?
- b. How long should it take for the world population to double? Show your work!
- c. The world population is growing exponentially. Does this mean that it will double in the year calculated above? Why or why not?

5. List three countries with very high rates of natural increase. Where do they stand economically?

6. What regions of the world seem to be experiencing:
 - a. Low rates of increase?

 - b. Medium rates of increase?

 - c. High rates of increase?

7.
 - a. What country had the highest population in 2014?

 - b. What country will likely be the highest population in 2050?

 - c. Why do you think this is?

8. What is the U.S. rank in total population in 2014? 2050?

9.
 - a. Draw the population pyramids (aka, age-class or age structure histograms) of developing (ie, Africa) vs developed (ie, Europe) regions of the world:
 - b. In which age groups do you find most of the population in a typical developing country? Why do you think this is the case?
 - c. How does your answer to the above question relate to the rate of population growth in developing countries?
10. Compare Bolivia and Austria with regard to the % populations under 15 and over 65
 - a. Which country has higher % of population under 15?
 - b. Which country has higher % of population over 65?
 - c. Are both countries growing? Explain:
 - d. What do you think Bolivia's growth rate will look like in the next 20 years? Why?

11. a. What benefits could come from population growth?

b. What would be some of the drawbacks of population growth?

12. a. What benefits could come from a population decrease?

b. What would be some of the drawbacks of a population decrease?

13. a. What are potential strategies to reduce population growth? List at least three.

b. What types of issues surround those actions?

14. a. In which phase of the demographic transition are most developing countries?

b. According to the demographic transition model, why are these countries experiencing rapid growth?

15. a. In what region is AIDS/HIV the highest? Why do you think this is?

b. What region of the world has the lowest use of women using birth control? Why do you think this is? How is this related to the question in part a?

16. a. What is population density?

b. What countries have the lowest population density? (pick a few)

c. What countries have the highest? (pick a few)

16. What do you think increasing human population density means for natural habitats and resources?

17. Observations show that, the larger the gap between rich and poor, the greater the damage to natural resources. Why do you think this is?

18. Populations are said to be under both density dependent and density independent controls.

a. List examples of density dependent limits to human population growth.

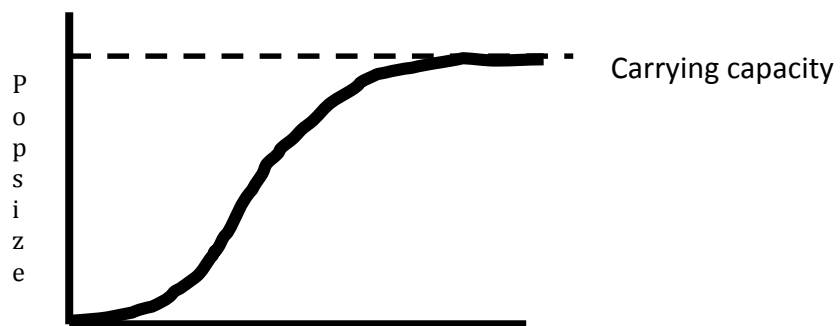
b. List examples of density independent limits to human population growth.

19. a. What type of growth curve is shown below?

b. Where on the curve do you think density dependent controls are important? Why?

c. Where on the curve do you think density independent controls are important? Why?

d. Where on the curve do you think world population is as of today?



Name: _____

Plant Biodiversity at IHCC Pre-Lab Assignment

1. Define biodiversity.

2. Why is biodiversity important?

3. How do exotic species affect biodiversity?

Plant Biodiversity at IHCC

OBJECTIVES:

- Use observations to develop hypotheses about plant biodiversity
- Understand the difference between species evenness and species richness
- Examine the effects of an exotic species on biodiversity

INTRODUCTION:

Biodiversity is the “variability among living organisms and the ecological complexes of which they are part” according to the Millennium Ecosystem Assessment. Put another way, biodiversity is the diversity of living things found in the natural world. Biodiversity is important for a variety of reasons. For example, natural species are sources for agriculture, forestry, aquaculture, and animal husbandry. Many of our medicines, including aspirin, originated in wild plants. There is recreational value in nature, whether it be by fishing, hunting, camping, or hiking. Finally, natural species provide ecosystem services, such as the biological degradation of wastes.

It has been estimated that approximately 1/3 of wild species are in trouble (vulnerable, imperiled, or extinct). There are five major causes of biodiversity loss: habitat destruction, invasive species, human population growth, pollution, and overexploitation. In this lab, we will focus on the effect of an invasive species, common buckthorn, on plant biodiversity. **Invasive species** (also called exotic species) tend to overtake, or push out, native species. Because these species come from another area, there is typically no predator, parasite, or disease to keep their numbers in check.

Buckthorn was brought to Minnesota from Europe in the mid-1800s. It was a popular shrub to plant, as it is one of the first plants to leaf out in the spring and one of the last to drop its leaves in the fall. However, it was found to be highly invasive, outcompeting many native plants. Nurseries stopped selling buckthorn in the 1930s, but it is still found throughout Minnesota.

ACTIVITY:**Week 1:**

In the first part of this lab, we will be conducting field work on campus to collect data on the plant species found around campus. While we will do our best to avoid these areas, there are places around campus with poison ivy and old barbed wire. Therefore, you must dress appropriately for this lab. Long pants/skirt and sturdy closed-toed shoes are required! Please also note that this lab will take the entire class time. Be on time, as we'll head outside right away!

We will be visiting four or five different sites on campus. Your instructor will give you some background information about each site, as well as help you learn how to identify the plants.

1. Choose a sampling area. Spread out, so that the entire class ends up with some variation.
2. Place your 1m² quadrat on the ground.
3. Identify each plant species in your quadrat and record them on your data sheet. If you need help identifying a plant, please ask your instructor. It is important that everyone in the class is identifying and naming species in the same way. Ignore fungi and moss. If grass is extremely abundant do not count it all, but estimate it as described by your instructor.
4. Count the number of plants of each species and record on your data sheet. Be careful and accurate, as the entire class will be using this data.
5. Repeat steps 1-4. Each group is responsible for collecting data from two samples at each of the four sites on campus.
6. Make observations about your sampling site. Are there any factors that you think could influence plant diversity? What is the canopy cover, ground cover, slope, soil, moisture, distance from edge, etc. like? What makes this site unique?

Site 1**Sample #1**

Plant Name	Number

Sample #2

Plant Name	Number

Site Observations (canopy cover, ground cover, slope, predominant vegetation, etc.)

Site 2**Sample #1**

Plant Name	Number

Sample #2

Plant Name	Number

Site Observations (canopy cover, ground cover, slope, predominant vegetation, etc.)

Site 3

Sample #1

Plant Name	Number

Sample #2

Plant Name	Number

Site Observations (canopy cover, ground cover, slope, predominant vegetation, etc.)

Site 4

Sample #1

Plant Name	Number

Sample #2

Plant Name	Number

Site Observations (canopy cover, ground cover, slope, predominant vegetation, etc.)

Site 5**Sample #1**

Plant Name	Number

Sample #2

Plant Name	Number

Site Observations (canopy cover, ground cover, slope, predominant vegetation, etc.)

Week 2:

1. Based on your site observations, write a formal hypothesis (if...then...) predicting which site will have the lowest plant diversity. Why did you make this particular prediction (what factor is causing a decrease in biodiversity)?

2. Based on your site observations, write a formal hypothesis (if...then...) predicting which site will have the highest plant diversity. Why did you make this particular prediction (what factor is causing an increase in biodiversity)?

3. Record your data on the board, as described by your instructor. Do this carefully as your data will be used by everyone in the class!

Biodiversity can be described in several different ways. We are focusing on species diversity in this lab, but biodiversity also includes genetic diversity and habitat diversity. Even within the concept of species diversity, there are several components to consider: species richness, species dominance, and species evenness. We will analyze our data in several different ways to account for this different components to species diversity.

4. **Species richness** refers to the total number of species. In other words, how many species are present? Using the class data (on the board), generate a table and a graph that shows the species richness at the four sites visited in last week's lab. Don't forget to give your table and graph descriptive titles and axes labels as appropriate. Attach your table and graph to this lab before turning it in!

Based on your table and graph, which site had the highest species richness?

Based on your table and graph, which site had the lowest species richness?

5. **Species dominance** refers to the most abundant species. In other words, which species has the most individuals? Using the class data (on the board), generate a table and a graph that shows the species dominance at the four sites visited in last week's lab. Don't forget to give your table and graph descriptive titles and axes labels as appropriate. Attach your table and graph to this lab before turning it in!

Based on your table and graph, what was the dominant species at each site?

- 1.
- 2.
- 3.
- 4.

Based on your table and graph, are there differences among the sites as to how abundant each of the dominant species is? In other words, did some of the dominant species "dominate" over the others to a greater extent than others?

6. **Species evenness** refers to the relative abundance of species. In other words, how many individuals are there of each species? We will use the Shannon-Weaver diversity index calculation to determine the relative distribution of all of our species in each of our sites. Your instructor will provide you with an Excel spreadsheet that will do the calculations for you. After entering the class data (on the board) into the Excel spreadsheet, use the ANOVA tab to generate a table and a graph that shows the species evenness at the four sites visited in last week's lab. Don't forget to give your table and graph descriptive titles and axes labels as appropriate. Attach your table and graph to this lab before turning it in!

Based on your table and graph, which site had the highest species diversity?

Based on your table and graph, which site had the lowest species diversity?

7. Based on your data, it is possible to have abundance without richness, and richness without abundance? Explain your answers, using the results of your data analyses.

8. Do you accept or reject your hypotheses? Why or why not?

9. Based on your data analysis, which site(s) had the lowest biodiversity? Explain why biodiversity was so low in this site(s).

10. Based on your data analysis, which site(s) had the highest biodiversity? Explain why biodiversity was so high in this site(s).

Name: _____

Soil Nutrient Testing Pre-Lab Assignment

1. How should chemical waste from this lab be handled? (Review p. 5-6)
2. Which tests can be done only after the "Extraction Procedure" has been completed? In other words, which tests call for the use of "general soil extract"?
3. What does the term "bioavailable" mean?

Soil Nutrient Testing

OBJECTIVES:

- Use a variety of chemical tests to determine the nutrient contents of a soil
- Understand the importance of macronutrients and micronutrients for agriculture
- Make recommendations based on data

INTRODUCTION:

Soil fertility is one of the most important factors in agriculture. In this lab, we will be testing for the “bioavailable” portion of nutrients in the soil that would be “available” for the plant to use.

Relative acidity (**pH**) refers to the amount of acid or base in a solution. pH 7 is **neutral**. pH below 7 is **acidic**, and pH above 7 is **basic**. Most plants do best with a soil pH of about 7.

Weathering of rocks introduces minerals to the soil and leaching removes minerals when water moves through soil. Plants require nutrients like phosphate and calcium in order to grow, so a healthy soil is one that contains and holds an appropriate level of nutrients. Not all nutrients are needed in the same amounts. **Macronutrients** are those required by plants in relatively large amounts. **Micronutrients** are also necessary, but in much lower amounts.

Humus is partially decomposed organic matter. Humus is important because it helps the soil retain both water and nutrients. It also helps loosen the soil, which can improve aeration and workability.

ACTIVITY:

It is very important to follow the directions carefully in order to obtain accurate results. It is recommended that you (re-)read each section's instructions and find all necessary equipment and reagents before you start each test. Some equipment and reagents may look similar to each other, which is why there are numbers in parentheses throughout the directions. These are the numbers that the contents of your soil test kit are labelled with. If at any point you are unsure of something (the directions, which equipment or reagent to use, how to measure a specific volume, etc.) please ask your instructor for help. You must wear safety goggles!

A. Soil Sampling

Choose an area to sample, based upon your instructor's directions. Remove any mulch covering the soil, and then use the trowel to remove the soil from the entire space where you would expect to find plant roots.

B. pH

pH is a measure of acidity or alkalinity. Soils can have a pH from 3.5 to 11.0, but plants grow well in the range of 5.0 to 8.5. In soils with a low pH (acidic), some nutrients can reach toxic levels and the activity of soil microbes is greatly reduced. Soils with a high pH (alkaline) generally have a lower micro-nutrient availability and some levels may be deficient.

1. Fill a test tube (0204) approximately one-third full of soil. Add DI water to the tube, until it is one-half inch from the top. Cap and shake until the soil is well dispersed.
2. Add 5 drops of Soil Flocculating Reagent. Cap and shake to mix. Allow contents to settle before proceeding to Step 3. This may take up to an hour. Carefully set aside and move to other tests while you are waiting.
3. Use a 1 mL pipet (0354) to transfer 1 mL (fill to the 1.0 mL mark) of the clear solution above the soil to one of the large depressions on a spot plate (0159; this is simply a plate/tray with several depressions/spots). Transfer a second 1 mL sample to the other large depression on the spot plate.
4. To the first sample on the spot plate, add 2 drops of Duplex Indicator. Compare the resulting color reactions against the Duplex Color Chart chart. Use this chart and the chart below to select which indicator and color chart you need to use for step 5. Choose the indicator and chart with a mid-point that is close as possible to the value obtained in step 4. For example, if the Duplex test result is pH 8.0, then you should choose the Phenol Red indicator and chart for Step 5.

<u>Indicator</u>	<u>pH Range</u>	<u>Indicator Code</u>	<u>Color Chart Code</u>
Bromersol Green	3.8-5.4	2207	1328
Chlorphenol Red	5.2-6.8	2209	1329
Bromthymol Blue	6.0-7.6	2210	1331
Phenol Red	6.8-8.4	2211	1332
Thymol Blue	8.0-9.6	2213	1335

5. Add 2 drops of the chosen indicator to the second sample on the spot plate. Compare the resulting color reaction against the appropriate color chart to obtain a precise soil pH reading.

Interpretation of pH Reading:

<u>If the pH is</u>	<u>Then the soil is</u>
Below 5.5	Strongly Acid
5.5-6.0	Moderately Acid
6.1-7.0	Slightly Acid
Above 7.0	Alkaline

6. Record your results and answer the questions on the data sheet.

C. Humus

Humus consists of the complex remains of fresh plant and animal residue after extensive chemical and biological breakdown. Humus accounts for 60-70% of the total organic carbon in soils. It can modify the physical properties of a soil, strongly affecting its chemical and biological properties.

1. Use the 0.5 g spoon (0698) to add eight level measures of soil to a soil extraction tube (0704).
2. Fill the tube to the 14 mL mark with DI water. Cap and shake to mix.
3. Use a 0.5 g spoon (0698) to add two level measures of Humus Screening Reagent. If necessary, add more DI water to return the level of the liquid to the 14 mL mark. Cap and shake vigorously for one minute.
4. Add 15 drops of Soil Flocculating Reagent. Cap and mix gently. Allow to settle for several minutes.
5. Use a piece of filter paper and a plastic funnel to filter the mixture into a second extraction tube. (Fold filter paper in half and then in half again, then open so that there is one piece of paper on one side and three sides of paper on the other side; this cone can then be fitted into the funnel).
6. Compare the clear filtrate in the second extraction tube with the Humus Comparator. Interpretation: The color comparator is labeled with values of 1-5. The results are interpreted as follows:

<u>Comparator #</u>	<u>Relative Amount of Humus</u>
1	Low
2	Medium
3	High
4	High
5	High

7. Record your results and answer the questions on the data sheet.

D. Extraction Procedure

You will now produce a single soil extract to perform the remaining soil tests.

1. Fill an Extraction Tube (0704) to the 14 mL line with Universal Extracting Solution.
2. Use the 0.5 g spoon (0698) to add eight level measures of the soil sample. Cap and shake for one minute.
3. Use a piece of filter paper and a plastic funnel to filter the soil suspension into a second extraction tube. (Fold the filter paper as described in step 5 of the humus test and fit this cone into the funnel). The filtrate in the second extraction tube is the “general soil extract” called for in the following tests.

E. Nitrate Nitrogen

Nitrogen is a macronutrient, meaning that plants require it in relatively large amounts.

Nitrogen in the form of N_2 is very abundant in the atmosphere, but plants cannot use nitrogen in this form. Most plants require nitrogen in the form of nitrate (NO_3) in the soil. These can either be supplied by decaying matter, nitrogen fixing bacteria, animal waste, or through the agricultural application of purpose made fertilizers. Nitrogen deficiency most often results in stunted growth, slow growth, and chlorosis (insufficient chlorophyll).

1. Use a 1 mL pipet(0354) to transfer 1 mL of the general soil extract (from step D) to one of the larger depressions on a spot plate (0159).
2. Add 10 drops of Nitrate Test Reagent #1.
3. Use a 0.5 g spoon (0698) to add one level measure of Nitrate Reagent #2.
4. Stir thoroughly with a clean stirring rod. Allow to stand 5 minutes for full color development.
5. Match sample color with the Nitrate Nitrogen Color Chart.
6. Convert from pounds per acre to parts per million. Do this by dividing the number of pounds per acre by 2.
7. Record your results and answer the questions on the data sheet.

Interpretation:

deficient	less than 5 ppm
medium	5-20 ppm
high	20-40 ppm
excessive	greater than 50 ppm

8. Dispose of your sample in the appropriately labelled waste container.

F. Potassium (Potash)

Potassium is a macronutrient, meaning that plants require it in relatively large amounts. Potassium deficiency may result in higher risk of pathogens, wilting, chlorosis, brown spotting, and higher chances of damage from frost and heat.

1. Use a transfer pipet (0364) to fill a Potash “A” Tube (0245) to the lower mark with the general soil extract (from Step D).
2. Add one Potassium Reagent B Tablet. Cap and shake until dissolved.
3. Add Potassium Reagent C until the Potash “A” Tube is filled to the upper mark. Allow the Potassium Reagent C to run slowly down the inside of the tube as you fill it. Twirl the tube to mix. A precipitate will form if potassium is present.
4. Stand the empty Potash “B” tube (0246) on the Potassium Reading Plate (1107), a rectangular piece of white plexiglass with a solid black line down the middle. Place the tube directly over the black line.
5. Fill a transfer pipet (0364) with the test sample from the Potash “A” Tube.
6. Slowly add the test sample to the Potash “B” Tube, allowing it to run down the inside of the tube. Observe the black line down through the Potash “B” Tube. Continue to add the test sample until the black line just disappears.
7. Record as pounds per acre Available Potassium where the level of the liquid meets the scale printed on the side of the Potash “B” Tube.
8. Convert from pounds per acre to parts per million. Do this by dividing the number of pounds per acre by 2.
9. Follow this step ONLY if the test result is equal or greater than 400 pounds per acre.
 - a. Fill a Potash “C” Tube (0247) to the lower mark with the general soil extract (from Step D).
 - b. Add Universal Extracting Solution to the upper mark and mix.
 - c. Using this diluted extract, follows Steps 1-7 above. Multiply the test result by 2 to obtain pounds per acre Available Potassium. Then convert to parts per million as described in Step 8.
10. Record your results and answer the questions on the data sheet.

Interpretation of Potassium Results

0-60 ppm	Very Low
61-120 ppm	Low
121-181 ppm	Moderate
over 181 ppm	Sufficient

G. Phosphorus

Phosphorus is a macronutrient, meaning that plants require it in relatively large amounts. Phosphorus is limited in most soils because it is released very slowly from insoluble phosphates. Phosphorus deficiency in plants is characterized by an intense green coloration in leaves. If the plant is experiencing high phosphorus deficiencies the leaves show signs of necrosis. High levels of phosphorus can result from over-fertilizing. Excessive phosphorus not only harms plants, but persists in the soil for several years.

1. Use a transfer pipet (0364) to fill a "Phosphorus B" Tube (0244) to the mark with the general soil extract (from Step D).
2. Add 6 drops of Phosphorus Test Reagent #2. Cap and shake to mix.
3. Add one Phosphorus Test Tablet. Cap and shake until dissolved.
4. Immediately compare the color that develops in the test tube against the Phosphorus Color Chart. Hold the tube about 1 inch in front of the white surface in the center of the color chart. View the chart and sample under natural light for optimum color comparison. If artificial light is used, the chart and sample should be held close to the light source.
5. Record your results and answer the questions on the data sheet.

Interpretation of Results

<16 ppm	Very Low
16-25 ppm	Low
26-35 ppm	Medium
36-50 ppm	Optimum
>50 ppm	Above Optimum (High)

H. Magnesium

Magnesium is a constituent of chlorophyll, and chlorosis can result from magnesium deficiency.

1. Use a transfer pipet (0364) to transfer 10 drops of the general soil extract (from Step D) to one of the larger depressions on a spot plate.
2. Add one drop of Magnesium Test Solution #1. Stir with a clean rod. A pale yellow color will develop.
3. Add Manganese-Magnesium Test Solution #2 one drop at a time while stirring, until the pale yellow color changes to one of the darker shades indicated on the Magnesium Color Chart. About 2 drops are usually required. Do not be concerned if a precipitate forms...it will not affect the test reading.
4. Record your results and answer the questions on the data sheet.
5. Dispose of your sample in the appropriately labelled waste container.

I. Calcium

Calcium deficiency is seldom a direct limiting factor, because the lack of adequate calcium in a soil causes other growth limiting deficiencies to occur first. Calcium prevents excessive soil acidity and stimulates beneficial biological activity. Low calcium levels may cause high soil acidity, diminishing the availability of some nutrients (like nitrogen), and permitting toxic levels of other minerals (like aluminum) to develop in the soil. In general, calcium plays an essential role in maintaining the chemical equilibrium of the soil.

1. Use a transfer pipet (0364) to transfer 5 drops of the general soil extract (from Step D) to a flat-bottomed glass turbidity vial (0242).
2. Add one drop of Calcium Test Solution. Swirl gently to mix.
3. Match the milky turbidity of the test sample against the turbidity standards on the Replaceable Calcium Chart. Lay the chart flat under natural light and hold the turbidity vial one-half inch above the black strip in the middle of the chart. View the black strip down through the turbid sample and compare the resulting shade of gray with the six standard shades.
4. If the test sample turbidity corresponds to or exceeds the lightest standard (2800 ppm), repeat the test on a diluted sample.
 - a. Transfer one drop of the general soil extract (from Step D) to a clean turbidity vial (0242).
 - b. Add 4 drops of DI water.
 - c. Follow Steps 2-3 above. Multiply the test result by 5 to obtain parts per million replaceable calcium.
5. Record your results and answer the questions on the data sheet.

Interpretation of Results

0-150 ppm	Low
151-299 ppm	Medium
>300 ppm	High (Optimum)

6. Dispose of your sample in the appropriately labelled waste container.

Soil Nutrient Testing Results

Record your data and recommendations based on the data here. You may need to do additional research outside of class in order to make the best recommendations. Do not take this lightly, as your recommendations may be taken by the people using this soil to grow crops!

1. Soil pH=_____

Interpretation of pH reading=_____

What recommendations do you have regarding this result? Should any actions to be taken to improve the soil pH? If so, what actions should be taken? If not, why are no actions necessary?

2. Relative Amount of Humus=_____

What recommendations do you have regarding this result? Should any actions to be taken to increase humus levels? If so, what actions should be taken? If not, why are no actions necessary?

3. Nitrate Nitrogen= _____pounds per acre.

Convert to parts per million by dividing this number by 2. Nitrate

Nitrogen=_____ppm

Interpretation of nitrate nitrogen level=_____

What recommendations do you have regarding this result? Should any actions to be taken to alter nitrate nitrogen levels? If so, what actions should be taken? If not, why are no actions necessary?

4. Potassium= _____pounds per acre.

Convert to parts per million by dividing this number by 2. Potassium=_____ppm

Interpretation of potassium level=_____

What recommendations do you have regarding this result? Should any actions to be taken to alter potassium levels? If so, what actions should be taken? If not, why are no actions necessary?

5. Phosphorus= _____pounds per acre.

Convert to parts per million by dividing this number by 2. Phosphorus=_____ppm

Interpretation of phosphorus level=_____

What recommendations do you have regarding this result? Should any actions to be taken to alter phosphorus levels? If so, what actions should be taken? If not, why are no actions necessary?

6. Interpretation of magnesium level=_____

What recommendations do you have regarding this result? Should any actions to be taken to alter magnesium levels? If so, what actions should be taken? If not, why are no actions necessary?

7. Replaceable Calcium= _____ppm

Interpretation of calcium level=_____

What recommendations do you have regarding this result? Should any actions to be taken to alter magnesium levels? If so, what actions should be taken? If not, why are no actions necessary?

Name: _____

Testing Amphibians for *Bd* Pre-Lab Assignment

1. Watch the 3 minutes YouTube Video and answer the following questions:
<https://www.youtube.com/watch?v=rsezFdQ6w34>
or search YouTube for “Amphibian Research at Inver Hills Community College”
 - a. What does *Bd* stand for?
 - b. What does *Bd* do to amphibians?
 - c. What do the student researchers in the video do with the frogs they catch (be specific)?
 - d. What will be done with the samples after our class is finished collecting them?
2. Find an article that discusses the effects of *Bd* on amphibian populations (frogs, toads, salamanders).
Summarize 2 main points for your article

Cite your source here (include author, date published, title, URL, date accessed):

- 3. What OTHER factors (besides *Bd*) are causing amphibian declines?
Find at least 3.

Cite your source here (include author, date published, title, URL, date accessed):

4. Read through the lab protocol.
 - a. What will you do to prevent scaring frogs away?
 - b. What kind of walking pattern will you take to make sure you don't lose an opportunity to see/hear a frog?
 - c. Where will you look for frogs?
 - d. What will you do to prevent contamination?
Specifically for your hands?

Specifically for the net?

Testing Amphibians for *Bd*

OBJECTIVES:

- Understand the impacts of an environmental pathogen, *Bd* (*Batrachochytrium dendrobatidis*), on amphibians world-wide
- Participate in novel research that addresses patterns of *Bd* infection on our campus
- Gain experience in biology field techniques

INTRODUCTION:

Bd (*Batrachochytrium dendrobatidis*) is a fungus that causes chytridiomycosis infections worldwide. While there are many factors responsible for amphibian declines and extinctions, *Bd* seems to be playing a significant role. Student researchers have used genetic techniques to test for the presence of *Bd* in the frogs on our campus. Our goal in this study will be to contribute to a larger set of data for our campus. This lab will involve the first step in this process, collecting frogs and swabbing their lower limbs and feet. The samples will then have genetic testing to determine which frogs are positive for *Bd*.



RESOURCES:

A 3 minute video was made to summarize the purpose of this work on our campus as well as to highlight the variety of techniques used in the field and in the lab. The video can be accessed at: <https://www.youtube.com/watch?v=rsezFdQ6w34> or you can search YouTube for “Amphibian Research at Inver Hills Community College.”

MATERIALS:

- | | |
|---|---|
| *Waders | *Spring Scale for measuring weight |
| *D-nets (nets can only be used for one frog)
If net has touched a frog, then it needs to be set aside and not used to sample frogs until it is completely dry) | *Calipers for measure length (Tip to rump) |
| *Sample cups with a hole in the lid | *Rayon sampling swabs (up to 30) |
| *Clipboard and Pencil | *Permanent marker for labeling cups, swab |
| *Data Sheet (Record: Sample ID, Date, Time, Species, Weight, Length, Caught by, Sampled By, Notes) | *Gloves (change between handling of each frog specimen) |
| | *Trash bag for gloves, cups and trash found on campus |
| | *MN Amphibian ID book |
| | *Bucket to carry all supplies |

PROCEDURE FOR AMPHIBIAN SAMPLE COLLECTION

Our class will be searching for and catching frogs for sampling. Frogs will be released at the end of the day of sampling.

- As a class, hike out to a campus pond (usually just West of the Fine Arts Building).
- Be **quiet** upon arrival. If the frogs sense danger, they will hide and we won't catch any
- When searching for frogs, it is important to take only **one step at a time**. A frog will jump when it is startled, but then remain still. Your main clue in frog hunting is the sound it makes when it jumps. If you take two steps at a time, you will lose your opportunity to hear the frog jump.
- Search for frogs in one of several places:
 - Under logs (please replace log to its original position after searching)
 - In the grass/mud
 - In the water
- When you see a frog, be quick.
- Catch it in your hands or with a net.
 - Note on **net contamination**: Once a net has touched a frog (even if it got away) then it needs to be set aside and not used to sample frogs until it is completely.
 - Note on **hand contamination**: Once you handle a frog (even if it got away), then you must wear gloves and change your gloves for every subsequent frog.
- Bring your frog to the designated sampling area
- Place your frog in a cup. Make sure the data recorder gets your name and that your sample cup gets a number before searching for more frogs.

PROCEDURE FOR PREPARING THE FROG FOR SWABBING

- Find out the next sample ID number: It will be IH### (ex. IH072), and write this number on the cup
- Make sure all the information is recorded on the data sheet
- Weigh the frog and its cup with the spring scale. Subtract the weight of the cup and record the frog's weight.
- Put a little water in the cup through the hole in the lid and set aside until someone is ready to swab the frog.

PROCEDURE FOR SWABBING THE FROG

- Write on the swab case in permanent marker (sample ID, Species, Date, Location)
- **Change gloves** before handling each specimen!!
- Hold frog gently and measure length from tip to rump using the calipers
- Record the species of the frog using the MN amphibian ID book (most common: W Chorus Frog, N Leopard Frog, American Toad, Gray Tree Frog)
- Remove the swab from its case. Hold the swab near the tip for better control.
- Rub the swab 5 times along each of the following areas. Then, flip the swab over and repeat. Repeat again for each limb. This will total 80 swabbing motions.
 - Ventral drink patch (hip crease)
 - Tibia/fibula
 - Femur
 - Webbing in between toes
- Replace the swab to its case. In order to prevent double sampling, leave the frog in the cup until all of the day's sampling is to complete.
- **Change gloves** before handling each specimen!! If you forget to change gloves between samples, record which specimens may have been contaminated on the data sheet.

PROCEDURE FOR STORING THE SWABS

- Swabs from each lab period should be wrapped together in a rubber band and placed in the **refrigerator** until DNA extraction can take place.

WHAT NEXT?

The samples you collected today will be use to look at patterns of *Bd* infection on our campus over time and across species. Students will extract DNA from the samples and use molecular biology techniques to determine where each sample is positive for *Bd*. Molecular biology techniques will include PCR (Polymerase Chain Reaction) to amplify DNA of the fungus and gel electrophoresis to visual the DNA if it is present.

Name: _____

Is IHCC Carbon Neutral? Pre-Lab Assignment

1. Determine the distance, in miles, of your 1-way commute from your home (or place of work) to the IHCC campus.
2. Why are carbon dioxide (CO₂) emissions from cars an environmental concern?
3. What does the term “sequestration” mean in terms of CO₂?

Is IHCC Carbon Neutral?

OBJECTIVES:

- Locate air quality information from reputable internet sources
- Estimate the average amounts of CO₂ released by cars annually
- Estimate the average amounts of CO₂ sequestered by vegetation annually

INTRODUCTION:

Climate change is one of the biggest environmental challenges Earth is facing. Climate change includes not just warming of temperatures, but also changes in patterns of precipitation and severe weather outbreaks. Climate change is being induced by several factors, including anthropogenic air pollutants.

One of these anthropogenic air pollutants that contributes to climate change is **carbon dioxide (CO₂)**. Carbon dioxide is produced naturally (it is a byproduct of your body's cellular respiration, for example), but it is also produced by non-natural activities. For example, carbon dioxide is a product of fuel combustion. Carbon dioxide is a **greenhouse gas** that traps Earth's heat and is a leading contributor to global climate change.

Driving a vehicle is probably a typical U.S. citizen's most polluting daily activity. In addition to being a major source of carbon dioxide, vehicle emissions include nitrogen oxides (NO_x), volatile organic compounds (VOCs), particulate matter (PM), and carbon monoxide (CO).

Photosynthetic organisms, such as trees, grasses, and algae, **sequester** or absorb CO₂ as a process of their metabolism (converting CO₂ into carbohydrates through the process of photosynthesis). Carbon that is sequestered in plant biomass does not contribute to climate change, as long as it remains in the form of plant biomass.

In this lab, we will calculate the annual average CO₂ emissions from the vehicles being driven to and from the Inver Hills Community College campus and the annual average CO₂ sequestration by the vegetation on the IHCC campus. We will then compare these values to determine whether or not IHCC is **carbon neutral** with respect to automobile emissions.

ACTIVITY:

1. Determine the average amount of CO₂ released by people commuting to campus. We will first need to consider several things to determine this, such as:

- car types (make, model, approximate year)
- how many students commute
- how far do they commute

To determine the types of cars being driven, your group will be assigned to a parking lot. At the parking lot, record the make, model, and year of 15 different vehicles (e.g., 2007 Toyota Prius). If you do not know the exact year, make a reasonable guess as to the age. Record the data on table on the next page.

Vehicle Tally. Parking Lot Assessment.

Make	Model	Year
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		

Next we need to determine how many students commute to and from campus. In other words, how many students drive their own vehicle, versus how many students get here by walking, biking, busing, or carpooling. In Fall 2013 (latest available data), there were 5,675 students enrolled at IHCC. Of those students, 35% were attending full-time and 65% were attending part-time. Using this information, make an estimate as to how many students are using their personal vehicle to commute to campus. Show your work!!! If you collect any additional data or make any assumptions, you must explain them as well.

Now we need to determine how many miles students put on their cars by commuting to IHCC. Use the information from question #1 in your pre-lab, along with the information from your classmate's answers to calculate how many miles an average student would drive in one year driving to and from campus. Again, show your work!!! If you collect any additional data or make any assumptions, you must explain them as well.

Finally, we will calculate CO₂ emissions. Use the website <http://www.fueleconomy.gov/feg/sbs.htm> to calculate CO₂ emissions by car type. You can calculate CO₂ emissions for up to 4 vehicles at a time. Once you have entered your vehicle information, click compare. On the next page, click on the “Energy and Environment” tab. Scroll down to find the “Greenhouse Gas Emissions” box. The data provided is in grams (of CO₂) per mile. You will need to record this data in the table below, and then use this data to calculate the tons (of CO₂) per year, using the mileage you calculated above and the conversion factor of 907185 grams per ton.

Vehicle CO₂ Emissions

Make	Model	Year	Tailpipe CO ₂ (grams per mile)	Tailpipe CO ₂ (U.S. tons per year)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
Average				

We are now ready to determine the total amount of CO₂ released per year by IHCC students driving to and from campus. Use the data you have already collected to determine the total amount of CO₂ released per year by all IHCC students driving to and from campus. Again, show your work and explain any assumptions that you make.

2. Determine the amount of CO₂ that is sequestered by vegetation on IHCC campus. We will need to think about:

- how much forest is on campus
- how much prairie is on campus
- how much wetland is on campus

Use Google Maps to roughly estimate the area of each of these ecosystems on the IHCC campus. Go to <https://www.google.com/maps> and type in “Inver Hills Community College”, then set the view to “Earth”. Use 80th St E, Blaine Ave E, College Trail, and Broderick Blvd as the campus boundaries. Use the scale (in feet) at the bottom right of the webpage to estimate the sizes of the ecosystems. Your instructor will help you determine where each type of ecosystem exists on campus. You may roughly estimate using box shapes (where area = length x width).

Area of forest:

Area of prairie:

Area of wetland:

Now we can use the following data to determine the amount of CO₂ sequestered on campus each year:

- average acre of hardwood forest sequesters about 3.5 tons of CO₂ per year
- average acre of prairie sequesters about 1.5 tons of CO₂ per year
- average acre of wetland sequesters about 3.0 tons of CO₂ per year
- mowed lawns do not sequester substantial amounts of CO₂
- 1 acre = 43,500 square feet

CO₂ sequestered annually by forest:

CO₂ sequestered annually by prairie:

CO₂ sequestered annually by wetland:

Total amount of CO₂ sequestered by vegetation on campus per year:

3. Compare the amount of CO₂ emitted by cars to the amount of CO₂ sequestered by vegetation on the IHCC campus.

Is IHCC carbon neutral? Why or why not?

Briefly provide some appropriate policy recommendations to reduce IHCC's CO₂ emissions due to the use of personal vehicles.

Name: _____

Modeling of Land Use Types Pre-Lab Assignment

1. What are total suspended solids (TSS)? Why are they an important consideration in terms of agriculture? Why are they an important consideration in terms of aquatic ecosystems (both rivers and lakes)? You'll probably have to do some research to answer this. Be sure to state your sources of information.

2. What is total phosphorus (TP)? Why is it an important consideration in terms of agriculture? Why is it an important consideration in terms of aquatic ecosystems (both rivers and lakes)? You'll probably have to do some research to answer this. Be sure to state your sources of information.

3. Define the term "eutrophic".

Modeling of Land Use Types

OBJECTIVES:

- Model different land use types in a watershed dominated by agriculture for both maximum corn production and minimum environmental effects
- Understand the potential effects agricultural erosion can have on aquatic ecosystems
- Understand the role of modeling in environmental management

INTRODUCTION:

The ways in which we use land has direct impacts on surrounding ecosystems. Different **land use types** will have different types and degrees of impacts. As you can imagine, leaving land in its natural state (say as a forest or prairie) will have a lower degree of impact on a nearby river than will converting land for human use (in the forms of agriculture or urban areas).

Knowing this, the USDA created the **Conservation Reserve Program (CRP)**, which is a cost-share and rental payment program which encourages farmers to convert environmentally sensitive or highly erodible cropland into grasslands, windbreaks, riparian buffers, etc. By doing this, erosion is reduced, water quality is improved, and wildlife habitat is increased, along with other environmental benefits.

Not all farmers participate in the CRP. This is mainly due to money. There are limits as to how much money is budgeted in each Farm Bill for rental payment and cost-sharing. Additionally, some farmers may find it more economically beneficial to put CRP-eligible land into agricultural production.

ACTIVITY:

We will work our way through a scenario in this lab that explores the balance between agricultural productivity and environmental protection when planning land use types.

Background:

The Rolling Rock River flows through an agricultural watershed (approx 1200ha) before emptying into Schlitz Lake. The ethanol boom has resulted in all farmers taking their land out of the conservation reserve program and putting it into high yield corn production. After two years of this high intensity farming, people began to notice that Schlitz Lake was becoming more turbid and frequent algae blooms were seen. The residents are worried that Schlitz Lake is becoming too eutrophic.

You were recently hired as a consultant to plan and design the landuse throughout the watershed that will reduce total suspended sediments (TSS) and total phosphorus (TP), but also keep the corn crop yields at a high level.

Procedure:

1. Your mission is to plan the land use in this watershed for three different goals.
 - the first goal will be to maximize corn yield
 - the second goal will be to minimize pollution
 - the third goal will be to maximize corn yield, while keeping pollution levels as low as possible
2. Your instructor will demonstrate the general methods that you will be using.
3. As a reference, here is a brief description of what your instructor will demonstrate that is in the excel spreadsheet.

Information to note on the spreadsheet

- *Stream runoff key:* This is where you copy the different land use types that you will be pasting into the watershed.
- *Running Tally:* Here you can keep track of how your choice of land use type placement affects the stream.
- *TSS per year (kg):* This is the total amount of suspended sediments that will end up in the stream each year.
- *TP per year (kg):* This is the total amount of phosphorus that will end up in the stream each year.

- *TSS per day (kg)*: This is the amount of suspended sediments that will enter the stream on a daily basis.
- *TP per day (kg)*: This is the amount of phosphorus that will enter the stream on a daily basis.
- *Total bushels of corn per acre*: This is the amount of corn that will be produced per acre.
- *bushels/TSS*: This is the ratio of corn bushels per acre to total suspended sediments. If this value is high it means you grow more corn while polluting less. If this is a small value it means that you are polluting more and growing less corn.
- *bushels/TP*: This is the ratio of corn bushels per acre to phosphorus sediments. If this value is high it means you grow more corn while polluting less. If this is a small value it means that you are polluting more and growing less corn.
- *ha used so far*: Here you can keep track of the amount of land you've "created" within each landuse category.
- *Runoff category*: these tables tell you the amount of total suspended solids and phosphorus that will runoff each landuse type. The higher the values the more impact you will have on the stream

4. Complete goal #1. Maximize the corn production per acre. You don't care how high the values are for TSS and TP.

Important things to note about this simulation are that land closer to the river is more productive (you'll get more corn on it) due to rich nutrients being deposited during floods. However, the further away from the river you are, the less TSS and TP will end up in it due to the natural filtering ability of the landscape. Some land cover types are able to absorb more of the agricultural pollution than others.

Use the following amounts of land for all three goals:

500 ha of agriculture

150 ha of urban land, every urban ha must be adjacent to 3 other urban ha. Also, the urban land must be divided into 3 small towns that are not directly adjacent

280 ha of prairie

80 ha of wetland

190 ha of forest

When you are done with goal #1, record your values for the five factors that are in the orange cells under the running tally heading.

TSS per day (kg)	
TP per day (kg)	
total bushels of corn per acre	
bushels/TSS	
bushels/TP	

5. Complete goal #2. Minimize TSS/day and TP/day runoff. You don't care about corn production. It's probably easiest to just close the previous excel sheet and open a new one.

Use the same amount of land as above.

Be sure to record your five values below.

TSS per day (kg)	
TP per day (kg)	
total bushels of corn per acre	
bushels/TSS	
bushels/TP	

6. Complete goal #3. Maximize corn production, while keeping TSS and TP at a minimum. You want big numbers for the bushels/TSS and bushels/TP.

Use the same amount of land as above. Record your values.

TSS per day (kg)	
TP per day (kg)	
total bushels of corn per acre	
bushels/TSS	
bushels/TP	

Questions:

1. This is a broad scale exercise, with rough estimates of TSS and TP loadings for each land use type. What information are we missing (hint: would all agricultural land contribute the same amount of TSS and TP, do we only plant corn)?

2. What are some other practices besides just changing the land use that could reduce TSS and TP levels?

3. The price of corn and its products (such as ethanol) have been at very high values. How do you think this is influencing our water quality?

4. Go to this website to get the current price of corn per bushel. Note that if the price is 589 cents that means it is \$5.89 per bushel.

<http://www.quotecorn.com/>

If one farmer owned all 500 hectares of agricultural land, how much money for corn does she earn under each of the three goals?

As the consultant who was charged with reducing TSS and TP, what do you tell the farmer? I expect some decent reasoning here as there are thousands of dollars difference between each scenario.

5. Compare bushels/TSS and bushels/TP between Goal #1 and Goal #3. What do you notice? The goal here would seem to be to have a high number of bushels relative to a lower value of TSS or TP.

Name: _____

Wastewater Treatment Plants Pre-Lab Assignment

1. How have you planned ahead for this lab?

- How will you be getting to the assigned location? How long will it take you to get to the assigned location (you MUST be on time)?
- Will you need to leave another class early or arrive at another class late? If so, have you spoken to your Environmental Science instructor? (He or she will help you make arrangements with your other instructors).

2. Briefly describe each stage of wastewater treatment:

- preliminary treatment
- primary treatment
- secondary treatment
- tertiary treatment

3. Watch the Metropolitan Council's video on wastewater treatment

(<https://www.youtube.com/watch?v=D1aABVbl4JE>). Based on this video, what is one question you would like your tour guide to answer?

Wastewater Treatment Plants

OBJECTIVES:

- See how wastewater treatment occurs firsthand
- Describe the process of wastewater treatment
- Understand issues associated with the treatment of wastewater

INTRODUCTION:

Wastewater treatment is the process by which contaminants are removed from household sewage and, depending on the municipality, industrial and commercial waste and stormwater runoff. Treatment plants were first developed in the late 19th and 20th centuries, with most modern facilities being established in the 1970s and 1980s in order to comply with EPA regulations.

Water is treated in a variety of physical, chemical, and biological ways, with the goal of producing environmentally safe **effluent** (liquid) and **sludge** (solid). There are typically four steps to wastewater treatment: preliminary treatment, primary treatment, secondary treatment, and tertiary treatment.

Preliminary treatment removes large pieces of debris, grit and gravel by passing the wastewater through a series of screens followed by passage through a grit chamber, where the water velocity is slowed to allow large particles to settle out. Primary treatment uses a settling tank to physically remove solids, fats, and oils. The material removed is referred to as sludge and is treated separately. Secondary treatment involves the use of bacteria and other microorganisms to break down dissolved organic materials. This typically involves the use of aeration tanks, filters, and/or leaching ponds. Tertiary treatment removes inorganic nutrients through the use of filters and microorganisms and disinfection with chlorine, ozone, or UV radiation. Due to these processes, the effluent that is discharged is often cleaner than the water into which it is discharged!

The sludge that remains is usually treated through digestion by microorganisms and a drying process. It may then be dumped into landfills, converted into a fertilizer treatment, or burned as a fuel.

ACTIVITY:

Listen carefully as the tour guide explains the wastewater treatment plant and process to you. Ask questions if you need clarification during the tour, or at the end of the tour if you have a question that was not answered. Then answer the questions below in a typed Word document.

1. How does this treatment plant work? Does it employ all four stages of treatment? What processes are used during each stage to remove wastes?
2. What type of education and training does one need to have in order to gain employment at a wastewater treatment plant?
3. How is the sludge produced treated? What happens to the sludge after treatment?
4. What sorts of standards for both environmental and human health are in place for wastewater in our state? How does this plant ensure that they meet these standards?
5. What kinds of wastewater does this facility treat? Does it treat household waste, stormwater, and/or industrial waste?
6. How is the water sanitized before discharge? Where is the water discharged (into what body of water)?
7. Are any seasonal changes needed to operate this plant? If so, what are they?
8. What are some challenges currently facing this facility?
9. How many people and which communities does this facility serve?
10. What can you do to reduce your contribution to the wastewater stream?

Name: _____

Biomonitoring Pre-Lab Assignment

1. What is biomonitoring?

2. Briefly describe each of the four functional feeding groups:

- collectors
- shredders
- predators
- scrapers

3. What three groups of organisms are we looking for in an EPT richness metric?

Biomonitoring

OBJECTIVES:

- “Sample” organisms from different locations along a stream system
- Use these organisms to assess water quality and identify what changes in the land use have contributed to a decline in stream water quality
- Understand functional feeding groups and their significance in stream ecosystems

INTRODUCTION:

Aquatic **biomonitoring** is a way of understanding the health of a body of water (stream, river, pond, lake, etc.) based upon the types of organisms living there. Biomonitoring can occur in a variety of ways, such as **bioassays** (exposing organisms to an environment and then looking at mutation or death rates) and **biosurveys** (sampling a community to see what taxa are there).

In this lab, we will simulate a biosurvey (or community assessment) in a hypothetical river. Biosurveys may focus on a variety of organisms, such as invertebrates, algae, aquatic plants, fish, or amphibians, as well as birds and mammals. In our lab we will be studying invertebrates (“bugs”).

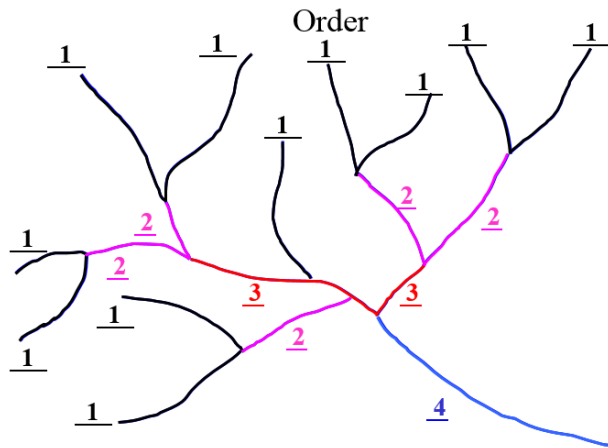
Aquatic invertebrates are one of the most commonly studied groups of organisms in biomonitoring studies. Different groups of these invertebrates tend to live in different places, depending on the health of the body of water. In healthy, unpolluted and undisturbed, ecosystems, invertebrates from the groups Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) tend to predominate. In ecosystems that have been disturbed by human activities (urbanization, industry, farming, etc.), we instead tend to see invertebrates from the groups Diptera (flies) and Chironomidae (midges).

There are several different metrics to determine the health of a body of water based on the invertebrate community. One of those metrics is the **EPT richness** metric, which measures the number of different kinds of mayflies, stoneflies, and caddisflies. A higher EPT richness (greater number of different kinds of mayflies, stoneflies, and caddisflies) is typically an indication of high water quality. Another metric is the **functional feeding group (FFG)**. This metric studies the proportion of the different functional feeding groups in a sample. There is an expected proportion of these FFGs in a habitat, depending on the food sources. Deviation from the expected proportion of FFGs indicates disturbance.

Functional feeding groups refer to how an invertebrate collects its food: shredder, collector, predator, or scraper. In a forested stream ecosystem, about 50% of the energy in the stream comes from algae and the other 50% comes from the **riparian** vegetation (the trees and plants along the river bank). **Scrapers** are organisms that eat the algae. **Shredders** eat coarse

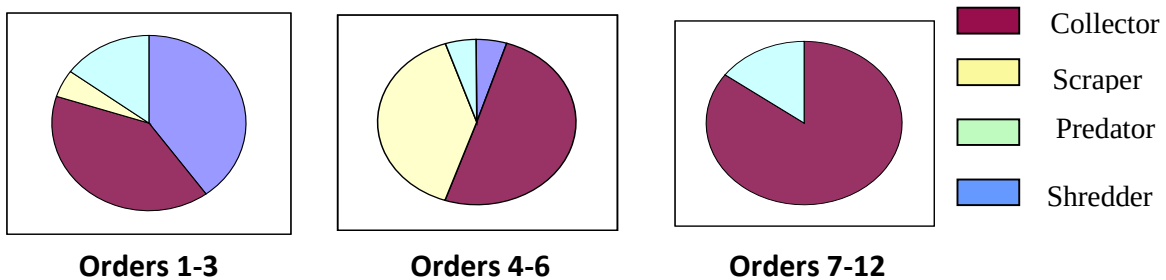
particulate matter, or CPOM (>1mm). **Collectors** eat fine particulate matter, or FPOM (<1mm). **Predators** eat other invertebrates.

The proportion of functional feeding groups is dependent on the **order** of the stream or river. Streams (and rivers) range in size from 1st to 12th order. A 1st order stream is the smallest. When two 1st order stream flow together, we now have a 2nd order stream, and so on, as shown below.



1st through 3rd order streams are known as the **headwaters**. 4th through 6th orders refer to large streams and small rivers, and anything larger is known as a large river.

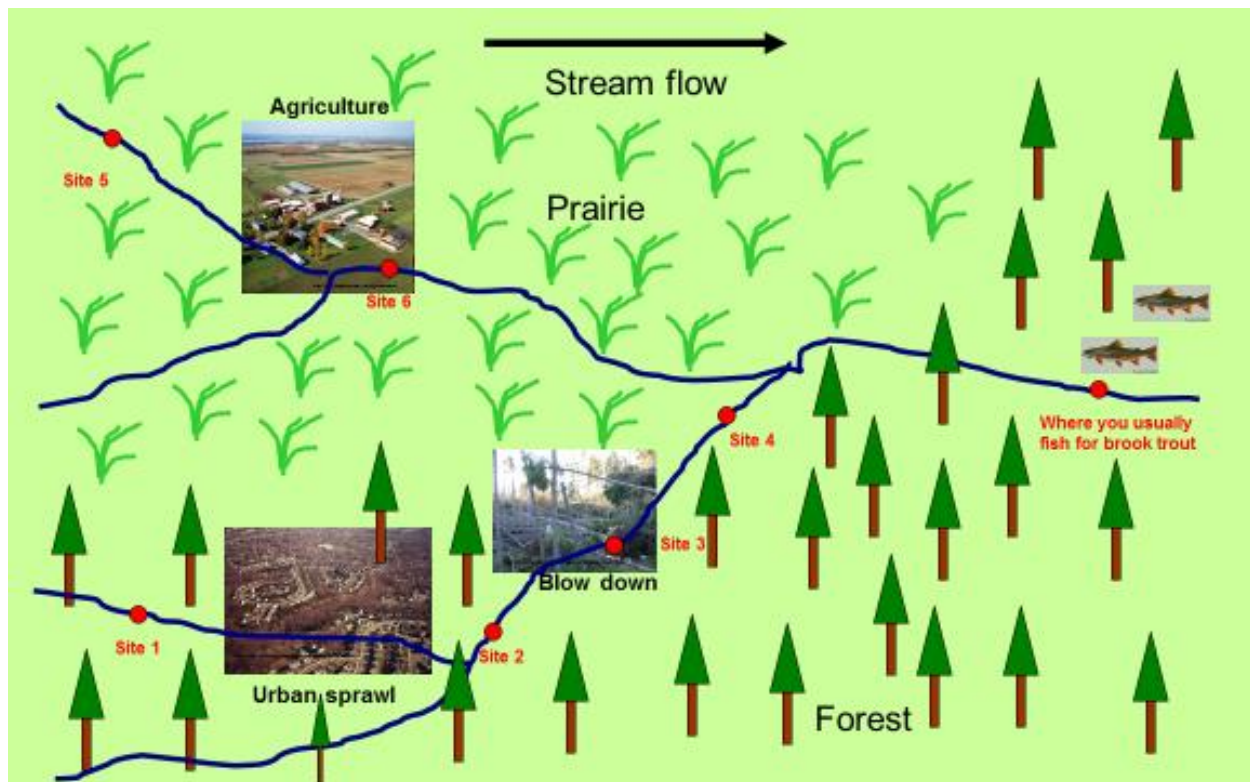
Because headwaters are typically surrounded by a large amount of riparian vegetation, the predominant source of energy is leaf litter, in the form of CPOM. Therefore, most of the invertebrates are shredders, as shown in the chart below. In large streams and small rivers, most of the CPOM has been broken down into FPOM and there is more algae (due to more sunlight penetration), so collectors and scrapers become more abundant. In large rivers, collectors predominate (the river is typically too **turbid** to allow for photosynthesis).



ACTIVITY:

Background:

Lately you've begun to notice that the trout fishing in the Rapid River has been getting worse and worse. You're pretty sure that it has to do with something going on upstream from your house. You know that trout like to feed on a diverse assemblage of bugs, so you are going to sample the invertebrates upstream and determine the quality of the water using biological metrics. Your results should help determine if a reduction in food quality is what is leading to a decline in trout. Here are a few things you know about the Rapid River: 1) It is a 3rd order stream, and historically it was within a forested/prairie area, 2) in the last 10 years suburban sprawl has started to encroach on one branch of the river. 3) Two years ago a large tree blow down occurred 5km upstream from you, and 4) within the last ten years agriculture has expanded in part of the Rapid River watershed.



Procedure:

1. You are going to simulate the process of collecting macroinvertebrates (“bugs”) from six different locations along the stream. Hopefully, the information provided by the bugs will help you determine why the water quality has decreased in the areas where you fish.
2. One common way to collect bugs is to take net samples throughout your site. We’re going to pretend that one net sample is obtained by kicking the bottom of the stream fifty times in your location. Kicking the bottom of the stream should dislodge the bugs, and they should flow into your net. You will simulate this by shaking your envelope and then randomly collect 20 invertebrates from the envelope.
3. Repeat step #2 for each of your sites (envelopes). Be sure to keep each sample straight!
4. Once your samples for each site have been obtained, you will be calculating two different pieces of information to help assess the stream water quality at each site. You will calculate both an EPT metric and FFG metric, as described in the introduction to this lab.
5. First you will calculate the EPT metric for each of your sample sites. Use the invertebrate key at your table to identify the organisms in your samples. The key contains pictures and names of the 16 invertebrates you will find throughout this stream. Notice that there are 9 families within the EPT group. To calculate the EPT metric, you simply score 1 point for the presence of each family (it does not matter how many you have, just simply whether or not they are present). Since there are only 9 families available, the highest the EPT index could ever get would be 9, which indicates outstanding water quality. Generally speaking, 0-4 = poor, 5-6 = fair, 6 and up = good.
6. Fill in the table on the board with your EPT data. Your instructor will calculate averages, and you should use the class average data (not your group data) to answer the questions below.
7. The second piece of information you need is the percentage of functional feeding groups at each site. Use the description of each invertebrate on the key to determine its functional feeding group. Ask your instructor for help if you aren’t sure what functional feeding group to place an invertebrate in.
8. Fill in the table on the board with your FFG data. Your instructor will calculate averages, and you should use the class average data (not your group data) to answer the questions below.

Questions:

1. On a separate sheet of paper (attach to your lab before turning in!), construct a table with the class EPT metric data.
2. On a separate sheet of paper (attach to your lab before turning in!), construct a table with the class FFG data.
3. What are the potential forms of pollution or changes in stream habitat that could be contributed by
 - a) the blow down?
 - b) the farming?
 - c) urbanization?
4. What site seems to have the worst water quality near it (use the data from #1-2 to support your answer? Why do you think this is (you can use the info from #3 to help with this answer)?
5. What seems to be the cause of the lower trout catch? Is it due to the blow down the farming, or urbanization? How do you support your argument? Is it the same or different from the site in question #4?

6. What are some possible consequences of lowering the biodiversity of macroinvertebrates within the stream (relate this to energy flow and matter cycle)?

7. Explain the percentages of functional feeding groups at each site if it deviates from what you would expect under natural conditions. Your control site for a forest area is site 1, and the control site for a prairie is site 5. If sites 2, 3, and 4 differ substantially from site 1, explain why. For example if site 3 has many more scrapers and fewer shredders than site 1, you should explain why. If site 6 differs from site 5, explain why.

8. Why is it important to collect more than one sample from single site? In other words, why did you use the class data (as opposed to just your own data) to answer these questions?

9. Where are some additional locations along this stream system where you would like to see more sample sites? Indicate their locations on the map (be sure to turn it in), and explain why they would be useful sites to add.

Name: _____

Energy Pre-Lab Assignment

1. Define the following terms:

- renewable energy sources
- direct solar energy
- indirect solar energy
- passive solar heating
- active solar heating

2. Review and define the following terms (refer back to the “Scientific Method and Experimental Design” lab):

- hypothesis
- independent variable
- dependent variable
- constants

3. Besides the title, what are the 5 sections a lab report should contain (read the information on “How to Write a Lab Report” in the Appendix, pg. 200-203).

Energy

OBJECTIVES:

- Identify variables, design and perform an experiment, collect and analyze data
- Learn advantages of solar energy
- Investigate passive solar heating

INTRODUCTION:

Solar energy originates with **thermonuclear reactions** on the Sun. Hydrogen atoms fuse to form helium atoms, releasing energy in the process. Solar energy reaching the earth is radiant energy (ultraviolet, visible, and infrared—all different wavelengths of light). The potential of solar power is incredible: 40 minutes of sunlight on the earth's surface is equivalent to one year's use of fossil fuel. Another way to look at it is that we need less than 1% of earth's surface to collect enough solar energy for all of the electricity needs of the whole world. Solar energy is sustainable, as it does not change the energy balance of the biosphere because all of the energy is eventually given off as heat to the atmosphere.

A wide variety of technologies for capturing and using solar energy exist. Solar energy can be used to heat water and space, as well as to generate electricity. In **passive solar heating**, the sun's energy is used to heat buildings without the use of pumps or fans to distribute the collected heat. Certain design features can be used to warm buildings and retain heat in the winter and help them to remain cool in the summer. In today's lab, you will be investigating design features that retain heat.

ACTIVITY:

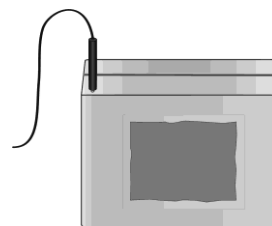
Throughout the semester you have gained experience in working with data and the scientific method. After completing an introductory activity, you will work in groups to devise your own researchable question, plan and conduct an experiment, collect and analyze your data, and draw a conclusion based on your experimental results.

Preliminary Activity:

You will monitor temperature and determine the cooling rate of a model solar house that has been heated by a lamp representing the sun.

PROCEDURE

1. Connect the Temperature Probe and the data-collection interface.
2. Set up the data-collection program to collect data for 300 seconds following your teacher's instructions.
3. Note and record room temperature.
4. Obtain a model solar house. Insert the Temperature Probe into the hole provided in the top of the model house. Position a lamp with its bulb about 3 cm away from the model solar house's window.
5. Turn the lamp on and allow it to warm the model house.
6. Turn the lamp off when the internal temperature of the model house is 7.0°C greater than room temperature. **Caution: Do not touch the bulb. It will be very hot.**
7. When the temperature drops to exactly 6.0°C greater than room temperature, start data collection.
8. After data are collected, use the linear regression function to determine the cooling rate. The slope of the line represents the cooling rate.



QUESTIONS

1. What was the classroom temperature (in $^{\circ}\text{C}$) at the beginning of the Preliminary Activity?
2. What was the cooling rate (in $^{\circ}\text{C}/\text{s}$) of your model solar house?
3. List some features of passive solar houses that help capture solar energy and retain heat.

4. List at least one researchable question for this experiment.

Inquiry Experiment:

On a separate piece of paper, prepare a research plan that includes the following:

- the question to be investigated
- the hypothesis to be tested
- the independent and dependent variables
- the constants (controlled variables) and how you will keep them constant
- a materials list
- a procedure
- data tables and graphs

Some possible researchable questions:

- how does insulation thickness affect heat retention?
- how does insulation material affect heat retention?
- how does shiny aluminum foil affect heat retention?
- how does the number of window panes affect heat retention?
- how do window covers affect heat retention?
- how does thermal mass (concrete, stone, water, etc.) affect heat retention?
- how does the amount of thermal mass affect heat retention?

Once you have prepared your research plan, present it to your instructor for his/her approval. Once your plan has been approved, you may conduct your experiment. After you have collected and analyzed your data, you will write up your findings in the form of a brief lab report. Information about how to write lab reports can be found in the Appendix on pg. 200-203.

Name: _____

Recycling at IHCC Pre-Lab Assignment

1. What sorts of things do you recycle while you are on the IHCC campus?
2. How can you tell the difference between a recycling bin and a trash can on the IHCC campus?
3. What are some deterrents to recycling that you have encountered on the IHCC campus?

Recycling at IHCC

OBJECTIVES:

- Collect and analyze data regarding recycling at IHCC
- Consider ways to reduce the amount of MSW generated and disposed of at IHCC
- Create educational materials to promote waste reduction at IHCC

INTRODUCTION:

The stuff that we throw away from our homes and businesses is called **municipal solid waste** (MSW). The amount of MSW generated keeps increasing as our lifestyles change. We grow accustomed to using more disposable items and excess packaging. According to the U.S. EPA, we generate an average of 4.4 pounds of MSW per person per day in the U.S.

That's a lot of waste! First, we need to reduce the amount of waste we produce. Then we must dispose of our waste in a manner that is efficient and protects the environment and human health. Much of our MSW consists of paper, yard waste, plastics, metals, wood, glass, textiles, and food waste. Most MSW is recyclable or compostable, but less than 30% of it actually gets recycled.

The best way to deal with MSW and prevent pollution is to simply create less of it by **source reduction**. Examples of source reduction (or waste prevention) include lightening the weight of products like metal cans and disposable diapers, reusing items like used textbooks and clothing from consignment shops, buying items with longer lives, and reducing the amount of junk mail and catalogs we receive.

Source reduction will help greatly. But what do we do with the trash that is still inevitable? Our next step is **recycling**. Over 75% of MSW is recyclable. Materials that can be recycled include paper and paperboard, glass, plastic (some forms), metals, yard wastes, textiles, and tires.

The least desirable way of dealing with MSW is to dispose of it in landfills and incinerators. But by engaging in source reduction and recycling, we can minimize the amount of MSW being disposed of. This benefits not just the environment, but is also economically advantageous, as buying less "stuff" saves us money while the cost of disposing MSW is on the rise.

In this lab, we will explore ways to reduce the amount of MSW that is generated and disposed of on the campus of Inver Hills Community College.

ACTIVITY:

Your group will be assigned to one of the buildings on campus. It is your responsibility to complete a detailed study of the generation and disposal of MSW in your building. You should investigate all of the public areas of the building. If a door is locked, you may skip that room. Similarly, do not disrupt classes to complete your investigation. You may politely explain the purpose of your study and ask permission to enter offices, etc.

1. Which building are you investigating?
2. Begin by making a table on a separate sheet of paper listing the types and locations of recycling and trash bins in your building. Be specific and descriptive as to the type (is it a trash bin, paper-only bin, mixed recycling bin, small bin vs. large bin, etc.). If it's not clear what type of bin it is, then you should indicate that ("unknown"). You should also be detailed as to the location of each bin, so that I can find it. For example, located next to room 302, or at the north window in the 2nd floor hallway.
3. Examine the trash containers. You should only do this visually. ***Do not put your hands in the containers and risk personal injury; this is especially true in the bathrooms where you may encounter hypodermic needles and other hazards.*** Gloves are available if you'd like them, as you will likely need to lift the lid off of some of the bins on campus. Make a table (on a separate sheet of paper) that includes the following items: waste item, type of waste (is it paper, plastic, glass, metal, food, etc.), disposed of properly or not, possible source(s) of the waste, whether the item is recyclable or compostable, is there a reusable alternative for this item (if so, what is it).
4. Examine the recycling containers. You should only do this visually. ***Do not put your hands in the containers and risk personal injury; this is especially true in the bathrooms where you may encounter hypodermic needles and other hazards.*** Gloves are available if you'd like them, as you will likely need to lift the lid off of some of the bins on campus. Make a table (on a separate sheet of paper) that includes the following items: waste item, type of waste (is it paper, plastic, glass, metal, food, etc.), disposed of properly or not, possible source(s) of the waste, whether the item is recyclable or compostable, is there a reusable alternative for this item (if so, what is it).
5. Make a table (on a separate sheet of paper) listing the numbers, types and locations of materials (for example, signs) that explain recycling.
6. Based on your assessments, what additional steps could IHCC (administration, faculty, staff, and students) do to prevent waste through source reduction? Refer to the data you collected to support your ideas.

7. Did you find recyclables in the trash bins? Did you find trash in the recycling bins? If so, why do you think this happened?

8. Why is contamination (trash in recycling bins, and recycling in trash bins) an issue? How does this impact recycling rates? You may need to do some additional research to answer this question.

9. What could be done to prevent contamination of recycling and trash bins?

10. Generate a poster, flyer, brochure, YouTube video, or other type of material that promotes (or provides education on) waste reduction, reuse, or recycling at IHCC.

Name: _____

Oil Spill Clean-Up Pre-Lab Assignment

1. Crude oil is composed of a variety of hydrocarbons. You likely already learned about hydrocarbons in this class. What is a hydrocarbon?
2. Crude oil and motor oil are hazardous to the environment. What hydrocarbon will we use in place of these oils in this lab simulation?
3. Which infamous oil spill will we be simulating in today's lab? Briefly explain where and how this oil spill occurred.

Oil Spill Clean-Up

OBJECTIVES:

- Understand why oil spills pose a danger to aquatic wildlife
- Simulate various methods of oil spill clean-up and evaluate their effectiveness
- Consider the costs and benefits, both environmental and economic, of oil spill clean-up methods

INTRODUCTION:

Most (79%) of the energy that is used worldwide is in the form of the **fossil fuels—coal, natural gas, and oil**. Of the fossil fuels, oil is the most widely used, accounting for about 32% of the world's energy sources. We are highly dependent upon crude oil in the U.S., where it is used to produce gasoline, heating oil, propane, asphalt, lubricants, etc.

While we use oil and other fossil fuels throughout the U.S., oil did not form throughout the U.S. Oil and other fossil fuels were created hundreds of millions of years ago, under specific conditions that were common in only a few places on the Earth. During that time, photosynthesis greatly exceeded respiration and decomposition, leading to the accumulation of large amounts of dead organic material. That organic material was eventually covered with sediments, and pressure and heat converted the organic material into the fossil fuels.

Because oil was not deposited evenly throughout the Earth, we must now transport it from its site of extraction, to the refineries, and then to the points of its use. In this process, there have been many serious spills, such as the 1989 grounding of the supertanker *Exxon Valdez* in Prince William Sound in Alaska. On March 24, 1989, the *Exxon Valdez* collided with a reef, resulting in a spill of over 10 million gallons of crude oil into the sound. This oil eventually covered more than 1,300 miles of coastline and 11,000 square miles of ocean, and caused billions of dollars' worth of environmental damages.

Oil spills not only through tanker accidents, but also through exploration losses (such as the 2010 Deepwater Horizon accident) and the leaking and inadvertent losses from tankers as well as recreational boats and motor vehicles.

When crude oil is spilled some of it spreads across the water (a single gallon can cover four acres of water!), some evaporates into the atmosphere, and some of it emulsifies, becomes thick and sticky and sinks to the bottom of the ocean. As it emulsifies, though, it sticks to any solid object it encounters along the way.

ACTIVITY:

Most oil spills have occurred as a result of human error (in the case of the *Exxon Valdez* accident, it appears that the radar system had not been properly maintained, the crew was likely fatigued due to a heavy workload and the captain may have been under the influence of alcohol).

1. What could be done to prevent oil spills? What actions could be taken by individuals, such as yourself, as well as by oil companies and the government?

2. How do you think humans are impacted by oil spills?

In addition to impacting humans, oil spills have impacts, both immediate and long-term, on plants, animals, and ecosystems. It has been estimated that 100,000-250,000 seabirds, at least 2,800 sea otters, 300 harbor seals, nearly 250 bald eagles, and up to 22 killer whales died as an immediate result of the *Exxon Valdez* oil spill. Oil spills affect aquatic food chains by reducing light transmission (and therefore photosynthesis), reducing dissolved oxygen, and through the actions of toxic compounds (such as benzene, toluene, xylene, naphthalene, and phenanthrene) which kill fish, shellfish, invertebrates, etc.

In aquatic birds, feathers act as insulation. Oil-soaked birds die due to an inability to obtain food or as a result of exposure in cold water.

3. Immerse a feather in a beaker of water. What do you notice about this water-soaked feather?

4. How do birds dry their wet feathers? Try it with your feather; does it work?

5. Write a hypothesis predicting what will happen if you immerse a feather into a mixture of oil and water.

6. Immerse a feather into beaker containing a mixture of oil and water (we will substitute vegetable oil for crude oil in this lab). Was your prediction correct?
7. Try drying your feather, as in question #4. How effective is it?
8. Based on your observations, how would a bird's ability to fly be affected if it were covered in crude oil?
9. Aquatic birds not only need to fly, but also to swim. How would a coat of oil affect a bird's ability to float and swim? Can you test this with your feathers? How? What are the results?
10. Birds rescued from oil spills are usually treated by washing them with dishwashing soap. Why would animal rescuers use this method? How would it help the birds? Try washing your oil-soaked feather with plain water and then with soap and water; which is more effective?

In addition to cleaning up birds and other wildlife, the oil itself needs to be cleaned up after a spill. There are two main ways of doing this—mechanical and bioremediation (using microbes to break down and digest the oil). In this lab, we will look at the different types of mechanical methods and evaluate their effectiveness.

Clean up of the *Exxon Valdez* spill initially involved the use of booms and skimmers. **Booms** are barriers that simply contain the oil spill and try to prevent it from spreading. **Skimmers** remove the oil, along with some water, from the surface of the water. Skimming is only effective in calm conditions.

11. Fill your aluminum pan halfway with water, to simulate Prince William Sound. Tie your string into a loop (this will be your boom) and float it in the center of the pan. Add several drops of vegetable, to create an oil spill, on the surface of the water in the center of the boom. How well does your boom prevent oil from spreading?

12. Use the spoon as a skimmer and try to remove as much of the oil as possible. How effective do you think skimming is?

During the cleanup, high winds developed making the water rough and choppy.

13. Remove your boom and throw it away. Add oil to create an oil slick. Have one or two group members gently blow through the straws, across the water surface, to simulate the high winds. Another group member should use the skimmer to try to clean up as much of the oil as possible. How did the wind impact your ability to clean up the oil spill?

In addition to booms and skimmers, **sorbents** were used to clean up the oil. Sorbents are materials that absorb oil, such as straw, sawdust, feathers, ground-up corncobs, peat moss, clay, sand, perlite, and vermiculite.

14. Why do you think feathers would make effective sorbents?

15. Again, create an oil spill in your pan of water. Use the provided sorbent materials to try to clean up your oil spill, one at a time. Evaluate the effectiveness of each sorbent (poor, fair, good, excellent) in the table on the next page.

16. Now evaluate the effectiveness of each sorbent in windy conditions. Record your observations in the table on the next page.

Detergents (along with **dispersants** and **solvents**) are sometimes used to break down the oil. However, their use is controversial, as many of the chemicals used are toxic to organisms, including the humans involved in the clean up efforts.

17. Next evaluate the effectiveness of the sorbents when combined with detergent. Record your results in the table on the next page.

Sorbent	Effectiveness in Calm Conditions	Effectiveness in Windy Conditions	Effectiveness with Detergent
Paper Towel			
Cotton Ball			
Sponge			
Sphagnum Moss			
Wood Shavings			

18. Based on your results, what method (or combination of methods) would have been most effective at cleaning up the oil in Prince William Sound? Why?

19. The costs associated with cleaning up Prince William Sound have reached into the billions of dollars range. Why do you think it is so expensive to clean up oil spills? In other words, what was all of this money spent on?

20. In addition to clean up costs, Exxon Mobil paid to settle criminal and civil cases stemming from this oil spill and was also been ordered to pay punitive damages. Besides the costs of cleaning up the oil spill, what economic costs do you think this oil spill caused? What about environmental costs?

21. Was the time and money spent to clean up this spill worthwhile? What are the benefits (both economic and environmental) to cleaning up oil spills, and how do they compare to the costs?

22. The *Exxon Valdez* oil spill was not the most recent or the biggest oil spill. The largest marine oil spill was the Deepwater Horizon accident in April-July 2010. Research this accident. Did we learn any lessons from *Exxon Valdez* that were applied to the Deepwater Horizon accident? If so, what were they and how were they applied? If not, why not?

Name: _____

Watershed Management Pre-Lab Assignment

1. What is meant by ecosystem management?
2. What is a 3rd order stream? (review the “Biomonitoring” lab if you don’t remember).
3. What is meant by “old growth” forest? Do a google search or review your textbook and/or lecture notes.

Watershed Management

OBJECTIVES:

- Understand and apply the process and goals of ecosystem management
- Consider the diverse wants and needs of various members of current and future generations
- Create an ecosystem management plan integrating viewpoints of different stakeholders

INTRODUCTION:

Ecosystem management is a process that aims to conserve major ecological services and restore natural resources while meeting the socioeconomic, political and cultural and needs of current and future generations. The process of ecosystem management involves the consideration of social values and priorities. It requires a clearly defined ecosystem (with boundaries) and aims to maintain the ecosystem in such a way that is sustainable and also achieves social benefits. Scientific information is important in making ecosystem management decisions, but it is not the only type of information used in making decisions.

The process of making ecosystem management decisions involves public input and typically depends upon compromise amongst the various **stakeholders**. Stakeholders are individuals or groups of people who are affected by environmental decisions and actions, but they also may have power to influence the outcomes of environmental decisions relating to ecosystem management. In order to make appropriate ecosystem management decisions, the knowledge and wishes of various stakeholders needs to be taken into account. Stakeholders include scientists, businesspeople, politicians, farmers and ranchers, the general public, etc.

ACTIVITY:

We will conduct a role-play debate about a hypothetical situation (described below). There will be four characters (roles) who will discuss and debate the issues and must come to some sort of decision in the form of an ecosystem management plan. Each group will have at least one character from each of the four categories of stakeholders (socio-cultural, political, economic, and ecological).

Situation

The Blatz highlands occupy a 30,000 acre (approximately 50 square miles) old growth forest section on state land. Historically logging has been avoided in this area because of a large supply of timber on neighboring land and the difficult access to the highlands. The highlands contain an assemblage of flora and fauna which stands apart from the nearby areas which are harvested every 30-40 years. The main uses of the highlands is as a recreational area. People come here to hike through the tall pines, camp, and especially to fish on Lunker Creek.

Lunker Creek is a 3rd order stream which annually produces some of the largest brook trout in the state. The large size seems to make up for the lack of fish numbers because people come from many areas (including many from out of state) just to have a shot at the “Lunker lunker”. The highlands generate a modest revenue from license sales and camping permits. An economic study completed 5 years ago revealed that more people would come to the area if better lodging were available and also if there was better access to more areas of the highlands (right now there is only one gravel road).

Historically local loggers have continually harvested the aspen which grows just outside of the highlands on a 30-40 year rotation. Most aspen goes directly to the paper mill. Lately the price of paper has decreased dramatically and loggers have begun to lobby the state for rights to log the old growth timber in the Blatz highlands. They can sell this high quality timber at a premium to various forest product industries. If the loggers do not get access to the highlands there is a chance that many will go out of business and that could lead to an eventual shut down of the paper mill.

The state is in the middle of the recession and currently is operating with a \$2 billion deficit. It could really use the revenue from logging, but it also realizes that many people will be angry if the logging proceeds. It is an election year so many politicians decide the best way to proceed is to hold public meetings and get a feel for the situation. The goal of these meetings is to come up with some sort of plan for the future management of the Blatz highlands.

Meeting Attendants:

DNR representative

Logging representative

State representative

Trout angler/outdoor enthusiast

Step 1: Grouping, researching, and determining key pieces

Your instructor will assign you to a role/character and give you a handout with additional information about your role/character. Read the provided information and then get together with everyone who was assigned the same role as you. Research and discuss the issues from your character's point of view. Devise and share strategies, find facts to present, and prepare a list of common goals and objectives you will try to establish in the Blatz highlands. Each person should leave this group ready to present a similar case.

Goals that should be addressed:

- how much land to harvest
- how to protect the stream
- lodging and access concerns

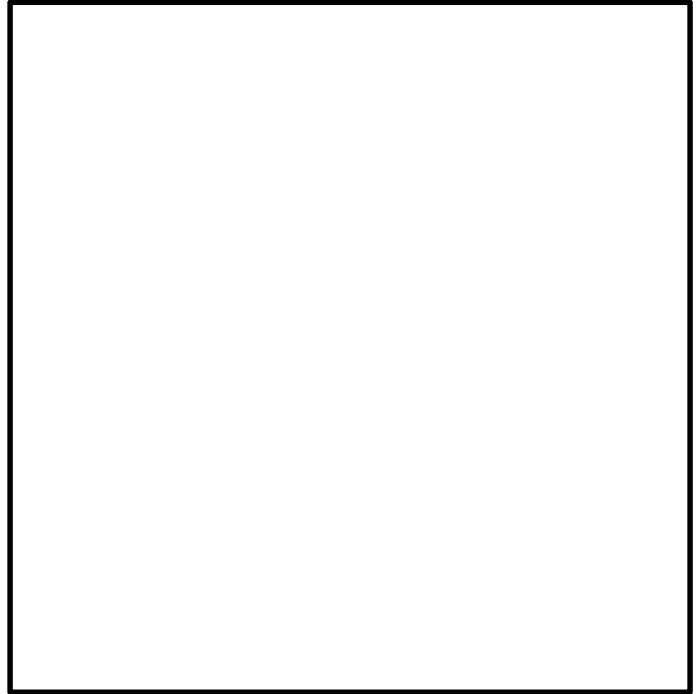
Step 2: Regrouping, discussing, and developing a management plan

Your instructor will assign you to a small group, with one person from each role. Your small group will discuss the situation from each character's point of view, respectfully question and debate with each other's positions, and then work together to come to a consensus. You will develop a management plan and answer the questions below. Be prepared to discuss your final plan with the rest of the class.

Draw a design for your management plan.

Management Goals:

1. Harvest goal
2. Stream protection goal
3. Lodging and access goal



Describe objectives on how you plan to accomplish your goals. Objectives need to be measurable and have a timeframe.

1. What methods will you use to harvest? How much will you harvest? Where will you harvest? Other considerations?

2. How will you protect the stream? Will you include buffer strips? What kind of fishing regulations will you enact? Any restrictions on road building? Other considerations?

3. What kinds of development will you allow? What kind of roads will you build? What are the human impacts of these activities and how will you mitigate them? Other considerations?

Name: _____

Ecological Footprints Pre-Lab Assignment

1. What is an ecological footprint?

2. You will need some information to complete this lab activity. Prior to lab, determine the answers to these questions:
 - a. What is the size of your home (in square feet)?
 - b. How far do you travel by car (as a driver or passenger) per week (in miles)?
 - c. What is the gas mileage of the car you travel in most often (in miles per gallon)?
 - d. How far do you travel by motorbike per week (in miles)?
 - e. How far do you travel on public transportation (bus or train) per week (in miles)?
 - f. How many hours do you fly each year?
3. Write a hypothesis predicting one simple way in which you might reduce your ecological footprint.

Ecological Footprints

OBJECTIVES:

- Understand the purpose of ecological footprint analysis
- Calculate your ecological footprint and determine actions to lower your impact
- Consider the implications of high ecological footprints

INTRODUCTION:

An **ecological footprint** is a way to measure an individual's personal impact on the Earth. It is an estimate of the area of land required to provide the goods and services a person consumes. Examples of goods and services considered in a footprint analysis include food, energy, shelter, healthcare, entertainment, government, etc. These analyses consider how much land it takes to produce timber used to build your home, how much land it takes to grow vegetation to absorb the CO₂ emitted from your electricity, heating and transportation needs, how much land it takes to grow the food you eat, and so forth.

Several different online footprint calculators exist. Typically at the end of the survey, results are given in terms of how much land in total is required to support your lifestyle, a breakdown of how that land is used for different good and services, the tons of CO₂ you produce in a year, and/or the number of Earths that would be required to support the world's population if everyone had a lifestyle similar to yours.

ACTIVITY:

In this activity, you will use an online calculator to determine your ecological footprint. Because everyone's lifestyle is different, you will work individually (not in groups) to complete this lab. Be honest with your answers. Your grade will be determined by the completeness and thoughtfulness of your answers, not by your personal footprint outcome.

1. You will use the calculator found at <http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/>. For each set of questions that follows, work through the calculator (you may simply "Enter Basic Information"). Record your data as requested and answer the questions.
2. Go through the calculator's questions, answering honestly about your current lifestyle. When you are finished you will get your resulting data on the "Your Ecological Footprint" page.
3. How many Earths would be required if everyone lived like you?
4. How many tons of CO₂ would be produced?
5. How many global acres does it take to support your lifestyle?
6. In the space below, draw the pie chart (don't forget to include a legend and label the percentages) showing your breakdown of your ecological footprint.

7. Click on "Explore Scenarios". How many Earths are needed if you:
 - a. reduce the amount of animal products you eat by half?
 - b. purchase items that use less packaging and have recycled content?
 - c. take a local vacation to avoid flying?
 - d. do all of the above?
8. Return to the website, unclick your choices from #7, click "Return to the Quiz" and click on "Edit Your Footprint." You have decided to minimize your transportation footprint by only using public transportation. By how much has your carbon footprint (tons of CO₂ produced) decreased?
9. After your edit, how many Earths are required?
10. Return to the website and click on "Edit Your Footprint." Return your choices in #8 to your original choices (#2). Your job requires you to fly from the Twin Cities to Chicago (a 90 minute flight) once a month. How has your carbon footprint changed?
11. After your edit, how many Earths are required?
12. Return to the website and click on "Edit Your Footprint." Return your choices in #10 to your original choices (#2). You have started a family (or increased the size of your current family) and decide that you need to purchase a car. In order to accommodate your entire family, you purchase a large SUV. How has your carbon footprint changed?

13. After your edit, how many Earths are required?

14. Return to the website and click on “Edit Your Footprint.” Return your choices in #12 to your original choices (#2). You have decided to purchase a new home. You purchased a 2,500 square foot home. How has your carbon footprint changed?

15. After your edit, how many Earths are required?

16. Return to the website and click on “Edit Your Footprint.” Return your choices in #14 to your original choices (#2). You have decided to eat a vegan diet and to purchase the majority of your food locally. How has your carbon footprint changed?

17. After your edit, how many Earths are required?

18. Return to the website and click on “Edit Your Footprint.” Return your choices in #16 to your original choices (#2). What other choices can you make to lower your footprint?

19. Run the simulation. How has your carbon footprint changed?

20. After your edit, how many Earths are required?

21. Return to the website and click on “Reset Quiz”. Try running through the simulation (assume a USA citizen) making choices that you think have the lowest ecological impact. What is the carbon footprint of this person?

22. How many Earths are required for this person?
23. Why do you think it still takes more than one Earth to support this person?
24. What are the implications of high ecological footprints?
25. What is one simple action you can take, starting today, to minimize your ecological footprint?

Name: _____

Design a Sustainable Community Pre-Lab Assignment

1. What is meant by the term “sustainable”? Refer back to lecture notes, textbooks, etc. if you need to, but put your answer into your own words! (In other words, what does “sustainable” mean to you?)
2. What is urban planning?
3. List three things a person might need to incorporate into a sustainable community.

Design a Sustainable Community

OBJECTIVES:

- Apply knowledge of various course concepts to planning a sustainable community
- Understand the idea of urban planning
- Consider ways in which to live sustainably in your current community

INTRODUCTION:

In the U.S., prior to World War II, most people lived in town, and all of a person's needs could be gotten within walking distance. During the war, people went without a lot of new material possessions, because money and factories were dedicated to the war effort. After the war, there was an industrial boom, as people bought the creature comforts that were not available to them physically or financially during the war. People also wanted "The American Dream." They wanted to move from their cramped surroundings to someplace where they could have their own house and yard. Low income loans from the government made this possible. Also during this time, many people bought automobiles. Automobiles meant that a person could live farther away from work, but not have a longer traveling time to work. As a result, more people moved to the suburbs. The resulting **urban sprawl** has caused a lot of environmental impacts, such as habitat destruction (and biodiversity loss) and air pollution, as well as human health impacts.

Urban planning is a way to use **zoning** and **growth boundaries** to plan for growth while also limiting sprawl. Zoning is the designation of specific areas for specific categories of land use (such as residential, commercial, industrial, and open space). Growth boundaries are a type of zoning that separate areas of high-density urban development from low-density activities.

Urban planning can also design for **smart growth**, which works to prevent and correct the negative impacts of urban sprawl. The goal is to allow growth to happen in economically, socially, and environmentally sustainable ways. Smart growth initiatives may set boundaries on urban sprawl, save open space, develop existing (but deteriorating) urban space, or create new towns (in a pre-WWII style).

New urbanism is a movement that promotes compact communities, mixed land uses, the creation of a range of housing choices, communities that provide a sense of uniqueness and belonging, the conservation of open space, the strengthening of existing communities, providing a variety of transportation choices, making neighborhoods walkable, and making decisions in ways that are fair, cost-effective and take community involvement.

Building sustainable communities can also involve the use of **green building** techniques, building rating systems such as **LEED**, public transportation systems, the use of **green infrastructure**, providing habitat for urban wildlife, and the creation of city parks and **greenways**.

ACTIVITY:

You have been hired to design a prototype town which will serve as a model for other towns and cities to follow as we make the necessary transition towards sustainable living. You will work with your group to discuss your town's layout and needs, using the questions below as guidelines (but you may also add in other considerations that you've learned about this semester). You will then create a "map" or "blueprint" to your town on the paper provided that shows how you town will be laid out, what industries it includes, transportation systems, etc. Don't forget to name your town! Towards the end of lab, each group will briefly present their town plans to the rest of the class. You should then answer the follow-up questions on the next page.

Rules:

- The community must be sustainable—producing necessary energy and resources (food, jobs, etc.)
- The community must resemble modern society as much as possible.
- Your town consists of roughly 100,000 people.
- You must include farmers, industry, and governmental workers.

Consider the following as you design your community:

- You may choose the terrain and physical features of your city (i.e., near ocean, river, mountains, prairie, etc.).
- What kind of industries and businesses do you need? What about government and other services?
- What resources does your city require?
- How will it get these resources?
- Where will energy come from? What types of energy will be used?
- Define the types of transport available.
- Where will you get resources to build houses and businesses?
- What kind of layout will you design for your community? Define city zoning and land use (the location of residential areas, farms, schools, commercial and industrial sites).
- Integrate the residential, agricultural, and industrial lands so that you provide ideal living and working environments.
- Do residents of this city have good access to their work places from home? Have you addressed urban sprawl?
- Address any pollution/environmental problems that may arise from energy production, industry, transport, etc.

Follow-up questions:

1. Would you be willing to live in community your group planned? Why or why not?

2. Did people in the community have to give anything up? What was it? Are there sustainable alternatives for these things?

3. Which of the class's communities do you think would be the "nicest"/"easiest" community to live in or transition into from your present community?

4. How has focusing on sustainability influenced your community's composition and layout?

5. How would the placement of your community into a different ecosystem (desert, arctic, mountains, tropics, etc.) affect your design? How would it affect the number of people you could support? How would it affect the kinds of businesses and industry?

6. How can YOU support sustainable living in your present community?

APPENDIX

BASIC MATH SKILLS

Averages/Mean:

To calculate an average, add all the numbers in the data set and divide by the number of numbers.

Example: If you had test scores of 93%, 98%, and 74%, what is your average test score? Add up 93, 98, and 74. Then divide that number by 3 (the total number of test scores). Your average test score is 88.3%.

Percentages/Frequencies:

To convert a fraction to a percentage, divide the numerator (top number) by the denominator (bottom number) and multiply by 100.

Example: If 19 out of 26 students attended lab this week, what percent of students attended class? Divide 19 by 26, and then multiply by 100. The percent of students attending class is 73%.

To convert a decimal to a percentage, multiply by 100.

METRIC CONVERSION WORKSHEET

The meter (m) is the basic length in the metric system. The gram (g) is the basic unit of mass. The liter (l) is the basic unit of volume.

Some equivalencies in the unit of length are:

1 meter (m) = 100 centimeters (cm)

1 meter (m) = 1000 millimeters (mm)

1 meter (m) = 1,000,000 microns or micrometers (μm)

1 meter (m) = 1,000,000,000 nanometers (nm)

1 meter (m) = 10,000,000,000 Angstroms ($\text{\AA}$)

ALSO:

1 cm = 1/100 m or 0.01 m or 1.0×10^{-2} m

1 mm = 1/1000 m or 0.001 m or 1.0×10^{-3} m

1 μm = 1/1,000,000 m or 0.000001 m or 1.0×10^{-6} m

1 nm = 1/1,000,000,000 m or 0.000000001 m or 1.0×10^{-9} m

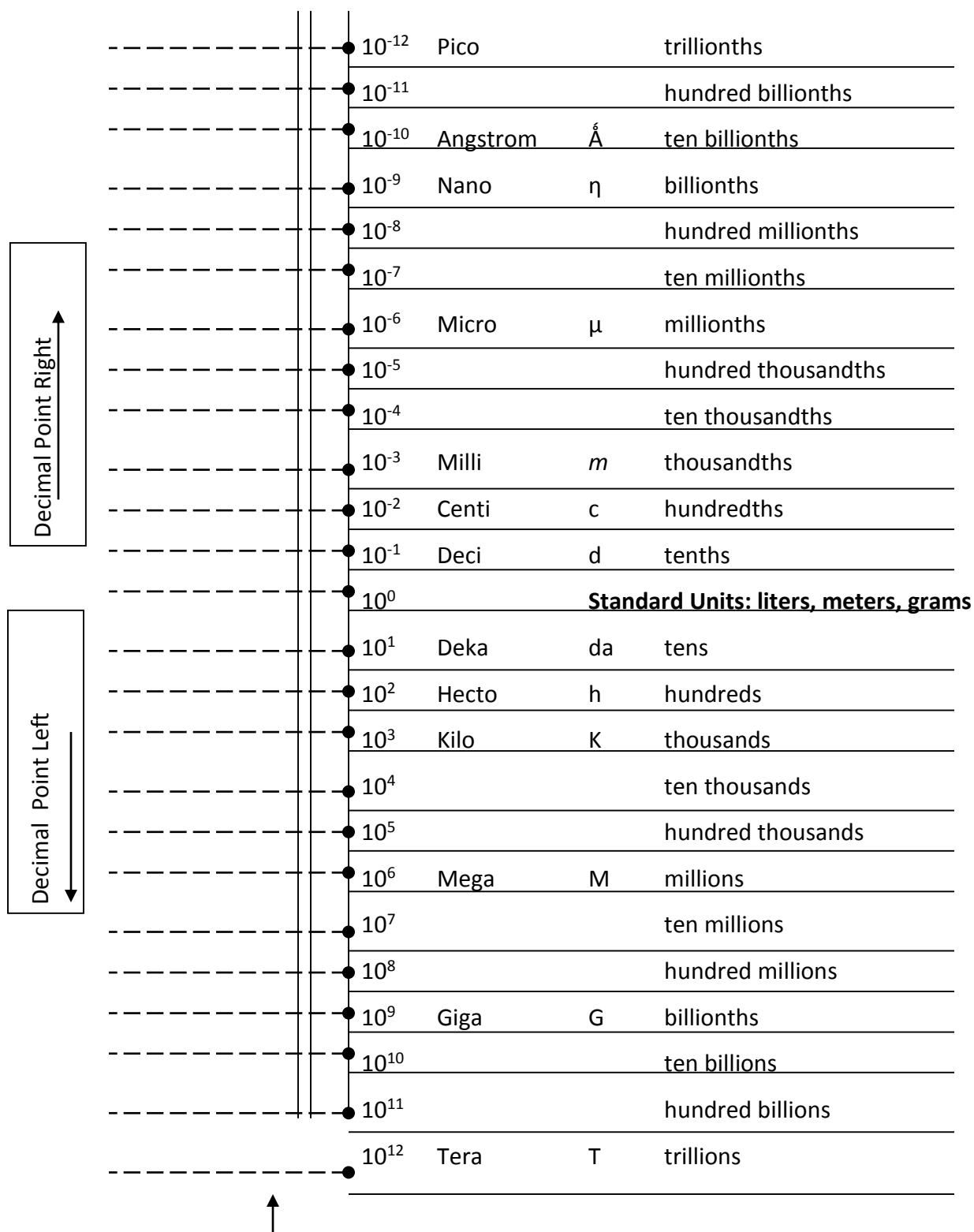
1 $\text{\AA}$ = 1/10,000,000,000 m or 0.0000000001 m or 1.0×10^{-10} m

For practice or to be handed in, make the following metric conversions. N.B.

In converting values within the metric system, you need to make two major decisions:

- a. Which direction you must move the decimal (right or left), and
- b. How many places to move the decimal

METRIC CONVERSION CHART



SCIENTIFIC NOTATION

Very large numbers with many zeros such as 1,000,000,000,000,000 or very small numbers such as 0.000000000000000001 are very cumbersome to work with. Consequently, the numbers are expressed in a kind of mathematical shorthand known as scientific notation. Scientific notation has the following form, where M is a number between 1 and 9

$$M \times 10^n$$

and where n specifies how many times the number M is raised to the power of 10. The exponent n has two meanings, depending on its sign. If n is positive, M is multiplied by 10 n times. For example, if n = 2 and M = 1.2, then:

$$1.2 \times 10^2 = 1.2 \times 10 \times 10 = 120$$

In other words, if n is positive, the decimal point of M is moved to the right n times. In this case the decimal point of 1.2 is moved two places to the right.

$$1.20.$$

If n is negative, M is divided by 10 n times.

$$1.2 \times 10^{-2} = \frac{1.2}{(10 \times 10)} = \frac{1.2}{100} = 0.012$$

In other words, if n is negative, the decimal point of M is moved to the left n times. In this case the decimal point of 1.2 is moved two places to the left.

$$0.01.2$$

If M is the number 1.0, it often is not expressed in scientific notation. For example, 1.0×10^2 is the same thing as 10^2 .

Two common examples of the use of scientific notation in chemistry are Avogadro's number and pH. Avogadro's number, 6.023×10^{23} , is the number of atoms in 1 g molecular weight of an element. Thus:

$$6.023 \times 10^{23} = 602,300,000,000,000,000,000,000$$

which is a very large number of atoms. The pH scale is a measure of the concentration of hydrogen ions in a solution. A neutral solution has 10^{-7} moles of hydrogen ions per liter. In other words:

$$10^{-7} = 0.0000001$$

which is a very small amount (1 ten-millionth of a gram) of hydrogen.

HOW TO WRITE A SCIENTIFIC LAB REPORT

Before you start writing a scientific paper, you need to realize that this is not like other papers you have written! A scientific paper follows a specific format with separate labeled sections. Typically these sections are as follows. Check with your instructor regarding which ones you are expected to include.

Title

- Make the title informative and specific. “Assignment” doesn’t cut it.
 - EX: “The effect of temperature on sucrose fermentation by yeast”
- Be concise and if appropriate, include taxonomic information.
- Avoid specialized terminology. Use terms familiar to most readers.

Introduction

- Background information: Summarize or review current knowledge about the topic. This requires you do some research so that you may introduce the reader to the background information about your topic. Introduce key concepts, define terms and explain important researched hypotheses. Cite key references. Start broad and narrow down to your question. Know your audience to help you decide how broad or detailed to go. Your audience is probably your classmates.
- State the purpose of the study. How does this fit into the broader framework?
- State your hypothesis.
- Define your independent and dependent variables, controls and constants.

Methods

Describe your study’s methodology in enough detail so it could be **repeated**.

- Be sure to include:
 - a description of the procedures you followed, in detail, including the specific materials/supplies (and amounts) that you used
 - for field studies, describe the site and locale

- Be organized! Be specific!
- Omit unnecessary information (just the facts - no opinions please).

Results

Summarize and illustrate your findings:

- **Make all tables and graphs “stand-alone.” This means that if removed from the report, the table or graph is understandable by itself.**
- Create a narrative that summarizes the data and *emphasizes* important patterns and trends. **Do not interpret the data or draw major conclusions! Don’t discuss the “why” of the study. Leave this for your “discussion/conclusion.”**
 - Support generalizations with details, statistics, and references to tables and graphs.
 - Integrate quantitative data with the text. Refer to the tables and figures. Point out the most important information and patterns. You may want to include the following:
 - the sense of variability of the data through its range and sample size, standard error, or standard deviation
 - include numerical differences - how much did things change? how different is each group studied?

Discussion/Conclusion/Critique

- Accept or reject your hypothesis.
- Interpret your results. What do your results mean? Does the data support your hypothesis? Refer to your data to justify. Are your findings consistent with others?
 - “No differences” is just as important as finding differences.
 - Start specific and end up general.
 - focus on your most important findings
 - answer the “why” question
 - compare to others (if appropriate)

- critique your materials and methods (at least 2 suggestions– see last bullet)
 - close with a statement of how this study furthers our understanding and questions that remain.
- **You will be required to critique the experiment. This requires that you point out potential problems and how they might affect the experiment. It is also important that you offer solutions if ever the experiment is to be repeated again.**

Literature Cited

- Cite all sources of information that are not your own. Any background information that you have used to inform you and your audience about the purpose of the study is information that you must have taken from another source.
- “Hearsay” is not at source of information. If you heard something about your subject that is not directed from a specific source or formal interview it is considered *hearsay* and must be backed up with a valid source of information in order to be used.

Think you're done? Use this checklist:

- Is the title specific and informative?
- Does the Introduction state your main objectives, hypothesis, or thesis?
- Is your background information adequate enough to inform the reader?
- Have you identified your constants, controls, and variables in your Introduction?
- Have you included enough information in the Methods section to enable someone else to repeat your study?
- Have you explained in your Methods the procedures for collecting *all* the data presented in your Results?
- Are figures and tables numbered consecutively in separate series?
- Is every figure or table cited correctly in the text?
- Do the data in each figure or table agree with your in-text discussion?
- Do any figures or tables present conflicting data?
- Are data in related figures or tables shown in a consistent manner?
- Is each table and figure understandable apart from the text (i.e. "Stand-alone")?
- Are any important results missing?
- Have you used enough headings and subheadings to guide the reader?
- Does the Discussion address the major implication of your findings?
- Have you considered problems, inconsistent results, and counter-evidence?
- Have you cited all necessary sources?
- Are all sources cited in the text listed in the Literature Cited section?
- Does the Literature Cited section include any sources not cited in the text?

TABLE AND GRAPH GUIDELINES

CONSTRUCTION OF TABLES

Tables and figures (graphs, drawings, flowcharts, or photographs) are used when words alone are not effective.

- Use a table to present many numerical values or to summarize verbal material. If you need to show a pattern, use a graph as well.
- Make tables understandable on their own. Can the reader make sense of it apart or without reading the text? This requires a decent title--specific and informative. Use a footnote to add more information if necessary. Include things like column or row labels, units. The title is put at the top.
- Use a logical format.
- Make contents concise. Don't be redundant. In other words, don't repeat information.
- Check for consistency between your tables, data sheets, and written text!

CONSTRUCTION OF GRAPHS:

Graphs play an important role in the presentation and interpretation of data in biology. Some simple rules will help you to construct graphs which accurately represent the results of your observations and experiments.

There are two general types of graphs: **line graphs** and **bar graphs**. Line graphs are used to present continuous data: bar graphs are used to present discontinuous data. Both types of graphs have two axes: the vertical axis or Y-axis is called the ordinate. The ordinate (Y-axis) is normally used to designate the dependent variable, which is the characteristic or quality that varies either as a result of the experiment or during the period of observation. Examples of these are: size, weight, oxygen consumed, number of offspring, etc. The horizontal axis or X-axis is called the abscissa. The abscissa is commonly used to designate the independent variable, such as temperature or time. The experimenter usually has little or no control over this variable or it is predetermined for the particular experiment.

You can also compare groups using a **pie chart**. This is similar to a bar graph only in that you are trying present discontinuous data. The difference is that it is used when the groups you are comparing are parts of a whole or percentages that add up to 100%. A **scatterplot** is used to find

a continuous trend (similar to line graphs) when one is not immediately obvious. Often the data is messy due to repeating values. This makes it hard to find a continuous pattern. Therefore, using a scatterplot allows you to pick out a “general” trend (or best fit line) in a series of *disconnected* dots. Instead of looking for a relationship between independent and dependent variables, the presenter may simply be trying to find a correlation between two variables.

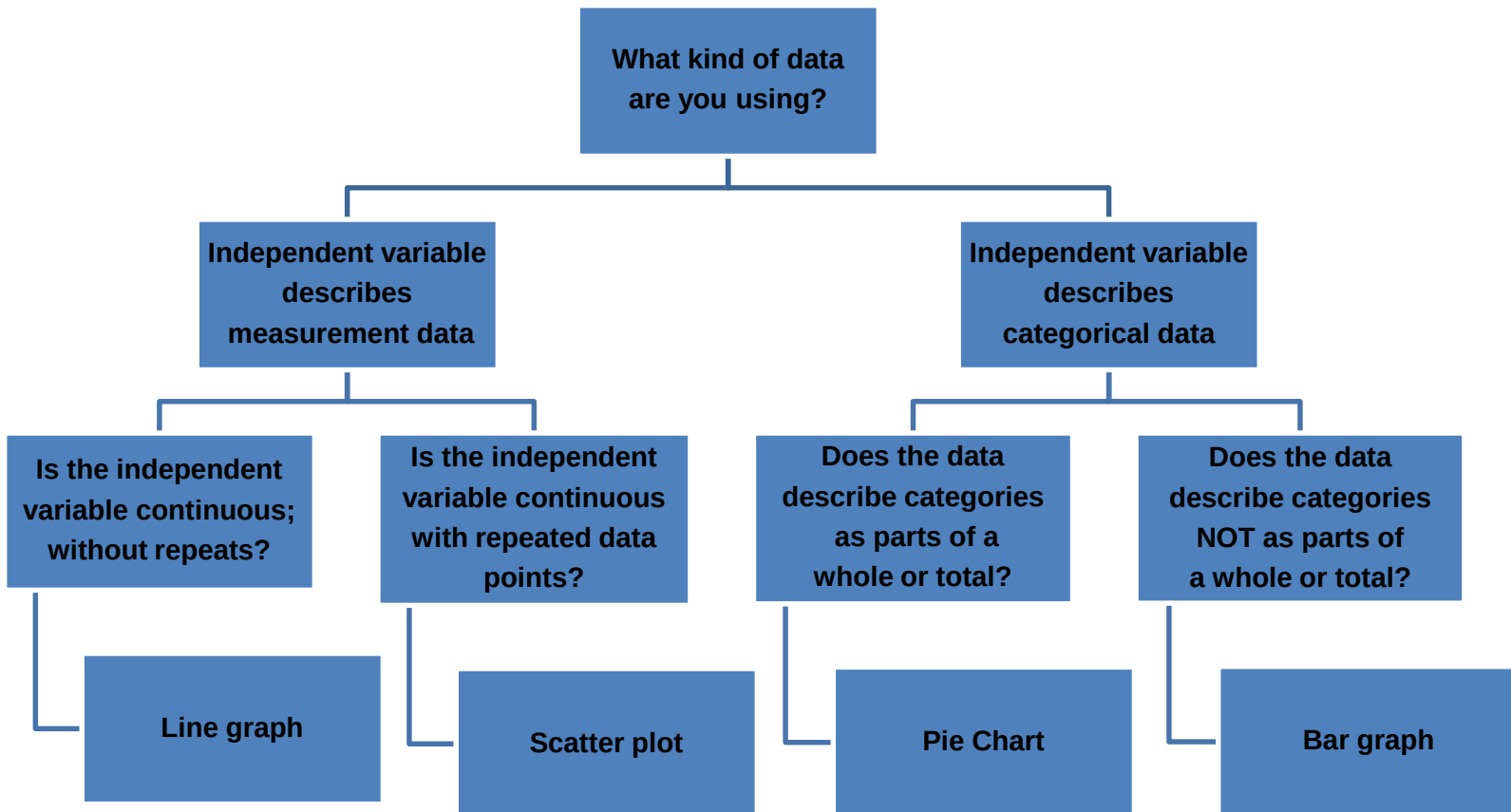
See the flowchart below to aid in identification of appropriate graphing illustration.

Neatness and accuracy are essential in preparing a graph. Often a graph is the most important part of your report. The reader can quickly see the result of your work from a well-prepared graph.

SOME RULES FOR MAKING A GRAPH:

1. Clearly label both axes to identify what each represents (e.g. oxygen consumed versus time, length vs. temperature.)
2. Carefully mark off the units along each axis to identify the units of your data (time in days or hours, height in inches, milliliters of oxygen consumed, weight in grams, etc.) Adjust the scale of units on each axis so that your graph is large enough to read and easily interpreted. A graph with points placed too close together can be unintelligible; graph with points too widely separated will not fit on the paper. Plan the scale of units for both axes before you begin to construct the graph. Consider the **range** covered by your data and set the scale of units on each axis accordingly.
3. Provide a title at the bottom of the graph which briefly but identifies the subject of your graph.
4. Sometimes it is also necessary to add a sentence or key explaining briefly what the graph shows. This is known as your **legend**.

How do you decide what graph to use for a data set?



HOW TO WRITE A HYPOTHESIS

Often it is difficult for students to come up with a testable hypothesis, even after researching a topic of interest. First, start by making a general statement about an observation or research topic. Second, make the hypothesis more specific by adding direction. Finally, make sure your hypothesis is testable. This three-step process may be more difficult at first, but becomes easier with practice. An example is found below.

Research scenario:

A rancher has noticed that the large ponds nearest her cattle pastures have fewer fish and higher amounts of algae growing on the surface. She wonders if this could be caused by the cattle grazing nearby. The grazing areas have less grass and she fears that water is running off her pastures into the ponds carrying cow manure into the water. The ponds are covered with algae which may be obtaining the nutrients from manure and growing at a higher rate. Her research leads her to believe that the amount of phosphate in cow manure is causing the increased growth of algae. Phosphates are a nutrient used by algae - too much of this nutrient may be the cause an overgrowth in small bodies of water.

She proposes a general hypothesis:

“Grazing cattle may cause favorable growing conditions for the algae in nearby small bodies of water.”

Although it is a good general hypothesis, it gives no direction to designing the research or experiment. The hypothesis needs to be refined to give some direction.

She adds direction to her hypothesis:

“Grazing cattle increase nutrient runoff into nearby small bodies of water causing an increase in the growth of algae.”

Now there is some directionality, but the hypothesis is not really testable, so the final stage is to design an experiment around which research can be designed, a testable hypothesis.

She forms a testable hypothesis:

“Grazing cattle cause an increase in algal growth because an increase in runoff of phosphate nutrients from cattle manure into nearby small bodies of water.”

This is a testable hypothesis – she has established variables, and by measuring the amount of phosphate in the water, eliminating other controlled variables, such as temperature and other potential nutrient sources, she can see if there is a correlation against the amount of algae in the ponds.