CONCEPTS OF BIOLOGY

BIOL 111

Laboratory Manual

Spring 2013

Minot State University

Prepared by

The Faculty of MSU Department of Biology

CONCEPTS OF BIOLOGY -- BIOL 111

Laboratory syllabus and schedule, Spring 2013

Lab room: Swain Hall - Room 304

Sections & Attendance

Unless problems arise, students may attend whichever lab section they choose, regardless of which section they have registered for. It does however, become difficult to track progress when a different lab is attended each week. So, please make every effort to remain in the same section from week to week**. If class is missed for any reason, simply attend another section <u>the same week</u> to make it up. If a student misses an entire week of class, arrangement for credit must be made with their instructor <u>in advance</u>.**

Lori S. Ihli ihlilori@hotmail.com

Tuesday 8:15 – 9:50am
Tuesday 10:00 – 11:50am
Tuesday 1:00 – 2:50pm
Tuesday 3:00 – 4:50pm
Tuesday 5:00 – 6:50am

Dr. Aaron Ament aaronament@me.com

Thursday 8 – 9:50am
Thursday 10:00 – 11:50am
Thursday 1:00 – 2:50pm

If you learn anything from the lab portion of this course, we hope you gain some appreciation of the following:

First, Biology is a huge topic. Those who study it must be familiar with the very small (e.g., how individual molecules, e.g., H_2O) and the very large (e.g., how pods of whales interact, how forests affect global CO_2). It can be easily argued that no other field of study encompasses such a broad range. In addition, no other area of science is so directly connected to how we live our lives. Recent advances in technology are constantly causing humans to think about what sciences offers and whether or not one ought to use these technologies (e.g., DNA fingerprinting, cloning, stem cell research, environmental degradation, threat of bioterrorism).

Second, Biology is studied by scientists. This method of knowing (i.e., science) provides the most efficient means of understanding the breadth and complexity of the hugeness and importance described above. It is our central goal that we communicate how scientists think about and approach biological problems. There are other "ways-of-knowing" but none is as effective in pursuing cause-effect relationships.

The lab portion of this course will show you how to approach these two areas, i.e., biology and science. Because of the influence and underlying significance of biology and science, this course is intended make you a better citizen in this world where breakthroughs usually outpace the capacity of the general public to make informed decisions.

Lab Schedule

In contrast to other laboratory courses, this lab portion is not always meant to work hand-in-hand with the lecture. We view this part of the course as our opportunity to expose you to a greater variety of biological principles than will be covered in lecture. This may seem awkward at first. As with all things, just play along and try hard!

Folders

The "requirements" section (and only the requirements section) of each lab must remain in your folder. The folder will be turned in at the end of each lab period. Keeping all your work in a single folder ensures that I can examine your work each week and will allow me to ascertain your progress and detect problems in understanding. Additionally, **it is your responsibility to make sure I can find each lab**. Do not "hide" your work behind older labs. If I can't find it, I assume you were not here and you'll get a zero for the day!

Grading

At Minot State University, **the lab and lecture grades are combined to equal one overall score for the course.** This means that attending, and doing well in lab can considerably improve your overall grade. To determine your overall grade, simply add your earned lecture points to your earned lab points and divide by the total points available (lecture earned + lab earned/lecture available + lab available).

There are a total of 13 labs. Each lab is worth 15 points. The lab portion of the course is worth a total of 200 points (13 labs X 15 points each = 195). The additional 5 points are awarded if all labs are attended.

Please keep it in mind that it is not easy to get full credit on each lab. In order to earn full credit, students must follow all rules described in the lab requirements section on the next page!

Lab Requirements

The ability to understand and assimilate this material requires you to be a willing participant, i.e., read and think about the lab exercises before lab, and then continue to be thoughtful during lab and as you complete the requirements due at the end of each lab. **Lack of preparation will be reflected in your grade.**

You must have the lab print out when you arrive in class. This means that you cannot print it in class while we all wait for you! I will print out the 1st lab for you.

All labs must be submitted on the lab requirement page (last page of the lab). Students submitting requirement sections in any other form will automatically lose 5 points for that lab! Illegible labs will not be accepted!

Since this is a science class, so you are expected to write in a scientific way! This means that simple answers are unacceptable (e.g. Yes, No, 5, It didn't work, etc.) and will be graded as such. All answers/hypotheses must be thoroughly explained! All equations and mathematical work must be shown! All units must be defined!!

Below is list of rules for writing good labs. It would be a good idea to review this list prior to turning in each lab (hint, hint). If you have further questions, please ask!!

1. Use complete sentences.

2. Proofread.

3. DO NOT PLAGIARIZE!!!

Copying someone else's work (including your neighbor's) is "illegal" is academia. You can be expelled from the ND University System for plagiarizing. Don't do it; use your own words instead!

4. Hypotheses must be worded properly.

ex. I hypothesize that……..because……

5. "Support" is a naughty word! Use "fail-to-reject" instead.

We do not attempt to support a hypothesis; we attempt to reject it. Therefore when we find information that indicates our hypothesis might be valid, we fail-to-reject it!

6. Answers must be specific! Explain, explain, and explain some more.

Someone who has never taken biology should understand your answer.

LABORATORY #1 -- BIOL 111
Science and the Scientific Method

The **scientific method** is the "program" that scientists use to understand the patterns (e.g., how far away is Mars?) and processes (e.g., how did the rocks on Mars form?) that we observe in the natural universe. Because the method is used to understand the natural universe, it cannot be used to ask more metaphysical questions (e.g., did God create Mars?). Anyone who uses the scientific method considers themselves a **scientist**, and you will be a scientist anytime this semester that you use this method to understand the biological patterns and processes that you explore in lab.

The most important tool used in the scientific method is not fancy equipment, rare chemicals, or supercomputers; it is the **hypothesis** (plural form is "hypotheses"). A hypothesis is a direct and bold statement/prediction about some aspect of the natural world. For example, the statement "All swans are white" is a hypothesis. A scientist "formulates" or "makes" a hypothesis and then seeks to "test" the hypothesis (called the **hypothesis test**). This is where the fancy (or sometimes quite plain) equipment comes in. The hypothesis test is not designed to support the hypothesis; it is designed to **attempt to reject** the hypothesis.

"Sounds silly, huh?" Part I:
It may sound like a silly procedure, but the idea is to make as strong an inference about nature as one can. Consider this: one can choose to attempt to support the hypothesis that "all swans are white." How to do this? Find every swan that has ever existed (or will exist), and determine its color. Sound impossible (or at least very expensive)? Indeed it is. The best one can do in this case is to find a little bit of evidence that might support the idea that "all swans are white." Not very convincing.

Now try this: Find a single non-white swan. You have now rejected the hypothesis that all swans are white and have made the very strong statement that "Not all swans are white." That's convincing.

"Sounds silly, huh?" Part II:
Another advantage of the "silly" procedure of rejecting hypotheses is that it provides a good scientist a means of being objective (i.e., non-biased). The good scientist tries hard to reject the favorite hypothesis; this helps to avoid the temptation to find support by biasing one's observations/data collection or by falsifying ("fudging") data.

In addition, this procedure of rejecting hypotheses is much faster and cheaper than supporting hypotheses. For example, it is much easier, faster and cheaper to reject the hypothesis that the world is flat (the observation that one sees the top of a ship on the horizon before any other part clearly rejects the "flat earth" hypothesis) that to support the hypothesis that the world is round (sailing around the world takes time, money, a lot of luck, and patience).

Procedure

1. Each team should obtain one box. Each box has some unknown item inside. You will be attempting to characterize (i.e., describe) the item without ever seeing it or touching it.

2. After doing some preliminary observation (scientists would call this a "pilot study"), form/make a hypothesis about the object (e.g., "I hypothesize that box # 4 contains three dimes, and a toilet paper tube."). **Your entire group must agree on the contents!!**

3. Explain your hypothesis. Write it down, being as explicit as possible (i.e., how did the box feel, sound, weigh, etc. How did this information lead you to your hypothesis?)

(Note that steps 2 and 3 take a lot longer than steps 4-5.)

4. Develop a test for your hypothesis.

5. Interpret the results, i.e., would you "reject" or "fail-to-reject" your hypothesis? Make sure you explain your interpretation.

Keeping track of each hypothesis on scratch paper, repeat steps 1 & 2 with each of the other boxes. **Remember, your team must agree upon the contents of each box.** Further instruction will be given by your instructor.

Importantly, you may never look inside the box. This is an important lesson of this exercise. Scientists often do not get to look "inside the box." Your sense of this idea will increase during this semester. Thus, good scientists always entertain the notion that what they think is completely wrong. The scientific method is what defines the scientist. **Science is <u>not</u> a collection of facts about the universe (a collection of facts about the universe is called "a collection of facts about the universe"). Science is a process by which things can be known.**

Name_____

Requirements Lab 1

1. *(Observe)* Record your observations of the box your team has been given (sounds, weight, size, etc.). What characteristics do the contents possess? How do those characteristics indicate what the box contains? *(4 pts)*

2. *(Hypothesize & Explain)* Develop a hypothesis for the box your team has been given. Be specific!! *(2 pts)*

3. *(Experiment)* Develop an experiment that could provide further information on the contents of the box. (Assume you have unlimited resources, but you cannot open the box.) What would you look for, and why? *(4 pts)*

4. *(Interpret)* If the information you obtained from your experiment indicated the item(s) was what you hypothesized, would you "reject" or "fail-to-reject" your hypothesis? *(1 pt)*

5. For which item was there the greatest consensus (i.e., agreement) among all groups of scientists? How confident are **you** that the item is actually in the box (provide a comparison or a percentage)? Provide some reasoning with your answer. *(4 pts)*

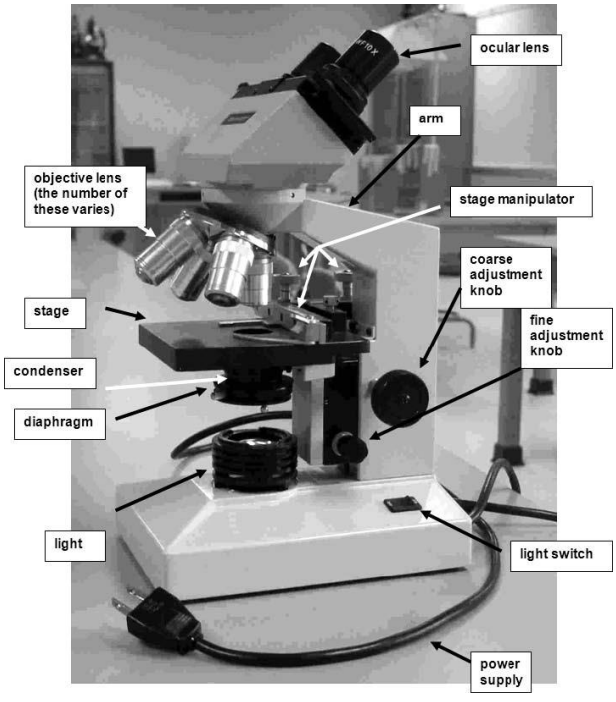
LABORATORY #2 -- BIOL 111
Microscope Use & Intro to Cells

To be able to distinguish two objects (i.e. to resolve them), they must be separated by some minimum distance, i.e., the limit of resolution. If they are any closer they will appear as one object. The best human eyes have a limit of resolution of about 0.1 mm.

To observe objects that are too small to be seen (or resolved) with the naked eye, we must use a microscope. The simple purpose of the microscope is to observe phenomena that are too small to be seen clearly. All microscopes are designed to both magnify and to increase resolution. The limit of resolution of the light microscope is 0.2 μm. This means that many objects of biological importance, from cells and some subcellular structures to small tissues and organs are visible with the aid of a light microscope. However, truly small objects like molecules and some small subcellular structures cannot be seen (they are inferred using the scientific method).

The compound light microscope
This microscope is used for magnifying objects, typically 100X (or "100 times larger than actual") to 1000X. There are several additional features of this microscope. First, there are two adjustment knobs: coarse and fine. **The coarse adjustment knob is only used when using the lowest power objective lens.** When the higher power objective lenses used, focus using only the fine adjustment knob.

A magnifying glass is a simple microscope because it consists of only one lens. This microscope is called compound because it consists of two or more lenses. The two lenses on the microscope are called the ocular lens (the eyepiece, or lens closest to your eye) and the objective lens (the lens that is variable and can be changed). The ocular lens typically magnifies objects 10 times, whereas the objective lenses (used one at a time and mounted on a nosepiece) vary from 4 to 100 times.



As two or more lenses are used together, their effects are multiplicative; this means that a lens that magnifies objects 10 times used with a lens that magnifies objects 4 times will together magnify an object 40 times (4x X 10x = 40x). **Total magnification** refers to this magnification produced together by the ocular lens and the objective lens in use.
When discussing magnification, the user should be clear about whether "objective lens magnification" or "total magnification" is being used.

Measuring

It is easy to calculate the size of a microscopic object. All you need is the diameter of the circle of light and the number of objects which fit across this diameter. If, for example, the field diameter is 1mm and 10 objects fit across the diameter, then the size of the object is 1mm/10 = 0.1mm.

Today, we will use a total magnification of 400x, that is, the ocular lens is 10x and the objective lens is 40x (10x X 40x = 400x). At 400x, the field diameter is 0.23mm.

Note: there is almost no reason to use the 100X objective (or 1000X total magnification) in this course. This means that it would be really great if you didn't bother with the 100X objective lens!

Cells

The basic unit of life is the cell. Some organisms are composed of a single cell (e.g., a bacterium like *E. coli*) whereas others are multicellular (e.g., us). Regardless of what type of organism one considers, all are composed of cells and these cells are remarkably similar, from algae to anteaters and from *Hirudo* to *Homo*. This means that examining a single cell can give you a picture of the cell anatomy of almost any living thing.

There are two classes of cells: prokaryotic ("before nucleus") and eukaryotic ("true nucleus"). Organisms that have prokaryotic cells are called "prokaryotes"; if organisms have eukaryotic cells, they are called "eukaryotes." No organism has both kinds. Prokaryotes are the bacteria; eukaryotes are everything else (algae, protozoa, fungi, plants, and animals). Prokaryotes are very small and difficult to see easily.

We will be examining eukaryotic cells (from plants and animals). Eukaryotic cells differ from prokaryotic cells in that there is compartmentalization. All the functions that were accomplished by prokaryotes in the mishmash of cytoplasm are now separated into their own chambers. The result is a much higher level or organization. This organization appears to be necessary in order to achieve higher levels of complexity seen in eukaryotes (all of you would agree that a cottonwood appears to be a more organized and specialized form of life than a bacterium). The compartments are called organelles.

When you examine the cells, you will see two types of organelles: implicit and explicit. Explicit organelles are those which are plainly visible (e.g., the nucleus will be clearly seen); implicit organelles are those that we cannot truly observe but must exist (i.e., if there is a nucleus to see, then there must be a nuclear membrane around it). If we include implicit organelles, then you will observe many different aspects of cells today.

We will examine plant (from onions and an aquatic plant called *Elodea*) and animal cells (your own inner cheek cells of your mouth). We examine both plants and animals because plant cells have three structures not seen in animal cells, and these three structures are responsible for the obvious differences between these two kinds of life that you have always known about: plants make their own food (via chloroplasts), don't move much and may grow very tall (via cell walls), and plants can store stuff in their cells much longer than animals (via the vacuole).

Procedure

Using the directions provided to you by your instructor, prepare three slides:
One with onion skin (epidermis), one with an *Elodea* leaf, and one with human cheek cells.

Slide 1. Using a drop of IKI (iodine in potassium iodide) prepare a wet mount slide of onion skin from the inner side of a bulb leaf. **The sample must be extremely thin!!** Observe the cells at low, medium and high magnification. Address question 1.

Slide 2. Using a drop of water, prepare a wet mount of an *Elodea* leaf. Observe the cells at low, medium and high magnification. Address question 2.

Slide 3. Prepare a slide of cheek cells stained with methylene blue. Observe the cells at low, medium and high magnification. Address question 3.

Name_____

Requirements Lab 2
Don't forget units!!!

1. Prepare a diagram of one (or more) onion skin cells. Label the **cell wall** and the **nucleus**. List their function/definition. Include a **scale bar** indicating the approximate length and width of an average cell. Determine the size of the nucleus. Please show your math! *(6 pts)*

2. What is the length and width of a cell from an *Elodea* leaf? How big is a chloroplast from an *Elodea* leaf? Please show your math! *(3 pts)*

3. Which cells are larger: cheek cells or onion cells? Please show your math. *(3 pts)*

4. Your animal cells are different from plant cells in 3 major ways. Tell me all three differences and how you can **see** these differences!! *(3 pts)*

a.

b.

c.

LABORATORY #3 -- BIOL 111
Osmosis

One of the most obvious and prominent processes in the universe is **diffusion**, which is defined as "the movement of a substance from an area of high concentration to an area of low concentration." For example, when you exhale air, it is composed principally of carbon dioxide (a toxic gas). As soon as it leaves your mouth, the carbon dioxide is at a high concentration (relative to the surrounding air) and so diffuses away from your mouth to all the surrounding air. It is important to understand the distinction between "concentration" and "abundance." In the example, air is more abundant in the atmosphere than in a balloon. But the critical factor is "concentration." There is more air per volume in a filled balloon than in the atmosphere. So the air in a filled balloon is at a higher concentration.

Everything, including water, is subject to diffusion. **Osmosis** is a specific type of diffusion. **Osmosis is the diffusion of <u>water</u> across a semi-permeable membrane**. A "semi-permeable membrane" is any object that allows free passage of only some substances. The prime example of a semi-permeable membrane is the covering around every cell in your body, i.e., the plasma membrane. The plasma membrane allows free passage of water, oxygen, carbon dioxide and other small compounds, but resists the crossing of larger molecules like sugars & salts.

Because many solutions contain different amount of compounds (e.g., pure freshwater has nothing in it; saltwater is water <u>and</u> salt), osmosis is a very important biological process. For example, a walleye has saline (i.e., salty) solution coursing through its body, yet it swims in freshwater that has very little salt. This means that the salt is more concentrated in the walleye's body than in the environment that it swims in. Conversely, the water in the walleye is less concentrated than it is in the lake (i.e., salt is taking up some of the space in the walleye where there could be water). Because the walleye is composed of cells (which have cell membranes that are semi-permeable; they allow free passage of water but prevent the passage of salts), the water will move from the area of high concentration (the lake) to an area of low concentration (within the walleye's body). The result would be a walleye that gains water and swells. Eventually the walleye would burst from all the excess water flowing in by osmosis. Fortunately, the walleye has kidneys that prevent this; walleyes urinate often and their urine in very dilute (i.e., rich in water and low in salts). The opposite process occurs in fishes that live in the ocean.

(Because freshwater fishes constantly have water pouring into their body by osmosis, there is little need to drink. However, marine fishes are constantly losing water and so must drink constantly. This has the interesting everyday result that the statement "drinks like a fish" needs to be modified to "drinks like a saltwater fish.")

Procedure

1. Each table of students will work as a team. Each team should obtain 2 vials, 1 carrot, 1 metric ruler, a digital scale and a small knife. Sorry, no stabbing allowed!!

2. Fill each of the 2 beakers 3/4 full of the appropriate solution (either H2O/distilled water or 1 M sodium chloride/NaCl). (Note: the "M" refers to how much stuff there is in the water. The larger the number, the more stuff there is in the water. "M" stands for "molarity." By the way, typical molarity of NaCl *inside* a plant cell is 0.15. This means that 1 Molar salt water is really salty!)

3. Prepare 2 pieces from the same carrot. Slice narrow rectangular strips as close to 100mm long x 10mm wide x 5mm thick as possible. (The instructor will give a demonstration of this).

4. Measure each strip's length in millimeters and weigh each strip in grams. Place them in the cups according to the table (question 2). Be careful to keep track of which strip is in which cup! Leave the strips in the environments for at 30 minutes.

5. Meanwhile, you might want to answer questions 1, 4 & 5 from the report page.

6. After 30 minutes, remove the strips, blot dry, re-measure & re-weigh them. Record the final length and weight for each strip. Compute the change (final minus initial length). Be sure to record changes with "+" or "–".

7. There are lots of random factors which all influence our results. This is why we need statistics. Your instructor will lead you through a statistical analysis to determine if the group data represent significant changes.

For each set of before & after length data, we will calculate the probability of the null hypothesis ("Carrots strips ***did not*** change in length") using so-called *t-test*. We will use an on-line t-test calculator (http://studentsttest.com/). Enter initial data on the left and final data on the right. Make sure that "groups are matched" and "two tails" are selected. Then press "calculate". You will be given with p-value which reflects the *probability of the null hypothesis*. This is the probability that there was not a change. Record the p-value.

8. Address question 3. If p-value is less than a threshold (0.05), this is an indication of very low probability of null hypothesis and a high probability of the hypothesis. Consequently, if p-value < 0.05 it's likely there was a significant change. We should reject the null hypothesis, and fail-to-reject the initial hypothesis!

9. Clean up as instructed.

Name_____

Requirements Lab 3 (page 1)

1. List hypotheses that predict what will occur in the carrot's cells. As with any hypothesis, provide the basis for your sensible prediction (Why?). *(2 pts)*

A. freshwater experiment

B. saltwater experiment

2. Fill out the table below. Don't forget units! *(3 pts)*

A. Freshwater Experiment		**B. Saltwater Experiment**	
Initial length_____	Initial weight_____	Initial length_____	Initial weight_____
Final length_____	Final weight_____	Initial length_____	Final weight_____
Change_____	**Change_____**	**Change_____**	**Change_____**
p-value_____	**p-value_____**	**p-value_____**	**p-value_____**

3. Does your data reject or fail-to-reject each hypothesis?
Explain why or why not using total changes, p-values and common sense. Be thorough! *(6pts)*

A.

B.

There is a page 2 to this lab!!!!!

Name_____

Requirements Lab 3 (page 2)

4. Describe a situation where a cell/organism is **losing** water through osmosis. Be sure to explain which direction the water is moving and why. Please do not use the examples given in the lab manual. *(2 pts)*

5. Describe a situation where a cell/organism is **gaining** water through osmosis. Be sure to explain which direction the water is moving and why. Please do not use the examples given in the lab manual. *(2 pts)*

LABORATORY #4 -- BIOL 111
Photosynthesis and Respiration

There are two great processes that make the world of life go 'round: **photosynthesis** and **respiration**. One is about making energy in a form useful for us organisms; the other is about utilizing this energy to drive everything us organisms do. One seems to be the opposite of the other, and when you consider where the "first" process begins and where the other ends, then these two processes indeed form a circle. If there is actually a "circle of life" this is it: photosynthesis makes energy and respiration uses it. All cells (and thus all organisms) perform respiration (often in an organelle called the mitochondria), whereas only certain kinds of organisms that have a specific organelle called a chloroplast carry out photosynthesis. Those organisms that are capable of photosynthesis are known as producers, and all the remaining organisms can be termed consumers.

Photosynthesis can be defined as the transfer and storage of solar energy to a chemical form called **glucose** (a type of sugar). Glucose (and other kinds of sugar) is an arrangement of atoms of carbon (C), hydrogen (H) and oxygen (O). Much like a battery stores energy used to power your portable CD player, glucose is designed to be a temporary holding pen for some of the energy that arrives from the sun. From the standpoint of chemistry, photosynthesis is written like this:

$$6CO_2 + 6H_2O \xrightarrow{\text{solar energy}} C_6H_{12}O_6 + 6O_2$$

Carbon dioxide comes from the air, the water comes from the soil or the surrounding environment, the glucose is either used by the plant or gets stored (we eat the stored stuff), and the oxygen gets released into the air. This reaction requires energy input (the sun provides this) and can be called **endergonic**.

Respiration can be defined as the release of the stored energy from glucose; this stored energy is transferred to a molecule called ATP that is used to drive any process in your cells that needs energy input.

$$2C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 12H_2O + \text{ATP (energy)}$$

Because this reaction releases energy, it can be called **exergonic**.

An example of this reaction occurs during intense physical exertion. While contracting muscles, you need lots of ATP. This is because your muscles need ATP to do what they are supposed to do (i.e., contract and release, contract and release). Where does this ATP come from? You obtain it by retrieving sugars that are stored in your liver (they got there by digesting more complex foods in your digestive tract) and carrying them via your bloodstream to your muscles where respiration occurs to move the energy from glucose (that began as energy in the sun) to ATP which make your muscle cells work.

Note that the balance sheet is even. The only discrepancy is the energy budget. A lot more solar energy is available than gets stored as glucose, and more energy is available in the glucose than gets transferred to ATP. All the energy that is not stored is "lost" as heat. Have you ever noticed that you warm up during intense physical exertion? Duh.

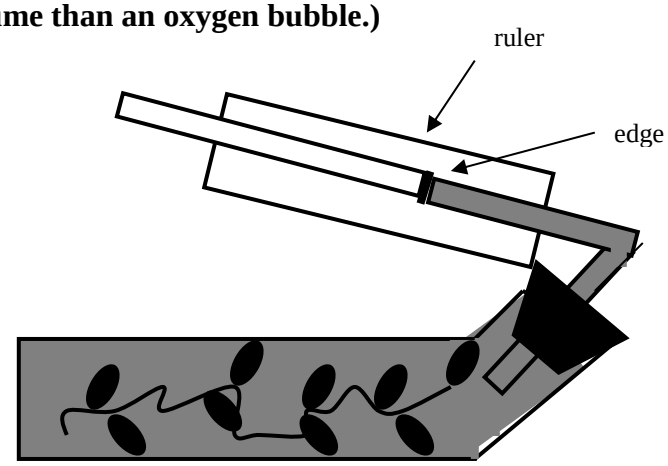
In an earlier lab, you learned about osmosis and diffusion, two pervasive chemical processes. These processes are free; they require no energy because stuff is moving from a high concentration to a low concentration. It just happens. However, life often requires that we move stuff the opposite way: from a low concentration to a high concentration. It also requires that this movement happens in an organized fashion. This takes energy. In short, life needs energy. ATP is this energy.

In this lab you will perform a simple procedure that will illustrate the extent to each of these processes in an aquatic plant.

Procedure

1. Place an *Elodea* sprig in a test tube that is equipped with a rubber stopper and a bent glass tube. Before capping the tube, fill the tube with $NaHCO_3$ (sodium bicarbonate) solution. Add enough solution so that when the stopper is inserted into the tube, the solution comes to rest at about one-fourth the length of the bent glass tubing.

($NaHCO_3$ provides an abundant source of CO_2. When the edge moves forward or backwards, it indicates if O_2 is being released by the plant or used by the plant. Any CO_2 that is produced immediately goes into solution, i.e., occupies much less volume than an oxygen bubble.)



Formation of O_2 bubbles displaces the $NaHCO_3$ solution and moves the edge to the left in this diagram. Consumption of O_2 makes the edge move to the right in this picture. The distance moved is directly proportional to the amount of O_2 produced or consumed.

2. Place the tube near a light source on the lab bench.

3. Record the position of the solution "edge." As soon as the edge of the solution in the thin glass tube begins to move away from the *Elodea*, time the reaction for 10 minutes. At the end of the 10 minutes, record the new position of the edge of the solution in the tube. **Record in millimeters [mm] how far the edge moved.**

4. Wrap the test tube in aluminum foil. Wait 10 minutes and measure the distance the edge recedes.

5. Replace the *Elodea* and $NaHCO_3$ solution and clean and dry the equipment and lab area.

Note: always pay attention to the direction that the fluid is moving. Moving in opposite directions must mean that something is either being consumed or produced. Be sure to record direction of movement with '+' or '-'.

Name_____

Requirements Lab 4

1. Provide hypotheses stating when (day/night) the bubble will move toward or away from the test tube in each experiment. Include background information on oxygen production and usage in regards to photosynthesis and respiration. (What is happening and why/how?) *(6 pts)*

2. How far (in mm) did the bubble move during the "daytime" (photosynthesis and respiration)? How far (in mm) did the bubble move during the "night" (respiration only)?

Photosynthesis & Respiration (daytime)	Respiration Only (night)
Initial_____	Initial_____
Final_____	Final_____
+ or - Distance moved_____	+ or – Distance moved_____

If the *Elodea* had not been respiring during photosynthesis, how far would the edge have moved? (**Tell exactly how far, i.e., a number.**) Please show your super easy math. *(5 pts)*

3. Why exactly do plants carry out photosynthesis? What organelle allows them to do this? *(2 pts)*

4. Why exactly do plants carry out respiration? What organelle allows them to do this? *(2 pts)*

LABORATORY #5 -- BIOL 111
Cell Craft Game

Eukaryotic cells are extremely complex units where organelles work together as a finely organized team. The Cell Craft game does an excellent job illustrating this complexity in a step by step process.

The game is self-explanatory. You will need to grow your own virtual "cell" and make it survive virus attacks. As you work through the game, you always have the option to review specific processes, chemical compounds and organelles by clicking on the "Encyclopedia" tab on the main page. I highly recommend you spend a few minutes at home reviewing the information located here prior to attending lab. In fact, it is possible to do this lab at home and simply drop it off in lab.

Procedure

1. Clear any previous data and switch the sound off.

2. Read through the Encyclopedia tabs to be sure you are familiar with all compounds, organelles and processes utilized in the game.

3. Play through the game several times. You may wish to read through the questions in your lab manual first, so you know what to really pay attention to.

http://www.cellcraftgame.com/downloads/ CellCraft.swf here.

Name_____

Requirements Lab 5

1. What are the following items in the game, and why do you need to maintain certain amounts of these things? *(4 pts)*

ATP:

AA:

FA:

G:

2. How can a virus damage a cell? What is the most dangerous virus in the game and why? *(3 pts)*

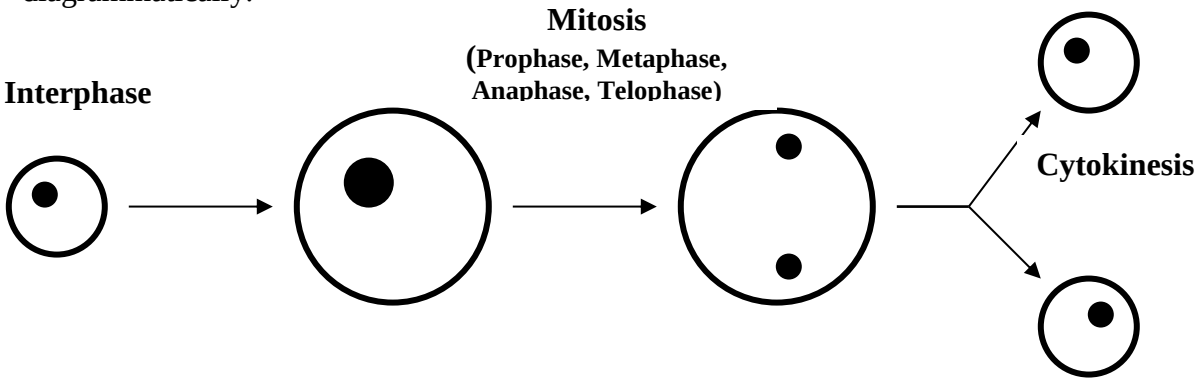
3. What are the similarities and differences between peroxisomes and lysosomes? *(2 pts)*

4. Explain how nucleic acids, amino acids, ribosomes, endoplasmic reticulum, mRNA and the nucleus related? *(6 pts)*

LABORATORY #6 -- BIOL 111
DNA, Chromosomes and the Cell Cycle

Life is about growing, developing and reproducing. One of the ways that an organism can grow is to make new cells. Every cell in every organism grows, develops and reproduces at some point (i.e., one cell turns into two cells). This means that every cell can produce an exact copy of itself. If the process does not work perfectly, then the mistakes remain forever. For example, we all started off as a single cell (known as a zygote); if a mistake was made in producing one of the two cells that came from this first cell, then this mistake would be present in ½ of all the cells in your body. This is why some people have different colored eyes. A mistake in copying genes was made very early in life, with the result that half of the eye cells produce blue eye color and the other half produce brown eye color. This is a harmless example, but most mistakes result in cell death. Obviously, the cell cycle must be done perfectly. This lab shows us how this cell cycle proceeds.

All living organisms are composed of cells and (nearly) all cells have a set of instructions for constructing proteins called genes. Genes are composed of DNA and are found on structures called chromosomes. Because all cells that are destined to give rise to new cells must contain genes (that among other things, direct the division of the cell to make two new cells), a mechanism is needed to ensure that both new cells have a full set of genes. This means that all the genes of the old cell must be copied, and then sorted into two new cells. This sentence summarizes much of the cell cycle and can be represented diagrammatically.



Note that this diagram indicates all the parts of the cell cycle.

I. INTERPHASE -- This is the period directly after cytokinesis and before mitosis. During this chunk of time the cell does most of the functions that each cell type is known for (e.g., stomach cells secrete digestive enzymes). This phase contains three portions (occurring in this order)**: G_1, S,** and **G_2**. During the **G_1** and **G_2** portions of interphase, the cell grows, (thus the "**G**") functions and checks itself for possible errors. During the **S** portion, the cell synthesizes (thus, the "**S**") new DNA (i.e., it duplicates its genes in a process called **replication**). After making new genes, the cell also spends part of **G_2** preparing for the next step of the cell cycle: **mitosis**.

Cells in INTERPHASE can be identified by the presence of the nuclear membrane wrapped around the 1 clearly defined nucleus.

II. MITOSIS contains four separate subphases known as prophase, metaphase, anaphase, and telophase. The critical importance in understanding and studying mitosis is that each process is a necessary step for ensuring that each new cell has exactly the same genes as the old cell. If something goes wrong during this process, then the mistake is there forever because the cells with the incorrect genes will pass on the mistakes to the new cells. Here's how to tell each phase apart:

Prophase -- the nuclear membrane begins to disintegrate and the chromosomes "condense"; this means that you can actually begin to see the chromosomes (they are not apparent during interphase). This marks the beginning of mitosis;

Metaphase -- the chromosomes (now fully condensed) align along the "equatorial plane of the mitotic spindle." This just means that all the chromosomes are in the middle of the cell and the nuclear membrane is completely gone (for now);

Anaphase -- the chromosomes are pulled apart. Each half of each chromosome gets "pulled" by a microtubule (part of the mitotic spindle) to one end of the cell;

Telophase -- the nuclear membrane begins reforming and the chromosomes begin "decondensing" (or unraveling). This marks the end of mitosis.

III. CYTOKINESIS is the actual division of the cell to make new cells. In this phase, the onion cell that you will examine looks longer than usual, appears to contain 2 nuclei, and is showing evidence of a new cell wall (this should be between the 2 nuclei).

Procedure

1. Obtain a slide of *Allium* root tips. Be able to focus on individual cells near the tips of the root. This is the part of the root where the most growth is occurring. You should be able to see cells at 100X but will probably need 400X (or 450X) to see clearly enough to proceed to step 2.

2. Examine a single cell located near the tip of the growing onion root tip. Determine if the cell is in interphase, prophase, metaphase, anaphase, telophase, or cytokinesis. Place a mark on the table below that indicates the stage of the cell cycle that the cell is in.

3. Repeat step 1 for 49 more cells. When done, there should be 50 marks on the table (one mark for each cell).

4. Calculate the proportions, and estimate the amount of time spent in each phase and subphase. The table will lead you through how this works. Take the number of cells in a particular phase, divided by the total number of cells examined (i.e., 50), then multiply by 24 (the number of hours an average onion root tip cell takes to complete the entire cycle. This should give the hours a cell spends in each phase.

Attach this page to the Requirements section!!
FILL-IN this table with the results of your count of 50 cells

Phase/Subphase	# of cells in	calculation	# of hours an onion cell spends in this phase/subphase of the cell cycle
Interphase			
	/ 50 =	X 24 =	
Prophase			
	/ 50 =	X 24 =	
Metaphase			
	/ 50 =	X 24 =	
Anaphase			
	/ 50 =	X 24 =	
Telophase			
	/ 50 =	X 24 =	
Cytokinesis			
	/ 50 =	X 24 =	

Mitosis = add the number of hours spent in each subphase = _____
(prophase + metaphase + anaphase + telophase)

Name_____

Requirements Lab 6

Please attach the associated table!

1. Provide a hypothesis indicating the order of the 3 main phases in the cell cycle (interphase, mitosis or cytokinesis) from the slowest to the fastest. As always hypothesize prior to any survey or experimentation! *(3 pts)*

2. According to your data, which **phase** (interphase, mitosis or cytokinesis) does an onion root tip cell spend most of its time in? The least time? Can you explain these observations (i.e., why is one process very brief while another is very long)? Does this lead you to reject or fail to reject your hypothesis? *(5 pts)*

3. According to your data, which **subphase** (prophase, metaphase, anaphase or telophase) does an onion root tip cell spend most of its time in? The least time? Can you explain these observations (i.e., why is one process very brief while another is very long)? *(4 pts)*

4. Do you think that **all types of cells** spend the same amount of time in each stage as onion root tip cells? Explain your answer. *(3 pts)*

LABORATORY #7 -- BIOL 111
Genetics and Inheritance

This lab is an introduction to how one analyzes genes without ever seeing or touching them. The first person to do this was **Gregor Mendel**, also known as the "Father of Genetics" (interesting name for a monk). In 1866, Mendel published a paper that documented a breeding experiment in bean plants. Using several different traits (including seed coat color and texture), Mendel was the first to understand that the traits of an organism are determined by bits of genetic information, or **genes**.

Mendel's work was unappreciated and/or undiscovered by the biological community until the beginning of the 20th century. Because of this, **Charles Darwin's** principle of natural selection (the other revolutionary theory of the time) fell into disrepute. Darwin's critics thought that all variation would be lost (or "blended away") by interbreeding. Without variation, natural selection does not occur. Thus, the rediscovery of Mendel's principles at the turn of the century would spark new interest in natural selection. Interestingly, both revolutionary thinkers were dead by the time that their ideas gained full support.

Mendel understood that the genes were hidden away from view (in the DNA of the nucleus). Therefore he had to infer that the genes of an organism determined what the organism would look like. **The appearance or traits of an organism are called its phenotype**. **The genetic information (genes) can be referred to as the genotype.** A phenotype is what we can see, therefore it is observable. Until recently, a genotype was unobservable and had to be inferred. Based on his principles, Mendel was able to make predictions (<u>hypotheses</u>) about how many different phenotypes should result from crossing one type of parent to another.

Mendel's principles of inheritance follow from his idea of genes as particulate and that each individual contained a pair of **alleles** (the variant forms of the genes):

> <u>Law of Segregation</u>: the alleles for each gene are not blended;
>
> <u>Law of Dominance</u>: the alleles of each gene are dominant or recessive to each other. The dominant allele is expressed in individuals with one or two dominant alleles. The recessive allele is only expressed in individuals with two recessive alleles;
>
> <u>Law of Independent Assortment</u>: genes for different traits are unaffected by one another, therefore the presence/absence of one trait in offspring is not affected by the presence/absence of another trait.

What is amazing is that Mendel had no knowledge of DNA, the nucleus or the principle of meiosis. However, his laws predicted the existence of the properties for all eukaryotic organisms. His work remains a classic example of how the scientific method can allow one to explain unobservable phenomena.

A gene is most simply defined as a position on a chromosome that codes for a trait. Because humans spend most of their life cycle as diploid organisms (i.e., possessing two sets of identical chromosomes), each person has two copies of each gene, i.e., **two alleles per gene**. It is the alleles that determine how individuals differ from one another. For example, there is a gene for eye color, and alleles for blue eyes and brown eyes.

HERE'S WHAT ALL THIS MEANS
Your parents each have 46 chromosomes. Nonetheless**, it's better to say that they have 2 sets of 23 chromosomes**, because the chromosomes come in pairs. (Having 2 sets of chromosomes makes humans, and many other organisms, diploid.) When your mother and father made their gametes (egg and sperm), they split up the pairs of chromosomes so that each gamete received only 23 chromosomes. Because they each contributed 23 chromosomes, you now have 2 sets of 23 chromosomes (= 46 chromosomes). This is good because more/less than 46 chromosomes is problematic (e.g., Klinefelter's syndrome, Down's syndrome).

Why say "2 sets of 23 chromosomes" instead of 46? Each chromosome carries only one allele of a gene; its matching chromosome also carries only one allele of the same gene, but the alleles may be different! This is why we say you have two alleles per gene. Since you have two alleles for every gene, this explains why some alleles are expressed more than others (dominant and recessive). It also explains why a trait that did not appear in your parents may appear in you.

(The process that determines which of your parents' chromosomes ended up in the gametes is called **meiosis**.)

We use symbols (usually using letters) to keep track of genetics and inheritance. **Capitalized or uppercase letters refer to dominant traits while lowercase letters refer to recessive traits.** Every individual has two alleles and we list them both. For example, "E" will be used to indicate the allele that codes for "unattached earlobes" and "e" indicates the allele for attached earlobes. "e" is recessive, so anytime it appears with a "E", it's expression is masked by this dominant allele (i.e., "Ee" is a genotype that means a person has both alleles, but whose phenotype is unattached earlobes). Keep in mind that we, like Mendel, will never see the genotype. It's hidden away in the nucleus of your cells. But if we know the phenotype of the parents and their children, then we can infer the genotypes of everyone involved.

Keep in mind that most traits are not controlled by only one gene (e.g., height is controlled by many genes and by environmental pressure as well). In this lab we keep things simple by examining traits that are controlled by one gene only (e.g., skin freckles).

Procedures0

PART A: Analysis of several single gene characteristic in humans

An important and useful tool provided by Mendel is that one's genotype can often be inferred by knowing the phenotype of the individual's parents, grandparents, children, etc. Furthermore, one can also infer whether the alleles are dominant or recessive.

If individuals are **homozygous dominant** (e.g., AA) or **heterozygous** (e.g., Aa), their phenotype will show the dominant characteristic. If individuals are **homozygous recessive** (aa), their phenotype will show the recessive characteristic.

Work with a partner to determine your phenotype for the traits listed in Table 1. Record your phenotype and possible genotypes (circle the letters on the appropriate line). After the totals for class are tallied, calculate the percentage of the class with each characteristic.

Table 1. Genetic analysis of personal characteristics

Your phenotype	Your genotype	Number in class with each phenotype	% of class with trait
Hairline			
-widow's peak	WW or Ww		
-continuous	ww		
Earlobes			
-unattached	EE or Ee		
-attached	ee		
Skin pigmentation			
-freckles	FF or Ff		
-no freckles	ff		
Hair on back of hand			
-present	HH or Hh		
-absent	hh		
Thumb hyperextension			
-cannot be bent back	TT or Tt		
-can be bent back 60^{o}	tt		
Bent pinky			
-pinky bends	LL or Ll		
-straight pinky	ll		
Interlacing of fingers			
-left thumb over right	II or Ii		
-right thumb over left	ii		

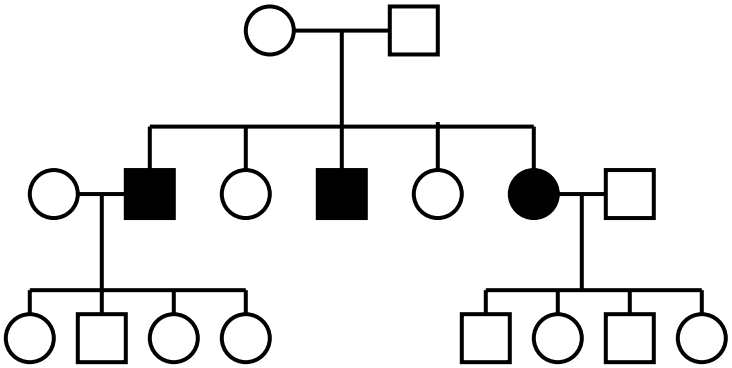
PART B: Human genetics and pedigree analysis

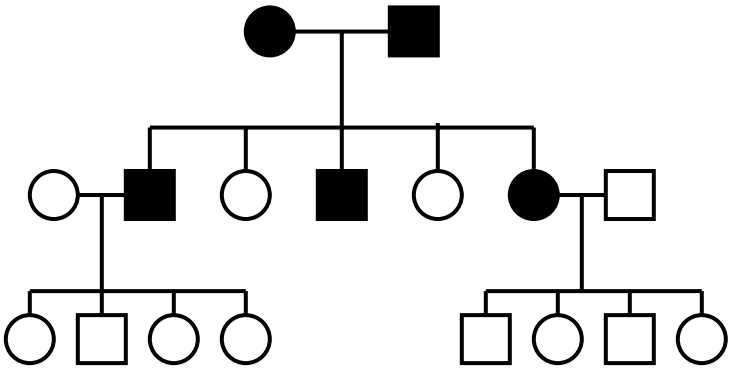
Genetic counselors are sometimes able to identify parents who are likely to produce children with genetic disorders. Fetal cells can then be tested to determine if the newborn does indeed have the disorder. This is called prenatal analysis.

Another type of genetic counseling uses **pedigree analysis**. Pedigree charts show the inheritance of a genetic disorder within a family and make it possible to determine whether any particular individual has an allele for that disorder.

In pedigree charts, symbols are used to indicate:
- normal (clear) and affected (filled-in),
- males (squares) and females (circles),
- reproductive partners (linked at midline), and
- siblings (linked from above)

For the below practice pedigrees, determine how the characteristic is passed. Is it dominant or recessive (attempt to use both)? Determine as many genotypes as possible.





Name_____

Requirements Lab 7 -- please remember that, when pertinent, it is expected that you will explain your answers with references to your data (i.e., if you think that recessive traits are rare, give me a recessive trait and its frequency).

---

1. Based on Part A, do you think that recessive traits are rare? Why or why not? *(3 pts)*

2. Case #_____; answer all questions at the bottom of the pedigree. *(6 pts)*

a.

b.

c.

3. Case #_____; answer all questions at the bottom of the pedigree. *(6 pts)*

a.

b.

c.

LABORATORY #8 -- BIOL 111
Animal Diversity - Phylogeny

In the past, biologists used the diversity of plants and animals as the basis for exploring the principles of biology. However, the rapid increase in understanding of molecular biology and biochemistry in the past 30 years has seen the displacement of diversity as the central theme of study. These next two labs are an attempt to provide you with an overview of the diversity of living plants and animals.

Scientific Names ("Taxonomy")

Most organisms have familiar names, such as the red maple or the brown-headed cowbird. However, these familiar names are often misleading. Many different species are called the same thing in different parts of world, and many identical species are called different names. Formal latin names are used by scientists to establish a unique name for each species on the earth. Each latin name is made, approved and used by scientists worldwide. Every species name consists of two parts: the first part is the generic name (or genus, e.g., *Homo*); the second part is the specific epithet (or species, e.g., *sapiens*). This Linnaean binomial system of nomenclature was introduced by Carrolaus Linnaeus in the 18th century and has been in use ever since. The study and practice of naming organisms is known as **taxonomy**.

Larger groups contain smaller groups, which contain even smaller groups and so on. This is similar to the old Kingdom system (which became problematic and is no longer used.).

For example, the taxonomy of corn (*Zea mays*) looks like this:

Plantae contains Anthophyta
Anthophyta contains Monocotyledons
Monocotyledones contains Commelinales
Commelinales contains Poaceae
Poaceae contains *Zea*
Zea contains *mays*
Mays

Note that the genus and species names are always *italicized* (or underlined), and the species is not capitalized.

This naming game may seem silly and bewildering now, but with time and practice, a scientist finds that placing organisms into categories makes it easier to understand some of biology's most important principles.

When taxonomy was created, all organisms were considered as either plants or animals. In retrospect, this system was too simple. Some organisms have characteristics of both plants and animals. It turns out that many organisms do not belong to either the Plantae or the Animalia. As a by-product of this history, the study of plants has also included some non plants: bacteria, fungi, and protists (single-celled organisms).

All animals belong to the Anamalia, and all animals are eukaryotes (i.e., having membrane-bound organelles). In terms of species, Anamalia is probably the most successful of all eukaryotic groups. For example, for every currently identified species of plants, there are at least 10 species of animals. Animals are heterotrophs, that is, they do not produce their own food and must consume other organisms. In the same vein, animals are also referred to as consumers.

In this lab you will be exposed to just a smidgeon of the bewildering diversity of animal forms.

A short history of animals

While bacteria and algae had their origins billions of years ago, animals were a bit tardy in the scene of life. The earliest evidence of animal life consists of burrows of early forms of worms. These burrows are found approximately 700 million years ago in the fossil record.

The next chapter in the evolution of animal life was the most exciting in its history. 600 million years ago, in a blink of geologic time called the Cambrian Explosion, every major body plan of animal evolved. The relationship of one form to another is exceedingly complex and hotly debated, even now. Arthropods, molluscs, even chordates, are seen during this time although no extant forms (i.e., those alive today) were present. At this time, the trilobites, an extinct form of arthropods, were the dominant life form.

The first fishes arrived on the scene about 450 million years ago, and invaded land in the form of amphibians about 375 million years ago. Several forms of invertebrate animals (i.e., animals without backbones) became very successful on land even before these amphibians and the true plants. The reptiles appeared 300 million years ago. At the end of the Paleozoic era, 230 million years ago, many animals and plants went extinct rapidly and at the same time. This was the first of the great mass extinctions.

The Mesozoic era saw the origin of the dinosaurs, which included the largest animals to ever walk on land (although dinosaurs are not the largest animal ever). In addition, mammals now appear in the fossil record 190 million years ago. Mammals quickly evolved to fill many niches, although the role of the large animals was still filled by dinosaurs and some other reptiles (e.g., plesiosaurs). At the end of the Mesozoic era, all dinosaurs and many, many other species of plants and animals went extinct in another mass extinction. The reasons for this extinction are still hotly debated but include the extra-terrestrial impact hypothesis (which was the centerpiece for the movies “Deep Impact” and “Armageddon”).

Following this mass extinction, mammals diversified and became the numerically dominant species of vertebrates on earth. Early man appeared as early as 3-6 million years ago, but modern man has existed for at most, 1 million years.

Histories of life typically focus on the success of the vertebrate line. However, one must always realize that this is an anthropocentric viewpoint. Other groups like the arthropods, nematodes, and molluscs have always been more abundant and diverse than vertebrates. They have also been subjected to mass extinctions just like vertebrates. Vertebrates make up only 3% of all animal species currently recognized. If all species were known, then vertebrates would certainly make up less than 1%. Many biologists have always known that it is the small, unknown, and inconspicuous animals that are more important in the ecology of the biosphere.

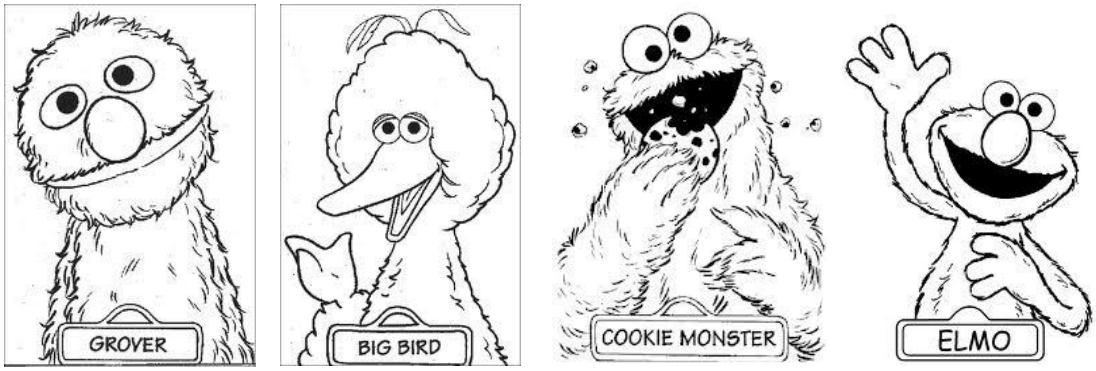
Today, the earth is experiencing the greatest mass extinction in its long history. Currently, species are going extinct at a rate of approximately 30,000 species a year. **During this lab period, 20 species will probably go extinct, mostly due to habitat loss and degradation of the environment.** Most of these are considered small and unimportant by most persons. However, they probably play a crucial role in the functioning of the ecosystem. Continued loss of species will someday pass a threshold where the effects of wiping out biodiversity for human needs will have a very large effect on the earth and all creatures on it.

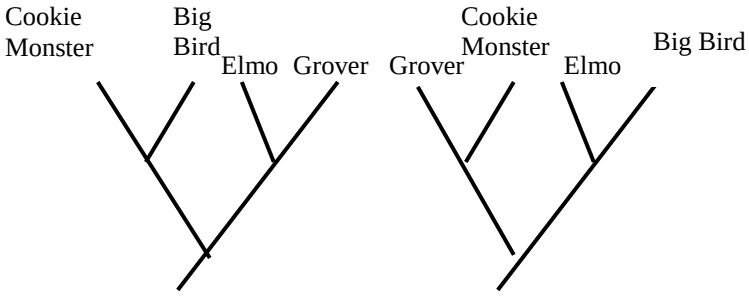
Procedure

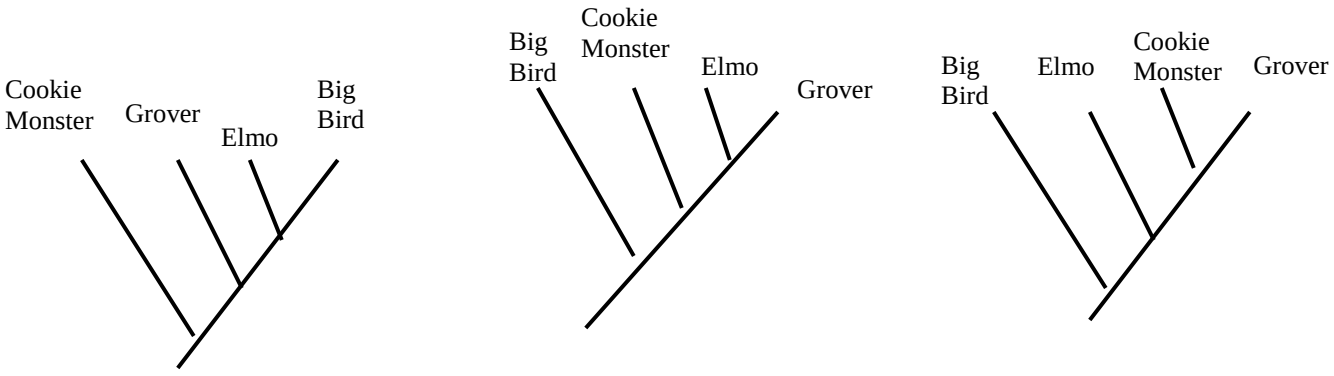
1. Representatives of each group listed above are distributed throughout the room. Examine each set of specimens and note the features that distinguish this group from all others.

2. While examining the organisms, keep in mind that the features of each group can be used to determine which groups are closely related to each other. The questions that you will turn in consist of choosing a "phylogenetic tree" that is most correct and listing the evidence (characteristics) for it.

How to do this? Here's a really simple example: using this technique we can estimate the relative relatedness of Grover, Elmo, Cookie Monster and Big Bird.







Note that on this most likely tree, a characteristic should only appear once. You will be doing this for the organisms listed in lab today. This technique is called "phylogenetic analysis." The remaining trees are "less preferred", i.e., they have more "steps."

CHEAT SHEET FOR LAB #8

Protista
- Protozoa - single-celled animals

Anamalia
- Porifera -- sponges
- Cnidaria -- jellyfishes, sea anemones, corals
- Nematoda -- nematodes
- Rotifera -- rotifers
- Annelida -- earthworms and marine relatives (e.g., fanworms)
- Mollusca -- clams, mussels, squids, snails, octopi
- Arthropoda -- animals with hard exoskeletons and jointed legs
  - Crustacea -- shrimps, crabs, lobsters (have two pairs of antennae)
  - Uniramia -- have a single pair of antennae
    - Insecta -- insects
    - Diplopoda -- millipedes
    - Chilopoda -- centipedes
  - Chelicerata -- no antennae, have chelicerae for jaws
    - Arachnida -- spider, scorpions, mites and ticks
    - Xiphosura -- horseshoe crabs

- Echinodermata -- starfish, brittlestars, sand dollars, sea urchins
- Chordata -- chordates
  - Vertebrata
    - Osteichythyes -- bony fishes
    - Chondrichthyes -- cartilaginous fishes: sharks and rays
    - Amphibia -- frogs and salamanders
    - Reptilia -- snakes, lizards, turtles, alligators
    - Mammalia -- mammals

Procedure
Utilize the information in the classroom as well as the info listed above to determine the most parsimonious phylogeny. Use these characteristics as synapomorphies for the requirements page.

For question #1
1 - radial symmetry
2 - bilateral symmetry

For question #2
1 - mammary glands
2 - aquatic eggs
3 - terrestrial eggs

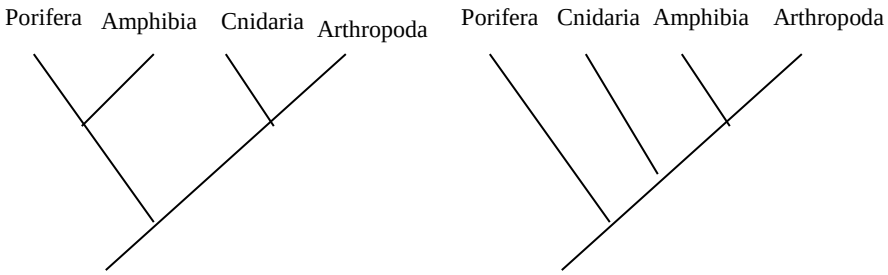
For question #3
1 - antennae
2 - water vascular system
3 - hard, chitinous exoskeleton
4 - pentaradial symmetry

Name_____

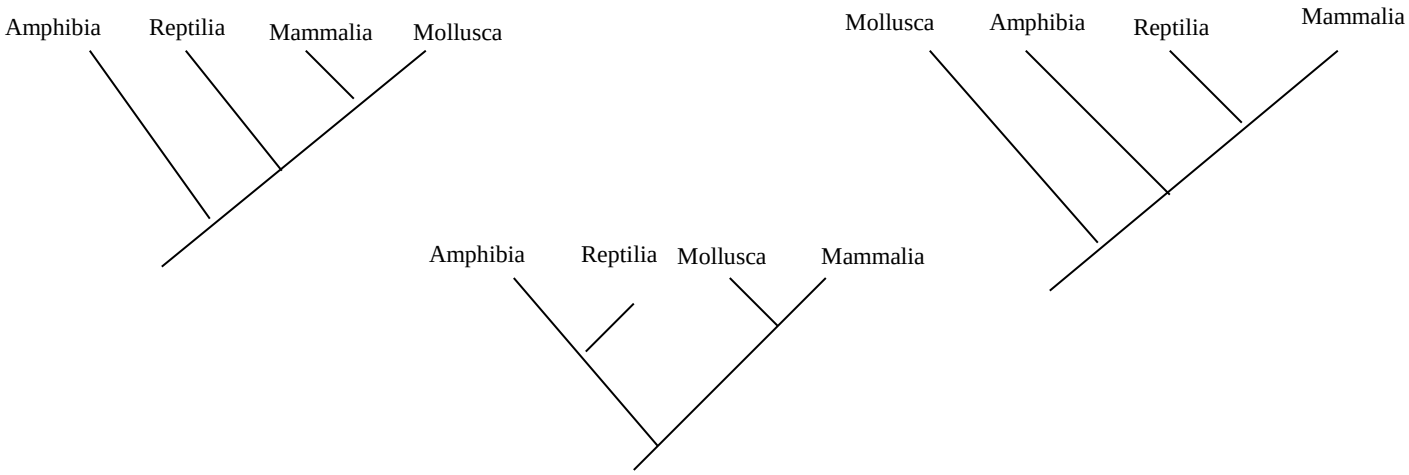
Requirements Lab 8

For each group of phylogenies (trees), place the synapomorphies (characteristics) given with the appropriate group. Synapomorphies may be used more than once. The phylogeny with the fewest characteristics is the most parsimonious. Carefull!! You will lose .5 pt for each incorrect or missing synapomorphy!!

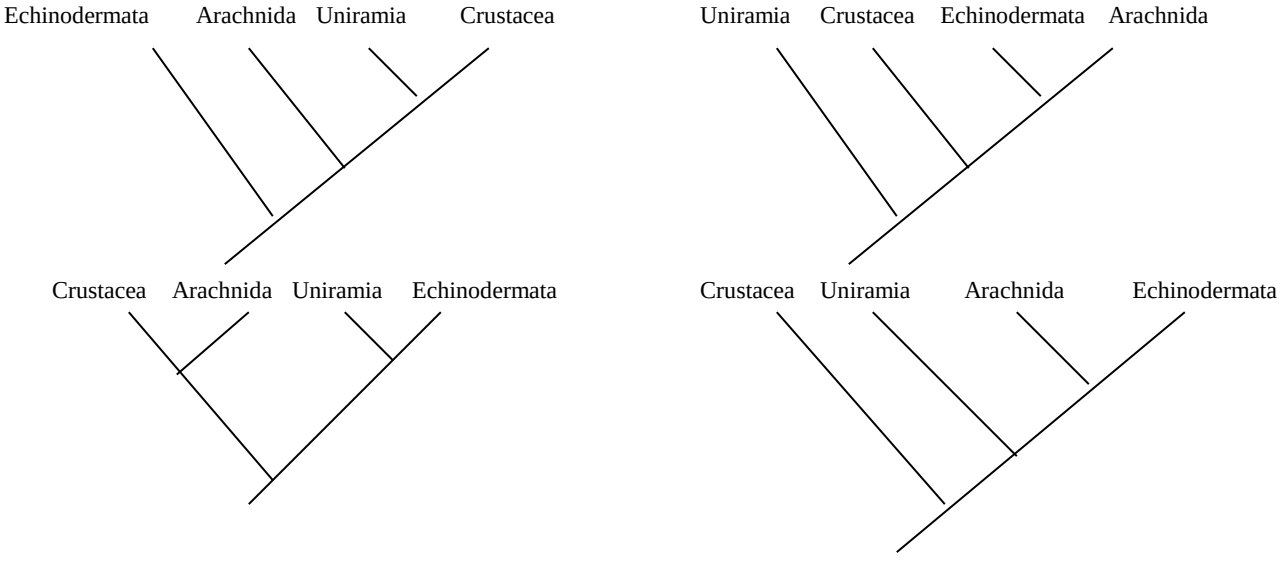
1. Indicate which phylogeny is the most parsimonious. Show all symapomorphies.



2. Indicate which phylogeny is the most parsimonious. Show all symapomorphies.



3. Indicate which phylogeny is the most parsimonious. Show all symapomorphies.



LABORATORY #9 -- BIOL 111
Plant Diversity – Dichotomous Keys

Anyone with even a mild interest in studying organisms must be able to differentiate similar species from one another. This sounds easy, but can be very difficult since many species appear almost identical. The most common way of determining plant species is to use a descriptive or dichotomous key. The idea came from an 18th century French naturalist, Jean-Baptiste Lamarck. Legend has it that when Lamarck first demonstrated the key, he gave it to a random stranger. The stranger, who did not know much about plants, was able to determine plant species without trouble!

A key consists of a series of steps. Each step has 2 or more choices that systematically lead you to species identification. Flow charts are an example of a simplified dichotomous key.

To make a key, you will need plants, but you will also need to describe them. Today we will use leaf-related characteristics such as arrangement, position, venation, and shape ratios. Be careful! Even on the same plant, leaves may be diverse. Always use a typical, average leaf from a plant. If all leaves are different, use a middle leaf from the main stem.

Table 1. Leaf Arrangement

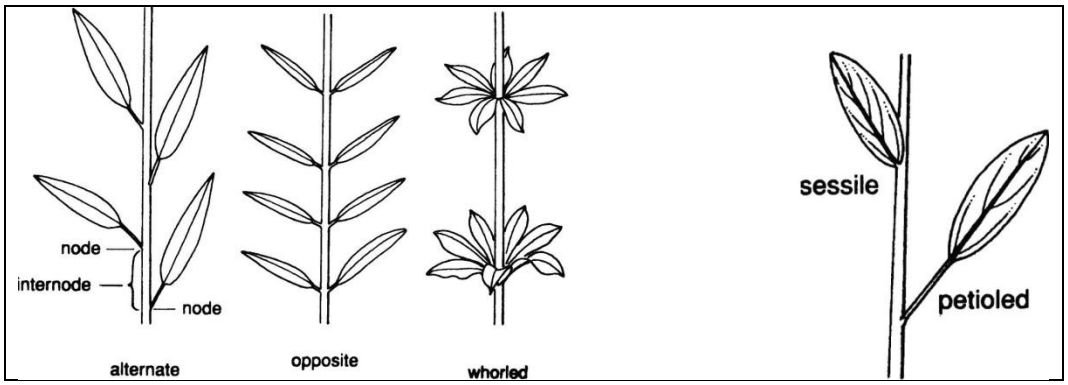


Table 2. Leaf Base

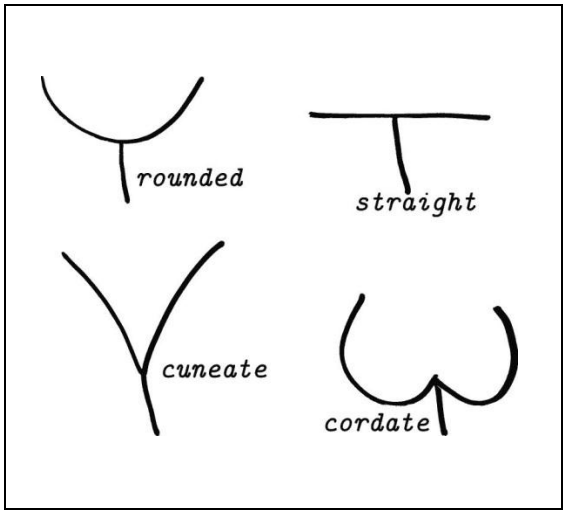


Table 3. Venation

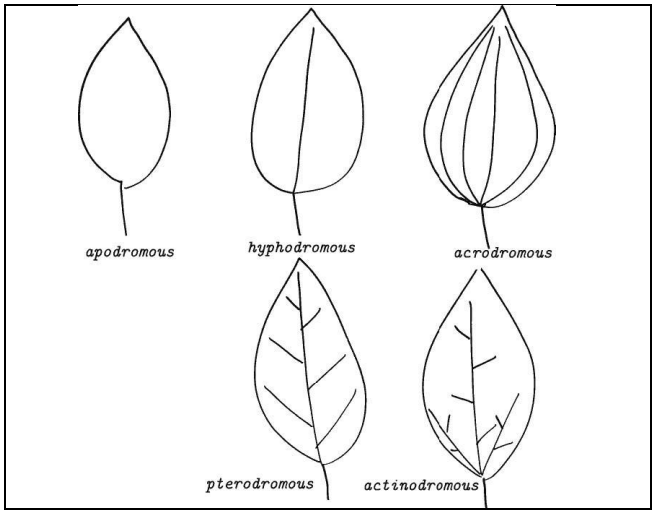


Table 4. Leaf shape ratios

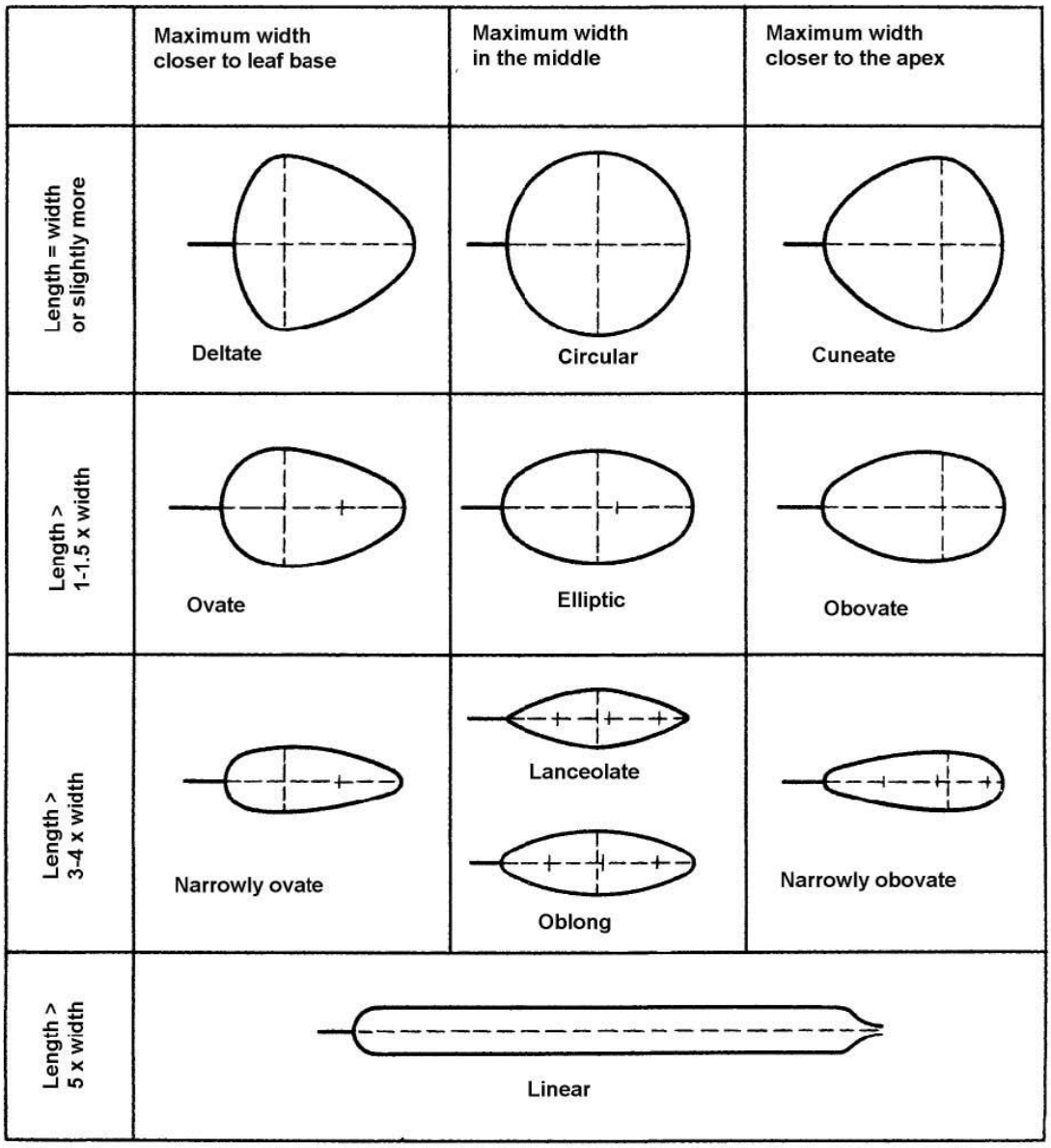


Table 5. Leaf Edges

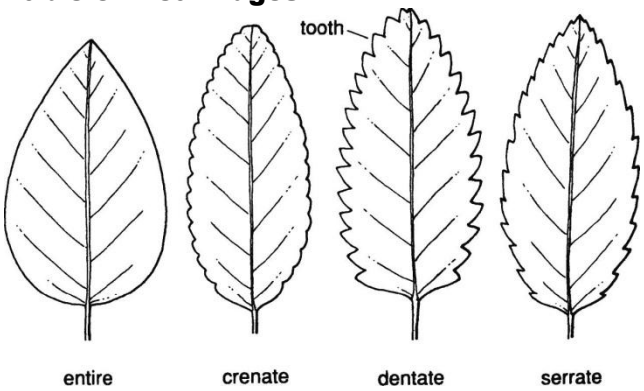


Table 6. Leaf Tips

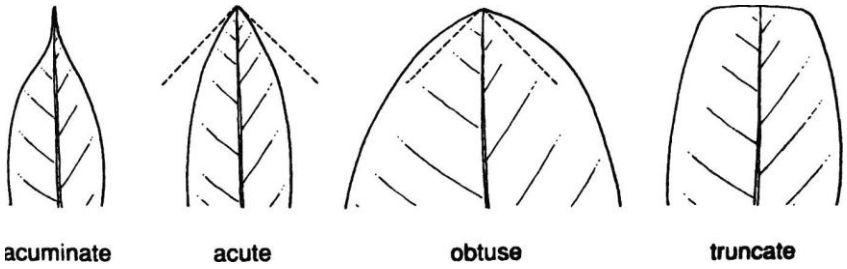
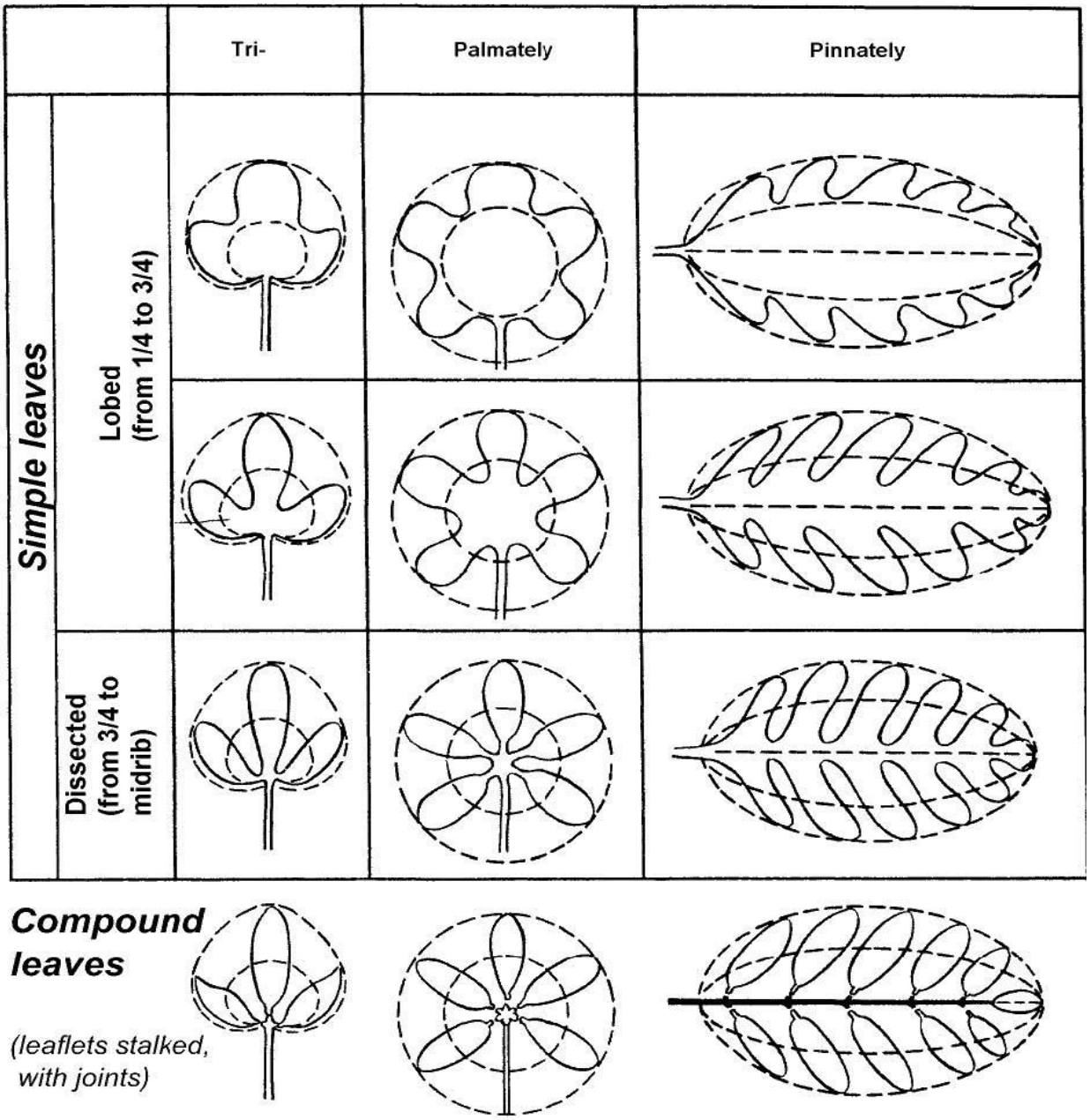


Table 7. Simple vs. Compound and Dissected vs. Lobed



Procedure

1. Each table is a team. Each team should obtain 6 different plants. Start by determining which characteristics given fit each plant. Gather as many characteristics for each plant as possible.

2. Now you will determine which characteristic you will use to begin splitting the plants up. Begin with a 3/3 or a 4/2 split. 5/1 splits really don't work out well and you end up starting over.

3. In this step your team will build a complete key using the characteristics you have gathered. Name each plant using the number written in the lower right hand corner of the paper the plant is mounted on.

4. Now you should make a key without the final solutions (the plant number). Have a neighboring team try to determine the number of each plant. Revise if necessary.

5. Continue with the additional questions.

Name_____

Requirements Lab 9

1. Copy your team's key here. Be sure it's neat, orderly and most of all that it works!! *(10 pts)*

2. What are the similarities and differences between a phylogeny and a dichotomous key? *(3 pts)*

3. Imagine you have eight plants rather than six. How many steps will your key have? *(2 pts)*

LABORATORY #10 -- BIOL 111
Evolution Board Game

The First Creature appeared on land. The Second followed. The First ate grass, The Second became a predator. The First camouflaged itself, The Second developed keen eyesight. The First escaped by water—The Predator learned to swim. The First hid in a burrow, the Second had to eat roots. More and more animals appeared on Earth and food was becoming in short supply... The eternal struggle between predator and prey for survival—survival of the fittest—this is "Evolution".

"Evolution" the game is based on the theory of **Charles Darwin**. It allows players to create their own species of animals with their own abilities while fighting to control the one important resource—**food**. By regulating the population of your creatures, obtaining new useful abilities and fighting off opponents, you must survive till the end of the game and stand at the head of the food chain.
At the beginning all players receive 6 cards; with them you can either create a creature or place an ability on an already created one: for example make it Huge or Poisonous.
The game is turn based and each turn is divided into separate phases:

1. Players create creatures and apply abilities to them;

2. With the help of a dice the amount of food is decided;

3. Players, turn-by-turn take food tokens from the pile to feed their creatures: some need only one, while others, depending on their abilities may require two, three or even more to satisfy their hunger;

4. Animals that are not completely fed will starve and become extinct. The completely fed animals survive and grant their player more cards to create new creatures and new abilities.

Once the deck is empty everyone counts their points. Points are awarded for each creature that survived and for each ability on them. The winner is the one who creates the most balanced ecosystem.

Procedure
Every table becomes a team. I will show you a YouTube video explaining how to play. The game's instructions are included below for reference. We'll all play an experimental game first to learn how to play. This should last about 10 min. The team will then play one or two full games. When these game(s) are finished, prepare your report.

After all animals are fed and their FAT TISSUE is filled, or the food bank is empty and all players have used any traits of their animals they wanted to use, the feeding phase is over. Any remaining red tokens in the food bank are set aside.

Extinction and Draw phase

At the beginning of this phase all animals which are not fully FED are put into a discard pile, along with their traits, and all the pairwise traits associated with them. Each player has his own discard pile. The cards are put into a discard pile with facing up. You may look at cards in your own discard pile, but not in other players' piles.

The first player now deals new cards to players from the top of the deck. The cards are dealt one at a time in order, beginning with the first player. Each player gets in total the following number of cards: **1 + the number of surviving animals** belonging to the player. If the deck is empty it's possible that one or more players get fewer cards than they are due.
If a player has no surviving animals and his hand is empty then he takes **6 cards** from the deck during this phase.

After the cards are dealt the turn is over. All food tokens except the fat tokens are removed from the cards and set aside. The new turn starts with the development phase; the role of first player passes clockwise from the first player of the previous turn.

End of the Game

After the deck is empty the last turn begins. After the extinction phase of the last turn the victory points are counted. Each player is awarded victory points as follows:

- **+2 points** *for each surviving animal;*
- **+1 point** *for each trait of a surviving animal;*
- **additional points** *for the traits which increase food requirements:* **+1** *point for Carnivorous or High Body Weight;* **+2** *points for Parasite.*

If several players have an equal number of victory points, the one who has the most cards in the discard pile is the winner.

Traits

An animal may combine any number of traits. However, **no animal can have two identical traits**, with the exception of the FAT TISSUE trait and pairwise traits.

You may only add traits to your own animals. The only exception is the Parasite trait, which you may only add to another player's animal.

The sign in the description of a trait on a card denotes an "animal". The sign denotes a red token from the food bank. The sign denotes a blue extra food token which you can get as a result of using some traits.

Some traits such as High Body Weight or Swimming have permanent effects; others can only be used at specific moments during the game. For example the Running, Tail Loss, and Mimicry traits can only be used when an animal is to be eaten by a Carnivore.

If your animal has several traits which can be used at the same time, you decide in which order to use them. For example if your animal is attacked by a Carnivore, you can first use the Running trait (i.e. try to run away), and, if your attempt failed, use the Tail Loss trait (i.e. survive by loosing one of your traits).

Some of the traits may be only used during your feeding round. This means that when you are to take a red token from the food base, **you may use this trait together with, or instead of, taking a token**. This is possible even if there are no tokens left in the food bank.

Some traits, such as Carnivorous, Piracy, or Hibernation Ability, may only be used once per turn or every other turn. After using such a trait, rotate the card of the trait horizontally to identify that it has already been used in this turn. At the end of the turn, you may rotate the cards back into the vertical position.

Carnivorous Trait

This trait may be used during your feeding round. At this round **don't take food tokens from the food bank**. Instead, use your Carnivorous animal to attack one of the animals on the table, and if it succeeded in eating this animal get **two blue extra food tokens**. Each Carnivorous animal may only use its Carnivorous trait once a turn. In each feeding round only one of your Carnivorous animals may use its Carnivorous trait. Your Carnivorous animal may attack any animal on the table that is not protected by additional traits, including your own animals or another Carnivorous animal. For the animal eaten, all its traits and all pairwise traits associated with it are put into a discard pile. A Carnivorous animal can't attack and eat other animals if it is fully fed and has no empty Fat Tissue. You can use the Carnivorous trait even if there are no tokens left in the food bank.

Fat Tissue

A single animal may have several Fat Tissue traits. At any time during the game, when your animal with this trait which is already FED and can receive another food token, you can deposit it into its Fat Tissue. In this case, exchange the food token for a yellow fat token and put it on the top of the Fat Tissue card. You can put no more than one fat token on the top of each Fat Tissue card. If there are fat tokens on the top of each Fat Tissue, the Fat Tissue is considered filled and the animal can't get additional food tokens during this turn.

You may use the yellow fat token only during your feeding round. **Instead** of getting one red token from the food base take **any number** of yellow fat tokens from **one of your animals** and convert them into blue food tokens. This conversion isn't considered the same as **getting food tokens** and isn't bound up with using other traits of the animal.

Pairwise Traits

Pairwise traits are played on a pair of animals simultaneously. You can't play two identical pairwise traits onto the same pair of animals. If one of the animals is put into a discard pile, all pairwise traits associated with it are also put into the discard pile. During any player's action during a feeding round you can use each pairwise trait only once; however, you can use each trait during each feeding round. You decide in which order to use your pairwise traits to get food tokens for them. For example, if both Communication and Symbiosis traits are played onto the same pair of animals, you can first take a red token from the food bank to feed the symbiont, and if the symbiont is then fed, immediately take a second red token for the other animal.

If there are not enough tokens of a certain color at some point during the game, you can use tokens of another color or self-made tokens to substitute for them.

Playing with Two Game Sets

You can mix cards from two game sets to accommodate up to 8 players. The size of the food bank is then determined as follows:

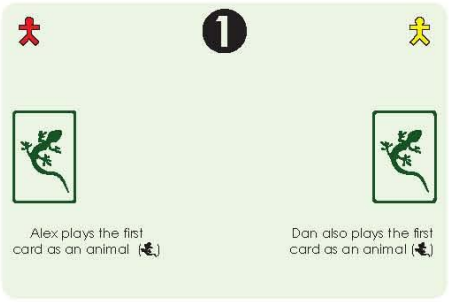
5 players - sum of **three dice + 2**
6 players - sum of **three dice + 4**
7 players - sum of **four dice + 2**
8 players - sum of **four dice + 4**

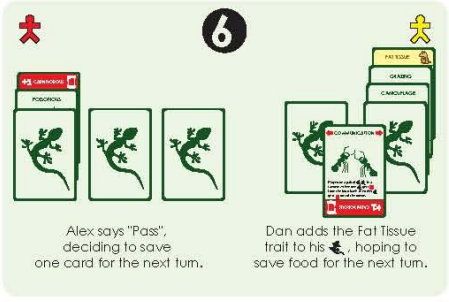
Special thanks: D. Bazikin, E. Bulyshkin, I. Gambashidze, A. Glagoleva, Richard Ham, L. Machina, A. Mironov, A. Pahomov, I. Tulovsky, D. Shahmatov.

FIRST TURN

The game starts. Two players are playing: Alex ( ) and Dan ( ). Each has 6 cards in his hand. Alex makes the first move.

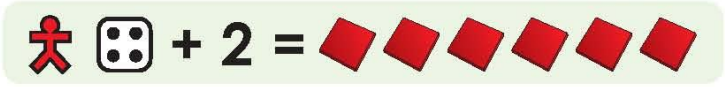
Development phase



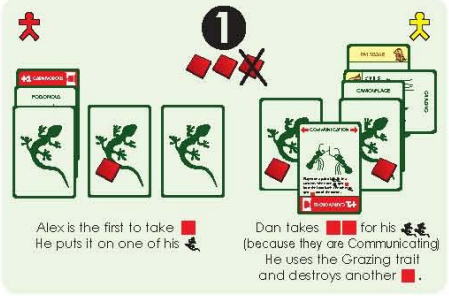


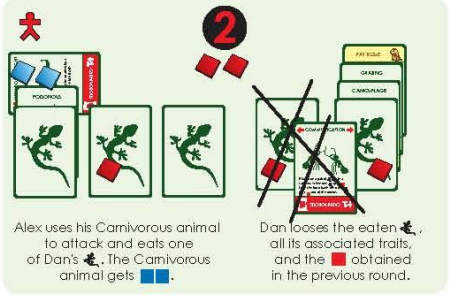
Food Bank Determination Phase

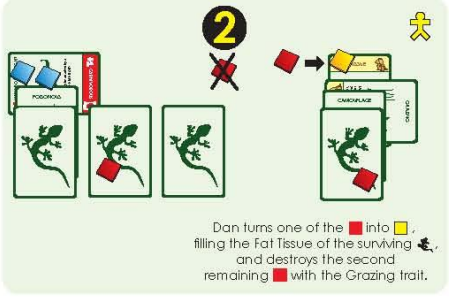
Alex rolls a die. The roll is . This is a two-player game, so **2** should be added to the die result. Therefore, the food bank during this turn is **6 food tokens**



Feeding Phase

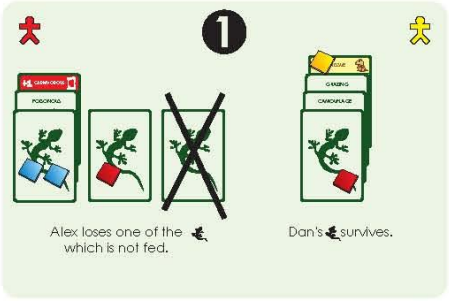






Extinction and Acquisition of New Cards

There are no tokens left in the food bank. All animals that are not fed die.



The turn is now over. In the next turn Dan will make the first move in all phases.

Comment: in order to win, it is very important to play the right cards in the development phase and to distribute food properly in the feeding phase. Note that in this example, in the second round of the feeding phase, Alex could have taken the red food token for his second , and could have used the Carnivorous trait in the third round. In that case all his animals would have been fed, and he would have had a tactical advantage by the end of the turn.

Name_____

Requirements Lab 10

1. Describe the most successful ecosystem (from the winner). Explain how the traits utilized made it the most successful. *(10 pts)*

2. Why do carnivores require more food than "ordinary" critters? Why do critters with parasites require more food than "ordinary" critters? (2 pts)

3. The creators of this game think that an ecosystem complete with carnivores and parasites is better than one without them (they give you more points). Give two reasons why ecosystems with carnivores and parasites should get more points. *(2 pts)*

4. How goes the game correspond with the idea of Natural Selection (differential survival and/or reproduction)? *(1 pt)*

LABORATORY #11 -- BIOL 111
Natural Selection

Alleles determine phenotype and phenotypical percentages change from generation to the next. Since evolution is merely a change in allele frequency over time, then all life is constantly evolving. Some populations evolve faster than others due to competition or environmental pressure. We can document these populations to illustrate the processes of evolutionary change.

The principal process involved in evolutionary change is **natural selection**, which is defined as "differential survival and/or reproduction."

There are three requirements that must be met for natural selection to actually take place:

1. There must be variation among the members in the population for the trait in question

2. The variants of the trait must result in differences in survival and/or reproduction.

3. The trait in question must be controlled to some degree by genes (e.g., when you dye your hair, this new variant is not controlled by genes).

Note that if no variation exists in a population, then natural selection cannot work.

A classic case of natural selection is industrial melanism in peppered moths. Prior to the Industrial Revolution in England, nearly every peppered moth had light-colored speckled wings. This coloration enabled the moths to blend in on the lichen-covered tree trunks. The much rarer black peppered moths were so obvious that birds (the primary killer [i.e., the important "selector"] of peppered moths) easily caught and killed them. The result is that these forms differed in survival probability and thus the light-colored moths survived and reproduced. Black moths were only maintained because of the rare mutation.

Later on, the Industrial Revolution was responsible for the production of huge amounts of soot (from factory smokestacks). The soot was produced so rapidly that it covered the once-light-colored tree trunks. The now-dark tree trunks exposed the light-colored moths and the dark moths now were blending in. The birds now caught mostly light-colored moths, thus dark moths had higher survival and reproduction. Because they were producing more offspring (which had better survival probability), the dark moths now became abundant. The population now contained a larger fraction of dark moths, and this follows the definition of evolution (i.e., change in allele frequencies). Since then, the factories have cleaned up their act. Soot is no longer being produced is great abundance. The black moths are easily seen (and eaten) once again, and light-colored moths are able to blend in to the now light-colored lichen covered trees. This demonstrates yet another change in allelic frequency over time, and again, another example of evolution.

Procedure
Today, we will have two species: a predator (you) and prey (bean species). Every table will become a battleground between a population of prey and a population of predators.

In all, there will be 4 predators (you and your neighbors) and 200 prey (different beans). In each round, you will "eat" beans by collecting them into your "stomach". To catch beans, every predator will be assigned one (and only one) **tool**:

- plastic fork
- knife
- ordinary spoon
- soup spoon

Before the game starts, all varieties of prey should be equal. Therefore, there should be:

- 50 **small white** beans (Navy beans)
- 50 **large white** beans (Lima beans)
- 50 **medium red** beans (Kidney beans)
- 50 **medium camouflage** beans (Pinto beans)

Rules:
1. Every table becomes a team of players. Carefully read instructions, formulate hypotheses to answer question 1.

2. Put all prey (200 beans, 50 of each variety) to the center of the table, **mix** them, place your dishes in each corner.

3. Ready tools, remove all items from the table other than beans and dishes.

4. Start the hunt: **you have a given number of seconds to catch and "eat" as many beans as possible**. **The prey may be caught only with the designated tool in your non-dominant hand, everything else is forbidden!**

> You are allowed to catch more than one bean at a time, but you cannot move your "stomach"! Try not to hinder your teammates' progress. After the "stop" command, stop catching immediately. If you just caught the prey but did not put it into "stomach", release it.

- Calculate the results for predators: the predator that caught the most prey will *reproduce* to replace the most unsuccessful predator. In other words, if the predator with fork caught the maximal number of prey, and the predator with teaspoon caught the minimal number of prey, the teaspoon will starve and be replaced by the fork.

- Prey reproduce: all surviving beans should be **doubled**. For example, if 15 Limas, 18 Navys, 28 Kidneys and 12 Pintos survived, add 15, 18, 28 and 12 beans of each variety, respectively.

Play several rounds (5 or more) until you see the obvious changes in the prey-predator frequencies.

Name_____

Requirements Lab 11

1. Hypothesize which predator will be the most successful. Hypothesize which prey species will be the most successful? As with all hypotheses, be sure to include a reason for your thoughts. Did you reject or fail-to-reject your hypotheses? *(3 pts)*

2. Describe below the final ecosystem on your table. Who survived and why? *(2 pts)*

3. Did the other tables end up with an ecosystem similar to yours? Why or why not? *(2 pts)*

4. Apart from natural selection, real evolutionary processes will also be influenced by (a) mutations, (b) migrations from other populations and (c) random processes (genetic drift). How you would change the rules of game in order to accommodate one or more of these processes? *(8 pts)*

a. mutation

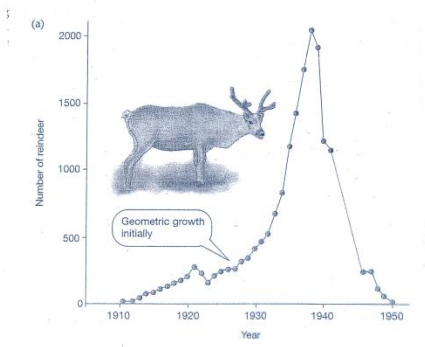
b. migration

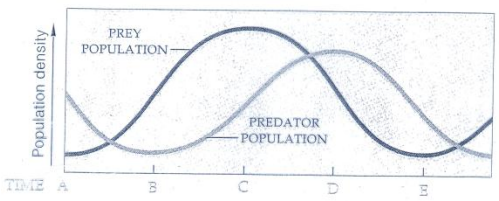
c. genetic drift

LABORATORY #12 -- BIOL 111
Predator-Prey cycles

One of the most influential kinds of relationships that species of animals can have with one another is that of **predator** (the hunter and eater) and **prey** (the hunted and eaten). Lions and gazelles, salamanders and insects, corals and zooplankton, and lynx and hares are all examples of a predator-prey relationship. The individual predator benefits while the individual prey suffers from the short-term effects of this relationship. However, the long-term effects are more intriguing at the population level, i.e., when we consider the fates of large groups of a predator and large groups of prey.

In this lab you will be exposed to the concept of oscillations ("ups and downs") in predator and prey population sizes. Of course, a prey population will be larger if predators are not present. However, this is not always a healthy situation. For example, in 1944, 29 reindeer were introduced to Saint Matthew Island in the Bering Sea. Without a predator population, the reindeer population underwent <u>exponential growth</u> (meaning "really, really fast and uncontrolled population increase").





By the year 1963, the population on this small island consisted of 6000 individuals. Consequently, a population crash occurred because the reindeer denuded the area (i.e., consumed all food to the point where it could not grow back). Only 40 animals remained in 1965. By the 1980s, the population had died off completely.

The point is that many prey populations benefit from the presence of predators because the predators selectively "thin" the prey population and maintain it at an ecologically healthy level. In our work today, we will attempt to mimic the effects of predator population size on prey population size.

Procedure

This exercise requires that each team become familiar with the simulations through an exercise in bean counting. After becoming familiar with each simulation, you will then proceed to extending the time of the simulation and the complexity of the simulation by using a computer. The computer will allow you to run each simulation for hundreds of generations and in every conceivable variation.

Keep in mind that the bean-counting is done primarily to help you understand what the computer will be doing. While there are four "teams" listed below, you only need to attempt bean counting under the condition of one of the teams.

Team 1 -- Efficient predator; prey with low reproductive rate

Count out 40 PREDATORS (red beans) and 50 PREY (white beans). Mix them in a cup and draw them out in pairs (without looking!). Drawing them out in pairs is meant to represent an encounter between two individuals. Treat the pair of beans in the following manner:

(A) When a predator and prey occur together, remove the prey and add 1 predator (the predator ate the prey and was able to reproduce). Put these two predators in a different pile (called the "survival pile"). Put the dead prey in a discard pile.

(B) When 2 prey occur together they reproduce. Add 1 more prey (the prey avoided predation and were able to reproduce) and put these 3 prey in the survival pile.

(C) When 2 predators occur together they starve (die and fail to reproduce). Remove both of them to the discard pile.

(D) After drawing all pairs out of the original container record the number of prey and predators in the survival pile. This ends the first generation.

(E) Now start the process over using only individuals from the survival container. You are now beginning the second generation.

(F) Proceed until predator or prey population goes extinct or after 2 generations.

(G) Now repeat the same process with 10 PREDATORS (red beans) and 50 PREY (white beans).

COMPUTER SIMULATIONS:

You may now use the computer to assist you in addressing the importance of the variables included in the bean-counting exercise:

Initial population size
Predator efficiency
Prey reproductive rate

Team 2 -- Efficient predator; prey with high reproductive rate

Count out 40 PREDATORS (red beans) and 50 PREY (white beans). Mix them in a cup and draw them out in pairs (without looking!). Drawing them out in pairs is meant to represent an encounter between two individuals. Treat the pair of beans in the following manner:

(A) When a predator and prey occur together, remove the prey and add 1 predator (the predator ate the prey and was able to reproduce). Put these two predators in a different pile (called the "survival pile"). Put the dead prey in a discard pile.

(B) When 2 prey occur together they reproduce. Add 2 more prey (the prey avoided predation and were able to reproduce) and put these 4 prey in the survival pile.

(C) When 2 predators occur together they starve (die and fail to reproduce). Remove both of them to the discard pile.

(D) After drawing all pairs out of the original container, record the number of prey and predators in the survival pile. This ends the first generation.

(E) Now start the process over using only individuals from the survival container. You are now beginning the second generation.

(F) Proceed until predator or prey population goes extinct or after 2 generations.

(G) Now repeat the same process with 10 PREDATORS (red beans) and 50 PREY (white beans).

--- --- ---

COMPUTER SIMULATIONS:

You may now use the computer to assist you in addressing the importance of the variables included in the bean-counting exercise:

Initial population size
Predator efficiency
Prey reproductive rate

Team 3 -- Moderately efficient predator; prey with low reproductive rate

Count out 40 PREDATORS (red beans) and 50 PREY (white beans). Mix them in a cup and draw them out in pairs (without looking!). Drawing them out in pairs is meant to represent an encounter between two individuals. Treat the beans in the following manner:

(A) When a predator and prey occur together, flip a coin:

If tails: remove the prey and add 1 predator (the predator ate the prey and was able to reproduce). Put these two predators in a different pile (called the "survival pile"). Put the dead prey in a discard pile.

If heads: remove the predator (it failed to capture the prey and, as a result, starved). Put the prey in the survival pile.

(B) When 2 prey occur together they reproduce. Add 1 more prey (the prey avoided predation and were able to reproduce) and put these 3 prey in the survival pile.

(C) When 2 predators occur together they starve (die and fail to reproduce). Remove them to the discard pile.

(D) After drawing all beans out of the original container, record the number of prey and predators in the survival pile. This ends the first generation.

(E) Now start the process over using only individuals from the survival container. You are now beginning the second generation.

(F) Proceed until predator or prey population goes extinct or after 2 generations.

(G) Now repeat the same process with 10 PREDATORS (red beans) and 50 PREY (white beans).

COMPUTER SIMULATIONS:

You may now use the computer to assist you in addressing the importance of the variables included in the bean-counting exercise:

Initial population size
Predator efficiency
Prey reproductive rate

Team 4 -- Inefficient predator; prey with low reproductive rate

Count out 40 PREDATORS (red beans) and 50 PREY (white beans). Mix them in a cup and draw them out in pairs (without looking!). Drawing them out in pairs is meant to represent an encounter between two individuals. Treat the beans in the following manner:

(A) When a predator and prey occur together, flip two coins:

If both tails: remove the prey and add 1 predator (the predator ate the prey and was able to reproduce). Put these two predators in a different pile (called the "survival pile"). Put the dead prey in a discard pile.

If any heads: remove the predator (it failed to capture the prey and, as a result, starved). Put the prey in the survival pile.

(B) When 2 prey occur together they reproduce. Add 1 more prey (the prey avoided predation and were able to reproduce) and put these 3 prey in the survival pile.

(C) When 2 predators occur together they starve (die and fail to reproduce). Remove them to the discard pile.

(D) After drawing all beans out of the original container, record the number of prey and predators in the survival pile. This ends the first generation.

(E) Now start the process over using only individuals from the survival container. You are now beginning the second generation.

(F) Proceed until predator or prey population goes extinct or after 2 generations.

(G) Now repeat the same process with 10 PREDATORS (red beans) and 50 PREY (white beans).

COMPUTER SIMULATIONS:

You may now use the computer to assist you in addressing the importance of the variables included in the bean-counting exercise:

Initial population size
Predator efficiency
Prey reproductive rate

Name_____

Requirements Lab 12

1. Which team do you hypothesize will have the most stable predator-prey relationship? Why? *(2 pts)*

2. Use the graphs/common sense to explain why each of the **"doomed"** teams failed. Note: One team survives – this means it is not **"doomed"** and does not need a blank. *(7 pts)*

Team ___ - 40/50 _____

Team ___ - 10/50 _____

Team ___ - 40/50 _____

Team ___ - 10/50 _____

Team ___ - 40/50 _____

Team ___ - 10/50 _____

3. Based on the computer simulations **given**, what kind of predators do you expect exist in nature: inefficient, moderately efficient, or very efficient? (Circle one) *(1 pt)*

4. Based on the computer simulations **given**, what kinds of prey do expect exist in nature: those with high or low reproductive rates? (Circle one) *(1 pt)*

5. In general, how does changing the initial population (40 vs. 10) of predators in the **"doomed"** groups change the graph? Show me & Explain. *(3 pts)*

6. Use the computer to find **another** viable combination of predator efficiency/prey reproduction (one that doesn't die off). Be sure to check 40/50 & 10/50. *(1 pt)*

LABORATORY #13 -- BIOL 111
Conway's Game of Life

In computer science, there is always a tendency to explore things that are somewhat similar to biological life. Computer scientists tried to create programs which simulate real life features: growth, feeding, moving, reproduction and even evolution. These simulations help create robots, self-replicating systems and serve as steps toward artificial intelligence. From a biological point of view, such simulations demonstrate self-organization, or how organized life may emerge from a chaotic system of inorganic molecules.

The most well-known simulation of this kind is Conway's Game of Life. This is not a game in a strict sense, it is more like programming. You will have a field of indefinite size, and a time (generations). The field is separated into dead cells (white) and live cells (black). Actually, the field is initially white, and you will introduce black cells yourself. Every cell has 8 neighbors. Rules are simple:

- **A live cell with 2 or 3 (live) neighbors survives, but dies otherwise (easier to survive in groups).**
- **A dead cell with exactly 3 (live) neighbors comes to life, and remains dead otherwise (reproduction).**

1. Open the game from this web site: http://ashipunov.info/shipunov/school/biol_111/game_of_life.htm, switch the sound off, skip the ad

There are an infinite number of cell combinations. However, some of them are different. They behave, sometimes just like real cells. You can see some "creatures" that arise from chaos by clicking on the down arrow next to "clear". Explore the **varieties**.

- Still-life. Creatures which do not change. Examples: block or boat.
- Oscillators. They change shape cyclically. Examples: blinker, 10 cell row or tumbler.
- Spaceships. They are moving! Examples: glider, lightweight spaceship.
- Transient lives. Sometimes, they just vanish. Sometimes, they live for a long time and only then stabilize. Examples: small exploder or exploder.
- Infinitely growing lives. They live forever and even produce offspring! These creatures are big and complicated. One of the smallest is Gosper glider gun.

2. Start the game, explore the start/stop button, speed and creation menus.

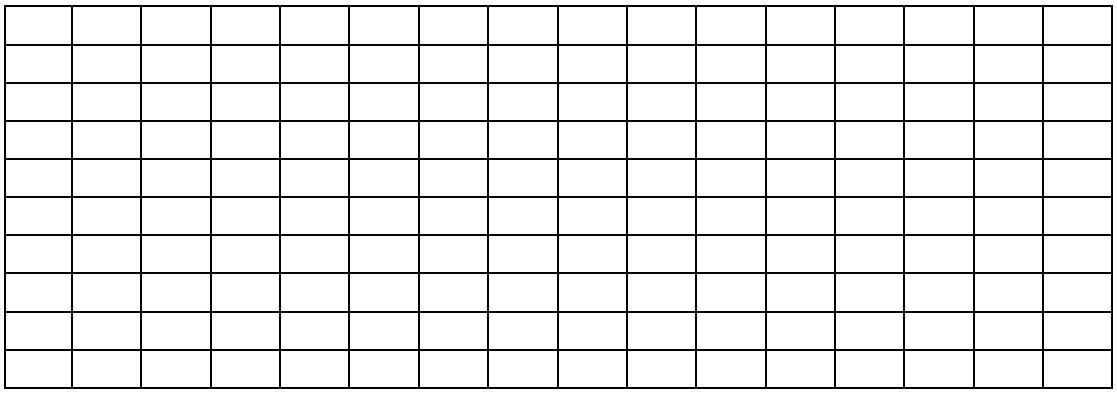
3. Fill the field with random cells three times. Observe the result on different speeds.

4. Invent two your own creatures of different types. Explore their behavior.

Name_____

Requirements Lab 13

1. Make a sketch of two creatures you have created. Describe how each behaves. Hint: look at the varieties listed above. *(6 pts)*



2. We may describe self-organization as an *emergence from chaos*. How is Conway's Game of Life a model for self-organization? *(4 pts)*

3. How are Conway's creatures similar to real cells? Find as many similarities as possible. *(3 pts)*

4. How are Conway's creatures different from real cells? *(2 pts)*