BIOL 111 —Laboratory Manual

The Faculty of MSU Department of Biology[1]

Fall 2014
Swain Hall, Room 304

[1]Links in this PDF are *active*, you may click on them.

Contents

Introduction

Sections & Attendance

If you have a legitimate reason it is possible to come for the lab with different section. Please, however, do not forget to inform **both** instructors in advance. Their e-mails:

Chris, Keller	`christopher.keller@minotstateu.edu`
Ihli, Lori	`ihlilori@hotmail.com`
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Super, Heidi	`heidi.super@minotstateu.edu`

Only these four instructors teach our Intro labs. There is a separate Biol 111 course with different instructor; please do not come to these sections.

Sections

BIOL	Section	Instructor	Class	Start	End	Day	Room
111	111-1	Ihli, Lori	11277	10:00 am	11:50 am	Mo	Swain 304
111	111-2	Chris, Keller	11280	1:00 pm	2:50 pm	Mo	Swain 304
111	111-3	Ihli, Lori	11281	8:00 am	9:50 am	Mo	Swain 304
111	111-4	Super, Heidi	11282	10:00 am	11:50 pm	We	Swain 304
111	111-6	Chris, Keller	11287	1:00 pm	2:50 pm	We	Swain 304
111	111-8	Ihli, Lori	11289	8:00 am	9:50 am	We	Swain 304
111	111-11	Ihli, Lori	11952	3:00 pm	4:50 pm	We	Swain 304

About labs

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 interact) and the very large (e.g., 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 bio-terrorism).

- 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 out-pace the capacity of the general public to make informed decisions.

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" (report) 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 we can examine your work each week and will allow to ascertain your progress and detect problems in understanding. Additionally, it is your responsibility to make sure that instructors can find each lab. Do not "hide" your work behind older labs.

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.

There are a total of 12 labs. Each lab is worth 15 points. The lab portion of the course is worth a total of 180 points (12 labs × 15 points each = 180).

Please keep it in mind that it is not always 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.

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!**

All labs must be submitted on the lab report page (last page of the lab). Students submitting report 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 generally 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 in 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. **Answers must be specific. Explain, explain, and explain some more.**

6. Answers should be simple. Someone who has never taken biology should understand your answer.

Laboratory 1

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.

1.1 "Sounds silly, huh?", first part

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.

1.2 "Sounds silly, huh?", second part

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).

1.3 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 a process by which things can be known.

Lab 1 report

Your name _____

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 hypotheses for the box your team has been given. Be specific!! (2 pts)

3. (*Experiment*) Develop critical experiment(s) 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. How confident are you and your team that the item is actually in the box (provide a comparison or a percentage)? Provide some reasoning with your answer. (4 pts)

Laboratory 2

Microscope and cells

2.1 Microscope

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 sub-cellular structures to small tissues and organs are visible with the aid of a light microscope. However, truly small objects like molecules and some small sub-cellular structures cannot be seen (they are inferred using the scientific method).

The compound light microscope is used for magnifying objects, typically $100\times$ (or "100 times larger than actual") to $1000\times$. 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.
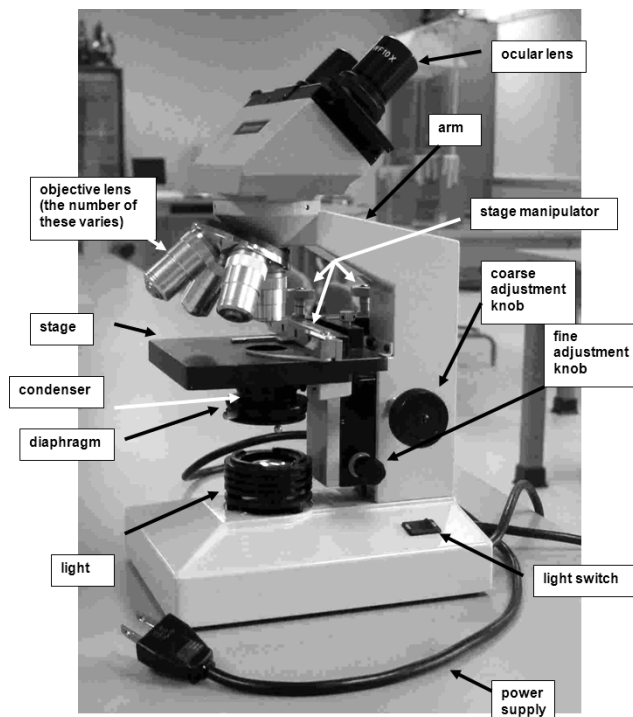
2.2 Measuring objects

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 (i.e., $4 \times 10 = 40$). Total magnification refers to this magnification produced together by the ocular lens and the objective lens in use. When

discussing magnification, the microscope user should be clear about whether "objective lens magnification" or "total magnification" is being used.

It is easy to calculate the size of microscopic object. All what you need is a diameter of field (the whole visible circle) and number of objects which fit in this diameter. If, for example, the field diameter is 1 mm and 10 objects will fill this diameter, then the size of object is 1 mm /10 = 0.1 mm.

Today, we will use mostly $400\times$ (or less) total magnification ($40\times10 = 400$). The field diameter for this magnification is **0.23 mm**. If you use higher magnification, you should decrease the field size *proportionally*. If you use lower magnification, you should proportionally increase it. For example, if you use $10\times$ objective lens instead of $40\times$, the magnification is four times smaller, and the field diameter is four times **bigger**.

2.3   Characteristics of cells

The basic unit of life is the cell. Some organisms are composed of a single cell (e.g., a bacterium like *Esherichia 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).

2.4   Procedure

1. 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:

   (a) Using a drop of IKI (iodine in potassium iodide) prepare a wet mount slide of onion skin from the bulb leaf. The sample must be extremely thin! Observe the cells at different magnifications.

   (b) Using a drop of water, prepare a wet mount of an *Elodea* leaf.

   (c) Prepare a slide of cheek cells stained with methylene blue.

2. Using the approach discussed above, estimate the size (maximal length) of each kind of cells.

Lab 2 report

Your name _____

1. (a) Prepare below a diagram of one (or more) onion skin cells. (b) Label the cell wall and the nucleus, (c) list their definitions and functions. (d) Include a scale bar indicating the approximate length and width of an average cell. (e) 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 bigger: cheek cells or onion skin cells? Please show your math! (3 pts)

4. Name 3 ways your animal cells are different from plant cells. Explain how you can see these differences. (3 pts)

    (a)

    (b)

    (c)

Laboratory 3

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 water 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 (e.g., glucose, sucrose).

Because many solutions contain different amount of compounds (e.g., pure freshwater has nothing in it; saltwater is water and 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.")

This example also applies to cells. In today's procedure, you will use cells of carrot root to observe the cumulative effect of osmosis. Cells (in our case, pieces of carrot which contain thousands of small cells) will be placed in two "environments" that differ in amount of salt: no salt (distilled water) and 1 M solution of salt (1 M NaCl). You can observe osmosis in action by monitoring the change in length.

3.1 Procedure

1. Each table of students will work as a team. Each team should obtain 2 beakers (plastic cups), 1 carrot, 1 metric ruler, and a small knife. Sorry, no stabbing allowed!

2. Fill each of the 2 beakers $^3/_4$ full of the appropriate solution (either H_2O/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 100 mm long × 10mm wide × 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 20 minutes.

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

6. After 20 minutes, remove the strips, blot dry, re-measure and 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 and 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 is likely there **was a significant change**. We should reject the null hypothesis!

9. Clean up as instructed.

Lab 3 report

Your name _____

1. List hypotheses that predict what will occur in carrot cells.Which way will the water move and what is the scientific principle behind it (Why?)? (2 pts)

   (a) freshwater experiment:

   (b) saltwater environment:

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

	freshwater experiment		saltwater experiment	
Initial length				
Final length				
Change				
p-value				
Significant?				

3. Is a change in weight a good indicator of osmosis in these cells? Is change in length a good indicator of osmosis in these cells? Explain why or why not. (3 pts)

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

   (a) freshwater experiment:

   (b) saltwater environment:

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

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

Laboratory 4

# Photosynthesis and Respiration

4.1 Background

There are two great processes that make the world of life go around: 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. Almost all cells (and thus majority organisms) perform respiration, whereas only certain kinds of organisms that have a specific organelle in their cells 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 into ATP (see below) which then used to assimilate carbon dioxide into carbohydrate, a kind of sugar called glucose. Glucose (and other carbohydrates) is an arrangement of atoms of carbon (C), hydrogen (H) and oxygen (O). From the standpoint of chemistry, photosynthesis is written like this:

$$CO_2 + H_2O \xrightarrow{\text{solar energy}} \text{carbohydrates} + O_2$$
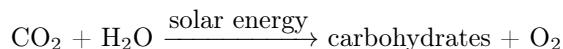
Carbon dioxide comes from the air, the water comes from the soil or the surrounding environment, the glucose is either used by the plant or gets stored (we eat the stored stuff), and the oxygen gets released into the air. This reaction requires energy input—the sun provides this.

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.

$$\text{carbohydrates} + O_2 \rightarrow CO_2 + H_2O + \text{ATP}$$
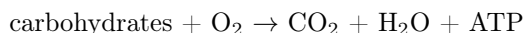
This reaction releases energy.

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.

4.2 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 hydrocarbonate) 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.
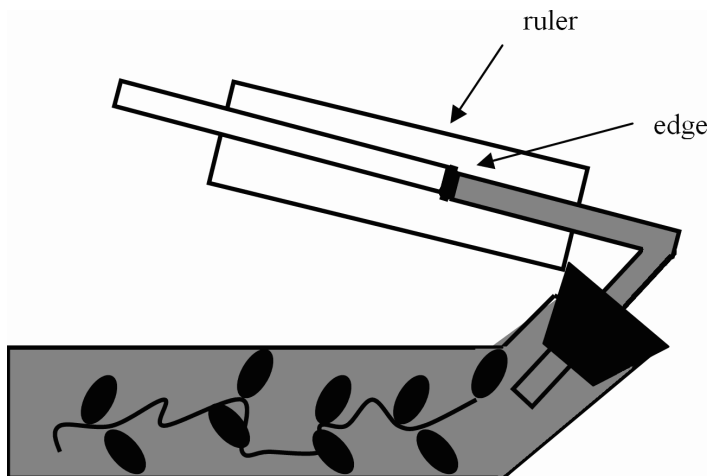
(NaHCO$_3$ provides an abundant source of CO_2. When the edge moves forward or backwards, it indicates if O_2 is being released by the plant or used by the plant. Any CO_2 that is produced immediately goes into solution, i.e., occupies much less volume than an oxygen bubble.)

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 "−".

Lab 4 report

Your name _____

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, emphasize the role of $NaHCO_3$. (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		
final		
+ 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 math. (5 pts)

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

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

Laboratory 5

Cell Craft game

5.1 Background

Eukaryote cell is an extremely complex chemical fabric where all parts (organelles) work together as a finely organized team. To understand this concerted work, we will play a "Cell Craft game".

The game is self-explanatory. You will need to grow your own virtual "cell" and make it survive virus attacks. If any questions arise, you always may click on "Encyclopedia" link and read about all parts of cell and their functions.

5.2 Procedure

1. Open the game from course Web site: http://ashipunov.info/shipunov/ school/biol_111/cellcraft.htm or from http://www.cellcraftgame.com/downloads/ CellCraft.swf here.

2. Clear previous data. Switch the sound off!

3. Start to play game from the lowest (first) level. You may skip movies to save time but please do **read the info**.

4. Play for 30 minutes, record the level achieved (name and/or number), then start to answer questions (next page).

Lab 5 report

Your name _____

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. Using the back of this page, explain how nucleic acids, amino acids, ribosomes, endoplasmic reticulum, RNA and the nucleus all work together to make protein. Hint: take notes as you work through the game. (6 pts)

Laboratory 6

Sensitive plant

6.1 Background

The movement of plant organs in response to environmental stimulus is an interesting phenomenon. The response of *Mimosa pudica* to seismic stimulus is immediate and captures the attention of anyone observing it. Even Charles Darwin was intrigued enough to devote time to describing the leaf-closing response of this plant to external stimuli.

Mimosa pudica is a short-lived sub-shrub that is native to Brazil but has become pan-tropical. It has prickly stems that can grow to a height and spread of one meter. In some areas it is considered a noxious weed. *Mimosa* can grow in most well-drained soils with high or low nutrient availability but is not shade tolerant. As a member of family Leguminosae, the roots of *Mimosa* contain nitrogen-fixing nodules. In cultivation the plant will produce pink fluffy flowers from which viable seeds may be collected. All parts of the plant are potentially toxic and should not be ingested.

6.2 Procedure

1. First, your team will need to design the set of experiments in order to answer the following questions:

   (a) What is the response when the plant is stimulated?

   (b) Which part of the plant is most sensitive to stimulus (touch, movement, light)? (i.e. where must you touch the plant to get the response)

   (c) How fast is the response?

   (d) What is the recovery time?

   (e) Is the response all-or-none or can you get a partial response? (In other words, do all leaves respond, or only those stimulated?)

   (f) What level of stimulus is required to get a response?

   (g) (Invent your own question, and design experiment which will answer it)

   "Design experiment" here means to write down a short plan of what should be done in order to properly answer the question. Do not take plant until all seven experiments will be designed!

2. When you have all plans done, take one plant and proceed with your experiments.

Lab 6 report

Your name _____

Below, describe your experimental plans and the results of each experiment.

1. What is the response when the plant is stimulated?

   - Plan:

   - Results:

2. Which part of the plant is most sensitive to stimulus (touch, movement, light)? (i.e. where must you touch the plant to get the response)

   - Plan:

   - Results:

3. How fast is the response?

   - Plan:

   - Results:

4. What is the recovery time?

   - Plan:

   - Results:

5. Is the response all-or-none or can you get a partial response? (Do all leaves respond, or only those stimulated?)

- Plan:

- Results:

6. What level of stimulus is required to get a response?

- Plan:

- Results:

7. _____

- Plan:

- Results:

Laboratory 7

Genetics and Inheritance

7.1   Background

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". 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 (*hypotheses*) 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):

Law of Segregation: the alleles for each gene are not blended;

Law of Dominance: 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;

Law of Independent Assortment: 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).

7.2 Procedure

7.2.1 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.

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°	tt		
Bent pinky:			
pinky bends	LL or Ll		
pinky straight	ll		
Interlacing of fingers:			
left thumb over right	II or Ii		
right thumb over left	ii		

1. Work with a partner to determine your phenotype for the traits listed in the table below.

2. Record your phenotype and possible genotypes (circle the letters on the appropriate line).

3. After the totals for class are tallied, calculate the percentage of the class with each characteristic.

7.2.2 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)

1. 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:

(1)

(2)
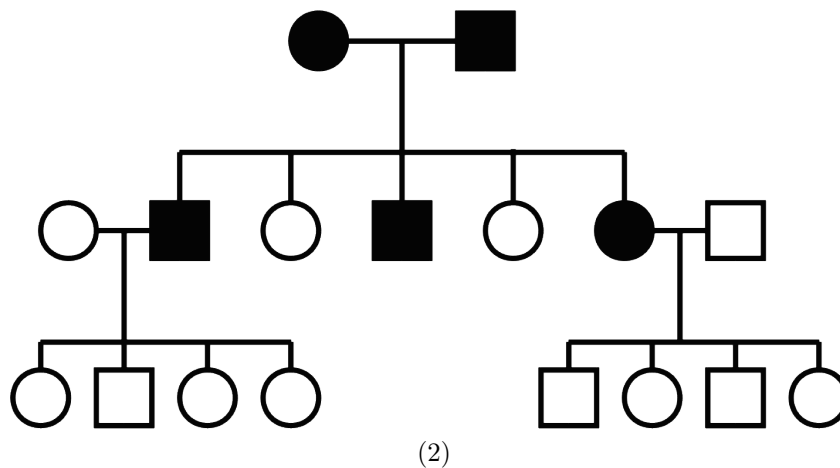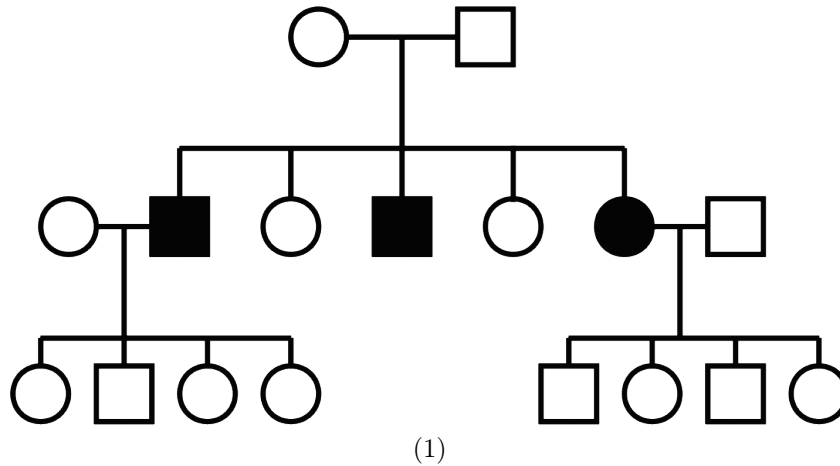
2. You will be given with two different cases of pedigrees. Write down the number and answer questions on the next page. Please note that if the disease phenotype is not listed for one spouse, then he or she has no manifestation of the disease.

Lab 7 report

Your name _____

1. Based on first part of procedure, do you think that recessive traits are rare? Why or why not? 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 a recessive trait and its frequency). *(3 pts)*

2. Choose two cases from four. Answer all questions from both cases chosen *(12 pts)*.

   Case 1
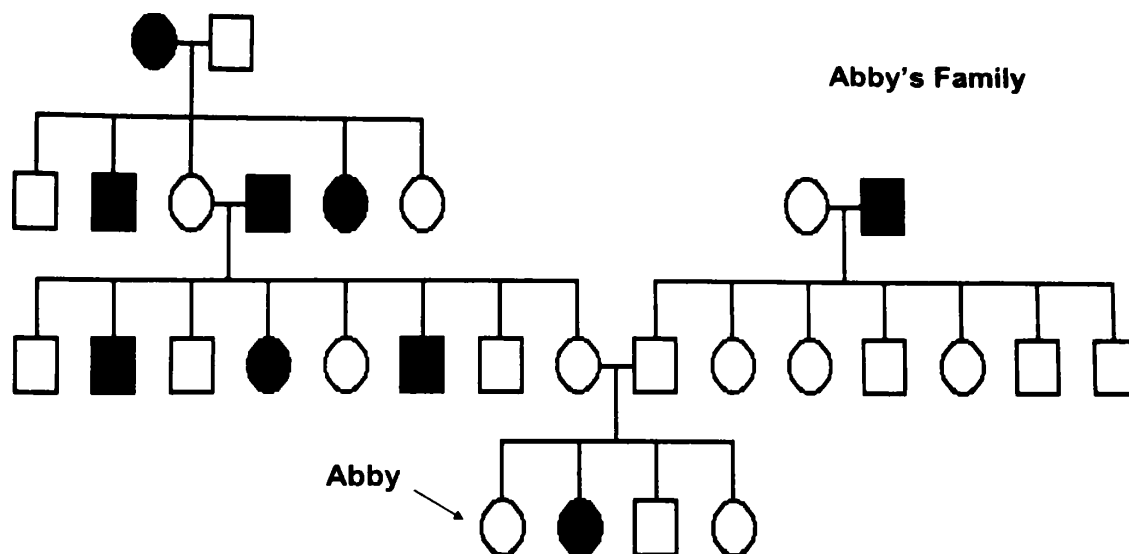
   Abby's family has a history of Phenlketonuria (PKU). Individuals with PKU lack the enzyme that converts a non-essential amino acid (phenyalanine) into a useful one (tyrosine). High levels of phenylalanine accumulate in the blood affecting neuronal development—especially in children. Mental retardation can be a result. Since phenylalanine is found in many proteins, patients afflicted with PKU can escape the disease by strictly limiting themselves to low protein diets.

Steven's Family
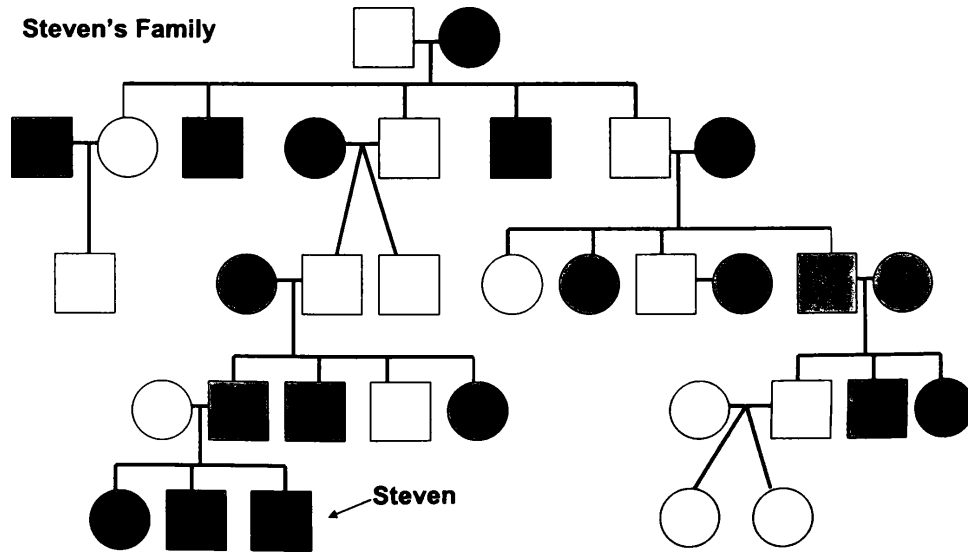
Steven has Huntington disease. Huntington's disease is characterized by degeneration of the nervous system causing uncontrollable movements, dementia, and psychiatric disturbances. Loss of motor skills eventually prevent swallowing and speech. Huntington's generally develops in a person's thirties or forties, leaving the afflicted children and spouse to care for them.

a. Is it possible for Steven and Abby's children to have PKU? Explain.

b. Is it possible for Steven and Abby's children to have Huntington's disease? Explain.

c. Are these traits dominant or recessive?

Case 2

Jake's Family
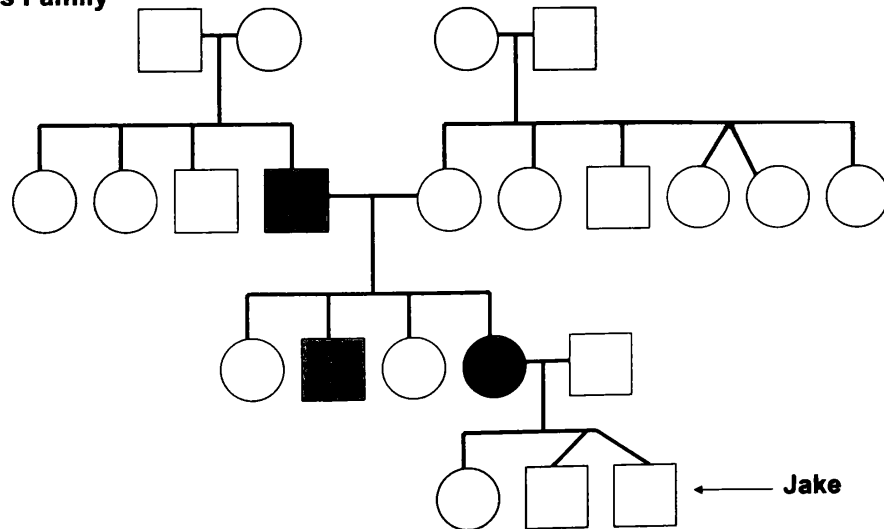
Jake's family has the most common lethal genetic abnormality in the United States—Cystic Fibrosis. Cystic Fibrosis is characterized by excessive secretion of mucus from the lungs, pancreas, and other organs. The mucus is very thick, causing problems with breathing, digestion and liver function. It also makes the person especially vulnerable to infections like pneumonia. Without a special diet, and frequent pounding on the chest and back (to clear the lungs of mucus), most children with CF die by the age of 5.

Rebecca's Family
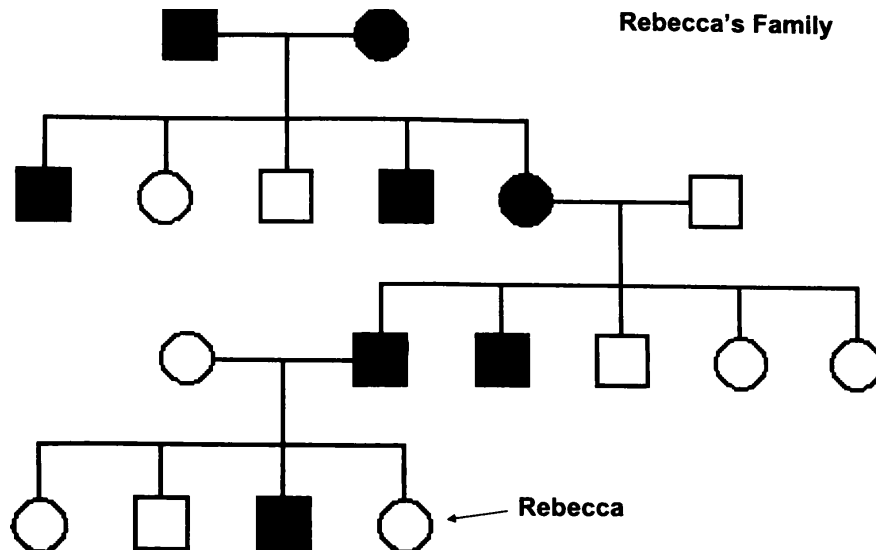
A rare trait in Rebecca's family causes Marfan's syndrome, in which the connective tissue is not as rigid as it should be. The long bones of the body continue to grow causing an abnormally tall, thin individual, with a narrowed face. The lens of the eyes may be dislocated. The heart valves and arteries stretch and leak, Lung, skin and neurological problem are also common. Rebecca does not have Marfan's, but is concerned she might be a carrier of the disease.

  a. Is it possible for Rebecca and Jake's children to express Marfan's syndrome? Explain.

b. Is it possible for Rebecca and Jake's children to express Cystic Fibrosis? Explain.

c. Are these traits dominant or recessive?

Case 3

Gary is an albino. Albinos lack pigment, causing very pale skin, hair and eyes. They tend to suffer more UV damage than normal individuals, and are therefore forced to wear long sleeves, pants, sunglasses, hats and gloves whenever exposed to sunlight.

Many of Jillian's family have a type of dwarfism called achondroplasia. In this condition, the head and torso develop normally, but the limbs are short. Only heterozygous individuals have this disorder. The homosygous genotype causes death of the embryo. Jillian does not have this achondroplasia, but wants to be sure she will not pass on the disorder.

   a. Is it possible for Gary and Jillian's children to be dwarfs? Explain.

   b. Is it possible for Gary and Jillian's children to express albinism? Explain.

   c. Will the cousin marriage in Jillian's family produce albinos? Explain.

Case 4

Leptodigitalia occasionally shows up in Mike's family. Leptodigitalia is a condition where the fingers and toes are excessively long and slender. Such digits are extremely fragile and often suffer frostbite in conditions considered normal to unaffected individuals. Mike has this trait, but does not wish to pass it on to his children.
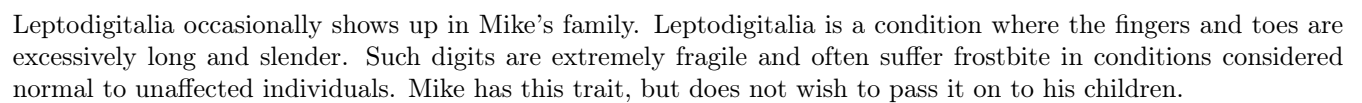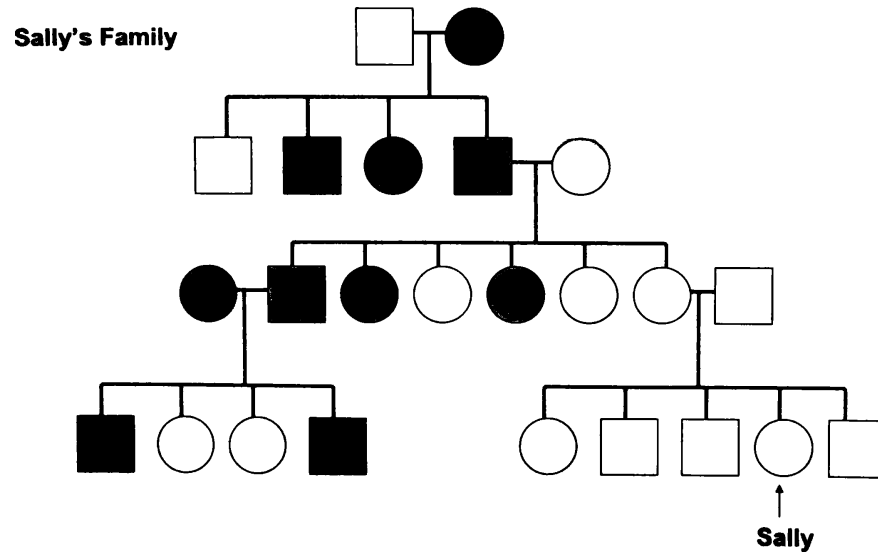
Sally's family has genetic predisposition to syndactyly, a condition in which two or more digits are fused together. While she does not exhibit this condition, she is concerned that she might be a carrier of this trait.

    a. Is syndactyly conferred by dominant or recessive allele(s)? Does Mike possess the syndactyly allele?

    b. Is leptodigitalia conferred by dominant or recessive allele(s)? Does Sally possess the syndactyly allele?

    c. What are the odds that Sally and Mike's children will have both syndactyly and leptodigitalia?

Laboratory 8

Population growth and Predator-Prey cycles

8.1 Background

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 exponential growth (meaning "really, really fast and uncontrolled population increase"):
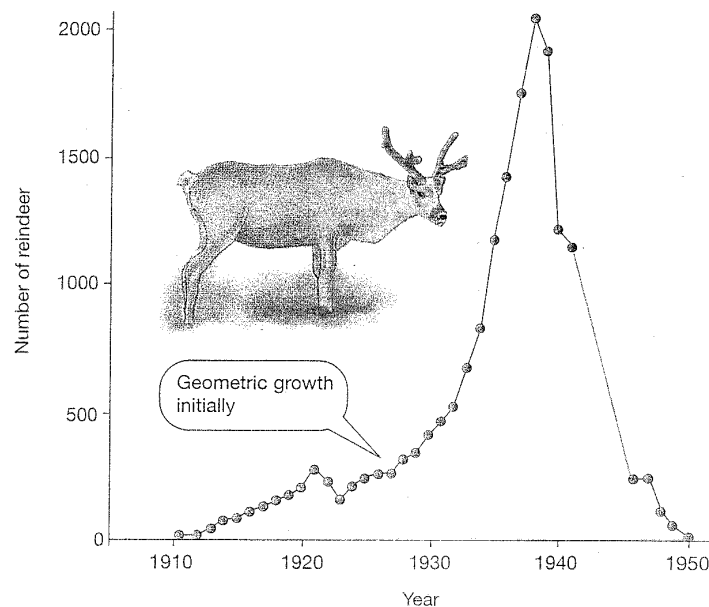
By the year 1963, the population on this small island consisted of 6000 individuals. Consequently, a population crash occurred because the reindeer denuded the area (i.e., consumed all food to the point where it could not grow back). Only 40 animals remained in 1965. By the 1980s, the population had 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. This interaction often forms cycles, the most famous (lynx/hare) was discovered when ecologists started to analyze fur trapping records of the Hudson's Bay Company:
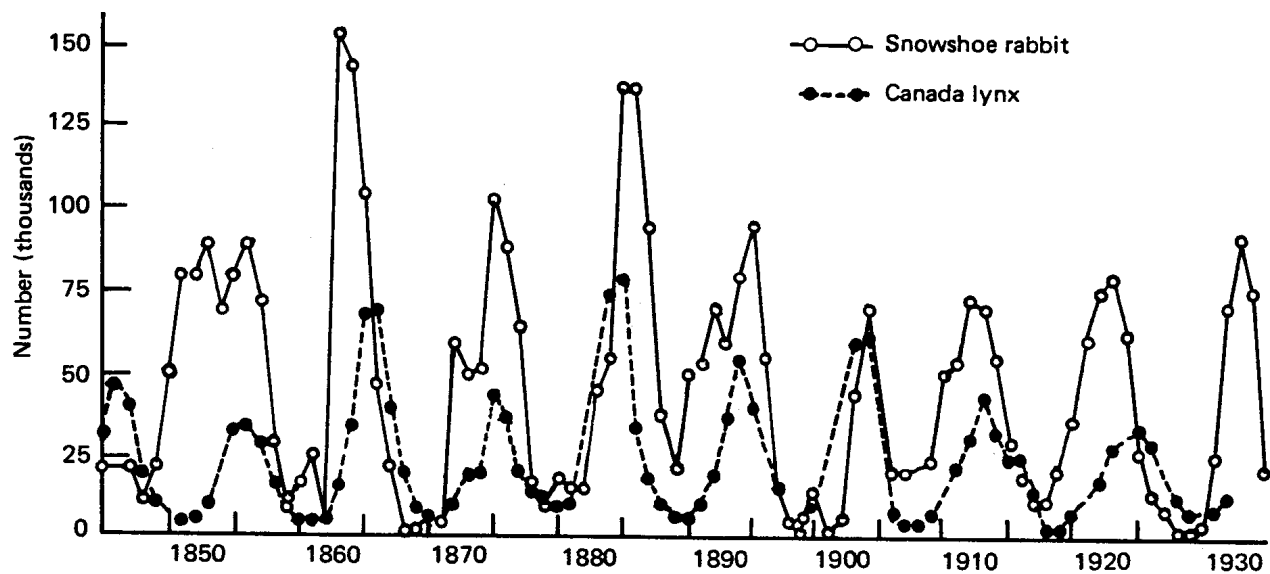
In our work today, we will attempt to mimic the effects of predator population size on prey population size.

8.2 Procedure

You need to become familiar with the simulations through an exercise in bean counting. Every table should try at least **one bean simulation**. After becoming familiar with algorithm, you will then proceed to the computer. Download Gnumeric (recommended) or Excel spreadsheet from `http://ashipunov.info/shipunov/school/biol_111/`, open it and run different combinations of prey and predator features and numbers. This spreadsheet will allow you to run each simulation for hundreds of generations and in every conceivable variation. (Please do NOT save spreadsheet when you close it; delete it instead.)

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 them.

Team 1. Efficient predator; prey with low reproductive rate

1. 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.

2. 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).

3. 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

1. 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.

2. 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).

3. 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

1. 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.

2. Treat the pair of 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).

3. 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

1. 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.

2. Treat the pair of 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).

3. 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

Lab 8 report

Your name _____

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. (4 pts)

   Team ____; predator ____ / prey 50. _____

   _____

   Team ____; predator ____ / prey 50. _____

   _____

   Team ____; predator ____ / prey 50. _____

   _____

   Team ____; predator ____ / prey 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. Draw a single graph that explains how doomed predator populations compare to each other (10 vs. 50). Use two lines only. Explain. (3 pts)

6. Use the computer to find **another** viable combination of predator efficiency/prey reproduction (one that does not die off). Be sure to check both 40/50 and 10/50. (3 pt)

Laboratory 9

Plant diversity—dichotomous keys

9.1 Background

We will assess today diversity of plants not in phylogenetic, but in another formalized way. Everybody who have even a little interest in plants, need to know their names. The best way of determining plants was invented in the end of 18 century by famous French naturalist, Jean-Baptiste Lamarck. He created the descriptive key (sometimes called dichotomous key, or descriptive table). The legend says that when Lamarck demonstrated this key for the first time, he gave it to the random stranger (who had no idea about plants and their names), and plant were determined without problems!

How to make a key? The example is below:

Phase 1. Start with "players". In this example, it will be three plants:

> **Alpha**
> **Beta**
> **Gamma**

Phase 2. Assess descriptions of these three plants:

> **Alpha**: Flowers red, petioles short, leaves whole, spines absent
> **Beta**: Flowers red, petioles long, leaves whole, spines absent
> **Gamma**: Flowers green, petioles short, leaves dissected, spines present

Phase 3. Start with a character which let to split the list into two nearly equal groups. Then add other character(s). It is always good to use more characters!

1. Petioles long . . . . **Beta**.

— Petioles short . . . . 2.

2. Flowers red, leaves whole, spines absent . . . . **Alpha**.

— Flowers green, leaves dissected, spines present . . . . **Gamma**.

As you see here, key consists of steps. Every step has a number and two choices. Number is attached to the first choice whereas the second choice is marked with minus "–". The choice will lead either to the name, or to another step.

To start the key yourself, you will need plants. But you also need to know how to describe them, what are their characters. Today, we will use only leaf-related characters, namely characters describing leaf arrangement, position, shape and structure (see seven tables below). Apart from these qualitative characters, you may also use quantitative characters: length, maximal width and the position of maximal width on the leaf blade (all measurements should be in millimeters).

Be careful! Even on same plant, leaves may be diverse. Always use the typical, average leaves. If all leaves are different, use the middle leaf from a main stem.
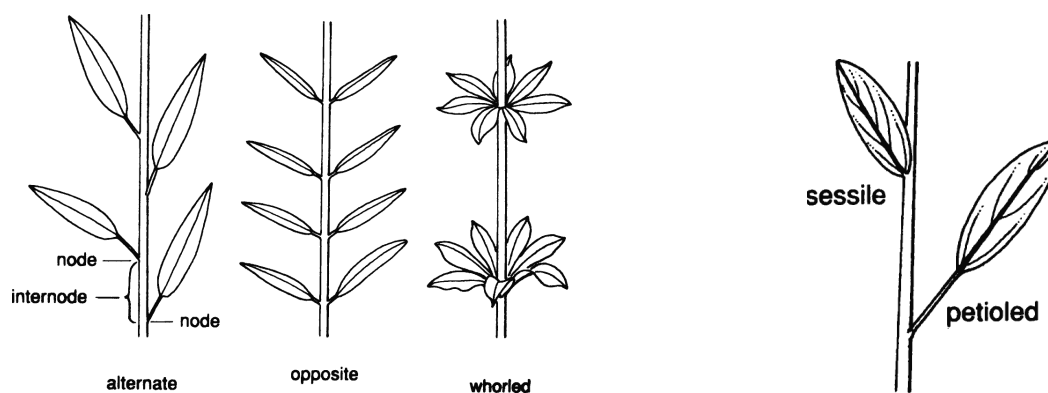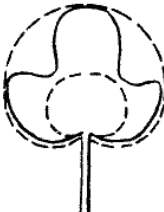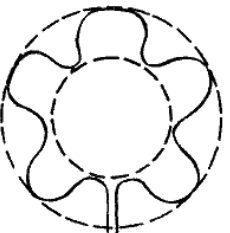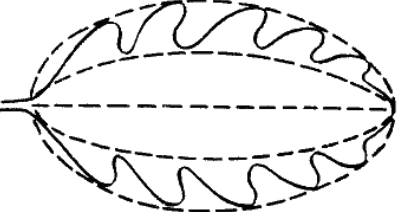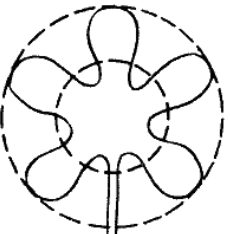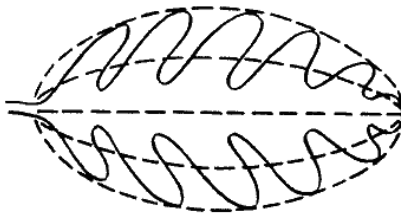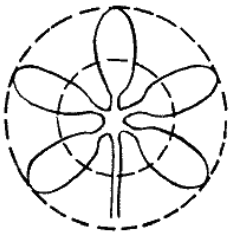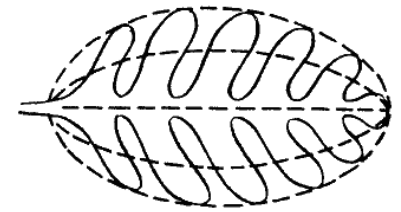
Table 1. Leaf arrangement

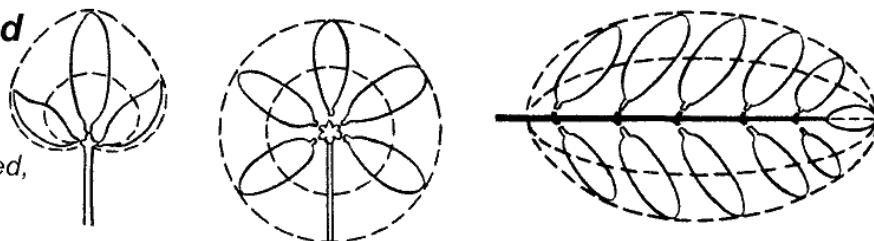|	Tri-	Palmately	Pinnately
Simple leaves — Lobed (from 1/4 to 3/4)			
Dissected (from 3/4 to midrib)			

Compound leaves

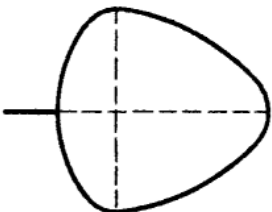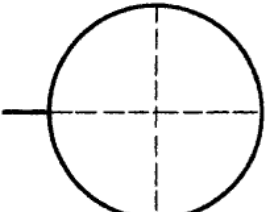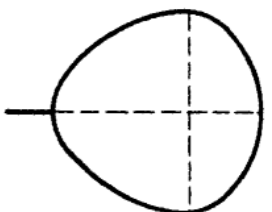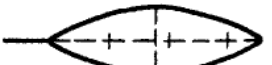(leaflets stalked, with joints)

Table 2. Variants of leaf dissection
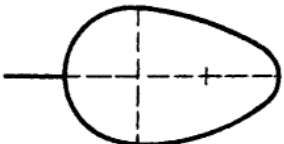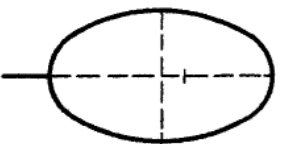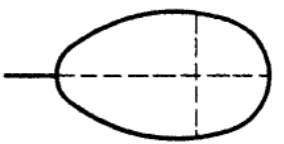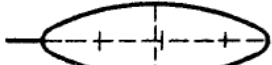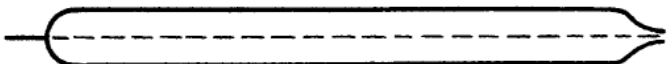
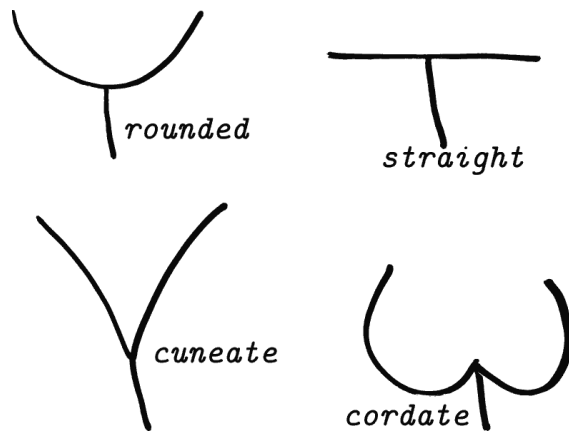|	Maximum width closer to leaf base	Maximum width in the middle	Maximum width closer to the apex
Length = width or slightly more	Deltate	Circular	Cuneate
Length > 1-1.5 x width	Ovate	Elliptic	Obovate
Length > 3-4 x width	Narrowly ovate	Lanceolate Oblong	Narrowly obovate
Length > 5 x width		Linear	

Table 3. Variants of leaf shapes
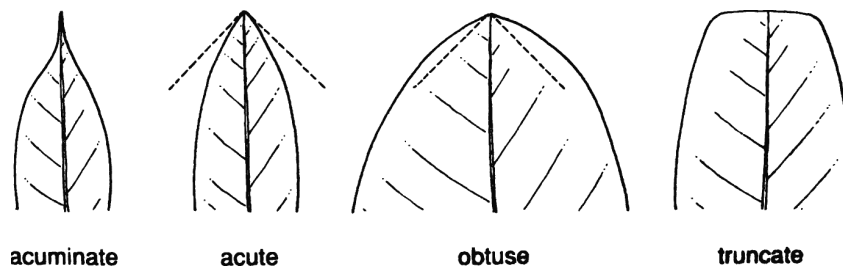
Table 4. Bases of leaf blade
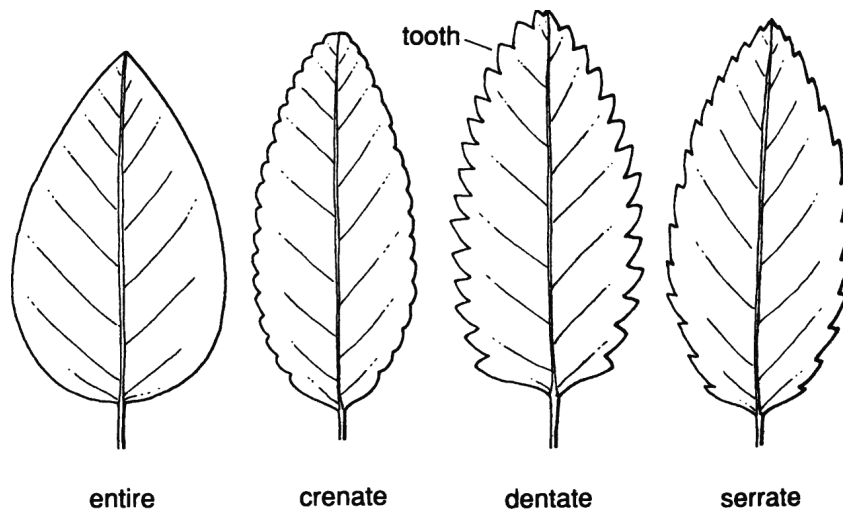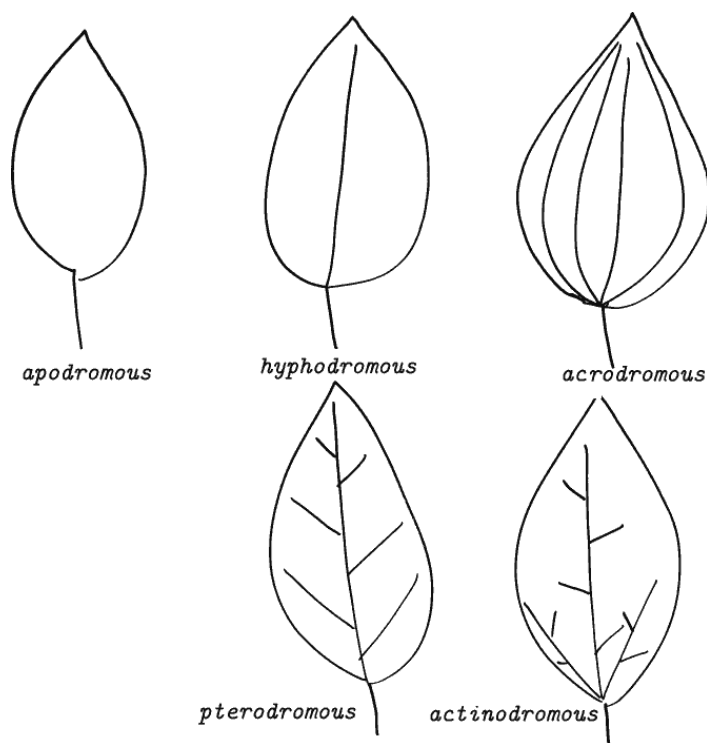

Table 5. Tips of leaf blade

Table 6. Margins of leaf blade

Main vein / Lateral veins	No	One	Several
No	Apodromous	Hypho-	Acro-
Several	Acrodromous	Ptero-	Actino-

Table 7. Types of venation

9.2 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.

Lab 9 report

Your name _____

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

2. Does your key reflect evolution of these plants? Why and why not? (3 pts)

3. Imagine you that have eight (not six) plants. How many steps minimum will be in your key? (2 pts)

Laboratory 10

"*Evolution. The Origin of Species*" board game

10.1 Background

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 offers players to create their own species of animals with their own abilities all the 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. first players create creatures and apply abilities to them;

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

3. players turn-by-turn take food (counters) 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 left to starve become extinct, but the ones that survived 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.

10.2 Procedure

Every table becomes a team. Instructor will show you a YouTube video (`http://youtu.be/OzDigM1vcNU`) explaining how to play. The game's instructions are included below for reference. We will 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.

EVOLUTION
The Origin of Species
Rules of the Game

An astonishing diversity of life forms inhabits our planet. The evolutionary theory explains what differences have arisen from the struggle for existence, when each species used a different approach for survival. Some species adapted to forage on previously unfit resources; others gained advantage by learning to defend themselves from predators effectively; still others moved into habitats where they alone could survive. New adaptations arose in different groups of animals. For example dinosaurs, birds and mammals evolved flight independently. All the adaptations "invented" by evolution were recombined and tested by natural selection. During this process some species went extinct, while others came to dominate the planet.

In Evolution, you are the one who combines different traits (adaptations) of animals, and grows your own population while dealing with an ever changing amount of food resources. By regulating the number of animals, gaining new useful traits and struggling with other players, your population can fight for survival, and by the end of the game, dominate the planet!

Winner
The player with the largest number of victory points at the end of the game is the winner. Points are awarded to a player for all his surviving animals and their traits.

Preparation
Mix the deck thoroughly. Each player gets 6 cards from the top of the deck; these cards are now the player's hand. The deck is put at the center of the table with 🦎 facing up. The food tokens are placed near the deck: red ("food bank"), blue ("extra food") and yellow ("fat"). Then each player rolls a die. The player whose throw is the highest starts the game

The game turn
Each turn of the game consists of four phases:
- development phase
- food bank determination phase
- feeding phase
- extinction and draw phase

During each phase players act in order moving clockwise from the first player. The phase of development and the phase of feeding may include several rounds; after the first round is over, the first player acts again, etc. The player who can't or doesn't want to act passes.

Development Phase
During this phase you may play your cards by putting them from your hand onto the table in front of you. You may play each card either as an animal (with 🦎 facing up) or as a trait of an existing animal (with 🦎 facing down). If you play a card as a trait, put the card underneath the corresponding animal (or pair of animals).

Some of the cards carry two traits, with one trait at the top and the other (e.g. Carnivorous) on the bottom of the card. When playing such a card, you should decide which of the two traits you will use, and place the card with the desired

trait on the top. This decision is final, and you can't change your mind and use the second trait later in the game.

Some cards, such as "Communication", can only be played onto a pair of animals. Such cards are placed between the two cards onto which they are played.

The development phase includes several rounds. Each player can play just one card at a time, starting from the first player and going clockwise in order. During this phase you may play any number of cards from your hand. If you don't want to play a new animal or add a new trait to existing animals, you say: "I pass". You must pass if you have no cards left. After passing, you can't choose to play more cards during this phase. The phase ends after all players pass.

Food Bank Determination Phase
The amount of food available during this turn is determined at this time. The amount is indicated by the dice, depending on the number of players:

> 2 players - number indicated by **one dice + 2**
>
> 3 players - sum of **two dice**
>
> 4 players - sum of **two dice + 2**

The first player rolls the dice. When the amount of food is determined, the corresponding number of red tokens is put in the center of the table; this is **the food bank** for the current turn.

Feeding Phase
During this phase players in order take one red food token from the food bank and put it on the top of one of their animals. The first player takes the first token, and other players continue clockwise, going in several rounds if necessary and if there are enough tokens.

You may only take one red token from the food bank at a time. However, some traits, such as "Communication", allow to take several tokens.

As a result of their additional traits, your animals can also get blue "extra food" tokens during this phase.

An animal with **one food token** on the top of it is considered **FED**, unless it carries traits which increase its food requirements. Such cards show a number at the top left corner, indicating how many additional food tokens are required to feed the animal. For example, an animal (which, by itself, requires one food token) with the HIGH BODY WEIGHT trait (+1) carrying a PARASITE (+2) is only considered fed if it has four food tokens on the top of it.

Any animal can be fed by red or blue food tokens, or any combination thereof.

Important! A fed animal can't get more food tokens, except to fill its FAT TISSUE (see Fat Tissue section below). If all your animals are fed and their FAT TISSUE is filled you can't obtain more tokens from the food base or in other ways.
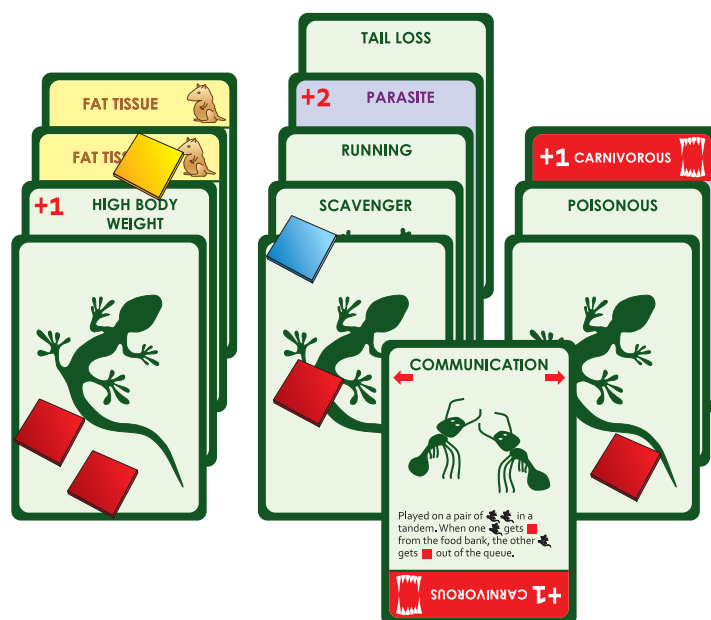
After all animals are fed and their FAT TISSUE is filled, or the food bank is empty and all players have used any traits of their animals they wanted to use, the feeding phase is over. Any remaining red tokens in the food bank are set aside.

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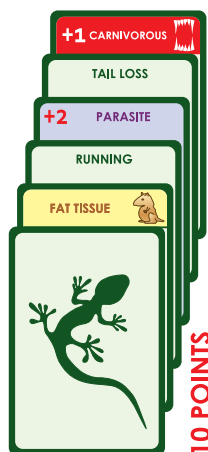
Traits
An animal may combine any number of traits. However, **no animal can have two identical traits**, with the exception of the FAT TISSUE trait and pairwise traits.

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**

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

**① ** Alex plays the first card as an animal (🦎) — Dan also plays the first card as an animal (🦎)

**② ** Alex adds a new trait Poisonous to his 🦎 — Dan plays the second card as 🦎

**③ ** Alex also plays the second 🦎 — Dan plays the pairwise Communication trait onto both his 🦎🦎

**④ ** Alex adds a new trait Carnivorous to his poisonous 🦎 — Dan adds the Camouflage trait to one of his 🦎 to defend it from the carnivore

**⑤ ** Alex puts the third 🦎 into game — Dan adds Grazing trait to his camouflaged 🦎 to deprive the opponent of food.

**⑥ ** Alex says "Pass", deciding to save one card for the next turn. — Dan adds the Fat Tissue trait to his 🦎, hoping to save food for the next turn.

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**

🔴 ⚃ + 2 = 🟥🟥🟥🟥🟥🟥

Feeding Phase

① Alex is the first to take 🟥 He puts it on one of his 🦎 — Dan takes 🟥🟥 for his 🦎🦎 (because they are Communicating) He uses the Grazing trait and destroys another 🟥.

② Alex uses his Carnivorous animal to attack and eats one of Dan's 🦎. The Carnivorous animal gets 🟦🟦. — Dan looses the eaten 🦎, all its associated traits, and the 🟥 obtained in the previous round.

② Dan turns one of the 🟥 into 🟨, filling the Fat Tissue of the surviving 🦎, and destroys the second remaining 🟥 with the Grazing trait.

Extinction and Acquisition of New Cards

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

① Alex loses one of the 🦎 which is not fed. — Dan's 🦎 survives.

② All food tokens except the fat tokens are removed from 🦎🦎. The players get new cards from the top of the deck, for a total of **1 + the number of surviving animals**. Alex gets **3** cards; Dan gets **2** cards.

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.

Lab 10 report

Your name _____

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 as these are awarded more points. Give two reasons why the game creators believe ecosystems with carnivores and parasites deserve more points. (2 pts)

4. How does the game correspond with the idea of natural selection (differential survival and/or reproduction)? (3 pts)

Laboratory 11

Animal diversity—creating a phylogeny

11.1   Background

Phylogeny is the genealogy (i.e., "family tree") of organism. In other words, the phylogeny represents the ancestor-descendant relationships. The inference of phylogeny is one of the foci of evolutionary biologists. It is also one of the most difficult tasks that these scientists undertake. Because one can never replay the "tape of history", one can never "know" the true phylogeny. Species are subject to extinction and parallel evolution, and these phenomena obscure phylogeny. At best, a "phylogeny" is really a "phylogenetic hypothesis." In no other field is appreciation of the strengths and weaknesses of the scientific method more appropriate.

The basis for inferring phylogeny is the **synapomorphy** = *a shared derived characteristic*. For example, the presence of a cranium (= skull) is a synapomorphy for the *Vertebrata*. No other animals have a skull. Thus, this synapomorphy supports a phylogenetic hypothesis that states that all vertebrates (fishes, mammals, amphibians, etc.) are more closely related to each other than to any other groups of animals. For example, fish and frogs are more closely related to each other than they are to crayfish.

To infer a synapomorphy, one must have some idea what the ancestral (**plesiomorphic**) state of that character is. For example, the ancestral amphibian had lungs. Because there is a large group of salamanders that do not have lungs, we call "lunglessness" a synapomorphy that unites all lungless salamanders into a single family. Lunglessness is a *derived condition* that all these species of salamanders share.

Using synapomorphies, one can place species on a "family tree" or phylogeny. Because traits are subject to natural selection, it is uncommon to find concrete synapomorphies that define 100% of the group. Terrestrial vertebrates are called *Tetrapoda* in reference to a significant synapomorphy: presence of four limbs. However, snakes are a member of the *Tetrapoda* even though they lack external evidence of legs. Yet there are numerous other characteristics that clearly make snakes reptiles, thus members of the *Tetrapoda*. Use of only one characteristic (presence or absence of four limbs) would lead one to an incorrect phylogeny that did not include the snakes with the reptiles. Use of as many characters as possible is critical to developing a rigorous phylogenetic hypothesis.

Loss of legs in the snakes is an example of what is referred to as *evolutionary reversal*. The best phylogenetic hypothesis is one in which the number of evolutionary events (reversals etc.) is minimal. This is known as the **principle of parsimony**. There is a consensus among evolutionary biologists that the most parsimonious phylogenetic hypothesis is the one that is most likely to represent the true genealogy of a group of organisms.

$$* * *$$

Most organisms have familiar names, such as the "red maple" (*Acer rubrum*) or the "brown-headed cowbird" (*Molothrus ater*). 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** (e.g., *sapiens.*) This Linnaean binomial system of nomenclature was introduced by Carolus Linnaeus in the 18th century and has been in use ever since. The study and practice of naming organisms is known as **taxonomy**. Taxonomic groups have ranks: they may be species, genera, families, orders, classes, phyla, kingdoms or stay between them like subclass or superfamily.

Biologists would like taxonomy to reflect phylogeny. For example, all the frogs in *Ranidae* are hypothesized to be more closely related to one another than to any frogs from other groups. However, because phylogeny is difficult to

infer, taxonomy is always changing. As scientists' opinions of phylogeny change, so does taxonomy. As more information is gathered, phylogenetic hypotheses may change; this often results in a change in taxonomy. This is the reason that textbooks often present different taxonomies. This is also the reason that the taxonomy presented in any textbook will not be the same one that is found in textbooks in 20 years.
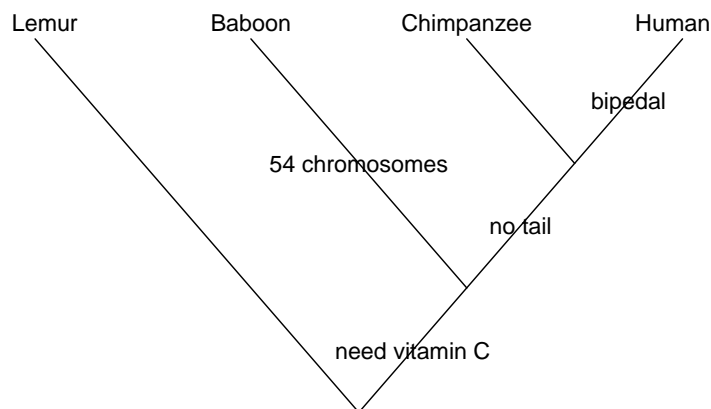
11.2 Understanding phylogenetic trees

1. Tree edges may be freely rotated in any direction. For example, these trees are same:

2. Direction of branches also does not matter. These trees are same:

3. Apomorphies (and reversals) may be shown as edge labels:

4. Phylogenetic tree is directly related with taxonomy (classification):

- Suborder Strepsirrhini: lemur
- Suborder Haplorrhini:
  - Superfamily Cercopithecoidea: baboon
  - Superfamily Hominoidea:
    * Genus *Pan*: chimpanzee
    * Genus *Homo*: human

11.3 How to make a phylogeny tree

1. Start with the group you need to classify, assign the name for every member of the group

2. Review all characters. For every character, guess its plesiomorphic (ancestral) and apomorphic (derived) states. Encode plesiomorphic character states as "0", and apomorphic as "1". Make the table of characters: rows are members of group, columns are characters, each cell contains 0 or 1.

3. Start to draw the tree from the most ancestral ("primitive") member (which has most zeroes). This is the first branch.

4. Attach the second member as a second branch. Continue to grow the tree attaching branches. Actually, you may even attach members at random because this tree will be optimized anyway.

5. Look on the complete tree, label all apomorphies (from the character table) as edge labels. If somewhere on the tree apomorphic character was lost, this is *reversal*. Label all reversals. Calculate the length of tree (number of evolutionary events: apomorphies plus reversals).

6. Now start to think how to make your tree shorter. The basic method is to prune (take off) branch and attach it to another place, re-label tree and calculate the length again. If the length is shorter, this is more parsimonous tree. Try to find the most parsimonous (shortest) tree, , i.e. the tree with as low number of apomorphies and reversals as possible.

7. The most parsimonous tree is your answer.

11.4 Procedure

1. Planet Aqua is entirely covered with shallow water. The ocean is inhabited with various flat organisms (see the figure). These creatures (let us call them "kubricks") can photosynthesize and/or eat other organisms or their parts (which match with their mouths), and move (only if they have no stalks). Make the phylogeny tree of kubrick species A–G. Kubrick H is an **outgroup**, it has only plesiomorphic (ancestral) characters.
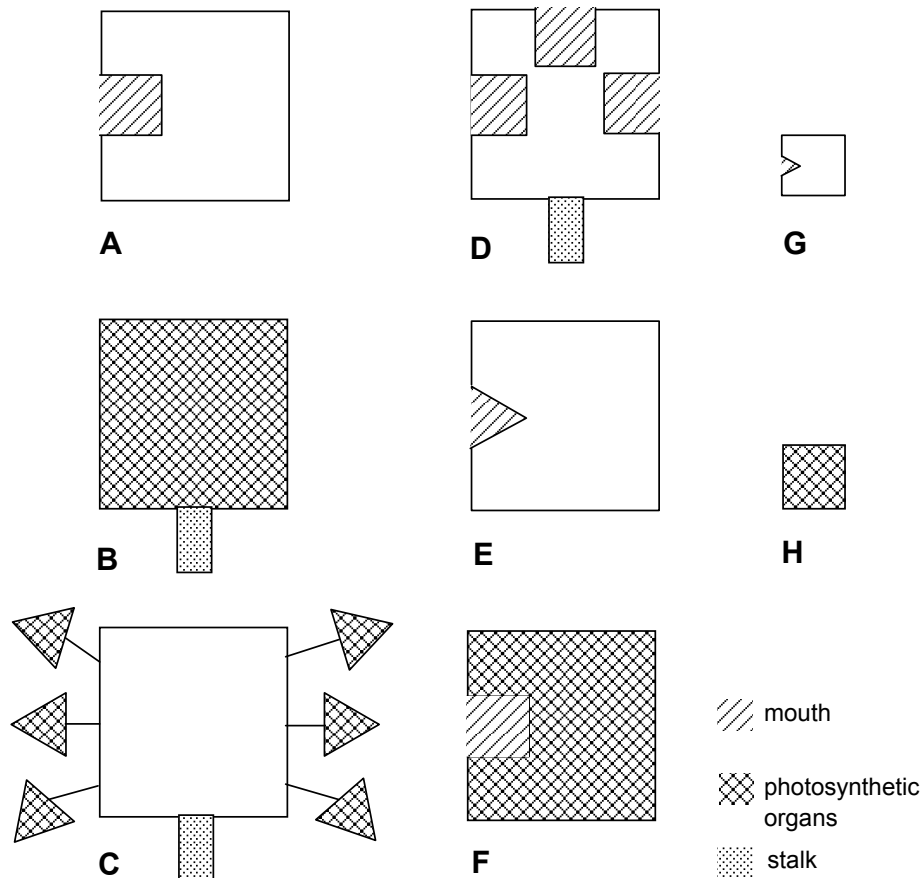
(a) Find as many characters as possible (ideally, 6–8)

(b) Determine ancestral (plesiomorphic) and derived (apomorphic) characters states of each character (do not forget to use outgroup)

(c) Make character table

(d) Make phylogenetic tree(s) starting from outgroup, then most primitive group, then attach groups which are most similar to previous groups, then calculate length of tree.

(e) Rearrange branches in order to find the shortest (most parsimonous) tree, do not forget that tree branches may rotate freely. Good tree should have length $< 2N$ where N is number of characters.

2. Take 7 *different* plastic dinosaur plastic toys, name them, make character table, make initial tree, calculate its length, modify the tree to make it as most parsimonous as possible, label apomorphies and reversals (if any).

(a) To name dinosaurs, check the image below. Among toys, we have:

Pteranodontidae (dinosaur "bats")   Dromaeosauridae ("raptors")   Tyrannosauridae and relatives
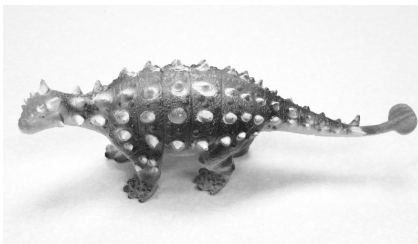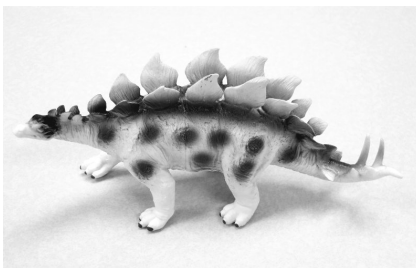
Diplodocidae ("titans")   Hadrosauridae ("duck-billed")   Pachycephalosauria ("skull-domed")

Ankylosauria ("club-tailed")   Stegosauria (with osteoderms)   Ceratopsidae ("frilled")

Disclaimer. Not all toys are imaged here. These toys are not supposed to serve as proper reconstructions of dinosaur groups mentioned above.

(b) To polarize character states (i.e. decide which of them are plesiomorphic and which are apomorphic), you may use either the outgroup (think which outgroup is better here, this is not necessarily one of your 7 toys), or comparative and paleontological arguments (developmental arguments are not applicable here.) You must state clearly which approach you took and why you call some characters apomorphic (derived, "1") and some plesiomorphic (ancestral, "0"). Avoid terms "advanced" and "primitive", phylogeny does not work with these!

Lab 11 report

Your name _____

1. Draw your character table for kubricks below. Describe why we need outgroup. (3 pts).

2. Draw your phylogenetic tree for kubricks below. Do not forget to label all apomorphies and reversals (if any). Note the length of tree. (3 pts).

3. Draw your dinosaur character table below. How did you determine which character state is plesiomorphic and which is apomorphic? Explain. (4 pts).

4. Draw your dinosaur phylogeny tree below. Do not forget to label all apomorphies and reversals (if any). Note the length of tree. (4 pts).

5. How making phylogeny tree is different from making dichotomous keys? Explain. (1 pt).

Laboratory 12

Natural selection

12.1 Background

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.

There is one well-known classic case of natural selection: melanism mutation in peppered moths. Prior to the Industrial Revolution in England, nearly every peppered moth had light-colored speckled wings, only some months had the mutated black peppered phenotype. 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.

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).

The idea of natural selection will be explained today through the game (yes, again!) which will take into account **both** predator-prey interactions and survival of fittest.

12.2   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 or

- soup spoon

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

- 50 white **small** beans, Navy beans (*Phaseolus vulgaris*, multiple cultivars

- 50 white **large** beans, Lima beans (*Phaseolus lunatus*)

- 50 brown **medium** beans, kidney beans (*Phaseolus vulgaris* cv. 'Red Kidney')

- 50 camouflage **medium** beans, Pinto beans (*Phaseolus vulgaris* cv. 'Pinto')

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.

5. Calculate the results for predators: the predator who caught most of 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.

6. 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.

7. 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.

Lab 12 report

Your name _____

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 (2 pts)

2. Did you reject or fail-to-reject your hypotheses? Describe below the final ecosystem on your table. Who survived and why? (3 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, the real evolution process 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)

   - mutations

   - migration

   - genetic drift