**Workshop - Carbon, nutrients, and life**

**Introduction**: This workshop introduces the formal process of scientific experimentation. You will propose a hypothesis for one of the factors that influence plant seedling growth, then, using an experiment similar to ones used by NASA, when they were trying to determine how to grow food in space. You will learn about the scientific method, why seed germinate and why seedlings grow.

**Key concepts:**
- The scientific method
- Nutrients and other requirements for life

**OVERVIEW**

**D2L Workshop 1 Discussion of “Hypothesis:”** (5 pts multiple choice)
In class (bring paper & pencil) you will be assigned to groups to define the word “hypothesis.” Your definition should include as many of the five words: control, measurement, methods, prediction and replication as possible. Before you leave, write it down. You will **not hand it in**, but you will use it to answer D2L workshop questions. Answer 5 multiple-choice questions in D2L about the correct use of the five words.

**D2L Workshop 1 Definition of Hypothesis: part 2** (5 pts written answer). Cut-and-paste your hypothesis into the space provided at the bottom of the D2L quiz, saying **why** one environmental factor influences seedling germination or growth. It will be graded by your GTA. In addition to experiment results, they will grade your writing.
Grading Rubric (total 5 points)
- Not a hypothesis (a prediction is not a hypothesis) (up to -5)
- Incomplete sentences (-1)
- Poor grammar (-1)
- Wrong capitalization (-1)
- Wrong spelling (-1)

**After class**, begin your seedling experiment at home as soon as you have a hypothesis stating **why** one selected environmental factor influences seedling germination or growth. See [http://www.geo.arizona.edu/Antevs/nats104/wk1_lect.html](http://www.geo.arizona.edu/Antevs/nats104/wk1_lect.html) on p. 2.

**In order to be eligible for credit for D2L Workshop 1**, you must first show your seedling experiment to your GTA (the one grading your section): labeled bag containing germinating seedlings.
HYPOTHESIS: What influences plant growth?

Written Report submitted in D2L dropbox next week

Water and nutrients: All life needs water and nutrients to survive. Nutrients that exist in such low levels, relative to their need, are often called “limiting nutrients” because these nutrients are what control plant growth. For plants, nitrogen and phosphorus are often limiting nutrients.

Light: Plants are primary producers, which means they use an energy source, the sun, to make their own food. Like nutrients and water, the amount of available light can control how fast a plant grows. 

Temperature: As temperature increases, growth rates increase at first, then decrease. Thus, temperature plays an important role in controlling plant growth. Plants in polar regions of the world tend to grow slowly whereas plants that live in the tropics grow much faster. However, this assumes that the environment provides all the other requirements for growth! Although Tucson is warm, plants grow slowly because the lack of water limits plant growth.

Materials: fertilizer, markers, paper towels, rulers, seeds, tape, aluminum foil, plastic sacks, table, light stand, lights. see http://www.geo.arizona.edu/Antevs/nats104/wk1_lect.html

1. Seedling growth experiment

You are going to conduct an experiment to study the influence of temperature, light, and nutrients on plant growth. Basically, you are asking 'What is the best way to grow seeds?’ The list below provides the possible experiments (Methods) you might conduct. Some of them can be combined, for example, if you want to see whether fertilized seeds grow better in the light or in the dark. Select one of the following parameters for your experiment (or check with TA or Prof.)

1. light (vs. dark)
2. tap water (vs. tap water with fertilizer or other substances mixed in)
3. amount of water in bag
4. heat (vs. room temperature)
5. air in bag (vs. no air in bag)

A. Forming hypotheses
First, think about what you would like to test. Are you interested in the effects of light on seed growth? One of the other factors? Based on the introduction and your personal experience, explain why the factor you choose influences plant growth – this is called a ‘hypothesis’. A trivial example would be “dough needs to be baked to make cookies.” What are the implications of this hypothesis?
Predict how lesser or greater amounts of the physical factors will influence plant growth. Formulate a specific prediction about your experimental manipulation of
the results. The hypotheses should be stated in complete sentences, describing cause and effect. For example, if you were interested in the effect of temperature on baking cookies, and you turned the oven up to its maximum temperature your hypothesis might be “The cookies will burn when the oven is really hot” or “At low temperature, the dough will not become cookies”.

Think of how you will test your prediction! You will need to measure something! Write your hypothesis and prediction on p 6. (Remember, everything must be in your own words. Never copy from someone else.)

B. Methods Measurements and Control
To properly test your hypothesis, you need to be as careful as possible about the conditions and measurements of your experiment. In the cookie example, it makes a big difference how long we leave the cookies in the oven. If we leave them in for a short time, they might not burn, but if we leave them in for as long as the recipe says we are supposed to, they might. Record the date and time your experiment begins: show it to your GTA as soon as it's started.

Part of the experiment is eliminating confounding variables – factors that were not intended to influence the results of the experiment. The easiest way to do this is to have two copies of the experiment that differ only in the amount of the key factor. The copy without the key factor is the experimental control. For example if your hypothesis involves nitrogen fertilizer, the control would not contain the nitrogen fertilizer but would be the same in all other regards – for the cookie example, you would have two identical ovens, one turned on, the other not turned on at all.

An important aspect of experimentation is replication. To avoid accidents and improve measurements, run two identical trials of your prediction. For the cookie example, have two hot ovens, not just one.

How will you measure the amount / level of the variable you manipulate? If it's temperature, frequently record the temperature where the experiment takes place. For the cookie example, you would record BOTH the temperature of the hot oven AND the temperature of the cold oven (the control).

Instructions (see illustrations at http://www.geo.arizona.edu/Antheus/nats104/wk1_lect.html)

These are examples of how to conduct an experiment. You can obtain the materials from your GTA or Prof. Davis, or buy your own at the supermarket or hardware store. Either way, you'll need to list your materials in your report. You'll need to write down the names of the seeds, kind of bag, etc.

These are examples of methods: Label the ziplock bags (example: two controls and 2 replicates) with your name, the date, and the treatment it will receive. Fold
a paper towel in four and place it inside the ziplock bag, lying it on its side. Moisten the towel (less than 25 ml of the appropriate liquid [record the amount]) – the entire paper towel will absorb the water in a few seconds. Carefully place 10 seeds on the paper towel. Put the towels containing the seeds in the labeled ziplock bags and place them in the experimental locations.

**Results** (written report [file] submitted in D2L Dropbox in 1 week [see schedule])

**How might you determine which seedlings are the ‘biggest’?** (i.e. How do you define ‘biggest’?) How will you measure the length of the seedling? Since the seed will not change in length, will you include the seed length in your measurement, the green shoots, the white roots?

Seven days after the beginning of the experiment (record date and time of beginning and end) measure the full length of each of the seedlings, including the root. Create a table on a separate sheet of paper to display your measurements. To better compare the effect of different treatments, scientists often compare the average value for a treatment. **Calculate and record the average length for each treatment as follows:**

\[
\text{average length} = \frac{\text{length}_1 + \text{length}_2 + \ldots + \text{length}_{10}}{\text{total number of seedlings}}
\]

**Include the averages with the other measurements, in your table.** Example:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Length (10 seeds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.2 mm</td>
</tr>
<tr>
<td>Replication 1</td>
<td>9.2 mm</td>
</tr>
<tr>
<td>Replication 2</td>
<td>9.3 mm</td>
</tr>
</tbody>
</table>

A **bar graph** (example below) is optional. It will help you to interpret and explain your results. If you plot a figure, it needs to be imbedded in your report.
PARTS OF YOUR PAPER

**Hypothesis** Explain why the factor you chose influences seedling growth? Cite supporting observations or publications (1/10)

**Prediction** What influence should the active factor will have on seedling growth. Include measurement and direction and magnitude of change (1/10)

**Experiment Methods and Measurements.** Include enough information (a table) about your materials and procedures so that someone else could repeat your experiment. (1/5)

**Results** (include table) Summarize and discuss your measurements as shown in the table and optional graph (5 pts). You should state the average growth for each bag’s seedlings in your written explanation and compare the treatment with the control. (1/5 text + 1/5 table)

**Conclusions:** What did you learn from your experiment? Do the results support your hypothesis? What would you do differently if you did it over again, and what factor would you like to test next? (1/5)

**Writing Exercise Grading Rubric** (submitted in D2L Dropbox)
Type your experimental results using the 5 “Parts of Your Paper” above, and save it in a file format accepted by the Dropbox: RTF, DOC, PDF. Your GTA will use the rubric below to grade your paper. Each of the five “parts” above will be graded and 40% of your grade will based on “good English.”

**SCIENTIFIC CONTENT**  **(add up to max 30 points)**
Hypothesis correct form (5 pt) ___
Prediction measurable (5 pt) ___
Methods & Measurements adequate (5 pt) ___
Results clear and supported by data (5 pt) ___
Data table, averages (optional graph) clear (5 pt) ___
Conclusions (not illogical, pop-science, implications) (5 pt) ___

Sub Total ___/30

**SPELLING, GRAMMAR**  **(add up to max 20 points)**
Spelling, homonyms, confusing pairs (5 pt) ___ ___
Punctuation (5 pt) ___ ___
Sentence structure: fragments, run-ons, incorrect word usage (5 pt) ___ ___
Paragraph construction (topic sent., 1 idea per para., para. cohesion) (5 pt) ___ ___

Sub Total ___ ___/20

**TOTAL ___ ___/50**