Lab 2: The Scientific Method
Objectives

• Understand how to make testable observations
• Understand the roles of a hypothesis and null hypothesis
• Understand how to conduct a successful experiment
• Understand the role of variables and control in an experiment
• Understand the importance of organized data collection
• Recognize what makes a successful analysis

Introduction

Testable Observations: A testable observation is one that lends itself to further investigation. The observation must be detailed enough to raise a question that can be challenged.

For Example:

• Plants grow well in soil.
• Plants grow faster in soil with nutrients than in soil without nutrients.

The first observation makes a statement but provides no information to warrant further investigation. The second observation is more detailed and provides a rational to investigate factors that make plants grow faster.

Hypothesis and Null Hypothesis

Hypothesis Generation: A hypothesis is an educated guess. By considering both the question asked and explanation posed, a testable relationship can be designed—this is the hypothesis. A Null Hypothesis is a testable statement, that if proved true means the hypothesis was incorrect. Both statements must be testable, but only one can be true.

From the second observation above we can develop both a Hypothesis and a Null Hypothesis:

Hypothesis:

The addition of nutrients to soil increases the speed of growth of plants.

Null Hypothesis:

The addition of nutrients to soil does not speed up the growth of plants.
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Conducting an Experiment

**Experimental Approach:** There are often many ways to test a hypothesis. When designing an experiment to test a hypothesis there are 3 rules to follow:

1. The experiment must be replicable
2. Only test one variable at a time
3. Always include a control

**Variables** are defined and measurable components of an experiment. There are three types of variables:

- **Independent Variable:** The variable that the scientist alters to test the hypothesis. For our example, the independent variable would be the addition of nutrients.
- **Dependent Variable:** This variable is measured in regards to conditions of the independent variable. In our example, the dependent variable would be speed of growth.
- **Control:** A group that is not subject to the independent variable being tested. This group becomes the standard for comparison. For our example, the control would be soil without added nutrients.

**Data Collection:** In designing the experiment, establish a clear and concise procedure. Specify what data are needed and when they should be collected in advance. As these data will be the basis for your conclusions, they must be accurately recorded. Remember, replication is fundamental to scientific experiments.

Often, the best way to organize data for analysis is as a table or a graph. Remember, any table or graph should be able to stand on its own. In other words, another scientist should be able to pick up the table or graph and have all of the information necessary to interpret it, with no other information.

If the plants DO grow more quickly when nutrients are added:

Then, the hypothesis is supported and the null-hypothesis is wrong.
Tables and Graphs

**Table:** A well organized summary of data collected. Only include information relevant to the hypothesis (e.g. don’t include the color of the plant when it is not relevant to what is being tested). Always include a clearly stated title, label your columns and rows and include the measuring units. For our example:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Height Day 1 (mm)</th>
<th>Height Day 2 (mm)</th>
<th>Height Day 3 (mm)</th>
<th>Height Day 4 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (without nutrients)</td>
<td>3.4</td>
<td>3.6</td>
<td>3.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Independent (with nutrients)</td>
<td>3.5</td>
<td>3.8</td>
<td>4.3</td>
<td>4.9</td>
</tr>
</tbody>
</table>

**Graph:** A visual representation of the relationship between the independent and dependent variable. Graphs are useful in identifying trends and illustrating findings. Rules to remember:

- The independent variable is always graphed on the x axis (horizontal), with the dependent variable on the y axis (vertical).
- Use appropriate numerical spacing when plotting the graph, with the lower numbers starting on both the lower and left hand corners.
- Always use uniform (0, 5, 10, 15 . . . ) or logarithmic (1, 10, 100, 1000 . . . ) intervals. For example, if you begin by numbering, 0, 10, 20, do not jump to 25 and then to 32.
- Title the graph and both the x and y axes such that they correspond to the table from which they come. For example, if you titled your table “Heart Rate of those who eat vegetables and those who do not eat vegetables”, be sure to title the graph the same.
- Determine the most appropriate type of graph. Typically, line and bar graphs are the most common.

**Line graph:** A line graph shows the relationship between variables using plotted points that are connected with a line. There must be a direct relationship and dependence between each point connected. More than one set of data can be presented on a line graph. Figure 1 uses the data from our previous table:
Bar graph: A bar graph is used to compare results that are independent from each other, as opposed to a continuous series. Since the results from our previous example are continuous, they are not appropriate for a bar graph.

The following bar graph shows the top speeds of four cars. Since there is no direct relationship between each car, each result is independent and a bar graph is appropriate.

Figure 2: Top Speed of 4 Different Cars

<table>
<thead>
<tr>
<th>Speed</th>
<th>Car A</th>
<th>Car B</th>
<th>Car C</th>
<th>Car D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80</td>
<td>120</td>
<td>140</td>
<td>160</td>
</tr>
</tbody>
</table>

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Analysis

**Interpretation:** Based on the data you collected, is your hypothesis supported or refuted? Based on the data, is the null hypothesis supported or refuted? If the hypothesis is supported, are there other variables which should be examined? For instance, was the amount of water and sunlight consistent between groups of plants; or, were all four cars driven on the same road?

Exercise

Dissolved oxygen is oxygen that is trapped in a fluid, such as water. Since virtually every living organism requires oxygen to survive, it is a necessary component of water systems such as streams, lakes and rivers in order to support aquatic life. The dissolved oxygen is measure in units of ppm—or parts per million. Examine the data in Table 2 showing the amount of dissolved oxygen present and the number of fish observed in the body of water the sample was taken from, then answer the questions below.

<table>
<thead>
<tr>
<th>Dissolved Oxygen (ppm)</th>
<th>0 2 4 6 8 10 12 14 16 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Fish Observed</td>
<td>0 1 3 10 12 13 15 10 12 13</td>
</tr>
</tbody>
</table>

Questions

1. Based on this information, what patterns do you observe?

2. Develop a hypothesis relating to the amount of dissolved oxygen measured in the water sample and the number of fish observed in the body of water.

3. What would your experimental approach be to test this hypothesis?
4. What are the independent and dependent variables?

5. What is your control?

6. What type of graph is appropriate for this data set? Why?

7. Graph the data from Table 2 (above) in the space below.

8. Interpret the data from the graph made in Question 7.
9. Determine which of the following observations are testable.

For those that are testable:

- Write a hypothesis and null hypothesis
- What would be your experimental approach?
- What are the dependent and independent variables?
- What is your control?
- How will you collect your data?
- How will you present your data (charts, graphs, types)?
- How will you analyze your data?

A) When a plant is placed on a window sill it grows faster than when it is placed on a coffee table in the middle of the living room.

B) The teller at the bank with brown hair and brown eyes is taller than the other tellers.
C) John caught four fish at the seven o’clock in the morning but didn’t catch any at noon.

D) Salaries at Smith and Company are based on the number of sales, and Billy makes 3,000 dollars more than Joe.

E) When Sally eats healthy foods and exercises regularly, her blood pressure is lower than when she does not exercise and eats fatty foods.

F) The Italian restaurant across the street closes at 9 pm, but the one two blocks away closes at 10 pm.
G) Bob bought a new blue shirt with a golf club on the back for twenty dollars.

H) For the past two days the clouds have come out at 3 pm, and it has started raining at 3:15 pm.

I) George did not sleep at all last night because he was up finishing his paper.

J) Ice cream melts faster on a warm summer day than on a cold winter day.