Lab 1: The Scientific Method

The Scientific Method

Science is a method of understanding nature based on empirical logic. "Empirical" knowledge is that based on observation and experience, and "logic" is a method of building arguments from a set of facts. Empirical logic allows us to make generalizations based on particular observations, called **inductive reasoning**. Scientists also use **deductive reasoning**, which involves drawing specific conclusions or making a prediction based on a previous generalization. Scientists use two main approaches to science:

- ***Discovery science***
  - Primarily describes nature through verifiable observations and measurements

- ***Hypothesis-based science***
  - Attempts to explain nature by studying specific questions drawn from observations made during "discovery science"
  - ***Hypothesis***: a tentative answer to a problem or question that is being asked

Hypothesis-based science applies the <u>five steps of the scientific method</u>:

(1) Observations

(2) Questions about unclear aspects of the observations: How? Why? When?

(3) Hypotheses or tentative explanations of a phenomenon

- Must be **testable** in the empirical world—accessible to our senses and our instruments
- Must be **falsifiable** – if a hypothesis is disproved through experimentation, it is rejected and a new hypothesis must be developed

(4) Predictions developed by the use of deductive reasoning (if...then)

(5) Experiments to test predictions to determine if the predictions are supported or falsified

It is important to recognize that science is a process of *disproving, not proving*! If a hypothesis is not disproved through experimentation, then we say that this hypothesis is **supported**. This is not to say that it is necessarily true! Science is ever-changing as our body of knowledge increases and our instruments improve. Hypotheses that seemed perfectly logical in the past may turn out to be incorrect. However, if a working hypothesis is subjected to tests enough times without being disproved, it is termed a **theory**, which is a reproducible scientific fact.

Experimental Design

Every scientific investigation must include **variables** and **controls**. Scientific variables are conditions that the experimenter manipulates or measures in order to explore its influence. Variables are divided into two discrete types, **independent variables** (controlled by the experimenter) and **dependent variables** (measured by the experimenter). Usually, the experimenter decides the conditions of the independent variable and the dependent variable *depends* on those conditions.

Scientific controls are conditions that are known or are held constant by the experimenter in order to assess the effect of the independent variable on a particular system. Scientific controls are essential because they allow the experimenter to eliminate or minimize unintended influences on the experiment. In a controlled experiment, one set of samples (**experimental group**) has been (or is believed to be) modified and the other set of samples (**control group**) are either expected to show no change (**negative control**) or expected to show a definite change (**positive control**). Another type of scientific control is to maintain constant treatment conditions across all samples.

For example, imagine that you discovered a new type of bacteria (**observation**) and you want to know if it is affected by antibiotic treatment (**question**). You know that other bacteria are affected by antibiotics, so you **hypothesize** that the new bacteria will also be affected**.** You then **predict** that introducing antibiotics will kill the bacteria and **test** this prediction with an experiment.

What is your experimental group?

What is your control group?

What is your independent variable?

What is your dependent variable?

The Great Paper Caper

In this experiment, we will use the scientific method to test three unknown brands of paper towels to determine which brand really is "the quicker picker upper." We will expose each brand of paper towel to the same treatment and then measure how much water each brand of towel absorbs in 30 seconds.

Equipment (each group)

1 x 250 ml beaker

1 x 1000 ml beaker

1 x 100 ml graduated cylinder

Materials (each group)

1 sheet each brand paper towel

water (in 1000 ml beaker)

Methods

1. Observations: Record your observations of each brand of paper towel in the space below. For example, what does it look like? How does it feel? How much does it weigh? What does it look like under the microscope? What are the differences between the brands? Draw a picture, if you like.

Towel Brand	Observations
1	
2	
3	

2. What is your hypothesis (your prediction about which paper towel will absorb the most water in 30 seconds)?

_____

_____

_____

_____

_____

_____

_____

_____

3. Control your experiment for the size of the paper towel (cut all sheets to the same size!). What size are the paper towels?
4. Fill your 1000 ml beaker with water.
5. Use the graduated cylinder to measure and fill the 250 ml beaker with 100 ml of water.
6. Fold each paper towel in half **4** times.
7. Dip each brand of paper towel in the water for 30 seconds. **One at a time!**
8. After 30 seconds, remove the paper towel from the water and hold until no more water is dripping out of the paper towel. **Do not shake the towel!** Put the paper towel aside.
9. Pour the water remaining in the beaker into the graduated cylinder and record the "finish amount" on the table below.

Towel Brand	**Start Amount (ml)**	**Finish Amount (ml)**	**Amount Absorbed (ml)**
1	100		
2	100		
3	100		

10. Subtract the "finish amount" from the "start amount" to determine how much water each brand of paper towel absorbed.

11. Combine the "amount absorbed" for your group with data collected in other groups in the table on the following page.

Amount Absorbed (ml)	**Towel Brand**		
	1	2	3
Group 1			
Group 2			
Group 3			
Group 4			
Group 5			
Group 6			
Group 7			
Group 8			
Group 9			
Group 10			
Average			

12. Plot the average amount absorbed for each brand of towel on the graph provided. The independent variable is always on the X-axis (horizontal), while the dependent variable is always on the Y-axis (vertical). Label each axis with the variable and the unit of measure.

Questions

1. What can we conclude from the results of the experiment?

_____

_____

_____

_____

_____

2. Do the results support your hypothesis?

_____

_____

_____

_____

_____

_____

_____

3. Which variables were controlled in the experiment?

4. Why is repeating the experiment (replication) always important?

5. What are the potential sources of variability among groups?

6. What new questions do you have after completing this experiment?

7. How could you design an experiment to address your new questions? Include a figure of your experimental design below, if you like.