The Scientific Method
Generating and Testing Hypotheses

Objectives:
1. Students will review the scientific method.
2. Students will generate their own hypotheses on the effectiveness of antibacterial products.
3. Students will test their hypotheses and revise if necessary.

The Scientific Method

As you probably learned all the way back in elementary or middle school, the **scientific method** is a way of testing ideas. One of these ideas is called a **hypothesis** (plural: hypotheses). Often, a hypothesis starts with a question. At some point in history, someone wondered why objects fall to the floor when dropped, why the sky is blue, and how water helps plants grow. These questions led to hypotheses, which were tested. If a hypothesis is correct, it is proven; otherwise it is disproven. In today's lab, we will be formulating and testing our own hypotheses.

How do we design an **experiment**? Most people who attempt to solve a problem in a logical and organized manner are using the scientific method to a certain degree. Scientists have been trained to apply this tool in a more rigorous and disciplined manner, making it a powerful means of solving problems. Some textbooks provide a list of steps to define this thought process. Although you might think that all scientists follow these steps in performing their experiments, researchers do not always follow an exact sequence of steps as they work toward solving a problem.

One of the most important characteristics of scientific work is the use of careful observation. Through observations, researchers begin to ask questions, and these questions eventually lead to hypotheses. A hypothesis is typically defined as an "educated guess", but a well-stated hypothesis is much more than this. It not only postulates an answer to the question, but it also gives researchers a sense of direction in their work. A workable hypothesis must be logical and, most importantly, testable.

In many cases, a hypothesis is tested by doing a controlled experiment. An experiment is a situation designed to produce results supporting the hypothesis being tested. Well-designed experiments have an experimental group and a control group. In the experimental group (or groups), one factor - **the experimental variable** - is altered in some manner. In the **control group**, the same test is performed under the same conditions as in the experimental group; however no change is made to the experimental variable. Experiments produce quantitative data and help scientists arrive at conclusions that indicate whether or not the hypothesis is substantiated. An unsubstantiated hypothesis is usually abandoned for a new hypothesis.

Not all hypotheses are easily tested by controlled experiments; some must be tested by making detailed observations of conditions that already exist. For example, evolutionary biologists sometimes test hypotheses by collecting and observing fossils and then drawing conclusions based on this information.

An example of experimental design to answer the question:
Does exercise affect heartbeat in humans?

1. Make some observations.
2. Ask questions about these observations.
3. Set up the testable hypotheses
    a. It is easier to test a hypothesis that calls for a YES or NO answer
4. Determine the experimental conditions needed to test these hypotheses
    a. How do you measure the variables involved?
    b. How many times should the experiment be repeated?
    c. How can you draw satisfactory conclusions (that is, how will you analyze your results?)
    d. What is the control?
5. Make predictions based on what you expect to find.
6. Test the formulated hypotheses.
7. Report results and draw conclusions - that is, accept or reject each of the hypotheses

The Scientific Method

Ask a Question ↓
Form a Hypothesis ↓
Test Hypothesis (Experiment) ↓
Record Data ↓
Analyze Results (hypothesis correct?)

The Discovery of Antibiotics

The discovery of antibiotics was a mistake. Alexander Fleming, who studied bacteria, had the fungus *Penicillium notatum* contaminate his infectious bacteria cultures. He realized that the patches of *Penicillium* were secreting a substance that caused the bacteria around it to die. Antibiotics have since played a role in the explosion of the human population by increasing the survival rate. Today, we will be using antibacterial products as the basis for our hypotheses.

Procedure for today's lab

Students will be working in groups of 3 today. Each GROUP should start with:

- ➔ 3 sterile agar plates (*keep covered!*)
- ➔ a timer

Students will share the:

- ➔ regular soap
- ➔ antibacterial soap
- ➔ antibacterial hand sanitizer
- ➔ fine tip permanent markers

1) Obtain three sterile agar plates. *Be sure to keep the plates closed at all times to prevent contamination.* Use a fine tip permanent marker to draw a straight line down the center of the **BACK** of each plate (not the lid). On one side of the line, write "**Before**" and "**After**" on the other side. Each person in your group will be responsible for one of the plates. Label each "**A**," "**B**," or "**C**." ***Don't forget to write your name on the plate.***

A = regular soap
B = antibacterial soap
C = antibacterial hand sanitizer

2) **Form your hypotheses:**
Each person in the group is responsible for making his or her own unique hypothesis. Your hypothesis must in some way include the treatment from the list above that YOU are washing your hands with. Remember to write down the other hypotheses made by your group members in the space provided in the table below.

Forming a testable hypothesis:

→**Write your experimental variable** (the one factor you are varying)

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→Remember, it is easier to test a hypothesis that calls for a **YES or NO** answer.

→**How many times should the experiment be repeated?** *(Sorry, restrict your study to our lab time.)*

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→**How can you draw satisfactory conclusions**? *(That is, how will you analyze your results?)*

____

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→**What is the control**? Is there more than one control in your experiment?

____

→**Make predictions** based on what you expect to find. Write your predictions below.

____

Group Member & Treatment	Hypothesis
Name: Treatment:	
Name: Treatment:	
Name: Treatment:	

3) Gently lift the lid off of your labeled agar plate and hold it in one hand, being careful to only touch the outside of it. On the "**before**" side, touch your thumb and index finger to the agar, and slowly wipe them across ONLY that side. **Put the lid back on the agar plate while you wash your hands.**

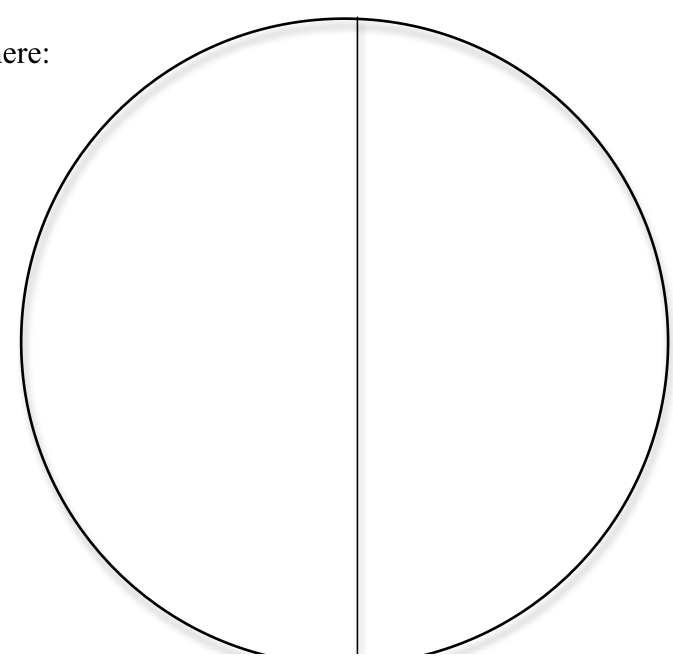
4) You're now ready to begin washing! Depending on which treatment you have chosen (A, B, or C), wash your hands for **30 seconds**, not including rinsing and drying. Be sure to use **one pump** of soap (with water) or hand sanitizer. Have one of your group members time you. After washing—without touching anything else!—open the lid on your agar plate and wipe your thumb and index finger down the "**after**" side.

5) Give your agar plate to your TA. The plate will incubate overnight. You will start Lab 2 by examining your group's three agar plates and observing results.

Data *(To be completed during your next lab!)*

Record your observations based on the evidence you said you would look for:

Draw your plate here:



Questions

1. What things were controlled (the same) for all three experiments for your group?

2. If either of these parameters were to have not been the same for each of your three experiments, do you think this would affect any of the hypotheses formed by your group?

3. What will you do if you observe unexpected results that do not support your hypothesis?

4. *To be completed during the next lab:* Was your hypothesis correct or incorrect? How can you tell? Were you surprised by the results you observed?