Biology 196 Laboratory
Introduction/Safety/Scientific Method

Laboratory Objectives

After completing this lab you should be able to:

- Define science and determine which questions can be answered via scientific investigation.
- Define the meaning and differences among: hypothesis, theory, and fact.
- Describe and interpret the components of the scientific process.
- Design a scientific experiment.
- Identify control groups and variable groups in an experimental procedure.
- Summarize and present results in graphical form.

Laboratory Safety

All students must read and understand the following laboratory safety guidelines. You will also be required to write and sign a document affirming that you understand each of these guidelines:

1. Always follow the instructions in the lab manual, and those given by the lab instructor. When in doubt, ask.
2. Personal belongings should be placed in the space designated by the instructor.
3. Smoking (or tobacco of any kind), eating, and drinking are prohibited in the laboratory.
4. Children and/or guests will not be admitted to the laboratory.
5. No unauthorized laboratory experiments are permitted.
6. Students will NOT be permitted to work in labs without instructor supervision.
7. Students must wear/use all of the protective clothing and/or equipment designated by the laboratory instructor. If the student does not, he/she will not be permitted to remain in the laboratory.
8. All laboratory materials must be cleaned up and put away at the end of the laboratory session. Students must leave the work area clean and dry.
9. All waste materials MUST be disposed of in the manner designated by the instructor.
10. There will be no unauthorized removal of laboratory materials or equipment from the classroom.
11. The student is responsible for knowing the location of, and proper use of, all safety equipment in the classroom and its immediate surroundings.
12. In case of fire, students should inform the instructor immediately, and evacuate the area. Pull the fire alarm. Inform CSN campus security.
13. All classroom accidents/injuries must be reported to the instructor immediately.

14. The student is responsible for reading the labels of all laboratory materials and for reading and understanding the posted safety information concerning these materials. The information will always be available in a designated site within the department. Your instructor will inform you of the location.

15. A list of emergency procedures is available in Section XIII of the College of Southern Nevada Hazardous Materials Right to Know Safety Training manual. The student is responsible for reading and understanding these procedures. Your instructor will inform you of its location.

Worksheet #1 - A Survey of Science.

Working as a team, answer the following questions with your group/table. Do not use your book or this lab manual - there is no definitive right and wrong answer for each question. Discuss each one and come to a common conclusion. If you have a different answer than others in your group, think about what *evidence* leads you to believe why your answer is correct.

1. Science is inherently a group effort. Introduce yourself to your table of peers; you will be working as a team each week.

2. Describe what *science* is. How exactly is it different from other fields of 'enlightenment', such as philosophy or religion?

3. Do you like science? Why do you think someone might not like science?

   Are there any downsides to science?

4. What are the steps in the scientific process? Be as detailed as possible, but do not use your textbook or this lab manual. Think about which steps fit into every-day life, and which do not.

5. What is the difference between a scientific hypothesis and a scientific theory?

Write an example of a scientific hypothesis.

6. Evolution is an extremely important biological theory. What is *another* example of a theory in biology?

7. How does a theory differ from a fact?

Give an example of a fact.

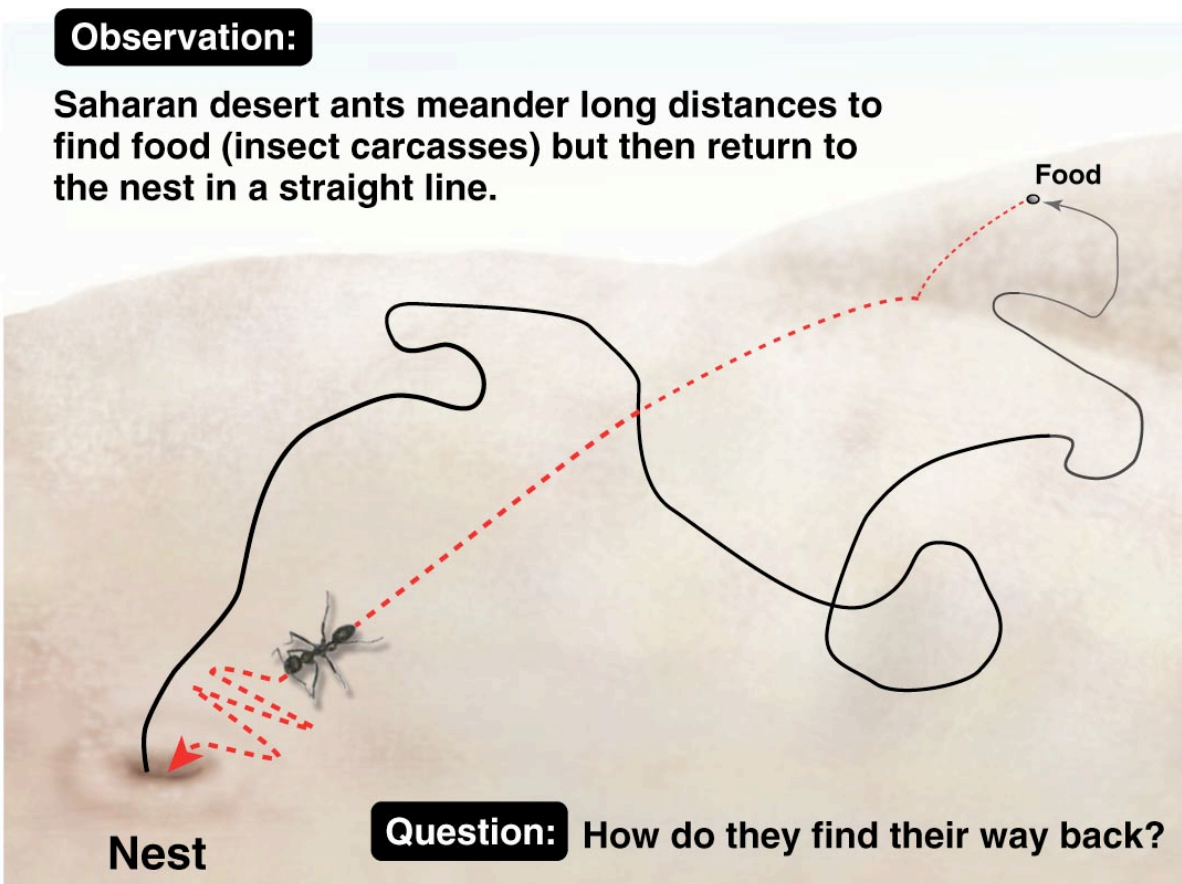
8. What is the most important difference(s) between astronomy and astrology?

The Scientific Method - The Hypothesis

Biologists, and other scientists, ask questions about the world. The questions asked can be answered through systematic observation and the collection of data. Questions that cannot be answered through **experimentation** are not subject to scientific study, an important distinction.

The first step in answering any question is the formulation of a **hypothesis** - a statement that would provide an explanation to the question. A good hypothesis is essential to experimentation. It is common for scientists to start with many hypotheses and next determine which to evaluate based upon several factors such as: (1) its plausibility at being correct and (2) its feasibility to be tested. Even the most intriguing hypotheses are unsuitable if an experiment cannot be performed to test them.

<u>Example: The ant pedometer study.</u>
To demonstrate hypotheses and the scientific method used to test them, consider the following observation made about Saharan desert ants by Matthias Wittlinger and his colleagues in 2006[1]:



The ants travel hundreds of meters from their nests but, you'll notice from the diagram, that they do not return by the same route. They travel in a straight line until only a few meters from the nest before making back-and-forth turns in search of the exact spot. It was already known that ants use the sun as a compass for direction, but that would not explain how they would know how *far* they've gone.

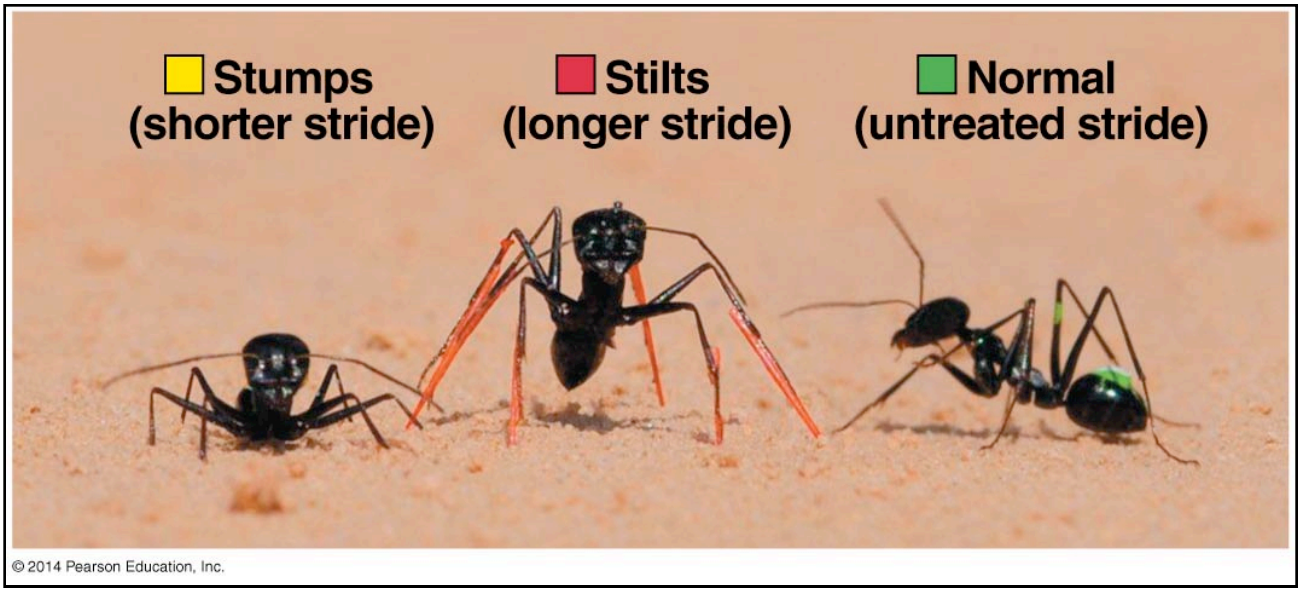
How do the ants do this?

[1] The Ant Odometer: Stepping on Stilts and Stumps. *Science* 30 June 2006: Vol. 312 no. 5782 pp. 1965-1967

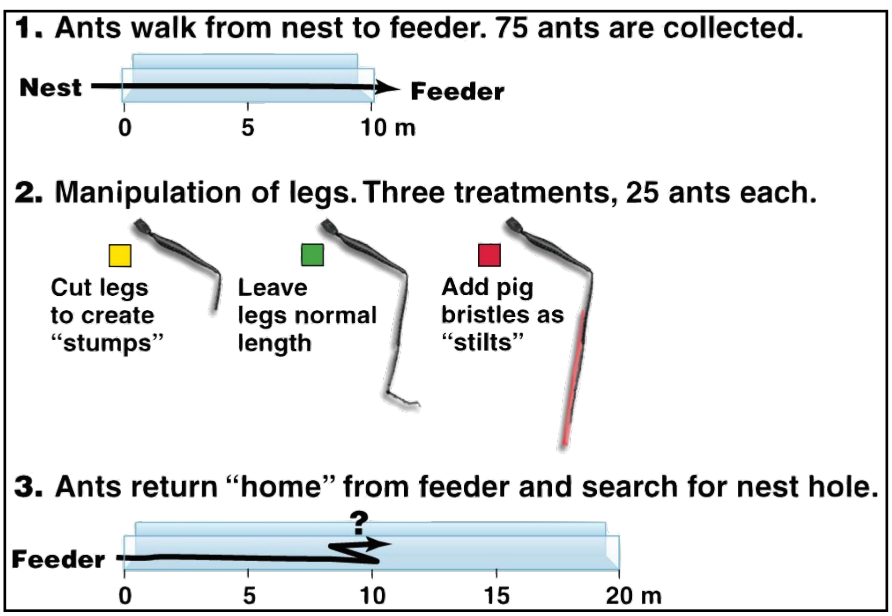
Wittlinger, et. al. proposed the "ant pedometer hypothesis" that suggested they tracked the number of steps they take and their stride length to calculate the distance (i.e. distance = number of steps X leg stride length).

The Scientific Method - Experimentation

The hypothesis proposed by Wittlinger, et. al. is intriguing but is not considered *science* unless they can perform an experiment and collect data to support their hypothesis. Using a large collection of ants they set up a "feeder" station for the ants to travel to that was ten meters away from the nest, and they then modified three groups of ants to have different leg length, and therefore different strides. Photos of the ants with modified legs, and summaries of the experiments by Freeman are shown below[2].



Look at the next figure for how they performed the experiment.

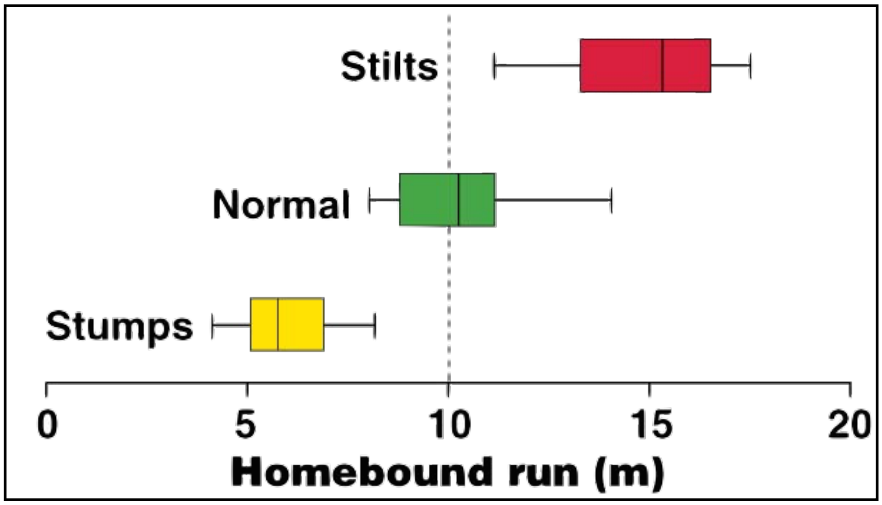


[2] Freeman, F. (2014) *Biological Science*. Benjamin Cummings.

The hypothesis for this experiment is that the ants rely on a counting mechanism of strides multiplied by the length of their stride to determine the distance back to the nest. Using their hypothesis they formulated **predictions** regarding the outcome of the experiment. If the data matches the predictions they can reasonably accept the hypothesis.

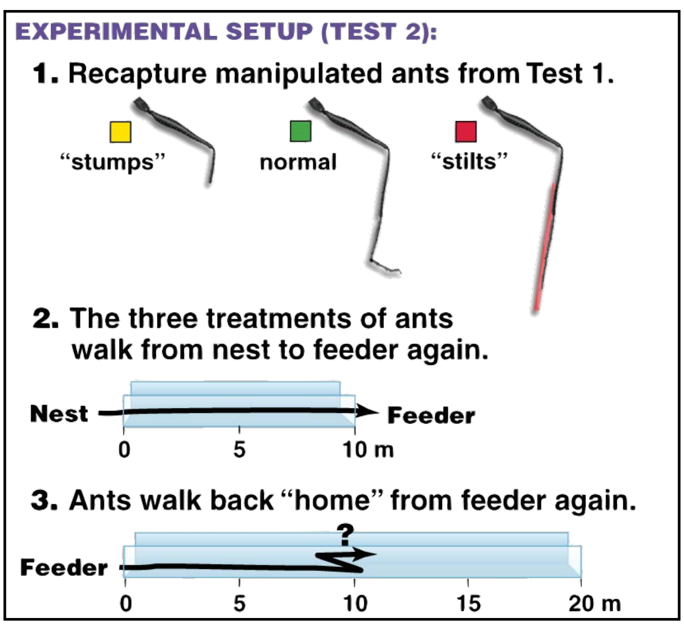
Prediction#1 : *Ants with stilts on their legs will travel too far looking for the nest; ants with stumps will not travel far enough.*

The results of this experiment are shown below:



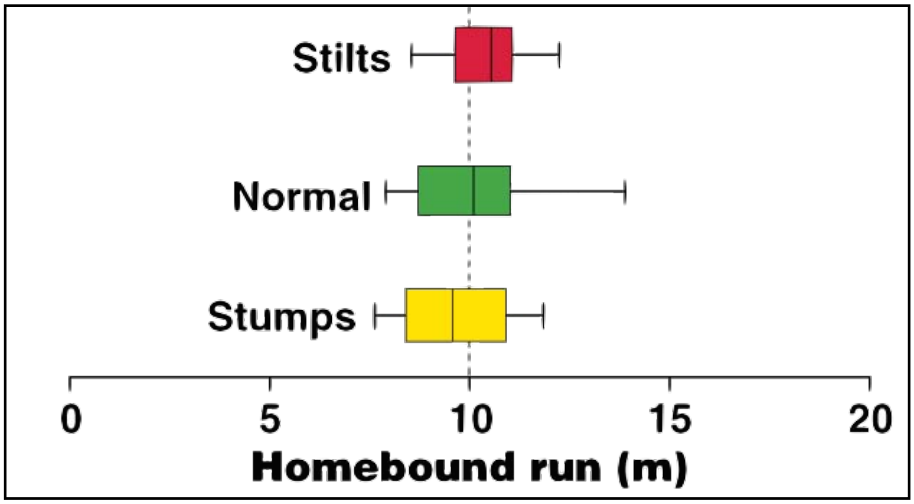
Since the nest was 10 meters away from the feeder, the prediction did indeed turn out to be correct. However, scientists are always skeptical, and open to new hypotheses that are supported by experimental data. In this experiment the scientists wanted to be certain that the change in distance traveled was truly due to the ants counting the strides and length of stride. If the hypothesis is correct then if the ants *start out* with modified legs they should also be able to return to the nest with the same accuracy as the those with normal legs.

To test this they set up a second experiment, and made the following predictions as below:



Prediction#2: *All groups will begin searching for the nest at the same distance.*

The results of this second experiment:



While there was some variation, statistically, all three were very similar in their search for the nest at approximately 10 meters. This data supports the "ant pedometer hypothesis" and allows the researchers to accept it, unless new data is presented that contradicts it. After many supporting experiments, and if there are no other contradicting hypotheses supported by data, a hypothesis can be elevated to a **theory**.

The Scientific Method - Controls, Groups, and Variables.

Controls:

Proper experimental design is as important as the hypothesis that is being tested. It is essential that the experiment be as **controlled** as possible. The researcher wants every variable to be identical, except for the variable being examined by the hypothesis. In the ant pedometer experiment every effort was made to ensure the ants were the same species, from the same nest, under the same environmental conditions, etc.

Imagine an experiment where a drug in pill form is expected to cure a disease. One group of test subjects would receive a pill that would contain the drug, and would be considered the **experimental group**. Another group would receive an identical pill, except it would not contain the drug. This second group would be called the **negative control**. The negative control should give a *negative* response with respect to the hypothesis (i.e. the drug cures the disease). In medical experiments the negative control group is often called a "**placebo**" group.

When possible, a third group is included as a **positive control**. The positive control should give a *positive result* with respect to the hypothesis. So, for the medical example, something other than the drug that *is known to cure the disease* would be the positive control. Positive controls are not always possible with every experiment.

Identify negative and positive controls for the ant pedometer experiment?

Negative: ____

Positive: ____

Variables:

While performing experiments there are at least 2-3 groups of **variables.** An **independent variable** is that which the scientists are changing or controlling. The **dependent variable** is typically the recorded data that is *dependent* upon the differences in the independent variables.

A very common example of a variable is time. Think about recording some observation over time, such as the number of raindrops falling in a cup during a storm. Many things can change or be altered over the passage of time, but very few things change the pace of time. Therefore, in this example, time is clearly the *independent variable*, as the number of raindrops counted would *depend* on time, but not the other way around (*see graph below*).

A third type of variable are **control** variables, and, if possible, they should remain constant. In fact, they are sometimes referred to as *constant variables*. As an example, in the ant pedometer experiment, the scientists used ants of the same species and from the same nest whenever they modified the independent variable(s). This helps to prevent the introduction of unwanted independent variables. The best designed experiments have the fewest differences in controlled variables.

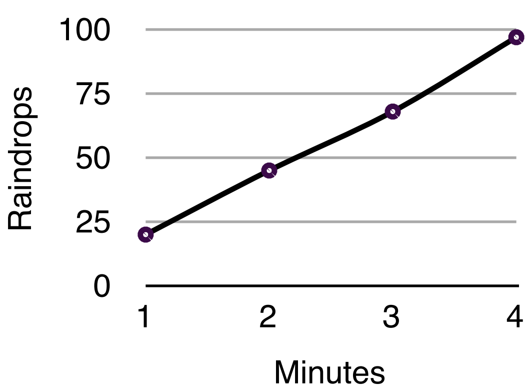
Identify independent and dependent variables for the ant pedometer experiment

Independent: ____

Dependent: ____

Presentation of variables:

The most common and useful way of presenting numerical forms of independent and dependent variables is by graphing. To present the "cause and effect" expression of independent to dependent variables the X-Y graph is very useful. By mathematical convention the independent variable is displayed on the **X axis**, while the dependent variable is on the **Y axis**. An example is shown below.



Worksheet #2 - Assessment of Scientific Methods.

Part One: Analyzing an experiment.

An experiment was performed to test the effect of methamphetamines on hand-eye coordination. People were asked to string 25 paperclips together as fast as possible. Three people took the drug in liquid form. Two received identically colored water that did not contain the drug. The results are shown below.

Person	Drug	Trial #1	Trial #2	Trial #3
1	Yes	45 sec	62 sec	53 sec
2	Yes	57 sec	41 sec	50 sec
3	Yes	62 sec	79 sec	70 sec
4	No	30 sec	32 sec	27 sec
5	No	35 sec	40 sec	33 sec

1. State a reasonable hypothesis that this experiment tested.

2. What is the experimental group?

3. Is there a negative control group? If so, what is it?

4. Is there a positive control? If so, what is it?

What else could act as a positive control for this experiment?

Part Two: Creating an experiment.

As a group, create an experiment. This can be virtually anything, but keep in mind the importance of the hypothesis. Make sure it is something that can be both experimented on and properly controlled.

1. Write your hypothesis

2. Describe your experimental procedure.

3. What can you come up with for positive and negative controls?

Part Three: Presentation of data.

Imagine a basketball player shooting baskets from the free-throw line. You are recording the data as the number of shots made and the amount of time that has passed since the player began shooting.

In the space below, draw a line graph that represents the following data. Be sure to identify which set of data represents the **independent variable** and which is the **dependent variable**, and which belong on the X versus Y-axis of your graph.

Time (minutes)	# free throws made
0	0
1	2
2	5
3	6
4	9
5	11

Study Checklist

To perform well on the first quiz, you need to have a thorough knowledge of the following:

- The safety policy and procedures
- The location of the fire extinguisher, fire blanket, first aid kit, and eye wash station.
- You should know and understand all of the terms which appear in **boldface** type.
- You should know and understand the steps of the scientific method: observation, hypothesis formation and logical interpretation, hypothesis testing, and data analysis and interpretation. If given a set of observations and a question you should be able to form a hypothesis, explain how it could be tested, and explain how the possible results could be interpreted.
- You need to understand the following terms used in experiments: dependent variable, independent variable, controlled variables, placebo, negative and positive controls.
- If given a set of data you should be able to draw a line or bar graph as appropriate and following the convention that the dependent variable is plotted on the vertical axis.