The Scientific Method

Introduction

The scientific view of the world relies on observable phenomena. Scientists use their experience and logic to suggest causes of phenomena that interest them. Importantly, they test these ideas and reject those shown to be false. They often approach their work as a puzzle to be solved. Just as puzzles vary, so do the methods used by scientists.

Scientists typically begin their studies when some new **observation** stimulates their curiosity. Once stimulated, a scientist asks **questions** about the phenomenon and eventually formulates a **possible explanation** for their observation(s). These possible explanations are based on their prior knowledge of related phenomena and are called **hypotheses** (singular = **hypothesis**)*. Typically, a hypothesis suggests a cause and effect relationship.

For example, a scientist notices that a blue-headed fish disappears every day about 6 PM. She asks: 'Does the fish disappear because the sun is about to set?' She might also ask, 'Why would the fish disappear when the sun sets?' Based on her knowledge of ecology, she might also attempt to explain the fish's disappearance with this hypothesis: 'The fish takes refuge to avoid the dark and nocturnal (night-active) predators.'

The next step in the scientific method is for the scientist to **test her hypothesis**. These tests are aimed at specific predictions of the hypothesis. 'If the fish takes refuge to avoid the dark, then we expect to find that fish disappear before sunset and reappear after sunrise.' To test this prediction, she and her students followed fish every day from 5 PM until they disappeared. She found each hid under a coral head just before sunset (6 PM). They also made dives at 5 AM and found that fish came out from the same refuge just after sunrise. These observations **support** her hypothesis. The fish were seen to take refuge just before sunset and to come out from the same refuge after sunrise. However, these new **data** only demonstrate a **correlation** between the presumed cause and effect.

* Note: **A hypothesis** may be described as an **'educated guess'**. Some scientists find this description inaccurate, because hypotheses are formulated by scientists based on years of prior experience with related phenomena. On the other hand, hypotheses are not facts and only become accepted after rigorous tests. Thus, if you wish to refer to a hypothesis as an educated guess be sure to emphasize the 'educated' part.

To better test her hypothesis, Dr. Saunders captures some of the blue-headed fish and brings them into her laboratory. In the lab she can artificially manipulate sunset by use of lights and a timer. She places some fish in aquaria where the lights go off at 5 PM, others with lights that go off at 6 PM, and a third group with lights off at 7 PM. This type of **controlled experiment** provides a direct test of the hypothesis. **'Sunset'** is the **independent variable** in this experiment. Sunset is varied by the scientist to create three **treatment groups** (5PM, 6PM & 7PM sunset). The behavior of the fish (**when it hides**) is the **dependent variable**. If the hypothesis is correct, the dependent variable depends on how the independent variable is manipulated.

Dr. Saunders also needs to be concerned about food for the fish, water temperature, salinity, and other factors that affect fish health and behavior. She keeps all the fish at the same temperature, salinity, etc. These factors are **controlled variables** in this experiment. By controlling these variables, she can be confident that any differences in fish behavior will be due to the different time of sunset. She also provides pieces of PVC pipe for fish to hide in. The fish then spent two weeks in their new homes to adjust to the new time of sunset. Then Dr. Saunders and her student, Ken Briggs, tested their behavior: the time fish went into their PVC pipes.

Based on their initial hypothesis, what predictions would you make about the behavior of these fish in the three different treatments?

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Should they also vary the time of sunrise? Explain what you would design for this part of the experiment.

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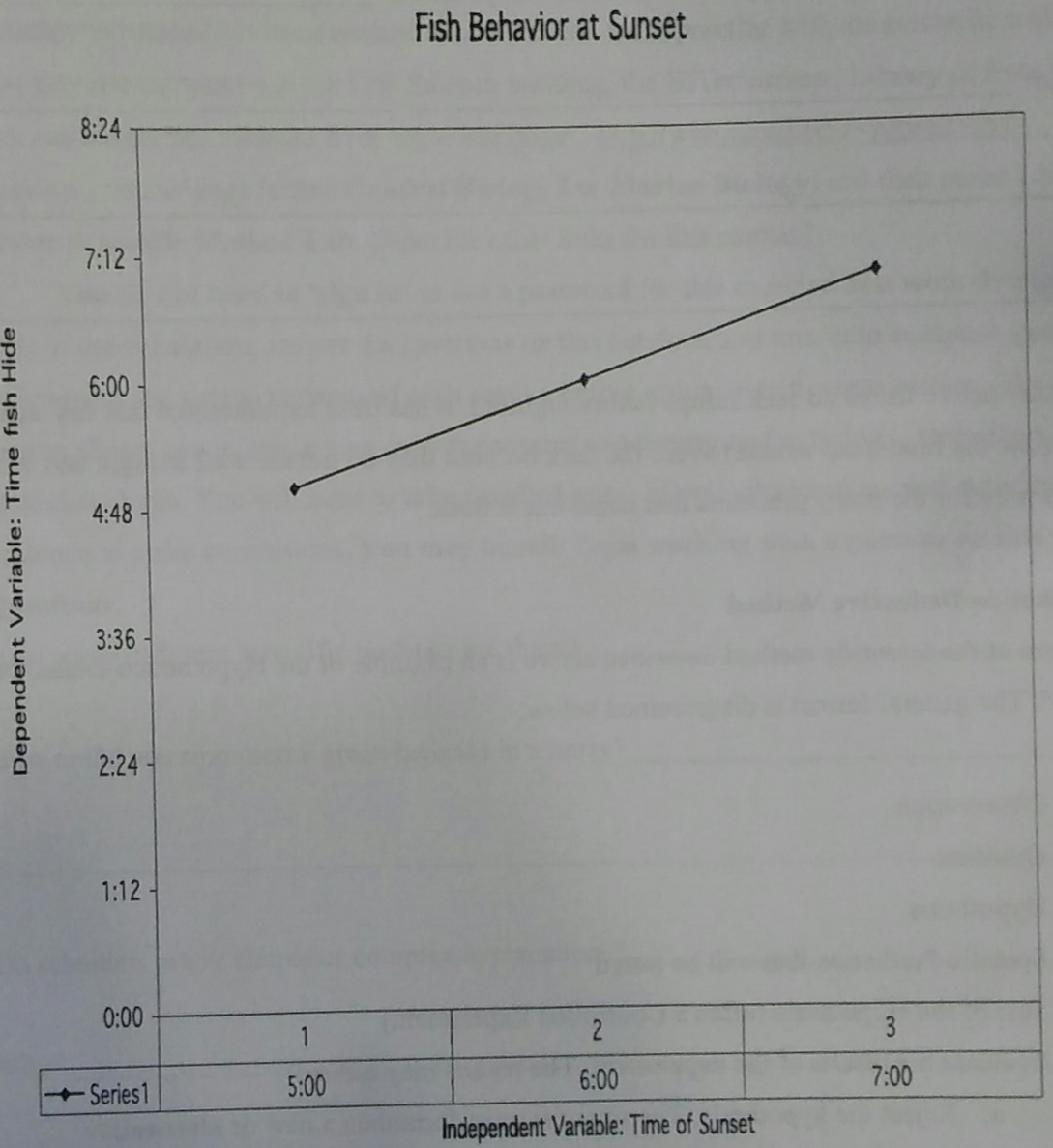

They found fish with a 5 PM sunset (Treatment 1) hid in their tubes at 4:50 PM fish with a 6 PM sunset (Treatment 2) went into their tubes at 5:50 PM and the 7 PM sunset group (Treatment 3) went inside at 6:50 PM. These data are graphed above. Note that the independent variable is displayed on the abscissa or x-axis (horizontal) and the dependent variable is displayed on the ordinate or y-axis (vertical).

Do you think these results support Dr. Saunders' hypothesis? _____

Explain: _____

_____

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Many day-active fishes do seek refuge before nightfall. It has been hypothesized that day-active fishes (like the blue-head wrasse) avoid the dark because they do not see well at night and would be easy prey for the many predators that come out at dusk.

Hypothetico-Deductive Method

The form of the scientific method described above is an example of the Hypothetico-Deductive Method. The general format is diagrammed below.

1. Observation
2. Question
3. Hypothesis
4. Specific Prediction that will be tested
5. Test of the Hypothesis (often a Controlled Experiment)
6. Evaluate the results of the experiment. The results may either:
    a. Reject the hypothesis. The scientist must formulate a new or **alternative hypothesis** which must be tested, or
    b. Support the hypothesis. This support does not prove the hypothesis, but the hypothesis may be provisionally accepted.

Exercise

A computer tutorial has been created to provide you more practice with the scientific method. You may use computers in the Life Science building, the HiTec centers, Library or from home. You can access this exercise from my home page http://web.gccaz.edu/~robru21251/ Click on a course page (either **General Biology I** or **Marine Biology**) and then under **Lab Links: Scientific Method Lab**. [Note the other links for this course.]

You do not need to 'sign in' or use a password for this exercise. Just work through all parts of the simulation, answer the questions on this handout, and turn in to complete your assignment. Be sure to understand each section before going on to the next section. The second section allows you to create your own experiment and determine the factor(s) that affects the rate of cricket chirps. You will need to **take detailed notes** of your observations and experimental evidence to make conclusions. **You may benefit from working with a partner on this tutorial.**

Questions

How many different scientific methods are there? _____

How could you ripen some green bananas in a hurry? _____

_____

Do scientists prefer simple or complex explanations? _____

Why? _____

Cricket Study

What **initial observations** were made about crickets in the White Tank Mountains?

_____

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_____

In your experiment, **the rate of cricket chirps is the dependent variable.** You should test each of the five possible independent variables to determine which of these might affect chirp rate. However, you are only allowed to manipulate one variable at a time. Why?

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List the **five independent variables you tested** and their effect on chirp rate.

Independent Variable	**Effect on Chirp Rate**
Air Temperature	
Wind Speed	
Humidity	
Air Pressure	
Number of Crickets Nearby	

Write a hypothesis for chirp rates based on air temperature. Be sure to write it in the form of a falsifiable statement.

_____

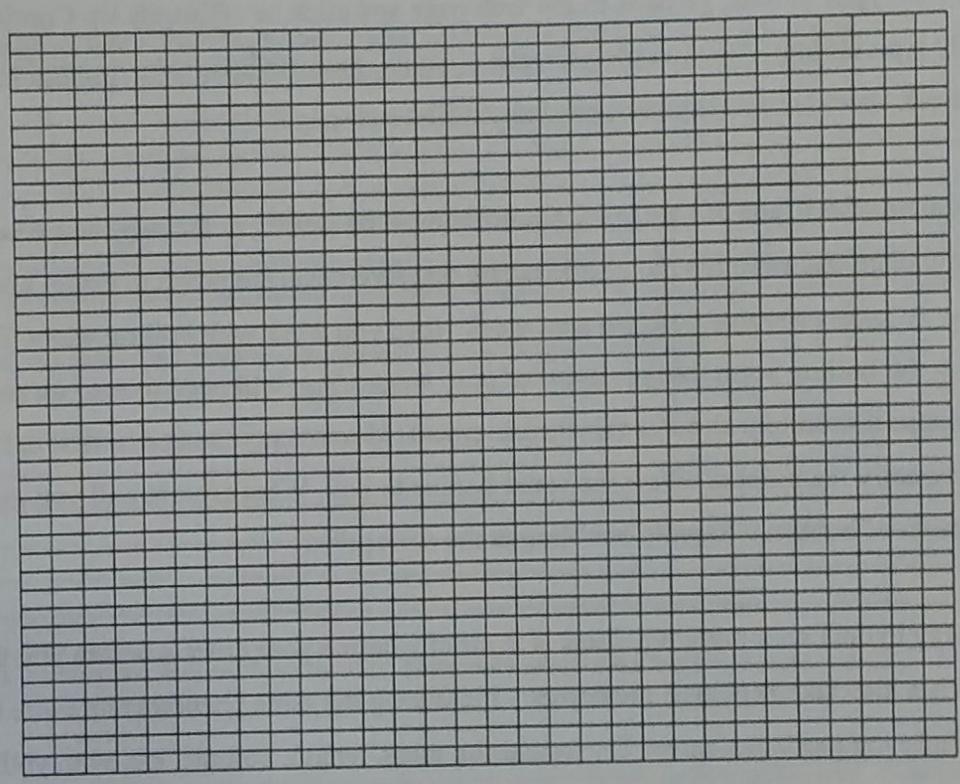
When testing the hypothesis above:

- how many crickets were near the chirping male? _____
- what was the wind speed? _____
- what was the humidity? _____

Graph the results of your experiment using air temperature. Label the independent and dependent variables and indicate the units for each

FIGURE I. Title:

Dependent Variable (units):



Independent Variable (units):

Based on these results, what do you conclude about your hypothesis?

_____

_____

What other factors, not available on this simulation, might you test?

_____

_____

Discrete vs. Continuous Data

The initial observations on cricket chirps occurred at three discrete time points that differed in time of day and season. These 'snapshots' of nature are typical of the data that scientists use to understand the world around and inside us. Imagine how different our interpretations might be if we watched (listened, recorded, etc.) nature on a continuous basis. To illustrate the difference in these two types of data, go back to my web page and click on 'Discrete vs. Continuous Data', or simply type in: http://www.coolclassroom.org/cool_projects/lessons/miniunits/lesson1.html
The work sheet has already been printed out (the next page).

Regardless of the type of data used, scientists must be careful in making their observations and acknowledge that even the most painstaking measurements are prone to error. You will have a chance to appreciate this problem next week when you work with boiling water. For example, what is the boiling point (temperature) of pure water? You will need to read an accurate thermometer carefully to make this measurement. Moreover, you need to first define operationally the point at which the water begins to boil. What criteria will you use? The first formation of bubbles? Rapidly bubbling at the surface?

One way to deal with these problems is to strictly define your criteria before you measure. Scientists also take **repeated measures** – measuring the same phenomenon more than once. Hopefully the measures agree! Try measuring mass, length, volume, etc. with your lab partners. Scientists take **random samples** of a phenomenon. For example, if we wanted to determine the average height of students in our class, we might be tempted to pick the tallest or shortest individuals, simply because they stand out. However, they would not necessarily be representative. Picking individuals (or any data point) must be chosen randomly to avoid **observer bias**. Remember, we are built to perceive (see) patterns – even when they do not exist. Recall the optical illusions in class.

Welcome to the COOL Classroom

Hosted by Oceanographers from
Rutgers University Marine & Coastal Sciences

Lesson #1: Introduction – Continuous vs. Discrete Data

Take a look at the series of photographs and attempt to determine what has happened based on the information available to you.

1. Write a description (frame by frame) of what you think the girl in the pictures is doing:

2. Watch the video clip and write a description of what the girl actually did:

3. Does the story you deduced from the still photographs match what happened in the video?

4. Which method gave you more information about what she was doing?

(circle one) A. Photographs B. Video

Scientists attempt to interpret events and processes that occur in the ocean based on the data available to them. The more data that can be collected to fill in the unknown gaps, the more accurately scientists can interpret the hidden world of the ocean.