Exercise 1

THE PROCESS OF SCIENCE

This lab defines science as a process, the sequence of the scientific method, and the ability to develop productive observations, questions, and hypotheses. Learn to calculate a range, mean, and standard deviation for a set of replicate measurements. Develop, design, and conduct a controlled experiment to test a null hypothesis.

Suggested Elements for an Introductory Lecture

* We learn about most things in our lives primarily through simple observation and faith in others (mother, teachers).
* The natural world includes so much variation that simple observation is not always adequate to answer complex questions.
* Science is defined many ways. One functional definition is that science is a *process* of answering *questions* about the *natural world*.
* The scientific method is a rigorous process that helps us deal with variation, and couch our “answers” in terms of probabilities rather than ‘black and white’ conclusions.
* People think best in terms of questions. During the process of science, questions are refined and narrowed until they are translated into hypotheses.
* Well-written hypotheses must be testable.
* Statistical tests are designed to ultimately assign a probability that your results (the difference between two means, for example) could be due to random chance.
* If the probability that your results could be due to random chance is 5% or less, then we reject the null hypothesis.

Activities

1. Develop insightful observations using pill bugs.

2. Refine experimental questions.

3. Formulate a hypothesis.

4. Develop an experiment and collect data.

5. Analyze experimental data.

Vocabulary

|  |  |  |
| --- | --- | --- |
| Science  Null hypothesis (Ho)  Response variable  Mean  Standard deviation (SD) | Scientific method  Treatments  Replication  Range  Significantly different | Hypothesis  Treatment variable  Controls  Observation  Independent variable  Dependent variable |

Materials for All Procedures

Number of lab sections \_\_\_\_\_\_\_\_\_\_ Total work groups \_\_\_\_\_\_\_\_\_\_

Work groups per section \_\_\_\_\_\_\_\_\_\_ Students per work group \_\_\_\_\_\_\_\_\_\_

Time Line For Laboratory Preparation

**Beginning of the semester:**

Determine the number of sections, work groups, and students in the course.

Inventory supplies and, if necessary, reorder supplies.

After the supply of each material is verified, check off the supply in the spaces in the list(s) below.

**Two weeks before lab:**

Determine how many work groups you will have.

Verify that the needed quantities of disposable supplies are available.

Order live animals.

**One–Three days before lab:**

Distribute materials to each work station.

Make up protein and sucrose solution.

**One hour before the lab:**

Make yeast suspension.

Turn on incubator or hot water bath.

Prepare supplies for each group.

### Quantity Needed

## √ Materials Total Per Group Catalog Number

Equipment

\_\_\_ fermentation tubes  
(or nested test tubes) \_\_\_\_\_\_\_ \_\_\_\_\_\_ 15 W 9863

\_\_\_ calculator or computer \_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ incubator \_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ yeast \_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ pillbugs \_\_\_\_\_\_\_ \_\_\_\_\_\_ 87 W 5525

\_\_\_ various leaves \_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ Carboy \_\_\_\_\_\_\_ \_\_\_\_\_\_ 18 W 1711

\_\_\_ Sugar \_\_\_\_\_\_\_ \_\_\_\_\_\_

Supplies: one set per group

\_\_\_ meter stick or metric tape measure \_\_\_\_\_\_\_ \_\_\_\_\_\_\_

\_\_\_ fermentation tubes (or nested   
 test tubes) 24 per group \_\_\_\_\_\_\_ \_\_\_\_\_\_\_ 15 W 9863

\_\_\_ 5-ml pipet \_\_\_\_\_\_\_ \_\_\_\_\_\_\_ 17 W 1307

\_\_\_ pipet dispensing bulb \_\_\_\_\_\_\_ \_\_\_\_\_\_\_ 15 W 0511

\_\_\_ pencil/marker \_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ 10-mL graduated cylinders \_\_\_\_\_\_\_ \_\_\_\_\_\_ 18 W 1705

\_\_\_ Test tube rack \_\_\_\_\_\_\_ \_\_\_\_\_\_ 18 W 4209

\_\_\_ Stop Watch \_\_\_\_\_\_\_ \_\_\_\_\_\_

Solutions

\_\_\_ 5% sucrose solution -20 ml per group \_\_\_\_\_\_\_ \_\_\_\_\_\_

\_\_\_ protein solution-20 ml per group \_\_\_\_\_\_\_ \_\_\_\_\_\_\_ 944 W 4602

\_\_\_ yeast suspension \_\_\_\_\_\_\_ \_\_\_\_\_\_ 947 W 3403

\_\_\_ distilled water \_\_\_\_\_\_\_ \_\_\_\_\_\_

Solution Preparation for Procedures

* Prepare solutions of sucrose (table sugar) in water at room temperature: 5% = 50 g/liter of water.
* Prepare egg albumen by dissolving 0.1 g of powdered egg-albumen to approximately 20 mL of distilled water. Stir gently and do not allow the albumen to foam (foaming often denatures the protein). After the albumen dissolves, bring the total volume to 100 mL. Store in refrigerator. Shelf life is several days.
* Yeast solution—1 g yeast per 3 liters of water.

Comments on Procedures

* We prepare the yeast suspension 15–30 min before each lab section by mixing 10 g yeast in one liter of 40°C tap water. If yeast activity is low, we also mix 5 g of sucrose with the suspension. Our teaching assistants dispense the yeast to students individually, because the suspension must be swirled and kept homogeneous.
* Unless otherwise noted, all catalog numbers are Ward’s Natural Science. Comparison shopping at the following scientific companies might save you money on some supplies:
  + Carolina Biological Supply Company, [www.carolina.com](http://www.carolina.com)
  + Fisher Scientific, [www.fishersci.com](http://www.fishersci.com)
* Smith fermentation tubes can be expensive, and nested test tubes are adequate substitutes. Obtain two test tubes, both of about the same height, but one with a slightly smaller diameter. If possible, the larger tube should be flat-bottomed. We use 11X100 mm inside 16X100 mm tubes. For the experiment, fill the smaller tube with the appropriate ingredients, invert the larger tube and slide it completely over the smaller tube. Invert the nested tubes and the contents will remain in the smaller tube. Support these tubes with test tube racks. These tubes do not need to be covered with parafilm.
* A warm-water bath with a test tube rack may be better than an incubator if you have frequent opening and closing of the incubator. The bath maintains a more constant temperature.
* Safety first: Be sure and cover any safety issues that may be specifically related to this lab procedure.

Investigative Procedure

* Inventory/survey class on what supplies are needed for this procedure

Answers to Questions

1. What practices besides science are used among world cultures to learn about the natural world?

*Paranormal activities, religious activities, and many other activities*

2. What factors might be responsible for variation in measurements of traits such as the heights of 10-year-old pine trees, or the kidney filtration rates of 10 replicate lab mice?

*Hereditary, environmental traits*

3. Consider the questions “What color is your roommate’s car?” and “How many legs do cats have?” To answer these questions would you use the scientific method, or would you rely on observation? Why?

*Observation; all these values have little or no variation and do not require scientific investigations*

4. Even the seemingly simple question “How tall are mature males of the human species?” can be difficult to answer. How would you best express the answer?

*Use the mean, range, and standard deviation in the random, global observations to give statistical value to your answer*

5. What are some examples of biological theories?

*Theory of evolution, cell theory*

**Questions for Further Thought and Study**

1. Newspaper articles often refer to a discovery as “scientific” or claim that something has been proved “scientifically.” What is meant by this description?  
   *Science is a formal process for acquiring knowledge and open to other scientific investigations and hypothesis testing.   
   Scientific hypotheses must be falsifiable.*
2. Experimental results in science are usually reviewed by other scientists before they are published. Why is this done?  
   *All scientific principles are open to modification.   
   Peer-review is part of self-correcting nature of science.*
3. Have all of our discoveries and understandings about the natural world been the result of applying the scientific method? How so?  
   *No. Simple observation is often productive and adequate.  
   Science can be qualitative or quantitative.  
   Science can deal with variables that may be measured or may be described.*
4. Suppose that you hear that two means are *significantly* different. What does this mean?  
   *The differences among treatments are not likely (less than 5% probability) to have occurred by chance. Events other than random effects have occurred.  
   Sampling error often accounts for different means even when the samples come from the same population.  
   There is a “treatment effect.”*
5. Can means be different but not significantly different? Explain your answer.  
   *Yes, but not different enough to rule out random chance.*
6. How can science be used to address “big” issues such as climate change?  
   *Tough to account for every global variable, because of long term natural processes. Hypotheses testing using data from temperature observations can lead to predictions.*
7. Some people dismiss evolution by natural selection as being “only a theory.” Biologists often respond that yes, evolution *is* a scientific theory. What does this mean?  
   *A theory includes general, unified, and often complex hypotheses that make predictions and explain many observations of evolution without direct tests over time.  
   A theory is complex; its specifics are being continually modified and polished.*
8. A hallmark of a scientific theory is that it is falsifiable. What does this mean, and why is it important?  
   *Boundaries of science are observable facts.  
   Those that are not descriptive are testable and investigative in nature.  
   Supporters of a theory should be able to describe plausible data that would disprove the theory.  
   Falsifiable means that the theory is subject to the clear support of clear evidence, and by implication, the theory could possible be disproved by similarly clear evidence.   
   If there is no way that a theory could ever be proven wrong then the theory is weak.*

Additional Outside Resources

* The Scientific Method video: TBRA-354439, Teacher’s Media Company, 1-800-262-8837
* Scientific method, DVD, 25 min. Insight media, [www.insight-media.com](http://www.insight-media.com), order #BAS3232
* The Scientific method (CD-ROM) [www.insight-media.com](http://www.insight-media.com), order #BAS3672