Exercise 2
MEASUREMENTS IN BIOLOGY: THE METRIC SYSTEM AND DATA ANALYSIS

This is a simple lab exercise, especially the information about the metric system, but we've found that well over half of our students do not understand the concepts of mean, range, median, and variance. The most critical words to be defined in an introduction to the lab exercise are <u>central, tendency</u> and <u>variation</u>. Biology is filled with variation and students must learn not only to document variation, but to view variation as part of natural processes rather than a sign of error. The basic theme of this exercise is that understanding any simple biological data set begins with measures of central tendency and measures of variation about the mean.

SUGGESTED ELEMENTS FOR AN INTRODUCTORY LECTURE

- Quantifying of data is essential for good science.

- The natural world, especially the life sciences, is filled with variation.

- Natural variation often makes simple observation inadequate for the study of living processes.

- To deal with variation, biologists employ the scientific method and careful quantification of data.

- The most conventional and widely used tool to express scientific data is the metric system.

- The metric system need not replace the English system in all walks of life. But, it is a powerful and efficient tool for the usually calculation-intensive sciences.

- Scientists rarely convert from one system to the other. Instead, they work within the metric system. Conversions within the metric system are more important than conversions between systems.

- Metric units fall neatly into measures of length, volume, mass, and temperature, and are based on multiples of ten.

- The initial and most fundamentally important analysis of a data set is to determine the central tendency (mean, mode, median) and the variation (range, variance, standard deviation) inherent in the data.

INVESTIGATIVE PROCEDURE

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

ACTIVITIES

1. Make metric measurements of length, width, volume, mass, and temperature for common objects.
2. Calculate mean, median, range, variance, and standard deviation for example data.
3. Gather and statistically summarize a data set of student heights.

VOCABULARY

density	kilogram	mean
median	meniscus	meter
metric system	range	standard deviation
statistics	sum of squared deviations	variance
volume		

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.

One–Three days before lab:
Place beaker of tap water in refrigerator.
Distribute materials to each work station.

One hour before the lab:
Fill the ice chest with crushed ice.
Heat water if hot tap water is not available. A large flask of water should be fine for the entire class.

√ Materials	Quantity Needed Total	Per Group	Catalog Number
Equipment			
___ triple beam balance	_____	_____	15 W 6057
___ refrigerator	_____	_____	
___ calculator or computer	_____	_____	
___ small open-topped ice chest	_____	_____	

Supplies: one set per group

___ meter stick or metric tape measure	_____	_____	
___ common items to measure (coffee cup, book, nickel, paper clip, golf ball)	_____	_____	
___ 10-ml graduated cylinder	_____	_____	18 W 1705
___ 100-ml graduated cylinder	_____	_____	18 W 1730
___ 100-ml beaker	_____	_____	17 W 4020
___ 10-ml pipet	_____	_____	17 W 1308
___ 5-ml pipet	_____	_____	17 W 1307
___ pipet dispensing bulb	_____	_____	15 W 0511
___ gallon jug (milk jug)	_____	_____	
___ eye dropper	_____	_____	
___ centigrade thermometer	_____	_____	
___ pencil	_____	_____	
___ marble	_____	_____	
___ small rock (1")	_____	_____	

Solutions
___ hot, cold, and refrigerated tap water _____ _____

COMMENTS ON PROCEDURES

- A guide to the metric system and conversions may be helpful in addition to the information provided in the lab manual.

- We also provide a few objects of unknown mass, volume, and dimensions for the students to measure. The class results are put on the board, collated, and the variation is discussed.

- 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:

  o Carolina Biological Supply Company, www.carolina.com

  o Fisher Scientific, www.fishersci.com

- Safety first: Be sure and cover any safety issues that may be specifically related to this lab procedure.

ANSWERS TO QUESTIONS

1. Make the following conversions.
1 meter = 100 centimeters = 1000 millimeters; 92.4 millimeters = 0.0924 meters = 9.24 centimeters; 10 kilometers = 10,000 meters = 100,000 decimeters; 82 centimeters = 0.082 meters = 820 millimeters; 3.1 kilograms = 3,100 grams = 3,100,000 milligrams

2. What are some potential sources of error in your measurements?
angle of vision, building, posture when measuring height, variation in dimensions of a page, table, room, ceiling, mistakes in reading the ruler, etc.

3. What volume of liquid did you measure?
variable

4. **a.** Density is mass per unit volume. Use data that you've already gathered to determine the density of water at room temperature. r.
Density of water = (mass/volume = 1 gram / 1 milliliter).

   b. What is the density of the wooden pencil? Does it float?
   Because wood is less dense than water, the pencil will float. The density of the pencil will vary.

   c. What is the density of the rock? Does it sink?
   Because the rock has a higher density than water, it will sink. The exact density of the rock will vary.

5. **a.** Does the mean always describe the "typical" measurement? Why or Why not?
   No, because the mean can be dramatically affected by a single, extreme atypical measurement. And, the mean may be calculated to a portion of a single unit; i.e., the mean number of children per family is 2.3, but no family actually has 2.3 children.

   b. What information about a sample does the mean not provide?
   It does not provide information about variation, range, and extremes outside of the mean.

6. **a.** What is responsible for this difference between the mean and median?
   The distribution of numbers throughout the range is uneven.

   b. How would the median change if the 9-mm-long shrimp was not in the sample?
   The median would not change.

   c. How would the mean change if the 9-mm-long leaf was not in the sample?
   The mean would change from 58.6 to 62.4.

   d. What is the mean for sample 1?   sample 2?
   Both means = 30.

7. **a.** Could two samples have the same mean but different ranges? Explain.
   Yes, the mean does not reflect the distribution of numbers.

   b. Could two samples have the same range but different means? Explain.
   Yes, uneven distributions of numbers within the same range could produce different means.

8. **a**. What does your calculation tell you?
   Conclusions vary (males usually taller than females, range for males usually greater than range for females, etc.).
   b. What are the limitations of your sample?
   There can be great variation in any sample size.

Questions for Further Thought

1. What are the advantages and disadvantages of using the metric system of measurements?
   base 10 of units, easy to convert between scales
   Unfortunately many scientists and businesses are in countries using the English standards of units and measurement scales.
2. Why is it important for all scientists to use a standard system of measures rather than the system that may be most popular in their home country or region?

Good science must be repeatable.
Standards assist scientists from different countries who are working together to repeat investigations. Their cooperative effort and repetition of the experiments strengthen the validation of the results.

3. Do you lose or gain information when you use statistics to reduce a population to a few characteristic numbers? Explain your answer.
   fewer examples in regulation, greater the rise of detecting a difference when none really exists
   One loses information. A few "characteristic numbers" can not =fully describe the variation among all members of a population.

4. Suppose that you made repeated measurements of your height. If you used good technique, would you expect the range to be large or small? Explain your answer.
   Small, with repeated measures improve technique and thus more precision and accuracy.

5. Suppose that a biologist states that the average height of undergraduate students at your university is 205 cm plus or minus a standard deviation of 17 cm. What does this mean?
   The mean value is 205 cm. 68% of students range between 118cm – 222cm

6. What does a small standard deviation signify? What does a large standard deviation signify?
   low variance
   high variance

7. Is it possible to make a perfectly precise measurement? Explain.
   No, only in theory. Uncertainty is in all measurements.

8. *When in our everyday lives do we not want precise measurements?*
   late for work, utilities rates, physical attributes, age

ADDITIONAL OUTSIDE RESOURCES

- Powers of 10 by Charles and Ray Eames, can be purchased online at:
  HTTP://WWW.POWERSOF10.COM/

- Measurements in Science (Powerpoint), www.insight-media.com, order no. BAS3650