INTRODUCTION TO THE LABORATORY
PROCEDURES FOR OBTAINING AND PRESENTING DATA
Exercises for Lab 1

Introduction

In science, precision in obtaining and reporting information is essential. This information is collected as data that will then be analyzed and used to help us understand and explain the world around us. Data is obtained by direct observation or by experimentation. Observational data are obtained by watching but not altering the system we are studying. Experimental data are obtained by altering one variable in the system and recording the response of the system to that alteration. This type of data collection requires the use of a control to validate the experimental design. A control is the same as the experimental group in all aspects except the variable being tested. This factor, called the "independent variable," is varied in the experimental group and held constant in the control group. The factor in the experimental group, which varies in response to alterations in the independent variable, is called the "dependent variable." Various instruments are often used to aid in the collection of both observational and experimental data.

Objectives

A. To learn how to make measurements, in metric units, using appropriate laboratory equipment.

B. To learn how to organize data and present it in tabular and graphic forms.

Principles

Both observational and experimental data require precise information. Sometimes this data is qualitative but more frequently it involves quantitative measurements. This means that some specific type of measurement is made. In this exercise you will examine and evaluate some aspects of data collection.

Once data has been collected, the results must be analyzed. To facilitate interpretation and analysis, the data must be carefully organized. Usually this means recording it in tables and graphs rather than in written form. Tables and graphs are more concise presentations of the data; thus, comparisons are easier to make and the effect of the independent variable on the dependent variable is more easily seen. In this exercise you will become familiar with the presentation of data in tabular and graphic form. Quantitative data will initially be analyzed using a few statistical tools. The mean (average) and the standard deviation (variability about the mean) can be readily calculated with inexpensive statistical calculators or computer spreadsheet programs. In addition, you will use spreadsheet programs to quickly produce several scattergrams displaying calculated trend lines and the appropriate correlation coefficients for the data. The analyzed data will help you to draw up a few tentative conclusions

Procedures

A. Before you begin this exercise, make certain that you have all of the following materials readily available:

Meter stick
1 mL pipette
5 mL pipette
10 mL pipette
Pump pipetter
1000 μL Micropipetter and tips
Plastic containers filled with colored water
100 mL beakers, empty and labeled "for collection"
100 mL graduated cylinder
125 mL Erlenmeyer flask
100 mL beakers
Electronic balance, 500 g capacity
Weighing boats
10 g of NaCl in plastic containers
Weighing spatula
Human skeleton

B. Measuring mass

1. You will use the provided electronic balance to obtain mass measurements. It can weigh objects from 0.01 to 500 grams with an accuracy of 0.01 grams. Your Laboratory Instructor will demonstrate how to weigh objects with the electronic balance. Keep the balance pan clean and level. Be sure nothing on the lab table (wires, etc.) is touching the balance tray.

2. Obtain a weighing boat and place it on the balance. Tare the balance.

3. Using a weighing spatula, carefully add just enough NaCl to the weighing boat to obtain a total mass of 2.00 g of this material. *Do not put excess salt back into the source container. Dispose of excess salt in the assigned*

waste container. Remove the weighing boat with the NaCl from the balance and set them aside for later use.

4. Fill the 100 mL graduated cylinder with 50 mL of water. Pour the 50 mL of water into a beaker.

5. Add the NaCl to the water. Then place the beaker with the salt-water mixture onto the pan of the balance and determine the total mass.

6. Compare the actual mass of the solution to what you expected the mass to be. (Recall that the density of pure water at room temperature is very close to 1.00 g/mL). Can you explain any differences between the expected total mass and the actual mass?

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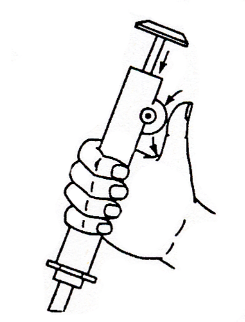
C. Practice Measuring volume

Pipets

1. Obtain a 1 mL, a 5 mL, and a 10 mL pipette.

Determine how each of the pipettes is calibrated. Both the largest and smallest volumes that a pipette can be used to measure are marked on the upper end of the pipette. The first number gives the total volume and the second number indicates how the pipette is calibrated into smaller dimensions. For example, the numbers 1 in 1/100 would indicate that the pipette measures a maximum of 1 mL volume but is graduated in 0.01 of a mL so that accuracy is to two decimal places.

Obtain a pump pipetter. Your laboratory instructor will demonstrate its use.



Pump pipetter

2. Using the 1 mL pipette, carefully draw the colored water into the pipette to a point slightly above the 0 level. Release water until the meniscus reaches the 0.8 mL mark. To read the level correctly, your eye should be directly in line with the meniscus. The bottom of the meniscus marks the correct volume. Release the water into the beaker labeled "for collection." Repeat this measurement.

3. Using the 5 mL pipette, practice measuring 3.2 mL and 4.8 mL of the colored water.

4. Using the 10 mL pipette, practice measuring 6.1 mL and 7.3 mL of the colored water.

Micropipetter

1. Obtain the appropriate micropipetter to measure a volume of 800 μL. Your laboratory instructor will demonstrate its use. Unlock the micropipetter and dial it to 800 μL and relock it (avoid over-tightening). Select the appropriate plastic pipetter tip.

2. Obtain a clean and dry weighing boat and tare it on the electronic balance. Draw 800 μL of distilled water, place the volume in the weighing boat, and find its mass on the electronic balance. Make a note of the mass (actual volume) in the table below.

3. Use a Kimwipe® to dry the weighing boat and find the mass of a second volume of 800 μL of water. Make a note of the mass.

4. Repeat the procedure until you have made ten samples. Use MS Excel® or a calculator to calculate the mean volume and standard deviation.

Mass of 800 μL measured on an electronic balance

Mass 1	Mass 2	Mass 3	Mass 4	Mass 5	Mass 6	Mass 7	Mass 8	Mass 9	Mass 10

Mean volume: _______________ Standard Deviation:________________

Graduated Cylinder, beaker, and Erlenmeyer flask

1. Obtain a 100 mL graduated cylinder and weigh it to the nearest 0.01 g on the electronic balance. Fill the cylinder with 60 mL (determined visually) of colored water. Compare the volume made at the correct position, which is

eye level, with those made from a standing position and from below (See Figure 1).

Weigh the graduated cylinder and the water on the electronic balance. Determine the volume of water in the graduated cylinder by its mass. How accurate was your determination of the volume of water in the cylinder when you viewed the meniscus at eye level compared to the volume determined by its mass?

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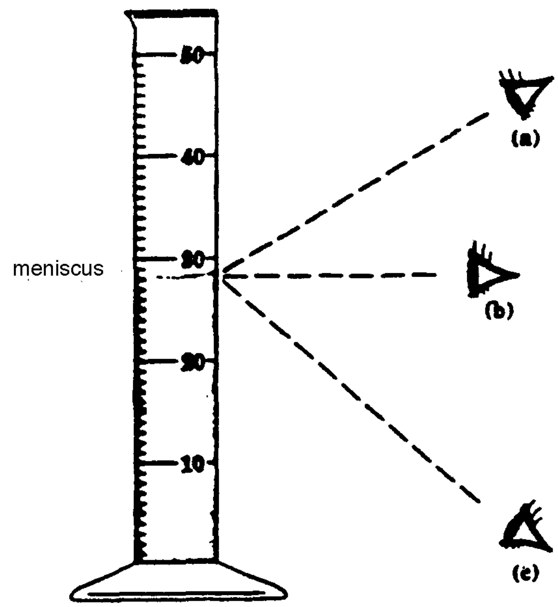

Figure 1. Different views yield differing volumes

Volume of a 60 mL water sampled determined by two methods

	Volume 100 μL cylinder	Volume 100 μL beaker	Volume 100 μL Erlenmeyer flask
Determined by meniscus			
Determined by mass			

2. Repeat the same procedure with a 100 mL beaker.

3. Repeat the same procedure with a 100 mL Erlenmeyer flask

4. Which device was most accurate for measuring a 60 mL volume? ______

D. Measuring length

1. It is possible to estimate a person's height by knowing the dimensions of other parts of the body. For example, the height of an individual can be estimated from length of his/her femur or from the width of their hand span. Anthropologists can make such estimates when they obtain only part of a skeleton. Such knowledge can also help artists render anatomy correctly.

2. Divide your class into two groups of students (8-16 students per group); make sure that there is a wide range of heights in both groups.

3. Measure the height of all of the students in your group. Make sure that all subjects stand with both heels flat on the floor. (*Note: For safety reasons, students should keep their shoes on during all height measurements since there might be unseen sharp objects on the floor*. *Can you compensate for the addition to height provided by shoes? How many other variables can you list that might influence the accuracy of your measurements?)* Record the data in the table below.

4. Measure the femur length and hand span, in centimeters, of all of the students in your group.

   For the femur length, measure from the knee joint to the hip joint. Observe the femur bones of the human skeleton to help you determine the end-points of a femur. Figures 2-4 may help with points of reference for the making accurate measurements. Record the data in the appropriate table.

   For the hand span, spread the fingers out fully and measure distance in centimeters from the tip of the thumb to the tip of the smallest finger. Again examine the human skeleton and check with figures 5 and 6. Record the data in the appropriate table.

5. Calculate the height-to-femur ratio for each of the subjects in your group. To do this, divide each subject's height in centimeters by his/her femur length in centimeters. Record the data in the following table 1.

Table 1. Heights and femur lengths of your group

Subject name	Height (cm)	Femur length (cm)	Height / femur

Calculate the height-to-hand span ratio for each of the subjects in your Group. To do this, divide each subject's height in centimeters by his/her hand span in centimeters. Record the data in the following table 2.

TABLE 2. Heights and hand spans of your group

Subject name	Height (cm)	Hand span (cm)	Height / span

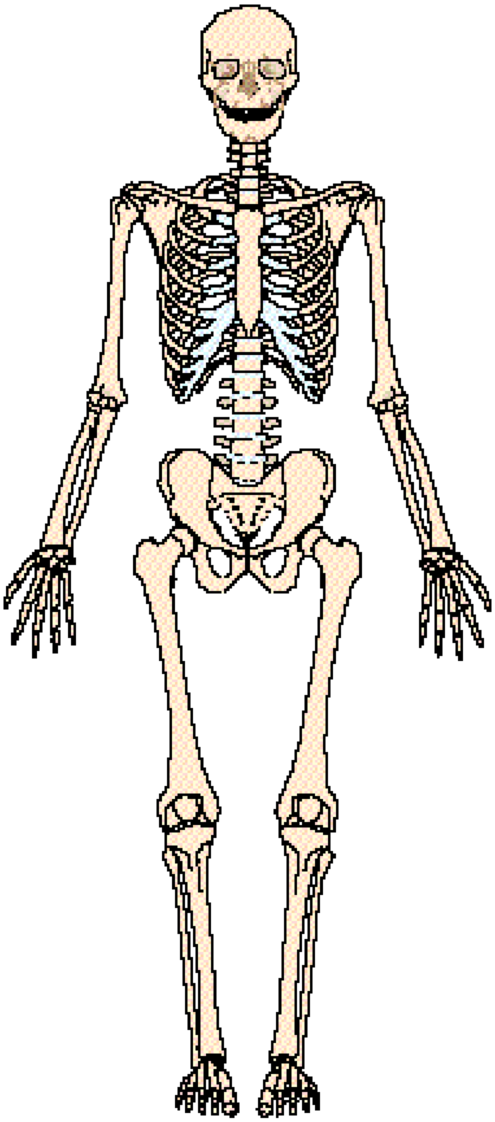

Figure 2. Human skeleton

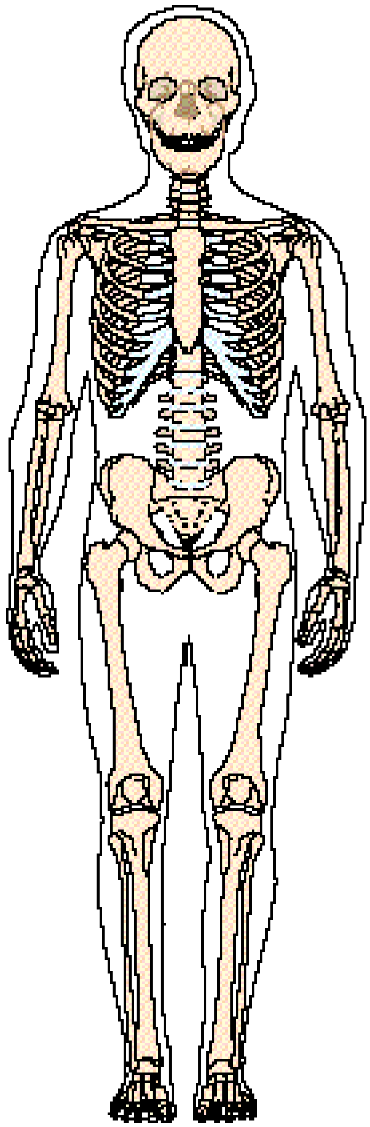

Figure 3. Skeleton with soft tissue outlined

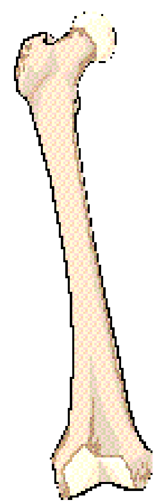

Figure 4. Femur

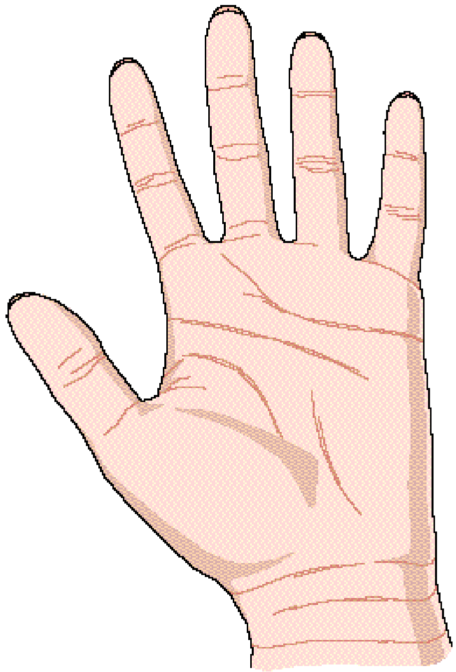

Figure 5. Human hand

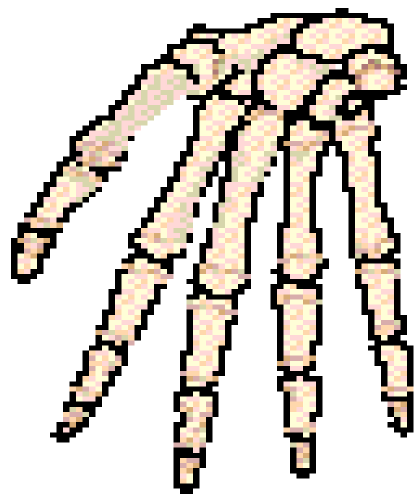

Figure 6. Bones making up human hand

6. a. Calculate the average height-to-femur ratio and the standard deviation for your group. Record that number here: __________

   b. Calculate the average height-to-hand span ratio and the standard deviation for your group. Record that number here: __________

7. Obtain the femur length, in centimeters, of all of the students in the other group. Record the data in Table 3 below.

   Obtain the hand span, in centimeters, of all of the students in the other Group. Record the data in Table 4 below.

8. a. Estimate the height of each student in the other group by multiplying each subject's femur length by the average height-to-femur ratio for calculated for your group. Record these estimates in Table 3.

   b. Estimate the height of each student the other group by multiplying each subject's hand span by the average height-to-hand span ratio for Group

   Record these estimates in the appropriate columns in Table 3.

9. Now obtain the actual height of each of the students in the other group. Record the data in table 3 below.

Table 3. Other group's estimated and actual heights

Subject name	Femur length (cm)	Estimated Height (cm)	Hand span (cm)	Estimated Height (cm)	Actual height (cm)

E. Presenting data in tabular and graphic forms

1. When arranging data in a table, the values for the independent variable are arranged in order of increasing or decreasing size. The values for the dependent variable are then recorded beside the corresponding values for the independent variable.

   Set up a table for recording the following data on the growth of a plant over time: After 2 days of growth, the plant is 1.7 cm tall; after 4 days of growth, it is 2.8 cm tall; after 6 days of growth, it is 5.2 cm tall; after 8 days of growth it is 8.2 cm tall; after 10 days of growth, it is 9.6 cm tall; after 12 days of growth, it is 10.2 cm tall; and after 14 days of growth, it is 10.3 cm tall.

2. Fill in the table with the data given above. Make sure you understand which is the independent variable and which is the dependent variable before you complete the table. Be sure to include an appropriate title for your table.

3. Now you will construct a graph using this same data. Before you begin, read the following general rules for graph construction:

   a. When constructing a graph by hand, always use graph paper to plot the points accurately.

   b. Unless the graph is being printed as a described figure as part of your formal report, always use a descriptive title for a graph.

   c. The independent variable should be represented on the X- (horizontal) axis. The dependent variable is always represented on the Y- (vertical) axis. Label both axes with the name of the variable and the units of measurement used.

   d. Set the minimum values on both axes slightly below the minimum values of the data, or at zero, whichever is most appropriate for the data. Set the maximum values on both axes slightly above the maximum values of the data. The data should extend over most of the graph's area.

   e. Space intervals evenly along each axis.

   f. Plot data points only at coordinates where data were collected.

4. Construct a scatter gram graph of the plant growth data given above by either using one of the sheets of graph paper at the end of this protocol or a spreadsheet program such as MS Excel®. Connect adjacent data points with a best-fit curve (not a trend line).

Results and analysis

1. On your graph of plant growth over time, draw in a broken line extending the line you previously drew between points out beyond the range of the data. The broken line portion of the graph is called an "extrapolation" because it goes beyond our actual experience with this particular experiment. Extrapolation can be used to predict data beyond the given limits of this experiment. What would you predict the height of this plant would be after 15 days of growth?

2. Between any two measured points it is possible to make what is called an "interpolation" or estimate of size if one assumes that growth is occurring at a uniform rate between two points. What would you estimate the height of this plant to have been after 3 days of growth?

3. Construct two separate scatter grams using the height/femur length data for one graph and the height/hand span data for the other. Plot the height on the Y-axis. Plot a trend line and label the graph with the formula for a line and the correlation coefficient.

   a. Is there any obvious correlation between height and femur length and height and hand span?
   b. How good are your height/femur length and height/hand span ratios for predicting a person's height?
   c. Which system of estimating height appears to be more accurate? What are some possible reasons why one system of estimation appears to work better than the other?

4. How closely did the height-to-femur and height-to-hand-span ratios predict the height of the students in Group 2? Why might the height-to-femur ratio be more useful to an anthropologist than the height-to-hand-span ratio? When might the height-to-hand-span ratio be a more useful tool for predicting height of an individual?

5. In 1984 a skeleton of a 12-year-old *Homo erectus* boy (Nariokotome boy, KNM-WT 15000) was discovered on the prehistoric shores of Kenya's Lake Turkana. The skeleton was 1.6 million years old. Except for the skull, the skeleton is very similar to that of *Homo sapiens*. From the fairly complete skeleton, anthropologists calculated that the boy was about 1.6 meters tall. Using your calculations on the height-to-femur ratios, estimate the length of the boy's femur. Suggest some variables that will confound your estimates?

6. What are some possible sources of error in the techniques and instruments you used to measure length, volume, and mass?

7. Would a 1.0 mL pipette or a 10 mL graduated cylinder be the most appropriate instrument to measure 8 mL of water? Explain your answer. What generalizations can you make about the accuracy and precision of measurements of volume and length?

Text reference pages On reserve in the Life Science Library

Starr, C (2006). *Biology: Concepts and Applications. Pp. 538-539.*

Introduction: The Nature of Science (pp. 14 - 19)

Photo Atlas reference pages

Perry and Morton (1996). *Photo Atlas for Biology*, 1st ed.,

Page 136: Figure 136a (Human femur)

Further Readings

Brothwell, D.R. (1972). *Digging Up Bones: The evacuation, treatment, and study of human skeletal remains*. London: British Museum of Natural History

Christiansen, J.M. & Steele, D.G. (2000). *The Anatomy and Biology of the Human Skeleton*, College Station. TX: Texas A&M Press.

Leakey, R. & Walker, A. (1985). A Fossil skeleton 1,6000,000 years old: *Homo erectus* unearthed. *National Geographic*. 168: 624-629.

Schwartz, J.H. (1995). *Skeleton Keys: An introduction to human skeletal morphology, development and analysis*. New York: Oxford University Press.

Walker, A. & Leakey, R. eds. (1993). *The Nariokotome* ***Homo erectus*** *Skeleton*. Cambridge, MA:Harvard University press.

Walker, A. & Shipman, P. (1996). *The Wisdom of the Bones: In search of human origins*. New York: Vintage Books.

Addendum: Examples of various types of laboratory equipment