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Converting the labs in an introductory biology course from cook-book to investigative

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http://zoology.okstate.edu/zoo_lrc/biol1114/guest

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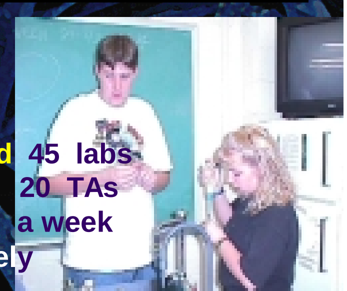
Course Context



The course:

- for ALL majors
- 900 students / semester
  - in 6 lecture sections and 45 labs
  - by 6 lecture faculty and 20 TAs
- Labs are three hours once a week
- Students work collaboratively
  - Three students per group
  - Lab reports written as a group
  - Same groups in Lecture & Lab

Goals for the lab

- To promote an understanding of the process of science, so students can
  - Form testable hypotheses to answer questions
  - Design & conduct experiments to test hypotheses
  - Analyze and graph data and report findings
  - Cope with unsupported hypotheses and design flaws
- To allow students to engage in explorations that will lead them to biological concepts
- To familiarize students with current technology and techniques.

Motivating Factors

Pedagogy/Educational needs

- Student performance/attitude was lower than desired ....."Labs are BORING"
- Lab exercises were primarily verification
  - TA tells them what they will find
  - Students follow set directions for 2 hours to achieve desired result and fill in lab manual
  - TA tells students what they should have found
  - TA gives a quiz to test students' recall of facts presented by TA
- Students learn nothing about conducting research

National Science Education Standards

Promote science education that stresses inquiry, experimentation, and critical thinking over memorization of detail

So how do you get started?

?

Plan outcomes

Choose your goals & objectives

- **Process**
  - Which experimental skills should students pursue in lab?
  - Which experimental skills should students master in lab?
- **Concepts**
  - Toward which concepts should students be directed?
  - Which concepts should students master?
    - Use terms appropriately in context
    - Apply concepts to interpretation of results
- **Technical**
  - What laboratory, computer, data analysis skills should students learn to perform?

Goals/Objectives - Example

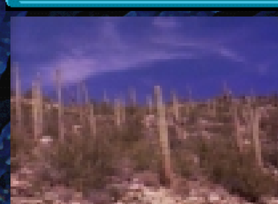
Target Concepts and Skills:

- Process (Scientific Method)
  - Write a clear Hypothesis
  - Design a Controlled experiment to test hypothesis
  - Recognize biases that affect results
  - Make Predictions based on hypothesis/experiment
  - Collect Data
  - Display results
  - Draw appropriate conclusions
  - Discuss in comparison to literature/theory
- Concepts
  - Introduce Rate
  - Introduce S/V Ratio
  - Begin to develop an understanding of the relationship of S/V Ratio and heat loss
  - Introduce gradient

Pose a Question

1. Larger *Quattro variegatus* are eaten more often because they are easier to see.
2. Body Shapes influence the rate of heat gain of loss in a predictable way.
3. How is metabolic rate influenced by ambient temperature?
4. How do various factors influence the passage of materials through a membrane?
5. How can cell structure be used to identify cell type, function, or location?
6. How does nut diversity and abundance influence survival of birds with different beak types?
7. How does the color of light influence the rate of photosynthesis?
8. How do environmental or anatomical factors effect the rate at which plants remove water from the soil?
9. How does drug type or UV radiation influence evolution of antibiotic resistance?
10. How can the genetic composition of bacteria be altered in the laboratory?
11. How can genetic material be identified in the laboratory?
12. How does sewage affect benthic and algal species diversity in streams?
13. How is anoxia caused in polluted streams?
14. How do guppies select mates?

Provide a Background/Context

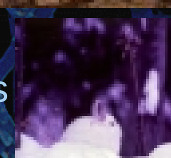


Biomes

(environment)

Characteristics

(Adaptations)



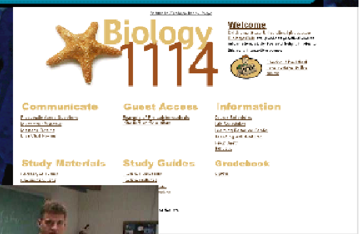
Background Story in Lab

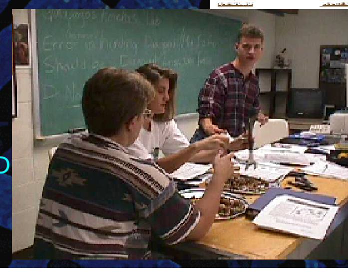
A scientist spent a great deal of time observing these two birds and measuring their internal body temperatures under different environmental temperatures. Based on her observations and temperature data, she is convinced that body shape and thermoregulatory ability are related. Furthermore, she is convinced that she can find a way to predict the rate of heat gain or loss from some measure of body shape.

How will you prepare students?

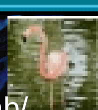
Pre-Lab Activities

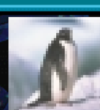
- Subject
  - Technique
  - Analytical Skills/ Calculation
  - Information
- Sources
  - LRC
  - WWW
  - Lab Manual, Textbook. CD





Possible Student-Generated Hypotheses





Are they:

- Derived from observations (pre-lab/ lecture/ background material)
- causal
- testable within context of laboratory
- falsifiable
- leading to specific predictions
- should help you define necessary equipment for laboratory
- Not necessarily the correct answer

What will students need?

Lab Specific

- Equipment
- Instructions
- Failure Points

Larger *Quattro variegatus* are eaten more often because they are easier to see.

I. BACKGROUND

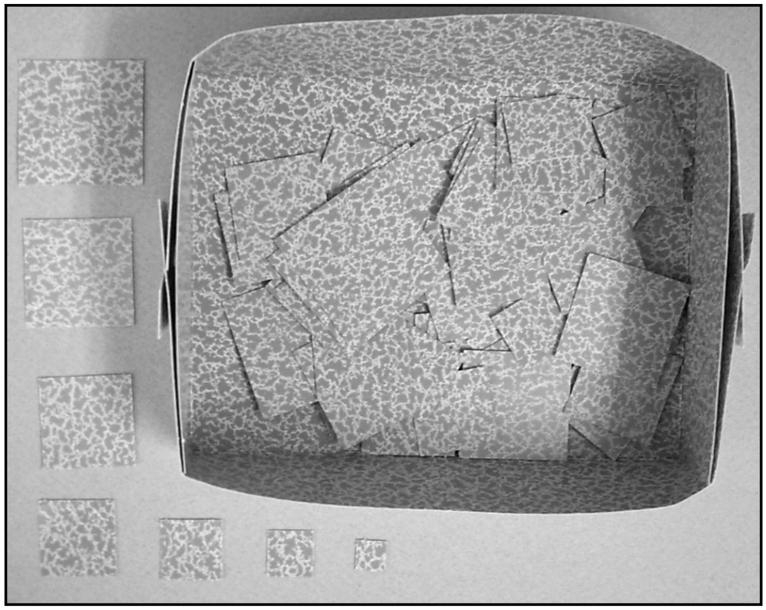


Figure I1.1—*Quattro variegatus* in its natural habitat. Surrounding the "live" individuals in the container are seven museum specimens representing the seven commonly found sizes. For reference, the largest *Q. variegatus* pictured is 51 mm on a side.

A scientist is investigating the alarming rate of disappearance of the largest, most mature, and best breeding *Quattro variegatus*. This species is four-sided in shape and highly dorso-ventrally compressed. It lives communally in a highly patterned environment and is extremely cryptic, taking advantage of disruptive coloration. Its major predator is a large, bipedal, ambidextrous mammal with binocular, color vision. The scientist spends time observing predation techniques and examining the stomach contents of the predator and finds that the larger *Q. variegatus* are eaten more frequently than the smaller ones. Unfortunately, there has never been an easy way to determine the gender or age of a *Q. variegatus*. When she samples populations, she does not find equal numbers of all sizes. She hypothesizes that larger individuals are eaten more frequently than smaller ones because they are more readily seen. Is she correct?

A. Pre-lab Activities

After completing this pre-lab, you should be:

- familiar with the organization of the lab manual
- aware of how to conduct lab and write a report
- familiar with the experimental conditions for this lab
- able to discuss some mechanisms that organisms use for camouflage and how they work
- able to explain how the probability of capturing a particular type of prey is related to its relative abundance

1. Carefully read the sections “How to successfully conduct a lab” and “How to write a lab report” in this lab manual.
2. Observe the photograph of *Quattro variegatus* in its natural habitat (Figure I1.1) and be prepared to discusses your ideas on how it is predated and why certain sizes are eaten more frequently. There are “live” *Q. variegatus* in the LRC.
3. Complete the tutorial on Disruptive Coloration and/or Predator Avoidance Mechanisms on your lab computer, the LRC computers or the WWW.
4. Find the bucket of beads or marbles in the lab or LRC or on the WWW. In it are two colors of beads or marbles. If you reach in and grab ten of them, how many of each color would you expect to have? Why? Test your prediction. How many did you actually get? If you replaced the beads and repeated the procedure again, what would you expect? What happened? Why? What would the results of 100 repetitions be?

B. Terms/ Concepts of Potential Interest for use in Report

Disruptive Coloration	Foraging Theory	Visual Acuity
Encounter Rate	Size Distribution	Alternate Hypotheses
Crypsis	Search Image	Double-blind Experiment

C. Special Equipment and Materials

Quattro variegatus squares and box

D. Special Instructions

None

E. For additional assistance, check the investigation’s website at http://zoology.okstate.edu/zoo_lrc/biol1114/study_guides/labs/lab1.htm

Planning Form

Name ________________________________ Section # ______

General Question Under Investigation:

Hypothesis(es) to be investigated:

Predictions:

Outline of Experiment

1. Procedures

2. Equipment

3. Type of Analysis ❑ Table ❑ Descriptive ❑ Graph ❑ Mean ❑ Statistical ❑ Other

   Describe:

References (textbook, library articles, URL)

____

____

____

Summary of results from Pre-Lab activities: (Use other side)

Lab Instructor Only											
Score	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**

Lab Notes

Name ______________________________ Section # ______ Date __________

Objective:

Experiment #____ —Goal

Hypothesis to be tested:

Alternate Hypotheses:

Rationale for hypotheses:

Experiment #____ —Design

Independent (Manipulated) Variable(s)

Dependent (Measured) Variable(s)

Prediction(s) and what they would tell you

Modification(s) of laboratory manual procedures

Experiment #____ —Observations during experiments

Experiment #____ —Data

Experiment #____ —Calculations/Analysis Scratch Space

Name: Section #	Score				
Grading Scheme for Lab Reports	**1**	¾	½	¼	**0**
Introduction					
1 Statements of question & hypothesis(es) under investigation are clear and correct.					
2 Provides logical argument for why question & hypothesis(es) are being investigated.					
Methods					
3 Experimental design is described completely and clearly.					
4 Steps/procedures are justified.					
5 Experimental and control variables and assumptions are correctly chosen and justified.					
6 Methods provide for appropriate test of selected hypothesis.					
Results					
7 Data are presented without causal interpretation or implications.					
8 Data are summarized and displayed appropriately in graphs or tables.					
9 Trends in data are made clear in text without repeating the information in tables or graphs.					
10 Figures and tables are properly numbered, captioned, and are referred to in text.					
11 Figures and tables can be properly interpreted without reference to text.					
Discussion					
12 Questions and hypotheses stated in introduction are addressed.					
13 Conclusions are supported by the data.					
14 Alternative explanations are discussed.					
15 Speculations are clearly stated as such and logically derived from data.					
16 Additional hypotheses are generated.					
17 Unexpected results are interpreted without unnecessary reference to experimenter error.					
18 Appropriate comparisons to textbook(s) are made and properly cited.					
19 Interpretations and information presented are correct given sources available to student.					
General					
20 Writing is clear and free of grammar, spelling, and punctuation errors.					
Extra Credit (+ 1 pt each)					
1 Data are analyzed statistically. (x3)					
2 Appropriate comparisons to literature are made and properly cited.					
3 Methods are illustrated by images or graphics.					
4 Additional experiments are designed.					
5 Additional experiments are completed.					
Subtotal:					
Total:					

Body shapes influence the rate of heat gain or loss in a predictable way.

I. Background

A scientist spent a great deal of time observing the two birds shown below (Figures I2.1 and I2.2) and measuring their internal body temperatures under different environmental temperatures. Based on her observations and temperature data, she is convinced that body shape and thermoregulatory ability are related. Furthermore, she is convinced that she can find a way to predict the rate of heat gain or loss from some measure of body shape. Generate a specific hypothesis about the relationship between body shape and ability to gain/lose heat then test your hypothesis(es).

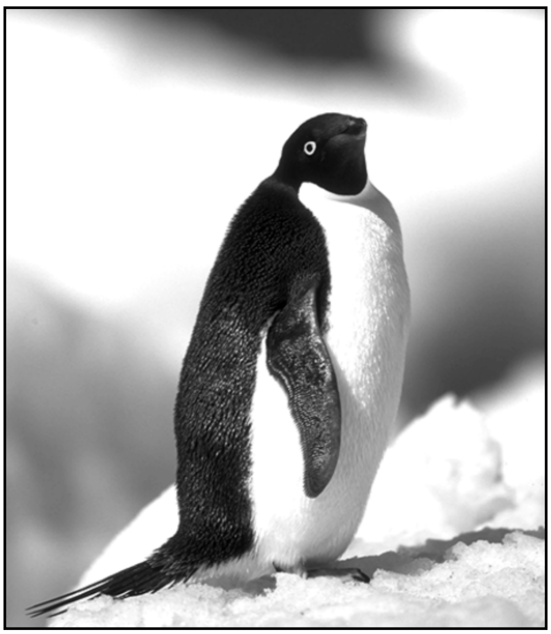


Figure I2.1—Penguin

Figure I2.2—Flamingo

A. Pre-lab Activities

After completing this pre-lab, you should be able to:

- use Excel to graph data
- use the temperature sensor
- fit a trend line to data and explain what it represents
- use calipers to measure objects
- determine rate from a graph
- explain the relationships among length, weight, surface area, and volume, and to predict one from another

1. Surface & Volume

a. Obtain a set of wooden cubes in the LRC.

b. Measure the length, width & height of each using calipers.

c. Calculate the surface area of each.

d. Calculate the volume of each.

e. Weigh each.

Block	**Length**	**Width**	**Height**	**Surface Area**	**Volume**	**Weight**
1						
2						
3						
4						
5						

2. Use Excel to create an X-Y graph with volume on the X axis and surface area on the Y-axis. Be sure to label it properly.

☐ ______
TA Initials

a. Fit a trend line to the data. Be sure it shows the equation.

b. Which increases faster, surface area or volume?

c. Explain whether a straight line is the best line to fit to the data.

3. Use Excel to create an X-Y graph with length on the X axis and weight on the Y-axis. Be sure to label it properly.

☐ ______
TA Initials

a. On the same graph, plot Volume on a second Y-axis

b. Fit a trend line to each of the data sets. Be sure it shows the equation.

4. **Assuming the following objects are made of the same material as the objects you measured, answer the following questions using the technique you learned above and the equations you created.**
   a. What is the surface area of a cube with a volume of 49 mm^3? __________
   b. What is the weight of a cube that is 16 mm long? __________
   c. What is the volume of a sphere that weighs 18 g? __________

5. **Using a Vernier temperature sensor, measure the temperature of 50 ml of water every 15 seconds for 2 minutes after you microwave it for 30 seconds. Graph the data and determine its rate of cooling.**

☐ ______
TA Initials

B. Terms/Concepts of Potential Interest for Use in your Lab Report

Thermoregulation	Heat Radiation
Evaporation	Convection
Conduction	Core Body Temperature

C. Special Equipment and Materials

Because birds are difficult to handle and clean-up after (would you want to?), you will be given the opportunity to test your hypothesis with about 12 ½ oz. of clay in four different colors. You may mold your clay into whatever shape you think best. Keep in mind that you will need to quantify shape to answer the question. In addition to clay, you will have thermometers (thermal probes) and lamps or water baths.

D. Special Instructions

Warnings: Clay melts—it cannot be placed on a hot plate! The lamps can get very hot. After they have been on for a while you should be careful when handling them.

E. For additional assistance, check this investigation's website at zoology.okstate.edu/zoo_lrc/biol1114/study_guides/labs/lab2.htm

Planning Form

Name ________________________________ Section # ______

General Question Under Investigation:

Hypothesis(es) to be investigated:

Predictions:

Outline of Experiment

1. Procedures

2. Equipment

3. Type of Analysis ❑ Table ❑ Descriptive ❑ Graph
   ❑ Mean ❑ Statistical ❑ Other

   Describe:

References (textbook, library articles, URL)

____

____

____

Summary of results from Pre-Lab activities: (Use other side)

Lab Instructor Only											
Score	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**

How does sewage affect benthic and algal species diversity in streams?

Lab created with help from Christine Cooper

I. Background

People along Runningwater Creek have reported that sections of the creek emit an offensive odor. Older citizens claim that the fishing isn't as good as it used to be (and they don't notice as many mayflies in the spring) since they put in that new wastewater outlet. Your consulting company has been awarded a contract from the Environmental Protection Agency (EPA) to investigate the problem and determine whether the effluent is having an effect on the community structure of the stream. The EPA also has asked that you take baseline Dissolved Oxygen (D.O.) measurements above, at, and below the effluent.

Your initial observations confirm what the citizens reported, but these data are insufficient. From your observations you can see that the stream appears different upstream from the wastewater outlet, immediately below the wastewater outlet, and downstream from the wastewater outlet. What will you need to report? Your partner suggests that because benthic invertebrates are near the bottom of the community food web and are easily sampled and identified, that they would make good indicator organisms of community health. The Palmer Pollution Index (Table I12.1), which is based on relative abundance of algal species, can be used to measure the pollution level of a body of water. Based on the interpretation of your results, what will you report?

A. Pre-lab Activities

After completing this pre-lab, you should be able to:

- explain how organic pollution affects stream organisms
- describe the use of different stream organisms as indicators of the presence of polluted water

1. Visit the "Biological Stream Assessment—Water Watch Biological Monitoring Procedures" link from this laboratory's WWW page.
   a. Describe how stream organisms can be used to locate sources of pollution.

   b. Determine which organisms listed in the Key to Benthic Invertebrates (p. I12.11) indicate good, moderate, and poor water quality.

B. Terms/Concepts of Potential Interest for Use in your Lab Report

Food Web	Species Diversity	Non-point Source Pollution
Random Sampling	Species Richness	Community
Species Evenness	Species Diversity Index	Effluent
Dissolved Oxygen	Point Source Pollution	

C. Special Equipment and Materials

Water and algal samples	Simulated stream
Key to Benthic Invertebrates	Simulated dredge
D. O. probes	Palmer Index Spreadsheet
Species Diversity Index Spreadsheet	

D. Special Instructions

To insure that we can conduct this lab regardless of the weather, you will be sampling from a simulated stream in the classroom. The stream is a laminated banner onto which images of stream invertebrates have been stamped. The stream is based on data from the Stillwater area (Wilhm, 1967, 1969)

1. Protocol for Dredge Sampling
   a. To collect live benthic invertebrates in the field, a dredge, which consists of a brass box the bottom of which has two metal jaws, is lowered into the water until it touches bottom and the jaws snap shut or a dredge net is dragged along the bottom. Your dredge is a wooden hoop.
   b. To sample randomly, close your eyes and toss the hoop into the area of the stream you have selected. Identify the species (using the Key to the Benthic Invertebrates found below) and the number of individuals found within the boundaries of your dredge. Record your data on a species diversity log sheet. Individuals under the edge of the hoop should be counted in the sample.
   c. Repeat this procedure 10 times within your chosen study site to obtain the necessary samples for calculating a species diversity index.
2. Method for calculating a Species Diversity Index
   a. By hand:
      1) Total the rows of your species diversity log sheet to calculate the total frequency for each species.
      2) Add all the frequencies to calculate the total number of individuals (n).
      3) Count the number of different species (s).
      4) Use the following formula (You can find the Windows calculator program under **Start > Programs > Accessories > Calculator**):

$$\text{Species Diversity (d)} = \frac{\text{Number of species (s)}}{\sqrt{\text{Total number of individuals (n)}}}$$

   b. Using the Species Diversity Index Spreadsheet
      1) Start the Spreadsheet (**Start > Programs > Office 97 > Species Diversity Index**).
      2) Transfer your data to the spreadsheet.
      3) The spreadsheet will calculate your data, plot Species Diversity Index by site, and plot frequency distributions for the different species.

c. Interpret the Species Diversity Index (d) as follows. A high species diversity is representative of a community with many species but few individuals per species. Low species diversity indicates a community with few species but many individuals per species.

3. Palmer Pollution Index

The presence of particular algal genera is used as an indicator of water quality. Palmer (1969) developed individual pollution factors for algae tolerant to organic pollution. By summing pollution index values we can estimate the presence of high to low levels of organic pollution in a stream.

a. Samples have been taken from a stream. To identify and count the number of algae per sample use the Key to Algal Genera (on following pages) for identification.

b. Using a pipet, place a 0.1 ml volume sample on a clean microscope slide and cover with a 25 × 25 mm cover slip.

c. Using the 10× objective on your microscope and the Key to Algal Genera provided, identify the type of algae and record the number of each species on your Algal Tally Sheet. This is accomplished by scanning the length of the cover slip (end to end) in a straight line through the field of view of the microscope. Repeat two more times on a different section of the cover slip, remembering to scan from end to end each time.

d. Note: Not all algal species that you observe are indicators of pollution and do not have a pollution index value. Furthermore, indicator species must be present in numbers of 50 or more individuals per ml of water sample to contribute to the pollution index total (Table I12.2).

e. Sum the totals of each species from your Algal Tally Sheet. Enter sample totals into the spreadsheet for this technique (**Start > Programs > Office 97 > Palmer Pollution Index**), the pollution index will automatically be calculated for you.

f. Interpret the pollution index total as follows. A pollution index total of 20 or more is indicative of high organic pollution. Scores between 15 and 19 indicate moderate organic pollution. Scores less than 15 indicate low organic pollution. It is based on the equation:

$$\frac{(\text{area of coverslip}) \times (\text{number of one type of alga})}{(\text{area of 1 strip}) \times (\text{number of strips counted}) \times (\text{volume under coverslip})}$$

If count more than 50, add the Pollution Index Value for that organism to others to get the Palmer score.

E. For additional assistance, check this investigation's website at zoology.okstate.edu/zoo_lrc/biol1114/study_guides/labs/lab12.htm

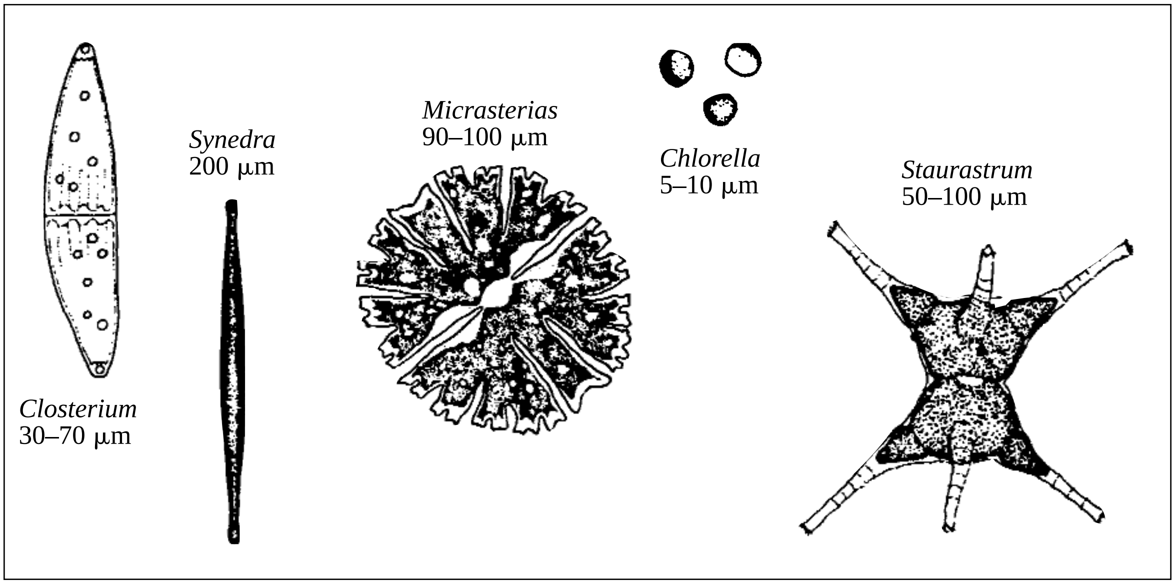
Literature Cited

Palmer, C. M. 1969. A composite rating of algae tolerating organic pollution. *Journal of Phycology*. 5(1):78–82.

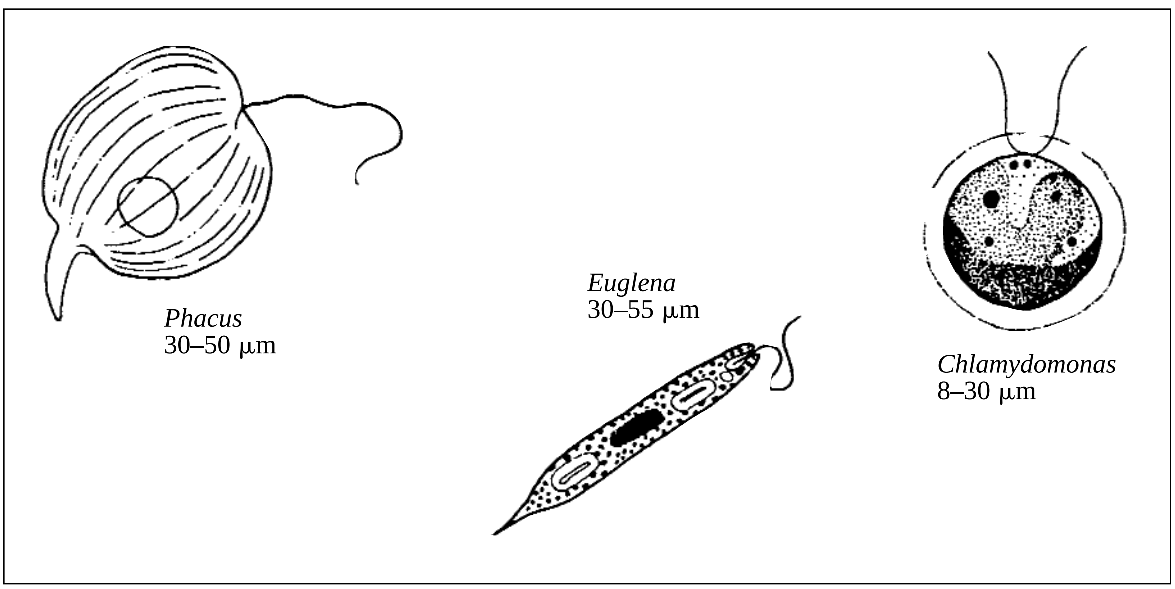
Wilhm, J. L. 1967. Simulation of sampling populations of benthic macroinvertebrates. *The American Biology Teacher*. 29(6): 471–474.

Wilhm, J. L. 1969. Patterns of numerical abundance of animal populations. *The American Biology Teacher*. 31(3): 147–150.

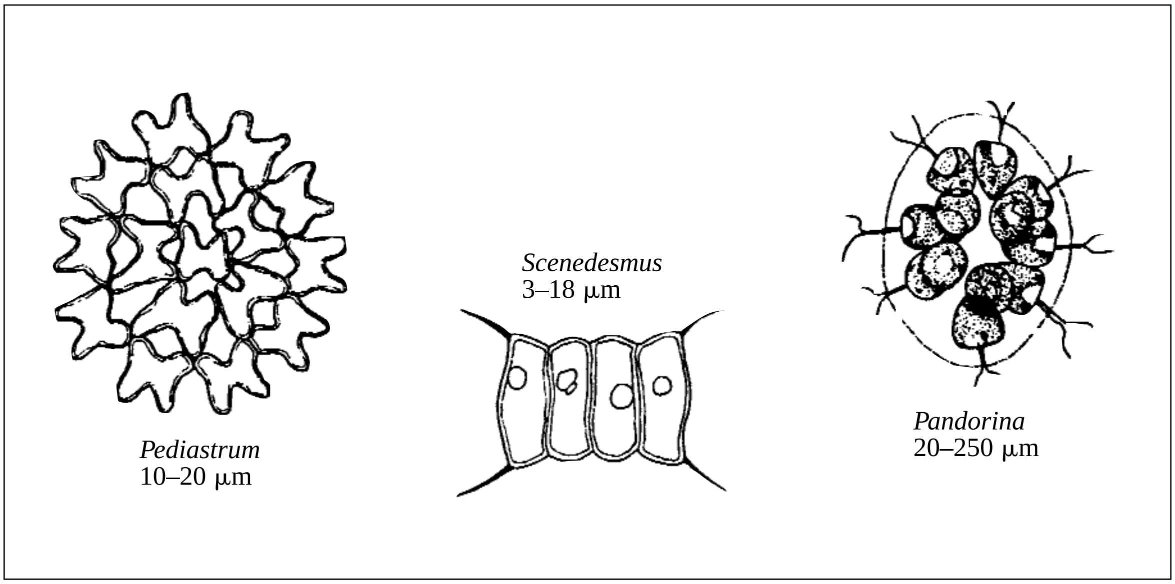
Key to Algal Genera



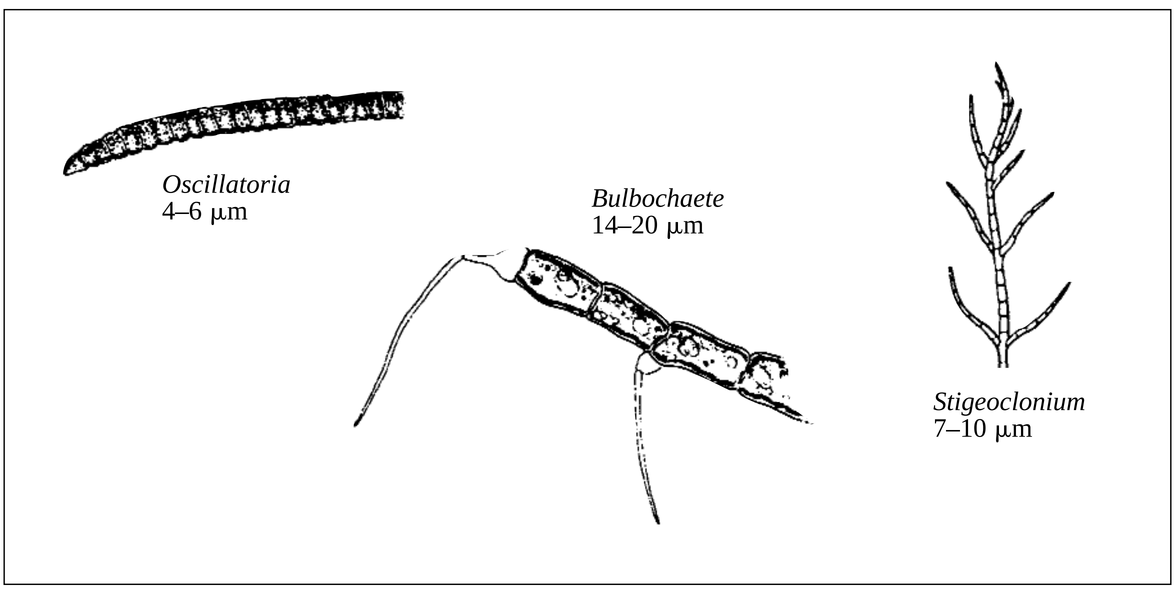
Single cells, Non-motile



Single cells, Motile



Colonial



Filamentous

Algal Tally Sheet **Site #:** **Site Location:**

Algal Genera	**Sample 1 Count**	**Sample 2 Count**	**Sample 3 Count**	**Total of Three Samples**
Chlamydomonas				
Chlorella				
Closterium				
Euglena				
Oscillatoria				
Scenedesmus				
Synedra				
Phacus				
Stigeoclonium				
Pandorina				
Micrasterias				
Staurastrum				
Pediastrum				
Bulbochaete				

TABLE I12.1—PALMER POLLUTION INDEX

ALGAL GENERA POLLUTION INDEX (Palmer 1969)	
Genera	**Pollution Index**
Anacystis	1
Ankistrodesmus	2
Chlamydomonas	4
Chlorella	3
Closterium	1
Cyclotella	1
Euglena	5
Gomphonema	1
Lepocinclis	1
Melosira	1
Micractinium	1
Navicula	3
Nitzschia	3
Oscillatoria	5
Pandorina	1
Phacus	2
Phormidium	1
Scenedesmus	4
Stigeoclonium	2
Synedra	2

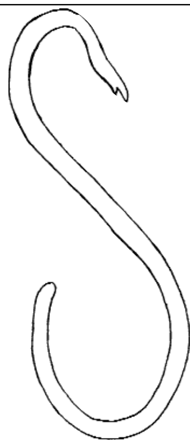
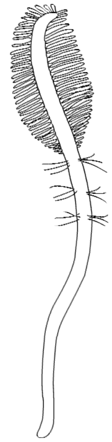
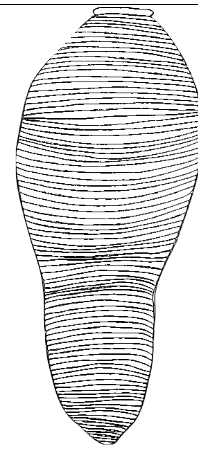
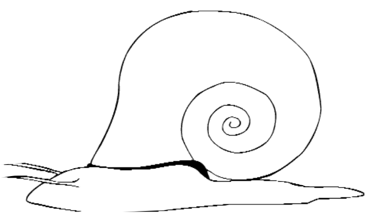
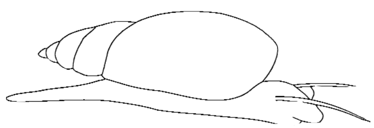
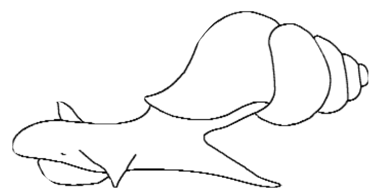
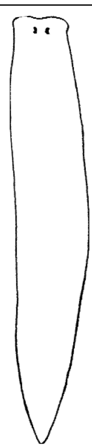
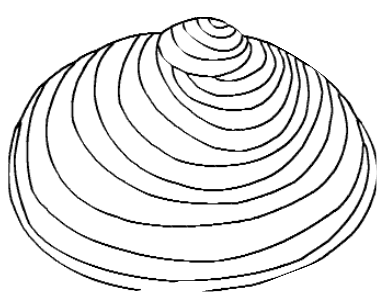
TABLE I12.2—EXAMPLE OF STREAM SURVEY DATA

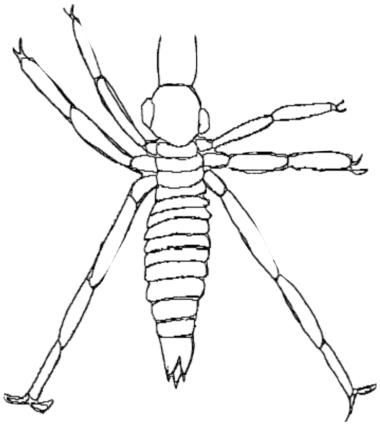
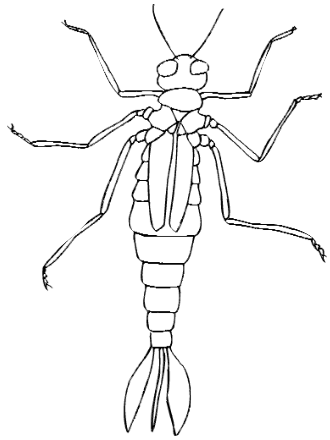
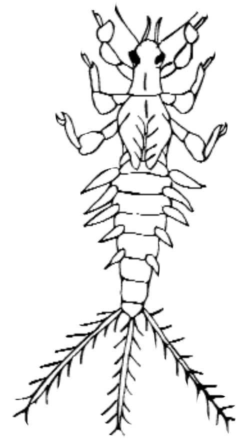
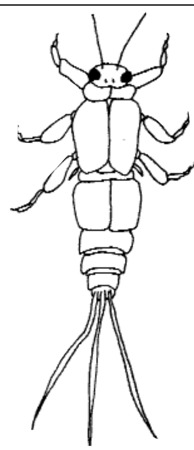
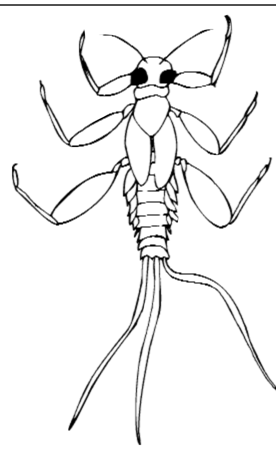
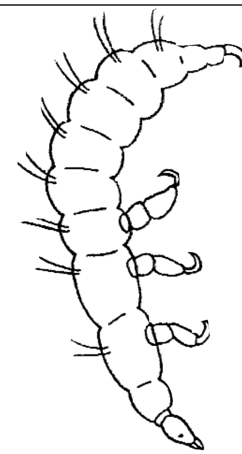
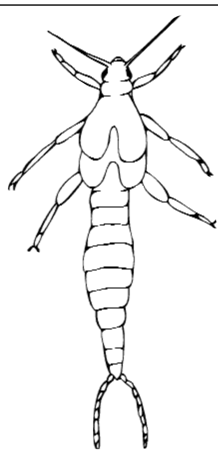
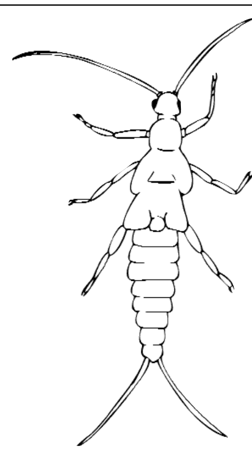
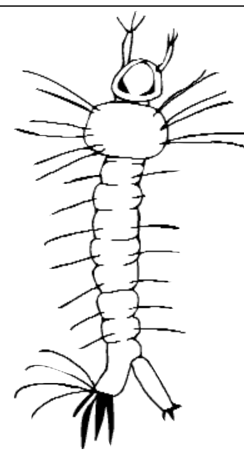
Number of Organisms	Genera	Pollution Index Value
75	*Phacus*	2
105	*Euglena*	5
90	*Micrasterias*	not an indicator
205	*Pandorina*	1
10	*Scenedesmus*	insufficient number
140	*Oscillatoria*	5
62	*Pediastrum*	not an indicator
50	*Chlamydomonas*	4
Total		17

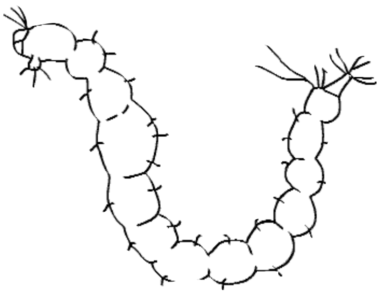
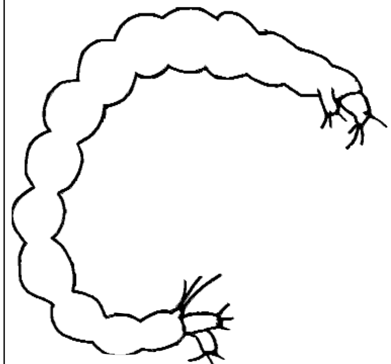
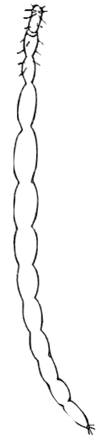
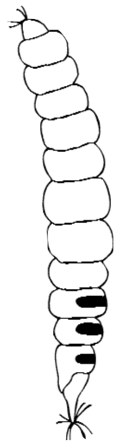
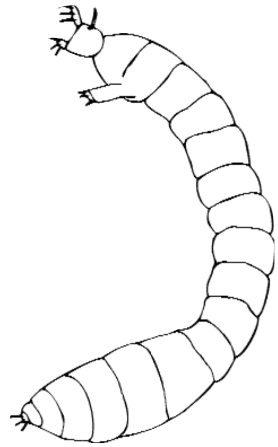
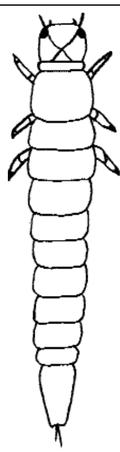
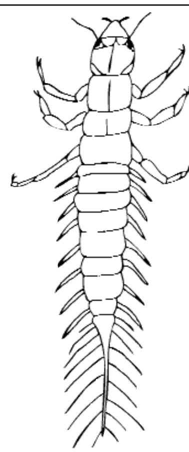
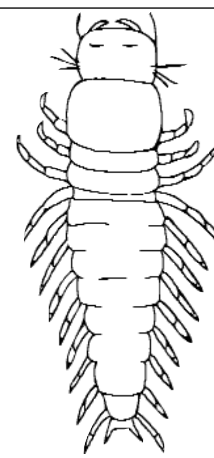
Site Description: **Species Diversity Log Sheet**

Name:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Annelida										
Branchiura sowerbyi										
Glossiphonia complananta										
Limnodrilus hoffmeisteri										
Coleoptera										
Stenelmis lateralis										
Diptera										
Chironomus thummi										
Cricotopus sylvestris										
Culex pipiens										
Culicoides variipennis										
Glytotendipes senilis										
Simulium vittatum										
Psychoda sp.										
Ephemeroptera										
Caenis moesta										
Hexagenia bilineata										
Stenonema frontale										
Gastropoda										
Helisoma trivolvis										
Lymnaea bulimoides										
Physa anantina										
Megaloptera										
Corydalus cornutus										
Sialis lutaria										
Odonata										
Libellula sp.										
Argia emma										
Pelecypoda										
Sphaerium transversum										
Plecoptera										
Allocapnia vivipara										
Hastaperla brevis										
Trichoptera										
Cheumatopsyche sp.										
Turbellaria										
Phagocata relata										

Key to Benthic Invertebrates

 Order: Annelida Family: Tubiticidae Scientific Name: *Limnodrilus hoffmeisteri*	 Order: Annelida Family: Tubiticidae Scientific Name: *Branchiura sowerbyi*	 Order: Annelida Family: Glossiphoniidae Scientific Name: *Glossiphonia complananta*
 Order: Gastropoda Family: Planorbidae Scientific Name: *Helisoma trivolvis*	 Order: Gastropoda Family: Physidae Scientific Name: *Physa anantina*	 Order: Gastropoda Family: Lymnaeidae Scientific Name: *Lymnaea bulimoides*
 Order: Turbellaria Family: Planariidae Scientific Name: *Phagocata velata*	 Order: Pelecypoda Family: Sphaeriidae Scientific Name: *Sphaerium transversum*	

 Order: Odonata Family: Libelluidae Scientific Name: *Libellula*	 Order: Odonata Family: Argidae Scientific Name: *Argia emma*	 Order: Ephemeroptera Family: Ephemeridae Scientific Name: *Hexagenia bilinearta*
 Order: Ephemeroptera Family: Caenidae Scientific Name: *Caenis moesta*	 Order: Ephemeroptera Family: Heptageniidae Scientific Name: *Stenonema frontale*	 Order: Trichoptera Family: Hydropsychidae Scientific Name: *Cheumatopsyche*
 Order: Plecoptera Family: Chloroperlidae Scientific Name: *Hastaperla brevis*	 Order: Plecoptera Family: Capniidae Scientific Name: *Allocapnia*	 Order: Diptera Family: Culicidae Scientific Name: *Culex pipiens*

 Order: Diptera Family: Chironomidae Scientific Name: *Cricotopus sylvestris*	 Order: Diptera Family: Chironomidae Scientific Name: *Glytotendipes senilis*	 Order: Diptera Family: Ceratopogonidae Scientific Name: *Culicoides variipennis*
 Order: Diptera Family: Chironomidae Scientific Name: *Chironomus thummi*	 Order: Diptera Family: Psychodidae Scientific Name: *Psychoda*	 Order: Diptera Family: Simuliidae Scientific Name: *Simulium vittatum*
 Order: Coleoptera Family: Elmidae Scientific Name: *Stenelmis lateralis*	 Order: Megaloptera Family: Sialidae Scientific Name: *Sialis luteria*	 Order: Megaloptera Family: Corydalidae Scientific Name: *Corydalus cornutus*

Planning Form

Name ______________________________ Section # ______

General Question Under Investigation:

Hypothesis(es) to be investigated:

Predictions:

Outline of Experiment

1. Procedures

2. Equipment

3. Type of Analysis ❑ Table ❑ Descriptive ❑ Graph
   ❑ Mean ❑ Statistical ❑ Other

   Describe:

References (textbook, library articles, URL)

____

____

____

Summary of results from Pre-Lab activities: (Use other side)

Lab Instructor Only											
Score	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**