EVALUATION OF A STREAM STUDY UNIT
USED AS AN INTRODUCTION TO HIGH SCHOOL BIOLOGY

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ABSTRACT

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The stream study unit was used as an introduction to a first year biology course required of high school sophomores. The unit set out to help students understand the underlying principles of environmental biology, to increase student achievement in later units, and to increase positive student attitudes toward science.

The students' understanding of ecological principles and their attitudes toward science were measured using pre- and post-tests and pre- and post- attitude surveys. The results indicated significant student achievement and positive attitude changes as a result of the implementation of the unit.

Student test scores on later units in respiration and in photosynthesis were compared over a five year period. The scores from the latter two years of that period (during which the ecology unit was used as an introduction) were significantly higher than those from the prior three years.

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CHAPTER 1

INTRODUCTION

The traditional approach to most high school biology courses is determined not by what makes sense to a student, but by what made sense to a textbook author. Most courses and texts begin with a review of chemistry, a unit on biochemistry, and a longer unit on cells and their processes. Most courses next attempt to cover genetics, reproduction, animals, plants, microorganisms, ecology and evolution in varying sequences. This instructor, teaching exactly that type of course, has long felt the burden of too much content in our biology courses and too little concentration on the really basic themes that underlie all biology. This opinion is shared by many others. Dr. Paul Hurd (1989) states:

> This basic model of what a high school biology course should be like has remained about the same for more than a century, modified now and then to reflect advancements in research. Organs and tissues--their structure and function--continue to be the organizational theme. In recent years extensions have been added downward to the molecular level and upward to include topics on ecology, population and the biosphere. Whatever the level of organization, the number of facts and terms increase with each new edition of a textbook, and the significance of these facts for understanding the realities of life and living decreases.

The course used for this thesis was divided into four basic units to reflect the need to organize material into manageable categories: cells and their biochemistry, reproduction, evolution and ecology. A great deal about the biology of individual organisms or of phylogenetic groups may be taught within the context of their overwhelming similarities to each other in these four areas. Some of the topics included in each of these units are:

Cells and Their Biochemistry

1. Size, shape and basic structures of cells
2. Transport of materials into and out of cells
3. Enzymes
4. Respiration
5. Photosynthesis
6. DNA, RNA and protein synthesis

Reproduction

1. Cellular reproduction--Mitosis and Meiosis
2. Genetics
3. Animal sexual reproduction
4. Plant sexual reproduction

Evolution

1. Adaptation
2. Natural selection
3. Populations

Ecology

1. Cycling of elements in the environment
2. Limiting factors in the environment
3. Food chains/webs in communities
4. Taxonomy, structures, behavior of representative organisms

After these units were decided upon, the problem became the order in which to teach the topics. Cellular organization seemed an obvious place to begin to a person with many college hours in biology. However, the cell unit with its strange and lengthy vocabulary and its reliance on molecular or chemical concepts may have been the most difficult of all those listed for a high school sophomore. Perhaps the logical place to begin was with ecosystems, which are visible, familiar and nonthreatening. This idea is supported by the authors of one popular ecology text. In the preface to this book they state:

> Unlike some other sciences the subject matter of ecology is apparent to everybody; to the extent that most people have observed and pondered nature, most people are ecologists of sorts. (Begon, Harper, and Townsend 1986).

The preface of the BSCS Green Version biology text echoes this theme with a quote from Marston Bates of the University of Michigan. Dr. Bates defines ecology as the study of "outer physiology" as contrasted to the "inner physiology" of the organism. After describing the relationship between the two, he states, "We stress the outside rather than the inside on the assumption that this is more familiar and more easily understood." (BSCS 1987)

The opinion of this instructor was that ecology and evolution together made up the two unifying themes of biology. Ecology was used in this context to deal with the relationship between organisms and their environment. Evolution referred to that relationship as it changed by adaptation over periods of time. Everything else in biology could be understood in reference to these two aspects. In the same preface to the ecology text quoted earlier the authors go on to say:

> If as T. H. Dobzhansky said, 'Nothing in biology makes sense, except in the light of evolution', then, equally very little in evolution makes sense, except in the light of ecology--that is, in terms of the interactions between organisms and their physical, chemical, and biological environment." (Begon, Harper, and Townsend 1986)

The decision was made to begin the biology course with ecology and to end with evolution, as a result of the philosophical thinking described above. This was an effort to put the more abstract and unfamiliar concepts of biochemistry, reproduction and evolution into a framework that would make more sense to students. If students could see the undeniable importance of photosynthesis, for example, in the overall scheme of the ecosystem, it might make that process seem more relevant and thus more easily learned at a later time.

Based on that analysis, the teaching unit in ecology was constructed as an introduction to biology. The concept of an ecosystem was broken down into three parts: the abiotic, the biotic, and the relationships between those two. These three were equally appropriate at any level of the ecosystem, such as, individual organisms, populations or communities.

One of the most important abiotic principles to be considered in this unit was the cycling of materials into and out of living things in an ecosystem. Students had a difficult time grasping the idea of organisms using and reusing atoms. Even more difficult for them to understand was that the atoms making up their bodies have been part of other organisms for eons. Since it was not necessary for students to know the details of a great many of these cycles, this unit included only the water cycle, the carbon/oxygen cycle, and the nitrogen cycle.

The second abiotic principle was the notion of limiting factors. Some of the factors studied in this unit were temperature, oxygen, pH, light, water, nitrogen, pressure and trace elements. The discussion of limiting factors began with Liebig's Law of the Minimum and expanded to include the idea that too much is as limiting as too little. It was also important for students to understand the interaction between several factors. For example, a plant uses less zinc if it grown in the shade rather than the sun, and grasses use more water when nitrogen in the soil is low.

The third abiotic principle was the distribution of energy in an ecosystem. This was almost impossible to divorce from the biotic area since it involved food webs, which inevitably included organisms. It was essential for students to understand the sun as the source of all energy for most processes on earth. Once the students had grasped the idea that food chains begin with autotrophs, he/she could follow the energy as it passed through food from one organism to another. Only the energy which is stored in an organisms' body is available to its predators, as the energy used in movement or as heat, for example, are converted into unusable forms. Thus, the available energy decreases with each step in the food chain which led the students inevitably to the idea that energy does not cycle, as do the elements, but must be renewed constantly.

The biotic aspects of an ecosystem consisted of all the organisms in the community. These began with producers, which create food from the incoming solar energy. Green plants, of course, are the most important producers in most ecosystems, and therefore, stress was put on their processes, especially on photosynthesis.

The consumers, the middle steps in food chains or webs, are mostly animals. Herbivores, predators, parasites and scavengers were all included as consumers. The use of food by all organisms as a source of energy and building material was discussed as an example of their relatedness to one another.

The decomposers, third and last in the food chain, were defined as bacteria and fungi for this beginning course. These are the recyclers of nature, returning the atoms of the food chain to the abiotic component of the ecosystem. Stress was put on the idea that these microbes receive their own quota of energy in the respiratory processes they use, some of which are anaerobic.

Probably the most important principle involved in the ecology unit was the relationship between the abiotic and biotic factors of any ecosystem. One can not study simply the cycling of elements without also studying the microbes and the other organisms involved in that cycle. The concept of distribution of energy in the ecosystem is intimately connected to the organisms in the food chain or web. Students usually understood the influences of the abiotic factors on organisms quite easily. However, they very often found it difficult to grasp the other half of that interaction, the organisms' effects on their environments.

Students also were introduced in this unit to the process of thinking we refer to as the scientific method. Most of the investigations in this unit were designed in an attempt to allow students to pose problems, gather data, and draw conclusions increasingly on their own.

Another corollary concept was taxonomy. Students had to identify at least some animals, plants, and microbes in order to understand the food chain. Taxonomy is utterly boring unless tied to other ideas which make the naming of organisms relevant.

The third and fourth corollaries were the related processes of photosynthesis and respiration. These were introduced in this unit as fundamental to plants and animals and were taught in more detail in the unit on cells and their biochemistry. Since these were considered uniquely important to an understanding of the ecosystem, they were chosen to be used in the evaluation of the ecology unit as described in Chapter 3.

The teaching unit which preceded this thesis set out to answer three central questions. 1) Would the students be able to learn the underlying principles described in this section? 2) Would understanding of food chains make the later units on respiration and photosynthesis more relevant and therefore easier to learn? 3) Would this unit with its emphasis on lab and field work increase positive student attitudes toward science in general and toward environmental concerns as well?

CHAPTER 2

INSTRUCTION

OVERVIEW

The ecology unit, which is the central topic of this thesis, was used with high school sophomores in a first year biology course required for graduation. The students were from a rural/suburban area in southern Michigan and were almost exclusively middle class and Caucasian. The school was small, so all sophomores took biology from the same instructor. The total number of students in the course varied from sixty to eighty. Class sizes averaged between twenty and twenty-five. The abilities of the students ranged from gifted to learning disabled, and there was no ability grouping. Therefore, the entire range of abilities could be found in any one section of biology. This made the selection and writing of materials to be used by the whole class challenging for the instructor. The use of several methods, especially hands-on activities, represented an effort to increase the interest level of all the students, especially at the lower end of the ability range.

The ecosystem studied in this unit is a stream flowing through the town within walking distance of the high school in a fifty-five minute class period. The river was partially diverted many years ago to provide a mill stream. The mill stream flows into a dammed mill pond from which water flows over the dam and quickly rejoins the river water.

The unit is designed to begin at the start of school in late August or early September and to continue until the end of the first marking period, approximately eight weeks later. The field work continued through the fall, and students experienced field work in hot as well as cool weather. Field work was also done in the winter and again in the spring to allow students to understand the effect of changing seasons on the stream ecosystem.

The eight week period was divided into two parts, consisting of studies on abiotic and biotic factors. Each of these involved field work, laboratories, reading assignments, audiovisuals, lectures and testing. It remained important, however, for the teacher and students to keep in mind that all the concepts taught in these two sections are totally interrelated.

OUTLINE OF UNIT

Abiotic Factors

A. Limiting Factors

1. Handout--Reading assignment (See Appendix A)
2. Class discussion of various limiting factors
3. Lab: Limiting Factors for Algae (See Appendix B)
4. Class Discussion: Writing Laboratory Reports
5. Handout: Writing Laboratory Reports
6. Class Activity: Graphing
7. Lab: Effect of Temperature on Dissolved Oxygen Concentration (See Appendix B)
8. Lecture: pH
9. Lab: pH of Common Household Substances (See Appendix B)
10 Film: <u>Bitter Rain</u> (See Appendix F)
11. Class Discussion: pH as Limiting Factor
12. Field Work: Mill Stream
13. Field Work: River
14. Lecture: Averages and Deviations
15. Group Work: Figuring Averages from Stream Data
16. Lab: Organisms and pH (See Appendix B)
17. Lab: Testing for Common Ions in Water Samples (See Appendix B)
18. Film: <u>Greatest Lakes</u> (See Appendix F)
19. Film: <u>Ocean of Light</u> (See Appendix F)
20. Film: <u>Water Crisis</u> (See Appendix F)

B. Cycling of Elements

1. Lecture: Cycling of Elements
2. Reading Assignment: Chap. 704-709 <u>Modern Biology</u>
3. Film: <u>Into the Abyss</u> (See Appendix F)
4. Film: <u>Communities of Living Things--Abiotic Cycles</u>. (See Appendix F) Statement from film: "Living things only borrow the chemicals (atoms) of which they are made". Each student is to write a paragraph explaining that statement.

C. Test: Ecology I--Abiotic Factors

Biotic Factors

A. Food Chains

1. Reading Assignment: Ch 49 Modern Biology
2. Lecture: Food Chains and Food Webs
5. Handout: Food Web Assignment (See Appendix A)
6. Predator/Prey Simulation Game (See Appendix E)
7. Lab: Biochemical Oxygen Demand (See Appendix B)_
8. Film: Communities of Living Things--G (See Appendix F)

B Organism Identification

1. Lab: Microscope Introduction (See Appendix B)
2. Reading Assignment: Ch 14 Modern Biology
3. Taxonomy Game/Belly Taxonomy
4. Taxonomy Activity: Sharks/Salamanders/Leaves: Using a Dichotomous Key
5. Assignment: Making A Key for Mythical Animals
6. Field Work: Collecting Mill Stream "Critters"
7. Field Work: Collecting River "Critters"
8. Lab: Analysis of Feeding Groups of Stream Macroinvertebrates (See Appendix B)
9. Lab: Live Crayfish Observation (See Appendix B)
10. Lab: Crayfish/Insect Comparison
11. Reading Assignment: Ch 30, 31, 32 Modern Biology
12. Handouts: Worksheets on Ch 30, 31, 32
13. Lab: Observation of Algae and Protozoa
14. Film: Mayfly (See Appendix F)
15. Film: Life in Lost Creek (See Appendix F)
16. Film: Dragonfly (See Appendix F)
17. Lab: Schooling Behavior (See Appendix B)

C. Test: Ecology 2--Biotic Factors

ANALYSIS OF LABORATORIES

The laboratory exercises in this unit can be divided into those which are inquiry-based and those which are not. Some techniques, such as microscope use or pH measurement were easier to teach using a lab format with questions, drawings, etc. rather than an hypothesis-based format.

All the inquiry labs based on the scientific method used the same format. The introduction set up the problem to be studied and gave the student information. The student was then asked to write three possible hypotheses concerning the problem and to choose the hypothesis which he/she felt was the best. Standard materials and methods sections then followed. The student was asked to make his/her own data tables, graph the data if appropriate, and write observations in the data section of the lab report. Finally the student was instructed to draw a conclusion referring back to the hypothesis chosen.

Prior to handing out the materials and methods sections, the students were asked to suggest possible ways to set up experiments to test their hypotheses. Their activities required guidance on the part of the teacher, but usually the students came very close to the lab as it was written. This gave them ownership in the lab and a feeling of doing "real science" as opposed to following directions.

Lab reports were written for all the "scientific method" labs. Students were helped by written suggestions from the teacher for improving their writing or their methods. The effectiveness of the labs was evaluated using the students' written reports. Students disliked writing the reports, but their writing did improve over the course of the unit. Most of them saved each report and used the written suggestions when they were preparing the next report.

The following is an analysis of each of the labs used in this unit:

1. LIMITING FACTORS FOR ALGAE

The purpose of this lab was to deal with a limiting factor problem. The algae used were scraped from aquaria to make a standard population from which the students initially drew measured amounts. The algal growth was measured using a Spec 20 set at a wavelength of 430, and the absorbance was graphed against the concentration of nitrogen used in each sample. Student results indicated that the algae colonies grew fastest with the middle range of fertilizer. The lab was effective in teaching the concept that too much of a needed substance can be as limiting as too little. The student handout for this lab is included in Appendix B.

2. EFFECT OF TEMPERATURE ON DISSOLVED OXYGEN CONCENTRATION

There were two reasons for using this lab in this unit. The first was to acquaint the student with the technique for measuring dissolved oxygen (DO) using a kit available from Hach Co. of Loveland, Colorado. The second was for the student to gain an understanding of the interrelationships among limiting factors. A common misconception among students was that the warmer the water is, the more living things it is likely to contain. Typical student results indicated that warmer water dissolves more oxygen than colder water. These results came as a surprise to many students. Any temperatures may be chosen for convenience as long as they are widely different from each other. In order to get best results an aquarium aerator was used to bubble the water at each temperature for an equal amount of time. The student handout for this lab is included in Appendix B.

3. pH OF COMMON HOUSEHOLD SUBSTANCES

This was a technical rather than an inquiry-based lab. This lab introduced the student to the types of pH measurement devices available and to help them understand the range of pH which they encounter in everyday living. They were given a variety of substances such as vinegar, milk, cleansers, window cleaners, lemon juice, alcohol or bleach and were asked to measure them using the laboratory pH meter and the portable meters they would be using in the field. One benefit of this comparison between meters was that the students became aware that not all meters give the same reading from the same sample. They tended to believe any numbers read from a meter are always correct. The student handout for this lab is available in Appendix B.

4. ORGANISMS AND pH

This lab was used to introduce the students to the pH buffering of many biological materials. pH can be a limiting factor for many organisms, but because of the inherent ability of their proteins to buffer, it often is not. The students were asked to add measured amounts of HCl and NaOH to tap water and to make data tables and graphs of the results. They were then asked to do the same thing using egg white, gelatin, liver or potato homogenate. A third part asked the students to make the same experiment using a buffer of pH 7. Student results indicated that the pH changed more slowly in the buffered solutions than in pure water. Most striking to the students were the results with the biological materials which were more similar to the buffered solutions than to the water. The student handout for this lab is included in Appendix B.

5. TESTING FOR COMMON IONS IN WATER SAMPLES

The methods in this lab were qualitative rather than quantitative; nevertheless the students became aware of the minerals in various water sources. Actually most students realized that the water sources had high mineral content, as they live in an area of hard water. Students were asked to test mill stream, river, distilled and tap water. Also students could bring in water from a home source (well, spring, stream) for testing. The methods used for testing were taken from the water quality section of ChemCom (1988). Since the tests involved color changes or precipitates, this lab was written to use microscale chemistry techniques. These methods allowed the students to repeat each test several times in a short period and required much less investment in chemicals. The ions tested were ferric iron, calcium, chloride, and sulfate. For each test a reference solution was provided so that the students might learn the appearance of a positive test. The student handout for this lab is included in Appendix B.

6. MICROSCOPE INTRODUCTION

The students in this course had very little experience with microscopes and needed to be taught the proper techniques of microscope use. This lab introduced them to care and cleaning of the instruments as well as to the concepts of magnification, field of view and depth of field. They were introduced to binocular dissecting microscopes as well as to the standard monocular instruments. Both of these were used in subsequent identification of stream organisms.

7. ANALYSIS OF FEEDING GROUPS OF STREAM MACROINVERTEBRATES

The objective of this lab was to quickly assess the food base of the stream by focusing on the roles played by the macroinvertebrates present. Students were asked to collect samples of the leaf litter on the bottom of the river. These samples were returned to the lab and refrigerated. The following day organisms were identified. The key used in this lab was given to participants in the Frontiers Program at Michigan State University by Dr. Mike Klug of Kellogg Biological Station. According to Cummins and Wilzbach, the original authors of the key, about 80-90% of the organisms found in stream leaf litter can be classified using this key. Emphasis in the key was on common names of organisms and on their roles in the food chain, rather than on formal taxonomic identification. This was the first opportunity for many students to use any type of biological key. The organisms found included small clams and snails, tiny Crustaceans, insect larvae/nymphs and worms. Most of the organisms survived the collecting and subsequent refrigeration quite well, probably because this was done late enough in the fall that the river water temperature was close to that of the refrigerator. It would have been preferable to identify the organisms the same day as they were collected, but schedule constraints made this impossible. The alternative of having the teacher collect the samples before the identification class would not have allowed the students the fun of collecting their own samples. This was probably the most popular lab involved in this unit. The students giggled and resisted touching the leaves at first, but that soon changed when they began finding living, fast-moving little "critters". This lab, using the same collection and identification paradigm, was repeated in the winter and again in the early spring. Students predicted that all these "critters" would be killed by the winter temperatures, without thinking of the disaster that would have been to the species involved. Contrary to their expectations, they found the same organisms not only present in the colder winter water, but larger yet each time the examination was done over the course of the school year. Perhaps they were surprised enough to change their misconceptions about the lifelessness of winter streams.

8. LIVE CRAYFISH OBSERVATION

The purpose of this lab was to familiarize students with the anatomy and behavior of the crayfish, a common invertebrate in the stream. Students were first asked to identify the major external structures of the crayfish and to predict the functions of each appendage from the crayfish behavior. Each group of students then observed the reaction of the crayfish to the following stimuli: a rock in the tank, touch, light, saturated salt solution and India ink. At no time was any crayfish allowed to be injured or left in an uncomfortable situation for any length of time. The crayfish used were captured by the students from the river being studied and were released following the lab. The student handout for this lab is included in Appendix B.

9. CRAYFISH/INSECT COMPARISON

In the preceding macroinvertebrate lab, the students found many crustaceans and insects in the leaf litter, making arthropods a focus for the stream analysis. In this lab students were given preserved specimens of crayfish and grasshoppers, as typical representatives of their classes, and were asked to compare them. This was the only activity that approximated dissection in the entire introductory course. The observations were made on the exterior of the specimens only. Internal observations were made with the aid of diagrams. As a result the specimens were used from class to class and indeed from year to year. The time it would have taken to actually dissect either crayfish or grasshopper seemed inappropriate to the objective which was to compare rather than to identify specific structures. This lab provided a good compromise between observation and dissection. The student handout for this lab is included in Appendix B.

10. OBSERVATION OF ALGAE AND PROTOZOA

In this lab students were given the opportunity to become familiar with the common types of algae and protozoa found in the stream. Students were given prepared micro-slides containing six types of algae and assorted types of protozoans as well as colonies of living plankton gathered from river, ponds, etc. and were asked to identify the basic types. Stress was placed on roles in food chains rather than on sophisticated identification. Common names were used wherever possible. The keys used were those borrowed from the school library, but this instructor would like to write keys for this lab similar in intent to the one used with macroinvertebrates.

11. SCHOOLING BEHAVIOR

Students rarely encountered any fish in all the field work at the river and mill stream. Trout and bass are known to be present, but the students were too exuberant and too numerous to have much chance to find them. This lab gave students the opportunity to work with the major type of vertebrates, fish, in the stream. Tropical fish were used in the lab because they tended to survive life in the aquarium better than those from the stream. However, this did make the lab fairly expensive. The behavior of tropical fish with visible markings was compared to that of unmarked fish. Fish were placed in aquaria large enough to accommodate large beakers covered with cheesecloth. The school of fish was placed in the beaker and one specimen fish was allowed free in the aquarium. Students monitored the number of seconds spent swimming in the sector of the beaker and the number spent swimming away from the rest of the school. Variations to this procedure were then allowed. Typically the marked fish spent more time swimming with the "school" than did the unmarked fish. The student handout for this lab is included in Appendix B.

ANALYSIS OF FIELD TECHNIQUES

Discipline of students in the freedom of the field trip was of major concern initially. This turned out to be of little consequence. The students walked to the day's site in a group and began their assigned tasks right away. At no time did anyone leave the site or cause any problems beyond high spirits. The reason for this responsible behavior on the students' part was probably that they saw the tasks as real science and were interested in the results. Another reason could also be that they knew field trips would become an extinct activity if they misbehaved.

An unforeseen difficulty did arise, however, which could have presented a real problem without the help of the principal of the high school. A young woman with cerebral palsy was in one of the classes. She simply could not walk the few blocks to the river, and it was felt the instructor should walk with the other students rather than driving. The principal of the high school agreed to drive her to the river and return to pick her up. Without his help this could have been a real problem.

Each class of students was divided into six groups, which were lettered A - F for all field work. Groups averaged four students each. Tasks were divided into three sets with two groups assigned to each set of tasks. For example, groups A and D could be assigned to measure DO;

groups B and E could be assigned to measure depth, pH, temperature and flow rate; groups C and F could be assigned to measure nitrate. The groups would be rotated on the next field trip so that each group of students had an opportunity to do every test at least once. Each group was given a data sheet for recording their data at the stream. The data sheets were signed by each person in the group and turned in after the group posted their data on the class data table on the classroom bulletin board. The next day this data could be averaged from all three classes and deviations figured.

The following is an analysis of the procedures assigned to the students on the field trips for the past two years. As more funds become available and more equipment can be purchased, more procedures will be added.

1. DISSOLVED OXYGEN.

Because of limited funds only two dissolved oxygen (DO) kits were available. Each of the two groups of four students assigned to measure DO were given a kit. The instructions that came with each kit were removed, enlarged (the print is small), and duplicated. This was a good decision because chemicals were spilled on some of the instructions and they had to be replaced. Most of the students had little problem following the instructions. They measured the DO of water at the surface and also of water near the bottom of the mill stream. The two groups assigned to DO shared a waste bucket with those assigned to nitrate so that no chemicals were poured into the stream or on the ground. Typical student results for DO were in the range of ten parts per million in the fall, increasing to eleven ppm in the winter.

2. NITRATE

Hach kits were used in much the same way as in the DO test. Low range test kits worked quite well as the stream carried only a small amount of nitrate in spite of the agricultural nature of the area. Typical student data were in the range of .01 - .05 ppm.

3. DEPTH

The river is shallow enough for wading, and thus meter sticks were used to measure depth. In the mill stream, however, the depth is several feet so wading was not possible. There was, however, a bridge across the mill stream which allowed students access to the center of the stream. A long wooden pole was marked off to use as a measuring device from the bridge. In all cases the students marked a line across the stream and made several measurements. They were able to profile the bottom with greatest and average depth.

4. TEMPERATURE

A standard laboratory thermometer was used for measuring temperature at the surface. Temperature at depth was measured using a small thermometer attached inside the water-collecting apparatus.

5. pH

Two portable pH meters made by Corning were purchased. The accuracy of these was found to be within .2 pH units of the laboratory pH meter. The portable meters were wonderful for students to use at the stream because they gave a digital readout with no colors to compare. The meters seemed to be quite sturdy and student-proof. Typically the students measured the pH of the stream between 8.0 and 8.5.

6. FLOW RATE

The students marked off a thirty-foot section of stream, in this unit thirty feet. The time it took for a ball or orange was allowed to float in the current for that distance was timed in seconds. The feet per second could then be calculated and converted into miles per hour. An orange was the most accurate measuring device, as it floated right in the current, not above or below. However, as this unit covered several weeks, a tennis ball was used because it did not decompose. Stopwatches were used for timing. Students had no difficulty retrieving the ball from the river because they could wade. In the deeper mill stream the ball was always started upstream from the bridge and a long-handled net was used for retrieval. This test was the most enjoyable task in the field work for the students. They liked watching the ball (and throwing it at each other occasionally), and they enjoyed knowing the speed of the current and comparing it to their own walking speed.

ANALYSIS OF SIMULATIONS

Some concepts lend themselves more easily to simulation activities than to actual lab or field work. Two such simulations were used in this unit.

1. PREDATOR/PREY SIMULATION.

This activity compared the population of mice (prey) and owls (predator) in a woods over a span of several generations. The woods was an area of the classroom lab tables marked off with masking tape. The squares representing mice and owls were duplicated so that plenty were on hand. Mouse squares, especially, were needed in large numbers! The instructions told the students to drop the owl from a certain height, and any mouse square touching the owl was "caught". Each remaining mouse was allowed to reproduce by adding more mouse squares. Each owl reproduced only if it received three mice. The data was recorded on a table and the two populations were graphed at the conclusion of the activity. The activity reinforced the concept of interdependence between predator and prey. Many students dislike predators, believing the "Bambi myth". It was helpful for them to see that the mouse population was not exterminated even when the owl population was high. The only problem with this activity was that it was time-consuming and the counting of the mouse squares was tedious at times. The results, however, were so good that the activity will be used again.

2. TAXONOMY GAME/BELLY TAXONOMY

The objective of this activity was to allow the students to increase their understanding of the encompassing nature of a kingdom, a phylum, a class, an order, etc. Index cards were marked with selected names of kingdoms, phyla, classes and orders. Each student selected one card at random and pinned it to his/her clothing (hence the name "Belly Taxonomy"). The class was given time to look up the groups represented in the appendix of their book so that they knew to what type of group each name referred. The "classes" used string to gather all their "orders". The "phyla" gathered all their "classes" (and "orders") and the "kingdoms" gathered all their divisions within one big string circle. Usually two or three kingdoms were used so the entire class ended up in two of three large groups. It was possible to play the game twice in one hour and if different cards were used, the students enjoyed it. It had long been a problem to make students understand that if an animal belongs to the class Mammalia, for example, it MUST belong to the phylum Chordata. Somehow in the chaos of this activity, many students seemed to get the message.

ANALYSIS OF FILMS

The purpose for using the films in this unit was to allow the students to observe aquatic environments at great distances from Michigan. It was not possible to take students on field trips to the ocean or even to the Great Lakes, and yet it was thought to be important for them to understand that these other ecosystems have much in common with the familiar hometown river.

The films listed in this thesis were used over the two year period. However, not every film was used each year because of scheduling problems. The average number used in any one year was about eight. All the films discussed below were of value in teaching this unit. The students enjoyed them, and they made a welcome break from lab and field work.

A list of the sources for these films is found in Appendix F. They are all in the library of the Calhoun Intermediate School District and available to all county schools.

1. BITTER RAIN. 22 min. Recommended for grades 7-12.

This film discusses the effects of acid rain, the causes, and the solutions now available. It centers primarily on lakes in Scandinavia and Canada. It really brings home the point that acid rain is a problem in relatively nonindustrial areas and is a major contributing factor to pollution of drinking water.

2. GREATEST LAKES. 30 min. Recommended for grades 9-12.

This film deals with the geographic history of the Great Lakes, the latest scientific approaches to the current environmental problems facing the lakes, and the possible future problems as well. In Michigan it would seem to be necessary to drive home the point that any factor affecting the surface or ground water also affects the lakes.

3. OCEAN OF LIGHT. 58 min. Recommended for grades 9-12. Part of the series Atlantic Realm

This long film is worth the time as the photography is so well done. It deals with the effects of winds and currents on the behavior of sea life near the surface. The students are able to get a glimpse of aquatic life in an ecosystem very different from the stream in this unit.

4. WATER CRISIS. 57 min. Recommended for grades 9-12.

Water problems in the Adirondack Mountains, on the Mississippi River, and in California are discussed. Many of the controversial issues are those still in the news. Troubles highlighted include acid, rain, overdrafting of aquifers, drought, disinfecting methods that may cause cancer, toxic industrial waste.

5. INTO THE ABYSS. 58 min. Recommended for grades 9-12. Part of a series ATLANTIC REALM

This was one film that the students remembered and referred to during the entire year. It deals with high pressure, low temperature, and complete darkness as extreme examples of limiting factors. Many of the organisms photographed have never been seen by these students before. Especially interesting are colonies of bacteria living around "black smokers" and using chemosynthesis of sulfur compounds as producers in the food chain. It is a long film, but well worth the time.

6. COMMUNITIES OF LIVING THINGS--A--Part 2--Abiotic Cycles. 15 minutes. Recommended for grades 7-12.

This film includes a good discussion of element cycles in ecosystems. The music is a little too loud and distracting. The quote "Living things only borrow the chemicals (atoms) of which they are made." was used as the basis for a student writing assignment.

7. COMMUNITIES OF LIVING THINGS--D--Creeks and Oceans--Streams and Lakes 15 minutes per section. Recommended for grades 7-12.

Part 1 discusses organisms that live in salt creeks where the environment varies with the tide from mud flats to being under water. Organisms mentioned are fiddler crabs, blue crabs, hermit crabs, shrimp, barnacles, anemones, oyster toads (fish), and snails.

Part 2 discusses organisms that live in lakes where there is little movement of the water, and oxygen levels are relatively low. Organisms mentioned are flatworms, hydra, dragonfly larva, segmented worms, rotifers, and bloodworms (insect larva). The film also discusses mountain streams where currents are a large factor, and oxygen levels are high. Organisms mentioned are dragonfly larva, stonefly larva, mayfly larva, and crayfish.

8. <u>COMMUNITIES OF LIVING THINGS--G--Energy</u>

3 parts--15 minutes each. Recommended for grades 7-12

Part 1 (Origins) introduces chlorophyll, phototropisms, photosynthetic reactions, leaf structure and arrangement, and bacterial chemosynthesis. The quote "Plants are the gateway for chemical energy to enter the world of living things" was used for class discussion following the film.

Part 2 (Use and Storage) introduces uses for energy in specific animals, respiration reactions, mitochondria, plant starch storage. animal fat storage, and passage of energy through food chains.

Part 3 (Energy Distribution) introduces food chains, dependence on plants, and food webs. The quote "The ultimate use of energy is in reproduction in which it is passed to the young who must in turn get their own further energy" was used in class discussion following the film.

9. DRAGONFLIES--FLYING HUNTERS OF THE WATERSIDE

13 minutes. Recommended for all ages

This film follows the life cycle of dragonflies from egg to adult. Time lapse photography shows their outstanding acrobatic ability. Excellent use of concept of body adaptations to life style.

10. LIFE IN LOST CREEK 15 minutes. Recommended for grades 7-12.

This film uses underwater photography to show the ecology of three fresh water ecosystems. It introduces the concepts of habitat, adaptation, niche, population, food chain, transfer of energy.

11. MAYFLY--ECOLOGY OF AN AQUATIC INSECT. 15 minutes. Recommended for grades 7-12.

This film discusses the mayfly life cycle very clearly. It portrays the mayfly as a vital part of food chain and as an important indicator of water quality. It was especially interesting to the students in this unit because they found so many mayfly nymphs in the stream leaf litter.

CHAPTER 3

EVALUATION

Evaluation of this new unit was accomplished in a variety of ways. Pre- and post-tests were given to measure the content learned. Pre and post attitude surveys were used to measure attitudes toward science and toward environmental issues. Interviews were done with randomly selected students at the end of the year. Comparisons were made of grades on subsequent topics (respiration and photosynthesis) between the two years covered by this unit and the previous three years.

PRE-TESTS AND POST-TESTS

The pre- and post-tests are included in Appendix C. All of the questions from the pre-test are found in the post-tests, but other questions have been added as well. The pre-test was administered in the first week of school in the biology classes. The post-test was divided into two sections: abiotic and biotic. The abiotic test, which is called Ecology I, was given mid-way through the unit and the biotic test, which is called Ecology II, was given at the end. The results are shown in the following tables:

Table 1. RESULTS OF PRE-TESTS AND POST-TESTS

		Pre-test		Ecology I		Ecology II	
Class	Highest Possible Score	Mean	S.D.	Mean	S.D.	Mean	S.D.
3rd Hr	100	38.6	8.0	69.5	12.8	75.2	12.6
5th Hr	100	36.0	11.0	75.7	11.5	65.7	15.4
6th Hr	100	43.4	9.8	74.1	14.3	75.4	16.7
Total	100	39.8	9.4a	72.7	13.1a	73.2	14.9a

a. Significant at the 0.001 level

COMPARISON TO PAST YEARS

Prior to 1986 an ecology unit was taught at the end of the biology course. This previous unit included no field work and was often squeezed into the final days of school when students were busy preparing for final exams.

The "new" ecology unit was taught at the beginning of the year for two years (1989-90, 1990-91) before this thesis was written. In both of these years the cell unit followed ecology, and in time the students were taught and tested over the processes of respiration and photosynthesis. The teaching modules and the tests on these cellular processes had been virtually unchanged for a number of years. This allowed a comparison to be made between the achievement of students in the years 1989-91 with that of students in the years 1986-89. The comparison was based on the percentage scores for the three years prior to the implementation of the ecology unit as an introduction. The results are shown in the tables that follow:.

Table 2. RESULTS OF RESPIRATION TESTS

School Year	Mean Percentage	S.D.
1986-87	55.4	17.9
1987-88	54.6	17.2
1988-89	53.2	21.7
Total 1986-89	54.4	18.9 a
1989-90	60.9	18.6
1990-91	63.4	16.6
Total 1989-91	62.2	17.6 a

a. Significant at the 0.001 level

Table 3. RESULTS OF PHOTOSYNTHESIS TESTS

School Year	Mean Percentage	S.D.
1986-87	61.2	17.3
1987-88	59.9	16.2
1988-89	64.8	15.9
Total 1986-89	61.7	16.5 a
1989-90	68.2	16.1
1990-91	70.9	14.3
Total 1989-91	69.6	15.2 a

a. Significant at the 0.001 level

ATTITUDE SURVEYS

The attitude survey used was prepared as part of the research done by Sue Townsend, Jerry Kovach, Joe Kuester and this instructor at the Kellogg Biological Station as part of the Environmental and Behavioral Ecology workshop for high school teachers sponsored by National Science Foundation and Michigan State University. The questions came in part from a survey written by Becky Stout (1986) in a Master's Thesis for Michigan State University. Other questions were added by the four researchers in an attempt to test for the specific attitudes of high school students toward science and toward environmental issues. It was recognized by the authors of this survey that attitudes are difficult to change and perhaps even more difficult to measure. This survey needs to be revised, especially as to vocabulary. For example, this instructor found that some of the lower ability students did not recognize the word "inhabited" in print, although they would have understood it had it been given orally.

The survey gave students a choice of two opposite ideas and asked them to choose between them on a scale of 1-5. Those ideas considered negative and positive were mixed; that is, 5 was not always positive. In the scoring, however, those were turned around so that 5 became the most positive score and 1 became the most negative.

The survey was given to the students in their sophomore English classes during the first week of school. The cooperating English teacher did not tell them that the results would be used in their biology classes. This was an effort to keep them from biasing the results by worrying about the instructor's feelings. At the end of the unit the survey was repeated in English class. Three sections of the survey were appropriate to this unit. 1) questions on science as a whole, laboratory activities, working in teams to solve problems, and the scientific method. 2) questions on science careers. 3) questions on the degree of pollution, water quality, and importance of the local rivers. The actual survey questions are included in Appendix D, and the results of the three sections of the attitude survey are shown in Table 4.

Table 4. RESULTS OF ATTITUDE SURVEY

Section of Survey	Pre Mean	Pre S.D.	Post Mean	Post S.D.
All Science (1-28, 66-85)	3.3	0.44 a	3.5	0.36a
Science Careers (83-84)	2.3	1.00 b	2.8	0.75b
Local Rivers (61-65)	3.4	0.66 c	3.6	0.44c

a. Significant at the 0.01 level.
b. Significant at the 0.01 level.
c. Significant at the 0.10 level.

EXIT INTERVIEWS

Twenty-four of the sixty-five biology students were interviewed at the end of the school year. This group was chosen at random and consisted of six students from each of four grade categories (A, B, C and D) based on the first marking period during which the class completed this ecology unit. There were no students who failed this unit. The interview group was also selected by sex; half were male and half were female.

The students were reminded of the four units covered in biology that year. Each was then asked a series of seven questions and was given a chance to make comments which were also recorded. The questions asked are the following:

1. Which of the four units did you enjoy most?

2. Which of the four units did you enjoy least?

3. In which of the four units did you learn the most (that you did not already know)?

4. In which of the four units did you learn the least (that you did not already know)?

5. Another way to build a biology course is to begin with cells, work up to animals and plants, and end with ecology in the spring. Would you rather have had the ecology (stream study) unit in the fall or in the spring?

6. Do you think learning about food chains, producers, consumers and decomposers in advance helped you learn about photosynthesis and respiration later?

7. We divided the year into units and jumped around in the book quite a lot. We also did quite a lot of work that was not in the book at all. Did you like this or would you have been more comfortable going through the book chapter by chapter so that you would have known more what was going to happen next?

The results of this survey are given in the following table:

Table 5. RESULTS OF EXIT INTERVIEWS.
QUESTIONS 1 - 4 ALL STUDENTS

Questions	Percentage Answering Per Unit			
	Ecology	Cells	Reprod	Evolution
1 Enjoyed Most	50.0	4.2	29.2	16.7
2 Enjoyed Least	8.3	62.5	12.5	16.7
3 Learned Most	16.7	16.7	33.3	33.3
4 Learned Least	16.7	33.3	33.3	16.7

Table 6. RESULTS OF EXIT INTERVIEWS
QUESTIONS 1 - 4 BY GRADE CATEGORY

Questions	Percentage Answering Ecology			
	A	B	C	D
1 Enjoyed Most	50.0	16.7	66.7	66.7
2 Enjoyed Least	0	16.7	16.7	0
3 Learned Most	16.7	0	33.3	16.7
4 Learned Least	16.7	33.3	16.7	0

Table 7. RESULTS OF EXIT INTERVIEWS--QUESTIONS 5 - 7

Grade Category	Percentage Answering Per Question 5 Fall	Spring	6 Yes	No	7 Unit	Chapter
A	83.3	16.7	66.7	33.3	100.0	0
B	83.3	16.7	66.7	33.3	100.0	0
C	100.0	0	83.3	16.7	100.0	0
D	100.0	0	50.0	50.0	66.7	33.3
ALL STUDENTS	91.7	8.3	66.7	33.3	91.7	8.3

Many of the students interviewed found it difficult to choose among the units covered in the course. They only made a choice when pushed to do so by this instructor.

Some of those students who stated that they enjoyed the ecology unit most gave the following comments:

"I liked experimenting with the river."
"I liked being outside."
"It made biology real."
"I liked it that we got to do things for ourselves."
"I really liked doing the DO test."
"It didn't seem like work."

One of those students who stated that they learned the most from the ecology unit said, "I learned more because I actually did it instead of just learning what other people had done."

Two students commented on why they would have preferred the ecology unit in the spring:

"It would have put the least concentrated (unit) at the end of the year."
"It would have made more sense to go from cells up to the environment."

Comments from students who liked the unit in the fall were the following:

"It let us see the same things (organisms) as they started out all the way through the year."
"It was an exciting way to start the class."
"It was a fun way to start the class."
"It made the class not boring at first."
"It would be too hot in the spring."
"It let you mix up the hard stuff with the easy stuff so it wasn't all at one time."
"It taught us things we needed to know later in the class."
"It made us look forward to the rest of the year."

Students who thought they had been helped by the ecology unit when they had to learn photosynthesis and respiration later on made these comments:

"It made us understand what was going on."
"It let us know why we need to know that stuff."
"It showed us why it was important."

Finally students commented as follows on the unit format rather than a chapter-by-chapter type of class:

"It made us pay more attention rather than relying on the book.:
"It made it more interesting."
"It made it funner!"

TEACHER OBSERVATIONS

In addition to these comments during the interviews, this instructor made a great many observations of student behavior during the unit. One of the most obvious was that students could not wait to get to the river. They were extremely disappointed if a field trip had to be cancelled due to a downpour They came equipped with what they considered to be appropriate clothing on the days of scheduled trips. Very few were absent or tardy during the ecology unit. They worked well together in the small groups, each person taking some responsibility for the results. The students seemed to have less apprehension about their own abilities to do well in biology compared to students in other years. They were interested in the stream and asked questions. They challenged things they heard in films, from their teacher or on television. They brought in reams of newspaper clippings and magazine articles concerning environmental topics. Perhaps best of all, they seemed to begin to see their teacher as a person, one who got hot or cold, thirsty, tired and wet right along with them, but who had a passion for biology. This may have been the most important result of the field work. The rest of the year went more smoothly than at any other time in a twenty-three year career, and it seemed to be because each class was coalesced into a cooperative unit with the instructor part of that unit.

CHAPTER 4

CONCLUSIONS AND DISCUSSION

Three questions were asked in the introduction to this thesis concerning the efficacy of this unit to promote learning and to induce attitudinal changes. The tests and surveys used to evaluate the unit and to answer these questions are discussed in Chapter 3.

LEARNING OF ECOLOGICAL CONCEPTS

The first question dealt with the effectiveness of this unit in teaching ecological concepts. Pre-test and post-test data indicate that the unit was very effective. The statistical differences between the pre-test and post-test scores were highly significant. Students were able to learn the concepts involved. Perhaps one of the reasons for the success of the unit was its length. Too often a unit on ecology is squeezed into the last two weeks of school in the spring. In this unit time was taken to make sure that essential facts were learned and concepts were understood.

A second reason for effectiveness was that this unit did not rely on just one method of teaching. Many films were used and many of the labs produced highly visible results, assisting those students who were visual learners. Labs and field work also provided an instructional tool for those students who needed to manipulate things in order to learn. And last, of course, traditional lectures and class discussions were used to help those who found it easier to learn in an auditory mode.

A third reason for the success of the unit in teaching ecological concepts was the motivation of the students to learn. It is unreasonable to expect students to learn isolated facts for which they see no relevance. This unit provided material to which the students could relate, and they became confident of their abilities to succeed. They were interested in the river and they found the activities fun. When students want to learn, they generally do.

LEARNING OF RESPIRATION/PHOTOSYNTHESIS

The second question posed in the introduction concerned the effect of the ecology unit on later learning of related topics. Student test scores on respiration and photosynthesis were compared over a five year period. The scores from the latter two years of that period, during which the ecology unit was used as an introduction to biology, were significantly higher than those from the prior three years. The mean on the respiration test from the latter two years was 62.2% which was an increase from the 54.4% of the prior three years. The mean score on the photosynthesis test increased from 61.7% to 69.6%. Both of these increases are significant at the .001 level. The conclusion that the ecology unit did indeed make a difference on later learning is also supported by the students' answers to question 6 in the exit interviews. Fully two-thirds of the students interviewed indicated that they had been helped in understanding the later biochemical units by first learning the concepts of food chains and energy transfer in an ecosystem. In this instructor's opinion the reason has to be that students could see the relevance of the abstract work in cell biochemistry.. Students have always asked why it was important for them to know any details of the Kreb's Cycle or of the ability of chlorophyll to absorb photons of energy. They asked those kinds of questions much less often during the two years covered by this thesis. It would be interesting to know if the ecology unit also helped in student learning of other related material. For example, the large unit on evolution contained a great deal of material on population growth limits. It would be interesting to compare the scores of those students who had already learned thoroughly the concept of limiting factors with those who were not exposed to it. Unfortunately, the evolution unit was also completely rewritten and enlarged at the same time as the ecology unit so there are no scores available for comparison.

ATTITUDINAL CHANGE

Much of the educational literature seems to support the belief that attitudes are difficult to measure and even more so to change. Two areas of attitudinal change were investigated in this thesis. The first area was toward environmental concerns. The survey used to measure this was constructed to be generic; that is, it would fit into almost any environmental unit. It asked many questions that were not covered in the unit under present consideration. Those questions were considered for this thesis. The questions of most immediate importance were those which dealt with local rivers (See Appendix D). Given the amount of time spent at the river and the abundance of interest shown by the students, it was disappointing to find that their attitudes, as measured by this survey, had changed very little. For example, when asked to choose between "inhabited" and "uninhabited" as terms applied to the local river, six students marked "uninhabited" on the post-test. Although no clear data was available on the reading ability of these students, it is possible that they did not understand "uninhabited" in the context in which it was used.

An oral attitude survey would be an interesting undertaking in an effort to solve the problem with students who have low reading abilities. However, the time needed to interview each student in detail would be prohibitive. This instructor will continue to use a written attitude instrument, but one with extensive revisions. The intent is to rewrite the questions of the survey to accomplish two goals. 1) to a custom fit the survey to this particular unit, to eliminate many of the current questions and add more on rivers and water quality; 2) to change the wording of the questions to accommodate the reading skills of low ability students.

The second attitudinal area under investigation in this thesis was student attitudes toward science in general. There were a large number of questions dealing with science methods on the survey. These were all analyzed together and the results are shown in chapter 3 to be significant at the .01 level, indicating that student attitudes had indeed become more positive toward the use of scientific methods. This is considered by this instructor to be quite important in the context of the difficulty of changing attitudes to any measurable degree. Perhaps the reason for success was that students in this school district have had almost no experience with science as a process. Science classes at the middle school level are taught in a classroom with no lab facilities at all. Therefore, students have had very little experience with hands-on science investigations. The river study came as a pleasant surprise to them, and they really enjoyed conducting their own "real science". Given that situation, perhaps it is not surprising that students marked choices more favorable toward scientific methods on the post-test compared to the pretest. Of more interest to this instructor would be the results of an attitude survey of these students in their adult years. An important question is: Are the attitude changes measured in this thesis permanent or will they be obscured in the maturing process of the students, most of whom will take no further science classes?

Another form of attitudinal evaluation was used in the exit interviews of twenty-four students, forty percent of the class. The most striking result of these interviews is that fifty percent of those interviewed chose the ecology unit as the one they enjoyed the most. This is gratifying to the teacher who spent so many long hours preparing this unit. On the other hand if any teacher had the time and patience to spend two full years in the preparation of a unit, would the results be the same as in this case?

A second interesting observation based on the interview results is that more of the C and D students most enjoyed the ecology unit than did the A and B students. In a class which is required of all students, those with lower ability levels or lower motivation levels are at most risk, yet no students failed this unit! This instructor had observed a higher level of confidence on the part of these C and D students as the year progressed. Perhaps it is important to begin a course of this type with units that allow these "at-risk" students to experience success at the very start. Perhaps it is by capturing their interest, as in the stream study, that their overall success can be increased.

Another interesting revelation from the interviews is that although a majority of the students enjoyed the ecology unit more than any other, they did not choose it as the one from which they had learned the most. To understand this one must read the actual question asked, which stressed learning of NEW material ("In which of the four units did you learn the most THAT YOU DID NOT ALREADY KNOW?"). Students have had some instruction in ecological concepts in middle school, but have learned almost nothing about genetics or evolution, the two areas in which the students indicated they had learned the most. One premise of this thesis and the reason for beginning with the stream study was that students are more familiar with ecological concepts than with others in biology. The results of the interviews indicate that this strategy was successful.

Students were asked in the exit interviews to choose between having the stream study in the fall or in the spring. Over ninety percent of them chose the fall. This would indicate that students were aware of the good reasons for beginning with the familiar material.

A final observation from the interviews is that the students' overwhelmingly prefer the unit approach (question 7). Only two students (both of whom received a D on this unit) would have preferred to work strictly from the textbook. The rest (almost ninety-two percent) were comfortable with jumping around in the text to find material that applied to the unit. They seemed to thrive on wondering what their eccentric instructor would ask of them next. In the interviews they left little doubt of their negative feelings the "read the chapter--answer the questions" mode of teaching.

The conclusion of the data analysis and interview evaluation is that the ecology unit was very successful in teaching material and in preparing the students for difficult concepts, as well as in making some attitude changes.

FUTURE PLANS

For the first time in a twenty-three year teaching career this instructor has a data base (reviewed in this thesis) for making decisions regarding the sequence of units in the introductory biology course. Instructors usually make decisions on the basis of what the text offers or on the basis of how she was taught. That is no longer the rationale for curriculum design. The ecology unit will continue to be the introduction for the reasons explained in the preceding section. The labs and field work will be expanded to allow more data to be collected on the river. There are almost limitless possibilities for expanding studies in this stream area in future years. One of the most exciting of these is the chance to work with other science teachers in other area schools in a collaborative effort to gather data on streams in the watershed of the St. Joseph River.

The current biology textbook will be up for review at the end of the 1991-92 school year. On the basis of the effectiveness of an ecology unit as the underlying theme for a biology course, the book that will be chosen will be the newest edition of Biological Science: An Ecological Approach (BSCS Green Version).

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APPENDIX A

STUDENT HANDOUTS

LIMITING FACTORS

If you examine the distribution of animals and plants over the surface of the earth, it becomes obvious that no species is found everywhere. Why? Some parts of the earth are too hot, too cold, too dry, too wet for any one species to survive. Biologists only became aware that each species has its own special requirements for existence in the 1800's. Liebig stated in 1840 that the rate of growth of each population of organism is limited by whatever essential nutrient is present in the shortest supply or minimal amount. He had studied crops and found that the yield of those crops was limited not by water and carbon dioxide, which they need lots of and which are usually present in large amounts, but by elements such as boron or manganese which they need only in trace amounts. We now call Liebig's law the LAW OF THE MINIMUM. The drawing (Figure 1) illustrates this law. Regardless of how tall the rest of the staves may be in the bucket, the shortest stave determines the level of water in the bucket. So too, the requirement that is in the shortest supply, the limiting factor, governs the life of an individual organism or population of organisms.

Today we recognize that Liebig was correct, but that there are also cases in which it is the interaction of more than one factor in the environment that causes the limit on growth. In other words a high concentration of one factor may effect the need for another. An example is that Mollusks such as clams can substitute strontium for calcium in making their shells if calcium is present only in small amounts. That makes calcium less limiting than it would normally be. Another example is that plants require less zinc if they are grown in the shade than if they are grown in the sun. Grasses use more water when the nitrogen in the soil is low.

The types of interactions in the above paragraph complicate the idea of the Law of the Minimum so that we have now come to realize a wider concept--the LAW OF TOLERANCE. The basic idea is that the various factors in the environment are tolerated by a given organism in a range. We call this the range of tolerance. It may be a narrower range at different stages of an organisms life. Usually the range is narrowest or most restrictive during the reproductive stages. Larvae or eggs are less tolerant than adults.

One example of this difference in range of tolerance of an organism is found in the case of the blue crab. This crab normally is found in salt water, although the adults can tolerate the lower salt levels of rivers and frequently migrate up the rivers. But the larvae cannot tolerate the low salt levels so permanent populations of blue crabs have never become established in the fresher water of rivers.

Another example of the range of tolerance is the repeated attempts to introduce ring-necked pheasants into the southern states of the US. The adults survive quite well, but the eggs are evidently killed by the daily high temperatures. As a result the species has never become established in the South.

Now we know that a population of a type of organism in a given environment is limited mostly by those factors which are at or approach the limits of its range of tolerance. These factors are called LIMITING FACTORS. You must understand that too much of any factor is just as limiting as too little. Stop reading at this point and make a list of things which you think could work as limiting factors for many plants or animals. When you have listed as many as you can, continue reading the next section.

SPECIFIC LIMITING FACTORS

1. Temperature.

You have only to think of how few animals and plants live in the arctic to know how limiting temperature can be. In general water environments change temperature less than those on land, so the organisms which live in the water are less well adapted to temperature fluctuations. They are less tolerant or have narrower ranges of tolerance than those which live on land. For example some types of Antarctic fish have a tolerance range of -2 C to +2 C. Now that's a narrow range! Some bacteria have a range of tolerance on the other end of the temperature scale. There are bacterial colonies living and thriving in deep sea hot springs at temperatures around 250 C!

Some organisms live at the extreme limits of their range of tolerance by having evolved strategies for dealing with the extreme temperature. For example, many animals burrow into the soil or snow to escape the heat or cold. This is effective for many burrowing animals in Alaska where the surface temperature of the snow is often around -55 C, but the temperature under the snow at the surface of the soil is a much warmer -7 C. Other strategies include being active only in the cooler desert night, building thick layers of fat or fur as protection from cold, or migrating to other areas during the winter. These strategies are controlled by the animal's inherited genes, not by its own reasoning abilities. So we must think of these as adaptations by the whole species, not by any individual.

2. Light

Sunlight is, of course, the ultimate source of energy for all ecosystems so it is one of the most important factors involved in the distribution of plants and animals. However, prolonged exposure to high intensities or short wavelengths can kill cells, so that, as with every environmental factor too much can be as damaging as too little. If light is completely absent from an area, such as in the deepest water or in caves, the community is limited to animals, bacteria, and fungi. This type of community is dependent on energy sources that come in from other areas where plants can live and carry on photosynthesis.

One of the most interesting effects of light on organisms is the PHOTOPERIOD, which is the number of hours of daylight per day. It has an effect on the flowering of plants, the migration of birds, the spawning of fish, and the seasonal changes in color of some birds and mammals. Some crops will not do well in a given area because the photoperiod is outside their range of tolerance.

3. Water

Obviously water is a factor needed in various amounts by all organisms. It is a limiting factor primarily for land organisms. Most land organisms' bodies consist primarily of water. For example, humans are about 70% water and pineapples are almost 90% water! Plants and animals have developed various strategies to keep from losing valuable water while living on land. Cactus have developed needles instead of broad leaves, because this shape exposes less of the leaf tissue to the air and decreases evaporation. Cactus also have large amounts of water storing tissues in their stems. Desert rats excrete their urine in solid form to save the water normally used to dilute it. Most land animals have thick, water-proof skin. Earthworms, which have thin, moist skin that evaporates water very quickly, survive by burrowing into the soil where the humidity is much higher than in the air.

Water, like all other limiting factors, can be a problem also when there is too much of it. Earthworms cannot get oxygen from water, so when their burrows are flooded by large rains they come to the surface. Plants often die if their roots are completely flooded.

Water is such an important limiting factor that it is used to define some land ecosystems as shown in the following table:

RAINFALL PER YEAR	ENVIRONMENT
0-10"	Desert
10-30"	Grassland
30-50"	Dry forest
over 50"	Wet forest

4. Oxygen

Oxygen is not usually limiting for land organisms, except those living deep in the soil, on the tops of mountains, or within other animals (like a tapeworm). But it is a very important limiting factor in all AQUATIC environments (those in water). The reason for this difference is that oxygen is so much less soluble in water than in air. The gills of a fish or clam will have to pump 26 gal of water to extract only 1 gram of oxygen. That is a ratio of 100,000 to 1! The lungs of air breathers, in contrast, only have to pump 1 gal of air to get 1 g of oxygen. That is a ratio of only 5 to 1. This has had an effect on the structure of gills. The water flow in gills is in one direction; the water does not turn around to flow back out. That is because it costs energy to turn water or air around. We can afford to do this in our lungs because we breathe air, but a fish can not afford it in its gills.

It is very important that you understand that animals which live in water do not use the oxygen atom that is part of the H_2O molecule. Instead they use only the free oxygen (O_2) that is dissolved in the water. The sources of this dissolved oxygen are mostly from the air where the water and air meet and from the oxygen given off by water plants when they are using sunlight to make food in the process of photosynthesis. Do you see that the amount of dissolved oxygen in water could depend on the amount of light?

5. Carbon dioxide

CO_2 is normally not a limiting factor except that it can be in excess (too much) for fish and insect larva in water ecosystems. It does have an effect on the pH of water, which we will discuss later. The sources of CO_2 in water are from the air where it meets the water, from respiration by animals as they burn their food, from the process of decay of dead organisms and their waste, and from underground sources.

6. pH

Remember from your study of physical science that pH is the measure of how acidic or basic a water solution is. The range of tolerance of most water organisms to pH is usually quite broad, but some types of pollution can be a real problem. The most famous example of this is ACID RAIN in which certain gases from air pollution dissolve in the rain water and increase the acidity of streams, soil, etc. Carbon dioxide is one of the gases that dissolve in water to give an acid. The equation for this is:

$$CO_2 + H_2O \text{ -----> } H_2CO_3$$

7. Water currents

In swiftly flowing streams the water current is definitely a limiting factor as it will sweep away any organisms that do not have strategies for dealing with it. You will find in our study that animals which live in fast-moving water are often very stream-lined in shape, have strong swimming ability, or have devices for clinging to rocks or plants.

8. Trace elements

Even though these are elements which organisms need in only very tiny quantities, they are very often limiting because they are found in small amounts in the environment. For example parts of Australia are very low in copper and cobalt and this causes disease in plants and animals, like sheep. Other elements in this category are manganese, zinc, iron, sulfur, selenium, boron.

9. Soil

The type of soil, the amount of topsoil, the soil's pH, water-holding capacity, etc. are often limiting factors for plants. The ability of many animals to survive in a certain environment depends on the presence of certain plants, so soil is important indirectly to animals also.

10. Fire

It took a long time for us to understand that fire is a necessary factor in some populations. An interesting example of this is that the jack pine trees in Michigan have cones that will not release their seeds unless they have been exposed to the heat of fire. So when we controlled ALL forest fires, we caused population of Jack pines to decrease enormously. The little bird, Kirtland's warbler, nests only in jack pine trees of a certain height. When we decreased the number of jack pines, we inadvertently decreased the nesting sites for this bird which is found only in Michigan out of the entire US. The DNR now does CONTROLLED burning of certain areas to allow jack pines to reproduce and the number of Kirtland's warblers is beginning to increase again.

11. Pressure

This is a limiting factor in two areas on earth. See if you can think of these two before reading on. One of these areas is high in the mountains where air pressure is low. This causes oxygen to pass slowly across the membranes of the lungs into the blood. Animals which live in these areas have special physiological strategies for dealing with this lack of oxygen. Another area of the earth in which pressure is a problem is in the deepest oceans. There are some deep sea bacteria which can live only at pressures of 500 atmospheres!

FOOD WEB ASSIGNMENT

For each of the food webs below first draw a diagram showing the producers on the bottom and the third level consumers on the top. Place the decomposers a little to one side as we did in class. The second thing you are to do is to make a separate list of all the producers, decomposers, first-, second-, third-level consumers in all the food chains. If there are any organisms in these lists with which you are not familiar, you must spend a little time in the library looking them up.

1. Bacteria, Bird (small), Earthworm, Fox, Grass, Grasshopper, Mountain lion, Mouse, Owl, Rabbit, Raspberry bush, Shrew, Snake, Spider

2. Algae, Bird, Crab, Clam, Fish (small), Fish (large), Human, Protozoa, Starfish, Worm (eats algae)

3. Aquatic plants, Grasshopper, Hawk, Heron, Land plants, Mallard duck, Mouse, Owl, Rat, Sandpiper, Sparrow, Smelt, Shrimp, Vole

Now make your own list and food web diagram of all the organisms found in a temperate deciduous forest (if you do not know what that is, look it up). Make sure NOT to include man and make sure TO include predators which man has destroyed as part of that environment. In other words make the food web as it was before we interfered with it.

QUESTION: Why do you think the third level consumers are usually shown on the top of the food web diagram? What does this signify? Why doesn't any other animal eat the animals which are third-level consumers?

APPENDIX B

STUDENT LABORATORIES

LIMITING FACTORS FOR ALGAE

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Phosphorus (P) and nitrogen (N) are necessary nutrients for the growth of any plant life. The production of carbohydrates, through photosynthesis, does not in itself satisfy the needs of plant cells. Various fats and proteins must be formed from carbohydrates to furnish the additional components needed for life. Phosphorus and nitrogen enable this to take place. But, if either of these nutrients is in short supply, it becomes a limiting factor, retarding further growth. This is Liebig's Law of the Minimum.

In this experiment you will be testing this law using a solution of nutrient fertilizer in varying concentrations and a suspension of algal cells from an aquarium. The problem you will be dealing with is the amount of growth in each concentration of fertilizer (containing both P and N). You will be graphing your results.

HYPOTHESIS:

Write three or more hypotheses dealing with the relationship between the growth of the population of algae and the concentration of fertilizer. Choose the one which you feel is the best.

MATERIALS:

Dropper
7 bottles
teaspoon
tablespoon
suspension of green aquarium scum
liquid plant fertilizer
distilled water
half-inch pieces of chalk
Spec 20 and cuvettes

CAUTIONS AND PITFALLS:

1. Be sure to mark the bottles and tubes accurately with numbers 1--7 and DO NOT mix them up.

2. It will help if each week you will rotate the bottles so that all sides are exposed to sunlight.

PROCEDURE:

1. Set up 7 bottles each containing a piece of chalk and 10 drops of the aquarium scum. This scum is the source of the algae colonies. Label each bottle with 1-7.

2. Fill the bottles according to the following chart:

BOTTLE	AMT FERTILIZER	AMT. H_2O
1	full	none
2	5 tablespoons	fill
3	1 tablespoon	fill
4	1 teaspoon	fill
5	20 drops	fill
6	2 drops	fill
7	none	fill

3. Place a cover over each bottle and place them in the sun.

4. At the end of each week swirl each bottle and withdraw enough of the colony to fill a cuvette tube which is marked with the same number as the bottle.

5. Using the Spec 20, measure the absorbance/ transmittance of each tube and record in your data table. Use a wavelength setting of 430.

6. Return the material from each tube to the bottle from which it came. BE SURE NOT TO GET THE TUBES AND BOTTLES MIXED UP.

7. At the end of five weeks graph the absorbance against the time for each colony. Use a different color for each colony (bottle).

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypothesis on the basis of observable and tabulated data.

TEMPERATURE AS A FACTOR IN DETERMINING DISSOLVED OXYGEN

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Water quality is essential to many forms of life other than mankind. Land and aquatic organisms all depend on water for survival. There are many ways to test for water quality, just as there are many different kinds of water systems to test, such as lakes, rivers, and streams. In doing this laboratory exercise you will be performing a task similar to those used by water researchers and scientists: collecting data and interpreting the results.

You will be testing for the amount of dissolved oxygen, abbreviated D.O. Dissolved oxygen is essential to the metabolism of all aerobic aquatic organisms. Therefore, the concentration of DO is a direct indicator of the distribution, behavior, and growth of aquatic organisms.

The factors that control dissolved oxygen concentration are important in determining oxygen availability to these creatures. The rates of oxygen input (atmospheric, photosynthetic, and wave action) are counterbalanced by oxygen output (metabolism and respiration). The rate of this oxygen use allows for the evaluation of the metabolism of fresh water organisms.

The problem you will deal with in this lab is the effect of water temperature on the concentration of dissolved oxygen.

HYPOTHESIS:

Write three or more hypotheses for the problem of the relationship between temperature and concentration of dissolved oxygen. Choose the one which you feel is the best.

MATERIALS:

Ring stand
Ring
Wire gauze
Bunsen burner
Beaker tongs
1 beaker 400-500 ml
2 beakers 100 ml
Thermometer
DO Hach kit

CAUTIONS AND PITFALLS:

Be sure to eliminate all air bubbles in bottles before shaking.

Bottles must be thoroughly rinsed before continuing.

Keep PAO dropper vertical to maintain proper drop size.

PROCEDURE:

1. Follow all steps according to the Hach kit manual for each sample to determine DO. All readings will be taken at 10 C intervals. The flocculent (woolly) precipitate may be flushed down the sink with copious amounts of water.

2. Remove 350 ml of the sample to be tested. Place the thermometer in the beaker; wait one minute and record the temperature. Re-read "Cautions and Pitfalls". Now take the concentration of dissolved oxygen. Record. Rinse bottle thoroughly.

3. Heat the remaining sample on the ring stand until a temperature increase of 10 C is achieved. Take the DO concentration and record both temperature and DO. This is trial 2.

4. Repeat step 3 until you have 6 readings. Be sure to rinse bottle thoroughly between each step.

DATA:

Make a data table to include the temperature and concentration of DO for each of the 6 trials.

Graph your results using temperature on the X axis (horizontal) and DO concentration on the Y axis (vertical).

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypotheses on the basis of observable and tabulated data.

QUESTIONS:

1. Why is it important to be sure there are no air bubbles in the sample bottle?

2. What is the purpose of rinsing the bottle thoroughly before making more tests?

3. According to your data and graph, was there one 10 C interval that had a much greater/smaller change than the other 5? Suggest a reason for this.

4. By extrapolation of your graph, determine the concentration of DO at the boiling point (100 C)

5. Suggest two other inorganic factors that may influence the level of DO and discuss how they might effect the DO content. (Hint: most inorganic factors are also in the water.)

BIOLOGY LAB
pH OF COMMON SUBSTANCES

INTRODUCTION:

You have learned that pH is a scale measuring the concentration of hydrogen ions in solutions. The scale is from 0 to 14 with 7 being neutral. pH lower than 7 is acidic and pH higher than 7 is alkaline or basic. In this lab you will gain experience with various methods of measuring pH by comparing pH of several household substances.

PROCEDURE:

1. To use the large pH meter first make sure it is set on STAND-BY. Remove the electrode CAREFULLY from its holder and rinse it with water from the wash bottle. The rinse water should go into the waste beaker. GENTLY place the electrode into the solution to be tested. Turn the meter to "pH MODE" and read the pH to the nearest 0.1 on the top scale. Turn the meter to STAND-BY, remove the electrode from the solution, rinse it from the wash bottle, and replace the electrode into its holder.

2. To use the portable pH meter remove the protective cover and place the electrode in the solution to be tested. Turn the meter on and read the pH to the nearest 0.1. Remove the electrode from the solution, turn the meter off, and rinse the electrode with water from the wash bottle.

3. To use the pH paper, dip a small strip of the general paper into the solution to be tested and compare the color to the chart on the side of the paper holder. Using this approximate pH as a guide, choose a more specific paper and repeat the procedure. BE VERY CAREFUL NOT TO ALLOW COLOR CHARTS TO COME OUT OF THE HOLDERS. Replace all pH paper holders into the tray.

4. Using the three methods above, measure the pH of as many of the substances as you have time for. Be sure to use more than one method in order to compare the readings. Make a data table for reporting your results.

LABORATORY INVESTIGATION
ORGANISMS AND pH

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

In your reading assignment on limiting factors you learned that pH is the measure of how acidic or basic a water sample is. You also learned that pH can be limiting to organisms, but often is not. In this lab we will deal with the problem of how living tissue deals with changes in pH. Often the changes in pH come about because of the metabolic activities of the tissue itself, and so is unavoidable. How do organisms survive and maintain themselves in spite of metabolic activities that tend to shift pH either toward acidic or basic ends of the pH scale?

MATERIALS:

pH meter or pH paper
tap water
small beakers
graduated cylinder
dropping pipets
0.1 N NaOH
0.1 N HCl
liver or potato homogenate
egg white--diluted
2% warm gelatin
sodium phosphate pH 7 buffer solution

CAUTIONS AND PITFALLS:

Both HCl and NaOH are strong chemicals which are harmful to your skin and to your clothes. Goggles and aprons are ABSOLUTELY REQUIRED. Should you spill either chemical on you begin rinsing with tap water immediately and tell your teacher. Should you spill either chemical on the lab table or floor, tell your teacher.

PART A

In order to compare the reaction of living substances to that of nonliving materials in relation to pH changes, you will first use tap water as the solution to be tested. You will add progressively larger amounts of first HCl (hydrochloric acid) and then NaOH (sodium hydroxide--a base) to tap water and will measure the pH after each addition.

HYPOTHESIS:

Write a hypothesis concerning the effect of HCl on the pH of tap water.

Write a hypothesis concerning the effect of NaOH on the pH of tap water.

PROCEDURE:

1. Prepare a data table with a section for the changing pH after HCl additions and another section for the changing pH after NaOH additions.

2. Pour 25 ml of tap water into a small beaker.

3. Record the initial pH of the tap water.

4. Add 0.1 N HCl a drop at a time, swirling CAREFULLY tomix after each drop. Determine the pH after each 5 drops have been added until 30 drops have been used. Record the pH measurements in your table. Rinse the beaker thoroughly.

5. Pour another 25 ml of tap water into the beaker and record its initial pH.

6. Add 0.1 N NaOH drop by drop, recording the pH changes in exactly the same way as for the 0.1 N HCl.

7. Make a simple graph, plotting 2 lines for the change of pH in tap water against the drops of acid and base solutions added. Use two colors, one for the acid and one for the base.

CONCLUSIONS:

Carefully analyze the data table and graph you have developed. Discuss the effect that acid/base had on the pH of tap water. Accept or reject your hypothesis on the basis of the data you have collected. Be sure to explain your reason for accepting or rejecting the hypothesis.

PART B

In this part of the lab you will be doing the same procedure as in Part A, except you will use samples from living tissues--a tissue homogenate, egg white, and gelatin instead of the tap water. A tissue homogenate is simply plant or animal tissue chopped with a little water in a blender. This separates the cells and releases the chemicals which were inside the cells.

HYPOTHESIS:

Write a hypothesis concerning the relative amount of pH change with HCl and NaOH between tap water and the tissues. (Will the tissue homogenate change pH more or less than the tap water did?)

PROCEDURE:

1. Prepare a data table similar to the one you used in Part A. You will need a separate section for the tissue homogenate, for the egg white, and for the gelatin. Each will be measured with NaOH and with HCl.

2. Repeat the steps from Part A but use the tissues instead of tap water.

3. Plot simple graphs, plotting 2 lines for the change of pH in the tissues against the drops of acid/base solutions added. Use 2 colors, one for the acid and one for the base.

CONCLUSIONS:

Carefully analyze the data table and graph you have developed. Compare them to those developed in Part A. Accept or reject your hypothesis on the basis of the data you have collected. Be sure to explain your reason for accepting or rejecting the hypothesis.

PART C

What accounts for the behavior of living tissue in response to changes in pH? Why aare the changed not as great as when nonliving material, such as tap water was used in the lab? Frequently in biology, it is difficult to study living tissue. Investigators have found that they can learn as much, and sometimes more, by substituting a model for the real thing. We will use aa model to get data to help us answer the questions asked at the beginning of this paragraph.

PROCEDURE:

1. Prepare a data table similar to that used in part A.

2. Test the buffer solution (a nonliving chemical solutions--a model) using the same techniques as used in parts A and B. The only difference will be to substitute the buffer solution for the tap water and the tissues. Record all your data.

3. Prepare a graph of the buffer solution in the same way that you did the graphs for parts A and B. Use one color for acid and one for base.

QUESTIONS:

1. Is the response of the nonliving buffer solution to change in pH more like that of water or of the tissues?

2. How does the reaction of the buffer solution serve as a model for the response of the biological materials (tissues) ?

3. Would the presence of buffers in living cells aid or hinder the response of that organism to changes in the pH of the environment?

BIOLOGY LABORATORY
WATER QUALITY
TESTING FOR IONS

Background:

The water that we use on a daily basis is more than just H_2O. Dissolved in it are various ions, atmospheric gases and possibly a variety of other contaminants. Contaminants such as mercury and lead compounds, pesticides, and organic solvents exist in lakes and streams and in our drinking water and are toxic to wildlife and to humans. These contaminants are typically found at VERY low concentrations in the part per million to part per billion range and require sophisticated and expensive analytical techniques to detect.

Ions are usually found at much higher concentrations in the gram per liter or part per thousand range and are easy to detect at these levels by using one-step chemical reactions that form a visible result such as a precipitate (settles to the bottom) or a color change. However, it must be kept in mind that these tests can only confirm that an ion is present. A negative test result (no color change or no precipitate) does not necessarily indicate that the ion is not present, since it may be present in such a small amount that the color or precipitate cannot be seen.

Ions are not always considered contaminants in water, for it is ions that give "mineral" water its pleasing taste. In our drinking water, ionic forms of chlorine prevent the growth of bacteria that cause disease and fluoride ions help prevent cavities by stopping the growth of bacteria that form plaque on our teeth. Some ions, while harmless at low concentrations, can cause problems at too high concentrations. For example, high iron or sulfur ion concentrations can lead to the growth of bacteria that make drinking water taste bad..

Objective:

To test for the presence of iron, calcium, chloride, and sulfate ions in water.

Proceaure:

A. SET UP

1. Rinse 5 test tubes with distilled water.

2. Use a graduated cylinder to measure 2 ml of tap water into a test tube; mark the level with a marker. Mark the other four test tubes at the same level so that further measuring is not necessary. Be very careful of these marks. Label the test tubes in the following manner:

R = reference solution
T = tap water
D = distilled water
N = Nottawa river water
M = Mill stream water

B. TEST FOR Fe^{+3} IONS.

1. Pour 2 ml of iron nitrate solution into the test tube labeled R.

2. Add 2 ml of distilled water to the tube labeled D.

3. Add 2 ml of river water to the tube labeled N.

4. Add 2 ml of mill stream water to the tube labeled M.

5. Add 2 ml of tap water to the tube labeled T.

6. Add three (3) drops of KSCN solution to each test tube, mixing thoroughly.

7. Holding a sheet of white paper behind the test tubes, look for a color change (usually red) in any of the test tubes. Positive test will be in test tube R.

8. Discard solutions in the proper waste containers. Wash test tubs with tap water and rinse them with distilled water before going on to the next test.

C. TEST FOR Ca^{+2} IONS.

1. Add 2 ml of Calcium chloride solution to the test tube labeled R.

2. Prepare the other four test tubes in the same manner as in part B.

3. Add three drops of $HC_2H_3O_2$ and three drops of $Na_2C_2O_4$ to each test tube. Mix thoroughly

4. Observe each test tube carefully for any changes. Positive test will be in test tube R.

5. Discard solutions in the proper waste containers. Wash test tubes with tap water and rinse them with distilled water before going on to the next test.

D. TEST FOR Cl^{-1} IONS

1. Add 2 ml of Calcium chloride solutions to the tube labeled R.

2. Prepare the other four test tubes in the same manner as in part B.

3. Add three drops of $AgNO_3$ to each test tube, mixing thoroughly.

CAUTION: SILVER NITRATE STAINS SKIN BLACK!

4. Observe each test tube carefully for any changes. Positive test will be in test tube R.

5. Discard all solutions in proper waste containers. Wash each test tube in tap water and rinse with distilled water before going on to next test.

E. TEST FOR SO_4^{-2} IONS.

1. Add 2 ml of iron sulfate solution to the tube labeled R.

2. Prepare the other four tubes in the same manner as in part B.

3. Add three drops of $BaCl_2$ solution to each tube and mix thoroughly.

4. Observe each test tube carefully for any change. Positive test result will be in tube R.

5. Discard all solutions in proper waste containers and clean up entire lab area.

DATA:

Make a data table listing all waters tested, marking each positive or negative for each ion.

Write a description of the positive test for each ion.

BIOLOGY LAB
INTRODUCTION TO MICROSCOPES

Part A. Becoming familiar with the microscope.

1. Label the parts of the microscope on the diagram.

2. Turn the objectives to low power. Notice a faint click as it slides into place.

3. Look through the eyepiece. A circle of bright light should now be seen.

4. Adjust the mirror and diaphragm to make the circle of light as bright as possible.

5. Look at the SIDE of the microscope. Slowly turn the coarse adjustment back and forth. Notice the movement of the low power objective.

6. Turn the fine adjustment. Notice the movement of the low power objective. It may be difficult to see.

Part B. Preparation of a temporary wet mount slide.

1. Remove a piece of hair from your head. We will use this as an example specimen.

2. With your finger place a drop or two of water on the center of the slide.

3. Place the hair (or any other specimen) in the water.

4. Place a cover slip over the drop of water. To avoid trapping air under the cover slip, lower the cover slip at an angle as demonstrated by your teacher.

Part C. Location of an object under the microscope.

1. Be sure the microscope is on LOW POWER! LOW POWER IS ALWAYS USED FIRST IN LOCATING OBJECTS! Adjust the mirror and diaphragm for best light.

2. Place the wet mount of a hair on the stage of your microscope. Position the slide so the hair is directly over the center of the stage opening. Secure the slide in place with the clips.

3. Look to the side of the microscope. Slowly lower the low power objective by turning the coarse adjustment wheel until the objective almost touches the slide. On our microscopes that means lowering it as far as it will go.

4. Look through the eyepiece. Turn the coarse adjustment so the objective rises from the stage. The hair should become visible within the first turn and a half of the adjustment. If it does not, move the slide around to center the hair under the objective.

5. Bring the hair into sharp focus by turning the fine adjustment.

6. Failure to see the specimen may be due to one of the following:
   a. Hair not centered over the stage opening.
   b. Objective raised too far.
   c. Not properly focused
   d. Improper lighting.
   e. Low power objective not clicked into place.

Part D. Increasing the magnification.

1. Locate the hair on LOW POWER as in PART C.

2. Turn the nosepiece until the high power objective clicks into position. Do NOT move the coarse adjustment knob. If the microscope is properly focused on low power, the high power objective will NOT hit the slide. If it does, do not force it; call your teacher.

3. Look through the eyepiece. The hair should be visible. However, it may need to be focused. USE THE FINE ADJUSTMENT ONLY. NEVER USE THE COARSE ADJUSTMENT WITH HIGH POWER!

4. Adjust the diaphragm if needed for best lighting.

5. Failure to see the specimen may be due to reasons listed above.

Part E. Position of objects when viewed under the microscope.

1. Cut a lower case "e" from a ditto.

2. Prepare a wet mount slide of the "e". Place it on the stage and position the slide so that the "e" faces you as it would on a newspaper page.

3. Use low power and focus on the "e".

4. While looking through the eyepiece, move the slide slowly from left to right.

5. While looking through the eyepiece, move the slide slowly from right to left.

6. While looking through the eyepiece, move the slide slowly away from you.

7. While looking through the eyepiece, move the slide slowly toward you.

Part F. Use of the diaphragm.

1. Prepare a wet mount slide of a few strands of absorbant cotton.

2. Observe the cotton under low power. While looking through the eyepiece, change the amount of light entering the microscope by adjusting the diaphragm.

3. Observe the cotton under high power. Again change the diaphragm from maximum to minimum light and back again.

Part G. Depth of field.

1. Prepare a wet mount slide of two threads of different colors. Cross the two strands to form an X before adding water and the cover slip.

2. Locate the strands under low power. Center the slide at the point where the strands cross. Adjust the diaphragm.

3. Change to high power and observe both strands where they cross. Turn the fine adjustment back and forth by a quarter of a turn while looking at the strands. This should allow you to see first one and then the other in proper focus.

INTRODUCTION TO MICROSCOPES
ANALYSIS

Write the functions for the following microscope parts:

1. Diaphragm
2. Stage opening.
3. Mirror or lamp.
4. Eyepiece.
5. Low power objective.
6. High power objective.
7. Revolving nosepiece.
8. Coarse adjustment.
9. Fine adjustment.
10. Stage.
11. Stage clips.
12. Total magnification is determined by adding the eyepiece lens magnification to the objective lens magnification.
13. An object should always be located first with low power. TF
14. Which adjustment is used to sharpen focus with high power?
15. A microscope should be carried with both hands, upright, and close to the body. TF
16. What part of the microscope controls the amount of light through the opening?
17. What is the total magnification of our low power lens?
18. What is the total magnification of our high power lens?
19. What is the total magnification obtained when using low power with our eyepieces?
20. What is the total magnification obtained when using high power with our eyepieces?

21. Which adjustment is used to locate an object under low power?

22. Which adjustment is used when focusing with high power?

23. The objectives should never be lowered toward the stage with the coarse adjustment without looking at the microscope from the side. TF

24. What was the position of the "e" viewed with the microscope compared to its position on the slide?

25. What is the effect of the lenses of the microscope on the movement of the "e"?

26. How could you position an object under the microscope so it is viewed right side up?

27. Using low power, under what diaphragm setting are the cotton fibers sharpest? (maximum, medium, minimum light)

28. Using high power, under what diaphragm setting are the cotton fibers sharpest? (maximum, medium, minimum light)

29. Can you see both threads fairly clearly at the same time when using low power?

30. Can you see both threads fairly clearly at the same time when using high power?

31. Which has greater depth of field--high or low power?

32. State the relationship between increasing magnification and increasing depth of field.

ANALYSIS OF FEEDING GROUPS
STREAM MACROINVERTEBRATES

TAKEN FROM
CUMMINS AND WILZBACH

The objective of this exercise is to do a quick initial assessment of the food base of a stream ecosystem by focusing on the roles played by the macroinvertebrates present. Macro means larger than microscopic and invertebrates are those animals without backbones. According to the authors of the original lab, about 80-90% of the organisms that you will find can be classified accurately this way. This is good enough for our purposes, but for a more detailed study, we would need to use more complex keys.

Stream macroinvertebrates are separated into four FEEDING GROUPS. SHREDDERS are dependent on large pieces of organic matter such as leaves, needles, wood, and other plant parts. COLLECTORS use small particles of organic matter (generally less than 1 mm in size), either by filtering from the passing water or gathering from deposits in the sediments on the stream bottom. SCRAPERS are adapted for removing attached algae, especially where it grows on rocks or log surfaces in the current. PREDAOTRS are adpated through behavior and specialized body parts for the capture of prey.

We will take handfuls of organic materials from four areas of the stream as follows:

a. Coarse Particulate Organic Matter (CPOM) = litter accumulations of leaves, needles, bark, twigs, other plant parts, and coarse fragments of these materials from a riffle.

b. Fine Particulate Organic Matter (FPOM) = particles less than 1 mm in size from the fine organic-rich sediment of a pool.

c. Periphyton = Predominantly attached algae (diatoms) on rock and wood surfaces.

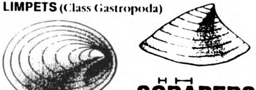
d. Large Wood = Branches and logs. Taken from soft punky wood fallen into the streams.

KEY TO FUNCTIONAL FEEDING GROUPS

⊢⊣ ⊢——⊣ Indicates size or range of sizes

1. ANIMALS IN HARD SHELL (Phylum Mollusca)

a. LIMPETS (Class Gastropoda)



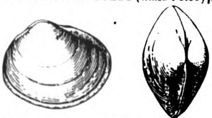
SCRAPERS

b. SNAILS (Class Gastropoda)

SCRAPERS

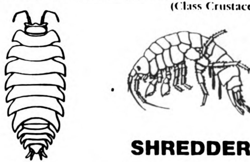
Snails are generalized (facultative) feeders and can also function as Shredders.

c. CLAMS OR MUSSELS (Class Pelecypoda)



FILTERING COLLECTORS

2. SOW BUG OR SHRIMP-LIKE ANIMALS (Class Crustacea)



SHREDDERS

Generalized, can also function as Gathering Collectors.

3. LARVAE IN PORTABLE CASE OR "HOUSE"
Go to page 6.

4. LARVAE IN FIXED RETREAT WITH CAPTURE NET

Note: Care must be taken when collecting to observe nets.

Go to page 8.

5. WITHOUT CASE OR FIXED RETREAT

a. WORM-LIKE LARVAE WITHOUT JOINTED LEGS
Go to page 10.

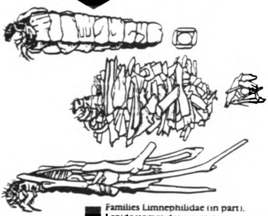
b. NYMPHS OR ADULTS WITH JOINTED LEGS
Go to page 12.

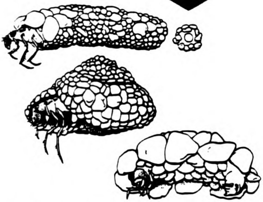
FIRST LEVEL OF RESOLUTION

LARVAE IN PORTABLE CASE
Caddisflies (Order Trichoptera)

CASES ORGANIC
Leaf, stick, needle, bark

CASES MINERAL
Sand, fine gravel





Families Limnephilidae (in part), Lepidostomatidae (in part), Phryganeidae, Leptoceridae (in part)

Families Glossosomatidae, Limnephilidae (in part), Helicopsychidae

SHREDDERS

SCRAPERS

SECOND LEVEL OF RESOLUTION considers a few fairly common caddisflies that would be misclassified above on the basis of case composition alone.

CASES ORGANIC

CASES MINERAL

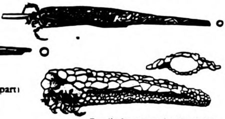
Cases square in cross section and tapered, with no bark or flat leaf pieces included. Front attached to substrate. Larvae extend legs and filter the current.

Cases long, slender, and tapered, made of plant material

Cases long, slender, and tapered (mostly fine sand) *or* cases ovoid and very flat in cross section

Family Brachycentridae

Family Leptoceridae (in part)



Family Leptoceridae (in part)

FILTERING COLLECTORS

GATHERING COLLECTORS

GATHERING COLLECTORS

FIRST LEVEL OF RESOLUTION

LARVAE WITH FIXED RETREAT AND CAPTURE NET

Note: Care must be taken when collecting to observe nets.

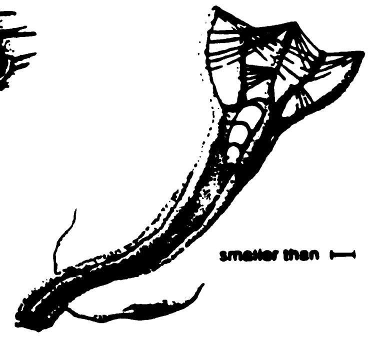
Caddisflies (Order Trichoptera)

True Flies (Order Diptera)

COARSE NET IN "SCAFFOLDING"

FLATTENED SOCK-LIKE OR TRUMPET-SHAPED NET OF FINE MESH

TUBE WITH SILK STRANDS STRUNG BETWEEN TERMINAL PRONGS



True Midges (Family Chironomidae)

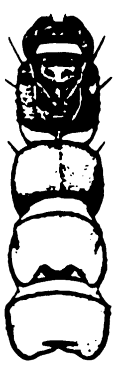
Families Hydropsychidae, Philopotamidae, Polycentropodidae

FILTERING COLLECTORS

SECOND LEVEL OF RESOLUTION separates from free living larvae those net spinning caddisflies that may have been inadvertently collected without being associated with their nets.

NET SPINNING CADDISFLIES

Frequently separated from their nets



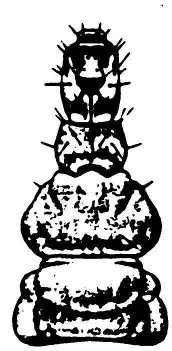
HEAD AS WIDE AS THORAX

Especially Philopotamidae (bright yellow) and Hydropsychidae (bright green or brown)

FILTERING COLLECTORS

FREE LIVING CADDISFLIES

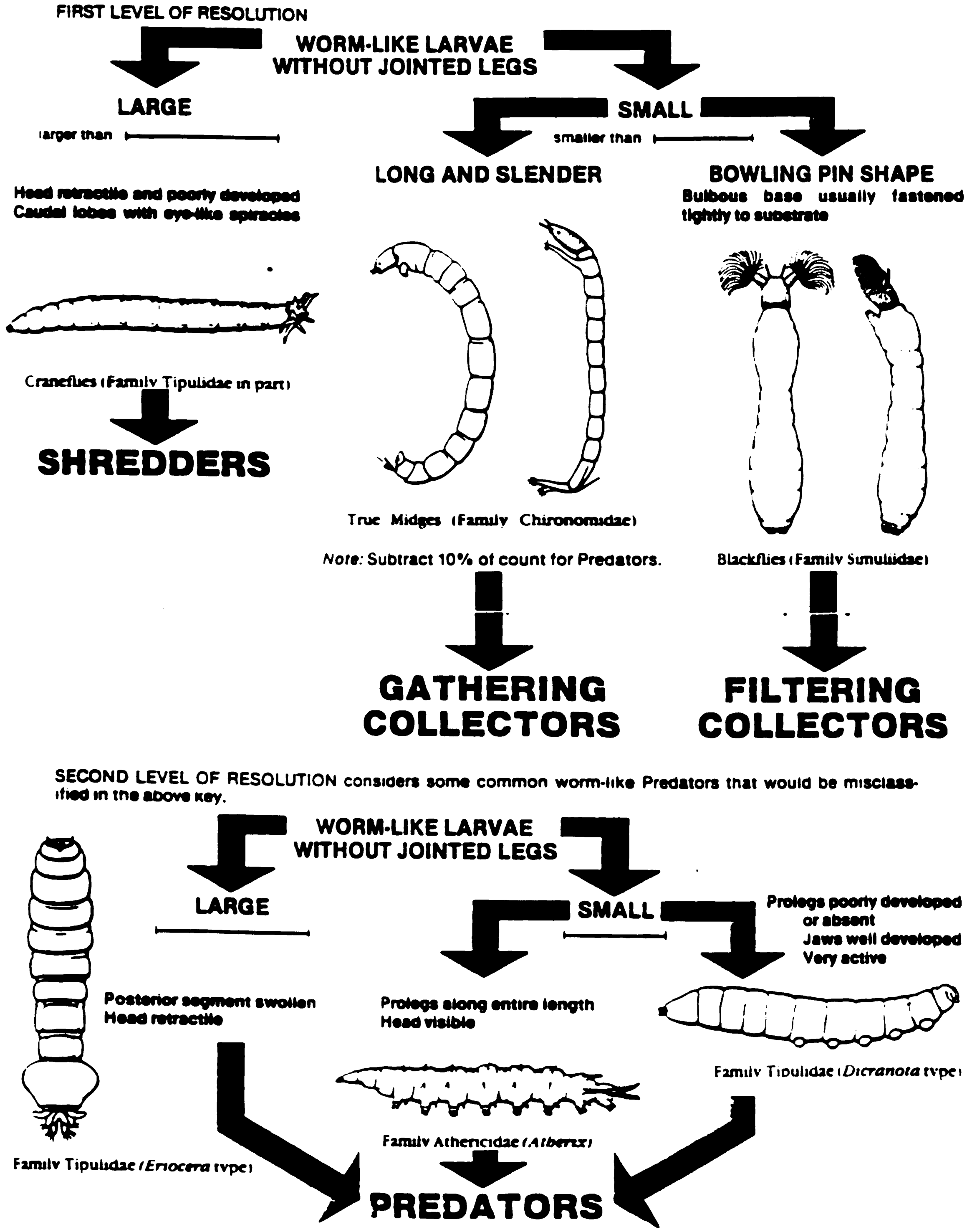
Non net spinning



HEAD LONG, SMALL, AND NARROWER THAN THORAX

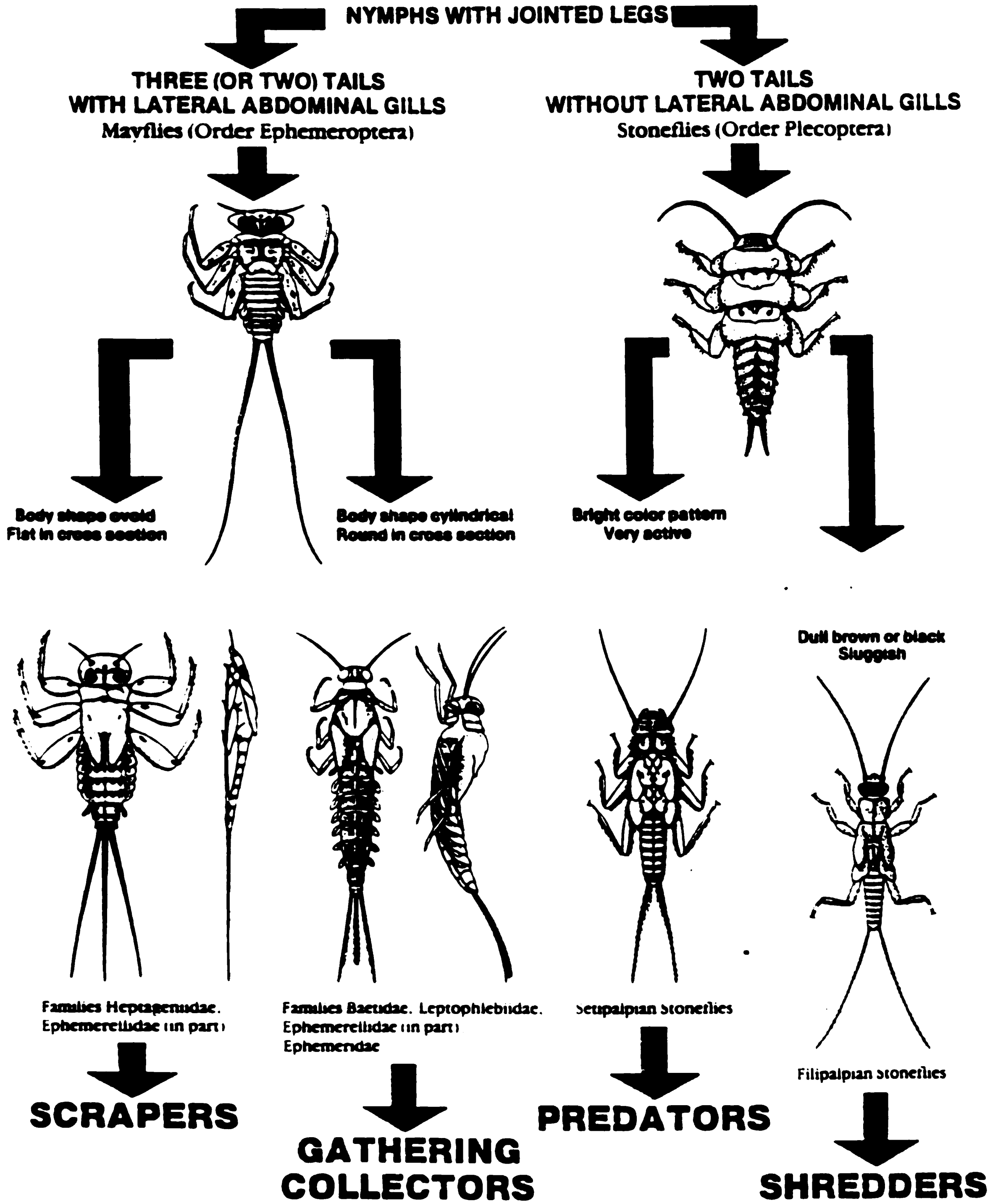
Rhyacophilidae (often bright green)

PREDATORS


FIRST LEVEL OF RESOLUTION
WORM-LIKE LARVAE WITHOUT JOINTED LEGS
LARGE
larger than
SMALL
smaller than
LONG AND SLENDER
BOWLING PIN SHAPE
Head retractile and poorly developed
Caudal lobes with eye-like spiracles
Bulbous base usually fastened tightly to substrate
Craneflies (Family Tipulidae in part)
SHREDDERS
True Midges (Family Chironomidae)
Note: Subtract 10% of count for Predators.
Blackflies (Family Simuliidae)
GATHERING COLLECTORS
FILTERING COLLECTORS
SECOND LEVEL OF RESOLUTION considers some common worm-like Predators that would be misclassified in the above key.
WORM-LIKE LARVAE WITHOUT JOINTED LEGS
LARGE
SMALL
Prolegs poorly developed or absent
Jaws well developed
Very active
Posterior segment swollen
Head retractile
Prolegs along entire length
Head visible
Family Tipulidae (Dicranota type)
Family Athericidae (Atherix)
Family Tipulidae (Eriocera type)
PREDATORS

11

FIRST LEVEL OF RESOLUTION



13

SECOND LEVEL OF RESOLUTION considers some fairly common insects that do not fit in the above key or would be misclassified on the basis of body shape alone.

LARVAE OR NYMPHS WITH JOINTED LEGS WITHOUT CASE OR FIXED RETREAT

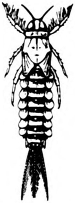
WITH LONG TAILS
Mayflies (Order Ephemeroptera)

Body shape ovoid
Rear end often erected scorpion-like when disturbed

Families Ephemerellidae (in part), Caenidae, Tricorythidae

GATHERING COLLECTORS

Body shape cylindrical
Long hairs on inside of front legs
Often with stripe down back

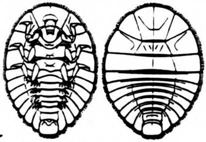


Family Siphlonuridae

FILTERING COLLECTORS

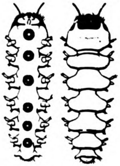
WITHOUT LONG TAILS
Beetles (Order Coleoptera)

Disc shape
Head and legs totally concealed beneath



Water Pennies (Family Psephenidae)

Lobed body
Ventral suckers



Family Blephariceridae

SCRAPERS

Slender
Triangular in cross section
Hard, yellowish brown covering

If larva has spines along lateral margins it is a wood-eating Shredder.

Riffle Beetles (Family Elmidae)

GATHERING COLLECTORS

BIOLOGY LAB
CRAYFISH

Section A--PRESERVED CRAYFISH

1. Observe the specimen. Does it have an endo- or an exo-skeleton?

The body of the crayfish is divided into two distinct regions. The region toward the head (anterior) is called the CEPHALOTHORAX. It is the combination of the head and the thorax common to all arthropods. The region away from the head (posterior) is called the ABDOMEN. The abdomen ends in a reduced segment called the TELSON.

2. How many segments are there on the abdomen?

3. The cepahlothorax is covered by the CARAPACE. How many pieces make up the carapace?

Notice that a groove marks the division between the head and thorax. Observe that the carapce extends forward. This forms a horny beak called the ROSTRUM.

4. Where are the large compound eyes in relation to the rostrum?

The most anterior appendages are the branched ANTENNULES. Locate the antennae which are attached to the head, posterior to the antennules.

5. What is the structure of the antennae?

Turn the crayfish over so that you can see its mouthparts. Use a probe to move the mouthparts.

6. Do the mouthparts move up and down or side to side?

The thorax has eight pairs of appendages. Three pairs are MAXILLIPEDS and are used in handling food. Five pairs are legs. Try to find all eight pairs.

7. How are the maxillipeds different from the legs?

8. The first pair of legs are well-developed pincers called CHELIPEDS. Are these the same size? If not, explain why this might be so.

9. The next four pairs of legs are called WALKING LEGS. In what ways do they differ from one another?

The abdominal appendages of the crayfish are called SWIMMERETS. In the female, the first pair of swimmerets are small. In the male, the first two pairs are modified for transferring sperm.

10. Can you determine the sex of your specimen?

The sixth pair of swimmerets are enlarged to form the UROPODS. The uropods and the tlson form the powerful tail fin used in backward swimming. Find the ANAL OPENING on the ventral (belly) side of the telson.

Section B--LIVING CRAYFISH

1. Observe a living crayfish for 5 minutes. Record any behavior that you see.

2. Describe the manner in which the crayfish walks.

3. Gently touch a probe to an antennae. Describe the reaction.

4. Shine a penlight flashlight on the anterior end of the crayfish. Then, shine it on the posterior end of the animal. Compare the reactions and explain this behavior.

5. Put 5 drops of saturated salt solution in the water near the animsl. Describe the crayfish's reaction.

6. Put 5 drops of vinegar near the animsl. Describe its response.

7. Change the water in the bowl and add a drop of India ink just posterior to the cephalothorax. What is the direction of the flow of water through the gill chambers?

8. What creates these water currents?

Part C--SUMMARY:

:

Give the function of the following structures of the crayfish.

1. Antenna

2. Mandible

3. Maxilla

4. Maxilliped

5. First walking leg--Cheliped

6. Walking legs

7. First swimmerets

8. Swimmerets

9. Uropods/Telson

ARTHROPODS
CRAYFISH/INSECT COMPARISON

The handout for this lab is available in the following published lab book:

Hummer, Paul J., Albert Kaskel, James E. Kennedy, and Raymond F. Oram. Laboratory Biology: Investigating Living Systems. Columbus, Ohio: Charles E. Merrill Publishing Co., 1976.

OBSERVATION OF ALGAE AND PROTOZOANS

No handout is necessary for this lab. Simply use dichotomous keys available for these organisms.

SCHOOLING BEHAVIOR IN FISH

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Animals may gather in a group for different reasons. If they are attracted to the same spot by the presence of food, light, or some external stimulus, the group is called the aggregate. If, however, they form a group because they are mutually attracted to one another, the group is called a school in the case of fish, and a herd, or flock, in the case of mammals or birds. In fish, vision, swimming movements in the water, and olfaction (sense of smell) may all contribute to keeping the members of the schools together, but vision is the most important cue. Schooling fish seem to be attracted to each other mainly by their appearance, and the attraction is the strongest for other members of the same species. Schooling is a form of communication between members of the same species, but fish of different species do sometimes school together as well.

Schooling is very prevalent among all sorts of fish, from very primitive ones to more advanced species. The members of the school may be better protected from predators than single fish, and they seem to be able to swim more efficiently. A predator in a school has a greater chance of locating food than does a lone predator. For plankton-feeding fish, however, food is always present, and there will be less food for each fish in a school than there would be for a single fish. Members of a school can learn from each other more quickly than a single fish can learn, and they do not have to spend energy locating mates for reproduction.

However, one big disadvantage of schooling behavior is that it has made the human fishing industry very successful and efficient and may ultimately lead to the decline or even extinction of many fish species.

In this experiment you will be testing the role of the visual component in schooling behavior. Because the fish will be separated by a glass barrier, there can be no communication by sound or chemical signals. In many fish vision is the prime factor in the attraction of schooling fish toward each other, but olfaction and sound seem to help maintain the cohesion of an established school. In this lab the problem you will be dealing with specifically is whether brightly marked fish depend more on vision for their schooling cues than do unmarked fish.

HYPOTHESIS:

Write three or more hypotheses dealing with the relationship between dependence on vision and markings on fish. Choose the one which you feel is the best.

MATERIALS:

2 large aquaria per group
4 large beakers per group
10 fish with markings
10 fish without markings
cheesecloth--enough to cover 4 beakers
large rubber bands

CAUTIONS AND PITFALLS

BEHAVIOR EXPERIMENTS WILL NOT WORK UNLESS THE ANIMALS ARE TREATED WITH CARE AND PATIENCE.

DO:

1. Always use a net to transfer the fish.

2. Allow time for the fish to adjust to new conditions before beginning your observations.

3. Wash and rinse your hands before reaching into the experimental tanks to place beakers.

4. Treat fish with care.

5. Report any sick-looking or dead fish to the instructor.

6. Return all fish to the proper tanks when you are finished.

DON'T:

1. Disturb the fish more than necessary for the experiments.

2. Expect the fish to respond instantaneously to a new stimulus.

3. Reach into the stock tanks where the fish are kept.

4. Leave the fish in the experimental apparatus or tanks.

PROCEDURE:

Part 1

Work with a partner and try these tests of schooling behavior. The experimental set-ups are shown in Figure 1 and Figure 2.

Test 1 (Figure 1)

1. Place several fish with markings in a beaker. Cover the beaker with cheesecloth, secure with a rubber band, and immerse the entire beaker slowly in the aquarium. Place it into position on side A of the aquarium.

2. Place an empty beaker on side B to serve as a control.

3. Place a single test fish of the same species in the tank.

4. Use a stopwatch to time the number of seconds spent by the test fish in each half of the tank during a 5 minute period (300 seconds). Record the results on your data sheet.

5. Calculate the percentage of time the test fish spent on side A and on side B.

Question: Did the fish spend more time on side A or side B?

Test 2 (Figure 1)

1. Place two fish in the beaker and repeat the experiment using aa different single test fish of the same species. Record the results.

2. Calculate the percentage of the test period that the fish spent on each side of the tank.

If you have time, repeat the test using different numbers of fish in the beaker and using a different test fish each time.

3. Calculate the percentage of the test period that the fish spent with the school and the percentage that it spent alone.

Question: Did the number of fish in the school affect the tendency of the single test fish to spend time with the school?

Test 3 (Figure 2)

1. Place 3 fish with markings in a beaker on side A of the aquarium and 3 fish of another species without markings in a beaker on side B. Be sure to put the same number of fish in each beaker.

2. Place a single test fish with markings in the center of the aquarium.

3. Use a stopwatch to time how many seconds in a 5 minute period the test fish spends with its own species (section A), with the other species (section B), and alone (section C).

4. Calculate the percentage of time that the test fish spent in each section of the tank.

Question: In which of the 3 sections did the fish spend the most time?

Is there a big difference in the percentaage of time spent with the two species?

Part 2 Visual markings may help fish to identify other members of the same species, but not all schooling fish have prominent markings. Test the schooling tendency of fish without prominent markings in the following experiments and compare your results to those you obtained for the fish with markings.

Test 4 (Figure 1)

1. Place several fish without markings in a beaker on side A of the aquarium, an empty beaker on side B, and a single test fish of the same species free in the aquarium.

2. Use a stopwatch to time the number of seconds spent in each half of the aquarium during the 5 minute period. Record the results.

3. Calculate the percentage of time the test fish spent on side A and on side B.

Question: On which side did the test fish spend more time?

Test 5 (Figure 1)

1. Place 2 fish in the beaker, and repeat the experiments using a different fish of the same species. Record the results.

2. Calculate the percentage of the test period that the fish spent on each side.

If you have time, repeat the test using a different number of fish in the beaker and using a different single fish each time.

3. Calculate the percentage of time the fish spent with the school and alone for each test.

Question: Did the number of fish in the school effect the tendency of the single test fish to swim with the school?

Test 6 (Figure 2)

1. Place 3 fish with markings in a beaker on side A of the aquarium and 3 fish without markings on side B. Be sure to put the same number of fish in each beaker.

2. Place a single test fish without markings in the center of the tank.

3. Use a stopwatch to time how many seconds in a 5 minute period the test fish spends with its own species (section B), with the other species (section A), and alone (section C). Record your results.

4. Calculate the percentage of time that the test fish spent in each section of the tank.

Question:
In which of the 3 sections did the fish spend the most time?

Is there a big difference in the percentage of time spent with each of the 2 species?

Was the test fish more attracted to visual markings or to members of its own species?

RETURN ALL FISH TO THE PROPER TANKS WHEN YOU ARE FINISHED.

DATA:

Construct a data table to record all six tests. Include time spent in zones A, B, and C and the percent time spent in zones A, B, and C.

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypotheses on the basis of observable and tabulated data.

KEY: $= test fish
&= marked fish
#= unmarked fish

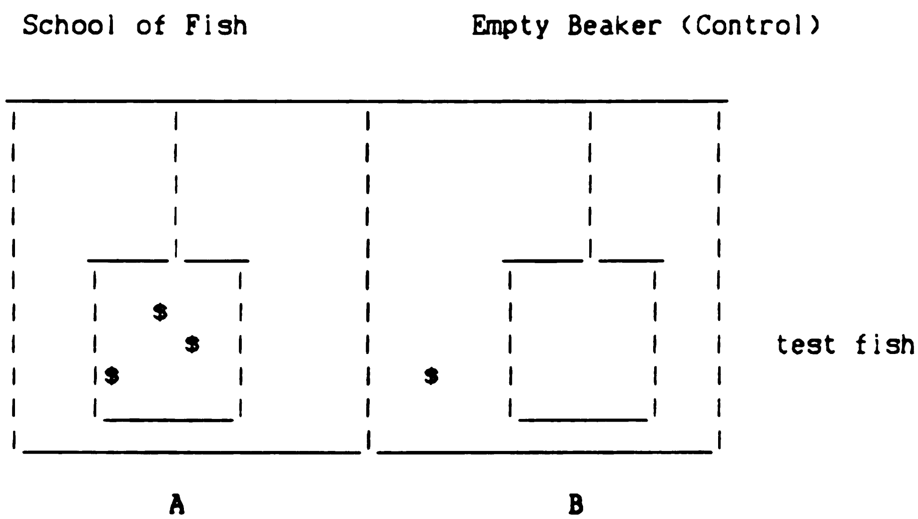


Figure One: Schooling Behavior. In the aquarium setup for testing with one school, a beaker with fish is placed an side A and an empty beaker on side B to serve as an control. The test fish is free to swim throughout the aquarium

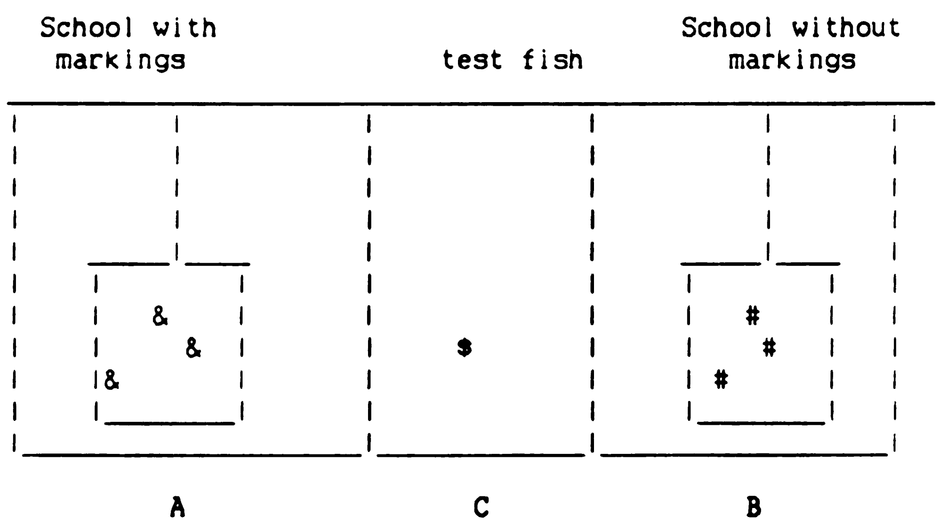


Figure Two: Schooling behavior. When two schools are used, the aquarium is divided into three parts. A school of one species is placed on side A and a school of another species on side B. The free test fish can choose school A, school B, or neither school.

APPENDIX C

STUDENT TESTS

BIOLOGY PRETEST
AQUATIC ECOSYSTEMS

1. Which would contain more dissolved oxygen?
   A. Fast-flowing brook
   B. Slow-moving stream
   C. Pond
   D. Lake

2. Which would contain more floating microorganisms or insect larva?
   A. Stream
   B. Pond

3. What is the ultimate source of energy for all the living things in any environment?
   A. Food
   B. Light
   C. Heat
   D. Electricity

4. Which of the following would most limit the growth or numbers of organisms that live in water?
   A. Oxygen
   B. Light
   C. Pressure
   D. Temperature changes

5. At each successive level of a food chain the amount of energy available from food
   A. Increases
   B. Decreases

6. What type of organism produces oxygen?
   A. Bacteria
   B. Animal
   C. Plant
   D. Fungus
   E. All of those

7. The most common oxygen producing process in living things is
   A. Respiration
   B. Digestion
   C. Photosynthesis
   D. Fermentation

8. The most common carbon dioxide producing process in living things is
   A. Respiration
   B. Digestion
   C. Photosynthesis
   D. Fermentation

9. What type of organism produces carbon dioxide?
   A. Bacteria
   B. Animal
   C. Plant
   D. Fungus
   E. All of those

10. Would a poisonous compound, such as mercury, be more concentrated in a pike or in a tadpole?
    A. Pike
    B. Tadpole

11. If a large amount of manure is dumped into a small lake, what will happen to the amount of dissolved oxygen available in the water?
    A. Will increase   B. Will decrease

12. Decomposers cause things to rot. Are they beneficial or harmful to the environment?
    A. Beneficial   B. Harmful

13. Which of the following often act as decomposers?
    A. Bacteria   E. A, C, and D
    B. Plant   F. A and D
    C. Animal   G. B and C
    D. Fungus

14. Which would be an example of a first level consumer?
    A. Horse   C. Oak tree
    B. Eagle   D. Bacteria

15. Which would be an example of a second level consumer?
    A. Horse   C. Oak tree
    B. Eagle   D. Bacteria

16. Which of the following would be a producer in a pond?
    A. Bass   C. Algae
    B. Crayfish   D. Bacteria

17. What are the major producers for a small, spring-fed brook, about 2 feet wide?
    A. Algae   C. Moss
    B. Trees around it   D. Duck weed

18. Is the total mass of consumers in an environment greater or less than the total mass of producers?
    A. Greater   B. Less

19. Choose whichever of the following would be important factor(s) affecting the pH of a stream's water.
    A. Acid rain
    B. Type of bottome to the stream
    C. Type of animals found in stream
    D. Type of plants along the bank

20. Which would you expect to find in water that is low in oxygen?
    A. Trout   C. Carp
    B. Perch   D. Snails

21. Which would you expect to find in water that is high in oxygen?
    A. Trout   C. Carp
    B. Perch   D. Snails

22. Which would you expect to be most affected by the amount of calcium in water?
    A. Carp   C. Clam
    B. Frog   D. Algae

23. Would there be most dissolved oxygen in cold or warm water?
    A. More   B. Less

24. Fish breathe
    A. Water
    B. The oxygen in the water molecule
    C. The oxygen dissolved in the water from the air

25. If a perch eats an insect, what per cent of the energy from the insect's body actually becomes stored in the perch's body (for a larger fish to eat)?
    A. 90%   B. 10%   C. 50%   D. 25%   E. 100%

26. E. coli is a type of bacteria. Why is it important?
    A. It causes diseases like colitis.
    B. It is an indicator of the presence of human sewage
    C. it is a common decomposer in streams
    D. It produces oxygen

BIOLOGY TEST
ECOLOGY I

Multiple Choice: Place the letter of the best answer in the blanks.

1. What is the effect of making smokestacks taller?
   A. Cuts down on pollution in lower atmosphere.
   B. Spreads pollution over a greater area.
   C. Changes dangerous gases into harmless ones.
   D. All of those

2. What elements in smog are largely responsible for making rain acid?
   A. Ca and C
   B. O and N
   C. Cl and O
   D. S and N

3. A lake dead because of acid looks
   A. Scummy and polluted
   B. Clear and blue
   C. Green and foamy
   D. Clear and green

4. Which would be more vulnerable to acid rain?
   A. Lakes with granite rock bottoms.
   B. Lakes with limestone rock bottoms.
   C. Lakes with mud bottoms.
   D. All of those are equally vulnerable.

5. Large fish are killed by acid rain in what way?
   A. By pH going up.
   B. By pH going down.
   C. By starvation
   D. By DO going down

6. How could increasing acid make drinking water dangerous to humans?
   A. Leeches heavy metals like aluminum or mercury out of rocks.
   B. Dissolves copper pipes.
   C. Creates too much acid in our stomachs.
   D. Kills fish and dead fish lead to pollution.

7. What substance is dumped into lakes to reduce acidity temporarily?
   A. Sulfur
   B. Granite
   C. Dirt
   D. Limestone

8. If rivers are not acidic at all times, they are most likely to be so in what season?
   A. Fall
   B. Spring
   C. Summer
   D. Winter

9. What stage of insect life cycle is most important to food chains in streams?
   A. Egg C. Pupa
   B. Larva D. Adult

10. What do most crabs eat?
   A. Little fish C. Dead animals
   B. Clams D. Plants

11. Besides food, what would be the most important limiting factor in a mountain stream?
   A. Light C. Oxygen
   B. Water currents D. pH

12. Animals which live in a fast-moving stream are often
   A. Flattened C. Long and skinny
   B. Round D. Square

13. What is one limiting factor that is almost always important for all animals in ALL environments?
   A. Food C. Light E. Water
   B. Oxygen D. pH

14. How is fire a limiting factor for jack pines?
   A. Warblers only nest in certain size trees.
   B. Fire destroys the seeds.
   C. Fire opens the cones.
   D. All of those

15. Why might a mountain stream have more oxygen than the Kalamazoo River?
   A. It is smaller
   B. It has more algae
   C. It is faster moving
   D. It has more animals
   E. All of those

16. What is the advantage of the thin, flat shape of most leaves?
   A. Catch more water C. Catch more light
   B. Keep H_2O from evaporating D. All of those

17. Most photosynthesis occurs in what plant part?
   A. Root B. Stem C. Leaf D. Flower

18. 90% of all photosynthesis on earth happens in plants which live where?
   A. On land C. In forests
   B. In water D. In fields

19. What animal process uses up the most energy?
    A. Movement
    B. Digestion
    C. Communication
    D. Food-getting

20. The form of nitrogen most common in the air is
    A. Nitrate
    B. Ammonia
    C. N_2
    D. Nitrite

21. The organisms which "fix" nitrogen into forms which organisms can use are
    A. Legumes
    B. Bacteria
    C. Soy beans
    D. Plants

22. What happened to the amount of nitrogen when trees were logged off in a given area?
    A. Increased in fields
    B. Increased in streams
    C. No affect unless trees were burned

23. Grasses need more water when
    A. Nitrogen in soil in low
    B. Zinc in soil is low
    C. Strontium is substituted for calcium

24. Plants need less zinc if
    A. They are high in calcium
    B. They are in the shade
    C. They have lots of water

25. What part of an animal's life cycle if likely to be east tolerant to limiting factors?
    A. Larva B. Adult C. All are equal

26. Which type of organism would be least tolerant to changes in temperature?
    A. Land organisms
    B. Water organisms
    C. Plants
    D. Animals

27. The biomass at each successive level of a food chain must
    A. Increase B. Decrease C. Stay the same

28. Which would contain more dissolved oxygen?
    A. Fast-flowing brook
    B. Slow-moving stream
    C. Pond
    D. Lake

29. Which would contain more floating microorganisms or insect larva?
    A. Stream B. Pond

30. What is the ultimate source of energy for all the living things in any environment?
    A. Food C. Heat
    B. Light D. Electricity

31. Which of the following would most limit the growth or numbers of organisms that live in water?
    A. Oxygen C. Pressure
    B. Light D. Temperature changes

32. At each successive level of a food chain the amount of energy available from food
    A. Increases B. Decreases

33. What type of organism produces oxygen?
    A. Bacteria D. Fungus
    B. Animal E. All of those
    C. Plant

34. The most common oxygen-producing process in living things is
    A. Respiration C. Photosynthesis
    B. Digestion D. Fermentation

35. The most common carbon dioxide-producing process in living things
    A. Respiration C. Photosynthesis
    B. Digestion D. Fermentation

36. What type of organism produces carbon dioxide?
    A. Bacteria D. Fungus
    B. Animal E. All of those
    C. Plant

37. Would a poisonous compound, such as mercury, be more concentrated in a pike or in a tadpole?
    A. Pike B. Tadpole

38. Decomposers cause things to rot. Are they beneficial or harmful to the environment?
    A. Beneficial B. Harmful

39. Which of the following often act as decomposers?
    A. Bacteria E. A, C, and D
    B. Plant F. A and D
    C. Animal G. B and C
    D. Fungus

40. Which would be an example for a first level consumer?
    A. Horse C. Oak tree
    B. Eagle D. Bacteria

41. Which would be an example of a second level consumer?
    A. Horse C. Oak tree
    B. Eagle D. Bacteria

42. Which of the following would be a producer in a pond?
    A. Bass C. Algae
    B. Crayfish D. Bacteria

43. What are the major producers in a small, spring-fed brook, about 2 feet wide?
    A. Algae C. Moss
    B. Trees around it D. Duck weed

44. Is the total mass of consumers in an environment greater or less than the total mass of producers?
    A. Greater B. less

45. Choose whichever of the following would be important factor(s) affecting the pH of a stream's water.
    A. Acid rain
    B. Type of bottom to the stream
    C. Type of animals found in stream
    D. Type of plants along the bank

46. Would there be more dissolved oxygen in cold or warm water?
    A. Cold B. Warm

47. Fish breathe
    A. Water
    B. The oxygen in the water molecule
    C. The oxygen dissolved in water from the air

48. If a perch eats an insect, what per cent of the energy from the insect's body actually becomes stored in the perch's body (for a larger fish to eat)?
    A. 90% B. 10% C. 50% D. 25% E. 100%

Matching: Place the letter of the best answer from the list at the right in the blanks at the left.

49. Any condition which approaches or exceeds limits of tolerance
50. Process of converting light energy into food energy
51. Process of breaking down food and releasing stored energy
52. Molecule which traps light energy
53. Rate of growth of each organism is limited by whatever essential nutrient is in shortest supply
54. Organism which converts light energy into food energy
55. Organism which recycles atoms from living things back to soil or air
56. Organism which gets energy by digesting body materials of other organisms.
57. Living and nonliving surrounding of an organism.
58. Flow or passage of energy through an ecosystem.
59. Organism which preys on other LIVING organisms for food.
60. Pertaining to water or to those organisms which live in water.
61. Pertaining to salt water or to those organisms which live in salt water.
62. Scale used to indicate the acidity of a water solution.
63. Weight of all of one type of organism in an environment.

A. Aquatic
B. Biomass
C. Chlorophyll
D. Consumer
E. Decomposer
F. Environment
G. Food chain
H. Law of Minimum
I. Limiting Factor
J. Marine
K. pH
L. Photosynthesis
M. Predator
N. Producer
O. Respiration

True-False: Place + in the blank if the statement is true; 0 if the statement is false.

64. Too much of an environmental factor can be as limiting as too little.
65. Plants produce carbon dioxide.
66. Plants produce oxygen.
67. Animals produce carbon dioxide.
68. Animals produce oxygen.
69. The short cycle of carbon usually involves respiration and photosynthesis.

Short Answer:

70. In our stream water, we measured DO. What does this stand for?

71. All food chains must begin with what type of organism?

72. Name four elements which are needed in large amounts by living things.

73. Name two elements which are needed in large amounts by living things which are often limiting factors.

74. Name four elements which are needed in small amounts by living things.

75. In what type of environment would pressure be a limiting factor?

76. In what type of environment would oxygen most likely be a limiting factor?

77. Name two uses for food in living things.

78. Compare the amount of energy which land and water organisms must use in order to get oxygen.

79. Why is nitrogen often a limiting factor for plants when the air is 78% nitrogen?

80. Give an example of a SLOW cycle of carbon into and out of organisms.

81. Choose an appropriate type of atom and describe how it cycles from atmosphere to organisms and back again.

82. Explain why any food chain can only go for a limited number of steps.

83. What does it mean to say that an animal is at the "top of the food chain"?

84. Name an animal that would be a first level consumer. Explain why you chose that animal.

85. List the steps in an example food chain in a lake.

86. List the steps in an example food chain in a forest.

87. Using the diagram below, relate the staves (boards) in the bucket of water to the Law of the Minimum.

BIOLOGY TEST
ECOLOGY II

Multiple Choice: Place the letter of the best answer in the blanks.

1. Which would you expect to find in water that is low in oxygen?
   A. Trout   C. Carp
   B. Perch   D. Snails

2. Which would you expect to find in water that is very high in oxygen?
   A. Trout   C. Carp
   B. Perch   D. Snails

3. Which would you expect to be most affected by the amount of calcium in water?
   A. Carp   C. Clam
   B. Frog   D. Algae

4. Which animal is a mollusk in the class Gastropoda?
   A. Mayfly   C. Snail
   B. Clam   D. Shrimp

5. Which animal is a mollusk in the class Pelecypoda?
   A. Mayfly   C. Snail
   B. Clam   D. Shrimp

6. Which animal is an arthropod in the class Crustacea?
   A. Mayfly   C. Snail
   B. Clam   D. Shrimp

7. To which phylum does a crayfish belong?
   A. Arhtropoda   C. Chordata
   B. Mollusca   D. Annelida

8. To which phylum does a leech belong?
   A. Arthropoda   C. Chordata
   B. Mollusca   D. Annelida

9. To which phylum does a trout belong?
   A. Arthropoda   C. Chordata
   B. Mollusca   D. Annelida

10. To which phylum does a mayfly belong?
    A. Arthropoda   C. Chordata
    B. Mollusca   D. Annelida

11. How many kingdoms are there in the modern system of taxonomy?
    A. 2 B. 3 C. 4 D. 5 E. 6

12. Insects have how many body regions?
    A. 2 B. 3 C. 4 D. 5 E. 6

13. Insects have how many legs?
    A. 2 B. 4 C. 6 D. 8

14. An insect which resembles the adult but is smaller and has no wings is what?
    A. Larva B. Pupa C. Nymph

15. An insect which looks nothing like the adult and is worm-like instead is what?
    A. Larva B. Pupa C. Nymph

16. Choose the letters of the stages of complete metamorphosis and place them IN ORDER in the blank.
    A. Adult D. Nymph
    B. Egg E. Pupa
    C. Larva

17. Choose the letters of the stages of incomplete metamorphosis and place them IN ORDER in the blank.
    A. Adult D. Nymph
    B. Egg E. Pupa
    C. Larva

18. Which insect lives in a case made of twigs, leaves, etc. during its aquatic life?
    A. Caddisfly C. Mayfly
    B. Cranefly D. Stonefly

19. Which insect is worm-like, has legs, 2 tails, and obvious gills?
    A. Caddisfly C. Mayfly
    B. Cranefly D. Stonefly

20. A snail is a
    A. Collector C. Scraper
    B. Predator D. Shredder

21. A clam is a
    A. Collector C. Scraper
    B. Predator D. Shredder

22. The little shrimp-like crustaceans we saw in the river were
    A. Collectors   C. Scrapers
    B. Predators   D. Shredders

23. A cranefly larva is a
    A. Collector   C. Scraper
    B. Predator   D. Shredder

24. What percentage of all animals are arthropods?
    A. 25%   B. 50%   C. 78%   D. 95%

25. Green algae belong to what kingdom?
    A. Fungi   D. Monera
    B. Plantae   E. Protista
    C. Animalia

26. Which of the following algae are filamentous?
    A. Desmid   C. Spirogyra
    B. Diatom   D. Volvox

27. Which of the following algae have "glass" cases?
    A. Desmid   C. Spirogyra
    B. Diatom   D. Volvox

28. Which of the following algae is colonial and spherical?
    A. Desmid   C. Spirogyra
    B. Diatom   D. Volvox

29. What type of organism is spirogyra?
    A. Algae   C. Bacteria
    B. Bacteria   D. Protozoa

30. What color is spirogyra?
    A. Blue-green   C. Golden
    B. Brown   D. Green

31. What is the structure of spirogyra?
    A. Colonial   B. Filamentous   C. Unicellular

32. Which is the smallest?
    A. Ameba   B. Euglena   C. Paramecium

33. Animal without a spine or backbone	A. Abdomen
34. Outer covering of arthropod	B. Antenna
35. Sense of touch, taste, smell in crayfish	C. Antennule
36. Sense of equilibrium in crayfish	D. Cheliped
37. Shedding of exoskeleton	E. Exoskeleton
38. Middle body section of arthropods	F. Foot
39. Last body section of arthropods	G. Gills
40. Respiratory organ in aquatic mollusks	H. Invertebrate
41. Respiratory organ in aquatic insects	I. Mantle
42. Membrane covering body of mollusks	J. Molting
43. Claw of crayfish	K. Radula
44. Hatchet-shaped digger in clams	L. Siphon
45. Secretes shell of mollusk	M. Thorax
46. Scraper inside mouth of snail	
47. Tubes which move water in and out of clam	

48. Floating algae and protozoans	A. Autotroph
49. Green pigment found in algae	B. Chlorophyll
50. Process by which algae make food	C. Eukaryote
51. Group of cells living together and dividing up the work	D. Heterotroph E. Multicellular
52. Group of individual organisms living together, but still independent	F. Photosynthesis G. Plankton
53. One-celled organism	H. Prokaryote
54. Contain a nucleus	I. Unicellular
55. Make own food	

Fill-in and Short Answer:

56. Organisms in the same species can ____________ and produce _______________ offspring.

57. Scientific names are in what language?

58. When we say that two organisms are related, it means that they share a common ______________________.

59. Which 2 kingdoms contain only organisms which are multicellular?

60. Why are phytoplankton so important?

61. What shape of diatoms are most common in lakes and ponds?

62. What is the difference between a snail and a slug?

63. How can you tell if a clam is dead?

64. What is the function of the anterior sucker of a leech?

65. What type of animal is the natural host (prey) for a leech?

66. What are two functions of the exoskeleton of arthropods?

67. Why are arthropods considered to be the most successful phylum of animals?

68. Where should you look for crayfish eggs?

69. At what time of year should you look for crayfish eggs?

70. Why do nymphs or larva usually eat very different foods from the adults of the same species?

71. List the classification groups in order starting with the most general.

72. Which two classification groups are used in scientific names?

73. Sketch Spirogyra.

74. What is the food for adult mosquitoes of both sexes at all times?

75. What is the food for mayfly nymphs?

APPENDIX D

ATTITUDE SURVEY

OPINION SURVEY ABOUT SCIENCE

Science							
1.	Strange	1	2	3	4	5	Familiar
2.	Good	1	2	3	4	5	Bad
3.	Dull	1	2	3	4	5	Fun
4.	Interesting	1	2	3	4	5	Boring
5.	Easy	1	2	3	4	5	Difficult
6.	Unimportant	1	2	3	4	5	Important
7.	Career	1	2	3	4	5	Hobby
Laboratory Activities							
8.	Strange	1	2	3	4	5	Familiar
9.	Good	1	2	3	4	5	Bad
10.	Dull	1	2	3	4	5	Fun
11.	Interesting	1	2	3	4	5	Boring
12.	Easy	1	2	3	4	5	Difficult
13.	Unimportant	1	2	3	4	5	Important
14.	Dangerous	1	2	3	4	5	Safe
Working in Teams to Solve Problems in Class							
15.	Good	1	2	3	4	5	Bad
16.	Strange	1	2	3	4	5	Familiar
17.	Unimportant	1	2	3	4	5	Important
18.	Dull	1	2	3	4	5	Fun
19.	Useful	1	2	3	4	5	Wasteful
20.	Busy	1	2	3	4	5	Quiet
21.	Difficult	1	2	3	4	5	Easy
Scientific Method							
22.	Strange	1	2	3	4	5	Familiar
23.	Good	1	2	3	4	5	Bad
24.	Dull	1	2	3	4	5	Fun
25.	Interesting	1	2	3	4	5	Boring
26.	Easy	1	2	3	4	5	Difficult
27.	Unimportant	1	2	3	4	5	Important
28.	Useful	1	2	3	4	5	Unnecessary
Waste Recycling							
29.	Strange	1	2	3	4	5	Familiar
30.	Good	1	2	3	4	5	Bad
31.	Important	1	2	3	4	5	Unimportant
32.	Easy	1	2	3	4	5	Difficult
33.	Necessary	1	2	3	4	5	Unnecessary

Lawn Fertilizing

34.	Strange	1	2	3	4	5	Familiar
35.	Good	1	2	3	4	5	Bad
36.	Permanent	1	2	3	4	5	Temporary
37.	Easy	1	2	3	4	5	Difficult
38.	Necessary	1	2	3	4	5	Unnecessary
39.	Dangerous	1	2	3	4	5	Safe

Hunting

40.	Strange	1	2	3	4	5	Familiar
41.	Good	1	2	3	4	5	Bad
42.	Dull	1	2	3	4	5	Fun
43.	Interesting	1	2	3	4	5	Boring
44.	Easy	1	2	3	4	5	Difficult
45.	Unimportant	1	2	3	4	5	Important
46.	Career	1	2	3	4	5	Hobby

Wildlife Management

47.	Strange	1	2	3	4	5	Familiar
48.	Good	1	2	3	4	5	Bad
49.	Dull	1	2	3	4	5	Fun
50.	Interesting	1	2	3	4	5	Boring
51.	Easy	1	2	3	4	5	Difficult
52.	Unimportant	1	2	3	4	5	Important
53.	Career	1	2	3	4	5	Hobby

Clearcutting forests (this means clearing part of a forest by cutting all the trees down.)

54.	Good	1	2	3	4	5	Bad
55.	Strange	1	2	3	4	5	Familiar
56.	Unnecessary	1	2	3	4	5	Necessary
57.	Ugly	1	2	3	4	5	Beautiful
58.	Useful	1	2	3	4	5	Wasteful
59.	Permanent	1	2	3	4	5	Temporary
60.	Safe	1	2	3	4	5	Dangerous

Our Local Rivers

61.	Polluted	1	2	3	4	5	Clean
62.	Beautiful	1	2	3	4	5	Ugly
63.	Important	1	2	3	4	5	Unimportant
64.	Drinkable	1	2	3	4	5	Undrinkable
65.	Uninhabited	1	2	3	4	5	Inhabited

Directions: Read each of the following statements carefully. Fill in the circle on your answer sheet which describes your feelings about the statement.

66. Most people can leave science to the experts and do not need to understand how science works.

67. In order to solve a problem scientifically, scientists should not use information (data) unless they have collected it through their OWN research.

68. Careful observation is less important in modern science since the development of new instruments like the electron microscope.

69. Science deals with all problems and it can provide answers to all questions.

70. The knowledge of science is final.

71. A good scientist must have the aibity to ask the right questions.

72. A scientist should only do research on those projects that will provide something useful.

73. Since a measurement involves the use of numbers, it rarely can be wrong.

74. Scientists assume that if events A and B occur at the same time, then one must be the cause of the other.

75. Good science does not require that scientists share their findings with other scientists.

76. A good scientist always defends fellow scientists and their scientific ideas when others say they are wrong.

77. Scientists do not make errors in their conclusions if they follow scientific processes.

78. To make good decisions about how to use our natural resources (land, forests, wildlife, etc.), all we need to consider is the scientific information.

79. The observations a person makes are influenced by his past experience.

80. If a scientist carefully reports his or her experiment, other scientists will accept the experimental conclusions without question.

81. Hunters today are the cause for most of the decline in wildlife populations.

82. If a scientist measures two variables (such as water temperature and growth of fish) and finds they both increase or decrease together, it proves changes in water temperature causes changes in fish growth.

83. I would like a career working as some type of scientist.

84. I would like a career working with wildlife, forests, rivers or other natural resources.

85. Big industries like UpJohn and Dow Chemical are the Michigan polluters and should pay for the clean-up.

APPENDIX E

STUDENT SIMULATION HANDOUTS

BIOLOGY PREDATOR-PREY GAME
OWLS AND MICE

INTRODUCTION:

Animals spend much of their time looking for and consuming food. Some eat plants, some eat meat, and some eat both. Many meat-eating animals obtain their meat by hunting other animals. The hunters are known as predators and the hunted animals are known as prey.

In this activity you will do a simulation of a predator-prey relationship, with owls as predators and mice as prey. In nature, owls and mice are often found living in forests. The forest in your simulation will be HOOT WOODS.

Owls are excellent hunters. The various kinds of owls eat many different kinds of animals, including rabbits, squirrels, rats, mice, shrews, birds, fish, and insects. To simplify the simulation, you will limit the owls' food supply to mice.

PROCEDURE:

Using masking tape, mark off a square approximately 50 cm on a side on the surface of your lab table. This square represents Hoot Woods, where the mice and owls live.

You will simulate 25 generations of owls and mice. The mice can be eaten and the owls can starve. Surviving mice and owls can reproduce. To make calculations easier, each surviving mouse will be considered capable of producing one offspring. In each generation, the surviving mouse population will double to form the next generation. For example, if six mice are living in the woods and two are caught by an owl, then four mice will survive. These four mice will each produce one offspring, and the next generation will begin with eight mice. Remember, the number of offspring is always the same as the number of surviving mice. At any one time, the maximum mouse capacity of Hoot Woods is 400 mice.

In order to survive, each owl must catch at least three mice in every generation. If an owl does not catch three mice, it will starve. For each three mice that an owl catches, it will reproduce one offspring. For example, if an owl catches eight mice it will reproduce two new owls, making a total of three owls to begin the next generation.

At the beginning of EACH generation there must be at least three mice and one owl in the woods. If the populations drop below these numbers (by being eaten or starving), new mice and owls will migrate in. For example, if just one mouse survives the first generation, just one offspring will be produced, for a total of two mice. One mouse must migrate in to bring the mice total to three. If all owls die, one owl must migrate in.

PLAY:

Place the mouse squares at random in Hoot Woods. Then, from a height of about 30 cm, drop the owl square into the woods. Try to hit as many mice as you can in one drop. When an owl square fully or partly covers a mouse square(s), that is a "catch". If there is more than one owl in a generation, drop the owl square once for each owl.

Remove and count the number of mice CAUGHT BY EACH OWL AT EACH DROP. Keep all mice from each owl catch in separate stacks. Record the data on your chart. You will want to have different people do the dropping and the recording.

EXAMPLE:

Suppose generation 3 begins with 20 mice and 2 owls. You make a drop for the first owl and catch 7 mice. On the second drop, the second owl catches only 2 mice. The owls have caught a total of 9 mice. There are 11 mice left in Hoot Woods, and they reproduce 11 mice. The next generation will start with 22 mice. Because the first owl caught 7 mice, it reproduces 2 offspring for the next generation. The second owl caught only 2 mice; it starves and does not survive or reproduce. The data chart line for that generation would look like this:

Gen.	No. Mice Start	No. Owls Start	No. Mice Caught	No. Owls Starved	No. Surviving Mice + Offspring	No. Surviving Owls + Offspring
3	20	2	9	1	11+11=22	1+2=3
4	22	3				

ANALYSIS:

1. Which population first increases in size?

2. Describe the pattern of the fluctuations in the sizes of the two populations.

3. By looking ONLY at the graph, can you tell which species is the prey and which species is the predator? How can you tell?

4. Which species gets to the largest number of individuals? Why?

5. What do you think would happen to the mouse population in Hoot Woods if the owls were all hunted to extinction? Why?

6. Prepare a line graph of the number of mice in each generation and in a different color the number of owls in each generation

APPENDIX F

FILM SOURCES

FILM SOURCES

1. Bitter Rain.
   Available from Journal Films

2. Greatest Lakes.
   Available from Public Broadcasting System

3. Atlantic Realm
   Ocean of Light
   Into the Abyss
   Available from Films, Inc.

4. Water Crisis
   Available from Time-Life Films

5. Communities of Living Things--Parts A - G
   Available from ITEC (M Star)

6. Dragonflies--Flying Hunters of the Waterside
   Available from Learning Corporation of America

7. Life in Lost Creek
   Available from Coronet Instructional Films

8. Mayfly--Ecology of an Aquatic Insect
   Available from Encyclopedia Brittanica
   Education Corporation