BIOLOGY

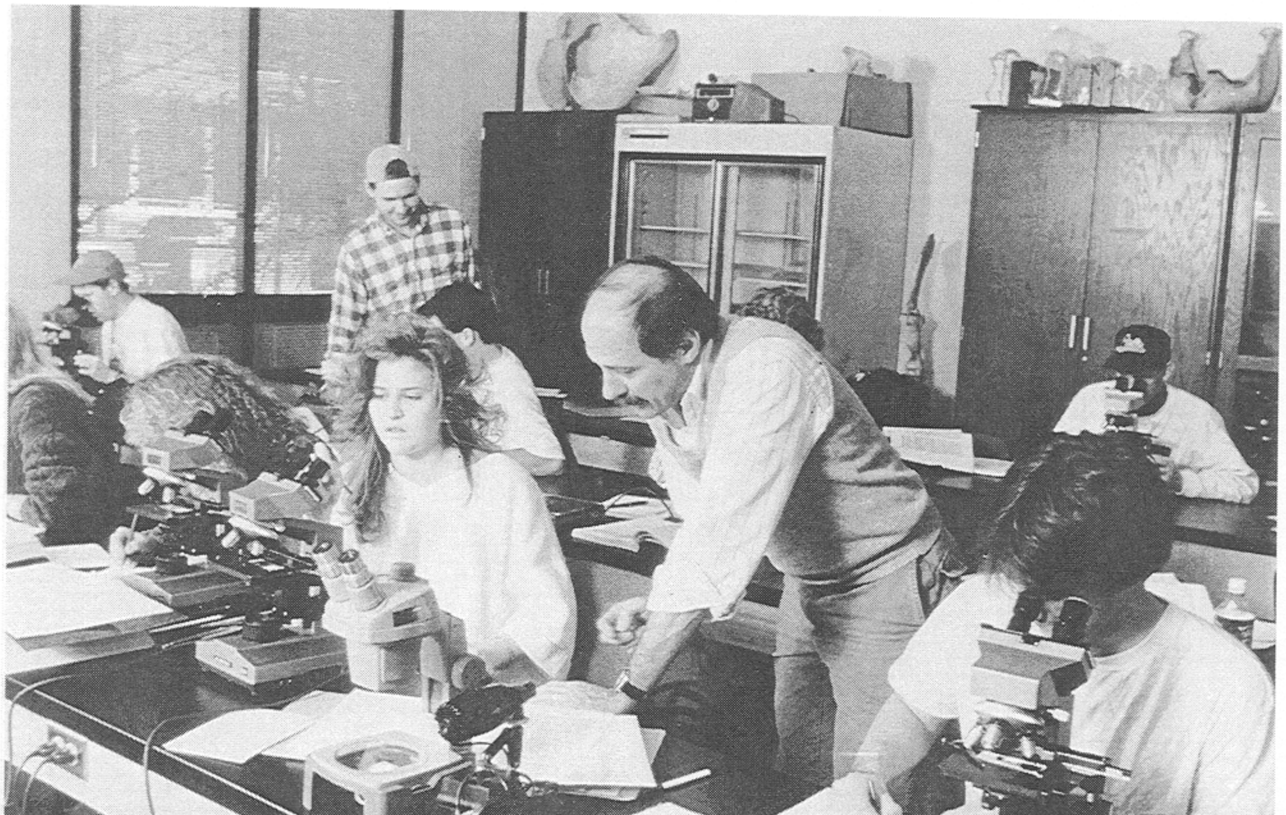


TABLE OF CONTENTS

Preface

During the summers of 1992-1994 eight USC system biology faculty* developed modules with support from a FIPSE grant. These modules combine the assessment of content and abilities for Biology 110 which is a natural science course designed for the non-science major. The major objectives of this course are to teach the core philosophy and principles of the natural sciences and biology, and apply this information to daily life (specific objectives are in the appendix). The student will acquire knowledge of some important biological concepts and participate in discussions of some of the current issues in biology which will affect our future as a species and our interrelationships with the rest of the biosphere. It is assumed that the entering Biology 110 student will possess mathematical skills at the entering college algebra level and be able to write an effective paragraph in standard american english at the entering freshman composition level.

The USC system biology faculty are deeply committed to helping their students become educated, globally responsible citizens capable of critical thought and analysis. In addition to the biological and science concepts presented to the students, the student will also develop the ability to communicate effectively in writing and speech. The course will offer many opportunities to practice communication and critical thinking skills.

The compulsory laboratory portion of this course will allow the student to personally experience the scientific method of learning and to investigate some of the examples discussed in lectures. The student will have opportunities to "do science" with a practicing scientist. The laboratory modules were written to be completed in a two hour session. The modules assume that the basic principles addressed have been presented in lecture. The modules are designed to follow a logical sequence, and the later modules assume knowledge learned in prior modules. The modules are designed to be easily modified depending on available supplies, time and budget concerns. Each module includes a variety of assessments for selective use by the facilitator.

These modules utilize a paradigm shift to a pedagogy using course embedded assessments. Through the processes of continuous feedback and self-assessment students will be active participants in the learning process. It is our sincere hope that the Biology 110 students and the faculty will find the time spent in this course enjoyable, productive, and can learn from each other more about "life/living" and its many peculiarities and wonders.

* Mary Barton, USC Union
Charles Denny, USC Sumter
Charles Duggins, USC Columbia
Howard Kramer, Coastal Carolina University
Bill Lamprecht, USC Salkahatchie
John Logue, USC Sumter
W. Harold Ornes, USC Aiken
Harry Shealy, USC Aiken

Introductory Notes for Instructor

Biology 110 is a general biology course for non-science majors that includes a mandatory two hour laboratory session per week. Major objectives of the lecture discussion sessions are to teach biological principles and to encourage critical examination of content relative to scientific methodology. Contemporary issues are utilized to stimulate student interest and to emphasize that a knowledge of biological principles is prerequisite to an understanding of the biotechnology which is an integral part of modern day-to-day existence.

Instructional strategies in the accompanying modules differ from the so-called traditional approach in that course embedded assessment is utilized as a learning technique. Three lecture discussion modules (Evolution, Chemistry and Enzymes) are included to serve as models for the design of assessment activities for topics that you wish to include in your course. As you will note there is a title and clearly elaborated objectives or projected outcomes of student learning to provide the baseline for self assessment by the student and continuous feedback from the instructor and/or peers. Criteria are listed to identify behaviors and/or products which provide the bases for evaluation and various assessment strategies are suggested as means of checking for understanding of topic principles. Many of the assessments may be used for self assessment by students and/or for purposes of evaluation by the instructor.

As you will see in the lecture discussion modules, an institution's basic educational goals may also be addressed. The University of South Carolina system's status as a leading liberal arts institution, for instance, behooves us to develop an educated citizenry capable of clear, concise and accurate communication and versed in the sciences, humanities, social sciences and the arts. Hence, general education objectives (abilities) are noted and addressed along with those of primary concern to the subject area.

The major objectives of the laboratory portion of the course are to provide an experiential mode for investigation of many of the concepts covered via lecture discussion and to reinforce the scientific method of problem solving. Typically, laboratory exercises will embody topics previously covered during lecture discussion sessions. The six laboratory modules contain similar assessment strategies to the lecture discussion modules along with detailed directions for performing a laboratory exercise which meet the major objectives.

Chemistry for Students of Biology
Lecture Discussion Module

Prior Assumed Knowledge

None

Content Outcomes (Student Objectives)

1. Students should be familiar with the chemical components of living things.

2. Students should understand the basic structure of the atom.

3. Knowing the concept of electron shells, students should be able to explain ionic and covalent bonds (this includes the octet rule).

4. Students should be able to understand hydrogen bonding and relate same to the properties of water and how these properties are important to life.

5. Students should be able to describe the interrelationships among subatomic particles, atoms, molecules, compounds, mixtures and living organisms.

6. Students should understand the concept of acids, bases, pH and buffers, especially as they relate to living things.

7. Students should appreciate the unique chemistry of the carbon atom and its significance to life on this planet.

8. Students should understand the structure and function (in living things) of carbohydrates, lipids, proteins and nucleic acids.

Assessment 1

The atomic number of carbon is 6, nitrogen is 7, oxygen 8 and sulfur 16. Using your knowledge of the octet rule and electron shells, predict the maximum number of covalent bonds each atom will form with other atoms at any one time.

Carbon ___

Nitrogen ___

Oxygen ___

Sulfur ___

Explain your reasoning.

Abilities covered

Communication
Analytic capability

Content outcomes
2,3, 5 and 7.

Criteria

>Ability to interpret atomic structure from atomic number,

>Ability to explain the use of the octet rule to determine the number of covalent bonds the atom will form.

Assessment 2

From your knowledge of the molecular structure of water and proteins, postulate why liquid water when heated forms a gas, whereas egg white (a protein) when heated forms a solid.

Abilities covered

Communication
Analytic capability

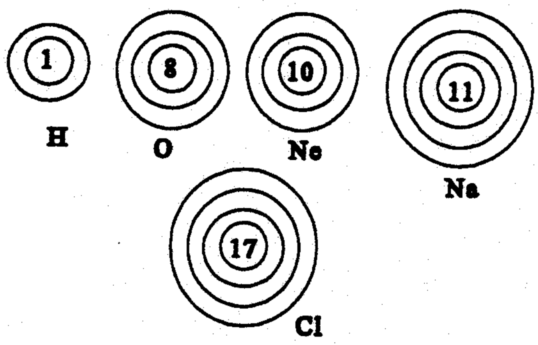
Content outcomes
1,4 and 8.

Criteria

>Student will demonstrate understanding of hydrogen bonding in water and proteins as well as an understanding of protein structure. The student will use this knowledge to explain the difference between the results of heatin water and proteins.

Assessment 3

Below are shown 5 atoms. The atomic number is indicated for each atom, as well as electron shells. (H, O, Ne, Na, Cl)



a. Describe the number of electrons for each shell of an atom. Then indicate the valence of each atom.

b. Using atoms of the elements shown, construct two different molecules (one covalent and one ionic). Show how the electrons are distributed between the bonded atoms in the diagrams that you draw. Indicate whether the bonds are covalent or ionic, and if ionic, the charge on each ion?

c. Which of the atoms shown cannot form a bond with the others? Why not?

Student: make the drawings asked for in the space below:

Abilities covered (Assessment 3)

Communication
Analytic capability

Content outcomes
2,3 and 5.

Criteria

>Ability to interpret atomic structure from atomic number,

>Ability to explain the use of the octet rule to determine the number of covalent bonds the atom will form.

Assessment 4

Consider a typical ham sandwich and identify the specific portion which would include:
a. carbohydrates
b. lipids
c. proteins
d. nucleic acids

Abilities covered

Communication
Analytic capability

Content outcomes
1,5 and 8.

Criteria

>Student will show knowledge of the major organic macromolecules in the context of common foods.

Assessment 5

Fishing spiders and water striders can be seen running across the surfaces of slow moving streams. How is this possible?
(Explain in terms of the chemical properties of water molecules).

Abilities covered

Communication
Analytic capability

Content outcomes
4 and 5.

Criteria

>Student will appreciate significance of hydrogen bonding to the physical properties of liquid water.

>The student will describe the relationship of hydrogen bonding to the ability of insects to walk on water.

Assessment 6

Students are often confused by the following statement:

"The smallest unit of a compound is a molecule while oxygen, which normally occurs as a molecule, is not a compound."

Explain the statement as if you were talking to a seventh grade class.

<u>Abilities covered</u>

Communication
Analytic capability

<u>Content outcomes</u>
5

<u>Criteria</u>

>The student will explain the similarities and differences between molecules and compounds.

Assessment 7

An old-fashioned remedy for "acid indigestion" is to drink a solution of sodium bicarbonate (baking soda) and water.

What function would the baking soda have in treating the condition?

Explain your answer using the terms protons and hydroxyl ions.

List four other food additives or medicines that when ingested would alter the pH of the stomach. Beside each ingredient indicate whether it would raise or lower the pH.

<u>Abilities covered</u>

Communication
Analytic capability
Problem solving

<u>Content outcomes</u>
5 and 6.

<u>Criteria</u>

>The student will apply knowledge of acids, bases and buffers to the situation and explain why baking soda relieves heartburn.

>The student will be aware of common compounds which can alter pH.

Assessment 8

Acid rain is formed when atmospheric pollutants, especially NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide) and CO_2 (carbon dioxide) react with water (rain, snow, etc.). The reactions follow:

$NO_X + H_2O$ ---> HNO_3

$SO_X + H_20$ ---> H_2SO_4

$CO_X + H_2O$ ---> H_2CO_3

(The X represents variable numbers of oxygen atoms depending on what the initial compound is, i.e. nitrate, nitrite....).

The products of the above reactions are referred to as acids because they are __?__ donors.

Canada and the United States have had vigorous political disagreements over acid rain. Pollutants from steel mills and other factories in the northern United States are carried by the prevailing winds into Canada and fall back to earth as acid rain. Acid rain in some areas is more serious than others, depending on the mineral content of the soils. Based on what you know about pH in living systems, why might acid rain be harmful?

Why might more minerals in the soil make a difference?

What minerals might be important?

Under the Carter administration, a tentative agreement had been struck with Canada in which both countries would limit emission of atmospheric pollutants contributing to acid rain. Later, the Reagan administration decided not to honor those commitments, citing concern for U.S. business interests.

Using the evidence that you are able to organize, you will join either a pro or a con side. Your task will be to convince peers who have an opposing point of view to join your side. Be prepared to cite the sources of any information that you use and identify the information as to observation, inference, opinion, or others.

You may want to record your thoughts below before making an oral presentation.

Assessment 8 (continued).

North Carolina mountains seem to exhibit a greater amount of acid rain damage than their Tennessee counterparts. A geological difference between the two areas is the large amount of limestone in Tennessee. Suggest a rationale which would describe how limestone could mediate the effects of acid rain.

<u>Abilities covered</u>

Communication
Social Interaction
Valuing
Analytic capability
Global Perspective

<u>Content outcomes</u>
5 and 6.

<u>Criteria</u>

>The student will apply knowledge of acids, bases, pH and buffers to ecological situations and speculate appropriately why acid rain is more serious in some regions than others.

>The student will demonstrate an appreciation of the international nature of acid rain pollution.

>The student will demonstrate a willingness to consider the values of an opposing point of view, either by making some positive reference to it when forming their own argument, or by actually changing sides during the acid rain debate.

>The student demonstrate a willingness to listen to opinions other than his or her own, to take part in class discussion, to support the opinions of others with an isolated point of view.

Assessment 9

Most of the diversity of biological material and process is the result of carefully regulated chemical activity. The chemical reactions which produce new combinations of atoms take up energy or release it to the environment.
List two everyday examples of chemical activity which demonstrate

a. liberation of energy.

b. storage of energy.

Abilities covered

Communication
Analytic capability

Content outcomes
5

Criteria

>The student will have been able to internalize the characteristics of chemical reactions to the point where it is possible to provide practical examples.

Assessment 10

A local restaurant chain has solicited your help as a college biology student. A number of patrons have complained over a period of time about the peculiar taste associated with their sweet tea. Think about the possibilities in terms of the following levels of organization of matter. List an example of each level, and explain how your example might have influenced the taste of the tea. Organize your thoughts by filling in the following chart. Then using your logic, write a letter to the manager of the restaurant chain suggesting at least two tentative causes of the problem and techniques to solve the problem.

Level of Organization	Example	Explanation
Subatomic		
Atomic (including ions)		
Molecular		
Organismal		

Abilities Covered

Communication
Analytical Ability
Problem Solving

Criteria

>Examples fit levels of organization.

>Explanation of peculiar taste in tea uses chemical concepts appropriately.

>Explanation of peculiar taste is logical.

>Explanation of peculiar taste is accurate.

>Projects process that could lead to a feasible solution.

Enzymes
Lecture Discussion Module

Prior Assumed Knowledge - Basic Organic Chemistry

Content Outcomes (Student Objectives)

1) The students should identify enzymes as globular proteins and as organic catalysts.

2) The students should understand that enzymes have catalytic activity and are not permanently changed as a result of catalysis.

3) The students should understand the dynamics of catalysis: enzymes convert a substrate(s) to a product(s) with an intervening enzyme-substrate complex.

4) The students should demonstrate that the substrate specifically fits into a groove on the enzyme surface called the active site with a "lock and key" fit.

5) The students should understand that when the substrate fits into the active site, both the enzyme and substrate can and do change shape slightly to conform to one another, this is referred to as the INDUCED FIT HYPOTHESIS OR MODEL.

6) The students should identify some examples of enzyme specificity to the substrate.

7) The students should comprehend that enzymes and other catalysts increase the rate of a chemical reaction by lowering the activation energy; this allows the chemical reaction to proceed at a temperature which is compatible with the living cell.

8) The students should understand that enzymes function within very narrow physical parameters (temperature, pH). Extremes of these parameters can denature or otherwise permanently inactivate an enzyme.

9) The students should give examples showing that enzymes require the presence of inorganic molecules called cofactors, or organic molecules called coenzymes in order to function.

10) The students should observe that enzyme function can be affected by chemical parameters such as substrate concentration, enzyme concentration and the presence of other molecules termed inhibitors.

11) The students should understand that competitive inhibition occurs when the substrate and a molecule shaped similarly to the substrate compete for the same active site on the enzyme.

12) The students should understand that noncompetitive inhibition occurs when non-substrate molecules bind to the enzyme irreversibly, therefore permanently inactivating the enzyme.

Assessments

Assessment 1

The student will identify the relationships among globular proteins, enzymes and organic catalysts through a multiple choice quiz.

Abilities Covered

Analytical Capability

Content Outcomes
1

Criteria

>The student will accurately select from a variety of choices the descriptive terms for enzymes.

Assessment 2

The students will work in small groups and demonstrate orally to the class that enzymes have catalytic activity and are not permanently changed.

Abilities Covered

Social Interaction
Communication

Content Outcomes
2

Criteria

>The students demonstration shows catalytic activity and no permanent change.

>Students will demonstrate appropriate group behavior by describing their contributions to the group.

Assessment 3

The student will write a paragraph describing the dynamics among an enzyme, its substrate, and the product.

Abilities Covered

Communication

Content Outcomes
3

Criteria

>The student's descriptive paragraph will be evaluated for content explaining the concept of enzyme function as well as the ability to express scientific ideas in written form.

>Written material will be assessed using General Criteria for Written Communication (Appendix)

Assessment 4

The student will create a diagram or model to illustrate the lock and key fit analogy.

Abilities Covered

General Communication

Content Outcomes
4

Criteria

>The student's diagrams charts will show the relationship of the lock and key fit to the enzyme.

Assessment 5

The students will work in groups to develop a graphic descriptor to illustrate the induced fit hypothesis and present it to the class.

Abilities Covered

Communication
Social Interaction

Content Outcomes
5

Criteria

>The students graphic descriptor will clearly demonstrate the induced fit hypothesis.

>The General Communication guidelines (Appendix) will be used to assess the presentation.

Assessment 6

The student will make a chart showing how every enzyme has a specific substrate. The chart should also identify the locations in nature where each enzyme demonstrated occurs.

Abilities Covered

Communication

Content Outcomes
6

Criteria

>The student's chart will clearly and accurately demonstrate the relationship between the substrate and enzyme. The locations of the enzymes must be demonstrated correctly.

Assessment 7

The student will prepare a graph demonstrating changes of energy content of the reaction system without the enzyme versus progress of the reaction with the enzyme.

Abilities Covered

Communication

Content Outcomes
7

Criteria

>The student's graph will be assessed based on their accurate demonstration of the relationship between the energy content and reaction progress and correct format (legibility, labels, scale, size etc.).

Assessment 8

The student will graph the relationship between enzyme activity versus pH and enzyme activity versus temperature.

Abilities Covered

Communication

Content Outcomes
8

Criteria

>The student's graphs will be assessed based on their accurate demonstration of the relationships between enzyme activity and changes in Ph and temperature and correct format (legibility, labels, scale, size etc.).

Assessment 9

The students will work in small groups to develop a list of examples of enzymes and their cofactors and coenzymes. This information shall be organized on a chart, labeling the enzyme and its cofactor/coenzyme.

<u>Abilities Covered</u>

Communication
Social Interaction

<u>Content Outcomes</u>
9

<u>Criteria</u>

>Enzymes, cofactors and coenzymes must correlate.

>Chart should be accurate and neat.

>Appropriate group behavior will be assessed by observation.

Assessment 10

The students will write conclusions regarding changes in enzyme structure from observations of the effects of chemical parameters on enzyme activity.

Abilities Covered

Communication

Content Outcomes
10

Criteria

>The student's written conclusions will be evaluated based on their validity.

>The written presentation will be assessed using the general abilities guidelines.

Assessment 11

The student orally describes the difference between competitive and noncompetitive inhibition.

Abilities Covered

Communication

Content Outcomes
11

Criteria

>The student's demonstrations will correctly illustrate competitive and noncompetitive inhibition.

>The oral presentation will be assessed using the general abilities guidelines.

Evolution
Lecture Discussion Module

Prior Assumed Knowledge

Basic Organic Chemistry
Molecular Genetics
Mendelian Genetics
Photosynthesis and Cellular Respiration (re: Cytochrome C)

Content Outcomes (Student Objectives)

1) Students should understand evolution as a dynamic (active and ongoing) process; therefore they should be familiar with the forces which contribute to change and they should be able to describe the nature of the change.

2) Students should be able to cite the types of evidence used by Darwin to formulate the steps in his theory of Evolution. (This should include the influence of geology, geography, sociology, observation, inference, opinion, etc.).

3) Students should be able to critically examine theories attributed to Lamarck, Darwin, modern synthesis, and punctuated equilibrium, so as to outline similarities and differences among them.

4) Students should be able to describe the types of evidence used to support the fact that evolution occurred in the past.

5) Students should be familiar with the forces of evolutionary change. These would include various types of selection, isolating mechanisms, and sources of variation. The student would also become familiar with populations, gene pools, speciation and extinction.

Assessment 1

Debate between creationists and evolutionists.

Students: read the section in your text which covers evidence for historical evolution. You may also want to refer to other sections in your text and/or other sources which cover aspects of the following scenarios:
>Fossil evidence: does it suggest evolution or creationism, and why?
>Do humans and apes have a common ancestor? Evidence for and against.

Using the evidence that you are able to organize, you will join either a pro or a con side. Your task will be to convince peers who have an opposing point of view to join your side. Be prepared to cite the sources of any information that you use and identify the information as to observation, inference, opinion, or others.

<u>Abilities Covered</u>

Oral Communication
Analytical Capability
Valuing
Social Interaction
Historical Perspective (optional -- may be used by student debaters)

<u>Content Outcomes</u>
1, 2 and 5 -- possible;
3 and 4 -- definite

<u>Criteria</u>

>The student will demonstrate a willingness to consider the values of an opposing point of view, either by making some positive reference to it when forming their own argument, or by actually changing sides during the evolution/creationism debate.

>The student will demonstrate a willingness to listen to opinions other than his or her own, to take part in class discussion, to support the opinions of others with an isolated point of view.

>The student should come to class with evidence supporting both the Darwinian and creationist points of view, and be prepared to identify whether this information is based upon observation, inference or opinion or other.

Assessment 2

Genetic drift and Founder Effect

Directions: Refer in your text to the section dealing with Genetic Drift and Founder Effect, and complete the following calculations. You may want to work with one or more of your classmates to corroborate your calculations.

Be prepared to share your answers and process with the rest of the class.

Genetic Drift

A family of 6 has the following blood genotypes

Mom I^Ai
Dad I^BI^B
Child 1 ii
2 I^AI^B
3 I^Bi
4 I^AI^B

1) Calculate the allele frequencies for this population of 6 people.

I^A= ____.

I^B= ____.

i= ____.

2) A meteor strikes the family home. Two family members are killed. Pick two family members and eliminate them from the gene pool.

List the two family members who were eliminated. ________.

Recalculate the allele frequencies.

I^A= ____.

I^B= ____.

i= ____.

3) Explain how this phenomenon can be important in the process of speciation. Outline your logic below. You may be called upon to share your logic with the class.

4) Make up your own data, but have a population size of twenty.

Eliminate two from your population and compare the change in allele frequency with the change that you observed in the example of the family of six.

<u>Genotype</u> <u>Number of each</u>

I^AI^A ___

I^Ai ___

I^BI^B ___

I^Bi ___

I^AI^B ___

ii ___

Allele Frequencies

I^A= ____.

I^B= ____.

i= ____.

List the two individuals eliminated. ______________.

Using the 18 remaining individuals, recalculate allele frequencies.
<u>Allele Frequencies</u>

I^A= ____.

I^B= ____.

i= ____.

Why is population size an important factor in the speed and direction of changes in gene frequency (microevolution)? Outline your logic in the space below and be prepared to share it with the class.

Founder effect

Suppose that the allele frequencies of the ABO locus of the population of people in the state of South Carolina is I^A=0.6, I^B=0.3 and i=0.1. You and the mate of your choice get to start a new human population on a desert island in paradise.

1) Who would your mate be? ______________.
List the reason(s) for the choice of your mate (phenotype, love, global responsibility). Outline your logic in the space below and be prepared to share it with the class.

2) If you do not know the blood type genotypes of you and your proposed mate, make them up.

you____, mate____.

3) Now, for the new population of two on the desert island, calculate the allele frequencies.
<u>Allele Frequencies</u>

I^A= ____.

I^B= ____.

i= ____.

4) Compare the allele frequencies of the population of two to the allele frequencies of the entire population of people in South Carolina. Why are they different?

5) Using the example referred to in this assessment (2B) compose your own definition of founder effect and record it in the space below.

6) How might founder effect influence the process of speciation?

<u>Abilities Covered</u>

Communication
Analytical Capability
Social Interaction
Problem Solving
Valuing

<u>Content Outcomes</u>

1 and 5

<u>Criteria</u>

>Students should be able to solve the calculations correctly.

>Students should be able to demonstrate an understanding of genetic drift and the founder effect and their importance to speciation.

>Students should be able to provide a clear rationale for their choice of mate in founder effect item #1.

>Students should participate in class discussions, in such a way that they favorably influence the proceedings.

Assessment 3

Directions List the anatomical and/or physiological changes necessary for the evolution of a terrestrial mammal into a mammal living in a marine environment (such as a primitive mammal evolving into a dolphin, whale or seal).

(Alternative Approach: ask the same question, but refer to the evolution of fish into amphibians, amphibians into reptiles, reptiles into birds, etc.).

Select two principles from the following list, and briefly indicate how each of these principles might have contributed to the changes listed above: genetic variation; stabilizing selection; directional selection; disruptive selection; isolating mechanisms.

Abilities

Communication
Analytical Ability

Content Outcomes

1 and 5; possibly 2

Criteria

>Students should demonstrate an understanding of at least two evolutionary forces, and their roles in the dynamic process of change.

Assessment 4

Would you consider the great dane and the chihuahua to be members of the same species? (yes or no) ____. Use the concept of speciation to defend your answer. Outline your logic in the space below and be prepared to participate in the class discussion.

Abilities

Communication
Analytic Ability

Content Outcomes
1 and 5

Criteria

>Students should demonstrate a clear understanding of the species concept.

>Students should be able to logically apply their definition of species to the example provided.

>Students should participate in class discussions in such a way that they favorably influence its proceedings.

Assessment 5

Refer to your text to the example of industrial melanism (peppered moth) and prepare three one paragraph explanations of the process as if you were each of the following:
>C. Darwin
>J.B.Lamarck
>S. J. Gould (punctuated equilibrium)

Abilities

Communication
Analytic Ability
Historical Perspective

Content Outcomes
1, 2, 3 and 5

Criteria

>Students should be familiar with the processes of evolution championed by each of the three scientists.

>Students should be able to apply these processes to the example given in an understandable way.

Assessment 6

You have discovered a previously unknown plant growing on top of a tall building in the city. It may be a variant of another plant that you know, or it may represent a new species. List below the types of evidence that you might use to determine its status?

Abilities

Communication
Analytic Capability

Content Outcomes
1 and 5

Criteria

>Students should demonstrate a clear understanding of the species concept.

>Students should be able to logically apply their definition of species to the example provided.

Assessment 7

Refer to your study of scientific method and offer a suggestion as to why Darwin's ideas are referred to as a theory rather than a fact or as a series of hypotheses.

Abilities

Communication
Analytic Abilities
Historical Perspective

Content Outcomes
2, 3 and 4

Criteria

>The student must clearly differentiate between theory, fact and hypothesis.

>The student must show and understanding of Darwin's concept of evolution.

>The student should be able to explain why Darwin's ideas are a theory.

Assessment 8

Geologic time

Scientists have considerable data which supports the hypothesis that the Earth is 4.5 billion years old. Humans are thought to have evolved approximately one million years ago.

Calculate the percentage of time that humans have existed compared to the time that earth has existed.

Assume that one million years equals a mile. Therefore, the age of the earth would be equivalent to 4,500 miles (about the width of the United States).

Calculate the distance that would represent the time between the birth of Christ and the present.

Using the data generated above, comment on geologic time compared to the time we use in our everyday lives.

Can you explain why there are so few examples of evolution that can be observed directly?

Abilities

Communication
Analytic Abilities
Historical Perspective

Content Outcomes
1 and 5.

Criteria

>The student should perform the calculations correctly.

>The student should be able to communicate, in writing, an appreciation of the vastness of geological time.

>The student should be able to communicate the relevance of the vastness of geological time to the process of evolution.

Assessment 9

Scientists often offer contrasting evidence for events such as the extinction of dinosaurs. These have included collision with an asteroid, evolution of small egg-eating mammals, and drastic changes in the Earth's climate. Detractors often cite the disagreement as evidence that such hypotheses are poor science.

They argue that evolution is doubtful because scientists disagree among themselves as to the cause and timing of major events.

Do you agree with the opinion that these multiple hypotheses represent poor science?

a. Defend your opinion.

b. Considering that it is impossible to go back in time and directly gather evidence, why are hypotheses particularly important in understanding evolutionary processes ?

Abilities

Communication
Analytical Ability
Valuing
Historical Perspective

Content Outcomes
2, 4 and 5

Criteria

>The student should communicate, in writing, the role of the hypothesis as a tool for directing the gathering of information and the testing of ideas, rather than as an end in itself for answering scientific questions.

Assessment 10

After the last ice age, the number of species of North American warblers increased tremendously. Select two or more of the following processes and devise an explanation of how the process might have contributed to speciation in warblers. You may want to refer to the section in your text referring to adaptive radiation in Darwin's finches.

>Founder Effect
>Bottleneck Effect
>Adaptation by Natural Selection
>Geographic Isolation
>Genetic Drift

Abilities

Communication
Analytic Ability
Historical Perspective

Content Outcomes
1, 2 and 5

Criteria

>The student should demonstrate an understanding of some of the processes of evolution.

>The student should be able to apply two or more of these processes to explaining rapid speciation among warblers.

Introductory Notes for the Student

Welcome to the laboratory portion of Biology 110. In this laboratory you will perform exercises to demonstrate and reenforce concepts learned in the lecture portion of the course. Laboratory exercises may include test tubes, chemical solutions, tests on living animals and plants and dissection of preserved specimens. In these exercises you will often collect your own data. An important portion of this laboratory is learning how to handle, present and interpret your data. The exercises also will incorporate procedures which utilize the scientific method, a method of problem solving and reasoning critical to the advancement of science.

These laboratory modules allow you to explore the process of experiment and discovery of some concepts that will be considered in lecture. Each module begins with Student Objectives. These objectives precisely state what you should learn. Next are the Student Criteria, the criteria state what you must accomplish in order to satisfactorily complete the exercise. The criteria are followed by the Procedure, and the procedure is followed by Assessments. The assessments are activities which your instructor may have you complete to determine whether you have accomplished the objectives of the laboratory.

The procedure of the laboratory exercises typically follow a standard format. A general introduction provides a background for the exercise. Materials used in the exercise are listed and a detailed set of directions are provided. The student should identify the questions being considered in each exercise, be able to formulate a hypothesis and recognize the procedures as necessary to support or reject the hypothesis. The laboratory also should be recognized as an environment which encourages the use of collaborative work. It is important that you learn to work effectively and efficiently in small groups.

Biology 110
Scientific Method Laboratory

Introduction

The concepts you learn about biology from your textbook were developed using the scientific method. Because the scientific method is so important we will consider it first, and it will be used in virtually every exercise. The scientific method is a logical, consistent way to answer questions about the universe around us. During this laboratory you will learn the components and application of the scientific method through an actual experiment.

Student Objectives

The student will:

>Recognize the components of the scientific method.

>Recognize the difference between the experimental variable and the control.

>Make concise, useful observations.

>Collect, record and manipulate data.

>Make conclusions, predictions and inferences.

>Communicate your results both orally and in writing.

>Work productively in a small group with each member actively involved.

>Exercise respect for all forms of life.

Student Criteria

The student will:

>Follow the experimental procedure exactly as written and follow all safety procedures specified by your instructor.

>Make careful measurements over time and precisely record data.

>Present data in tables accurately, neatly and clearly.

>Be able to make pertinent predictions based on collected data.

>Be able to clearly explain, both orally and in writing, the results, significance and applications of the laboratory exercise.

>Effectively involve each member of your group in the laboratory exercise and be able to describe how you and the other members contributed.

Procedure

Reference:

Jacklet, A. 1992. Laboratory manual to accompany life. W.C. Brown Pub. Ex. 1, pp. 1-8.

Assessments

The student may be required to:

>Explain why the control procedure was necessary.

>List and define the components of the scientific method.

>List the steps of the scientific method in the correct sequence.

>Interpret the experimental data and draw a conclusion.

>From every day experiences, make an observation (for example, grass is greener next to the sidewalk), create a hypothesis (for example, minerals from the sidewalk are supplying a nutrient to the grass) and design an experiment using the principles of the scientific method to test the hypothesis.

>Explain, based on the experimental data and (personal experience), whether alcohol and caffeine are stimulants or depressants.

>Based on the experimental data, predict the effects of 20% alcohol on the heartrate of *Daphnia*.

>Based on personal observations, determine the number of chambers in a *Daphnia* heart.

>As a self evaluation, write a paragraph answering the following questions:

- what did you contribute to the group effort, and why did you choose to make that particular contribution?

- what did the other members of your group contribute?

- did all members of the group participate equally? why or why not?

>Be prepared to orally explain variations in the data collected.

>Be observed for correctly handling living organisms following animal care protocol.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

References

Denny, C. F., J. F. Logue and C. A. West. in press. Experiences in Biology. Wm. C. Brown Publishers., Dubuque, Iowa.

Jacklet, A. 1992. Laboratory manual to accompany life. W.C. Brown Pub.

Morgan, J.G. and M. E. B. Carter. 1993. Investigating Biology, A Laboratory Manual for Biology. Benjamin/Cummings Pub. Co. Inc.

Biology 110
Microscopy Laboratory

Introduction

The invention of the microscope in the 1600's revolutionized biology. For the first time, scientists were able to see life at the cellular level leading to numerous scientific insights (e.g. cell theory, germ theory). In this exercise the student will learn the parts and use of the compound microscope for use as a tool in future exercises.

Student Objectives

The student will:

>Become familiar with all the parts of the microscope and their functions.

>Be able to focus the light and the objectives on the specimen.

>In the use of the microscope be able to apply the terms parfocal, resolution and paracentral.

>Make concise, useful observations.

>Collect, record and manipulate data.

>Make conclusions, predictions and inferences.

>Communicate results effectively in a written formal lab report.

>Work productively in a team with each member actively involved.

>Exercise respect for all forms of life.

>Present data graphically in a meaningful way.

>Interpret graphical data correctly.

Student Criteria

The student will:

>Properly manipulate the microscope.

>Follow the experimental procedure exactly as written.

>Make careful measurements over time and precisely record data.

>Present data in tables and graphs accurately, neatly and clearly.

>Make pertinent predictions based on collected data.

>Clearly explain, both orally and in writing, the results, significance and applications of the laboratory exercise.

>Effectively involve each member of the team in the laboratory exercise and be able to describe how each member contributed.

Procedure

Reference:

Jacklet, A. 1992. Laboratory manual to accompany life. W.C. Brown Pub. Ex. 2, pp. 9-17.

Assessments

The student may be required to:

>Demonstrate the ability to correctly focus the microscope and adjust light on a given specimen.

>Demonstrate knowledge of the microscope parts and functions as well as the concepts of parfocal, resolution and paracentral.

>Explain how the microscope revolutionized biology in a paragraph utilizing three or more examples.

>Demonstrate correct handling of living organisms following animal care protocol.

>Define phototaxis, based on the experimental results.

>Explain what advantage phototaxis would have for Euglena.

>Write a laboratory report using the guidelines in the laboratory procedure (pp. 11-13, appendix B).

>Briefly state her/his contributions to the team as a self evaluation.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

References

Note: laboratory instructors may wish to substitute other procedures or materials depending on available supplies, budget concerns and time constraints.

Denny, C. F., J. F. Logue and C. A. West. in press. Experiences in Biology. Wm. C. Brown Publishers., Dubuque, Iowa.

Jacklet, A. 1992. Laboratory manual to accompany life. W.C. Brown Pub.

Morgan, J.G. and M. E. B. Carter. 1993. Investigating Biology, A Laboratory Manual for Biology. Benjamin/Cummings Pub. Co. Inc.

Biology 110
Measurement and Graphing Laboratory

Introduction

Many laboratory investigations will require quantification or numerical representation of collected data. The purpose of this exercise is to explore some laboratory techniques and to provide an opportunity to sharpen associated basic science skills (observation, measurement, inference and prediction).

Student Objectives

The student will:

>Make concise, useful observations.

>Measure linear distances, volumes, weights and temperatures using the proper S.I. (Systeme International d'unites).

>Collect, record and manipulate data.

>Identify the different types of graphs and their components.

>Present data graphically in a meaningful way.

>Interpret graphical data correctly.

>Make conclusions, predictions and inferences.

>Communicate results both orally and in writing.

>Work productively in a small group with each member actively involved.

Student Criteria

The student will:

>Follow the experimental procedure exactly as written.

>Make careful measurements over time and precisely record data.

>Present data in tables and graphs accurately, neatly and clearly.

>Be able to make pertinent predictions based on collected data.

>Be able to clearly explain, both orally and in writing, the results, significance and applications of the laboratory exercise.

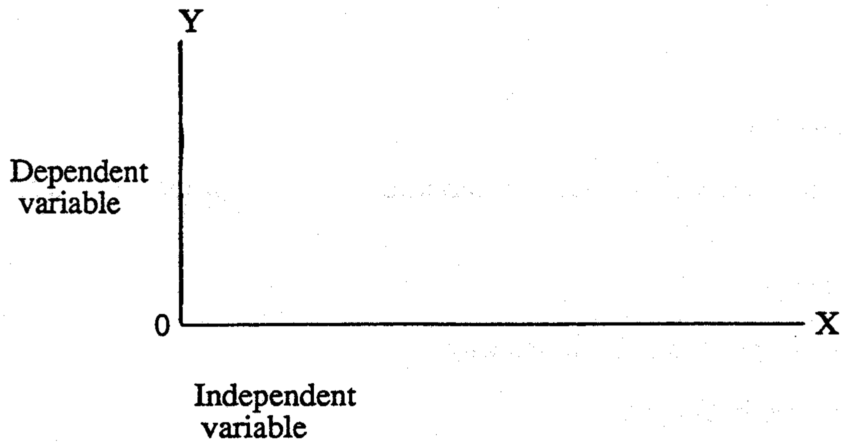
>Effectively involve each member of the group in the laboratory exercise and be able to describe how each member contributed.

Procedure

I. Graphing

Graphs provide a concise presentation of data. Graphs also provide a "picture" of the data and eliminate the necessity of listing a large number of data points. Whenever possible, data should always be summarized and presented in either the form of a graph, table or figure.

Axes on a graph are labeled as follows:



The INDEPENDENT VARIABLE is defined as a varying aspect of the environment which is measured and recorded or that the experimenter directly manipulates. An example of an independent variable would be time. Name/describe another example of an independent variable? ______________________________ The DEPENDENT VARIABLE is defined as the aspect of the experiment whose changes depend on changes in the independent variable. The dependent variable is often the subject of the experiment which the experimenter counts, measures, observes or records. An example of a dependent variable would be the number of individuals in a population.

Some rules that may aid in the construction of graphs are as follows:

1. Center the graph on the page. Draw a straight line, x- axis (horizontal line), and a straight line y-axis (vertical line) about three-fourths of the length of the x-axis. Where the axes meet perpendicularly, label the point "O" (origin). Axes should not be drawn on the border margins of the graph paper.

2. Axes should be labeled clearly. Include both variables and the units in which they are being measured. Printing should be in capital letters, including abbreviations. In general, abbreviations are not punctuated, MIN or SEC, etc. The independent variable should be placed on the x-axis and the dependent variable on the y-axis.

3. Labeling should be clear, parallel to the proper axis, and centered.

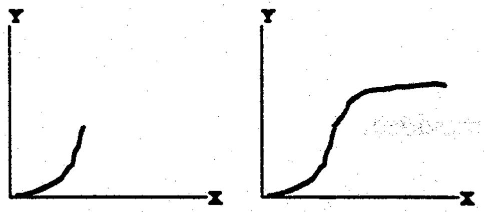
4. Grid marks should be drawn inside the axes and equidistant from each other.

5. Assign numerical values to each of the grid marks drawn.

6. Plot data points at appropriate intervals. A point represents a single unit (x,y). Once you have assigned values at the grid marks on both axes, look at your first x-value and your first y-value as a unit, and plot that point at the appropriate interval of your axes.

7. Connect the plot points sequentially (from left to right) by drawing straight lines; that is, from point 1 to point 2, point 2 to point 3, and so on.

Using the information above answer the following questions. The two graphs below represent two methods of graphing human population growth over many years.



With which of the following should the x-axis on both graphs be labeled? (circle your answer)
TOTAL POPULATION NUMBER or TIME
The y-axis? TOTAL POPULATION NUMBER or TIME

A biologist investigated the increase in population number of a one-celled organism over time. The data for this experiment are:

DAY	NUMBER OF ORGANISMS
5	10
10	20
15	28
20	40
25	40
30 (FORGOT TO RECORD)	?
35	30
40	20

Graph these data on the graph paper provided.

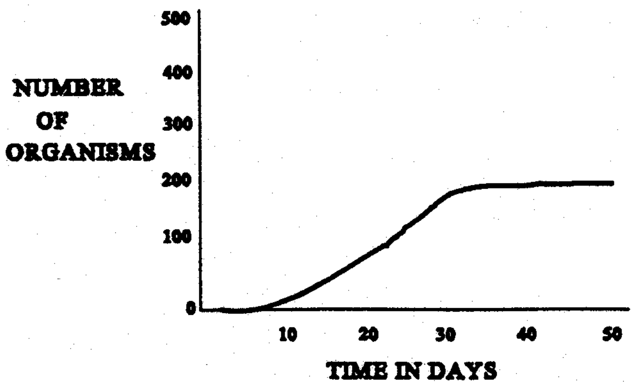
Using your growth curve for this population of organisms, indicate the periods during which the following conditions prevail.

1. The organisms are reproducing at the same rate they are dying between day _______ and day _______.

2. The organisms are reproducing faster than they are dying between day ________ and day ________.

3. The organisms are dying faster than they are reproducing between day _______ and day _________.

A biologist was running an experiment to determine a population growth curve for a particular species of organism. He ran the experiment for 50 days and obtained the data shown in the following graph.



From the data he predicted that the population would stay the same over the next 30 days. For his prediction to hold, what assumptions must be made?

1. There will be enough food to sustain the population after day 50.

2. Temperature and other physical variables will stay constant.

3. The organisms will not significantly alter the environment in which the population is located.

4. Birth and death rate will be equal.

5. All of the above assumptions must be made.

6. Assumption 4 need not be made.

7. Assumptions 3 and 4 need not be made.

II. MEASUREMENT

Scientific observations must be expressed with precision and accuracy. Many observations and experiments are designed so that data are recorded as some type of measurement. The universal scientific system of measurement is the METRIC SYSTEM. Important measurements that may be obtained using the metric system include determining volume, temperature, and weight. These units of measurement will be investigated during this exercise, linear measurement will be covered in a later excercise.

A. VOLUME -

1. Obtain the following equipment to do this part of the exercise:
   a measuring cup
   a quart sized container
   a one liter volumetric flask
   a one gallon container
   a graduated cylinder

Using water whenever measurement are required, answer the following questions.

a. What does the prefix Mill mean? ____________________ How many milliliters are there in one liter? ______________________

b. Which is greater, a quart or a liter? _____________ By approximately how much is it greater?

____

c. How many liters are there in a gallon? ______________________

d. If you know that the current price for gasoline is $.85/gal, and you are buying gasoline at a service station that is selling gasoline by the liter, what would you expect the price for one liter of gasoline to be? ____________________

2. Using a standard medicine dropper, determine the number of drops contained in one milliliter. ____________________?
in 5 ml ____________? in 10 ml ____________? Predict the number of drops contained in 25 ml ____________? What is the basis for your hypothesis concerning the number of drops in 25 ml?

Record your observations for 1, 5, and 10 ml on the blackboard. Compare your results with those of others in your class. Based on the observations of your and other groups, are the drops of uniform size? ____________ How could you further test these conclusions?

____

____

3. The volumetric metric system is actually a logical extension of the linear measurement system. To illustrate this, obtain from your instructor a small cuvette. Measure and record the internal dimensions of the square made by the top of the cuvette. _____cm x _____cm Use a 5 milliliter pipet to dispense 1 ml of water into the cuvette. How high is the column of water? ______cm Notice that the water has a tendency to adhere to the sides of the cuvette. All such volumetric measurement are made to the bottom of the curve made by this water or MENISCUS. Dispense a second and third milliliter into the cuvette and determine the height each time. Place your data in the space provide on the next page.

Volume Dispensed	Height to Meniscus
1 ml	________
2 ml	________
3 ml	________

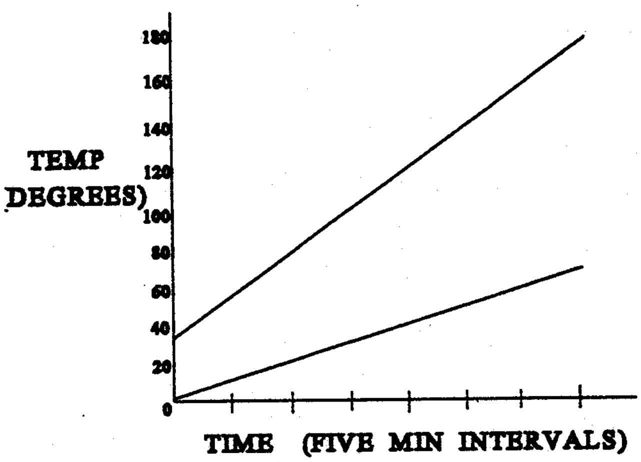
Based on the above observations, how many cubic centimeters are found in one milliliter? ____________________. Remember cm x cm x cm = cubic centimeter (cc).

B. TEMPERATURE - While most students can relate to temperature measurements when they are expressed in degrees fahrenheit, they often do not have the same practical knowledge of temperature expressed in degrees Centigrade. For example, if you were to read in your text book that a certain species of bacteria could not survive at temperatures above 40 degrees Centigrade,

would you expect the organism to survive in the human body? ____________________

Although you may have memorized formulae to convert degrees Fahrenheit to Centigrade and vice versa, these formulae are easily forgotten. We will compare some temperatures on the Fahrenheit scale with those on the Centigrade scale.

The following graph was constructed by recording, at five minute intervals, the temperature of a container of oil which was placed on a hot plate and heated for a period of 40 minutes. Temperature was recorded with a thermometer calibrated in degrees Centigrade and with a thermometer calibrated in degrees Fahrenheit. Use the graph to determine the temperature readings requested in the two questions at the end of this section. Check your answers with the formulae.



The following formulae connect the different scales:

$F = 9/5\,C + 32$
$C = 5/9\,(F - 32)$

A thermostat is set to maintain a temperature of 69.8 degrees F. What is the corresponding Centigrade temperature? ______________

If a clinical thermometer were graduated in Centigrade degrees, what temperature would it show for a patient with a fever of 102.2 degrees F? __________________________

C. WEIGHT - Weigh the can of food that you are provided. What is the weight of the can of food and its contents? ________

Now open the can and drain off the excess fluid. Weigh the drained contents of the can. Also weigh the empty can.

Weight of food ________________

Weight of can _________________

Record your observations on the blackboard. Do all cans have the same weight? __________________ Does the amount of food vary from can to can? ____________________

Approximately how many grams are in a pound? (you will probably be given a 1 lb can of food)

____

Assessments

The student may be required to:

>Observe the graph below and answer the following five questions.

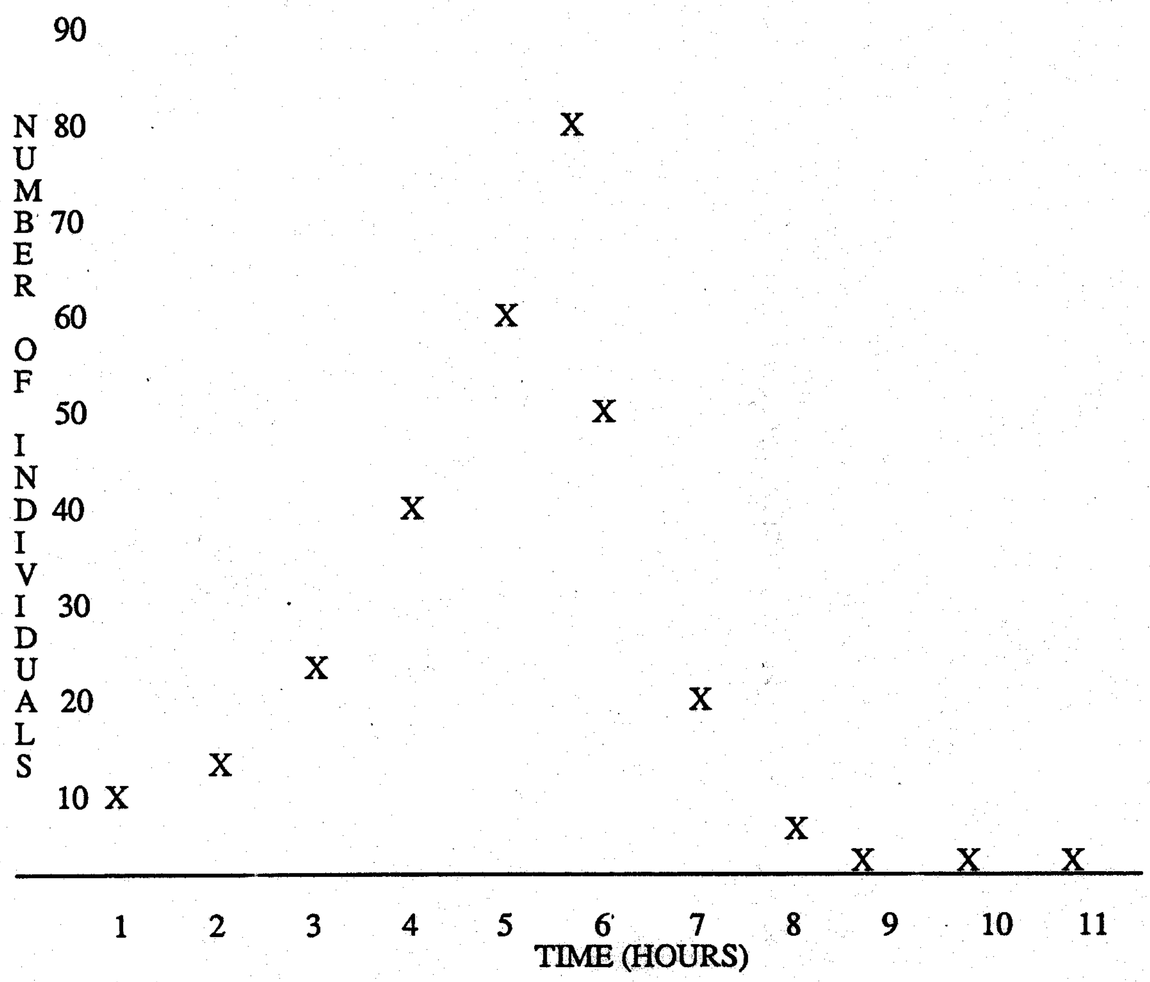
How long did it take for the population to reach maximum size?

At 4 hours how many organisms were present?

At what time was half the maximum number of organisms present?

Was the rate of population decrease equal to the rate of population increase?

Identify the dependent variable, explain your answer.

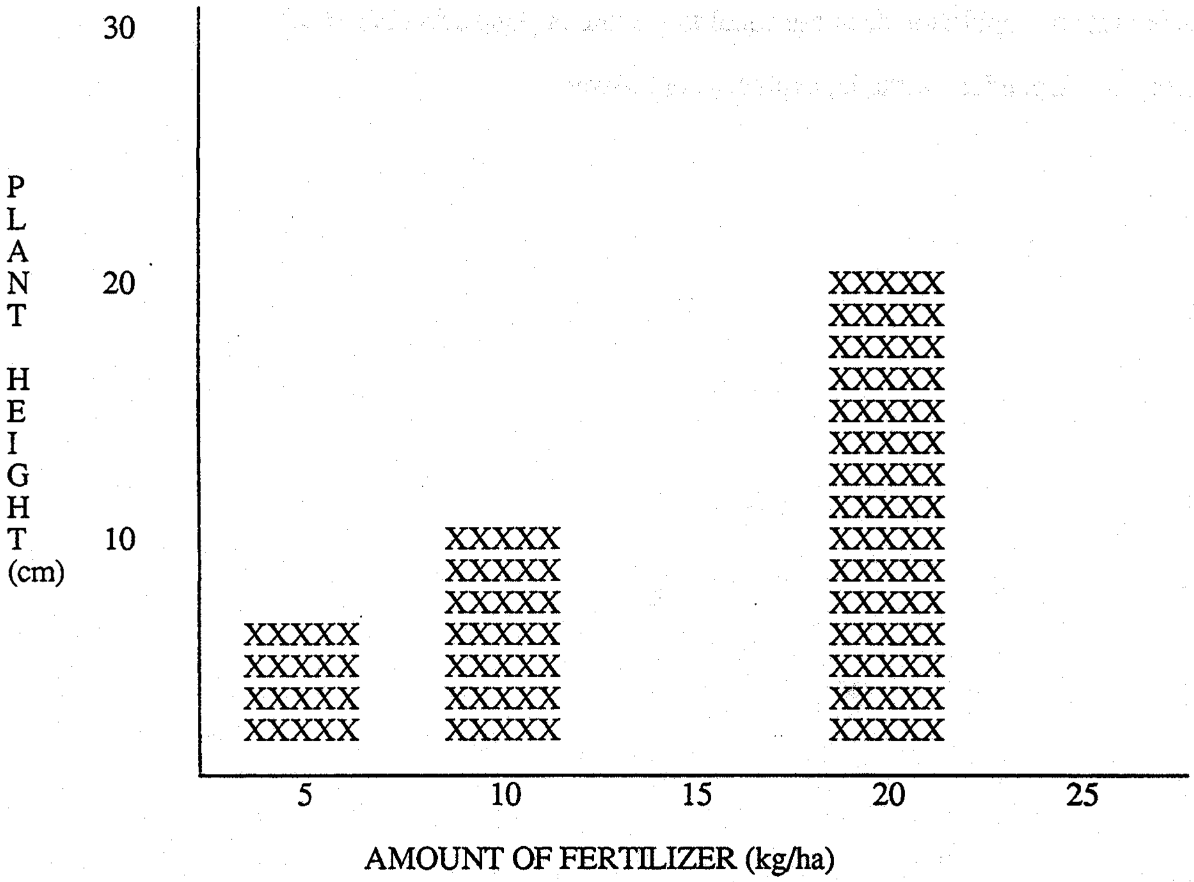


>Work in groups. For the graph below, answer the following three questions:

Predict the plant height if 15 kg of fertilizer is applied to each hectare. Add the prediction to the following graph.

Predict the plant height if 25 kg of fertilizer is applied to each hectare. Add the prediction to the following graph and be prepared to defend your answer orally.

Kmart sells fertilizer only in 20 pound bags. Based on the original graph, how many bags will be needed for maximum growth in your one hectare garden? (one pound equals 0.454 kg)



>Turn in a graph prepared as described on page 4 on this exercise.

>Prepare to orally report group results, methods and rationale for Part II A of this exercise. Include in the report both data and the steps used.

>Briefly state her/his contributions to the team as a self evaluation.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

Reference

Denny, C. F., J. F. Logue and C. A. West. in press. Experiences in Biology. Wm. C. Brown Publishers., Dubuque, Iowa.

Biology 110
Enzyme Laboratory

Introduction

In the presence of enzymes chemical reactions requiring tremendous energy and exacting circumstances take place in the bodies of plants and animals under quite ordinary physical conditions. Therefore, without enzymes, life as we know it would not exist. In this exercise we will study enzyme structure and activity.

Prior Knowledge/Skills

> The student has performed laboratory exercises which include
a) the writing of a scientific paper.
b) measurements and graphs.
c) manipulation of laboratory glassware and equipment.
d) laboratory safety

> Lectures on the chemistry of organic molecules.

> Introductory lecture and readings on enzymes (see appendix).

Student Objectives

The student will:

>Make concise, useful observations.

>Collect, record and manipulate data.

>Interpret and present data in a meaningful way.

>Make conclusions, predictions and inferences.

>Relate the laboratory exercise to the conceptual model of enzyme structure and function.

>Give examples of the action of enzymes in everyday life.

>Give examples of enzyme function in living organisms.

>Communicate results both orally and in writing.

>Be able to work productively in a small group with each member actively involved.

>Recognize the basic components of a well designed experiment.

Student Criteria

The student will:

>Follow the experimental procedure exactly as written.

>Make careful measurements over time and precisely record data.

>Present data in tables and graphs accurately, neatly and clearly.

>Make pertinent predictions based on collected data.

>Identify the controls, experimental units and the variables used in this laboratory.

>Show how results support the induced fit enzyme hypothesis.

>Describe two examples of enzymes or enzyme action that you observe or use in your everyday life.

>Give two examples of plant or animal enzymes.

>Demonstrate communication skills by clearly explaining, both orally and in writing, the results, significance and applications of the laboratory exercise for the appropriate audience.

>Demonstrate effective group skills by identifying your contribution and that of others in the performance of the laboratory exercise.

Introduction to Procedure

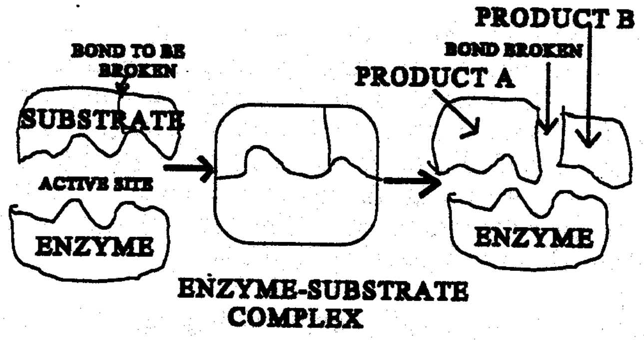
Introduction.-- Enzymes are proteins (it has recently been discovered that some RNA molecules have catalytic activity) which function as organic catalysts. They increase the rate of a chemical reaction without undergoing permanent changes. The reaction can be visualized as a two step process in which the enzyme chemically binds with the substrate to form a temporary enzyme-substrate complex. Immediately after the enzyme-substrate complex forms, catalysis occurs and the enzyme and newly formed product separate.

The activity of an enzyme is determined by the three-dimensional shape of the enzyme molecule and by the distribution of electrical charge (creating hydrophilic and hydrophobic regions) on the surface of the enzyme molecule. Somewhere on the enzyme molecule there is an active site into which the substrate molecule fits. Both the shape and electrical charge of the enzyme and substrate must match if the reaction is to proceed. Each enzyme is therefore specific for a particular substrate molecule or class of substrate molecules. An analogy is frequently drawn to a lock and key, with the enzyme being the lock and the substrate the key, although to match the induced fit hypothesis the lock would change its' shape slightly to perfectly fit the key.

Your instructor will divide the class into small groups, each group will perform tasks designated by the instructor.

Procedure

Enzymes are proteins which function as organic catalysts. They increase the speed of a chemical reaction without undergoing permanent changes. The reaction can be visualized as a two step process in which the enzyme chemically binds with the substrate to form a temporary complex. The enzyme is quickly released when the substance breaks down to yield reaction products.



The activity of an enzyme is determined by the three-dimensional shape of the enzyme molecule and by the distribution of electrical charge on the surface of the enzyme molecule. Somewhere on the enzyme molecule there is an active site into which the substrate molecule fits. Both shape and electrical charge of the enzyme and substrate must match if the reaction is to proceed. Each enzyme is <u>SPECIFIC</u> for a particular substrate molecule or class of substrate molecules.

Molecules of a size and shape similar to that of the substrate molecule may fit into the reactive site of an enzyme and not be acted upon. Although these molecules (called inhibitors) occupy the active site for only a brief period of time, while they are there they prevent the substrate from entering the active site, thus slowing the reaction. This is termed <u>COMPETITIVE INHIBITION</u>.

When substances such as iodine, lead, mercury, etc. combine with the active site on an enzyme they form a compound through chemical bonding and is referred to as <u>NONCOMPETITIVE INHIBITION</u>.

The following exercise will demonstrate the effect of an enzyme, urease, on a substrate, urea, and will allow the student to conduct experiments related to specificity, competitive and non-competitive inhibition, and the effect of substrate concentration. For each section I-IV, you should be able to: state a hypothesis; understand how the experiment tests the hypothesis; recognize the controls; and, indicate whether the results support or render the hypothesis null.

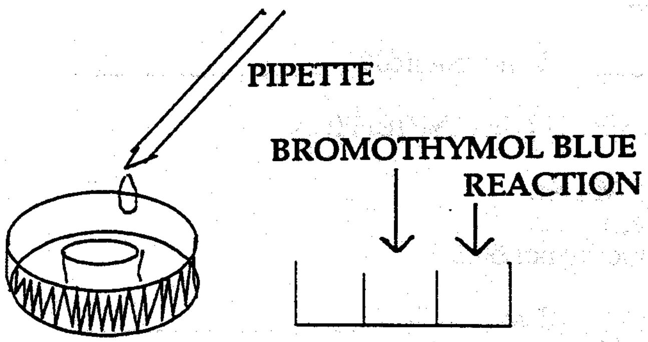
MATERIALS:

0.75 M Urea, 0.075 M Urea, 0.015 M Urea
Urease
Bromothymol blue
Thiourea
IKI (Iodine-Potassium iodide)
75:25 thiourea:urea
50:50 thiourea:urea
0:100 thiourea:urea

PROCEDURE:

Urease hydrolyzes (splits chemically through addition of water) urea to form ammonia and carbon dioxide. Bromothymol blue is used to detect the presence of ammonia.

A. Obtain a diffusion dish. Set it on a white surface and pipette 1 ml of bromothymol blue into the central chamber. The outer chamber will serve as the reaction chamber.



B. Add materials to the outer chamber in the following order:
1. Substrate
2. Enzyme
3. Lid on diffusion dish

C. The dish should then be agitated with a rotary motion (be careful that NONE of the bromothymol blue spills into the outer chamber). Bromothymol blue is an indicator of pH.. The relative amounts of hydrogen (H+) and hydoxyl (OH-)
determines the pH. At high concentrations of H+ (low OH-), the indicator (bromothymol blue) is yellow, at medium concentrations green, and at low H+ concentrations (high OH-) it is blue.

The basic function can be summarized as follows:

UREA + UREASE ------> AMMONIA + CARBON DIOXIDE
(Substrate) (Enzyme) (Products)

+ UREASE (Enzyme)

You will be provided with acid (yellow) bromothymol blue. As ammonia is provided by the action, it diffuses to the central chamber, dissolved in the indicator and produces a basic (high OH- concentration) solution. The blue color, without any
traces of green, should be used as the end point of each test that results in a chemical reaction. Each time a test is completed the diffusion chamber should be emptied and rinsed three times with distilled water.

I. HYDROLYSIS OF UREA

a. 2 ml 0.75 M urea - substrate
b. 1 ml urease solution - enzyme
c. 1 ml bromothymol blue

Color change?_______________Time required?_______________

II. SPECIFICITY AND NON-COMPETITIVE INHIBITION

1. a. 2 ml 0.75 M urea
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_______________

2. a. 2 ml 0.75 M urea + one drop iodine-potassium iodide
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_______________

3. a. 2 ml thiourea
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_______________

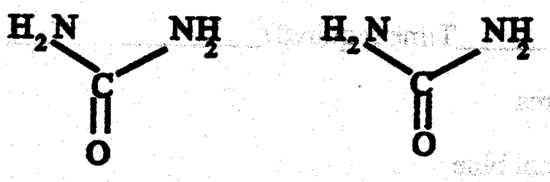
Explain the results obtained in the three procedures____

____

____

____

III. COMPETITIVE INHIBITION



UREA THIOUREA

1. a. 2 ml 75:25 thiourea:urea
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_________________

2. a. 2 ml 50:50 thiourea:urea
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_________________

3. a. 2 ml 0:100 thiourea:urea
b. 1 ml urease
c. 1 ml bromothymol blue

Color change?_______________Time required?_________________

Explain the results obtained in the three procedures_________________________

____

____

____

IV. EFFECT OF SUBSTRATE CONCENTRATION

1. a. 2 ml 0.75 M urea
   b. 1 ml urease
   c. 1 ml bromothymol blue

Color change?_______________Time required?__________________

2. a. 2 ml 0.075 M urea
   b. 1 ml urease
   c. 1 ml bromothymol blue

Color change?_______________Time required?__________________

3. a. 2 ml 0.015 M urea
   b. 1 ml urease
   c. 1 ml bromothymol blue

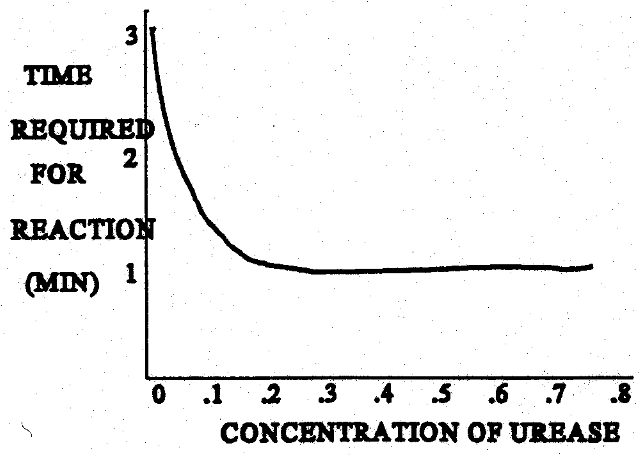
Color change?_______________Time required?__________________

Explain the results obtained in the three processes.__________________________

____

____

V. EFFECT OF ENZYME CONCENTRATION



Based on the above graph, what is the relationship between the concentration of urease and the time required for bromothymol blue to indicate the reaction? Explain. ____________________

____

____

____

Assessments

The student may be required to:

>Write a laboratory report using a scientific format:
Introduction
Methods and Materials
Results
>Present the data you collected in tabular form.
>Graph the data from part 4, substrate concentration versus time required.
>Discussion/conclusion
>Literature Cited

Criteria for the laboratory report:

Introduction- Describe the present day knowledge of enzyme structure and function, including documentation from at least one reference which may be a textbook, scientific journal or personal communication with a recognized expert. Also describe examples of enzymes you encounter in everyday life and enzymes important in the physiology of plants and animals.

Methods and materials- Use the narrative form. This section should be complete enough so that one of your peers should be able to replicate your experiment.

Results- The data are presented in a tabular and/or graphical format, units and categories clearly labeled. The data should be scientifically reasonable based on prior knowledge of enzyme function.

Discussion/conclusion- The student should compare and explain results within the framework of the induced fit hypothesis of enzyme function and state conclusions based on the results.

Literature cited- In correct scientific format.

>Present group results orally to the class, including comments on what worked well and what did not work, and suggestions for improvement. (Note to instructor: this assessment may necessitate a second laboratory session.)

Criteria for the oral report (option: videotape for self-assessment, discussion and portfolio):

Content- Summary and interpretation of the laboratory experience within the framework of a, c, and d above.

Time duration of oral report 5-10 minutes.

Creative use of media is encouraged.

Delivery- Delivery will be clear, concise, using correct grammar and pronunciation.

>Demonstrate knowledge of enzymes in a laboratory quiz.

>Briefly answer the following questions as part of a self evaluation :

What did you contribute to the group effort?

What did the other members of your group contribute?

Why study enzymes?

What did you learn in addition to the content of this lab?

>Create a poster/graphic descriptor demonstrating examples of enzymes in daily life.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

Literature Cited

Denny, C.F., C.A. West and J.F. Logue. in press. Experiences in Biology. Enzymes. Wm. C. Brown Publishers., Dubuque, Iowa.

References

Note: laboratory instructors may substitute other enzymes and substrates depending on available supplies, budget concerns and time constraints. Some suggested references:

Mader, S.S. 1993. Laboratory Manual Biology. Exercise 5, pp.55-62. Wm. C. Brown Publishers., Dubuque, Iowa.

Perry, J. W. and D. Morton. 1992. Laboratory manual for Starr and Taggarts Biology, The Unity and Diversity of Life and Starr's Biology, Concepts and Applications. Exercise 6, pp. 63-73. Wadsworth Publishing Co., Belmont, California.

Wilke O.A. 1993. Exploring Biology Today. Exercise 7, pp. 71-82. Mosby-Yearbook, Inc. St. Louis, Missouri.

Photosynthesis Laboratory

Introduction

Photosynthesis is the process whereby plants capture energy from the sun and convert it into the chemical bond energy of a carbohydrate. During this process carbon dioxide is reduced and oxygen is released. In this exercise we will measure oxygen and starch production as indicators of the rate of photosynthesis.

Prior Knowledge/Skills: Completion of the following laboratory exercises; measurement and graphics, microscope, and enzymes.

Student Objectives

The student will:

>Make concise, useful observations.

>Collect, record and manipulate data.

>Interpret and present data in a meaningful way.

>Make conclusions, predictions and inferences.

>Communicate results both orally and in writing.

>Recognize the basic components of a well designed experiment.

>Understand that the process of photosynthesis is associated with green plants.

>Understand that oxygen is produced and carbon dioxide consumed by the process of photosynthesis.

>Comprehend that to produce food, green plants convert light energy to the chemical bond energy of sugar molecules for later conversion to starch for storage.

>Relate the green color of leaves with the presence of chloroplasts in leaf cells.

>Prepare slides of living plant material (Elodea), gain experience using the microscope, and be able to sketch 4 basic parts of a green plant cell.

>Identify the components of the scientific method used in this exercise.

<u>Student Criteria</u>

The student will:

>Complete the experimental procedure exactly as written.

>Make careful measurements over time and precisely record data.

>Present data in tables and graphs accurately, neatly and clearly.

>Make pertinent predictions based on collected data.

>Identify the controls, experimental units and the variables used in this laboratory.

>Demonstrate an understanding of the process of photosynthesis and its importance to life.

>Describe the role of carbon dioxide and oxygen in photosynthesis.

>Correlate the rate of oxygen production with photosynthetic activity.

>Demonstrate communication skills by clearly explaining, both orally and in writing, the results, significance and applications of the laboratory exercise for the appropriate audience.

<u>Procedure</u>

MATERIALS
2 large test tubes (70ml)
1 % sodium bicarbonate solution
sprig (10 cm) **fresh**, healthy *Elodea*
2 manometer apparatuses
graduated cylinder (100ml)

A. Prepare *Elodea* for testing :

1. Select a sprig of the *Elodea* (10 cm) and determine its volume by submerging the sprig in a graduated cylinder containing 70 ml of water. **Record** the resulting increase in volume which will be used as the volume of the plant.______ ml.

2. Place the *Elodea* sprig in a large test tube and fill the tube with 1% sodium bicarbonate solution. The bicarbonate solution will act as a source of CO_2 for the plant.

3. The manometer apparatus (see drawing) should be affixed to the test tube containing the *Elodea* in such a manner as to exclude any air bubbles from the top. Prepare a second experimental setup (test tube, bicarbonate solution, and manometer) without *Elodea*. This is the control setup and will allow you to monitor changes in volume which are not due to activities involving the plant material. **Note:** An increase in volume will force water outward in the graduated pipette of the manometer.

4. Use the syringes to adjust water volume in the graduated pipettes to the 0.5ml mark on each pipette.

B. Place each manometer apparatus-test tube combination near one end of your lab table and with tape, mark spots at 10 cm., 40 cm., and 70 cm. in a straight line from the manometers.

C. Place a light source at the 70 cm. position, shining directly at the test tubes and allow them to stabilize for 10 minutes.

D. Following the 10 minute stabilization period, reset the water in the graduated pipettes to the starting mark using the attached syringes. Allow the *Elodea* to photosynthesize for an additional 10 minutes. **Record** the gas volume which accumulates by recording the movement (displacement) of water in the pipettes.

E. Move the light source to the 40 cm. position, repeat the rest of steps C & D, and **record** the gas volume which accumulates in each manometer after 10 minutes.

F. Repeat the steps C & D with the light source at the 10 cm. position and **record** the resulting volume of oxygen produced after 10 minutes.

G. Subtract any volume increase in the control setup without *Elodea* from the volume increases recorded in the *Elodea*-containing setup. The resulting volume should represent the amount of oxygen produced by the process of photosynthesis.

H. Plot the data obtained from the experimental procedures on the graph paper using the volume of oxygen (calculated in G.) and the distance from the light source as the variables. If you do not remember how to plot the variables on the graph, refer back to the Measurement & Graphing lab exercise.

GAS VOLUME
DATA

Manometer	20 cm	40 cm	70 cm
Elodea			
No Elodea			
Oxygen produced			

I. Since you recorded the volume of *Elodea* at the beginning of this exercise (Part A. 1), and you know how long you ran the experiment, you can now calculate the rate of oxygen production in milliliters of oxygen produced by each milliliter of plant per hour. ____________________
Why might it be useful to know this?

DEMONSTRATION

Your instructor will have prepared the following demonstration for you to observe. Several pieces of fresh, healthy *Elodea* have been placed inside the bowl of an inverted funnel in a large beaker filled with 1% sodium bicarbonate. The sodium bicarbonate solution furnishes the plant with carbon dioxide and the *Elodea* continues to photosynthesize. Gas produced by photosynthesis is being trapped and collected inside a test tube which has been placed over the stem of the funnel.

What gas is probably accumulating in the test tube? ______
If a glowing wood splint is rapidly placed into the test tube what will happen?

Assessments

The student may be required to:

>Write a short (one or two paragraph) critique on the portion of this exercise dealing with the effect of light intensity on the volume of oxygen produced by an Elodea sprig. The critique should focus on controls. What were the controls? Suggest variables which might be better controlled.

>State how farmers measure photosynthesis.

>Prepare or suggest how to prepare a demonstration that would convey the process of photosynthesis to a typical fifth grade class.

>Prepare a general outline (using traditional format) of what would be included in a laboratory report on this exercise.

>Describe the parts of this exercise which contributed most and least to understanding photosynthesis. Explain why.

>Draw a diagram showing the relationship between starch and chlorophyll distribution in a green leaf.

>Sketch and label the four parts of a green plant cell visible with a light microscope.

>Sketch accurate graphs using the data collected in this exercise.

>Describe how this experiment fulfills the laboratory educational goal of using the scientific method.

>Develop a graphic descriptor (visual representation) that demonstrates the relationship between O_2 release and CO_2 uptake in the process of photosynthesis.

>Speculate whether more oxygen is released during daylight or darkness. Explain your reasoning.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

Cellular Respiration Laboratory

Introduction

Respiration is considered by the layperson to be breathing. At the cellular level, however, respiration is the chemical reactions which result in the use of oxygen and the release of carbon dioxide. To study some aspects of cellular respiration, in this exercise we will measure oxygen uptake and carbon dioxide release by living animals.

Prior Knowledge/Skills

Completion of the Measurement and Graphics and the Enzyme laboratories.

Student Objectives

The student will:

>Make concise, useful observations.

>Collect, record and manipulate data.

>Present and interpret data in a meaningful way.

>Make conclusions, predictions and inferences.

>Communicate results both orally and in writing.

>Be able to work productively in a small group with each member actively involved.

>Recognize the basic components of a well designed experiment.

>Understand the essential role of oxygen in aerobic cellular respiration.

>Understand that both plants and animals exhibit aerobic cellular respiration.

>Comprehend that cellular respiration is a basic life process.

>Practice the scientific method of problem solving.

>Handle living organisms following animal care protocol.

Student Criteria

The student will:

>Complete the experimental procedure exactly as written following animal care protocol.

>Make careful measurements over time and precisely record data.

>Present data in tables and graphs accurately, neatly and clearly.

>Make pertinent predictions based on collected data.

>Identify the controls, dependent and independent variables used in this laboratory.

>Demonstrate an understanding of the process of respiration and its importance to life.

>Dscribe the role of oxygen in aerobic cellular respiration.

>Correlate the rate of oxygen use with biological activity.

>Demonstrate communication skills by clearly explaining, both orally and in writing, the results, significance and applications of the laboratory exercise for the appropriate audience.

>Demonstrate effective group skills by identifying your contribution and that of others in the performance of the laboratory exercise.

Procedure

To most students the word, respiration, means breathing. Respiratory system is brought to mind by terms such as lungs, trachea, coughs, and wheezes. These expressions imply that our experience with the human respiratory system relates mostly to movement of air. This movement of air, evidenced by breathing in humans, is directly related to concepts that we will test during this exercise; namely, 1) plants and animals (most of them) use oxygen and give off carbon dioxide and 2) rates at which oxygen is consumed in plants and animals can be measured.

The use of oxygen and the production of carbon dioxide (the gases exchanged during "breathing") are part of a process termed cellular respiration which involves an assembly line-like series of chemical changes. Food (fuel) molecules such as glucose are gradually broken apart and energy liberated by the process is stored in molecules of ATP. A generalized equation for cellular respiration is:

$$C_6H_{12}O_6 + 6O_2 \text{ -------->} 6CO_2 + 6H_2O + 38 \text{ ATP}$$

or one molecule of glucose and six molecules of oxygen will enable the cell to produce 38 molecules of ATP plus the by-products, six molecules of carbon dioxide and six molecules of water.

The energy stored in ATP molecules is readily available to cells and is used for a variety of processes such as muscle contraction, maintenance of body temperature, manufacture of chemicals, active transport of materials across cell membranes, bioelectricity (electric eels) and bioluminescence (lightning bugs).

Crickets and various plant materials will be used as test subjects in this exercise. The respiratory system of crickets (insects) is termed a tracheal system and is composed of a branching network of tubes which deliver oxygen from the external environment to the individual's body cells. In insects, therefore, blood (hemolymph) is not needed for transportation of oxygen and carbon dioxide. Observe the rhythmic pulsation of a cricket's body as it moves air (therefore oxygen and carbon dioxide) in and out of the tracheal system.

Emphasis on the process of photosynthesis often results in confusion about respiration in plant materials and students are often unclear as to whether respiration occurs in green plant cells. Respiration occurs in all living cells with certain plant cells exhibiting both respiration and photosynthesis. The resulting gases diffuse through membranes, cell walls and often special plant structures. In the leaf, for example, openings (stomata) which are usually concentrated on the lower surface facilitate gas movement into and out of the leaf.

METHODS AND MATERIALS:

crickets	germinating bean seed
plastic straw	paper toweling
KOH in dropper bottle	respirometer (vial, rubber stopper,
test tube	capillary tubing)
5% barium hydroxide	balance

I. Carbon dioxide production in plants and animals

Barium or calcium hydroxide will react with carbon dioxide (CO_2) to form an insoluble white precipitate (barium or calcium carbonate). Obtain a straw and a test tube containing 5% barium hydroxide. Exhale normally (but slowly) through the straw and into the solution eight times. This represents the amount of CO_2 exhaled by the average human (at rest) per one-half minute.

What do you observe? ______________________________

With a bulb syringe bubble air through a fresh solution of 5% barium hydroxide for one half minute. Compare the amount of white precipitate with that formed by the exhaled air.

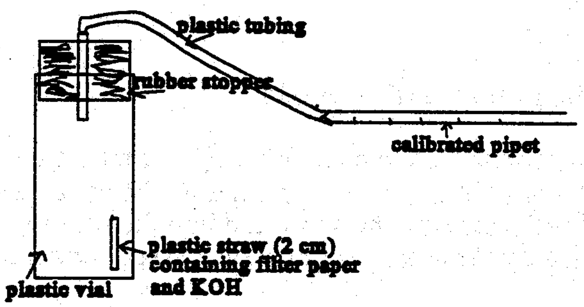
What would you conclude? ______________________________

Potato slices will be used to demonstrate that plant materials also give off CO_2. Sketch the apparatus that allows your instructor to force the air from the container of potato slices through the barium hydroxide solution.

What was the result of bubbling the air exposed to the potato slices through the barium hydroxide?

II. Oxygen Consumption in Crickets

A. Construction of a respirometer



You will use a respirometer (sketched above) to measure oxygen consumption in plants and animals. Plant material or animals is/are placed in the plastic vial which is then sealed with a tightly fitting rubber stopper. A hole in the rubber stopper is fitted with plastic tubing and the tubing, in turn, fitted to a calibrated pipette. By placing a drop of water in the pipette you may directly measure changes in the volume of gas contained in the system. Decreases in gas volume will cause the drop to move toward the vial while increases will result in the drop moving away from the vial and toward the open end of the pipette.

You will use the respirometer to measure the amount of oxygen consumed by plant and animal materials. In order to measure a decrease in gas volume due to oxygen consumption, we must prevent the addition of carbon dioxide to the system. Carbon dioxide can be absorbed by adding several drops of 20% potassium hydroxide (KOH) to filter paper isolated in a section of plastic straw. Be careful, KOH will injure plant and animal tissues. If the filter paper is oversaturated absorb the excess with paper toweling. <u>If you get KOH on yourself wash immediately and extensively with water</u>.

Once you have added respiring material to the vial, sealed it with the rubber stopper and added a drop of water to the open end of the pipette, it is essential that you check to determine whether the respirometer is airtight. The check is accomplished by placing your hand on the vial. The volume of the gas should increase due to the heat of your hand and the water drop should be forced from the pipette. If your respirometer does not seal request help from the instructor.

1. Weigh the plastic vial (with KOH in straw) and record the weight. ________grams

2. Place 5 crickets in vial and record the total weight. ________grams

3. Determine the weight of crickets. Record here and in table 1.

trial 1 ___gm trial 2 ___gm trial 3 ___gm

4. Assemble the respirometer and allow it to equilibrate 10 minutes (remember what the heat from your hand does to gas volumes).

5. Introduce a drop of water into the end of the pipette with a dropper.

6. Record the time required for the drop to move a distance of 0.2 ml. This is essentially the time required for the crickets to consume 0.2 ml of oxygen.

trial 1 ___ trial 2 ___ trial 3 ___

7. Use the weight of the crickets to determine ml of oxygen consumed per gram of body weight.

trial 1 ___ trial 2 ___ trial 3 ___

8. Calculate ml of oxygen consumed per gram of body weight per hour (this is the respiratory rate in the standard form by which oxygen consumption is usually recorded).

trial 1 ___ trial 2 ___ trial 3 ___

9. Remove the drop of water from the pipette and repeat steps 1-8 (above) for two additional trials. Use new crickets each time. The results will be used to determine the accuracy of your procedure.

10. Record your data in table 1.

Table 1 - Oxygen Consumption in Crickets

trial #	wgt. of 5 crickets	ml of O_2 consumed	ml of O_2 consumed per gram	time (min.) to consume 0.2 ml O_2	ml of O_2 consumed gram/hr
1	___	0.2ml	___	___	___
2	___	0.2ml	___	___	___
3	___	0.2ml	___	___	___
				Average	_____

III. Oxygen Consumption in Germinating Beans

To measure oxygen consumption in plant materials, obtain 15 germinating bean seeds from the lab instructor. Weigh them and record their weight in table 2. The seeds have been germinating in the dark and should be exhibiting cellular respiration. Photosynthesis should not occur because the green pigment, chlorophyll, necessary for the process will not develop in the absence of light. Moisten the bean seeds, then place them in the vial and repeat the procedure used to determine the respiratory rate of the crickets. Note precisely the time it takes the beans to consume 0.2 ml of oxygen. Repeat the process twice (each time use new seeds). Use the weight of bean seeds to calculate the rate of respiration (ml of O_2 used per gram/hour). Enter your results and calculations in table 2.

Table 2 - Oxygen Consumption in Germinating Bean Seeds

trial #	wgt. of 15 bean seeds	ml of O_2 consumed	ml of O_2 consumed per gram	time (min.) to consume 0.2 ml O_2	ml of O_2 consumed gram/hr
1	___	0.2ml	___	___	___
2	___	0.2ml	___	___	___
3	___	0.2ml	___	___	___
				Average	_____

IV. Comparative Rates of Respiration.

Which, crickets or beans, exhibited the higher rate of respiration? ____________________

What was your original hypothesis?

____

Discuss your conclusions.

Assessments

The student may be required to:

>Correlate the sandwich eaten for lunch with oxygen consumption.

>Design another method which could be used to detect and measure cellular respiration.

>Describe why someone in medicine and/or health promotion would recommend "aerobic exercise."

>Describe how this experiment fulfills the laboratory educational goal of using the scientific method.

>Identify and comment on the use of controls in this experiment.

>Develop a graphic descriptor (visual representation) that demonstrates the relationship between O2 use and CO2 release to the process of aerobic respiration.

>State how the experiments that were completed in this laboratory exercise relate to the fact that aerobic exercise elevates heart rate and increases the rate of breathing.

>Describe a way to measure the rate of respiration in green leaves considering that green leaves exhibit both photosynthesis and respiration. Note that the gas produced by one process is used by the other.

>State what hypothesis is being tested by the experimental measurement of oxygen consumption by crickets.

>Speculate whether more oxygen is used while sleeping or while awake. Explain your reasoning.

>Demonstrate the correct handling of living organisms following animal care protocol.

>State the contribution of each member of the group.

Feedback

Written assignments and quizzes will be graded and returned. Oral responses will be evaluated on the basis of participation/content. Feedback on group work and proper laboratory procedure along with feedback on oral responses will periodically be provided through short written critiques.

Appendix

Not all of the objectives below are contained in the preceding modules; rather they are intended for a complete introductory course in biology.

Biology 110 Course Objectives

>Students will use the scientific method of inquiry and problem solving and become familiar with library resources/information systems and data collection.

>Students will explain biological processes at the molecular, cellular, system, organismal, population and ecosystem levels of organization.

>Student will demonstrate an awareness of emergent properties of life which are associated with increasing levels of biological organization and recognize evolutionary connections of various life forms.

>Students will: a) be able to read and interpret data and follow procedures safely; b) write and give oral presentation of results and conclusions to peers and other non-science persons.

>Students will be able to discuss knowledgeably topics involving biology presented in popular literature/media.

>Students will become informed citizens who will be able to apply the knowledge and skills gained in this course to the problems of an increasingly scientific and technological society.

Biology 110 Laboratory Objectives

>The student will use the scientific method in a laboratory situation.

>The student will correctly use scientific laboratory equipment.

>The student will gather and statistically analyze scientific data.

>The student will gain first hand knowledge of the internal structures and systems of representatives of the major animal and plant taxa.

>The student will investigate the structure and physiology of cells.

>The student will observe life at the microscopic level and become familiar with the diagnostic features of certain microorganisms.

>The student will learn about animal and plant phylogenies and how those phylogenies are constructed.

>The student learn about patterns of embryonic development in plants and animals.

>Students will: a) be able to read and interpret data and follow procedures safely; b) write and give oral presentation of results and conclusions to peers and other non-science persons.

Broad Criteria of Abilities

The following are components of the basic abilities/skills covered in the preceding modules.

Communication:

Written - The student demonstrates the ability to do the following:

>Set context (Who you are, topic of paper, why you are writing)

>Synthesize ideas (logical, addresses topic, organized)

>Clarity (concise, accurate, precise, not pompous)

>Use of standard rules accurately (grammar, spelling, punctuation, paragraph, citations)

Oral - The student demonstrates the ability to do the following:

>Set context (Who you are, topic of talk, why you are speaking)

>Synthesize ideas (logical, addresses topic, organized)

>Clarity (concise, accurate, precise, not pompous)

>Use of standard rules accurately (grammar, citations)

>Effective delivery (articulation, volume, mannerisms, pace, variety of voice, fillers, emotion, appearance, follows time line)

>Appropriate use of media

Analysis--The student demonstrates the ability to do the following:

>Observe- use five senses to collect data.

>Infer- come to conclusion about significance of observations.

>Predict- Using observations and inferences to forecast future events.

>Compare/ contrast- examination of similarities and differences with other things.

Problem Solving--The student demonstrates the ability to do the following:

(General Definition - Use information and process to approach new and unique situations in order to solve problems)

>Identify the problem.

>Use the scientific method and/or brainstorming to analyze the problem.

>Provide solution(s) to the problem.

Hints for Effective Teaching

>Minute paper.-- At the end of a lecture ask the students to, in a few sentences, explain some key point of the lecture (the professor specifies the key point).

>Muddiest point.-- At the end of the lecture ask the students to write down which part of the lecture they least understood, or are confused about.

>Focused listing.-- At the beginning of a class ask the students to write down four important points from the previous lecture. (Consider making this anonymous so that the students do not feel threatened).

>On exams, have the students indicate to you, among the questions on the test, which two the students most expected and which two the students least expected.

>Have the students self-assess their preparation for a lecture, laboratory etc., frequently.

>Give frequent unannounced quizzes as a tool to enforce attendance, punctuality, and preparation for class.

>Directed paraphrase.-- Have the students paraphrase an important definition or concept (e.g. photosynthesis).

>Study log.-- Student keeps a written record of study time and techniques for a specified amount of time and turns in for extra credit.