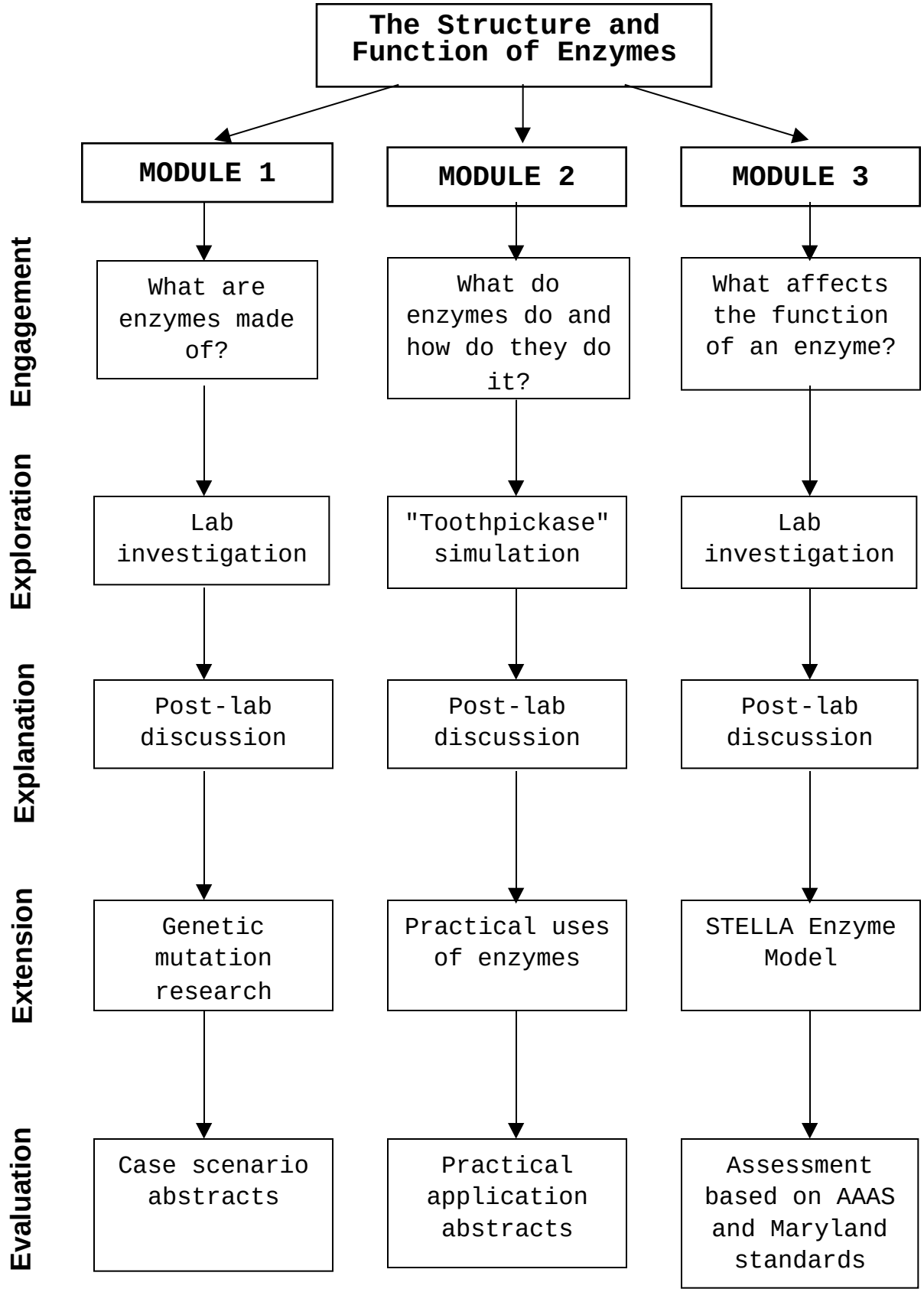
The Structure and Function of Enzymes
MODULE 1
MODULE 2
MODULE 3
Engagement
What are enzymes made of?
What do enzymes do and how do they do it?
What affects the function of an enzyme?
Exploration
Lab investigation
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Lab investigation
Explanation
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Post-lab discussion
Post-lab discussion
Extension
Genetic mutation research
Practical uses of enzymes
STELLA Enzyme Model
Evaluation
Case scenario abstracts
Practical application abstracts
Assessment based on AAAS and Maryland standards

The Structure and Function of Enzymes

Title of unit: The Structure and Function of Enzymes

Unit goal: Students develop an understanding of the importance of enzymes to their survival and in their daily lives.

Grade Level: 9 – 12

General Subject Area: Biology

Minimum time required for the unit: Eight 45-minute class periods

Concepts learned across all unit modules:
- Basic enzyme structure and function
- Experimental design
- Data organization
- Data analysis

Standards addressed by unit modules
Maryland State Department of Education High School Science Core Learning Goals (see www.mdk12.org)

Goal/Expectation	Indicator/Assessment Limit
Goal 1	**The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.**
1.2	**The student will pose scientific questions and suggest experimental approaches to provide answers to questions.**
	1.2.7 *The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.*
1.3	**The student will carry out scientific investigations effectively and employ the instruments, systems of measurement, and materials of science appropriately.**
	1.3.1 *The student will develop and demonstrate skills in using lab and field equipment to perform investigative techniques.*
	1.3.2 *The student will recognize safe laboratory procedures.*
	1.3.3 *The student will demonstrate safe handling of the chemicals and materials of science.*
1.4	**The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.**
	1.4.1 *The student will organize data appropriately using techniques such as tables, graphs, and webs. (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title)*
	1.4.2 *The student will analyze data to make predictions, decisions, or draw conclusions.*

	1.4.6 *The student will describe trends revealed by data.*
	1.4.8 *The student will use models and computer simulations to extend his/her understanding of scientific concepts.*
	1.4.9 *The student will use analyzed data to confirm, modify, or reject an hypothesis.*
1.5	**The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.**
	1.5.1 *The student will demonstrate the ability to summarize data.*
	1.5.2 *The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.*
	1.5.3 *The student will use computers to produce the visual materials (tables, graphs) that will be used for communicating results.*
	1.5.5 *The student will use computers to produce tables, graphs, and spreadsheet calculations.*
1.6	**The student will use mathematical processes.**
	1.6.1 *The student will use ratio and proportion in appropriate situations to solve problems.*
	1.6.2 *The student will use computers to perform calculations for tables and graphs.*
	1.6.3 *The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.*
1.7	**The student will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology.**
	1.7.4 *The student will recognize mathematics as an integral part of the scientific process.*

Goal 3	**The student will demonstrate the ability to use the scientific skills and process and major biological concepts to explain the uniqueness and interdependence of living organisms, their interactions with the environment, and the continuation of life on earth.**
3.1	**The student will be able to explain the correlation between the structure and function of biologically important molecules and their relationship to cell processes.**
	3.1.1 *The student will be able to describe the unique characteristics of chemical compounds and macromolecules utilized by living systems. [structural and functional role of enzymes]*
	3.1.2 *The student will be able to discuss factors involved in the regulation of chemical activity as part of a homeostatic mechanism [enzyme regulation: effect of temperature on enzyme activity]*
3.2	**The student will demonstrate an understanding that all organisms are composed of cells which can function independently or as part of multicellular organisms.**
	3.2.2 *The student will conclude that cells exist within a narrow range of environmental conditions and changes to that environment, either naturally occurring or induced, may cause death of the cell or organism. (pH)*
3.3	**The student will analyze how traits are inherited and passed on from one generation to another**
	3..3.4 *The student will interpret how the effect of gene alteration through natural or technological advances may have beneficial or harmful effects on the individual, society, and/or environment [mutations]*

Technology needed in unit modules

STELLA software, Inspiration software, and Internet access are needed. Graphing calculators and CBL probes can supplement some of the activities.

Technology-enhanced instructional strategies employed

Students participate in telecollaboration and telecommunication to review their work and receive prompt feedback on their work. Inspiration is used to access prior knowledge during engagement activities and organize information during the explanation phases of instruction. STELLA computer software exposes students to systems dynamics thinking and computer modeling.

Title of Each Module:

Module 1: What Are Enzymes Made Of?
Module 2: What Do Enzymes Do and How Do They Do It?
Module 3: What Affects the Function of An Enzyme?

Unit Culminating Activity:

Enzymes are usually studied as part of a larger unit, biochemistry. The unit culminating activity should be the integration of application or higher order questions on the biochemistry test or project.

Unit Author: George L. Morse

MODULE #1

Module Title: What Are Enzymes Made Of?

Estimated time to complete: 90 minutes

Module objectives:
- Distinguish between an experimental control and a variable.
- Distinguish between an observation and an inference.
- Identify the characteristics of an enzyme.
- Identify the general relationship between genes and proteins/enzymes.

Concepts learned in this module:
- Students develop an understanding of qualitative testing.
- Students construct a conceptual understanding of protein structure.
- Students develop an understanding of the interrelationships among organic molecules.

Standards addressed in this module:
Maryland State Department of Education High School Science Core Learning Goals

Goal/Expectation	Indicator/Assessment Limit
Goal 1	**The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.**
1.4	**The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.**
	1.4.1 *The student will organize data appropriately using techniques such as tables, graphs, and webs.*
	1.4.2 *The student will analyze data to make predictions, decisions, or draw conclusions.*
1.5	**The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.**
	1.5.1 *The student will demonstrate the ability to summarize data*
Goal 3	**The student will demonstrate the ability to use the scientific skills and process and major biological concepts to explain the uniqueness and interdependence of living organisms, their interactions with the environment, and the continuation of life on earth.**
3.1	**The student will be able to explain the correlation between the structure and function of biologically important molecules and their relationship to cell processes.**
	3.1.1 *The student will be able to describe the unique characteristics of chemical compounds and macromolecules utilized by living systems. [structural and functional role of enzymes]*
	3.1.2 *The student will be able to discuss factors involved in the regulation of chemical activity as part of a homeostatic mechanism [enzyme regulation: effect of temperature on enzyme activity]*

Standards (continued)

3.3	**The student will analyze how traits are inherited and passed on from one generation to another.**
	3.3.4 *The student will interpret how the effect of gene alteration through natural or technological advances may have beneficial or harmful effects on the individual, society, and/or environment [mutations]*

Technology-enhanced instructional strategies utilized in this module: Web-based research, telecommunication, and Inspiration software (brainstorming) are used in this activity.

MODULE OVERVIEW

Components	Brief description of module activities	Student Grouping	Materials/ Technology
Engagement	Brief brainstorming session to assess and access student prior knowledge.	Whole class	Inspiration software
Exploration	Lab investigation involving gelatin, fresh pineapple, cooked pineapple, and meat tenderizer	Small group	
Explanation	Post lab	Whole class	Inspiration software
Extension/ Elaboration	Problem-based learning utilizing web-based research	Individual	WWW
Evaluation	Lab questions, product of the web-based research, and/or Blackboard quiz	Individual	Blackboard

Expected module outcomes: The student will:
- Construct a basis for distinguishing controls from variables in an experiment;
- Distinguish between what is observed and what is inferred from those observations, noting that different inferences can be logically made from the same observations;
- Identify the effect that cooking foods has on the proteins contained in those foods;
- Begin to construct a basis for understanding molecular biology.

Performance-based assessment of module outcomes:
- Students use data collected during laboratory observations to make inferences about enzymes.
- Students demonstrate an awareness of the importance of enzymes and proteins to their health by researching and writing abstracts based on case scenarios.

MODULE #2

Module Title: What Do Enzymes Do and How Do They Do It?

Estimated time to complete: Two 45-minute class periods

Module objectives:
Upon successful completion of this module the student shall:
- Identify the components of an enzyme.
- Identify factors that affect the rate of enzymatic activity.
- Define activation energy, active site, enzyme, catalyst, and substrate.
- Identify the commercial, medical, and research values of enzymes

Concepts learned in this module:
- Basic enzyme structure and function
- The importance of enzymes to society

Standards addressed in this module:
Maryland State Department of Education High School Science Core Learning Goals

Goal/Expectation	Indicator/Assessment Limit
Goal 1	**The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.**
1.4	**The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.**
	1.4.1 *The student will organize data appropriately using techniques such as tables, graphs, and webs. (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title)*
	1.4.2 *The student will analyze data to make predictions, decisions, or draw conclusions.*
	1.4.6 *The student will describe trends revealed by data.*
1.5	**The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.**
	1.5.1 *The student will demonstrate the ability to summarize data (measurements/observations).*
Goal 3	**The student will demonstrate the ability to use the scientific skills and process and major biological concepts to explain the uniqueness and interdependence of living organisms, their interactions with the environment, and the continuation of life on earth.**
3.1	**The student will be able to explain the correlation between the structure and function of biologically important molecules and their relationship to cell processes.**
	3.1.1 *The student will be able to describe the unique characteristics of chemical compounds and macromolecules utilized by living systems. (structural and functional role of enzymes)*

Technology-enhanced instructional strategies utilized in this module: Students participate in telecollaboration and telecommunication through the use of Blackboard; Internet search engines are employed.

MODULE OVERVIEW

Components	Brief description of module activities	Student Grouping	Materials/ Technology
Engagement	Students participate in a "silent" demonstration" of catalysis.	Individual	Blackboard Threaded Discussion
Exploration	Students perform the "Toothpickase" activity to simulate enzyme action.	Pairs	Toothpicks
Explanation	Post-lab discussion	Class	Blackboard
Extension/ Elaboration	WWW research is performed to answer three problems.	Individual or small group	www/electronic media, Blackboard Discussion Thread
Evaluation	The product of the web-based search can be used for evaluation. Laboratory-based questions can also be used. It should be noted that informal evaluation occurs during each component of the module.	Individual	Blackboard Quiz

Expected module outcomes: Students will use appropriate scientific terms to describe the functions of an enzyme, such as substrate, product, activation energy, and enzyme-substrate complex.

Performance-based assessment of module outcomes:
Students write abstracts to identify the practical applications associated with enzymes. A student-designed or teacher-designed rubric can be used to evaluate the abstracts.

MODULE #3

Module Title: What Affects the Function of an Enzyme?

Estimated time to complete: Four class periods (180 minutes)

Module objectives: Upon successful completion of this module, the student shall:
- State that the shape of an enzyme is important to its function.
- Recognize that cells exist within a narrow range of environment conditions, such as pH and temperature, and changes may cause death of the cell or organism.
- State the effect of pH on the function of catalase.
- State the function of catalase in the decomposition of hydrogen peroxide.
- Identify the reactants and products of the reaction in which hydrogen peroxide is decomposed.
- Use STELLA computer software to generate models of enzyme behaviors.

Concepts learned in this module:
- Students learn that enzyme behavior is affected by numerous environmental factors.
- Students learn that enzyme behavior can be predicted using computer models.

Standards addressed in this module:

Maryland State Department of Education High School Science Core Learning Goals

Goal/Expectation	Indicator/Assessment Limit
Goal 1	**The student will demonstrate ways of thinking and acting inherent in the practice of science. The student will use the language and instruments of science to collect, organize, interpret, calculate, and communicate information.**
1.2	**The student will pose scientific questions and suggest experimental approaches to provide answers to questions.**
	1.2.7 *The student will use relationships discovered in the lab to explain phenomena observed outside the laboratory.*
1.3	**The student will carry out scientific investigations effectively and employ the instruments, systems of measurement, and materials of science appropriately.**
	1.3.1 *The student will develop and demonstrate skills in using lab and field equipment to perform investigative techniques.*
	1.3.2 *The student will recognize safe laboratory procedures.*
	1.3.3 *The student will demonstrate safe handling of the chemicals and materials of science.*

1.4	**The student will demonstrate that data analysis is a vital aspect of the process of scientific inquiry and communication.**
	1.4.1 *The student will organize data appropriately using techniques such as tables, graphs, and webs. (for graphs: axes labeled with appropriate quantities, appropriate units on axes, axes labeled with appropriate intervals, independent and dependent variables on correct axes, appropriate title)*
	1.4.2 *The student will analyze data to make predictions, decisions, or draw conclusions.*
	1.4.6 *The student will describe trends revealed by data.*
	1.4.8 *The student will use models and computer simulations to extend his/her understanding of scientific concepts.*
	1.4.9 *The student will use analyzed data to confirm, modify, or reject an hypothesis.*
1.5	**The student will use appropriate methods for communicating in writing and orally the processes and results of scientific investigation.**
	1.5.1 *The student will demonstrate the ability to summarize data (measurements/observations).*
	1.5.2 *The student will explain scientific concepts and processes through drawing, writing, and/or oral communication.*
	1.5.3 *The student will use computers to produce the visual materials (tables, graphs) that will be used for communicating results.*
	1.5.5 *The student will use computers to produce tables, graphs, and spreadsheet calculations.*
1.6	**The student will use mathematical processes.**
	1.6.1 *The student will use ratio and proportion in appropriate situations to solve problems.*
	1.6.2 *The student will use computers to perform calculations for tables and graphs.*
	1.6.3 *The student will express and/or compare small and large quantities using scientific notation and relative order of magnitude.*
1.7	**The student will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology.**
	1.7.4 *The student will recognize mathematics as an integral part of the scientific process.*

Goal 3	**The student will demonstrate the ability to use the scientific skills and process and major biological concepts to explain the uniqueness and interdependence of living organisms, their interactions with the environment, and the continuation of life on earth.**
3.1	**The student will be able to explain the correlation between the structure and function of biologically important molecules and their relationship to cell processes.**
	3.1.1 *The student will be able to describe the unique characteristics of chemical compounds and macromolecules utilized by living systems. (structural and functional role of enzymes)*
	3.1.2 *The student will be able to discuss factors involved in the regulation of chemical activity as part of a homeostatic mechanism. (pH; effect on living systems)*
3.2	**The student will demonstrate an understanding that all organisms are composed of cells which can function independently or as part of multicellular organisms.**
	3.2.2 *The student will conclude that cells exist within a narrow range of environmental conditions and changes to that environment, either naturally occurring or induced, may cause death of the cell or organism. (pH)*

Technology-enhanced instructional strategies utilized in this module:
Inspiration software can be used to access prior knowledge; a STELLA computer model is used to make predictions and evaluate laboratory results.

MODULE OVERVIEW

Components	Brief description of module activities	Student Grouping	Materials/ Technology
Engagement	Silent demonstration	Class	Inspiration, paper, scissors, stapler
Exploration	Enzyme catalysis activity	Paired	H_2O_2, containers, various commonplace supplies
Explanation	Post laboratory session	Class	
Extension/ Elaboration	STELLA computer model	Individual or pairs	STELLA software, computers, STELLA enzyme model
Evaluation	Laboratory and STELLA problems	Individual	

Expected module outcomes: Students will identify:

- What changes in the environment can affect the survival of an organism
- What changes in the activities of an enzyme may indicate about the environment in which the organism lives

Performance-based assessment of module outcomes:
Students respond to a variety of higher level questions that are based on the MSDE Science Core Learning Goals.

What are Enzymes Made Of?

Module 1 Engagement Activity

This activity assumes some student knowledge of protein and protein structure.

Use Inspiration software to brainstorm what the students already know about enzymes. This accesses their prior knowledge and can be useful in guiding the post lab discussion (explanation phase of the lesson). A chalkboard or overhead projector can be used to list terms/ideas if Inspiration is not available.

The engagement activity begins with a teacher-generated question.

Question

What effect does cooking food have on the nutrients in the food?

Sample student responses

- The food changes color.
- The texture of the food changes.
- The nutrients in the food are changed.
- Harmful organisms that are in some foods are destroyed.

Lead-in to laboratory investigation

The lead-in to the laboratory investigation begins with another question posed by the teacher.

Question

How can you determine the effects that cooking has on a food?

This provides an opportunity to discuss scientific method and experimental design prior to the exploration phase of the lesson. It also allows the teacher an opportunity to distinguish between inferences and observations.

Closure

Closure is not achieved as this activity leads to the laboratory investigation. Closure is achieved during the post lab (explanation phase) session.

Should You Put Fresh or Canned Pineapple in Gelatin?

Module 1 Exploration Activity

Adapted by George Morse from an activity created by Leslie Greenberg, Einstein High School

Background

The pineapple, *Ananas comosus*, belongs to the bromeliad family. Pineapple fruit contains the protein-degrading enzyme bromelain. Unlike fresh pineapple, canned pineapple is heated to very high temperatures during the canning process in order to kill bacteria.

Problem

Does gelatin contain protein?

Hypothesis

If gelatin contains protein, then treatment with a protein-degrading enzyme should alter the gelatin.

Procedure

- Examine the plain gelatin and record your observations in the table below.
- Take a small sample of plain gelatin in a petri dish.
- Liberally sprinkle meat tenderizer on the gelatin sample and let it sit for five minutes. Continue to the next step of the procedure.
- Examine the gelatin made with fresh pineapple and the gelatin made with canned pineapple. Record your observations in the table below.
- Examine the gelatin sprinkled with meat tenderizer and record your observations in the table below.

Data

Table 1: Observations recorded during the experiment.

Type of Gelatin	Observations
Plain Gelatin (Gelatin + Water)	
Plain Gelatin + Fresh Pineapple	
Plain Gelatin + Canned Pineapple	
Plain Gelatin + Meat Tenderizer	

Questions

1. Does pineapple contain an enzyme that digests protein? Support your answer with observations made during the laboratory investigation.

2. How do your observations of gelatin + fresh pineapple differ from your observations of gelatin + cooked pineapple? Explain why they differ.

3. What can you *infer* about the ingredients in meat tenderizer?

What are Enzymes Made Of?

Module 1 Explanation Activity

The post-lab activity is the explanation phase of the module.

Go over the questions that were posed in the exploration activity (*Should You Put Fresh or Canned Pineapple in Gelatin?*). This is a good time to distinguish between inferences and observations. The concept of qualitative testing should be identified – if a change occurs, it is a positive test result. If not, it is a negative result. Students frequently hear about this type of testing (he tested positive for strep throat, for example) but do not have a practical understanding of what it means.

Question 1

Does pineapple contain an enzyme that digests protein? **Yes [Note: Some students may state that the enzyme is only in fresh pineapple.]**

Support your answer with observations made during the laboratory investigation. **The plain gelatin that had fresh pineapple in it did not solidify. The plain gelatin (without pineapple) did solidify. [This is a good time to identify the control & variable treatments in a lab activity.]**

Question 2

How do your observations of gelatin + fresh pineapple differ from your observations of gelatin + cooked pineapple? **The gelatin + fresh pineapple did not solidify while the gelatin + cooked pineapple did solidify.**

Explain why they differ. **The heat *denatured* the enzyme in the pineapple. [This is a good time to discuss the effects of heat on proteins if it has not been covered before.]**

Question 3

What can you *infer* about the ingredients in meat tenderizer? **Meat tenderizer contains a *protease*. [The *ase* suffix denotes an enzyme; students can be asked to defend their answers based on information obtained in class from the previous answers.]**

Closure

Return to the list of items that were developed by the students during the brainstorming activity. Confirm or reject items that were dealt with by the lab. The explanation activity can be closed with a summary of the structural properties of an enzyme.

What are Enzymes Made Of?

Module 1 Extension Activity

The discovery that enzymes were made of protein was a significant step toward determining where they come from.

We now know that genes determine the enzymes that we possess in our bodies. When an enzyme is not working properly it infers that the gene has been altered or mutated. A mutation in a gene coding for an enzyme almost always impairs or destroys enzyme function (*Audesirk 1999, page 216).*

Here are some scenarios of conditions that result from genes that code for abnormal enzymes or proteins. Select ***one*** of the scenarios and write an abstract that contains the

- name of the condition,
- number of the chromosome that the gene causing the condition is found on, and
- name of the enzyme or protein that causes the condition.

Note: *Some of the scenarios are more difficult to research than others; the teacher may wish to limit the scenarios from which the students can choose.*

Scenario #1
The red blood cells of a person may appear normal until the person exercises or travels to high altitudes. The red blood cells may change shape and block capillaries, causing pain, stroke, or a heart attack. Some believe that this condition provides resistance to malaria. *[The condition is sickle cell anemia. Valine is substituted for glutamic acid as the seventh amino acid of hemoglobin.]*

Scenario #2
This condition prevents a person from breaking down a certain amino acid. The amino acid, phenylalanine, is converted to other chemicals that accumulate in the bloodstream. These abnormal substances are harmful to infants because they interfere with the development of brain cells. Infants with this disorder suffer severe mental retardation and rarely live more than thirty years. When detected early enough, individuals with this condition can be given special diets and develop and mature normally. The condition is not usually harmful to adults (*Raven & Johnson 1992, page 270).*
[The disorder is Phenylketonuria. A defective form of the enzyme phenylalanine hydroxylase is produced.]

Scenario #3
This incurable human disease causes a slow, progressive deterioration of the brain. It results in the loss of motor coordination, flailing movements, personality disturbances, and eventual death. The symptoms typically do not appear until 30 to 50 years of age *(Audesirk 1999). [The condition is called Huntington's disease. It is on chromosome 4; the gene's product is a protein dubbed "huntingtin".]*

Scenario #4
Some people cannot manufacture all of the molecules needed for blood to clot properly. This means that they bleed excessively from the slightest wound. There are "clotting

factors" that can be given to a person with this condition. *[The condition is hemophilia. It is found on the X chromosome.]*

Scenario #5
This condition is not considered to be life threatening but it may prevent you from being a boat captain. It is one of the reasons that stoplights are standardized – that is, the color of the lights always appear in the same order. *[The condition is red-green color blindness. It is carried on the X chromosome.]*

Scenario #6
This life-threatening disease causes individuals to secrete thick mucus that clogs the airways of their lungs and the passages of their pancreas and liver *(Raven & Johnson, 1992). [The disorder is called cystic fibrosis.]*

Scenario #7
There is deterioration of the central nervous system in infancy. There is also a "late onset" form of this condition that occurs between adolescence and the mid-30's. In either case, fat (lipid) accumulates in nerve cells and affects the functioning of the nervous system. *[The disorder is Tay-Sachs disease. Individuals produce a defective form of the enzyme hexosaminidase A. The gene is located on chromosome 15.]*

Scenario #8
There is a wasting away of muscles. *[The condition is Duchenne's muscular dystrophy.]*

Scenario #9
There are excessive cholesterol levels in the blood, leading to heart disease. *[This is hypercholesterolemia and causes an abnormal form of cholesterol cell-surface receptor.]*

What do Enzymes Do and How Do They Do It?

Module 2 Engagement Activity

Silent Demonstration of Catalysis

Materials required: two test tubes, test tube rack, wooden splints, matches, manganese dioxide, 3% hydrogen peroxide, weighing scale, and filtering apparatus (funnel, funnel stand, filter paper, and waste beaker).

Teacher Activity	Student activity
The teacher announces that a ***silent demonstration*** is about to take place. Students may neither ask questions of the teacher nor talk to one another once the demonstration begins. Students should move to where they can see the demonstration and record their observations as the demonstration takes place.	Move to where you can see; get materials out so that a record of the demonstration can be made. Students log on to Blackboard.com and enter the discussion thread.
The teacher simulates the weighing of a piece of filter paper. A ***very*** small amount of manganese dioxide (MnO_2) is then placed on the filter paper and weighed. The masses are written on the chalkboard. The molecular formula for MnO_2 is written on the board. The MnO_2 is placed in a test tube.	Students record masses. Students record the molecular formula for manganese dioxide.
The teacher pours hydrogen peroxide (H_2O_2) into a second test tube, filling the tube about a third of the way. The teacher points to the tube and writes the molecular formula for hydrogen peroxide on the chalkboard.	Students record the molecular formula for hydrogen peroxide. Students record the approximate amount of liquid in the test tube.
The teacher performs the glowing splint test on each tube (the test is negative – it does not burst into flames).	Observations are recorded
The hydrogen peroxide is added to the MnO_2 (furious bubbling is observed).	Observations are recorded
The glowing splint test is performed on the tube. The splint ignites (this a positive test for the presence of oxygen gas).	Observations are recorded
The teacher pours the solution into the filtering apparatus. The filter paper is weighed. This is simulated in such a way that the mass of MnO_2 remains the same. The mass is written on the chalkboard.	Observations are recorded
End of silent demonstration	
Closure Option 1. This presumes that the students have been exposed to fundamental chemistry.	Write the equation for the reaction that you observed.
Closure Option 2. Students can analyze the demonstration and come to conclusions with minimal teacher direction.	Write an abstract or summary of the demonstration.
Closure Option 3. The teacher directs a class discussion to guide students in making inferences.	Verbal summation

Closure for the Activity

There are three options for the teacher to use in achieving closure of the demonstration. Regardless of the method used, the teacher should present a summary of the concepts. The summary should

- identify the difference between an inference and an observation.
- make a link between a catalyst (inorganic MnO_2) and an enzyme (organic catalyst). This link should introduce terms such as active site, activation energy, and substrate.

Use of Technology

This activity is enhanced for the students and the teacher by employing Blackboard, a free service that teachers can use to create a web-based course (or activity). The benefits of using this service are

- the students and teacher can view the observations made by all members of the class immediately.
- the students get immediate feedback on their work.
- the teacher can quickly direct a discussion to distinguish between observations and inferences using the students' own work.
- the teacher can award points for the activity without collecting papers from students.
- the teacher has a permanent record of student performances on the activity.

Teachers can access Blackboard by going to www.blackboard.com and signing on as an instructor. The service allows the user to create a course. The directions are reasonably intuitive and easy to follow.

Toothpickase Activity

Module 2 Exploration Activity

Adapted by George Morse from an activity created by Peggy O'Neill Skinner, The Bush School
and modified by Barbara Grosz, Pine Crest School

Introduction

You have recently observed a demonstration involving the decomposition of hydrogen peroxide (H_2O_2) using manganese dioxide (MnO_2) as a catalyst for the reaction. Hydrogen peroxide is decomposed into water and oxygen gas. The glowing splint test that was performed helped to identify one of the products as oxygen.

Did you notice that the glowing splint test was negative for the hydrogen peroxide by itself? This shows that hydrogen peroxide did not *spontaneously* decompose.[1] This is because there was not enough energy for the reaction to get started. Manganese dioxide lowered the activation energy[2] needed for the reaction.

Biologists are very interested in *enzymes* – organic catalysts that control many of the reactions that occur in living organisms.

Toothpickase Procedure

You are going to simulate the action of an enzyme by breaking toothpicks during this activity. Hold a toothpick between your thumbs and fingers and break it. Your index fingers and thumbs represent the enzyme and the toothpick represents the *substrate*, the substance that the enzyme works on. The place where the toothpick fits between your fingers represents the *active site* of the enzyme. The active site is where the enzyme and substrate "fit together."

Count out 40 toothpicks and drop them in a pile in front of you. Pick up ***one*** toothpick and break it. Repeat this process as fast as you can for ten seconds. Drop the two broken pieces back onto the pile after you break the toothpick. Record the number of "reactions" that occur during the ten seconds. Record your data in Table 1.

Repeat this procedure for twenty more seconds. One group member counts the number of reactions and records them at ten second intervals. It is important to record the reactions at regular intervals so that they can be easily graphed.

Repeat the procedure for thirty more seconds. Again, one group member records the data at ten-second intervals.

Repeat the procedure for 60 more seconds and record the data.

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[1] Some spontaneous decomposition does occur but the rate of decomposition is very slow. There is not enough oxygen gas being produced to make the glowing split burst into flames. If you leave a bottle of hydrogen peroxide open long enough it will "go flat."

[2] Activation energy is the energy needed to start a chemical reaction.

Table 1: This is a data table for recording the number of reactions in 10-second intervals.

Time (seconds)	Number of Reactions	Time (seconds)	Number of Reactions	Time (seconds)	Number of Reactions
10		50		90	
20		60		100	
30		70		110	
40		80		120	

Figure 1:

Analysis

1. Write an appropriate title in the space next to "Figure 1." Plot a graph of the number of reactions verses time. Draw the curve that best conforms to the data. Label each axis of the graph.

2. Summarize Figure 1. What inferences can you make about enzyme reaction rate?

3. What do you think would happen to the reaction rate if the toothpicks were spread out so that the "enzyme" has to reach for them?

4. What do you think would happen to the reaction rate if the number of toothpicks were doubled? Use a colored pencil to draw a second curve on Figure 1 to describe your prediction.

5. What do you think would happen to the reaction rate if two students break toothpicks instead of one?

Toothpickase Post laboratory Session

Module 2 Explanation Activity

Overview

This is a teacher-directed, but student-centered post-lab lesson based on the "Toothpickase" activity. It emphasizes the skills and processes of science.

Procedure

Students complete a data table and two graphs, along with several brief constructed response items at the beginning of the post lab. These items serve as the framework to explain enzyme function. The emphasis should be on their thinking processes as they complete the items and the items are reviewed in class.

In addition to the problems within the lab, students should be asked to identify analogies.

What do the broken toothpicks represent?

Answer The broken toothpicks represent the newly formed products.

Why were the broken toothpicks placed back with the unbroken ones?

Answer The products of the reaction are still in solution. They may interfere with the chances of an enzyme forming an enzyme-substrate complex. This slows down the rate at which the enzyme can work.

Closure

Time should be provided for students to ask questions and provide summaries of what they have learned.

What Do Enzymes Do and How Do They Do It?

Module 2 Extension Activity

The goal of this activity is to show the practical applications of what they have learned so far about enzymes.

Assignment

The student is asked to find uses for enzymes that fit each of the following criteria.

- How are enzymes used in commercial, non-medical applications? That is, there are companies selling enzymes to other companies so that they can make or improve a product that they then sell to consumers. Identify one enzyme and briefly describe its use.
- How are enzymes used to improve general health, treat diseases or otherwise improve the quality of life? Name one enzyme and briefly describe how it is used.
- How are enzymes used in research? There are many enzymes available to scientists that allow them to learn new information about nature. These enzymes are not used to produce a commercial product but to assist pure research. Name one enzyme and briefly describe how it is used.

Procedure

Assign the problem and provide students part of a period (20 minutes or so) to search the web. It should not take long to locate one enzyme in each category. The information is plentiful!

Students can send the results of their research to a discussion thread within Blackboard. They can run this concurrent with their web search and enter the information in as they find it. They should provide the web address in their response (document their work).

What Affects the Function of an Enzyme?

Module 3 Engagement Activity

Silent Demonstration

Directions for the demonstration

Students are instructed to take notes, move to where they can see, and remain silent during the demonstration. The teacher holds up a pair of scissors and a piece of paper so that everyone can see them. The paper is then cut in half. The teacher holds up the two pieces of paper (from the first part of the demonstration) and a stapler. The pieces of paper are then stapled together. The teacher announces that the demonstration is over.

Questions posed to students

The demonstration that you have just seen is an analogy for enzyme action. Name the enzymes, substrates, and products of the demonstration. [The scissors and stapler are enzymes; the whole paper and pieces of paper are substrates for one reaction and products of another reaction] *Note: Inspiration, an overhead, or a chalk board can be used to record the responses. This gives time for students to visualize the answers.*

What types of reactions were observed? [Synthesis and decomposition/hydrolysis; this question may be inappropriate if students are not familiar with the content.]

Other than enzymes and substrates, what was needed for the reactions to occur? [Energy was needed; the teacher supplied this in the demonstration.]

What would alter or prevent the reactions from occurring? [Lack of energy, change in the shape of the enzyme – dull or damaged scissors, no staples in the stapler.] The teacher guides the students to these answers during the summary if they are not established here. Shape-fitting toys can be used to emphasize the importance of shape.

Summary

Energy is necessary for reactions to occur. The amount of energy needed is called the *activation energy.* Enzymes work by lowering the activation energy needed for a reaction. The shape of an enzyme is critical to accomplishing this. If sufficient energy is not available, the reaction does not occur. This is why we refrigerate or freeze foods. Enzymes are made of protein and proteins can be denatured. That is, temperature, pH, salinity, or other environmental factors may change the shape of the molecule.

Teacher note

This leads into *The Effects of pH on the Function of Catalase* laboratory investigation (Exploration Activity).

What Affects the Function of an Enzyme?

Module 3 Exploration Activity

The Effects of pH on the Function of Catalase - Teacher Notes

Advanced Preparation:

1. Each group of students should be instructed to bring in four small clear plastic cups and one potato for the lab. Groups may consist of 2 – 4 students.
2. To save class time, students should slice the potato at home, seal the slices in plastic wrap, and bring them in for the lab.
3. The pH paper (Hydrion or similar universal pH indicator strips) can be cut into 1 cm squares and placed in petri dishes for use by the students (one dish per lab station). The original pH paper container must be available for the students to interpret their results. Keeping empty containers around is useful for this.
4. The 0.1 M NaOH is prepared by placing some water in a 1-liter volumetric flask, adding 4 grams of NaOH, and adding water to bring the volume to 1 liter. Dispense 100 ml aliquots into labeled 250 ml beakers or Erlenmeyer flasks. Students will need 10 – 15 ml of this solution to run the test.

Hints:

1. Students can bring in supplies (vinegar, potato, detergent, and cups) for the lab. This simplifies the distribution of materials and prevents cross contamination of the stock supplies. Students need about 15 ml of vinegar and detergent to run their tests.
2. The 3% hydrogen peroxide can be diluted 1:1 with water to increase the volume with little impact on the results.
3. Liver produces more dramatic results but is messier to use and may not be readily available at home.
4. Potato, cantaloupe, and pear work well for this lab when the students wait a few minutes before they record their results. As long as the slices are small enough, all of these substances sink at first and float to the surface as the reaction develops.
5. You can use 0.1 M HCl instead of vinegar (add 8.3 ml of concentrated HCl to water and bringing the volume to 1 liter).
6. Supplemental information
    - Part of the cell damage (apoptosis) that occurs during the development of a person with Down's Syndrome is due to an elevated hydrogen peroxide level.
    - Hydrogen peroxide is used in the human defense system to kill bacteria, yeasts, and parasites and helps regulate the immune system.
    - Oxidative therapy includes treatments in which a weak hydrogen peroxide solution is injected into a person to elevate the blood oxygen level.
    - Over-the-counter products, such as Oxy-Gen Caps, advertise that they can increase the oxygen levels in the body because they contain magnesium peroxide, which is more stable and easier to use than hydrogen peroxide.
    - The USDA is working on a hydrogen peroxide test to determine if poultry are sufficiently cooked. They are developing a mathematical relationship between catalase activity and heating conditions.

7. Works cited

   - Audesirk, Teresa, and Gerald Audesirk. *Biology: Life on Earth.* Upper Saddle River, N.J: Prentice-Hall, Inc, 1996.
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   - Liu, R., et al. "Total Process Lethality as related to Residual Catalase Activity in Cooked Chicken Breast." ARS Report Number 0000069806 (16 April 1996): 2 pp. On-line. Internet. 16 July 1998. Available WWW: http://www.nal.usda.gov/ttic/tektran/data/000006/98.
   - "Science of Oxidative Therapy." *The International Oxidative Medicine* Association. 2 pp. On-line. Internet. 16 July 1998. Available WWW: http://www.healthy.net/othersites/farr/ioma/science.html.
   - "Life Plus – Oxy-Gen Caps." 3 pp. On-line. Internet. 15 July 1998. Available WWW: http://www.unibio.com/spirit/biways/oxygen.html.

Technology:

· There are a variety of resources available on the Internet for students to research the uses and functions of enzymes.

· The lab activities can be run using a CBL instead of pH paper. The changes in pH during the course of the experiment would allow students to quantify the rate at which catalase is working.

The Effects of pH on the Function of Catalase - Student Worksheet

Introduction: Hydrogen peroxide is a toxic compound produced by living organisms. Under normal conditions these organisms also produce an enzyme that quickly changes hydrogen peroxide into two harmless substances, oxygen and water. However, the function of the enzyme is affected by changes in the environment. Our knowledge of the decomposition of hydrogen peroxide and the function of enzymes is leading to a variety of applications, from treating influenza patients to testing for properly cooked poultry.

Purpose: What is the effect of altering the pH on the function of catalase?

Materials:

potato	pH paper	3% hydrogen peroxide (H_2O_2)
vinegar	permanent marker	0.1 M sodium hydroxide (NaOH)
scalpel	10 ml graduated cylinder	4 disposable cups (9 oz or less)
vinegar	liquid laundry or dishwashing detergent	

Procedure:

1. Cut four cubes of potato approximately 1 cm on each side. Remove the skin from each cube.
2. Cut each cube into four slices.
3. Number small plastic cups 1, 2, 3, and 4 using a permanent marker.
4. Place the four slices of potato into each of the four cups.
5. Cover the potato slices in cup 1 with water.
6. Cover the potato slices in cup 2 with vinegar.
7. Cover the potato slices in cup 3 with 0.1 M NaOH.
8. Cover the potato slices in cup 4 with detergent.
9. Determine the pH of the solution in each cup by holding a piece of pH paper with forceps and dipping it into the liquid. Use a new piece of pH paper for each solution. Record the pH in Table 1.
10. Measure exactly 5 ml of hydrogen peroxide in a graduated cylinder and add it to each container.
11. Observe each container for three minutes before you record your observations in Table 1. You are making qualitative measurements for this activity. Positive (+) indicates that a reaction is observed; negative (-) means that a reaction is not observed.

Observations:

Table 1: Results of a study of the effects of pH on enzyme behavior.

Test performed	**pH**	**Test result (+/-)**	**Additional observations**
Water			
Vinegar			
0.1 M NaOH			
Detergent			

What Affects the Function of an Enzyme?

Module 3 Explanation Activity

The Effects of pH on the Function of Catalase - Student Questions

Analysis:

1. Enzymes are reaction specific. That is, they catalyze a specific chemical reaction. Which lab observations permit you to infer that catalase acted on the hydrogen peroxide and not on the other solutions that were used in the lab?

2. The shape of a protein can be changed by environmental factors such as pH and temperature. Which laboratory observation permits you to infer that catalase contains a protein?

Application of principles

1. Placing 3% hydrogen peroxide on a cut produces bubbles. What causes the bubbles to form in the wound, but not on the surrounding skin?

2. Hydrogen peroxide is an effective antiseptic on inanimate objects but is less effective on a skin wound. Account for this difference.

3. When an apple is cut and left out for awhile, the wound turns brown because of the action of an enzyme found in the apple cells. Applying lemon juice (pH = 3) prevents the apple from turning brown. Use the results of your laboratory investigation and your knowledge of enzymes to account for this.

4. Dr. T.H. Oliver reported the first intravenous use of hydrogen peroxide in 1920. Influenza patients were given hydrogen peroxide treatments with good results. What was accomplished by injecting the patients with hydrogen peroxide?

Conclusions:

1. State the pH range in which catalase can decompose hydrogen peroxide.

2. What environmental factors affect the rate at which an enzyme functions?

3. How does the protein portion of an enzyme affect the behavior of the enzyme?

The Effects of pH on the Function of Catalase - Answer Key

Observations:

Table 1: Results of a study of the effects of pH on enzyme behavior.

Test performed	pH	Test result (+/-)	Additional observations
Water	**7**	+	**Bubbles form around the potato. The slices float to the surface.**
Vinegar	**2- 3**	-	**No reaction occurs.**
0.1 M NaOH	**13**	-	**No reaction occurs.**
Detergent	**10 – 11**	+	**The reaction that occurs is not as vigorous as it is with water.**

Analysis:

1. Enzymes are reaction specific. That is, they catalyze a specific chemical reaction. Which lab observations permit you to infer that catalase acted on the hydrogen peroxide and not on the other solutions that were used in the lab?

Bubbles did not form when the solutions were added. Bubbles formed only after the hydrogen peroxide was added.

2. The shape of a protein and its ability to function can be changed by environmental factors such as pH and temperature. Which laboratory observation permits you to infer that catalase contains a protein?

The tests at the extreme pH values (acetic acid and sodium hydroxide) produced negative results while the other tests were positive.

Application of principles

1. Placing 3% hydrogen peroxide on a cut produces bubbles. What causes the bubbles to form in the wound, but not on the surrounding skin?

The damaged cells around the wound release catalase (or some similar enzyme). The unbroken skin around the wound does not release catalase.

2. Hydrogen peroxide is an effective antiseptic on surfaces but is less effective on a skin wound. Account for this difference.

Since catalase is present at the site of a skin wound, hydrogen peroxide is being decomposed rapidly. Surfaces do not have enzymes and so the hydrogen peroxide lasts longer and can more effectively kill any bacteria in the area.

3. When an apple is cut and left out for awhile, the wound turns brown because of the action of an enzyme found in the apple cells. Applying lemon juice (pH = 3) prevents the apple from turning brown. Use the results of your laboratory investigation and your knowledge of enzymes to account for this.

Enzyme action is affected by the pH of the environment. The result of the acetic acid test shows that a low pH prevents an enzyme from functioning.

4. Dr. T.H. Oliver reported the first intravenous use of hydrogen peroxide in 1920. Influenza patients were given hydrogen peroxide treatments with good results. What was accomplished by injecting the patients with hydrogen peroxide?

Hydrogen peroxide, in the presence of catalase, was rapidly converted to water and oxygen. The oxygen level of the blood increased. Note: the answers to problems 1 and 2 provide evidence for inferring that catalase is present in the blood.

Conclusions:

1. State the pH range in which catalase can decompose hydrogen peroxide.

Catalase decomposes hydrogen peroxide when the pH is between 3 and 13.

2. What environmental factors affect the rate at which an enzyme functions?

Temperature, pH, and salinity affect the rate at which an enzyme functions. The results of this lab demonstrate the effects of pH on the enzyme rate.

3. How does the protein portion of an enzyme affect the behavior of the enzyme?

Proteins have specific shapes that can be altered by environmental factors such as pH and temperature. Altering the shape of the protein also alters the shape of the enzyme, affecting its behavior.

What Affects the Function of an Enzyme?

Module 3 Extension Activity

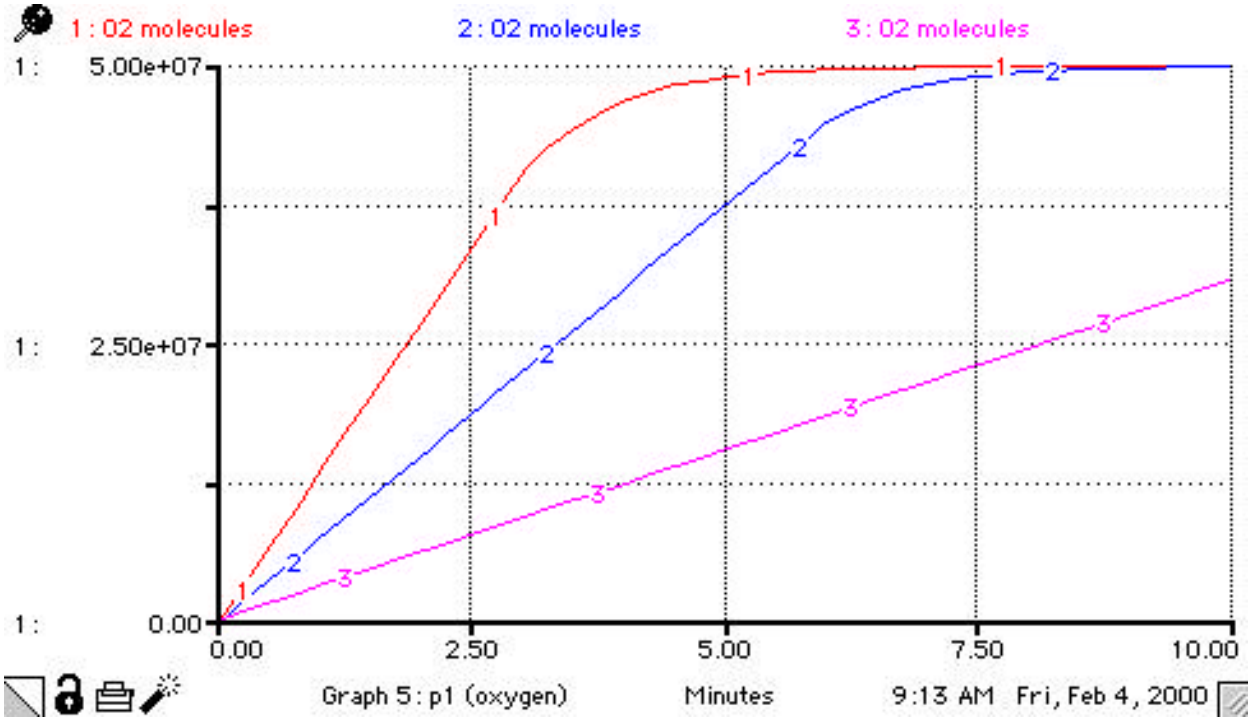
See the Enzyme STELLA model and packet.

What Affects the Function of an Enzyme?

Module 3 Evaluation Activity

1. The curves on the graph below represent the amounts of oxygen created during a reaction between the enzyme catalase and hydrogen peroxide in an experiment conducted under three different conditions.

- Describe and interpret each of the curves with regard to the speed of the reaction being displayed.
- Describe, in general, what is happening in the enzyme reaction. What conditions could account for the varying results as shown by the graph?



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2. Computer models are tools for learning about the things they are meant to resemble. A model's usefulness in understanding a real world situation can be determined by examining the assumptions underlying the model and by comparing its output to actual observations in the real world.

- Determine the usefulness of the enzyme model by describing at least two similarities between the model and science lab or real world outcomes. Give specific details to support your answer.
- Describe at least one limitation of the enzyme model with respect to its ability to replicate real world behavior.

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HSA Rubric for Constructed-Response Items

SCIENCE

LEVEL 4

There is evidence in this response that the student has a full and complete understanding of the question or problem.

- The response reflects a complete synthesis of information.
- Pertinent and complete supporting details demonstrate an integration of ideas.
- The response is enhanced through the use of accurate terminology to explain scientific principles.
- An effective application of the concept to a practical problem or real-world situation reveals an insight into scientific principles. *

LEVEL 3

There is evidence in this response that the student has a good understanding of the question or problem.

- The response reflects some synthesis of information.
- The supporting details are generally complete.
- Mostly accurate terminology is used to explain scientific principles.
- The concept has been applied to a practical problem or real-world situation. *

LEVEL 2

There is evidence in this response that the student has a basic understanding of the question or problem.

- The response provides little or no synthesis of information.
- The supporting details may be incomplete or have minor errors.
- Limited accurate terminology is used to explain scientific principles.
- The application of the concept to a practical problem or real-world situation is inadequate. *

LEVEL 1

There is evidence in this response that the student has some understanding of the question or problem.

- The response addresses the question.
- The supporting details are only minimally effective.
- Little or no accurate terminology is used to explain scientific principles.
- The application, if attempted, is irrelevant. *

LEVEL 0

There is evidence that the student has no understanding of the question or problem.

- The response is completely incorrect or irrelevant.

* On the High School Assessment, the bullet that defines applicaion criteria will be used only when an application is requested in the item stem.