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BIOLOGICAL CHEMISTRY: A FOUR WEEK UNIT FOR ADVANCED BIOLOGY CLASSES

By

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ABSTRACT

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ADVANCED BIOLOGY CLASSES

by

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Today, more and more emphasis is being placed on the chemical, molecular and physical aspects of the biological sciences. For this reason students need to be well grounded in basic chemical and physical concepts, as well as their application to biological systems.

This unit on Biological Chemistry is designed to meet this goal. The unit includes topics on atomic theory, water and pH, organic molecules and thermodynamics. The lab exercises that accompany the unit are designed to illustrate the concepts presented with applications to real-world situations that the students should be familiar with. The lab exercises also introduce the students to some of the analytical procedures used by scientists such as gel electrophoresis and reverse-phase column chromatography.

The lab exercises, together with student worksheets, lectures and outside readings, provide the students with a framework upon which the rest of the Advanced Biology course can be built.

This thesis is dedicated to my wife, Pam,
and to our children, Christopher and Katie.
Thank you for the sacrifices that you made
so that I could accomplish this goal of mine.

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I. Introduction

General Discussion of the Problem

Every year more and more material is added to the science curriculum but the school year is never made any longer. While this growth is true of all subject areas, the extent of the problem is unique to science. Scientific knowledge increases at an exponential rate[1] doubling every ten years. Obviously, not everything can be taught so it is up to the science teacher to determine concepts to include and concepts to exclude from a science course. In addition, science teachers need to prioritize the concepts presented to determine how much time will be spent on each.

The study of biology in high schools can be traced back to the early 1900's.[2] The first courses emphasized zoology, botany and physiology and were modelled after comparable college courses. Today, more emphasis is being placed on the chemical, molecular and physical aspects of the biological sciences. In fact, there is a movement to remove or de-emphasize the boundaries that exist between the science-related subject areas. In 1989, the American Association for the Advancement of Science released a report that stated that the science curriculum in high schools should be changed "to reduce the sheer amount of material covered; to pay more attention to the connection among science, mathematics and technology..."[3] The National Science Teacher's Association also advocated greater coordination between high school science courses and to make science courses less "abstract and theoretical".[4]

This four week unit on biological chemistry is designed to help address these issues. It focuses the students (and teacher) into a very narrow range of objectives and, thus, limits the amount of material to be presented. The unit also gives a definite time-frame for completion. The subject matter clearly cuts across the scientific disciplines and the application of these concepts from these disciplines to biological situations make them less abstract.

There are four major reasons why biological chemistry serves as the basis for this thesis. The first reason is that the concepts presented in the unit clearly cut across the sciences; the application of basic chemical and physical principles to biological systems. The major principles included in this unit are:

1. a review of atomic/molecular structure and bonding
2. the physical and chemical properties of water
3. the physical and chemical properties of acids, bases and buffers
4. the structure and significance to living things of carbohydrates, lipids, proteins and nucleic acids
5. the First and Second Laws of Thermodynamics
6. the structure and function of enzymes

The second reason is that this unit is the first unit taught in many biology courses and is included at the beginning of most biology textbooks. *Understanding Biology* by Peter H. Raven and George B. Johnson[5] reserves Chapter 3 for chemistry and Chapter 7 for the energy concepts. Chapters 2 and 3 of *Biology* by Karen Arms and Pamela S. Camp[6] contains chemistry concepts while Chapter 6 contains the energy and thermodynamics concepts. The chemistry concepts are presented in Chapters 1 through 3 and energy and thermodynamics is presented in Chapter 8 of *Biology* by Helena Curtis and N. Sue Barnes[7]. These three texts are all introductory college texts that are commonly used in Advanced Placement Biology courses in high schools.[8] *Modern Biology*, an introductory high school text by Albert Towle[9], includes chemistry and energy concepts in Chapters 3 and 4. The third reason is that all other units covered in a biology course are built on the framework laid down in this unit. For example, the polarity of molecules is directly responsible for cell membrane structure and the porosity of the membrane to various substances. All the chemical reactions of glycolysis, oxidative phosphorylation and photosynthesis are related to the laws of thermodynamics. The final reason for basing this thesis on biological chemistry is that in the past I have had trouble gauging the amount of time that should be spent on this unit.

As stated before, textbooks include this material in the first chapters but the depth of their presentation of the material varies widely. Table 1 is a summary of the number of paragraphs each of the examined texts spends on each topic area. The topic areas are purposely loosely-defined. This summary does not take into account the length of the various paragraphs, any diagrams or tables included in the section or the difference in the writing styles of the various authors. In spite of this, one can still make generalities about the similarities and differences between the texts.

The most obvious difference among the texts is the total coverage of all the topics. Text A, by far, has the most in-depth coverage with 216 paragraphs; Text D has the least coverage with only 59 paragraphs. Texts B and C have approximately equal coverage with 101 and 113 paragraphs, respectively. Text D is an introductory high school text for ninth and tenth graders so less detail is expected. In texts A and C, enzymes are included along with energy and thermodynamics, while in texts B and D enzymes are included in the discussion of proteins. Only text A goes into any detail on buffers. Text B has one sentence on buffers in a later chapter on gas exchange in animals. Texts C and D do not mention buffers at all. Also, text A is the only text that contains the Gibbs Free-Energy equation and its role in determining whether a reaction will proceed or not. Even though these concepts are central to the study of Biology, no textbook adequately covers these concepts internally. This unit fills in the gaps.

The priority each author gives to each topic can be inferred from the number of paragraphs spent on each topic. In each of the three college texts, the topics of energy/thermodynamics, enzymes and the properties of water are among the most covered. All three texts also allot very little space to discussions of the types of chemical reactions and to nucleic acids. However, all three texts contain a much more complete discussion of nucleic acids in their sections on molecular genetics.

Table 1. Summary of Topic Coverage by Paragraphs in Various Textbooks.

Topic	Text A	Text B	Text C	Text D
Atomic Structure	22	6	8	7
Bonding	18	11	14	10
Types of Chemical Reactions	3	3	0	0
Water and Its Properties	26	14	10	4
Acids, Bases, Buffers and pH	19	5	4	6
Properties of Carbon	4	2	4	3
Functional Groups	7	1	0	0
Carbohydrates	18	6	11	6
Lipids	15	9	8	8
Proteins	20	12	9	4
Enzymes	34	14	17	2
Nucleic Acids	3	5	7	2
Energy and Thermodynamics	30	13	21	7
Totals	216	101	113	59

Text A: *Biology 5th Ed.* by Helena Curtis and N. Sue Barnes
Text B: *Biology 2nd Ed.* by Karen Arms and Pamela S. Camp
Text C: *Understanding Biology* by Peter H. Raven and George B. Johnson
Text D: *Modern Biology* by Albert Towle

There are numerous lab exercises available for these topics in various lab manuals. The lab manual that accompanies *Modern Biology*[11] contains three labs that pertain to this unit. "Investigation 3.1: Acids and Bases" is divided into two sections. The first section tests the pH of ten common household substances using full-range pH paper. The second section compares the buffering ability of water and an egg-white solution using bromothymol blue as an indicator. Drops of acid are added to each solution until the color changes. The initial and final pH of the solutions are measured using full-range pH paper. The teacher's guide for this investigation gives a time-frame of 40 minutes for completion of each section. "Investigation 3.2: Calorimetry" involves burning various food items and measuring the change in the temperature of a water sample suspended over the burning food. The time-frame for completion of this investigation is two 40 minute periods. "Investigation 4: Catalase" is also divided into two sections. Part 1 measures normal catalase (extracted from beef liver) activity quantitatively by rating how fast oxygen bubbles are given off from a hydrogen peroxide solution containing small pieces of liver. The "reusability" of enzymes is shown by transferring the piece of liver to another sample of hydrogen peroxide. Finally, the wide occurrence of catalase is shown by substituting chicken, carrots, apple and potato for the liver. Part 2 demonstrates the effect of temperature and pH on catalase activity. This part also demonstrates the effect of adding a competitive inhibitor (hydroxylamine) on the reaction rate. Again, the reaction rates are qualitatively described. The time-frame for this investigation is 40 minutes for each section. The format for each lab is basically the same. Interspersed throughout the procedure are numbered questions and instructions for entering data into data tables. Each investigation contains a separate section to be turned in that has numbered blanks corresponding to the questions and tables for entering data.

More Biology in the Laboratory[12], which accompanies *Biology* by Helena Curtis, also contains an exercise on pH and buffers and an exercise on enzymes. These lab exercises go into much more detail and are much more quantitative in design as would be expected in a higher level course. "Laboratory 3: pH and Buffers" contains six exercises. "Exercise A: Understanding pH" is an introduction to acids, bases, ionization and the pH scale. It includes exercises in calculating the pH of solutions of varying concentrations. "Exercise B: Using Indicators to Measure pH" involves making an indicator solution from red cabbage and determining the color of the indicator in solutions of known pH. The indicator is then used to measure the pH of solutions of unknown pH. pH paper is also used to determine the pH of the unknown solutions. "Exercise C: Determining the pH of Some Common Solutions" uses the cabbage indicator to determine the pH of various beverages, medicines and cleaning solutions. "Exercise D: Soil pH and Plant Growth" has students test different types of soil using pH paper. This exercise also contains some questions dealing with the effect of soil pH on plant growth and development. "Exercise E: The pH Meter" introduces the students to the pH meter and has the students measure the pH of various substances using the meter. Students then calculate the hydrogen ion and hydroxide ion concentrations from the pH. "Exercise F: Buffers" defines buffers and illustrates the concept by having the students add HCl and NaOH to a potassium phosphate buffer and measuring the changes in pH. The laboratory concludes with a set of review questions based on all six exercises. The time requirements for "Exercise A", "Exercise B" and "Exercise C" is one hour each. "Exercise D" has a time requirement of 20 minutes, "Exercise E" has a time requirement of 30 minutes and "Exercise F" has a time requirement of 45 minutes. "Laboratory 9: Enzymes" is divided into two exercises. "Exercise A: Investigating the Enzymatic Activity of Catecholase" uses a spectrophotometer to determine the activity of catecholase and the effect of changing temperature, pH, substrate concentration and enzyme concentration on the activity. The second exercise involves making cheese from milk using the enzyme rennin. This laboratory also concludes with review questions and problems based on the entire laboratory. "Exercise A" is estimated to take 90 minutes to complete, while "Exercise B" is estimated to take 60 minutes.

The College Entrance Examination Board has developed a series of 12 labs that are to be incorporated into the Advanced Placement Biology curriculum[13]. Students taking the annual AP Biology Test will be responsible for the objectives from these labs.[14] There is one lab out of the 12 that is appropriate for this unit. "Enzyme Catalysis" has the students quantitatively measure the activity of catalase in the catalysis of hydrogen peroxide to water and oxygen. The activity is measured by assaying the amount of hydrogen peroxide remaining in a sample after various time intervals by titrating with potassium permanganate. Students also measure the spontaneous rate of hydrogen peroxide decomposition and compare this with the enzyme-catalyzed reaction rate. This lab does not demonstrate the effect on enzyme action of changing pH, temperature or enzyme concentration. In general, the AP labs are very quantitative, involving a lot of data manipulation.

These laboratory exercises do not fit into the general dynamics of my Advanced Biology class. The lab exercises from *Modern Biology* are much too basic for the seniors in the class. The fill-in-the-blank format does not lend itself to the higher-order thinking skills that lab work should foster in the students. The exercises from *Biology* are designed for a longer period than the one hour lab period I have. The lab exercises developed specifically for this unit are adapted from these exercises and share basic objectives. They have been designed to be completed in one lab period and to make the students think about how the lab exercise relates to the world outside of the classroom.

How the Module Fits Into the Curriculum

Northridge Prep School (NRP) is an independent day school for boys in grades six through twelve. The school is located in Des Plaines, Illinois, a suburban community located northwest of Chicago. It just celebrated the 15 year anniversary of its founding. Northridge draws students from all over the Chicago metropolitan area. The students come from a wide range of socioeconomic and cultural backgrounds from the poorest sections of Chicago to the most exclusive North Shore suburbs. Every year Northridge Prep accepts a few foreign students. This really helps to increase the diversity of the student body. Most of these students come from Spain or Mexico, but we have had students from Sweden, Argentina and Venezuela. The projected enrollment for the 1991/1992 school year is 165 students, up from 133 students the previous year. Tuition for 1991/1992 school year is $3800 for the high school (grades 9-12) and $3100 for the junior high (grades 6-8). Approximately 50% of the students receive some type of financial aid and about 25% of the students are minorities. All of the students go on to college, over 95% to four-year colleges. There are 16 faculty members including administrators, who also teach.

The curriculum of NRP is designed to emphasize the basic academic subjects. Due to the small size and limited number of faculty, NRP can not offer many elective courses. Unless special circumstances exist, all students must take all classes. There is no tracking of students with the exception of math. Students in the same grade take the same class at the same time. For example, all the eighth graders have Earth Science in the same room at the same time. This will change, though, as the school continues to grow. The basic curriculum in grades seven through twelve includes History, Math, Science, English, Foreign Language and Religion (optional). Students in grades seven and eight learn Spanish as the foreign language, while students in grades nine through eleven learn Latin. Seniors have a choice of Spanish or Latin as their foreign language. Physical Education classes are required for students in grades seven through ten. Juniors have a flexible class period every day that is used for a wide range of activities including college prep and guest speakers. Class periods are 40 minutes long and all classes meet five days a week. The Advanced Biology and Calculus classes for Seniors are one and one-half periods (60 minutes). The sixth grade curriculum is separate from the rest of the school and is designed to prepare the students for seventh grade at Northridge. The curriculum is very flexible but includes topics in social studies, grammar, spelling, science, math and reading comprehension. The emphasis is placed not on content but on developing exceptional study habits. There is a lot of "teaching across the curriculum" at Northridge since the faculty is small in number and has good communication. There is also continuity in each discipline since the same teacher might teach three or four levels in the same subject area. One teacher teaches all three levels of Latin, for instance.

All of the students at Northridge in grades eight through twelve take science. Seventh graders have Geography instead of a science. Eighth graders take Earth Science. This course stresses the theme that the earth is constantly undergoing change. Ninth graders have an introductory biology course that emphasizes Cell Biology, Genetics, Human Physiology and Ecology. Tenth graders have an introductory chemistry course that highlights basic chemical concepts such as atomic theory, acids/bases, stoichiometry and the Gas Laws. Juniors are enrolled in Physics. This course focuses on mechanics, waves and Modern Physics. Seniors are required to take

Advanced Biology which is based on the College Entrance Examination Board's AP Biology program.[15] It is designed to be the equivalent of an introductory college-level biology course. Even though the course follows the AP syllabus, the students are not required to take the AP Biology test. The course stresses the chemical and physical concepts the students have been exposed to in the previous science courses at Northridge and serves to tie all of the sciences together. All of the science courses at Northridge highlight the importance of hand-on activities and the importance of problem-solving. Real-world situations are used whenever possible to illustrate concepts. I personally teach the eighth, ninth, eleventh and twelfth grade science classes, as well as being the department chairman. In my role as department chairman over the last seven years, I have been responsible for developing the entire science curriculum at Northridge.

This unit on biological chemistry is intended for the Advanced Biology course. It is designed to be taught during the first four weeks of the year. Before designing this unit, I tried to follow as closely as possible the AP syllabus.[16] This syllabus divides the course into three main sections or units. The first unit is on molecules and cells. It is recommended that 25% of the year or about nine weeks be spent on this unit. "Molecules and Cells" is divided into the categories of "Biological Chemistry", "Cells" and "Energy Transformations". The guidelines call for about 2-1/2 weeks to be spent on "Biological Chemistry", 3-1/2 weeks to be spent on "Cells" and three weeks to be spent on "Energy Transformations". The second nine weeks of the year is to be devoted to "Genetics and Evolution". The third major unit is on " Organisms and Populations" and includes topics such as taxonomy, plant anatomy and physiology, animal anatomy and physiology, microbiology and ecology. Roughly 50% of the year is to be spent on this unit according to the guidelines.

I felt that I was rushing to complete the chemistry unit in years past and that I did not do an adequate job in presenting the material to the students. The material was presented almost entirely as lecture in order to get through it. Lab exercises were thrown together as time permitted. The students did not know what to study because objectives were not clearly defined. I spent a lot of time reteaching (actually relecturing) the same material. Even then students did not seem to grasp the concepts I was trying to get across to them. This belief was reinforced later in the year when I would have to go back and review some of the material, especially polarity, when we encountered it in some other context. The four week time-frame is a compromise between adequate coverage and "staying on schedule". Four weeks is almost half of the first marking period. I feel that this amount of time is justified because of the importance of the material and its relationship to the rest of the year. Since a great deal of time is spent on human anatomy in ninth grade, I make up the time during that unit.

In designing this unit, as well as the rest of the NRP science program, I have tried to give priority to the five goals of biology education as expressed by Paul Hurd[17]. These goals state that biology education should:

1. develop a fundamental understanding of biological systems
2. develop a fundamental understanding of scientific methods and the ability to use those methods
3. prepare students to make responsible decisions as citizens with regard to science-related issues
4. help to contribute to a greater understanding and fulfillment of the student's personal needs
5. inform students about science-related careers.

Paul Beisenherz[18] hypothesized that the primary goal of most second-level biology courses is to prepare students for college science and for eventual careers in science. While this is a practical goal in second-level courses that are electives, it goes against one of the major tenets of curriculum reform: that science courses should be for all students, not just for future scientists. Phillip Jackson[19] argues that science courses, in general, should be made relevant to daily life through "laboratory and field experiences that stress skills of inquiry, problem solving and decision making". Dominick A.

Labianca and William J. Reeves[20] extend the "science for all" idea to college curriculums. They believe that science should be at the center of core curricula being developed to give students an overview of western civilization. The primary goal of all science courses at NRP is to make our students "science literate" so that they can make responsible decisions as adults. This makes sense since all of the science courses are required for all students and the number of students who go on in science in college is very small.

In choosing the materials for this unit, I kept in mind the recommendations of Paul Hurd[21] for establishing curricula. Lab studies should allow students to see the connections between natural events, people and biological knowledge through real-life problems. Lab studies should involve issues that require students to make judgements based on values, ethics, aesthetics and morals. Since the real-world problems scientists deal with will most probably be solved through mutual cooperation, students should also work together on problems resulting in agreement or compromise. Topics should be chosen that allow students to perceive that the biological knowledge learned in school does not only pertain to paramecium and oak trees, but also pertains directly to humans. Finally, students should be given the opportunity to solve problems and make decisions since students who are experienced in decision-making are more likely to make rational decisions. These recommendations were implemented by carefully selecting objectives and activities. During lab periods the students always work in small groups of between two and four students. This helps to foster a spirit of cooperation. I also encourage students to work together when studying for tests and quizzes (if possible). Performing the nine lab exercises gives the students the opportunity to become familiar with laboratory procedures, specifically, gel electrophoresis, reverse-phase column chromatography and various methods for testing pH. Social issues such as acid rain, the effect of diet on health and food ingredients are also addressed in this unit.

II. Instruction of Module

Basic Outline

This unit on biological chemistry is basically divided into three interrelated components that work together to familiarize the students with the objectives for each topic (see Appendix A for a complete list of objectives). The topics chosen for this unit are:

Topic A: Review of Atoms, Molecules and Bonding

Topic B: Water

Topic C: pH

Topic D: Carbon, Carbon Chains and Functional Groups

Topic E: Carbohydrates

Topic F: Lipids

Topic G: Proteins

Topic H: Nucleic Acids

Topic I: Chemical Reactions, Free-Energy Changes and Equilibrium

Topic J: Enzymes

The first component of the unit encompasses work done by the students on their own time. This involves outside reading in the textbook (we use *Biology* by Curtis) and from other assigned sources (see Appendix B for a daily list of assignments). It also involves completing worksheets based on the reading assignments (see Appendix C). The worksheets are used to focus the students' reading on important points and to highlight information that should be review and will not be emphasized during lecture/discussion. The second component of the unit is the lecture/discussion format. This component is used primarily for new material or material that needs a more detailed explanation. This component also gives the students a chance for asking questions and for clearing up any misconceptions from the reading. Appendix B contains lecture notes and hand-outs for the unit. The third, and probably the most important component, is the laboratory component of the unit. There are nine labs associated with the unit. The complete lab exercises along with teacher guides are in Appendix D. The labs are designed to reinforce and further explain the information presented in the reading and in lecture. Most of the labs confront the students with real-world applications for the concepts presented. Again, the group work associated with the lab work helps to promote cooperation.

Each objective is covered by one or more of the components depending on the relative difficulty or newness of the concept involved with the objective. Lower cognitive level objectives such as defining terms might only be covered in the reading and/or on the student worksheet. Objectives requiring analysis or synthesis might also be covered in the lecture and in a lab exercise. Table 2 shows which components are used to present each objective.

Table 2. Topic Objectives and Their Method of Coverage

Objective	A	B	C	D	E
Define terms: element, atom, atomic mass, isotope, etc.	X		X		
State mass, charge and location of proton, neutron and electron	X		X		
Determine number of protons, neutrons and electrons in an atom	X		X		
Discuss advantages/disadvantages of each atomic model	X		X	X	
Diagram or explain formation of ionic bonds	X		X	X	
Diagram or explain formation of covalent bonds	X		X	X	
Predict type of bond formed between two elements	X		X	X	
Differentiate between polar and non-polar covalent bonds	X		X	X	X
Predict the relative polarity of a molecule	X			X	
Diagram or explain the formation of double and triple covalent bonds	X			X	
List and describe characteristics of the biologically important elements	X		X		
Define the terms: cohesion, adhesion, imbibition, solution, solute, etc.	X		X	X	
Explain how the properties of water are caused by water's polarity	X		X	X	X
Analyze why water is important to living things based on its properties	X		X	X	X
Compare boiling points/freezing points of solutions and pure solvents	X		X		
Describe how water density and temperature causes lake stratification	X		X		X
Describe adaptations various organisms use to prevent freezing	X		X		X
State the products of the dissociation of water	X		X	X	
Fully define acids and bases	X		X	X	
Differentiate between weak and strong acid/bases	X		X	X	X
Explain the basis of and the uses for the pH scale	X		X	X	X
Describe the function of buffers	X		X	X	X
Explain why/how organisms need to regulate pH using blood buffers	X			X	
Discuss the causes of and solutions to the acid rain problem	X	X			
List the properties of carbon that make it so prevalent in living systems	X		X	X	
Recognize, name and draw carbon chains	X		X	X	X
Recognize, name and common functional groups	X		X	X	X
State the biological significance of each common functional group	X			X	
Define terms: monosaccharide, disaccharide, polysaccharide, etc.	X		X	X	
Recognize or draw common monosaccharides	X		X	X	
Differentiate between aldose and ketose sugars	X		X	X	
Draw or recognize common disaccharides	X		X	X	
Draw or recognize common polysaccharides	X		X	X	
Describe the biological uses of common carbohydrates	X		X	X	

Column A = In-Text Reading
Column B = Outside Reading
Column C = Student Worksheet
Column D = Lecture/Discussion
Column E = Laboratory Exercise

Table 2 (cont'd.)

Objective	A	B	C	D	E
Explain the role lipids play in living systems	X		X	X	X
Describe the basic structure of fats and oils	X		X	X	X
Compare the energy content of fats/oils with carbohydrates	X		X	X	
Differentiate between saturated, unsaturated and polyunsaturated fats	X		X	X	
Differentiate between phospholipids and glycolipids	X		X	X	
Describe and give examples of steroids	X	X	X	X	
Discuss the role of HDL's and LDL's in cholesterol regulation	X	X	X	X	
Draw or recognize the basic structure of an amino acid	X		X	X	
Describe the four levels of protein structure	X		X	X	X
Describe the roles proteins play in biological systems	X		X	X	X
List the parts of a DNA nucleotide	X		X		
List the parts of an RNA nucleotide	X		X		
Differentiate between purines and pyrimidines	X		X		
Describe three structural differences between RNA and DNA	X		X		
Describe the roles nucleic acids play in biological systems	X		X		
Define terms: thermodynamics, exergonic, endergonic, etc.	X		X	X	
Discuss how energy flows through living systems	X			X	
Recognize and predict products for the major types of reactions	X				
State and explain the First Law of Thermodynamics	X		X	X	
State and explain the Second Law of Thermodynamics	X		X	X	
Discuss the application of the Gibbs Free-Energy Equation	X		X	X	
Discuss how organisms deal with the two laws of thermodynamics	X			X	
Define terms: activation energy, catalyst, substrate, cofactor, etc.	X		X	X	
Describe the general structure of an enzyme	X		X	X	
Using the Induced-Fit Model, explain how enzymes function	X			X	
Describe how cofactors/coenzymes regulate enzyme activity	X			X	
Explain how enzymes become denatured	X			X	X
Describe effects of temp., pH and substrate/enzyme concentration	X		X	X	X
Discuss importance of enzymatic pathways to biological systems	X		X	X	
Differentiate between various types of enzyme inhibition	X		X	X	X
Determine rates of enzymatic reactions				X	X

Column A = In-Text Reading Column B = Outside Reading
Column C = Student Worksheet Column D = Lecture/Discussion
Column E = Laboratory Exercise

Pedagogical Value of the Laboratory Exercises

The nine lab exercises contained in this unit have been designed or adapted to fulfill different purposes, but they all have some goals and objectives in common. Each lab requires the students to work together on a task. Each lab allows students to gain experience in making accurate measurements, recording data, analyzing the data in some way (usually by graphing) and drawing conclusions based on the data. Questions at the end of each lab call on the students' ability to apply what they have discovered in the activity to real-world situations. Each of these labs have been adapted to fit my Advanced Biology class. Each lab is designed around a one-hour lab period. Each student writes up each lab in a dedicated lab notebook. Students record the title of the lab, any changes to the written procedure, data (in student designed tables), any graphs required and the answers to the analysis questions. The most important thing that these labs have in common is that they have been designed with low-budget, limited-equipment, limited-time and limited-space class in mind. NRP rents space in a closed public Junior High building. Lab facilities are geared for younger students. There is a shortage of gas jets, water and electrical outlets. All of these factors were figured into the development of each exercise.

The nine labs are:

Lab 1: Separation of Dyes By Reverse-Phase Chromatography (page 97)

This lab introduces the students to the separation of mixtures by reverse-phase column chromatography. The columns used for the separation are relatively inexpensive and disposable. Students separate the different dyes in grape drinks based on the polarities of the dyes. Ethanol and isopropanol are used as the solvents. The real-world experience in this lab is derived from using common products that the students are familiar with and by asking interpretation questions based on every-day situations such as cleaning oil-based paints with a non-polar solvent. The exercise reinforces the concept of polarity addressed in Topic A (Objectives 8 and 9). The concept of solutes and solvents needing the same polarity is used later in the course when describing how the structure of amino acids in proteins imbedded in the cell membrane (which is non-polar) must be different from the structure of the amino acids in the sections of membrane proteins which are sticking out into the environment surrounding the cell or into the cytoplasm (both are polar environments due to water). The movement of polar materials and non-polar materials into and out of the membrane also depend on the concept of polarity.

<u>Lab 2: Comparing Specific Heats</u> (page 100)

This lab involves comparing the specific heats of sand and water by measuring the temperature change in each over a specific time interval and correlates with objective 2 of Topic B (water). The lab stresses the importance of homeostasis to living systems and how the high specific heat of water helps to maintain temperature homeostasis. Students gain experience in graphing data, comparing graphs and in the manipulation of mathematical equations. Using a computer and temperature probe for taking data has the added benefit of exposing students to the world of computer interfacing. This exercise connects concepts from biology, physics and math. The applications to the real-world in this exercise involve the cause of sea and land breezes (which the students have been introduced to in Earth Science), the difference in temperature along Lake Michigan and inland during the year and the fact that babies have a higher concentration of water in their cells than do adults. This exercise reinforces and correlates with objectives 2,3,5 and 6 of Topic B on water.

<u>Lab 3: Measuring pH</u> (page 103)

Lab 3 is an adaptation of a basic pH measurement lab. The pH of various common household items is tested using litmus paper, hydrion test paper, an indicator made from red cabbage, methyl orange indicator and phenolphthalein indicator. A teacher-prepared set of buffers is also tested using each method and displayed for the entire class. This saves time and money since only one set needs to be prepared. This lab has the students present their data in a bar graph, ranking the household items from most acidic to most basic. Students are asked to make comparisons of the accuracy and of the precision of the various tests they used. Students gain real-world experience by noting that common items found around the house are chemicals and exhibit chemical properties that the students need to be aware of. Organisms must regulate internal pH since changes in pH have an effect on reaction rates and enzyme function. This laboratory exercise reinforces objectives 1, 2 and 4 of Topic C (pH).

Lab 4: Buffers in Biological Systems (page 107)

Lab 4 compares the buffering ability of various solutions including water, phosphate buffer solution, egg and liver extract. It correlates with objective 5 of Topic C (pH). This lab also stresses the concept of homeostasis in that buffers are a way of maintaining a stable pH. Students record the initial pH of each test solution and then add vinegar, measuring the pH after each addition. The steps are repeated with ammonia. Students analyze their data using a line graph and make comparisons of each solution's buffering ability. Students then apply their results to the real-world situation of why living systems need buffers and why buffers would be found in liver and eggs.

Lab 5: The Structure of Simple Organic Molecules (page 110)

This exercise reinforces the concepts presented in Topic D (Carbon, Carbon Chains and Functional Groups). The specific objectives the exercise covers are 2, 3 and 4. Students build and compare different organic molecules using ball and stick molecules. This model building allows students to get an idea of the spatial arrangement of atoms in molecules and reinforces the concepts of bonding and polarity taught earlier in the unit. The models help students get a more concrete foundation for the abstract ideas of atoms and molecules. Common substances like propanol, isopropanol and ethanol are modelled because students are familiar with these compounds. Most of the components of living systems are built of these organic molecules and this gives students an opportunity to picture the structure of these molecules and to manipulate them.

Lab 6: Comparing the Fat and Water Content in Hot Dogs (page 114)

Hot dogs are probably a major staple in the diet of most high school students, so they can easily relate to this lab. The fat and water content of three types of hot dogs are analyzed and compared, along with the cost for each type. The fat is extracted using an organic solvent, while the water content is determined by dehydrating the hot dog in an oven. The students' results are compared to the analysis printed on the wrapper for each type of hot dog. The concept of polarity is reviewed and the role of fats and proteins in nutrition is introduced. This lab ties the sciences of biology, chemistry and math together, but also connects these sciences to consumer awareness. The lab exercise correlates with objective 1 and 3 of Topic F (Lipids).

Lab 7: Determining the Molecular Weight of Proteins (page 117)

This is primarily an introduction, to the students, of gel electrophoresis as a common separation technique. This lab uses gel electrophoresis to measure the molecular weight of unknown proteins by comparing their migration distances with the migration distances of known proteins. Students will use the same technique later in the year to separate DNA and construct a map of a plasmid. The cost of this lab is very reasonable since the electrophoresis boxes used are constructed out of plastic storage containers with carbon electrodes. The chemicals and supplies are purchased in kit form. I feel that the cost of this lab is justified because of the important role electrophoresis plays in studying molecular biology and the publicity it has been receiving in the news. This laboratory exercise reinforces the concepts presented in objectives 2 and 3 of Topic G (Proteins).

Lab 8: Measuring Enzyme Reaction Rates (page 120)

The rate of the breakdown of hydrogen peroxide to water and oxygen in a reaction catalyzed by catalase extracted from beef liver is measured. In this version, the rate is determined by measuring the volume of oxygen generated per unit time. The students can then graph the volume of oxygen versus the time and determine the rate from the slope of the graph. The experiment is repeated using a much lower concentration of enzyme to show the effect of enzyme concentration on the reaction rate. The importance of this catalyzed reaction to all aerobic organisms, including humans, and the isolation of the enzyme from something the students are familiar with provide the real-world experiences for this lab. The objectives of this lab coincide with the objectives from the Advanced Placement lab on enzyme rates[23] which are fair game to be included on the annual AP Biology test and reinforce the concepts presented in objectives 1, 7 and 9 from Topic J (Enzymes).

Lab 9: Enzyme Function and Inhibition (page 123)

This final lab deals with the effects of pH, temperature and heavy metal poisoning on enzyme function. It addresses the concepts presented in objectives 1 and 5 of Topic J (Enzymes). Again, this lab uses things that are common to the students' every-day experiences. The enzyme, bromelain, is extracted from fresh pineapple. The enzyme normally breaks down the peptide bonds in proteins. After being subjected to various treatments, the activity of the enzyme is tested by mixing the extract with gelatin. Gelatin sets due to the formation of long, intertwined protein chains. The active enzyme will prevent the gelatin from setting. The gelatin will set, however, if the enzyme has been denatured. The fact that fresh pineapple will prevent gelatin from setting while canned pineapple allows gelatin to set is one consequence of the concepts presented in this lab that students are asked to explain.

Innovative Methods, Demonstrations and Special Audio-Visual Aids

Throughout the unit, various demonstrations and audio-visual aids were used, especially in the lecture/discussion component, to help the students grasp the concepts. Original hand-outs (see Appendix B) supplemented the lecture materials. Demonstrations were used to highlight concepts in the topics of water and thermodynamics. To help illustrate the concept of surface tension, a razor blade was made to float in a cup of water. By adding a drop of detergent, which reduced the surface tension, the razor blade was made to sink. Capillary action was shown in two ways. Two glass plates were held together and inserted into a beaker of colored water. The water could be seen rising between the plates. Ordinary paper towels were rolled up into a cylinder and placed in the water. The difference between adhesion and cohesion was demonstrated using a small test tube of mercury and a small test tube of water. The meniscus in the water curved down due to the greater adhesion of the water to the walls of the cylinder. The meniscus in the mercury curved up due to mercury's high cohesive properties.

To dramatize the effects of imbibition, a handful of bean seeds were mixed with plaster of paris and the plaster was allowed to harden. As the seeds swelled with water the plaster cracked apart. I was able to video-tape this demonstration using a time-lapse video camera that condensed ten hours of real time down to about four minutes. This demonstration helped the students to see how a tiny plant could cause damage to sidewalks or even big rocks.

A series of chemical reactions were used to review the concepts of exergonic, endergonic, exothermic and endothermic reactions. The first reaction demonstrated a spontaneous endothermic reaction[24]. It is based on the technology used in instant cold packs. As ammonium nitrate dissolves in water, energy is absorbed. This lowers the temperature dramatically. A temperature probe hooked up to the computer was used to allow students to visualize the temperature drop. A more dramatic effect was demonstrated by mixing barium hydroxide octahydrate with ammonium chloride[25].

Table 3. Innovative Methods, Demonstrations and Special Audio-Visual Aids

Description	Topic	Objective	Appendix	Thesis Page
Handouts				
Atomic Models	A	4	B	67
Bonding	A	5, 6	B	69
Common Functional Groups	D	3	B	71
Common Monosaccharides	E	2	B	73
Common Disaccharides	E	4	B	75
Demonstrations				
Razor Blade in Water	B	2		
Capillary Action	B	2		
Adhesion and Cohesion	B	1		
Imbibition Video	B	1		
Endothermic Reactions	I	1, 6		
Exothermic Reactions	I	1, 6		

An exothermic reaction was demonstrated by mixing lithium chloride with water[26]. As the lithium chloride dissolves, heat is released raising the temperature. Again, a temperature probe dramatically showed the increase in temperature.

III. Student Transformation

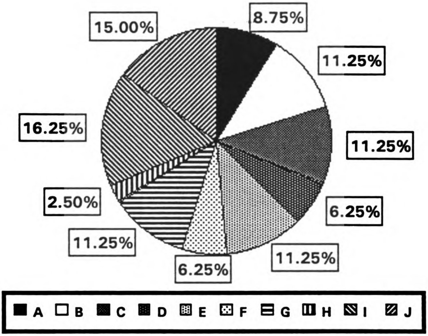
Pre-Test and Post-Test Results

The seniors in the Advanced Biology class were a very diverse group. There were 15 students in the class from a wide range of backgrounds. One of the students was visiting for the year from Mexico and had a very limited working knowledge of the English language. Seven of the 15 started at NRP in seventh grade, one started in eighth grade, three started in ninth, three in tenth and the visitor from Mexico was there only for his Senior year. All the students, with the exception of the student from Mexico, took Introductory Biology, Chemistry and Physics. They were a very close-knit class due to the small class size and the number of years they had been together. I had taught their class three times in the past (in eighth, ninth and eleventh grades), so we all knew each other pretty well.

The pre-test and post-test for this unit is composed of 80 multiple choice questions (see Appendix E). The same set of questions is used for both the pre-test and the post-test to facilitate an analysis of the results. The specific questions were chosen to cover specific objectives. The large number of questions is necessitated by the large number of objectives and the importance of this unit to the rest of the course. Table 3 denotes the correlation between the objectives and the questions. Each topic is covered on the tests in approximately the same proportion as it was covered in class. The percentage of the test devoted to each topic is shown in Figure 1. The topics on thermodynamics and enzymes receive the greatest coverage followed by water, pH, carbohydrates and proteins. The topic of carbon chains and functional groups and the topic of lipids receive equal coverage. Questions about nucleic acids make up only 2.50% of the test.

Table 4. Correlation Between Test Questions and Topic Objectives.

Question No.	Objective	Question No.	Objective
1	A1	41	F1
2	A1	42	F3
3	A1	43	F6
4	A4	44	F6
5	A6	45	F5
6	A7	46	G3
7	A11	47	G1
8	I3	48	G1
9	B2	49	G2
10	B1	50	G2
11	B1	51	G3
12	B1	52	G2
13	B3	53	G2
14	B2	54	G3
15	B4	55	H1
16	B6	56	H3
17	C1	57	I2
18	C4	58	I4
19	C2	59	I4
20	C4	60	I4
21	C7	61	I5
22	C7	62	I1
23	C6	63	I6
24	C6	64	I5
25	C5	65	I6
26	B5	66	I6
27	D1	67	I6
28	D3	68	I5
29	D3	69	J1
30	D3	70	J3
31	D1	71	J2
32	E6	72	J2
33	E6	73	J3
34	E4	74	J1
35	E1	75	J1
36	E6	76	J7
37	E5	77	J6
38	E6	78	J8
39	E6	79	J8
40	E6	80	J8



Topic A = Review of Atoms, Molecules and Bonding
Topic B = Water
Topic C = pH
Topic D = Carbon, Carbon Chains and Functional Groups
Topic E = Carbohydrates
Topic F = Lipids
Topic G = Proteins
Topic H = Nucleic Acids
Topic I = Chemical Reactions, Free-Energy Changes and Equilibrium
Topic J = Enzymes

Figure 1. Topic Coverage on Pre- and Post-Test

Giving the students the pre-test accomplished two goals. The first goal was to have a baseline from which to judge improvement on the post-test, both as a class and as individuals. The second goal was to determine how well the students had mastered and remembered concepts presented in previous classes. I expected students to do better on the questions dealing with atoms, molecules and bonding because they had had those concepts in at least three previous classes at NRP (Earth Science, Biology and Chemistry). The goal of the post-test was to analyze quantitatively the knowledge gained from the unit both as a class and as individual students. The results of the post-test also will allow me to go back over the unit and add more emphasis to those topics that the students did not do well on.

Table 4 and Figure 2 summarizes the class results for the pre-test and the post-test. Student M was absent on the day the pre-test was given, so there is no pre-test data for him.

Table 5. Pre-Test and Post-Test Scores

	Pre-Test		Post-Test		
Student	Raw Score	% Score	Raw Score	% Score	% Change
A	20	25	37	46	21
B	29	36	66	83	46
C	26	33	46	58	25
D	20	25	56	70	45
E	22	28	72	90	63
F	31	39	59	74	35
G	21	26	38	48	21
H	24	30	39	49	19
I	16	20	57	71	51
J	24	30	33	41	11
K	29	36	61	76	40
L	17	21	38	48	26
M	--	--	54	68	68
N	25	31	51	64	33
O	21	26	52	65	39
Average	25	29	51	63	36

The class average went up from 29% on the pre-test to 63% on the post-test. I ran a *Student's T-Test*[27] on the pre-test and post-test scores to see if this was a statistically important increase. My null hypothesis was that there was no statistical difference between the class mean on the pre-test and the class mean on the post-test (see Table 5). The t-test results for the data gave a t value of 7.98 with 27 degrees of freedom. This allows me to reject the null hypothesis beyond the 0.001 confidence level. In other words, there is a statistical difference between the results of the pre-test and the post-test[28]. Three students had over a 50% improvement in their scores. This group included the student who did not take the pre-test and whose pre-test grade was computed as a zero. Three students had an improvement of between 40% and 50%, three students showed an improvement of between 30% and 40% and six students showed an increase of between 10% and 30%. The two students with the smallest improvement (H and J) did not work very hard during the entire year, so their small improvement was not a surprise.

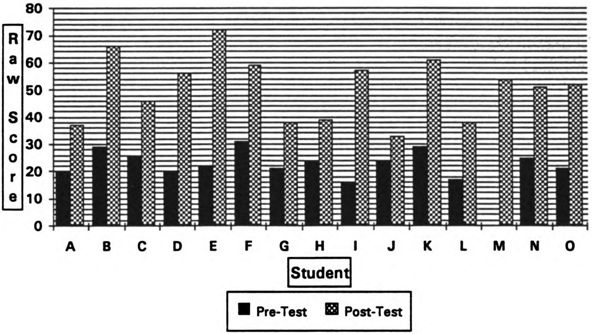


Figure 2. Pre-Test and Post Test Scores

Table 6. T-Test Results

	Pre-Test		Post-Test	
Student	X	X^2	X	X^2
A	20	400	37	1369
B	29	841	66	4356
C	26	676	46	2116
D	20	400	56	3136
E	22	484	72	5184
F	31	961	59	3481
G	21	441	38	1444
H	24	576	39	1521
I	16	256	57	3249
J	24	576	33	1089
K	29	841	61	3721
L	17	289	38	1444
M	---	---	54	2916
N	25	625	51	2601
O	21	441	52	2704
Means	25		51	
Sums	325	7807	759	40331
n	14		15	
Sum of Squares	262		1926	
Standard Deviation	4.49		11.73	
Standard Error	1.20		3.029	

Standard Difference of the Mean	3.26
t Value	7.98
Degrees of Freedom	27

One of the goals of the test was to determine which concepts need more coverage the next time the unit is taught. Figure 3 shows the degree of difficulty for each question on the pre-test and the post-test. The degree of difficulty is a measure of how many students answered the question correctly. A high degree of difficulty on a pre-test question, for instance, implies that the student already had a grasp of that concept. Questions one through three deal with definitions of atomic mass and atomic number plus the roles of protons, neutrons and electrons. As expected, most students answered these questions correctly. Even though it appears from Figure 3 that more people answered question six correctly on the pre-test than on the post-test, it turns out that seven students answered the question correctly on both tests. The difference comes from having only 14 students that took the pre-test, while 15 students took the post-test. That question dealt with predicting the type of bond that would form between the carbon and nitrogen atoms in a molecule of hydrogen cyanide. The correct answer was a triple covalent bond. Of the students that answered that question incorrectly, most responded that the bond should be covalent. The "covalent" choice was before the "triple covalent" choice and that may have affected the results. Question seven dealt with the six most important biological elements. The choices for this question are confusing. Most students answered that these six were the most common naturally occurring elements rather than responding that each needed to gain electrons in order to become stable. In the future, I need to warn the students even more vigorously to read the questions carefully. Based on the results of the tests, students also showed marked improvement in the topics on water, pH, carbohydrates and nucleic acids.

There were many areas, however, where the students did not show a large improvement. Questions 28, 29 and 31 deal with the topic of carbon and functional groups. Less than 30% of the class got these questions correct on the post-test. I need to reinforce this topic before the unit is taught again. Question 39 asked what type of organisms can hydrolyze cellulose. Six students answered correctly with "certain

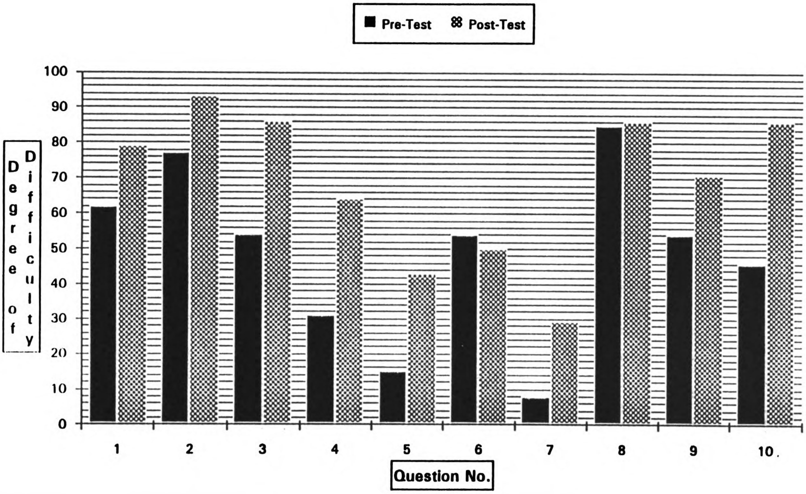


Figure 3. Comparison of Question Difficulty on Pre- and Post Test (Quest. 1 - 10)

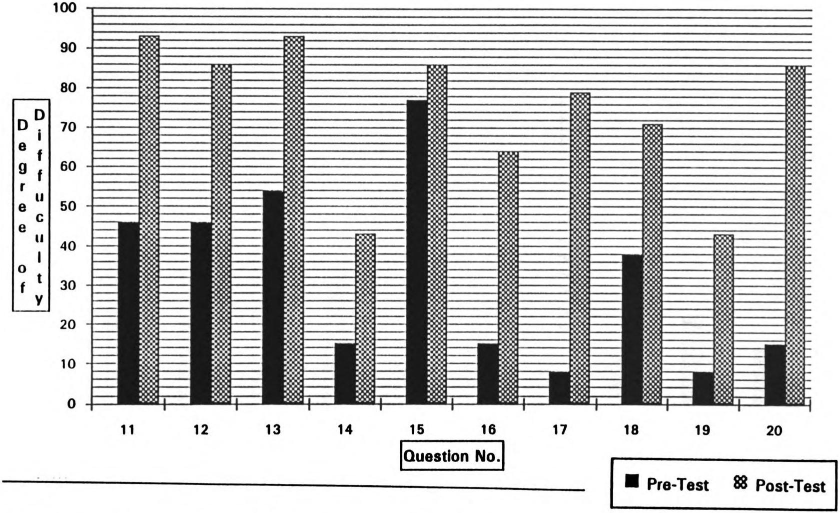


Figure 4. Comparison of Question Difficulty on Pre- and Post Test (Quest. 11 - 20)

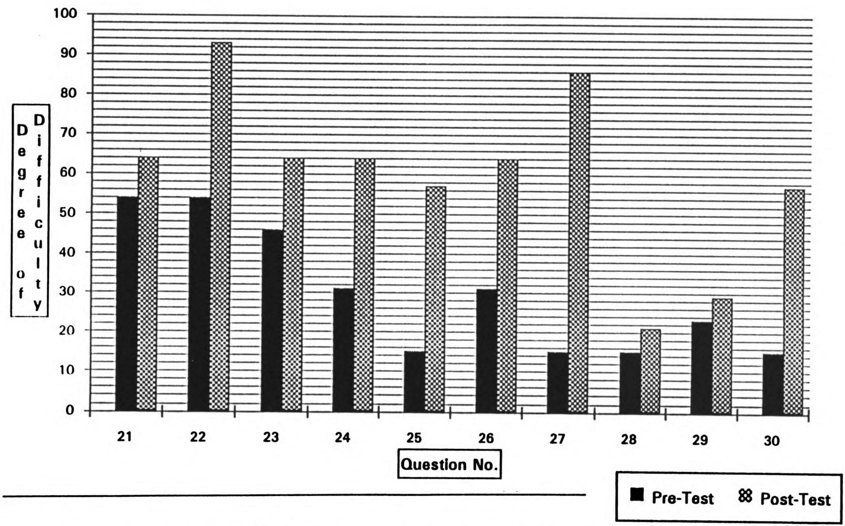


Figure 5. Comparison of Question Difficulty on Pre- and Post Test (Quest. 21 - 30)

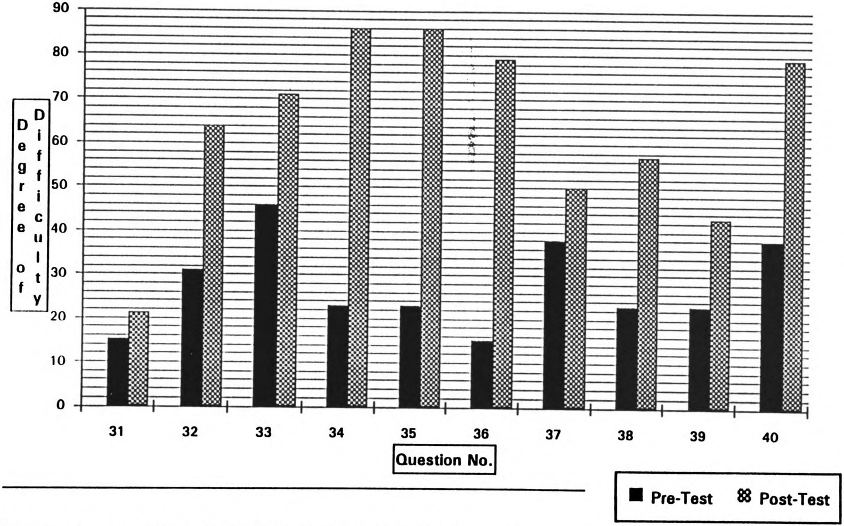


Figure 6. Comparison of Question Difficulty on Pre- and Post Test (Quest. 31 - 40)

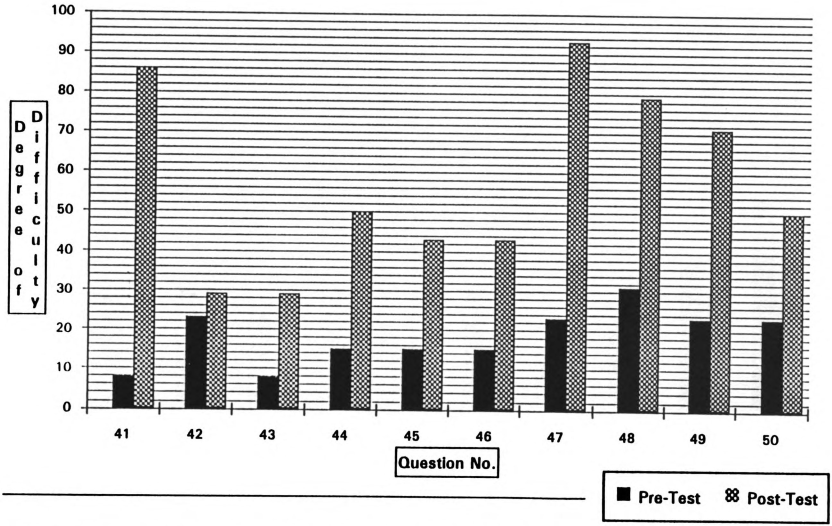


Figure 7. Comparison of Question Difficulty on Pre- and Post Test (Quest. 41 - 50)

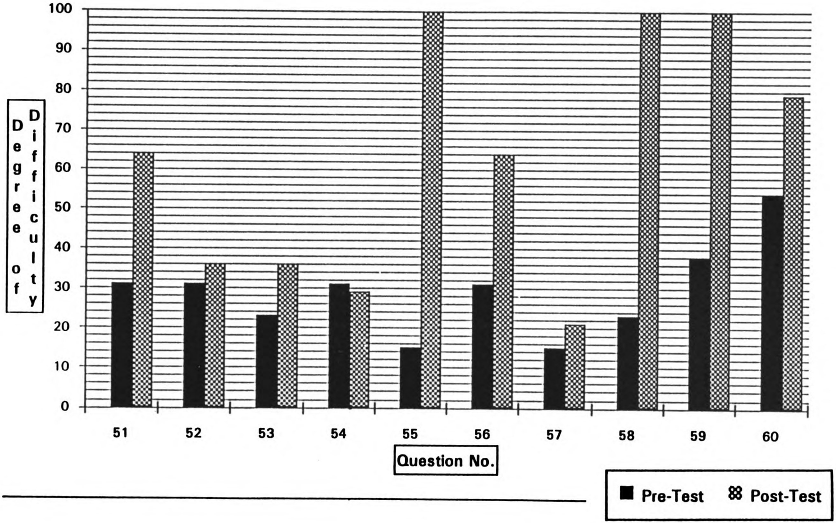


Figure 8. Comparison of Question Difficulty on Pre- and Post Test (Quest. 51 - 60)

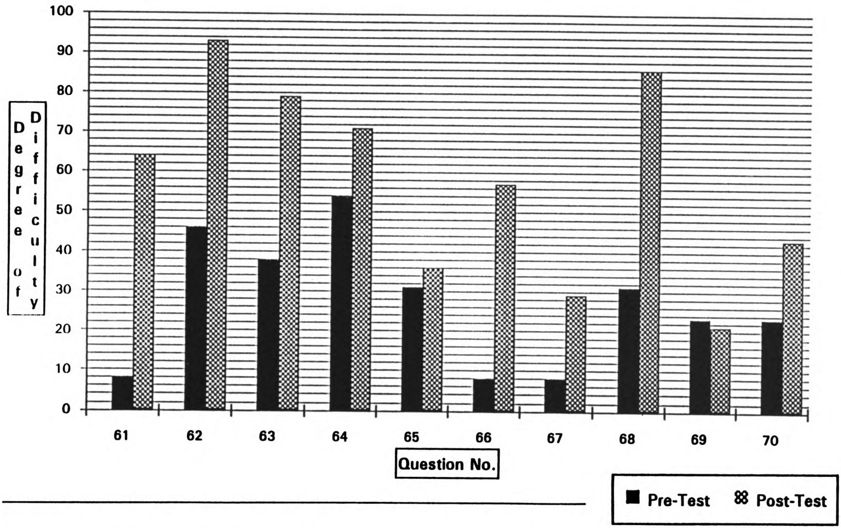


Figure 9. Comparison of Question Difficulty on Pre- and Post Test (Quest. 61 - 70)

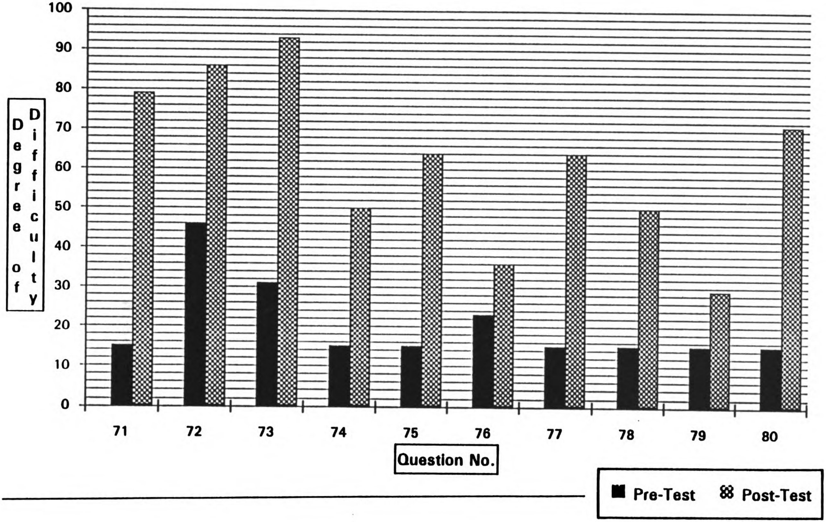


Figure 10. Comparison of Question Difficulty on Pre- and Post Test (Quest. 71 - 80)

fungi". Four students answered with "all microorganisms". Those students, at least, grasped part of the concept that higher animals can not digest cellulose. Questions 42 through 45 all dealt with lipids. Question 42 asked which type of organic molecule releases the greatest amount of energy. Most of the better students (three out of four) answered "triglycerides" correctly. The other students spread their answers out over the other choices. They might have been confused over the use of the term "triglycerides". When I teach this unit again, I will change the choice from "triglycerides" to "fats" since the question in its present form is more a test of vocabulary than of energy comparison. Question 45 is a particularly difficult question because it asks to pick out the one false statement about the similarity between glycolipids and phospholipids. The question was missed by all ability groups equally. Again, this question will be replaced since it does not adequately test the objective. Question 46 also calls for a false statement to be picked out of the group. In general, students seem to have trouble with this type of question.

The students did well on a majority of the questions dealing with proteins, nucleic acids and thermodynamics. The exceptions were the questions dealing with Gibbs Free-Energy equation. In question 65, students had to pick the variable that affected the total change in free energy in a chemical reaction. The correct choice included all of the other choices. Question 67 had the students distinguish between positive and negative ΔG's and ΔH's in exergonic reactions. The wide distribution of answers for this question indicate that more time will need to be spent on this concept. In the section of the test dealing with the final topic of enzymes, students, again, had trouble dealing with questions that called for a false answer to be chosen. Questions 69, 70 and 76 are of this type.

Student Interviews and Evaluations

I had the entire class complete the written evaluation on the unit due to the small size of the class (see Appendix F). During the unit, I conducted informal interviews with the students to check on how they felt the unit was progressing. The following paragraphs summarize the results of the written evaluations and the interviews.

All of the students agreed that they felt adequately prepared from their previous classes in the topic dealing with atoms, molecules and bonding. Six students also felt that the topics dealing with water and pH had also been adequately covered in other classes. The students did not feel adequately prepared for any of the other topics, which is understandable considering the difference in scope between Advanced Biology and the other classes. One of the top students commented that "even though we had most of these topics freshman year, we covered them in much greater detail in Advanced Biology".

A majority of the students felt that enough time was spent on the individual topics. However, one student thought that more time should have been spent on proteins, three students thought that nucleic acids should have been emphasized more and two students suggested that the topic of thermodynamics needed more coverage.

All the students agreed that the objectives were clear and were adequately covered by the combination of components of the unit. One student recognized that if he would had put more effort into studying the objectives, he would have done much better. The students, as a group, stated that the assignments were clearly spelled out in the syllabus.

The students were very honest in discussing the usefulness of the worksheets. They all thought that the worksheets were very useful in focusing their reading. Four of the students admitted to just completing the worksheets and not using them as a study tool for the post-test.

The students also agreed that the post-test reflected the objectives. "Did it ever !" and "Yes, perfectly !" were two of the comments made. Only one student felt that he had put in enough time studying for the post-test. One student said that he only looked at the first couple of objectives for each topic and another wished he would had paid more attention during class discussions.

As a class, the students thought that all the lab procedures were clear and adequately detailed, that there was enough background material provided for each lab and that the labs reinforced the concepts presented in lecture/discussions. Two students expressed the thought that more time was needed to complete the lab on enzyme function. All the students concurred that none of the labs should be deleted.

The last question on the evaluation asked the students for an overall critique of the unit including suggested changes for the next time the unit is taught. One student felt that the policy of collecting and grading worksheets on a regular basis should be more strictly enforced to force "lazy students (including myself) to get them done". Another student suggested having more small quizzes to help check on student progress and to give the students practice in answering questions. A third student recognized the emphasis placed on this particular unit and wondered if this was a proper balance compared to other units presented during the year. The best comment came from the top student in the class when asked about how the unit was going. His reply was "everything is just peachy !"

IV. Discussion and Conclusions

Effective Aspects of the Unit

Based on the results of the post-test and the student responses on the evaluation, I feel that the unit presented in this thesis was very effective. The difference in class average grades between the pre-test and the post-test showed a considerable, statistically-significant difference. In other words, the students did learn something. The use of the three inter-related components also proved to be successful. Common sense alone dictates, and this unit's results back-up the conclusion, that more students will be able to achieve if information is presented in a variety of ways. By their success and comments, the students agreed that the worksheets, lectures and labs worked together to help them better understand the material. We were able to stay on schedule without having to rush through any of the topics.

I personally feel that the most effective sections of the unit were the labs and the demonstrations. The videotape showing the plaster breaking apart was a very dramatic visualization of how powerful seemingly small natural forces can be. The students enjoyed the demonstrations and the demonstrations helped to break up the lecture/discussion period. The labs also helped to break up the routine, but also let the students work together to solve a problem. Seven of the nine labs worked out perfectly. Each lab was designed to fit into a certain time frame, one hour for most of them. The students were able to finish each of the labs in the lab period assigned even though they had to do most of the write-ups for homework. Discussions following each lab period demonstrated that the students had accomplished the objectives for the specific lab. We discussed each analysis question to be sure all the students had a chance to grasp the concepts represented by each question. Students did gain practical experience working with scientific instruments, taking measurements, analyzing data and drawing logical conclusions.

The coverage of atoms, carbohydrates, thermodynamics, pH, water and proteins went very well, but some improvements need to be made. The next time I teach this unit I would like to include even more real-world examples to clarify concepts. I am also going to include one or two more small demonstrations on the properties of water and thermodynamics. Something as simple as a glass of water with ice floating in it might make the difference in comprehension for a student. I am also planning on having students bring in pictures from newspapers and magazines that illustrate the concepts presented in the unit. This might make some of the students further realize that the principles discussed in class occur in the real world, not just in the laboratory.

Even though the post-test, as a whole, was a valid instrument for measuring student progress, I need to go back over some of the questions and either change them or reword them. It is tempting to go through and eliminate any question that calls for picking a false statement since the students as a group did so poorly on that type of questions. Since all of my students are college-bound, however, I think it would be to their advantage to keep those questions in the test. They must learn to carefully read questions before choosing an answer. Instead of eliminating those questions, I will give students in lower grades more practice in answering questions like that and push for the same in other classes.

Ineffective Aspects of the Unit

The students did not do as well on the topic of carbon, carbon chains and functional groups as they did on the other topics. To help remedy this, I am going to add a quiz after the lab on building organic molecules. The lab, itself, should be effective if the students use it as a study tool when they complete it. More emphasis also needs to be put on the topic of lipids. The section in the textbook dealing with the energy stored in proteins, carbohydrates and lipids needs to be highlighted. If time permits I may do the calorimetry experiment from *Modern Biology Laboratories* as a demonstration.

Two of the labs did not work out as planned. An unscheduled fire drill during class prevented the class from doing the electrophoresis of proteins. I did the lab and showed the students the resulting gel. They were able to take measurements from it, but did not have the benefit of actually doing it themselves. Budgetary problems prevented us from doing the electrophoresis of DNA later in the year. The other lab that did not work out as planned was "Determining the Fat and Water Content in Hot Dogs". Students were able to find the water content without much problem. However, we used plastic culture dishes to hold the hot dog pieces and solvent overnight. When we came in the next morning, the solvent had eaten through the culture dishes. To prevent this from happening again, glass culture dishes have been ordered specifically for this lab. Both of these labs will be tried again the next time the unit is taught.

One thing that needs to be changed, from a procedural point-of-view, is the way I collected lab reports. I collected lab notebooks twice during the unit. Instead of keeping up with the work, a majority of the students waited until the night before the notebook was collected and tried to write-up all the labs that were due. This was very apparent in the quality of the work. I think that I will have to collect all write-ups the day after the lab is completed. This will force the students to stay caught up.

I am planning to use this unit next year after implementing the changes outlined above. I will be able to use this unit for many years to come since these very basic concepts are not likely to undergo much change. In order to keep the material fresh and up-to-date, the unit will have to undergo continual revision. Now that the basic framework is in place, any changes can easily be made. This unit was so successful that my goal is to eventually convert the entire year into units that follow the format of this module. The organization of the units, coupled with the emphasis on hands-on activities and real-world experiences will promote the basic goals of achieving increased scientific literacy and an improved appreciation of science in my students.

V. References

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Appendix A:

Topic Objectives

Advanced Biology
Mr. Foley

Unit One Objectives

Topic A: Review of Atoms, Molecules and Bonding

1. Define the following terms: element, atom, atomic number, atomic mass, isotope, molecule, compound and mixture.

2. State the mass, charge and location in the atom of the proton, neutron and electron.

3. Determine the number of protons, neutrons and electrons in atoms and ions using the charge, atomic mass and atomic number.

4. Discuss the advantages and disadvantages of each of the following models of atomic structure: Billiard-Ball Model, Plum-Pudding Model, Bohr Model and Orbital (Quantum) Model.

5. Using the Bohr Model of the atom, diagram or explain the formation of ionic bonds.

6. Using the Bohr Model of the atom, diagram or explain the formation of covalent bonds.

7. From their relative positions in the periodic table, predict whether two elements will form covalent or ionic bonds.

8. Differentiate between polar and non-polar covalent bonds.

9. From its structural formula, predict the relative polarity of a molecule.

10. Using the Bohr Model of the atom, diagram or explain the formation of double and triple bonds.

11. List the six elements that make up 99% of all living tissues. Describe the characteristics that these elements share.

Topic B: Water

1. Define the following terms and give specific examples that illustrate each: cohesion, adhesion, imbibition, solution, solute, solvent, hydrophillic and hydrophobic.

2. Explain how the following properties of water are caused by the polarity of the water molecule: surface tension, capillary action, heat of fusion, heat of vaporization, specific heat and density.

3. Based on the properties above, analyze why water is so important for living things.

4. Compare the boiling point of water and freezing point of a pure solvent to the freezing and boiling points of a solution.

5. Discuss how the relationship between water density and water temperature causes

seasonal stratification in lakes.

6. Describe some adaptations that various organisms use to prevent freezing.

Topic C: pH

1. State the products of the dissociation of water.

2. Fully define acids and bases in terms of their ability to increase or decrease the number of hydrogen and hydroxide ions in a solution.

3. Differentiate between weak and strong acids and bases.

4. Explain the basis of the pH scale and how it is used to measure the acidity or alkalinity of a solution.

5. Describe what a buffer is and how it works to resist changes in pH.

6. Use the buffer system in blood to explain why and how organisms regulate internal pH.

7. Discuss the causes of and possible solutions to the acid rain problem.

Topic D: Carbon, Carbon Chains and Functional Groups

1. List the properties of carbon that make it so prevalent in living systems.

2. Recognize, name and draw carbon chains that contain from between one to ten carbons.

3. Recognize, name and draw organic molecules that contain the following functional groups: hydroxyl, carboxyl, amine, aldehyde, ketone, hydrocarbon and phosphate.

4. State the biological significance of each of the above functional groups.

Topic E: Carbohydrates

1. Define the following terms: monosaccharide, disaccharide, polysaccharide, monomer, polymer, condensation reaction and hydrolysis.

2. Recognize or draw the following monosaccharides: glyceraldehyde, ribose, deoxyribose, alpha glucose, beta glucose, alpha galactose, beta galactose, alpha fructose and beta fructose.

3. Differentiate between aldose and ketose sugars.

4. Draw or recognize the following disaccharides: sucrose, lactose and maltose.

5. Draw or recognize the following polysaccharides: starch, cellulose, glycogen and chitin.

6. Describe the biological uses of the carbohydrates listed above.

Topic F: Lipids

1. Explain the major role lipids play in living systems.

2. Describe the basic structure of fats and oils.

3. Compare the energy content of fats and oils with carbohydrates.

4. Differentiate between saturated, unsaturated and polyunsaturated fats.

5. Differentiate between phospholipids and glycolipids in terms of structure and function.

6. Describe the general structure of and give examples of steroids.

7. Discuss the role of HDL's and LDL's in cholesterol regulation.

Topic G: Proteins

1. Draw or recognize the basic structure of an amino acid.

2. Describe the four levels of protein structure. Discuss how the structure of the individual amino acids contribute to these levels.

3. Describe the various roles that proteins play in biological systems. Give examples for each.

Topic H: Nucleic Acids

1. List the three parts of a DNA nucleotide.

2. List the three parts of an RNA nucleotide.

3. Differentiate between purines and pyrimidines.

4. Describe three structural differences between RNA and DNA.

5. Describe the roles nucleic acids play in biological systems.

Topic I: Chemical Reactions, Free-Energy Changes and Equilibrium

1. Define the following terms: thermodynamics, exergonic, endergonic, oxidation, reduction, anabolism and catabolism.

2. Discuss how energy flows through living systems.

3. Recognize and predict the products for the four main types of chemical reactions.

4. State and explain the First Law of Thermodynamics.

5. State and explain the Second Law of Thermodynamics.

6. Discuss the application of the Gibbs Free-Energy Equation to the Second Law of Thermodynamics.

7. Discuss how organisms deal with the two laws of thermodynamics.

Topic J: Enzymes

1. Define the following terms: activation energy, catalyst, substrate, cofactor, coenzyme, denaturation and auxotroph.

2. Describe the general structure of an enzyme.

3. Using the Induced-Fit Model, explain how enzymes function.

4. Describe how cofactors and coenzymes regulate enzyme activity.

5. Explain how enzymes become denatured and list four agents of denaturation.

6. Describe the effects of temperature, pH, substrate concentration and enzyme concentration on enzyme activity. Analyze graphs that show these effects.

7. Discuss the importance of enzymatic pathways to biological systems.

8. Differentiate between competitive inhibition, non-competitive inhibition, irreversible inhibition and allosteric inhibition. Give specific examples of each.

9. Given data from an experiment, determine the rate of an enzymatic reaction.

Appendix B:

Daily Lesson Plans/Lecture Notes and Handouts

Lecture Notes

- Lecture: Atomic Models, Bonding and Polarity
- Lecture: Water: Structure and Properties
- Lecture: pH and Buffers
- Lecture: Structure and Function of Common Organic Molecules
- Lecture: The Structure and Function of Carbohydrates
- Lecture: The Structure and Function of Lipids
- Lecture: Lipid Nutrition
- Lecture: Amino Acids and Proteins
- Lecture: Energy and Thermodynamics
- Lecture: Enzymes

Handouts

- Handout: Atomic Models
- Handout: Bonding
- Handout: Common Functional Groups
- Handout: Important Monosaccharides
- Handout: Important Disaccharides

Unit One
Daily Syllabus

Date	Assignment	Homework
9/6	**UNIT I PRE-TEST**	A. Read pg. 23-35 B. Complete W.S. 1: Concepts of the Atom
9/7	Lecture: Atomic Models, Bonding and Polarity	
9/10	Lab 1: Separation of Dyes by Reverse-Phase Chromatography	A. Read pg. 40-47, 53 B. Complete W.S. 2: Water: the Molecule of Life
9/11	A. Lecture: Water: Structure and Properties B. Lab 2: Comparing Specific Heats	A. Read pg. 47-52 B. Complete W.S. 3: pH and Buffers
9/12	Lecture: pH and Buffers	
9/13	Lab 3: Measuring pH	A. Read acid rain article and answer the assigned questions: Mohner, Volker A. "Challenge of Acid Rain". Scientific American, Aug. 1988, pg 30-38.
9/14	Lab 4: Buffers in Biological Systems	
9/17	A. **Quiz: Topics A, B & C** B. Lecture: Intro to Carbon and Carbon Chains	A. Read pg. 55-59 B. Complete W.S. 4: Carbon, Carbon Chains and Functional Groups
9/18	Lecture: Structure and Function of Common Organic Molecules	
9/19	Lab 5: The Structure of Organic Molecules	A. Read pg. 59-66 B. Complete W.S. 5: Carbohydrates
9/20	Lecture: The Structure and Function of Carbohydrates	A. Read pg. 67-70, 71 B. Complete W.S. 6: Lipids
9/21	Lecture: The Structure and Function of Lipids	

9/24	A. Lecture: Lipid Nutrition B. Lab 6: Comparing Fat and Water Content of Hot Dogs	A. Read pg. 70, 72-80 B. Complete W.S. 7: Proteins and Nucleic Acids
9/25	Lecture: Amino Acids and Proteins	
9/26	A. Lecture: Amino Acids and Proteins (cont.) B. Begin Lab 7: Determining the Molecular Weight of Proteins	
9/27	Complete Lab 7	
9/28	**Quiz: Topics D, E, F, & G**	A. Read pg. 161-168 B. Complete W.S. 8: Energy and Thermodynamics
10/1	**NO SCHOOL: IN-SERVICE**	
10/2	Lecture: Energy and Thermodynamics	A. Read pg 169-180 B. Complete W.S. 9: Enzymes
10/3	Lecture: Enzymes	
10/4	Lab 8: Measuring Enzyme Reaction Rates	
10/5	Lab 9: Enzyme Function	
10/8	**NO SCHOOL: COLUMBUS DAY**	
10/9	**UNIT I POST-TEST**	

Lecture: Atomic Models, Bonding and Polarity

I. Atomic Models **(15 min)**

A. Billiard-Ball Model

1. earliest model by John Dalton (early 1800's)
2. emphasizes indivisibility and homogeneity of the atom
3. explains chemical but not electrical nature of the atom

B. Plum-Pudding Model

1. developed by J.J. Thomson in 1903
2. negative charges (electrons) are imbedded in positively charged bulk of atom
3. accounted for electrical nature of the atom

C. Planetary Model

1. developed by Ernest Rutherford in 1911
2. atom consists of mostly empty space
3. atom has extremely dense, positively-charged center of nucleus
4. electrons orbit around the nucleus
5. diameter of atom is 1000X the diameter of the nucleus

D. Bohr Model

1. electrons are located at different distances from the nucleus in shells
2. each shell has a different energy level
3. each shell can hold only a certain number of electrons
4. explained the bright-line spectrum of hydrogen but not for any other element
5. useful in explaining simple ionic and covalent bonding

E. Orbital (Quantum) Model

1. electrons are grouped into energy levels
2. describes electron motion rather than location
3. orbitals describe region of space where the electrons are most likely to be found
4. no two electrons can have the same set of quantum numbers because no two electrons can have the same energies.
5. electrons change energy levels in distinct jumps or quanta

II. Bonding **(30 min)**

A. General Information

1. each energy level can only hold a certain number of electrons
2. lower energy levels fill before higher energy levels can fill
3. the first level can hold 2 electrons, the second can hold 8 electrons and the third can hold 8 electrons before the fourth can start to fill
4. an atom is stable when its outer (valence) shell is filled
5. atoms that are naturally stable are inert (Noble Gases)
6. atoms tend to share or transfer electrons in order to become stable

B. Ionic Bonds

1. ions are charged atoms formed by the gain or loss of electrons in order to become stable
2. positive and negative ions stick together to form ionic compounds that are electrically neutral
3. when ionic bonds are broken, electrons stay with the new atom
4. ionic bonds are easily broken by dissolving in water (ionization)
5. atoms that gain electrons are said to be reduced
6. atoms that lose electrons are said to be oxidized
7. examples: Na, Ca, Al, F, O and N

C. Covalent Bonds

1. covalent bonds are formed by the sharing of electrons
2. when bonds are broken, electrons return to their original atoms
3. single covalent bonds consist of one shared electron pair while double bonds consist of two electron pairs
4. elements close together in the Periodic Table tend to form covalent bonds
5. covalent bonds do not easily break down in water

III. Polarity **(15 min)**

A. Polar Bonds

1. polar covalent bonds are formed by unequal electron sharing
2. electrons spend more time with one atom than with the other atom giving that atom a slight negative charge
3. in non-polar covalent bonds the electrons are shared equally

B. Polar and Non-polar Molecules

1. polar molecules have charged areas due to polar bonds
2. in non-polar molecules charged areas cancel each other out
3. symmetrical molecules are usually non-polar (example: hydrocarbons)
4. asymmetrical molecules are usually polar (example: water)

Lecture: Water: Structure and Properties

I. Structure of Water **(10 min)**
- A. Water is a polar molecule
- B. Oxygen attracts electrons more than the hydrogens
- C. Oxygen region has a slight negative charge while hydrogen regions have a slight positive charge
- D. Hydrogen bonding occurs between hydrogen of one water molecule and the oxygen of another water molecule

II. Physical Properties of Water **(25 min)**
- A. Definitions
  1. cohesion - tendency for the same molecules to stick together
  2. adhesion - tendency for different molecules to stick together
  3. surface tension - upward force caused by cohesion of water molecules
  4. capillary action - the drawing up of water into thin tubes by the combination of cohesive and adhesive forces
  5. imbibition - the soaking up of water into wood or seeds by capillary action

- B. Demonstrations
  1. cohesion and adhesion - mercury and water in 10 ml graduated cylinders
  2. surface tension - razor blade floating on water
  3. imbibition - videotape of seeds in plaster
  4. capillary action - colored water rising between two microscope slides

III. Thermal Properties of Water **(15 min)**
- A. Definition
  1. specific heat - the amount of energy needed to raise one gram of water one degree Celsius
  2. heat of vaporization - energy needed to change a substance from the liquid phase to the gaseous phase
  3. heat of fusion - energy needed to change a substance from the solid phase to the liquid phase
- B. Specifics
  1. due to polarity and hydrogen bonding, water has a relatively high specific heat, heat of vaporization and heat of fusion
  2. most of the energy goes into breaking the hydrogen bonds rather than increasing the kinetic energy of the molecules
  3. water tends to stay a liquid and to resist temperature changes
     (refer to table 2.1 and 2.2 on pg. 43 of text)

IV. Lake Stratification **(10 min)**
- A. Water has a maximum density at 4.0 °C
- B. Lakes freeze from the top down
- C. Ice layer at top acts as insulating layer
- D. Deep lakes will stratify in winter and summer due to density gradient
- E. Mixing occurs in spring and fall
- F. Mixing brings up nutrients from the bottom and distributes oxygen

Lecture: pH and Buffers

I. Acids and Bases **(30 min)**

A. Water

1. water ionizes to form H_3O^+ and OH^- ions
2. only a small amount of water actually ionizes
3. amount of H^+ ions and OH^- ions are equal in water (1×10^{-7} M)
4. any polar or ionic substance may change the H^+/OH^- balance

B. Definitions

1. acids have more H^+ ions than OH^- ions
2. acids cause a relative increase in the number of H^+ ions
3. bases have more OH^- ions than H^+ ions
4. bases cause an increase in the relative number of OH^- ions
5. the strength of the acid or base depends on the amount or degree of ionization that takes place

II. The pH Scale **(15 min)**

A. pH stands for -log $[H^+]$ measured in molarity

B. pH < 7 = acids, pH > 7 = bases

III. Buffers **(15 min)**

A. Definitions

1. buffers are substances that resist changes in pH
2. buffers are combinations of weak acids and salts of weak acids
3. the weak acid absorbs excess OH^- ions while the salt absorbs excess H^+ ions

B. Importance

1. buffers maintain homeostasis in cells
2. pH influences chemical reactions
3. carbonic acid (H_2CO_3) buffer in blood maintains pH of blood
4. If blood is overloaded with excess of H^+ or OH^-, then buffer will fail

Lecture: Structure and Function of Common Organic Molecules

I. Carbon and Carbon Chains **(15 min)**

A. Structure
1. 6 protons and 6 electrons, 4 unpaired electrons
2. can produce up to 4 covalent bonds
3. carbon readily forms double bonds and triple bonds
4. carbon readily bonds with other carbon atoms to form long chains

B. Carbon Chains
1. forms backbone for organic molecules
2. named for the number of carbon atoms in the chain

II. Functional Groups **(45 min)**

A. Hydroxyl (-OH)
1. alcohol group
2. polar and water soluble
3. can form hydrogen bonds
4. named by dropping -yl from carbon chain and adding -anol

B. Carboxyl Group (-COOH)
1. ionizes to form H^+ ions (weak acid)
2. named by dropping -yl from carbon chain and adding -anoic acid

C. Amine Group ($-NH_2$)
1. accepts H^+ ions to form NH_3^+ (weak base)
2. named by adding "amine" to carbon chain

D. Aldehyde Group
1. polar and water soluble
2. characterizes some (aldose) sugars
3. named by adding "aldehyde" to carbon chain

E. Ketone Group
1. polar and water soluble
2. characterizes some (ketose) sugars
3. named by adding "ketone" to both carbon chains

F. Hydrocarbons (-H)
1. very non-polar
2. just hydrogen and carbon
3. alkanes have only single bonds
4. alkenes have double bonds
5. alkynes have triple bonds

G. Phosphate
1. ionizes to form H^+ ions
2. remainder of group has a negative charge

Lecture: Structure and Function of Carbohydrates

I. Monosaccharides (CH_2O) **(20 min)**

A. Hexose Sugars ($C_6H_{12}O_6$)
1. alpha and beta glucose - aldose sugar
2. alpha and beta fructose - ketose sugar
3. alpha and beta galactose - aldose sugar

B. Pentose Sugars
1. ribose - found in RNA
2. deoxyribose - found in DNA

C. Function of Hexose Monosaccharides
1. energy - 673 kcal/mole
2. vertebrates transport sugar as glucose
3. animals lack enzymes necessary to break beta linkages

II. Disaccharides **(20 min)**

A. Sucrose
1. composed of alpha glucose and beta fructose
2. transport sugar in most plants

B. Lactose
1. composed of alpha glucose and galactose
2. found in milk

C. Maltose and Trehalose
1. composed of alpha glucose and alpha glucose
2. trehalose transport sugar in insects
3. maltose is malt sugar

III. Polysaccharides **(20 min)**

A. Starch
1. composed of two forms: amylose and amylopectin
2. amylose consists of 1000+ alpha glucose molecules in 1,4 linkages
3. amylopectin consists of 1000 - 6000 alpha glucose molecules in 1,4 and 1,6 linkages
4. starch is the storage polysaccharide in plants

B. Glycogen
1. similar in structure to amylopectin
2. storage polysaccharide in higher animals
3. glycogen is stored in the liver and in muscle tissue

C. Cellulose
1. composed of beta glucose in 1,4 linkages
2. structural polysaccharide in plants
3. animals lack enzymes to digest cellulose due to beta linkages

D. Chitin
1. structural polysaccharide that comprises the shells of arthropods and the cell walls of many fungi
2. polymer of n-acetyl glucosamine

Lecture: Structure and Function of Lipids

I. Fats and Oils **(30 min)**

A. General

1. animals tend to store energy as fats and oils rather than as carbohydrates, plants store fats and oils in seeds
2. fats contain 9.3 kcal/gram of energy
3. fats are non-polar and hydrophillic so they do not attract water like carbohydrates

B. Structure

1. composed of 3 fatty acids bonded to glycerol
2. fatty acids are long hydrocarbon chains with carboxyl group on the end
3. saturated fatty acids contain only single bonds
4. unsaturated fatty acids contain double bonds
5. unsaturated fats are common in plants as an oily liquid
6. saturated fats common in animals

C. Function

1. energy storage
2. thermal insulation
3. electrical insulation
4. fat-soluble vitamins

II. Phospholipids and Glycolipids **(10 min)**

A. Structure

1. phospholipids are composed of 2 fatty acids and a phosphate group bonded to glycerol
2. glycolipids have short carbohydrate chain bonded to third carbon of glycerol
3. both molecules have polar and non-polar regions

B. Both function as important component of cell membrane

III. Waxes **(5 min)**

A. Waxes are structural lipids

B. Waxes provide a protective and water-proof coating on skin, fur, feathers, leaves and fruits

IV. Steroids **(15 min)**

A. Structure

1. composed of 4 carbon-linked rings
2. insoluble in water

B. Cholesterol

1. found in cell membranes (except in bacteria) and myelin sheaths of nerves
2. synthesized in the liver from saturated fatty acids and obtained in the diet from animal products
3. high cholesterol levels can contribute to atherosclerosis

C. Other Examples

1. sex hormones (estrogen, testosterone)
2. adrenal cortex hormones

Lecture: Lipid Nutrition

I. Cholesterol **(5 min)**

A. Synthesized in the liver from saturated fatty acids
B. Excess cholesterol is degraded in the liver
C. Cholesterol is transported in the bloodstream even though it is insoluble
D. Cholesterol is transported in lipid containers with water-soluble proteins imbedded in them

II. Control of Cholesterol Levels **(15 min)**

A. Low Density Lipoproteins (LDL's) function as delivery trucks to carry cholesterol around the body
B. High Density Lipoproteins (HDL's) carry cholesterol to the liver for degradation
C. Normally, HDL's and LDL's are in balance
D. Factors that throw the system out of balance
  1. if intake of cholesterol is too high, liver can not keep up
  2. if intake of saturated fats is too high, liver automatically makes more cholesterol
  3. damaged LDL receptors on cell membranes cause liver to synthesize and export cholesterol

E. Effects of High Cholesterol Levels
  1. excess cholesterol (in LDL's) are taken up by walls of coronary arteries
  2. this can cause a blockage of the artery (atherosclerosis) leading to a heart attack

F. Propensity to high cholesterol levels may be hereditary
  1. cells lack LDL receptors
  2. may synthesize large amounts of HDL's

G. Other factors that influence cholesterol levels
  1. exercise tends to raise HDL levels
  2. smoking tends to decrease HDL levels
  3. limiting cholesterol and saturated fats in the diet

Lecture: Amino Acids and Proteins

I. Amino Acids **(20 min)**

A. Basic Structure

1. carboxyl group and amine group bonded to central carbon
2. open bond on central carbon contains residue (R) group
3. there are twenty basic amino acids = twenty residue groups
4. amino acids bond to each other by condensation reactions (peptide bond)
5. chain of amino acids is a polypeptide or a protein

B. Residue Groups

1. non-polar residue groups
2. polar but uncharged residue groups
3. acidic residue groups (donate H^+ ions)
4. basic residue groups (accept H^+ ions)

II. Proteins **(40 min)**

A. Levels of Organization

1. primary - straight chain
2. secondary - alpha helix or pleated sheet held together by hydrogen bonds
3. tertiary - intricate 3-dimensional structure held together by hydrophobic interactions, hydrophillic interactions, disulfide bridges and hydrogen bonds
4. quaternary - more than one polypeptide chain bonded together

B. Uses and Functions

1. structural proteins - collagen, viral coats
2. regulatory proteins - protein hormones (insulin)
3. contractile proteins - actin, myosin
4. transport proteins - hemoglobin, myoglobin
5. storage proteins - egg white
6. blood proteins - antibodies
7. membrane proteins - receptors, antigens
8. toxins - botulism toxin
9. enzymes - sucrase, pepsin, lipase

Lecture: Energy and Thermodynamics

I. Laws of Thermodynamics **(30 min)**

A. First Law - Energy can not be created or destroyed but it can change form

1. potential energy is stored energy or the energy of position
2. kinetic energy is the energy of motion
3. all molecules are in continual motion
4. nothing is 100% efficient in converting energy
5. gasoline engines are only about 25% efficient in energy conversion

B. Second Law - Potential energy is always decreasing while entropy is always increasing

1. endothermic reactions absorb heat energy
2. exothermic reaction give off more heat energy
3. a negative ΔH is characteristic of an exothermic reaction ($C_6H_{12}O_6$ --> $6CO_2$ + $6H_2O$ ΔH = -673 kcal/mole)
4. a positive ΔH is characteristic of an endothermic reaction ($2N_2O_5$ --> $4NO_2$ + O_2 ΔH = 26.18 kcal/mole)
5. a larger number of smaller objects is more disordered than 1 large object

II. Gibbs Free Energy ($\Delta G = \Delta H - T\Delta S$) **(30 min)**

A. In exergonic reactions, ΔG is always negative
B. In endergonic reactions, ΔG is always positive
C. Entropy (ΔS) is always a positive value since entropy is always increasing
D. Examples: oxidation of glucose, dinitrogen pentoxide, ice melting, ice forming

Lecture: Enzymes

I. Enzyme Function **(20 min)**

A. Enzymes are proteins in tertiary structure that act as biological catalysts

1. because of the tertiary structure, they have a very specific shape
2. anything that changes the shape of the protein, changes its function
3. catalysts are not used up in the reaction

B. Enzymes lower the activation energy of the reaction

1. allows reactions to proceed that otherwise would not be able to
2. speeds up reactions that would normally take a very long time

C. Enzyme + Substrate --> Enzyme-Substrate Complex --> Enzyme + Product

D. Active site of enzyme is complimentary in shape, hydrophillic/hydrophobic areas and +/- charges

E. Induced-Fit Hypothesis

1. active site is flexible
2. binding of substrate causes a structural change in the active site making a tight fit
3. tightness of fit may cause additional stress on the substrate to break it apart in some cases

II. Cofactors **(10 min)**

A. Cofactors are non-protein portions of the enzyme necessary for enzyme function

B. Ions can act as cofactors

1. Mg^{2+} is needed in all reactions involving phosphate group transfer
2. K^+ and Ca^{2+} are also important cofactors

C. Coenzymes are organic cofactors. Vitamins play an important role as coenzymes

III. Enzymatic Pathways **(10 min)**

A. Enzymes work in series

B. Advantages

1. groups of related enzymes can be segregated in the cell
2. there is little accumulation of intermediate products
3. there is a shift in equilibrium to product's side that moves the reaction along

IV. Regulation of Enzymes **(20 min)**

A. Denaturing is a change in tertiary structure

1. heat denatures by breaking hydrogen bonds
2. pH changes also interferes with hydrogen bonding as well as +/- interactions
3. heavy metals bind in the enzyme changing its structure

B. Allosteric Interaction - temporary activation or inactivation of an enzyme caused b by the binding of an effector to the allosteric site

C. Competitive Inhibition

1. completely reversible
2. inhibitor and substrate compete for active site (based on concentration)
   (PABA ---> folic acid, sulfanilamide binds instead and bacteria dies)

D. Non-Competitive Inhibition

1. inhibitor binds elsewhere than active site
   (lead forms covalent bond with sulfhydryl groups, breaking disulfide bridges)
2. may be reversible

E. Irreversible Inhibition

1. inhibitor binds permanently at active site
2. thoroughly and irreversibly denatures enzyme

Atomic Models

Billiard Ball Model

- proposed by John Dalton in early 1800's
- atom is an indivisible, uniformly dense solid sphere
- atom enters into chemical reactions, but is not changed by those chemical reactions
- accounted for the chemical, but not the electrical nature of the atom

Plum-Pudding Model

- developed by J. J. Thomson in 1903
- negatively-charged electrons are imbedded in the positively charged bulk of the atom
- accounted for the electrical nature of the atom
- atom was seen as being made of smaller parts

Planetary Model

- developed by Ernest Rutherford in 1911
- atoms consist of a positively-charged, dense nucleus with electrons orbiting around the nucleus
- vast majority of the atom consists of empty space

Bohr Model

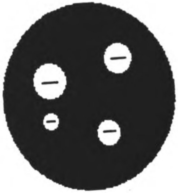
- named for Niels Bohr
- electrons are located in energy shells at different distances from the nucleus
- each shell can hold only a certain number of electrons
- explained the bright-line spectrum of hydrogen, but not of any other element

Orbital Model

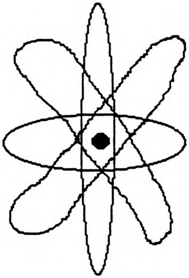
- electrons are grouped into orbitals
- describes electron *motion* rather than *position*
- orbitals describe a region of space in which the electron is most likely to be found
- no two electrons can have exactly the same set of quantum numbers because no two electrons can have exactly the same energy

Billiard Ball Model

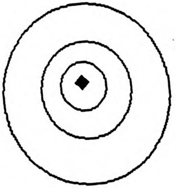
Plum-Pudding Model



Planetary Model



Bohr Model



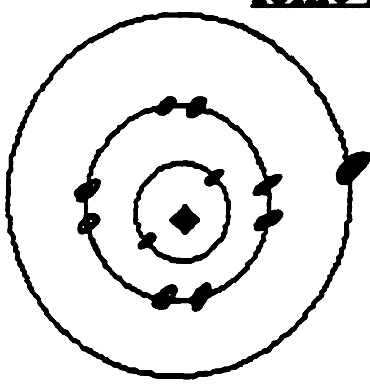
Bonding

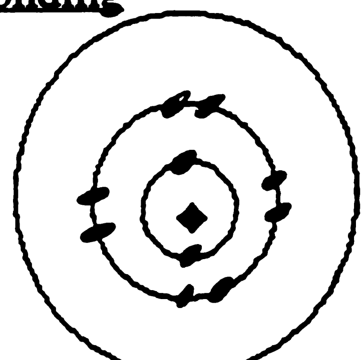
- Atoms are stable with a full outer shell
- Atoms transfer or share electrons in order to gain a full outer shell
- In **ionic bonds**, electrons are transferred from one atom to another forming charged particles or ions
- In **covalent bonds**, electrons are shared between two atoms forming a covalent compound
- When covalent bonds break, electrons return to their original atoms
- When ionic bonds break, electrons remain with the atoms they are transferred to

---

Ionic Bonding

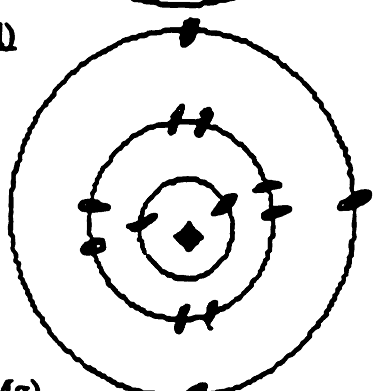
Sodium (Na)
11 protons
11 electrons
0 net charge

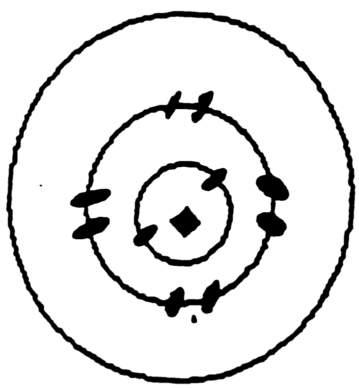




Sodium Ion
11 protons
10 electrons
+1 net charge

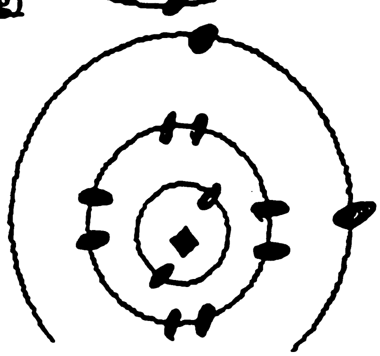
Aluminum (Al)
13 protons
13 electrons
0 net charge

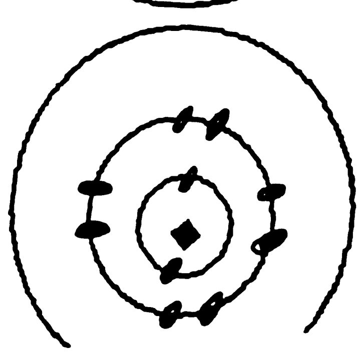




Aluminum Ion
13 protons
10 electrons
+3 net charge

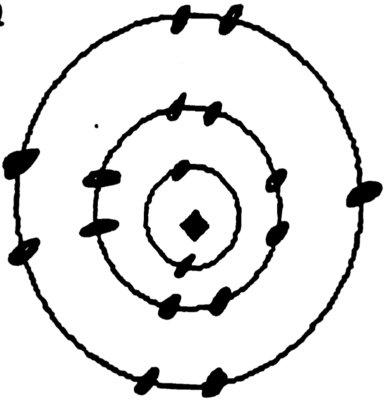
Magnesium (Mg)
12 protons
12 electrons
0 net charge



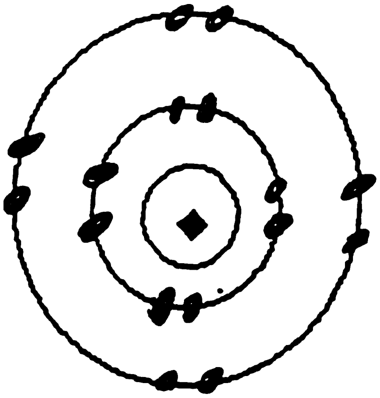


Magnesium Ion
12 protons
10 electrons
+2 net charge

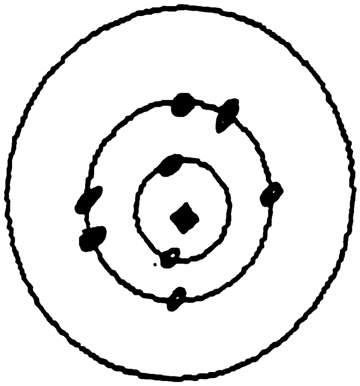
<u>Chlorine (Cl)</u>
17 protons
17 electrons
———
0 net charge



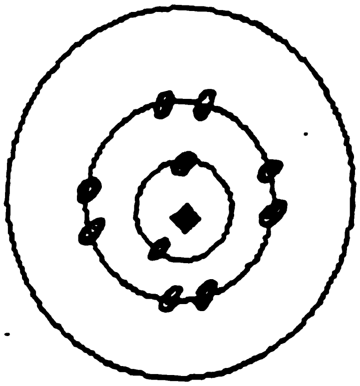
<u>Chloride Ion</u>
17 protons
18 electrons
———
-1 net charge



<u>Oxygen (O)</u>
8 protons
8 electrons
———
0 net charge



<u>Oxide Ion</u>
8 protons
10 electrons
———
-2 net charge



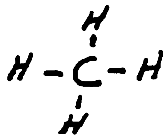
Common Functional Groups

<1> Hydrocarbon

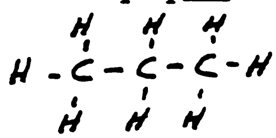
-H

Alkanes ==> Contain only single bonds
named by dropping -yl and addinh -ane

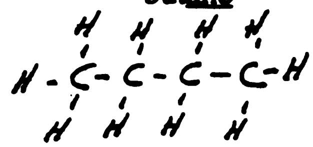
methane



propane

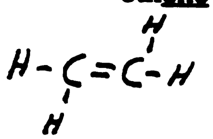


butane

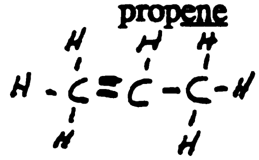


Alkenes ==> Contain at least 1 double bond
named by dropping -yl and adding -ene

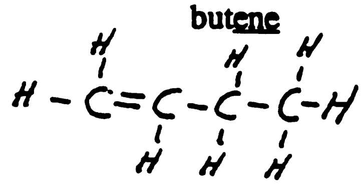
ethene



propene

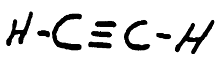


butene

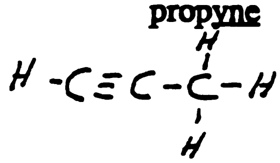


Alkynes ==> Contain at least 1 triple bond
named by dropping -yl and adding -yne

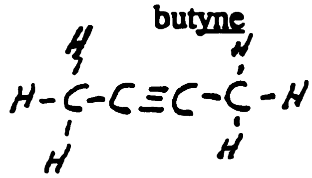
ethyne



propyne



butyne

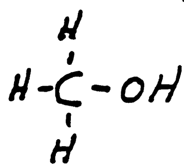


<2> Hydroxyl (alcohol)

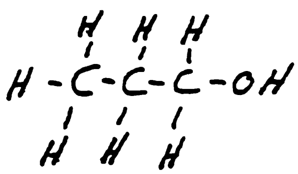
-OH

named by dropping -yl and adding -anol

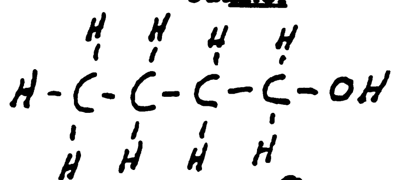
methanol



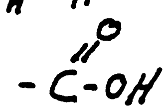
propanol



butanol

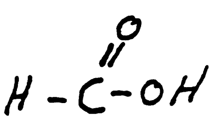


<3> Carboxyl

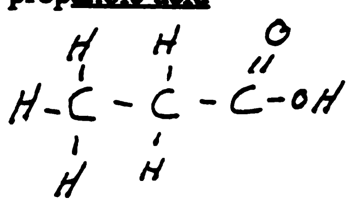


named by dropping -yl and adding -anoic acid

methanoic acid



propanoic acid

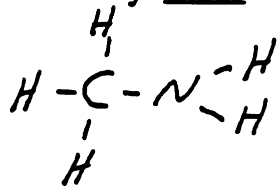


<4> Amine

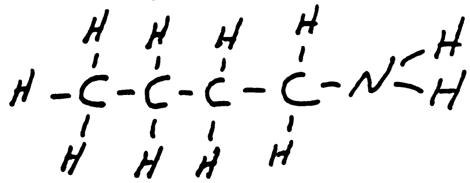
named by carbon chain and "amine"

$-NH_2$

methyl amine

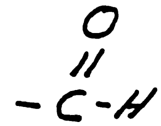


butyl amine

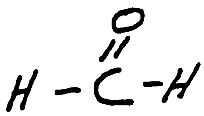


<5> Aldehyde

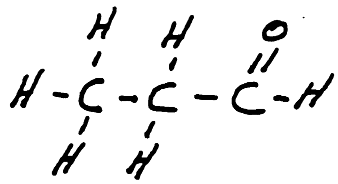
named by carbon chain and "aldehyde"



methyl aldehyde

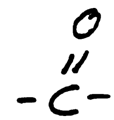


propyl aldehyde

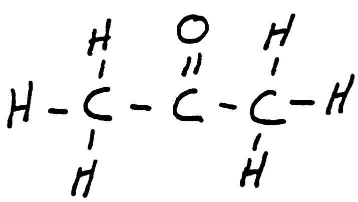


<6> Ketone

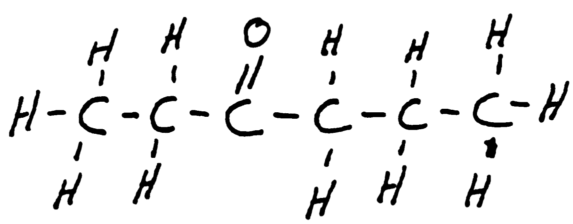
named by carbon chains and "ketone"



dimethyl ketone
(methyl ketone)

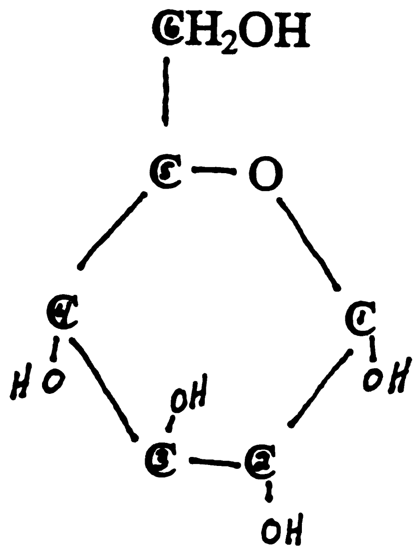


ethyl propyl ketone

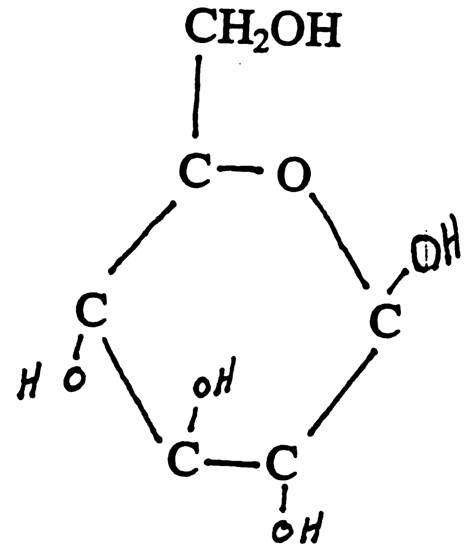


Common Monosaccharides

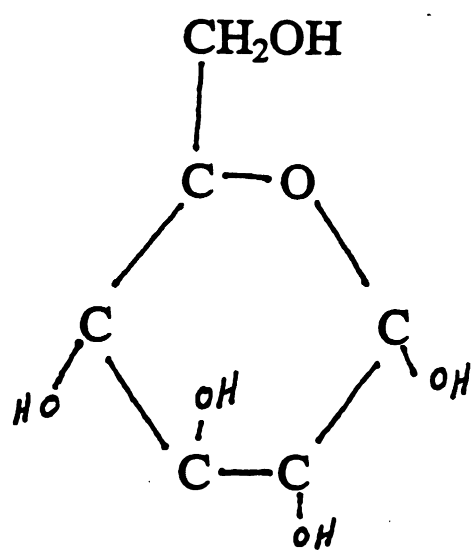
Hexose sugars consist of six carbons ($C_6H_{12}O_6$)



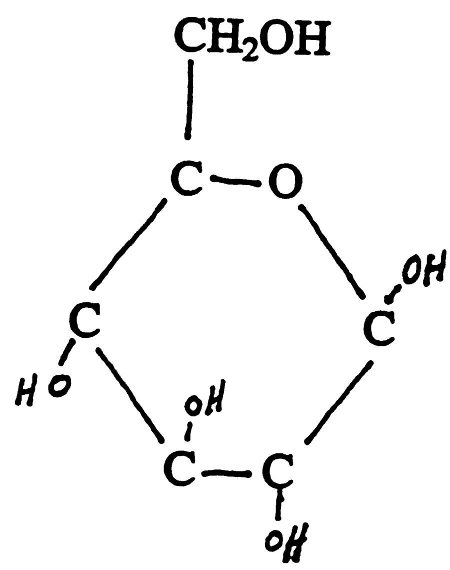
alpha glucose



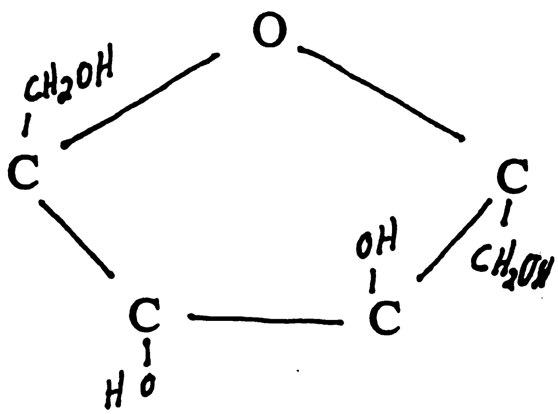
beta glucose



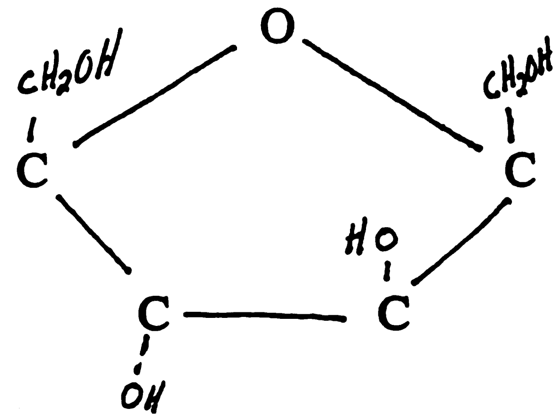
alpha galactose



beta galactose

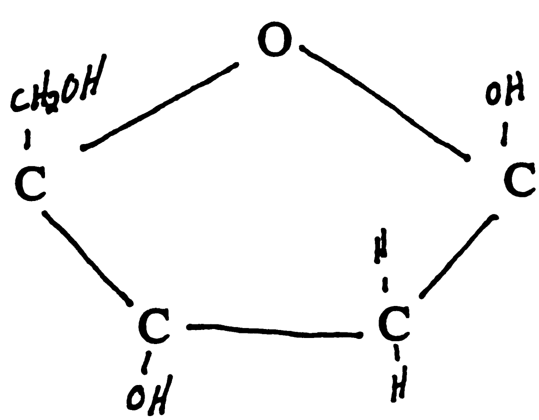


alpha fructose

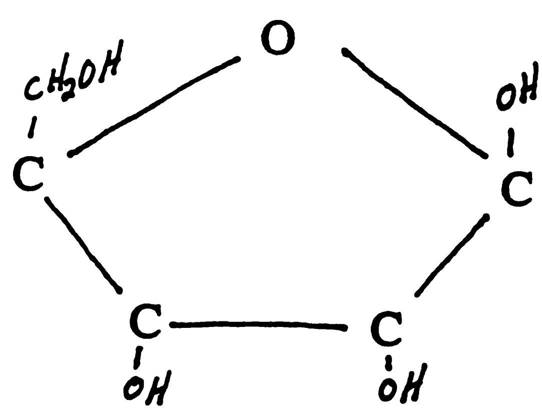


beta fructose

Pentose sugars: 5 carbon sugars



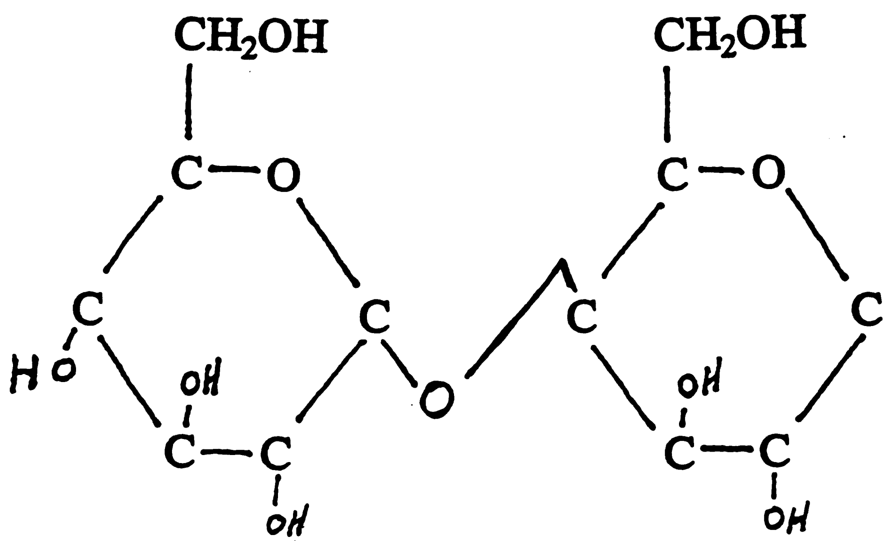
deoxyribose



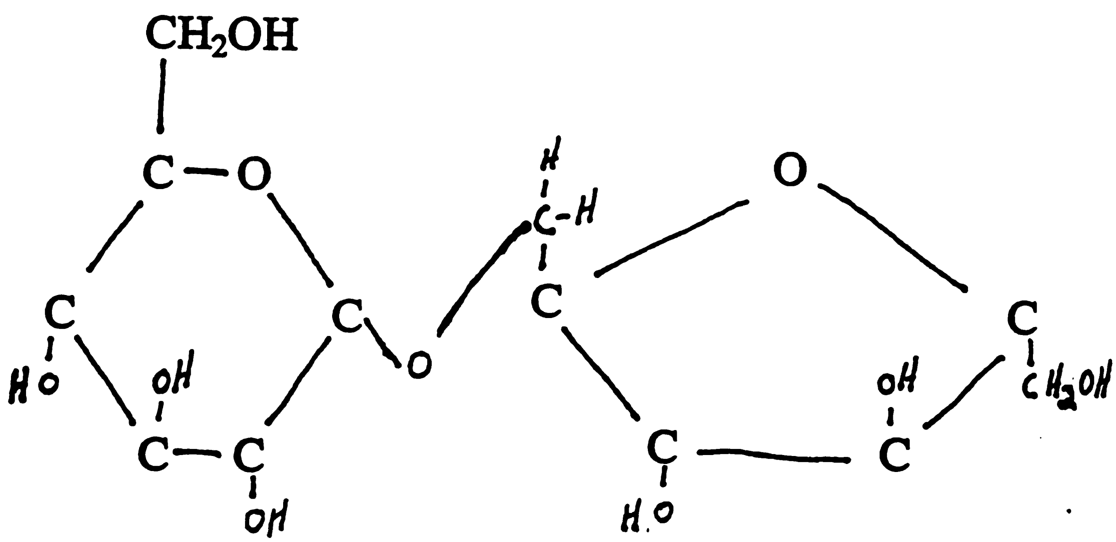
ribose

Common Disaccharides

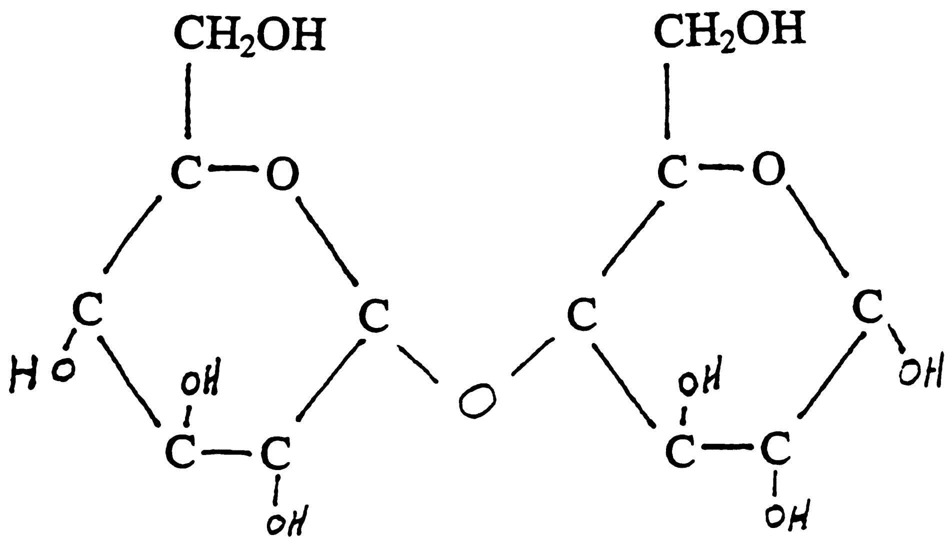
Lactose = alpha glucose + galactose



Sucrose = alpha glucose + fructose



Maltose = alpha glucose + alpha glucose



Appendix C:

Student Worksheets

- W.S. 1: Concepts of the Atom
- W.S. 2: Water: The Molecule of Life
- W.S. 3: pH and Buffers
- W.S. 4: Carbon, Carbon Chains and Functional Groups
- W.S. 5: Carbohydrates
- W.S. 6: Lipids
- W.S. 7: Proteins and Nucleic Acids
- W.S. 8: Energy and Thermodynamics
- W.S. 9: Enzymes

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W.S. 1: Concepts of the Atom

1. Define the following terms:
A. element:

B. atom:

C. atomic number:

D. atomic mass:

E. isotope:

F. molecule:

G. compound:

H. mixtures:

2. Protons are located in the ______________ of the atom, have a charge of ______________ and a mass of ___________ dalton(s).

3. _______________ are found surrounding the nucleus, have a charge of ______________ and a mass of ________________ dalton(s).

4. Neutrons are located in the ______________ of the atom, have a charge of _______________ and a mass of ______________ dalton(s).

5. Which particle participates in chemical reactions ? ______________

6. An atom of sodium (Na) has 11 protons, 12 neutrons and 11 electrons. Determine the atomic number and the atomic mass of this atom.

7. An atom of phosphorus (P) has an atomic number of 15 and an atomic mass of 31 daltons. Determine the number of protons, neutrons and electrons in this atom.

8. Although no model of the atom gives an exact "picture", different models can help to visualize different important characteristics of atoms. What characteristic(s) of the atom was stresses by the **Planetary Model** ? What important characteristic(s) of electrons is illustrated by the **Bohr Model** ? What additional information about electrons is provided by the **Orbital Model** ?

9. What makes an atom chemically "stable" ?

10. How many electrons can "fit" into the first energy level ? Into the second ?

11. Using the **Bohr Model** diagram in figure 1-3 as a guide, diagram the arrangement of protons, neutrons and electrons in each of the following: A. He B. Na C. O D. N E. C F. Ne

12. Based on the arrangement of electrons in the valence shells, predict the ionic charge on each of the following:

A. H ________ C. Na ____________ E. O ____________

B. F ________ D. Ba ____________ F. N ____________

13. Describe three ways in which **ionic bonds** differ from **covalent bonds.**

14. How do **polar covalent bonds** differ from **non-polar covalent bonds** ?

15. Based on the arrangement of electrons in the valence shell, predict the maximum number of covalent bonds that each of the following can form:

A. H ______________	C. N ______________	E. P ______________
B. C ______________	D. O ______________	F. S ______________

16. List the properties that the six biologically important elements share.

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W.S. 2: Water: The Molecule of Life

1. Based on its structure, explain why water is polar ?

2. Describe and give a **specific example** that illustrates each of the following properties of water.

A. surface tension:

B. capillary action:

C. imbibition:

D. cohesion:

E. adhesion:

3. Define the following properties **and** describe how water compares to other compounds for each:

A. specific heat:

B. heat of vaporization:

C. heat of fusion:

4. How does the density of water change as the temperature drops from 10 degrees Celsius to 0 degrees Celsius ?

5. On a molecular level, what work is accomplished by the equivalent of the heat of fusion ?

6. The freezing point of a solution is ___________________ than the freezing point of the pure solvent.

7. List 3 or 4 adaptations that various organisms use to survive freezing temperatures.

8. Differentiate between **hydrophillic** and **hydrophobic** compounds.

9. How can you predict, given their relative polarities or structures, whether a certain solute is soluble in a given solvent ?

10. Describe the three layers in s stratified lake and the changes that occur in these layers during each season.

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W.S. 3: pH and Buffers

1. When water ionizes, what ions are actually formed ?

2. In any sample of pure water, only a(n) ____________ percentage of the water actually will ionize.

3. Define **acids** and **bases** in terms of their hydrogen ion and hydroxide ion concentrations.

4. How do **strong** acids and bases differ from **weak** acids and bases ?

5. Why does the **carboxyl group** exhibit basic properties in solution ?

6. Why does the **amine group** exhibit basic properties in solution ?

7. What are the molar concentrations of hydrogen ions and of hydroxide ions in pure water ?

8. What is the **pH scale** ? What is the basis for its measurement ?

9. What is the pH of pure water ? ______________

10. Describe the three criteria that are used to fully define acids and bases.

11. What is a **buffer** composed of ? Describe the basic function of buffers.

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W.S. 4: Carbon, Carbon Chains and Functional Groups

1. List the four major types of organic molecules.

2. Organic molecules are basically composed of two parts: a(n) __________ skeleton and a(n) ______________ group.

3. How many carbons are in each of the following chains:

A. methyl	__________	E. pentyl	__________	H. octyl	__________
B. ethyl	__________	F. hexyl	__________	I. nonyl	__________
C. propyl	__________	G. heptyl	__________	J. decyl	__________
D. butyl	__________				

4. ______________ are organic molecules that contain only hydrogen and carbon.

5. For each of the following functional groups, draw its structure and state whether it is polar or non-polar:

A. hydroxyl:

B. carboxyl:

C. amine:

D. aldehyde:

E. ketone:

F. hydrocarbon:

G. phosphate:

6. Where is energy "stored" in a molecule ?

7. What type of bond has more energy stored in it: a single bond or a double bond ?

8. Even though silicon (Si) is more abundant in nature than carbon (C), it is rarely found in living systems. Give four reasons for carbon's abundance in living systems.

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W.S. 5: Carbohydrates

1. What is the most common organic molecule in the biosphere ? ________________

2. Differentiate between **monosaccharides**, **disaccharides** and **polysaccharides**.

3. What is the general formula for a monosaccharide ? ________________

4. Look carefully at the structural formula of alpha and beta glucose. What is the specific difference between these two isomers ?

5. Which functional groups provide the structural difference between fructose and glucose ?

6. In what form is sugar principally **stored** in vertebrates ? ________________

7. In what form is sugar principally **stored** in non-vertebrate organisms ?

8. How do two monosaccharides join together to form a disaccharide ?

9. For each of the following disacharides, state the two monosaccharides of which it is composed:

A. <u>sucrose:</u> ________________ and ________________

B. <u>maltose:</u> ________________ and ________________

C. <u>lactose:</u> ________________ and ________________

10. When a molecule is hydrolyzed, energy is ____________________.

11. ____________________ is the principal food storage molecule in plants.

12. How does **amylose** differ structurally from **amylopectin** ?

13. ____________________ is the principle structural molecule in plants.

14. ____________________ is the principal form of sugar storage in higher animals.

15. How does **cellulose** differ structurally from **starch** ? What is the biological significance of this difference ?

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W.S. 6: Lipids

1. Why do animals store food as fats rather than as carbohydrates ?

2. Describe the structure of a **fatty acid**. What property does this structure give to the fatty acid ?

3. Describe the formation of a fat from glycerol and fatty acids.

4. How do **saturated, unsaturated** and **polyunsaturated** fats differ structurally ? How do they differ in appearance ? How do they differ in where they are normally found ?

5. One of the main functions of fats is as an energy source. Describe two other functions of fats in organisms.

6. Describe the structure and function of **phospholipds**.

7. Describe the structure and function of **glycolipids**.

8. Why are **steroids** grouped with the other lipids ?

9. Briefly describe the general structure of a steroid.

10. Where is **cholesterol** formed and what is its function ?

11. List three other steroids along with their functions.

12. What role do **HDL's** and **LDL's** play in cholesterol regulation ?

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W.S. 7: Proteins and Nucleic Acids

1. Proteins are polymers of _____________ _____________.

2. Describe the different biological functions of proteins and give a specific example for each.

3. Draw the basic structure of an **amino acid**. Circle and label the **carboxyl group** and the **amine group**.

4. There are only _________________ different amino acids.

5. Describe the four structural groups that the amino acids can be divided into.

6. Amino acids join together in a simple _______________ reaction.

7. Proteins are broken down in a(n) ______________________ reaction.

8. The linkage between two amino acids is called a(n) ________________ bond or linkage.

9. Which atoms from each amino acid participate in the formation of the peptide bond ?

10. Describe the four structures of proteins. How is each structure maintained.

11. Amino acids and fats are synthesized from ________________ by cells.

12. What element(s) is found in amino acids but not in fats or sugars ?

13. What nutritional problems do vegetarians have to carefully avoid ?

14. Why do rice and beans make such a good combination from a nutritional standpoint ?

15. List the four types of **fibrous proteins** and the function of each.

16. Using hemoglobin as an example, discuss how a change in the amino acid sequence can affect both the structure and function of the protein.

17. What is the basic function of a **nucleic acid** ?

18. Nucleic acids are polymers of ______________.

19. List the three molecules that comprise a nucleotide.

20. How do **purines** and **pyrimidines** differ ?

21. How do **DNA** and **RNA** differ structurally ?

22. How does the function of DNA and RNA differ ?

Advanced Biology
Mr. Foley

W.S. 8: Energy and Thermodynamics

1. ___________________ is the science of energy transformations.

2. State, in your own words, the **First Law of Thermodynamics.**

3. State, in your own words, the **Second Law of Thermodynamics.**

4. Define the following terms:

A. endergonic:

B. exergonic:

C. exothermic:

D. endothermic:

5. What is **entropy** ?

6. State the **Gibbs Free Energy** equation and define each term in the equation.

7. How can the Gibbs free energy of a reaction determine if the reaction will proceed spontaneously or not ?

Advanced Biology
Mr. Foley

W.S. 9: Enzymes

1. Define *activation energy.*

2. A(n) ______________ is a substance that lowers the activation energy of a reaction without being used up itself.

3. Why do living things need catalysts ?

4. A(n) ______________ is a biological catalyst.

5. The ______________ is the molecule on which an enzyme acts.

6. Describe the basic structure of an enzyme.

7. ______________ are non-protein parts of the enzyme that are necessary for normal enzyme function.

8. ______________ are organic cofactors necessary for normal enzyme function.

9. Briefly describe 3 advantages cells derive from *enzymatic pathways.*

10. How does a rise in temperature affect uncatalyzed chemical reactions ?

11. How is this effect different for a catalyzed reaction ?

12. An enzyme is _____________ when its tertiary structure is disrupted.

13. How do changes in pH affect enzyme function ?

14. Define and give a specific example for each of the following regulatory processes:
A. allosteric interactions:

B. competitive inhibition:

C. non-competitive inhibition:

D. irreversible inhibition:

Appendix D:

Lab Exercises (with instructor's manual)

- Lab 1: Separation of Dyes by Reverse-Phase Chromatography
- Lab 2: Comparing Specific Heats
- Lab 3: Measuring pH
- Lab 4: Buffers in Biological Systems
- Lab 5: The Structure of Organic Molecules
- Lab 6: Comparing Fat and Water Content in Hot Dogs
- Lab 7: Determining the Molecular Weight of Proteins
- Lab 8: Measuring Enzyme Reaction Rates
- Lab 9: Enzyme Function

Lab 1: Separation of Dyes By Reverse-Phase Chromatography

Introduction

This lab utilizes a laboratory separation technique called **Reverse-Phase Chromatography** to separate the dyes from various grape drinks. Separation techniques have always been important in pure and applied science. The separation and identification of pure components of a mixture allows scientists an in depth understanding of the overall properties of the mixture. Historically, separation techniques have been time-consuming, tedious and inexact. The products that resulted were often impure and in an undesirable condition for precise identification and analysis. Reverse-phase column chromatography was invented in mid-1970. It is a simple, rapid and accurate method of separation. It may be used to separate drugs from urine or certain toxins from food samples. Reverse-phase column chromatography allows separation based on the different polarities and solubilities of the components. When the grape drink sample is injected into the column containing silica gel with octadecyl bonded to it, the relatively non-polar dyes will bond to the non-polar octadecyl. The dyes will be clearly visible in the gel. The water and other polar components can not stick to the gel and will run through the column. Additional water will be used to wash out any impurities from the column. Two elution solvents of different polarities will be used to separate the dyes. The first solvent (dilute ethanol) will dissolve the more polar of the dyes. The second solvent (dilute isopropanol) will dissolve the more non-polar of the dyes. By changing the concentrations of these solvents or by using solvents of different polarities, other molecules may be separated using reverse-phase column chromatography.

By completing this lab, students will:

- Become familiar with the technique of reverse-phase column chromatography
- Use reverse-phase column chromatography to separate the dyes in grape drinks
- Compare the dyes used in different grape drinks
- Compare reverse-phase column chromatography with other separation techniques
- Introduce students to the concept of polarity and the relationship between the polarity of solute and solvent in a solution
- Develop the essential laboratory skills of following directions, making accurate observations and analyzing data

Materials and Methods

Each group will need:

1 reverse-phase column
1 3 ml syringe
8 small test tubes
9 ml dilute isopropanol
9 ml dilute ethanol
20 ml 70% isopropanol
distilled water
grape drink samples

1. Label the test tubes A1-A4 and B1-B4

2. Fill the syringe with 70% isopropanol and pre-wet the column by dispensing the alcohol through the column. Allow it to drip through. Use air pressure from the syringe to help force the solution through. Discard solution.

3. Flush column with 3 ml of distilled water. Discard the water.

4. Load syringe with 1 ml of grape drink (sample A). Inject the sample into the column. Force sample through the column by using the syringe to force air into the column. Collect the fraction that comes out in tube A1.

5. Wash column with 3 ml of distilled water. Collect this fraction in tube A2.

6. Wash column with 1 ml of the dilute ethanol solution. **DO NOT** force the solution through the column. Let gravity do the work. Collect fraction in tube A3.

7. Wash column with 1 ml of dilute isopropanol. Collect fraction in tube A4.

8. Wash column with 3 ml of 70% isopropanol. Discard fraction.

9. Repeat steps 3-8 using the other sample and the other test tubes.

10. When finished, wash the column with 70% isopropanol. Force air through the column 3 or 4 times to completely discharge the alcohol.

Results

Present data in a neat, orderly and logical table

Interpretations and Conclusions

1. Which properties of the dyes were used to separate them in this lab ?

2. Describe the relationship between the polarity of a solute and the polarity of the solvent it is dissolved in.

3. Why can't water be used to effectively clean a brush used with oil-based paints ?

4. Why don't the dyes come off in the water wash ?

5. Sugar is a polar substance. In which fraction(s) would you expect to find sugar ?

6. From the results of this lab, what can you determine about the composition of the two samples ?

Teacher's Guide

Time Frame: One 40-60 minute period

Target Group: Advanced or Regular Biology students

Preparation of Materials: Assuming 10 groups

70% isopropanol - Use 200 ml as purchased

dilute isopropanol - Dilute 20 ml of 70% isopropanol with 70 ml of distilled water

dilute ethanol - Dilute 20 ml of 70% ethanol with 70 ml of distilled water

Sources of Materials:

Most materials are commonly and easily available. The chromatography column can be purchased from:

J.T. Baker
Phillipsburg, NJ 08865
Phone: (201) 859-2151

The column used is the "Baker" spe™ 3 ml disposable column packed with silica gel with octadecyl bonded to it (cat # 7020-02).

Comments:

The procedure was derived using grape KOOL-AID. Grape juices tend to clog the column and do not work well. It is important to expel the solvents very slowly through the column. If the solvents are forced through too quickly, the break between the dyes is not "clean" and some mixing will occur.

References:

Lowe, C.R. and P.D.G. Dean. Affinity Chromatography. New York: John Wiley and Sons, 1974.

Baker - 10 spe Applications Guide, Vol. 1 (1982), Vol. 2 (1984). Phillipsburg, NJ: J.T. Baker Inc.

J.T. Baker Solid Phase Extraction Manual. Phillipsburg, NJ: J.T. Baker Inc.

High School Biology and Chemistry Teachers Research Manual. Workshop in Molecular Biology: Michigan State University, 1989.

Lab 2: Comparing Specific Heats

Introduction

One of the characteristics that all living things possess is **homeostasis**. They must maintain a relatively stable internal environment that can be quite different from their external environment. Living things rely on many processes in order to maintain this balance. In fact, homeostasis will be a recurring theme throughout this course. In order to maintain a steady temperature, living things rely in large measure on the high specific heat of water.

The **specific heat** of a substance is a measure of how much energy it takes to change the temperature of 1 gram of the substance by 1 Celsius degree. In other words, it takes more energy to heat up a substance with a higher specific heat than a substance with a lower specific heat. This value is constant for each substance. The equation used to represent this relationship is:

$$Q = M * C * \Delta T$$

Q = the heat energy added or removed (joules)
M = mass of the substance (grams)
ΔT = the change in Celsius (or Kelvin) temperature
C = the specific heat (joules/gram * ^{o}C)

Water has an unusually high specific heat compared with all other common substances. For example, the specific heat of water is 10 times that of iron. In this lab, the rate of temperature increase and decrease for sand and water will be compared and the relative specific heats will be calculated.

By completing this lab, students will:

- Gain a better understanding of the property of specific heat
- Calculate the relative specific heats of sand and water based on the rates of temperature change
- Appreciate the importance of water in maintaining homeostasis
- Develop the essential laboratory skills of making accurate measurements, recording data, graphing data and analyzing data

Materials and Methods

<u>Each group will need:</u>
2 small insulated containers (styrofoam cups)
100 grams of water
100 grams of sand
2 thermometers
high-intensity light source

1. Place 100 grams of sand into an insulated container. Place 100 grams of water into the other container.

2. Place the cups next to each other and **carefully** insert a thermometer into each.

3. Measure and record the initial temperature of each.

4. Suspend the high-intensity light source above the containers so the light strikes both equally. Turn on the light.

5. Record the temperature in each container at 1 minute intervals for 30 minutes. After 15 minutes, turn off the light.

6. Plot the results for both containers on the same graph using different colors. Mark the point where the light was turned off.

Results

Data should be presented in a neat, logical and orderly table. Graphs should be plotted following the prescribed format.

Interpretations and Conclusions

1. Which substance has the higher specific heat ? Support your answer with specific evidence from your data.

2. Calculate the ratio of the specific heat of water to the specific heat of sand. Assume both received the same amount of light.

3. An adult human is composed of about 60% water while a baby is almost 80% water. Based on the results of this lab, discuss the advantage *to the baby* of this difference.

4. Based on your results, explain why coastal areas are usually warmer in winter and cooler in summer when compared to inland areas in the same region.

Teacher's Guide

Time Frame: One 40-60 minute period

Target Group: Advanced Biology or Physics class

Preparation of Materials: No preparation necessary. Sand and water may be placed in containers ahead of class to save time.

Source of Materials: All materials can be obtained easily from various sources.

Comments: This lab can also be done as a demonstration using computer-interfaced temperature probes. The students can copy the data from the computer after class. Some students may have trouble working through the calculations to find the relative specific heats, especially if they have not had physics.

References:

Brady, James E. and John R. Holum. Fundamentals of Chemistry. New York: John Wiley and Sons, 1984.

Curtis, Helena and N. Sue Barnes. Biology 5th Ed. New York: Worth Publishers, 1989.

Lab 3: Measuring pH

Introduction

Molecules that are dissolved in water may **ionize** or **dissociate** into charged fragments or ions. This is true for ionic compounds and for some covalent compounds as well. One of these fragments may be the hydrogen (H^+) ion. Compounds that dissociate to form hydrogen ions are called **acids**. Compounds that dissociate to form hydroxide (OH^-) ions are called **bases**. In fact, any compound that causes an increase in the number of hydrogen ions or a decrease in the number of hydroxide ions is classified as an acid. Any compound that causes an increase in the number of hydroxide ions or a decrease in the number of hydrogen ions is classified as a base. When water dissociates it forms both hydrogen (in the form of hydronium) ions and hydroxide ions. Since the number of hydrogen ions formed equals the number of hydroxide ions formed, water is said to be **neutral**. The **pH** of a solution is a measure of the hydrogen ion concentration in the solution. The pH value of a solution is equal to the negative logarithm of the hydrogen ion concentration. The pH of a 1.00×10^{-3} M HCl solution would have a pH of 3, while a 1.00×10^{-5} M HCl solution would have a pH of 5. Acidic solutions have lower pH values than do basic or **alkali** solutions. A solution with a pH of 8 is more acidic than a solution with a pH of 10. Pure water has a pH of 7. In this lab, the pH of some common substances will be determined and compared using several different techniques.

By completing this lab, students will:

- Gain a better understanding of the concept of acids vs. bases
- Gain a better understanding of the concept of pH
- Determine the pH of several common substances using several techniques
- Understand that different techniques involve different levels of accuracy
- Determine the effective range of some common indicators
- Develop the essential laboratory skills of following directions, making and recording accurate measurements and observations and analyzing data

Materials and Methods

Each group will need:
12 10 ml test tubes or other comparable containers
15 ml of each of the following solutions:

decarbonated **7-Up**	coffee
apple juice	decarbonated cola
tomato juice	milk
aspirin	**Maalox**
ammonia	dish soap
Alka-Seltzer	acetaminophen

red and blue litmus paper
hydrion test paper
cabbage indicator solution
methyl orange indicator solution
phenolphthalein indicator solution

> **Be extremely careful handling all solutions. Treat all solutions as if they were strong acids or bases**

1. At the front of the room are solutions of known pH. The five tests that will be performed on solutions of unknown pH have been performed on these solutions. Record the results for each test noting color changes especially.

2. Place 5 ml of each unknown solution into separate test tubes.

3. Perform the red/blue litmus paper test and the hydrion paper test on each of the samples. Use forceps to hold the test papers. Record the results for each test.

4. Add 1 ml of cabbage indicator to each sample. Record your observations.

5. Rinse out each tube and repeat step 2.

6. Add 1 ml of phenolphthalein indicator to each unknown solution. Record your observations.

7. Rinse out the test tubes and repeat step 2.

8. Add 1 ml of methyl orange indicator to each unknown solution. Record your observations.

Results

Results should be presented in a neat, orderly and logical table. Rank the unknowns from the most acidic to the most basic. Show this ranking in a bar graph following the prescribed format.

Interpretations and Conclusions

1. Rank the tests from the most precise to the least precise and give reasons for your rankings.

2. Were you surprised at any of the results ? Explain.

3. Could methyl orange alone be used to determine if an unknown were an acid or a base ?

4. **Buffers** are substances that resist changes in pH by "soaking" up excess hydrogen and hydroxide ions. Why are most aspirins labelled as being buffered, while acetaminophen is not ?

5. It is often recommended that aspirin be taken with milk or water. Why are these substances better than coffee or cola ?

6. Spicy foods, coffee, aspirin and cola can all cause extreme stomach irritation. Why ?

7. What is the active ingredient in **Alka-Seltzer** ? What very common household chemical would make a much more economical alternative ? (Think ahead to when you will be a pizza-eating, low-on-money, stress-ridden college student !)

Teacher's Guide

Time Frame: One 40-60 minute class

Target Group: Advanced Biology classes

Preparation of Materials: Assuming 10 groups

Demonstration
A. Use prepared buffers of 2, 4, 6, 7, 8, 10, and 12. Follow the directions that come with the buffers. Prepare 150 ml of each.
B. Set up 3 sets of beakers. Each set will consist of a beaker containing 50 ml of one of the buffers.
C. Perform the litmus paper tests and the hydrion paper test on each of the first set of beakers. Place the papers in front of the beakers for the students to observe.
D. Add 5 ml of cabbage indicator to each beaker in set 1. Let stand for students to observe.
E. Add 50 ml of a buffer to each beaker in set 2. Add 5 ml of phenolphthalein indicator to each beaker. Let stand for students to observe.
F. Add 50 ml of a buffer solution to each beaker in set 3. Add 5 ml of methyl orange indicator to each. Let stand for students to observe.

Unknown Solutions
decarbonated 7-Up: allow to stand overnight
decarbonated cola: same as above
aspirin: dissolve 1.5 tablets in 150 ml of distilled water (use un-buffered aspirin)
Alka-Seltzer: dissolve 1 tablet in 150 ml of distilled water
acetaminophen: dissolve 1.5 tablets in 150 ml of distilled water

All other solutions can be used as they come packaged.

phenolphthalein indicator: dissolve 1.0 gram of dye in 700 ml of 95% ethyl alcohol. Dilute to 1.0 liter with distilled water.

methyl orange indicator: dissolve 1.0 gram of dye in 1.0 liter of distilled water.

cabbage indicator: Finely chop 1/4 head of red cabbage. Add to 500 ml of water. Boil until pigments are extracted. Filter.

Comments: Other substances may be substituted or students can bring in their own solutions. The prep time for the demonstration is extensive but saves class time for the main part of the exercise.

References:

Helms, Doris R. and Philip M. Coker. Preparator's Guide to Accompany More Biology in the Laboratory. New York: Worth Publisher's, 1989.

Helms, Doris R. and Carl W. Helms. More Biology in the Laboratory. New York: Worth Publisher's, 1989.

Joseph, Alexander, et al. A Sourcebook for the Biological Sciences. New York: Harcourt, Brace and Jovanovich, 1966.

Lab 4: Buffers in Biological Systems

Introduction

To remain alive, an organism must maintain a relatively constant internal environment. This balance is commonly known as **homeostasis**. One factor that must be maintained within very narrow limits is pH. This is accomplished through **buffer systems**. A buffer is a solution that resists changes in pH when small amounts of an acid or a base are added. Buffers are a mixture of a weak acid and a salt of that acid. The acid can release hydrogen ions while the salt can absorb hydrogen ions thus maintaining the pH. In this lab, the effects of adding acids and bases to distilled water and a known buffer solution will be compared. In addition, the buffering capabilities of various other substances associated with biological systems will be analyzed.

By completing this lab students will:

- Gain an understanding of buffers and their importance to biological systems
- Compare the buffering capabilities of various substances
- Develop the necessary laboratory skills of accurate observation, data collection, data graphing and data analysis
- Gain experience using common scientific tools correctly

Materials and Methods

Each group will need the following:

6 containers
2 eyedroppers
50 ml vinegar
50 ml ammonia
pH meter or pH test paper

Always be extra cautious when working with acids and bases !

1. Label the 6 containers A-F. Place 50 ml of solution into each according to the following procedure:
   A - distilled water
   B - phosphate buffer
   C - egg yolk solution
   D - egg white solution
   E - liver extract
   F - antacid solution

2. Measure and record the initial pH of each solution.

3. Add 3 drops of vinegar to each solution. Mix thoroughly by gently swirling.

4. Measure and record the pH of the solution.

5. Repeat steps 3 and 4 until either 48 drops of vinegar have been added or the pH has changed by 5 pH units (dropped from 7 to 2, for example).

6. Empty and thoroughly rinse each container. Repeat steps 1-5 substituting ammonia for the vinegar.

7. Plot a graph of drops of vinegar added vs pH for your data. Plot all data on the same graph using a different color for each solution.

8. Plot a graph of drops of ammonia added vs pH for your data. Plot all data on the same graph using a different color for each solution.

Results

Record results in a neat, orderly and logical table. Follow the prescribed format for graphing.

Interpretations and Conclusions

1. Rank the solutions in order from the smallest pH change to the largest pH change following the addition of the vinegar.

2. Rank the solutions in order from the smallest pH change to largest pH change following the addition of the ammonia.

3. Did any solution differ drastically in its ability to buffer when vinegar was added compared to when the ammonia was added ?

4. Which solution (C-F) showed the best overall buffering ability ?

5. Which solution (C-F) showed the greatest buffering ability against acids ?

6. Which solution (C-F) showed the greatest buffering ability against bases ?

7. Based on your data, do organisms tend to buffer acids or bases better? Explain.

8. Was there anything unusual or unexpected in your results ? Discuss possible reasons for any incongruities.

Teacher's Guide

Time Frame: One 40 - 60 minute class period

Target Group: Advanced Biology classes

Preparation of Materials: Each group will need 100 ml of each solution plus 50 ml of vinegar and 50 ml of ammonia. Preparation instructions assume 10 groups.

[A] Distilled water

[B] 1 liter of 0.25 M phosphate buffer (pH=7.4):
Mix together 35 grams of potassium phosphate dibasic (K_2HPO_4) and 7 grams of potassium phosphate monobasic (KH_2PO_4). Dissolve to 1 liter with distilled water.

[C] Dilute 6 egg yolks to 1 liter with distilled water.

[D] Dilute 6 egg whites to 1 liter with distilled water.

[E] Homogenize approximately 100 grams of fresh liver with 1 liter of distilled water. Strain through cheese cloth.

Use the ammonia and vinegar directly from the bottle in a well-ventilated area.

Sources of Materials: All materials are common and easily available.

References:

Arms, Karen and Pamela S. Camp. Biology, 3rd ed. New York: Saunders College Publishing, 1987.

Helms, Doris and Philip M. Coker. Preparator's Guide to Accompany More Biology in the Laboratory. New York: Worth Publishers, 1989.

Helms, Doris and Carl W. Helms. More Biology in the Laboratory. New York: Worth Publishers, 1989.

Lab 5: The Structure of Simple Organic Molecules

Introduction

An **organic** molecule is defined simply as a molecule that contains carbon. The simplest organic molecules consist of a carbon chain, 1 to 10 carbons long, bonded to a functional group. The functional group gives the compound its unique properties. A ten carbon chain with a hydroxyl group on it has different properties than a ten carbon chain with a carboxyl group attached to it. In this exercise, models will be used to show three-dimensionality of the molecules.

By completing this lab students will:

- Gain practice naming and recognizing organic molecules
- Gain an appreciation of the three-dimensionality of molecules
- Better understand isomers and the difference between chemical and structural formulas
- Demonstrate the ability of carbon to form single, double and triple bonds with itself
- Discover how the polarity of a molecule is related to its structure
- Demonstrate **hydrolysis** and **condensation** (dehydration synthesis) reactions
- Gain experience in using models to represent abstract ideas

Materials, Methods and Results

Each group will need:
1 Styrofoam ball
4 toothpicks
1 molecular model set

Part A: Carbon and its Bonds

It has been shown that carbon forms four bonds that are at equal angles from each other. Using the Styrofoam ball and the toothpicks, come up with a model of how the bonds are actually arranged.

1. Draw an accurate representation of how the model looks.

2. How is this model different from the way the bonds are usually represented ?

Part B: Hydrocarbons

The simplest of the organic molecules are the **hydrocarbons**. Hydrocarbon chains are an integral part of fatty acids. They consist of only hydrogen and carbon. The hydrocarbons are divided into 3 groups. The **alkanes** have only single bonds between the carbons. The **alkenes** have at least one double bond and the **alkynes** have at least one triple bond between carbons.

3. The simplest hydrocarbon is methane. How many carbons does methane have ?

4. Construct a model of methane. Draw the chemical and structural formulas for methane.

5. Is it relatively polar or non-polar ?

6. How many carbons are in ethane ?

7. Construct a model of ethane. Draw its chemical and structural formulas.

8. Is it relatively polar or non-polar ?

9. Construct molecules of propane and butane. Give their structural and chemical formulas.

10. Are these molecules relatively polar or non-polar ?

11. In general, are hydrocarbons polar or non-polar ?

12. Construct a molecule of ethene. Give its chemical and structural formulas.

13. Construct a molecule of ethyne. Give its chemical and structural formulas.

Part C: Alcohols

Alcohols consist of a carbon chain bonded to a **hydroxyl** (-OH) group. Ethanol is an important product of fermentation. Glycerol, which has three hydroxyl groups, comprises the backbone of triglycerides.

14. Construct a molecule of methanol. Draw the structural formula. Circle and label the carbon chain and the functional group.

15. Construct a molecule of ethanol. Draw its structural formula. Does changing the position of the hydroxyl group change the structural formula ?

16. Construct a molecule of propanol. Bond the hydroxyl group to one of the end carbons. Draw the structural formula. What is its chemical formula ?

17. Move the hydroxyl group to the middle carbon. What is the chemical formula of this compound ? Draw its structural formula.

18. What is the relationship between the molecules made in 16 and 17 ?

19. What is the name of the common household compound made in 17 ?

20. In general, as the number of carbons in a compound increases, what happens to the polarity of the compound ?

Part D: Amines and Acids

The amines consist of a carbon chain bonded to an **amine** ($-NH_2$) group. This group can accept hydrogen ions and acts as a base in solution. Organic acids consist of a carbon chain bonded to a **carboxyl** (-COOH) group. This group can ionize in solution to form hydrogen ions. Both the amine group and the carboxyl group are found in amino acids. The removal of the amine groups (deamination) from amino acids produces the nitrogenous wastes (urea, uric acid and ammonia) that living things must excrete.

21. Construct molecule of methyl amine, ethyl amine and propyl amine. Draw the structural formulas for each.

22. The carbon in the acid group is included when naming the molecule. Construct molecules of methanoic acid, ethanoic acid and propanoic acid. Draw the structural formulas for each.

23. Describe why these molecules are classified as acids.

24. Bond an amine group and an acid group to a carbon. Fill in the other two bonds with hydrogens. This is a model of the **amino acid** glycine. Draw the structural formula for glycine. Circle and label the amine group and the carboxyl group.

Construct a second glycine molecule. Remove a hydrogen from the amine group of one glycine and the -OH from the carboxyl group of the other glycine. Join the molecules together at these open bonds. The bond that forms between two amino acids is called a **peptide bond.**

25. Bond the left-over hydrogen and hydroxyl groups together. What molecule is formed ?

26. When two molecules bond together and produce water, what type of reaction is it ?

27. Separate the two glycine molecules where they were joined. What must be added in order to accomplish this ?

28. What type of reaction occurs when two molecules are split with the addition of water ?

Lab 6: Comparing the Fat and Water Content of Hot Dogs

Introduction

Even though over 19 billion hot dogs are consumed by Americans each year, they are not very nutritious. Hot dogs are mostly fat and water. The average cooked hot dog is a little over half water. Most of that is naturally found in meat, but the USDA allows manufacturers to add an additional 10%. The USDA also allows manufacturers to make hot dogs with up to 30% fat. That leaves only about 13% protein. The rest is made up of sweeteners, flavoring agents, preservatives and inorganic materials. Hot dogs are a very expensive source of protein. The average cost of protein in hot dogs is about $15.00 per pound. Different types of hot dogs are made from different meats and contain different amounts of fat, water and protein. More expensive hot dogs should contain more protein and less fat and water. Hot dogs made from chicken or turkey should have less fat than those made with beef and pork. In this lab, the fat and water content of an all-beef hot dog, a mixed meat hot dog and a chicken hot dog will be analyzed and compared.

By completing this lab, students will:
- Learn to apply basic extraction techniques
- Compare the contents of different types of hot dogs
- Compare the results of this lab with the results reported on the package
- Discover any relationship between cost and contents
- Discover any relationship between meat content and fat/water content
- Develop the essential laboratory skills of following directions, making and recording accurate measurements and analyzing data

Materials and Methods

Each group will need:
3 hot dogs (1 of each type)
3 evaporating dishes
3 beakers
3 drying dishes
scalpel

Part A: Fat Content
Be careful working with the solvent. Avoid long exposure to the fumes. Wash hands immediately after use.

1. Cut hot dog in half. Measure and record the mass of one half. Set aside the other piece for part B. Cut the piece into very small pieces with the scalpel. Scalpels are extremely sharp. Be careful. Place the pieces in the beaker.

2. Add 15 ml of methylene chloride to the pieces in the beaker. Using a stirring rod, smash the pieces around. The solvent will extract the fat.

3. Repeat for each type of hot dog.

4. Label 3 evaporating dishes. Measure and record their masses.

5. Filter the solvent-fat solution from the beakers into the evaporating dishes.

6. Set the evaporating dishes under the fume hood overnight. The solvent will evaporate leaving the fat behind.

7. After all the solvent has evaporated, measure and record the mass of the evaporating dish. Determine the mass of fat by subtraction.

8. Determine the percentage of fat in the hot dogs.

Part B: Water Content

1. Label 3 drying dishes. Measure and record the masses of the remaining hot dog halves.

2. Cut up the hot dogs into small pieces. Place the pieces on the drying dishes.

3. Measure and record the masses of the drying dishes with the hot dogs.

4. Place the hot dogs in a 250° (F) oven to dry. Measure and record the mass of the hot dog and drying dish. Assume the difference in masses is due to water loss.

5. Determine the percentage of water in each hot dog.

Results

Results should be displayed in a neat, orderly and logical table. Compare the water and fat percentage for each hot dog type in separate bar graphs using the prescribed format.

Interpretations and Conclusions

1. Which hot dog had the highest percentage of fat ? Was this expected ?

2. Which hot dog had the highest percentage of water ? Was this expected ?

3. Did the fat content show any relationship with the cost of the hot dogs ? How about the water content ?

4. List the ingredients, in order, for each hot dog.

5. Compare the results of this lab with the government standards and the package analysis. Present findings in a table showing brand, government standard, package analysis and the results of this lab for fat and water content.

Teacher's Guide

Time Frame: Two 20-30 minute periods on consecutive days

Target Group: Advanced Biology classes

Preparation of Materials: per group
1 all-beef hot dog
1 mixed-meat hot dog
1 all-turkey/chicken hot dog
50 ml of methylene chloride or butyl alcohol

Source of Materials:
All materials are easily and commonly available. The solvent might be available from a dry cleaning supplier at a lower cost.

Comments: The final weighings may be done on the students own time. The solvent used is relatively safe but common sense precautions should be taken.

References:
"Hot Dogs". Consumer Reports, June 1986, pg. 364-368.

Eby, Denise and Roger Tatum. The Chemistry of Food (Teacher's Guide). Seattle, WA: Unigraph, 1977.

Lab 7: Determining the Molecular Weight of Proteins

Introduction

There are many techniques that scientists use to separate substances from each other. One of the most important to the molecular biologist is **electrophoresis**. Electrophoresis is used to separate molecules based on their abilities to move in an electric field. The speed at which molecules move depends on their size and charge. In this lab, a mixture of known proteins will be separated by electrophoresis in an agarose gel. In addition, the molecular weights of two unknown proteins will be determined by comparing their movement with the movement of the known proteins.

By completing this lab, students will:

- Become familiar with the technique of electrophoresis
- Contrast electrophoresis with other separation techniques
- Develop the essential laboratory skills of making and recording accurate measurements, plotting graphs and analyzing data

Materials and Methods

Each group will need:
an electrophoresis chamber and power supply
250 ml of electrophoresis buffer
60 ml of gel buffer
3.2 g of agarose

1. Carefully read the entire attached manual.

2. Follow the directions **exactly** as given in the manual with the following exceptions:

   [A] Use 3.2 grams of agarose and 60 ml of gel buffer to prepare the gel. Tap the gel gently against the table top to remove air bubbles.

   [B] Fill the electrophoresis chamber with 250 ml of electrophoresis buffer.

   [C] Load wells with 15 microliters of solution instead of 10 microliters.

   [D] DO NOT cover the wells with agarose.

   [E] Run the gels at 50 volts for 3 to 4 hours. Check the gel occasionally to be sure the proteins have not run off the edge.

Results

Carefully measure the distance the four known and two unknown proteins migrated from the well. Record data in a neat, orderly and logical table. Plot a graph of distance travelled vs the log_{10} of the molecular weight for the four known proteins. Follow the prescribed format for graphing.

Interpretations and Conclusions

1. Using the graph, determine the molecular weights of the unknown proteins.

2. Interferon is a protein with a molecular weight of 25 000 daltons. How far would it have migrated based on the data from this lab ?

3. The average amino acid residue in a protein has a molecular weight of 120 daltons. Assuming that your unknown proteins are average, how many amino acids are in each ?

4. Why is SDS added to the buffer solutions ? What would happen if it were not included as an ingredient ?

5. What property was used to separate the proteins in this lab ?

6. Polyacrilamide is a much better medium than is agarose for the electrophoresis of proteins. Why is agarose used instead ?

Teacher's Guide

Time Frame: Two 40-60 minute periods plus time in between to run the gels

Target Group: Advanced Biology students

Preparation of Materials: **Follow the directions given in the literature that accompanies the kit.**

Source of Materials: **This exercise is based on Experiment 201 from:**

Modern Biology Inc.
P.O Box 97
Dayton, IN 47941-0097
1-800-733-6544

Besides ordering the chemical package for this specific experiment, the electrophoresis kit (EP-2) must also be ordered.

References:

Anderson, John. Molecular Biology of Proteins (Student Manual). 1986.

Lab 8: Measuring Enzyme Reaction Rates

Introduction

Enzymes act as catalysts in biological systems. A catalyst affects the rate of a chemical reaction without itself being used up. Most of the chemical reactions that occur in biological systems only proceed spontaneously at relatively high temperatures. Enzymes allow these reactions to proceed at much lower temperatures. Enzymes can also act to speed up the rate of the reactions. One important reaction in which this is very apparent is the decomposition of hydrogen peroxide to water and oxygen gas:

$$2H_2O_2 \text{ -----> } 2H_2O + O_2 \text{ (gas)}$$

This reaction does occur spontaneously, but at a very slow rate. **Catalase**, an enzyme with a molecular weight of approximately 240 000 daltons, catalyzes this reaction. Catalase is found universally in aerobic organisms and prevents the accumulation of toxic hydrogen peroxide, which is a by-product of metabolism. In this lab, catalase will be extracted from beef liver. The rate of the catalyzed reaction will be calculated by measuring the rate of oxygen production. The effect of enzyme concentration on the reaction rate will also be determined.

By completing this lab, students will:

- Increase their understanding of enzyme function
- Measure and calculate the rate of a catalyzed reaction
- Become familiar with enzyme extraction procedures
- Develop the essential laboratory skills of following directions, making and recording accurate measurements and analyzing data

Materials and Methods

Be extremely careful with the sharp hypodermic needles. Hydrogen peroxide is a strong oxidizing agent. Avoid prolonged contact and wash hands after handling !!

Each group will need:
100 ml of 3% hydrogen peroxide
10 ml of liver extract
reaction rate apparatus
stopwatch

1. Set up the apparatus according to the teacher's directions.

2. Fill the graduated tube to over-flowing (preferably over a sink) with the hydrogen peroxide. Carefully insert the stopper, with the needle attached, into the tube.

3. Attach the tube to the clamp stopper-side up.

4. Pull 1 ml of extract into the syringe. Attach syringe *carefully* to the needle. Turn tube stopper side down.

5. Inject the extract into the tube at the same instant that the stopwatch is started. Have one partner keep time while the other reads off volumes of gas collected.

6. Record the time for each ml of gas to be collected. Continue until 15-20 ml of gas has been collected.

7. Thoroughly rinse the entire apparatus to remove all reactants and products.

8. Repeat the entire experiment using 0.5 ml of liver extract and 0.5 ml of distilled water in the syringe.

9. Plot the data for both enzyme concentrations on the same graph.

Results

Record results in a neat, logical and orderly table. Plot graphs following the prescribed format.

Interpretations and Conclusions

1. Calculate the initial rate for each enzyme concentration from the graphs. Remember: the rate is equal to the slope of the line at any point.

2. What effect does enzyme concentration have on the initial rate of the reaction ?

3. Why do the graphs level off after a period of time ?

4. In this exercise the amount of oxygen produced was used to determine the reaction rate. Based on the equation for this reaction, describe two other variable that could have been measured instead.

5. Design and outline an experiment that would measure the effect of pH, temperature or substrate concentration on the initial reaction rate.

Teacher' Guide

Time Frame: One 40-60 minute period

Target Group: Advanced Biology students

Preparation of Materials:

Liver extract: Macerate 1 g of liver in 20 ml of distilled water. Strain through cheese-cloth into a clean beaker. Repeat with another 20 ml of distilled water. Dilute to 200 ml with distilled water. Keep this extract on ice.

Apparatus: Any 12-50 ml graduated device is suitable such as a centrifuge tube, a graduated cylinder or a gas-collecting tube. A one-holed stopper that fits the apparatus is also required along with a 1 ml syringe with a detachable needle.

Carefully insert the needle through the stopper from the outside. The needle can remain in the stopper permanently. Attach the tube to a ring stand with a test-tube clamp.

Sources of Materials: All materials are readily and commonly available. The hydrogen peroxide used is found in any drug store.

Comments: A two-holed stopper can also be used to replace the hypodermic needle. Attach a small piece of rubber tubing to one of the holes. The syringe can then be attached directly to the tubing. The teacher must run the reaction ahead of time to check the activity of the enzyme. If the reaction occurs too quickly for accurate timing, the extract needs to be further diluted with distilled water.

References:

Advanced Placement Course Description (Biology). The College Board, 1989.

Buysse, Bruce and Sarah Ely. "The Effects of pH on Catalase Activity". NSF Biology Honors Workshop, 1989.

Lab 9: Enzyme Function and Inhibition

Introduction

Proteins in tertiary structure have a very specific three-dimensional shape. That specific shape is crucial to the functioning of enzymes, which are proteins in tertiary structure. Any change in that shape will change the function of the enzyme. An enzyme is said to be **denatured** when the three-dimensional structure of the enzyme is changed so as to make the enzyme non-functional. Anything that affects the structure of the protein can cause denaturation. Three things that have a tremendous denaturing effect are changes in pH, heat and the addition of heavy metal solutions.

Gelatin is a collagen-based protein composed of long, stringy polypeptide chains. Gelatin "sets" because these long strands become entangled. Pineapples (along with other fruits) contain a proteolytic enzyme called **bromelain**. When bromelain (or an extract containing bromelain) is added to gelatin, the bromelain catalyzes the hydrolysis of the peptide bonds in the protein molecules. These shorter molecules can not get entangled, so the gelatin does not set. In this lab, the effect of pH, temperature and the addition of heavy metal compounds on the ability of bromelain to function will be investigated.

By completing this lab, students will:
- Gain a better understanding of how the effects of temperature, pH and heavy metal compounds inhibit enzyme function
- Gain a greater appreciation for the role of enzymes in commercial applications
- Develop the essential laboratory skills of making accurate observations, recording data and analyzing data

Materials and Methods

Each group will need:
7 test tubes
1 test tube rack
solutions of HCl, NaOH, copper sulfate, pineapple extract
and gelatin will be available at each work station

Be extremely careful with the HCl, NaOH and copper sulfate solutions !!

1. Label the test tubes 1-7. Include initials on each.

2. Add approximately 2 ml of distilled water to tube 1.

3. Add approximately 2 ml of pineapple extract to tubes 2-7 and treat each as follows:

Tube 2:	Untreated Bromelain. Do nothing.
Tube 3:	Heat sample in boiling water for 10 minutes.
Tube 4:	Freeze sample in ice bath for 10 minutes. Allow to thaw.
Tube 5:	Base. Add 5 drops of 5 M NaOH. Let stand for 5 minutes. Neutralize with 5 drops of 5 M HCl.
Tube 6:	Acid. Add 5 drops of 5 M HCl. Let stand for 5 minutes. Neutralize with 5 drops of 5 M NaOH.
Tube 7:	Heavy Metal. Add 5 drops of 5% copper sulfate solution. Mix gently.

4. Carefully add 3 ml of prepared gelatin solution to each of the test tubes. Mix thoroughly by inversion.
5. Place all seven test tubes into the ice-water bath. Be careful not to freeze any of the tubes.

6. Predict which tubes will gel. Record your predictions in your data table. Remember gelation requires inactive enzyme !

7. Examine each tube for gelation and record results.

Results

Results should be presented in a neat, logical and orderly table.

Interpretations and Conclusions

1. Write a paragraph summarizing your results. Did the results support your hypothesis ? Explain.

2. Specifically, how do pH, heat and heavy metals each work to denature enzymes ? Discuss the effect of each on the amino acid interactions in the protein.

3. Directions on the gelatin package state that canned pineapple may be used in preparing the gelatin ? Why ?

4. **Adolph's Meat Tenderizer** contains the proteolytic enzyme **papain**. Based on this lab, why does this product "tenderize" meat ?

5. **Axion Pre-Soak** also contains proteolytic enzymes. How does Axion work to remove blood stains ?

6. Peeled bananas left out quickly turn brown. This reaction is catalyzed by an enzyme found in the bananas. Why does adding lemon juice to the bananas prevent this browning ?

7. Freshly peeled potatoes also turn brown quickly. Why don't cooked potatoes turn brown ?

8. Based on the results of this lab, discuss why it so important for organisms to tightly regulate their internal pH and temperature.

Teacher's Guide

Time Frame: One 40-60 minute period

Target Group: Advanced Biology students

Preparation of Materials: Assuming 10 groups

Pineapple extract: Prepare a 0.5 M phosphate buffer (pH=7) by combining 27 grams of dibasic potassium phosphate (K_2HPO_4) with 13 grams of monobasic potassium phosphate (KH_2PO_4). Dissolve with 500 ml of distilled water. To this, add 1 gram of cysteine. Discard the skin and core of a *fresh* pineapple. Cut the remainder into small pieces. Add 250 g of pineapple to 200 ml of the buffer solution. Homogenize the mixture for 1 minute in a blender. Filter through cheese-cloth to remove the pulp. The liquid contains the enzyme.

Gelatin: Follow the directions given on the package exactly.

5 M NaOH: Carefully dissolve 10 grams of NaOH in 50 ml of distilled water.

5 M NaOH: Carefully add 21 ml of concentrated HCl to 29 ml of distilled water.

5% Copper sulfate: Dissolve 2.5 grams copper sulfate in 50 ml of distilled water.

Source of Materials: All materials are easily and commonly available.

References:

Tucker, David. "A Safe Lab on Nerve Gas". The Science Teacher, Feb 1986, pg. 27-30.

Appendix E:

Pre- and Post- Test

Unit One Test

1. The different elements are determined by the number of __________ in their __________
   a. protons; atomic nuclei
   b. neutrons; atomic nuclei
   c. electrons; atomic nuclei
   d. protons; outer energy levels
   e. electrons; outer energy levels

2. The atomic weight of an element is essentially equal to the:
   a. total number of protons and neutrons.
   b. sum of the weights of electrons and protons.
   c. sum of the weights of electrons and neutrons.
   d. total numbers of electrons, protons, and neutrons.
   e. atomic number plus the number of electrons.

3. The chemical properties of an atom of a given element are determined by its:
   a. electrons.
   b. protons.
   c. neutrons.
   d. electrons plus neutrons.
   e. neutrons plus protons.

4. Which model of atomic structure first accommodated the concept that most of an atom consists of empty space?
   a. orbital
   b. plum pudding
   c. billiard ball
   d. Bohr
   e. planetary

5. Which statement is NOT true of covalent bonds?
   a. The positive and negative atoms attract each other.
   b. The outer energy levels of both atoms may be completed.
   c. A new orbital envelopes the nuclei of both atoms.
   d. Both atoms involved had an unfilled outer energy level.
   e. The nuclear charges of both atoms tend to be neutralized.

6. The hydrogen atom needs one electron to complete its outer energy level, carbon needs four, and nitrogen needs three. Use this information to determine the kind of bond that exists between carbon and nitrogen in a molecule of hydrogen cyanide $(HCN)^-$
   a. ionic
   b. covalent
   c. double ionic
   d. double covalent
   e. triple covalent

7. What do the elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur have in common?
   a. They are the six most common naturally occurring elements.
   b. They are all large atoms with unstable nuclei.
   c. They form the most important ions in living organisms.
   d. They all need to gain electrons to complete their outer energy level.
   e. They can all form two or more bonds with atoms of other elements.

8. When sodium hydroxide and hydrochloric acid combine they yield table salt and water: $NaOH + HCl \longrightarrow NaCl + H_2O$. This equation conforms to which of the following general forms?
   a. A + B ---> AB
   b. AB ----> A + B
   c. A + B ---> C + D
   d. AB + CD ---- > AD + CB
   e. AB + CD ---- > EF + GH

9. The properties of water, such as its surface tension, specific heat, and solvent strength, are a direct consequence of the water molecule's:
a. polarity.
b. overall net positive charge.
c. overall net negative charge.
d. overall neutral charge.
e. ability to form covalent bonds with other molecules.

10. Atoms of liquid mercury are strongly attracted to other atoms of liquid mercury. This phenomenon is an example of __________ between the mercury atoms.
a. cohesion
b. nonpolar covalent bonding
c. polar covalent bonding
d. adhesion
e. ionic bonding

11. When you wash dishes, drops of water cling to the surface of a glass. This is an example of:
a. ionization.
b. adhesion.
c. cohesion.
d. covalent bonding.
e. imbibition.

12. If you have ever planted a garden, you may have soaked the seeds before you planted them. This process aids germination because the seeds __________ water, swell and burst their seed coats.
a. ionize
b. vaporize
c. covalently bond with
d. buffer the
e. imbibe

13. Aquatic organisms have an environment that has less temperature fluctuation than that of land-dwelling organisms due to water's high:
a. molecular weight.
b. specific heat.
c. specific gravity.
d. ability to ionize.
e. average kinetic energy.

14. As 1 gram of ice melts and its temperature rises to 4 degrees C:
a. the average distance between any two molecules will increase.
b. it will give off energy to its environment.
c. it will become less dense.
d. it will gain energy equivalent to its heat of fusion plus 4 calories

15. Some fish will not freeze even if the surrounding water is at 0 degrees C because the presence of solutes of their body fluids.
a. lowers the heat of fusion
b. lowers the heat of vaporization
c. lowers the freezing point
d. raises the specific heat
e. raises the molecular weight

16. It has recently been discovered that certain frogs use ________ as an antifreeze.
a. glucose
b. glycerol
c. glycogen
d. protein
e. fatty acid

17. When two water molecules that are hydrogen bonded separate, occasionally one of the hydrogen atoms will be transferred, forming H_3O^+ and OH^-. This is called the __________ of water
a. reduction
b. oxidation
c. ionization
d. catalyzation
e. hydrogenation

18. In pure water, the:
A. pH is greater than 7.
B. pH is less than 7.
C. concentration of H^+ is equal to the concentration of OH^-
D. concentration of H^+ is less than the concentration of OH^-
E. concentration of H+ is greater than the concentration of OH^-

19. When placed in water, NaOH almost completely dissociates into Na^+ and OH^{+-}. Therefore, NaOH is:
a. a strong acid.
b. a strong base.
c. a weak acid.
d. a weak base.
e. neutral.

20. The pH of a solution is a measure of the __________ the solution.
a. total of all ions in
b. concentration of H in
c. molecular weight of
d. number of solutes in
e. potential energy of

21. In some areas of the world, the rain is extremely acidic due to the presence of:
a. carbonic acid.
b. lactic acid.
c. hydrochloric acid.
d. acetic and malic acids.
e. sulfuric and nitric acids.

22. Which of the following is NOT an effect of strongly acidic precipitation on plants growing in unbuffered soils?
a. reduced seed germination
b. reduced growth
c. decreased seedling survival
d. decreased disease resistance
e. increased nutrient availability

23. Which statement about buffers is NOT correct?
a. Large, sudden pH shifts are moderated (resisted) by the presence of a buffer in a solution.
b. Each buffer has a particular pH range at which it is most effective at resisting changes in pH.
c. A buffering system is usually composed of a weak acid (hydrogen donor) and its base (hydrogen acceptor).
d. The equilibrium between the H^+ donor form and the H^+ acceptor form does not change with the addition of acid or base to the solution.
e. A major buffering system in the human bloodstream is the carbonic acid-bicarbonate system.

24. With the exception of chemical processes in the stomach, almost all other chemical reactions in living systems take place in which pH range?
a. 5 to 6
b. 5 to 7
c. 6 to 7
d. 6 to 8
e. 7 to 8

25. Any substance that causes an increase in the relative concentration of hydroxide ions and/or decrease in the relative concentration of hydrogen ions in a solution is known as a(n):
a. solvent.
b. buffer.
c. acid.
d. base.
e. salt.

26. During the summer, the layer(s) in a lake in which the water circulates is(are) the:
a. epilimnion.
b. thermocline.
c. hypolimnion.
d. epilimnion and thermocline.
e. thermocline and hypolimnion.

27. All organic molecules have a basic skeleton composed of carbon atoms. Carbon can play this central role in the structure of biologically important molecules because it:
a. has six electrons in its outer energy level.
b. can only form single bonds.
c. can form four stable covalent bonds.
d. can only bond to other carbon atoms.
e. readily forms ionic bonds.

28. The _____ functional group gives its parent molecule the property of _____ .
a. hydroxyl; an acid
b. carboxyl; a base
c. methyl; water solubility
d. aldehyde; water insolubility
e. amino; a base

29. Aldehyde functional groups are associated with:
a. fatty acids.
b. molecules that have acidic properties.
c. molecules that have basic properties.
d. the property of insolubility in water.
e. sugars and other distinctively flavored substances.

30. A carboxyl group is associated with:
a. most hydrocarbons.
b. molecules that have acidic properties.
c. molecules that have basic properties.
d. the property of insolubility in water.
e. sugars and other distinctively flavored substances.

31. Which statement is NOT true of both silicon and carbon?
a. Both have four electrons in their outer energy levels.
b. Both combine with oxygen by double bonds.
c. Both are capable of bonding to other atoms like themselves.
d. Both have an atomic number less than 15.
e. Both tend to form covalent bonds.

32. Which of these is NOT a function or role of carbohydrates in living organisms?
a. food storage in plants
b. body insulator in animals
c. major component of plant cell walls
d. source of quick energy for animals
e. energy transport in plants

33. The type of organic molecule most readily oxidized by human bodies for quick energy is a(n):
a. monosaccharide.
b. disaccharide.
c. fatty acid.
d. triglyceride.
e. amino acid.

34. Which carbohydrate is composed of glucose and fructose?
a. cellulose
b. trehalose
c. sucrose
d. lactose
e. starch

35. When two monosaccharide molecules condense into a disaccharide, a molecule of _____ is removed.
a. sodium chloride
b. carbon dioxide
c. hydrogen
d. oxygen
e. water

36. The principal form of food storage in plants is:
a. sucrose.
b. starch.
c. glucose.
d. glycogen.
e. trehalose.

37. Human saliva contains enzymes that hydrolyze starch. If a baby chews up a cracker, what is the starch broken down into in the baby's mouth?
a. a polysaccharide
b. glucose
c. fatty acids
d. cellulose
e. an organic compound containing a carboxyl group

38. Vertebrates, including humans, can store sugars in their livers as _____, which can later be broken down and released as _____ .
a. sucrose; glucose
b. galactose; glycogen
c. glycogen; glucose
d. amylose; galactose
e. starch; glucose

39. Which of these organisms produce enzymes capable of hydrolyzing cellulose?
a. certain fungi
b. cows
c. termites
d. certain cockroaches
e. all microorganisms

40. The exoskeletons of arthropods are formed from the structural polysaccharide:
a. cellulose.
b. amylopectin.
c. chitin.
d. amylose.
e. glycogen.

41. Which of the following is NOT a function of lipids?
a. energy storage forms
b. enzymes
c. hormones
d. structural components of membranes
e. thermal insulators

42. The organic molecules that release the greatest amount of energy when burned are the:
a. monosaccharides.
b. polysaccharides.
c. triglycerides.
d. amino acids.
e. proteins.

43. Which statement is NOT true of cholesterol?
a. It is a component of the cell membranes of vertebrates.
b. Its basic structure consists of four linked carbon rings.
c. It is synthesized from fatty acids.
d. High blood cholesterol levels are associated with atherosclerosis.
e. It is classified as a phospholipid.

44. Which of these is a lipid that is composed of four linked carbon rings?
a. a triglyceride
b. a fatty acid
c. a phospholipid
d. a steroid
e. an oil

45. Which of the following is NOT a similarity between a phospholipid and a glycolipid?
a. The functional group for each molecule is negatively charged.
b. Both molecules contain two fatty acid molecules and a molecule of glycerol.
c. Each molecule has a polar group on a terminal carbon of glycerol.
d. Both are components of cell membranes.
e. They assume a similar configuration when in aqueous solutions.

46. Which of the following is NOT a function or role of proteins?
a. transportation of materials
b. structural scaffolding of the cell
c. contraction of muscle elements
d. transmission of genetic information
e. development of immunity to disease

47. How many different amino acids are found in living things?
a. 2
b. 20
c. 200
d. 2,000
e. 20,000

48. Proteins are made of amino acids linked together by _____ bonds.
a. nonpolar covalent
b. peptide
c. hydrogen
d. double
e. ionic

49. The sequence of amino acids in a protein makes up its _____ structure.
a. primary
b. secondary
c. tertiary
d. alpha
e. beta

50. The tertiary structure of a protein results primarily from the interaction of:
a. two or more R groups.
b. one carboxyl and one amino group.
c. two or more aldehyde groups.
d. two or more hydroxyl groups.
e. the R groups of two polypeptide chains.

51. Enzymes and antibodies are examples of _____ proteins.
a. alpha
b. hydrophobic
c. acidic
d. fibrous
e. globular

52. Some proteins consist of two or more polypeptides. Which of the following is NOT a type of force that may hold these polypeptides together?
a. disulfide bridges
b. hydrophobic forces
c. hydrogen bonds
d. attraction between amino groups
e. attraction of positive and negative charges

53. The level of organization of proteins that involves the interaction of two or more polypeptides is the ________ structure.
a. primary
b. secondary
c. tertiary
d. quaternary
e. pentanary

54. About one-third of all of the protein in vertebrates is present as:
a. hemoglobin.
b. collagen.
c. amylopectin.
d. egg white.
e. immunoglobulin.

55. Which of the following lists the components of a nucleotide?
a. phosphate, ribose, amino acid
b. phosphate, deoxyribose, peptide
c. peptide, six-carbon sugar, nitrogenous base
d. peptide, amino group, glycerol
e. phosphate, five-carbon sugar, nitrogenous base

56. The purines found in DNA and RNA are adenine and thymine.
a. true b. false

57. Which statement about energy is NOT true?
a. The flow of energy is the essence of life.
b. The use of energy is the basis of competition among organisms.
c. A cell is a complex of system for transforming energy.
d. Most of the solar energy that strikes earth is reflected into space.
e. Less than I percent of the solar energy that strikes earth is used to power life processes.

58. The study of energy transformations is called:
a. quantum mechanics.
b. cytology.
c. kinesiology.
d. thermodynamics.
e. enzyme kinetics.

59. Although energy can be neither created nor destroyed, it can be changed from one form to another. This is a statement of:
a. the first law of thermodynamics.
b. the second law of thermodynamics.
c. the third law of thermodynamics.
d. Einstein's theory of relativity.
e. Newton's law of falling apples.

60. Which statement is NOT true of energy conversions?
a. Some useful energy always dissipates into the surroundings as heat.
b. The total energy of the system and surroundings remains constant.
c. Exergonic reactions take place spontaneously.
d. The potential energy of a system always remains constant after an energy conversion.
e. Exergonic reactions usually result in a final state that has less potential energy than the initial state.

61. Our bodies convert food to energy at less than 100 percent efficiency. This is an illustration of:
a. a series of endergonic reactions.
b. decreasing entropy.
c. the second law of thermodynamics.
d. changing kinetic energy into potential energy.
e. the inefficiency of uncatalyzed reactions.

62. Reactions that require a net input of energy are known as:
a. endergonic.
b. exergonic.
c. exothermic
d. reductive.
e. oxidative.

63. All reactions that occur spontaneously are called:
a. exergonic.
b. oxidative.
c. exothermic.
d. reductive.
e. endergonic.

64. Which situation exemplifies a decrease in potential energy?
a. burning a sparkler
b. a plant synthesizing glucose from carbon dioxide and water
c. going from the ground floor to the 10th floor in an elevator
d. climbing to the top of a water slide
e. brewing your morning cup of coffee

65. In a chemical reaction, the total change in free energy depends on the:
a. change in heat content of the reaction.
b. change in entropy of the reaction.
c. absolute temperature.
d. change in both heat content and entropy of the reaction.
e. absolute temperature, change in heat content, and change in entropy of the reaction.

66. When one mole of glucose is oxidized to carbon dioxide and water, 673 kilocalories of heat are released. But the free energy change is -686 kilocalories. The difference of 13 kilocalories is due to:
a. an increase in potential energy.
b. a decrease in potential energy.
c. an increase in entropy.
d. a decrease in entropy.
e. the inefficiencies of oxidation, causing heat to be lost to the surroundings.

67. In an exergonic reaction:
a. delta G is always positive.
b. delta G is always negative.
c. delta H is always positive.
d. delta H is always negative.
e. delta S is always positive.

68. The second law of thermodynamics states that without input of energy the randomness of a system will increase with time. In spite of this, living things maintain orderliness because:
a. they only undergo exergonic reactions.
b. they only undergo reduction reactions.
c. the second law only applies to nonliving systems.
d. they are closed systems.
e. they extract energy from their environment.

69. Which statement does NOT apply to interacting substrate molecules (reactants)?
a. Substrates must collide with sufficient force to overcome their mutual repulsion.
b. The more kinetic energy possessed by interacting substrates, the more forcefully they will collide.
c. Without enzymes, the reactants of chemical pathways of a cell would not interact at all.
d. In the absence of enzymes, the more stable the reactant molecules, the greater the force of collsion required for them to interact.
e. Because of the moderate kinetic energy of molecules in living systems, only a small fraction of reactants may interact without enzymes.

70. Which statement is NOT true of enzymes?
a. They bring reactants very close together with the proper orientation.
b. They are effective in very small quantities.
c. They cause molecules to interact with enough force to overcome any mutual repulsion.
d. They are permanently altered during the reaction.
e. They are sometimes composed of more than one polypeptide subunit.

71. Which statement is NOT true of enzyme structure?
a. They are large, complex globular proteins.
b. They have a three-dimensional region called the active site that reacts with the substrate.
c. They are composed of one or more polypeptide chains.
d. Some need a cofactor or coenzyme to be active.
e. They are relatively nonspecific and each one will catalyze several different reactions.

72. The region of the enzyme that is complementary in shape and charge to the substrate is known as the:
a. active site.
b. allosteric site.
c. cofactor binding site.
d. coenzyme binding site.
e. product releasing site.

73. The induced-fit hypothesis of enzyme action states that:
a. the structure of an enzyme is rigid, like a keyhole.
b. all enzymes have hydrophobic regions to attract hydrophobic reactants.
c. when the substrate binds with the enzyme, the enzyme's shape may change.
d. substrate molecules are attracted to the enzyme by differences in polarity.
e. the presence of coenzymes characteristically changes the shape of the enzyme.

74. The nonprotein, low-molecular-weight substances that are required by some enzymes in order for them to be functional are known as:
a. catalysts.
b. vitamins.
c. substrates.
d. reactants.
e. cofactors.

75. Many enzymes require a nonprotein organic molecule such as a vitamin or vitamin component to be active. These molecules are known as:
a. catalysts.
b. coenzymes.
c. allosteric effectors.
d. substrates.
e. reactants.

76. Which statement does NOT describe enzymatic pathways?
a. There is little accumulation of intermediate products.
b. Enzymes that are used in a common pathway may be segregated to a particular region or structure of the cell.
c. A product of the first enzyme in a pathway is the substrate for the second enzyme.
d. When one enzyme in the pathway is nonfunctional, the other enzymes increase their activity to compensate for the deficit.
e. Cellular efficiency is increased by coupling exergonic reactions with endergonic reactions.

77. Increased temperatures can denature enzymes and render them ineffective by:
a. changing the charges on their active sites.
b. disrupting the hydrogen bonds that maintain their tertiary structures.
c. causing their subunits to aggregate in large clumps.
d. sealing off the active site, preventing substrates from entering.
e. increasing their kinetic energy to the point where substrate molecules cannot catch them.

78. A common scenario of feedback inhibition is that the ________ acts as an allosteric effector on the first enzyme in the pathway.
a. substrate of the first enzyme
b. product of the first reaction
c. substrate of tlie last enzyme
d. product of the last reaction
e. coenzyme NAD

79. Competitive inhibition of an enzyme pathway is:
a. a rare form of metabolic regulation.
b. achieved when a molecule similar to the allosteric effector binds to the effector binding site.
c. reversible in the presence of excess substrate.
d. reversible in the presence of excess allosteric effector.
e. irreversible.

80. Nerve gas is an irreversible inhibitor of some enzymes. The inhibition may be successfully treated using:
a. sulfonilamide.
b. cysteine.
c. folic acid.
d. PABA.
e. Since the inhibition is irreversible, it cannot be treated.

Appendix F:

Module Evaluation

Advanced Biology
Mr. Foley

Unit One Evaluation

This evaluation is required as part of my thesis requirements, as well as being a tool for helping me to make the unit better next year. Please be completely honest. The more specific the information, the more of a help it will be. Thank you for your cooperation !

<u>Topic</u>
A. Review of Atoms, Molecules and Bonding
B. Water
C. pH
D. Carbon, Carbon Chains and Functional Groups
E. Carbohydrates
F. Lipids
G. Proteins
H. Nucleic Acids
I. Chemical Reactions, Free Energy Changes and Equilibrium
J. Enzymes

<u>Labs</u>
1. Separation Of Dyes By Reverse-Phase Chromatography
2. Comparing Specific Heats
3. Measuring pH
4. Buffers In Biological Systems
5. Structures Of Simple Organic Molecules
8. Measuring Enzyme Reaction Rates
9. Enzyme Function

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1. Before starting this unit, which topic(s) did you feel the best prepared for by a previous class ?

2. Before starting this unit, were there any topics that you felt totally unprepared for ?

3. Which topic(s) if any should we have spent more time on during this unit ?

4. Were there any topics that you felt we spent too much time on during this unit ?

5. In general, were the topic objectives adequately covered through the combination of readings, worksheets, lectures and labs ?

7. Did you feel that any objectives were not adequately covered ? Please be specific.

8. Did the syllabus clearly spell out the assignments ?

9. Were the worksheets a helpful tool in guiding your reading ?

10. Did you use the worksheets as a study tool or just complete and forget them ?

11. Did the post-test reflect the objectives ?

12. Do you feel that you adequately studied as much as you should have for the post-test ?

13. In general, were the lab procedures clear and adequately detailed ?

14. For specific labs, what improvements could be made to make the instructions more clear ?

15. Was enough time provided for completion of the labs ?

16. Was enough background information provided to help you to understand the concepts presented in the lab ?

17. Did the labs reinforce objectives presented in class ?

18. Should any of the labs be deleted ?

19. Please give an overall critique of the entire unit. What things should be changed ? What things should be kept the same ? What can be done to improve the unit for future classes ?