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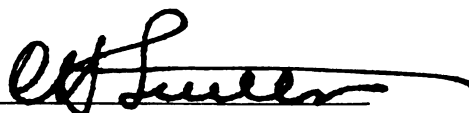
An Introductory Chemistry Unit
To Prepare High School Students
For Human Physiology

presented by

Marie Eileen Rediess

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Interdepartmental
Biological
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AN INTRODUCTORY CHEMISTRY UNIT TO PREPARE HIGH SCHOOL
STUDENTS FOR HUMAN PHYSIOLOGY

By

Marie Eileen Redless

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Interdepartmental Biological Science

1989

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ABSTRACT

**AN INTRODUCTORY CHEMISTRY UNIT TO PREPARE HIGH SCHOOL
STUDENTS FOR HUMAN PHYSIOLOGY**

By

Marie Eileen Redless

High school students entering Human Physiology before taking chemistry have difficulty understanding topics that refer to the molecular level of function. They also have little skill using laboratory equipment and procedures. In order to correct this, a chemistry unit was developed to overcome these deficiencies in the students' backgrounds

A five to six week base unit with expanded laboratory activities was developed to enhance the understanding of chemistry and illustrate the practice of science to the students. Each topic was covered from several approaches to increase the interest and broach individual learning styles. A pretest and posttest were given to assess the impact of the module on learning.

Although analysis of the posttest compared to previous years showed no significant improvement, other evidence shows that students retained the information much longer, used it in other units and understood chemistry's relevance to their lives. Students learned use of laboratory equipment and were able to apply what they learned to unfamiliar problems. Overall grades improved following the study.

ACKNOWLEDGMENTS

I wish to thank the generous help and support of my committee: Dr. Clarence H. Suelter, my chairman, who convinced me that not only could this project be completed, but that I would make a good "guinea pig"; Dr. Howard H. Hagerman, who taught me all I know about parasitic worms and statistics; and Dr. Martin T. Hetherington who has been guiding my career since undergraduate days. Without their inspiration, I would not have had the courage to begin this work. I must also express gratitude to "the second year NSF gang" Michael Brundage, Mary Fowler, Van McWilliams and Tammy Voss who sweated out the summer of '88 with me revising laboratory activities and teaching ourselves how to revise. The seeds of this thesis were planted at a molecular biology workshop funded by NSF at MSU. This workshop was put on by Drs. Hagerman, Hetherinton and Suelter, along with Dr. Glenn Berkhelmer (who provided the teaching methods I use today). This program eventually expanded, through the concerted efforts of these people, to a three year program and what seems like an almost effortless way to get a master's degree. Without these workshops and the National Science Foundation who funded them this thesis may never have been. Last, but not least, I wish to thank the school board and administration of Algonac High School who have so generously supported me with facilities, students, funding and release time.

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Introduction

Human physiology is a complex and varied study of homeostasis. The body is wondrous in its intricate and diverse mechanisms. We teachers must show students the dynamic balancing act that bodies must go through to maintain this balance. We must also show what can go wrong when this balance is lost. Most of this balancing act takes place at chemical levels within the cell. Students who study physiology need to have a basic understanding of how chemicals behave before they can truly understand, instead of merely memorize, how their body works.

At Algonac High School, when money was in short supply and there weren't quite enough teachers or hours in the day to provide a complete offering, physiology was taken in the sophomore year. It was the only bridge between biology and chemistry for college preparatory students. Chemistry was perceived as a junior course. Now that the district has more resources, the science department has tried to change

the image of physiology to that of a junior or senior course. This has met some success in that there is now an equal mix of sophomores and upper classmen in the course, but many students are still coming into the class with little or no chemistry in their background.

The first three years that I taught this class, the chemistry unit (see appendix A for outline) was two weeks or less as suggested by a curriculum guide developed by the district and science department staff. However, the students' performance was not satisfactory when anything that required a chemistry background was covered. The kidney is probably the most difficult unit for the students to understand. It includes diffusion, movement of positive and negative ions, filtration, osmotic pressure -- all things that rely on a chemistry background.

In the 1988/89 school year, five weeks were spent on chemistry. A week each of study on the heart, kidney and end of year pig dissection were cut to make room for the extra material. Lectures were supplemented by labs and labs were supplemented by lecture, but most of all we practiced. Everything was presented in two or three different ways. Often we would have more than one lab covering the same concept.

I had hoped that using more labs to develop the concepts of basic chemistry would have a quantitative

effect on the students doing the exercises. This idea seems intuitively right. And for the last fifty years or so (Hounshell 1989), this was the practice carried out in the classroom using various methods to present the lab activities. The science teaching reforms in the 60's and 70's kept the idea of laboratory activities being necessary in the classroom, although the reform labs tended to be "discovery" instead of "confirmation" labs.

Discovery labs are wonderful fun and an excellent educational opportunity. The students learn so much about how things work, although I'm not sure that the concepts meant to be enforced are the ones that are retained. There are several methods of conducting these discovery labs. One method is to state the purpose of the activity for the students, and then have them decide on materials and procedure that will verify (or disprove) the hypothesis. The other method is to give them material and equipment to 'play' with and let them design the lab from scratch, including the hypothesis. A third method is to give the students purpose and procedure while having no idea of the actual outcome yourself (but the succeeding times these labs are used, teachers must pretend lack of knowledge or else change the purpose or procedure). While these design labs are pleasant for both the student and

instructor, and really let students see how things are happening, they use up a lot of class time. Ample time must be allowed for student modification. Students are rarely satisfied with their first, second or even third try. So, while experimentation is a good thing, a design lab once in a while is about all the time we can expend. I end up interspersing design labs with lab exercises to be sure the concepts I'm trying to develop actually are being developed.

At this point in time, researchers have not completely examined whether lab activity is more effective than other methods at strengthening students understanding of the subject matter (Blosser 1988). So far, there has been no significant statistical evidence that laboratory exercises are any better than lecture in changing achievement or attitude. Blosser wonders whether we are looking at the 'right' variables to test. We do all these labs and then try to pigeonhole these skills to a written objective test which is not designed to evaluate the skills learned in laboratory activities. I believe (but have found no supporting evidence in the literature) that labs increase problem solving ability, analysis skills, patience, coordination and encourages independent thinking. These skills are useful in any classroom or career, but are difficult to test objectively. Laboratory activity

certainly gives the students an idea of what science as a career can be. As Hounshell states that the first objective of lab work is "to enhance students understanding of the subject matter....The second objective of lab work should be to produce more scientists....If lab work is to produce more scientists, then teaching lab skills is essential. If these skills aren't taught it will be like trying to train chefs without letting them into the kitchen." We do need more scientists -- by the 21st century the U.S. will need 130,000 to 700,000 scientists and engineers (Hetherington 1989). It will be up to us, as science teachers, to provide students with the excitement and perseverance to pursue these careers.

Student Transformation

Having a chemistry background before physiology is supported by most authors and publishers of physiology and biology texts. The texts that I have evaluated and used; Kilburn and Howell's Exploring Life Science, Morrison's et al Human Physiology, Otto and Towle's Modern Biology, Tortora and Anagnostakos' Principles of Anatomy and Physiology, Vander's et al Human Physiology, the Mechanisms of Body Function, Weinreb's Anatomy and Physiology and others; include a chapter on chemistry near the beginning of the book. The only variances seem to be the depth of detail the student is expected to learn. The topics covered in books aimed at both the high school and junior college market varied little from book to book. The books intended for high school use only, however, covered little, if any chemistry. All the books for both the high school and junior college market cover elements and atomic structure. Most texts discuss lipids, nucleic acids, proteins, carbohydrates, ATP, molecular movement,

concentration, acids/bases and pH scale. Some cover reactions and molecular bonding. One text (Tortora and Evans Principles of Human Physiology) had a chapter on physical principles such as motion, simple machines and properties of matter. With such universal adherence to a theme, can we avoid the same theme in our teaching if we expect the students to understand their own bodies?

Of the physiology texts surveyed, most included chemistry in an early chapter, some just before the cell, and some just after. Of those that did include chemistry, almost all put the structure of the atom first. Since all bonding, and hence reactions, are based on how the electrons combine, this would seem the logical place to start. The proton and its mass was first discussed, then the neutron, and then the electron, although some did not adequately stress that the electron is for all intents and purposes, massless. Atomic number was then introduced, as well as mass number. Some books (including our text Tortora and Anagnostakos) still insist on using the not-quite accurate term, atomic weight. The one misconception that seemed to exist in all but one book (Vander et al 1980) was the simplified Bohr model of the atom; a central nucleus with concentric rings around it indicating electron paths. Some would start the chapter with a three dimensional drawing of a very

simple atom and then revert to the Bohr model. The Vander text showed only three dimensional drawings, including one with two electron energy levels, although even that one did not go into the projected shapes of the p orbital. The Bohr model, even though not the current model of an atom, is very easy to use to show and predict electron transfer for bonding.

After the atom was introduced, molecules with formulas and then reactions and equations were presented. Some texts then introduced osmosis and diffusion while others went straight to inorganic and organic molecules. Inorganic molecules always included water, and nearly always acids and bases, along with pH and buffer systems. With our society's increasing reliance on technology and recent scientific investigations in the headlines of the daily papers, it seems rash not to include basic chemistry in every students background.

The chemistry unit was taught from September 12 to October 15, 1988. Before teaching the unit, an evaluation test was given. A similar test (37 identical objectives with 10/11 objectives covering same concept; see appendix D) was given at the end. Analysis of the pre and post test scores showed that there was less than 10% probability that increase in scores were due only to chance. On April 3rd of the

following semester, a test identical to the post test was given again to check retention. No specific mention had been made of chemistry before the test, and the students were not aware that they would be given a test on that day. Analysis of the post and April test results indicated that there was less than 0.001% probability that the correlation between scores was due to chance.

I interviewed nine students on the fifth and sixth of April about the chemistry unit. The students were selected by computer generated random numbers. The randomness of the selection was modified by absences and volunteers who asked to speak after they saw others interviewed. One of the two students with low grades was absent both days and the other refused to be interviewed. The students who were interviewed have an average of C or better.

The interview questions (appendix E) were designed to determine what the students remembered most from the unit, what had been most helpful with the other work, what was easiest to learn and what was most difficult to learn. They commented on the appropriateness of the length of the unit. They were also asked whether they thought the unit should have more or fewer labs and whether it was easier to learn the material from the

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book or whether the laboratory exercises facilitated the learning process.

Table 1, Tally of Student Answers to Interview

Topic	Atoms	Bond- ing	Buffer system	Chem- istry	En- zymes	For- mulas	Periodic table	pH	Sym- bols
Remember most		1			1		2	2	2
Most helpful				1	1		2	3	
Easiest to learn	1				1	1		3	
Hardest to learn		1	1			1	3		

When they answered (see exact text in appendix E) what they remembered most or found most helpful or easiest, pH was the big winner. They apparently liked working with indicators and testing because they are so colorful. It is also a topic that I consider especially exciting. Others thought that the symbols, elements and/or periodic table was outstanding. Another girl mentioned enzymes, several times. Remembering the names of the formulas, compounds, symbols and "things" seemed to be the most difficult. Most of the students interviewed thought the length of the unit was about right, although one student wished it were shorter, and another would have liked it longer. Three of the eight students thought there was an appropriate amount of laboratory activity, although

one suggested that it might be better spread out a little more; two students favored having more labs, while three said fewer would be better. Two of those three also said that they learned better from the text than from labs and the other said labs were better for helping them learn. One other student said the text was easiest for him to learn from, even though he could see things work in a laboratory exercise. The rest of the students said they got more out of the labs than they did the text.

The students in this class are outspoken and independent. I believe that the opinions are their own, given without thought as to what might please Teacher. I also ran a survey on how important chemistry concepts might be in their lives. Not surprisingly, even though they all plan to go on to college, some even in the science area, they didn't think chemistry was very important in their lives (see appendix F). The topics they thought would be most important in their lives would be salts and the major organic molecules; carbohydrates, lipids, proteins; none of which was remarked on (with the exception of enzymes) in the oral interviews. A significant number also cited the elements or periodic table to be of value in their lives. It seems they remember the

colorful and/or spectacular things, and think they will
use topics that are much in the public eye -- diet.

Instruction

My mistake the first couple of years was to think that the students had (or would remember having) many of these topics in their previous biology course. I considered the chemistry chapter to be a review. After all, someone else had taught this, and I should not have to. Every year reinforced the fallacy of my thinking, the students just didn't do well on topics that required a chemistry background. In 1986, an introductory biology course was added that covered plants and animals instead of the cellular and human biology of the advanced course. 1987 was the first time that I had a combination of students from both courses in the physiology class. I had expected the advanced biology students to do much better -- they already had the basics and would only be adding detail while the introductory biology students would have to learn it all. To my surprise, there was no difference in performance between the two groups. All the students appeared to be learning anew. The chemistry

studied in their previous advanced biology course was not being retained. That's when I decided to expand the chemistry unit from one or two weeks to five or six weeks.

After much thought, and study of the text used in the course (Tortora and Anagnostakos 1987) and other supplemental texts, I decided on the chemistry topics that would be most useful for my students understanding of human physiology. There were many things that they had to be comfortable with before they could begin to comprehend the cellular behavior of their bodies. (See detailed outline in appendix B.)

In designing the chemistry unit, I had to keep two things clearly in mind. One, would a longer unit really benefit the students' understanding and achievement in physiology? Two, would laboratory exercises enhance that achievement? In order to understand the kidney, one must have a firm knowledge of both passive and active transport. To realize what is happening in a neuron, one must know the ions as well as how they can be expected to react with their surroundings. To understand blood chemistry, one must first know what a buffer system is as well as how it works to maintain equilibrium. One must also have some picture in one's head as to what equilibrium is. To assimilate all these concepts, one must certainly know

about atoms, elements and molecules and how they work. With these things in mind, I designed a unit that would include the chemical concepts that the students would later need to understand cellular workings of the body.

Besides covering chemistry concepts, I hoped to give the students analytical skills. I think that, given a set of data, any student should be able to draw logical conclusions from them, even though those conclusions may not be what we, as teachers, expect. I also expect that the student will be able to clearly state these conclusions, in writing, in a fashion that will make their thinking clear to the reader. I wanted to develop in my students an ability to solve problems, by using a process of thinking that would allow them to reason out what they knew of the problem and then determine what they would need to know to solve it. In order to have either of these, the student would first have to develop some sort of sequencing skills. Since these are areas that go beyond simple discussion, it seemed reasonable to start out with an unknown laboratory exercise on the first day. I would be able to observe their skills in reading and following directions as well as their ability to manipulate the scientific equipment necessary for the lab. I could also ascertain from post lab discussion what kind of analytical skills they already had. Could they

determine a reason for the results and cite specific observations that showed this reason?

The student objectives (appendix C) were planned with the subsequent units in mind. The students would first have to be familiar with elements, ions and their symbols. They would need to know electron valence numbers to understand bonding. From there we would have to explore types of reactions, and see them taking place with inorganic molecules. Students would need to understand hydrogen ion concentration and how to test for it. They would need to know major types of organic compounds in their body and know how to test for each, as well as why and how each was important to their bodies. They would need to know the basic structure of DNA and RNA in order to understand how hereditary material was reproduced.

First, we discussed matter in general, with the emphasis on the elements important to the human body, especially carbon, hydrogen, oxygen and nitrogen. We then went on to the structure of atoms which led us to bonding. Now that we had molecules and their structure, we were ready to study chemical reactions, which took us to body metabolism and energy. The next logical topic seemed to be inorganic compounds, particularly acids, bases, salts and pH indicators. From there, we learned about maintaining the body's

buffer system. Now, we were ready for organic compounds. The first organic compounds we covered were carbohydrates, and then we went on to lipids, proteins including enzymes, nucleic acids and adenosine triphosphate. The unit in previous years had only covered energy, structure of the atom and molecules, compounds, and motion of molecules (see appendix A for 1986/87 outline and appendix B for 1988).

On the first day of the unit, the students took a 49 question pre-test, 33 of the questions were multiple choice and the rest were short answer and essay. The students attempted to answer all of the questions, even though they would not be expected to know anything about some of the material. The students were weak in many areas, and showed little knowledge of chemistry. The students then began studying the chemistry chapter and related readings. The second day began with an overview of matter, with an introduction to the elements and their symbols. We then went on the third day to the structure of atoms. I try to make it very clear that our model of the structure of atoms is based only on indirect evidence, and to that end, began the introduction to our first chemistry lab, "The Atom Lab". (See Appendix J for lab activities.) We also began a write-up for a black box lab.

The fourth day, students are given a clay sphere with a small household item embedded somewhere within it. They must surmise a model of the "nucleus" after poking the "atom" five times with a probe. Each time the probe enters the "atom" they must describe what, if anything, they encountered. When the first model is drawn they are allowed to take five more stabs, make a model and so on until they are very sure they know what is in the center. As their knowledge of the "nucleus" expands, the model they draw changes and becomes more exact. They then write a conclusion telling why they think the "nucleus" is what they state it is, based on the observations they made. It is an excellent time to stress the writing of conclusions because the steps are so simple to see. The "atom splitting" ceremony is always a big draw with many oohs, ahs, and groans of disappointment. Some students of course, cheat and some guess correctly without cheating, but most have the problem of basing their guess on discovery of only part of the object, somewhat like the blind men who tried to describe an elephant by only touching one part.

A discussion is scheduled the next day of why the identity of the hidden item was so difficult to predict, as well as how models are useful to further our understanding of things that we cannot see. We

also begin a discussion of bonding, using the inaccurate but easy-to-see Bohr model of the atom. We then spend several days on reactions and the energy produced or used. The energy discussion takes us to diffusion and osmosis with demonstrations. By the middle of the second week, we are ready to start a learning compounds, pH, acids and bases. We spend a day on concepts, such as the blood buffer system, with lecture and discussion and then start to read and write laboratory exercises. On Friday of the second week, the students have their first review quiz. The third week is spent entirely on the acid/base related laboratory exercises. The students are given a group of labs, and proceed at their own pace with any lab they choose. This procedure cuts down on long lines for particular chemicals and waiting to use specialized equipment, although it is more hectic for the teacher. We finish the week with a discussion on conclusion writing and a short quiz on reactions and energy.

Week number four finds us back to lecture and discussion of background material. We cover carbohydrates, lipids, proteins, enzymes; watch a couple of demonstrations on protein structure and denaturing; and begin writing protein lab exercises. A short quiz is given on Friday, as well as the opportunity to test some enzyme action in the lab. The

following Monday we start on nucleic acids. We do two exercises, one which requires the students to figure out the structure of DNA by assembling pieces of a DNA puzzle. The other one is done the following day and the students produce a three dimensional DNA structure that they can coil. We also use rubber bands to demonstrate supercoiling. We start with enough bands knotted together to cross the room. It's amazing how small a space one can coil rubber bands into. After spending two days on review, the students took the post-test.

I start each unit by asking students to read the chapter to be covered. "Reading" probably isn't a good word to use, as I expect the students to do more than read. First, I ask them to skim the chapter by reading the things that are printed differently, and all the captions under graphs and pictures. They also need to look at the end of chapter questions so they can see what is most important to me as well as to the authors. The present text was chosen with this accord in mind. The second time through, I expect them to read from beginning to end. The third time through, they stop at the end of every section and close their eyes and try to remember what they just read. If they can't do that, then they are to go back and read the first paragraph of the chapter, close their eyes and recall. When they

have mastered that, then they again work on a section at a time. The last time through is another skim, this time finishing with the study outline at the end of the book. This process, if done correctly, should take them many days to complete. (I doubt however, if any but the best of my students actually do more than plow through from beginning to end, even though reading for meaning is a skill all should master to understand the significance of the written word.)

The first day of a unit, we begin with an overview of the material. I tell them what they can expect time-wise as well as the work I will be expecting them to do. The textbook (Tortora and Anagnostakos, 1987) has an accompanying study guide, and selected material is assigned out of the guide during this time. I try to give them seven full days (over a weekend) to prepare the material, because so many students are busy with after school activities. I then give the students a little background, and review of what has gone before. We have up to twenty minutes of lecture on days we aren't in lab, and then throw the floor open to discussion. Of course, it does not always work as planned, sometimes we get sidetracked on discussion by interesting questions brought up during the notes. In lecture, I cover the material that I consider to be the most important for them to learn, and the majority of

the test questions will come from this material. During lecture, I use overheads (Appendix K) where appropriate, draw on the chalkboard, show specimens pertaining to the subject and try to verbally draw as many analogies as I can. Demonstrations are an ever popular favorite. I also try to focus on examples of the material that will affect them directly.

After a day or two of background, everyone seems to tire of talking, no matter who is doing it, so once the ground work is laid, we begin to prepare for laboratory activities. If at all possible, I try to have at least two labs that focus on the material at hand, preferably those that approach the concept from different directions. Often, we have several labs on similar topics that the students can work on at their own pace as materials and equipment become available. Before the lab exercises, we discuss what we are trying to do, and then refocus direction during the lab. Often, the students will want to know "what will happen if....?", "we're finished with this, can we try to do....?" It often takes more time, but when that does happen, the students are truly learning. We try to have a post lab discussion on what happened and why to help the students with conclusions.

Black box labs are pretty standard stuff in the science classroom, but our "atom lab" is unique, as far

as I know. I think that this lab really shows how difficult exploring the unknown can be. It also lets them see what models and theories are all about. I have brought in new material developed by fellow teachers at summer workshops. (See Appendix J for specific laboratory exercises used in this unit.) This new material allows me to bring university techniques (which are often the techniques that modern science technology industry uses) to the high school. They learn what is being done in commercial labs around the country.

The students especially enjoyed the labs we did on pH and indicators. We prepare many of the indicators and many of the things we test for pH from fresh fruits and vegetables. It is astounding to them that red cabbage juice worked just as well, if not better, than universal indicator to determine pH. They all brought lots of things from home to test for pH as well as indicators. Next time, however, I plan to use a blender and suction filtration -- no more mortar, pestle and gravity filtration. It slows the process up too much.

At the beginning of the unit, most of my students are still apprehensive about using some of the equipment for lab activities. All the students are in at least their second year of high school science. I

was appalled when they all reached for a beaker instead of a graduated cylinder to measure larger amounts of liquids. Stop! Wait! Measure 150 milliliters of water using a beaker. Now, measure 150 milliliters of water using a graduated cylinder. Put the water from the cylinder into an identical beaker and notice the difference. Oh....! The light dawns -- at least for a little while. Next week we must go over the same thing. As they grow more familiar with accurate measuring, and more familiar with pipettes and cylinders, their lab results did improve, as did their lab skills. They are soon handling small amounts or large amounts of materials with all the equipment available. When experiments were done with blood later, not one of the students wanted to be shown how to use a capillary tube. They all knew from using pipettes.

These students are comfortable using laboratory equipment and supplies after five weeks in the lab. Even unfamiliar procedures are quickly mastered because they draw on past experience with similar items. The students this year are more aware of what is going on, what they might expect to happen, than students in years past. For example, I always do a food analysis lab in early February. We spend days testing known materials for monosaccharides, proteins, amino acids, starches and fats. For a test, I give the students an

unknown - something that is available for them to test during the exercise, even if they don't get around to it. In years past, students did not use time well, a lot of lab time was wasted in chatter or other delaying tactics, so not all substances got tested. When it came time for the unknown, many of the previous students did not even seem to know what the test they were using was testing for. Many tested for simple sugars using Biurets solution (a amino acid test) instead of Benedict's solution (a test for simple sugars). After all, they are both blue, right? Needless to say, we did not have a high number of accurately identified unknowns. This year, each and every student identified the substance they were given, and amply supported that identification with observations from their testing. The only fault that I could find was that the students wanted to identify specific amino acids and simple sugars, and you just can't do that using the tests they had available, but they tried. Many even went back and tested the substance they thought they had as an unknown, just to compare. I believe that this is a direct result of all the work we did in the chemistry section, both in lab and in lecture. To sweeten things even further, since the students know what they are doing, instead of trying to follow poorly understood directions, there is

far less time wasted on trivial pursuits. When doing a lab, these students are on task most of the time.

A major goal I have is to teach students to develop good observational skills and to use care in recording them. I also have the students use these observations to make conclusions so they can tell why something happened. "I think that this must have been what was going on because I saw these things happening....." These capabilities are not only important in the lab, but in life as well. Predicting what should happen is another skill that we work on. The first couple of lab exercises are designed to force observations and clear, logical thinking. It is also important that the students become familiar with various laboratory equipment and are comfortable, and precise, while using them. We do lots of measuring, and massing, and manipulating. The students learn the process of making extracts, doing dilutions, testing solutions for various components. We even borrowed a spectrophotometer so the students could use electronic equipment similar to what commercial labs are using. Pipetting is a new technique for the students this year -- another way to stress accuracy. The students seem more comfortable with pipettes than with graduated cylinders.

In order to make lab exercises seem a little more special, I prepared a booklet to record data. Condensing the handouts (when there are any) is a good way to insure that the lab directions are at least read, if not studied, before we actually do the experiment. Using a lab book also eliminates all those scraps of papers that students always want to use to keep haphazard observations. (Sometimes I think they do that so the observations are easier to lose!) Most of the students are very careful and take pride in keeping their books neat. The booklet also organizes all their laboratory activities in one place, as well as enhances data recording and retrieving, so they can easily refer to previous work. Many take advantage of this.

Evaluation

Any evaluation instrument has limitations. The standard "chapter test" is the one most commonly used in the high school. However, it is impossible to present all the topics that were covered in a unit in just one evaluation. The items on an objective test must necessarily reflect the ones that the teacher thinks is most important for the students to know. Perhaps these topics will be significant in the students' lives, or they will be necessary to understand the next unit, or they may reflect the personal bias of the teacher. When choosing from a bank of questions, the process ends up to be somewhat subjective, no matter how careful teachers are. A more difficult evaluation, and perhaps the way we should be grading our students, is performance of the daily tasks and laboratory work. Essay exams, while favoring those that are comfortable with words, gives a better idea of what the students are sifting out from the information we give to them. Essay tests are wonderful ways to see

inside the students mind, and are very easy to write, but so time-consuming to grade and almost impossible to grade objectively enough to compare performance from one student to the next, or from one year to the next. That leaves us with the old stand by, multiple choice tests. Multiple choice tests are easily scored, analyzed and can be compared objectively with one another. We must remember, however, that some students are much better than others at analyzing the teacher through the questions and can figure out the answer that the teacher wants.

For my main evaluation instrument, I chose a multiple choice test supplemented with some short answer questions. I have a computerized data bank of test questions written by the author (or is it really the publisher?) of the text we use. I have added many of my own favorite questions, so there are quite a variety to choose from. After I had determined the objectives for the unit, I went through the test bank and chose the questions that I thought would be especially important for my students to know. I made two different versions, one for the pre test and the other for the post test. There were 36 multiple choice questions, nine of which were not identical, but covered the same objectives. In addition, there were eleven short answer, diagram and analysis questions to

cover material that would be difficult to answer adequately in the item choice format. (Appendix D)

The first day of the unit, we began with a pretest. I explained that the object of the test was just to determine how much they knew about the subject, not to go in the grade book. During the unit we had several short quizzes to make sure the material was making sense to the students, and at the end of the unit, we had the other version of the multiple choice, short answer test. The post test was given again to the students in April to check retention, with no advance warning, so they were not able to study for it.

The raw score data from the pretest was put into a standard score (T-score) format (Good and Brophy 1981). The most common method uses a mean score of fifty and a standard deviation of ten. The raw score at the original mean would be given a value of fifty and a raw score that was one standard deviation above the mean would be assigned a value of sixty, while a raw score one standard deviation below the mean would be given a value of forty. This allows one to use a normal curve to examine test scores in relationship to one another.

Figure 1, Pre test T scores 1988

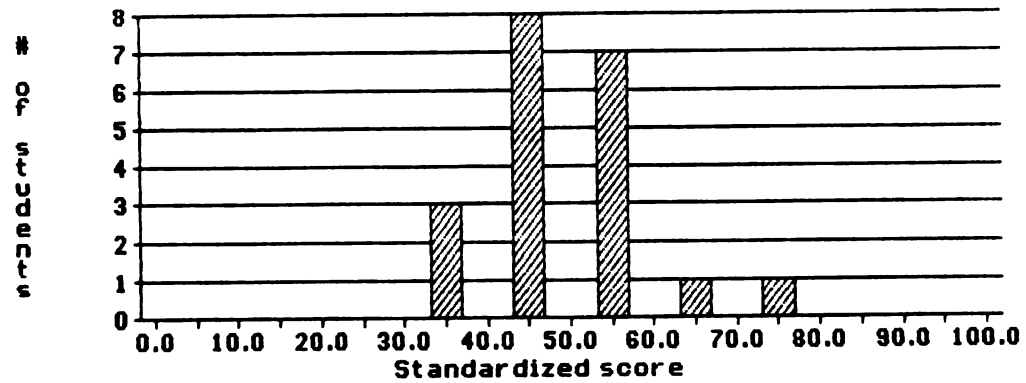


Figure 2, Post Test Standardized T Scores

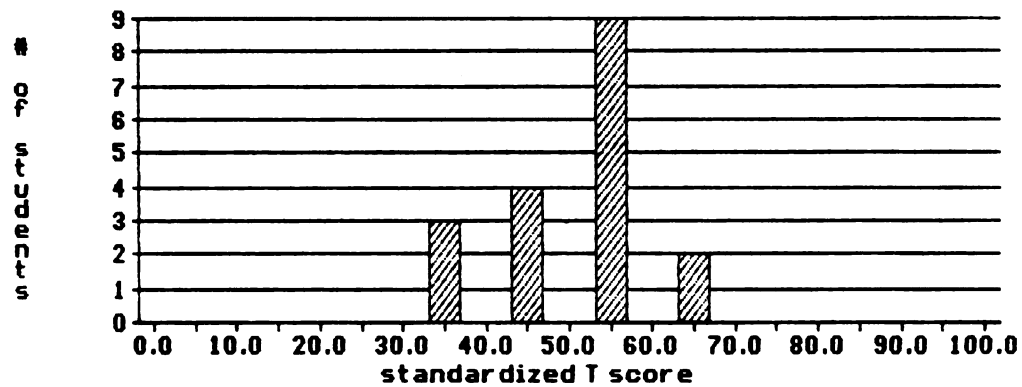
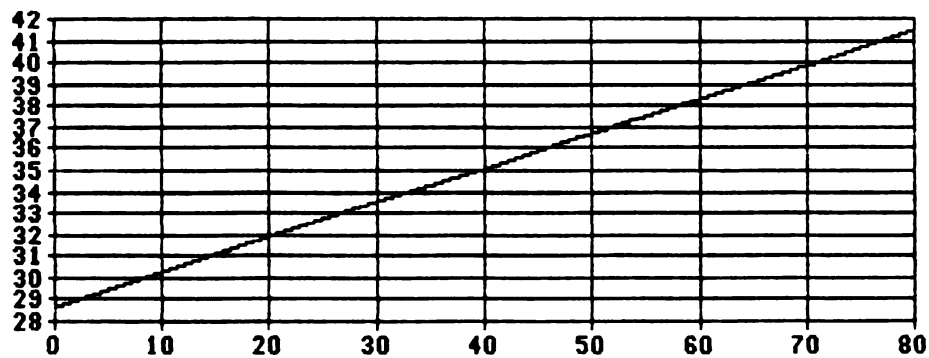


Figure 3, Linear Regression of Pre Vs. Post Tests



In the 49 point pre test, as expected, the students did rather poorly. The raw score mean was 16.5, the median was 15.5 and the standard deviation from the mean was 7.7. Twenty students took the pre test. To get the standard T scores, one must first find the difference of the students score from the mean, and then find how many standard deviations (7.7 in this instance) there is in the difference. This number is then multiplied by 10 and then added to the T mean of 50 if the original score was over the mean or subtracted from 50 if the original score was under the mean. When this is plotted in graph form, T scores versus the number of students receiving that T score, one has the "standard curve". Statistically, we can expect 65% of the students to be within one standard deviation of the mean (Good and Brophy 1981). There were 15 of 20 students (75%) in this range on the pre test - a little better than expected (see Figure 1). Good and Brophy tells us that statistically we can expect 95% of the students to fall within two standard deviations of the mean, and the students fit statistics with 19 out of the 20 (95%) in that range.

In the post test, students improved an average of 31% in raw scores. This varied from a low of 16% (8 point) increase to a high of 57% (13 point) increase. The mean on the post test was 31, the median was 33.5

and the standard deviation was 9. When this data was put into standardized T scores (Figure 2), 13 of the 18 students taking the test (72%) fell within one standard deviation on either side of the mean. All of the students fell within two standard deviations of the mean.

The data from the pre and post test was analyzed to determine if there were any correlation between the tests (Hagerman 1989). If there was a high correlation, one might expect that the material taught was the material that was being tested, although strictly speaking, it only means that the tests are very similar. An exact correlation (abbreviated as r) would be 1.0. In this case, the correlation between the pre and post tests was 0.896; a very high positive correlation. This analysis gave us a t test of 8.30 which means that there is less than a 0.001% chance that the correlation is due to chance. The analyzed data is used to make a linear regression graph (Figure 3) which forces our data into a straight line format. Figure 5 is a graphic comparison of raw scores between the pre and post tests.

When results on the post test were compared with the same unit tests from 1986 and 1987, there was no significant statistical difference. 1988's class scored an average of 66%, 1987's classes (one week on

chemistry) scored an average of 65% and the classes of 1986 (two weeks on chemistry) had an average of 71%. Two years ago, there were 61 students and last year there were 23 students. More students give a larger data base to work with, and one or two students doing poorly is not as likely to lower class averages as much as one or two students in a class of 19. If we take this into account, last year's classes did worse on the unit than either the class of two years ago or this year's class, probably because less time was spent on the material. If we eliminate the two lowest students this year, then the average percentage score becomes 68%. My best scoring student this year was not included in any of the calculations because he was not in class the day of the pre test. (For exact scores and percentages, see appendix G.)

Figure 4, April Test Standardized T Scores

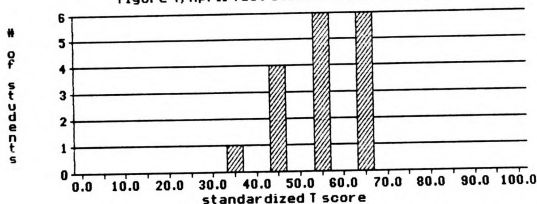


Figure 5, Pre Test Vs. Post Test Scores, 1988

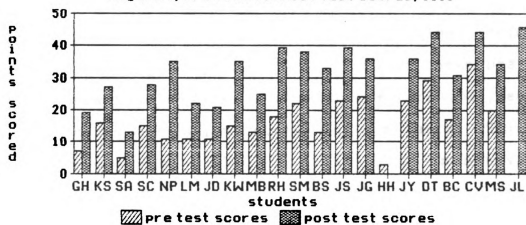
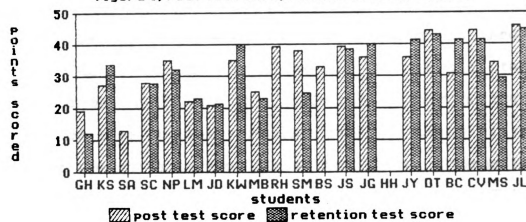


Figure 6, Post Test vs. April Test Scores, 1988/89



On the retention test in April, (see Figure 4 for standardized T scores) three students were not available to take the test. One of the students scored high on both the pre and post test, and the other scored low on both. The third scored low on the pre test and above the mean on the post test. A student who had not taken the pretest was present for both the post and the retention test and that data is included. (appendix H) The mean of the April test was 28.9, the median was 32 and the standard deviation was 9.4. Thirteen of the students either did better than their original score or came within 3 points of their post test scores (see Figure 6). The scores were analyzed to determine correlation between the two tests. This correlation was 0.998, another high positive correlation. However, when a t test was done, the probability that the correlation was due to chance turned out to be greater than 10%. In pure science, this would be unacceptable, but in education, where testing cannot be as exact, it isn't enough to throw out the data. These similar scores tell me that the students are retaining this information over a long period of time, probably because they are using it in most of the units covered since then. I was pleasantly surprised to see so much retention over time. This retention convinces me that the unit has produced the

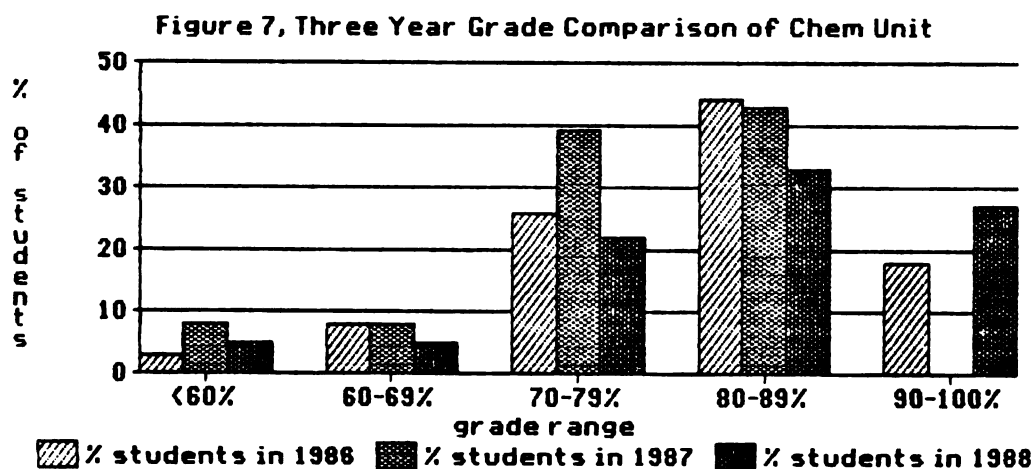
desired results, even though I can see no statistical differences from last year's test scores.

The end of the year grades has borne out my theory that a strong chemistry background enhances the study of physiology. In 1986 there were sixty-one students. Among those students were the five 4.0 students that shared valedictorian honors at graduation in 1989. We were using a simpler book, but the competition was stiff. That year, 18% of the students earned an A, 44% earned a B, 26% a C, 8% a D and 3% and E.

In 1987, due to an increase in the number of science course offered (some of which were less difficult), the student numbers dropped to 23. Of that number, none received an A. 43% of the students earned a B as a semester grade, about the same percent as the previous year. There were 39% with C's, up from the previous year. 8% earned D's and 8% earned E's, both percentages up somewhat, but the academic caliber of the students wasn't as strong.

This year, of the eighteen students who finished the class, 27% earned A, 33% earned B, 22% earned C, 5% earned either a D or an E. If we compare this to the two previous years (Figure 7), 27% A's is significantly higher than either previous year. There are as many A's in the class as there are B's, and more than there are C's. The A students are probably on an academic

par with those of two years ago, but I consider the B students to be my shining glory. Many of these students are those who struggled, really worked hard, to get D's and C's in introductory biology. Physiology is a much more difficult class, due to both the subject matter and the amount of work required. Some of the improvement is due to added maturity, of course, but I think the some of it comes from the basic understanding of chemistry needed to understand physiology. It would be interesting to find a way to find out exactly what caused the better grades in a "harder" class.



When I look at the item analysis of the tests (appendix I), there was a mean item difficulty of 63 on the pre test and a mean item difficulty of 34 on the post test. This is a decrease of 29%, due to increased knowledge of the material. An individual item analysis of the post test (appendix I) shows that item number 19

and item number 23 on the post test had a difficulty index of 95%. Only 2 or 3 students got them correct, and they aren't the students who normally do well on tests. I think that these students chose that answer by chance rather than knowledge. The questions should be considered invalid. There was also one test item in which the answer key was inadvertently scored incorrectly. These three items may have skewed the data analysis to show a higher item difficulty than there actually was. It does tell me that these items should be reworked if they are to be included in another test because they are not discriminating the top ability students from the lower ability students.

Analyzing the unstructured tasks of the students is a more complicated job than analyzing tests. These students seem so much more sure of themselves in almost every aspect of the class work than previous students. Their analytical skills are better, they see correlations more quickly, they can more easily divide problems up into subunits and then synthesize the resulting information. They are more adept at using laboratory equipment, and quicker at figuring out how something unfamiliar should be used.

Reflections

In summary, the pre-physiology chemistry unit was expanded from one or two weeks to nearly six. More laboratory exercises were included, including some that were more complex than those presented in previous years. The extra time allowed the students to test and investigate beyond the original scope of the lab activities. It also allowed the students to hear, see and experience the concepts in several ways, many different times. The first labs built on their natural curiosity and presented common things in an uncommon light. Discrepancy provided for learning. Later labs built on their growing understanding of molecular reactions and provided visual evidence to back up the information gleaned from the text and the teacher. Laboratory notebooks taught neatness and organization.

We have all heard that practice makes perfect, and that surely applies to learning as well. The students had access to more details about the chemical make-up and working of common body chemistry. These details

seemed to help their understanding of the topics covered. Imagine learning as a deep mine, with levels every few feet, corresponding to the amount of detail presented. I have always believed that students never go quite as deep in the mine as you would like to have them, and that their level of understanding is one or two levels above where you are teaching from. If we teach from the surface, they quickly decide that perhaps the topic isn't all that important and very little is retained. If we dig quite deeply into a subject, they follow and learn more than they would have with just a surface presentation. This longer unit allowed us to dig deep enough into chemistry -- and thus physiology -- to understand what many things are doing at the molecular level.

I think this five or six week unit is particularly strong in investigative and manipulative skills. These are lab based activities, at least to start with. It provides the student with an overview of chemistry in general as well as providing enough specifics to understand what is happening in their bodies on a molecular level. This unit is practiced enough and understood well, so the knowledge is retained for long periods of time. The students carried the information through to the next units instead of forgetting at the end of the chapter. The extra time we spent on the

chemistry unit allowed for the expansion of knowledge. This extra time was a drawback, however, when it came to the units covered the rest of the year. Even though the students have a much better sense of what is going on, something else had to be cut to make room for this unit. It is difficult to decide where to make the cuts. In 1986, a week was cut out of the circulatory system, the excretory system, and the end of year pig dissection. Another weakness is the testing method. The tests that I used weren't complete enough in assessing what the students actually learned.

The tests need to be revised. I would like to include an essay on problem solving and a section on writing conclusions from given observations. There should be a pre test for every unit as well as a post test. That might help me decide what could be cut another year to make the time for chemistry. We could have used the extra week that I took from the cardiac section. I would like to add at least another week to the unit so I could encourage independent investigations using the present labs as a springboard. I see this unit as one that constantly evolves as we learn what works best to help with subsequent units. I also see it changing with the introduction of more sophisticated equipment in our laboratory and as the industrial technology changes. I think we need to have

a quicker trickle-down from industry and colleges than we have had in the past. People from these areas of science should be brought into the classroom to present some of the material.

It seems to me that the longer time spent on chemistry has improved the physiology course in many ways. The students seem to retain information longer. The students find it easier to analyze and determine unknowns. The students are more at ease with the techniques and equipment of science. They understand better how their bodies work at the molecular level. They perceive more chemistry concepts to be important to their daily lives. The students learn first hand how scientists work. These are all skills that we want our students to learn when they do science, and the whole idea of physiology is to understand the human body's homeostasis. It seems to me that increased time on chemistry, which covers all these areas, has served that purpose for these students.

REFERENCES CONSULTED

REFERENCES CONSULTED

Alexander, Bahret, Chaves, Courts, D'Alessio
Biology
1986
Silver Burdett, New Jersey

Bartar, Moeller, Kleinberg, Guss, Castellion & Metz
Chemistry
1978
Academic Press, NY

Blosser, Patricia E.
"Labs -- Are They Really As Valuable As Teachers Think
They Are"
The Science Teacher
May 88
NSTA

Bryant, Richard J. & Marek, Edmund A.
"They Like Lab-Centered Science"
The Science Teacher
Nov 87
NSTA

Crager, Jean G., Jantzen, Paul G. & Mariner, James L.
Biology
1985
Macmillan Publishing Company, NY

Dressel, Paul & Nelson, Clarence
"Questions and Problems in Science"
Test Item Folio #1
1956
Cooperative Test Division, New Jersey

Frazier, Richard
"Beginning Without A Conclusion"
The Science Teacher
May 88
NSTA

Good, Thomas L. & Brophy, Jere E.
Educational Psychology
 1980
 Holt, Rinehart and Winston

Hagerman, Howard H.
 Lectures on Statistical Analysis, unpublished
 NSF-MSU Behavioral/Environmental Workshop
 1989

Hetherington, Martin
 "Scientific Literacy Can Be Achieved"
Michigan School Board Journal
 Apr 89

Hounshell, Paul B.
 "Labs Off Limits"
The Science Teacher
 Apr 89
 National Science Teachers Association

Kilburn, Robert E. & Howell, Peter S.
Exploring Life Science
 1981
 Allyn & Bacon, Boston

Kraus, David
Concepts in Modern Biology
 1984
 Globe Book Company, NY

Mahadeva, Madhu N.
 "From Misinterpretations to Myths"
The Science Teacher
 Apr 89
 NSTA

McCormack, Alan J. & Yager, Robert E.
 "A New Taxonomy of Science Education"
The Science Teacher
 Feb 89
 NSTA

Metcalfe, Williams & Castka
Modern Chemistry
1986
Holt, Rinehart, NY

Morrison, Cornett, Tether & Gratz
Human Physiology
1977
Holt, Rinehart & Winston, NY

Otto, James H. & Towle, Albert
Modern Biology
1985
Holt, Rinehart & Winston, NY

Pizzini, Edward L., Abell, Sandra K. & Shepardson,
Danie
"Rethinking Thinking in the Science Classroom"
The Science Teacher
Dec 88
NSTA

Rubin, Amram & Tamir, Pinchas
"Meaningful Learning in the School Laboratory"
The American Biology Teacher
November/December 88
NABT

Slesnick, Balzer, McCormack, Newton, Rasmussen
Biology
1985
Scott, Foresman, Illinois

Stryer, Lubert
Biochemistry
1981
W.H. Freeman, San Francisco

Tinnesand, Michael & Chan, Alan
"Step 1: Throw Out the Instructions"
The Science Teacher
Sep 87
NSTA

Tortora, Gerard J. & Anagnostakos, Micholas P.
Principles of Anatomy and Physiology
 1987
 Harper & Row, NY

Tortora, Gerard J. & Evans, Ronald L.
Principles of Human Physiology
 1986
 Harper & Row, NY

Vacca, Richard
Content Area Reading
 1981
 Little, Browne and Co., Boston

Vander, Arthur J, Sherman, James H.& Lucian, Dorothy S.
Human Physiology, the Mechanisms of Body Function
 1980
 McGraw-Hill, NY

Wallace, Rober A., King, Jack L. & Sanders, Gerald P.
Biology - The Science of Life
 1981
 Scott, Foresman, Ill.

Weinreb, Eva Lurie
Anatomy and Physiology
 1984
 Addison-Wesley, Mass.

Yager, Robert E.
 "Assess All Five Domains of Science"
The Science Teacher
 Oct 87
 NSTA

BSCS Handbook

Biological Science, a Molecular Approach
 BSCS Blue Version
 1985
 D.C. Heath, Mass.

GLOSSARY

GLOSSARY

acid	substance that produces hydrogen ions when dissolved in water
active site	place on an enzyme that binds its substrate
ATP	adenosine triphosphate, molecule that provides short-term storage of energy in the cell, easily broken down to release that energy
anabolism	synthesis reaction, two or more substances combining to form new and larger molecule
anion	negatively charged ion
atom	smallest unit of structure entering into reactions
atomic number	the number of protons in an atom
base (alkali)	substance that produces hydroxyl ions when dissolved in water
buffer	solution of chemical compounds capable of neutralizing both acids and bases, able to maintain an equilibrium pH
carbohydrates	organic compound with formula $(CH_2O)_n$, sugars, starches, cellulose, chitin
catabolism	breaking bonds to form newer, smaller molecules to release energy
catalyst	substance that will change the rate of a chemical reaction without being changed in that reaction
cation	positively charged ion
colloids	mixture of solvent and intermediate sized particles that are too small to settle out, but too large to dissolve
compound	a pure substance with two or more elements in a fixed ratio; consisting of a single molecule type

covalent bond	interaction of elements in which pairs of electrons are shared to form a molecule
catabolism	breaking bonds to form newer, smaller molecules to release energy
diffusion	movement of molecules from an area of high concentration to an area of low concentration
disaccharides	dimers of two simple sugars
DNA	deoxyribose nucleic acid, contains all information needed to build or repair an organism
electron	negatively charged particle found outside the nucleus
elements	substances that cannot be broken into simpler ones by chemical means. It is a pure substance containing atoms of only one type
energy levels	areas around the nucleus where there is a large probability of finding electrons
enzymes	organic catalyst
equation	shorthand way of denoting a chemical reaction
exchange rxn	combination of synthesis and decomposition reactions; atoms being broken apart then each combining with another to form other molecules
formula	symbols that give ratio and number of elements present in a molecule or compound
hydrogen bond	weak intermolecular electrostatic attraction between two polar molecules
indicator	organic dye used to tell the pH of a substance
induced fit	theory to describe enzyme - substrate interaction

inert	without active chemical properties, not likely to react
inorganic	simple compounds that usually lack carbon atoms
ionic bond	attraction of cation with an anion to form a molecule
ionization	dissociation of ionically bonded molecules into their component ions when dissolved in water
isotope	atom that has the same chemical properties but slightly different atomic mass caused by a difference in the number of neutrons
lipids	type of organic molecule containing carbon, hydrogen and oxygen in no particular empirical ratio
lock and key	theory to describe the way an enzyme interacts with the substrate, no longer considered to be valid
mass number	number of protons and neutrons found in an atom, also known as atomic mass
matter	anything that occupies space and has mass
metabolism	the sum of all anabolic and catabolic reactions in the body
molecules	two or more atoms bonded together
monosaccharide	simple five or six carbon sugar
neutralization	reaction of an acid and base to form a salt and water
neutron	neutral particle found in the nucleus
nucleic acids	found in the nucleus of the cell, made of simple five carbon sugars, nucleotides and phosphates
nucleotide	purines or pyrimidines found in nucleic acids

nucleus	area of atom that contains most of the mass
organic	molecules that contain long chains of carbon atoms bonded in a 1:2:1 ration to hydrogen and oxygen atoms
osmosis	movement of water molecules from an area of high water concentration to an area of low water concentration across a selectively permeable membrane
periodic table	arrangement of elements in chart form, based on their chemical characteristics
pH	an exponentially derived scale that indicates the relative concentration of hydrogen ions in a substance
polysaccharide	polymer of numerous simple sugars
proteins	large, complex organic molecules with nitrogen, sulfur or phosphorous atoms as well as carbon, hydrogen and oxygen atoms
proton	positively charged particle found in the nucleus of an atom
radioisotopes	radioactive isotope, unstable, gives off some type of radiation
reaction	the bonding or unbonding of molecules
reversible rxn	reaction in which the end product can revert to the original reacting substance
RNA	ribonucleic acid, single stranded nucleic acid that has diverse functions in the production of proteins
salt	substance when dissolved in water will dissociate but not into hydrogen or hydroxyl ions
saturated	lipids containing carbons singly bonded to each other and as many hydrogen atoms possible

solute	smaller part of any mixture, usually was a solid before being dissolved
solution	liquid or gas in which another material has been dissolved
solvent	larger part of a mixture, usually a liquid
substrate	any substance involved in a reaction except the enzyme, can also be a protein or enzyme
suspension	mixture of substances in which the particles are so large that they end up settling out of the solvent liquid
symbols	one or two letter abbreviation for chemical elements
unsaturated	lipids containing carbons with double or triple bonds to another carbon
valence number	combining capacity of atom, usually related to the number of electrons in the outer shell.

APPENDICES

APPENDIX A
TOPIC OUTLINE FOR PREVIOUS YEARS

I. Introduction to Chemistry (pre 1988/89)

A. Element

1. Matter
 - a. takes up space and has mass
 - b. solid, liquid, gas
2. elements
 - a. not decomposed into simpler substances by ordinary chemical means
 - b. 106 - 92 natural, rest man-made
3. Letter abbreviations of elements
 - a. H, C, O, N, Na, K, Fe, Ca, P
4. 26 in body
 - a. 96% C, O, H, N
 - b. 99% C, O, H, N, Ca and P
 - c. 20 trace elements

B. Structure of atoms

1. Smallest units of matter entering into chemical reactions
2. Element has only one kind of atoms
3. Nucleus
 - a. center --> mass
 - b. proton is +, neutron no charge
 - c. nucleons = neutrons and protons
4. Electrons, - charge
 - a. move around nucleus
 - b. = to # of protons
 - c. atom is neutral
5. Atomic # = # protons
6. Atomic mass = protons + neutrons
 - a. H has 1 proton
 - b. He has 2 protons and 2 neutrons

C. Atoms and molecules

1. Chemical reaction
 - a. atoms combining or breaking apart
 - b. foundation of life processes
2. Energy levels
 - a. two in first
 - b. eight in second
 - c. simple molecules have 8 in third, more complex have up 18
 - d. filled shells are best, so atoms without filled shells tend to combine
 - e. valence (combining capacity
 - 1) extra or deficient electrons in outer shell
 - 2) Cl (7 valence electrons) and Na (1 valence electron)

3) inert elements have filled outer shell

3. Combine in reactions to form molecules
 - a. same kind of atoms --> multiatomic elements
 - b. different kinds of atom --> compound
 - c. held by bonds which are attractive forces

D. Ionic Bonds

1. electrons gained or lost = ion
 - a. electron donor gives up an electron and has a positive charge
 - b. electron acceptor takes an electron and has a negative charge
 - c. positive and a negative join (opposites attract) to form ionic bond
 - d. less than half filled outer shells will lose electrons --> positive cations
 - e. more than half filled outer shells will gain electrons --> negative anions

E. Covalent bonds

1. Shared electrons
2. Single bond = one shared pair
3. Double bond = two shared pairs
4. Triple bond = three shared pairs
5. same or different kind of atoms

F. Hydrogen bonds

1. Covalently bonded to N or O but attracted to another N or O
2. will not make molecules but makes bridges in or between molecules
3. formed and broken easily
4. many bonds make a molecule more stable

II. Radio isotopes

- A. Isotope - atoms chemically alike but with different nuclear mass from extra neutrons
- B. radioisotopes are unstable and decay by emitting radiation to reach a more stable state

III. Chemical reactions (same atoms rearranged)

A. Synthesis (anabolism)

1. two or more atoms, ions or molecules forming new, larger molecules
2. reactant + reactant --> product
3. $2N + 3H_2 \rightarrow 2NH_3$

B. Decomposition (catabolism)

1. Breaks molecules down into smaller parts
2. Bonds are broken

3. reactant $\rightarrow$ product + product
 4. $\text{CH}_4 \rightarrow \text{C} + 2\text{H}_2$
 - C. Exchange (syn. & decomp.)
 1. $\text{AB} + \text{CD} \rightarrow \text{AC} + \text{BD}$ or $\text{AD} + \text{CB}$
 - D. Reversible
 1. reaction will go in either direction
 2. some need special conditions
 - E. Metabolism
 1. all syn. and decomp. rxns in body
 2. High = faster than normal, eat w/o weight gain, high energy level
 3. low = slower than normal, lethargic, weight gain, slow healing
 - F. Collision Theory
 1. constant movement of atoms or molecules
 2. collide with each other
 3. energy transferred can disrupt electron structure to make or break bonds
 4. Factors
 - a. velocity of particles
 - b. energy of particles
 - c. specific configuration of particles
 - d. orientation of particles
 5. Activation energy - is amount needed to disrupt a stable electron arrangement
 - G. Energy and reactions
 1. E = capacity to do work
 - a. potential
 - b. kinetic
 2. Chemical -energy released when breaking bonds and absorbed when forming bonds
 3. Mechanical- energy of motion
 4. Radiant - heat and light in waves
 5. Electrical - flow of charges or ions
 6. Energy can be transformed from one type to another, but not created nor destroyed
- IV. Chemical composition and life processes
- A. Inorganic compounds
 1. Most w/o C
 2. Vital to body functions
 3. Water - most important and abundant (60% of RBCs, 75% of muscle tissue, 92% of plasma)
 - a. solvent and suspensory medium
 - 1) solute in solvent = solution, will not settle out
 - 2) particles in solvent = suspension, will eventually settle out
 - b. participant in many reactions
 - c. moderates heat changes

- d. cools body
- e. acts as lubricant
- 4. Acids, bases and salts
 - a. dissociate in water
 - b. called electrolytes, will conduct current
 - c. acid --> hydrogen ions plus negative anion
 - d. base --> hydroxyl ions plus positive cations
 - e. salt --> anion and cation
 - 1) acid + base -> water + salt
 - 2) ions of salts in body are essential elements
- 5. Acid/Base balance (pH)
 - a. more hydrogen ions; the more acid
 - b. more hydroxyl ions; the more basic (alkaline)
 - c. pH describes degree of acidity or alkalinity
 - d. scale from 0 - 14
 - 1) number of hydrogen ions in solution in moles per liter
 - 2) pH 7 = 10^{-7} M/L, equal hydrogen and hydroxyl ions
 - 3) pH 4 = 10^{-4} M/L
 - 4) pH 10 = 10^{-10} M/L
 - e. mole
 - 1) mass in grams of combined atomic mass of substance
 - 2) contains 6.023×10^{23} atoms
- 6. Maintaining pH: buffer systems
 - a. normal limits are narrow
 - b. buffer system maintains balance within limits
 - 1) reacts with strong acids and bases and replaces with weak acids and bases
 - 2) strong substances dissociate easily and add many ions to the system
 - 3) weak substance do not dissociate well
 - c. Carbonic acid/bicarbonate buffer
 - 1) weak acid (carbonic acid) and weak base (sodium bicarbonate)
 - 2) if strong acid is added to system, weak base will react to form salt and weak acid
 - a) $\text{HCl} + \text{Na}_2\text{CO}_3 \rightarrow \text{NaCl} + \text{H}_2\text{CO}_3$

- 3) If strong base is added, weak acid will react to form water and weak base
 - a) $\text{NaOH} + \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{NaHCO}_3$
- 4) extra water and salt removed by kidneys

V. Organic compounds

A. Contain chains of carbon

1. react with other molecules to form larger molecules
2. do not dissolve easily in water
3. Large sizes for body structures
4. covalently bonded and decompose easily (ionic bonds break down easier, but reform very quickly)

B. Carbohydrates (sugars and starches)

1. structural units in DNA
2. converted to proteins or fats for energy
3. readily available source of energy for life
4. food reserve as glycogen
5. monosaccharide - 3 to 7 C's
6. proportions $(\text{CH}_2\text{O})_x$
7. disaccharides - 2 or more mono's
 - a. joined by dehydration
 - b. water soluble
 - c. broken down by hydrolysis, sweet taste
 - d. sugars
8. polysaccharides - many joined units
 - a. broken down by hydrolysis, but no sweet taste
 - b. usually not water soluble
 - c. starches

C. Lipids

1. Combinations of C, H, and O
2. dissolve in solvents like alcohol and ether, but not water
3. made of 3 fatty acids and a glycerol by dehydration synthesis
 - a. saturated, no double bonds, animal fat
 - b. unsaturated, some double bonds, vegetable oil
4. Highest concentrated form of energy (twice that of sugars or proteins), but is 10-12% less effective
5. phospholipids
6. steroids
7. carotenes

- 8. prostoglandins (PG)
 - a. membrane associated
 - b. influence function of cell
 - c. produced by cell membranes
 - d. mimics hormones
 - e. modulates hormone reactions
- D. Proteins
 - 1. make body structures
 - 2. related to many physiological functions
 - 3. always C,H,O, & N, may contain S & P
 - 4. made of amino acid chains
 - a. combined by dehydration
 - b. bonds called peptide bonds
 - c. only 20 amino acids used
 - 5. Complex structural organization
 - a. primary - sequence of amino acids
 - b. secondary - colling in 2 dimensions
 - c. tertliary - folding into 3D shapes
 - d. quaternary - several tertiary bonded
- E. Nucleic Acids
 - 1. DNA & RNA
 - 2. made of units called nucleotides
 - a. Nitrogen bases: rings
 - 1) adenine: purine double ring
 - 2) guanine: purine double ring
 - 3) thymine: pyrimidine single ring
 - 4) cytosine: pyrimidine
 - b. Pentose sugar
 - c. Phosphate group
 - 3. Model 1953 by Watson, Crick and Wilson
 - 4. Characteristics of DNA
 - a. 2 strands with crossbars
 - b. twists into double helix
 - c. uprights are alternatng sugars and phosphates
 - d. rungs are paired bases, pyrimidine with a purine
 - e. deoxyribose sugar
 - 5. Genes are segments of the DNA molecule
 - a. determine traits
 - b. control cell activities
 - 6. RNA
 - a. single strand
 - b. thymine replace by uracil
 - c. ribose pentose sugar
 - d. messenger, transfer and ribosomal varieties
- F. Adenosine Triphosphate (ATP)
 - 1. Short term storage of energy for cellular activities

2. 3 phosphate groups, adenine and a ribose sugar
3. one phosphate broken off by hydrolysis to give energy

APPENDIX B
UNIT OUTLINE FOR 1988/89
THE CHEMICAL LEVEL OF ORGANIZATION

I. Introduction (1988/89)

A. In general

1. Matter

a. anything that occupies space and has mass

b. made up of building units called chemical elements

1) can't be broken down into simpler substances by ordinary chemical reactions

2) composed of atoms all of the same type

3) 106 elements; 92 occur naturally

4) symbols

a) one or two letter abbreviation from either Latin or English name

b) MUST know

i) H - hydrogen (usually in water)

ii) C - carbon (backbone of other compounds)

iii) O - oxygen (usually in water)

iv) N - nitrogen

v) Na - sodium

vi) K - potassium

vii) Fe - iron

viii) Ca - calcium

ix) Mg - magnesium

x) Cl - chlorine

xi) He - helium

xii) S - sulfur

xiii) Cu - copper

xiv) Zn - zinc

xv) P - phosphorous

c) subscript gives atomic number

d) superscript gives mass

4) ~26 elements in human body

a) O_2 , C, H_2 , & N_2 = 96% of body weight

b) with Ca and P = 99% body weight

c) other trace chemicals

i) K, S, Na, Cl, Mg

ii) Fe, I, Cu, Zn, Mn, Co, Cr, Se, Mo, F, Sn, Si, V, B

d) refer to p 34, exhibit 2-2, Tortora

B. Structure of atoms

1. smallest unit of matter entering into reactions
 - a. size range from $1.0 \times 10^{-8}\text{cm}$ to $5.0 \times 10^{-8}\text{cm}$
 - b. 50 million of largest end to end would be $\sim 2.5\text{cm}$
2. Parts
 - a. nucleus
 - 1) most of atomic mass
 - 2) protons - + charged particles (1 amu)
 - 3) neutrons - neutrally charged particles (1 amu)
 - 4) ends up with net positive charge
 - 5) P and N together called nucleons
 - b. electrons
 - 1) negatively charged particles that move around nucleus so rapidly they form a cloud
 - 2) in element, # electrons = # protons, so atom has no net charge
 - 3) $1/1836$ of proton mass, therefore mass = 0
3. Differences in elements is number of protons in atom
 - a. atomic number = # P
 - b. atomic weight = # P + N

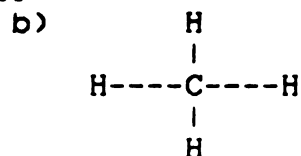
C. Atoms and molecules

1. Chemical reaction occurs when atoms combine or break away from one another
2. Electrons actively participate in reactions
3. Energy levels
 - a. areas around nucleus where electrons are likely to be found
 - b. each level has a maximum number of electrons it can hold
 - 1) level one holds max. of two electrons and is closest to nucleus
 - 2) level two holds 8 electrons
 - 3) level three
 - a) atoms that have an atomic weight of less than 20 can hold maximum of 8 electrons
 - b) atoms that are more complex can hold up to eighteen electrons
 - 4) inner levels held very tightly

- 5) outer levels held less tightly
- 4. Outer energy level is more stable when completely filled
- 5. Valence (combining capacity)
 - a. # of extra or deficient electrons in outermost energy level
 - b. Inert element has the outer level filled
 - c. atoms with incomplete energy level tend to combine with other atoms by trading or sharing
 - 1) If outer level is less than half full, the atom tends to lose electrons when combining
 - a) form positive charged ion called CATION
 - b) Na has 1 electron in outer level and less energy is used to lose electron than to "find" 7 others
 - 2) If outer level is more than half full, the atom tends to gain electrons when combining
 - a) forms negative charged ion called ANION
 - b) Cl has 7 electrons in the outer shell and takes less energy to gain an electron than lose 7
 - 3) If outer level is half full, the atom tends to share electrons when combining, but can gain or lose electrons
- 6. Molecule
 - a. two or more atoms combined with chemical reaction
 - b. two of the same kind of atoms or two different kinds of atoms
 - c. held together by chemical bonds
- 7. compound
 - a. substance that can be broken down into two or more other substances by chemical means
 - 1) chemical changes involving sharing or transferring electrons
 - b. must have at least two elements involved
 - c. always bond in specific amounts that will not vary

8. Formulas

- a. symbols
- b. coefficients indicate the number of molecules
- c. subscript tells number of atoms
- d. gives the ratio and number of elements present
- e. two types of formula
 - 1) molecular
 - a) gives number of molecules
 - b) CH_4
 - 2) structural
 - a) tells the way molecules are put together



D. Ionic bonds

- 1. Ion - atom that has gained or lost 1 or more electrons
 - a. if gains electrons - ends up with negative charge - called electron acceptor
 - b. if loses electrons - ends up with positive charge - called electron donor
 - c. written with a + or - sign after the symbol
- 2. Ions have a net neg. or net pos. charge.
 - a. + and - attracts atoms together
 - b. bond results
 - c. bond is broken when compound is dissolved in water
 - 1) ions move around in solution
 - 2) even water ionizes to a small degree into H^+ and OH^-

E. Covalent bond

- 1. Common in organisms, more stable than ionic
- 2. Two or more atoms share electrons so each has a filled outer shell
- 3. Electrons circle the nuclei of all atoms, spending an equal amount of time around each
- 4. Single bond - one pair of electrons are shared, designated with single horizontal line

5. Double bond - two pairs of electrons are shared, shown by two parallel horizontal lines
6. Triple bond - three pairs of electrons are shared, shown by three parallel horizontal lines.

F. Hydrogen Bonds

1. A hydrogen atom covalently bonded to one oxygen atom or one nitrogen atom, but attracted to another oxygen or nitrogen atom
2. Weak bond (5% of covalent) so will not bind molecules together
3. Serve as bridges between molecules or parts of same molecules
4. Easily formed and broken
5. Even though weak, several hundred in one molecule can add a lot of strength and stability

G. Radioisotopes

1. Isotope
 - a. atom that has the same chemical properties, but a slightly different atomic weight than another
 - b. caused from have a different number of neutrons in the nucleus - all have the same # of P
 - c. atomic weight on periodic table is an average of all the isotopes
 - d. examples of hydrogen isotopes
 - 1) protium ${}_1\text{H}^1$
 - 2) deuterium ${}_1\text{H}^2$
 - 3) tritium ${}_1\text{H}^3$
2. Radioisotopes
 - a. stable isotopes do not emit radiation
 - b. some isotopes are unstable - they "decay" (change nuclear structure) to a more stable form
 - c. during decay they emit radiation that can be detected by instruments
 - 1) instruments can estimate amount of radioisotope in a sample of material and form and image of distribution.
 - d. nuclear medicine

- 1) radioisotope scanning
 - a) doctors inject radioactive isotope, such as ^{32}P , into patient
 - b) note where isotopes gather
 - c) ^{32}P used to treat leukemia
 - d) ^{59}Fe used to study RBC production
- 2) Positron emission tomography (PET)
 - a) short-lived radioisotopes (^{11}C , ^{13}N , ^{15}O) are produced and [put into a sol'n that can be injected into the body
 - b) as they circulate through the body they emit + charged electrons call positrons
 - c) positrons collide with - electrons in body tissues, causing their destruction
 - d) electrons release gamma rays as they are destroyed
 - e) gamma rays are detected by PET receptors
 - f) computers construct a picture that shows where the radioisotopes are being used in the body
 - g) show the effects of drugs in body organs, measure blood flow through organs, detect cancers etc.

H. Chemical reactions

1. equations are a shorthand way to describe chemical rxn
2. Certain conditions must be present in body for rxn to occur
 - a. temperature
 - b. pH
 - c. enzymes present
3. synthesis reactions - anabolism
 - a. 2 or more atoms, ions or molecules combine to form new and larger molecules
 - b. $\text{A} + \text{B} \rightarrow \text{AB}$
 - c. combining substances are called reactants
 - d. new substance is called product
 - e. arrow indicates direction in which the reaction is proceeding
 - f. ex. $\text{N} + 3\text{H} \rightarrow \text{NH}_3$ (ammonia)

- g. ex. in body, glucose combines to form glycogen and amino acids combine to form proteins
- h. often syn rxn is dehydration rxn when water is given off as a product
- 4. Decomposition reactions - catabolism
 - a. bonds of large molecule are broken and smaller molecules, atoms or ions are produced.
 - b. $AB \rightarrow A + B$
 - c. ex. $CH_4 \rightarrow C + 4H$
 - d. ex. in body, digestion and oxidation of food molecules
 - e. often a hydrolysis rxn where water is a reactant that is used up
- 5. Exchange reactions
 - a. partly synthesis and partly decomposition
 - b. $AB + CD \rightarrow AD + BC$ or $AC + BD$
- 6. Reversible reactions
 - a. the end product can revert to the original combining molecules
 - b. $A + B \rightleftharpoons AB$
 - c. can occur because neither the reactants nor the end products are stable or under special conditions
 - 1) special conditions are written under or over the arrows
 - 2) special conditions can be heat or addition of water
- 7. Metabolism
 - a. The body must break down molecules in small steps so the energy released does not destroy the body
 - b. The sum of all the synthesis and decomposition reaction in the body.
 - c. High metabolism means that the reactions are occurring at a faster rate than normal and body can't always store it
 - 1) tend to eat a lot without gaining weight
 - 2) generate a lot of heat so often say they are hot
 - d. Low metabolism means that the body reactions are taking place at a slower rate than usual
 - 1) food is only partially broken down, and it occurs quite slowly
 - 2) often have little energy, gain weight and feel cold

8. How chemical reactions occur

a. collision theory

- 1) all atoms, ions, and molecules are always moving and colliding with each other.
- 2) energy transferred by the particles in the collision might disrupt their electron structures enough so that chemical bonds are broken and/or formed
- 3) factors
 - a) velocities of particles
 - b) energy of particles
 - c) specific chemical configuration
 - d) certain energy needed to disrupt bonds
 - e) particles must be in particular orientation to react.

b. Catalyst usually will be present

- 1) will alter rate of reaction without itself being affected

9. Energy and chemical reactions

a. energy - the capacity to do work

- 1) potential - stored
- 2) kinetic - motion

b. forms

- 1) chemical energy released during breaking of chemical bonds and absorbed during the formation of bonds.

a) building processes of body are synthesis reactions which use energy

b) digestion is decomposition reactions which release energy

- 2) mechanical energy is energy involved in moving (when the muscles move a part of the body)

- 3) Radiant energy, such as heat and light

a) travels in waves

b) some release during decomposition reactions

- 4) electrical energy from flow of charges, electrons or ions (essential for nerve impulses)

- c. forms of energy can be changed from one to another, but never created or destroyed

II. Chemical compounds and life processes

A. Inorganic compounds - usually lack carbon

1. Water (cannot live without more than a few days)

a. most abundant and important inorganic substance in body

- 1) 60% of RBC, 92% of blood
- 2) 75% of muscle tissue

b. excellent solvent and suspending medium (no chemical change required, amounts involved can vary)

- 1) solution - liquid or gas, the solvent, in which some other material, the solute, (solid, liquid or gas) has been dissolved

- a) can have more than one solute (or solvent)

- b) solute recovered by chemical means or evaporation

- c) example - salt and water

- 2) suspension - material mixed with the suspending medium will eventually settle out.

- a) example - cornstarch and water

- 3) colloids

- a) particles too large to dissolve

- b) too small for suspension

- c) change easily from liquid to semi-solid and back

- d) gelatin is good example

- 4) essential to survival

- a) blood in solution with oxygen/ CO_2

- b) carries dissolved nutrients

- c) suspend molecules to bring them in contact with other materials

c. participates in chemical reactions, both synthesis and decomposition

d. absorbs and releases heat slowly to moderate temperature fluctuations in body

e. good cooling mechanism because when it evaporates, it takes large quantities of heat with it

- f. serves as a lubricant - chest, joints, digestive tract
- g. is a stable element, it takes large amounts of energy to decompose it
- h. ionizes to be used in chemical reactions

2. Acids, bases and salts

a. Ionization

- 1) when molecules of inorganic acid, bases or salts are dissolved in water, they dissociate into ions
 - a) also called electrolytes because they can conduct electric current

b. acid

- 1) a substance that dissociates into one or more hydrogen ions (H^+) and one or more anions.
- 2) also defined as a proton (H^+) donor because it provides hydrogen ions to the solution
- 3) examples--vinegar and lemon juice

c. base (alkali)

- 1) dissociates into one or more hydroxyl ions (OH^-) and one or more cations
- 2) viewed as a proton acceptor because it removes hydrogen ions from the solution
- 3) feels slippery because it removes the top layer of skin
- 4) examples - ammonia and most detergents

d. salt

- 1) when dissolved in water, dissociated into cations and anions, but neither is (H^+) or (OH^-)
- 2) formed from reactions of acid with base (water is other product) This is called neutralization
 - a) $KOH + HCl \rightarrow HOH + KCl$
 - b) $2 KOH + H_2SO_4 \rightarrow 2 HOH + K_2SO_4$
- 3) many found in the body and are essential

3. Acid-base balance: the concept of pH

- a. explanation - in water, acids dissociate into hydrogen ions and bases dissociate into hydroxyl ions
- b. the more H^+ in solution, the more acid the solution
- c. the more OH^- in solution, the more basic the solution
- d. equal amounts of H^+ and OH^- mean the solution is neutral
- e. acidity expressed on pH scale that runs from 0 - 14
 - 1) based on the number of H^+ ions in solution expressed in moles/liter
 - 2) at pH 7 there is 0.0000001 moles/L of H^+
 - a) when this is written in exponential form 1×10^{-7}
 - b) convert the exponential number to positive and it is the pH number
 - c) 1×10^{-4} M solution of H^+ is pH 4
 - 3) a change of one pH number represents a 10 fold increase or decrease in the concentration of hydrogen ions
 - 4) refer to exhibit 2-3 on page 36 of Tortora
- f. Neutral $[OH^-] = [H^+]$

4. Maintaining the pH: buffer systems

- a. pH of body fluids may vary but range for each are specific and narrow
- b. buffer system reacts with strong acids and bases and replace them with weak acids and bases that won't change pH values very much
- c. most common is carbonic acid-bicarbonate buffer system
 - 1) acid component $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
 - 2) base component $NaHCO_3 \rightleftharpoons Na^+ + HCO_3^-$
 - 3) If strong acid is introduced, the weak base is activated
 - a) $HCl + NaHCO_3 \rightleftharpoons NaCl + H_2CO_3$
 - b) forms a weak acid and table salt

- 4) If strong base is introduced, the weak acid is activated
 - a) $\text{NaOH} + \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}_2\text{O} + \text{NaHCO}_3$
 - b) forms water and a weak base
- 5) whenever buffering occurs, the concentration of one member of the pair is increased while the other is decreased
- 6) The buffer substances (HCl and NaOH) are removed at the kidneys, and the buffer solutions are ready for reuse

5. Indicators

a. pH scale

- 1) indicate degree of [ion] in solution
- 2) most acidic (0) to most alkaline (14)
- 3) 7 = neutral

b. measuring pH

- 1) electronic pH meter
- 2) pH paper
 - a) turns different colors at different pH
 - i) mixture of chemical indicators
 - ii) matched to color chart to find pH
- 3) litmus
 - a) indicates acid or base only
 - b) pink = acid, blue = base
 - c) can be liquid or on paper
- 4) phenolphthalein turns pink in bases over pH 8

B. Organic compounds

1. In general

a. made of long chains of carbon molecules

- 1) carbon can form four bonds with other atoms
 - a) has four electrons in outer shell
 - b) especially reactive with hydrogen
- 2) relatively large
- 3) do not dissolve easily in water

b. other common elements

- 1) hydrogen - one bond (1 electron in outer shell)
- 2) oxygen - two bonds (6 electrons " " ")
- 3) nitrogen - three bonds (5 ")
- 4) sulfur - two bonds (6 electrons in outer shell)
- 5) phosphorous - five bonds (5 electrons)

c. useful for building body structures

d. usually held together with covalent bonds

- 1) good source of energy
- 2) ionic bonds not good for energy because they form new ionic bonds as soon as the old ones are broken

2. Carbohydrates made by plants

a. sugars and starches

b. functions

- 1) building block of DNA
- 2) converted to proteins or fats
- 3) food reserves (glycogen)
- 4) most important is ready source of energy

c. components

- 1) carbon, hydrogen and oxygen
- 2) ratio H:O is 2:1
- 3) general formula $(CH_2O)_n$
 - a) glucose $C_6H_{12}O_6$
 - b) ribose $C_5H_{10}O_5$
 - c) sucrose $C_{12}H_{22}O_{12}$

d. groups, based on size

- 1) Monosaccharides - simple sugars made from three to seven carbons ($C_6H_{12}O_6$)
 - a) 3 are trioses
 - b) 4 are tetroses
 - c) 5 are pentoses
 - d) 6 are hexoses) most important in body
 - e) 7 are heptoses
 - f) isomers can have the same number of carbons and be called by different names because the arrangements of atoms in the molecule determine its properties
 - vii) sweet taste, soluble in water

- 2) disaccharides - two monosaccharides joined chemically ($C_{12}H_{22}O_{11}$)
 - a) formation is a dehydration synthesis - water is a product
 $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$
 - b) can be broken down by hydrolysis which uses a water molecule
 - c) sweet taste, soluble in water
 - 3) polysaccharides - several monosaccharides joined [$(C_6H_{10}O_5)_x$]
 - a) dehydration synthesis to form
 - b) hydrolysis to break down
 - c) do not have a sweet taste
 - d) not usually soluble in water
 - e) storage form
 - i) starch in plants (white of potato)
 - ii) cellulose in plants (strings in celery)
 - iii) glycogen in animals
3. Lipids (essential for cell membrane)
- a. used for long term storage of food, release the most energy when oxidized
 - b. composed of CHO but H:O ratio are not 2:1
 - c. insoluble in water, but should dissolve in alcohol, chloroform and ether
 - d. examples of types - fats, phospholipids, steroids, and vitamins E and K (see exhibit 2-4, p 39, Tortora)
 - e. molecule of fat is made up of a glycerol and 3 fatty acid molecules (dehydration synthesis)
 - f. saturated fat
 - 1) no double bonds between any carbons and all C's are bonded to the maximum number of hydrogens
 - 2) occur mostly in animal foods
 - 3) also in cocoa and palm butters
 - 4) many times are solid (nearly) at room temperature

g. unsaturated fat

- 1) one or more double covalent bonds between carbon
- 2) olive or peanut oil
- 3) quite often a liquid at room temperature

h. poly unsaturated fat

- 1) two or more (many) double covalent bonds between carbons
- 2) corn oil, sunflower oil, soybean oil
- 3) usually liquid at room temperature

i. most highly concentrated form of energy

- 1) twice as much energy as proteins or CHO
- 2) but 10-12% less efficient as fuels than CHO

j. prostaglandins (PG) associated with membranes and influence functioning of the cell by mimicking hormones

k. lipo-proteins

- 1) HDL - remove cholesterol from blood so it can be excreted
- 2) LDL - seems to deposit cholesterol on artery linings

4. Proteins

a. in general

- 1) complex
- 2) much of body structure and related to many physiological activities
- 3) denatured by change in temperature or pH (changes shape)
- 4) specific sequence of amino acids

b. components

- 1) C, H, O & N; sometimes S & P
- 2) built of 20 different amino acids joined with peptide bonds (dehydration synthesis)
- 3) 2 a.a. = dipeptide
- 4) 3 a.a. = tripeptide
- 5) 4 to several hundred = polypeptide

c. structure

- 1) primary level
 - a) sequence of amino acids in molecule
 - b) single substitution can result in a deformation of molecule (Hb)
- 2) secondary level
 - a) coiling or zig-zag arrangement along two dimensions
 - b) spirals or pleated sheets
- 3) tertiary level
 - a) bending or folding into a 3-D shape
- 4) quaternary structure
 - a) two or more tertiary patterns bonded to each other

5. Enzymes

a. characteristics

- 1) organic catalyst which changes the rate of the reaction without being involved in the reaction
 - a) can speed reaction up to 10 billion times without an increase in temperature or pressure which can kill the cell
- 2) large protein molecules with characteristic 3-D shape
- 3) specific in reactions catalyzed and molecules (substrate) reacting
 - a) lock and key model
 - b) induced fit
 - i) slightly plastic active site
 - ii) can mold around substrate that "almost" fits
- 4) end in suffix "-ase"
- 5) shape is important in determining activity
 - a) altered by heat
 - i) most won't function above 60°C
 - ii) high heat kills enzymes needed for life

- b) lead and mercury compounds affect active sites of some enzymes
 - i) Pb and Hg poisonous
 - ii) Hg absorbed through skin
 - iii) Pb ingested or inhaled
- 6) needed only in small quantities
 - a) can be reused
 - b) one molecule of catalase can catalyze the breakdown of 5 million molecules of H_2O_2 within one minute
- 7) enter into reaction with substrate to form temporary complex
- 8) Have an active site where the substrate can bind
- 9) actions are reversible
 - a) $A + B \rightarrow AB$ can also be $AB \rightarrow A + B$
 - b) usually written with double arrow
- 10) rates vary with environmental conditions
 - a) temperature
 - i) rate increases until optimum is reached then is denatured and stops working
 - ii) denaturization starts about 40 C (104F) and rxn rate drops sharply
 - b) amount of enzyme and substrate
 - i) rate increases until all enzymes are actively engaged and then it levels off
 - c) pH
 - i) optimum pH varies with enzyme
 - ii) many at around 7 but there are exceptions such as pepsin which works best about 2

b. Parts

- 1) some are only proteins
- 2) most have protein component called apoenzyme that is inactive without a non-protein cofactor -- whole thing called holoenzyme
 - a) metal ions such as zinc, iron and calcium
 - b) vitamins, especially the B vitamins

c. mechanism of action

- 1) surface of substrate makes contact with specific region on surface of enzyme molecule known as active site
- 2) temporary intermediate forms called enzyme-substrate complex
- 3) substrate is transformed
 - a) by rearrangement of existing atoms
 - b) by breakdown of substrate molecule
 - c) by combination of several substrate molecules
- 4) transformed substrate molecules = product
- 5) product moves away from enzyme
- 6) enzyme attaches to new substrate

6. Nucleic acids: DNA (from parent to offspring) and RNA (from nucleus to cytoplasm)

- a. first discovered in nucleus of cells
- b. large organic molecules with C, H, O, N & P
- c. basic building unit is nucleotide (basic pH)
 - 1) one of four possible nitrogen bases in a ring arrangement
 - a) A and G are double ring purines
 - b) T and C are single ring pyrimidines
 - 2) pentose sugar called deoxyribose in DNA and ribose in RNA
 - 3) phosphate groups
 - 4) named according to nitrogen base
- d. structure deduced in 1953 by James Watson and Frances Crick from x-ray diffraction studies done by Roselyn Franklin and Maurice Wilkins

e. characteristics of DNA

- 1) two strands with crossbars
- 2) strands twist around each other in double helix, most to the right
- 3) sides of strands are made up of alternating phosphates and sugar
- 4) crossbars are paired nitrogen bases - a large purine paired with a smaller pyrimidine, A-T and G-C
- 5) genes
 - a) hereditary material found in cells
 - b) made up of segments of DNA molecules
 - c) determine traits we inherit
 - d) control all cell activities

7. Adenosine Triphosphate (ATP)

- a. found in all living systems and stores energy for cellular activities
- b. three phosphate groups and adenosine unit with adenine and ribose
- c. when terminal phosphate group is hydrolyzed the reaction liberated a great deal of energy
- d. energy is used by cell for its activities
- e. left over molecule is ADP which can be bond another P if energy is added from decomposition reactions
- f. $\text{ATP} \rightleftharpoons \text{ADP} + \text{P} + \text{energy}$

APPENDIX C

BEHAVIORAL OBJECTIVES FOR CHEMISTRY UNIT

BEHAVIORAL OBJECTIVES FOR CHEMISTRY UNIT

1. define matter, elements, atoms
2. given symbols of 15 selected elements, give names and vice versa
3. list 4 major element and 12 of 20 trace elements in body
4. explain simple Bohr model of atom; list parts and define each
5. recognize elements from atomic drawing; sketch any element when given either atomic mass or atomic number
6. calculate atomic mass from atomic number, electron number, proton or neutron number
7. define and describe electron energy levels; given an electron number, be able to assign to the correct energy level
8. predict atomic bonding relative to the number of electrons in the outer shell and/or position of the element on the periodic table
9. define and give examples of molecule, compound, ionic, covalent and hydrogen bonding
10. discuss importance of hydrogen bonding relative to human body
11. define and discuss importance of radiol isotopes in detection of homeostasis breakdown.
12. discuss and give examples of types of chemical reactions; be able to recognize type of reaction from an equation
13. list and explain 4 of 5 factors that affect the rate of reaction
14. describe 3 of 4 forms of energy; given examples, tell form of energy involved
15. List 4 of 6 important characteristics of water, be able to explain and give examples of each
16. define and give examples of acids, bases, salts and pH.
17. describe what makes a solution acidic or basic and how to test for acidity; derivation of most indicators
18. given molarity, $[H^+]$, or $[OH^-]$ determine pH and vice versa
19. explain the properties of a buffer, and describe how the carbonic acid/ bicarbonate buffer system works in the body.
20. define and recognize an organic molecule by name or formula; define
21. list characteristics of carbohydrates, proteins, lipids, nucleic acids
22. describe a simple chemical test for the three major types of organic molecules

23. given model parts of a DNA molecule, recognize that there is only one way to assemble; list bases and pairing order; draw simplified DNA or RNA molecule
24. explain briefly how energy is stored and released in the body.
25. interpret graphed or tabulated data
26. write conclusions from observations, citing the observations for support

APPENDIX D
TESTING INSTRUMENTS

PHYSIOLOGY PRE-TEST FOR CHEMISTRY
Fall 1988

Name_____

Date_____Hour_____

Read all of the following questions carefully and answer them according to the instructions provided.

MULTIPLE CHOICE: Select the lettered choice that best answers each question.

1. Chemically, the protoplasm of cells consists of
 - a) mostly rare elements
 - b) hundreds of different elements
 - c) elements, each of which usually retains its own elemental characteristics
 - d) mostly common elements
 - e) mostly elements with high atomic masses
2. The four most common elements in the human body are
 - a) carbon, hydrogen, oxygen and chlorine
 - b) carbon, oxygen, nitrogen, and chlorine
 - c) carbon, hydrogen, nitrogen and calcium
 - d) carbon, hydrogen, oxygen and iron
 - e) carbon, oxygen, hydrogen and nitrogen
3. Which of the following statements regarding pH is true?
 - a) a dilute solution of almost any acid will have a pH of somewhere above 7
 - b) the pH scale is used to indicate the acidity of solutions, but not the alkalinity
 - c) a solution of pH 4 is twice as acidic as one with pH 2
 - d) a solution with pH 8 is more acid (less alkaline) than one with pH 9
 - e) none of the above is true
4. A molecule of carbohydrate contains the chemical elements
 - a) nitrogen, carbon and hydrogen
 - b) calcium, carbon and chlorine
 - c) carbon, hydrogen and oxygen
 - d) carbon, oxygen and phosphorus
 - e) carbon, oxygen and nitrogen

5. $C_6H_{12}O_6$
a) is an example of a structural formula
b) represents a hexose
c) is a form of glycerol
d) is a product of the digestion of proteins
e) is formed by the digestion of fatty acids
6. Polysaccharides a) are a type of complex carbohydrate b) include lecithin c) are reduced to fatty acid on digestion d) contain nitrogen e) have a definite empirical formula
7. A molecule of fat a) may be stored as part of a protein molecule b) is known as a "protein saver" c) is converted into amino acids d) can repair or replace protoplasm e) is composed of one molecule of glycerol and three molecules of fatty acid
8. The most complex organic compounds are
a) disaccharides b) starches c) proteins
d) fats e) monosaccharides
9. Which of the following is true
a) both adenine and DNA are found in the cytoplasm of the cell
b) neither adenine nor DNA are found in the nucleoplasm of a cell
c) DNA constitutes a part of the adenine molecule
d) adenine constitutes part of the DNA molecule
e) adenine and DNA are completely unrelated
10. Genetic information for cell use is replicated from deoxyribonucleic acid into another type of nucleic acid a) called amino acid b) found only in the nuclei of cells c) having a more complex molecular structure than DNA d) after DNA has passed from the nucleus to the cytoplasm e) known as ribonucleic acid (RNA)
11. The expenditure and transformation of energy which is the basis for all life processes a) is called anabolism b) is also the basis for organic evolution c) depends upon plant and animal hormones d) is controlled by chemicals called enzymes e) may be related mathematically using the Hardy-Weinberg law

12. A substrate a) is a substance that is affected by a vitamin b) is the substance that is affected by an enzyme c) forms the dentine of teeth e) is as easily affected by temperature as an enzyme is
13. In enzyme action a) an enzyme precursor forms a complex (combination) with the enzyme b) large molecules are always reduced to smaller ones c) a given enzyme may react chemically with a large numbers of molecules d) the substrate is the substance acted on e) a high concentration of enzyme molecules is necessary for proper catalytic action
14. The role of vitamins in metabolism is that they combine with other substances to form larger molecules called a) coenzymes b) hormones c) substrates d) pangenes e) antienzymes
15. Enzymes a) are highly resistant to the action of strong acids b) can easily be made in a laboratory c) are not affected by temperature changes d) are unchanged by the reactions they bring about e) are inorganic compounds
16. Which of the following is the most complex compound? a) protein b) amino acid c) nitrate d) inorganic nitrite e) ammonia
17. A catalyst is a) a substance which affects the rate of a chemical reaction b) a powerful oxidizing agent c) a substance that does not take place in any part of a chemical reaction d) a strong electrolyte e) the negative pole of an electrolytic cell
18. Which of the following is NOT a compound? a) water b) sugar c) hydrogen d) salt e) carbonate
19. The atom can be seen by means of a) an electron microscope b) a compound microscope c) a geiger counter d) no instrument now available d) a spectroscope
20. The most abundant compound in protoplasm is a) protein b) carbohydrates c) fat d) sugar e) water

21. The elements always contained in proteins are
a) carbon, hydrogen and oxygen b) carbon, hydrogen, sulfur and phosphorous c) carbon, hydrogen, oxygen and nitrogen d) hydrogen and oxygen e) calcium, sulfur, potassium and iron
22. Simple sugars, double sugars, starches and cellulose belong to a group of organic compounds known as a) fats b) proteins c) carbohydrates d) enzymes e) amino acids
23. The substance which in the body acts as a solvent for mineral salts and many organic compounds, that favors the movement of materials, and that changes temperature slowly is a) protein b) water c) fat d) carbohydrate e) enzyme
24. An enzyme is a) an organic catalyst b) an organic digestive juice c) an organic hormone d) an acid e) a complex inorganic protein
25. The number of different COMPOUNDS now known to exist is
a) greater than b) less than c) the same as
the number of ELEMENTS known to exist
26. Which class of foods yields the greatest number of calories per unit? a) proteins b) fats c) vitamins d) carbohydrates e) mineral salts
27. Any substance which tends to minimize the fluctuations in the hydrogen ion concentration within the cell is called a(n) a) acid b) salt c) buffer d) catalyst e) amino acid
28. the units of structure of proteins are
a) glycerine b) amino acids c) monosaccharides d) fatty acids
29. The units of structure of fats are a) glycerol and fatty acids b) amino acids c) monosaccharides d) fatty acids e) none of the above
30. Simple substances which can be neither decomposed nor transferred into one or another by ordinary means is a) an element b) a heterogeneous mixture d) a homogeneous mixture e) a compound e) none of these

31. Which one of the following terms includes the other four?
a) molecule b) atom c) element d) compound
e) matter
32. When a fat is synthesized, a) fatty acids combine together b) simple sugars combine together
c) fatty acids combine with glycerol d) glycerol combines with a simple sugar e) amino acids combine to form large molecules
33. If distilled water were tested with a pH meter, its pH should be a) 2 b) 7 c) 13 d) 4 e) 8

SHORT ANSWER: answer the following questions completely. You do not need to use complete sentences. Be sure diagrams are well labeled.

34. List three properties of water that make it important to the body
35. Make a diagram to show the arrangement of protons, neutrons and electrons in a carbon atom.
36. What kind of bond (ionic or covalent) would an atom be likely to form if it had one or two outer electrons?
37. Use chemical symbols to write the formula for carbon dioxide.
38. Write an equation (it does not have to be balanced) to show that water and carbon dioxide combine to form carbonic acid H_2CO_3 .
39. What is the pH scale used to express?
40. Define the term: chemical formula.
41. Define acid and give an example of one.

PHYSIOLOGY POST-TEST FOR CHEMISTRY
Fall 1988

Name_____

Date_____Hour_____

Read all of the following questions carefully and answer them according to the instructions provided.

MULTIPLE CHOICE: Select the lettered choice that best answers each question.

1. Chemically, the protoplasm of cells consists of
 - a) mostly rare elements
 - b) hundreds of different elements
 - c) elements, each of which usually retains its own elemental characteristics
 - d) mostly common elements
 - e) mostly elements with high atomic masses
2. The four most common elements in the human body are
 - a) carbon, hydrogen, oxygen and chlorine
 - b) carbon, oxygen, nitrogen, and chlorine
 - c) carbon, hydrogen, nitrogen and calcium
 - d) carbon, hydrogen, oxygen and iron
 - e) carbon, oxygen, hydrogen and nitrogen
3. Which of the following statements regarding pH is true?
 - a) a dilute solution of almost any acid will have a pH of somewhere above 7
 - b) the pH scale is used to indicate the acidity of solutions, but not the alkalinity
 - c) a solution of pH 4 is twice as acidic as one with pH 2
 - d) a solution with pH 8 is more acid (less alkaline) than one with pH 9
 - e) none of the above is true
4. A molecule of carbohydrate contains the chemical elements
 - a) nitrogen, carbon and hydrogen
 - b) calcium, carbon and chlorine
 - c) carbon, hydrogen and oxygen
 - d) carbon, oxygen and phosphorus
 - e) carbon, oxygen and nitrogen

5. $C_6H_{12}O_6$
a) is an example of a structural formula
b) represents a hexose
c) is a form of glycerol
d) is a product of the digestion of proteins
e) is formed by the digestion of fatty acids
6. A molecule of fatty acid
a) has the same structural formula as a monosaccharide
b) has the same empirical formula as a monosaccharide
c) is either saturated or unsaturated
d) has an equal number of carbon and oxygen atoms
e) contains nitrogen
7. Amino acids
a) are a true acid
b) are present in carbohydrates
c) are present in cellulose
d) contain nitrogen
e) are also called fatty acids
8. Each unit comprising the DNA macromolecule is made of
a) a nitrogenous base
b) a five carbon sugar
c) a phosphate
d) all of the above
e) a nitrogenous base and a phosphate.
9. Genetic information for cell use is replicated from deoxyribonucleic acid into another type of nucleic acid
a) called amino acid
b) found only in the nuclei of cells
c) having a more complex molecular structure than DNA
d) after DNA has passed from the nucleus to the cytoplasm
e) known as ribonucleic acid (RNA)
10. The expenditure and transformation of energy which is the basis for all life processes
a) is called anabolism
b) is also the basis for organic evolution
c) depends upon plant and animal hormones
d) is controlled by chemicals called enzymes
e) may be related mathematically using the Hardy-Weinberg law
11. The main function of an enzyme is to speed up or slow down a specific chemical reaction. This statement is most closely related to which of these life characteristics?
a) irritability
b) metabolism
c) reproduction
d) adaptability
e) growth

12. In enzyme action a) an enzyme precursor forms a complex (combination) with the enzyme b) large molecules are always reduced to smaller ones c) a given enzyme may react chemically with a large numbers of molecules d) the substrate is the substance acted on e) a high concentration of enzyme molecules is necessary for proper catalytic action
13. The role of vitamins in metabolism is that they combine with other substances to form larger molecules called a) coenzymes b) hormones c) substrates d) pangenes e) antienzymes
14. When enzymes act a) the energy for their actions is derived from the enzymes themselves b) the resulting products are called substrates c) an intermediate enzyme-substrate complex is probably formed d) the enzymes are destroyed during the enzyme action, so much be constantly produced e) their reactions are not affected by the pH or concentration of the substances acted on.
15. Enzymes a) are highly resistant to the action of strong acids b) can easily be made in a laboratory c) are not affected by temperature changes d) are unchanged by the reactions they bring about e) are inorganic compounds
16. Subdivision of large, complex molecules into their smaller, simpler components is accomplished by chemical reaction known as a) condensation b) hydrolysis c) plasmolysis d) synthesis e) agglutination
17. Which of the following is NOT a compound?
a) water b) sugar c) hydrogen d) salt
e) carbonate
18. The atom can be seen by means of a) an electron microscope b) a compound microscope c) a gelger counter d) no instrument now available d) a spectroscope
19. Which of the following groups of elements make up almost 99% of the protoplasm of organism?
a) hydrogen and oxygen b) carbon, hydrogen, oxygen and nitrogen c) carbon, hydrogen and oxygen d) carbon, hydrogen, oxygen, sodium and phosphorous

20. The most abundant compound in protoplasm is
a) protein b) carbohydrates c) fat d) sugar
e) water
21. Simple sugars, double sugars, starches and cellulose belong to a group of organic compounds known as
a) fats b) proteins c) carbohydrates
d) enzymes e) amino acids
22. The substance which in the body acts as a solvent for mineral salts and many organic compounds, that favors the movement of materials, and that changes temperature slowly is
a) protein b) water
c) fat d) carbohydrate e) enzyme
23. Which of the following statements best characterizes fats?
a) they are synthesized from amino acids
b) they contain hydrogen and oxygen in the same proportions as these elements occur in water
c) They are made up of more complex molecules than are proteins
d) they serve primarily as a protoplasm-building material
e) they have less oxygen in proportion to hydrogen than do carbohydrates
24. An enzyme is
a) an organic catalyst b) an organic digestive juice
c) an organic hormone
d) an acid e) a complex inorganic protein
25. The number of different COMPOUNDS now known to exist is
a) greater than b) less than c) the same as
the number of ELEMENTS known to exist
26. Which class of foods yields the greatest number of calories per unit?
a) proteins b) fats
c) vitamins d) carbohydrates e) mineral salts
27. Carbohydrates, fats and proteins always contain at least
a) carbon, hydrogen and oxygen
b) carbon and hydrogen but not necessarily oxygen
c) carbon and oxygen but not necessarily hydrogen
d) oxygen and hydrogen but not necessarily carbon
e) nitrogen

28. Which of the following statements best describes an organic substance?
a) it is a material which is less combustible than an inorganic substance
b) it is a material capable of being produced by a living organism only
c) it is a long chain carbon compound that can be easily synthesized in either the body of a living organism or in the laboratory
d) it is a compound which always contains nitrogen, sulfur and phosphorous
e) it is the bridge between living and non-living matter
29. Any substance which tends to minimize the fluctuations in the hydrogen ion concentration within the cell is called a(n) a) acid
b) salt c) buffer d) catalyst e) amino acid
30. the units of structure of proteins are
a) glycerine b) amino acids c) monosaccharides
d) fatty acids
31. Simple substances which can be neither decomposed nor transferred into one or another by ordinary means is a) an element b) a heterogeneous mixture d) a homogeneous mixture e) a compound
e) none of these
32. Which one of the following terms includes the other four?
a) molecule b) atom c) element d) compound
e) matter

SHORT ANSWER: answer the following questions completely. You do not need to use complete sentences. Be sure diagrams are well labeled.

33. List three properties of water that make it important to the body
34. Make a diagram to show the arrangement of protons, neutrons and electrons in a carbon atom.
35. What kind of bond (ionic or covalent) would an atom be likely to form if it had one or two outer electrons?
36. Use chemical symbols to write the formula for carbon dioxide.

37. Write an equation (it does not have to be balanced) to show that water and carbon dioxide combine to form carbonic acid H_2CO_3
38. What ion causes a solution to be an acid?
39. Define the term: chemical formula.
40. Define acid and give an example of one.

APPENDIX E
STUDENT INTERVIEWS

INSTRUMENT FOR INTERVIEWING STUDENTS ABOUT CHEMISTRY
UNIT

What do you remember most about the unit on chemistry?
Why?

What part of the unit has been most helpful with the
other topics you've studied? Why?

What do you think was easiest to learn? Why?

What was the most difficult to learn? Why?

Do you think the time spent on the unit was
appropriate, too long, or too short? Why?

Would you rather see more (or fewer) labs? Why?

Do you find it easier to learn from the labs or text?
Why?

STUDENT INTERVIEWS CONCERNING CHEMISTRY UNIT

The Physiology class this year is made up of a mix of tenth, eleventh and twelve grade students. They all expect to attend college. The chemistry unit was taught from September 12 to October 14, 1988. Interviews were conducted April 5 and 6, 1989. The students took a retest of the material on April 3, 1989 to compute retention and remind them of the unit. The criteria for selection of students for interviews was based on a set of random numbers generated by the computer and modified by absences and volunteers. One of the two students with low grades refused to be interviewed, and the second was absent both days. The following questions were put to the students. Answers are written in order given.

1. What do you remember most about the unit on chemistry? Why?
2. What part of the unit has been most helpful with the other topics you've studied? Why?
3. What do you think was easiest to learn?
4. What was most difficult for you? Why?
5. Do you think the time spent on the unit (6 weeks) was appropriate? Why or why not?
6. Would you rather see more or fewer labs? Why?
7. Do you find it easier to learn from the book or the labs?

Student #14 is an A/B student. He must study to do well on the tests and does daily work consistently. When asked what he remembered most on the chemistry unit, he could not remember anything. He was the first person to be interviewed.

Student #10 is an A/B student. He is conscientious about tests and daily work, but good grades do not come easy for him.

1. The, ah, symbols for the elements. [no answer on why]
2. probably the unit on chemistry
3. the atoms [no answer to why]
4. the bonding, they're hard to separate
5. just right because it wasn't too long to make you bored and it wasn't too short so you didn't get enough
6. fewer, too tedious
7. reading text [no answer to why]

Student #8 is a high achiever. He consistently sets the curves on tests and quizzes. He takes his book home almost every night and actually does the assigned reading.

1. covalent bonding 'cause I had a little bit of it in ninth grade
2. probably when we learned all the names of the elements and symbols and everything so because there's a lot of that in like the nervous system and the intestinal system
3. um, hum let's see
4. can't really remember anything that was easy or difficult
5. It was fine the way it was, if you make it any longer you sort of get out of the class because its physiology, not chemistry so
6. probably just around where it was
7. I'd say the textbook, but then you can see it work in the labs, but I learn more from the text.

Student #4 is a B student. I think she is working a little over capacity because she is competing with her younger brother who is also in the class.

1. the element chart because we used it a lot
2. the element chart and when we did the pH and stuff like that
3. the pH because it just was
4. the element chart because there was so many to learn
5. It was a little long
6. fewer cause I don't like labs
7. textbook!

Student #9 is a C student and has to work very hard to keep her grade at that level. She focuses on facts rather than concepts.

1. the elements
2. the pH scale, because I like [unintelligible for rest of answer]
3. learning to work with the pH scale
4. the elements and compounds cause it was difficult for me
5. [no answer]
6. more, I like labs
7. the labs

Student # 19 is a C/B student. He could do better but tends to be a little lax on the daily work.

1. ah, pH [long pause, no answer to why]
2. [no answer]
3. um, ah, the section on bones and muscles [interviewer "that wasn't in the chemistry unit."] Oh, ah, I, I...
4. the... um... the formulas
5. no, it was about....right, because it was a... um... a complex subject
6. fewer,[no answer to why]
7. the lab because you experience it instead of reading it.

Student #11 says she does not understand anything that is going on in the class and at one time had contemplated dropping the course, but she consistently maintains a B average.

1. um, I remember the stuff about enzymes and about different substances that, you know,[rest of answer unintelligible]. We worked on that a lot and did stuff about it and then we....
2. well, like the stuff we learned about enzymes that you use with other stuff about your body
3. well, like when we did all those labs about the enzymes it makes it easy to remember and everything
4. well, I can't remember like all the different names and different functions and that. I know 'em but I don't know all the names and stuff
5. well, I think that was about the right amount of time, not too long or too short
6. um, I'd say more because labs are pretty easy. You don't have much homework or anything, you're just working
7. from a lab because you can see it and touch it. If you read you can't really visualize what's happening but a lab it's there and it shows you.

Student #2 is a C/D student. She is active in extracurricular functions and often neglects her daily work as a result. She does poorly on most tests.

1. the symbols. There was just a lot of them to get mixed up
2. Just knowing what the things were and it wasn't as much trouble and the units were mentioned and we knew what they were
3. the structural formulas were easy to remember
4. just remembering them
5. more would be better, but it wouldn't be the class, you need to spend an equal amount on everything.
6. well, we did a lot at once and then we didn't and then we did a lot again, it would be better spread out and then more wouldn't matter
7. The labs, its hand's on

Student #17 probably is able to understand concepts covered in labs easier than most of the students in the class. He has improved much since the start of the year and now carries an A average. He scores high on the tests and does most of his daily work.

1. the pH scale and buffers 'cause of all the color
2. um, the part with the pH scale cause we did a lot of that when we went to the food stuff, it had all the ph scale
3. the pH scale
4. um, can't remember.... the buffer system because you had to remember all the different stuff
5. I think that it was pretty good
6. We did a lot of labs
7. From the labs

APPENDIX F

STUDENT SURVEY ON CHEMISTRY IMPORTANCE

SURVEY FORM FOR CHEMISTRY UNIT

Please answer the following questions by circling the appropriate response. Five indicates a strong positive response such as very much or quite often. One indicates a strong negative response such as not at all or never. Each topic will have three areas to give your opinion on:

A. How often do you run across this concept in your daily life?

B. How often do you apply what you learned about this?

C. How important do you think it is in your life?

Acid/base balance

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Atomic bonding

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Atomic structure

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Buffers

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Carbohydrates

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Catalyst/enzymes

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Chemical reactions

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Compounds

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Element or molecular symbols

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Elements

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Indicators

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Lipids

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

Metabolism

A	1	2	3	4	5
B	1	2	3	4	5
C	1	2	3	4	5

pH					
	A	1	2	3	4
	B	1	2	3	4
	C	1	2	3	4
Proteins					
	A	1	2	3	4
	B	1	2	3	4
	C	1	2	3	4
Salts					
	A	1	2	3	4
	B	1	2	3	4
	C	1	2	3	4

Survey for Chemistry unit

- A. How often do you run across this concept in your daily life?
 B. How often do you apply what you learned about this?
 C. How important do you think it is in your life?

Scale: 1 (not at all, never) to 5 (quite often, very much)

Concept	responses	average
Acid/base balance		
b	111111111222233333	1.78
c	111111222222233344	2.06
a	111122222222333444	2.28
Atomic Bonding		
a	111111111122233344	1.83
b	111111111122233344	1.89
c	112222222233333355	2.56
Atomic Structure		
a	111111111122223344	1.78
b	111111111122223344	1.83
c	111122222222333334	2.17
Buffers		
a	1111111111222223444	1.89
b	111111112222222344	1.89
c	111111222222233344	2.06
Carbohydrates		
a	1111113344444445555	3.11
b	111223334444444455	3.22
c	1122333334444444555	3.33
Catalyst/enzymes		
a	111111112222333444	2.06
b	1111111122222223334	1.89
c	111122222222333345	2.28
Chemical reactions		
a	1111111122223334455	2.33
b	111112222233333444	2.33
c	111112222333344455	2.61
Compounds		
a	111111222222333445	2.22
b	11112222223333345	2.39
c	11112222223334444	2.39
Element or molecular symbols		
a	111111111123333445	2.06
b	111111222222233444	2.11
c	112222223333344444	2.72
Elements		
a	111111112222333345	2.06
b	111111222222233444	2.11
c	112222223333344444	2.72

Indicators

a	111111111222222434	1.78
b	111111111222222333	1.67
c	111111222222223334	1.94

Lipids

a	111122223333344555	2.78
b	111222233333344445	2.78
c	12222223333334555	2.89

Metabolism

a	111111233334444455	2.78
b	111222233333444444	2.78
c	112222233334444445	2.94

pH

a	111111122223333445	2.22
b	111112222222233333	2.00
c	111112222223333344	2.22

Proteins

a	111112222223344555	2.56
b	1122233333344444445	3.11
c	122333333334455555	3.44

Salts

a	1111112233333444555	2.72
b	111222223334444555	2.94
c	122222233333444455	3.00

APPENDIX G
TEST SCORE DATA

Student	sex	grade	pre-score	possible	% grade	post-score	possible	% grade	% change	Apr score	poss=32	score	if
												poss=49	
GH	F	12	7	49	14.29%	19	49	38.78%	24.49%	8	25.00%	12	
KS	M	12	16	49	32.65%	27	49	55.10%	22.45%	22	68.75%	34	
SA	M	12	5	49	10.20%	13	49	26.53%	16.33%	-	0.00%	0	
SC	F	11	15	49	30.61%	28	49	57.14%	26.53%	18	56.25%	28	
NP	F	11	11	49	22.45%	35	49	71.43%	48.98%	21	65.62%	32	
LM	F	11	11	49	22.45%	22	49	44.90%	22.45%	15	46.88%	23	
JD	F	11	11	49	22.45%	21	49	42.86%	57.14%	14	43.75%	21	
KW	F	11	15	49	30.61%	35	49	71.43%	40.82%	26	81.25%	40	
MB	F	11	13	49	26.53%	25	49	51.02%	24.49%	15	46.88%	23	
RH	M	11	18	49	36.73%	39	49	79.59%	42.86%	-	0.00%	0	
SM	M	11	22	49	44.90%	38	49	77.55%	32.65%	16	50.00%	24	
BS	F	10	13	49	26.53%	33	49	67.35%	40.82%	25	78.12%	38	
JS	F	10	23	49	46.94%	39	49	79.59%	32.65%	26	81.25%	40	
JG	F	10	24	49	48.98%	36	49	73.47%	24.49%	26	81.25%	40	
HH	F	10	3	49	6.12%	NO SCORE		ERROR	ERROR	0	0.00%	0	
JY	M	10	23	49	46.94%	36	49	73.47%	26.53%	27	84.38%	41	
DT	M	10	29	49	59.18%	44	49	89.80%	30.61%	28	87.50%	43	
BC	M	10	17	49	34.69%	31	49	63.27%	28.57%	27	84.38%	41	
CV	M	10	34	49	69.39%	44	49	89.80%	20.41%	27	84.38%	41	
MS	M	10	20	49	40.82%	34	49	69.39%	28.57%	19	59.38%	29	
JL	M	10	NO SCORE		ERROR	46	49	93.88%	ERROR	29	90.62%	44	
averages			16.5		28.16%	32.25		65.82%	31.15%	21.35	63.02%	32.70	
sums			330		673.47%	645		1316.33%	591.84%	363	1134.38%	55.84375	

102
1987/88 CHEMISTRY TEST SCORE DATA

=====					
PHYSIOLOGY 1987 (one week on chemistry)					
=====					
Student	sex	grade	post-score	possible	% grade

GS	M	12	28	42	66.67%
EW	F	11	33	42	78.57%
TY	F	11	35	42	83.33%
JA	F	10	23	42	54.76%
GC	F	10	37	42	88.10%
KD	F	10	21	42	50.00%
EH	F	10	31	42	73.81%
JH	F	10	33	42	78.57%
LM	F	10	29	42	69.05%
SM	F	10	28	42	66.67%
KP	F	10	16	42	38.10%
JO	F	10	29	42	69.05%
DB	M	10	21	42	50.00%
SD	M	10	27	42	64.29%
JF	M	10	32	42	76.19%
RH	M	10	24	42	57.14%
PM	M	10	28	42	66.67%
BR	M	10	18	42	42.86%

LK	F	12	33	42	78.57%
JP	M	11	26	42	61.90%
RS	M	11	21	42	50.00%
TG	F	10	23	42	54.76%
AK	F	10	30	42	71.43%
KK	F	10	30	42	71.43%
SL	F	10	25	42	59.52%
SA	M	10	38	42	90.48%
CB	M	10	32	42	76.19%
DH	M	10	33	42	78.57%
MH	M	10	20	42	47.62%
HM	M	10	20	42	47.62%
BS	M	10	22	42	52.38%

Averages			28.12		66.96%
=====					

1986/87 CHEMISTRY TEST SCORE DATA

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PHYSIOLOGY 1986 (two weeks on chemistry)

Student	sex	grade	post-score	possible	% grade
MD	M	12	16	22	72.73%
PH	M	12	20	22	90.91%
SB	F	10	21	22	95.45%
DC	F	10	9	22	40.91%
SC	F	10	21	22	95.45%
AC	F	10	14	22	63.64%
JC	F	10	20	22	90.91%
CC	F	10	12	22	54.55%
HF	F	10	15	22	68.18%
SG	F	10	22	22	100.00%
DG	F	10	17	22	77.27%
KG	F	10	18	22	81.82%
JH	F	10	22	22	100.00%
PH	F	10	2	22	9.09%
MH	F	10	20	22	90.91%
JA	M	10	16	22	72.73%
CA	M	10	13	22	59.09%
PB	M	10	16	22	72.73%
BD	M	10	18	22	81.82%
JL	M	12	15	22	68.18%
KM	F	10	15	22	68.18%
TO	F	10	12	22	54.55%
RS	F	10	18	22	81.82%
RS	F	10	22	22	100.00%
BM	M	10	15	22	68.18%
JM	M	10	20	22	90.91%
MS	M	10	20	22	90.91%
CS	M	10	14	22	63.64%
NS	M	10	21	22	95.45%
BS	M	10	21	22	95.45%
AW	F	12	14	22	63.64%
RH	F	10	19	22	86.36%
DH	F	10	13	22	59.09%
JK	F	10	7	22	31.82%
TL	F	10	12	22	54.55%
HM	F	10	21	22	95.45%
NM	F	10	14	22	63.64%
TO	F	10	17	22	77.27%
CP	F	10	4	22	18.18%
LP	F	10	18	22	81.82%
AR	F	10	13	22	59.09%
TT	F	10	17	22	77.27%
RT	F	10	12	22	54.55%
SD	M	10	14	22	63.64%
SM	M	10	9	22	40.91%

AVERAGES

15.55

70.69%

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APPENDIX H

COMPUTERIZED ANALYSIS OF MULTIPLE CHOICE PORTION OF TESTS

COMPUTERIZED ANALYSIS OF PRE TEST DATA

MSU COMPUTER LAB GRADER III
FILE-9550 COURSE-BCH100

ITEM RESPONSE SUMMARY DATA

DISTRIBUTION OF ITEM DIFFICULTY INDICES

	NUMBER OF ITEMS	PERCENTAGE		NUMBER OF ITEMS	PERCENTAGE
91 - 100	1	3	91 - 100	0	0
81 - 90	2	6	81 - 90	0	0
71 - 80	10	30	71 - 80	7	21
61 - 70	5	15	61 - 70	0	0
51 - 60	8	24	51 - 60	4	12
41 - 50	4	12	41 - 50	0	0
31 - 40	2	6	31 - 40	8	24
21 - 30	0	0	21 - 30	0	0
11 - 20	1	3	11 - 20	8	24
00 - 10	0	0	00 - 10	3	9
			LESS THAN 00	3	9

DISTRIBUTION OF DISCRIMINATION INDICES

MEAN ITEM DIFFICULTY 63
MEAN ITEM DISCRIMINATION 37
KUDER RICHARDSON RELIABILITY #20 .7549
STANDARD ERROR OF MEASUREMENT 2.4762

COMPUTERIZED ANALYSIS OF PRE TEST DATA

MSU COMPUTER LAB GRADER III
 RAW SCORE DISTRIBUTION
 FILE-9550 COURSE-8CH100

RAW SCORE	FREQUENCY	CUMMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE	TOTAL ITEMS ON TEST	33	MEAN	12.37	STANDARD DEVIATION	5.00	AND STANDARD DEVIATION OF	10	VARIANCE	25.02
22	1	1	97	69.2	33									
21	1	2	92	67.2										
20	1	3	86	65.2										
18	1	4	81	61.2										
14	1	5	76	53.2										
13	3	8	65	51.2										
12	3	11	50	49.2										
11	2	13	36	47.2										
9	1	14	28	43.2										
8	3	17	18	41.2										
7	1	18	7	39.2										
3	1	19	2	31.2										

MSU COMPUTER LAB GRADER III
ITEM ANALYSIS SHORT FORM
FILE-9550 COURSE-BCH100

333 ITEMS	PERCENTAGES	UPPER	MIDDLE	LOWER
	STUDENTS PER GROUP	27	46	27
		5	9	5

ITEM	KEY	1		2		3		4		5		OMIT		ERROR		DIFF
		U	M	U	M	U	M	U	M	U	M	U	M	U	M	
1	4	0	11	0	40	22	0	20	44	80	40	22	0	0	0	32
2	5	0	11	0	0	0	0	0	11	0	0	0	0	0	0	53
3	4	20	11	20	40	11	60	0	11	20	0	20	100	78	80	53
4	3	20	0	0	0	22	0	80	44	60	0	11	40	0	0	84
5	2	40	33	80	0	11	0	0	40	44	0	0	0	22	0	79
6	1	100	56	60	0	11	20	0	22	20	0	0	0	11	20	17
7	5	20	11	20	0	22	0	20	22	40	0	0	0	11	0	14
8	3	40	56	20	40	11	20	20	22	0	0	0	0	44	40	58
9	4	0	22	20	0	33	0	0	22	0	60	0	20	11	60	68
10	5	0	22	20	0	11	20	0	11	20	0	11	20	44	20	74
11	4	40	33	0	20	22	20	0	11	40	40	22	40	0	11	14
12	2	20	0	40	80	33	20	0	22	0	0	22	20	0	22	58
13	4	0	11	20	20	11	20	40	22	40	40	33	20	0	22	68
14	1	0	44	0	0	22	20	60	11	0	20	11	0	11	80	79
15	4	40	11	40	20	11	0	20	44	20	20	22	40	0	11	74
16	1	80	44	20	0	0	60	0	11	0	0	11	20	33	0	53
17	1	60	56	20	40	11	0	0	11	0	0	22	40	0	40	53
18	3	0	0	40	0	0	0	100	67	20	0	0	0	0	0	37
19	4	80	56	40	0	22	20	0	0	0	20	11	40	0	11	79
20	5	20	11	0	0	11	20	0	11	40	0	22	20	80	44	63
21	3	0	22	0	0	0	20	80	44	20	20	11	20	0	22	53
22	3	0	11	0	0	0	0	100	56	20	0	22	0	0	11	142
23	2	0	11	20	60	0	20	0	33	20	0	11	20	40	44	79
24	1	60	22	20	20	44	20	20	22	20	0	0	0	11	40	158
25	1	100	56	20	0	11	40	0	22	40	0	11	0	0	0	174
26	2	20	22	0	20	33	40	0	22	20	60	22	40	0	0	188
27	3	20	33	40	0	11	40	20	33	0	40	11	0	20	11	179
28	2	0	22	0	100	22	20	0	44	40	0	11	20	0	20	188
29	1	80	44	0	0	22	20	0	11	20	20	11	40	0	11	158
30	1	40	22	20	0	11	0	0	11	60	0	0	0	56	20	174
31	5	0	11	0	20	11	40	0	11	20	40	22	20	44	20	163
32	3	0	22	40	0	11	40	80	33	0	20	22	20	0	11	63
33	2	60	44	40	40	33	0	0	11	0	0	11	0	0	40	74

COMPUTERIZED ANALYSIS OF POST TEST DATA

MSU COMPUTER LAB GRADER III
FILE-9551 COURSE-BCH100

ITEM RESPONSE SUMMARY DATA

DISTRIBUTION OF ITEM DIFFICULTY INDICES DISTRIBUTION OF DISCRIMINATION INDICES

	NUMBER OF ITEMS	PERCENTAGE		NUMBER OF ITEMS	PERCENTAGE
91 - 100	1	3	91 - 100	3	9
81 - 90	1	3	81 - 90	0	0
71 - 80	0	0	71 - 80	3	9
61 - 70	3 2	9	61 - 70	0	0
51 - 60	1	3	51 - 60	8	25
41 - 50	3	9	41 - 50	0	0
31 - 40	7	22	31 - 40	8	25
21 - 30	6 7	19	21 - 30	0	0
11 - 20	8	25	11 - 20	8	25
00 - 10	2	6	00 - 10	1	3
			LESS THAN 00	1	3

MEAN ITEM DIFFICULTY 34
MEAN ITEM DISCRIMINATION 46
KUDER RICHARDSON RELIABILITY #20 .8829
STANDARD ERROR OF MEASUREMENT 2.1112

COMPUTERIZED ANALYSIS OF POST TEST DATA

MSU COMPUTER LAB GRADER III
 RAW SCORE DISTRIBUTION
 FILE-9551 COURSE-BCH100

RAW SCORE	FREQUENCY	CUMULATIVE FREQUENCY	PERCENTILE RANK	STANDARD SCORE	TOTAL ITEMS ON TEST	MEAN	STANDARD SCORE HAS MEAN OF	STANDARD DEVIATION AND STANDARD DEVIATION OF	VARIANCE
30	1	1	97	64.2	32	21.21	50	6.17	38.07
28	3	4	86	61.0					
27	1	5	76	59.3					
24	3	8	65	54.5					
23	1	9	55	52.9					
22	2	11	47	51.2					
21	1	12	39	49.6					
18	1	13	34	44.8					
17	2	15	26	43.1					
16	1	16	18	41.5					
14	2	18	10	38.3					
6	1	19	2	25.3					

COMPUTERIZED ANALYSIS OF POST TEST DATA

MSU COMPUTER LAB GRADER III
ITEM ANALYSIS SHORT FORM
FILE-9551 COURSE-BCH100

ITEM	KEY	32 ITEMS										PERCENTAGES STUDENTS PER GROUP										UPPER 27										MIDDLE 46										LOWER 27										DIFF																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		19	20	21	22	23	24	25	26	27	28	29	30	31	32																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX I
ITEM ANALYSIS

Post Test Item Analysis by Item

Student Item Numbers (correct response indicated by "X")		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
ONE								X				X									X												X
TWO		X	X					X	X			X	X								X					X	X				X		X
THREE		X	X	X				X				X	X								X					X	X				X		X
FOUR		X	X	X		X		X				X									X					X	X						X
FIVE		X								X		X									X					X	X						X
SIX		X	X	X	X	X	X	X	X		X		X	X							X					X	X						X
SEVEN		X	X	X	X	X	X	X	X		X		X	X							X					X	X						X
EIGHT		X	X			X				X			X	X							X					X	X						X
NINE		X						X													X							X					X
TEN		X	X	X				X	X				X	X							X					X	X						X
ELEVEN		X	X	X	X			X	X			X	X	X							X					X	X						X
TWELVE		X	X		X	X	X	X				X	X	X							X					X	X						X
THIRTEEN		X	X	X	X	X		X				X		X							X					X	X						X
FOURTEEN		X	X	X				X	X			X	X	X							X					X	X						X
FIFTEEN		X	X		X		X	X	X		X		X	X							X					X	X						X
SIXTEEN		X	X	X	X	X	X	X	X		X		X	X							X					X	X						X
SEVENTEEN		X	X	X	X	X	X	X	X		X		X	X							X					X	X						X
EIGHTEEN		X	X	X	X	X	X	X	X		X		X	X							X					X	X						X
NINETEEN		X						X				X	X	X							X					X	X						X

APPENDIX J
DETAILED LABORATORY EXERCISES

"ATOM" LAB

Purpose: To determine the location and composition of the "nucleus" of the "atom"

Test: You will be given a clay ball containing a small common household or classroom item. You will also get a dissecting probe. Make five probes into the ball, writing down what you found after each one. You must make each probe in a different location. You will probably want to make a record of where you make the probes. After five pokes, draw the location and shape of the nucleus of your atom.

Now, you may make 5 more pokes. Again, write down what you find with each one, and at the end, draw the location and shape of the nucleus.

You may make five more probes. (The limit is 15! I will count.) Draw the location and shape of the nucleus. Using your written observations, tell what you think is in the clay ball, and why you think it is what you think it is. After I have read your conclusion, you may "split" your atom.

BLACK BOX LAB I

Purpose: To determine the shape of the maze inside the box using all your senses but sight.

Test: Carefully roll, twist, shake, or otherwise manipulate the black plastic box that contains a ball bearing and a maze. From the feel and sound of the ball moving inside the box, determine the shape of the maze. Write down all your observations and write your conclusions using the observations you took. You will need to have a drawing of the maze before you can see what your maze is. Then, compare what you thought you had with what you did have. How can you account for the differences?

BLACK BOX LAB II

Purpose: To determine the contents of a small cardboard box containing small household items without using sight.

Test: Use all your senses, except sight to try and determine what is in the box. You may shake, slide, roll or drop the box. Be sure to write down each manipulation. This will be the procedure part of your lab write up. Write down what happened during each manipulation. This are the observations. If you wish you may use some other items to help you test. You may wish to use a magnet, or balance, or you may wish to put the objects you suspect you may have into another box to see if they sound the same. Just make sure everything you do gets written down as a procedure. You may not open or poke into the box. When you are fairly sure what is in the box, write your conclusions telling me why you think that, using observations to support your guesses. A box will be opened tomorrow so you can check your guesses.

ACID AND BASE LAB

(adapted from a Chemtech kit)

Introduction:

Acids and bases have long been known to chemists. Bases cause foods to have a smooth "soapy" feel when rubbed between tow fingers. They have a bitter taste and turn litmus paper blue. Acids make foods taste sour and turn litmus paper pink. Indicator dyes, in addition to litmus, turn various colors according to the strength of acid or base solution that is mixed with the indicator.

An acid in water contains more hydrogen ions than hydroxide ions. A base produces an excess of hydroxide ions. Pure water, which is "neutral", exists mostly as water molecules, but to a very slight degree, it does break up into an equal number of hydrogen and hydroxyl ions.



The following compounds are considered acids:

HCl	Hydrochloric acid
HNO ₃	Nitric acid
CH ₃ COOH	Acetic acid
H ₂ SO ₄	Sulfuric acid

Properties of aqueous solutions of acids, shared by the above compounds:

1. They all produce hydrogen ions in water solutions.
2. Hydrogen gas can be liberated when aqueous solutions of these acids react with certain metals.
3. Acid solutions affect indicators. Litmus turns red in acid, and phenolphthalein remains colorless.
4. Acid solutions react with carbonates to produce carbon dioxide gas
5. Acids neutralize bases to form water. The metallic ions from the base and the non-metallic ions from the acid usually remain in solution; but if the resulting salt is insoluble in water, it will precipitate.

The following compounds are considered to be bases:

NaOH	Sodium hydroxide
KOH	Potassium hydroxide
NH ₃ (aq)	Ammonia water

Properties of aqueous solutions of bases, shared by the above compounds:

1. They have a slippery feel, like soapy water.
2. They cause litmus to turn blue and phenolphthalein to turn pink, and change the colors of other indicator dyes.
3. Bases neutralize acids.

Theory: Acids and bases are identified by their unique properties. Substances called acids may differ from each other in many ways, but they have some common properties. This will also be true of bases.

PLEASE KEEP IN MIND THAT YOU WILL BE WORKING WITH ACIDS AND BASES, AND BOTH CAN BURN YOUR SKIN. PLEASE TRY NOT TO GET ANY OF THE SOLUTIONS ON YOUR HANDS. IF YOU DO, WASH THEM THOROUGHLY UNDER RUNNING WATER FOR AT LEAST THREE (3) MINUTES.

Procedure:

1. Effect on Indicator dyes.
 - a. Place 3-4 drops of 6M HCl solution in a Chemplate cavity. Test with litmus paper. Observe and write down the color.
 - b. Place a drop of phenolphthalein in the acid. Observe and write down the color.
 - c. Place 3-4 drops of 0.5M NaOH solution in another Chemplate cavity. Test with litmus. Observe and write down color.
 - d. Place a drop of phenolphthalein in the base solution. Observe and write down the color.
2. Effect of acids on metals.
 - a. Place small amount (with a tiny spatula) of each of the following metals, each in a separate cavity; iron, zinc, magnesium, copper. One at a time, making observations between each, add enough drops (3-4) of 6M HCl to cover the metal. Write down the vigor of the reaction (DO THEM ONE AT A TIME). Repeat with each of the other metals. List them in order from most reactive to the least reactive. The reaction is the same in each case, differing only in the speed of the reaction. The relative reaction rates may be used to compare the activities of the metals.

- b. Repeat the test, using a fairly active metal and 6M acetic acid. Again, the reaction varies only in the rate, resulting from the differences in the strength of the acids. Compare the strength of acetic acid with that of hydrochloric acid.
3. The production and collection of hydrogen.
 - a. Place a spatula of zinc in a cavity and add enough HCl (4-5 drops) to just cover the zinc.
 - b. Quickly cover the cavity with the gas collecting cap on which a rubber tube has been placed
 - c. Put an upside down test tube over the cavity with the rubber tubing inside the test tube
 - d. After about 30 seconds, remove the test tube from the tubing and test with a burning splint, held under the mouth of the tube. (Since the gas is hydrogen, you must keep the test tube upside down or else all the gas will escape.) Record the effect of a flame on hydrogen mixed with air.
4. Effect of acids on carbonates.
 - a. Place a chip of calcium carbonate in a cavity and cover with HCl.
 - b. Place the cap and gas delivery assembly on the cavity.
 - c. In the next cavity, place 5 drops of lime water solution.
 - d. Place the end of the gas delivery tube in the lime water solution. Note the bubbling, and record the appearance of the lime water. This result is typical of the effect of acids on carbonate compounds.
5. Measuring the concentration of an unknown acid by "titration"
 - a. Titration is usually carried out using burettes to measure accurately the volumes of acid and bases used. A drop controlled bottle will be used to make the measurements. The result will be the same in principle, but will be less accurate.
 - b. Place EXACTLY 10 drops of the unknown acid in the large cavity.
 - c. Add one drop of phenolphthalein to the acid.
 - d. Add NaOH, one drop at a time, stirring after each drop. BE SURE TO COUNT THE DROPS. When the last of the acid is neutralized, the phenolphthalein will turn faint pink, and stay that way when stirred.

- e. Compare the concentration of acid to the concentration of the base using the following formula. Remember, the volume unit is in Drops.

$$\text{conc. of unknown acid} = \frac{\text{volume of base} \times \text{conc. base}}{\text{volume of acid}}$$

TEACHER'S GUIDE TO pH OF HOUSEHOLD SUBSTANCES LAB**AUTHORS:**

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BEHAVIORAL OBJECTIVES:

After this lab activity, given several common household substances, the student will be able to predict the pH of those items with reasonable accuracy.

The student will recognize that indicator substances change color according to the pH of the substance tested.

TIME REQUIRED:

Teacher preparation: Coffee, orange juice and other thin substances can be used with no dilution. Baking soda can be put in water at almost any concentration without changing the pH. Any other substance you may wish to use, especially if it is thick, should be diluted 1:5 with distilled water.

Student lab time: 1 - 2 fifty-minute lab periods, depending on the amount of time used in discussion. The actual testing can be done easily in one class period. There will probably be time for discussion after clean-up.

MATERIAL PREPARATION:

Dilute thick substances 1 part to 4 parts distilled water. Students can do this at their lab stations, using either graduated cylinders or pipettes.

BACKGROUND INFORMATION:

Orange Juice has a pH of about 3, black coffee is about 5, tap water and milk are about pH 7, and baking soda is 8.5 in water solution. These solutions are used as the known pH solutions. Students will bring in lots of other things to test. These should be water soluble or in liquid form. Your unknown should be taken from the substances that the students actually test. You can disguise the unknown using food coloring, which does not seem to affect the actual pH, but may stain light colored indicator strips. The data for substances the students bring in can be posted in the data table on the board. This data can be used to identify unknowns. Stress NO TASTING.

Substances tested - Ketchup = 3.5, dilute fresh tomato = 4.5, sweet and sour sauce = 3, 1 M NaCl solution = 7, Cremora solution = 7, Miracle whip = 4, German mustard = 4, regular mustard = 4, liquid detergent = 8, white wine = 3, and aspirin = 3. The tap water pH in the given data table may have to be adjusted for the water in your area.

ANSWERS TO QUESTIONS:

Answers will vary depending on the substances the students bring in to test.

SOURCES OF MATERIALS:

Materials for this lab are easily available at any biological or chemical supply house.

DISCOVERY OF pH USING COMMON HOUSEHOLD SUBSTANCES

INTRODUCTION:

Everyone is interested in the taste of food at some level. Herbs, spices and other substances are often used to affect the flavor of food, but the average person does not know the chemical basis of food flavoring. Food chemists investigate how and why foods taste different. Using applied chemical principles, chemists have given us scientific explanations about the flavors of foods. One particular aspect of the flavoring process will be investigated in this activity.

Chemists discovered long ago that ions (electrically charged atoms) of the chemical element hydrogen move easily from one dissolved substance to another. On this basis, they grouped substances into two classes: substances which donate hydrogen ions - called acids, and substances which accept hydrogen ions - called bases.

The number of hydrogen ions donated, or accepted varies from substance to substance. In 1909, a chemist named Sorenson gave the name "pH" to this number, and set up a scale for measuring it. The scale uses the numbers 1 to 14 with a pH of 7 being "neutral." This means that at a pH of 7, the number of hydrogen ions "donated" from the acid equals the number of hydrogen ions "accepted" by the base in a solution which contains water. At a low pH (such as 1 or 2), many hydrogen ions are donated, which means there are many in the solution. At a high pH (such as 13 or 14), many hydrogen ions can be accepted, which means there are almost none in the solution.

The pH of a solution may be measured using substances called "indicators." An indicator is a substance which changes color when exposed to different concentrations of hydrogen ions. These substances can be soaked into a paper strip and are sold commercially. We will be using these strips, and some solutions of known pH to determine the colors they become at a particular pH. After that, we will use the color information to determine the pH of some common household items and identify an unknown.

OBJECTIVES:

To demonstrate that indicators can be used to determine pH of a substance.

To familiarize students with the fact that different items have a different pH.

To identify an unknown substance by its pH

CAUTIONS AND PITFALLS:

Do NOT taste any material

Use a new strip for each test

Be careful not to spill, some solutions stain clothing.

MATERIALS:

5-10 small test tubes (depends on number of substances tested)

Wide range pH indicator strips for each tube

Unknown solutions brought from home

Labeled known solutions

Distilled water

5 mL graduated cylinders

or pipettes

PROCEDURE:

1. Obtain samples of each of the solutions of known pH
2. Test each sample with a separate strip of pH paper. Record the color of the strip and the material's pH in the data table provided.
3. Test solutions of the materials you brought from home.
 - a. Put a 1 mL sample of the liquid portion of the material in a test tube. Add 4 mL of distilled water to each tube. This will dilute the substance 1:5
 - b. Note the name of the substance in the correct place in the data table. Test the sample with the pH paper, and write the resulting color next to the name of the substance.

- c. Using the color and the data from step 2, estimate the pH of the substance and write it in the data table.
 - d. Repeat steps a through c for each substance your group brought.
 - e. Put the name of the substance and its pH on the chalkboard
4. Obtain an unknown from the teacher.
 5. Use steps 3a through 3c to determine the pH of the unknown.
 6. From the data on the chalkboard, try to determine what the unknown substance is.

DATA TABLE:

[illegible]

QUESTIONS:

pH Continuum

1 7 14

-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

1. Place the substances tested on the appropriate location of the pH continuum above.
2. What pH seems to be the most common for your samples?
3. From previous experience, what flavor or taste do the foods at pH 3 or pH 4 have in common?

CONCLUSIONS:

FURTHER INVESTIGATIONS:

Test the strength of detergents versus pH

REFERENCES:

"Acids, Bases, and the pH Scale", 1984, On Foods and Cooking, McGee & Harold, Charles Scribner, publisher

TEACHER'S GUIDE TO BIOLOGICAL MATERIALS AS pH
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BEHAVIORAL OBJECTIVES:

After preparation of the biological extracts used in this investigation the learner will be able to list some sources of biological materials which would make good indicators.

After completion of this lab and the post-lab discussion the learner will be able to determine the approximate pH of various teacher prepared solutions by using biological extracts as the indicators.

After completing this lab and the post-lab discussion the learner will be able to write a short paragraph explaining how the change in color of particular biological pigments can be used as an analytical tool.

TIME REQUIRED:

Teacher preparation: Preparation of the solutions of variable pH will take approximately an hour.

Student lab time: This will vary according to the complexity of extraction and number of materials to be tested. We found that the filtering process is the most time consuming. In one lab period a group of 3 or 4 students ought to be able to prepare 3 extracts and test them. If the extracts are made the day prior to the testing 10 could easily be completed.

MATERIAL PREPARATION:

1. Make a 0.1 M boric acid solution. Dissolve 0.62 g of boric acid crystals in 90 mL of distilled water. Add additional water to bring to a volume of 100 mL. The pH of student dilution will be near 7.
2. Make a 0.1 M potassium phosphate solution by dissolving 2.12 g of tribasic potassium phosphate in 90 mL of distilled water. Add additional water to bring to a volume of 100 mL. The pH of student dilution will be near 12.
3. Make a 0.1 M sodium bicarbonate solution by dissolving 0.84 g of sodium bicarbonate in 90 mL of distilled water. Add additional water to bring to a volume of 100 mL. The pH of student dilution will be near 8.
4. Make a 0.1 M solution of potassium tartrate by dissolving 2.35 g of potassium tartrate in 90 mL of distilled water. Add enough water to bring the volume to 100 mL. The pH of student dilution will be near 7.
5. Make a 0.1 M acetic acid solution by adding 1 mL of glacial acetic acid to 160 mL of distilled water. The pH of student dilution will be near 3.
6. Make a 0.1 M ammonium hydroxide solution by adding 3 mL of 3 M ammonium hydroxide (stock) to 90 mL of distilled water. The pH of student dilution will be near 11.
7. Make a 0.1 M sodium hydroxide solution by dissolving 0.4 g of sodium hydroxide in 90 mL of distilled water. Add enough water to bring the volume to 100 mL. The pH of student dilution will be near 13.

8. Make a 0.1 M hydrochloric acid solution by adding 1 mL of concentrated HCl to 99 mL of distilled water. The pH of student dilution will be near 1.

This list is offered only as a suggestion but will give you a wide range of different pH values. There are many other acidic or basic compounds which will give satisfactory results, including a range of buffers.

BACKGROUND INFORMATION:

Indicators may usually be regarded as weak organic acids (or bases) whose un-ionized molecules appear one color and their anions (or cations) appear as another color. At the pH equivalent to the dissociation constant for the indicator there may exist a third intermediate color. Bromthymol blue exhibits this pattern as it changes from yellow in acid to green near neutral pH and turns blue in base. Since indicators are organic acids it is not surprising that some of the pigments we observe in organisms will act as indicators of acids and/or bases. The purpose of this investigation is to have students investigate a variety of pigments from organisms which may act as indicators of relative pH. At the finish, students should be able to readily identify available materials and use them to determine if an unknown solution is acidic, neutral, or basic in nature.

Wide range pH indicator paper strips or pH meters should be on hand for this lab. If you do not have spot plates, plastic wrap covering white paper works well with the small quantities used.

Colored extracts can be prepared in various ways. The easiest is by soaking the tissues in distilled water or alcohol. The use of a blender decreases the time involved in moving the pigments from the tissue into solution. Some plant materials may need to be boiled to remove the pigments while others can be helped along by the addition of small amounts of dilute acid or base. 10 to 20 mL of each solution per lab group should be more than enough. The solutions should be well colored so students do not have difficulty identifying color changes. Juices from frozen or canned fruit and vegetables also work well. Materials which are shades of red or blue usually work best, but students should also try orange and yellow colored extracts. The color changes which occur with the yellow pigmented flower petals are very subtle,

becoming more or less intense in our trials. The process of pigment extraction can be done by the teacher but we feel it is important for the student to see exactly where the pigmented solutions come from.

This is a relatively easy lab for students to do using berry juices or red cabbage. With higher level students increase the number of sample extracts to give students a variety of data to evaluate.

It is suggested that the data table be organized in the same arrangement as the spot plate, with columns for the pigment source, original color, test solutions (with subheadings for each solution), and then rows for pH, and the data for each source tested.

ANSWERS TO QUESTIONS:

1. Hydrochloric acid pH 1, acetic acid pH 3, and boric acid pH 6.5.
2. Potassium tartrate pH 8, sodium bicarbonate pH 8.5, ammonium hydroxide pH 11, potassium phosphate pH 12, sodium hydroxide pH 13.
3. This will vary depending on extracts used.
4. This also will vary depending on extracts used.
5. Variable
6. Those pigments are not dissociating and producing ions.
7. Variable
8. Variable

SOURCES OF MATERIALS:

1. The best results were obtained from the following extracts: red cabbage, concord grape juice, red beets, red geraniums, pink roses, purple and yellow snapdragons.
2. Major scientific and chemical supply companies will provide the chemicals necessary to produce the range of pH solutions.

BIOLOGICAL MATERIALS AS pH INDICATORS

INTRODUCTION:

Many of the colors we observe in organisms are due to the presence of molecules which have gained or lost a hydrogen (H^+) ion. You may have observed hydrangeas, which were blue when purchased as potted plants, changed to pink as time passed when they were watered with well water. You may also have observed that while you were washing dishes stained with red fruits the color of the fruit stain changed to blue because of the basic soap or detergent being used. Some of these colored compounds will work as pH indicators, others simply respond to changes in pH by becoming oxidized or reduced to other compounds.

OBJECTIVES:

During this investigation you will be testing various colored solutions to determine if they may be used as indicators of acids or bases.

You will also determine the approximate pH at which the colored solutions change color.

CAUTIONS AND PITFALLS:

Some of the solutions may bleach or stain clothing. Some may also burn the skin.

When transferring materials onto the spot plate be careful not to spill.

It is easy to get mixed up with locations on the spot plate so organize the plate in a manner identical to your data table.

MATERIALS:

0.1 M Potassium phosphate	Distilled water
0.1 M Acetic acid	Tap water
0.1 M Potassium tartrate	pH meter or wide range
pH indicator paper	
0.1 M Sodium bicarbonate	10 small beakers or
short test tubes	
0.1 M Boric acid	Eye droppers or Pasteur
pipettes	
0.1 M Ammonium hydroxide	Spot plate
0.1 M Sodium hydroxide	10 mL graduated cylinder
0.1 M Hydrochloric acid	Colored plant materials

PROCEDURE:**Part I Preparation of data table**

1. Prepare a data table in which you can record the pH of each solution, the name of the organism, the color of the extract, and its color with each of the solutions it is tested in.

Part II Preparation of biological extracts

1. Determine the method to be used to break the biological material into small pieces. A blender works very well, but mortar and pestle or tearing by hand are sufficient.
2. When using a blender cover the broken up material with water and 1 to 3 mL of ethanol. A similar process should be employed if using a mortar and pestle. If tearing by hand is the process of choice the torn material should be soaked overnight in distilled water or alcohol. Some plant material needs to be boiled to get the pigment out. A volume of 10-20 mL of extract per lab group will be sufficient.

Part III Extract testing procedure

1. Add 9 mL of distilled water to each of 8 small beakers.
2. To each beaker add 1 mL of one of the acid or base solutions. Label the beaker.

3. Determine the pH of each solution by testing with a pH meter or dipping pH test paper into the solution and comparing its color with the standard. Record the pH of each solution on your data table.
4. Obtain a prepared plant extract and record its name and color.
5. Transfer 1 to 5 drops of the plant extract, per position, to wells on a white spot plate.
6. Transfer 1 to 5 drops of the acid or base solutions to spots which contain the plant extract. Record the color.
7. Repeat steps 4 through 7 with as many other colored extracts as you have time for.

DATA:

QUESTIONS:

1. Keeping in mind that acids have a pH below 7 and bases have a pH above 7, list the solutions which are acids.
2. List the solutions which are bases.
3. Examine the extracts of the plant (organism) and list those which were originally red.

4. List those plants which did not produce a red extract and state the color of each extract.
5. Which extracts did not change color over the entire pH range of solutions used?
6. What can be said about the chemical nature of the pigments that did not change color?
7. Examine the data for the pigments which did change color. For each pigment extract list the pH at which its color changed and the color it was above and below this value.
8. Which pigment extracts could be used to identify a strong acid, a strong base, a weak acid, and a weak base?

CONCLUSIONS:

TEACHER'S GUIDE TO FLORAL PIGMENT LAB

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BEHAVIORAL OBJECTIVES:

The student will be able to prepare pigment extracts from plants.

The student will use the spectrophotometer to determine transmittance of various pigments.

The student should be able to graph the wavelength versus absorbance from the data collected.

After this lab, the student should be able to determine peak absorbances from transmittance data and correlate this with the type of pigment.

The student will determine how a change in pH affects the amount of light absorbed by the pigment at a specific wavelength.

The student will be able to correlate various colors on chromatograms with the peaks of absorbance on graph.

TIME REQUIRED:

Teacher preparation: It will take between 15 and 20 minutes to prepare the acidic and basic solutions needed.

Student lab time: With the students extracting their own pigments, it is suggested that one day be used for the preparation. The pigments can be safely stored overnight with little change in absorbance. The actual analysis will take one or two days, depending on the number of spectrophotometers available. If there are enough Spec 20s, the analysis could be done in one fifty-minute lab period, but it would probably be easier to take the second day and avoid having to rush. Because the spotting of the extracts on the chromatography filter paper will take some time, it might be best to have students work in groups of four, two for work on the chromatography and two for work on the spectrophotometry. You could also have the students spot one day and run the development the next.

MATERIAL PREPARATION

1. Prepare 0.1 M solution of NaOH by dissolving 4 g of solid NaOH in 100 mL of distilled water.
2. Prepare 0.1 M solution of HCl by adding 1 mL of concentrated HCl to 100 mL of distilled water.

BACKGROUND INFORMATION:

It is assumed that students have been previously introduced to the concept of pH and to the use of spectrophotometers. If this is not the case, allow additional class time to cover this vital material. This activity is a good introduction to the concepts of light absorbance and transmittance and to the relationship between wavelength and color. In this lab exercise, the independent variable is the wavelength and the percent transmittance is the dependent variable.

Each student should bring in a flower, colored fruit or vegetable to extract a pigment. A large quantity of material is needed to get 25 g. For example, about three medium size marigolds, 5 grapes, 1 1/2 leaves of cabbage, or 1/4 of a pepper would give 25 g of chopped up material.

An easy way to prepare for chromatography with flowers and leaves is to put the leaf directly on the paper, and roll the edge of a beaker across it in a straight line. This will leave a clear even line of pigment just where you want it to be. We found that the easiest way to run the chromatography is to cut the filter paper about 10 cm wide and fold it in half or thirds lengthwise. This way it will stand by itself in a large developing chamber and many can be run at the same time. Remember, the peak transmittance will be at the wavelength of color the pigment appears to the eyes. The peak absorbance will be at the wavelength of the complimentary color.

ANSWERS TO QUESTIONS

1. Student will have a graph that shows three lines, two with pH adjustments, and one without.
2. Answers will vary. Use the appended below to determine colors if that information is not in the text.
3. Answers will vary. We found that, in general, absorbance at maximum wavelength increased with the addition of the base.
4. Answers will vary. We found that HCl tended to increase absorbance at maximum.
5. Answers will vary depending on pigments tested. Blue pigments tend to absorb at high wavelengths and red pigments tend to absorb at low wavelengths.
6. The pigment would appear orange to the eyes.
7. The chromatogram should show a color line for each absorbance peak in the graph.

Wavelengths of the Visible Colors in the Electromagnetic Spectrum

Color (nm)	Wavelength range (nm)	Pure color
---------------	-----------------------	------------

Violet	400-420	410
Blue	420-490	470
Green	490-580	520
Yellow	580-590	580
Orange	590-650	600
Red	650-700	650

SOURCES OF MATERIALS

All the materials listed are readily available from most chemical supply houses. The plant materials can be brought from home by the students or purchased at a grocery store or florist's shop.

FLORAL PIGMENTS: SPECTRAL ANALYSIS AND pH DYNAMICS

INTRODUCTION:

Most people can appreciate the showy displays of many flowering plants. Perhaps you are aware that the colors in floral displays are produced by chemical compounds called pigments. The color perceived by the eye is due to selective reflection of various visible light wavelengths by these pigments. In this experiment, you will separate pigments from their cellular compartments, analyze their absorption spectra, and investigate the behavior of the pigments in a changing environment.

At one time or another we have all wondered why the sky is blue or why plants are green. Someone's sweater appears red because red light is reflected by the pigments in the dye and reaches your eyes. All the other colors are absorbed. The shape of the pigment molecule determines the wavelength of light reflected.

The colors observed in flowers are due to the presence of a variety of organic compounds such as carotenoids (lipid-soluble) and flavonoids (water-soluble substances). The array of colors includes light yellow and yellow, orange-yellow, orange to red, and purple to blue. The color varies with the number and conjugation of the double bonds present in the compounds. The greater the number of conjugated double bonds, the more the absorption is shifted to the longer wavelengths of light. The resulting pigments are thus more orange or red in color.

When you use the spectrophotometer, you will be reading percent transmittance. When the transmittance is high, the absorbance will be low, and when the transmittance is low the absorbance will be high. Use the chart included to convert transmittance to absorbance.

Some of the compounds producing color in plants can be used as pH indicators. Anthocyanins, a type of flavonoid, are blue-purple in an alkaline environment and pinkish-red in an acid one. The pale yellow colors (flavonols, chalcones, avrones) become brighter at high pH. Nearly colorless flavones will turn yellow and darken when exposed to a base.

OBJECTIVES:

To determine the wavelength of maximum absorbance of light for a variety of pigments.

To determine the color of light at each maximum absorbance. Remember, this will be at minimum transmittance.

To determine if a variation in pH will change the absorbance.

To plot and interpret a graph of wavelength versus absorbance.

To separate pigments by paper chromatography

CAUTIONS AND PITFALLS:

Acetone is extremely flammable, and dangerous if inhaled. Use only in a well-ventilated area, or under the fume hood. Make sure no burners are lit and all reagent bottles are tightly capped after use.

Sodium hydroxide (NaOH) and hydrochloric acid (HCl) are caustic and will burn the skin and eyes. GOGGLES MUST BE WORN. If acid or base gets on skin, rinse thoroughly for three to five minutes. If either solution gets in eyes, flush with water for fifteen minutes and consult a physician.

Blenders should not be used because of the possibility of fire.

MATERIALS:

Spectrophotometer (3/pigment)	13 mm X 100 mm test tubes
Mortar and pestle	Scissors
Graduated cylinder	Dropper
Pipettes (5 mL)	Funnels
Filter paper	Battery jar, to use for developing
0.1 M NaOH	0.1 M HCl
Acetone	Distilled water
Balance	Capillary tube or dip-type pen
Plastic wrap to cover battery jar	
Fresh flowers, fruits, and/or vegetables in various colors	

PROCEDURE:

1. Turn on the spectrophotometer and warm up for at least 10 minutes.

2. Place about 25 g of cut-up flower petals (fruit or vegetable) in a mortar and pestle. Add 50 mL of acetone to immerse the tissue. Crush until the mixture is deeply colored.
3. Filter the mixture and save the filtrate. Repeat if necessary.
4. You should have a transparent, colored sample of pigment. Place 3 mL of pigment into a test tube. Use 3 mL of distilled water as a blank to set the Spec 20 to read 100% transmittance. Record the transmittance of your pigment sample at increments of 20 nanometers from 400 nm to 700 nm. RESET THE SPEC 20 TO 100% TRANSMITTANCE WITH THE BLANK EACH TIME YOU CHANGE THE WAVELENGTH.
5. Place 3 mL of pigment into each of two clean test tubes.
6. To one test tube, add 0.1 M NaOH a drop at a time, swirling after each drop, until you notice a color change. DO NOT ADD MORE THAN 10 DROPS. Record the number of drops of NaOH added.
7. Repeat step 5 with 0.1 M HCl in the other test tube.
8. Read the percent transmittance of sample of pigment at each wavelength used with the pure pigment. Plot on the same graph as transmittance of the original pigment.
9. Cut a strip of filter paper almost as wide and long as your developing chamber.
10. Draw a line in pencil 2 cm from one end.
11. With the capillary tube or dip-type pen draw a line with pigment over the line you drew in pencil. Let it dry.
12. Repeat step #10 until you have 10 to 15 layers of pigment on the same line.
13. Put 1 cm of developing liquid (5 mL acetone in 50 mL distilled water) in the developing chamber (battery jar).
14. Fanfold paper lengthwise and put it in chamber with the pigment line near the bottom. Cover chamber.
15. Leave filter paper in chamber for 20 minutes (or until liquid is nearly to top of paper). Take out the paper. Record the colors and locations of the pigments on the paper.

DATA:**QUESTIONS:**

1. Graph the data you obtained. Put the independent variable along the X-axis and the dependent variable along the Y-axis. Plot all sets of data on the same graph, using a different color for each. Label each of the three lines.
2. What is the maximum absorbance (minimum transmittance) of your substance? What color light does this wavelength correspond to?
3. How is the peak absorbance altered as the environment becomes more alkaline with the addition of NaOH?
4. How is the peak absorbance altered as the environment becomes more acidic with the addition of HCl?
5. Which pigments are absorbing best at 400-450 nm? At 650-700 nm?
(You may have to compare information with others in class.)
6. If the graph showed a peak absorbance around 520 nm what color would that pigment appear to your eyes?
7. How do the colors separated from the pigment in paper chromatography correspond to the wavelengths of maximum absorbance?

CONCLUSIONS:

FURTHER INVESTIGATIONS:

Develop an experiment to determine the relationship between pH and absorbance by comparing the absorbance of a particular flower's extract at a specific wavelength over a wide range of pH.

Compare absorbance of different species of flowers of the same hue (color) at various wavelengths.

REFERENCES:

Cleavenger, S. 1964. "Flower pigments" Scientific American 210(6):84-92

Dean, J. 1979 Lange's Handbook of Chemistry, McGraw Hill 2-91/93

Hess, D. 1963. "Die lute als Ort der Anthocyansynthase" Z. Fur Bot. 51(2):142-155

Parry et al. 1982 Chemistry Experimental Foundations Prentice-Hall 268

% TRANSMITTANCE (T) - ABSORBANCE (A), CONVERSION TABLE

%T	A		%T	A		%T	A		%T	A
1	2.0		26	.59		51	.30		76	.12
2	1.8		27	.58		52	.28		77	.11
3	1.5		28	.55		53	.28		78	.11
4	1.4		29	.54		54	.27		79	.10
5	1.3		30	.52		55	.26		80	.10
6	1.2		31	.51		56	.25		81	.09
7	1.2		32	.50		57	.24		82	.09
8	1.1		33	.48		58	.24		83	.08
9	1.0		34	.47		59	.23		84	.08
10	1.0		35	.46		60	.22		85	.07
11	1.0		36	.44		61	.22		86	.07
12	.92		37	.43		62	.21		87	.06
13	.89		38	.42		63	.20		88	.06
14	.85		39	.41		64	.19		89	.05
15	.82		40	.40		65	.19		90	.05
16	.80		41	.39		66	.18		91	.04
17	.77		42	.38		67	.17		92	.04
18	.75		43	.37		68	.17		93	.03
19	.72		44	.36		69	.16		94	.03
20	.70		45	.35		70	.16		95	.02
21	.68		46	.34		71	.15		96	.02
22	.66		47	.33		72	.14		97	.01
23	.64		48	.32		73	.14		98	.01
24	.62		49	.31		74	.13		99	.0
25	.20		50	.30		75	.13		100	.0

adapted from Lange's Handbook of Chemistry

141TEACHER'S GUIDE TO EFFECT OF SALIVARY AMYLASE ON
STARCHAUTHORS:

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BEHAVIORAL OBJECTIVES:

After this laboratory activity is completed, the student will be able to read and record data using a spectrophotometer.

The student will be able to correlate the disappearance of iodine's blue-black color with the breakdown of starch.

TIME REQUIRED:

Teacher preparation: The starch and iodine solutions should take no more than 1 hour to prepare.

Student lab time: The lab will take less than one fifty minute class period.

MATERIAL PREPARATION:

1. Using a soluble starch solution such as Baker's Analyzed potato starch, make a 0.5% starch solution by dissolving 5 g of potato starch in 1 L of distilled water. Heat to boiling, stirring occasionally. Allow solution to cool to room temperature before using. Boiling the starch solution will prevent settling in the test tube.
2. To prepare Lugol's solution, dissolve 3 g of potassium iodide (KI) in 25 mL of water. Then add 0.6 g of iodine crystals, and stir until dissolved. Make a 1:10 dilution of this stock. Store stock in a dark bottle.

BACKGROUND INFORMATION:

Chemically, saliva is 99.5 % water and 0.5 % solutes. Among the solutes are salts - chlorides, bicarbonates, and phosphates of sodium and potassium. Saliva also contains some dissolved gases and various organic substances including urea and uric acid, serum albumin and globulin, mucin, the bacteriolytic enzyme lysozyme, and the digestive enzyme salivary amylase. The chlorides in saliva activate the salivary amylase. The bicarbonates and phosphates buffer chemicals that enter the mouth and keep the saliva at a slightly acidic pH of 6.35 to 6.85. (Tortora 1987) The watery portion of saliva contains the highest percentage of salivary amylase, so the teacher may wish to filter out mucus to concentrate the enzyme being studied. Salivary amylase breaks polysaccharides into the disaccharide maltose. Food is usually swallowed too quickly for all of the starches to be reduced to disaccharides in the mouth. However, salivary amylase in the swallowed food continues to act on starches for another 15 to 30 minutes in the stomach before the stomach acids eventually inactivate it. Starch digestion continues when the chyme (stomach contents) reaches the small intestine which contains pancreatic amylase and several other enzymes that digest carbohydrates.

The structure of a starch molecule is a long spiral of sugars which have hydroxyl groups (hydrophilic ends) on the outside and non-polar (hydrophobic) ends on the inside. Iodide ions collect inside the spiral, resonating to emit the characteristic blue-black color we see when we add an iodine solution to starch. As salivary amylase breaks the carbohydrate down to disaccharides the spiral is broken into pieces and the

Iodine is no longer able to resonate inside. We observe that the color simply disappears. It is important to note that at pH below 6 iodine starch interactions do not show the characteristic blue black color.

ANSWERS TO QUESTIONS:

1. The independent variable is time. The dependent variable is percent transmittance.
2. You need to rinse your mouth before collecting saliva in order to eliminate starches and other foods left in the mouth after eating.
3. The blue-black color decreased as transmittance increased.
4. The starch, a large molecule made of many saccharide rings, was broken into pieces containing two saccharide rings each.
5. Test tube A- no change
Test tube B- should be clear to light blue
Test tube C- may still be a medium blue to dark blue.
Test tube D- should be clear

SOURCES OF MATERIALS:

1. Most biological supply houses carry soluble potato starch, potassium iodide, and iodine crystals.
2. If a Spec 20 is unavailable, lower cost colorimeters will provide graphable data.

GENERAL EFFECT OF SALIVARY AMYLASE ON STARCH

INTRODUCTION:

Amylase is an enzyme found in human saliva. Its function is to begin the breakdown of carbohydrates in the mouth prior to swallowing. The physical changes that occur when amylase hydrolyzes starch to maltose can be discovered by using an instrument known as a spectrophotometer. The spectrophotometer measures a light beam that is passed through a test tube containing the sample to be measured. The sample absorbs some of the light and transmits the rest. In this experiment, the Spec 20 will measure the amount of light transmitted through samples of starch and iodine, both with and without an enzyme. The amount of light transmitted varies directly with the concentration of the starch in the solution.

OBJECTIVES:

To discover some of the physical changes that occur during starch digestion.

To practice the use of the Spec 20 or other colorimeter.

PITFALLS AND CAUTIONS:

Begin timing as soon as saliva is added. Careful timing and reading will lead to the most precise data.

MATERIALS:

0.5% soluble potato starch solution (boiled and cooled)
Saliva
Lugol's iodine solution (stock) also called Wagner's reagent
100mL beaker
Medicine dropper
Stop watch or clock with a second hand
Three 13x100 mm test tubes
Spectrophotometer/colorimeter

PROCEDURE:

1. Warm up the Spec 20 for at least 10 minutes.
2. Set the wavelength to 550 nanometers.
3. Label the test tubes A, B, and Blank near the mouth of the test tube.
4. Use 3 mL of distilled water as the blank. A test tube of distilled water transmits 100% of the light passed through it. Use the blank to set the scale of the Spec 20 to 100% transmittance (T).
5. Collect 2 mL of saliva in a small beaker. Be sure to rinse out your mouth thoroughly before expectoration.
6. Place 2 mL of the starch solution into test tubes A and B.
7. Add one drop of the iodine solution to each test tube. Mix thoroughly by swirling.
8. Observe and record the transmittance of both test tubes. Describe the color of each test tube. This is time zero.
9. Add three drops of saliva to test tube B. Mix the contents of the test tube rapidly and thoroughly by swirling.
10. Record transmittance readings of test tube B every 30 seconds for the next five minutes. Describe the color change after each reading.
11. Take a transmittance reading of test tube A after 5 minutes and record any color change.

DATA:

Test tube B

Elapsed Time (sec.)	% Transmittance	Color Change
0		
30		
60		
90		
120		
150		
180		
210		
240		
270		
300		

Test tube A

Time(sec)	% Transmittance	Color Description
0		
300		

QUESTIONS:

1. Graph the data, putting the independent variable on the x axis and the dependent variable on the y axis.
2. Why must the mouth be rinsed before collecting the saliva?
3. Describe the correlation of the changes in color and transmittance.
4. What changes in the physical properties of starch have occurred during its hydrolysis?
5. Predict the color and percent transmittance of test tube A and B after 10 minutes. What information can you use to make this prediction?

CONCLUSIONS:FURTHER INVESTIGATIONS:

Do this experiment at several different temperatures.

Use different enzymes with their corresponding substrates.

REFERENCES:

BSCS Yellow Version, teacher manual

Feldman, Solomon, Experiments in Biological Design; Holt, Rinehart, and Winston

Tortora, Gerard J., 1987, Principles of Anatomy and Physiology; Harper and Row.

DETERMINING CONCENTRATION OF PROTEINS IN SALIVA USING BIURET SOLUTION

INTRODUCTION:

Determining protein concentrations in biological tissues is an important component of many molecular biology experiments. The concentration of pure proteins is often determined by reacting it with a substance to give it a color. The colored product will absorb light of a particular wavelength which can be measured in a spectrophotometer. There are several tests for protein. One of these tests is the Biuret test. This test is specific for the presence of the peptide bond. Materials containing this bond give a pink to purple color in the Biuret test. The concentration of the purple product formed by the interaction of the protein and Biuret solution can be measured in a spectrophotometer at 562 nanometers.

You will prepare a standard curve using known concentrations of protein. By plotting the known concentrations of protein against the absorbance, a straight line should be obtained. As you increase the concentration, the absorbance increases. From this standard curve you can determine the concentration of an unknown protein in solution.

Your body contains many different types of proteins. One of the more important types of protein is enzymes. Enzymes catalyze most of the reactions taking place in your body. Many enzymes are involved in digestion of food. This experiment determines the concentration of protein in your saliva. Most of the protein in saliva is amylase, which is an enzyme that digests starch.

OBJECTIVES:

To determine the concentration of proteins in saliva.

To gain experience using a pipette.

To gain an appreciation of the use and operation of the spectrophotometer.

To make and interpret a graph.

To gain experience using a standard curve of known protein concentrations to interpolate the concentration of an unknown protein.

MATERIALS:

Biuret solution
Bovine Serum Albumin 1 mg/ml
8 test tubes (13 X 100 mm)
Spectrophotometer
Pipettes
Graph paper
Test tube rack
Small beakers

CAUTIONS AND PITFALLS:

SAFETY GOGGLES MUST BE WORN. BIURET SOLUTION CONTAINS 10 M NaOH. IF BIURET TOUCHES YOUR SKIN RINSE IN RUNNING WATER FOR 3 TO 4 MINUTES. IF BIURET GETS IN YOUR EYES, RINSE IN WATER FOR 15 MINUTES. CONSULT A PHYSICIAN.

Swirl the contents of test tubes to mix before measuring percent transmittance in Spec 20. If any material spills on outside of test tube, wipe it dry with paper towel before inserting in Spec 20.

PROCEDURE:

1. Turn the Spec 20 on, and let it warm up 10 minutes. Set Spec 20 at 562 nm. Use Tube # 8 as the blank.
2. Rinse your mouth thoroughly with water. Collect a small amount of saliva in a small beaker.
3. Pipette 1 mL of saliva and 9 mL of distilled water into another small beaker. This produces a 1:10 dilution. Mix thoroughly.
4. Label the test tubes 1-8 and make up the following mixtures. The 8th test tube will contain only water and is used for the blank.

Test Tube #	Sample	Sample Volume (mL)	Water Volume (mL)	Biuret Amount(mL)
1	BSA	2.0	0.0	1
2	BSA	1.8	0.2	1
3	BSA	1.5	0.5	1
4	BSA	1.0	1.0	1
5	BSA	0.5	1.5	1
6	BSA	0.1	1.9	1
7	Saliva	2.0	0.0	1
8	Blank	0	3.0	0

- 5 Read percent transmittance of samples at 562 nm.
Record on your data sheets.
6. To determine the absorbance of the solution, which is the data that you must graph, you substitute the transmittance percentage (T) into the following mathematical relationship:

$$\text{absorbance} = \log [100] - (\log [T])$$

For example, if your sample has a transmittance of 75%, the equation you would set up is: $A = \log [100] - (\log [75])$.

DATA:

Test Tube#	Sample	Sample Volume (mL)	Water Volume (mL)	BCA Amount (mL)	% TRANS	ABSORBANCE
1	BSA	2.0	0.0	1		
2	BSA	1.8	0.2	1		
3	BSA	1.5	0.5	1		
4	BSA	1.0	1.0	1		
5	BSA	0.5	1.5	1		
6	BSA	0.1	1.9	1		
7	Saliva	2.0	0.0	1		
8	Blank	0.0	3.0	0		

CALCULATIONS AND QUESTIONS:

1. Graph the data. Plot independent variable on the x axis and dependent variable on the y axis.
2. Use the graph prepared in Question 1 to determine the concentration of proteins in your saliva.
3. Why did you have to graph the BSA in order to get the concentration of your saliva?
4. Explain how you used interpolation to find the concentration of protein in saliva.
5. Why was a blank used in this experiment? What important part of an experiment does the blank stand for? Why would the test be invalid without some sort of blank?
6. How does the concentration of protein in your saliva compare with others in the classroom?

CONCLUSIONS:

FURTHER INVESTIGATIONS:

1. Design an experiment to determine the concentration of other materials such as milk. Most of these will have to be diluted.

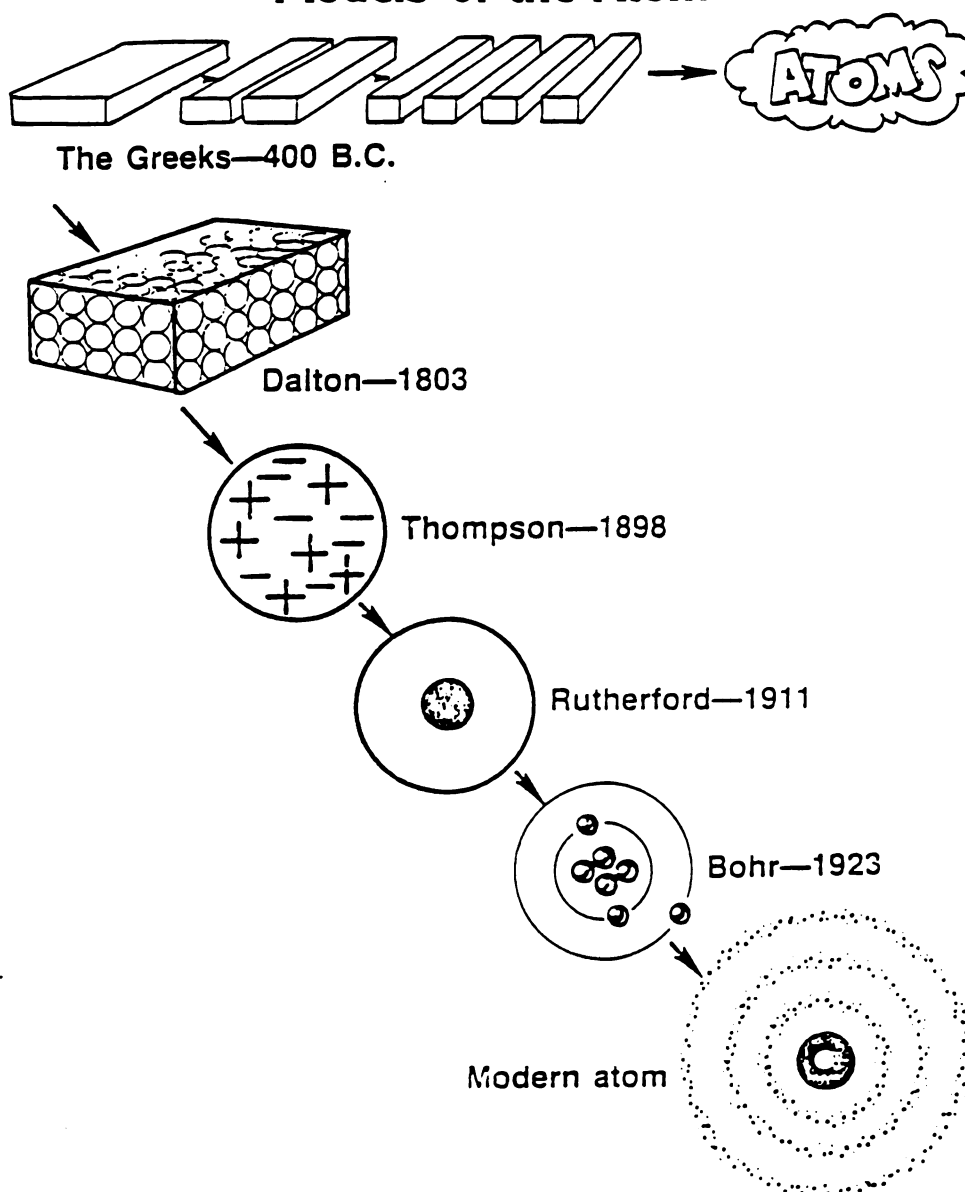
REFERENCES:

Suelter, C. S. 1987. "Determine Protein Concentration by the BCA Assay", Michigan State University

Tortora, Gerard. 1987. Principles of Anatomy and Physiology, Harper and Row

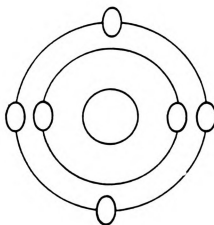
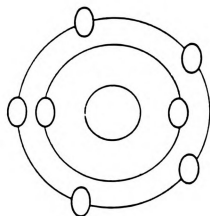
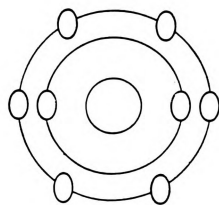
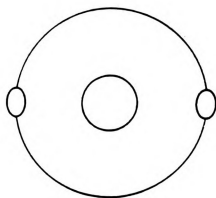
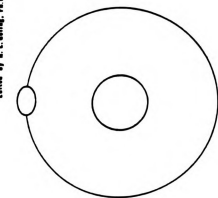
APPENDIX K
COPIES OF OVERHEADS USED IN LECTURE

Models of the Atom

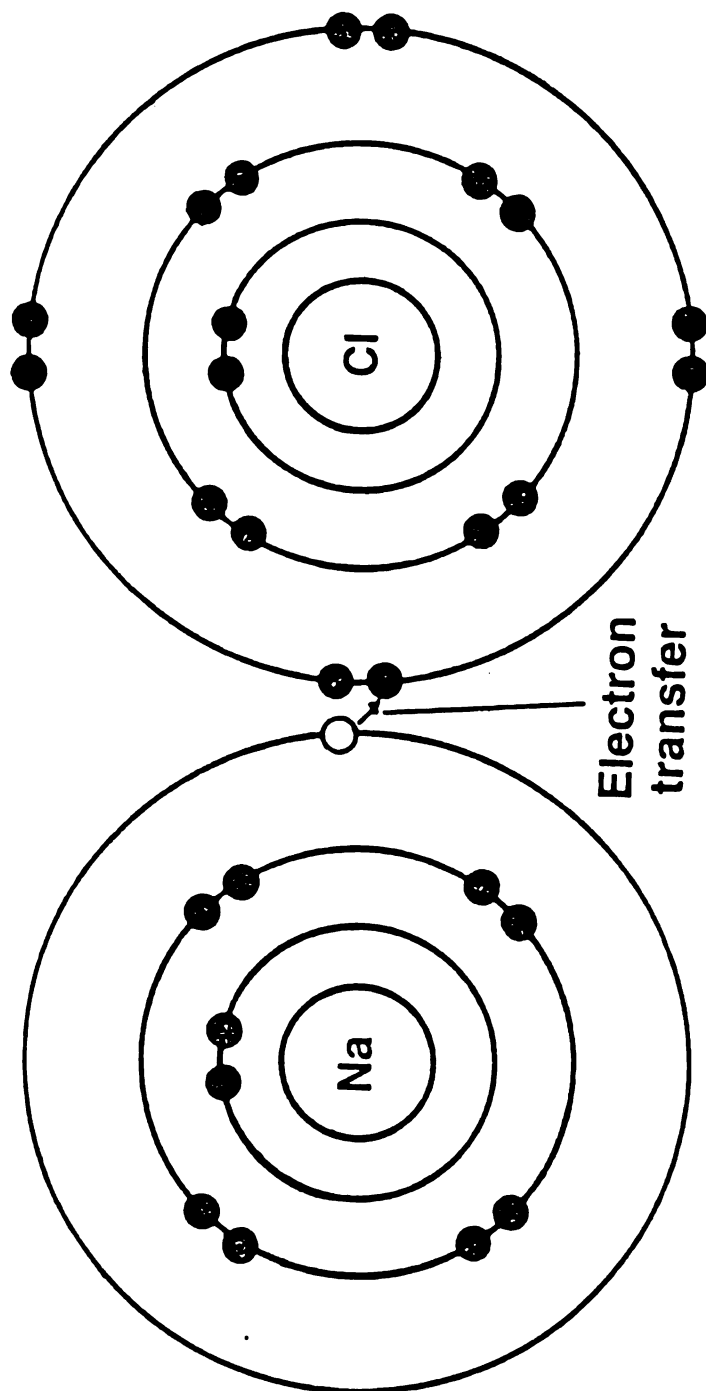


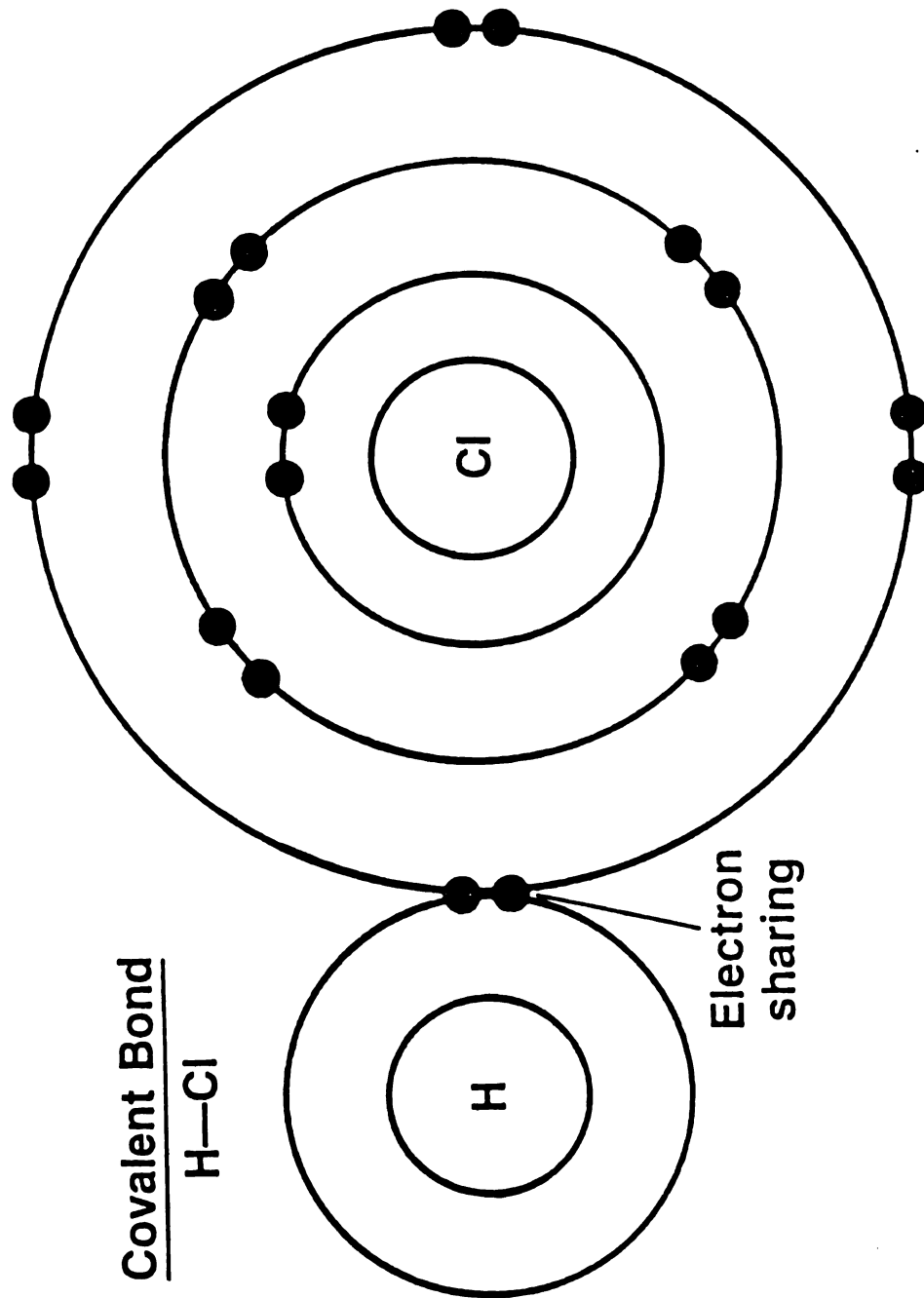
ATOMIC STRUCTURE

DYNAMICS
 Edition of 1980, No. 1



Ionic Bond
Na—Cl





columns —		The Periodic Table																4 — columns	
rows ↓	I	II											III	IV	V	VI	VII	VIII	rows
↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	↓
1	H Hydrogen																	He Helium	1
2	Li Lithium	Be Beryllium																B Boron	2
3	Na Sodium	Mg Magnesium																C Carbon	3
4	K Potassium	Ca Calcium	Sc Scandium	Ti Titanium	V Vanadium	Cr Chromium	Mn Manganese	Fe Iron	Co Cobalt	Ni Nickel	Cu Copper	Zn Zinc	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium	Br Bromine	Kr Krypton	4
5	Rb Rubidium	Sr Strontium	Y Yttrium	Zr Zirconium	Nb Niobium	Mo Molybdenum	Tc Technetium	Ru Ruthenium	Rh Rhodium	Pd Palladium	Ag Silver	Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium	I Iodine	Xe Xenon	5
6	Cs Cesium	Ba Barium	La Lanthanum	Hf Hafnium	Ta Tantalum	W Tungsten	Re Rhenium	Os Osmium	Ir Iridium	Pt Platinum	Au Gold	Hg Mercury	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium	At Astatine	Rn Radon	6
7	Fr Francium	Ra Radium																	

atomic number —	12	24.3	— average atomic mass
symbol of element —	Mg		
element name —	Magnesium		

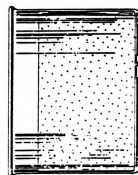
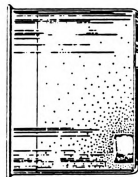
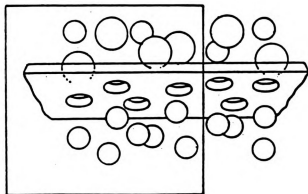
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
Lanthanum	Cerium	Praseodymium	Niodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium	

89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lanthanum	

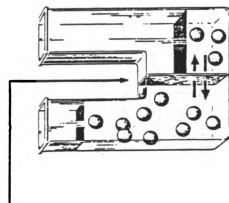
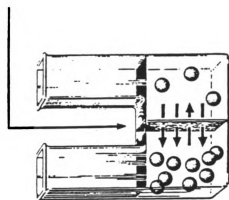
DIFFUSION AND OSMOSIS

 **DYNAMILIS**
 Edited by R. L. Searcy, Ph.D.

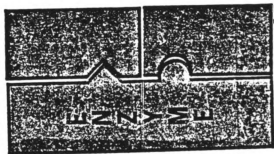
Diffusion



Osmosis



ENZYMES: Organic Catalysts

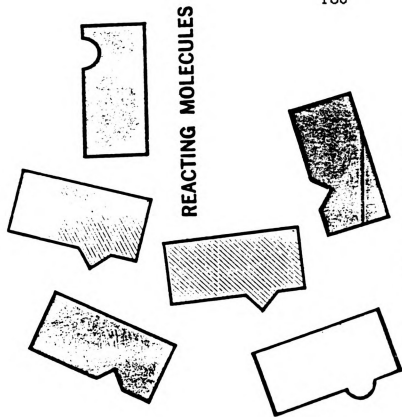


A molecule attaches to the surface of the enzyme.

Another molecule attaches to the enzyme and combines with the first molecule.



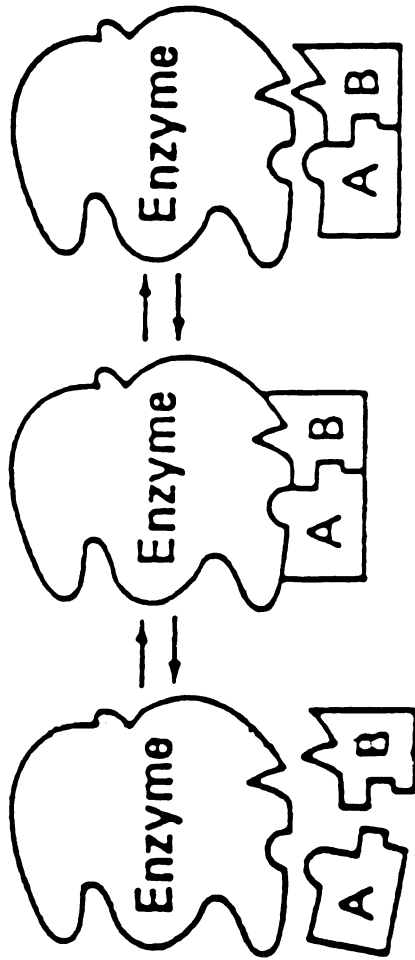
The newly formed substance peels off the enzyme.



REACTING MOLECULES

CHARACTERISTICS OF ENZYMES

- Alter the rate of chemical reactions
- Not used up in reactions
- Effective in small amounts
- Specific in their activity
- Protein substances
- Work best at definite temperature and pH levels



The “lock and key” concept of enzyme and substrate explains the specificity of enzyme action

pH scale 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Litmus

	red		blue
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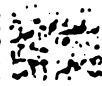
Methyl orange

reddish brown		yellow
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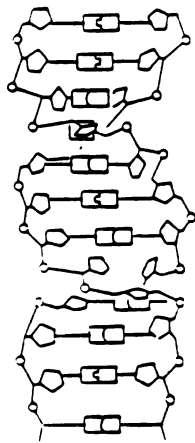
Phenolphthalein

colorless		pink → red
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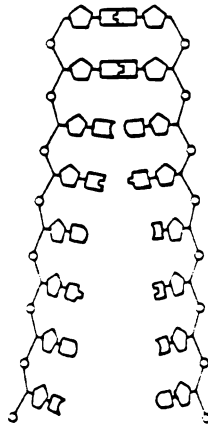
Bromthymol blue

blue		yellow
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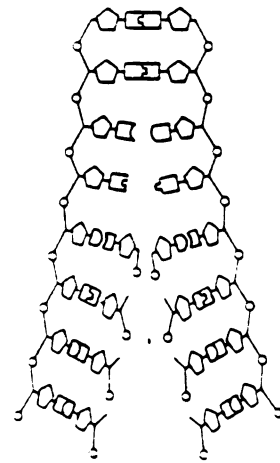
Replication of DNA



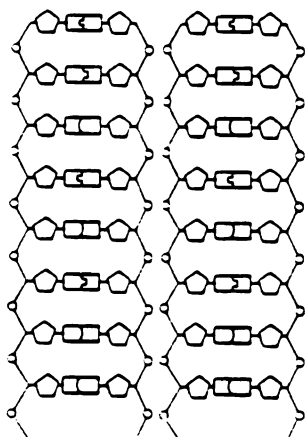
Uncoiling



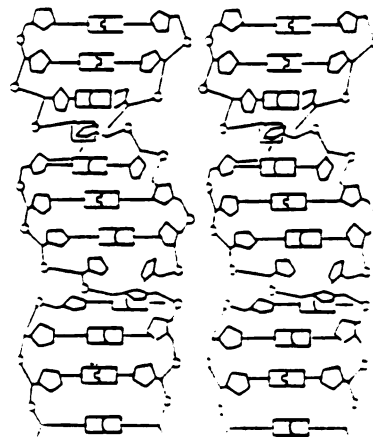
Unzipping



Adding
new parts

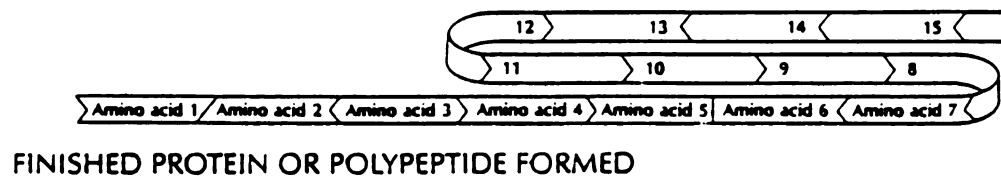
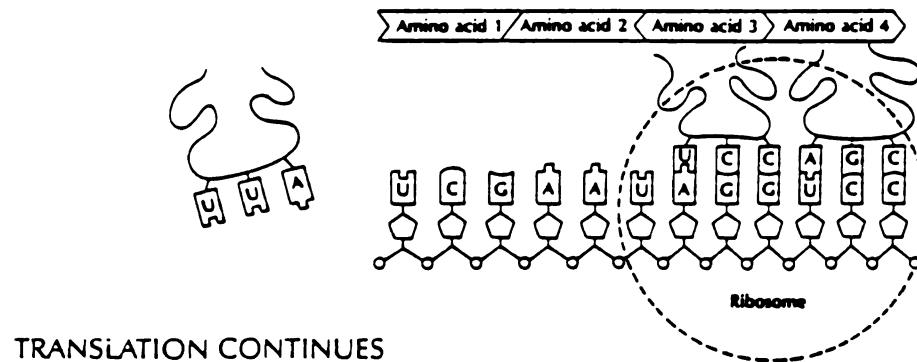
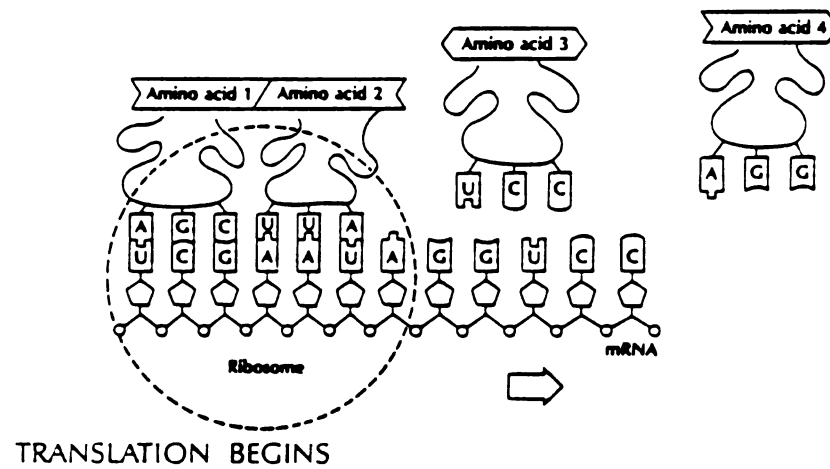
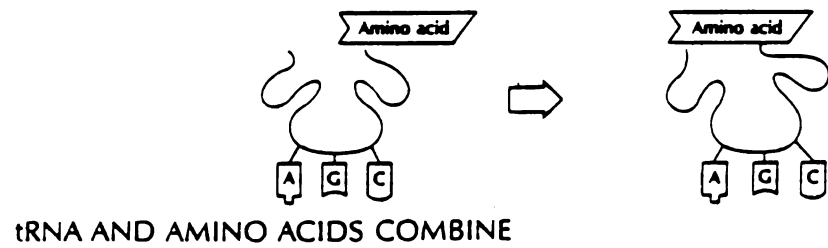


Two DNA
molecules



Recoiling

Translation



FURTHER READING

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ADDITIONAL READING

Science Report Card. Elements of Risk & Recovery.
Trends & Achievement
 1986 National Assessment
 1988
 Education and Testing Service

"Changing America: The New Face of Science and
 Engineering"
 Interim Report
 1988
 Task Force on Women, Minorities & Handicapped in
 Science & Technology

"Education of Scientists & Engineers, from Grade to
 Grad School"
 1988
 Congress of U.S. Office of Technology Assessment

"Rediscovering the Lab"
The Science Teacher
 Jan 86

Ausubel, D.P.
Educational Psychology: a Cognitive View
 1968
 Holt, Rinehard and Winston

Bates, G.C.
 "The Role of the Laboratory in Secondary School Science
 Programs"
What Research Says to the Science Teacher Vol 1
 1978
 NSTA

Blosser, P.E.
 "A Critical Review of the Role of the Laboratory in
 Science Teaching"
 1981
 ERIC Clearinghouse for Science, Math and Environmental
 Education

Brandwein, P.F.
Memorandum On Renewing Schooling and Education
 1981
 Harcourt Brace Jovanovich

Brennan, J.W.
An Investigation of Factors Related to Safety In the HS
Science Program
 Doctoral dissertation
 1982
 University of Denver, Colorado

Coleman, D.C.
A Historical Identification & Examination of Factors
Influencing the Research Findings of Science Lab
Instruction in Public High School in the United
States
 1986
 Doctoral Dissertation
 University of North Carolina, Chapel Hill

Cunningham, R.T. and J. Welgand
 "Developing Questioning Skills"
Developing Teacher Competencies
 1971
 Prentice Hall

Goodlad, J.
A Place Called School
 1984
 McGraw Hill

Hofstein, A. & Lunetta, V.A.
 "Role of the Laboratory in Science Teaching:Neglected
 Aspect of Research"
Review of Educational Research
 1982

Hurd, P.D.
 "Science education for a new age: The reform movement"
 NASSP Bulletin 69, 83-92
 1985

Huxley, T.H.
Science and Education
 1897
 D. Appleton & Co. NY

Linn, M.D.
 "Theoretical and Practical Significance of Formal
 Thought: Some Considerations"
 1979
 Berkely: Lawrence Hall of Science

Marquand, R.
 "Educators Rework the Ways Schools Teach Science"
The Christian Science Monitor
 1988, Feb. 2

National Assessment of Educational Progress
 Released Exercise Set
The Third Assessment of Science
 1978
 Education Commission of the States

Pickering, M.
 "Lab is a Puzzle, Not an Illustration"
Journal of Chemical Education
 Oct 85

Pizzini, E.
 "Project STEPS: Science Textbook Extensions Through
 Problem Solving"
 Proposal No 8652312
 1987
 NSF

Pizzini, E. Abell, S. and J. VanderWilt
 "Scrape, Scrape, Scrape: Problem Solving in the
 Lunchroom"
Science and Children
 1987

Pizzini, E.L.
 "Teaching Thinking Skills: Can We? Do We?"
Iowa Science Teachers Journal
 1988

Renner, J.W.
 "The Power of Purpose"
Science Education
 May 82

Rowe, M.B
 "Wait Time and Rewards as Instructional Variables:
 Their Influence on Language, Logic and Fate Control"
 1974
Journal of Research in Science Teaching

Shulman, L.S. and Tamir, P.
 "Research on Teaching in the Natural Sciences"
Second Handbook of Research on Teaching
 1973
 Rand McNally

Stake, R. and Easley, J.
 "Case Studies in Science Education"
 Centre for Instructional Research and Curriculum
 Evaluation
 1978
 University of Illinois

Sund, R. and Trowbridge, L.W.
Teaching Science by Inquiry
 1967
 Merrill

Tamir, P.
 "The Role of the Laboratory in Science Teaching"
 Technical Report No. 10
 1976
 The University of Iowa

Wasserman, S.
 "Teaching for Thinking: Louis E. Rath Revisited"
Phi Delta Kappan
 1987

Yager, R.E. and Lunetta, V. N.
 "New Foci for Science Teacher Education"
Journal of Teacher Education
 November/December 84

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