CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

DEVELOPMENT OF AN AUDIO-TUTORIAL BIOLOGY
PROGRAM AT CANYON HIGH SCHOOL

A project submitted in partial satisfaction of the requirements for the degree of Master of Arts in Education

by

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Abstract

DEVELOPMENT OF AN AUDIO-TUTORIAL BIOLOGY PROGRAM AT CANYON HIGH SCHOOL

by

David Lewis Crissman

Master of Arts in Education

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Because students are unique individuals with varying abilities and learning rates, methods for individualizing classroom instruction are being developed and used across the country. Audio-Tutorial (A-T) is one method of individualizing instruction which allows a student to work on a unit of instruction, aided by audiotapes, filmstrips and other specially created visuals, and printed instructions. Guided by the audiotapes, the student may work at his own speed individually in a study booth, in a science laboratory, or in other settings. Under the tutelage of the audiotapes, he reads, writes, performs experiments, handles materials, makes observations, repeats any segment or procedure desired, and takes tests. Large and small group meetings each week allow the student to interact with other students and the instructor.

An audio-tutorial biology program was developed for a college preparatory biology course at Canyon High School in Canyon Country, California in 1973-74 to meet the vary-
ing needs and abilities of the students enrolled in biology. Because the teacher was no longer the center of classroom activities, the students could no longer be passive receivers of teacher lectures and demonstrations. Thus, the A-T method placed a greater demand on student participation in the course and required more responsibility on the part of the student to learn the course materials. Not all the students originally enrolled in the program were capable of, or willing to accept the responsibility for learning the course material without constant direction from the teacher. Some of these students had been below average achievers in other classes; others had records of misbehavior in other classes, and some students simply did not want to do all the work themselves. They wanted the teacher to do most of it for them. However, most of the students enrolled in the course worked effectively in the A-T program to achieve the course objectives. These students had records of above average achievement in other courses and did not have records of misbehavior in other classes. The A-T method fostered the development of greater self-determination in students because these students were able to achieve the course objectives with less direction from the teacher than in a traditional lecture-lab course.

Because A-T is a less structured method of learning than a traditional lecture-lab course, success in the course will come only to students that have the ability to
achieve in a college prep course and are willing to accept the responsibility of learning without constant direction from the teacher.

The A-T biology program succeeded at Canyon High School because it allowed students to learn at their own rate using a variety of media, and it helped students develop self-determination and self-reliance in their ability to learn.
Chapter I

The Problem

Introduction and Background of the Problem

Throughout the history of education, students have been placed together in classrooms and instructed at the rate the instructor deemed sufficient. Little attempt was made to individualize instruction in the classroom. For three hundred years, many teachers have assumed that all students learn at the same rate and in the same way with the teacher being the center of classroom activities; the only tools that these teachers had to work with were chalk, blackboard, pen, pencil, and possibly, a textbook.

Because people are unique individuals with varying learning rates and different educational backgrounds, there is a need for individualized methods of instruction. Individualization of instruction includes techniques that are designed to allow for individual needs in learning. For example, rate of learning and method in which subject matter is learned have been incorporated into the methodology of individualized instruction. There are various methods of individualizing instruction such as learning activity packages (LAP), contract learning, programmed instruction, and a relatively new technique called audio-tutorial instruction (A-T). In science education, much is now being
done in audio-tutorial instruction. A thorough investigation of individualizing learning has been made by Weisgerber (1971).

Statement of the Problem

Having to teach to groups of students rather than individual students has been a problem for the author who is an instructor at Canyon High School in Canyon Country, California. With some students falling behind the pace of the instructor and others trying to move ahead, it has been difficult to meet the needs of all students with varying abilities entering the biology program at Canyon High School. Many of these students came from structured educational experiences in which they had little opportunity to be responsible for their own learning. They were very much used to the teacher being the center of classroom activities and telling them exactly what to do, how to do it, and when to do it. They had become very dependent upon the teacher for their learning and had little ability or confidence to be independent learners. A recent study (De Charms, 1971) defines two kinds of learners: origins and pawns.

An Origin is a person who feels that he is the director of his life. He feels that what he is doing is the result of his own free choice; he is doing it because he wants to do it, and the consequences of his activity will be valuable to him. He thinks carefully about what he wants in this world, now and in the future, and chooses the most important goals, ruling out those that are for him too easy or too risky. He is not 'Dependent of
Destiny' since he is aware of his abilities and limitations. Relying on personal insight gleaned from instructive failures and skillful successes, he contrives to allow his strengths to outweigh his weaknesses. In short, an Origin is master of his own fate.

A Pawn is a person who feels that someone, or something else, is in control of his fate. Since he feels that external factors determine his fate, the Pawn does not consider carefully his goals in life, nor does he concern himself about what he himself can do to further his cause. Rather he hopes for Lady Luck to smile on him. He is a passive receiver of the 'slings and arrows of outrageous fortune,' always hoping for the one great chance occurrence that will change his life (pp. 382-3).

De Charms states that no one is purely an origin or pawn but that the origin-pawn concept makes up a continuum upon which people fall. Having to teach to groups of students using traditional methods which do not foster individualized learning, in the author's opinion, is not a viable method of instruction for it emphasizes the "pawn" concept rather than the "origin" concept.

Teaching to groups of students rather than individuals is the problem this instructor has faced in the past.

**Purpose of the Project**

The purpose of this project was to develop an individualized instructional program in high school biology at Canyon High School. This program required students to learn independently using the instructor as a resource rather than the only source of their learning. At the
conclusion of the project, student attitudes about the program were assessed.

**Importance of the Project**

Since 1961, the A-T method has been used in many colleges and universities throughout the country including Purdue University, Ohio State University and Michigan State University. However, it has not been as extensively used at the secondary level of education in this country. The large amount of money required to develop an A-T program and the amount of time and labor required to implement such a program may be two reasons why it is not used more at the secondary level (Cryde, 1971).

The project also attempted to measure student attitude towards an A-T program in biology and to determine if certain groups of students were more successful than others when working independently. The criteria of success for the program was completion of 70% of all the objectives of the A-T biology course by 80% of the students who were enrolled. A successful A-T biology program at Canyon High might convince educators that the A-T method would be a useful tool in education in helping students to become independent learners.

**Definition of Terms**

**Audio-Tutorial**

A method of instruction which allows a student to work on a unit of instruction, aided by audiotapes, film-
strips and other specially created visuals, and printed instructions. Guided by the audiotapes, the student may work at his own speed individually in a study booth, in a science laboratory, or in other settings. Under the tutelage of the audiotapes, he reads, writes, performs experiments, handles materials, makes observations, repeats any segment or procedure desired, and takes tests. Large and small group meetings each week allow the student to interact with other students and the instructor.

General Assembly Session (GAS)

A large group meeting once each week in which films are shown, guest speakers are presented, and material is reviewed by the instructor.

Independent Study Session (ISS)

The time spent by each student working individually with audiotapes, demonstrations, observations, and experiments.

Integrated Oral Quiz Session (IQS)

A small group quizz session comprising eight to ten students and an instructor. Each student explains to the group a concept the instructor gives him based upon the objectives they were to achieve for a particular chapter in the textbook.

Cassette Recorders

Tape recorders that use small cassette cartridge tapes.
Headphones

These are used for private listening of taped explanations.

Overlays

Transparencies, mounted on cardboard frames, used as visual aids.

Activity Options and Objective Sheet

A list of behavioral objectives a student is to achieve for a particular chapter in the textbook along with activity options which may be selected to achieve these objectives. For example, a student may wish to achieve an objective by using the textbook or by using an A-T packet.

Study Guide

A booklet of instructions for a particular A-T packet. There is one packet for each chapter covered in the textbook. The booklet is a guide for the student to proceed through the textbook chapter using the A-T packet containing taped explanations of concepts in the chapter accompanied by visual aids.

Study Booths

A booth containing one tape recorder, headphones, and filmstrip viewer used by students to work independently on A-T packets.

A-T Packets

Packets that contain one study guide with relevant illustrations, one or more overlays, one cassette tape cartridge to explain visual materials. There is one packet
for each chapter covered in the textbook.

**Solo Learn Kit**

Commercial learning kits containing one filmstrip, one instruction booklet, one cassette tape cartridge to explain visual materials, and one student review sheet. Each kit explains a particular concept, such as respiration or DNA. These kits do not accompany the BSCS textbook but are separate kits dealing with various biological concepts.

**Filmloop**

A movie filmloop in which the ends of the film are connected so that the film plays continuously.

**Filmstrip**

A continuous strip of 35mm frames with approximately 40 to 60 frames.

**Filmstrip Viewer**

A compact filmstrip viewer suitable for use in a study booth.

**Filmstrip Projector**

A projector that projects the filmstrip image on a screen.

**Modular Scheduling**

A schedule for instruction that divides instructional time into modules of a particular length of time. Some classes may be composed of one or more modules meeting one or more days per week. This type of schedule also provides modules for students to work independently in areas of particular interest to them, providing greater
flexibility in time allotments for particular courses and more opportunity for students to be responsible for their own in-school activities.

**BSCS Blue Version Biology**

A course in biology developed by the Biological Sciences Curriculum Study in Boulder, Colorado emphasizing the chemical evolution of life and living processes. The title of the textbook is *Molecules to Man*. Each chapter of the textbook contains experiments, investigations, and study questions.

**Scope of the Project**

This project was specifically undertaken to solve the problem of having to teach to groups of students rather than individual students. An individualized instructional program in high school biology was developed which involved independent student learning. Student attitudes about the program were assessed. The final determination of whether or not students succeeded in the program came from the results of the exams used to measure the achievement of the objectives.

**Outline of the Remainder of the Report on the A-T Project**

In Chapter II, the current literature on A-T is reviewed. The cost and scheduling factors of A-T are also discussed in this chapter. Advantages of the A-T system and methods used to develop an A-T program are included.

In Chapter III the developmental work, methodology,
and procedures used by this instructor to develop and implement an A-T system at Canyon High School are presented, including the type of scheduling, the cost factors, the physical layout of the A-T laboratory, a description of the type of biology course taught, how the materials were developed, and a typical week of a student going through the A-T program.

In Chapter IV, the instructor's observations of the program, student achievement of the objectives, and student evaluations of the program are presented. A conclusion regarding the effectiveness of the program at Canyon High School is included with suggestions and implications for those who may wish to develop similar programs at other schools.
Chapter II

Review of the Literature

Origin of the Audio-Tutorial System

Samuel Postlethwait (1967), a professor of botany at Purdue University in Indiana, realized that the students in his botany courses did not all have the same science background. Since they had attended a wide variety of high schools, some had excellent training in science while others did not. This diversity of abilities in science amongst the botany students created a problem of instructing groups of students at a particular level and at a particular rate. Postlethwait believed that the instructional program must allow for individual differences in interests, capacity, and background and that the instructor should provide attention and individual tutelage to students who needed more help. Postlethwait believed that the role of the instructor in an individualized instructional program should be to provide direction, facilities, and motivation to the individual learner.

To assist the students with poor backgrounds, Postlethwait developed a special lecture on tape each week and filed this tape with the language tapes in the Audio Visual Library. Students went to this facility to listen to previous lectures they did not fully understand. At a
later time it seemed feasible to provide the student with plants and experimental material so that these too could be related to the laboratory manual, text book, and tape lecture. Eventually, learning activities included a great range of experiences such as reading from the text, conducting an experiment, collecting data, analyzing data, manipulation of a microscope, watching a time lapse movie, observing plant specimens, charts, diagrams, photographs and listening to brief lectures or discussions as appropriate. These activities were integrated so that students could achieve stated weekly objectives (Postlethwait, Novak, & Murray, 1969).

Experimental and control groups of 36 students each were selected to test the effectiveness of the A-T method. The experimental group used the A-T method while the control group was given a conventional lecture-lab approach. The same material was covered and the same tests were used to measure the achievement of both groups. However, Postlethwait does not mention how he chose his sample groups, what tests he used to measure their progress, or what statistical tools he used to analyze the results of the tests. Postlethwait (1967) states that there was no significant difference in the amount learned by the students in each group, but he believed the new technique was a success because students were able to learn individually at their own rates and receive individual attention. At the end of the second semester, Postlethwait met with his students to
get their input on structuring a revised program of instruction that would meet their needs more effectively.
The course was restructured, disregarding all traditional limitations and placing total emphasis on student learning.
In the restructured course, a student would meet one hour per week in a General Assembly Session (GAS) where films, guest lecturers, and new material could be introduced; one hour per week in an Integrated Quiz Session (IQS) and X hours per week in the Independent Study Session (ISS). The ISS was a modification of the original audio taped tutorial. The IQS was a seminar and oral quiz involving eight to ten students seated informally around a table with one instructor. Each student presented and taught one portion of the week's material. This provided an excellent method of feedback as to the success or failure of the learning activities used by students in attempting to achieve the objectives. It also allowed students to see relationships and concepts which were not evident to them from the ISS.
In other words, they could see the material in a different light through someone else's eyes (Postlethwait, 1967).

The first year the Postlethwait A-T system was used under the restructured plan, there was a myriad of problems such as improper scheduling, lack of tape recorders, lack of study booths, as well as tape duplicating problems and procrastination by students in completing examinations. Postlethwait (1967) states that the program's success came about only because of sheer tenacity on the part of the
staff.

Postlethwait (1970) states that in his ten years of experience with the A-T system, 90% of the students preferred the A-T method over any other method, 20% higher scores were achieved, and 50% more course material was presented. A's increased from 7% to 22%, B's increased from 20% to 35% and F's decreased from 20% to 7%.

Postlethwait (1967) emphasizes that the mere use of tape recorders and other audio-visual equipment does not constitute an audio-tutorial system. These items are merely vehicles that permit integration of meaningful learning activities on an individual basis.

Since 1961, botany at Purdue has been taught with the A-T technique and has been expanded to include A-T minicourses in botany and zoology (Postlethwait, Hurst, Husband, & Hetherington, 1970). These were small, conceptual units that increased the versatility of the program by combining concepts which were common to both courses and permitted the concepts unique to plants or animals to be taught in separate minicourses. The student was given a certain amount of credit for each minicourse he completed. The students could choose which minicourse they wanted to take and were given the total amount of college credits for the minicourses they successfully completed during the semester. If they did not earn a C or better in the minicourse, they were not given credit for the course. The minicourses added another dimension to the A-T process in
allowing the individual student to plan his own botany and zoology learning experiences.

Purdue University has become a center of audio-tutorial science instruction in this country, influencing the development of similar programs in 500 colleges and 100 high schools across the country (Gryde, 1971). According to Gryde (1971), 88 out of the 90 community colleges in California use A-T in teaching one or more courses.

Current Developments in the Postlethwait Model Throughout the Country

The A-T courses at Purdue have influenced the development of similar programs throughout the country. The A-T physics course at Jefferson High School in Lafayette was designed by Knoop (Gryde, 1971). Since the course was operated under a traditional fixed schedule, students were limited as to when they could use the laboratory. The tape recorders could be checked out and taken home by the students and occasionally the lab was open at night. Otherwise, this was a Postlethwait model.

At West Lafayette High School in West Lafayette, Indiana, Curtis Smiley (Gryde, 1971) developed an A-T biology course in 1968 for 220 students. There were two full-time and one half-time instructors. The program was funded by the State Office of Instruction to the amount of $3,000. There were 36 study booths in which students could listen to tapes, look at filmstrips or slides, diagrams, charts, etc. Students were not on a fixed schedule and
could go to the laboratory, go on a field trip, or go to the tape room. There were a specific number of tasks required for each grade level. The student contracted for the grade level he wanted and was allowed to take tests when he believed he had mastered the tasks. There were discussion sessions where all the students met for a weekly review of the covered material.

At Munster High School in Munster, Indiana, John Eddington (1969) designed and developed a multisensory approach to biology using some of Postlethwait's ideas. The program was built around a three man teaching team and was comprised of four different programs: a reading laboratory, an audio-visual laboratory, a practical laboratory, and a seminar. All of these programs were coordinated by a student study guide. In the reading lab, the student was provided three different texts, each with a different reading level. The student could select the text which best suited his reading ability. Programmed instruction was also made available. In the audio-visual lab, there were two large group lectures each week. This lab also had 40 viewing stations where students could view and listen to any one of eight unit programs. These programs used slides, filmstrips, 8mm film loops, and video tapes or any combination of these. Each visual aid was accompanied by an audio-tape. Students did experiments when they were ready. When the student believed he had met all of the behavioral objectives in his study guide, he took an exam. The
student had to achieve a score of 80% to pass the exam. If he did not pass, he could study the areas in which he was weak and then take another version of the exam.

An individualized chemistry program at Marple Newtown Senior High School in Newtown Square, Pennsylvania was designed by James V. DeRose (1970). The program was initiated for high achievers in 1966 and was primarily designed to prevent the high achiever from being held back in conventional classroom teaching. DeRose (1970) states "It is the hope that a modification can be devised that makes students experience in learning how to learn whatever they need to learn the activity of prime importance (p. 553)."

He ranked his students according to their scores on the Sequential Test of Educational Progress in mathematics, science, and reading. The highest ranked students and their parents were briefed on the new program and fifteen students accepted the invitation to join. They were expected to study the same amount of material that conventional students would be covering and more. These students were given a list of behavioral objectives that covered the basic course and then they were to choose additional goals and objectives to go beyond the conventional students. They were not told how to accomplish these objectives but were given lab manuals, books, films and any other resources available, including the guidance of the instructor, to accomplish them. These students were given the same tests the control students had throughout the first year. The
control group was made up of high achievers that were
taking the course under conventional instruction. Using
teacher prepared exams and the Differential Aptitude Tests
(DAT) of Abstract Reasoning (AR) and Numerical Ability
(NA), DeRose found that the test means of the independent
study students were higher than the conventional students.
DeRose stated that this demonstrated that these students
could learn on their own without a structured or formal
learning environment. He further points out that although
every opportunity was given these advanced independent
students to go beyond the required course objectives, few
did. DeRose states, "One must face the fact that students
being students (or people being people?) the assumption
cannot be made that they will discipline themselves to do
what needs to be done in the absence of either deadlines or
of a policy that limits credit to those who do what needs
to be done (p. 555)." But since these students did achieve
the same objectives as the conventional classes, under self
planned and self paced conditions, DeRose believed the pro-
gram was a success.

Although few of the 500 colleges and 100 high
schools have reported their A-T work, fewer still have
actually done any statistical analyses of the A-T method in
comparison to the traditional lecture-lab method. However,
a study was done by James E. Arnwine and Bill Juby at In-
dependence Community Junior College, Independence, Kansas.
They compared A-T biology with traditionally taught biology
and found that students taking A-T biology had higher grades than students who were taking the traditional biology course.

At Laguna Beach High School in Laguna Beach, California, Charles Reich (Gryde, 1971) designed and developed an A-T biology program for 225 students in 1970-71. Two teachers, one non-credentialed teacher, and a clerk managed the A-T lab. There were large group sessions and small group seminar sessions. During the seminar block, each student presented a 15 minute report to the students in his section. The student was graded by his peers on content, knowledge, participation, and the use of visual aids. The A-T laboratory had sixteen cassette tape recorders, two 8mm film projectors and three 35mm carousel projectors. Demonstration tables with displays helped students visualize concepts. Experiments were performed at appropriate times in conjunction with the A-T sessions.

At Canyon High School in Canyon Country, California, Dean Hurd (1970) designed, developed, and implemented an A-T chemistry program. With help from students and money from the Hart District, ten study booths were constructed with a built in cassette tape recorder and earphones in each booth. There was a master panel that controlled each booth and a master reel tape recorder electronically connected to each cassette recorder. The script or audio portion was taped on ten cassette cartridges in each of the ten recorders simultaneously; ten cartridges
could be duplicated at one time from the master tape.

Since Canyon operated under a modular schedule, students could work in the A-T lab during their independent study periods. Because of the flexible scheduling, ten booths could accommodate 160 students during the course. The lab was open from 8:00 a.m. to 4:00 p.m. daily. Mr. Hurd and one teaching assistant together with several student assistants and lab assistants ran the program during these hours. There were large group meetings each week for viewing films and reviewing the material. Small seminar groups helped students work out any specific problems through oral discussion and allowed the instructor to evaluate student progress and comprehension of the material. Also the instructor or his assistant was always available for immediate help. When the student believed he had accomplished the objectives for that unit, he could take the post test. If he failed to achieve 80%, he could study the material again and take another version of the exam. He could do this up to four times to achieve the grade he wanted.

In an attitude survey administered to his students, Mr. Hurd states that 92% of the students preferred the A-T method over the conventional method because they could proceed at their own rate of learning, work at times convenient to them and have four chances to achieve the grade they wanted on the exam.

Prior to using the A-T method of teaching chemistry, Mr. Hurd reports that his students' average scores in the
course were about 60%. Since using A-T exclusively for teaching chemistry, the average scores are now 82%.

Mr. Hurd provided the following cost analysis of his A-T chemistry course:

1. 10 cassette recorders @ $40 = $400
   10 headphones @ $ 6 = 60
   AC power lines and shielded cable 50
   1 master recorder with high quality microphone 250
   Sub total $ 760

2. cassette tapes (high quality): cheap tapes will stick and break
   165 tapes @ $1.50 = $247

3. overlays - for visual displays (the student must not only hear the material but see it at the same time)
   1100 overlays @ 0.302 = $332.20
   400 frames @ 0.132 = $52.80

4. plastic envelopes - 200 @ 0.24 = $48

5. softwear package (study guide) containing behavioral objectives, pretests and answers; instructions leading the student through the unit
   200 copies @ $2.50 = $450

6. booths -
   teacher-made booths $20 to $50 per booth
   10 @ $20 = $200
   10 @ $50 = $500
   commercially prepared - $100 and up per booth
   10 @ $100 = $1000
overall, approximately $500 for booths

7. Teacher time and secretarial time is also needed to prepare the materials. The cost will vary from district to district but approximately 700 to 1000 man hours are needed to develop the program from start to finish.

Total cost = $2390.50 (not including teacher and secretarial time)

Other A-T programs across the country are found in the following schools: Golden West College, biology; Pittsburgh School of Medicine, obstetrics and gynecology; Pennsylvania Medical School, pathology, behavioral science; Rio Hondo Junior College, biology lab; Ohio State University, biology; Christian College, geology; University of Notre Dame, geology; University of Wisconsin, biology; John Muir High School, Pasadena, California, biology; Arcadia High School, Arcadia, California, botany.

Burgess Publishing Company, 426 South Sixth Street, Minneapolis, Minnesota 55415, has a division called Audio-Tutorial Systems in which they publish and produce A-T material and equipment. Most of this material is for college level courses. High school level material must be developed by the instructor or college material must be adapted to the high school level.
Chapter III

Procedure and Methodology

Development of the Audio-Tutorial Materials

Development of the A-T biology program at Canyon High School began in the Spring of 1973 with a formal request to the William S. Hart Union High School District for $3200 to purchase tape recorders, study booths, 3M transparencies and other materials needed for the program. Although the district was not able to appropriate funds for the development of the program, the principal of Canyon High School and the Hart District curriculum director contributed $1000 from their budgets. Canyon High School provided tape recorders, filmstrip viewers, filmstrip projectors and study booths from the school's Instructional Resource Center which houses audio-visual equipment. The $1000 was used to purchase filmstrips, 3M infrared transparencies, transparency frames, Scotch Brand cassette and reel tapes. Ward's Solo Learn Kits had been purchased the previous year. Headphones were acquired from the Canyon High School Science Department's planetarium. One cassette tape recorder and headphone was bolted into each of 13 study booths. Five of the booths had filmstrip viewers for the Solo Learn Kits. The author used his own money to purchase the electrical materials necessary for wiring the booths.
Early in the summer, behavioral objectives were written for chapters 1 through 11, 13, 15, and 16 of the BSCS textbook. Each student later received a copy of the objectives for a particular chapter when he began to work in that chapter. Test questions were written for each objective as an evaluation instrument to determine if students had achieved the objectives.

After the objectives were written, all the available resources such as filmstrips, textbook readings and diagrams, filmloops, Solo Learn Kits, pamphlets and books in the Biology department's library were assembled so that students could use these to achieve the objectives. Scripts explaining the concepts in a particular chapter were written which incorporated the use of these resources as visual and reading aids. The author wrote the scripts as if he were tutoring an individual through the chapter referring him to filmstrips, filmloops, transparency overlays, textbook pictures and diagrams, and drawings in the study guide. Later these scripts were recorded on reel tapes. The visual aids that were not available in the textbook, filmstrips, and other resources to illustrate a concept were drawn on paper by the author's wife and an infrared transparency or ditto was made from the drawing. These supplemented the available resources and provided ample visual materials to illustrate the concepts in the textbook chapter.

After the behavioral objectives and script were
written and all visual materials were assembled for a particular textbook chapter, an A-T packet was developed from these materials and a study guide explaining how to proceed through the A-T packet was written. The study guide informed the student when to read a section out of the text, do an experiment, or listen to a tape. The study guide was bound with dittoed drawings to form a study guide booklet. The booklet, transparency overlays, and cassette tape were put in transparent plastic envelopes or packets that students could check out when working individually on objectives for a particular chapter. Thirteen copies of each booklet, overlay, and cartridge were made and assembled into 13 identical packets. Each of the 12 BSCS chapters used in the A-T program then had 13 identical packets so that 13 students could work individually at the same time on a particular chapter. Thirteen packets accommodated a class of 30 students because there was a variety of other activities students engaged in besides using the packets. Although the course covered 14 BSCS chapters, only 12 chapters, 3 through 11, 13, 15 and 16 were studied using the A-T method. A-T units were not developed for chapters 1 and 2 of the BSCS textbook because the instructor needed time, at the beginning of the year, to orient the students toward the individualized A-T program.

The infrared transparencies were made from penciled drawings on a 3M transparency machine and then taped
to 3M cardboard frames. A dittoed backing was taped to the cardboard frame to provide a background for the transparency. Several transparencies were taped to each frame so that one transparency could be placed over another to illustrate sequential steps in the development of a particular concept. For example, in protein synthesis, the first transparency showed mRNA being made by DNA; the second transparency showed mRNA leaving the nucleus and attaching to the ribosomes on the endoplasmic reticulum; the third transparency showed tRNA transporting amino acids to the mRNA, and so on. Thirteen copies of each set of transparencies were made on the 3M transparency machine for each of the 12 chapters used in the BSCS textbook.

The study guide booklets were assembled and bound with Velo-Strips from the Velo-Bind Company. These were plastic strips with spines used with a binding machine that fused the pages of the booklet between the strips providing a strong, durable bind. Thirteen copies of the study guide were made for each of the 12 BSCS chapters in the A-T program.

Seven filmstrip projectors were bolted to a long table placed against a wall. Ten inch by 12 inch white cardboard screens were mounted on the wall in front of each projector, providing a filmstrip viewing center for single concept filmstrips such as respiration, protein synthesis and mitosis.

The script for a particular chapter of the textbook
was recorded on a tape reel using a stereo tape recorder. The taped explanations were divided into sections and numbered; each taped section was seldom longer than five minutes. For example, section 1 of the tape on evolution introduced Charles Darwin as an early biologist and discussed his life and his contribution to the field of biology. At the end of this explanation, the student was told he was at the end of section 1. Then, one minute of music followed with a joke to create a relaxed atmosphere. Next, the student was told he was at the beginning of section 2. The objectives discussed on each section of tape were also listed on the study guide which the student could review at any time. For example, the study guide would show that section 2 of the tape on respiration explained what a mitochondrion was. The format of including music and jokes between sections of tape broke up lengthy explanations into short, concise sections that maintained student interest. Breaking up the explanations into small sections also made it easier for students to find particular sections of the tape.

After the script was recorded on a reel tape, 13 cassette cartridge duplicates were made in the tape duplicating center located in the chemistry lab at Canyon High. One master reel tape recorder was electronically connected to ten cassette recorders so that ten cassette copies could be made at one time from a master reel.

The author spent approximately 230 hours writing
behavioral objectives, A-T scripts, study guides, tests, and designing supplementary drawings and diagrams for the A-T biology program. The written material for the course was typed and duplicated utilizing district material and personnel. Another 60 hours was spent recording the A-T scripts on tape reels and making cassette copies. Thirteen cassette cartridge copies were made for each of 12 chapters. Fifteen hours was spent bolting tape recorders to study booths, soldering the headphones into the recorders and wiring the 13 study booths for electricity. Thirty hours was spent binding study guides, making transparencies, taping the transparencies to cardboard frames, and assembling the transparencies, cassette cartridges, and study guides into the plastic envelopes which comprised the A-T packets.

Each BSCS A-T chapter was given a coded letter. For example, the chapter on evolution was given the letter E. Each of the thirteen duplicated packets and cassette cartridges for the chapter on evolution was labeled with a letter followed by a number, E-1, E-2, E-3, etc. The same procedure was used to code packets for the other chapters. The packets were placed in slots in a microscope case on one side of the room which served as the checkout station where students could get A-T packets, filmstrips, and Solo Learn Kits. On the opposite side of the room, students could get a small checkout slip from a cardboard box, put their name and the materials requested on the slip and
check out these materials from the student assistants at the checkout station. The assistant wrote the number of the packet on the slip and attached the slip to a small bulletin board. When the student returned the packet, his checkout slip was removed from the board. Students could check out packets overnight if they left a one dollar deposit. All materials were accounted for in this way and could be checked in and out very rapidly. Books, pamphlets, and filmloops were checked out to students by the instructor.

**Physical Layout of the A-T Lab**

The science lab used in the A-T program at Canyon High School was large; half of the lab housed seven lab tables, including one large lab table in the center. The large central lab table contained all the equipment and materials used in the lab. The other half of the lab was a lecture area with desks, an elevated lab demonstration table, sink, and blackboard. This area contained 30 desks, 13 study booths, and a checkout station for all the A-T materials. Most of the students' work was done in this main laboratory area. Adjacent to the main lab was a large office area containing a small work lab, mounted filmstrip viewers, filmloop library, filmloop projector, screen, and a small library of books, pamphlets, and magazines on biological topics.
Type of Scheduling

From its inception in 1968 through the Spring of 1973, Canyon High School had operated on a flexible modular schedule in which students were not programmed into classes the entire school day but were given independent study periods to work in areas of special need or interest to them. This independent study time was abused by some students but used productively by many others who worked in subject areas they especially liked and obtained individual tutoring, attention, and help from teachers. The modular schedule freed teachers from teaching to groups of students as a whole and made it possible for them to work with each student on an individual basis. Both the staff and the students believed this schedule was superior to any others because it allowed for more personal contact between the students and their teachers and provided the freedom for students to concentrate on topics of particular interest to them. However, in the Fall of 1973, Canyon was converted from a three year high school to a four year high school, increasing the school population by 1000, which made it difficult to use the modular schedule due to overcrowding. The principal of Canyon decided to discontinue the modular schedule and to use a fixed 9 period day. The overall school day began at 7:30 a.m. and ended at 3:35 p.m. Half the students arrived at 7:30 and left at 1:45 and the other half arrived at 9:20 and left at 3:35. The students were scheduled into their classes their entire school day
and had no independent study periods to pursue individual interests.

Perhaps the A-T program at Canyon would have functioned better under a modular schedule because it would have allowed students more time to work in the lab. However, it was easily adapted to a traditional classroom setting. The A-T biology students arrived as a class at the beginning of their assigned period and took their seats in the classroom. Roll was taken and the students were then dismissed to work individually or in small groups using the resources in the lab. The instructor worked with individual students during these independent study periods. If students needed to spend additional time working on the A-T packets, they could leave a one dollar deposit and take the packets home, which they often did. Once each week the class met as a group to review objectives, view films, or discuss particular problems. Once every two weeks, small seminar groups of 8 to 10 students met with the instructor for an oral quiz session on the objectives for the BSCS chapter they had been studying. The instructor had 5 by 8 inch cards with topics selected from the objective sheet which individual students were to discuss and explain to the group.

From the author's experience, tenth grade students at Canyon have been procrastinators, unable or unwilling to discipline themselves to achieve a certain number of objectives by a certain time. Students who have been
allowed in the past to work completely at their own rate without any deadlines usually did very little work at all. For this reason, the instructor set deadlines in which students had to achieve the objectives in a BSCS textbook chapter by a certain time. For example, the instructor gave the students two weeks to complete the chapter on evolution. Within that time they could work as fast or as slow as they wanted to, but at the end of the two week period they were required to take the oral quiz and examination on that chapter and hand in written reports for all experiments. The author found that students wanted some direction from the instructor and did not want to be left in a completely unstructured learning situation because they are used to being told exactly what to do and when. So initially, it was necessary to provide some structure and then gradually work students into independent study.

Description of the BSCS Blue Version Biology Course

The Biological Sciences Curriculum Study is an organization comprised of biology teachers, professors, and scientists across the country that first gathered together in 1960 to design and develop a biology course emphasizing the latest developments in the biological sciences and the inquiry approach to learning in which students could learn about concepts by performing open and closed ended experiments. However, the large group of educators could not agree on the main biological themes to
emphasize in the course. Some wanted to emphasize the biochemical evolution of life, while others wanted to emphasize the ecological relationships in life. A third group wanted to remain with the more traditional theme of the structure and function of living organisms. Consequently, three different textbooks were written emphasizing these three themes in biology. The theme of the BSCS Blue Version is the biochemical evolution of life from molecules to man. Much emphasis is placed on the processes of respiration, fermentation, photosynthesis, theories of the origin of life, genetics, the physiology of plants and animals and the evolutionary processes which brought these systems into being. The theme of the BSCS Green Version is ecology with much emphasis being placed on eco-systems, biomes, communities, food chains, and habitats. The theme of the BSCS Yellow Version is the structure and function of living organisms.

The author used the BSCS Blue Version textbook with the A-T program at Canyon High School. There were approximately 40 experiments in the textbook which students performed during the course and in which biological concepts were learned or reinforced. Students performed the experiments, collected the data and submitted written reports of the experiments. The reports consisted of a title, purpose, data, discussion questions and a conclusion summarizing the facts gathered in the experiment. The discussion questions involved students in the interpretation
of data.

The Cost of the BSCS A-T Program

1) 13 Craig cassette tape recorders @ $40  $ 520
2) 13 high quality headphones with comfortable foam pads @ $9  $ 117
3) 12 filmstrip projectors and viewers @ $40  $ 480
4) 13 study booths @ $100  $ 1300
5) 200 high energy Scotch Brand cassette tape cartridges @ $2  $ 400
6) 4 2800' Scotch Brand reel tapes @ $8  $ 32
7) 200 plastic envelopes @ $0.24  $ 48
8) 700 3M infrared transparencies @ $24 per hundred  $ 168
9) 300 3M transparency frames @ $0.13  $ 39
10) 200 Velo-Binders and 400 plastic covers  $ 35
11) rental of binder machine per month  $ 40
12) use of stereo tape recorder from the school library No charge
13) 60 filmstrips @ $6.60  $ 396
14) 33 Ward's Solo Learn Kits @ $25  $ 825
15) 24 filmloops @ $27  $ 648
16) filmloop projector  $ 250

Total $ 5558

In past years, the biology department had purchased the filmloops, filmloop projector, screen, and Solo Learn Kits. So the cost of this program was $3800.

The initial cost of an A-T program is high, but yearly costs thereafter are minimal involving mainly the replacement of worn-out materials, maintenance of equipment,
and revision of the materials. The maintenance cost of this program has not been determined because the program has not been in operation long enough. The costs described for the A-T program do not include teacher or secretarial preparation time which can be as much as 1000 man hours.

Theoretically, with a modular schedule, this program would be cheaper to operate in the long run because one fully paid instructor with two lower paid teaching assistants could accommodate the same number of students that three fully paid instructors would handle in a comparable traditional program.

A Typical Week of a Student in the A-T Program

When a student began studying a chapter in the BSCS textbook, he was given an Activity Options and Objective Sheet (refer to the chapter on Evolution in the Appendix). This sheet listed the objectives in the textbook chapter and the activities the student could do to achieve those objectives. For example, a student could learn about Darwin's theory of evolution by using the A-T packet on evolution or by looking at the filmstrip, "Introducing Evolution." At the beginning of each day, the student obtained a small A-T checkout slip from a cardboard box on one of the lab tables, put his name on the slip and listed the items he wanted to use. He then took the slip to the student assistant at the checkout station. The assistant put the coded numbers of the items the student requested on the
slip and tacked it to a bulletin board. The student used these materials to achieve the listed objectives. Also, at appropriate times, he performed experiments individually or in a small group of three students. The student prepared written lab reports, viewed films that were shown weekly on field biology, took oral quizzes and examinations. When he used the A-T packet, he first looked at the study guide (refer to the chapter on Evolution in the Appendix) and did step 1 by reading pages 67 to 69 in his text. He then did step 2 by turning on his tape recorder and listening to section 1 of the accompanying cassette tape. In these explanations, he was referred to pictures, drawings and diagrams in his book, in the study guide, and on accompanying overlays. These visual aids helped to illustrate the concepts being discussed. He then took notes on the concepts being explained so that he could later study these notes for his examination. He worked with this A-T packet as much or as little as he wished during a period. When he believed he had achieved all the listed objectives for a chapter, he could take the examination. He had to achieve 90% for an A, 80% for a B, 70% for a C and 60% for a D. If he did not achieve the score he wanted, he reviewed those objectives he did not achieve and discussed them with his teacher. He studied the material and then retook the examination. When the student had questions or needed additional explanations of concepts, he would get individual tutoring from the instructor.
Chapter IV

Conclusions and Recommendations

Student Achievement in the A-T Program

At the beginning of the school year, all five of the author's classes were placed in the A-T program. However, the author's third period class was composed of students that did not achieve very high scores on the first two examinations. When questioned by the instructor, the students in this class admitted that they did not study outside the classroom which is necessary for an academic college prep course. In addition, most of the students in this class were observed socializing, playing with equipment, loitering and wandering around the classroom during scheduled periods rather than seriously using the resources provided to achieve the objectives of the A-T program. On several occasions, the immaturity of some students in this class was demonstrated by their behavior. Once, the volume controls of two tape recorders were deliberately snapped off when the instructor was not looking. On another occasion, liquid soap was put into the aquarium almost killing the fish. The tank had to be immediately drained and rinsed.

The misbehavior and poor achievement of these third period students was not unique to this class alone. Upon
examining their Cumulative Records and talking to other teachers that had these students in other classes, the instructor discovered that the majority of the students' past grades and performances in other science and mathematics classes were below average and that the average IQ of these students was 95. Several students had records of misbehavior in other classes. These records seemed to indicate that the majority of the students in this class were below average achievers with some being somewhat maladjusted or immature in behavior.

The poor learning environment in this class may have been caused by the less disciplined students having a strong influence on the other students in the class, creating an environment that was not conducive to individualized learning. Perhaps the poor study environment and low IQ's of the students, coupled with the fact that some students were hyperactive because this was the first class of the day, contributed to their poor performance in the A-T biology program. Because the students in this class were incapable of, or unwilling to use the A-T system properly, the instructor was compelled to put this class into a traditional lecture-lab program in November in which they were strictly controlled by the instructor. Consequently, the first semester they were exposed to two methods of teaching: a less structured A-T program and a highly structured lecture-lab program. By the end of the first semester, only 56% of the students in this class had achieved 70% of
the course objectives. Even more discouraging was the fact that only 8% of these students had achieved 80% or more of all the course objectives. Although the behavior problems of the students in the third period class diminished when they followed the more structured biology program, their achievement of the course objectives continued to be average or below average.

Perhaps immature and undisciplined students are incapable of performing in a less structured instructional program where the responsibility of learning is placed solely on the student. Based on the results of the A-T program in biology at Canyon High, it is the author's opinion that such a program will not succeed with immature or low achieving students.

The A-T biology program was successful for the author's four remaining classes. Eighty-five percent of the students in these classes achieved at least 70% of all the course objectives which was above the minimum criteria for success. Fifty-nine percent of these students had achieved 80% or more of the course objectives. These students were above average in their achievement in past science and mathematics courses and used the A-T resources effectively to achieve the course objectives. However, some students in the A-T program wanted the instructor to tell them how to achieve each objective. They did not seem to have the desire to work without strict guidance and instructions from the teacher and wanted the teacher to be
their only source of learning the course material. But most of the students accepted the independent method of study as a challenge, functioning effectively in the program to achieve the grade they wanted. These students used the teacher as one of many resources available to them.

Because these students were successful in the course with less direction from the instructor than in a lecture-lab course, it is the author's opinion that the A-T method fostered the development of greater self-reliance and self-determination in students, while at the same time providing individualized attention to the needs of each student.

**Student Evaluation of the A-T Program**

After the 103 students in the four A-T classes completed the program, a survey consisting of 25 items was used to assess their attitudes toward the A-T method. The attitudes of the third period lecture-lab class were not assessed.

The following 5 point scale was used by the students to express their attitudes about factors described in the statements in the survey:

1. strongly disagree
2. disagree
3. neutral
4. agree
5. strongly agree

The total number of student responses for each item were averaged. For example, item 1 had 40 responses for number 5, 41 for number 4, 18 for number 3, 4 for number 2, and 0 for number 1. Five was multiplied by 40 and added to 4.
multiplied by 41 and so on, with the total being divided by 103. The average of the student responses for item 1 is 4.1. The average number of the student responses for each item is listed to the right of that item.

1) I liked having many materials such as filmstrips, learning kits, books, and filmloops to help me achieve the objectives. 4.1

2) I found that achieving the objectives with less direction from the instructor than in a lecture-lab course was very gratifying. I felt a sense of accomplishment. 3.7

3) After using the audio-tutorial method in this course, I have a greater confidence in my own ability to learn whatever I want to learn in life. 3.5

4) I believe I have succeeded in this course with less direction from the instructor than in other science courses I have taken in the past. 3.7

5) I liked the audio-tutorial method because, with so many independent study periods, I could get more individual help from the instructor than in a traditional lecture-lab course. 3.8

6) Most of the time, I used the independent study periods effectively. 3.8

7) I recommend that future biology students be given objectives so they will know what is expected of them in the course. 4.4

8) The Integrated Oral Quiz sessions helped me prepare
for the examination by showing me what objectives I did not achieve.

9) I was able to achieve a higher grade in the course because I was allowed to take the examinations more than once.

10) Most of the time I was able to learn new ideas and concepts from the experiments.

11) I think the Integrated Oral Quiz session should be used for students next year.

12) The class sessions were very helpful to me because I could get additional explanation from the teacher and pick up ideas I had missed using the A-T materials.

13) I received more attention from the instructor in this program than I would have in a traditional lecture-lab program.

14) Having two chances to take the examinations allowed me to achieve a higher grade on the exams the second time.

15) Most of the time I followed the instructions in the study guide when using the A-T packets.

16) Having objectives allowed me to know exactly what I was to learn.

17) The instructor did not allow me enough time to complete an A-T chapter.

18) Most of the time, the pictures, drawings, and diagrams I was told to look at by the audiotape
helped me to visualize concepts more easily. 4.0

19) The audio-tutorial method helped make biology more interesting because it provided a variety of activities to become involved in. 3.7

20) I believe this course has helped me improve my study habits. 3.5

21) I believe my grade would have been higher if I had taken the traditional lecture-lab biology course. 2.4

22) I believe the independent study periods were too unstructured, causing me to do less work than if I were in a regular class. 2.8

23) I believe this course allows for more individual differences among students than most of the other courses I have had in high school. 3.5

24) I believe the present A-T biology course should be made less difficult. 2.6

25) In comparison to the traditional method of teaching in other courses in this school, I believe the audio-tutorial method is superior to the traditional method. 4.1

Analysis of the means of the items in the survey indicates that students reacted favorably to most aspects of the A-T program. They liked having behavioral objectives so that they knew exactly what they were expected to learn in the course and enjoyed a variety of media to achieve those objectives. The mean for item 21 shows that
the students did not believe they would have done better in a traditional class, and the mean for item 14 shows they appreciated the opportunity of taking the exam on a chapter more than once. In addition, the students believed the oral quiz sessions were helpful in preparing for examinations. The students varied from neutrality to agreement on items 3, 20, and 23 and varied from neutrality to disagreement on items 17 and 24 indicating their attitudes about these statements were not very strong. Overall, they believed the A-T method was superior to more traditional methods of teaching.

General Conclusions

The A-T method of learning took the teacher out of the center of the classroom "arena" and placed him on the side, allowing the students to be the primary participants in the classroom activities. The teacher then became a mentor, designer and manager of student classroom activities and a private tutor to individual students. The teacher continuously monitored student progress in the course giving additional attention to those students who were not progressing as they should.

The A-T method placed a greater demand on the student than the lecture-lab method because it required more individual student initiative and participation. Because the teacher was no longer the center of classroom activities, students could no longer be passive receivers and
observers of teacher lectures and demonstrations. Each student was compelled to use the A-T resources to learn the course material on his own in order to succeed in the course.

Because the A-T method required more participation and initiative from the student than a lecture-lab course, some students did not succeed using this method. The unsuccessful students had not been high achievers in other more structured classes and were not self-disciplined enough to accept the responsibility of achieving in a less structured learning environment. The students that succeeded in the course using the A-T method were self-disciplined because they worked in the classroom without constant direction from the teacher and studied at home without being compelled to do so. These students had above average grades in other classes and received satisfaction from hard work and achievement. After being involved in the program for almost two semesters, the students reacted favorably to the A-T method, rating it superior to the traditional lecture-lab method.

The A-T method is a useful tool in promoting the development of De Charms' Origins and compensating for individual needs and differences in learning. The A-T method is an effective instructional technique for helping students learn how to learn.
Recommendations

Future investigators wishing to develop an A-T program may improve this project by statistically comparing the achievement of students in the A-T program with students in a traditional program.

Further study is also recommended to determine what kinds of students will succeed using the A-T method and what effects the A-T method has on the attitudes of students in the program. Measuring student changes of attitude toward science and their assessment of their abilities to learn and work independently would provide invaluable data concerning the effectiveness of the A-T program. Also, a long range study assessing student success in their subsequent academic pursuits would reveal more about the effectiveness of the A-T method in fostering self-reliance and self-determination in students.
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References


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Appendix
# Activity Options and Objectives

## Evolution

### Activities

<table>
<thead>
<tr>
<th>AT Kit</th>
<th>Evolution</th>
</tr>
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<tbody>
<tr>
<td>The Student shall:</td>
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<tr>
<td>1. explain one other theory of evolution prior to Charles Darwin.</td>
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<tr>
<td>2. state where Darwin seriously considered that species change.</td>
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<tr>
<td>3. list three evidences of evolution that Darwin found on the Galapagos Islands.</td>
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<tr>
<td>4. explain the Malthusian theory of overpopulation and how it influenced Darwin.</td>
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<tr>
<td>5. list and explain an experiment Darwin performed after the voyage of the Beagle that supported evolution which helped him form his theory.</td>
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<td>6. define selection and natural selection.</td>
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<td>7. outline the steps of Darwin's theory of natural selection.</td>
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<tr>
<td>8. do investigation 3-9, Investigating Natural Selection.</td>
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<tr>
<td>9. explain the modern day theory of evolution and how it differs from Darwin's theory.</td>
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<tr>
<td>10. explain how evolution occurs and where the most ideal places for evolution to occur are.</td>
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<tr>
<td>11. list and explain the present day examples of natural selection.</td>
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<tr>
<td>12. state another person that proposed the same theory of evolution at the same time Darwin did.</td>
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</tr>
</tbody>
</table>

### Filmstrips

<table>
<thead>
<tr>
<th>Filmstrip</th>
<th>Evolution of Man (6 objectives)</th>
<th>Introducing Evolution (5 objectives)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Evolution of Man</td>
<td></td>
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<tr>
<td>1) Physical Anthropology</td>
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<tr>
<td>2) Evolution of Primates</td>
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<tr>
<td>3) Ramapithecus and Australopithecus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Australopithecus (East Africa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) Homo erectus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) Homo sapiens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) The Species Problem</td>
<td></td>
<td></td>
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<tr>
<td>2) Theories of Evolution</td>
<td></td>
<td></td>
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<tr>
<td>3) Biological Evidence</td>
<td></td>
<td></td>
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<tr>
<td>4) Patterns of Evolution</td>
<td></td>
<td></td>
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<tr>
<td>5) Man and Evolution</td>
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### Film Loop - "Animal Camouflage"

Write a summary of the film loop. (1 objective)

### Experiments - "Extinct and Vanishing Birds of the World"

Purpose:
1. Consider Darwin's concepts of the mechanism of evolution.
2. Study some unsolved problems about evolution.
3. Understand the importance of accumulating as much evidence as possible to confirm a scientific theory.

### Books - Extinct and Vanishing Birds of the World

Voyage of the Beagle
Auto. of Charles Darwin
Pamphlet - Early Evolution of Life

Write 5-page summary and take oral quiz. (5 objectives)

YOU MUST DO 15 OBJECTIVES AND 1 EXPERIMENT.
The audio-tutorial system is a method of allowing you to learn at your own convenient and most comfortable pace. It provides a number of activities for you to do, as well as interaction with other students in lab work, oral quiz and group sessions. Follow the sequence of instructions in the study guide and you will find this method of learning easy to follow, allowing you to be totally involved in your own learning.

The first unit will introduce you to the theory of evolution which is the main theme of this biology course. Biology, as a science, really wasn't born until Charles Darwin discovered and formulated his theory of evolution. So in a sense, Darwin is the father of modern biology and a hero to modern biologists today. To some, Darwin is considered an evil atheist because he proposed a theory that has been used to explain how life could come into existence without God. To others, he is a giant among scientists because his theory explains so many previously unanswered questions and his scientific process of collecting facts and objectively proposing hypotheses to explain the known facts has become the accepted method in the modern world of investigation.

Darwin was born in 1809 to a wealthy family at a time when the two most honored professions in England was medicine and the ministry. His father wanted him to be a doctor and so Darwin began preparing for this profession.

Darwin was a mild mannered young man who had no desire to cause trouble by questioning what his father wanted him to do, so he followed his father's wishes even though he enjoyed being a naturalist and collecting and classifying animals and plants more.

One day, while observing an operation on a human being, Darwin got sick and stormed out of the operating room vowing never to return to such a gory profession. So with this, his father told him to prepare for the ministry. While studying at Cambridge, he spent a great deal of time working in the field studying nature, an activity his father thought to be wasteful and unrespectable. Upon graduating, Darwin had an opportunity to accept the position of naturalist on His Majesty's Ship Beagle that was commissioned to sail around the world and map the continents of South America and the South Pacific islands. The voyage was for five years and he had to pay his own way. Being afraid to get the money and permission from his father, he asked his closet professor to get this permission for him. With reluctant permission from his father he set sail with the Beagle on one of the most momentous voyages in history.
Evolution

At the time, Darwin was among the majority who believed that God had created all living things in seven days and that nothing changes on this earth from the original way God made it. But on the voyage, Darwin began making observations and collecting facts that didn't seem to support the idea of special, instantaneous creation of all things. He observed thousands of different species of living things, some slightly different but very similar to others. He read a theory by Charles Lyell that the earth's crust is continuously changing but very slowly except for occasional cataclysms such as earthquakes and volcanoes. Mountain ranges slowly rise and fall, islands come and go, shorelines change shape and form, valleys form from erosion and then are filled by erosion. If the earth is changing, then living things on the earth must also have changed. Darwin found the fossils of many organisms that no longer live on the earth. They are extinct. So the species that God made do disappear.

Turn to page 69 in the old version and 97 in the new version.

When the Beagle arrived at the Galapagos Islands six hundred miles off the West coast of South America, Darwin noticed many bizarre forms of life found nowhere else on the earth. Lizards or iguanas that swim in the ocean and eat seaweed. Large tortoises that weigh up to a half a ton and live up to 150 years. Finches that behave like woodpeckers and some that used tools. Look at figure E-1. Darwin wondered why God would create these freaky creatures on these islands different from all other living things. Darwin began to wonder if these animals had somehow changed after arriving on these islands from some other place. To support this hypothesis, Darwin found no animals on oceanic islands that could not survive a long migration on drift wood or drifting pieces of land. He only found, tortoises, lizards, birds, seals and small rodents. He found no large animals, predators or amphibians such as frogs that would dry up on a piece of drift wood. Why didn't God create elephants, giraffes, and bears on these islands?

Please do objectives two and three on your objective sheet. Darwin found iguanas that swim, tortoises, and finches that exist nowhere else on earth. It was here at the Galapagos Islands that Darwin first seriously considered that species change. Now turn your tape recorder off and read, pages 65 to 67 in the old version or pages 94 to 95 in the new version.

This is the end of Section 1.

Section 2

We will do objective one in this section. After the Galapagos Islands, Darwin could not help but think that with so many different kinds of living things existing
in so many different parts of the world, in many different climates, that as the earth and its climates change, living things must also change to survive. But Darwin was not the first person to believe that species change over a period of time. Jean Baptiste Lamarck published a book in 1809, the year Darwin was born, in which he outlined a possibly way species change. Lamarck reasoned that as the environment changes, living things change their life habits and the organism uses parts of its body it didn't use as much before and those parts will enlarge from greater use. Also, other parts of the body may not be used as much and those parts become smaller and eventually not able to be used. Lamarck believed that these new acquired traits could be passed on to offspring. So at one time, for example, the giraffe lived in a lush environment in which he grazed on the ground and looked very much like his cousin the okapi. Turn on the projector on the table and look at the slide. Now turn to page 66 in the old version or 95 in the new version and see what happened to the giraffe. As the climate got hotter in Africa and water scarcer, the bush vegetation began to dry up and the giraffe had to turn to the trees for food. He began stretching his neck to get into the trees. After awhile his neck became a little longer than it was before. When he had children they inherited the longer neck. They too stretched their necks longer and passed that trait on until eventually, the giraffe had a very long neck. Experiments have since shown this not to be true. You may want to look at the filmstrip "Theories of Evolution" for supplementary information.

Now turn off your tape recorder and read pages 72 to 75 in the old version or 97 to 99 in the new version.

This is the end of section 2.

Section 3 - We will now do objectives 4 through 7.

Look at figure E-2. Thomas Malthus, an English sociologist, believed that in populations the rate at which food can be produced is much slower than the rate at which people reproduce. Therefore, the human population would increase to a point where there would not be enough food for everyone and there would be widespread hunger and a struggle for existence.

Upon reading this theory in 1838, Darwin believed this could be applied to all living populations and, therefore, there would always be a struggle for survival. Only the organisms with the best characteristics or traits would be able to survive. Thus, in this kind of a continuous struggle, the individuals with the bad traits would die off and the individuals with the good traits would continue on and multiple. Thus, the species would continuously get better. - This is objective 4.
With years of experimentation, Darwin noticed that there are many differences amongst the individuals of a given species. Especially in domesticated animals. In one series of experiments, he crossed pigeons and found that there were new traits showing up in the offspring that weren't there before. So he noticed that variations or changes will recur in living things. This is objective 5.

In observing the breeding of horses, dogs, flowers, and cattle, he saw man deliberately selecting out certain traits he wanted and breeding animals or plants with those traits. Look at figure 3-8 in old version and 5-10 in new version.

So in domesticating and breeding animals, man was the selector of the new variations he wanted them to have. Look at figure E-3. Darwin wondered if this process went on in nature. He believed, for example, that the Galapagos lizard migrated to those islands, became overpopulated because of the lack of food and struggled to survive. Amongst this huge population there was one odd looking lizard with slightly webbed feet that had no trouble at all swimming in the water and eating sea weed while many of his land loving cousins were dying from lack of food. After mating, he had many children who also had webbed feet and took naturally to the water. Eventually a whole population of sea-going lizards arose from that one weird-o. In this case, the variation was the webbed feet which was very useful in this environment. So nature had selected for that trait over the land adapted traits of the other lizards. In nature this process of selecting the best traits is called natural selection. When man selects for certain traits in breeding animals and plants it is called selection. This is objective 6.

With all this knowledge about overpopulation of living things, struggle for survival, variations occurring in living things, Darwin began seeing a way that all the different kinds of living things on earth came into existence. Look at figure E-4 for an outline of Darwin's theory of evolution. First in any population the birth rate will always be faster than the rate at which food is produced. This overpopulation will tend to cause a struggle for survival. In this struggle only the individuals with the best variations for that environment will survive and reproduce more offspring with the same variations. Eventually the whole population will have the good variations and the bad ones will be gone. So the whole species will change in this way to adapt to the environment. Given enough time, many such changes could change the species into something entirely different than it originally was. This is called speciation. This is objective 7.

From observations scientists have made and experiments that have been done today, we know that species do change, but we have never observed one species
Evolution

changing into another species. We do not know for sure if frogs evolved from fish, or lizards evolved from frogs. But if changes do occur, given enough time, it is logical to assume that all these changes added up in a species over hundreds of thousands of years would give us a species entirely different from what originally began.

Turn off your tape recorder and do Investigation 3-9 in old version and 5-B in new version.

This is the end of Section 3.

This is Section 4

We will do objective 9. Look at figure E-5. Today the modern theory of evolution is about the same as the way Darwin outlined it except we know how variations occur. Darwin could see that new traits or variations would show up within a population but he did not know how these variations occurred. Today, we know that variations occur from mutations of genes in the sex cells of parents. Since the gene for a trait mutates or changes, the trait in the offspring is different or new. This new gene can then be passed on and spread throughout a population through mating. We know that these mutations only occur about once in every 100,000 sex cells.

This is the end of section 4.

Read pages 80 to 83 in the old version and pages 100 to 104 in the new version.

This is Section 5

We will do objective 11. After this section of the book, you can see that natural selection or evolution does occur within a species. In the case of the light and dark colored mice on pages 82 in old version and 100-101 in the new version, the selector in the environment were birds. The light colored mice were eaten up much faster than the dark colored mice. So dark color was the best trait for the mice to have in this environment. With the peppered moths of England, a mutation occurred and some moths became dark. At that time this was a bad trait to have because those moths would be seen by the birds more easily and get gobbled up. But when the environment changed and the trees became dark, the dark trait was good and the white moths began getting gobbled up. Eventually the population changed from a dark color to a light color. So through Darwin's natural selection, the moth population changed. If we were able to come back and look at this moth population 100,000 years from now, what would we find. Would they be recognizable as the same species?
It has been said that certain kinds of bacteria are becoming resistant to being killed with penicillin. How can this be? We know that bacteria reproduce very fast and can grow to extremely large numbers within a small area in a short time. Since mutations occur once in every 100,000 cells, a few billion bacteria would have many hundreds of thousands of mutations in the culture. Look at the reading of section 3-11 on pages 82 of old version or 5-11 on page 102 of the new version. If we took a culture of bacteria such as this a few of them could have a mutation in which penicillin would not affect them. All but a few bacteria would be killed. Look at figure E-6 for a summary of this. If we allowed these few survivors to grow and produce a large colony, this colony would not be affected by the same dose of penicillin as the other colony. So the dose would be increased and all but a few hardy mutants would survive. This could be done until, as the book says, a strain of bacteria could withstand 2500 times the original dose all because of variations or mutations and natural selection. When species change in nature, evolution is occurring. Possibly, with enough changes adding up over a long period of time, the species would be entirely different from when it originally started. This is called speciation.

This same phenomenon can occur with DDT and insects. This is objective 11 - colored mice, peppered moths, penicillin and bacteria, DDT and insects. You may want to look at the filmstrip - "Biological Evidences for Evolution." This is the end of Section 5. Turn off your tape recorder and look at figure E-7.

This is Section 6

We will do objectives 10 and 12. In this section we will discuss the theory of how evolution occurs. Today, most biologists believe evolution does occur and that all living things evolved into existence. In figure E-7 you will see several examples of how evolution may have occurred in the past. In figure "a" you will see a population of field rabbits. They are freely mating with each other and the flow of genes or of any new traits that may occur within the population is free and unhindered. But over a long period time, a mountain range develops and the population of rabbits becomes separated by this large mountain range. Now, if a new mutation occurs in one population, rabbits that have it cannot cross the mountain range and mate with rabbits on the other side and spread this trait to the offspring of the other population. So only the one population will have that trait and over hundreds of thousands of years many other mutations occurring will be isolated from the other population and eventually the two populations will become so different they can no
longer biologically mate and produce fertile offspring even if they could be brought into contact with the other group again. So they would become different species.

Look at figure "b". Here, a similar occurrence takes place with the Arizona Kaibab squirrels as with the rabbits in the other example. One species exists and slowly a canyon develops. Eventually the canyon becomes too deep for the squirrels to go across and the population is split into two isolated populations. If new mutations or traits occur in one population, it cannot be spread through mating to the other population. Over a long period of time, many such mutations occur and one population becomes entirely different from the other. A new species is formed.

Anything that acts as a barrier and isolates populations in this way will allow different species to come into existence. Since we know islands come and go; continents shift; mountain ranges rise and fall and canyons come and go, it is possible that the great diversity or differences in living things on earth was caused by the earth's construction of natural barriers in separating living populations so that new traits could not be spread amongst all living things but only isolated in various valleys, islands, continents, and canyons.

Thus, it is believed by some that life began by the chance combination of chemicals in an ancient primeval ocean forming a primitive cell that mutated and formed better cells, eventually forming organisms with many cells. Through this kind of evolution, fish evolved into amphibians that could breath air and live out of water for short times. Amphibians evolved into reptiles which in turn evolved into birds and mammals. Small rodent-like mammals evolved into lemurs, monkeys, ape-like creatures, half man and finally man.

So to complete objective 10 study figure E-7.

As you have already read, Darwin was very reluctant to publish his theory until he had completed many experiments and gathered much evidence in support of his theory. He worked on the theory over 20 years and then one day got a letter from a fellow naturalist in Africa who outlined a theory of evolution exactly like his! Darwin had never told this man what he was doing, so Alfred Russell Wallace apparently developed his theory independent of Darwin. Darwin, not knowing what to do, didn't want to detract from Wallace's discovery by turning it down and submitting his own. It was quite obvious that he discovered this theory long before Wallace ever did, but Darwin decided to submit Wallace's paper before the Royal Society. However, Darwin's friends convinced him that it would be better for both his paper and Wallace's to be submitted before the society at the same time. For this reason, the theory of evolution is credited to both Darwin and Wallace although Darwin is given more recognition since he did discover the theory first.
It is important that you do each step at a time. If you try to skip steps or try to beat the AT system by taking short cuts, you may get confused.

1. Read pages 67 to 69 in old version or 96 to 97 in new.
2. Turn on your tape recorder for an introduction to this unit. (Obj 2-3)
3. Read pages 65 to 67 in o. v. or 94 to 95 in n. v.
4. Turn tape on to section 2 for explanation. (obj. 1)
5. Read pages 72 to 75 in o. v. or 97 to 99 in n. v.
6. Turn tape on to section 3 for explanation. (obj. 4-7)
7. Do Inv 3-9 in o. v. and 5-B in n. v. (obj. 8)
8. Look at transparency E-6. (obj. 9)
9. Turn on tape recorder for explanation of section 4.
10. Read pages 80 to 83 in o. v. or 100 to 104 in n. v. (obj. 11)
11. Turn on tape for explanation to section 5. (obj. 11)
12. Look at figure E-7. (obj. 10-12)
13. Turn on tape recorder to section 6. (obj. 10 and 12)
I have also found dozens of other living things that exist only on these islands. They are found nowhere else on earth.

These creatures are found no where else on earth. How did they make it there and not other islands?
Thomas Malthus, an English sociologist, believed that food is produced at an arithmetic rate while people reproduce at a geometric rate. This would cause famine, disease and a struggle for survival in the human population. Upon reading this, Darwin believed that this was true of any living population and that out of this struggle, only the best suited individuals would survive.

![Figure E-2](image)

result: more people than food
Figure E-3

Darwin first sees unusual living things on the Galapagos islands off the west coast of South America and wonders if God made them that way there or if they became that way after migrating from some other place in the world.

This is what he thought might have happened:

Using the marine iguana to explain how all the living things changed—

1. The iguanas migrated to the Galapagos islands from South America on pieces of large drifting wood.

   ![Diagram showing currents running from South America to Galapagos Islands]

   the currents run from the coast of South America right through the Galapagos Islands

2. Once on the islands, the land lizards multiplied rapidly because there were no predators. They became overpopulated.

3. The lizards struggled to survive fighting for the limited amount of food and space.

4. Amongst the large population, one lizard was different than all the rest in that he had slightly webbed feet and didn't mind swimming in the water and eating sea weed instead of fighting for the limited amount of food on land. The webbed feet is a variation.

5. Since there was plenty of sea weed he spent little time feeding and much time mating—producing little iguanas that also had webbed feet.

6. Eventually, a large population of marina iguanas came from that one iguana.
Darwin's Theory of Evolution

1. Organisms in any living population increase in numbers at a geometric ratio, thus becoming overpopulated.

2. Since there are more individuals in the population than food or space, there is a struggle for survival.

3. There are always some individuals in a population that have different traits than the rest. These are called variations.

4. An organism that has good variations will survive better in the environment and have more time to produce more offspring that also have that good variation. This is called survival of the fittest.

5. After many thousands of generations and hundreds of such changes in this species, we will have a different species. The original species would have had so many changes that it would have become a different species. This is called speciation.

Summary

Darwin's Theory

1. overpopulation
2. struggle for survival then variations
3. survival of the fittest (the best variations survive and reproduce)
4. speciation
Figure E-6

100 million bacteria

add weak dose of penicillin

almost all bacteria are dead but a few are not affected by the penicillin

most bacteria are dead but again, a few were not affected by the penicillin

add twice as much penicillin as before

let these resistant bacteria grow into a new colony

let these resistant bacteria grow a new colony

many such generations later, it takes a dose 2500 times the original to kill the bacteria

HOW DO YOU EXPLAIN THIS?

Now do the problem on transparency E-6
Problem E-6

The temperature of the earth increases 30 degrees. Because of the energy shortage, there is no air conditioning available. Many people die from the heat. But a few individuals have a mutation, or variation in which their blood vessels are close to the skin surface and can keep them much cooler than the rest of the human population.

1. What will happen to most of the other people who do not have this mutation?

2. What will the few people do who have the mutation?

3. What will the population of people on earth eventually become?

4. What would happen if no individuals had this variation in the first place?

5. What has happened to most species that have lived on earth? Why?

6. What words describe the environment selecting for the best traits?

7. What causes changes to occur in living populations?
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AT SCRIPT

THE ORIGIN OF LIVING THINGS

This is Section 1

Look at figure 0-1. If living things are not the same today as they were when they originally came into existence we can now ask the question, "How did life begin?" Did God make life, or are there other possible explanations for how life began on earth? 250 years before Christ was born, the Greek thinker and philosopher Aristotle had an answer for this great question. In those days, the processes of controlled experiments were non-existent. Simple people made simple observations and came up with simple solutions. People saw living things coming from trash and garbage and rotten meat. Apparently, never seeing them go in, people saw rats coming out of trash and assumed that the trash produced the rats. Likewise, rotten meat produces maggots and cow dung produces flies. Aristotle believed that life could come into existence by itself or spontaneously from non-living materials. This is called spontaneous generation. Aristotle said that some kinds of non-living materials had a mysterious "active principle" that caused living things to be formed. However, this active principle needed oxygen and would be destroyed if heated too much. This is Objective 1.

This theory was widely accepted for 1800 years and even had some crude, experimental evidence to support it in the 17th century.

Look at figure 4-2 on page 89 of old version or 6-2 on page 110 of the new version. Jean Baptiste van Helmont, a 17th century scientist, fully believing in spontaneous generation as most everyone else did, decided to perform an experiment to support spontaneous generation. And so we get van Helmont's famous recipe for mice. Girls, this may be one you'll want to try out on Mom and Dad. Tonight take one filthy shirt full of stinking body odor, add some wheat and wait 21 days and you will get mice. Is this a good experiment? Van Helmont did this experiment and that is what he got. Therefore, he said the mice were made by the active principle in the filthy shirt. What was missing in his experiment?

An 18th century biologist, Anton van Leeuwenhook, discovered that when he put a bead of glass near an object, the bead of glass, acting as a lens magnified the object. Look at figure 4-4 on page 92 of the old version or figure 6-4 on page 113 of the new version. Van Leeuwenhook patiently developed one of the first microscopes and began using it to look at all kinds of microscopic objects. One day he was observing water through his microscope and saw for the first time minute animals swarming around in the water. Where did they come from and how did they get there? The numbers of beasties seemed to increase each day. Those who
believed in spontaneous generation thought that the active principle in the water made them. Thus, a little more evidence to support spontaneous generation. Look at figure 0-2. Another 18th century scientist, John Needhour performed an experiment that seemed to support spontaneous generation. He took a broth with many nutrients in it and put it in a flask. He heated the flask just enough to destroy any beasties already there but not enough to destroy the active principle and in a few days the flask was full of beasties. What may have been done wrong here?

This is the end of Section 1.

This is Section 2

It was about the 19th century before scientists seriously considered questioning the theory of spontaneous generation. Men such as Francisco Redi, Lazzaro Spallanzani, and Louis Pasteur began to doubt spontaneous generation through experiments they performed. These men believed that living things can only come from other living things and that God made the first living things. This theory is called biogenesis. Bio means life and genesis means beginning. This is objective 3.

Look at figure 4-3 on page 91 of old version or 6-3 on page 112 of new version. Redi took meat and placed it in open flasks. He saw flies go in to the flasks and lay their eggs. His control was placing meat in sealed flasks. No maggots ever developed in the sealed flasks because the flies could not get inside. You would think that that would disprove spontaneous generation. But remember what ingredient is needed for the active principle to work? Air! Redi had prevented the active principle in the meat from getting any air! So they refused to believe his experiment disproved their theory. Later, Redi used cheesecloth to allow the air into the jars and maggots sometimes formed on top of the cheesecloth. But again, the spontaneous generation people had said that the active principle had formed the maggots on top of the cheesecloth.

Look at figure 0-3. An Italian scientist, Lazzaro Spallanzani boiled some broth in a flask and sealed the flask. No beasties ever developed in the broth. The spontaneous generation people still refused to believe that this disproved their theory because Spallanzani had destroyed the active principle by keeping the air out of the flask and boiling the broth.

Look at figure 4-8 on page 96 of the old version or page 115 and figure 6-5 of the new version. The man who finally devised an experiment that disproved
spontaneous generation once and for all was Louis Pasteur. Pasteur had known about the existence and omnipresence of germs for a long time. He knew that germs could get into food and water from the air. It was Pasteur who developed the sterilization techniques to kill bacteria and other microorganisms that cause disease. Before Pasteur, people were not aware of germs and their presence throughout the air and water and everything on earth. A few people such as Leuwenhock had seen them through his microscope but most people were not aware of them.

Pasteur poured a nutrient broth into a long necked flask; heated the neck of the flask into a swan shaped form and boiled the broth. Some of the steam of the broth collected in the neck of the flask and condensed there into a liquid again. Later, beasties were formed in the broth, there in the neck of the flask but beasties were never found in the broth of the flask itself. Did Pasteur allow air in the flask? Did Pasteur destroy the active principle that could support beasties by boiling the broth? The spontaneous generation geople could not come up with an argument to discredit Pasteur's experiment. Pasteur had shown that the beasties had come from the air and were not created by the broth. This is objective 4.

You should now be ready to do investigation 4-6 in the old version or 6-A in the new. This is the experiment Spallanzani and Pasteur performed that refuted spontaneous generation. You will find the flasks sitting out in the room. You may make your observations for a few weeks after you have begun this experiment. Read the introduction and procedure to investigation 4-8 in old version and the handout for those using the new version. This experiment deals with where we will find microorganisms and your instructor will show you the techniques of doing this experiment.

This is the end of Section 2.

This is Section 3

This is objectives 8, 9 and 11. As you read in your book, some scientists propose that life came to earth from some other planet on meteors or possibly in space ships. This is being investigated now. Other scientists still wonder what the first living things on earth were and how they got here. Before considering this, we must see what conditions are necessary for living things to persist and survive on earth. What does a living thing need to survive and be sustained on earth? The two basic needs of all living things on earth are food and water.
Some scientists believe that life evolved into existence from organic chemicals in an ancient primeval \textit{sea} much like living things may have evolved from other living things. Since all living things are dependent on plants for food and energy, they reason, the first living organism on earth must have been a plant. Plants can make their own food. Any organisms that can make its own food is called an \textit{autotroph}. Any organism that cannot make its own food is called a \textit{heterotroph}. Turn to figures 4-10 and 4-11 on pages 100 and 101 of the old version or figure 6-8 on page 119 of the new version. The theory that the first organism to evolve into existence on earth, or the autotroph hypothesis, was an autotroph is not widely accepted by most biologists. An autotroph is very complex because of a very complicated chemical system of making food from carbon dioxide, water and sunlight. Evolution is believed to occur from the most simple things to the most complex living things. So the idea that something as complex as an autotroph evolving first and a heterotroph is not widely accepted.

It is believed by some scientists that heterotrophs evolved into existence first. Look at figure 9-4. On ancient earth, before life began, there was only land, oceans, and a very stormy atmosphere. Simple gases in the atmosphere collided by lightning and ultra-violet light from the sun and formed bigger, more complex chemicals such as sugar, starch, proteins and chemicals that can duplicate themselves called nucleic acids. These chemicals were washed out of the atmosphere by storms and began accumulating in the ancient oceans. As the oceans filled up with these organic compounds, the proteins, sugars, starches, and nucleic acids began clumping together forming chemical systems that could carry on chemical reactions and duplicate themselves. This was the first inklings of life on earth. These organisms were extremely simple and had to depend on other organic chemicals in the seas for food and energy. These primitive cells reproduced extremely fast and seriously began depleting the accumulating organic chemicals. Eventually, there wouldn't have been any organic compounds for food and all the heterotrophs could have died. But some of the heterotrophs developed mutations or variations that enabled them to make their own food. This was a big advantage and these organisms or autotrophs multiplied rapidly. Now the heterotrophs could feed on the autotrophs and life has continued this way ever since. This process took place over millions of years. It also took many hundreds of mutations for a fully developed autotroph to come into existence.

This is the end of Section 3.
This is the Beginning of Section 4

Look at figure 0-5. Our original question in the chapter was, "How did life begin?" Several explanations have been presented here, some not true and others, possibly true. Theories that propose that life came from non-living things, spontaneous generation and the heterotroph hypothesis are called abiogenesis. This is objective 10. Both these theories say that life came from non-life, but how are they different from one another? Spontaneous generation says that a whole complex organism can arise spontaneously because of the active principle. The heterotroph hypothesis says that life evolved over millions of years from organic chemicals in an ancient sea. Spontaneous generation has been disproven, but the heterotroph hypothesis could be true. Do you think God could have made life this way? Do you think this could have happened without a Supreme Being?

There are some things you should be aware of when considering how life began and whether or not God made life. There are many events that take place almost daily throughout the world that have no natural explanations. Events that defy natural laws. People's crushed spines instantaneously healed, Mongoloids that have an extra chromosome in each of the 7 trillion cells in their bodies becoming normal human beings without the extra chromosome in each of the 7 trillion cells in their bodies. People being brought back from the dead. Steel pins in people's legs disappearing. People with incurable muscular dystrophy instantaneously made to walk. How can these few events and thousands of others be explained. The Bible has recorded many such events. Could there be a God? Although the heterotroph hypothesis has not been disproven, there are many scientists that disagree with it. Mathematicians say the mathematical probability of life coming into existence by chance is extremely minute. Physicists say it defies one of the basic laws of physics and biochemists say that proteins cannot be made by chance hookups of amino acids because they won't hook up by themselves. The question of "How did life begin?" must still be answered within each individual who asks it on the basis of faith alone. Whether it be faith in spontaneous generation, the heterotroph hypothesis, biogenesis, the autotroph hypothesis, meteorites or space ships from outer space, or God creating life. There are few absolutes in the science of biology. Scientists must acquire a belief or faith in a variety of hypotheses, assumptions, and theories based upon evidence they see to support their beliefs. Also, those who believe or have faith in a God who is all powerful, base that faith on evidence they see to support their beliefs.
AT STUDY GUIDE

The Origin of Living Things

1. Read Sections 4-1, 4-2, 4-4, and 4-5 in old version or 6-1, 6-2, 6-4 and appendix 6-A in new version. Obj. 1 and 2.

2. Turn on tape recorder for an explanation of this section. Section 1. Obj. 1 and 2.

3. Read Sections 4-3, 4-5, and 4-7 of the old version or 6-3, appendix 6-A and 6-5 of the new version. Obj. 3 and 4.

4. Turn on your tape recorder to Section 2 of the tape for an explanation. Obj. 3 and 4.

5. Begin experiments 4-6 and 4-8 in old version or 6-A and handout in new version. Your instructor will demonstrate the techniques for these experiments.

6. Read Sections 4-9, 4-10, 4-11, and 4-12 in old version or 6-6, 6-7, 6-8 and 6-9 in new version.

7. Turn on your tape recorder to Section 3 for an explanation. Obj. 8, 9, 11.

8. Listen to Section 4 for a summary of the chapter and objective 10.
Problem: How did life begin?

Aristotle proposes an explanation 2000 years ago.

He believed that life could come into existence by itself, or spontaneously, from non-living materials.

He said that non-living materials had an "active principle" a mysterious force that could produce life.

1. the active principle needs a lot of air
2. the active principle cannot be heated too much
In 1745 John Needham believed in spontaneous generation and designed his experiment to prove it was true.

He heated it——
this supposedly kills
any beasties already there

This shows that
the broth produced
the beasties by the
active principle

What might Needham have done wrong in this experiment?
Lazzaro Spallanzani believed in biogenesis. He thought that Needham had allowed air into the flask along with germs and had not heated his broth enough to kill any bacteria already there.

The spontaneous generation people refused to believe that this experiment could disprove their theory because 1) Spallanzani kept the air out and 2) he boiled the broth. Thus, the active principle had been destroyed by Spallanzani and the broth could not produce life.
Figure 0-4

How did life begin?

Spontaneous generation has been disproven
Biogenesis may be true
God may have created life and all living things
The autotroph hypothesis is a possibility
Life may have come here from outer space

But there is still another possible explanation—(flip down the overlay)

How does this differ from spontaneous generation?
Should life begin?

Possible explanations:
1. Spontaneous generation
2. Heterotroph hypothesis
3. Autotroph hypothesis
4. Biogenesis—life comes only from life through normal reproduction of living things
5. Life coming from outer space on meteors or space ships
6. God created life and all living things

Questions to consider:

1. Is there a supernatural being that made this universe?
2. How can we explain events that occur that have no scientific explanation for them?
3. How good is the heterotroph hypothesis?
4. Is the autotroph hypothesis seriously considered by biologists?
5. What are some of the weaknesses of the heterotroph hypothesis?
6. How was spontaneous generation finally disproven?
7. How is spontaneous generation, the heterotroph hypothesis and the autotroph hypothesis different? They all say that life can come from non-life.
### ACTIVITY OPTIONS AND OBJECTIVE SHEET

#### THE FORERUNNERS OF LIFE

<table>
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<th>Activities</th>
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<td><strong>AT Packet</strong></td>
<td>The Student shall:</td>
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<td><strong>The Forerunners of Life</strong></td>
<td><em>1.</em> define the following terms: atom, molecule, electrons, protons, neutrons, elements, chemical reactions, chemical bonds, ions, acids, bases, pH</td>
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<td><em>2.</em> do Inv. 5-4 and explain exactly what takes place in a chemical reaction</td>
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<td><em>3.</em> explain what an organic compound is.</td>
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<td><em>4.</em> define energy.</td>
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<td><em>5.</em> list and explain the two kinds of energy there are.</td>
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<td><em>6.</em> list and explain the different forms of energy that exist.</td>
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<td><em>7.</em> discuss Miller's experiment and explain why it is an important contribution to the theory of the origin of life.</td>
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<td><em>8.</em> write out the formula and draw the stick diagram of amino acid.</td>
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<td><em>9.</em> explain how amino acids bond together into proteins.</td>
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<td><em>10.</em> do Inv. 5-9 and explain what an acid and base are.</td>
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<td><em>11.</em> do Inv. 5-14 and explain what coacervates are and why they are important in the heterotroph hypothesis.</td>
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#### Experiments:

| 5-4 | old version |
| 5-9 | new version |
| 7-A | new version |
| 7-B | new version |

**Purpose-5-4; handout**

1. Understand better the relationships between atoms, molecules, elements, and compounds.
2. Become acquainted with the standard tests for hydrogen and oxygen.
3. Distinguish between observations and assumption.

**5-9 or 7-A**

1. Train experience in determining pH.
2. Demonstrate the broad range of pH values of biological substances.

**5-14 or 7-B**

1. Determine the kinds of materials and conditions necessary for the formation of coacervates.
2. Relate the discussion of the heterotroph hypothesis in the text to the experiment.

#### Filmstrips

1) Carbon-Key Atom in Living Organisms
2) Carbohydrates
3) Proteins-Prime Molecules of Life

#### Solo Learn Kits

1) Amino acid structure and the peptide link
2) Introduction to Carbohydrates
3) Proteins and Deamination

#### Books

Chemistry for Biology Students - write 5 page summary and oral quiz

**YOU MUST DO 14 OBJECTIVES AND 3 EXPERIMENTS.**
How did the earth begin? How old is the earth? When, and under what conditions did life come into existence on earth? These and many more questions about the origin of life have been asked by men of all ages and will continue to be asked, for there are no pat answers to these very large questions. The explanation that follows is only theoretical or an educated guess. I really doubt that until we meet our Maker will we ever really know the details for sure.

It is estimated that the earth is around 4 1/2 to 5 billion years old. The most popular theory of the origin of earth is outlined on pages 109-110 of the old version or 123 of the new version. Clouds of dust and gases torn away from the edge of the sun condensed into small planets called "protoplanets", like small asteroids. Under gravitational forces between the protoplanets, they merged together into one large sphere, earth. Gases were trapped in pockets inside the earth. Tremendous pressures built up as these protoplanets were squeezed together and so much heat was generated that the earth partly melted. Eventually the earth began to cool and the surface of the earth became solid except where volcanoes continued to spew out molten rock and gases. One of the main gases coming out of volcanoes was water vapor. It rose high above the earth, cooled, and condensed into water droplets and fell to the earth as rain. As soon as the water hit the hot surface, it turned back to steam and rose back high above the earth, cooling and condensing into water and falling back down. This happened many, many times, thus gradually cooling off the earth's surface. There were violent rain, lightning, and thunder storms and much volcanic activity. Look at Figure 5-1 on page 110 of old version. Eventually the surface of the earth was cool enough that water began to accumulate into lakes, rivers, and oceans. The early atmosphere was probably composed of gases that escaped from the earth through volcanoes. Look at figure C-1. The force of the earth's gravity probably kept the gases from drifting out to space.

This is the end of Section 1.

Look at Figure C-1. Since it is hypothesized that the early atmosphere was composed of gases escaping the earth from volcanoes, it is only logical that we analyze the gases that come out of volcanoes today. It is reasonable to believe there has been little change in gases being emitted from within the earth since the earth's origin, although we cannot be absolutely sure this is so. The gases that are emitted from volcanoes are water vapor, as I have already mentioned,
carbon dioxide, carbon monoxide, nitrogen, hydrogen, and small amounts of methane and ammonia. Since oxygen gas is not part of volcanic emissions it's doubtful if it existed in the early atmosphere. Therefore any life that existed in this kind of environment, must have been able to live without oxygen. We know that there are primitive organisms that can live in environments lacking in oxygen. Yeast and many kinds of bacteria are good examples. The earliest known fossils dating back approximately three billion, one hundred million years are of bacteria-like organisms that may have lived without oxygen in water or mud.

Almost all living things today require oxygen. Therefore they could not have come into existence until oxygen was part of the earth's atmosphere. You will learn in photosynthesis how oxygen came into existence in the atmosphere.

This is the end of Section 2.

This is the Beginning of Section 3.

We will do part of Objective 1 in this section.

H-e-l-l-o my friend and welcome to Monsanto. You are about to take a trip with me in a remarkable machine that will reduce us in size to the point that we can wander through the realm of the molecule and maybe even the atom. Come in... Here we go... we are getting smaller and smaller and are now entering an ice cube. It is made of a lattice work of water molecules all stuck together, motionless. Look! We are getting small enough now to actually see the water molecules. The individual molecules are made of three atoms, the smallest unit of matter which retains the properties of a particular kind of element. We can see that when two or more atoms hook together, a molecule is formed. So a molecule is two or more, sometimes thousands of atoms all hooked together. If you look at figure 5-4 on page 113 in the old version or 7-3 in page 127 in the new version, you may visualize in greater detail what I am saying. Here we see that three atoms, hooked together form a molecule of water. We can also see that two atoms of hydrogen hooked together form a molecule of hydrogen gas. And likewise, two atoms of oxygen hooked together form a molecule of oxygen gas. But look at the water molecule. There are two different kinds of atoms hooked together, oxygen and hydrogen, whereas the oxygen and hydrogen molecules have only one kind of atom in them. When molecules contain more than one kind of atom in them, such as water, the molecules are called compounds. Look at Figure C-2. You can see on the overlay that in the molecule of methane, there are four atoms of hydrogen and one of carbon. Is this molecule or a compound? ... (pause)... Yes, it is a compound because it has more than one kind of atom. Now look at the nitrogen molecule. We can see that this molecule has
only one kind of atom in it. Is this molecule a compound? . . . (pause) . . . No, it is not a compound because there is only one kind of atom in it. You will find that most molecules have more than one kind of atom in them and are, therefore, compounds. Now, look at the remaining molecules and try to identify which ones are molecules. Few molecules have just one kind of atom in them. When we pass an electric current through water, the water molecules break up and we get separate molecules of hydrogen and oxygen gas. You will do this experiment in the next section. We will continue our journey after you do Inv. 5-4 in the old version or the handout if you have the new version. Turn your tape recorder off and read over the experiment. Don't do it yet, just read over it.

This is the end of Section 3.

This is the Beginning of Section 4

If investigation 5-4 was done correctly, you should have gotten twice as much hydrogen gas as oxygen gas. Why do you think this is so? . . . (pause). . . If you said that there are twice as many hydrogen atoms as oxygen atoms, you were correct. Look at the equation in the bottom right hand corner of Page 115 of the old version or page 128 for the new version. You can see that when one water molecule is split, the two atoms of hydrogen combine to form one molecule of hydrogen gas. But what about the one oxygen atom? Oxygen cannot exist as a free atom; it must always combine with other atoms or with one other atom of oxygen. It cannot exist by itself. So, if we take two molecules of water and split them both, we can get two molecules of hydrogen gas and one molecule of oxygen gas. Look at Figure 5-6 on page 116 of the old version or figure 7-4 on page 129 of the new version. You can see that hydrogen gas is a molecule of 2 hydrogen atoms and that oxygen gas is a molecule of 2 oxygen atoms. So, in the electrolysis of water, two water molecules are being split and two hydrogen molecules are being given off with one oxygen molecule. Now let's see how we write chemical formulas. Look at the equation for the splitting of water in the first column of page 116 or page 128 for the new version. In the formula $H_2O$ the "2" below and to the right of the "H" or hydrogen symbol means there are two atoms of hydrogen hooked into this molecule. Since there is only one oxygen in this molecule we don't write any number by it. If there is no number by it, it is understood that there is only one atom of that element in the molecule. The large "2" to the left of the water molecule means that there are two molecules of water. If there is no number next to the molecule, that means there is only one molecule. Look at Figure C-3. How many nitrogen atoms are there in the formula of letter "a"? . . . (pause) . . .
If you said three you were correct. Now look at the formula for letter "b". How many oxygen molecules are there? ... (pause) ... If you said six you were correct. How many oxygen atoms are in each molecule? ... (pause) ... If you said two you were correct. Now look at the formula in letter "c". How many carbon atoms, hydrogen atoms and oxygen atoms are in this formula respectively? ... (pause) ... If you said six carbons, twelve hydrogens, and six oxygens you were correct. Now do all of letter "d" on your own. ... (pause) ... There are two molecules of methane gas here. In each molecule there is one carbon atom and four hydrogen atoms.

This is the end of Section 4.

This is the beginning of Section 5

We have been talking a lot about molecules, compounds, and chemical formulas, but we have said little about the building block of these things, the atom. The word "atom" is derived from the Greek word Atomos meaning indivisible. It was originally believed that the smallest particle of matter was the atom. But today, we know that the atom is composed of many kinds of still smaller particles. The three main particles of the atom are electrons, protons, and neutrons. Look at C-4. You are already familiar with electrons. They are the fundamental units of electricity. Looking at letter "a" of figure two, you can see that each electron carries a charge of a minus one and that it has only about $\frac{1}{1800}$ of the mass of a proton. Looking at letter "b" you can see that the proton has a positive charge of one and in letter "c" the neutron has no charge at all. So its charge is zero.

The protons and neutrons are all stuck together in one ball in the middle of the atom. This is called the nucleus. Look at Figure 5-8 on page 117 of the old version or figure 7-6 on page 131 of the new version. You can see that in the nucleus of all of these atoms, there are equal numbers of protons and neutrons. For our purposes, we will say that the number of protons usually equals the number of neutrons in an atom. However, in many atoms this is not so. Neutrons many times outnumber the protons. How many protons are in the nucleus of carbon? ... (pause) ... That's right -- six. How about nitrogen and oxygen? ... (pause) ... 7 protons for nitrogen and 8 protons for oxygen. As you probably have already noticed, there are many kinds of atoms. You see three different kinds before you in this diagram. Actually there are 103 different kinds of atoms or elements. The kind of atom you have depends on the number of protons you have in the nucleus. I REPEAT. THIS IS VERY IMPORTANT. The kind of atom or element you have depends on the number of protons you have in the nucleus.

Look at Figure C-5. Any atom that has only one proton in the nucleus is a hydrogen. If the atom has two protons in the nucleus, it is helium. If it has three, it is lithium.
If it has four it is beryllium. If it has five, it is boron. Now let's review. If we have an atom with six protons in the nucleus, what element do we have? . . . (pause) . . . If you said carbon, you were correct. How about an atom with seven protons in the nucleus? . . . (pause) . . . That's right, nitrogen. If an atom has eight protons in its nucleus, what is it? . . . (pause) . . . If you said oxygen, you were correct. The word "element" refers to the different kinds of atoms there are. We could keep right on going to nine, ten, eleven, twelve, all the way to 103 protons in the nucleus. An atom with 103 protons in the nucleus is lawrencium.

TAKE A BREAK AND FINISH LISTENING TO THIS LATER. This will give you some more information to complete Objective 1.

Another general rule about the atom is that there are usually the same number of electrons as protons. If you look at Figure 5-8 and 7-6 again you can count up the number of electrons and see that this is true. Also, electrons with a negative charge are strongly attracted by protons with a positive charge. That is why electrons move about the nucleus where the protons are. A general rule to remember in chemistry is: unlike charges attract each other and like charges repel each other. An atom that does have the same number of electrons as protons is neutral and has no charge because the positive charges will cancel out the negative charges. However, sometimes an atom may have more protons that electrons or vice versa. In this case, the charges aren't balanced. If there are more protons than electrons, the atom will have a positive charge. If there are more electrons than protons, the atom will have a negative charge. Look at C-6. You can see in letter "a" that in this atom of lithium, there are three protons and only two electrons. Therefore, the atom has a net charge of plus one. In letter "b" you can see that there are four protons and five electrons leaving it with a net charge of negative one. Atoms that have charges on them are called ions.

Look at figure 5-7 on page 117 of the old version or 7-5 on page 130 of the new version. At first it was believed that electrons orbited around protons like planets orbit around the sun. But now with the quantum theory of the atom, we don't know how the electron moves about the proton. We do know that electrons are moving so fast they seem to be everywhere at once, and form a cloud around the nucleus. It has been said that the electron orbits around the nucleus seven million billion times a second. As you can see in this diagram, there is much space between the nucleus and the electrons. Indeed, most of the atom is empty space. If an orange, here in this building, were to represent the nucleus of an atom, the nearest electron would be orbiting the orange some forty miles from here.
Now look back at figure C-5 again. You can see that not all the electrons are moving at the same distance from the nucleus. Because of orbital patterns, there is a set number of electrons that can move at any given distance from the nucleus. The electrons that are the closest to the nucleus are held the tightest, but the electrons that are the farthest away from the nucleus are held with the loosest force and can be knocked off the atom much more easily than the closest electrons. It's like gravity and planets. The farther away from a planet you get the lesser the force of gravity on you and the easier it is for you to be knocked out of the gravitational pull altogether. Now when the outer electron shells of two atoms come into contact, electronic interactions can take place between those two atoms and in this way electrons can hook or join together by electron interaction or clouds. These electron interactions between atoms are called chemical reactions. Chemical reactions involve only electrons, or electron changes between the atoms and does not in any way affect or involve the nucleus.

Now turn your tape recorder off and make sure you have read section 5-7 before going on to the next explanation.

This is the end of Section 5.

As you probably know by now, atoms don't usually exist by themselves but react and combine with other atoms. Remember in section 5-6 or 7-6 that these "reactions" depend on the outer electrons of the atoms. Look at figure 5-9 on page 118 of the old version or 7-6 on page 131 of the new version. Here, you can see that the outer electrons of one atom interact with the outer electrons of another atom and hold or bond these atoms together in a molecule. These connections between atoms in a molecule are called chemical bonds. So, when a chemical reaction takes place, bonds are being broken and new bonds between different atoms are forming. Remember the electrolysis of water? Look at figure C-7. There, the bonds between the hydrogens and oxygen of water were being broken and new bonds between the hydrogens formed, and bonds between the oxygens of two water molecules formed. In the diagram, you can see the bonds between hydrogens and oxygen in water being broken, and the dotted lines forming between the hydrogens and oxygens. The resulting chemical reaction yielded two molecules of hydrogen gas and one molecule of oxygen gas. Now let me quiz you. What is a chemical reaction? . . . (pause). . . If you said the interaction between the outer electrons of atoms or the making and breaking of chemical bonds, you were correct. What is a chemical bond? . . . (pause). . . If you said the electronic connections between atoms in a molecule, you were correct.
As was mentioned earlier, electrons move about the nucleus at different levels or in different shells. Each shell can hold a certain number of electrons. Look at Figure C-8. The shell closest to the nucleus can hold 2 electrons. The next shell out can hold 8 electrons. The third shell can hold 8 electrons. There are more shells but we will not be discussing them.

In living things, we will only be dealing with a few of the 103 different elements there are. Look at figure C-9. The four main elements are carbon, oxygen, hydrogen, and nitrogen. Some of the other elements are in the cute little phrase to the right. Now look at figure C-10. How many electrons does hydrogen have? . . . (pause) . . . That's right: one. But how many electrons can fit into that one shell? . . . (pause) . . . That's right, two. So! Hydrogen then, can take on another electron to complete its shell. In fact it has a strong affinity to complete its shell so it can achieve a higher degree of stability. Since it has a strong affinity to take on one more electron, we say it has a valence of 1.

Hydrogen, as well as most other atoms, achieves this by sharing an electron with another atom that also needs to have an electron. So hydrogen can only bond with one other atom. If you look at letter "b", you can see what I mean. Hydrogen atom #1 says to hydrogen atom #2, "I need an extra electron, and I see you need an extra electron. How about you sharing yours with me and I'll share mine with you." So the electron of hydrogen #1 will move about the nucleus of not only itself but of hydrogen #2 as well; and the electron of hydrogen #2 moves about both nuclei as well. So now, by sharing electrons, the outer electron shell of both atoms is now complete. Not look at letter "c". How many electrons does carbon have in its outer shell? . . . (pause) . . . That's right, four. But! How many electrons can that shell hold? . . . (pause) . . . If you said "8" you were correct. Therefore, how many more electrons can carbon take on? . . . (pause) . . . That's right, 4 more electrons. So it can share electrons with 4 more atoms. Therefore it has a valence of what? . . . (pause) . . . That's right, four. Let's do the same thing in letter "d" for oxygen. How many electrons does it have in its outer shell? . . . (pause) . . . That's right, six. So what is its valence? . . . (pause) . . . Good, 2. I will let you figure out what the valence of nitrogen is. Now look at figure 5-9 on page 118 of the old version or 7-6 on page 131 of the new version. Here you can see that oxygen, which can bond with two other atoms, is sharing two of its outer electrons with two hydrogens that can each bond with one atom. You can now take note that you will never see hydrogen bonding with more than one other atom. You will never see oxygen bonding with more than two other atoms.
You will never see nitrogen bonding with more than three other atoms. And, finally, you will never see carbon bonding with more than four other atoms. Study figure 5-10 on page 119 of the old version or figure 7-8 on page 132 of the new version to see if I am right. However, sometimes you will see carbon combining with less than four other atoms. It may combine with 3, 2, or only 1. When this happens, carbon shares more than just one electron with the other atom. Look at figure C-11. Here you see carbon combining with another carbon but instead of just sharing one pair of electrons between them, they share three pairs of electrons. They get the other electron they need to fill their outer shell from hydrogen. (This molecule you see here is acetylene, an explosive gas used in torches). When two atoms share only one pair of electrons, they are said to be single bonded. Look at figure C-12. When two atoms share two pairs of electrons, they are double bonded. And when two atoms share three pairs of electrons they are triple bonded. The triple bond is about as high as you can go.

This is the end of Section 6.

This is the Beginning of Section 7

When you dissolve table salt in water, it separates into sodium and chloride ions. This process is called ionization. Water will also do this to a very small degree. H\textsubscript{2}O breaks up into hydrogen and hydroxide ions. This only happens in one out of every ten million molecules. But it is important in life functions. Look at figure 5-12 on page 120 of the old version or figure 7-10 on page 134 of the new version. Chemists and biologists use this pH scale to measure the amount of hydrogen or hydroxide ions in a solution. You will be using this tool in the next experiment and for several more to come throughout the course. Where there are an equal number of hydrogen and hydroxide ions in solution, the solution is said to be neutral and to have a pH of 7. A solution that has more hydrogen ions than hydroxide ions is said to be acidic and have a pH less than seven. And a solution that has more hydroxide ions than hydrogen ions is said to be basic and have a pH greater than 7. So, an acid is anything that has more hydrogen ions than hydroxide ions, and a base is anything that has more hydroxide ions than hydrogen ions. What pH do you think water would have? . . . (pause). . . If you said 7 or neutral, you were correct, because in water there are equal numbers of hydroxide and hydrogen ions. Now turn your tape recorder off and do program 5-1 under #18 in your study guide as a summary of everything we have done so far in this chapter.

This is the end of Section 7.
Look at Figure C-13. All living things are composed of chemical compounds called **organic compounds**. These compounds are made up of long chains or carbons hooked together with hydrogens, oxygens, or nitrogens attached to these chains. So **organic compounds** are any compounds with carbon chains or skeletons. These compounds were originally called "organic" because it was believed that only living things could make them. But in 1828, a German chemist by the name of Wohler accidently synthesized or made a molecule or urea, an organic compound found in urine. Later, other organic compounds were synthesized in the laboratory. So it became clear that living organisms were not needed to make these compounds. So maybe these compounds could have come into existence by chemical reactions from the gases of the early atmosphere. 

Refer to figure C-14. For organic compounds to be made from simple gases requires the breaking of bonds between atoms and new bonds forming between different atoms. This requires energy. Remember the electrical energy we used to break the bonds between the atoms in the water molecule and form new molecules of hydrogen and oxygen gas?

Since the origin of these organic molecules depended on energy, we must have an understanding of what energy is if we are to understand life processes. Energy is defined as the ability to do work. Energy causes things to move and be in constant motion. There are two kinds of energy, **Kinetic** and **potential**. **Potential energy** is energy that is stored or inactive. Look at figure 5-14 on page 124 of the old version. A boulder sitting on the top of a hill has potential energy. Gasoline has potential energy, **kinetic energy** is the energy a moving object has because of its motion. If you get in its way, you will experience this energy quite abruptly because it is giving it off. However, if you go up and touch the boulder sitting on top of the hill, nothing will happen because it is just sitting with its energy stored and not being given off.

Both kinds of energy, potential and kinetic may have different forms such as chemical, electrical, mechanical, radiant, heat, and nuclear energy. One form of energy can be transformed into another form of energy. For example, the potential chemical energy of gasoline can be changed to the kinetic mechanical energy of an automobile. So energy can be stored or changed from one form to another. Keep in mind that energy is never created or destroyed, only changed. This is called conservation of energy. The original source of energy that allowed organic compounds to come into existence was ultra-violet rays and lightning. These may have caused the gases to bang or smash into one another and react to form larger molecules. Look at table 5-1 on page 124 of the old version.

This is the end of Section 8.
This is the beginning of Section 9

Harold Urey and Stanley Miller at the University of Chicago built an apparatus that was air-tight. Look at figure 5-16 on page 126 of the old version or figure 7-11 on page 135 of the new version. Into this apparatus they put 4 gases; methane (CH₄), ammonia (NH₃), water and hydrogen. They circulated these gases past a high energy electrical spark. The water was boiled into a vapor and as it was circulated, would cool and condense as rain. So an artificial condition was set up that duplicated the theoretical conditions of the earth's early climate gases, heat, rain and flashes of lightning. After allowing this apparatus to run for a week, they noticed the clear color of the water had changed to red. Chemical tests showed there were several compounds present that weren't there when the experiment began. So the atoms of some of the gas molecules had recombined to form new and more complex molecules. One of the organic compounds that had been formed was amino acids. Amino acids are important because they are the building blocks of proteins and proteins are the main compound in all living things. Keep in mind that Miller's experiment didn't prove this is the way it happened, but only suggests that it might have happened this way. In fact, Miller's experiment assumes there was an abundance of methane and ammonia in the early atmosphere when geophysicists feel that there was probably little of the gases in the early atmosphere.

5-11 cont.

Turn to figure 5-17 on page 127 of the old version or 7-12 on page 137 of the new version. This figure gives you the general formula and structure of amino acids. The amino group is always characterized by two hydrogens attached to a nitrogen. This is what distinguishes this group as an amino acid. The organic acid portion of this molecule is always characterized by a carbon with a double bond oxygen and an OH group. It is the hydrogen on the OH group that comes off as a hydrogen ion that makes this an acid group. The "R" group there refers to the rest of the molecule, usually carbons and hydrogens along with sulfur. The simplest amino acid is glycine in the second structure there in this figure. This is its complete structure. The next simplest is alanine shown there as the last structure. There are approximately 18-20 more amino acids besides these two. Just as the 26 letters of the alphabet can spell an infinite number of words when put together in a certain arrangement, so can the 20 different amino acids "spell" or make an infinite number of proteins when hooked together in long chains in a
certain sequence. Now turn your tape recorder off and take a break, then come back and set up your filmstrip projector so you may view the rest of the filmstrip on the carbon atom you started earlier.

This is the end of Section 9.

This is the Beginning of Section 10

It is assumed that amino acids combined to form proteins in the early seas. Look at figure 5-19 on page 129 of the old version or figure 7-F-1 on page 688 of the new version. Here you see alanine combined with glycine. Since there are 20 different amino acids as I mentioned in the last section, they hook together in long chains as shown in this figure. These chains can contain anywhere from 50 to 3,000 amino acids. The bonds that hook the amino acids together are called peptide bonds. In the formation of these bonds, the COOH group, of one amino acid, joins with the amino group of the other amino acid. In the process of this reaction, the acid group loses a hydrogen and oxygen atom and the amino group loses one of its hydrogens. The two hydrogens and one oxygen come off as H₂O or water. You can see that when the two amino acids are hooked together in figure 5-19 or 7-F-1 that one end has the acid group, so other amino acids can come in and attach themselves on to the ends of this until we have a chain hundreds or even thousands of amino acids long. A particular protein is distinguished by the number of amino acids and what exact order or sequence those amino acids are in, just as a word is distinguished by what letters it has and the exact order the letters are in.

Today we know that for amino acids to hook together into long chains of protein it takes enzymes. Two amino acids cannot hook together unless an enzyme is there to cause them to hook together. However an enzyme is a protein itself! If it takes a protein to make a protein, how did the first protein come into existence? This is a question that has not yet been answered. Scientists like Sidney Fox have been working on this question for years. He succeeded in hooking amino acids together, but only when they were a dry powder and the water had been driven off by heat. The theory of the origin of life is based on the idea that these amino acids came into existence and were hooked together in water and that life originated in water.

This is the end of Section 10.

This is the Beginning of Section 11

You now know the theory of how amino acids and proteins came into existence. Simple gases like CO₂, CO, NH₃, CH₄, and H₂O collided into one another after
being struck by ultra-violet rays and lightning, and formed amino acids. These amino acids were then washed down by rain and began accumulating in the oceans. These amino acids then somehow became hooked together in long chains to form proteins. These complex proteins became grouped in clusters to form pre-cells. Look at assumption 4 on page 131 of the old version. These pre-cells had many chemical reactions. They took in other organic compounds from the surrounding oceans and broke them down to get energy to keep up their chemical reactions and their ability to reproduce themselves.

Whenever proteins are dissolved in water, part of the molecule gains an electrical charge. This charge attracts water molecules in such a way that an organized layer of water molecules forms around the large protein molecule. Whenever proteins clump together in this manner, they form coacervates. Pre-cells may have formed in the same way as this complex coacervate. In investigation 5-14, you will be making coacervates. Turn your tape recorder off and read over Inv. 5-14 or 7-B. DO NOT DO IT YET, just look it over. Your instructor will demonstrate the techniques of this experiment.

This is the end of Section 11.

This is the Beginning of Section 12

What is life? There is no clear-cut definition for life. Just as it is hard to classify some organisms as plants or animals, it is also hard to classify some things as living or non-living. We know that all living things carry on chemical reactions and can reproduce themselves. But there are some things that can carry on chemical reactions and reproduce themselves if they have special conditions, but if those conditions are taken away, they cannot function as living things but become inert chemicals. Viruses are a very good example of this. Only when they are in the cells of a living thing can they carry on chemical reactions and reproduce. When they are out of a living thing, they become an inert powder or crystal. Look at figure 5-22 on page 134 of the old version or 7-14 on page 141 of the new version to see a crystal of polio virus. Also look at the comparison of coacervates and amoebas in figure 5-4 on page 134 of the old version or figure 7-14 on page 141 of the new version.

This is the end of section 12.
AT STUDY GUIDE
FORERUNNERS OF LIFE

1. Read section 5-1 on pgs. 109 and 110 of old version or section 7-1 on pgs. 123 of new version.

2. Turn on your tape for an explanation.

3. Read section 5-2 on pages 110 and 111 of the old version or section 7-2 and 7-3 on pgs 123 and 124 of the new version.

4. Turn tape on to section 2 for an explanation.

5. Read sections 5-3 on pgs. 112 and 113 of the old version (obj. 1) or section 7-4 on pgs. 125 to 128 of the new version. (obj. 1)

6. Turn your tape recorder to section 3 for an explanation. Obj. 1

7. Read over and do Investigation 5-4. Obj. 1

8. Read section 5-5 on pgs. 115 and 116 of the old version or 7-5 on pgs. 128 and 129 of the new version. Obj. 1

9. Turn on your tape recorder to section 4 for an explanation. Obj. 1

10. Read section 5-6 on pgs. 116 and 117 of the old version or section 7-6 on pgs. 129 and 130 of the new version. Obj. 1

11. Turn on your tape recorder to section 5. Obj. 1

12. Read section 5-7 on pgs. 118 and 119 of the old version or section 7-7 on pgs. 131 to 133 of the new version.

13. Turn on your tape to section 6 for an explanation.

14. Read section 5-8 on pgs. 119 and 120 of the old version or section 7-8 on pgs. 113 and 134 of the new version.

15. Turn on your tape to section 7 for an explanation.

16. Do Investigation 5-9 in old version or 7-A in new.


18. Turn on your tape to section 8 for an explanation. Objs. 3, 4, 5, and 6.


20. Turn on your tape recorder to section 9 for an explanation. Objs. 7, 8, and 9.

21. Read section 5-12 on pgs. 127-130 of the old version or section 7-11 on pgs. 136-138 of the new version.

22. Turn your tape on to section 10 for an explanation.

23. Read section 5-13 on pgs. 131 and 132 of the old version or 7-12 on pgs. 139 and 140 of the new version.

24. Turn on your tape to section 11.

25. Do Investigation 5-14 in old version or 7-B in new.

26. Read section 5-15 on pgs. 134 and 135 of the new version or section 7-B on pgs. 140-143 of the new version.

27. Turn tape on to section 12 for an explanation.
1. Steam came spewing out of volcanoes.

2. It rose high above the earth and cooled and condensed into clouds.

3. The cool water now fell to the hot surface of the earth and turned to steam again rising high above the earth, cooling and falling again as rain.

4. This continued for hundreds of thousands of years until the earth was cool enough for the water to stay on the earth as rivers, lakes, and oceans.

Lakes could not determine what gases make up the earth's atmosphere.
Figure C-3

a) $\text{NH}_3$
nitrogen gas

b) $\text{O}_2$
oxygen gas

c) $\text{C}_6\text{H}_12\text{O}_6$
glucose

d) $2\text{CH}_4$
methane gas

Figure C-4

a) $e^{-1} = \frac{1}{1800}$ of a proton

b) $\text{P}^+$

c) $\eta^0$
Figure 3-5

(a) Hydrogen
(b) Helium
(c) Lithium
(d) Beryllium

Figure 3-6

(a) Lithium
(b) Beryllium

Figure 3-7

N→H

O

H→H

O

H→H

Hydrogen gas

... bond is forming

... bond is breaking
Figure 6\textsuperscript{2} a. MOLECBES CaFe

- C: carbon
- H: hydrogen
- O: oxygen
- P: phosphorus
- K: potassium
- I: iodine
- N: nitrogen
- S: sulphur
- Ca: calcium
- Fe: iron

Figure 6\textsuperscript{3}

a) Hydrogen 1

\[ \text{valence of } H = 1 \]

\[ \text{it needs } 1. \]

b) Hydrogen 2

c) Carbon

\[ \text{valence of } C = 4 \]

\[ \text{it needs } 4 \text{ electrons to complete its outer shell.} \]

d) Oxygen

\[ \text{valence of } O = 2 \]

\[ \text{it needs } 2 \text{ electrons to complete its outer shell.} \]
Program 3-1

a) When two or more atoms hook together, we have a structure called a _________________________________.

molecule

b) When molecules have more than one kind of atom or element in them, such as water, the molecule is called a _________________________________.

compound

b) Which of the following are compounds?

H-H   Fe-Cr   C-C
(He)  (Cu)  (O₂)
(N₂)  (H₂)  (SiO₂)
c) $\text{H}_2\text{O}$, $\text{H}_2$, and $\text{H}_2\text{O}_2$ are compounds because they are made up of more than one kind of atom. $\text{H}_2$ and $\text{H}_2\text{O}_2$ are just plain molecules of hydrogen and oxygen. $\text{H}_2\text{O}_2$ is hydrogen peroxide and oxygen is the only element in the molecule.

d) The process of splitting water into hydrogen and oxygen gas is called electrolysis.

e) electrolysis.

f) The ratio of hydrogen gas to oxygen gas in experiment 5-3 is

$\text{H}_2:\text{O}_2 = 2:1$.

g) In the formula $\text{H}_2\text{O}$, the "2" means there are two atoms of hydrogen in the molecule of water.

h) In the formula $\text{CO}_2$, the "2" means there are two molecules of carbon dioxide.

i) The three main particles of the atom are protons, neutrons, and electrons.

j) Negative

k) the proton carries a positive charge.

l) the neutron carries a neutral charge.

m) positive

n) The nucleus of the atom is composed of protons and neutrons in equal numbers, and the electrons spin around the nucleus at tremendous speed.

m) protons and neutrons.

n) There are many different kinds of atoms or elements, but the number of electrons determines that kind of atom you have.
a) protons

b) Electrons are the ones that have the following:

- charge

- mass

- size

- energy

- momentum

b) There are usually the same number of electrons as there are protons in the atom. Negative and positive charges attract each other. That is why electrons are held in the atom by protons and don't fly off.

c) negative, positive

d) Atoms that have charges on them are called ions.

a) When an atom has more electrons than protons, it has a negative charge. When it has more protons than electrons, it has a positive charge.

e) chemical reaction

b) The electronic connections that hold atoms together in a molecule are called chemical bonds.

c) chemical bonds

u) When bonds between the atoms of molecules are broken and new bonds between different atoms are formed, as in $\text{H}_2\text{O}$ to $2\text{H} + \text{O}_2$, this is called a chemical reaction.

d) chemical reaction

v) Electrons move around the nucleus at different distances or levels. These levels are called electronic shells. The first shell is the nuclear shell that holds electrons. The second shell can hold 8 electrons and the third shell can hold 18 electrons.

v) 2, 8, 3

w) The number of electrons an atom needs to fill its outer shell is called its valence.

x) For example, oxygen has 2 electrons in its first shell and 6 electrons in its outer shell. It needs 6 more electrons to complete its outer shell. Therefore, it has a valence of 6.
v) There are four different kinds of atoms or elements. By only 4 of these 102 create all the main elements of living things. These atoms are:

- carbon
- oxygen
- nitrogen
- hydrogen

x) Just as the letters a, o, and r make up the words are, ore, era, our, and many more, so can the atoms C, O, N, and H combine to combine to make up sugars, proteins, fats, starch and many more organic compounds found in living things. The valences of these four atoms are __________, __________, __________, and __________, respectively.

y) 1, 2, 3, and 4

z) When two atoms “share” electrons, this is called a __________ chemical bond.

a) covalent

b) ionic

c) A pH scale measures the amount of __________.

d) H⁺ or OH⁻ ions in solution

e) When there is more H⁺ in solution than OH⁻, the solution is said to be __________ and have a pH less than __________.

f) acidic, 7

g) When there is more OH⁻ in solution than H⁺, the solution is said to be __________ and have a pH greater than __________.

h) basic, 7
Figure 14: gases mixing together forming large organic compounds.
### ACTIVITY OPTIONS AND OBJECTIVES

#### CHEMICAL ENERGY FOR LIFE

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YOU MUST DO 20 OBJECTIVES AND 3 EXPERIMENTS.
In the last unit we learned what chemicals and chemical reactions are and how, according to the heterotroph hypothesis, life may have evolved from chemicals in an ancient ocean on Earth. Look at figure F-1. Simple gases collided to form organic compounds, such as amino acids. Then amino acids hooking together to form proteins and proteins clumping together with starches, sugars, and other chemicals to form coacervates. And then after millions of such gatherings, a living cell was formed. These cells were highly organized and complex compared to the disarray of chemicals around them. Look at figure F-2. A primitive membrane has contained a series of complex chemical reactions, each one taking place at a proper time and in proper order. This highly organized and complex set of chemical reactions we call life. This is objective 1.

These cells contained very large molecules and a sequence or assembly line of chemical reactions. Whereas simple compounds received energy from lightning and ultra-violet light to form organic compounds, such severe and forceful energy would destroy a living cell. For this and other reasons, the first living cells are thought to have been evolved in waters where this kind of energy is filtered out. This is objective 3.

It takes energy to keep a cell organized and carrying on its chemical reaction. If a cell cannot use lightning or ultra-violet light as sources of energy, where does it get its energy? Remember that, according to the heterotroph hypothesis, for hundreds of thousands of years organic compounds collected in the ancient oceans. Some of them became clustered into living things, but most of them just stayed floating around in the oceans as organic compounds. Early cells need a gentle source of energy to carry on chemical reactions and stay alive, so they fed on these organic compounds until later when the autotrophs evolved. Remember the chapter before last. So in review and to summarize objectives 4 and 5, organic compounds came into existence violently with lightning and ultra-violet light smashing simple gases together and then were rained down into the oceans accumulating in the seas for hundreds of thousands of years, while pre-cells were formed from the clustering of organic compounds in the oceans under warm and gentle conditions, with the early cells gently extrating energy from the organic compounds around them.

Look at figure 6-2 on page 141 of the old version of figure 8-2 on pages 146 of the new version. We can only speculate on what kinds of organic compounds existed in the early oceans by looking at the kinds of organic compounds living things use today for energy. Here you see a molecule of glucose. Glucose, along with starch,
which is a form of glucose, hooked together in long chains, comprises the carbohydrates, the food group that has more energy in them than any of the others in the fats. So today, carbohydrates and fats are the primary energy sources of organic compounds. What organic compounds did you take in this morning before coming to school? This is objective 6.

When chemicals are brought into contact and react with one another, one of two things happens to the new compounds formed in the reaction. Look at figure F-3. The new compounds may have less energy than the original compounds which means energy was given off in the reaction, or the new compounds will have more energy than the original compounds which means energy was put into the reaction. When living things break down organic compounds, they extract energy from them.

As you see in figure F-3, if a chemical reaction is to occur, the compounds must be brought into contact with one another. This bringing together of compounds takes a small amount of energy. We call it activation energy. The most common form of activation energy in a chemistry lab is heat. Heat will cause the molecules to collide and react. By now you know that a living cell is dependent upon many thousands of chemical reactions and is quite sensitive to heat or strong amount of energy. A living cell cannot rely upon heat to cause its chemical reactions. In chemistry we know of certain chemicals that can cause chemical reactions without using very much heat. We call these catalysts. A catalyst is a special chemical that can bring molecules together without using heat and cause them to react. This is objective 8.

Look at figure F-3 again. A catalyst acts as a template that corresponds to the shape of one or two molecules. Thus, if a catalyst is going to cause two molecules to react, it attaches itself on to them and fits them together gently, as you see here, so they can react. Catalysts cannot only bring two molecules together and cause them to react with one another, it can split a molecule apart into smaller molecules. Now, the word catalyst is a general word which applies to any chemical that can cause this to happen. In living things all the chemical reactions are caused by chemicals we call enzymes. An enzyme is made up of protein and one or more vitamins or minerals.

In investigation 6-4 or 8-A you will experiment with some catalysts found both in and out of living things. What is a catalyst found in a living thing called? . . . You were right if you said enzyme. In this experiment be sure you distinguish between the living and the non-living materials. Thus, you will know which are enzymes and which are not. Also, keep in mind that the chemical you are using the various catalysts on is hydrogen peroxide or \( \text{H}_2\text{O}_2 \). In this experiment you
want to determine what effect the catalysts have on this chemical; whether or not catalysts are used up in the reactions; whether or not this is a composition reaction (bringing two molecules together) or a decomposition reaction (breaking a molecule apart); and also what effect temperature, crushing and pH have on the rate of enzyme activity. Now read over and then do Investigation 6-4. Your instructor will show you the techniques of this experiment.

This is the end of Section 1.

In Investigation 6-4 you saw how enzymes can break down compounds. When you added the peroxide to the various catalysts you tested did you feel the test tube get warm? This was the energy being given off as peroxide was being broken apart. Energy is released when molecules are broken apart. When the molecule is broken apart all at once in a sudden chemical reaction, the energy is given off all at once as a lot of heat or if there is a great deal of energy it could be an explosion. Look at figure F-4. Living things cannot tolerate lots of heat being given off at once from sudden breakdowns of organic molecules. Living things rely solely on the chemical breakdown of organic compounds in a series of reactions as you see here. Each reaction is caused by an enzyme. As you discovered in Investigation 6-4, enzymes can cause chemical reactions without being used up themselves in the process. Remember when you took the used liver and cut it in half and put it in two test tubes. Then you divided the used peroxide into two test tubes and to one you added a new piece of liver and nothing happened and to the other you added fresh peroxide and the reaction went just as vigorously as before. So you can reuse the enzyme in the liver over and over again, but the peroxide is being used up. So enzymes will cause the chemical reactions without themselves being used up in the process and living things rely solely on organic chemical for energy breaking them down in a series of reactions and releasing the energy in small chemical packets. For a review of how enzymes work turn to figure 6-5 on pages 146 and 147 of the old version or figure 8-3 on page 151 of the new version. Enzymes can cause molecules to split apart or come together without involving high temperatures that would destroy the living cell.

How is energy released from organic compounds in living things if not as heat? In the breakdown of organic compounds to get energy, there is a basic energy compound in all living things on earth. This compound is called adenosine triphosphate or ATP for short. If you look at transparency F-5 you can see how this molecule works. This molecule is made of three parts as you can see. Because of its
structure it can behave like a mousetrap and cock itself once it receives the energy
to do so. If you flip the transparency down you can see how the molecule can cock
itself. The book says that ATP has high energy bonds. But this is not entirely
true. When an organic compound, such as glucose is going to be broken down, a
low energy ATP molecule comes in at various steps of the breakdown and takes on
another phosphate and absorbs energy by cocking itself. This is how the energy
is transferred in the breakdown of organic compounds. Instead of being released
all at once as heat or an explosion, the energy is released in small packets as ATP's.
One glucose molecule can give off 36 ATP's of energy. After ATP's are formed,
as many as needed give off their energy for the various activities of the living cell.
After ATP releases its energy it goes back to where glucose is being broken down
and gets more energy. So ATP becomes the vehicle for distributing the energy
from the breakdown of organic compounds throughout the living cell. All living
cells on earth use ATP as a vehicle of dispersing energy obtained from the break-
down of organic compounds. This is objective 11.

So far since Chapter 4 we have been intensely studying the heterotroph hy-
pothesis. We know that the first living things had to be very simple and probably
obtained the energy they needed by taking in and breaking down organic compounds
that had accumulated in the oceans around them. We have seen that they probably
broke down organic compounds in a series of reactions and dispersed the energy
in small chemical packets called ATP. But we also know that there was probably
no oxygen in the early atmosphere of the earth. Today, most organisms use
oxygen to break down organic compounds or food to get energy. Look at figure
F-6. Somehow primitive cells were able to break down food to get energy without
using oxygen.

To see how primitive cells may be able to break down organic compounds
to get energy without oxygen, do Investigation 6-8 or the handout. You will put
yeast, a primitive one-celled organism, in a soup of organic compounds, in this
case grape juice, in a thermos bottle and seal the bottle so no air can get in.
Using a thermometer and a flask with limewater and your own mouth and nose for
small and taste you will determine if the yeast can break down the organic com-
pounds to get energy and what the final products are.

This is the end of Section 2.

This is the Beginning of Section 3

As you have seen in the fermentation experiment, primitive organisms can
break down food to get energy without oxygen. However, they cannot break the
food down all the way and they cannot get very much energy out of it. Perhaps that is why only very primitive organisms can exist using this kind of process of getting energy out of organic compounds. Higher organisms would never survive using this process. But remember, the first cells, according to the heterotroph hypothesis, were very simple heterotrophs that could make it using fermentation as a method of obtaining energy from organic compounds. What were the final products of fermentation in your experiment? Was heat given off in the process? Were there more yeast cells when you were finished than when you started?

Over many years, the actual chemical reactions of fermentation have been discovered. Look at figure 6-13 on page 153 of the old version or 8-10 on page 156 of the new version. Here you can see a simple diagram of what happens in fermentation. To make glucose take part in chemical reactions we must activate it by using up 2 ATP's of energy first. After this glucose can now take part in chemical reactions. Keep in mind that each reaction that takes place here is caused by an enzyme. After glucose has become activated it is split into two through carbon phosphate compounds. After several reactions the energy is released as four ATP's. But remember, we used up two ATP's to start with so we have only gained two ATP's. At this point one carbon from each of the three carbon compounds comes off as a carbon dioxide molecule and we end up with two carbon compounds called ethyl alcohol. So altogether in fermentation, we have broken glucose down to two ethyl alcohols, two carbon dioxides and 2 ATP's. In summary then, fermentation is the process of breaking down organic compounds to get energy without oxygen.

This is objective 13.

This is the end of section 3.

This is the Beginning of Section 4

We know that early cells must have had a boundary or cell membrane to contain all the chemical systems of the cell as cells have today. In review, we also know now that these cells must take in organic compounds as a source of energy. The next thing we should look at is how they could take in these compounds through their membranes. About the only way molecules could move around in the ancient oceans is by a process called diffusion. Diffusion is a natural law that says that all molecules tend to be evenly distributed throughout an area. If molecules are in high concentration in a bottle, for example, or outside or inside a cell they will disperse to areas where there aren't very many of them. Look at figure F-7. The ammonia in the bottle goes and spread itself all over the room. This happens because the molecules are constantly moving and smashing into one another and
spreading themselves all over the room. So molecules in the ancient oceans probably dispersed themselves in this way going from areas of high concentration to areas of low concentration.

Do the handout experiment on diffusion and membranes to see how substances can pass through membranes.

This is the end of Section 4.

From the last experiment you know substances can diffuse through a membrane. But only certain sized molecules can get through the membrane. This would indicate that membranes have holes in them that will not allow large molecules such as starch to go through. A membrane that will allow only certain molecules to go through it is called a selectively permeable membrane. So, in review, certain substances can diffuse through a membrane into a cell. Cells of today not only passively allow substances through but can actively select what comes in or goes out. Investigation 6-12 or handout 2 will show you an experiment with two types of cells: a plant cell called elodea, a water plant and fungus cells called yeast. In the elodea cells you will see how osmosis and plasmolysis occurs. Look at figure 6-16 on page 167 of the old version or figure 8-12 on page 159 of the new version. When salt water is placed around the outside of a cell and a more concentrated water is inside a cell, there is a higher concentration of water inside the cell, so the water diffuses out of the cell where there isn't as much water and the cell shrinks. If pure distilled water is outside the cell and a lower concentration of water is inside the cell there is a higher concentration of water outside the cell and a lower concentration of water inside the cell and the water diffuses inside the cell and the cell bloats up. When water diffuses into a cell, this is called osmosis. When water diffuses out of a cell, this is called plasmolysis. When you observe the yeast cells in this experiment, look to see what shades of color are inside the cell. Usually it is bluish-green. You will take live yeast cells and add a deep red dye called Congo red. Handle this dye carefully because I traveled 15 thousand miles to and from the far reaches of the Congo to get this rare and special dye. After adding the dye look to see if the dye goes into the live yeast cells. Then you will take and boil about one or two milliliters of yeast suspension in a water bath. This will kill the yeast. Then you will add the Congo red dye again. Look to see if the cells have Congo red in them now.

This is the end of Section 5.
In Investigation 6-12 you saw two ways cells allow substances to pass through their membranes. They passively allow certain substances to diffuse in such as water or iodine diffusing in. When cells have no control over what goes in or out such as water in the elodea cells, this is called passive transport. But you saw that the live yeast cells did not allow the Congo red dye to go into the cell. Only when the yeast cells were dead could the dye get in. So in this case the membrane is actively determining what may or may not enter the cell. When cells can actively select what enters or does not enter, this is called active transport. We know that many times cells can take in chemicals against diffusion from an area outside the cell of low concentration to an area of already high in concentration inside the cell. For cells to do this requires them to use energy and active transport.

So in summary, cells take in organic compounds through active and passive transport and break down these compounds through fermentation yielding energy packets called adenosine triphosphophate or ATP.

This is the end of Section 6.
1. Read section 6-1, 6-2, and 6-3 on pages 139 to 142 of the old version or sections 8-1, 8-2, and 8-3 on pages 145 to 149 of the new version. Objectives 1, 2, 3, 4, 5, 6, 7, and 8.

2. Turn on your tape for an explanation. Objectives 1, 2, 3, 4, 5, 6, 7, and 8.

3. Do Investigation 6-4 or 8-A.

4. Read sections 6-5, 6-6, and 6-7 on pages 145 to 149 of the old version or sections 8-4, 8-5, and 8-6 on pages 150 to 154 of the new version. Objectives 10 and 11.

5. Turn your tape on to Section 2 for an explanation. Objectives 10 and 11.

6. Do Investigation 6-8 or handout.

7. Read Sections 6-9 and 6-10 on pages 151 to 153 of the old version or sections 8-7 and 8-8 on pages 154 to 157 of the new version. Objective 13.

8. Turn your tape on to Section 3 for an explanation. Objective 13.

9. Read Section 6-11 on pages 154 and 155 of the old version or section 8-9 on pages 158 and 159 of the new version. Objective 14.

10. Turn your tape on to Section 4. Objective 14.

11. Do the experiment on diffusion and membranes if you have the old version or 8-B.

12. Turn on your tape to Section 5. Objective 17.

13. Do Investigation 6-12 or handout 2.

14. Read sections 6-13 and 6-14 on pages 157 to 160 of the old version or sections 8-10 and 8-11 on pages 159 to 161 in the new version.

15. Turn on your tape to Section 6. Objective 16.
organic compounds form and accumulate in the ancient oceans

PROTEINS

amino acids link together into long chains to form proteins

CONSERVATISM

proteins and other organic compounds cluster together to form conservatosaurs, a non-living amoeba-like substance
The cell is highly organized and carrying on complex chemical reactions in an absolute sequence.

Compared to the disarray of organic chemicals surrounding the cell, the cell is a highly ordered sequence of chemical reactions contained by a cell membrane.
Hydrogen and oxygen has a lot of energy.

Water has little energy, much energy is released.

These molecules have little energy—light energy is put into this reaction.

Catalysts can cause molecules to come together gently and react without using a lot of heat to cause them to collide.

Catalysts in living things are enzymes.

Glucose has much more energy.
Figure F-4

\[ \text{glucose} \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} \]

all the energy is given off at once as heat.

the energy is given off a little at a time in chemical packets (ATP) that the living cells can use to carry on all their chemical reactions.
### ACTIVITY OPTIONS AND OBJECTIVES

#### LIGHT AS ENERGY FOR LIFE

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<td>AT Kit - Light as Energy for Life</td>
<td>The Student Shall:</td>
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<td></td>
<td>1. explain, according to the heterotroph hypothesis, what probably happened before the heterotrophs used up all the organic compounds in the early seas.</td>
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<td></td>
<td>2. construct a bar diagram of the solar spectrum, filling in the waves and wave lengths of solar radiation the sun gives off. Also describe what parts are harmful, and what parts are not (to living things) and why.</td>
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<td></td>
<td>3. explain what part of the solar spectrum we can see, giving the minimum wave lengths and maximum wave lengths.</td>
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<td>4. state what pigment plants use to capture solar energy.</td>
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<td></td>
<td>5. name three men who were responsible for gathering the first scientific information on photosynthesis and describe the experiments they performed.</td>
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<tr>
<td></td>
<td>6. do Investigation 7-5 and determine what substances plants must have for photosynthesis to occur and what substances plants give off.</td>
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<td>7. do Investigation 7-8 and determine what effect different amounts of light intensity has on the rate of photosynthesis.</td>
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<td>8. construct a diagram showing how photosynthesis works explaining the two main reactions and what takes place in each, including the role ATP has in each.</td>
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<td>9. do Investigation 7-14 and determine what pigments are contained in a green plant.</td>
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<td></td>
<td>10. construct a graph showing what wave lengths of the visible spectrum plants use most and the wave lengths they use least.</td>
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<td></td>
<td>11. design an experiment to test the hypothesis in #10</td>
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<tr>
<td></td>
<td>12. describe, according to the heterotroph hypothesis, what effect autotrophs had in the early ancient seas. Specifically state every consequence that would have occurred as a result of the evolution of autotrophs.</td>
</tr>
<tr>
<td></td>
<td>13. explain where our main source of oxygen is today and what effect man has on it.</td>
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<td>14. define photosynthesis.</td>
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<th>Experiments:</th>
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<td>1) Gather experimental evidence for some chemical activities of photosynthesis.</td>
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<td>7-6, 9-B</td>
<td>1) Observe evidence of chemical activity in plants related to the photosynthetic process.</td>
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<td>7-8, 9-C</td>
<td>1) Make quantitative studies of the effect of varying light intensity on the rate of photosynthesis.</td>
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<td>7-14, 9-D</td>
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Since chapter 4, we have been discussing the heterotroph hypothesis. We know that after the heterotrophs evolved into existence they used the organic compounds in the waters around them as a source of energy. But an inevitable dilemma would await them if a change would not occur in the life processes they had evolved. The heterotrophs would have continued multiplying very rapidly and would have used up the organic compounds in the oceans around them. So, the heterotrophs were rapidly using up their only source of energy, organic compounds. Look at figure L-1. According to the heterotroph hypothesis, some of the individual heterotrophs mutated for several thousand generations producing, eventually, descendents that could make their own food. What do we call organisms that can make their own food? . . . If you said autotrophs you were correct. These organisms could take sunlight for energy and assemble and store that energy with 6 CO₂'s and 6 H₂O's to make glucose, one of the most important organic compounds. Now, living things were divided into two basic categories: heterotrophs and autotrophs. Heterotrophs could now feed upon autotrophs for food and it's been that way ever since. So the evolution of autotrophs prevented life from dying off.

Before we can fully understand how autotrophs can make their own food using sunlight, we should see what sunlight is. Light from the sun represents only a small portion of the variety of energies the sun produces. The sun is made mostly of hydrogen nuclei in which nuclear fusions are taking place. In this reaction four hydrogen nuclei fuse together to form a helium nucleus. In this reaction some of the mass is converted into energy. The energy that is given off is composed of several types as you see in figure 7-1 on page 165 of the old version or figure 9-1 on page 163 of the new version. We know that energy travels in waves and that these waves can be measured. Look at the bottom of figure L-1. Different types of energy have different wave lengths. Since many of these waves are very small, we have to measure them in a unit called angstrom. An angstrom is 1/10 000,000 of a meter or 1/10 of a micron. You will see that the smallest wave ranging in length of up to 1A are gamma rays. The shorter the wave, the more energy it has. Gamma rays are extremely high in energy and extremely deadly if exposed to a living thing. Waves that are one to 1000A long are x-rays again which are high in energy and very dangerous. Waves from 1000A to 3800A are ultra-violet which are high in energy but not necessarily deadly. These are the unseen waves that can give us sunburns. It was probably this kind of wave that caused organic compounds to form before life began. To this point, these waves are not visible to the human eye. The next group of waves can be seen by the human eye and we call it visible light. 3800 to 4300 is violet, 4300 to 5000 is blue, 5000 to 5600 is green, 5600 to 6000 is yellow, 6000 to 6500 is
orange and 6500 to 7500 is red. So the spectrum goes from the shortest to the longest wave lengths: violet, blue, green, yellow, orange, and red. After this we again cannot see the waves and they get very long and low in energy. From 7500 A to one meter is infrared or heat. After that we have radio waves on which we transmit radio and t.v. programs and short wave, etc. The earth’s atmosphere filters out the shortest and most harmful waves. If this were not so, life could not exist on earth as we know it. Plants have a pigment called chlorophyll that can absorb light energy and change it to chemical energy.

This is the end of Section 1 and Objectives 1-4.

This is the Beginning of Section 2

Look at figure L-2. You can see now that carbon dioxide and water were found to be essential for photosynthesis. You can also see that without light, photosynthesis is impossible. Ingenhousz noticed that the plant gave off oxygen and kept the carbon. Later discoveries showed that the plant used this carbon to make organic products, or carbohydrates. These are food for the plant. We can summarize the equation simply by saying that carbon dioxide and water are used by the plant together with the energy from light to make carbohydrates and give off oxygen. Glucose: \(C_6H_{12}O_6\) is the product of photosynthesis.

The last equation in your guide: \(6 CO_2 + 6 H_2O \rightarrow C_6H_{12}O_6 + 6O_2\) is a more precise way of expressing photosynthesis and is preferred because it gives a better picture of photosynthesis. It is chemically correct. It is also balanced. This formula can be re-stated as follows:

Six molecules of carbon dioxide and six molecules of water are used by the plant together with the energy from light. The plant then produces one molecule of glucose as a building block from which it can make other carbohydrates, amino acids, proteins, fats and vitamins. Animals and man get the materials from plants to make the needed organic compounds. These give energy to keep organisms alive.

This is the End of Section 2.

This is the Beginning of Section 3

Read Investigation 7-5 on page 168 of the old version or Investigation 9-A in the new version. TURN TAPE OFF. You are now ready to begin investigation 7-5 or 9-A.

Look at questions 1 to 4 on designing an experiment on page 168 or 568. . . pause.
Read: Question 2 . . . pause . . . light is the answer because it can be easily handled, if you want to start or stop the process, you simply turn the light on or off.

Read: Question 3 . . . pause . . . if you said an indicator, you are correct. What is a good indicator for CO\textsubscript{2}? . . . pause . . . if you said bromthymol blue, you are correct.

Read: Question 4 . . . pause . . . if you said indicators again, you are right we can test leaves for the presence of glucose or starch.

You will do part A of Investigation 7-5. It is indicated in your book on page 169. You will have to think awhile to do procedure 3. If you have problems designing an experiment see your instructor or talk it over with your lab partners.

Parts B and C will also take some thinking. If you can design some good experiments you will be doing well. You should give it a try.

Record your findings in your data book. Draw a table like the one in figure L-3. It should be extended to fit all the test tubes you use for part A, B, C. A sample is given in your guide.

After you have obtained your results and recorded them on the table, you should answer the discussion questions on page 169 and 170 or 569 in your data book. Good luck! **TURN TAPE OFF.**

This is the End of Section 3.

This is the Beginning of Section 4

Turn your textbook to page 170: You should now be ready to do Investigation 7-6 - Investigating production of a carbohydrate by plants. You will be responsible for part A only. Read the experiment over carefully - **TURN TAPE OFF.**

Turn your textbook to page 170 . . . pause . . .

Part A. Can a plant produce starch without first carrying on photosynthesis? . . . You see the list of materials needed. Be sure that you have a way to keep the leaves from the plant in the dark from getting mixed up with the leaves from the plant in the light. You might cut a pointed notch on the edge or a block notch to tell the difference. See figure L-4. When you boil the leaf in the alcohol, be careful not to boil the alcohol over the fire; the beaker with the alcohol should remain in the water bath.

For recording your data, you might make a table in which you can describe the result of the iodine test for each leaf. See figure L-4.

Answer the discussion questions on page 171 in your data book. **TURN TAPE OFF, please.**

This is the End of Section 4.
One of the most important questions about photosynthesis is: What happens to the light energy that plants absorb during photosynthesis? The law of the conservation of energy states that energy cannot be created or destroyed; it can only be changed from one form to another. Therefore, we know the plant is not making energy. In photosynthesis, the water and carbon dioxide do not account for all the energy of glucose. The extra energy comes from the light. The plant is capable of changing light energy into chemical energy.

Man and animals cannot use the sun's energy directly, they get the energy through the plants. Plants are the only organisms that can change light energy into chemical energy. Plants use the energy of light to reshuffle the atoms of water and carbon dioxide. Look at figure L-5. This results in new molecules that are rich in chemical energy. This chemical is found in the bonds holding the atoms of the new organic molecules. These organic molecules are used as food by man, animals, and plants. They supply the energy needs of all living things.

We are still trying to answer the question: What happens to the light energy? To give a correct answer we must also ask the question: How is light energy changed into chemical energy? Look at figure 7-4 on page 172 of the old version or figure 9-4 on page 169 of the new version... Let the box with the question mark represent a leaf that has chlorophyll and is green. Light, water, and carbon dioxide are being taken into the leaf. Something happens in the leaf. This is what we want to answer. The products of whatever happens inside the leaf are oxygen and sugar as shown at the bottom of the box. We want to remove that big question mark. We want to know what happens in the leaf.

In 1905 an Englishman named F. F. Blackman decided to see if the rate of photosynthesis increases when the amount of light on a plant is increased. His results are seen on page 173 figure 7-5 of the old version textbook. Find page 173... The curve on the graph at the top shows that when the intensity of light is low and then is increased, the rate of photosynthesis goes up. He noticed that at a certain high light intensity, the rate did not increased.

Blackman next, wanted to know the effect of temperature and light on the rate of photosynthesis. See figure 7-6 on page 173 of your textbook. Find it... He found that between the temperatures of 30°C and 40°C, if you increased the temperature, the rate of photosynthesis went down. He also discovered that at low light intensity between 0°C and 30°C, if you increased the temperature, there was no change in the rate of photosynthesis. If, on the other hand, at high light intensity, an increase in temperature speeded up the rate of photosynthesis.
These results indicated that there might be two kinds of reaction going on in the leaf. First, a chemical reaction that does not need the energy of light. Secondly, a light reaction that has to have light to give it energy. Chemical reactions increase when temperature increases. Light reactions are not changed by temperature.

From this experiment, Blackman assumed that there is a chemical reaction that can take place without light. It is called the dark reaction and he assumed another reaction that has to have light. If you have the new version look at figure 9-6. It is called the light reaction. Photosynthesis has two reactions. The dark reaction that does not need light; and the light reaction that can take place only in light.

We are now ready to perform an experiment to show the importance of light in photosynthesis. You will receive a sheet that has investigation 7-8 or 9-6 in a modified form. Read over the investigation and then listen to the special directions. 

This is the End of Section 5.

This is the Beginning of Section 6

This investigation is interesting and very informative.

Setting up the apparatus is tricky. A sample apparatus will be set up in the lab. Use it as a model. Pay special attention to the following details. Look at figure L-6.

1. Do not close the clamp until you start the experiment. After you close the clamp check the level of the liquid in the manometer. This is your starting point.
2. Place the front edge of the light box on the 20 cm mark of the meter stick. Do this for each distance.
3. Use your lab partners well. One can record the changes in pressure on the manometer. Another can keep time and indicate the minutes. Still another can check the temperature of the water in the beaker. He should regulate temperature by adding pieces of ice and stirring the water.
4. After each distance, turn off the light, gently remove the clamp so that the liquid in the manometer returns to normal.
5. Leave the manometer in place. It can break easily. Do not remove the rubber tubing that connects the manometer to the glass tube of the rubber stopper.
6. Be sure you do numbers 5 and 6 on page 175. These graphs can serve as your recorded data. These can go in your data books.

You should now proceed with the investigation. It may take more than one period.
Light as Energy for Life

Record your water temperature and level of liquid in the manometer if you should have to finish at another period. . .

TURN TAPE OFF.

This is the end of Section 6.

This is the Beginning of Section 7

We shall continue our discussion on photosynthesis.

We know that glucose, which has C, H, and O in it is a product of photosynthesis. We also know that oxygen is given off. If a plant takes in CO₂ and H₂O, then we can reason that the CO₂ and H₂O must be broken up in order that glucose and oxygen may be given as products.

Early scientists felt that light broke up the CO₂ into C and O and that the carbon combined with water to form a simple carbohydrate. This simple carbohydrate was then believed to be a building block for more complex carbohydrates such as glucose or starch.

In the 1930's Van Niel of Stanford University came up with a different hypothesis. He worked with bacteria which carry on photosynthesis but do not give oxygen. These bacteria use hydrogen sulfide (H₂S) instead of water in making carbohydrates from carbon dioxide. Sulfur is the by-product. Van Niel compared the equation for plant photosynthesis with his equation for bacterial photosynthesis. He came up with some interesting conclusions. Look at figure L-7.

The top formula is for bacterial photosynthesis and the bottom is for plant photosynthesis. Both equations start with carbon dioxide. Plants have to have water, but bacteria use hydrogen sulfide. Van Niel noticed that in bacteria, sulfur is given off. This is represented by 2S. It could only come from the hydrogen sulfide or H₂S. Therefore light energy splits the hydrogen sulfide to release the sulfur and not the carbon dioxide. He looked at the formula for plant photosynthesis and saw that the water is in the same place as hydrogen sulfide. He also saw that the oxygen given off is in the same place as sulfur. He then assumed that light not only splits the hydrogen sulfide in bacterial photosynthesis but also the water in plant photosynthesis. He assumed that this takes place in the light reaction of photosynthesis. He concluded that the light reaction is the same in bacterial and plant photosynthesis.

When water is split in the light reaction in plants, the oxygen is given off and the hydrogen is transferred to the carbon dioxide. Water is called the hydrogen donor and the CO₂ the hydrogen acceptor.

Now look at figure 7-10 on page 178 of the old version or figure 9-6 on page 171 of the new version. The picture of photosynthesis becomes clearer. Can you look at the box and determine the following:
1. How many types of reactions does photosynthesis have? . . . pause. . . If you said 2, you are correct.

Now let me ask you another question:
1. Name the two types of reactions. . . pause. . . you should have said the light reaction and the dark reaction.

Keep your eyes on the figure and see if you can answer the following:
1. What important action occurs in the light reaction? . . . pause. . . The answer is that water is split into oxygen and hydrogen.
2. What action takes place in the dark reaction? . . . pause. . . The answer is that in the dark reaction several steps take place in which hydrogen, carbon dioxide are converted into sugar or glucose.

Here are 2 tricky questions. Think hard and see if you can come up with the answer:
1. Where does the energy to decompose water in the light reaction come from? . . . pause. . . It comes from the light.
2. Where does the energy for the production of sugar in the dark reaction come from? . . . pause. . . this is tricky at this time, but if you said it comes from chemicals, you're a very good student. . . . if you were more precise and said the energy comes from A.T.P., then you are a superb or a super-student. . . . congratulations!

It has taken many years of hard work to understand the various steps in photosynthesis. In recent years scientists have used modern techniques to study photosynthesis. The dark phase of photosynthesis has always been difficult. Here is an example of how one scientist studied the dark phase. Melvin Calvin at the University of California at Berkeley wanted to study how CO₂ is converted into sugar in the dark phase of photosynthesis.

One of the tools biologists use is a form of carbon called carbon 14. Ordinary carbon has a total of 12 protons and neutrons (six of each) in the nucleus of the atom. Carbon 14 has 6 protons and 8 neutrons. This makes the atom unstable. We say carbon 14 is radioactive. Since carbon 14 is radioactive, scientists can detect it in a substance by using a geiger counter. Radioactive carbon is used to make radioactive CO₂. Radioactive CO₂ is put into a transparent chamber that also contains a living plant. The light can get through the transparent chamber and the plant can carry out photosynthesis. Look at the diagram in your guide. At different time intervals parts of the plant were removed, chopped up, and the different molecules were separated. In the early stages they found that C14 was present in a 3 C compound called phosphoglyceric acid. We say simply PGA. At a later stage the carbon 14
was found in glucose or sugar. It is believed that PGA is a middle product on its way to become glucose. This was an important contribution by Melvin Calvin. He discovered that the CO₂'s were being converted into a 3 carbon compound and then to glucose.

With the discovery of Melvin Calvin as a background let us go on. We can now attempt to explain photosynthesis step by step.

In your packet, you will find a large transparency with 3 overlays. Get it please. . . pause. . . This is figure L-9.

Lift the 3 overlays. Look at the first dittoed page. It is called the raw materials and products of photosynthesis. Now listen carefully to the explanation.

The large box represents a leaf or the green part of a plant in which photosynthesis takes place. The area on the left represents the light phase of photosynthesis. This can take place only in light. The light supplies the necessary energy. The activities of the light phase depend on light energy. The area on the right represents the dark phase of photosynthesis. This phase can occur anytime as long as there is CO₂ and energy. On top of the box, or outside the leaf, we show the sun as the source of light energy. Actually, any source of white light can be useful. Have you noticed how many green houses in the San Fernando Valley have electric lights on at night? These are useful when one wants to speed up the growth of a plant. Easter lilies bloom in nature during July. Florists need them for the Easter season several months earlier. The electric light gives a plant 24 house of light in which to photosynthesize and grow. The result is that you make the plant develop much earlier.

At the top you also see that water is an essential raw material. This is used during the light phase. Over to the right you will see that carbon dioxide is also an essential ingredient. The gas comes from the environment. It is a by-product of the respiration of all living things. The CO₂ is converted into glucose or sugar in the dark phase.

At the bottom of the box, you will notice the oxygen is being given off as a by-product of photosynthesis. If you now look over toward the right, you will see that the product of the dark phase is glucose. This glucose can then be converted to other carbohydrates such as starch. It can also be converted into proteins, amino acids, fats and so forth. Turn off the tape and try quiz #1.

In summary, light splits water and oxygen gas comes off. The CO₂'s are made into sugar. It takes six CO₂'s to make one glucose molecule.

We can now go on with overlay number 2. Flip it over on top of number 1 . . . pause . . . We are going to discuss some of the things that happen during the light phase. This is shown in green.
One of the activities of the light phase is to make ATP. ATP is full of activation energy. The plant needs this energy to make food. ATP can be made in 2 ways in the plant. One way is called cyclic. You will see that rays of light energy strike the green surface of the plant. The green surface is made of a chemical substance called chlorophyll. The chlorophyll is found in little bundles called chloroplasts. I have shown only one chloroplast to make the explanation clear. Chlorophyll like any substance is made up of molecules. The molecules are made up of atoms. When light strikes the molecules of chlorophyll, the chlorophyll absorbs the light energy and becomes excited. In this energized state, electrons from the atoms of the chlorophyll jump out. The curvy arrow indicates an energy path. They have become energized. An electron is indicated by the letter e with an energy halo around it. The chlorophyll is therefore very important. In 1937, an Englishman by the name of Robert Hill was able to isolate some chloroplasts. He put them in a liquid with some iron in it. He shined light on them. The chloroplasts began to give off bubbles of oxygen. If he could have examined the chloroplasts further, he probably would have discovered some molecules with stored chemical energy. It was evident to Hill that some phase of photosynthesis occurs in the chloroplasts if light is present. A protein substance with iron atoms called ferredoxin, picks up these energized electrons. Ferredoxin is found in the leaves of most plants. It directs the electron from one substance to another. Everytime the electron is transferred from one substance to another, it gives off some of its energy. Ferredoxin is indicated on the overlay by the box with the letters Fd inside. The green curvy arrow leaves the ferredoxin. This indicates that some of the energy of the excited electron is used to convert ADP to ATP by attaching a phosphate group to the ADP. It is at this point that the energy from light has been converted into chemical energy. The addition of the phosphate group to ADP represents energy. If the phosphate group is removed from ATP, energy will be given off. Finally, notice that the electron has given off its energy and returns to the chloroplast. It has made a complete turn. It has completed a cycle. In the course of its cycle it has supplied the energy for ADP to become ATP. ATP will become a source of energy for the dark phase of photosynthesis.

Let us now explain the last part of the light phase. Flip the third overlay over and on top of number 2 . . . pause . . . The third overlay deals with another type of ATP formation. This is called noncyclic because the electron does not return to make more ATP. This cycle is also an energy-conversion cycle. This overlay can be followed easily because it is in red.

Look over at the chloroplast. This is happening at thousands and thousands of chloroplasts. We will look at one only; for the sake of simplicity. This cycle also begins with the absorption of light energy by chlorophyll. Notice an electron being given off by the excited chlorophyll. The electron with its energy is absorbed by the
ferredoxin. Follow the red curvy energy arrow. Some of the energy of the electron is used to convert 2 molecules of ADP into ATP. Some of the energy is also used to break up water. The water split up into hydroxyl and hydrogen groups. Some of the hydroxyl group bind with others to make water. Some of them produce oxygen and leave an oxygen gas. The hydrogen atoms are picked up by a molecule called TPN or NADP. This is a hydrogen carrier. TPN stands for triphosphopyridine nucleotide and NADP stands for nicotinide adenosine dinucleotide phosphate. Both of these are the same chemical but the name has been changed from TPN to NADP. The molecule accepts the hydrogen and makes it available for the production of sugar. You will see that we show hydrogen attached to NADP by NADPH. Several ATP's and NADPH's are needed for the making of sugar. The plant has to come up with all the ATP and NADPH's that it needs. This now completes the light phase.

In review, light energy has now been changed to chemical energy in the form of ATP's and NADPH's. The hydrogens on NADP have come from water and contain highly energized electrons from chlorophyll. This is how light energy is changed into chemical energy.

We should be ready to explain overlay number 4. This is not too complicated. You should listen carefully. I will ask you some questions at the end. Are you ready?

Flip over the last overlay. This is number 4. It is in purple. It is called the carbon cycle. It is also called the dark phase of photosynthesis.

Let us begin at the right hand side. You see there a box with 5C on it. This is a molecule that has 5 carbon atoms in it. It has a phosphate attached to it. This molecule is called ribulose phosphate or RP. It does not have the energy required to perform its task. Follow the arrow and you see that it acquires another phosphate from ATP. Remember that this ATP was formed in the light phase. The 5 carbon molecule, ribulose phosphate, now has 2 phosphate groups attached to it. We now call it RDP or ribulose di-phosphate. "Di" is a latin pre-fix which means 2, or 2 phosphates. This 5 carbon molecule now has sufficient energy to do its work. Follow the arrow. You can see that the 5C molecule is a CO₂ acceptor. It takes the carbon dioxide and becomes a 6 carbon molecule. This is indicated by the box with the 6C on it.

This new molecule with 6 carbons is too large, clumsy and unstable. It splits into 2 equal parts. Each is shown by a box with 3C on it. Each small molecule has 3 carbon atoms and a phosphate. As you follow the arrows you will see that each 3 carbon molecule now gets an extra phosphate from ATP. This ATP was also formed in the light phase. Each 3 carbon molecule now has 2 phosphates attached. This means each has more energy. This energy enables several steps to occur. It is during these steps that the hydrogens from NADPH₂ is incorporated into the carbon
cycle to make simple sugars. Dotted lines in your diagram show that NADPH₂ is being incorporated. Some simple sugars are converted into glucose. Some of the glucose is converted into proteins, fats and so on as indicated by the arrows showing the products of the dark phase. Notice that an arrow continues from the simple sugars to our starting point. What does this mean? This means that not all simple sugars become glucose or the other products. Through a series of steps, some of the simple sugars are converted into 5 carbon molecules. We referred to these earlier as ribulose phosphate. RP molecules are again attached to more phosphates. They continue on to accept carbon dioxide. The cycle continues on and on.

You will notice by now that it takes 6 CO₂'s to make one molecule of glucose and that it takes six waters to make one molecule of glucose. For that reason, I wrote those numbers in on the transparencies. For 6 waters we get a total of 18 ATP's glucerated and 12 NADPH₂'s.

This then is the dark phase.
This is the end of Section 7.

You can now proceed with Investigation 7-14. Investigating chlorophyll pigments. This is on page 187 of the old version or 9-D page 572 of the new version. Take time out to read the investigation and then I will proceed with some directions. TAPE OFF.

In this investigation we shall use fresh spinach leaves. Some of you may bring grass blades, geranium leaves, pine needles or whatever plant you wish. You can make chromatograms of the various leaves you bring in. Look at #5 on figure L-10.

What you will do basically in this investigation is to extract the chlorophyll from leaves. Apply tiny drops of this pigment on a strip of special paper. This paper is then suspended inside a large test tube. In the bottom of this test tube is a solvent that touches only the tip of the paper strip. The pigment drops are above the level of the solvent. As the solvent is absorbed by the paper it begins to move up. When the solvent comes in contact with the pigment, the pigment is broken down into its various molecules. The molecules are carried upward by the solvent. The molecules separate according to their kind. By the time the solvent has reached the top of the strip of paper, the various molecules of pigment have separated and you can see them by their bands of color.

You will find the steps for this procedure here in figure L-10.
This is the end of Section 8.
We learn that chlorophyll is not activated by light in general. We can explain this in the following way. If we take a beam of light and pass it through a glass prism, we discover that the light is made up of different colors of light. Each color has a different wavelength. Each wavelength also represents a given amount of energy. The question is which of these colors are the ones that activate chlorophyll the most? Another way of stating this is: which wavelengths of light does chlorophyll absorb and which does it reflect? Those wavelengths that are reflected hardly excite the chlorophyll. Those wavelengths that are absorbed do activate the chlorophyll. We are now prompted to ask the question: What wavelengths are absorbed by chlorophyll? To answer this question, we should consider an important experiment.

In 1882, Theodore Engelmann showed that photosynthesis depends on certain wavelengths of light that are absorbed by chlorophyll. This is what he did. Engelmann knew that one can measure the rate of photosynthesis by the amount of oxygen gas given off. If you remember, you did this in investigation 7-8 or 9-C. Look at figure L-11. He took a prism to break up a beam of light. He obtained the spectrum with the colors violet, blue, green, yellow, red, and orange. He used a long strand of algae as the plant to carry on photosynthesis. When algae photosynthesizes it will give off oxygen. To measure how much oxygen was given off he used special bacteria that thrive on oxygen. He reasoned that more bacteria would live where there was more oxygen. It would follow that there would be more oxygen where the greatest rate of photosynthesis occurred. Engelmann illuminated the test tube with the long strand of algae in it. He illuminated it in such a way as to allow the different colors of the spectrum to fall on different parts of the algae. His results were startling. He found the greatest cluster of bacteria gathered where red light was shining on the strand of algae. The second largest cluster was found on the part of the algae illuminated by the violet light. Between the violet and red light, few bacteria were observed. Since Engelmann's bacteria concentrated where oxygen production by photosynthesis was greatest, the experiment showed that the rate of photosynthesis was greatest in red and violet light. Other experiments have shown that the greatest rate of photosynthesis occurs on the two opposite ends of the spectrum, that is, the violet-blue end and the red end. Look at figure 7-19 on page 189 of the old version or figure 9-13 on page 178 of the new version... pause. If we made a graphic picture of Engelmann's experiment, it would look like that. The middle part indicates the colors of the spectrum. The blue graph curve at the bottom shows what amounts of light from the spectrum were absorbed by the algae chlorophyll. Notice that more violet and red...
STUDY GUIDE
LIGHT AS ENERGY FOR LIFE

1. Read sections 7-1, 7-2, and 7-3 on pages 163 to 166 of the old version or sections 9-1 and 9-2 on pages 163 and 164 of the new version. Objectives 1, 2, 3, and 4.
2. Turn on your tape for an explanation. Objectives 1, 2, 3, and 4.
3. Read section 7-4 on pages 166 to 167 of the old version or section 9-3 on pages 166 to 168 of the new version. Objective 5.
4. Turn on your tape to section 2.
5. Read over Investigation 7-5 or 9-A.
6. Turn on your tape to section 3 for an explanation.
7. Do Investigation 7-5.
8. Read over Investigation 7-6 or 9-B.
9. Turn on your tape to section 4. (in old version)
10. Do Investigation 7-6 or 9-B.
11. Read section 7-7 on pages 172 and 173 of the old version or section 9-4 on pages 168 to 169 of the new version.
12. Read over the handout for Investigation 7-8 or 9-C.
13. Turn on tape to section 6 for an explanation.
14. Do Investigation 7-8 or 9-C.
15. Read section 7-9 on 176 to 178 of the old version or section 9-5 on pages 169 to 172 of the new version.
16. Turn on your tape to section 7. Objective 8.
17. While listening to section 7 look and study Figure L-9 (transparency) and take quizzes 1 to 3 when instructed.
18. Read over Investigation 7-14 in old version or 9-D in the new version.
19. Turn on your tape to section 8 for an explanation.
20. Do Investigation 7-14 or 9-D.
21. Read sections 7-15 and 7-16 on pages 188 to 191 of the old version or sections 9-10 and 9-11 on pages 177 to 180 of the new version. Objectives 10, 11, 12, 13, 14
22. Turn on tape to section 9 for explanation. Objectives 10, 11, 12, 13, 14
Discussion of equations from section 7.
1. Do not close the clamp until you check the accuracy of your reading. Always check the level of the liquid in the reservoir. This is your starting point.

2. Close both clamps on the clamp arm. Place the sample on the holder. In this case, each distance.

3. For your left position, close the clamp on the holder, and check the accuracy of your reading. Another way to check is to adjust the sample. Still another way to check is by adjusting the sample. For each distance, the sample.

4. After each distance, turn off the light, gently remove the clamp or hook the clamp in the reservoir, and remove the sample.

5. Place the reservoir in place. If you have a sample, it can be removed. The reservoir can be replaced. Remove the sample. For each distance, the sample.

6. Do you do exercises 5 and 6 on page 17? These people should review your recorded data. These are to be your tools today.
CO₂ + 2H₂S → (CH₂O) + 2S + H₂O

CO₂ + 2H₂O → (CH₂O) + O₂ + H₂O
When soil is added to the rich with radioactive CO$_2$, radioactive Mg is produced. The Mg enters the sap in containers with the plants. The Mg will now begin to be incorporated through a series of steps to make glucose.
An equation on paper to fill into hole as seen in diagram.

- Wheel
- Boom
- Small rock

Place test in test tube with one side being pushed down in paper to hold it in place.
LIGHT AS ENERGY FOR LIFE

Quiz # 1

Try not to look at the transparency. See if you can answer these questions:

1. What are the two phases of photosynthesis?

2. Glucose is the product of what phase?

3. What phase needs CO₂ from the environment?

4. Oxygen is given off during what phase?

5. The light phase can take place only when

6. In what phase is water used?

If you feel that you did not get most of the questions correct, rewind the tape. Go over them again. This time you might look at the transparency.
LIGHT AS ENERGY FOR LIFE

Quiz # 2

1. When chlorophyll absorbs light energy, the molecules become so energized that they give off ____________.

2. ADP is converted into ATP when an extra ____________ is attached to it.

3. The iron chemical that absorbs excited electrons from the chlorophyll is ____________.

4. Some of the energy of excited electrons is used by NADP to grab ____________ atoms.

5. Some of the ____________ of electrons is used by ADP to attach a phosphate to become ATP ____________.

6. In the light phase, water is split into ____________ and ____________ ions.

7. The whole purpose of the light phase is to convert ____________ energy into ____________ energy.

If you had trouble answering these, you should turn the tape back. Listen again to the explanation of the light phase and try to answer the questions.
LIGHT AS ENERGY FOR LIFE

Quiz # 3

1. The extra phosphate that the 5c molecule gets comes from the ________________ phase.

2. When the 5 carbon molecule has 2 phosphate groups it is ready to accept the ________________

3. The 6 carbon molecule is too large and unstable. It splits into ________________ parts. Each part has ______ carbon atoms.

4. Each small 3 carbon molecule accepts another phosphate from the ATP. This was formed in the ________________ phase.

5. NADP supplies the ________________ that is needed to make simple sugars. The hydrogen of NADPH₂ came from the ________________ that was split in the light phase.

6. Not all simple sugars are converted into glucose. Some continue in the cycle and become ______ carbon molecules which accept carbon dioxide and continue the cycle.

Hope you got most of them. If you did not, turn the tape back. Go over the material once more and try the questions. If you have problems understanding the discussion, see the instructor.
# ACTIVITY OPTIONS AND OBJECTIVES
## LIFE WITH OXYGEN

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<td>Life With Oxygen</td>
<td>1. explain what took place in the atmosphere as oxygen accumulated.</td>
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<td></td>
<td>2. explain what new kind of heterotroph evolved as a result of the presence of oxygen.</td>
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<td>3. define respiration.</td>
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<td>4. construct a diagram comparing fermentation with respiration.</td>
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<td>5. make a diagram comparing photosynthesis with respiration.</td>
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<td>6. do Investigation 8-3 graphing the results and answering the discussion questions determining which process, fermentation or respiration, yields more energy.</td>
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<td>7. draw a flow diagram illustrating and explaining the carbon and hydrogen pathways of respiration.</td>
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<td>8. do Investigation 8-6 and determine how energy is released outside of living things (from a molecule of glucose).</td>
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<td>9. explain where or in what organelle in the cell respiration takes place.</td>
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<td>10. make a diagram illustrating the heterotroph hypothesis including everything that has been discussed to this point.</td>
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**YOU MUST DO 11 OBJECTIVES AND 2 EXPERIMENTS.**
I bid you W-E-L-G-O-M-E my friend. You are about to take a trip with me, back into time. We will go back 3 billion years ago when there was no life on earth. (Here we go)

(Cough, cough - There is no oxygen here - Let's put on our oxygen masks) The earth's seas are hot and steamy and the earth's land is a mass of volcanic activity: bubbling, boiling rock, volcanoes spewing tons of gases into the atmosphere. Probably all of the gases in the atmosphere came from these volcanoes.

Let's analyze the gases. (Turn to page 210 of the old version or 194 of the new version and you can see the diagrams). These primitive gases are hydrogen, water, carbon dioxide, carbon monoxide, nitrogen, a little methane, and ammonia. Look! at the lightning, it's striking all around, and the ultra violet light is cooking our skin! Let's put on our protective suits! The ultra violet light is causing our gases to smash into one another. They are sticking together in large molecules, organic molecules because they all have a carbon skeleton. Look! complex proteins are being made and they are beginning to stick together in globs, like... almost like cells or may pre-cells. They are beginning to take on all kinds of highly organized chemical activities. Enzymes are breaking down organic compounds to release energy for these pre-cells to function. But there is no oxygen! This must be fermentation, breaking down organic compounds to get energy without oxygen.

These primitive cells are multiplying so rapidly. They're everywhere! Pretty soon they are going to use up all of the organic compounds that have accumulated for the last billion years. Without organic compounds for energy, these primitive cells will all die and life will end before it has barely begun. But look! Some of the cells are developing a green pigment. Why they are photosynthesizing, take CO₂, H₂O, and sunlight and making their own organic compounds.

UNBELIEVABLE! They are also giving off a gas... Why it's oxygen! The oxygen gas is accumulating in the atmosphere now. Look, all kinds of living things are developing in the ocean: an infinite number of one celled animals and plants, sponges, jelly fish, sea anemones, tribolites, crabs, octopus, squid, sand worms, sea snails, star fish, sea weed. Look, fish are starting to develop! Look at the fish, they are all over the place; billions of fish. Pause.

Since all these animals and plants are in the water, they are protected from the dangerous ultra violet light on the surface above. Also with oxygen now in the water, all but the most primitive one celled organisms are using oxygen and breaking down organic compounds all the way to CO₂ and H₂O to get all the energy, not just some as in fermentation, but all of the energy out of the organic compounds. Pause...
Look! There is so much oxygen in the atmosphere now it is shielding the harmful ultra violet rays. The oxygen layer is absorbing all the dangerous rays. Some of the fish have adapted their fins to legs and are coming out of the water onto land. Now everything seems to be quite clear. Let's go back to our own time, now, and review everything we have learned about this primitive earth.

TURN THE TAPE RECORDER OFF AND DO THE PROGRAM IN YOUR STUDY GUIDE.

This is the End of Section 1.

This is the Beginning of Section 2

Prior to photosynthesis and the accumulation of oxygen in the earth's atmosphere, organisms had to break down organic compounds without oxygen, a process called fermentation. Look at figure 8-1 on page 196 of the old version or 10-1 on page 184 of the new version. You can see that when there is no oxygen present, fermentation yields 2 ATP's and breaks glucose down to 2 pyruvic acid molecules. But when there is oxygen present, the process of respiration yields 38 ATP's and breaks glucose all the way down to $6 \text{CO}_2$ and $6 \text{H}_2\text{O}$. You can see that you get 19 times more energy with respiration that you do with fermentation. Look at the bottom right hand page of 196 or the top right hand page of 184. Learn this definition for respiration. Let's read it together: Respiration is the process in which oxygen is used by living cells to release the chemical energy that is stored in foodstuffs. Let me ask you a couple questions and see if you can come up with the right answers.

What process is more efficient, respiration or fermentation? Pause... If you said respiration you were correct. Why is respiration more efficient than fermentation? Pause... If you said that respiration releases all of the energy in organic compounds while fermentation releases only a small portion of that energy, you were correct.

Now look at figure 8-2 on page 197 of the old version or 10-2 on page 185 of the new version. You can see here that the process of photosynthesis gives off oxygen and organic compounds or food. Respiration breaks down food with the aid of oxygen and gives off carbon dioxide and water as well as energy in the form of ATP's. Although energy flows from the sun to plants to other living things and finally dissipates, carbon dioxide and water flow in a circle or cycle. Photosynthesis takes in $\text{CO}_2$ and $\text{H}_2\text{O}$ and forms them into large organic molecules. Respiration breaks those large molecules right back down to $\text{CO}_2$ and $\text{H}_2\text{O}$ and the cycle starts all over again. So any given $\text{CO}_2$ molecule or gaseous $\text{H}_2\text{O}$ molecule has probably been part of a plant or animal at one time or maybe many times. It has been said that all of us have at least six carbon atoms of Julius Caesar in us.
So by comparing the overall equations of photosynthesis and respiration, you can see that one is just the reverse of the other. Now turn the tape recorder off and read over Investigation 8-3 in the old version or 10-A in the new version. Then turn the tape back on.

This is the end of Section 2.

This is the Beginning of Section 3

You will write this lab up the same way you write all your labs with a title, purpose, data, and discussion questions. For this lab, your data will be the graph.

As you already know, some organisms can live without air by fermentation. Name some that you have dealt with. Pause... remember back to Investigation 6-8 when the yeast was sealed up in a thermos bottle. There are many kinds of bacteria that can live with or without air. Aerofacter aerogenes is one such bacterium. If it is in an environment lacking in oxygen it will ferment. If it has oxygen, it will undergo respiration to get much more energy to grow and multiply much faster.

Let's look at table 8-1 in the old version or table 10-A-1 on page 575 of the new version. In the left hand column we can see that there are different concentrations of glucose. At the top of this column, you can see 18 milligrams of glucose has been added for every 100 milliliters of water. At the bottom of the column, 540 mg has been added for every 100 ml of water. Now let's look at the columns to the right of the first column. You see in the very next column, tube #1's 1A to 9A. All the bacteria in these tubes were deprived of oxygen. You can see that tube 1A, which has 18 mg of glucose/100 ml, has 50 million bacteria for every ml of water. Tube 9A, which has 540 mg glucose/100 ml, has 670 million bacteria for every ml. This is only logical. Since tube 9A has more sugar, therefore, more energy, it should have more bacteria. Now, let's look at the column that has the B tubes in it. Tube 1B which has 18 mg glucose/100 ml, the same as tube 1A, has 200 million bacteria/ml H₂, or 4 times the number in tube 1A. Keep in mind, the B tubes had a supply of oxygen. Why do you suppose tube 1B had four times more bacteria that tube 1A... pause. If you said tube 1B had oxygen, therefore it could undergo respiration and break glucose down to get much more energy, you were correct. Pause...

To get a visual idea of the different of series B and A, it is a good idea to graph. Let's look at the transparent overlay - figure R-1. To give you an idea of how to graph I have constructed a graph that you might use for this experiment, BUT FROM NOW ON YOU WILL HAVE TO CONSTRUCT YOUR OWN GRAPHS. This graph has twelve blocks to a side for a total of 144 blocks. Looking at table 8-1, I see that the concentrations range from 18 to 540 mg/100 ml. If I let each block represent 50 mg/ml with 12 blocks I will have a total range of 0 to 600 mg/100ml. Now flip the overlay on top of the graph. The books say to let the vertical left hand side of
the graph represent the "millions of cells per ml" and the horizontal axis as "glucose (mg/100 ml)." You can see this on the graph I have constructed. Now, I have decided to let each block = 200 million. You are going to have two sets of dots on this graph, one for series A and one for series B. I have decided to let blue dots and a blue line represent series A, and green dots and a green line represent series B. Now look at tube 1A. What is the concentration of glucose? . . . . If you said 18 mg/100 ml of H₂O you were correct. How many million bacteria for each ml in tube 1A? . . . . If you said 50, you were correct. Now look on your graph and approximate where 18 is along the horizontal axis. Also approximate where 50 is along the vertical axis. Put a dot where these 2 lines intersect, as I have done on your transparency. Now do the same for tubes 2A to 9A. After you have done this draw a line, as smoothly as you can through all nine dots. This is your graph for series A. Then do the same for tubes 1B to 5B. Turn your tape recorder off and write up this lab, constructing your own graph. Answer all discussion questions. If you have difficulty see one of the instructors.

This is the end of Section 3.

This is the Beginning of Section 4

As you now know, respiration breaks down organic compounds, to get energy, with oxygen. To this point we have said nothing of how this is done. Glucose is the main organic compound we will deal with here. Breaking glucose down to carbon dioxide and water requires many chemical reactions with an enzyme catalyzing, or causing each reaction. Look at figure R-2 for the structure of glucose. Pause. . . . As you can see, it exists in two forms, a straight chain and a ring. To make a ring from the straight chain, the right end is bent back to the second from the left carbon in the chain and hooked on there. The ring form is the form glucose is in most of the time.

Now let's see what chemical reactions are involved in the breakdown of the glucose to CO₂ and H₂O. As you read in the book these chemical reactions are divided into two categories. The carbon pathway and the hydrogen pathway. In this section we will deal with the carbon pathway. The carbon pathway is concerned with the breakdown of the six carbon glucose to six carbon dioxide. The hydrogen pathway is concerned with the break-off of hydrogens from glucose and the release of the energy of its electrons to make ATP. Now, take your transparent overlay marked "Carbon Pathway", figure R-3, unfold the two transparencies that are layed over the dittoed paper marked "Carbon Pathway". All you should be looking at now is the plain dittoed paper. As you can see, the breakdown of glucose to pyruvic acid is the same here in respiration as it was in fermentation. However, the similarities end at pyruvic acid.
Let's look back up to glucose again and we'll work our way down. For glucose to take part in chemical reactions, it must be activated. That is why 2 ATP's come in at the beginning here and attach their phosphates to glucose. Once glucose is activated to glucose diphosphate (not shown here) it, undergoes a chemical change to fructose-diphosphate. How many carbons does glucose and fructose have? . . . That's right - six carbons. Let's keep track of the number of carbons as we go down this chart so we can see just how glucose is being broken up.

Fructose diphosphate is split in half to 2 (3c) phosphate compounds. You don't need to know the names of these compounds so I did not include them on the diagram. Now - it is important to remember that whatever happens to the 3 carbon compound on the left, the same thing happens to the 3 carbon compound on the right. I am not showing the reactions of the 3 c on right because it is exactly the same as the one on the left. So I will just show the one on the left.

Let's look at the 3 c phosphate compound on the left. It undergoes a chemical reaction and becomes a 3C, 2 phosphate compound, a phosphate is added here. Then it loses a phosphate in another reaction. In 2 more reactions, our (3c) phosphate compound loses its last phosphate and becomes pyruvic acid. Now in fermentation, pyruvic acid would be changed to lactic acid, ethyl alcohol or acetic acid, depending on the organism. But if oxygen is present, pyruvic acid will go into the Kreb's cycle of respiration and be broken down all the rest of the way.

Pyruvic acid now loses one of its carbons as carbon dioxide and becomes a 2 carbon compound "active" acetic acid. This compound reacts and combines with a 4 carbon compound in the Kreb's cycle. How many carbons do we have in the resulting compound? . . . That's right, 6 carbons. This 6 carbon compound undergoes several reactions and loses one of its carbons as another carbon dioxide. How many carbons do we now have in the resulting compound? . . . If you said 5 you were correct. The 5c compound undergoes a reaction and becomes a 4c compound. Another CO$_2$ has been released. Several more reactions take place and the 4c compound goes right back to the original 4c compound we started with. How many CO$_2$'s were given off since our original 3c pyruvic acid? . . . That's right, 3. The 3 carbons originally in pyruvic acid have been broken apart chemically and converted to 3 CO$_2$ molecules that float away as gas! The gas you are exhaling now! Look at figure 8-4 on page 201. This diagram shows where the other food groups enter respiration. Fats are broken down to active acetic acid and enter the Kreb's cycle at that point. Carbohydrates are broken down to glucose, pyruvic acid and active acetic acid. Proteins are not used very much for energy, but when they are, they are broken down to pyruvic acid or acetic acid.
To this point, we have said nothing of the energy that has been released from these reactions. That is what we will take up in the hydrogen pathway which is next.

This is the end of Section 4.

This is the beginning of Section 5

Look at figure 7-17 on page 186 of the old version or figure 9-12 on page 177 of the new version. As you recall in photosynthesis, light strikes chlorophyll and electrons are excited, knocked off the chlorophyll and transferred to the H's of water. These H's are then incorporated into glucose $C_6H_{12}O_6$. So glucose is sort of a storage unit for the energy that originally came from the sun to chlorophyll. This is where the energy from the sun is locked up and stored until respiration can release it for use in living organisms. It is in respiration where these hydrogens are extracted from glucose and the energy in them is converted to ATP. Now, refer back to the overlay you were looking at in the last section. Lay overlay #1 over the dittoed sheet. The places the hydrogens are taken off are shown in blue. Let's look at the note. It is important to know that these hydrogens are extracted in chemical reactions and transferred to the hydrogen carrier NAD (NADP was the hydrogen carrier in photosynthesis but NAD in the carrier in respiration). Remember that hydrogen cannot float around free all by itself. It has to have something to latch on to and take it to the hydrogen pathway.

We can see that 2H's come off when the 3c - phosphate compound is converted to the 3c - 2 phosphate compound. After this an ATP comes in and extracts one of our phosphates and we get 1 ATP. We get another ATP when our 3c - phosphate compound is converted to pyruvic acid. This is the same thing that happened in fermentation. Since this is also happening on the other side of the diagram to the other 3c - phosphate (not shown), how many ATP's do we get from this? . . . Pause. If you said 4 you were correct. But how many ATP's did we use up at the beginning of these reactions? Pause. . . If you said 2 you were correct. Then if we used 2 and gained 4, what is our net gain of ATP's. . . . That's right, 2. So this is the same as fermentation. We get a net gain of 2 ATP's. Let's continue.

We get 2 more hydrogens when pyruvic acid is converted to active acetic acid. We get 2 more H's in the Kreb's cycle when the 6c compound is changed into a 5c compound, 2 more again when the 5c is changed into a 4c and 4 more in the last 2 reactions of the Kreb's cycle. Now let's see where these hydrogens go and what happens to them. Look at figure 8-6 on page 203 of the old version or figure 10-6 on page 189 of the new version. . . . Pause. 2 Hydrogen's come off the Kreb's cycle and enter a series of chemical reactions. Their highly energized electrons are pulled off hydrogens and transferred to a "staircase of enzymes." At each step on this staircase some of the energy is converted into an ATP. How many stairs are there?
. . . That's right, 3 stairs. How many ATP's are there then? . . . Good! 3 ATP's for every 2 H's that go down this staircase. Pause. . . . So a little bit of the energy is released at a time. Now we come to the very last step in the process and probably one of the most important steps. At the bottom of the staircase, the hydrogens re-combine with their electrons. At this point they have to have something to latch onto because hydrogen cannot exist freely in nature. This is where oxygen is so important in respiration. It comes in at this point and combines with the hydrogens to form water as the final by-product. If there is no oxygen there to combine with the hydrogens, the whole electron transport chain comes to a screeching halt. This also stops the Kreb's cycle. Unless you are a bacteria or a yeast cell, your cells will not be getting any energy, therefore they will become disorganized and die. If you are a human being, this happens very rapidly in the brain cells and you die.

Let's go back and look at the staircase of enzymes for a minute. These enzymes are usually composed of vitamins and minerals such as vitamin B$_2$, iron and copper. So now you see why it is so important to have vitamins and minerals in your diet.

Now, look back at the overlay you were looking at a minute ago. Count up all the places 2H's are coming off. How many places are there? . . . If you said 6 you were correct. How many ATP's do we get for every 2 hydrogens going through the hydrogen pathway? . . . If you said 3 you were correct. How many ATP's do we get altogether then from our original 3c phosphate compound? . . . If you said 18 you were correct. 3 x 6 is 18. But remember there were 2 3c phosphate compounds going through the same chemical reactions. Now I will give you a good question. How many ATP's do we get altogether from one glucose molecule? . . . If you said 38 you were correct. We get 18 from each of our 3 c phosphate compounds plus a net gain of 2 ATP's in the fermentation portion of respiration. Lay your last overlay down and you can see the total diagram of respiration.

Now - Turn your tape recorder off and do program S-2 on Figure R-4.

This is the end of Section 5.

This is the beginning of Section 6

You will write this lab up like you do all your lab write-ups with a title, purpose, data, and discussion questions. The apparatus for this experiment is already set up for you on the center lab table in the core. It will be there approximately one week.

In this experiment, you will see how energy can be chemically released from an organic compound, sugar. You will also see what it's by-products are. Keep in mind that the energy released from sugar in this experiment is released all at one time as heat. In living things, as you have already studied, the energy is released from sugar a little bit at a time in the form of ATP with some heat given off as well.
On page 204 you will see a list of the material that is needed for this experiment. Make sure your apparatus is set up exactly like it is shown in figure 8-7.

It is very important that you follow the procedure exactly as it is listed in your book. If you skip a step, or make an error, you will ruin the experiment. Also be very careful handling the concentrated sulfuric acid. IT IS VERY DANGEROUS IF YOU GET ANY ON YOU! If any acid does get on you, wash it off under a faucet immediately!

To help you interpret some of your results, I will tell you that cobalt-chloride paper is an indicator of water. And of course you remember from previous experiments that limewater is an indicator of carbon dioxide. Now, turn your tape recorder off and do investigation 8-6 and the lab write-up. Make sure you answer all discussion questions.

This is the end of Section 6.

This is the Beginning of Section 7

Unlike Investigation 8-6, respiration releases energy a little at a time instead of all at once. Let's look at the overall schematic diagram of respiration, figure 8-9 in your book on page 206 or figure 10-7 on page 190. The first part of respiration, glucose is broken down to pyruvic acid and 2 ATP's are gained from this. Also two hydrogens break off and go to hydrogen pathway. Keep in mind that no oxygen is needed for this first part of respiration. At pyruvic acid, one carbon comes off as CO₂ and the remaining two carbon acetic acid enters the Kreb's cycle where its two carbons break off as carbon dioxide also.

No energy release takes place in the Kreb's cycle, but hydrogens are pulled off there and sent to the hydrogen pathway or electron transport chain where energy is extracted from them in the form of ATP. Here we get an additional 36 ATP's and the hydrogens combine with oxygen to form waters.

By now you should be very familiar with the process of respiration and the major chemical changes involved in respiration that we have discussed.

This is the end of Section 7.

This is the Beginning of Section 8

I bid you W-E-L-C-O-M-E again my friend. As you remember from our opening journey back into time and assumptions 9 and 10 in this chapter, there was no oxygen on earth during the early stages of life. During this time, primitive life forms similar to bacteria and yeast fermented to get energy from organic compounds. But with
the evolution of plants and subsequent accumulation of oxygen in the atmosphere, organisms were able to evolve a more efficient way of breaking down organic compounds with oxygen to get energy. Look at figure 8-9 again. They added to the process of fermentation the Kreb’s cycle and the hydrogen pathway.

Having oxygen in the atmosphere also has another advantage. Look at figure 8-12 drawing 5. Oxygen reacts with ultra-violet to form ozone and ozone provides a shield that filters out harmful ultra violet radiation. With this, life could emerge from the oceans onto the land having the ozone shield to protect organisms from too much ultra-violet.

Where in the cell do the complicated chemical reactions of respiration take place... pause... If you said the mitochondria you were correct.

If you have mastered this unit and can answer all the questions in the practice test, you are ready to take the examination on this chapter.
1. Read section 8-1 on pages 195 to 196 of the old version or section 10-1 on page 183 of the new version.

2. Turn on tape for an explanation.

3. Read section 8-2 on pages 196 to 198 of the old version or section 10-2 on pages 184 to 185 of the new version.

4. Turn on your tape to section 2 for an explanation.

5. Read over Investigation 8-3 or 10-A.

6. Turn on tape to section 3 for an explanation.

7. Read section 8-4 on pages 200 to 201 or section 10-3 on pages 186 to 188 in the new version.

8. Turn your tape on to section 4.

9. Read section 8-5 on pages 201 to 203 of the old version or section 10-4 on pages 188 to 190 of the new version.

10. Turn on your tape to section 5 for an explanation.

11. Read over Investigation 8-6 or handout.

12. Turn on tape to section 6.

13. Do Investigation 8-6 or handout.

14. Read section 8-7 on pages 206 to 208 of section 10-5 on pages 190 to 191.

15. Turn tape on to section 7.

16. Read section 8-8 on pages 208 to 210 or section 10-6 on pages 191 to 193.
Exercise 3-1. Review for sections 3-4 and 3-5

1. The process by which organisms break down organic compounds, such as sugars, for energy with oxygen is called _____.

2. Respiration
   a. The final products of respiration are _______.
   b. The products of respiration are _______ and _______.
   c. O₂, H₂O, energy
   d. To break glucose down to CO₂, H₂O, and energy requires many chemical reactions. Each reaction is catalyzed or caused by an _______.
   e. Enzyme
   f. The chemical reactions that break glucose down in respiration are divided into two chemical pathways _______ and _______.
   g. carbon pathway
   h. In the carbon pathway the six carbon atoms of glucose can be broken down to _______.
   i. 6 CO₂

3. Glucose, by itself, is not reactive chemically. It cannot take part in chemical reactions very easily. To make it reactive chemically, we must add the _____.
Each of these 3 carbon compounds undergoes a series of reactions. The 3 carbon phosphate compound, from fructose, picks up another phosphate and becomes a two carbon compound.

It then loses a phosphate and becomes a one carbon compound.

It loses another phosphate and becomes

Up to this point, this part of respiration has been exactly like

Next, pyruvic acid loses a as CO₂.

Pyruvic acid then becomes

Active acetic acid which has carbons combines with a compound that has carbons to make a compound that has carbons.

This part of the carbon pathway is called the cycle.

The six carbon compound undergoes several reactions and loses a as CO₂.

We now have a carbon compound that undergoes a reaction and loses a as CO₂.

We now have a carbon compound that undergoes several reactions and ends up as the original four carbon compound with.

Pyruvic acid had carbons. We have lost carbons since pyruvic acid. So pyruvic acid has been converted to CO₂'s.
1. The electrons are highly energized as a result of this and are knocked off chlorophyll and transferred to the hydrogen of __________.

2. The hydrogens are then incorporated into glucose until glucose can be broken down and the hydrogens again released. \( \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} \)

3. It is in this portion of respiration (the hydrogen pathway) that involves the release of these hydrogens from glucose and the extraction of the energy contained in their small electrons.

4. Going back to the original 3 carbon phosphate compound \( \text{C}_3\text{P} \) from glucose, we see the two ____________ being pulled off of it as it is converted into a two phosphate complex.

5. Lastly, we see one of the two phosphates being removed by ____________ to make one ____________.

6. ADP, ATP

7. Here, the other phosphate is removed in the same manner to give us another ATP.

8. ATP

9. Instead, this is being done on the other ____________ for future. So altogether we have ____________ ATP.

10. b)

11. But, as we had to use up ____________ ATP's to start respiration.

12. c)

13. So we have a net gain of ____________ ATP's go far.

14. 2

15. This portion of respiration is just like ____________.

16. fermentation

17. Being done to provide fuel and we see the once being pulled off to produce fuel in charge with carbon, water etc.
The electrons of the hydrogens are transferred to a "staircase of enzymes" where, at each step on this staircase, some of the energy of the electrons is converted into an ATP. How many stairs are there?

How many ATP's are there?

How many ATP's are there for every two hydrogens coming down the hydrogen pathway?

The very last step of respiration involves the two hydrogens with their de-energized electrons combining with __________ to make __________.

If it weren't for oxygen, the hydrogens would have nothing to latch onto to carry them away and the whole hydrogen pathway would stop, shutting down the Krebs cycle and the rest of respiration. The organism would not be able to get energy. Therefore its cells would become unorganized and fall apart. The organism would die, unless it were a yeast or bacteria.

The "staircase of enzymes" on the hydrogen pathway is composed mostly of _______ and _______.
q2. vitamins, minerals

q2. Let's see how many ATP's we have gotten from one molecule of glucose. We got ____ ATP's for every 2 hydrogens.

q2. 3

q2. We get ____ ATP's for our (3e) (P) compound.

q2. 18 (6x3)

q2. Since we have two (3e) (P) we get ____ ATP's from them.

q2. 36

q2. But remember, we get a net gain of ____ ATP's from the first part of respiration.

q2. 2

q2. So the total number of ATP's we get from the breakdown of one glucose molecule is ____.
CARBON PATHWAY

GLUCOSE (6C)

2 ATP
2 ADP

FRUCTOSE DIPHOSPHATE (6C)

(3C) - P

PYRUVIC ACID (3C)

CO₂

ACTIVE ACETIC ACID (2C)

KREB'S CYCLE
3. Program for section 3-1  Program 3-1  R-2

a. The early earth was very hot and volcanic.

b. The gases of the early atmosphere probably were free.

c. The gases in the early atmosphere were hydrogen (H₂), carbon dioxide (CO₂), water (H₂O), helium (He), and traces of ammonia (NH₃), and methane (CH₄).

d. _____ and _____ caused these gases to collide and form large molecules, or organic compounds. This process took place for a trillion years and organic compounds were made.

e. Lightning & Ultra violet light

f. Complex organic compounds, proteins, began grouping or aligning together to form _____.

g. pro-cells

h. The pro-cells became highly organized and acquired cellular activities.

i. _____ break down organic compounds to release energy for the pro-cells.

j. enzymes

k. Since there was no oxygen, the process of breaking down organic compounds to release energy is called _____.

l. fermentation

m. The primitive cells could have used up all the organic compounds had it not been for the development of chlorophyll and the process of _____ that began producing organic compounds.
Since all life was developing in the ocean, the water protected it from the dangerous on the surface above.

The oxygen gas from green plants in the ocean, batted out of the ocean and accumulated in the atmosphere. It formed a shield that filtered out.

When ultra violet strikes oxygen (O2), the O2 molecule absorbs it and is knocked apart into O and O2 oxygen atoms. These atoms then combine with other O2 molecules to make O3 which is called.

It is this layer that prevents ultra violet from getting to the earth's surface in large, harmful quantities.

With the development of the ozone layer, it allowed life to come out of the sea and populate the land.

Read section 6.3 in Ch. 6

After reading 8.2 in Ch. 8 turn on the tape, where you left off before, for an explanation.

Read investigation 8.3 in your text - DO NOT WRITE NOTES, JUST LOOK IT OVER.

Turn your tape recorder on for a pre-lab and explanation of Lab. 8.3.

Write up Lab 8.3.

Read section 8.4 in Ch. 8.
### ACTIVITY OPTIONS AND OBJECTIVES

#### MASTER MOLECULES AND THE GENETIC CODE

<table>
<thead>
<tr>
<th>Activities</th>
<th>The Student Shall:</th>
<th>Objectives</th>
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<tbody>
<tr>
<td>AT Kit</td>
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<tr>
<td>Master Molecules and the Genetic Code</td>
<td>1. explain what nucleic acids are and why they are necessary for life to exist.</td>
<td>1. DNA Structure and Replication 3) DNA and Protein Synthesis 5) Control</td>
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<tr>
<td></td>
<td>2. identify the 3 parts of nucleic acids.</td>
<td>5) Control</td>
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<td></td>
<td>3. list two different kinds of nucleic acids explaining exactly how they are different.</td>
<td>2) DNA and RNA: Evidence for Structure and Function</td>
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<td></td>
<td>4. do Investigation 9-3 and give evidence for DNA controlling cell chemistry and containing the hereditary material that is passed on to offspring.</td>
<td>4) Protein Synthesis</td>
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<td></td>
<td>5. explain what a virus is and how it works. Compare viruses with cells.</td>
<td>1) DNA Structure and Replication</td>
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<td></td>
<td>6. construct a diagram explaining in detail how DNA duplicates itself.</td>
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<td></td>
<td>7. list three men who won Nobel prizes for their work on nucleic acids.</td>
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<td>8. explain how and by whom the DNA code was cracked.</td>
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<td>9. explain what the DNA code is and what exactly it codes for.</td>
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<td>10. explain what part each of the following has in protein synthesis:</td>
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<tr>
<td></td>
<td>a. ribosomes</td>
<td>1. Determine how x-rays change the genetic traits of molds.</td>
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<td></td>
<td>b. DNA</td>
<td>2. Determine how genes control the cell chemistry of all living things.</td>
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<td></td>
<td>c. m-RNA (messenger RNA)</td>
<td></td>
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<tr>
<td></td>
<td>d. t-RNA (transfer RNA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e. endoplasmic reticulum</td>
<td></td>
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<tr>
<td></td>
<td>f. amino acids</td>
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<td></td>
<td>11. explain exactly how protein synthesis takes place including the proper sequence of events.</td>
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<td>12. do Investigation 10-9 and explain what mutations are.</td>
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<td>13. construct a diagram using biochemical terminology explaining what a mutation is.</td>
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<td>14. do Investigation 10-12 and explain exactly how genes control the chemical reactions or chemical factory of the cell.</td>
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<td></td>
<td>15. determine what chromosomes are and what they are composed of.</td>
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<td>16. explain what part mutations play in evolution of organisms.</td>
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<td></td>
<td>17. define a gene.</td>
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<td></td>
<td>18. explain how genes are passed on from generation to generation.</td>
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<td></td>
<td>19. describe the two main functions of DNA.</td>
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| Experiments: | Purpose: |  |
|--------------|----------|  |
| 9-3 ) | 1. Observe experimental evidence of the role of DNA in determining structural and biochemical characteristics of bacteria. | 10-9, 12-A |
| 10-9 ) old version | 2. Observe experimental evidence that during sexual reproduction of bacteria DNA can be transferred from one bacterium to another. | 10-12, 12-C |
| 10-12 ) | | |
| 11-A ) | 1. Learn some microbiological techniques. | |
| 12-A) new version | 2. Observe the effects of antibiotics on the growth of bacteria. | |
| 12-C) | 3. Discover the selective nature of environmental agents such as antibiotics. | |

| Filmloop | Bacterial Techniques: Inoculating |  |
|----------|----------------------------------|  |
| Filmstrips | 1) DNA Structure and Replication 3) DNA and Protein Synthesis 5) Control  | 5 Objectives |
|           | 2) DNA and RNA: Evidence for Structure and Function |  |
Look at the pictures on page 215 of the old version or 199 of the new version. For many years biologists believed that the cell's nucleus controlled all the chemical reactions of the cell and was responsible for the cell's reproduction, but they didn't know what exactly in the nucleus did this. Over many years and through many biological investigations, chemicals in the nucleus were isolated and identified as nucleic acids. They are called nucleic acids because they are acidic and found in the nucleus of the cell. These giant molecules control the cell and its reproduction. Possibly molecules like this caused the very first living cell to come into existence on earth.

Chemists have identified two different nucleic acids. They have found that nucleic acids are made up of units called nucleotides. Look at figure 9-4 or 11-4. There are four different nucleotides that can be arranged in different order. As you can see here, the nucleotides are made up of 3 molecules. One of four base molecules adenine, guanine, cytosine, or thymine, a sugar molecule and a phosphate molecule in that order. In one of the two different kinds of nucleic acids the sugar is deoxyribose. You see it on page 216 of the old version or 200 of the new version. This nucleic acid is called deoxyribonucleic acid. Look at figure D-1. Lift up the transparency. Don't look at it yet. Here you can see a number of the four nucleotides hooked together at the phosphates to make a long chain. This is a short segment of a real molecule which would be extremely long. Lay the transparency down now. Here you can see another chain of nucleotides joined on the first chain. DNA is made up of two chains of nucleotides joined together as you see it here. Also on this transparency you will see a molecule of ribonucleic acid. It is made up of only a single chain of nucleotides and also has a couple of other differences from DNA. Turn off your tape recorder and see what all the differences you can find between these two molecules. This is objective 3.

DNA has deoxyribose sugar instead of ribose sugar and two chains of nucleotides instead of one and DNA has thymine in place of uracil. As you can see here oracit is a fifth base found only in RNA. Another difference we know of between these two nucleic acids is that DNA is found only in the nucleus of the cell and RNA can be found both in and out of the nucleus of the cell. Now look over Investigation 9-3 or 11-A.

This is the end of Section 1.

This is the Beginning of Section 2

You cannot do this experiment because it involves using a dangerous bacteria, Neisseria pneumoniae which causes pneumonia. So the data has been given for you and you will make the interpretations and answer the discussion questions.
here there are seven experiments. Write out short statements of the data in each experiment and answer the discussion questions as you come to them. Write a conclusion for the whole investigation at the end of your write-up.

This is the end of Section 2.

This is the Beginning of Section 3

Avery, McLeod, and McCarty found, in 1944, that DNA does control heredity through their work with the pneumonococcus cells. Since then, biologists have used viruses to study the behavior of DNA and RNA because viruses are mostly DNA and RNA. We don't know if viruses are living or not because when they are outside a living host they are just like any other "dead" chemical. They can sit as a crystal or powder in a jar for years. But when they get inside living cells they become "alive" using their DNA, they can take over the cells chemistry and reproduce themselves by the thousands engorging and finally rupturing the cells they are in. Look at figure 9-13 on page 222 of the old version or figure 11-9 on page 204 of the new version. Here you can see some electron micrographs of some viruses taken with a microscope that uses electron beams and can magnify objects more than 200,000 times. As you can see here, a virus is not a cell. It does not have a cell wall or carry on chemical reactions by itself. There are many kinds of viruses that can infect all kinds of living things. The ones that have been studied the most are the bacteriophages, viruses that infect bacteria. Look at figure 9-14 on page 223 of the old version or figure 11-10 on page 205 of the new version. Here you can see how viruses infect a cell. The virus itself made of a protein coat with a DNA molecule in it attaches itself to the wall of the cell. The DNA leaves the protein coat and enters the cell. Once in the cell, it uses the cell's chemical machinery to duplicate itself hundreds and even thousands of times also making protein coats for itself. Once the cell is jammed full of these viruses it bursts and the thousands of viruses are spread to thousands of other cells to do the same thing. So from these investigations, we know that the DNA in the viruses takes over the bacterial cells chemistry and can control all the living processes of the cell. There are viruses that infect plants as well as animals. Smallpox, flu, measles, mumps, viral pneumonia, chicken pox, mononucleosis, polio and the common cold are a few of the viruses that infect people. The virus that causes stomach flu gets inside the cells of the stomach and multiplies like crazy until those cells burst. That's what you feel when you get the stomach flu. Cells bursting all over and the stomach wreathing around, churning, and twisting with everything in it being thrust out one way or the other. The most frightening thing about virus infections is that there is no treatment for them. Unlike bacterial infections such as tuberculosis, syphilis, gonorhea, pneumonia, strep throat, plague, dysentery, etc. that can be treated with antibiotics and destroyed, there is nothing that can destroy
viruses once they are in a living thing without killing the living host also. All we can do is rest and hope that our bodies will overcome the infection.

So, in review, DNA must govern the chemical activities and reproduction of the cells.

To many biologists, just knowing that DNA controls cell chemistry was not enough. They wanted to know what DNA looked like and how it worked. X-rays were passed through pure samples of DNA on to a photographic plate. As the atoms in the molecule diffract the rays and show a pattern on the photograph much can be learned about the shape of the DNA molecule. Look at figure 9-15 on page 225 of the old version or figure 11-11 on page 206 of the new version. To the untrained eye, this picture makes no sense but to M. F. Wilkins who made this picture, the DNA molecule was a double helix like two spiral staircases fitted together. With this knowledge, two biochemists working at Cambridge University in the late 50's did further experiments. They found that in any quantity of DNA they studied there were always equal amounts of adenine and thymine; there were also equal amounts of cytosine and guanine. Knowing the structures of these base molecules and the structures of the phosphates and sugars, Watson and Crick fit together the models you see on pages 226 to 229 of the old version or 208 to 210 of the new version. Look back to figures 9-2 and 9-3 on pages 217 and 218 of the old version or figures 11-2 and 11-3 on pages 200 and 201 of the new version. In their analysis of the bases of DNA, Watson and Crick found that adenine and guanine were double ringed structures as you see here while cytosine and thymine were single ringed structures. Also they knew that there was always the same amount of adenine as thymine and there was always the same amount of cytosine as guanine. For this reason they believed that adenine somehow matched or paired with thymine and cytosine always paired with guanine. Look at figure 9-19 on page 227 of the old version or figure 11-15 on page 209 of the new version. Here you can see the single ringed cytosine combining with the double ringed guanine. You can also see that their shapes compliment or fit each other like two pieces of a puzzle or a lock and its key. Because of these shapes, cytosine can only combine with guanine. In the same way adenine can only combine with thymine. Their shapes will not fit any other molecules. Attached to each of the bases is deoxyribose sugar. There attached to the sugar is a phosphate. Watson and Crick reasoned that DNA must have the structure you see in figure 9-21 or 11-17 because this is the only way these separate molecules can be arranged so that the whole DNA molecule has a double spiral shape as you see in figure 9-20 or 11-16. The phosphates hold the nucleotides together in a chain and as we saw earlier, there are two chains in the DNA molecule.

Now, we know that DNA must be able to duplicate itself. We saw how viruses are duplicated in host cells and that DNA controls all cell chemistry, so DNA duplicates
itself and thus duplicates the viruses when it does. Look at and study figures 9-22, 9-23, and 9-24 on pages 229 to 231 of the old version or figures 11-18 and 11-19 on pages 211 to 213 of the new version. Whenever DNA is going to duplicate itself, the double chains separate as you see here. There are always free nucleotides floating around in cells and they come in and match up with the exposed nucleotides of the open DNA molecule. After each exposed nucleotide has been matched and paired by free floating nucleotides, we have two strands of DNA that are exactly alike. The two new strands of DNA are each composed of 1/2 the original DNA molecule. Now you can see why it was important that adenine can only combine with thymine and cytosine can only combine with guanine. If adenine could combine with any of the other bases or cytosine could combine with any of the other bases, these molecules would not be exact copies. The order of the bases would be different and as you will see shortly, the order of these bases is very important in the hereditary code.

You may want to look at the filmstrips on DNA structure and replication and on RNA. This is the end of Section 3.

This is the Beginning of Section 4

We now know what the structure of DNA is and how it duplicates itself. The next question we have to consider is how DNA controls the chemistry of the cell and thus control every hereditary trait of every living thing on earth. Biologists knew that it was DNA that was passed through sperm and eggs through reproduction. So they believed that it was DNA that contained all the hereditary information that makes a living thing what it is. Biologists knew the structure of DNA and that it was made of four different bases hooked together in long chains. Biologists also knew that enzymes, as you remember from an earlier experiment with liver, cause all the chemical reactions of the cell. Enzymes, which are proteins then must somehow be made by DNA. Marshall Nirenberg, a biochemist at the National Institute of Health believed that the arrangement of the bases A, T, C, and G in the DNA molecule somehow coded for amino acids which, as you remember, make up proteins and thus enzymes. Since all your physical and chemical traits are made of proteins which are hair, nose, ears, cheeks, skin, muscles, brain, arms, legs, etc., this could very well explain how DNA could control what all of these things would be. Biologists knew that there are approximately 20 different amino acids that make up all protein. So each base A, T, C, or G code must code for a different amino acid. There are only four different bases. Look at figure D2. Maybe a combination of bases code for different amino acids. If we use a combination of two bases, we get 16 possible combinations. This isn't enough because we have 20 different amino acids. How many different combinations could we get using 3 bases at a time? We could get 64 different combinations using four different
bases 3 at a time. Believing that this is what the code was, Nirenberg and his associates began to crack the code. Since RNA is made of bases like DNA, Nirenberg was able to artificially make RNA in his laboratory. He believed that if the 3 base code coded for one particular amino acid out of the 20, he could make an RNA that had only one base in it and thus one coded word in the whole molecule. Look at figure 10-3 on page 238 of the old version or figure 12-2 on page 221 of the new version. He made an RNA that had only oracil in it and thus only one added word UUU. By placing this RNA in a test tube along with the 20 amino acids and some enzymes, he wanted to see which of the 20 amino acids the UUU RNA would select to hook together in a long chain like it would if it were making protein. After running the reaction, he found a long chain phenylalanine hooked together. So he discovered that UUU codes for phenylalanine. By making 64 different RNA's with the 64 different 3 letter codes, Nirenberg was able to crack the DNA code. Look at appendix H on page 795 of the old version or appendix 12-A on page 703 of the new version. Here you can see all the code words for each amino acid. Since there are 64 possible 3 letter combinations from the four bases and only 20 amino acids, each amino acid has several code words. As you will see in the next section, it was thought that DNA codes for RNA which codes for the amino acids.

This is the end of Section 4.

This is the beginning of Section 5

DNA is found only in the nucleus and RNA is found in and out of the nucleus - look at figure D-3. It is also known that proteins are made on the endoplasmic reticulum which is outside the nucleus. How can DNA, which is inside the nucleus, control or code for proteins which are being made outside the nucleus? The answer must be RNA. DNA must make RNA which leaves the nucleus and makes proteins on the endoplasmic reticulum. Since this kind of RNA makes the coded message from DNA to where proteins are made, it is called messenger RNA or m-RNA for short.

Look at figure D-4 to see how proteins are made and thus now DNA controls all traits of living things. Lift up all transparencies and start with the ditto. First, DNA's double chains detach from one another or unzip. One of the exposed nucleotide chains now begins making a messenger RNA. The RNA nucleotides come in and match up with the corresponding nucleotides on DNA. After the new messenger RNA chain is assembled it breaks off from the DNA molecule and leaves the nucleus. The DNA molecule re-assembles itself the way it was before. The RNA attaches itself to the ribosomes on the endoplasmic reticulum. There are 64 different transfer RNA molecules each getting a specific amino acid and bringing it to the messenger RNA on the ribosomes. Here you can see the transfer RNA molecule getting leucine and bringing it to the appropriate
Master Molecules and the Genetic Code

place where t-RNA's code matches up with m-RNA's code. Let's review a little bit. Turn to the genetic code table on page 795 of the old version or 703 of the new version. Now, looking back at the diagram, what are the first 3 letters of this messenger RNA code. CUA are the first three letters. Look in the table to see what amino acid this code is for. . . . It codes for leucine. So here we see three codes at work. The DNA code is GAT which makes the messenger RNA code CUA. Now there is a transfer RNA with a code GAU which gets only leucine and no other amino acid. It will match up with only CUA on the messenger RNA. This is specifically how the three letter codes will spell out only one amino acid. Now here on the ditto again you can see leucine being brought in by the t-RNA GAU. Also, right next door you see the m-RNA triplet GGC. It spells out the amino acid glycine and the t-RNA CCG is bringing glycine in at that place. Glycine will joint on to leucine. Now, flip down the first overlay. Here you see that the m-RNA has moved. Leucine is hooked on to glycine but you also see that the next three letters spell out leucine again. Remember that each amino acid has several code words for it. Leucine will hook on to glycine and make the chain a little bit longer. You also see that the first t-RNA molecule has detached itself and is going back out to get another leucine. Now, flip down the last overlay. Here you see the original first ribosome and now the chain is longer. Leucine-glycine-leucine-asparagine-arginine. But you can also see that the m-RNA has moved on to a second ribosome and is beginning to practice a second identical chain of amino acids. Indeed, one messenger RNA usually makes five identical protein molecules on five ribosomes at the same time. This is how the arrangement of the letters determines the arrangement of amino acids and thus the different proteins that make us all so different from each other.

So in summary, DNA makes m-RNA which leaves the nucleus and goes out to the ribosomes where t-RNA's bring in the proper amino acids and place them in just the right order determined by the code.

This is the end of Section 5.

This is the Beginning of Section 6

After reading section 10-8 or 12-6 and doing Investigation 10-9 or 12-A you should be very familiar with what a mutation is. But I will also review it here with you. Look at figure D-5. When the DNA code is changed, even if one letter is changed, it can have an adverse affect upon the whole cell. One letter out of place may spell out a different amino acid which can change the whole protein or enzyme which may totally alter the chemistry of the organism. Many genetic diseases in people are due originally to mutations. 99% of all mutations are bad, but if it weren't for mutations we would not have variations amongst living things and, therefore, we could not have adaptations or evolution. Remember our chapter on evolution. Variations are caused by mutations.
Look at figure 10-10 on page 248 of the old version or figure 12-5 on page 226 of the new version. Biologists have further studied how DNA controls cell chemistry by studying the effects of mutations on various organisms. Here you can see that the bacterium cannot make a particular amino acid because of a mutation. Through chemical reactions some organisms can make their own amino acids. You will see this in the next experiment. But in the bacterium a DNA has mutated so that an enzyme protein which is not made properly and cannot cause a crucial chemical reaction to allow this particular amino acid to be made. Without supplying that particular amino acid, this bacterium will die. Such organisms that cannot make their own essential nutrients because of DNA. Mutations are called by biologists, nutritional mutants.

A new word that you should become familiar with for the rest of the course is called "gene". A gene is composed of letters on a DNA molecule that spells out a protein. Since the smallest protein has 50 amino acids in it, the smallest gene would be made up of 150 letters, three letters per amino acid.

Biologists today study mutations and gene behavior in microorganisms because they can be grown in petri dishes by millions in a short period of time. Thus, they can study the inheritance of genes or DNA in thousands of generations. Remember, that it is DNA or genes that are passed on from generation to generation. You have DNA that was given you by your parents.

Now turn off your tape and read over Investigation 10-12 or 12-C and then turn your tape back on for an explanation.

This is the end of Section 6.

This is the Beginning of Section 7

What controls the manufacturing or making of complex chemicals and, therefore, all chemical reactions? This is the question that George Beadle and Edward Patim asked and tried to solve through experiments they did with nutritionally mutant neurospora, a fungus or bread mold. You are going to analyze the results of their experiments and see if you can answer this question. Write out the facts of each experiment A through D and answer the discussion questions as you come to them. Write a conclusion at the end of the write up. If you need additional help, see the instructor.

This is the End of Section 7.

This is the Beginning of Section 8

As you discovered in Investigation 10-12 or 12-C apparently there were three genes responsible for the making of the amino acid orginine. Unlike people, neurospora could make all of its own nutrients if supplied with sugar (for energy), salts and biotin.
People must take in their amino acids and vitamins through meats and vegetables. Look at figure 10-11 or 12-6. Here you see that gene 1 makes m-RNA 1 which makes enzyme 1 which changes a prior substance into ornithine. Then gene 2 makes enzyme 2 which changes ornithine into atrulline. If anything happens to any of these genes, orninine cannot be made. So these experiments clearly show that genes or DNA does control the manufacturing or making of chemicals and proteins and thus controls the complete physical being of all living things.

This is the End of Section 8

This is the Beginning of Section 9

We know now that genes are DNA molecules. It is difficult to see a thin strand of a DNA molecule through the microscope. But we know that the dark material in every nucleus of cells is DNA. Look at figure 10-16 on page 254 of the old version or figure 12-9 on page 230 of the new version. Every time a cell divides, the DNA must duplicate itself so that the new cells will have complete genetic instructions. We can see in these photographs that DNA apparently forms itself into dark bodies that have double structures. We call these dark bodies chromosomes - chromo meaning color and somes meaning body. Apparently duplicated strands of DNA coil themselves up into these chromosomes so they can easily move into dividing cells. Look at figure D-6. Here you can see how DNA duplicates itself and then coils up to form double structures or chromosomes.

This is objective 15.

We have seen that when genes mutate it is usually harmful for the organism that has it. But we also know that variations cannot occur without mutations and, therefore, adaptions and evolution could not occur without mutations. So mutations provide the variations that allow evolution to occur. This is objective 16.

Did you ever wonder when you were small why everyone said you looked like your Daddy when you knew you came from your Mommy? What you didn't know then is that Mommy and Daddy got together and Daddy gave Mommy something. I think you are big enough now to know that Mommy and Daddy had sexual intercourse and Dad, through his sperm gave his genetic information in his DNA's to your mother's egg that contained your mother's genetic information in her DNA's. So DNA containing all the hereditary information is transferred from father to mother in sperm to the egg. This fertilization made you. And you will in like manner transfer your genetic information on to your children. This is objective 18.

In summing up this whole unit on master molecules and the genetic code, we have seen that DNA contains all the hereditary information that makes an organism what it is and this DNA duplicates and passes its duplicates on to other cells and its offspring.
We have also seen how DNA controls all cell chemistry and all traits by making messenger RNA which makes enzymes which cause all chemical reactions of an organism and which makes all the protein which is what all organisms are physically made of.

This is objective 19.

You may want to look at the filmstrips DNA and Protein Synthesis or Protein Synthesis for additional help or review.

This is the end of Section 9.
AT STUDY GUIDE

MASTER MOLECULES AND THE GENETIC CODE

1. Read sections 9-1 and 9-2 on pages 215 to 219 of the old version or sections 11-1 and 11-2 on pages 199 to 202 of the new version.
2. Turn on tape for an explanation. Objectives 1-3.
3. Read over Investigation 9-3 in the old version or 11-A in the new version.
4. Turn on your tape to section 2 for an explanation of this experiment.
5. Read sections 9-4 to 9-10 on pages 222 to 232 of the old version or sections 10-3 to 10-10 on pages 202 to 213 of the new version. Objectives 5, 6, and 7.
6. Turn on your tape to section 3 for an explanation. Objectives 5, 6, and 7.
7. Read sections 10-1 to 10-4 on pages 235 to 240 of the old version or sections 12-1 to 12-4 on pages 217 to 222. Objectives 8 and 9.
8. Turn on your tape to section 4. Objectives 8 and 9.
9. Read sections 10-5 to 10-7 on pages 240 to 243 of the old version or section 12-5 on pages 222 to 224 of the new version. Objectives 10 and 11.
10. Turn on your tape to section 5. Objectives 10 and 11.
11. Read section 10-8 on page 244 or 12-6 on page 225. Objective 13.
12. Read over Investigation 10-9 or 12-A. Your instructor will demonstrate the techniques of this experiment. You may also want to look at the filmstrip "Bacterial Techniques: Inoculating."
14. Read section 10-10 and 10-11 on pages 247 to 249 of the old version or sections 12-7 and 12-8 on pages 225 to 227 of the new version.
15. Turn on your tape to section 6. Objectives 13 and 17.
16. Read over Investigation 10-12 or 12-C.
17. Turn on tape to section 7.
18. Read section 10-13 on pages 252 to 259 of the old version or section 12-9 on pages 223 to 229 of the new version.
19. Turn your tape on to section 8.
20. Read sections 10-14 through 10-17 on pages 253 to 258 of the old version or sections 12-10 to 12-13 on pages 230 to 233 of the new version. Objectives 15, 16, 18, 19.
Figure D-1

- deoxyribose sugar
- adenine nucleotide
- thymine nucleotide
- cytosine nucleotide
- guanine nucleotide

Chain of nucleotides:

- D-A
- D-T
- D-T
- D-A
- D-G
- D-A
- D-C
- D-C
- D-G
Amino acids (aa) make up proteins. (review Ch. 5 to see how amino acids hook together)

The 20 amino acids hook together in long chains to form proteins (hair, eyes, nose, skin, ears, muscles, enzymes).

Could these bases somehow code for the 20 amino acids? This would explain how DNA could control all traits.

Possibly a combination of these bases codes for an amino acid.

If we use combinations of 3 bases——

\[ 4 \times 4 \times 4 = 64 \]

64 possible codes using 3 bases at a time. This would be more than enough codes for the 20 amino acids.
Cytoplasm=all the area outside the nucleus

Proteins are made on the ribosomes on the endoplasmic reticulum.

How can DNA make proteins when it is isolated in the nucleus??

DNA make RNA which makes proteins
1. DNA unzips as if it were going to duplicate itself.
2. Free RNA nucleotides match up with one side of the exposed DNA molecule.
3. The messenger RNA leaves the nucleus with the compliment of DNA's coded message and attaches itself on the ribosomes of the endoplasmic reticulum.
Figure D-5

A DNA molecule

mutation caused by:
1) mistake in DNA duplication
2) x-rays or radiation
3) excessive heat
4) chemicals

This mutation would change the amino acid in that place which would alter a whole protein.
DNA before coiling to form chromosomes

DNA coiling to form chromosomes

duplicated DNA's coiled up

This coiling of DNA into chromosomes insures that the duplicate DNA's will go into the two new cells—You will see this in the next unit on the cell.
### ACTIVITY OPTIONS AND OBJECTIVES

#### THE CELL THEORY

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<td><strong>AT Kit</strong></td>
<td><strong>Objective</strong></td>
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<tr>
<td><em>The Cell Theory</em></td>
<td>1. draw a diagram illustrating the structures found in most cells and explain the function of each structure.</td>
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<td></td>
<td>2. do Investigation 11-2 and explain the relationship of diffusion and cell size as the cell grows.</td>
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<td></td>
<td>3. explain how the hereditary material, DNA, is duplicated and evenly distributed into the new cells during cell division.</td>
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<td>4. explain what a chromosome is.</td>
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<td>5. identify the different phases of cell division and define mitosis.</td>
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<td></td>
<td>6. explain the major differences between plant and animal cells.</td>
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<td></td>
<td>7. do Investigation 11-5 and identify the phase of cell division a particular cell is in.</td>
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<td></td>
<td>8. identify the phases of cell division all the cells are in on page 273.</td>
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<td></td>
<td>9. view a time-lapse film of an actual cell dividing, identifying the moving phases each cell goes through.</td>
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<td></td>
<td>10. describe some of the diseases caused by chromosomal aberrations.</td>
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<td></td>
<td>11. explain how it can be determined if an unborn child is a chromosomal aberrant.</td>
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<th>Experiments:</th>
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<td>11-2, 13-A</td>
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<td>11-5)</td>
<td>1. Observe the relationship between the surface area and volume of a cube.</td>
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<td>13-A) new version</td>
<td>2. Acquire a background for a better understanding of cellular absorption, excretion, growth, reproduction and development.</td>
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<tr>
<td>13-B)</td>
<td>1. Observe the similarities and differences in plant and animal mitosis.</td>
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<td></td>
<td>2. Determine how cells divide.</td>
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<td>Filmloop</td>
<td>Mitosis in Endosperm of Haemanthus Katherinae 1 objective</td>
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<tr>
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<td>Pamphlet</td>
<td>Cell Division 3 objectives</td>
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</table>

**YOU MUST DO 13 OBJECTIVES AND 2 EXPERIMENTS.**
As you probably already know from what you have learned in this course so far, all living things are made of cells or a cell since there are many microorganisms that are only one celled. The cell is an extremely complex factory of chemical reactions many of which you already know about. This chapter will tie all the cellular processes you know about together into place where they occur, the cell. We have studied how materials get into and out of cells; fermentation and respiration; photosynthesis in plant cells and how DNA controls and duplicates the cell.

Look at Figure Ce-1. Here you see a number of structures, some of which you are already familiar with, but we will review them again. First there is the cell membrane. It passively and actively selects what enters and leaves the cell. You must keep in mind that it is a living part of the cell and uses chemical energy to regulate what passes through it. Next, take notice of those familiar submarine-like bodies, the mitochondria with its inner membrane is responsible for the processes of respiration, breaking down organic compounds with oxygen to get energy. It is on this inner membrane where the carbon and hydrogen pathways are operating in an assembly-line fashion. Next you'll notice two cylindrical-like bodies called the centrioles. The centrioles only function when the cell is about to divide. These centrioles move to opposite sides of the cell and send out threads which attach to the opposite sides of the duplicated DNA's of chromosomes and pulls them apart into different cells. Next, you'll notice the golgi bodies. They form an inner membrane that connects on to the endoplasmic reticulum and to the outside. They concentrate proteins until they can be disposed of. Another organelle is the endoplasmic reticulum. It is an inner membrane as you recall earlier. On this membrane sit little bodies called ribosomes. It is on these ribosomes that messenger RNA's attach themselves and make proteins. Another body in the cell is the lysosome. It contains enzymes that dissolve old worn out parts of the cell and even dissolve the cell itself when it becomes old and malfunctions. Now, turning to the nucleus. This is where DNA operates from to control all chemical reactions of the cell and to determine when the cell will divide. Here you will also see the nucleolus. This is a body that stores up RNA's that DNA makes.

Now look at figure Ce-2. In this cell you will notice a body we didn't see in the other cell, the chloroplast. It has stacks of disks called grana that contain chlorophyll and carry on photosynthesis. This cell also has no visible centrioles but it does have a rigid cell wall that encases the cell membrane. The other cell didn't have a cell wall. From what we have just discussed, try to do objective 6.

This is the end of Section 1.
This is the Beginning of Section 2

In this experiment you will make three agar cubes of different sizes from a block of agar that you will be given. These three agar blocks will represent cells and your primary purpose in this experiment is to see what sized cell will absorb nutrients around it the best. From your findings in this experiment, you should also be able to come up with an explanation for why cells divide. You should be able to describe when the fastest growing rate of cells is. So in this experiment you will determine the surface areas of your blocks and the volumes and compare the ratio of surface area to volume of each block and how each block absorbs the sodium hydroxide you place them in. Each block will have a base indicator called phenolphthalein in it which will turn the block pink when in contact with sodium hydroxide. Only that part of the block which has absorbed the sodium hydroxide will be pink or red. You will be able to see how much of each block absorbs the sodium hydroxide. Thus, which sized block would most efficiently absorb nutrients. Now do the experiment and write up the lab.

This is the end of Section 2.

This is the Beginning of Section 3

Now that you have done Investigation 11-2 or 13-A you will recognize that the smaller the cell, the more completely it can absorb nutrients and get rid of wastes. As the cell grows, that rate at which it can take in nutrients slows down until the cell stops growing altogether. This somehow triggers cell division so the one large cell can divide into two small cells and continuing growing and dividing. As you have read, this section deals with how the cell divides. Because each of the new cells has exactly the same traits as the original cell, we know that the hereditary material (or as you will recall, DNA) duplicates. Remember, in the last unit how DNA can duplicate itself and then coil up to form double structured chromosomes. This only happens when the cell is going to divide. Look at figure C-3. When you look at a cell through the microscope and cannot see any chromosomes in the nucleus the cell is in interphase. It is at this stage when DNA is making RNA. When the cell is about to divide the DNA duplicates itself as you recall in the last unit. After this the DNA coils up into double structured bodies called chromosomes. The double structures represent the duplicated DNA's. The chromosomes also have a protein coat around them at this point and you can clearly see the dark chromosomes in the cell. The nuclear membrane is also disappearing. When you can see chromosomes not in a particular order, this is prophase. Next, the chromosomes line up in the middle of the cell. The duplicated DNA's are getting ready to separate. When you can see the chromosomes lined up in this way,
this is metaphase. Next the centrioles send out threads from opposite sides of the cell and attach those threads on to each of the duplicated DNA's. You can see some pictures of centrioles on page 264 and 265 of the old version or 249 of the new version. Next, the duplicated DNA's separate to opposite sides of the cell. This is called anaphase. When you can see the cell dividing into two new cells and the duplicated DNA's in the new cells, this is telophase.

This is the end of Section 3.

This is the Beginning of Section 4

In this experiment you will use actual prepared slides of animal and plant cells and identify the different phases of cell division the cells were in when they were killed and stained. You will notice a big difference in the animal and plant cell divisions. The animal cells you will be using will be of whitefish embryos and plant cells you will be using will be of onion root tips. We use embryos and root tips because this is where cells are constantly dividing. These slides are very expensive so don't break them. You have 2 large charts of these cell divisions hanging in the room to refer to as you do this experiment. Make five drawings of five plant cells divisions and five drawings of animals cell divisions. Also look at the filmloop of mitosis in endosperm of Haemanthus katherinae. This is a time lapse film of living cells dividing so that you can actually see living cells in the process of dividing. Do this experiment and write up the lab as you normally do. This is the end of Section 4.

This is the Beginning of Section 5

Now that you know that all living things are made of cells and that cells are continuously growing and dividing, sometimes cells make mistakes and equal, duplicated chromosomes don't go into the new cells. When this happens in sex cells, the offspring are abnormal and usually die prematurely.

Look at Figure C-4. Diseases in which cells have more than or less than the normal number of chromosomes are shown here. The normal human number of chromosomes is 46. You can read the results of an abnormal number in human beings on this figure. If there is a history of mongolism or Turner's or Klinefelter's or other aberrations in your family and plan to have children, your doctor may recommend that you have amniocentesis. This is a process that takes place about the second or third month of pregnancy that involves inserting a long needle into the womb of the mother and extracting some of the fluids surrounding the fetus. Some of the cells of the developing baby come off into this fluid and since these cells are dividing because this is an embryo, medical technicians can analyze the chromosomes to see if there is a
normal number there. If there isn't, the mother has the option of aborting the baby. There are as many as 50 to 70 genetic diseases doctors can discover using this method. We will discuss this more later in the course.

This is the end of Section 5.
1. Read sections 11-7 to 11-11 on pages 272 to 280 of the old version or sections 13-1 and 13-2 on pages 237 to 240 of the new version to get an idea of the development of the cell theory.

2. Read section 11-1 on pages 261 to 264 of the old version or section 13-3 on pages 240 to 244 and appendix 13-A on page 705 of the new version. Objective 1.

3. Turn on your tape for an explanation. Objective 1.

4. Read over Investigation 11-2 in the old version or 13-A in the new version.

5. Turn on your tape to section 2 for an explanation of this experiment.

6. Read sections 11-3 and 11-14 on pages 267 to 270 in the old version or section 13-4 and 13-5 on pages 244 to 248 of the new version. Objectives 3, 4, 5.

7. Read over Investigation 11-5 in the old version or Investigation 13-B in the new version.

8. Turn your tape on to section 4 for an explanation of this experiment.

9. Read section 11-6 on page 272 of the old version or section 13-6 on page 249 to 251 of the new version.

10. Identify the phases of cell division each of the cells is on page 273 of the old version or 250 of the new version.

11. Read sections 13-7 to 13-9 on pages 251 to 256 of the new version.

12. Turn on tape for explanation of objectives 10 and 11.
Figure Ce-2

THE CELL

- CELL MEMBRANE
- CHLOROPLAST
- MITOCHONDRIA
- CENTRIOLLES
- LYSOSOME
- CELL WALL
HOW DO CELLS DIVIDE?

(Figure Ce-3)

(mitosis = nuclear division)

Interphase
DNA is balled up in long strands

Prophase
DNA is coiled up into chromosomes

Metaphase

Anaphase

Telophase
Mongolism
47 chromosomes
1. Mongolism facial characteristics
2. enlarged head
3. mentally retarded
4. sexually sterile
5. usually will not live passed the middle or late twenties
6. one of their parents sex cells that made them had an extra chromosome in it. When that cell divided through millions of mitoses, the extra chromosome was also duplicated. So each of this child's 7 trillion cells has an extra chromosome in it.

Turner's Syndrome
45 chromosomes
1. sexually sterile female
2. mentally retarded
3. usually will not live passed the middle or late twenties
4. is short one sex chromosome

There are others that we will talk about later in the unit on reproduction.

Anyone that is suspected of having problems such as those in their family history should have amniocentesis during their second or third month of pregnancy. Amniocentesis is capable of detecting as many as 50 to 70 chromosomal and genetic defects. Once the fatal defect is detected, the mother has the option of abortion.
### ACTIVITY OPTIONS AND OBJECTIVES

**REPRODUCTION**

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<td><strong>AT Kit Reproduction</strong></td>
<td>The Student Shall:</td>
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<tr>
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<td>1. define asexual and sexual reproduction.</td>
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<tr>
<td></td>
<td>2. explain and give examples of three different kinds of asexual reproduction.</td>
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<tr>
<td></td>
<td>3. break off a branch of a geranium and plant it in soil—determine if a whole new plant can arise from a part of another plant.</td>
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<tr>
<td></td>
<td>4. cut planaria in two and three pieces and observe to see if new worms arise from each piece.</td>
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<td></td>
<td>5. define meiosis.</td>
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<td>6. explain how sex cells are formed.</td>
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<td></td>
<td>7. explain how nature insures the union of sex cells in plant reproduction.</td>
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<tr>
<td></td>
<td>8. grow pollen grains in a sugar solution and observe the mechanism of gamete union in plants.</td>
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<tr>
<td></td>
<td>9. explain how nature insures the union of gametes in animals.</td>
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<td>10. explain, in detail, how plants reproduce including all the reproductive structures and the function of each.</td>
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<td></td>
<td>11. explain in detail, how humans reproduce, including all the reproductive structures and the function of each.</td>
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<td></td>
<td>12. draw diagrams illustrating the menstrual cycle including all the hormones involved and the function of each.</td>
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<td>13. explain the difference between identical and fraternal twins and how they come about.</td>
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<td>14. explain why women feel very unpleasant at certain times of the month.</td>
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<td>15. list and explain three methods of birth control.</td>
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<td>16. describe the effects menopause and hysterecetomy has on a woman.</td>
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**Experiments:**

- **Handout 1**
  - 1. Observe the regeneration of lost parts of planaria.
  - 14-6 or 15-C
  - 1. To determine if plants can reproduce by budding without sexual reproduction.
  - 2. Determine if some animals can reproduce asexually.
- **Handout 2**
  - 1. Determine how plants reproduce sexually.
  - 2. Determine how pollen grains are transported and what mechanism causes them to grow.
- **Handout 3**
  - 1. Determine how animals reproduce sexually.
  - 2. Observe the fertilization and partial development of animal eggs.

**Purpose:**

- **Handout 1**
  - 1. To determine if plants can reproduce by budding without sexual reproduction.
  - 2. Determine if some animals can reproduce asexually.
- **Meiosis**
  - 1 Objective
- **Solo Learn Kit**
  - Meiosis
  - 3 Objectives

YOU MUST DO 17 OBJECTIVES AND 4 EXPERIMENTS.
As you have already learned in this course, one of the chief characteristics of life is the ability of a cell to carry on chemical reactions when provided with energy. But another chief characteristic of life is the ability of a living thing to reproduce itself. That is what we will deal with in this unit, reproduction. There are many ways living things reproduce. Probably the most primitive form of reproduction is asexual reproduction. Asexual reproduction occurs when a new organism is formed from only one parent organism. This is objective 1. You may have observed asexual reproduction occurring when you were looking at your microorganisms under the microscope at the beginning of the course. For most of these organisms reproduce simply by dividing in two by mitosis. So simple cell division of one celled organisms is one way asexual reproduction occurs. Look at the pictures of the first two sections of this unit. Another way organisms can asexually reproduce is by budding. Here you see the hydra or planaria budding by breaking off a piece of itself and a whole new hydra or planaria developing from that piece. Plants can reproduce this way also. Have you ever broken off a piece of geranium plant and grown a whole, new plant from that piece? So budding is another form of asexual reproduction. Look at the undersides of the fern plant. Have you ever seen these round brown balls on the underside of the leaves of the fern plants. These are clumps of spores. Spores are cells with thick cases around them and can carry on chemical reactions but at an extremely slow rate so that they can last for a very long time. These spores can drop to the moist ground and miniature ferns can sprout from them. So plants producing spores is another way asexual reproduction can occur. Now, turn off your tape and do the investigation on handout 1.

This is the end of section 1.

Sexual reproduction occurs when the nuclei of two cells fuse to form a new individual. This is the remainder of objective one. There are many ways this union of two cells occurs. The two cells that fuse to form the new individual are called gametes. This is a word that's used only in sexual reproduction. In the last unit you learned that DNA coils up to form chromosomes when the cell is about to divide. The chromosomes of living things always come in pairs. Look at figure Re-1. Here you see the chromosomes of the fruit fly. There are eight chromosomes altogether but they are in pairs of the same shape and size. Not only do the paired chromosomes have the same shape and size, they both also have information for the same traits. For example, if chromosome a of pair 1 has DNA information for eye color, wing size, and body color, then chromosome b also has information for those traits. So for every trait of a living thing there are two sets of DNA information, in
the form of chromosomes, for those traits. For example, chromosomes a, c, e and g contain all the DNA information for every trait of the fruit fly. This makes up one set. Chromosomes b, d, f, and h also contain DNA information for every trait of the fruit fly. So for every trait you have, there are two genes that have information for that trait. So, we have two sets of genetic information for all the traits that make us what we are. The next question is where did we get these two sets of information. If you guessed that we got one set from our mother and one set from our father you were right. Human beings have 46 chromosomes. Human beings also reproduce sexually. Look at Figure Re-2. Could there be 46 chromosomes in every cell of the human body including the sex cells? Look at the results of such an occurrence. If this happened, we would have a population of freaks with all different numbers of chromosomes. What number of chromosomes must be in the sex cells for baby to have the normal 46 chromosomes? . . . If you said 23 in each you were right. All cells in the human body have two sets or 23 pairs of chromosomes except the sex cells which have only one set or 23 chromosomes. Now lay down the transparency. The sex cells have only one set of chromosomes or 23 chromosomes. When they join together, they form a new individual with the normal 46 chromosomes or two sets of chromosomes. Cells that have two sets of chromosomes in them are diploid and cells such as sex cells that have only one set of chromosomes in them are monoploid.

The next thing we must look at is how sex cells are made in human beings or in any organism that reproduces sexually. The process by which sex cells acquire the monoploid number of chromosomes is called meiosis. This is objective 5. Look at Figure Re-3. This will outline how meiosis works. As you can see, this looks very much like mitosis. From starting cells that have the diploid number of chromosomes, we must make sex cells that have the monoploid number of chromosomes. There are two divisions that occur in this process. The first division results in the reduction of chromosomes to one half their number. For this reason, this is called reduction-division. In prophase I the chromosomes form and pair up as you see here. In metaphase I the paired chromosomes live up along the middle of the cell. In anaphase I the paired chromosomes separate into different cells. And in telophase I we have two cells that each have half the original number that we started with. The next phase of meiosis is exactly like mitosis. In metaphase II the chromosomes, with their duplicate DNA's line up along the middle of the cell. In anaphase II the duplicated DNA's separate into different cells and in telophase II we now have four cells each with half the original number of chromosomes. These cells will become either sperm or eggs.

This is the end of Section 2.

This is the Beginning of Section 3

Look at Figure Re-4. This is objective 7 and 10. Now that we have discussed how
sex cells are made, we should discuss how sexual reproduction takes place first in plants then later in animals. Lift up the transparency and just look at the diagram of the flower. The flower is the reproductive organ of the plant. First you will notice two structures, the male structure which is the stamen and the female structure which is the pistil. The stamen is made of two parts, the anther where pollen grains containing sperm are made and the filament which holds up the anther. This pistil is made of three parts. First the stigma that has a sugary syrup on top called nectar; then the style or neck of the pistil. Then there is the ovary that produces the eggs that will be fertilized by the sperm in the pollen grain. Cells undergo neiosis in the anther and pollen grains form around these cells. In the spring, when the time is right, the anther breaks open exposing the pollen grains. The wind blows them or insects carry them on they fall. If by chance they land on the stigma of a flower, the sugary solution causes the pollen grains to grow a long tube down the style and into the ovary to meet the egg. The sperm travels down that tube and fertilizes the egg. Once the egg has been fertilized it develops a very hard coat around the outside to protect the embryo. This is now a seed. In many types of flowering plants the ovary now becomes very large and very juicy. This intices animals to eat them and, thus, eat the seeds in them. The seeds will go through the animals' digestive system and be deposited with the animals' waste some distance away. Being planted and fertilized at the same time, it will grow into a new plant. This is one way seeds are distributed. As you may have guessed, the juicy ovaries are very familiar to us, because we eat them. Peaches, plums, pears, apples, avacados, strawberries, apricots, beans, peas, corn, oranges, grapefruit, etc. are all ovaries of plants. So when you go home tonight, ask your mother if there are any ovaries in the house to eat. Most of the time plants do not fertilize their own eggs with their own sperm. They fertilize other plants. Now review how plants reproduce and then we will continue this section.

Now that you know how plants reproduce sexually it might be asked how nature causes gametes to come together to form new individuals. The mechanisms for gamete union in plants is fairly simple. Lay down the transparency on figure Re-4. First when the anthers are broken open often the winds blows pollen through the air. Some of the pollen will find its way to the stigmas of other flowers. Another, more common way, nature insures the union of gametes in by insects carrying pollen. Many types of insects like to fly to flowers to get the nectar on the stigma. While they are fumbling around in other flowers some of the pollen brushes off on to these flowers. Another less common way of fertilization in plants occurs when the pollen of a flower falls on to its own stigma and the sperm fertilizes its own egg. It is proper to mention here that not all plants have flowers with both a male and female
sexual organ. Some have flowers with only one of the sexual organs. Also not all plants are flowering plants. Pine trees, for example, reproduce sexually with pollen grains but without flowers. The most common plants you are familiar with though are flowering plants. Almost all of the native chapparral and trees that grow in the Santa Clarita Valley are flowering plants. So in summary, nature insures the union of gametes in plants by wind, insects, and self fertilization.

This is the end of Section 3.

This is the Beginning of Section 4

Mother Nature's way of insuring the union of gametes in plants is far simpler than the mechanisms involved in insuring the union of gametes in animals. The sperm of the male cannot be blown by the wind or carried by insects to the female. Usually, in land animals, there has to be a physical union of male and female to insure the union of gametes. Animals that live in the water such as fish, clams, sea urchins, etc. often simply release their eggs and sperm into the water and some of the eggs and some of the sperm will meet by chance. However, for most animals, this is not the way it happens. In the animal world members of the opposite sex must be wooed and attracted to each other by various means. Look at figure Re-5. For us human beings it seems as though the female is the most beautiful and attractive member of the two sexes. With soft skin and various soft and rounded parts, long hair, various makeups and jewelry, she can be extremely attractive to the male sex. But in nature the male animal is usually the most beautiful and attractive member of the two sexes. Here you see a male frigate bird with his great big red balloon inflated. When he wants to attract a female, he sits out in a field and blows up that large red balloon on his chest and flaps his wings. Various females who happen to be in the neighborhood will see this and this could be a stimulus to make them excited sexually. In other words, this really turns her on. She goes up to the most appealing male and they begin caressing which further stimulates sex hormones inside them and they then complete their desires in orgasm which transfers the sperm from the male into the female to fertilize her egg. Look at figure Re-6. Here you see the bright colors of the mandrill baboon and the beautiful feathers of the peacock. What sex are these? That's right, these are males. So mating colorations and caresses are two ways nature insures the union of gametes in animals. Look at figure Re-7. Here ostriches use dances to excite each other sexually. Dancing, chasing, and then, finally copulating. Copulate is a biological word meaning sexual intercourse. So mating dances is another way nature insures the union of gametes in animals. Look at figure R-8. Still another way of attracting members of the opposite sex is by mating calls. So mating colorations, caresses,
dances, and calls stimulate sex hormones in animals that instinctively forces two members of the opposite sex to copulate which will provide for the union of gametes in animals. It must be said at this point that for most of the animal kingdom mating can only occur during certain times of the year, usually during early spring. Nature has "activated" the sex hormones in animals only during this time. When animals come together in sexual intercourse it is strictly a biological urge that must be satisfied like getting food or water or eliminating wastes. This is truly an animal hunger. We will see later in this unit that people also have hormones but can mate at any time of the year. We will see too that for people mating is something more than just a biological urge. There are strong emotional and psychological factors associated with mating in people that cannot be ignored as much as the sex exploitation of various business concerns through various magazines, movies, and commercials would like us to ignore them.

As you have noticed, in nature the male is the colorful and attractive one while the female is camouflaged so that when the babies are born mother can hide them and protect them from predators.

If you are interested in finding out more about the mating habits of animals, see the instructor.

This is the end of Section 4.

This is the Beginning of Section 5

As you have read, the union of gametes in animals can occur outside the bodies of the parents if they live in the water. But if the animals live on land, the union of gametes must occur within the bodies of the parents which involves physical attractiveness as we saw in the last tape section and sex hormones to bring the two parents together. There are some land animals, such as birds and reptiles that copulate and then the female lays an egg and is guarded and protected by the parents until the embryo is developed and ready to come out of the egg. In other animals, such as mammals, the egg is fertilized internally and the embryo is developed inside the female until it is ready to be born. We will concentrate our attention on human reproduction since humans are mammals and very near and dear to us all. But keep in mind human reproduction is very similar to all mammalian reproduction. Mammals are called mammals because they have mammary glands that enables them to nurse their young after their young are born. This phenomenon doesn't occur in the rest of the animal kingdom.

Look at Figure Re-9. Here you will see a side view and front view of the human male reproductive organs. In the front view, you'll notice the two main male reproductive organs called the testes. These sit in a sack outside the body called the scrotum. This is necessary because sperm cannot be made at higher body temperatures.
This is where meiosis occurs or sex cells are made. In this case, sperm are made in these organs. You see a gland called the epidymis on top of the testes. This is where sperm are stored until needed. Leading from the top of the testes are the sperm ducts or vas deferens. These are the tubes that the sperm will travel through when sexual intercourse is engaged in. You can see that the two sperm ducts meet to form a common tube called the urethra. This tube is not only used to pass sperm through but also to pass urine through from the urinary bladder. Just before the two sperm ducts meet, you'll notice two glands called the seminal vesicles. These glands produce a starchy fluid that the sperm will swim in and get food from. This fluid is called semen and the sperm in the semen is what is put into the female during sexual intercourse. Leading into the bladder, you will see two tubes called the ureters. These tubes come from each of the kidneys and liquid waste trickles down these tubes and collects in the bladder. When the bladder is full, it stretches which stimulates nerves and gives you the urge to relieve youself and drain all that urine out of that bladder.

During sexual excitation, sex hormones cause blood to rush in to the erictile tissue in the penis. Look at the side view. When this happens, the penis becomes very stiff or hard. This is very important because the male could not penetrate into the female or engage in sexual intercourse if the penis were not hard. Some men who have psychological problems cannot get excited sexually or get their penis hard and therefore, cannot engage in sexual intercourse. This is called impotence. After the penis is hard, the owper's glands you see at the top of the urethra makes a very slippery liquid or lubricant that runs out the urethra and coats the penis. The female also has a similar fluid for her organ of sexual intercourse (the vagina) so that the penis can slide right into the vagina easily with little or no friction. It would be very uncomfortable for both parties if there was no lubricant there and possibly even quite painful for the woman. After the male has inserted the penis into the female vagina extreme sexual excitation occurs. The male's sperm ducts are engorged with semen heavily ladened with sperm. At the peak of sexual excitation the male has organism which means that highly concentrated hormones cause the erectile tissues to thrust the semen out the penis and up into the upper portions of the female vagina. With each ejaculation of semen there are about 250 to 750 thousand sperm cells. This is a good time to mention one quite popularly used method of birth control called the vasectomy. In the side view, look at where the sperm duct comes off the testes. At this point, the testes and part of the sperm duct are outside the body. In a vasectomy, it is at this point where the doctor makes a small incision and cuts these points above both testes. From that point on, sperm will not be able to be released from the testes. This person will be able to engage in sexual intercourse and release semen just as he has always done before, except now, his semen
will not have any sperm in it and he will not be able to father children. This operation is so simple, it is done in the doctor's office in about 15 minutes. However, once this operation is done it is irreversible. For this reason, many husbands are advised to store sperm in a sperm bank before they have this operation in case they ever change their minds. However, the ultimate in a vasectomy and in birth control is just around the corner. Medical researchers are testing a valve to be inserted at that point where the sperm duct is normally cut. If a person wants a vasectomy he can have two of these valves put in both his sperm ducts and have them turned off. Later, if he changes his mind, he can have his doctor make the small incisions and turn on his valves allowing his sperm once again to go through his sperm duct. Thus, he can be turned off and on at will by his doctor.

It seems, in this day, when there are so many people on this earth that something should be done to restrict the number of babies being born. This could be a very good way to do that. Many couples that want to have a higher standard of living for themselves and their children are limiting the size of their family by using various methods of birth control. With less bodies to feed, clothe, and educate, more of the family income can be spent on recreation, travel, and luxuries.

Now let's look at figure Re-10 and the female reproduction organs. Looking at the frontal view you'll see two female reproductive organs called the ovaries. It is in these organs that meiosis occurs and egg cells are made. Once each month, one or the other of these ovaries releases one egg. Leading from each ovary to the large central organ called the uterus are the oviducts. These are the tubes that the egg travels down. If the egg is fertilized by sperm, the embryo will attach itself to the wall of the uterus or womb and develop into a baby there. So the womb or uterus is to house and nourish the developing embryo until it is ready to be born. Now, look at the side view. Here you get a better view of the vulva and vagina. The vulva are thick folds of skin that protect the opening of the urinary bladder and the urethra. They also contain glands that provide lubrication for the vagina and sexual excitation during intercourse. The vagina serves two purposes. It is the organ of copulation where the penis is inserted and the birth canal where the baby comes through when it is being born. At the entrance to the vagina there may be a hymen which is a thin membrane covering the vagina. If the hymen is there, the girl is definitely a virgin; she has never had sexual intercourse. But if there isn't a hymen there, it doesn't mean that the girl is not a virgin because the hymen can break under various conditions other than by a penis. In the old days in the old country and also various religious sects, it was the custom for the parents of the bride to stand outside the bedroom door on the wedding night and wait for the bridegroom to bring a handkerchief of blood to indicate that the hymen was there and had just been broken by him indicating that
she was a virgin. It was misconceptions about sex such as these that caused great grief for many people and permanent damage to their sexual lives.

As mentioned before, during sexual excitation lubricants coat both the vagina and the penis so that the hard penis can be inserted easily into the vagina. The vagina stretches putting pressure on both the penis and the vagina further stimulating both individuals. It is not necessary for a woman to have organism for reproduction to occur as it is for a man. Indeed many women have had children galore without ever experiencing organism. However, orgasm can be just as exciting to the female as it is to the male. And since many human couples engage in sexual intercourse not as a result of satisfying animal hungers or having babies but because they love each other very much and when they engage in intercourse it is because they want to experience total union - mental, spiritual, and physical union. When humans enter into this kind of relationship, it is for a purpose far higher than mere animal copulation. It is for the ultimate expression of love, concern, and responsibility for the other individual. When sexual intercourse is engaged in for any purpose less than this, its full value and enjoyment is greatly reduced. Also the strong emotional and psychological feelings attached to this kind of an intimate relationship makes it a far more serious activity than a mere form of recreation as many of our movies depict it to be. People can be and have been psychologically damaged for life in their sexual activities because of bad sexual experiences when they were in their teens. Sex is a great experience when it is used by mature and responsible people who have a life-time commitment to each other and a deep love and respect for each other. When it is used in irresponsible ways, however, for selfish purposes or given into on spur of the moment hot spots due to hormonal surges, sex can be and often is a very unpleasant and degrading experience. Two people must know each other intimately in love and patiently work with each other in sex before all the life long psychological barriers are down and sex can be enjoyed to its fullest degree. Well enough for the psychological treatment of human sexual relationships. Look back at your diagram of the human female sex organs. When the male reaches orgasm, the sperm laden semen shoots out of the penis and into the upper portions of the vagina. The sperm then have a long journey to swim all the way through the uterus and up into the oviducts where they may fertilize an egg, if one is there and it is ripe and ready for fertilization. It will be explained later that a female egg can only be fertilized for a period of about 24 to 48 hours out of the whole month. Normally only one ovary will release one egg a month. But on rare occasions two eggs or more may be released during the same month. If sexual intercourse is engaged in at this time there will be 2 or more babies developing at the same time.
be fraternal twins, no different than any other brothers or sisters except that they were born at the same time. Each of them came from a different egg and are, therefore, different and unique individuals. Sometimes one egg comes out of the ovary but splits in two after it's been fertilized and the two identical cells lose contact with one another. These two identical cells with exactly the same DNA become identical twins. This is even more rare than fraternal twins. I think the world's record for one woman having babies is 64 babies in her child bearing years.

A common operation that is often performed on women with diseased reproductive organs is called a hysterectomy. Most commonly in cancer of the ovaries or uterus these organs are removed, thus making the woman sterile. This is an extremely painful and serious operation that has also been used quite commonly as a means of sterilizing women who no longer want children. This seems to be a drastic step to take to become sterile. A less serious but still painful operation is the severing of the oviducts so that no eggs can ever get to the uterus. If a married couple decide they don't want any more children, by far the least expensive, least serious and least painful operation is a vasectomy for the husband.

This is the end of Section 5.

This is the Beginning of Section 6

The female reproductive system is far more complex than the male reproductive system in the hormonal activities that occur in that system during the month. Hormones are chemicals that cause organs to do certain things. Look at figure Re-ll. Here you will see a diagram of the female menstrual cycle and the uterus at various times during the month. The first day of the cycle the lining of the uterus is heavily engorged with blood. At this time the lining starts to drain the blood off or bleed out through the opening of the uterus, the cervix, and down the vagina and out that way. The bleeding usually lasts from three to five days, depending on the individual. Underneath the brain there is a small gland called the pituitary gland. This gland makes hormones that control many of the organs of the body. One hormone it makes is called follicle stimulating hormone of FSH because this hormone stimulates the making of a follicle in the ovary. The follicle is a small sack filled with liquid that surrounds an egg. This follicle will push the egg out of the ovary. While the follicle is growing, it makes a hormone itself called estrogen. Estrogen causes the lining of the uterus to begin engorging itself with blood once again. Around the 14th day after the cycle began, the follicle has bulged out of the ovary and the egg comes out. The egg starts making its way up the oviduct. In the mean time, there is no longer a follicle. So the pituitary gland once again sends another hormone to the ovary called lutenizing hormone. This hormone causes a gland to grow where the follicle was called the corpus luteum gland. The corpus luteum gland produces another
hormone called **progesterone**. Since the estrogen level has dropped because there is no more follicle, progesterone picks up where estrogen left off. It continues to cause the lining of the uterus to be engorged with blood so in case the egg is fertilized, it will be able to attach itself to a rich oxygen and food ladened uterus to stay there and develop for nine months. Progesterone also has another function. It goes up to the pituitary gland and causes the pituitary gland to stop sending out any more follicle stimulating hormone. This will prevent any more eggs from being released from the ovary until the fate of the currently released egg is determined. If the egg is fertilized, progesterone will continue to prevent any more eggs from being released from the ovaries, thus, stopping the whole cycle. If the egg is not fertilized, the corpus luteum will die and progesterone will diminish and the cycle will start all over again. It is at this time of the month that girls usually feel irritable, uncomfortable or even sick. Because the two main female hormones, progesterone and estrogen not only cause the lining of the uterus to be engulfed with blood and prevent the release of eggs, they also make the girl feel feminine, sexy, and good. When this hormone level is low at this time of each month, the girl gets aches and pains, is irritable and grouchy, she feels unattractive and fat because she becomes bloated with water, and some girls can become violently ill.

Now that you know all about the menstrual cycle, let me give you this problem: You are a biochemist for a large drug company and you are asked to make a pill that will prevent women from getting pregnant. What would you make it out of? ... pause... If you have to turn off your tape and think about that one, then turn your tape back on. Looking at the cycle, you can see that the two hormones that prevent eggs from being released are progesterone and estrogen. As long as progesterone is at high levels in the bloodstream no eggs will be released from the ovaries. So most birth control pills are made from chemicals that closely resemble progesterone and estrogen. So that a woman on the birth control pill can have a normal cycle, she must take them daily from about the 4th day of the cycle until about the 26th day of the cycle.

Women will have their normal cycles from about the age of 11 to 13 until they are in their late 40's or early fifties. At that time the cycle stops. This is called menopause and for some women can be quite traumatic. The hormonal level of progesterone and estrogen is cut off and the woman feels constantly grouchy and irritable and many psychological depressions. For women that react harshly to this change in life, the doctor may recommend taking shots of progesterone and estrogen. Women that have hysterectomies may also react in this way.

This is the End of Section 6.
D. Crissman

AT STUDY GUIDE
REPRODUCTION

1. Read sections 13-1 and 13-2 on pages 299 to 301 of the old version or section 14-1 on pages 259 to 261 of the new version. Objectives 1 and 2.

2. Turn on your tape for an explanation. Objectives 1 and 2.

3. Begin the investigation that is on handout 1.

4. Read over Investigation 14-16 or 15-C; after your instructor has shown you the technique to use in this experiment, go ahead and do it.

5. Read section 13-3 on pages 301 to 304 of the old version or sections 14-2 and 14-3 on pages 261 to 264 of the new version.

6. Turn your tape on to section 2. Objectives 5 and 6.

7. Read sections 13-4 to 13-9 on pages 304 to 311 of the old version or 14-4 and 14-5 on pages 264 to 268 of the new version.

8. Turn on your tape to section 3. Objectives 7 and 10.

9. Do the investigation on pollen grains on handout 2.

10. Turn on your tape to section 4. Objective 9.

11. Read sections 13-11 to 13-15 on pages 313 to 321 of the old version or sections 14-7 to 14-10 on pages 269 to 273 of the new version.

12. Read sections 13-16 to 13-19 on pages 321 to 327 of the old version or sections 14-11 to 14-12 on pages 274 to 277 of the new version.

13. Turn on your tape to section 5. Objective 11, 13 and part of 15.

14. Read sections 13-21 to 13-24 on pages 332 to 337 of the old version or sections 14-13 to 14-17 on pages 277 to 282 of the new version.

15. Turn on your tape to section 6. Objectives 12, 14, 16 and part of 15.
To further understand the genetic information for hair and eye color, let's consider the following:

- **Chromosome 4**: This chromosome contains genes for hair and eye color. Each chromosome has two copies, one inherited from each parent.
- **Chromosome 6**: This chromosome also contains genes for hair and eye color. Similar to chromosome 4, it has two copies.

Each individual inherits one copy of each chromosome from their parents. The combination of genes from the parents determines the phenotype (hair and eye color) of the offspring.

In the diagram, chromosomes are depicted with genes for hair color and eye color. The presence of certain genes can result in specific traits, such as brown or blonde hair, and blue or brown eyes.
Humans have 23 pairs or 46 sets of chromosomes in every cell except the sex cells which have only 23 chromosomes or one set.

The set of chromosomes in a cell is called **NUCLEUS**

In a cell is called **NUCLEAR**

AND ALL THE SEX CELLS---SPERM or **Egg**
Meiosis—the process by which sex cells acquire the monoploid number of chromosomes

**First Division** — reduction (chromosomes are reduced to $\frac{1}{2}$ their number in the cells)

1. The chromosomes pair up in the nucleus

   **PROPHASE I**

2. The pairs line up along the middle of the cell

   **METAPHASE I**

3. The paired chromosomes now separate and move to opposite sides of the cell—the cell is now dividing

   **ANAPHASE I**

4. Two new cells are now formed, each with half the original number of chromosomes

   **TELOPHASE I**

**Second Division** — just like mitosis

5. Chromosomes line up in the middle of the cell

   **METAPHASE II**

6. The centromere breaks and the duplicated pairs move to opposite sides of the cell—the cells divide again

   **ANAPHASE II**

**TELOPHASE II** out of this four new cells each with half the original number of chromosomes are formed—these will become gametes
1. Sperms are in pollen grains in anther
2. Anther breaks open (Spring)
3. Wind or insects disperse pollen into the air
4. Some pollen grains will land on stigma of other flowers
5. The nectar on the stigma causes the pollen grains to grow long tubes down the style to meet the egg in the ovary
6. The egg is fertilized by the sperm in the pollen and becomes a seed
7. In some flowering plants the ovaries become fruits and vegetables
Figure Re-9

MALE REPRODUCTIVE ORGANS

ureters
(urine trickles into bladder from kidneys)

bladder

seminal vesicles (semen is made here)

prostate gland

cowper's gland (lubricant is made)

penis (male organ of copulation)

scrotum (sac the testes sit in outside the body)

epidymis (sperm are stored)

testes (sperm are made)

urethra (sperm and urine travel through this tube out the penis)

ureters

sperm duct

seminal vesicle

prostate gland

cowper's gland

sperm duct

epidymis

testes

scrotum
Figure Ke-11

FEMALE MENSTRUAL CYCLE

day 1

- the corpus luteum will die if fertilization does not occur—progesterone diminishes and the lining of the uterus begins to shed

- the corpus luteum produces progesterone which continues causing the lining of the uterus to be gorged with blood and also prevents the pituitary gland from releasing any more FSH—thus, no more eggs can be released

- the pituitary gland sends down luteinizing hormone that causes a corpus luteum to develop—now that the follicle is gone so is estrogen

- the lining of the uterus has now been shed

- the follicle produces estrogen

- estrogen causes the lining of the uterus to begin thickening with blood

- the egg is released and must be fertilized within 24 hours
**ACTIVITY OPTIONS AND OBJECTIVES**

**PATTERNS OF HEREDITY**

<table>
<thead>
<tr>
<th>Activities</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT Kit Patterns of Heredity</td>
<td>The Student Shall:</td>
</tr>
<tr>
<td>15-3</td>
<td>2. do Investigation 15-3 and explain what factors determines what organism will become.</td>
</tr>
<tr>
<td>15-8</td>
<td>3. explain how much influence the environment has in determining what an organism will become.</td>
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<tr>
<td>15-19</td>
<td>4. state who the founder of modern genetics is and briefly describe the experiments he performed that led to the discovery of inherited factors.</td>
</tr>
<tr>
<td>16-A</td>
<td>5. construct a diagram showing how a trait (or gene) is inherited.</td>
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<tr>
<td>16-B</td>
<td>6. define probability and explain what role it has in genetics.</td>
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<tr>
<td>16-C</td>
<td>7. successfully solve several problems in probability supplied by the instructor.</td>
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<tr>
<td>16-C</td>
<td>8. give a definition for each of the following terms used in genetics:</td>
</tr>
<tr>
<td>a) parental cross</td>
<td>g) allele</td>
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<tr>
<td>b) first filial generation (F1)</td>
<td>h) genotype</td>
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<tr>
<td>c) second filial generation (F2)</td>
<td>i) principle of segregation</td>
</tr>
<tr>
<td>d) pure-breed</td>
<td>j) phenotype</td>
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<tr>
<td>e) dominant trait or gene</td>
<td>k) homozygous</td>
</tr>
<tr>
<td>f) recessive trait or gene</td>
<td>l) heterozygous</td>
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<tr>
<td>16-C</td>
<td>9. explain and give an example of incomplete dominance.</td>
</tr>
<tr>
<td>15-8, 16-B</td>
<td>10. observe filmstrip #1 of genetics on Dominance and filmstrip #2 on Incomplete Dominance, Segregation, and the Punnett Square.</td>
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<tr>
<td>15-19, 16-C</td>
<td>11. do a monohybrid and dihybrid cross of mice in a Punnett square giving all the probabilities of each outcome.</td>
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<td>15-19, 16-C</td>
<td>12. explain what to do when an organism is not known to be a pure bred.</td>
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<tr>
<td>16-B</td>
<td>13. do Investigation 15-9 to determine the outcome of a simple Mendelian cross.</td>
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<td>16-C</td>
<td>14. do Investigation 15-19 and determine how blood types are inherited.</td>
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<td>15-19, 16-C</td>
<td>15. explain what erythroblastosis is; how it is acquired, and what treatment there is for it.</td>
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**Experiments:**

<table>
<thead>
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<th>Experiments:</th>
<th>Purpose:</th>
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<tbody>
<tr>
<td>15-8, 16-B</td>
<td>2. Obtain experimental results comparable to Mendel's data from his experiments with garden peas.</td>
</tr>
<tr>
<td>15-19, 16-C</td>
<td>4. Grasp the principles of segregation and independent assortment of genes.</td>
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</tbody>
</table>

**Filmstrips:**

<table>
<thead>
<tr>
<th>Filmstrips (Introducing Genetics)</th>
<th>1 Objective each</th>
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<tbody>
<tr>
<td>1. Dominance</td>
<td>4. Genetics and the Cell</td>
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<td>2. Incomplete Dominance: Segregation and the Punnett Square</td>
<td></td>
</tr>
<tr>
<td>3. Independent Assortment and Linkage</td>
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</tbody>
</table>
D. Crissman

AT SCRIPT

PATTERNS OF HEREDITY

Now that we have spent some time learning about DNA as the unit of heredity and a gene and have learned how cells divide and organisms reproduce we can look into the science of genetics, that branch of biology that attempts to develop explanations for the hereditary similarities and differences of organisms. Since you know what a gene is, another way of putting it is that genetics is the science that studies the behavior of genes and how they are passed down through the generations. This is objective 1.

We have said before that DNA or genes controls all the hereditary information that makes an organism what it is. But how much influence does heredity have on the total behavior and appearance of an organism such as a person. Are we all totally at the mercy of our genes to determine our future? Biologists have been asking this question for many years. Genes are not the only determiners as to what an organism will become. The environment also plays a major role in determining what we will become. But which one is more important, genes or the environment? Geneticists say genes while environmentalists say the environment is more important. No one really knows for sure which one is more important but one thing for sure, they are both very important. Your genes will determine your biological or physical potentials but the environment may alter those potentials. The kind of family you're raised in and the kind of friends you hang around with will help shape your personality, ambitions, and goals and in a very strong sense, your future. You may have the genetic potential to be very intelligent but if you are brought up by intellectually depraved parents who couldn't care less what their children become chances are you won't have that successful a life for yourself. You may have the genetic potential to be six feet tall, but if you are living in India and starving to death, you may only be four feet tall. So an organism must have a good environment for its genes to be fully expressed. So both genes and the environment play a very strong and equal role in determining what an organism will become.

Studies on identical twins that have been separated when they were babies and grew up in different families and consequently in different environments show how strong an influence the environment really is. As you recall, identical twins have exactly the same DNA or genes. So the only thing that is different here is the environment. The most drastic differences between identical twins in this situation is their personalities. Sometimes, even their appearances are different. Their intellectual abilities, hobbies, interests, etc. are usually quite different. This is objective 3.

This is the end of Section 1.
This is the Beginning of Section 2

In this experiment you will use tobacco seeds and grow tobacco in two different kinds of environments. But don’t get excited, you won’t be able to smoke the tobacco. This is a special kind of tobacco. Some have genetic mutations and cannot make chlorophyll and we call them albinos. The plants that made these seeds are not albinos but have masked genes for albinism and when the sex cells that made these genes combined, some of these seeds got albinos genes from both parents. Look at figure M-1. You will be given two round blotters. With a straight edge and pencil, mark off a square on the blotter. Then mark off five vertical and five horizontal lines in the square. This will give us 36 squares altogether. Now, with a probe, punch a small hole in the middle of each square. Completely moisten the blotter with distilled water. After getting the blotter very wet, place it in the petri dish and licking your probe, pick up one seed at a time and place it in the hole. Do this until each hole has a seed in it. After making up two petri dishes like this, put tin foil around one dish to keep out the light and a baggy around the other dish to keep in the moisture. Check your dishes each day to be sure the blotter is very wet. It will take about a week for your seeds to germinate and at that time you should see what effect the environment and heredity play in determining what an organism will become.

This is the end of Section 2.

This is the Beginning of Section 3

In 1865 Gregor Mendel, a monk in Czechoslovakia, discovered some of the basic laws of heredity. He noticed that the pea plants that grew in the monastery garden had many different traits. They were all peas, but as people have different traits and look different, these peas also had different traits and looked different. Some pea plants were tall while others were short. Some had round seeds while others had wrinkled seeds. Some had green pods while others had yellow pods. Because of the structure of the flower of the pea plant, they are all self fertilizing. The pollen grains of a plant can only fertilize the eggs of the same plant. Look at figure 15-7 on page 383 of the old version or figure 16-7 on page 315 of the new version. Because the petals completely enclose the male and female reproductive structures of this plant, the pollen grains have no where else to go but onto their own stigmas. Thus, a tall plant has always come from a line of plants that have been tall. Since it has only genes for tallness that’s all it can pass on to its offspring. Pollen grains from nearby plants that are short cannot get into the stigma and fertilize the tall plants. So tall plants always give rise to tall plants and short
Plants always give rise to short plants. The same genes are always kept in the same family. When organisms have the same traits as all their ancestors, those organisms are said to be pure bred for those traits. Thus, these pea plants are pure bred for all their traits. Mendel wondered what would happen if he crossed a pure bred tall plant with a pure bred short plant. He thought, as you might think, that the offspring of such a cross would be medium height. But he discovered that the offspring of this cross was all tall plants! Apparently the short gene from the short parent is being masked by the tall gene from the tall parent. He wondered if the short gene had been lost in the cross or just masked. So he crossed all the tall plants from his first cross to see what he would get in the second generation. Look at figure M-2. In the second generation, for every three tall plants he got there was one short plant. So apparently, the short gene had been hidden in the first generation. So Mendel discovered that some genes can dominate or mask other genes. When one gene can mask another gene we say that it is the dominant gene. The other gene is the recessive gene. Taking many of the pea plant traits and crossing them the same way he did with the traits tallness and shortness, he discovered which traits were dominant and which were recessive. Look at figure M-3. He found, for example, that round seeded genes were dominant over wrinkled seed genes. Colored seed genes were dominant over white seed genes, etc. Also, you'll see here that in the second generation in each of the crosses Mendel made that there was always a three to one ratio of the dominant trait to the recessive trait. From these experiments, Mendel believed that all organisms have two hereditary factors (or genes) for every trait, one from the mother organism and one from the father organism. Remember the cross with the tall plant and the short plant and all of the offspring were tall. But of the grandchildren of the tall and short parent plants, some were tall and some were short. So each parent, the tall and the short must have each contributed one gene for plant height, so that that trait had two genes one from each parent. And it must be the same with all traits. There must be two genes for every trait an organism has.

In making his crosses, Mendel used letters to represent the genes. For example, big T might represent the gene for tallness. Big R might represent the gene for round seed, etc. He always represented the dominant gene with the capital letter and the recessive gene with the uncapsulated same letter. For example, if big T represents tallness, then what would represent shortness? If you said small t you were right. If big R represents round seed, then what would the recessive wrinkled seed gene be represented by? If you said small r you were right.
Now, let's look back again and see how Mendel explained how two tall parents could give rise to small offspring. Look at the figure M-4. Lift the transparency up and just look at the ditto. Here you see two tall pea plants giving rise to mostly tall pea plants but also some short ones. How can this be explained? Well, lay the transparency down and see how Mendel explained it. For these two parents to produce small offspring, they must have each contributed a small gene. So they must each contain a hidden small gene. But since they are tall they must have a tall gene also. So they have two genes for plant height contained on matching chromosomes. Those two genes for each parent must be a big T and a little t. Now, when their sex cells are made, remember meiosis, the matching chromosomes separate into different sex cells so that these two genes also separate into different sex cells. There are four possible ways these four sex cells can combine. The big T sperm can fertilize the big T egg giving rise to a big T big T offspring. Or the big T sperm could fertilize the little t egg giving rise to a big T little t offspring. What would happen if the little t sperm fertilized the big T egg? Or if the little t sperm fertilized the little t egg? You can see now how two tall parents can give rise to a short offspring. Now look at the paired letters again on all of these pea plants. These are called genotypes because they show what each gene of a gene pair is. The letters that represent genes in a gene pair are called the genotype. The outward appearance of an organism as expressed by the genes is called the phenotype. What would the phenotype of these parent pea plants be? If you said tall, you were right. If both genes in a gene pair are alike, then the genes are said to be homozygous, homo meaning alike. If the two genes of a gene pair are different, then the genes are said to be heterozygous, hetero meaning different. What would you call the genotypes of the parent plants here? If you said heterozygous, you were right. One or two more terms and we will have the basic language of genetics described here. Since you know about meiosis, you will be able to visualize what happens in this next situation. Since the genes of a gene pair are on different matching chromosomes they separate into different sex cells during meiosis. This is called gene segregation or the principle of segregation. Segregation means separation. The genes on matching chromosomes are separating into different sex cells as you saw in meiosis. Each member of a gene pair is called an allele. Are the alleles of the small plant here in figure M-4 homozygous or heterozygous? If you said homozygous, you were right. This completes objectives four and eight.

This is the end of Section 3.

This is the Beginning of Section 4

Without realizing it, at one time or another you probably have engaged in using probability, the mathematical science that tries to predict the chances that a certain event
may happen. You may have flipped a coin, tossed the dice, or drew a card. At any rate, you may or may not have known your chance of winning at these games of chance. When you are dealing with a large number of possible events that can occur in a situation, it is useful to know something about probability. Look at figures M-5 and M-6. Here are some questions concerning the probability of certain events occurring in games of chance and two basic laws of probability that are underlined here. In order to know what the chance of a certain event occurring is, you must know what the total number of possible outcomes it. With a coin, there are two possible outcomes. With one die there are six possible outcomes. With one card, there are 54 possible outcomes. Sometimes we refer to our chances or probability as one chance in ten or one chance in two; a one sixth chance or one fourth chance. Sometimes we refer to it in percentages. A one fourth chance would be 25 percent. A one tenth chance would be ten percent.

Experts in probability have been known to go to Las Vegas and clean up the house on games they know give them the best odds or probability of winning. Probability experts, for example, can use statistical mathematics at the game of Black Jack and win far more than they lose. However, all the other games are highly stacked in favor of the house. Have you ever thought of what your chance of winning the jackpot on a slot machine is? Usually there are three or four wheels on a slot machine with a dozen or more symbols on each wheel. You get the jackpot only when the house symbol shows up on all three wheels at the same time. Each wheel is independent of the other wheel. What is the probability of getting the house symbol on one wheel? 1/12 if there are a dozen symbols on the wheel. The same probability would be true of the other wheels. So what would be the probability of getting the house symbol on all three wheels at the same time? 1/12 times 1/12 times 1/12 or one chance in 1728. Most of the games of chance in Las Vegas have odds such as these. So if you ever have the thought of winning some money or getting rich quick in Las Vegas forget it. The odds on the games are such that only a few out of a thousand come out with something substantially ahead of what they went in with and hundreds out of a thousand come out with a lot less than what they went in with.

You might ask at this point, what does this have to do with genetics? In meiosis, when sex cells are made, there are a number of possible ways the matching chromosomes can line up in the middle of the cell and separate into different sex cells. Look at figure M-7. This is a very simple illustration of the possible combinations of genes we can get in a sex cell depending on the way the matching chromosomes line up when sex cells are made. Here we are dealing with two different traits, tallness and roundness. In
Patterns of Heredity

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each case the individual is heterozygous for both traits. When you are talking about two different traits in this situation, you can get four different sex cells. But organisms have more than two traits. A human being, for example, has about 10,000 traits. These different genes can separate into different sex cells in many thousands of ways. So probability is used to predict the possible genetic outcomes of crosses when certain traits are known in the parents.

Look at figure M-8. This will show you how to do a simple genetic cross and figure out the probable outcome of the traits in this cross. Jim has brown hair and Joan has blond hair. Jim's mother had blond hair. Brown is dominant over blond. What is the probability that they will have blond haired children? The first thing you do is determine the genotypes of Jim and Joan. Since Jim's mother was blond haired, Jim must have a hidden black haired gene. He must have one gene for brown hair he got from his father and one gene for blond hair he got from his mother. So if we let big B symbolize brown hair and little b symbolize blond hair, what must Jim's genotype be? If you said big B little b you were right. Since Joan is blond haired she must have both blond haired genes. So what must her genotype be? If you said little b little b, you were right. The second thing you do in figuring out a genetic cross is to determine the different types of sex cells each parent has. Remember that in meiosis matching genes separate into different sex cells. Since Jim has a big B and a little b, in meiosis, these will separate into different sex cells. So half of Jim's sex cells will have the big B and the other half will have the little b. Since Joan is homozygous and both her genes are the same, all her sex cells will have the little b. The third thing you must do is to determine all the possible ways the sperm can fertilize the egg. Lay the transparency down now. If the big B sperm fertilizes the little b egg what will we have? A heterozygous brown haired child. However, if the little b sperm fertilizes the little b egg we will have a blond haired child. So we have a 1/2 probability of having a blond haired child. Now, turn off your tape recorder for a moment and look over figure M-9. This may also be a good time to do the problems in the first section under problems of your study guide booklet.

The kind of crosses we have just done and the ones you did under your problem section deal with only one trait at a time in the cross. For this reason, we call this a monohybrid cross or a one trait cross. The genetic crosses get a little more difficult when we cross organisms and try to keep track of two traits at a time. A two trait cross is called a dihybrid cross. Look at figures M-10 and M-11. This will show you how to do a dihybrid cross. The steps you take here are the same as the ones you take to do a monohybrid cross, except this time you are dealing with two traits at a time.
You will also take this cross through two generations. Now do the dihybrid crosses in the problem section of our study guide. If you have any difficulty, see the instructor for help.

This is the end of section 4.

This is the Beginning of Section 5

Now that you are familiar with the language of genetics and have solved a few simple genetic problems dealing with dominant and recessive genes it is time for you to become aware of the fact that not all genes dominate over other genes. Many times genes are equally expressed and produce a blending. If you have already studied filmstrip number two on incomplete dominance, you are already familiar with this idea. Look at figure 15-13 on page 395 of the old version or figure 16-11 on page 323 of the new version. In the old version you see a red bull being crossed with a white cow. These two parents are pure bred, so you would expect that all the offspring in the first generation would be red. But they're not red. The first generation offspring are halfway between red and white, a color called roan. Apparently red does not dominate over white here but both are equally expressed producing an intermediate color. If all the roan brother and sisters mate together, the second generation will produce one red, two roan, and one white and you can see how they inherited these genes. In the new version this same phenomenon is illustrated with the red and the white snapdragon. In this cross, the first generation are all pink, while the second generation there is one red, two pink, and one white.

You should now know how genes function and how they are inherited in various combinations. Some genes dominate over other genes while some genes are equally expressed in the gene pairs.

There is one last thing I will mention about genetic crosses for this unit. Since recessive genes are hidden, there is no way of knowing if organisms are homozgous or heterozygous. It may be handy to know whether or not an organism is pure bred for a particular trait before you do a cross with it. For that reason, sometimes it is necessary to do what is known as a test cross. Let's say you have a pure black guinea pig. You don't know for sure if it is pure bred, homozygous or heterozygous. So you will do a test cross. What do you think you should cross him with to see if he is pure bred? If you said a white female guinea pig you were right. If he is pure bred, what should all the offspring look like? If you said black, you were right. If he is not pure bred what should the offspring look like? If you said one half of them should be black and one half of them should be white, you were right. If you didn't quite understand this, try doing this cross on paper to see what the outcome should be. Now turn your
tape recorder off for a moment and look over Investigation 15-19 or 16-C and then turn your tape recorder back on again.

You know by now that genes control every trait you have including your blood type. In this experiment your blood will be typed and you will do a little pedigree chart of your parents and relatives to show how you inherited your particular blood type. Look at figure M-12. In the human population, there are four basic types of blood. As you can see here, the human blood cell is disc shaped, almost like a donut but not with a complete hole through it. These blood cells float in a clear fluid in the blood vessels of our bodies. This clear fluid is called plasma. Some people have red blood cells with a protein called "A" on them. Therefore, they have type A blood. People with this type of blood have a built-in antibody in their plasma called anti B. If B protein is ever introduced into their blood, their anti B will destroy that blood. Some people have blood cells with protein "B" on them. Therefore, they have type B blood. They have built-in antibodies that will destroy type A proteins. A person that has neither A or B proteins on his blood cells is said to be type O. This person has both antibodies A and B in his plasma. So if either type A or type B blood ever enters his body it will be destroyed. A person that has both A and B protein on their blood cells is said to be type AB. For obvious reasons this person has neither anti A or B in his plasma. When blood transfusions are needed for injured or sick people, it is always important to give them their own type of blood. But if there is a shortage of their type of blood, there is another possibility. Type O can be given to anyone since usually the amount of blood transfused into the body is small compared to the amount of blood already in the body, the small amount of anti A and B that accompanies the O blood will do a small amount of damage to a type A or type B person or to an AB person. Since there are no proteins on type O blood, the blood cannot be destroyed by the antibodies of other types of blood. For the same reasons, a type AB person can receive, in an emergency, any of the other types of blood. This person has no antibodies that will destroy other types of blood.

In addition to the four types of blood mentioned here, there is an additional protein associated with red blood cells. It is called the Rh protein. About 80 percent of our population has this protein on their red blood cells. This protein is called Rh after the Rhésie monkey where it was first discovered. Unlike the other types of proteins, people who do not have this protein aren't born with an antibody against Rh protein. They must be exposed to the Rh protein once before their body can make Rh antibodies. A person that has the Rh protein is said to be Rh positive. And a person that does not have the protein is said to be Rh negative. So a person can be A positive or negative, B positive or negative, AB positive or negative, or O positive or negative.
To type your blood I will use three different serums. A serum that has anti A, one that has anti B, and one that has anti Rh. I will extract three drops of blood from your left index finger and mix each drop with these serums. If anti A causes your blood to clot, then you must be A, etc. I'll let you interpret the results of this experiment.

Now, how do genes determine these blood types. Look at figure M-13. Remember, there are two genes for every trait. In this case, both type A and type B genes are dominant over type O but they are not dominant over each other. Rh\(^+\) gene is dominant over the Rh\(^-\) gene. So a person with type A blood could have the genotype AA or AO. However, a person with type O blood would have only the genotype OO. The rest is summarized in this figure.

One more thing to mention about blood genetics, and that's the disease erythroblastosis or the common name Rh babies. Remember, that I said that a person that does not have the Rh protein is not born with ready made anti Rh. They have to be exposed to Rh before their bodies will build antibodies against them. So a person that is Rh\(-\) will get away with having Rh\(^+\) blood transfused into him the first time only. But if he ever has Rh\(^+\) blood transfused into him after that, he will die. This same problem can exist in a different way when an Rh\(-\) mother has a Rh\(^+\) baby in her. If her husband is positive and she is negative, chances are good that her baby is positive. Look at the bottom of figure M-13. Even though the blood of the baby develops separately from the mother's blood, there is an organ called the placenta where the mother's blood drops off food and takes away waste. The baby's blood circulates on the other half of this placenta and picks up its food and leaves it waste. However, for some reason, in most instances, some of the baby's Rh proteins pass through the placenta and into the mother's blood. So during the time she is carrying her first Rh\(^+\) baby she is developing antibodies against Rh\(^+\) blood. Since she cannot develop antibodies fast enough to harm the first baby, the first baby is born unharmed. But if the mother ever has another Rh\(^+\) baby, the mother's already present Rh antibodies will leak through the placenta and destroy the baby's blood causing severe anemia or lack of red blood cells. This is called erythroblastosis. (Erythroblasts are the red blood cells.) The baby could be miscarried or born severely anemic. If the baby is born alive, it must have an immediate transfusion of Rh\(^-\) blood. Mother's that are known to have this condition are now treated in one of two ways. They are given vaccines after the first baby that suppress the mother's ability to make antibodies or about the seventh month of the pregnancy on the second Rh\(^+\) baby, the womb is opened and one of the baby's legs is lifted out and a complete blood transfusion is done then. The leg is then placed back in the womb and the womb is sewed up. Now do the Rh genetic crosses in the problem section of your study guide.

This is the end of Section 5.
D. Crissman

AT STUDY GUIDE

PATTERNS OF HEREDITY

1. Read sections 15-1 and 15-2 on pages 375 to 377 of the old version or sections 16-1 and 16-2 on pages 309 of the new version.

2. Turn on your tape to section 1. Objectives 1 and 3.

3. Read over Investigation 15-3 or 16-A.

4. Turn on your tape to section 2.

5. Begin Investigation 15-3 or 16-A.

6. Read sections 15-4 to 15-7 on pages 378 to 385 of the old version or sections 16-3 to 16-6 on pages 310 to 316 of the new version.

7. Turn on your tape to section 3. Objectives 4, 5, and 8.

8. Look over Investigation 15-8 or 16-B and the supplementary handout on this experiment. Your instructor will demonstrate all the techniques of this experiment. Be sure you have mastered all these techniques before you do this experiment. This experiment will take about five weeks.

9. Read sections 15-9 to 15-14 on pages 387 to 394 of the old version or sections 16-7 to 16-11 on pages 316 to 323 of the new version.

10. Turn on your tape to section 4. Objectives 6, 7 and 11.

11. Read sections 15-15 to 15-18 on pages 394 to 398 of the old version or sections 16-12 to 16-15 on pages 323 to 327 of the new version.

12. Turn on your tape to section 5. Objectives 9, 12, 15.
Figure M-1

Inv. 15-3 or 16-A Investigating The Influence Of Heredity And Environment on Plant Pigmentation

1. Divide the blotting paper into 36 equal squares by drawing one big square and dividing it up with 5 lines each way.

2. With your probe, punch a hole in the middle of each square.
3. Dip each blotter into distilled water.
4. Licking the tip of your probe, pick up one tobacco seed at a time and carefully place it in each hole.
5. Put one petri dish in a baggie and leave in the light—wrap tin foil around the other dish.
Figure M-2

Pure bred tall pea plant × pure bred short pea plant

$P_1$ parent cross

First filial generation

All the offspring are tall pea plants—was the short gene lost or is it just hidden?

Allow these two tall pea plants to reproduce

Second filial generation

A 3:1 ratio for every 3 tall plants, there is one short plant—so the short gene can be masked
### Figure M-3

**Mendel: Found Dominant and Recessive Traits**

Pea plants

<table>
<thead>
<tr>
<th>Trait Studied</th>
<th>Dominant</th>
<th>Recessive</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. seed shape</td>
<td>round</td>
<td>wrinkled</td>
</tr>
<tr>
<td>2. endosperm color</td>
<td>yellow</td>
<td>green</td>
</tr>
<tr>
<td>3. seed coat color</td>
<td>colored</td>
<td>white</td>
</tr>
<tr>
<td>4. pod shape</td>
<td>inflated</td>
<td>wrinkled</td>
</tr>
<tr>
<td>5. pod color</td>
<td>green</td>
<td>yellow</td>
</tr>
<tr>
<td>6. flower position</td>
<td>axial</td>
<td>terminal</td>
</tr>
<tr>
<td>7. stem length</td>
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<td>short</td>
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<th>P&lt;sub&gt;2&lt;/sub&gt; plants</th>
<th>ratio</th>
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<tbody>
<tr>
<td>1. round x wrinkled</td>
<td>all round</td>
<td>round x round</td>
<td>5474 round</td>
<td>2.96:1</td>
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<td></td>
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<td>1852 wrinkled</td>
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<tr>
<td>2. yellow x green</td>
<td>all yellow</td>
<td>yellow x yellow</td>
<td>6022 yellow</td>
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<td></td>
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<td>2001 green</td>
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<td>3. colored x white</td>
<td>all colored</td>
<td>colored x colored</td>
<td>705 colored</td>
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<td>seed coat</td>
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<td>224 white</td>
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<td>4. inflated x wrinkled pods</td>
<td>all inflated</td>
<td>inflated x inflated</td>
<td>882 inflated</td>
<td>2.95:1</td>
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<td></td>
<td>299 wrinkled</td>
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<tr>
<td>5. green x yellow</td>
<td>all green</td>
<td>green x green</td>
<td>428 green</td>
<td>2.82:1</td>
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<td>pods</td>
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<td></td>
<td>152 yellow</td>
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<td>6. axial x terminal flowers</td>
<td>all axial</td>
<td>axial x axial</td>
<td>651 axial</td>
<td>3.14:1</td>
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<td></td>
<td></td>
<td></td>
<td>207 terminal</td>
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<td>7. long x short stems</td>
<td>all long</td>
<td>long x long</td>
<td>787 long</td>
<td>2.84:1</td>
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<tr>
<td></td>
<td></td>
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<td>277 short</td>
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</tbody>
</table>
How can two tall parents give rise to a small offspring?

Lay down the transparency and see how Mendel explained this.
1. What is the probability of tossing heads on a coin?

2. What is the probability of rolling snake eyes on the dice?

Possible outcomes of the role:

- 1 1 2 1
- 1 2 2 2
- 1 3 2 3
- 1 4 2 4
- 1 5 2 5
- 1 6 2 6

ETC. There are 36 possible outcomes.

How many of these outcomes are snake eyes?

Since we have two different dice here, we have two quite separate and independent outcomes on each dice possible. It wouldn't matter if we rolled them at the same time or at different times.

**First Law of Probability**

If you want to know what the chances of two independent events occurring at the same time are, multiply the chances of them occurring separately.

For example:

There is a 1/6 chance of getting 1 (one) on the first die and a 1/6 chance of getting 1 on the second die. So the chance of getting 1's on both dice at the same time is 1/6 × 1/6 = 1/36.
3. What would the probability be of getting a heart out of a deck of cards?

First of all, you have to know how many cards are in the deck and how many of them are hearts.

If this is an honest deck, there should be 54 cards of which 13 are hearts.

\[ \frac{13}{54} = \frac{1}{4} \quad \text{So you have a 25\% chance of drawing a heart.} \]

4. What is the probability of tossing heads on a coin after you have tossed the coin 100 times without getting heads?

answer: 50:50 (each throw is independent of the other)

**Second Law of Probability**

The result of one trial of a chance event does not affect the results of later trials of the same event.
Figure M-7

POSSIBLE WAYS CHROMOSOMES CAN LINE UP IN MEIOSIS

Matching chromosomes can line up this way or this way

Gametes (sex cells)  gametes

FOUR POSSIBLE TYPES OF SEX CELLS

How many types of sex cells could we get with 100 different traits?

PROBABILITY IS USED TO PREDICT THE POSSIBLE GENETIC OUTCOMES OF CROSSES WHEN CERTAIN TRAITS ARE KNOWN IN THE PARENTS.
Jim has brown hair and Joan has blond hair. Jim's mother had blond hair. Brown is dominant over blond. What is the probability that they will have blond haired children?

**STEP 1**

**DETERMINE THE GENOTYPES OF THE PARENTS JIM AND JOAN**

Since Jim's mother was blond haired, Jim must have one gene for blond hair hidden. Let $B =$ brown hair and $b =$ blond hair

(YOU MUST ASSIGN LETTERS TO REPRESENT THE GENES)

Jim's genotype must be $Bb$. He is heterozygous

Joan must have $bb$. She is homozygous

**STEP 2**

**DETERMINE THE TYPE OF SEX CELLS EACH PARENT HAS**

**STEP 3**

**DETERMINE THE POSSIBLE COMBINATIONS OF THE SEX CELLS**

Make a box (called a punnett square)

```
  B  b
  B  B
  b  b
```
Figure M-9

Art has brown eyes and Nancy, his wife, has brown eyes. If Art's Dad has blue eyes and Nancy's mother had blue eyes, what is the probability Art and Nancy will have blue-eyed children?

**STEP 1**

Art's genotype

Nancy's genotype

**STEP 2**

**STEP 3**

**STEP 3**

Diagram showing the genetic process and outcomes.
HOW TO DO A DIHYBRID CROSS (TWO TRAIT CROSS)

If we take a pure bred tall, round seeded pea plant and cross it with a pure bred short, wrinkled seeded pea plant, what will the offspring look like? REMEMBER tall is dominant to short and round is dominant to wrinkled.

**STEP 1**

**ASSIGN LETTERS TO EACH TRAIT**

let $T =$ tall $t =$ short $R =$ round $r =$ wrinkled

**DETERMINE THE GENOTYPES OF THE PARENTS**

pure bred tall, round $= TTRR$ (remember two genes for each trait) (always homozygous)

pure bred short, wrinkled $= tt rr$

**STEP 2**

**DETERMINE THE GAMETES EACH PARENT HAS**

This will give up all the possible outcomes of this cross

Since all the sperm have the same genes for these two traits and the eggs all have the same genes for these traits, this is easy.

**STEP 3**

**DETERMINE THE POSSIBLE WAYS THE SPERM CAN FERTILIZE THE EGGS**

All the offspring will have this genotype for both these traits—WHAT IS THE PHENOTYPE? ARE THE OFFSPRING HOMOZYGOUS OR HETEROZYGOUS FOR THESE TRAITS?

NOW LOOK AT FIGURE M-11
Let all the offspring of the cross in figure M-10 reproduce.

STEP 1

DETERMINE THE GENOTYPES OF THE PARENTS

TtRr   TtRr

STEP 2

DETERMINE THE GAMETES EACH PARENT HAS

if you don't understand this, refer back to Figure M-7

four different types of gametes for each parent

STEP 3

DETERMINE THE POSSIBLE WAYS THE SPERM CAN FERTILIZE THE EGG

This will give you all the possible outcomes that could occur in the offspring.

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<th>Tr</th>
<th>tR</th>
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<td>TtRr</td>
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</tbody>
</table>

phenotype ratio:

9  tall, round
3  tall, wrinkled  9:3:3:1
3  short, round
1  short, wrinkled
Figure M-12

There are different types of human blood

- Blood cell (front view)
- Blood cell (side view)

- Type A: Antibody B, proteins A, plasma
- Type B: Antibody A, proteins B, plasma
- Type AB: No antibodies, proteins A, B
- Type O: No proteins, plasma
- Rh+ blood
- Rh- does not have Rh protein
Figure M-13

BLOOD TYPES AND THEIR GENOTYPES

<table>
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<th>Phenotype</th>
<th>Genotype</th>
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<tr>
<td>Type A</td>
<td>AA or AO</td>
</tr>
<tr>
<td>Type B</td>
<td>BB or BO</td>
</tr>
<tr>
<td>Type AB</td>
<td>AB</td>
</tr>
<tr>
<td>Type O</td>
<td>OO</td>
</tr>
<tr>
<td>Rh+</td>
<td>Rh+ Rh+ or Rh+ Rh-</td>
</tr>
<tr>
<td>Rh-</td>
<td>Rh- Rh-</td>
</tr>
</tbody>
</table>

ERYTHROBLASTOSIS
Rh Baby

- Father Rh+
- Mother Rh-
- Rh+ baby

First baby - Rh+
Mother begins making Rh+ antibodies

Second baby - Rh+
Mother's antibodies (anti Rh+) begin destroying baby's blood
# ACTIVITY OPTIONS AND OBJECTIVES

## GENETICS

### Activities

<table>
<thead>
<tr>
<th>Activities</th>
<th>Objectives</th>
</tr>
</thead>
</table>
| AT Kit - Genetics     | The Student Shall:  
  1. explain Sutton's reasoning, showing that genes are located on chromosomes.  
  2. explain linkage, crossing over, and gene segregation.  
  3. explain what sex linkage is and how Morgan discovered it.  
  4. construct a genetic chart of a cross between white and red eyed fruit flies.  
  5. explain how many and what chromosomes determine the sex of humans. Explain what chromosomes a male has and what chromosomes a female has.  
  6. list and explain two common, human sex linked traits.  
  7. construct a pedigree chart of Queen Victoria's family explaining how hemophilia was passed through the family.  
  8. explain what non-disjunction is and what human abnormalities express it.  
  9. explain what sex selection is and how it is accomplished.  
  10. discuss some of the recent advancements in human genetics (test tube babies, genetic engineering, etc.) |
| Filmstrips            | 1. New Trait Combinations and Mutations  
  2. Population Genetics | 1 Objective each |
| Solo Learn Kits       | 1. Linkage, Crossing Over and Chromosome Maps  
  2. Sex Determination and Sex Linkage  
  3. Mutations and Chromosomal Modifications | 3 Objectives each |
| Books                 | Sex Determination (Write 5 page summary and take oral quiz.) | 5 Objectives. |
| Pamphlet              | The Genetic Effects of Radiation | 4 Objectives |

**YOU MUST DO 15 OBJECTIVES.**
Around the turn of the century, little was known about how traits were inherited. Biologists who studied the cell knew about mitosis and meiosis, while other biologists were just beginning to pay attention to the laws of Gregor Mendel on the inheritance of traits. It took a man of great insight, Walter Sutton of Columbia University to put all of the known facts together and come up with a workable theory to explain how traits are inherited. A summary of his theory will be found in figure G-1. He reasoned that the hereditary link between organisms and their offspring is very small. The only physical thing that is passed on from parents to their offspring are sex cells, sperm and eggs. Out of one sperm and one egg comes a new offspring. Sutton said that the sperm and egg each contribute one half of the genetic material. Since sperm cells are mostly nucleus and the nucleus of the sperm and egg are very similar, but the cytoplasms are very different, he believe, therefore, that genes must be in the nucleus. The chromosomes are seen in the nucleus of the cell when the cell is dividing and behave much like Mendel's hypothetical laws of genetics. Therefore, genes must be on chromosomes and the process of meiosis is responsible for separating or segregating the genes into different sex cells. Look at figure 16-4 on page 411 of the old version or figure 17-1 on page 331 of the new version. Observations of the way chromosomes behave during meiosis are the support Mendel's proposed behavior of genes. Study this diagram. Columbia University has since become one of the leading centers of the study of genetics in the world.

This is the end of Section 1.

This is the Beginning of Section 2

A student of Sutton's at Columbia University made another great discovery in genetics, quite by chance. Thomas Hunt Morgan was an expert in genetic crosses of fruit flies. Fruit flies are used extensively in studying genetic behavior because a single male and female fruit fly can produce 200 or more offspring in less than two weeks. So selective mating of fruit flies with certain traits have yielded a vast amount of information of how genes are inherited. The story goes that Morgan was working with some fruit flies in his lab one day when he discovered a fly with a trait he had never seen before. Normal fruit flies have red eyes, but the one he found had white eyes! When examining fruit flies, they must be put to sleep with ether and while he was looking at this one it woke up and flew off. Not about to lose this great discovery, he locked the doors of his lab and took the place apart piece by piece to find the fly.
After many hours of searching he carefully caught the fly and mated it with a normal red eyed female. In the first generation all the flies were red eyed. What does this indicate to you? Red eyed must have been dominant over white eyed. This was not unusual. He allowed the brother and sisters to mate to produce a second generation. As expected in dominant crosses there were three red eyed flies to every white eyed fly. A Mendelian 3:1 ratio. But, all the white eyed flies were males! This trait was somehow linked to the sex of the fly. He began to think that maybe some traits are linked to the sex of the organism. Could there be some difference in the chromosomes of the male and female fruit fly? Careful observations of the cells of fruit flies show that the male has one chromosome that is different from that of the female. Look at figure 16-5 on page 412 of the old version or figure 17-2 on page 332 of the new version to see what they saw. They discovered that there is one pair of chromosomes that determine the sex of the organism. They labeled this pair of chromosomes X and Y. They found that a fruit fly that has two X chromosomes is a female and that one that has one X chromosome is a male. Later discoveries in other animals show similar findings. In humans, for example, a person that has two X chromosomes is a female and a person that has a Y chromosome is a male. Apparently in humans the Y chromosome determines the male's sex. What Morgan discovered here is that some genes are on the X chromosome. Look at figure 16-6 on page 413 of the old version or figure 17-3 on page 333 of the new version. This diagram shows how sex is determined in fruit flies. In meiosis, the X and Y chromosome pair of a male parent separates into different sex cells, so that half the sperm have the Y chromosome in them and the other half has the X chromosome in them. It is quite obvious that all of the egg cells of the female has X chromosomes in them. If a sperm with a Y chromosome fertilizes an egg, what sex will that fly be? It will be a male because it will have an X and Y chromosome pair. But if the sperm containing the X chromosome fertilizes the egg, what sex will the fly be? It will be a female because it has two X chromosomes. So, in sexual reproduction in many animals including people is determined by the male parent. If the Y sperm fertilizes an egg, it will be a male. If the X sperm fertilizes an egg, it will be a female.

Look at figure 16-7 in the old version or 17-4 in the new version. Here you can see some actual photographs of the chromosomes of human beings. As you recall, humans have 46 chromosomes or 23 pairs of chromosomes. Cell experts can take pictures of human cells undergoing cell division and can cut out the chromosomes and put them in their paired order as you see them here. This is called a karyotype. You can see the sex chromosomes in the last pair.
Morgan believed that the difference in appearance of sex chromosomes might have something to do with the sex linked inheritance of white eyes in fruit flies. He hypothesized that for every gene on the \( X \) chromosome in the male, there was not a matching gene on the \( Y \) chromosome as in all the other paired chromosomes. Look at figure G-2. So if the gene for white eyes is on the \( X \) chromosome, there is no matching gene for eye color on the \( Y \) chromosome and the male fly will have white eyes. Look at figure 16-8 in the old version or figure 17-5 in the new version. This diagram shows how male fruit flies inherit the white eyed gene. In meiosis, the white eyed male parents sex chromosome pair separate into different sex cells. One half the sex cells will get the \( X \) chromosome with the white eyed gene on it while the other half will get the \( X \) chromosome. If the sperm with the \( X \) chromosome fertilizes the egg, we will get normal eyed females that are heterozygous for white eyes. When this generation mates to produce the second generation, one half of the female’s egg cells will have the \( X \) chromosome with the white eyed gene on it. When the \( Y \) sperm fertilize these eggs, we will have white eyed males. When the \( X \) sperm fertilize these eggs, we will have a normal eyed heterozygous female. Study this diagram and be sure you understand it.

This is the End of Section 2.

This is the Beginning of Section 3

Since human beings have sex chromosomes as well as other animals such as fruit flies, it is reasonable to assume that there are some human sex linked traits. Color blindness and hemophilia are two common sex linked traits found mostly in men and seldom in women. As you recall from figure G-2, a male does not have any matching genes on his \( Y \) chromosomes to hide any recessive genes he may have on his \( X \) chromosome. So if he gets any recessive genes in his \( X \) chromosome they will show up in him. However, a female must have both recessive genes on both chromosomes for her to show the recessive trait. If she gets only one recessive gene on one \( X \) chromosome, chances are good that there will be a dominant matching gene to hide it on the other \( X \) chromosome. So it is rare for a female to show a recessive sex linked gene although it does happen on occasion.

Apparently in humans a recessive gene for color blindness is located on the \( X \) chromosome and is inherited in the same way that the male fruit fly inherited white eyes.

Another interesting human sex linked trait is hemophilia. This is called bleeder’s disease. The person’s blood who has this disease cannot clot when an injury is sustained either a cut or an internal bruise. Consequently, this person could bleed to
death even from the most minor injury. Even if this person merely bumps himself he could bleed internally and die. The gene that makes the enzyme that makes the chemical that causes the blood to clot seems to mutate at a certain rate within the human population. An interesting case history or pedigree chart on hemophilia can be seen in figure 16-9 in the old version or 17-6 in the new version. In looking back on the ancestry of Queen Victoria of England, hemophilia did not appear before she was born. It is believed that the gene responsible for making the enzyme that makes the chemical that causes the blood to clot mutated in Queen Victoria's mother and that she got this recessive gene. But since she got a normal gene from her father, she merely carried this gene and did not have the disease. In your genetic problems booklet, you will find several problems dealing with Queen Victoria and hemophilia. Do the first problem in the cross between her and Albert and determine the probability that her sons would have hemophilia. As you look at the chart, you will see that Queen Victoria had four sons and only one of them Leopold had hemophilia. However her daughters Alice and Beatrice carried the gene on one of their X chromosomes. Alice married Louis IV of France and they had five daughters and two sons. One of the sons, Frederick William had hemophilia but never married. Two of the five daughters carried the hemophilia gene on one of their X chromosomes. One of the daughters was Alexandra. She married Nicolai II of Russia. You'll notice that they had four daughters and one son. The one son, Alexis had hemophilia, but we don't know how many of the daughters carried the gene. You'll see question marks above each of their names. This is because they were all killed when they were teenagers before they could get married and have children. You see, Nicholas was the last Czar of Russia, an old line traditionalist that believed that the only family in Russia that was of value was his. He had a callous indifference toward the people he ruled. He was a weak and incompetent leader and consequently the Russian people lived in extreme poverty ill fed, ill clothed, and ill housed. Finally, a democratic coalition rose up and overthrew Nicholas but were too weak to maintain control of the country. Nicholas and his family were exiled to Siberia until Lennin and the communists took over and had complete control of the country. Then Nicholas and Alexandra and their family were moved to Moscow and held prisoners in a sealed up house. Late one night they were told to pack up their belongings, that they were going to be moved. They had all gathered into one room to wait for their transportation when several armed assassins entered the room and a volley of bullets rang out striking them all dead. Apparently Lennin had ordered their execution, perhaps out of revenge.

Now try some sex linked problems in your genetic problem booklet. This is the end of Section 3.
Calvin B. Bridges, a graduate student of Morgan's at Columbia University worked with a trait in fruit flies called vermilion eyes. Vermilion is a lighter red than the normal eye color and is a recessive sex linked gene (a gene found on the X chromosome). Look at figure G-3. Bridges did this particular cross many hundreds of times. He produced many thousands of offspring from this cross. If you followed the cross correctly, there should never be any females with vermilion eyes, only males. But Bridges found a very puzzling thing. In about one in 2000 offspring, he would fine a female with vermilion eyes. How could this be? The only way we can have a vermilion eyed female is if she has two vermilion eyed genes. The father of this female does not have any vermilion gene, so she must have got her two vermilion genes from her vermilion eyed mother. But in meiosis, her mother's two vermilion eyed genes are supposed to separate into different sex cells so that each sex cell has only one vermilion eyed gene. Bridges began to think that maybe once in every 2000 meioses the matching chromosomes that these two genes are on do not separate like they are supposed to into different sex cells but stay together and go into the same sex cell, giving that cell an extra chromosome. Look at figure 16-11 in the old version or figure 17-7 in the new version. This is the way chromosomes are supposed to behave in a normal meiosis. The vermilion eyed genes on matching chromosomes separate into different sex cells. When the normal sperm of the male fertilize these eggs we get a vermilion eyed male and a heterozygous normal eyed female. Now look at figure 16-12 in the old version or figure 17-8 in the new version. This is Bridges explanation for getting a vermilioned eyed female. The two vermilioned eyed genes in the mother did not separate in meiosis but both went into the same egg cell. When the Y sperm fertilized these egg cells, we got a vermilioned eyed female. Remember that in fruit flies the Y chromosome does not make a male. This is true only in humans. If a fly has two X chromosomes it is automatically a female. You can see the results of the other possible fertilizations. Now. How can we test this explanation. If you said to examine the dividing cells of the vermilion eyed female and see how many chromosomes she has, you were right. Microscopic examination showed that vermilion eyed females had two X chromosomes and a Y chromosome. Whenever paired chromosomes fail to separate into different sex cells during meiosis, this is called non-disjunction. Non-disjunction is not limited to fruit flies. It occurs with certain frequency in humans, producing human beings with abnormal number of chromosomes. We have already discussed two such cases in other units. Mongolism or Down's syndrome is one in which the chromosomes of pair number 21 fail to separate giving the new individual an extra chromosome. You can read about the other syndromes at the end of this chapter. If you are interested in seeing pictures of these individuals, see the instructor.
Look at figure G-4. It is estimated that there are as many as 10,000 genes that make up the human body. But there are only 46 chromosomes that are found in human cells. So there must be hundreds of genes linked together on the same chromosome. When genes are linked together on the same chromosome, this is called gene linkage. Mendel was not only ingenious but lucky. All the traits he used in his crosses happened to be on different chromosomes so they independently separated from one another freely in meiosis. But can genes separate freely from one another when they are on the same chromosome? Looking at figure G-4 it seems as though linked genes can be separated into different sex cells by chromosomal crossing over. Apparently in meiosis I when the matching chromosomes are paired, that they cross over each other and exchange parts. When they do this, one of the duplicated DNA's from each chromosome has given up some of its genes in exchange for the corresponding genes on one of the DNA's of the matching chromosome. In meiosis II when these duplicated DNA's separate, the formerly linked genes will be in different sex cells. We can now get four different sex cells; Bt, BT, bT, and bt. Before crossing over occurred, we could only get two different sex cells; Bt and bT.

This is the end of Section 4.

This is the beginning of Section 5

As mentioned earlier, we now know that one half of the human male's sperm contains the Y chromosome which is small and has very few genes on it. The other half contain the X chromosome. If a Y sperm fertilizes the egg, the baby will be a boy, but if the X sperm fertilizes the egg, the baby will be a girl. For years, some biologists tried to find some visual differences in human sperm since half contain a different sex chromosome. They thought that maybe the sperm containing the Y chromosome might be smaller than the sperm containing the X chromosome but they could never see any differences under the microscope. Dr. Landrum Shettles who is a gynecologist at the Columbia School of Physicians and Surgeons at Columbia University made some exciting discoveries. A gynecologist is a doctor that specializes in human sex organs and human sexual reproduction. Late one night Shettles was looking at human sperm under a phase contrast microscope which is a microscope that shines lights at different angles on the subject so that they can be seen with shadowy casts that illuminate them almost in three dimensions. He saw two distinctly different kinds of sperm. One kind was smaller and more rounder than the other kind. This is what he had been waiting years to see and by accident on this night he saw it. Using special techniques he was able to separate the small sperm from the larger ones and perform various experiments on them. Look at figure G-5. He believed that the small sperms contained the Y chromosome and he called them androsperms. He believed that the large sperm con-
tained the X chromosome and he called them the gynosperms. He discovered that when he put the androsperms in an acidic solution they were more easily destroyed than the larger gynosperms. But when the androsperms were in an alkaline solution they thrived and could swim much faster than the heavier gynosperms. He found that the androsperms outnumbered the gynosperms by 70% and only lived about 24 hours compared to the gynosperms life span of 72 hours. So apparently the androsperms are not as strong and durable as the gynosperms. Being a gynecologist, Shettles knew what the conditions of the female vagina and uterus were during sexual intercourse. He had also wondered for a long time why some families seem to have only children of one sex. Shettles believed that this is due partly to some men having far more androsperms than gynosperms or vice versa. But probably more often than this situation, he believed that it depended on the way the couple had sexual intercourse. The main part of the vagina is acidic while the mouth of the uterus and the uterus itself is basic or alkaline. Most married couples tend to have sexual intercourse the same way most of the time. If the penis is inserted all the way up into the vagina near the opening of the uterus, androsperms can outswim the gynosperms and get to the egg first causing the sex of the baby to be a boy. If the couple has intercourse in such a way that the penis only goes part way up the vagina, the sperm will be released into an acidic environment causing a large portion of the androsperms to be destroyed leaving the gynosperms to get to the egg first, thus, a girl. Also the timing of intercourse is important. If intercourse is engaged in more than a day before the egg is ready to be fertilized, the androsperms will be dead, leaving only the gynosperms to fertilize the egg, thus a girl. So with this knowledge, Dr. Shettles solicited patients who wanted a certain sex of a child either a boy or a girl to try his recipes for either boys or girls. If a couple wants a boy, the wife douches with baking soda prior to sexual intercourse. This will create an excellent environment for the androsperms. When intercourse is engaged in, the penis must be inserted all the way up to the mouth of the uterus. Also sexual intercourse must be engaged in only a day before the egg comes out of the ovary--this can be measured by the wife's temperature charts or test tape kits. If a girl is desired, the wife should douche with vinegar before intercourse. Vinegar is acetic acid and will destroy a large number of the androsperms. Also, the penis should be inserted only part way up the vagina so that the sperm is deposited in the acid. Intercourse should take place frequently up to the second or third day before ovulation. Shettles also found that with frequent intercourse the androsperm count drops severely leaving only gynosperms. In trying this with hundreds of couples he notes that between 80 and 90% of the couples got the sex they wanted. He believes that if his procedures are followed religiously, a couple will have better than a 90% chance of getting the sex they want in a child. Thus, couples that try time after time to get that little girl they
want so badly they often end up with five or more boys and never do get a girl or vice versa. Now they can plan their families better; restrict the number of children they have and have the sex they want in their children. This is called sex selection.

There have been other great discoveries recently made in the field of human reproduction and human genetics that we will talk about in class. For example, it may be possible for a busy career woman to hire someone to carry her baby for nine months. Or to genetically engineer a human being to any specifications you desire. We'll talk more about this in class.

This is the end of section 5.
1. Read sections 16-1 to 16-3 on pages 405 to 410 of the old version or sections 17-1 to 17-2 on pages 331 to 332 of the new version.

2. Turn on your tape. Objective 1.

3. Read sections 16-4 to 16-6 on pages 410 to 415 of the old version or sections 17-3 to 17-4 on pages 332 to 335 of the new version.

4. Turn on your tape to section 2. Objectives 3, 4, and 5.

5. Read section 16-7 on pages 415 to 416 of the old version or section 17-5 on pages 335 to 337 of the new version. Objectives 6 and 7.

6. Turn on your tape to section 3. Objectives 6 and 7.

7. Read sections 16-8 to 16-12 on pages 416 to 427 of the old version or sections 17-6 to 17-9 on pages 337 to 374 of the new version.

8. Turn on your tape to section 4. Objectives 2 and 8.

9. Turn on your tape to section 5. Objectives 9 and 10.
Figure C-1

Walter Sutton of Columbia University in New York reasoned that genes were on chromosomes about 1900.

Sutton's reasoning:

1. The biological link between organisms is very small.
2. This link consists of 2 tiny cells, a sperm cell and an egg cell.
3. Since genes are passed from one generation to another, they must be located in the sperm and the egg cell.
4. Sutton said the sperm and egg each contribute 1/2 the genetic material.
5. Sperm cells are mostly nucleus - the nucleus of the sperm and the egg are very similar but the cytoplasms are very different. Therefore, the genes must be in the nucleus.
6. The chromosomes are in the nucleus and behave much like Mendel's hypothetical laws of genetics.
7. Therefore, genes are on the chromosomes and the process of meiosis is responsible for separating or segregating the genes into different sex cells.
These are the chromosomes of a white eyed male. There is no matching normal eyed gene on the Y chromosome to hide or dominate over the recessive white eyed gene on the X chromosome.

This is a red eyed heterozygous female.

A female may carry a white eyed gene, but there is usually a dominant normal eyed gene to hide it. A female would have to have two X chromosomes each with a white eyed gene on it to actually have white eyes.

ANY GENES ON THE X CHROMOSOMES ARE SAID TO BE SEX LINKED.
Calvin B. Bridges, a graduate student of Morgan's worked with vermillion eyed flies, a sex-linked trait. Vermilion is a lighter red than the normal eye color of the fruit fly and is controlled by a recessive gene (v).

WHAT WOULD THE RESULTS BE IN A CROSS BETWEEN NORMAL EYED MALE AND A VERMILION EYED FEMALE? Let V represent normal eyes and v represent vermillion eyes.

After thousands of crosses, Bridges found a few puzzling outcomes. About one in every 2000 flies, a daughter with vermillion eyes was produced!

QUESTION: WHAT IS THE ONLY WAY WE CAN GET A VERMILION EYED FEMALE?

ANSWER: THERE MUST BE 2 VERMILION EYED GENES

WHEN 2 CHROMOSOMES FAIL TO SEPARATE IN MEIOSIS, THIS IS CALLED NON-DISJUNCTION.

QUESTION: WHAT WOULD BE A GOOD WAY TO FIND OUT IF BRIDGES THEORY WAS RIGHT?
Bridges observed the cells of these usual flies with a microscope. If his theory was right, what would you expect to find?

(one extra X chromosome) He found one extra X chromosome!

Thus, Bridges proved that genes are physically located on chromosomes.
Many genes are on the same chromosome—

For example, the human being has as many as 10,000 genes. But a human being only has 46 chromosomes. Therefore, many genes must be on the same chromosome.

Could B ever separate from t into different sex cells or b from T?

It is known that in meiosis I when paired chromosomes are side by side, they cross over and exchange parts, thus separating the linked genes.

So even if genes are located on the same chromosome, they can be separated into different sex cells. This is called gene segregation.
Dr. Landrum Shettle's of Columbia University discovers how to select the sex of your child before it is born---

He discovered that the male sperm are of two kinds: sperms with X chromosomes he calls gynosperms and sperms with the Y chromosome he calls andro sperms.

**Comparison of the two kinds of sperm**

<table>
<thead>
<tr>
<th>male sperms (andro sperms)</th>
<th>female sperms (gynosperms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. smaller and rounder</td>
<td>larger and oval shaped</td>
</tr>
<tr>
<td>2. destroyed more easily by acid</td>
<td>can survive longer than andro sperms in acid</td>
</tr>
<tr>
<td>3. thrive in an alkaline environment</td>
<td>thrive in an alkaline environment</td>
</tr>
<tr>
<td>4. are much lighter and faster than gynosperms</td>
<td>heavier and more bulky than andro sperms</td>
</tr>
<tr>
<td>5. there are 70% more of these than gynosperms</td>
<td></td>
</tr>
<tr>
<td>6. live only about 24 hours</td>
<td>live up to 72 hours</td>
</tr>
</tbody>
</table>