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A SCHEME FOR EVALUATING THE AUDIO-TUTORIAL
BIOLOGY LABORATORY IN THE COGNITIVE
AND AFFECTIVE DOMAINS

DISSERTATION
Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
John Hunter Wheatley, B.A., M.A.T.

The Ohio State University
1972

Approved by
Robert W. Howe

Advisor
College of Education
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I wish to express my appreciation to the many persons who gave their guidance and assistance in this study. Some of these individuals are listed.

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VITA

November 19, 1940 ...... Born - Beaufort, North Carolina

1963 ..................... B.A., Duke University, Durham, North Carolina

1963 - 1965 ............. Biology and General Science Teacher, George Wythe High School, Richmond, Virginia

1965 ..................... M.A.T., Duke University, Durham, North Carolina

1965 - 1969 ............. Instructor, Assistant Professor of Biology, Stratford College, Danville, Virginia

1969 - 1972 ............. Teaching Associate, Faculty of Science and Mathematics Education, The Ohio State University

PUBLICATIONS


FIELDS OF STUDY

Studies in Science Education: Professor Robert W. Howe
Studies in Biology: Professor C. Benjamin Meleca
Studies in Teacher Education: Professor Herbert L. Coon
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CHAPTER I

INTRODUCTION AND OVERVIEW

The laboratory has been an important part of science courses in high schools and colleges since the beginning of this century (Hollister, 1939); yet few attempts have been made to define the role that the laboratory should play in an introductory science course. Three important objectives that an introductory science course should teach are as follows:

1. the understanding of scientific concepts and principles,
2. the development and improvement of attitudes toward science,
3. the application of concepts and principles using the skills and methods of science.

These objectives should all fall to some extent within the range of the science laboratory.

Many authors (Anderson, 1968; Abell, 1970; Murray, 1969) have expressed the opinion that the primary objective of the biology lab should be to teach students the skills and attitudes which biologists employ in obtaining an understanding of their field. The role of the laboratory in
accomplishing this objective has been well established in modern learning theory by Gagne (1965) and Bruner (1968). Using the investigative skills and methods of science, the principles and concepts presented in other parts of the course are reinforced and drawn together in the laboratory; this approach restates the science concepts in more concrete terms, increasing the retention of the materials (Smith, et al., 1942). Recent studies (Coulter, 1966; Mahan, 1963; Sorenson, 1966) indicate that students express more positive attitudes toward science when taught with a laboratory-centered approach.

Yet despite the indications that an investigative laboratory should be effective in obtaining the objectives of science in the Cognitive (Bloom, et al., 1956) and Affective Domains (Krathwohl, et al., 1956) little research has been done to demonstrate this. An explanation for this lack of research may lie in the ineffectiveness of many evaluative instruments for assessing the laboratory.

**The Problem**

This study will investigate the development of a scheme for evaluating the science laboratory. This problem may be broken into several sub-problems:

1. To design a program for assessing science objectives
   a) in an innovative science program,
b) in a large, general laboratory setting,

2. To develop an evaluative instrument as a part of this program,

3. To use the instrument
   a) in assessing student achievement,
   b) in assessing student attitudes toward science,

4. To analyze the relationships between science experiences received in the laboratory and attitudes.

Need for Study

General Objectives for Science Courses

Since the dawn of the space age less than fifteen years ago, the interest in science courses has increased many fold. This concern has caused instructors of introductory college courses, as well as those in other areas, to re-assess the objectives for teaching science and to reorganize their courses around these new objectives in order to increase the effectiveness of their program. Three basic objectives that an introductory science course should teach, and as listed in the Introduction (page 1), are as follows:

1. the understanding of scientific concepts and principles,

2. the development and improvement of attitudes toward science,

3. the application of concepts and principles using the skills and methods of science.

These objectives have been stated in various forms by
many authors. The Fifty-Ninth Yearbook of the National Society for the Study of Education (Committee on the Re-thinking of Science Education, 1960) is devoted to science education and gives four general objectives of science education which are similar to the ones listed above:

1. the teaching of scientific concepts rather than isolated facts,
2. the teaching of science as a process involving problem-solving skills,
3. the development of such attitudes as open-mindedness and curiosity,
4. the development of scientific literacy.

The National Science Teachers Association has given similar objectives for the teaching of science (National Science Teachers Association Curriculum Committee, 1964); more recent NSTA publications (Eiss & Harbeck, 1969; Koran, et al., 1969) emphasize the interrelationship of the Cognitive, Affective, and Psychomotor Domains in science teaching.

Specific Objectives for Science Courses

The three objectives of science on page one can be seen to correspond basically with two of the domains of educational objectives: the Cognitive Domain (Bloom, et al., 1956)—the understanding of scientific concepts and principles—and Affective Domain (Krathwohl, et al., 1956)—the development and improvement of attitudes toward science.

The third objective of science (the application of concepts
and principles using the skills and methods of science) includes the application of the various levels of thinking within the Cognitive Domain.

**Cognitive Domain**

Bloom's work on the Cognitive Domain (1956) listed six categories for behaviors concerning cognition: knowledge, comprehension, application, analysis, synthesis, and evaluation. In order for a student to demonstrate an "understanding of scientific concepts and principles," he should be able to perform operations in all six categories of the cognitive domain.

It is stated in the Fifty-Ninth Yearbook of NSSE (Committee on the Rethinking of Science Education, 1960) that isolated facts in science are without value unless they are woven into generalized concepts. Novak (1953) agrees with this position and remarks that retention of isolated biological facts declines rapidly immediately following a testing situation. A study by Berger (1963) indicates that retention is greater if the material is taught through the understanding of principles.

The importance of constructing tests that evaluate students at various levels of understanding (i.e., levels of the Cognitive Domain) was pointed out by Tyler in 1933. He states that in order for an instrument to adequately measure complex outcomes, it must include test items for all the
levels of understanding which that particular task involves (Tyler, 1933).

The National Science Teachers Association (National Science Teachers Association Curriculum Committee, 1964) points out the importance of continuous evaluation in the Cognitive Domain; this is necessary in assessing both the student and the curriculum. The NSTA also suggests the possibility of constructing a hierarchy of important science concepts similar to Bloom's order of cognitive levels.

**Affective Domain**

This domain has been divided into five categories of affective behavior by Krathwohl and others (1956): Receiving, Responding, Valuing, Organization, and Characterization by a value or value complex. Each succeeding category represents a more definite or more complex feeling.

A National Science Teachers Association publication (Eiss and Harbeck, 1969) recognizes the importance of using affective objectives in teaching an interrelationship of the Affective Domain with the Cognitive and Psychomotor Domains.

Several pertinent studies (Mahan, 1963; Coulter, 1966; Sorenson, 1966) have indicated that favorable attitudinal changes on the part of the student may accompany inductive, problem-solving, laboratory-centered approaches to science.
Evaluating the Laboratory

The role of the laboratory in an introductory science course is to develop in the student an understanding of the concepts and principles of science through their application in the laboratory (Anderson, 1965; Murray, 1969). This work in turn may lead to positive changes in student attitudes toward science (Coulter, 1966; Mahan, 1963).

Unfortunately attempts at evaluating the students' understanding (Cognitive Domain) and attitude (Affective Domain) have not always been successful. The use of non-specific objectives and the failure to cover objectives in both domains, have been a handicap in this area. The Watson-Glaser Critical Thinking Appraisal (Howe and Ramsey, 1969), the Test on Understanding Science - TOUS (Test on Understanding Science, 1961), and the Cornell Critical-Thinking Test (Sorenson, 1966) are not always appropriate measures of the Affective Domain in science. Much work remains to be done in the area of instrumentation if appropriate assessment is to be made in these two domains.

Summary

Three general objectives for an introductory science course can be stated:

1) the understanding of scientific concepts and principles (Cognitive Domain),

2) the development and improvement of attitudes toward science (Affective Domain),
3) the application of concepts and principles using the skills and methods of science (application within the Cognitive Domain)

It would be desirable to teach these objectives in the science laboratory. Applying the concepts and principles of science in the laboratory seems to result in a greater retention of these concepts (Smith, et al., 1942; Novak, 1963; Berger, 1963). Student attitudes toward science become more positive when a laboratory-centered approach is used (Coulter, 1966; Mahan, 1963).

As a whole, research attempts at evaluating the laboratory in fulfilling these objectives have been unsuccessful. This has been partially a failure to designate specific objectives to evaluate (Jeffrey, 1965), but the critical problem in most studies has been the lack of an efficient assessment instrument (Howe and Ramsey, 1969; Buros, 1959). This study will attempt to design an evaluation technique that can be used in assessing the objectives of science at the higher levels of the Cognitive and Affective Domains. Although this scheme of evaluation will be tested in a specific situation, it is intended that it will serve as a general model for evaluation in other science laboratory programs.

**Hypotheses**

The hypotheses to be tested in this study are as follows:

1. There is no significant relationship between achievement at the higher levels of the two
domains and background variables.

2. There is no significant relationship between achievement at the higher levels of the two domains and sex.

3. The instruments developed for this study will be able to discriminate between students performing at various levels of the Cognitive and Affective Domains.

4. Students who have worked through activity units specially designed to teach the higher levels of the Cognitive Domain will score significantly higher on the cognitive instruments than students who have worked through the regularly assigned activity units.

5. Students who have worked through the specially designed activity units will show a significantly positive change in attitudes toward science as assessed by the Affective instruments than those students who work through the regular activity units.

6. The multi-media approach in Biology 100 at The Ohio State University is able to develop the higher levels of the two domains in a significant number of students as measured by the instruments used in this study.

Delimitations of the Study

The delimitations set forth in this study are:

1. The study will be limited to students enrolled in Biology 100 at The Ohio State University during the Summer and Academic Year 1970-71 or some portions thereof.

2. There will be no attempt to follow students through the two-quarter sequence of Biology 100 and Biology 101.

3. This study is not intended as an evaluation of the multi-media laboratory approach.

4. The evaluative instruments for the Cognitive Domain will be used for assessing only three
units of study in Biology 100 and not for the whole course.

Limitations of the Study

The limitations set by this study are:

1. The content of the three units of study which are assessed will influence the percentage of questions asked from each category of the two domains.

2. Due to the amount of time required of the participants in this study, volunteers were used and no attempt was made to obtain a random sample.

3. Since the participants in this study were volunteers, the number of students in each cell in the data analysis is not equal.

Assumptions

Assumptions related to this study are as follows:

1. The laboratory approach can be used as a means of developing in the student thinking patterns, skills, and attitudes that correspond to the higher levels of the Cognitive and Affective Domains.

2. An instrument can be developed that will evaluate student performance in the laboratory at the higher levels of both domains.

Definition of Terms

Some of the terms employed in this study are defined below in order to aid in the understanding of the problem.

1. ACTIVITY UNIT: the total activities for the week presented to the student during laboratory sessions in the Bio-Learning Center and pertaining to the concept under study for that
week. The activity unit may be presented through several media: an audio-tape lecture, work in the student study guide, a 35mm slide sequence, microscope work, manipulation of a laboratory experiment, the use of living materials, and other similar activities.

2. AFFECTIVE PROCESSES: categories of feeling as identified in Krathwol's Taxonomy of Educational Objectives: Affective Domain (1956), specifically: receiving (attending), responding, valuing, organization, and characterization by a value or value complex.

3. BIO-LEARNING CENTER (BLC): the physical facilities housing the study carrels where students perform the activity units; these facilities are located on the ground floor of Rightmire Hall on Carmack Road, West Campus, College of the Biological Sciences of The Ohio State University.

4. COGNITIVE PROCESSES: categories of thinking as identified in Bloom's Taxonomy of Educational Objectives: Cognitive Domain (1956), specifically: knowledge, comprehension, application, analysis, synthesis, and evaluation.

5. MULTI-MEDIA SYSTEM: the presentation of materials through several media, such as video-tapes, audio-tapes, 35mm slides, discussions and recitations, manipulation of living materials, experimentations, and other.

6. RECITATION PERIOD: a class taught by faculty, staff biologists, and/or graduate teaching
associates for the purpose of reviewing and discussing the material presented at the BLC during that week. Quizzes and other assignments may be given at this time. Many courses have similar recitation sections in addition to a more formalized lecture session.

7. STUDENT STUDY GUIDE (SSG): prepared laboratory guides distributed to the students to accompany the Activity Unit in the BLC. The SSG is designed with pictures, diagrams, charts, tables, terminology, laboratory hints, student objectives, and activity instructions, and is used to accompany an audio-tape presentation.

8. STUDY CARREL (STUDY BOOTH): the specially equipped booths in the BLC where the student performs the Activity Unit for each week. Each carrel is a miniature laboratory equipped with a dissecting microscope, a small sink and tap, an automatic slide projector and screen, a set of earphones, and a control panel to operate all functions of a remote control tape deck banked with other tape decks in the center of the room. Other equipment, such as film-loop projectors, is available for use by the student in the carrel. Similar study carrels are found in most auto-instructional programs.
9. TELEVISION PERIOD: a class conducted by faculty, staff biologists, and/or graduate teaching associates where the students view a short television presentation which is related to the material presented in the BLC; a discussion on the material presented usually follows the program. The television presentations often center around current research related to some biological concept. Similar television periods are found in various forms in other courses.

**Background of the Study**

It is recognized that the function of the laboratory is to teach the concepts and principles of science through the scientific method, to develop the skills necessary for investigative activities, and to instill within each student positive attitudes toward science and the scientist. To do this, the laboratory must provide a learning situation that develops the objectives of the higher levels of the Cognitive and Affective Domains. Having identified a serious lack of efficient evaluative techniques and schemes for those laboratory objectives, this study undertakes the task of developing such an instrument.

One of the laboratory methods being used as a means of teaching for the higher levels of learning is the multimedia approach. In this type of instructional program, in-
formation and activities are presented to the student in various forms, allowing for individualization and self-pacing. The College of the Biological Sciences of The Ohio State University in Columbus, Ohio, initiated a multi-media laboratory approach for the teaching of Biology 100 and 101 (General Biology) in 1969. It is in this laboratory situation that the instrument developed for this study will be tested.

A Survey of Multi-media Programs

The first major attempt at a multi-media approach to a college science course was made by Postlethwait and others (1964) at Purdue University in 1961 where the course involved was Introductory Botany. The success of this integrated program has been reported by Steiner (1965) in The American Biology Teacher.

Postlethwait (1964) felt that such an innovative program was necessary because of the knowledge explosion and the population expansion. He also gave three necessary ingredients in a multi-media approach to learning: 1) a variety of teaching techniques should be used, 2) the materials should allow the student to proceed at his own pace, and 3) personal contact should occur between the student and the teaching staff. All of these criteria are met in the Ohio State program.

Following in the wake of Postlethwait's work, several
colleges and universities have established similar programs. The University of Texas has tried the multi-media approach in their chemistry laboratory (McAda, 1966). The objectives that were set up for this program are quite similar to some of the ones being stressed in this study: students should develop the ability 1) to design an experiment to test an hypothesis, 2) to order data, 3) to predict the effects of an action, and 4) to formulate hypotheses.

Other states have also introduced multi-media programs. The State University College at Brockport, New York, has a course in biology that utilizes an audio-visual program (Syrocki and Thomas, 1968); similar programs are in use on several college campuses in the United States and Canada. Some current audio-tutorial programs include ones in the biological sciences at Purdue University, the University of South Carolina, Syracuse University, and the University of Guelph in Ontario, Canada and in humanities at Cabrillo Community College in California. Novak suggests the use of audio-tape programmed instruction for science in the elementary school (Novak, 1968). The University of Minnesota has established a Science Center where high school teachers and student teachers can make use of an auto-tutorial, multi-media program (Gross, 1967).

A 1968 study by Meleca at Syracuse University used the multi-media approach in an auto-instructional biology course. His findings indicated that such an approach can be used as
an effective means for teaching a college biology course.

The Multi-media Biology Program at

The Ohio State University

The College of Biological Sciences, Introductory Biology Program at The Ohio State University has integrated a multi-media approach with introductory biology-Biology 100 and 101. The students in this two-quarter sequence (Biology 100 may also be taken alone or advance placement may put a student directly into Biology 101) attend a weekly thirty minute video-tape recorded television presentation on "biological problems" plus a fifty minute recitation-discussion, but the heart of the program is the multi-media Bio-Learning Center (BLC). Here the students spend approximately three and one-half hours a week listening to audio-taped presentations and performing activities related to the course content.

The multi-media Bio-Learning Center at Ohio State is the result of an extensive study by former Assistant Dean Robert Menefee (The Ohio State University News Service, 1970). The resulting program was developed by C. Benjamin Meleca and used much of the theory in Postlethwait's original study. After the initial development and planning phase, Meleca was made director of the program; through his efforts the Bio-Learning Center was established on the Ohio State campus.
The Bio-Learning Center is the largest multi-media learning facility in the country, containing 194 study carrels designed for use by thirty-three hundred students. Each carrel serves as a miniature laboratory for the student; each is equipped with a dissecting microscope, a light microscope, an automatic slide projector and screen, a small sink and water tap, a set of earphones, and a control panel to operate a remote control tape deck (Meleca, 1971).

Listening to the audio-tape which he controls, the student receives an integrated lecture-laboratory demonstration which is geared to accompany the 35mm slides on the projector. Through the audio-tapes and student study guide, the student is presented with tasks to perform and problems to solve; the materials for these activities are available at a nearby demonstration table or are supplied in the carrel. The student can proceed through the material at his own pace, repeating any part of the instruction when he wishes (The Ohio State University News Service, 1970).

The Bio-Learning Center first began full operation at the start of the Winter Quarter in January, 1970, after the multi-media materials had been tested by approximately 475 students during the summer of 1969 (Meleca, 1971).
CHAPTER II

REVIEW OF THE LITERATURE

This study involves an attempt at using a large laboratory situation to develop cognitive reasoning at the higher levels of Bloom's taxonomy (Bloom *et al.*, 1956) and to generate positive attitudes toward science and scientific processes using the higher levels of the Affective Domain (Krathwohl, *et al.*, 1956). A review of the literature in this area can be divided into three sections:

1. General Objectives of the Science Laboratory,
2. Studies in the Cognitive Domain,

**General Objectives of the Science Laboratory**

Laboratories have been associated with science courses since before the turn of the century and have taken on increasing importance in recent years. Many authors have compiled general objectives for science, but most do not specifically relate these objectives to the laboratory. It should be pointed out that in many science courses the laboratory, or at least student-oriented activities, provides the focal point for learning.
The Fifty-Ninth Yearbook of the National Society for the Study of Education (Committee on the Rethinking of Science Education, 1960) gives four general objectives for science education:

1. the teaching of scientific concepts rather than isolated facts,
2. the teaching of science as a process involving problem-solving skills,
3. the development of such attitudes as open-mindedness and curiosity,
4. the development of scientific literacy.

Paul DeHart Hurd (National Science Teachers Association Curriculum Committee, 1964) points out some major goals of science teaching. Among these he includes the following:

1. teaching cognitive skills rather than the knowledge assumed essential to attaining these skills,
2. providing for complex inquiry skills and investigative strategies,
3. developing an understanding of the structure of science.

Hurd emphasizes that laboratory work occupies a central point in the teaching of these objectives in science. It is here that the student is able to explore ideas and ask questions. Inquiry skills are developed along with a
greater understanding of concepts in science as the student investigates relations between theory and practice. An appreciation of the structure of science evolves from this type of investigative approach.

Similar objectives for science teaching can be found throughout the literature. In 1932 Wilbur Beauchamp (Hoff, 1942) presented a rather lengthy list of objectives of science instruction in the Bulletin of the U.S. Bureau of Education; among these were the teaching of fundamental principles, the development of scientific literacy, the exploration of interests and capabilities, the establishing of scientific thinking patterns, and the generation of positive attitudes toward science.

Eugene Smith and Ralph Tyler (Smith, Tyler, et al., 1942) suggested a shift in emphasis in science teaching. They indicated that in the classroom and laboratory the students should gain knowledge and problem-solving techniques which could be applied in the solution of the problems which arise in daily life.

More recently books by John S. Richardson (1957) and Robert Haun (1960) have stressed the development of reflective or critical thinking as a major objective of science teaching. Both authors indicate that an important method of generating such scientific thinking is through the laboratory. A lab approach that allows for
individualization and uses fewer "cook book" techniques lends itself to the development of critical thinking.

The emphasis on developing scientific concepts, principles, skills, and attitudes in science courses has been reiterated by Taba (1962) and Thurber and Collette (1967). All point to the laboratory as the principal means of attaining these objectives. Thurber and Collette state that a major long-range objective of science teaching should be the development of "certain ways of thinking." Scientific questioning and reasoning is a process of paramount importance in science courses.

Many of the objectives of science teaching as expressed by the authors above can be summarized into three main objectives:

1. the understanding of scientific concepts and principles,
2. the development and improvement of attitudes toward science,
3. the application of concepts and principles using the skills and methods of science.

These three objectives can all be implemented in the laboratory through a problem-solving approach where the student is required to manipulate data and use critical thinking skills. Gagné (1965) points to the problem-solving method as a step-by-step means of understanding the
use of basic principles; through this method higher-order principles become part of the individual's repertory, and the individual's capability is permanently changed. Bruner (1968) agrees that the problem-solving approach teaches an individual to go beyond the evidence at hand to achieve new insights into the principle involved.

Woodruff (1961) is in agreement with both Gagné and Bruner on the importance of allowing students to become involved in the problem-solving process. He points out that a student can learn best by direct contact with activities which require the use of critical thinking skills. Such problem-solving activities could become a part of the science laboratory. Guilford (1967) suggests that the process of problem-solving is promoted when the student can receive information which is to be evaluated in more than one form, that is, in figural, semantic, symbolic, and behavioral forms.

The objectives given above for science teaching correspond basically with two of the domains of educational objectives. The first objective—the understanding of scientific concepts and principles—falls within the range of the Cognitive Domain as described by Bloom and others (1956); this includes the patterns of cognition which lead to understanding. The second objective—the development and improvement of attitudes toward science—
is a part of the Affective Domain of Krathwohl and others (1956). The final objective—the application of concepts and principles using the skills and methods of science—includes the application of the various levels of thinking within the Cognitive Domain.

Summary

General objectives for the teaching of science often emphasize the development of scientific concepts, principles, skills, and attitudes (Committee on the Rethinking of Science Education, 1960; National Science Teachers Association Curriculum Committee, 1964). It is possible to summarize much of this work into three main objectives:

1. the understanding of scientific concepts and principles,
2. the development and improvement of attitudes toward science,
3. the application of concepts and principles using the skills and methods of science.

Many authors (Smith, Tyler, et al., 1942; Richardson, 1957; Haun, 1960; Taba, 1962; Thurber and Collette, 1967) point to the laboratory as the principal means of attaining these objectives, and modern learning theory (Woodruff, 1961; Gagné, 1965; Bruner, 1968) tends to support this
idea. Other recent literature (Guilford, 1967) indicates that learning problem-solving skills in the laboratory can be facilitated by presenting information to the student in many different forms and allowing the student to constantly evaluate the information.

The objectives for the science laboratory outlined above fall generally into Bloom's Cognitive Domain (1956)—Objectives one and three, or Krathwohl's Affective Domain (1956)—Objective two.

Studies in the Cognitive Domain

The understanding and application of scientific concepts and principles should be a basic objective of the science laboratory. Darrel Murray (1969) writing for the Commission on Undergraduate Education in the Biological Sciences (CUEBS) of the American Institute of Biological Sciences (AIBS) points to the laboratory as the vehicle through which students can gain understanding of the basic concepts in science. Murray stresses that the primary role of the lab is to make the student aware of the attitudes, decisions, meanings, strengths, limitations, and values embodied in science; he feels that this can best be done by involving the students in scientific investigation.

Dana Abell (1970) also writing for CUEBS expresses the opinion that the laboratory should teach the student
the skills and attitudes which scientists employ in obtaining an understanding of their field. This can be done by giving the student some experiences in the kinds of things that scientists do.

Chatham (1965) agrees with both Murray and Abell in the importance of student laboratory investigations. A basic failure of science education is the stifling of imagination in the student. Chatham states that the laboratory can reduce this problem by encouraging flexibility in ideas and investigations. A problem-solving laboratory can allow the student to be creative and imaginative and to act on his own.

The teaching for understanding in science rather than for memorization of facts leads to a greater retention of scientific material. A study by Novak (1963) indicates that there is a sharp decline in the ability of students to retain biological facts following classroom tests over the material. Novak suggests that the teaching of basic biological ideas and the nature of science rather than factual material will lead to greater retention of the material. Another study involving chemistry students in high school (Berger, 1963) shows that students who gain an understanding of atomic structure retain the ability to write correct chemical formulas significantly longer than students who have only memorized the valence numbers.
Berger also demonstrates that those students who have been taught an understanding of atomic structure are able to apply this knowledge in new situations better than traditionally trained students.

The capacity of students to understand scientific principles and to apply this understanding in problem-solving situations is facilitated in the laboratory. The students can be taught to approach problems critically provided the laboratory involves the students in all aspects of experimentation (Anderson, 1968). Critical thinking ability can develop when students are actively engaged in planning, manipulating, and analyzing experimental data.

A study by Rickert (1967) using a physics course for college freshmen showed that a laboratory, problem-solving approach was better able to teach critical thinking than the traditional lecture-demonstration approach with laboratory and recitation sections. Rickert's experimental classes analyzed problems, examined assumptions, collected and organized data, and tested hypotheses; these classes scored significantly higher on the American Council on Education Test of Critical Thinking. The difference between the experimental and the traditional groups was significant for all ability levels. This seems to
indicate that high mental ability is not a prerequisite for critical thinking; in fact the low ability group in the experimental class showed the greatest amount of change.

A similar study was done by Sorenson (1966) in high school biology classes. Comparing traditional lecture-demonstration classes with laboratory-centered classes, Sorenson found that the students taught with the lab approach showed a significant increase in critical thinking ability as measured by the Watson-Glaser Critical Thinking Test while the traditional classes did not show a significant change. This study also indicated a "moderate but substantial" relationship between critical thinking and understanding scientific principles. Like Rickert, Sorenson found that there was no relationship between critical thinking and mental ability.

Other studies—Cousins (1963) and Zingars and Collette (1968)—have also indicated that students can be taught to think critically. Zingars used the laboratory in a college physical science course as the teaching method for critical thinking while Cousins used group discussions and questioning techniques in an eighth grade social studies class. Both studies based their findings on student performance on the Watson-Glaser Critical Thinking Test.

In the 1962 Harvard Educational Review R. H. Ennis
listed twelve skills that were a part of critical thinking (Baughman, 1964). These skills included grasping the meaning of a statement, judging a line of reasoning, drawing conclusions, and evaluating the accuracy of a statement. All twelve skills listed by Ennis can be related directly to one or more of the six levels of thinking in the Cognitive Domain as set forth by Bloom and others (1956); most of the skills fall at least partially in one of the top three levels—Analysis, Synthesis, or Evaluation. Ennis suggested that more research in evaluation would be necessary in order to explore all aspects of critical thinking. It may be that Bloom's taxonomy provides an evaluative technique that can be effectively used in this area.

Evaluative Instruments

Work by Jeffrey (1965) showed the importance of establishing behavioral objectives for a science laboratory and constructing tests which evaluate those objectives. Using Bloom's taxonomy (1956) behavioral objectives can be classified as to the cognitive level which they occupy. Thus it can be determined if the objectives set forth for a laboratory cover the higher levels of the domain and teach for creative or critical thinking. The same technique can be applied to test construction to determine if
students are being tested at the higher levels of Bloom's cognitive categories.

At the Forty-Fourth Annual National Association for Research in Science Teaching Annual meeting, Pancella (1971) reported a survey of test items from forty-one tenth grade biology commercial tests. Using Bloom's cognitive taxonomy (1956), Pancella showed that 71.88 percent of the 2,689 test items studied were classified at the lowest cognitive level—Knowledge. Less than one and one-half percent of the items were in the upper three levels. Among his recommendations Pancella pointed out that, except for BSCS tests, standardized and commercial high school biology tests should not be used to measure cognitive levels above Knowledge (1.00) and Comprehension (2.00).

Many studies involving evaluation of laboratory-centered science courses stand or fall on the instrument selected to assess the students. Several studies—Mandell (1966) and Schefler (1965) among others—have failed to find any significant difference in critical thinking ability or in understanding science processes between traditional lecture-demonstration classes and laboratory-oriented classes whereas quite similar studies—Rickert (1967), Sorenson (1966), Zingars and Collette (1968), and others—have reported a significant difference.
There are very few instruments that are effective in evaluating the objectives to be achieved through the laboratory. One of the most frequently used tests is the Watson-Glaser Critical Thinking Appraisal. Although this instrument selects some of the basic processes of critical thinking to assess—deduction, inference, interpretation, and recognition of assumptions, its content is not taken specifically from science; consequently, scores on this test could result from critical thinking developed in classes other than the science laboratory (Howe and Ramsey, 1969). This test also shows a high correlation with standardized intelligence tests (Howe, 1972); this may indicate that outcomes on the Watson-Glaser Appraisal are related to the IQ of the students.

Another instrument often used to evaluate laboratory performance is the Cornell Critical Thinking Test. This instrument was standardized with seventh and eighth grade students in New York state who came from upper-lower and lower-middle class families (Sorenson, 1966). Like the Watson-Glaser Appraisal, the Cornell Critical Thinking Test correlates highly with student IQ scores (Howe, 1972), and whether or not this test assesses convergent thinking should be questioned.

Many of the other tests being used in evaluating the laboratory are equally inappropriate. TOUS (Test on
Understanding Science) is one which is often used with students in science courses at the college level. This test was not designed to assess the higher levels of the Cognitive or Affective Domains (Howe, 1972); consequently, teaching methods aimed at developing the more complex behaviors—interpretation and explanation, experimentation, synthesis, evaluation, and others—are not adequately evaluated.

In recent years greater attention has been paid to the construction of instruments with items at the various levels of Bloom's classification, and various studies—Carey (1968), Evan (1968), and Benson (1970)—have aimed in this direction. Carey (1968) composed an instrument for use at the elementary school level with items at Bloom's lower three levels—Knowledge, Comprehension, and Application; level designation was determined by the agreement of three of four research students in science education at the University of Wisconsin.

Evan (1968) at the University of Toronto used Bloom's taxonomy to construct a high school chemistry test with items at the Knowledge, Comprehension, Application, and Analysis levels; Evan pooled the results of a three member panel plus two separate classifications by himself to determine the proper level for each item. Benson (1970)
reported the construction of an instrument for assessing the performance of high school biology students at all six levels of Bloom's classification where Benson himself was sole arbiter in classifying the items. However this instrument required the students to give individual verbal responses.

Summary

The science laboratory can facilitate the understanding of scientific principles as well as teach the methods of applying these principles in new situations (Murray, 1969; Abell, 1970; Chatham, 1965). Students who learn scientific facts through the application of principles tend to retain this knowledge to a greater degree than other students (Novak, 1963; Berger, 1963). Some studies (Anderson, 1968; Rickert, 1967; Sorenson, 1966) have shown that critical thinking skills can be taught through a laboratory, problem-solving approach. These skills (Baughman, 1964) can be related directly to one or more of the six levels of thinking in the Cognitive Domain (Bloom, 1956) and particularly to the top three levels.

The importance of evaluating students at the higher levels of Bloom cannot be denied (Jeffrey, 1956), but most cognitive tests fail to contain items at these levels
(Pancella, 1971). Some instruments—Watson-Glaser Critical Thinking Appraisal, Cornell Critical Thinking Test, Test on Understanding Science—are used frequently in testing for critical thinking skills, but their ability to discriminate high level thinking in the laboratory is questionable (Sorenson, 1966; Howe and Ramsey, 1969; Howe, 1972). In recent years various studied (Carey, 1968; Evan, 1968; Benson, 1970) have produced instruments which use Bloom's category system, and attempts are being made to assess the higher levels of the Cognitive Domain.

Studies in the Affective Domain

One basic objective of the science laboratory should be the development and improvement of attitudes toward science. Darrel Murray (1969) of the American Institute of Biological Sciences (AIBS) declares that the primary role of the laboratory is to engage students in scientific investigations which includes making them aware of the attitudes and values found in scientific fields. Earl Kelley (1965) agrees with Murray's viewpoint; affective learning goes on anyway, and if this learning is positive, the learner becomes more constructive in his behavior.

Milton Pella (1966) is even more strongly for attitudinal changes; he writes that for a person to be
aware of the interrelationship between science and society, of ethics in science, and of the nature of science is more important to the informed citizen than conceptual knowledge of the science itself.

A recent study on changes in affective learning outcomes was undertaken by Neidt and Hedlund (1969). This study involved freshmen and sophomore students taking General Psychology at Colorado State University and the University of Missouri. A total of 866 students took part in the study. Attitude toward psychology and achievement in the subject were measured five times during the course at regular intervals. Although there was a consistent improvement in achievement on the part of the students, there was relatively little change in attitude. From this Neidt and Hedlund concluded that cognitive and affective outcomes were independent.

Several studies (Sorenson, 1966; Coulter, 1966; Mahan, 1963) have shown that laboratory-centered instruction can effectively bring about attitudinal changes in the student. Working with high school biology classes Sorenson (1966) found that students demonstrated a significant increase in open-mindedness following a laboratory-centered course whereas students taught with a lecture-demonstration approach showed no such change. Coulter's study (1966) also involved the biology laboratory. He
compared students in an inductive laboratory situation where they were able to develop their own experimental design to solve problems that arose in class discussions with students taught with an inductive demonstration approach or with a deductive laboratory approach. Those students from the inductive, laboratory-centered classes showed a more positive attitude toward science and science instruction than did the other students.

Mahan (1963) in a study with ninth grade, college preparatory, general science compared students in a class taught by a problem-solving method with students in a lecture-discussion class. Although he found no significant attitudinal changes at the .05 level, he did find that students taught with the problem-solving approach showed a superior growth in interest in science than students taught by the lecture-demonstration approach. Those students in the problem-solving classes demonstrated a greater growth in personal adjustment and positive attitudes toward school. This seems to indicate that the laboratory-centered approach to science is capable of contributing to attitudinal changes in students.

Instrumentation in the Affective Domain is definitely lacking. Very few commercial tests which pertain directly to science are available (Buros, 1965). Many studies--
such as the one by Neidt and Hedlund (1969)—relies on student reaction to statements which are judged to be attitudinally positive, neutral, or negative. There is even some doubt as to the relationship between scores on paper-and-pencil tests and actual affective behavior (Howe and Ramsey, 1969). The field on instrumentation in the Affective Domain needs much work; it is hoped that the work of Krathwohl and others (1956) in categorizing affective objectives will be of some value in this area.

Summary

Several authors (Murray, 1969; Kelly, 1965; Pella, 1966) indicate the importance of developing positive attitudes toward science in the student. Work by Neidt and Hedlund (1969) suggests that cognitive and affective outcomes may be independent. Several studies (Sorenson, 1966; Coulter, 1966; Mahan, 1963) have shown that laboratory-centered instruction can bring about positive attitudinal changes in students.

Very little work has been done in developing instruments for use in the Affective Domain. Commercially available affective tests in the sciences are decidedly lacking (Buros, 1965), and doubt has been cast on the relationship between scores on paper-and-pencil tests and actual affective behavior (Howe and Ramsey, 1969). Further work is needed in this area.
Summary

In recent years many authors (Taba, 1962; Tyler, 1966; Thurber and Collette, 1967) have stressed the importance of the science laboratory in teaching concepts, principles, skills, and attitudes in science. This in turn has led to the establishment of general objectives for the laboratory that include these ideas; three basic objectives for the science laboratory may be:

1. the understanding of scientific concepts and principles,
2. the development and improvement of attitudes toward science,
3. the application of concepts and principles using the skills and methods of science.

These three objectives fall into the Cognitive (Objectives one and three) and Affective (Objective two) Domains.

Many studies--Berger (1963), Richert (1967), Sorenson (1966)--have indicated that the laboratory-centered science class is capable of increasing the retention of material by students and of developing creative or critical thinking abilities. Creative thinking skills coincide with the higher levels of the Cognitive Domain as established by Bloom and others (1956); yet few commercial tests actually present items at these higher levels (Pancella, 1971), although recent attempts have been made to remedy
Most studies in the Cognitive Domain rely on a relatively few tests—Watson-Glaser Critical Thinking Appraisal, Cornell Critical Thinking Test, Test on Understanding Science (TOUS)—which are not always appropriate for the way in which they are used (Howe and Ramsey, 1969).

Studies in the affective areas of science (Sorenson, 1966; Coulter, 1966; Mahan, 1963) seem to indicate that a laboratory-centered approach is better able to bring about positive attitudinal changes than the traditional lecture-demonstration approach. The instruments used in many such studies are often constructed specifically for that study and are not always applicable in other situations. The use of Krathwohl's taxonomy (1956) in constructing such tests may help to remedy the confusion in this area.

Studies from both the Cognitive and Affective Domains stand or fall on the evaluative instrument used, and the construction of effective instruments in both areas is sorely needed. Part of the difficulty lies in the varying approaches that a teacher may use in the classroom; if a teacher teaches for a specific test item, this may cause that item to shift from one level to another within a domain or may actually cause the item to shift from one domain to another. Although the objectives of the science
laboratory may be generally agreed upon, without proper means of assessing these objectives the role of the laboratory cannot be substantiated.
CHAPTER III

THE STUDY - DESIGN AND METHOD

Design of the Study

The study for Biology 100 used a developmental design that can be seen in Appendix A. The population who participated in the study was selected from students who took Biology 100 at The Ohio State University during either the Autumn 1970 or Winter 1971 Quarter.

The students were divided into two general groups - those who would work through Activity Units 2A - 8A at the BLC during the quarter and those who would work through Activity Units 2B - 8B. Both groups did Activity Units 1A, 9A, and 10A.

The A-Activity Units consisted of the total activities presented to all Biology 100 students during any one week at the BLC as outlined in the Student Study Guide (SSG). These activities pertained to the biological concept which was under study in the course that week. The B-Activity Units consisted of all the activities found in the A-Activity Units and presented through the SSG plus special exercises written especially for these units. The special exercises
were designed to teach for the higher levels of the Cog­
nitive and Affective Domains and constitute a major experi­
mental variable separating the two student groups.

Design for the Cognitive Domain

This design involved the evaluation of three Activity
Units - 4, 6, and 8 - in the Cognitive Domain (Bloom, et al.,
1956) comparing the performance of students following the
series of A-Activity Units with those students who followed
the series of B-Activity Units. The developmental design
for the Cognitive and Affective Domains can be seen in
Appendix A.

Two cognitive pretests were constructed - Pretest A and
Pretest B. Both pretests contained test items from all
three Activity Units chosen for evaluation - Units 4, 6, and
8. However Pretest A only contained items from the lower
three levels of Bloom's taxonomy, i.e. Knowledge, Compre­
hension, and Application. The items on Pretest B were writ­
ten at all levels of Bloom's taxonomy - Knowledge, Compre­
hension, Application, Analysis, Synthesis, and Evaluation.

Two types of cognitive post-tests - A and B - were con­
structed for each of the three units to be evaluated; these=post-tests were written along similar lines as the pretests.
Post-tests of the A-type contained only items which were
from the lower three levels of Bloom's taxonomy while post­
tests of the B-type contained items from all six cognitive
levels. Consequently each of the chosen Activity Units - 4, 6, and 8 - had two post-tests, one of the A-type and one of the B-type.

Post-tests 4A and 4B followed Activity Unit 4 and consisted of an evaluation of the objectives for Unit 4 as set forth in the Student Study Guide (SSG). Post-tests 6A and 6B following Unit 6 consisted of items which evaluated the objectives of Unit 6 plus selected items from Post-test 4 (items from 4A being used in 6A and items from 4B being used in 6B) as a means of testing for retention of the objectives of Unit 4. Post-tests 8A and 8B followed Unit 8; these tests were constructed of items evaluating Unit 8 plus retention items from Post-test 4 and Post-test 6.

The treatment design for the Cognitive Domain is summarized in Table 1 on page 42.

Table 1

<table>
<thead>
<tr>
<th>STUDENT GROUP</th>
<th>PRETEST</th>
<th>ACTIVITY UNIT SERIES</th>
<th>POST-TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>S2</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>S3</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>S4</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>S5</td>
<td>B</td>
<td>A</td>
<td>B</td>
</tr>
</tbody>
</table>
The students participating in the study were randomly assigned to one of the five student groups: S1 - S5. Group S1 took Pretest A which tested for the objectives at Bloom's lower cognitive levels. During the course of the quarter these students performed the A-Activity Unit series. After Units 4A, 6A, and 8A, the students in Group S1 took Post-tests 4A, 6A, and 8A. Post-test 6A contained retention items from Post-test 4A while Post-test 8A contained additional items from both Post-tests 4A and 6A.

Student Group S2 was treated the same as S1 except for the pretest. Group S2 took Pretest B which tested at all levels of Bloom's taxonomy. However like S1, the S2 group performed the A-Activity Units and took the A-Post-tests following Units 4A, 6A, and 8A.

The students in Group S3 took Pretest B which assessed objectives at all levels of Bloom's categories. During the quarter this student group performed the B-Activity Units which presented additional exercises designed to make the student perform at the higher cognitive levels. At the BLC the S3 group did Activity Units 2B, 3B, 4B, 5B, 6B, 7B, and 8B instead of the regular A-Units; like all students they also did the regular Activity Units 1A, 9A, and 10A. Following the units chosen for evaluation - Units 4, 6, and 8, the S3 group took the B-Post-tests; these were designed with test items at all six levels of Bloom's taxonomy. In addition Post-test 6B contained items testing for retention from
Post-test 4B, while Post-test 8B had retention items from both 4B and 6B.

The S4 Student Group had treatment similar to S3 except for the pretest. The S4 group was given Pretest A which had test items only from Bloom's first three cognitive levels - Knowledge, Comprehension, and Application. However this group performed the B-Activity Units - 2B - 8B, as well as Units 1A, 9A, and 10A. Following Units 4B, 6B, and 8B, the S4 group took Post-tests 4B, 6B, and 8B; as before, Post-tests 6B and 8B both contained retention items.

The fifth Student Group (S5) was administered Pretest B with items testing at all levels of Bloom's taxonomy. During the quarter this group followed the A-Activity Units; however after Units 4A, 6A, and 8A, the students took Post-tests 4B, 6B, and 8B which tested at all levels of the Cognitive Domain.

The developmental design described above for the Cognitive Domain was used generally for the Biology 100 students who participated in this study during either the Fall 1970 or Winter 1971 Quarters.

Design for the Affective Domain

An affective test was developed which would measure changes in student attitudes toward science and scientific processes. Each question was rated as falling into one of the four levels of Krathwohl's taxonomy (Krathwohl, et al.,
1956) - Receiving (attending), Responding, Valuing, and Organization. Krathwohl has pointed out that in our society the fifth and highest level of the Affective Domain - Characterization by a value or value complex - is not generally reached by an individual until long after his formal education has ceased; consequently no attempt was made to construct questions at this level.

The Affective Test was administered to the students as Pretest 2C during the second or third week of the quarter in which they took Biology 100. The identical test was re-administered as Post-test 9D during the ninth and tenth weeks of the same quarter. The developmental design for the Cognitive and Affective Domains is shown in Appendix A.

This basic design was used generally for all Biology 100 students who participated in this study during the Fall 1970 and Winter 1971 Quarters and is summarized in Table 2 on page 46.

Instrumentation

Two types of instruments were constructed for this study - cognitive and affective tests. These are both discussed below.

Cognitive Tests

Cognitive tests were constructed for this study. Based on Bloom's Taxonomy of Educational Objectives: Cognitive Domain (1956), tests of one type (designated as type A) were
TABLE 2
TREATMENT DESIGN FOR THE AFFECTIVE DOMAIN

<table>
<thead>
<tr>
<th>STUDENT GROUP</th>
<th>AFFECTIVE PRETEST</th>
<th>ACTIVITY UNIT SERIES</th>
<th>AFFECTIVE POST-TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>2C</td>
<td>A</td>
<td>9D</td>
</tr>
<tr>
<td>S2</td>
<td>2C</td>
<td>A</td>
<td>9D</td>
</tr>
<tr>
<td>S3</td>
<td>2C</td>
<td>B</td>
<td>9D</td>
</tr>
<tr>
<td>S4</td>
<td>2C</td>
<td>B</td>
<td>9D</td>
</tr>
<tr>
<td>S5</td>
<td>2C</td>
<td>A</td>
<td>9D</td>
</tr>
</tbody>
</table>

written to contain items at only Bloom's lower cognitive levels - Knowledge, Comprehension, and Application. Another type of test (designated as type B) contained items at all six levels of Bloom's taxonomy - Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation.

Three activity units from the Bio-Learning Center - Units 4, 6, and 8 - were selected to be evaluated. Post-tests of both the A-and B-type were constructed to follow each of the three units, giving a total of six cognitive post-tests: Post-tests 4A, 4B, 6A, 6B, 8A, and 8B. Post-tests 4A and 4B assessed only the material in Activity Unit 4 in the BLC. Post-tests 6A and 6B contained items which evaluated Activity Unit 6 but also contained review items.
from Post-test 4A or 4B. Post-tests 8A and 8B assessed Activity Unit 8 but also contained review items from both Post-tests 4A or 4B and Post-tests 6A or 6B. These post-tests are found in Appendices D through I.

Pretests of the A- and B-type were also constructed. Pretest A contained ten items from Post-test 4A, ten items from Post-test 6A, and ten items from Post-test 8A; each set of ten items represented all three of Bloom's lower levels. Pretest B contained ten items each from Post-tests 4B, 6B, and 8B; each set of ten contained items at all six of Bloom's cognitive levels. The pretests are found in Appendices B and C.

The cognitive instruments were tested on Biology 100 students during the Summer Quarter 1970. Based on an item analysis of this pilot study, various items were revised or eliminated.

Cognitive Level Designation

Items on both A- and B-type tests were originally written at the various cognitive levels based on the opinion of the author. The items were then judged by a member of the Faculty of Science and Mathematics Education of the College of Education at The Ohio State University in Columbus, Ohio. The judgment of this faculty member agreed with that of the author.

The author independently reclassified the test items
as to cognitive level and compared the results with the original level designations. The two classifications agreed on 63.1 per cent of the items and fell in adjacent categories for 28.1 percent of the items. Pretest and review items were not used in the reclassification.

During an item analysis of each test, an index of relative difficulty was obtained for each item; this index indicates the percent of people taking the test who missed that item. Following the evaluation model used by Walbesser (American Association for the Advancement of Science, 1968), the relative difficulty for all the items assigned to any one cognitive level was compared with the relative difficulty of items at other levels, a general increase in relative difficulty occurred for items at successively higher cognitive levels. This observation would tend to support the hierarchial concept of Bloom's cognitive levels.

Each test contained a small percentage of items which were modified from Testing and Evaluation in the Biological Sciences published by the Commission of Undergraduate Education in the Biological Sciences (CUEBS) and the American Association for the Advancement of Science (AAAS) in November, 1967. The test items in this publication have already been assigned to one of Bloom's cognitive levels by CUEBS and AAAS. The CUEBS-AAAS items used on the instruments in this study showed an increase in relative difficulty for the CUEBS-AAAS items at successively higher cog-
nitive levels. The relative difficulty of the CUEBS-AAAS items at any one cognitive level fell within the difficulty range of the other (non-CUEBS-AAAS) items at the same level.

For the A-Post-tests the number of items constructed for each of the three lower levels of Bloom's taxonomy varied from test to test. Each of the three activity units which was evaluated listed behavioral objectives for the students in the study guide; these objectives as listed in Biology 100 Student Study Guide (Meleca et al., 1969) were judged by the author to be at the lower three of Bloom's levels, i.e. Knowledge, Comprehension, and Application. The percentage of questions at the three levels on any A-type post-test approximated the percentage of student objectives at the three levels for the activity unit being evaluated. Post-tests 4A, 6A, and 8A and the level designation for each item can be found in Appendices C, E, and G.

The determination of the number of items at each cognitive level for the B-post-tests was entirely different, since the B-post-tests contained items at all six levels of Bloom's taxonomy and the student objectives were written at only the lower three levels. The author was particularly interested in the middle and higher levels of Bloom's classification but also recognized that the higher level questions were more difficult to construct. It was determined that for the Post-tests 4B, 6B, and 8B the percentage of questions at each level would be approximately as follows:
Knowledge - 15%, Comprehension - 20%, Application - 20%, Analysis - 25%, Synthesis - 10%, and Evaluation - 10%. 
Post-tests 4B, 6B, and 8B with the level designation for each item can be found in Appendices D, F, and H.

Validity

The validity of each item was determined through the objectives of the three activity units being evaluated as listed in Biology 100 Student Study Guide (Meleca et al., 1969). The author judged that each item assessed one or more of the listed student objectives. No attempt was made to match items to specific objectives.

Reliability

The internal consistency reliabilities for all the cognitive tests were determined through an item analysis program using the KR-20 and KR-21 (Kuder-Richardson 20 and 21) formulae. These reliabilities for both the Autumn and Winter Quarters and for the combined quarters are shown in Table 3 on page 51. It should be noted that Post-tests 4A, 6A, and 8A were not given during the Winter Quarter.

In summary there were two types of cognitive tests - A-type which contained items at the Knowledge, Comprehension, and Application levels of Bloom's taxonomy and B-type which contained items at Bloom's levels of Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. For each of the three activity units being evaluated - Units 4,
TABLE 3
KUDDER-RICHARDSON 20 AND 21
RELIABILITIES FOR COGNITIVE TESTS

<table>
<thead>
<tr>
<th>INSTRUMENT</th>
<th>AUTUMN QUARTER</th>
<th>WINTER QUARTER</th>
<th>COMBINED TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest A</td>
<td>.616</td>
<td>.535</td>
<td>.711</td>
</tr>
<tr>
<td>Pretest B</td>
<td>.748</td>
<td>.687</td>
<td>.500</td>
</tr>
<tr>
<td>Post-test 4A</td>
<td>.729</td>
<td>.628</td>
<td>--*</td>
</tr>
<tr>
<td>Post-test 4B</td>
<td>.840</td>
<td>.809</td>
<td>.748</td>
</tr>
<tr>
<td>Post-test 6A</td>
<td>.908</td>
<td>.894</td>
<td>--*</td>
</tr>
<tr>
<td>Post-test 6B</td>
<td>.834</td>
<td>.810</td>
<td>.847</td>
</tr>
<tr>
<td>Post-test 8A</td>
<td>.713</td>
<td>.628</td>
<td>--*</td>
</tr>
<tr>
<td>Post-test 8B</td>
<td>.683</td>
<td>.611</td>
<td>.748</td>
</tr>
</tbody>
</table>

*Post-tests 4A, 6A, and 8A were not administered during the Winter Quarter

6, and 8, an A-type post-test (4A, 6A, and 8A) was constructed with the number of items at each level being determined by the number of student objectives at each level for each unit. B-type post-tests (4B, 6B, and 8B) were also written for each unit. Pretest A was constructed with ten questions from each Post-test 4A, 6A, and 8A; Pretest B contained ten items from each Post-test 4B, 6B, and 8B. All pretests and
post-tests with cognitive level designation for each item can be found in Appendices B - I.

Affective Test

Only one affective test was constructed, the Personal Preference Test (see Appendix J). The same test was used as Pretest 2C during the second week of the quarter and as Post-test 9D at the end of the quarter; this procedure was followed for both Autumn Quarter 1970 and Winter Quarter 1971. All study participants were instructed to take Personal Preference Tests 2C and 9D regardless of which Student Group they were in.

The purpose of the affective test was to assess the attitude of students toward science and scientific processes. Krathwohl's Taxonomy of Educational Objectives: Affective Domain (1956) was used as a basis for constructing this instrument. An attempt was made to write items at the first four levels of this taxonomy - Receiving (attending), Responding, Valuing, and Organization. The fifth level used by Krathwohl - Characterization by a value or value complex - was deemed so difficult to assess that no attempt was made to construct questions at this level.

The Personal Preference Test was made up of forty multiple choice questions; each question had at least four possible choices. Thirty-six of the questions were assigned to one of the four levels of Krathwohl's taxonomy being used
in the assessment; each distractor for these questions was rated as being a positive response toward science or scientific processes, a neutral response, or a negative response. Each of the remaining four questions was designed so that it incorporated all four affective levels in one question; the selection of one of the four possible responses determined at which level the student was operating.

**Affective Level Designation**

The designation of affective level to each of the thirty-six items and to each distractor in the four "all level" items was made by the author in conjunction with a member of the academic faculty of Curriculum and Foundations of the College of Education of The Ohio State University in Columbus, Ohio. Working independently the author and the faculty member agreed on the level of thirty-seven of the forty questions; through discussion an agreement was reached as to the affective level of the remaining three items.

To check his consistency in classifying items at Krathwohl's levels, the author reclassified all affective items and compared the results with the original levels agreed upon earlier. The two classifications showed total agreement on 67.5 per cent of the items and adjacent level agreement on 30 per cent of the items.

**Validity**

A class of sixteen doctoral students in science educa-
tion at The Ohio State University during the Autumn Quarter, 1970 was used to determine the validity of the items on the Personal Preference Test. Each graduate student was asked to rate the responses of each item as to whether the response indicated a positive, a neutral, or a negative attitude toward science or scientific processes. Based on the majority decision of the graduate students, each response was designated as being positive, neutral, or negative. Each item had responses in at least two of the three categories.

Reliability

The internal consistency reliabilities (Kuder-Richardson 20 and 21) could not be determined for the Personal Preference Tests since each item may have had more than one response which was positive, neutral, or negative.

Scoring

The Personal Preference Tests were scored by assigning a value of three to all positive responses, two to the neutral responses, and one to the negative responses. The responses to the "all level" questions were given a value of one if the selected response was from affective level one, a value of two if the selected response was at affective level two, a value of three for level three responses, and a value of four for level four responses. Sub-test scores were also obtained for each of the affective levels and for
the four "all level" questions.

The Personal Preference Test, the affective level designation for each item, and the positive, neutral, or negative attitude assigned to each response is shown in Appendix J.

**Activity Units**

An Activity Unit is the sum of the activities for one week presented to the student during sessions in the Bio-Learning Center. Normally there are ten such units (Activity Units 1 - 10) presented one each week over a ten week quarter. Activity Units 1 - 10 correspond with the ten chapters in *Biology 100 Student Study Guide* (Meleca *et al.*., 1969).

For the purpose of this study the Activity Units have been divided into two types - A and B. The A-Activity Unit Series consists of the weekly activities normally followed by the Biology 100 students as given in the study guide. The B-Activity Unit Series consists of the A-Activity Unit Series plus additional exercises constructed to develop skills at the higher levels of Bloom's taxonomy. This series is undertaken only by the study participants who were in Student Groups S3 and S4; all other study participants (Student Groups S1, S2, and S5) as well as all non-participants (regular students in Biology 100) performed the A-Activity Unit Series.
A-Activity Unit Series

The ten units of the A-Activity Unit Series were identical with the ten chapters of the Biology 100 Student Study Guide (1969). The objectives for each unit were given in behavioral form at the end of each chapter; as judged by the author in consultation with a science education member of the Faculty of Science and Mathematics Education at The Ohio State University, these objectives were found to be generally at the lower levels of Bloom's taxonomy, i.e. Knowledge, Comprehension, and Application.

The first unit in this series (Unit 1A) was concerned with an introduction to the Bio-Learning Center. The unit also covered proper use of the compound microscope and the stereomicroscope. A third section dealt with the levels of organization of living and non-living materials.

Unit 2A developed the concept of the cell. Cellular organization and function were discussed, and students observed living cells. The process of mitosis also formed a part of this unit.

During the third week, Unit 3A was covered in the BLC. This unit dealt with energy and the structure of matter. Carbohydrates, proteins, lipids and nucleic acids were discussed, and the students learned to test unknown substances for many of these compounds.

The fourth and fifth units both developed an understanding of the chemical processes of life. Unit 4A per-
tained mainly to protein synthesis and bioenergetics; the roles of DNA, enzymes, and ATP were stressed particularly. Unit 5A concentrated on carbohydrate metabolism, photosynthesis, and diffusion in the living system. Glycolysis, alcoholic fermentation, and the Kreb Cycle were covered; exercises on the role of light in photosynthesis were carried out; demonstrations of diffusion and osmosis were shown.

Unit 6A dealt with genetics. The function of meiosis is gametogenesis was shown. Patterns of inheritance were demonstrated through the use of the Punnett square method, problem solving approach, and Drosophila demonstrations.

Week seven in the BLC (Unit 7A) pertained to the concept of embryonic development. Plant and animal embryology were covered as was human embryology. The students observed living chick embryos at various stages of development.

Unit 8A was concerned with evolution. The concepts of variation, adaptation, speciation, divergence, and convergence were developed, and the ideas of Lamarck, Darwin, and others were discussed.

The ninth unit (9A) dealt with the unity and diversity of living organisms. Classification systems were used as a means to briefly survey the plant and animal kingdoms. Many organisms were available in the BLC for students to observe. This unit was the longest unit covered in Biology 100.

The final unit for the quarter (Unit 10A) covered the field of ecology. The growth of populations was considered;
the interaction of organisms within a community and community succession were discussed; the cycling of energy and materials in an ecosystem was shown; and biogeography was mentioned briefly.

The ten activity units above (the A-Activity Unit Series) were those normally covered in Biology 100. For this study additional exercises were developed for Units 2 - 8 as a part of the B-Activity Unit Series; Units 1A, 9A, and 10A were the same for all students, regardless of which Activity Unit Series they were in.

During the Autumn Quarter, the inability of The Ohio State University administration to reach a decision concerning the length of the quarter necessitated the dropping of Unit 9A from the schedule (see "Discrepancies Between Quarters" below).

Due to the publication of a new study guide in January 1971, Unit 8A was dropped from the schedule during Winter Quarter 1971, and a unit on plant and animal behavior was substituted for it (see "Discrepancies Between Quarters" below).

Schedules of the A-Activity Units used during the Autumn and Winter quarters are shown in Table 4 and Table 5 on pages 59 and 60.

B-Activity Unit Series

The student participants in Groups S3 and S4 of the
### TABLE 4

SCHEDULE OF A-ACTIVITY UNITS

FOR AUTUMN QUARTER 1970

<table>
<thead>
<tr>
<th>WEEK</th>
<th>ACTIVITY UNIT</th>
<th>CHAPTER IN BIOLOGY 100 STUDENT STUDY GUIDE (1969)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1A</td>
<td>1. Introduction and Orientation to Audio-Tutorial Biology</td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td>2. Cellular Organization and Function</td>
</tr>
<tr>
<td>3</td>
<td>3A</td>
<td>3. Basic Chemistry of Life</td>
</tr>
<tr>
<td>5</td>
<td>5A</td>
<td>5. Chemical Processes of Life: Support System II</td>
</tr>
<tr>
<td>6</td>
<td>6A</td>
<td>6. Genetics</td>
</tr>
<tr>
<td>7</td>
<td>7A</td>
<td>7. Development</td>
</tr>
<tr>
<td>8</td>
<td>8A</td>
<td>8. Evolution and Adaptation</td>
</tr>
<tr>
<td>9</td>
<td>10A</td>
<td>10. Populations, Societies, and Communities</td>
</tr>
<tr>
<td>10</td>
<td>REVIEW</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 5

**SCHEDULE OF A-ACTIVITY UNITS**

**FOR WINTER QUARTER 1971**

<table>
<thead>
<tr>
<th>WEEK</th>
<th>ACTIVITY UNIT</th>
<th>CHAPTER IN <strong>BIO-LEARNING GUIDE</strong> (1971)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1A</td>
<td>1. Introduction</td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td>2. Cellular Organization and Function</td>
</tr>
<tr>
<td>3</td>
<td>3A</td>
<td>3. Chemistry of Life</td>
</tr>
<tr>
<td>5</td>
<td>5A</td>
<td>5. Chemical Processes of Life: Support System II</td>
</tr>
<tr>
<td>6</td>
<td>6A</td>
<td>6. Genetic Continuity of Life</td>
</tr>
<tr>
<td>7</td>
<td>7A</td>
<td>8. Development</td>
</tr>
<tr>
<td>8</td>
<td>--</td>
<td>12. Behavior</td>
</tr>
<tr>
<td>9</td>
<td>10A</td>
<td>13. Populations and Communities</td>
</tr>
<tr>
<td>10</td>
<td>REVIEW</td>
<td></td>
</tr>
</tbody>
</table>
study performed the B-Activity Unit Series in the Bio-
Learning Center instead of the regular A-Series. Experi-
mental B-Activities were only used for Units 2 - 8 and con-
sisted of all of the exercises in the A-Series plus an addi-
tional exercise constructed to develop skills at the higher
levels of Bloom's taxonomy, i.e. Analysis, Synthesis, and
Evaluation. Since these additional exercises were used only
in Units 2 - 8, the students taking the B-Activity Unit Se-
ries also performed Units 1A, 9A, and 10A.

After completing the regular week's activities as out-
lined in the study guide, the students in Groups S3 and S4
were instructed to complete the additional B-Series exer-
cises. In order to perform this additional activity, each
student was given an Activity Sheet which gave some problem
to be solved or set up a procedure to be followed. Ques-
tions were posed in the sheet, and the student was asked to
make observations, formulate hypotheses, or draw conclusions
based on the activity. After completing the Activity Sheet,
the student was given a Follow-up Sheet which suggested some
observations which he might have made. Both the Activity
Sheet and the Follow-up Sheet were given to the student to
keep.

The 194 carrels available to the students at the BLC
had been subdivided into nine rooms, or modules, with
twenty-one carrels in each module, except for Module 1 which
had twenty-six carrels. The Activity Sheets, Follow-up
Sheets, and necessary materials were set up only in Module 8; this module was chosen because it was less used than some of the other modules. The student did not have to do the regular week's work in Module 8, but most of them did so for convenience. A letter was posted for the graduate teaching assistants in Module 8 (see Appendix M) which explained the procedure of the study.

Each of the seven additional exercises which made up the B-Activity Series is discussed below. The Activity Sheet and Follow-up for each activity can be found in Appendix K.

No additional exercise was written for Unit 1 so that this first week of the quarter could be used to introduce the participants to the study and to administer the pretests. All students in Biology 100, study participants and non-participants, performed Unit 1A as outlined in Biology 100 Student Study Guide (1969).

The extra activity for Unit 2B was different from all the others in that it replaced an exercise in the study guide, and it had no follow-up. This activity was concerned with having the student make a mitosis slide of an onion root tip rather than use a prepared slide as directed in the study guide. With the student making his own slide, the viewing of the mitotic stages becomes more meaningful; the idea communicated through the slide was put in the proper prospective since the student was able to analyze the pro-
cess which resulted in the slide itself. This activity stressed the cognitive levels of Comprehension, Application, and possible Analysis. The involvement and success of the student would tend to make his attitude toward the activity a more positive one; this would be true for all the additional activities where the student plays an active role.

One of the exercises performed as a part of Unit 3 was the development of laboratory tests for sugar, starch, and protein. The additional activity for Unit 3B involved the use of this information. The student was presented with data showing the results of the Benedict test for sugar, the iodine test for starch, and the Biuret test for proteins on corn seed and leaves under various conditions. From this data the student was to draw certain conclusions and formulate hypotheses which accounted for the data. The Follow-up Sheet suggested possible hypotheses and conditions which might account for the results presented in the activity. This exercise required the student to analyze the data, to synthesize hypotheses, and to evaluate the hypotheses; thus the student operated at Bloom's higher cognitive levels.

The Activity Sheet and Follow-up for Unit 4B dealt with the role of enzymes in living tissue. The activity was similar to Unit 3B except the student had to collect the data himself before he could make conclusions. As with Unit 3B, this unit stressed skills at the Analysis, Synthesis, and Evaluation levels.
The activity for the fifth week (Unit 5B) was centered around the concept of diffusion and osmosis. The activity consisted of two exercises, each of which dealt with this concept. In both cases the student had to make observations and formulate hypotheses based on the observations. The levels of Analysis and Synthesis were stressed in this activity.

Activity 6B used inheritance in pea plants as the means of generating data as a basis for hypothesis formation. The student determined the ratios of peas in terms of seed color and seed coat appearance; from this he could determine that a dihybrid cross was involved in this mate. The student played an active role in generating the data and manipulating numbers as well as analyzing the data and synthesizing hypotheses.

Unit 7 in the BLC was concerned with the embryonic development of plants and animals. Activity 7B used this as a springboard to exercises dealing with the response of organisms to light, gravity, and temperature. Radish and corn seedlings were used in showing phototropism; germinating corn seeds were used to demonstrate geotropism; and bacteria was the experimental organism exposed to various temperature differences. Given certain factual information, the student was to make observations and try to explain what occurred. As with most exercises requiring the formulation of hypotheses, the student had to operate at Bloom's higher
levels of cognition.

The final activity for the B-Series was Unit 8B on evolution. One section in the activity directed the student to suggest a possible evolutionary pathway which would lead to the sequential development of the four-chambered heart. A second section made use of the Footprint Puzzle from the Earth Science Curriculum Project; using data given in the form of footprints, the student was asked to develop hypotheses on what might have occurred to make the series of footprints; as more and more of the prints were exposed to view, the student had to re-evaluate his hypothesis in terms of the new evidence. In both exercises the student operated at the higher levels of Bloom's taxonomy.

Additional exercises were not provided for Units 9 and 10 in order to insure sufficient opportunity for the study participants to complete all activities and post-tests prior to the termination of the quarter. Units 9A and 10A, as outlined in Biology 100 Student Study Guide (1969), were performed by all Biology 100 students, study participants and non-participants.

Discrepancies between Quarters

In this study data were collected during both the Autumn 1970 and Winter 1971 quarters with the intention of grouping the information gathered. It should be pointed out that several intervening factors occurred during one
quarter or the other which were not operating during both quarters. One of these was the change in graduate teaching associates between quarters. During the Autumn Quarter, Mr. Eischen, Mr. Hirsch, and Mr. Ruyan were the teaching associates; Mr. Ruyan taught only one section while the other associates taught two sections each. Mr. Ruyan was unable to continue with the study for the Winter Quarter so Miss Meister was assigned to take his place in the study. Consequently during the Winter Quarter the graduate associates were Mr. Eischen and Mr. Hirsch, who again taught two sections each, and Miss Meister, who taught only one recitation section.

Winter Quarter also had an additional class meeting for all Biology 100 students. In this quarter a television period was added to the schedule of two recitation periods a week. The television period used a videotape production via closed circuit television to present to each class section material related to that week's Activity Unit in the BLC. This material often centered around a discussion of current research in biology. Each presentation lasted from twenty to thirty minutes and was followed by a classroom discussion led by the teaching associate. The information presented during the television period was supplementary material and not specifically tested for on any of the regular course examinations. The student's biology class schedule during the Winter Quarter consisted of two recitation periods and one
television period meeting each week with the same graduate teaching associate; during the Autumn Quarter there was no television period, but the students did have two recitation periods each week.

Two different student study guides were used for the two quarters covered by this study. For Autumn Quarter 1970 the student guide for the BLC was Biology 100 Student Study Guide by Meleca, Jackson, Menefee, and Burnard which was copyrighted by Meleca and Menefee in 1969. This guide contained ten chapters, one to be covered each week in the BLC. During the Winter Quarter 1971 a new, up-dated study guide was put into use; this was Bio-Learning Guide by Meleca, Jackson, Burnard, and Dennis. This new edition was copyrighted by the Burgess Publishing Company in 1971. This publication contained fifteen chapters, nine of which were used during the Winter Quarter at The Ohio State University. The 1971 version of the study guide was based to a large extent on an up-dating and reorganization of the earlier study guide. The additional chapters in the 1971 edition were due principally to an expansion of the units on genetics and ecology. Units 1 - 10 of the 1969 study guide correspond greatly with Units 1 - 6, 8 - 11, and 13 of the 1971 edition.

There was one important difference in the unit on proteins and enzymes (Chapter 4 in both versions) which should be pointed out. Chapter 4 in the 1971 version of the study
guide contained an exercise (Exercise 4-2) on enzymes in living tissues which was a modified form of the additional activity from Unit 4B of this study. Consequently all Biology 100 students during the Winter Quarter were in effect performing Activity Unit 4B. To equalize the two quarters as much as possible on this point, the students in Groups S3 and S4 during the Winter Quarter were told to omit Exercise 4-2 from Unit 4 and to do the exercise originally scheduled for Activity Unit 4B.

Another discrepancy between the two quarters due to the use of different versions of the study guide involved Activity Unit 8, one of the units chosen for evaluation by this study. During the Autumn Quarter Activity Unit 8 was based on Chapter 8 in the 1969 study guide and was concerned with evolution and adaptation; consequently Post-tests 8A and 8B were based on these concepts. However during the Winter Quarter it was decided to replace the unit on evolution with one on behavior (Chapter 12 in the 1971 guide) in order to try one of the newly developed units. Consequently for the Winter Quarter Activity Unit 8 was concerned with animal and plant behavior rather than evolution. The decision to use this new unit came too late to allow for the construction of new Post-tests 8A and 8B based on the concept of behavior; the students in the study were given the same Post-test 8 on evolution as the students in the Autumn Quarter.
Schedules of the A-Activity Units used during the Autumn and Winter quarters are shown in Tables 4 and 5 on pages 59 and 60.

An unusual series of events occurred during Autumn Quarter that should be mentioned here. Toward the middle of Autumn Quarter the administration of The Ohio State University seriously discussed shortening the Autumn Quarter by one week. The debate on this point prolonged any final decision until the eighth or ninth week of the quarter. Although the final decision was not to shorten the quarter, the decision was so late in coming that it prompted the omission of Unit 9A (Unity and Diversity of Life) from the BLC schedule and the moving of Unit 10A (Populations, Societies, and Communities) into the ninth week. When the administrative decision not to shorten the quarter finally came, the extra week was used for a review of all BLC units covered that quarter. Therefore during the Autumn Quarter the Activity Units covered in the Bio-Learning Center were Units 1 - 8 and 10.

The texts used in Biology 100 were different during the two quarters of this study. For the Autumn Quarter the recommended text was Life - An Introduction to Biology (Shorter Edition) by Simpson and Beck and copyrighted in 1969 by Harcourt, Brace, and World, Inc. The Winter Quarter biology classes used Biological Science by Keeton and copyrighted by W. W. Norton and Company, Inc. in 1967. The book by Simpson
tended to give a broader and briefer view of the field of biology while Keeton's book covered the biological concepts in greater depth, especially in the area of genetics and evolution. Although neither book was required, they were both "strongly recommended" for their respective quarter, and for both quarters a list of suggested reading assignments was distributed to the students.

The scheduling of examinations in Biology 100 was different for the two quarters and may have had some influence on the participants in the study. Two midterm examinations were given during the Autumn Quarter; each exam consisted of fifty multiple choice questions, each question having a correct response and three distractors. Midterm I covered Activity Units 1 - 4 from the BLC; the examination was given during the fifth week of the quarter, the same week that the participants in the study were scheduled to take Post-tests 4A or 4B. The second midterm (Midterm II) covered Activity Units 5 - 8 and was given during the ninth week of the quarter when the study participants were scheduled to take Post-tests 8A or 8B and 9D (affective post-test). The Final Examination in Biology 100 covered Activity Units 1 - 8 and 10. There were eighty multiple choice questions on this examination; seventy-five questions were of the type given on past midterm and final exams while five questions (questions 76 - 80) were especially designed by this author to assess thinking at the higher levels of Bloom's taxonomy,
i.e. Analysis, Synthesis, and Evaluation.

The examinations during the Winter Quarter were scheduled differently from those of the Autumn Quarter. The Winter Midterm I consisted of forty-five multiple choice questions and covered Activity Units 1 - 3; the testing was done during the fourth week of the quarter, a week prior to the time scheduled for the study participants to take Post-tests 4A or 4B. The second midterm (Midterm II) was made up of fifty multiple choice questions covering Activity Units 4 - 6; the exam was given during the seventh week of the quarter which was the same week that study participants were to take Post-tests 6A or 6B.

The Final Examination for Biology 100 during the Winter Quarter was comprehensive, covering Activity Units 1 - 6, 7 (Unit 8 in the 1971 edition of the study guide), 10 (Unit 13 in the 1971 edition), and a unit on plant and animal behavior (Unit 12 in the 1971 study guide). The final exam had eighty-five multiple choice questions; eighty of these were of the same type used on past midterm and final exams while questions 81 - 85 were especially designed by this author to assess the higher levels of Bloom's taxonomy, i.e. Analysis, Synthesis, and Evaluation. These five special questions were almost identical to the five questions (76 - 80) given on the Autumn Quarter Final Examination; the wording and form of the questions were slightly altered to prevent the students recognizing the questions from a copy of
the final exam from the previous quarter.

Population and Samples

Autumn Quarter 1970

The sample of 141 students was taken for this study from all students registered during the Autumn Quarter 1970 for Biology 100 on the Main Campus of The Ohio State University in Columbus, Ohio. Some Biology 100 classes met on the West Campus of The Ohio State University, but these were eliminated from the study because the meeting time of the West Campus classes (on the half hour) overlapped that of the Main Campus classes (on the hour) and would thus prevent the administering of the pretests to all the classes during the same period of time.

The Registrar's Office assigned each student to one of five class meeting times on the Main Campus - 8:00 a.m., 11:00 a.m., 12:00 noon, 2:00 p.m., or 3:00 p.m.; the assignment was based on the student's schedule of classes. On the first day of the quarter all of the students who were signed up for a particular class time met together at that designated time. At this meeting an introduction to the course was given, and the students were assigned to recitation sections of no more than thirty-five students each. The number of recitation sections formed at each time period depended upon the number of students who were signed up for that time period. Approximately eight recitation sections were
formed during each time period.

Prior to the assignment of students to recitation sections, one section during each time period was randomly selected to participate in this study. It was hoped that students participating in the study during the Autumn Quarter could be followed through the sequential course Biology 101; toward this end it was announced to the students that only those who intended to take Biology 101 during the following quarter were to sign up for this specially designated recitation section. In each case there were more than enough students planning to continue into Biology 101 to fill the recitation section which would participate in this study. Unfortunately less than one-third of the study participants actually continued into Biology 101, and this was deemed an insufficient number to warrant a follow-up study during the following quarter.

Graduate Teaching Associates were assigned to each of the five participating recitation sections. These teaching associates were selected on the basis of their availability during the scheduled meeting time of the recitation section and on the basis of having had some teaching experience in biology, having previously taught either high school biology or Biology 100. The teaching associates were randomly assigned to one of the five recitation sections; since each associate could carry a maximum teaching load of two recitation sections, it was arranged so that only three teaching
associates taught the five sections with two of the associates teaching two participating sections.

Each of the five recitation sections and their graduate associate was then assigned to one of the five Student Groups - S1, S2, S3, S4, or S5 - outlined in the Study Design. The teaching associates were to meet each section for a recitation period of forty-eight minutes twice each week during the Autumn Quarter; this time was used to discuss the concepts brought out at the BLC during that week.

In summary it can be seen that five recitation sections were selected to participate in this study. These sections consisted of students on the Main Campus of The Ohio State University who were registered for Biology 100 during the Autumn Quarter 1970 and who anticipated taking Biology 101 during the following Winter Quarter. These recitation sections met twice a week and were taught by graduate teaching associates who had had some experience teaching biology. The teaching associate and Student Group randomly assigned to each recitation section is shown in the Table 6 (page 75).

During the first full week of the quarter, the author met with each of the five participating sections during one of their recitation periods. The students were told that they had been chosen to participate in a study to improve the biology program at The Ohio State University. It was explained that they would be asked during the quarter to take a series of six tests (one cognitive pretest, one
TABLE 6
GRADUATE TEACHING ASSOCIATE AND STUDENT
GROUP ASSIGNMENT FOR RECITATION SECTIONS
AUTUMN QUARTER 1970

<table>
<thead>
<tr>
<th>RECITATION SECTION</th>
<th>TEACHING ASSOCIATE</th>
<th>STUDENT GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 a.m.</td>
<td>Eischen</td>
<td>S3</td>
</tr>
<tr>
<td>11:00 a.m.</td>
<td>Hirsch</td>
<td>S5</td>
</tr>
<tr>
<td>12:00 noon</td>
<td>Hirsch</td>
<td>S4</td>
</tr>
<tr>
<td>2:00 p.m.</td>
<td>Eischen</td>
<td>S1</td>
</tr>
<tr>
<td>3:00 p.m.</td>
<td>Ruyan</td>
<td>S2</td>
</tr>
</tbody>
</table>

affective pretest, three cognitive post-tests, and one affective post-test), each requiring about thirty minutes; the students in the S3 and S4 sections were told that in addition they would be expected to perform some additional exercises in the BLC (the B-Activity Units) with each exercise requiring approximately thirty minutes of their time. Consequently the Student Groups S1, S2, and S5 were being asked to give three hours of extra time to the study over the quarter, and the Student Groups S3 and S4 were asked to give five and one-half hours of time.

In addition to the time requirement, the advantages of
participating in the study - learning more biology, practice at taking tests, greater retention of information - were stressed to the students in each section. On this basis the students were asked to volunteer to participate in the study for the whole quarter. Table 7 (page 77) gives the number of students from each section who agreed to participate in the study and the Student Group to which they were randomly assigned. In addition the table breaks down the participants by sex and their student classification (Freshman, Sophomore, Junior, Senior, or Continuing Education).

Winter Quarter 1971

A sample of 86 students was taken for the study during the Winter Quarter 1971 from all students registered for Biology 100 during that quarter at the Main Campus of The Ohio State University in Columbus, Ohio. As was the case during the preceding quarter, those students registered for Biology 100 on the West Campus were excluded from the study because of a time conflict due to overlapping schedules.

Based on the student's class schedule, the Registrar's Office had assigned each student to one of five class meeting times on the Main Campus - 8:00 a.m., 9:00 a.m., 11:00 a.m., 12:00 noon, or 3:00 p.m. On the first day of Winter Quarter all of the students who were signed up for a particular class time met together. At this meeting an introduction to the course was given, and the students were
## Table 7

### Recitation Section, Participants, Sex, and Student Classification for Each Student Group

#### Autumn Quarter 1970

<table>
<thead>
<tr>
<th>Student Group</th>
<th>Recitation Section</th>
<th>Number of Students</th>
<th>Number of Participants</th>
<th>Sex</th>
<th>Classification</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>F</td>
<td>FR</td>
</tr>
<tr>
<td>S1</td>
<td>2:00 p.m.</td>
<td>31</td>
<td>30</td>
<td>21</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>S2</td>
<td>3:00 p.m.</td>
<td>30</td>
<td>30</td>
<td>8</td>
<td>22</td>
<td>12</td>
</tr>
<tr>
<td>S3</td>
<td>8:00 a.m.</td>
<td>36</td>
<td>27</td>
<td>13</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>S4</td>
<td>12:00 noon</td>
<td>31</td>
<td>22</td>
<td>13</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>S5</td>
<td>11:00 a.m.</td>
<td>33</td>
<td>32</td>
<td>17</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>161</strong></td>
<td><strong>141</strong></td>
<td><strong>72</strong></td>
<td><strong>69</strong></td>
<td><strong>45</strong></td>
</tr>
</tbody>
</table>

*Continuing Education*
assigned to recitation sections of no more than thirty-five students each.

Prior to the assigning of students to recitation sections, one section during each time period was randomly selected to participate in the study. Since the sections used in the study during the Autumn Quarter had consisted of students who thought they planned to take Biology 101 during the following quarter and since comparisons were to be made between the two quarters, it was announced to the students at their first-day meeting that only those who intended to take Biology 101 during the following quarter were to sign up for the specially designated recitation section; in actuality no follow-up was intended, but this was done to make the student groups in the Autumn and Winter Quarters more homogeneous.

Two of the Graduate Teaching Associates from Autumn Quarter - Mr. Eischen and Mr. Hirsch - were able to arrange their schedules so they could again each teach two of the participating classes. However Mr. Ruyan was unable to continue with the study so Miss Meister, who had taught Biology 100 during the Autumn Quarter, was assigned to replace Mr. Ruyan in the study. This quarter the teaching associates met each section three times a week - twice in a recitation period and once in a television period - instead of twice a week as they had Autumn Quarter.

During the Winter Quarter it was desired to duplicate
most of the same type data gathered during the Autumn Quarter, especially concerning the Student Groups S3 and S4 who followed the B-Activity Unit Series. Toward this end teaching associates with their recitation sections were assigned to be in specific Student Groups; in addition the Student Groups S1 (Pretest A, A-Activity Unit Series, and Post-tests A) and S2 (Pretest B, A-Activity Unit Series, and Post-tests A) were eliminated from the study for this quarter. In their place Student Group S3 (Pretest B, B-Activity Unit Series, and Post-tests B) and S4 (Pretest A, B-Activity Unit Series, and Post-tests B) were both used for two class sections; Group S5 (Pretest B, A-Activity Unit Series, and Post-tests B) was used for one section.

In summary it can be seen that five recitation sections were selected to participate in this study. These sections consisted of students on the Main Campus of The Ohio State University who were registered for Biology 100 during the Winter Quarter 1971 and who anticipated taking Biology 101 during the following Spring Quarter. These sections met twice a week for recitation and once for a television period; the sections were taught by graduate teaching associates who had had experience in teaching Biology 100. The teaching associate and Student Group assignment for each recitation section is shown in Table 8 (page 80).

As in the previous quarter the author met with each recitation section during the first full week of the quarter.
At this time the purpose of the study was explained. The students were told that the study would require extra time on their part - three hours during the quarter if the students were in Group S5 and five and one-half hours if they were in Groups S3 or S4; the advantages of participating in the study were also explained to them. On this basis the students were asked to volunteer to participate in the study for the whole quarter. Table 9 (page 81) gives the number of students from each section who agreed to participate in the study and the Student Group to which they were assigned. The table also breaks down the participants by sex and
<table>
<thead>
<tr>
<th>STUDENT GROUP</th>
<th>RECITATION SECTION</th>
<th>NUMBER OF STUDENTS</th>
<th>NUMBER OF PARTICIPANTS</th>
<th>SEX</th>
<th>CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>FR</td>
</tr>
<tr>
<td>S3</td>
<td>12:00 noon</td>
<td>35</td>
<td>14</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>S3</td>
<td>3:00 p.m.</td>
<td>35</td>
<td>11</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>S4</td>
<td>9:00 a.m.</td>
<td>35</td>
<td>19</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>S4</td>
<td>11:00 a.m.</td>
<td>34</td>
<td>17</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>S5</td>
<td>8:00 a.m.</td>
<td>36</td>
<td>25</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>175</strong></td>
<td><strong>86</strong></td>
<td><strong>55</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>
student classification (Freshman, Sophomore, Junior, or Senior).

**Data Collection Procedure**

The procedure for collecting data was basically the same for both the Autumn Quarter 1970 and the Winter Quarter 1971. This procedure was explained to the volunteer participants in each recitation section during the first full week of each quarter. The students in Groups S3 and S4 who would be taking the B-Activity Unit Series were told that the Activity Sheets and their Follow-up Sheets would be on the desk in Module 8 of the BLC; the materials necessary for performing each activity would be on a demonstration cart in the module. During the week that a particular activity was to be done, the student was to first perform the exercises outlined in the study guide and then do the additional activity; he was to pick up the Activity Sheet from the desk, perform the exercise, and compare his results and explanations with those offered in the Follow-up. After performing a special activity each week, the student was to fill out an Activity Time Sheet stating which activity he had done and how much time he had spent on it; this was used as a means of ascertaining which activities a student did. The Activity Sheet, Follow-up, and materials were left in Module 8 for a two week period so that the activity for Week 2 was in the BLC during weeks two and three, and the
activity for Week 3 was there during weeks three and four, and so on. Consequently a student who was unable to perform an activity during one week could make up the work during the following week.

Test data were collected in a similar manner. The cognitive pretests (either A or B) were given to all study participants at the meeting during the first week of the quarter. Since all participants took the post-tests, they were all told that each post-test would be available in Module 8 along with the appropriate answer forms and pencils. It was pointed out to the students that they should check carefully for the test form which they were taking since several tests might be out at the same time. Each post-test would remain available in the module for two weeks. The cognitive post-tests were placed in the BLC during the week following the Activity Unit which the test evaluated, i.e. Post-test 4 was available during weeks five and six. The affective pretest (Personal Preference Test 2C) was made available during the second and third week, and the post-test (Personal Preference Test 9D) was placed in the BLC during the ninth week.

During the Winter Quarter one exception was made in the procedure discussed above. In order to obtain the maximum amount of data, permission was obtained to administer Post-test 8B to each recitation section during a regular class meeting in addition to having it available in the BLC. Information was thus collected from both study participants
and non-participants in these recitation sections. It was discovered at this time that the unit on evolution in the BLC had been replaced by a unit on plant and animal behavior. Despite this change, the Post-test 8B, which was based on concepts of evolution, was given to the students.

To aid the students in remembering which test or activity they should be taking, each student was given a Schedule of Activities and Tests (see Appendix L) summarizing the information. In addition the students in each recitation section were visited a minimum of three times during each quarter and reminded of their obligation to complete certain tests or activities.

A summary of the data collecting procedure for the study is outlined in Table 10 (page 85) for the Autumn Quarter and Table 11 (page 86) for the Winter Quarter.

**Statistical Analysis**

Hypothesis 1 concerns achievement at the higher levels of the Cognitive and Affective Domains and background variables. Data for this hypothesis were analyzed by using the BMD-03D Correlation with Item Deletion developed at the University of California (Dixon, 1970); correlations between subtest scores and background variables were obtained and reported. Means, standard deviations, and F-ratios of subtest scores were obtained through the
**TABLE 10**

**DATA COLLECTING PROCEDURE FOR STUDENTS PARTICIPATING IN THE STUDY DURING AUTUMN QUARTER 1970**

<table>
<thead>
<tr>
<th>STUDENT GROUP</th>
<th>WEEK</th>
<th>Pretest</th>
<th>Test 2C</th>
<th>Test 4A</th>
<th>Test 6A</th>
<th>Test 8A</th>
<th>Test 9D</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1</td>
<td>Pretest A</td>
<td>Test 2C</td>
<td>Test 4A</td>
<td>Test 6A</td>
<td>Test 8A</td>
<td>Test 9D</td>
</tr>
<tr>
<td>S2</td>
<td>2</td>
<td>Pretest B</td>
<td>Test 2C</td>
<td>Test 4A</td>
<td>Test 6A</td>
<td>Test 8A</td>
<td>Test 9D</td>
</tr>
<tr>
<td>S3</td>
<td>3</td>
<td>Pretest B</td>
<td>Act. 2</td>
<td>Act. 3</td>
<td>Act. 4</td>
<td>Act. 5</td>
<td>Act. 6</td>
</tr>
<tr>
<td>S4</td>
<td>4</td>
<td>Pretest A</td>
<td>Test 2C</td>
<td>Test 4B</td>
<td>Test 6B</td>
<td>Test 8B</td>
<td>Test 9D</td>
</tr>
<tr>
<td>S5</td>
<td>5</td>
<td>Pretest B</td>
<td>Test 2C</td>
<td>Test 4B</td>
<td>Test 6B</td>
<td>Test 8B</td>
<td>Test 9D</td>
</tr>
</tbody>
</table>

*Activity*
### TABLE 11

**DATA COLLECTING PROCEDURE FOR STUDENTS PARTICIPATING IN THE STUDY DURING WINTER QUARTER 1971**

<table>
<thead>
<tr>
<th>STUDENT GROUP</th>
<th>WEEK</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>S3</td>
<td></td>
<td>Pretest B</td>
<td>Act.* 2</td>
<td>Act. 3</td>
<td>Act. 4</td>
<td>Act. 5</td>
<td>Act. 6</td>
<td>Act. 7</td>
<td>Act. 8</td>
<td>Test 8B</td>
</tr>
<tr>
<td>(2 Classes)</td>
<td></td>
<td>Test 2C</td>
<td>Test 4B</td>
<td>Test 6B</td>
<td>Test 9D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td></td>
<td>Pretest A</td>
<td>Act. 2</td>
<td>Act. 3</td>
<td>Act. 4</td>
<td>Act. 5</td>
<td>Act. 6</td>
<td>Act. 7</td>
<td>Act. 8</td>
<td>Test 8B</td>
</tr>
<tr>
<td>(2 Classes)</td>
<td></td>
<td>Test 2C</td>
<td>Test 4B</td>
<td>Test 6B</td>
<td>Test 9D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td>Pretest B</td>
<td>Test 2C</td>
<td>Test 4B</td>
<td>Test 6B</td>
<td>Test 8B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Activity*
The Multivariate Analysis of Variance (MANOVA) program developed by Clyde Computing Service (Clyde, 1969).

The BMD-03D Correlation with Item Deletion (Dixon, 1970) was also used in the analysis of the data for Hypothesis 2. The correlation between student performance at the higher levels of the two domains and sex was obtained in this manner.

To determine if the cognitive and affective instruments developed in this study were able to discriminate between student performances at various levels of the two domains (Hypothesis 3), correlation coefficients were obtained between the various cognitive and affective levels. The BMD-03D program (Dixon, 1970) was used to determine this information.

Hypothesis 4 deals with differences between the control and experimental groups in student performance on the cognitive instrument. The computerized New Item-Analysis Program developed by the Center for Measurement and Evaluation at The Ohio State University was used in producing total and subtest scores on all tests. Information for the assessment of each item was also obtained through this program, as was test reliability as determined by Kuder-Richardson formulas 20 and 21. The statistical analysis of this data utilized the Multivariate Analysis of
Variance (MANOVA) program (Clyde, 1969) to obtain means, standard deviations, and F-ratios.

The analysis of the control and experimental group performance on the affective instrument (Hypothesis 5) made use of the WAS 1 and WAS 2 programs by Dr. Arthur L. White of the Faculty of Science and Mathematics Education of The Ohio State University. With the WAS 1 program the student responses for each affective item were converted to a weighted score; the MANOVA program (Clyde, 1969) utilized this data in the statistical analysis. The WAS 2 program was used to determine correlated t-ratios for those students who took both affective tests.

Achievement at the higher cognitive and affective levels by students in the regular audio-tutorial approach in Biology 100 at The Ohio State University (Hypothesis 6) was also determined. Sign tests and chi square tests (Glass and Stanley, 1970) were performed to determine if there were any significant changes in student performance between the pretests and post-tests.
CHAPTER IV

ANALYSIS OF RESULTS

The results of the study are presented in this chapter. The results pertaining to each hypothesis are discussed in the order that the hypotheses were presented in Chapter I; the hypotheses are

1. There is no significant relationship between achievement at the higher levels of the two domains and background variables.

2. There is no significant relationship between achievement at the higher levels of the two domains and sex.

3. The instruments developed for this study will be able to discriminate between students performing at various levels of the Cognitive and Affective Domains.

4. Students who have worked through activity units specially designed to teach the higher levels of the Cognitive Domain will score significantly higher on the cognitive instrument than students who have worked through the regularly assigned activity units.

5. Students who have worked through the specially designed activity units will show a significantly positive change in attitudes toward science as assessed by the affective instruments than those students who work through the regular activity units.
6. The multi-media approach in Biology 100 at The Ohio State University is able to develop the higher levels of the two domains in a significant number of students as measured by the instruments used in this study.

Five of the hypotheses deal with the higher levels of the Cognitive Domain. Since the number of test items at each of the six cognitive levels was relatively small for any individual test (see Appendices B - I), it was felt that the test results could be better analyzed if the various levels were grouped. The grouping of cognitive levels was done in two ways; one way grouped the six levels by pairs, resulting in three groups—Knowledge-Comprehension (K-C), Analysis-Application (Ap-An), and Synthesis-Evaluation (S-E); the second way divided the six levels into two groups—Knowledge-Comprehension-Application (K-C-Ap) and Analysis-Synthesis-Evaluation (An-S-E). This grouping can be diagrammed as follows:

```
<table>
<thead>
<tr>
<th>K-C</th>
<th>Ap-An</th>
<th>S-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Analysis</td>
<td>Synthesis</td>
</tr>
<tr>
<td>Comprehension</td>
<td>Comprehension</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The review items were kept as an additional group; however the review items at a particular level were included in that cognitive level group. The Kuder-Richardson internal consistency reliability (K-R 20) for each group on each
test is shown in Table 12 below.

The levels of the affective tests were not grouped. The levels used were Level 1, Level 2, Level 3, Level 4, and All-Level. The All-Level items were ones in which the four distractors represented all four levels of the Affective Domain rather than being positive, negative, or neutral as was the case with the other items.

TABLE 12
INTERNAL CONSISTENCY RELIABILITY (K-R 20)
FOR GROUPED COGNITIVE LEVELS FOR ALL COGNITIVE SUBTESTS

<table>
<thead>
<tr>
<th>Post-test</th>
<th>Number of Students</th>
<th>K-C</th>
<th>Ap-An</th>
<th>S-E</th>
<th>K-C-Ap</th>
<th>An-S-E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>4A</td>
<td>29</td>
<td>.733</td>
<td>---*</td>
<td>---*</td>
<td>.729</td>
<td>---*</td>
<td>.729</td>
</tr>
<tr>
<td>6A</td>
<td>26</td>
<td>.885</td>
<td>---*</td>
<td>---*</td>
<td>.908</td>
<td>---*</td>
<td>.908</td>
</tr>
<tr>
<td>8A</td>
<td>15</td>
<td>.636</td>
<td>---*</td>
<td>---*</td>
<td>.713</td>
<td>---*</td>
<td>.713</td>
</tr>
<tr>
<td>4B</td>
<td>83</td>
<td>.634</td>
<td>.589</td>
<td>.426</td>
<td>.642</td>
<td>.704</td>
<td>.812</td>
</tr>
<tr>
<td>6B</td>
<td>56</td>
<td>.463</td>
<td>.660</td>
<td>.729</td>
<td>.674</td>
<td>.773</td>
<td>.842</td>
</tr>
<tr>
<td>8B</td>
<td>79</td>
<td>.452</td>
<td>.556</td>
<td>.372</td>
<td>.530</td>
<td>.524</td>
<td>.747</td>
</tr>
</tbody>
</table>

*Post-tests 4A, 6A, and 8A have no items at the Analysis, Synthesis, or Evaluation levels.
Hypothesis 1. There is no significant relationship between achievement at the higher levels of the two domains and background variables.

Three background variables were selected for study under this hypothesis: these were the effects of the cognitive pretest on post-test performances, the college class of each student, and the influence of the teachers who participated in the study.

Two types of cognitive pretests were used in this study; pretest A contained items at the lower three levels of the Cognitive Domain—Knowledge, Comprehension, and Application—while Pretest B had items from all six cognitive levels—these lower three levels plus Analysis, Synthesis, and Evaluation. Similarly the A-Post-test series evaluated only the lower three cognitive levels while the B-Post-test series assessed all six levels. This hypothesis sought to determine if taking a particular pretest influences student performance on the post-tests; this was tested by using F-ratios to examine differences in post-test scores.

A second background variable was college class. Each student was ranked from one to five on the basis of whether he was a freshman, sophomore, junior, senior, or
in continuing education during the quarter in which he participated in the study. The number of students in each category is shown in Table 7 on page 77 and Table 9 on page 81. The effect of college class on pretest and post-test performances was studied by correlating this variable with student test scores in the Cognitive and Affective Domains.

The teacher of each class was chosen as a background variable because of the influence that a teacher may have on the performance of his class. Four teachers participated in this study; Teacher A conducted one class during the Winter Quarter; Teacher B conducted one class during the Autumn Quarter; and both Teacher C and Teacher D conducted two classes during each of the two quarters of this study. The number of students in each class for each teacher can be obtained from Tables 7 and 9 on pages 77 and 81. The effects of teacher influence were studied by correlating this variable with student performance on all pretests and post-tests in both the Cognitive and Affective Domains.

Cognitive Domain

Table 1 on page 42 shows the treatment design for the Cognitive Domain and the pretest-post-test sequence for each student group. Tables 7 and 9 on page 77 and 81 indicate the distribution of these student groups for the
Autumn and Winter Quarters when this study was carried out.

**Pretest-Post-test Effects**

**Control Group**

By examining student groups S1 and S2 the pretest effect on the A-Post-test series, which contained only lower cognitive level items, was determined. Group S1 took Pretest A with items at the lower three cognitive levels while group S2 took Pretest B which had items at all six cognitive levels; both groups performed the regular A-Activity Unit series in the Bio-Learning Center. The scores of these two groups on Post-tests 4A, 6A, and 8A are shown in Table 13 on page 95. It should be pointed out that since the A-Post-tests had items at only the lower three levels, the Knowledge-Comprehension-Application subtest scores (K-C-Ap) were the same as the total scores. From the data in Table 13 it can be seen that there are no significant differences at the .05 level between the two student groups S1 and S2 on post-test performances.

**Experimental Group**

Student groups S3 and S4 were examined for the influence of the pretests on the B-Post-test series. Group S3 took Pretest B while group S4 took Pretest A. Both groups performed the B-Activity Unit series which was designed to develop higher levels of cognitive
<table>
<thead>
<tr>
<th></th>
<th>Review</th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post-test 4A:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S₁ (14 cases)</td>
<td>M</td>
<td>--*</td>
<td>18.643</td>
<td>21.214</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>--*</td>
<td>4.343</td>
<td>5.132</td>
</tr>
<tr>
<td></td>
<td>S₂ (15 cases)</td>
<td>M</td>
<td>--*</td>
<td>20.214</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>--*</td>
<td>2.694</td>
<td>2.738</td>
</tr>
<tr>
<td><strong>F-Ratio (1,26; F.05 = 4.22)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post-test 6A:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S₁ (12 cases)</td>
<td>M</td>
<td>5.583</td>
<td>13.417</td>
<td>23.083</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.712</td>
<td>5.712</td>
<td>9.558</td>
</tr>
<tr>
<td></td>
<td>S₂ (14 cases)</td>
<td>M</td>
<td>6.071</td>
<td>14.143</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.774</td>
<td>3.920</td>
<td>5.923</td>
</tr>
<tr>
<td><strong>F-Ratio (1,24; F.05 = 4.26)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post-test 8A:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S₁ (8 cases)</td>
<td>M</td>
<td>10.375</td>
<td>16.875</td>
<td>27.500</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.825</td>
<td>2.532</td>
<td>3.703</td>
</tr>
<tr>
<td></td>
<td>S₂ (7 cases)</td>
<td>M</td>
<td>11.286</td>
<td>17.429</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.200</td>
<td>3.505</td>
<td>5.066</td>
</tr>
<tr>
<td><strong>F-Ratio (1,13; F.05 = 4.67)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Post-test 4A does not contain Review items

*aSignificant at the 0.05 level
reasoning; both groups also took Post-tests 4B, 6B, and 8B which assessed all six cognitive levels. These data are shown in Table 14 on page 97. From this table it is seen that there is no significant difference at the .05 level between student groups S3 and S4 on post-test performance. Only in Post-test 8B at the lowest cognitive levels, Knowledge-Comprehension (K-C), does the F-ratio even approach the .05 level.

The data in Tables 13 and 14 indicate that having taken either Pretest A or Pretest B has no significant influence on post-test performance—either on the A-Posttest series or the B-Post-test series—for students participating in this study. Consequently Hypothesis 1 may be accepted for the effects of cognitive pretests on post-test performances.

**College Class and Teacher Effects**

In considering the variables college class and teacher, Table 15 on page 98 shows that there are no significant correlations between these background variables and student performance on the subtests of Pretest A. Correlations were made between these background variables and student performance on Post-tests 4A, 6A, and 8A; Tables 16, 17, and 18 on pages 99, 100, and 101 show these results. The data on all three tests reveal that college
### TABLE 14
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR EXPERIMENTAL GROUPS

<table>
<thead>
<tr>
<th>S3 AND S4 ON COGNITIVE POST-TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Post-test 4B: S3 (20 cases)</strong></td>
</tr>
<tr>
<td>M --*</td>
</tr>
<tr>
<td>SD --*</td>
</tr>
<tr>
<td><strong>S4 (27 cases)</strong></td>
</tr>
<tr>
<td>M --*</td>
</tr>
<tr>
<td>SD --*</td>
</tr>
<tr>
<td><strong>F-Ratio (1,45; F.05 = 4.06)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Post-test 6B: S3 (14 cases)</strong></td>
</tr>
<tr>
<td>M 6.929</td>
</tr>
<tr>
<td>SD 1.859</td>
</tr>
<tr>
<td><strong>S4 (20 cases)</strong></td>
</tr>
<tr>
<td>M 6.850</td>
</tr>
<tr>
<td>SD 2.059</td>
</tr>
<tr>
<td><strong>F-Ratio (1,32; F.05 = 4.15)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Post-test 8B: S3 (18 cases)</strong></td>
</tr>
<tr>
<td>M 10.667</td>
</tr>
<tr>
<td>SD 1.940</td>
</tr>
<tr>
<td><strong>S4 (22 cases)</strong></td>
</tr>
<tr>
<td>M 10.773</td>
</tr>
<tr>
<td>SD 2.636</td>
</tr>
<tr>
<td><strong>F-Ratio (1,38; F.05 = 4.10)</strong></td>
</tr>
</tbody>
</table>

*Post-test 4B does not contain Review items:

*Significant at the 0.05 level.
TABLE 15

CORRELATIONS OF COLLEGE CLASS AND TEACHER WITH PRETEST A SUBTESTS

<table>
<thead>
<tr>
<th></th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Class*</td>
<td>-0.042</td>
<td>-0.071</td>
<td>-0.071</td>
</tr>
<tr>
<td>Teacher</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A**</td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher B**</td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher C (27 cases)</td>
<td>0.057</td>
<td>0.053</td>
<td>0.053</td>
</tr>
<tr>
<td>Teacher D (38 cases)</td>
<td>-0.057</td>
<td>-0.053</td>
<td>-0.053</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teachers A and B did not give Pretest A

aSignificant at the 0.05 level
### TABLE 16

**CORRELATIONS OF COLLEGE CLASS AND TEACHER WITH POST-TEST 4A SUBTESTS**

<table>
<thead>
<tr>
<th></th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>College Class</strong>* (29 cases, ( r_{.05} = .367 ))</td>
<td>0.113</td>
<td>0.117</td>
<td>0.117</td>
</tr>
<tr>
<td><strong>Teacher</strong> (29 cases, ( r_{.05} = .367 ))</td>
<td><strong>Teacher A</strong></td>
<td><strong>Teacher B</strong> (15 cases)</td>
<td>0.289</td>
</tr>
<tr>
<td><strong>Teacher C</strong></td>
<td><strong>Teacher C</strong></td>
<td><strong>Teacher D</strong> (14 cases)</td>
<td>(-0.256)</td>
</tr>
</tbody>
</table>

*1-Freshman, 2-Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teachers A and C did not give Post-test 4A**

*aSignificant at the 0.05 level
### TABLE 17

CORRELATIONS OF COLLEGE CLASS AND TEACHER

WITH POST-TEST 6A SUBTESTS

<table>
<thead>
<tr>
<th></th>
<th>Review</th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Class* (26 cases, r_{.05} = .388)</td>
<td>-0.136</td>
<td>-0.120</td>
<td>0.078</td>
<td>0.078</td>
</tr>
<tr>
<td>Teacher (26 cases, r_{.05} = .388)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A**</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher B (14 cases)</td>
<td>0.094</td>
<td>0.054</td>
<td>0.091</td>
<td>0.091</td>
</tr>
<tr>
<td>Teacher C**</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher D (12 cases)</td>
<td>-0.094</td>
<td>-0.054</td>
<td>-0.091</td>
<td>-0.091</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teachers A and C did not give Post-test 6A

^aSignificant at the 0.05 level
### TABLE 18

**CORRELATION OF COLLEGE CLASS AND TEACHER WITH POST-TEST 8A SUBTESTS**

<table>
<thead>
<tr>
<th></th>
<th>Review</th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>College Class</strong> (15 cases, $r_{.05} = .514)$</td>
<td>0.172</td>
<td>-0.019</td>
<td>-0.062</td>
<td>-0.062</td>
</tr>
<tr>
<td><strong>Teacher</strong> (15 cases, $r_{.05} = .514)$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A**</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher B (7 cases)</td>
<td>0.108</td>
<td>0.050</td>
<td>0.137</td>
<td>0.137</td>
</tr>
<tr>
<td>Teacher C**</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Teacher D (8 cases)</td>
<td>-0.108</td>
<td>-0.050</td>
<td>-0.137</td>
<td>-0.137</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teachers A and C did not give Post-test 8A

*Significant at the 0.05 level
class and teacher did not correlate significantly with any subtests of the three post-tests, indicating that these were not a factor in student performance.

Correlations were made between college class and teacher and student performance on the subtests of Pretest B; Table 19, page 103, shows the results. There is a significant negative correlation of college class with the Application-Analysis (Ap-An) subtest; this indicates that the students who ranked low in college class (i.e. freshmen) tended to score higher on this particular subtest than the higher ranking students. Although only this particular subtest shows a correlation coefficient significant at the .05 level, all of the correlations show a negative tendency.

The results of the correlations between teacher and the Pretest B subtests show significant negative correlations between Teacher B and student performance on the Analysis-Synthesis-Evaluation (An-S-E) subtest and on total score. All the other correlations for Teacher B are also negative and several approach the .05 level of significance. This indicates that on Pretest B the students under Teacher B performed significantly lower on this subtest and on total score than did students under other teachers; the students under Teacher B scored
## TABLE 19
CORRELATIONS OF COLLEGE CLASS AND TEACHER WITH PRETEST B SUBTESTS

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>College Class</strong> (115 cases, r = .185)</td>
<td>-0.035</td>
<td>-0.197*</td>
<td>-0.022</td>
<td>-0.127</td>
<td>-0.073</td>
<td>-0.116</td>
</tr>
<tr>
<td><strong>Teacher</strong> (115 cases, r = .185)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A (5 cases)</td>
<td>0.043</td>
<td>-0.057</td>
<td>0.040</td>
<td>0.053</td>
<td>-0.058</td>
<td>0.002</td>
</tr>
<tr>
<td>Teacher B (28 cases)</td>
<td>-0.164</td>
<td>-0.177</td>
<td>-0.124</td>
<td>-0.153</td>
<td>-0.190*</td>
<td>-0.192*</td>
</tr>
<tr>
<td>Teacher C (54 cases)</td>
<td>0.034</td>
<td>0.050</td>
<td>0.045</td>
<td>0.010</td>
<td>0.090</td>
<td>0.052</td>
</tr>
<tr>
<td>Teacher D (28 cases)</td>
<td>0.101</td>
<td>0.144</td>
<td>0.051</td>
<td>0.114</td>
<td>0.111</td>
<td>0.127</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

*aSignificant at the 0.05 level
generally lower on the other subtests also.

Tables 20, 21, and 22 on pages 105, 106, and 107 show the results of the correlations between the background variables and student performance on the subtests of Post-tests 4B, 6B, and 8B. None of the correlation coefficients are significant at the .05 level. This suggests that the significant correlation of college class with the Application-Analysis subtest on Pretest B is not of any real importance since it is not carried through on even the earliest post-test.

The background variables were also correlated with the standardized data collected for grades in the course. The data consisted of scores on the first and second midterm examinations, final examination, and the total score for the quarter. This quarter score was a combination of the two midterms, the final exam, and a score given by each teacher for class participation and assignments. Table 23 on page 108 shows the results of these correlations.

Table 23 indicates that there is no significant correlation between college class and student performance on the regular course material. When teacher is correlated with the course data, a negative correlation significant at the .05 level is shown between Teacher B and the final
<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>College Class*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(81 cases, ( r_{.05} = .219 ))</td>
<td>-0.059</td>
<td>-0.178</td>
<td>-0.078</td>
<td>-0.113</td>
<td>-0.122</td>
<td>-0.127</td>
</tr>
<tr>
<td>Teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(81 cases, ( r_{.05} = .219 ))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A (5 cases)</td>
<td>0.142</td>
<td>0.178</td>
<td>0.054</td>
<td>0.162</td>
<td>0.116</td>
<td>0.147</td>
</tr>
<tr>
<td>Teacher B**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher C (56 cases)</td>
<td>-0.033</td>
<td>-0.061</td>
<td>0.011</td>
<td>0.017</td>
<td>-0.073</td>
<td>-0.035</td>
</tr>
<tr>
<td>Teacher D (20 cases)</td>
<td>-0.044</td>
<td>-0.034</td>
<td>-0.042</td>
<td>-0.109</td>
<td>0.013</td>
<td>-0.044</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teacher B did not give Post-test 4B

*Significant at the 0.05 level
<table>
<thead>
<tr>
<th>College Class* (56 cases, $r_{.05} = .264$)</th>
<th>Review</th>
<th>K-C</th>
<th>Ap-An</th>
<th>S-E</th>
<th>K-C-Ap</th>
<th>An-S-E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.196</td>
<td>0.016</td>
<td>-0.180</td>
<td>-0.204</td>
<td>-0.122</td>
<td>-0.179</td>
<td>-0.168</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teacher (56 cases, $r_{.05} = .264$)</th>
<th>Review</th>
<th>K-C</th>
<th>Ap-An</th>
<th>S-E</th>
<th>K-C-Ap</th>
<th>An-S-E</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher A (3 cases)</td>
<td>0.124</td>
<td>0.044</td>
<td>0.140</td>
<td>0.182</td>
<td>0.114</td>
<td>0.162</td>
<td>0.153</td>
</tr>
<tr>
<td>Teacher B**</td>
<td>0.117</td>
<td>0.179</td>
<td>0.087</td>
<td>-0.050</td>
<td>-0.175</td>
<td>-0.011</td>
<td>-0.179</td>
</tr>
<tr>
<td>Teacher C (40 cases)</td>
<td>-0.103</td>
<td>0.011</td>
<td>0.021</td>
<td>0.090</td>
<td>-0.049</td>
<td>0.105</td>
<td>0.043</td>
</tr>
<tr>
<td>Teacher D (13 cases)</td>
<td>0.044</td>
<td>0.070</td>
<td>0.021</td>
<td>0.090</td>
<td>-0.049</td>
<td>0.105</td>
<td>0.043</td>
</tr>
</tbody>
</table>

*1-Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

**Teacher B did not give Post-test 6B

^Significant at the 0.05 level
### Table 22
CORRELATIONS OF COLLEGE CLASS AND TEACHER WITH POST-TEST 8B SUBTESTS

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>College Class</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(68 cases, (r_{.05} = .239))</td>
<td>0.036</td>
<td>0.154</td>
<td>0.175</td>
<td>0.006</td>
<td>0.193</td>
<td>0.080</td>
<td>0.149</td>
</tr>
<tr>
<td><strong>Teacher</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(68 cases, (r_{.05} = .239))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A (4 cases)</td>
<td>0.198</td>
<td>-0.099</td>
<td>0.149</td>
<td>-0.031</td>
<td>-0.096</td>
<td>0.123</td>
<td>0.027</td>
</tr>
<tr>
<td>Teacher B**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher C (42 cases)</td>
<td>0.048</td>
<td>0.098</td>
<td>-0.121</td>
<td>0.014</td>
<td>0.098</td>
<td>-0.134</td>
<td>-0.033</td>
</tr>
<tr>
<td>Teacher D (22 cases)</td>
<td>-0.149</td>
<td>-0.052</td>
<td>-0.051</td>
<td>0.031</td>
<td>-0.053</td>
<td>0.078</td>
<td>0.021</td>
</tr>
</tbody>
</table>

*1 Freshman, 2 Sophomore, 3 Junior, 4 Senior, 5 Continuing Education

**Teacher B did not give Post-test 8B

*aSignificant at the 0.05 level
<table>
<thead>
<tr>
<th></th>
<th>College Class* (180 cases, $r_{.05} = .147$)</th>
<th>Midterm I</th>
<th>Midterm II</th>
<th>Final Exam</th>
<th>Quarter Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.052</td>
<td>0.053</td>
<td>0.080</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>(180 cases, $r_{.05} = .147$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A (5 cases)</td>
<td>-0.031</td>
<td>0.083</td>
<td>0.072</td>
<td>0.062</td>
<td></td>
</tr>
<tr>
<td>Teacher B (28 cases)</td>
<td>-0.071</td>
<td>-0.032</td>
<td>-0.149$^a$</td>
<td>-0.127</td>
<td></td>
</tr>
<tr>
<td>Teacher C (81 cases)</td>
<td>0.141</td>
<td>-0.050</td>
<td>0.122</td>
<td>0.124</td>
<td></td>
</tr>
<tr>
<td>Teacher D (66 cases)</td>
<td>-0.081</td>
<td>0.045</td>
<td>-0.041</td>
<td>-0.056</td>
<td></td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

$^a$Significant at the 0.05 level
examination; that is, the students under Teacher B were performing significantly at a lower level on the final exam than students under the other three teachers. Teacher C shows a positive correlation on Midterm I that approaches the .05 level of significance.

Despite an occasional significant correlation, the over-all trend indicates that college class and teacher do not affect post-test performances at the higher cognitive levels. Thus Hypothesis 1 may be accepted for these variables in the Cognitive Domain.

Affective Domain

The background variables—college class and teacher—were also correlated with student performance in the Affective Domain on Personal Preference Tests 2C (pretest) and 9D (post-test). The results of these correlations are shown in Table 24 on pages 110 and 111. The first four levels of Krathwohl's taxonomy were used as subtests, as were four questions which contained distractors at all four levels (All-Level subtest) and total score.

College Class Effect

There are no significant correlations at the .05 level between college class and the affective subtests. However, on Test 9D the Level 2 and Level 4 subtests approach the significant level. The Level 2 correlation is negative,
### TABLE 24

CORRELATIONS OF COLLEGE CLASS AND TEACHER WITH AFFECTIVE LEVELS ON PERSONAL PREFERENCE

TESTS 2C AND 9D

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>College Class</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With 2C (148 cases, r .05=.157)</td>
<td>0.048</td>
<td>0.068</td>
<td>-0.020</td>
<td>-0.028</td>
<td>0.073</td>
</tr>
<tr>
<td>With 9D (52 cases, r .05=.273)</td>
<td>0.147</td>
<td>-0.253</td>
<td>-0.075</td>
<td>-0.265</td>
<td>-0.056</td>
</tr>
<tr>
<td><strong>Teacher</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With 2C (148 cases, r .05=.157)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher A (4 cases)</td>
<td>-0.007</td>
<td>-0.027</td>
<td>0.028</td>
<td>0.005</td>
<td>0.017</td>
</tr>
<tr>
<td>Teacher B (19 cases)</td>
<td>0.013</td>
<td>0.071</td>
<td>0.111</td>
<td>-0.138</td>
<td>-0.106</td>
</tr>
<tr>
<td>Teacher C (71 cases)</td>
<td>-0.107</td>
<td>-0.005</td>
<td>-0.086</td>
<td>-0.061</td>
<td>0.029</td>
</tr>
<tr>
<td>Teacher D (54 cases)</td>
<td>0.105</td>
<td>-0.034</td>
<td>0.004</td>
<td>0.155</td>
<td>0.036</td>
</tr>
</tbody>
</table>
TABLE 24, cont.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.110</td>
<td>-0.038</td>
<td>0.058</td>
<td>0.102</td>
<td>0.090</td>
<td>0.078</td>
</tr>
<tr>
<td>-0.108</td>
<td>0.116</td>
<td>-0.050</td>
<td>0.119</td>
<td>-0.263</td>
<td>-0.218</td>
</tr>
<tr>
<td>0.024</td>
<td>0.000</td>
<td>-0.051</td>
<td>-0.081</td>
<td>-0.073</td>
<td>-0.090</td>
</tr>
<tr>
<td>0.095</td>
<td>-0.083</td>
<td>0.079</td>
<td>-0.040</td>
<td>0.268</td>
<td>0.253</td>
</tr>
</tbody>
</table>

With 9D (52 cases, $r_{0.05} = .273$)

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher A (2 cases)</td>
<td>-0.110</td>
<td>-0.038</td>
<td>0.058</td>
<td>0.102</td>
<td>0.090</td>
<td>0.078</td>
</tr>
<tr>
<td>Teacher B (9 cases)</td>
<td>-0.108</td>
<td>0.116</td>
<td>-0.050</td>
<td>0.119</td>
<td>-0.263</td>
<td>-0.218</td>
</tr>
<tr>
<td>Teacher C (26 cases)</td>
<td>0.024</td>
<td>0.000</td>
<td>-0.051</td>
<td>-0.081</td>
<td>-0.073</td>
<td>-0.090</td>
</tr>
<tr>
<td>Teacher D (15 cases)</td>
<td>0.095</td>
<td>-0.083</td>
<td>0.079</td>
<td>-0.040</td>
<td>0.268</td>
<td>0.253</td>
</tr>
</tbody>
</table>

*1=Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education

Significant at the 0.05 level
indicating that the students in the lower college class ranks were scoring higher on this particular subtest; the Level 4 correlation is positive, indicating that the reverse was true for Level 4.

**Teacher Effect**

The correlations of teacher with affective levels also show no significance at the .05 level. However, for Test 2C Teacher D has a correlation with the Level 4 subtest that approaches .05 significance. This positive correlation suggests that the students of Teacher D are performing at Level 4 better than the other classes. On Test 9C Teacher B and the All-Level subtest have a negative coefficient approaching the .05 level; Teacher D and the All-Level and Total subtests both have a positive coefficient which approaches the .05 level.

Since no significant influence of college class and teacher effects is found as a continuous trend, Hypothesis 1 can be accepted for these variables in the Affective Domain.

**Summary**

The background variable of the effect of the cognitive pretests on post-test performance was examined for student groups S1 and S2 and for S3 and S4. Tables 13 and 14 on pages 95 and 97 indicate that neither Pretest A with items at the lower three cognitive levels nor Pretest B with items
at all six levels significantly influences the student performances on either the A-Post-test series or the B-Post-test series. Thus Hypothesis 1 is accepted for this background variable.

Using the background variables college class and teacher, correlations were made with student performance on subtests of Pretest A (Table 15, page 98) and Post-tests 4A, 6A, and 8A (Tables 16-18, pages 99, 100 and 101) and Pretest B (Table 19, page 103) and Post-tests 4B, 6B and 8B (Tables 20-22, pages 105, 106 and 107) in the Cognitive Domain. Except for three isolated incidents of Pretest B with college class and with Teacher B, no significant correlations at the .05 level are found. When the background variables are correlated with standardized course data (Table 23, page 108), a significant negative correlation is found between Final Exam and Teacher B, indicating that students under Teacher B scored lower on the Final Exam than other students. A positive correlation which approaches the .05 level of significance is observed between Teacher D and Midterm I, indicating that the students under Teacher D scored higher on Midterm I than did other students.

The background variables college class and teacher were also correlated with performance on affective subtests of the Personal Preference Tests 2C and 9D (Table 24, pages 110 and 111); no significant correlations are observed.
Several correlation coefficients on Level 4, All-Level, and Total subtests are seen to approach the significant level.

Except for the four incidents mentioned, there are no significant correlations between the background variables of college class and teacher with achievement on the subtests of the Cognitive and Affective Domains. Consequently, Hypothesis 1 is accepted for these variables.

Hypothesis 2. There is no significant relationship between achievement at the higher levels of the two domains and sex.

To determine if the sex of the students played a significant role in student performances in the two domains, sex was correlated with the background variables (college class and teacher), with student performance on cognitive tests (the instruments designed for this study and standardized course data), and with student performance on affective tests (the instruments designed for this study). The number of males and females who participated during each quarter is shown in Table 7 on page 77 and Table 9 on page 81. For correlation purposes males were given a rank of one, and females, a rank of two.

The correlations of sex with the background variables, college class and teacher, are given in Table 25, page 115. Teacher B shows a significant positive correlation
## TABLE 25

CORRELATIONS OF SEX WITH COLLEGE CLASS AND TEACHER

<table>
<thead>
<tr>
<th>College Class**</th>
<th>Teacher A (5 cases)</th>
<th>Teacher B (28 cases)</th>
<th>Teacher C (81 cases)</th>
<th>Teacher D (66 cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex* (180 cases, $r_{.05} = .147$)</td>
<td>-0.094</td>
<td>-0.040</td>
<td>0.238(^a)</td>
<td>-0.035</td>
</tr>
</tbody>
</table>

*1=male, 2=female  
**1-Freshman, 2=Sophomore, 3=Junior, 4=Senior, 5=Continuing Education  
\(^a\)Significant at the 0.05 level
at the .05 level; this indicates that his class contained a significantly larger number of females than males. This should be remembered in interpreting the results from other data analyses.

Cognitive Domain

Table 26, (page 117) shows the correlations of sex with student performance on the cognitive instruments especially designed for this study. Neither Pretest A nor Pretest B shows any significant differences in the performance of the male and female participants. The results of Post-tests 4A, 6A, and 8A also indicate that the males and females did not perform differently. Student performance on Post-tests 4B and 6B are not significant at the .05 level in terms of sex as a variable. However, Post-test 8B shows the females performing significantly higher on the review items and on the total test score; the performance of the females on the Knowledge-Comprehension-Application (K-C-Ap) subtest also approaches the .05 level of significance.

The lack of significance between sex and performance on Pretests A and B suggests that initially males and females were performing equally well on the various subtests. The significant correlations found on Post-test 8B on the review items and total scores indicate that
<table>
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<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.129</td>
</tr>
<tr>
<td>(65 cases, $r_{.05} = .245$)</td>
<td>**</td>
<td>0.156</td>
<td>***</td>
<td>***</td>
<td>0.129</td>
<td>***</td>
<td>0.129</td>
</tr>
<tr>
<td>Pretest B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.068</td>
</tr>
<tr>
<td>(115 cases, $r_{.05} = .185$)</td>
<td>**</td>
<td>-0.023</td>
<td>-0.067</td>
<td>-0.086</td>
<td>-0.029</td>
<td>-0.098</td>
<td>-0.068</td>
</tr>
<tr>
<td>Post-test 4A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.055</td>
</tr>
<tr>
<td>(29 cases, $r_{.05} = .367$)</td>
<td>**</td>
<td>0.003</td>
<td>***</td>
<td>***</td>
<td>0.055</td>
<td>***</td>
<td>0.055</td>
</tr>
<tr>
<td>Post-test 6A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.085</td>
</tr>
<tr>
<td>(26 cases, $r_{.05} = .388$)</td>
<td>0.154</td>
<td>0.048</td>
<td>***</td>
<td>***</td>
<td>0.085</td>
<td>***</td>
<td>0.085</td>
</tr>
<tr>
<td>Post-test 8A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.238</td>
</tr>
<tr>
<td>(15 cases, $r_{.05} = .514$)</td>
<td>0.217</td>
<td>0.328</td>
<td>***</td>
<td>***</td>
<td>0.238</td>
<td>***</td>
<td>0.238</td>
</tr>
<tr>
<td>Post-test 4B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.071</td>
</tr>
<tr>
<td>(81 cases, $r_{.05} = .215$)</td>
<td>**</td>
<td>-0.051</td>
<td>-0.139</td>
<td>0.034</td>
<td>-0.074</td>
<td>-0.059</td>
<td>-0.071</td>
</tr>
<tr>
<td>Post-test 6B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.025</td>
</tr>
<tr>
<td>(56 cases, $r_{.05} = .264$)</td>
<td>0.123</td>
<td>0.026</td>
<td>0.044</td>
<td>-0.007</td>
<td>0.094</td>
<td>-0.030</td>
<td>0.025</td>
</tr>
<tr>
<td>Post-test 8B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.245^a</td>
</tr>
<tr>
<td>(68 cases, $r_{.05} = .239$)</td>
<td>0.305a</td>
<td>0.180</td>
<td>0.216</td>
<td>0.158</td>
<td>0.233</td>
<td>0.201</td>
<td>0.245^a</td>
</tr>
</tbody>
</table>

*1 = male, 2 = female

**Pretests A and B and Post-test 4A and 4B had no Review items.

***Pretest A and Post-tests 4A, 6A, and 8A had no Analysis, Synthesis, or Evaluation items.

aSignificant at the 0.05 level
between the time of the pretests and Post-test 8B some factor had caused the performance of the females to significantly exceed that of the males. There is no indication from the earlier post-tests that this separation according to sex is a trend.

Sex was also correlated with the standardized scores obtained by the student during the biology course; these data are shown in Table 27 on page 119. These scores are on Midterm I, Midterm II, Final Exam, and the final Quarter score. None of the correlations are significant, indicating that sex did not play a role in student performance on these tests.

The significant correlations found in the above data do not occur in the higher cognitive subtests. Therefore Hypothesis 2 may be accepted for the Cognitive Domain.

**Affective Domain**

Sex was correlated with student performance at the various affective levels of the Personal Preference Tests 2C and 9D (see Table 28, page 120). On the pretest (2C) there were no significant correlations. However, on the post-test (9D) negative correlations with Level 3 and total score indicate that the males scored significantly higher than the females on these two subtests. The performance of the males on Level 4 subtest also approaches
## TABLE 27

**CORRELATIONS OF SEX WITH STANDARDIZED COURSE DATA**

<table>
<thead>
<tr>
<th></th>
<th>Midterm I</th>
<th>Midterm II</th>
<th>Final Exam</th>
<th>Quarter Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex* (180 cases, ( r_{0.05} = .147 ))</td>
<td>-0.011</td>
<td>0.057</td>
<td>0.002</td>
<td>0.035</td>
</tr>
</tbody>
</table>

*1=male, 2=female

*Significant at the 0.05 level
TABLE 28

CORRELATIONS OF SEX WITH AFFECTIVE LEVELS ON PERSONAL PREFERENCE TESTS 2C AND 9D

<table>
<thead>
<tr>
<th>Sex*</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>with 2C (148 cases, ( r_{.05} = .161 ))</td>
<td>0.145</td>
<td>0.045</td>
<td>0.019</td>
<td>-0.017</td>
<td>0.056</td>
<td>0.093</td>
</tr>
<tr>
<td>with 9D (52 cases, ( r_{.05} = .273 ))</td>
<td>0.106</td>
<td>0.070</td>
<td>-0.304(^a)</td>
<td>-0.268</td>
<td>-0.152</td>
<td>-0.282(^a)</td>
</tr>
</tbody>
</table>

\(*1=\text{male}, 2=\text{female}\\
\(^a\text{Significant at the 0.05 level}\)
the .05 level of significance. These results suggest that between the pretest and the post-test something occurred which caused the females to score lower than previously and the males to score higher. Consequently Hypothesis 2 must be rejected for the Affective Domain.

Summary

Correlations indicate there were no significant sex ratio differences between college class ranks or in the classes of Teachers A, C, or D (Table 25, page 115). However the class taught by Teacher B is shown to have a significantly larger number of females than males who participated in the study.

When sex was correlated with student performance on the cognitive subtests of Pretests A and B and Post-tests 4A, 6A, 4B, and 6B, no significant differences were found (Table 26, page 117). On Post-test 8B the females scored significantly higher on the Review subtest and on total score; the performance of the females on subtest Knowledge-Comprehension-Application approaches the .05 level of significance. However since the significant correlations are not on the subtests of the higher cognitive levels, Hypothesis 2 for the Cognitive Domain may still be accepted.

Sex was also correlated with student performance on standardized course data (Table 27, page 119). The results
show that no significant correlations were obtained.

On the Personal Preference Tests (Table 28, page 120), sex was not found to make any significant difference on Test 2C. However on Test 9D the males scored significantly higher than the females on Level 3 and on total score. The performance of the males on Level 4 also approached the .05 significance level. Consequently for the Affective Domain Hypothesis 2 must be rejected.

Hypothesis 3. The instruments developed for this study will be able to discriminate between students performing at various levels of the Cognitive and Affective Domains.

Cognitive Domain

The six levels of the Cognitive Domain were divided into three groups to test this hypothesis—a low level group, Knowledge-Comprehension (K-C); a middle group, Application-Analysis (Ap-An); and a high level group, Synthesis-Evaluation (S-E). Since Post-tests 4A, 6A, and 8A only contained the three lower cognitive levels, these tests were not used for testing this hypothesis.

Control Group

Correlation coefficients for the three cognitive groups were determined for the control and experimental
groups for Post-tests 4B, 6B, and 8B. The results are shown in Tables 29 and 30 on pages 124 and 125. For the control group (student group S5) the data indicate that on all three post-tests, the low level cognitive group (K-C) correlates more highly with the middle group (Ap-An) than with the high cognitive level group (S-E). The middle group (Ap-An) in turn correlates more highly with the high level group (S-E) than the low level group (K-C) does. These correlations suggest that on the B-Post-tests the student performances showed the same hierarchical tendency that Bloom points out in his cognitive taxonomy. It is particularly striking that on Post-test 4B and 8B for the control group, the correlations between the middle and upper levels and between the middle and lower levels are quite similar; this suggests the middle level items were situated equally between the high level and low level items.

**Experimental Group**

The data for the experimental group (student groups S3 and S4) in Table 30 on page 125 show the same results for Post-tests 4B and 6B as were found for the control group. With the experimental group the position of the middle cognitive group (Ap-An) between the two extremes is even more clearly seen. Post-test 8B for the experimental group shows interesting results; the correlation
TABLE 29
CORRELATIONS AMONG GROUPED COGNITIVE LEVELS ON POST-TESTS 4B, 6B, AND 8B FOR CONTROL GROUP

<table>
<thead>
<tr>
<th></th>
<th>K-C</th>
<th>Ap-An</th>
<th>S-E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Post-test 4B:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.776^b</td>
<td>.677^b</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.776^b</td>
<td>--</td>
<td>.731^b</td>
</tr>
<tr>
<td>S-E</td>
<td>.677^b</td>
<td>.731^b</td>
<td>--</td>
</tr>
<tr>
<td><strong>Post-test 6B:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.827^b</td>
<td>.522^a</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.827^b</td>
<td>--</td>
<td>.593^b</td>
</tr>
<tr>
<td>S-E</td>
<td>.522^a</td>
<td>.593^b</td>
<td>--</td>
</tr>
<tr>
<td><strong>Post-test 8B:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.440^a</td>
<td>.126</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.440^a</td>
<td>--</td>
<td>.310</td>
</tr>
<tr>
<td>S-E</td>
<td>.126</td>
<td>.310</td>
<td>--</td>
</tr>
</tbody>
</table>

*33 cases, r_0.05 = .345
**22 cases, r_0.05 = .423
***28 cases, r_0.05 = .374

^aSignificant at the 0.05 level
^bSignificant at the 0.01 level
TABLE 30
CORRELATIONS AMONG GROUPED COGNITIVE LEVELS ON POST-TESTS 4B, 6B, AND 8B FOR EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th></th>
<th>Grouped Cognitive Levels</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>K-C</td>
<td>Ap-An</td>
<td>S-E</td>
</tr>
<tr>
<td>Post-test 4B:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.698&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.532&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.698&lt;sup&gt;b&lt;/sup&gt;</td>
<td>--</td>
<td>.684&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-E</td>
<td>.532&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.684&lt;sup&gt;b&lt;/sup&gt;</td>
<td>--</td>
</tr>
<tr>
<td>Post-test 6B:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.675&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.557&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.675&lt;sup&gt;b&lt;/sup&gt;</td>
<td>--</td>
<td>.726&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-E</td>
<td>.557&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.726&lt;sup&gt;b&lt;/sup&gt;</td>
<td>--</td>
</tr>
<tr>
<td>Post-test 8B:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K-C</td>
<td>--</td>
<td>.171</td>
<td>.631&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ap-An</td>
<td>.171</td>
<td>--</td>
<td>.421&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>S-E</td>
<td>.631&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.421&lt;sup&gt;b&lt;/sup&gt;</td>
<td>--</td>
</tr>
</tbody>
</table>

*48 cases, \( r_{.05} = .286 \)
**34 cases, \( r_{.05} = .344 \)
***40 cases, \( r_{.05} = .308 \)

<sup>a</sup>Significant at the 0.05 level
<sup>b</sup>Significant at the 0.01 level
between the low and middle cognitive groups is very low while the correlation between the low and high groups is quite high. This suggests that on Post-test 8B content knowledge was more important in determining the performances of students at the higher cognitive levels than at the middle levels.

The data presented in Table 31 on page 127 gives the mean percent correct response for all items at each of the six cognitive levels on Post-tests 4B, 6B, and 8B; the mean percent for all three tests is also given. These data indicate a reduction in the number of correct responses from the lower to the higher cognitive levels. Only the application level for 4B and 6B is not in sequence; this may be the result of requiring higher cognitive skills in some of the application items.

The data obtained from the correlation of cognitive levels and from the percent of correct responses at each level indicate that the three cognitive tests—4B, 6B, and 8B—are indeed measuring student performance at different levels. Consequently Hypothesis 3 is accepted for the Cognitive Domain.

Affective Domain

To show that the affective test used in this study discriminates among student performances at various
TABLE 31
MEAN PERCENT CORRECT RESPONSE FOR ITEMS AT EACH COGNITIVE LEVEL ON B-POST-TEST SERIES

<table>
<thead>
<tr>
<th></th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis</th>
<th>Synthesis</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-test 4B</td>
<td>86.0*</td>
<td>72.3</td>
<td>56.0</td>
<td>69.0</td>
<td>62.8</td>
<td>52.5</td>
</tr>
<tr>
<td></td>
<td>(4)**</td>
<td>(6)</td>
<td>(6)</td>
<td>(8)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
<tr>
<td>Post-test 6B</td>
<td>89.0</td>
<td>88.0</td>
<td>66.4</td>
<td>71.1</td>
<td>68.4</td>
<td>59.5</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
<td>(5)</td>
<td>(4)</td>
</tr>
<tr>
<td>Post-test 8B</td>
<td>82.4</td>
<td>76.2</td>
<td>71.8</td>
<td>65.2</td>
<td>48.0</td>
<td>57.8</td>
</tr>
<tr>
<td></td>
<td>(5)</td>
<td>(6)</td>
<td>(8)</td>
<td>(8)</td>
<td>(5)</td>
<td>(5)</td>
</tr>
<tr>
<td>( \bar{X} )</td>
<td>85.8</td>
<td>78.8</td>
<td>64.7</td>
<td>68.4</td>
<td>59.7</td>
<td>56.6</td>
</tr>
</tbody>
</table>

*Mean Percent

**Number of items at cognitive level
levels, a correlation coefficient between each of the four affective levels was used. The results are shown in Table 32 on page 129. These results indicate that the affective test used in this study was unable to evaluate the various levels of the Affective Domain. The correlations among the various levels of each test are both positive and negative and never approach the .05 level of significance.

Table 33 on page 130 gives the mean percent of negative, neutral, and positive responses at the four affective levels for the Personal Preference Test. Not all items on the test had negative, neutral, and positive distractors; one item from Level 1 was eliminated from the data because all the distractors for that item were positive. The data in Table 33 indicate that the items were at various levels, but the differences from level to level were not significant. The difference in the percent of positive responses between Level 1 and Level 2 suggests that performances at these two levels could be discriminated. The lack of significant correlations among the various levels suggests that although levels exist among the items, these levels may not be related.

The data presented here show that the affective instrument used in this study measured responses at four levels, but the levels were not correlated with each other and the differences among levels were insignificant.
<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pretest 2C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>--</td>
<td>.015</td>
<td>.100</td>
<td>-.109</td>
</tr>
<tr>
<td>Level 2</td>
<td>.015</td>
<td>--</td>
<td>-.034</td>
<td>.045</td>
</tr>
<tr>
<td>Level 3</td>
<td>.100</td>
<td>-.034</td>
<td>--</td>
<td>-.119</td>
</tr>
<tr>
<td>Level 4</td>
<td>-.109</td>
<td>.045</td>
<td>-.119</td>
<td>--</td>
</tr>
<tr>
<td><strong>Post-test 9D</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>--</td>
<td>-.102</td>
<td>-.027</td>
<td>.021</td>
</tr>
<tr>
<td>Level 2</td>
<td>-.102</td>
<td>--</td>
<td>.021</td>
<td>-.088</td>
</tr>
<tr>
<td>Level 3</td>
<td>-.027</td>
<td>.021</td>
<td>--</td>
<td>.052</td>
</tr>
<tr>
<td>Level 4</td>
<td>.021</td>
<td>-.088</td>
<td>.052</td>
<td>--</td>
</tr>
</tbody>
</table>

*148 cases, \( r_{.05} = .161 \)

** 52 cases, \( r_{.05} = .273 \)

*aSignificant at the 0.05 level
TABLE 33
MEAN PERCENT OF NEGATIVE, NEUTRAL, AND
POSITIVE RESPONSES AT AFFECTIVE LEVELS
FOR PERSONAL PREFERENCE TEST*

<table>
<thead>
<tr>
<th>Level</th>
<th>Negative</th>
<th>Neutral</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>1.3**</td>
<td>35.7</td>
<td>71.5</td>
</tr>
<tr>
<td>(9 items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td>11.8</td>
<td>35.2</td>
<td>59.3</td>
</tr>
<tr>
<td>(11 items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3</td>
<td>6.3</td>
<td>35.0</td>
<td>65.8</td>
</tr>
<tr>
<td>(13 items)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4</td>
<td>0.0</td>
<td>62.0</td>
<td>36.5</td>
</tr>
<tr>
<td>(2 items)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Not all items had negative, neutral, and positive responses

**Mean Percent
Consequently Hypothesis 3 for the Affective Domain must be rejected.

Summary

The results of correlations between the various levels of the cognitive instruments (Tables 29 and 30, pages 124 and 125) and the decrease in percent correct response from lower to higher levels (Table 31, page 127) indicate that these instruments do indeed discriminate at the various levels of the Cognitive Domain. However, the correlations of the levels of the Personal Preference Test (Table 32, page 129) and the small decrease in positive responses from lower to higher affective levels (Table 33, page 130) suggest that although levels may be present, Tests 2C and 9D are not able to discriminate among the levels of the Affective Domain. Therefore, Hypothesis 3 may be accepted for the cognitive instrument but must be rejected for the affective instrument.

Hypothesis 4. Students who have worked through activity units specially designed to teach the higher levels of the Cognitive Domain will score significantly higher on the cognitive instruments than students who have worked the regularly assigned activity units.
It was demonstrated in the analysis of Hypothesis 1 that neither Pretest A nor Post-test B had any influence on cognitive post-test performance; therefore all student groups were used in evaluating this hypothesis. In considering this hypothesis the experimental group (student groups S3 and S4) was compared with the control group (student groups S1, S2, and S5) in two separate ways. The experimental group was analyzed first in its entirety, including any participant who had taken one or more of the seven specially designed laboratory units; the experimental group was then divided into two groups: 1) those participants who had performed less than half (1-3) of the activities and 2) those who had performed more than half (4-7) of the special activities.

The grouped cognitive subtests—Knowledge-Comprehension (K-C), Application-Analysis (Ap-An), Synthesis-Evaluation (S-E), Knowledge-Comprehension-Application (K-C-Ap), Analysis-Synthesis-Evaluation (An-S-E)—and the review subtest and total score were considered. In the case of Pretest A which only contained items at the lower three levels—Knowledge, Comprehension, and Application—only the appropriate subtests were used; review items were not included on Pretests A and B or on Post-test 4B.

The means and standard deviations for the performance of the control and experimental groups on Pretest A are
given in Table 34 on page 134. The F-ratio for the Knowledge-Comprehension level indicates that there is a significant difference between the two groups at the lowest cognitive levels; the other scores are not significantly different. When the performance on Pretest A is re-examined with the experimental group split (Table 35, page 135), none of the subtest scores are significantly different at the .05 level. Tables 36 (page 136) and 37 (page 137) show the subtest scores of the control and experimental groups on Pretest B. None of the F-ratios are significant at the .05 level.

These two pretests indicate that in terms of performance at the higher levels of the Cognitive Domain, the control and experimental groups were not significantly different at the beginning of the study.

When the data from Post-tests 4B (Tables 38 and 39, pages 138 and 139) and 6B (Tables 40 and 41, pages 140 and 141) are examined, there are no significant differences at the .05 level between the scores of the control and experimental groups on these two tests. These tests were given during the fifth and seventh weeks of the quarter respectively. It is suggested that the effects of the special laboratory activities begin to manifest themselves in student performance on the cognitive tests only after several of the activities had been performed; this seems
TABLE 34
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR
CONTROL AND EXPERIMENTAL GROUPS ON
PRETEST A

<table>
<thead>
<tr>
<th></th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td><strong>M</strong></td>
<td><strong>SD</strong></td>
<td><strong>M</strong></td>
</tr>
<tr>
<td>27 cases</td>
<td>8.370</td>
<td>2.648</td>
<td>13.889</td>
</tr>
<tr>
<td></td>
<td>13.889</td>
<td>3.886</td>
<td>3.886</td>
</tr>
<tr>
<td><strong>1-7 Activities</strong></td>
<td><strong>M</strong></td>
<td><strong>SD</strong></td>
<td><strong>M</strong></td>
</tr>
<tr>
<td>38 cases</td>
<td>9.711</td>
<td>2.609</td>
<td>15.658</td>
</tr>
<tr>
<td><strong>F-Ratio</strong></td>
<td><strong>(1,63; F</strong></td>
<td><strong>0.05 = 3.99)</strong></td>
<td><strong>4.114</strong></td>
</tr>
<tr>
<td></td>
<td><strong>F</strong></td>
<td><strong>.05</strong></td>
<td><strong>4.114</strong></td>
</tr>
<tr>
<td></td>
<td><strong>2.857</strong></td>
<td><strong>2.857</strong></td>
<td><strong>2.857</strong></td>
</tr>
</tbody>
</table>

\(^a\) Significant at the 0.05 level
TABLE 35
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR
CONTROL AND SPLIT EXPERIMENTAL GROUPS ON
PRETEST A

<table>
<thead>
<tr>
<th></th>
<th>K-C</th>
<th>K-C-Ap</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td>M</td>
<td>8.370</td>
<td>13.889</td>
</tr>
<tr>
<td>27 cases</td>
<td>SD</td>
<td>2.648</td>
<td>3.886</td>
</tr>
<tr>
<td><strong>1-3 Activities</strong></td>
<td>M</td>
<td>9.308</td>
<td>15.077</td>
</tr>
<tr>
<td>13 cases</td>
<td>SD</td>
<td>2.394</td>
<td>3.427</td>
</tr>
<tr>
<td><strong>4-7 Activities</strong></td>
<td>M</td>
<td>9.920</td>
<td>15.960</td>
</tr>
<tr>
<td>25 cases</td>
<td>SD</td>
<td>2.737</td>
<td>4.783</td>
</tr>
<tr>
<td><strong>F-Ratio (2,62; F_{0.05} = 3.15)</strong></td>
<td>2.270</td>
<td>1.605</td>
<td>1.605</td>
</tr>
</tbody>
</table>

^ Significant at the 0.05 level
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>M</td>
<td>5.305</td>
<td>5.427</td>
<td>2.293</td>
<td>8.305</td>
<td>4.720</td>
<td>13.024</td>
</tr>
<tr>
<td>SD</td>
<td>1.910</td>
<td>2.172</td>
<td>1.427</td>
<td>2.888</td>
<td>2.332</td>
<td>4.532</td>
</tr>
<tr>
<td>1-7 Activities</td>
<td>M</td>
<td>5.758</td>
<td>5.970</td>
<td>2.485</td>
<td>9.091</td>
<td>5.121</td>
</tr>
<tr>
<td>33 cases</td>
<td></td>
<td>1.953</td>
<td>2.243</td>
<td>1.253</td>
<td>2.578</td>
<td>2.342</td>
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<td></td>
<td></td>
<td></td>
<td>4.560</td>
</tr>
<tr>
<td>F-Ratio (1,113; F.05 = 3.93)</td>
<td>1.305</td>
<td>1.443</td>
<td>0.456</td>
<td>1.850</td>
<td>0.696</td>
<td>1.610</td>
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</table>

\(^a\)Significant at the 0.05 level
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>5.305</td>
<td>5.427</td>
<td>2.293</td>
<td>8.305</td>
<td>4.720</td>
<td>13.024</td>
</tr>
<tr>
<td>SD</td>
<td>1.910</td>
<td>2.172</td>
<td>1.427</td>
<td>2.888</td>
<td>2.332</td>
<td>4.532</td>
</tr>
<tr>
<td>1-3 Activities</td>
<td>M</td>
<td>5.625</td>
<td>6.000</td>
<td>2.813</td>
<td>9.188</td>
<td>5.250</td>
</tr>
<tr>
<td>16 cases</td>
<td>SD</td>
<td>2.029</td>
<td>1.826</td>
<td>1.328</td>
<td>2.588</td>
<td>2.145</td>
</tr>
<tr>
<td>4-7 Activities</td>
<td>M</td>
<td>5.882</td>
<td>5.941</td>
<td>2.176</td>
<td>9.000</td>
<td>5.000</td>
</tr>
<tr>
<td>17 cases</td>
<td>SD</td>
<td>1.933</td>
<td>2.633</td>
<td>1.131</td>
<td>2.646</td>
<td>2.574</td>
</tr>
<tr>
<td>F-Ratio (2,112; F₀.05 = 3.08)</td>
<td>0.721</td>
<td>0.718</td>
<td>1.111</td>
<td>0.935</td>
<td>0.392</td>
<td>0.836</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level*
### TABLE 38
MEANS, STANDARD DEVIATIONS, AND F-RATIOS
FOR CONTROL AND EXPERIMENTAL GROUPS ON
POST-TEST 4B

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>33 cases</td>
<td>M</td>
<td>7.424</td>
<td>8.364</td>
<td>4.455</td>
<td>10.788</td>
<td>9.455</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.165</td>
<td>2.547</td>
<td>1.889</td>
<td>2.945</td>
<td>3.474</td>
</tr>
<tr>
<td><strong>1-7 Activities</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48 cases</td>
<td>M</td>
<td>8.042</td>
<td>9.188</td>
<td>4.750</td>
<td>11.396</td>
<td>10.583</td>
</tr>
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<td></td>
<td>SD</td>
<td>1.557</td>
<td>2.498</td>
<td>1.682</td>
<td>2.386</td>
<td>3.093</td>
</tr>
<tr>
<td><strong>F-Ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1.79; F&lt;sub&gt;.05&lt;/sub&gt; = 3.96)</td>
<td>0.139</td>
<td>0.152</td>
<td>0.462</td>
<td>0.309</td>
<td>0.129</td>
<td>0.163</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level*
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>2.165</td>
<td>2.547</td>
<td>1.889</td>
<td>2.945</td>
<td>3.474</td>
<td>5.990</td>
</tr>
<tr>
<td><strong>1-3 Activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.286</td>
<td>2.203</td>
<td>1.136</td>
<td>1.779</td>
<td>2.587</td>
<td>3.833</td>
</tr>
<tr>
<td><strong>4-7 Activities</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>1.625</td>
<td>2.605</td>
<td>1.779</td>
<td>2.556</td>
<td>3.233</td>
<td>5.372</td>
</tr>
<tr>
<td><strong>F-Ratio</strong> (2,78; F&lt;sub&gt;.05&lt;/sub&gt; = 3.11)</td>
<td>1.461</td>
<td>1.069</td>
<td>1.280</td>
<td>0.565</td>
<td>1.477</td>
<td>1.174</td>
</tr>
</tbody>
</table>

<sup>a</sup>Significant at the 0.05 level
TABLE 40
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR
CONTROL AND EXPERIMENTAL GROUPS
ON POST-TEST 6B

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td>M</td>
<td>6.182</td>
<td>9.909</td>
<td>10.192</td>
<td>5.636</td>
<td>14.545</td>
<td>11.182</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>2.174</td>
<td>1.269</td>
<td>2.922</td>
<td>2.321</td>
<td>2.540</td>
<td>3.775</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.950</td>
<td>1.454</td>
<td>2.852</td>
<td>2.492</td>
<td>2.813</td>
<td>3.619</td>
</tr>
<tr>
<td>F-Ratio (1,54; F.05 = 4.02)</td>
<td>1.575</td>
<td>0.478</td>
<td>0.108</td>
<td>0.253</td>
<td>0.115</td>
<td>0.335</td>
<td>0.042</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level*
### TABLE 41

MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR CONTROL AND SPLIT EXPERIMENTAL GROUPS ON POST-TEST 6B

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD 2.174</td>
<td>1.269</td>
<td>2.922</td>
<td>2.321</td>
<td>2.540</td>
<td>3.775</td>
<td>5.725</td>
</tr>
<tr>
<td>1-3 Activities 3 cases</td>
<td>M 8.000</td>
<td>9.000</td>
<td>10.000</td>
<td>7.000</td>
<td>13.000</td>
<td>13.000</td>
<td>26.000</td>
</tr>
<tr>
<td></td>
<td>SD 1.000</td>
<td>2.646</td>
<td>3.464</td>
<td>2.646</td>
<td>5.568</td>
<td>3.606</td>
<td>8.718</td>
</tr>
<tr>
<td></td>
<td>SD 1.995</td>
<td>1.346</td>
<td>2.850</td>
<td>2.500</td>
<td>2.540</td>
<td>3.656</td>
<td>5.916</td>
</tr>
<tr>
<td>F-Ratio (2,53;F.05 = 3.17)</td>
<td>1.281</td>
<td>0.595</td>
<td>0.091</td>
<td>0.419</td>
<td>0.431</td>
<td>0.349</td>
<td>0.021</td>
</tr>
</tbody>
</table>

*aSignificant at the 0.05 level*
especially likely in light of the difference between the control and experimental groups on Post-test 8B and reported below.

The data collected on the performance of the control and experimental groups on Post-test 8B indicate a significant difference between the two groups on several subtests; the data are shown in Tables 42 - 44 on pages 143, 144, and 145. Table 42 shows that the control and experimental groups were significantly different at the .05 level on the Application-Analysis and Analysis-Synthesis-Evaluation subtests; thus the experimental group performed significantly better on these higher cognitive levels. It should be pointed out that both the Review and total scores, while not significant at the .05 level, approach the .10 level of significance.

The difference between the control and experimental group becomes more obvious when the latter is split into those students who have performed less than half of the special activities (1-3 activities) and those who have performed more than half (4-7 activities). These data are shown in Table 43. From this table it can be seen that the students who had done less than half of the special activities scored lower than the control group on several of the subtests, Review, Application-Analysis, and Knowledge-Comprehension-Application; however since
<table>
<thead>
<tr>
<th>No Activity</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>9.786</td>
<td>9.000</td>
<td>11.286</td>
<td>5.429</td>
<td>15.179</td>
<td>10.536</td>
<td>25.714</td>
</tr>
<tr>
<td>SD</td>
<td>2.515</td>
<td>1.764</td>
<td>2.580</td>
<td>1.834</td>
<td>2.450</td>
<td>2.835</td>
<td>4.569</td>
</tr>
<tr>
<td>1-7 Activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>10.725</td>
<td>9.200</td>
<td>12.375</td>
<td>5.950</td>
<td>15.475</td>
<td>12.050</td>
<td>27.525</td>
</tr>
<tr>
<td>SD</td>
<td>2.320</td>
<td>1.436</td>
<td>1.877</td>
<td>1.907</td>
<td>2.088</td>
<td>2.449</td>
<td>4.076</td>
</tr>
<tr>
<td>F-Ratio (1,66;F,05=3.99)</td>
<td>2.519</td>
<td>0.264</td>
<td>4.068a</td>
<td>1.270</td>
<td>0.288</td>
<td>5.529a</td>
<td>2.941</td>
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</table>

aSignificant at the 0.05 level


<table>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 cases</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.515</td>
<td>1.764</td>
<td>2.580</td>
<td>1.834</td>
<td>2.450</td>
<td>2.835</td>
<td>4.569</td>
<td></td>
</tr>
<tr>
<td><strong>1-3 Activities</strong></td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.204</td>
<td>2.188</td>
<td>0.991</td>
<td>2.816</td>
<td>2.774</td>
<td>2.915</td>
<td>5.330</td>
<td></td>
</tr>
<tr>
<td><strong>4-7 Activities</strong></td>
<td>M</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.172</td>
<td>1.230</td>
<td>1.867</td>
<td>1.666</td>
<td>1.874</td>
<td>2.328</td>
<td>3.689</td>
<td></td>
</tr>
<tr>
<td><strong>F-Ratio (2,65;F.05 = 3.14)</strong></td>
<td>4.102</td>
<td>0.135</td>
<td>4.638</td>
<td>0.682</td>
<td>0.868</td>
<td>3.230</td>
<td>2.229</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level*
### TABLE 44

**MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR CONTROL GROUP AND EXPERIMENTAL GROUP WITH 4 - 7 ACTIVITIES ON POST-TEST 8B**

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>9.786</td>
<td>9.000</td>
<td>11.286</td>
<td>5.429</td>
<td>15.179</td>
<td>10.536</td>
<td>25.714</td>
</tr>
<tr>
<td>SD</td>
<td>2.515</td>
<td>1.764</td>
<td>2.580</td>
<td>1.834</td>
<td>2.450</td>
<td>2.835</td>
<td>4.569</td>
</tr>
<tr>
<td><strong>4 - 7 Activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>11.156</td>
<td>9.188</td>
<td>12.750</td>
<td>6.000</td>
<td>15.688</td>
<td>12.250</td>
<td>27.938</td>
</tr>
<tr>
<td>SD</td>
<td>2.172</td>
<td>1.230</td>
<td>1.867</td>
<td>1.666</td>
<td>1.874</td>
<td>2.328</td>
<td>3.689</td>
</tr>
<tr>
<td><strong>F-Ratio (1,58; F .05 = 4.01)</strong></td>
<td>5.133a</td>
<td>0.233</td>
<td>6.455a</td>
<td>1.599</td>
<td>0.828</td>
<td>6.612a</td>
<td>4.344a</td>
</tr>
</tbody>
</table>

*aSignificant at the 0.05 level*
there are only eight students in this group who took 8B, these data must be considered carefully.

When all three groups—No Activity, 1-3 Activities, and 4-7 Activities—are considered together, there are significant differences at the .05 level on three of the subtests; these are Review, Application-Analysis, and Analysis-Synthesis-Evaluation. The first two of these subtests approach the .01 level of significance ($F_{.01} = 4.95$).

When the students who performed less than half of the special activities are eliminated from the analysis, the results shown in Table 44 (page 145) are obtained. In addition to significant differences on subtests Review, Application-Analysis, and Analysis-Synthesis-Evaluation, a significant difference is found between the two groups on total score. Two of the subtests, Application-Analysis and Analysis-Synthesis-Evaluation, approach the .01 level of significance.

The results obtained from student performances on Post-test 8B indicate that the experimental group differed from the control group significantly on several subtests. In all three tables the experimental group scored significantly higher than the control group on the Application-Analysis and Analysis-Synthesis-Evaluation subtests. This
indicates that working the specially designed activities may indeed make a difference in student performance at the higher levels of the Cognitive Domain, and Hypothesis 4 may be accepted.

As a final point of comparison, data were collected on the performance of the students in the control and experimental groups on regular course work. The data consisted of the scores on the two midterm examinations given during the quarter, the score on the final examination, and the total score for the quarter; this quarter score is a combination of the two midterms, the final exam, and a score given by each teacher for class participation and assignments. The examinations consisted of objective questions which fall mostly at the lower levels of the Cognitive Domain. All scores are standardized.

When the control and experimental groups are compared on the course data (see Table 45, page 148), no significance is found at the .05 level. However the scores of the experimental group are consistently higher than the control group, and F-ratio of Midterm I approaches the .05 level. When the experimental group is split into those who had done less than half and more than half of the activities (Table 46, page 149), all four standardized course scores of the experimental group are significantly higher at the .05 level, and the score on Midterm II and the Quarter
**TABLE 45**

MEANS, STANDARD DEVIATIONS, AND F-RATIOS

FOR CONTROL AND EXPERIMENTAL GROUPS

ON STANDARDIZED COURSE DATA

<table>
<thead>
<tr>
<th>Activity</th>
<th>M</th>
<th>Midterm I</th>
<th>Midterm II</th>
<th>Final Exam</th>
<th>Quarter Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Activity</td>
<td>M</td>
<td>-0.050</td>
<td>-0.032</td>
<td>-0.023</td>
<td>-0.029</td>
</tr>
<tr>
<td>109 cases</td>
<td>SD</td>
<td>1.099</td>
<td>0.901</td>
<td>0.936</td>
<td>0.983</td>
</tr>
<tr>
<td>1-7 Activities</td>
<td>M</td>
<td>0.231</td>
<td>0.184</td>
<td>0.207</td>
<td>0.214</td>
</tr>
<tr>
<td>71 cases</td>
<td>SD</td>
<td>0.815</td>
<td>1.089</td>
<td>1.012</td>
<td>0.968</td>
</tr>
</tbody>
</table>

F-Ratio (1,178; F.05=3.90)

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.416</td>
<td>2.083</td>
<td>2.425</td>
<td>2.679</td>
</tr>
</tbody>
</table>

*aSignificant at the 0.05 level*
<table>
<thead>
<tr>
<th>Activity Level</th>
<th>Midterm I</th>
<th>Midterm II</th>
<th>Final Exam</th>
<th>Quarter Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Activity</td>
<td>M: -0.050</td>
<td>-0.032</td>
<td>-0.023</td>
<td>-0.029</td>
</tr>
<tr>
<td></td>
<td>SD: 1.099</td>
<td>0.901</td>
<td>0.936</td>
<td>0.983</td>
</tr>
<tr>
<td>1-3 Activities</td>
<td>M: -0.019</td>
<td>-0.193</td>
<td>-0.126</td>
<td>-0.160</td>
</tr>
<tr>
<td></td>
<td>SD: 0.794</td>
<td>1.238</td>
<td>1.205</td>
<td>1.066</td>
</tr>
<tr>
<td>4-7 Activities</td>
<td>M: 0.403</td>
<td>0.444</td>
<td>0.437</td>
<td>0.473</td>
</tr>
<tr>
<td></td>
<td>SD: 0.792</td>
<td>0.900</td>
<td>0.789</td>
<td>0.810</td>
</tr>
<tr>
<td>F-Ratio</td>
<td>3.280&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.842&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.240&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.118&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Significant at the 0.05 level

<sup>b</sup>Significant at the 0.01 level
Score are significantly different at the .01 level. It should be pointed out that the experimental students who did less than half of the activities, scored lower than the control group on three of the four tests.

Table 47 (page 151) compares the control group with the students in the experimental group who took more than half of the activities (4-7 Activities). F-ratios on Midterm II, Final Exam, and Quarter Score show that the experimental group performed significantly better at the .01 level than the control group in these three areas. Midterm I is significantly different at the .05 level between the two groups; this difference approaches the .01 significance level.

Summary

To determine if there were any significant differences between the control and experimental groups on performance at the higher levels of the Cognitive Domain, F-ratios were obtained for student scores on grouped cognitive subtests for all pretests and post-tests. The results for Pretest A and Pretest B are shown in Tables 34 and 35 (pages 134 and 135) and Tables 36 and 37 (pages 136 and 137). The results of Pretest A show a significant difference in the lowest cognitive subtest (Knowledge-Comprehension), but when the experimental group is split
TABLE 47
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR CONTROL GROUP
AND EXPERIMENTAL GROUP WITH 4-7 ACTIVITIES
ON STANDARDIZED COURSE DATA

<table>
<thead>
<tr>
<th></th>
<th>Midterm I</th>
<th>Midterm II</th>
<th>Final Exam</th>
<th>Quarter Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Activity</td>
<td>M</td>
<td>-0.050</td>
<td>-0.032</td>
<td>-0.023</td>
</tr>
<tr>
<td>109 cases</td>
<td>SD</td>
<td>1.099</td>
<td>0.901</td>
<td>0.936</td>
</tr>
<tr>
<td>4-7 Activities</td>
<td>M</td>
<td>0.403</td>
<td>0.444</td>
<td>0.437</td>
</tr>
<tr>
<td>42 cases</td>
<td>SD</td>
<td>0.792</td>
<td>0.900</td>
<td>0.789</td>
</tr>
<tr>
<td>F-Ratio (1,149; F .05 = 3.91)</td>
<td>5.943a</td>
<td>8.459b</td>
<td>7.939b</td>
<td>8.688b</td>
</tr>
</tbody>
</table>

\[ a \text{ Significant at the 0.05 level} \]
\[ b \text{ Significant at the 0.01 level} \]
into those students who had taken less than half of the seven specially designed activities and those who had taken more than half, this significance disappears. Pre-test B shows no significant differences between the control and experimental groups in either case.

Thus, the data indicate that the control and experimental groups were not significantly different in their performance at the higher levels of the Cognitive Domain at the beginning of this study.

Tables 38 and 39 (pages 138 and 139) show the results of Post-test 4B; Tables 40 and 41 (pages 140 and 141) pertain to Post-test 6B. The data collected from these two tests indicate that the experimental and control groups did not differ significantly on their performance at the higher cognitive levels.

However, when the scores from Post-test 8B (Tables 42-44, pages 143, 144 and 145) are examined, the control and experimental groups are seen to differ significantly in two of the subtests—Application-Analysis and Analysis-Synthesis-Evaluation—with the experimental group scoring higher. Significances on other subtests—Review and Total—are found when the experimental students having completed more than half of the seven special activities are compared with the control group. It is suggested that significances between the control and experimental
groups are found only on Post-test 8B because several of the special activities must have been performed before the students were able to develop higher level cognitive thinking abilities. This suggestion is further strengthened by the fact that on Post-test 8B those students who had performed less than half of the activities (see Table 43) scored consistently lower than those students who had taken more than half of the activities; the only exception to this is the lowest cognitive subtest, Knowledge-Comprehension. These same students frequently scored lower than the control group on the subtests.

A final comparison is made between the control group and the experimental group using test data given as a regular part of the course; data from the two midterm examinations, the final examination, and the final quarter score are used. The results are given in Tables 45-47 on pages 148, 149 and 151. The midterms and final exam contained objective questions at the lower cognitive level.

When the two groups are compared in Table 42, no significant difference is shown, although the experimental group scored consistently higher and the F-ratios are relatively large. When the experimental group is split (Table 44), the F-ratios are significant at the .05 level for Midterm I and Final Exam and significant at the .01
level for Midterm II and Quarter Score. These data also indicate that experimental students who had taken less than half of the special activities consistently scored lower than the other experimental students and frequently lower than the control group; this further supports the suggestion that a minimum number of activities must be performed in order to develop higher cognitive skills.

The control group is compared with only those experimental students who performed more than half of the special activities in Table 47. The experimental group scored significantly higher at the .05 level on Midterm I and at the .01 level on Midterm II, Final Exam, and Quarter Score.

In light of the superior performance of the experimental students on Post-test 8B at the higher cognitive subtests, Hypothesis 4 may be accepted. The performance of the students on the course data is not considered in support of this hypothesis since the items on these tests are not at the higher cognitive levels.

Hypothesis 5. Students who have worked through the specially designed activity units will show a significantly positive change in attitudes toward science as assessed by the
affective instruments than those students who work through the regular activity units.

The affective instrument was rejected in Hypothesis 3 as being unable to discriminate between students performing at various levels of the Affective Domain (see Tables 32 and 33, pages 129 and 130). This can be further substantiated by examining the data on Tables 48 (page 156) and 49 (page 157). The comparison of control and experimental group performances on Test 2C (Table 48) shows that there are no significant differences at the .05 level between these two groups; Level 4 subtest scores do approach the level of significance. Table 49 shows the subtest results for Test 9D. No significant differences are indicated except in the All-Level subtest; it should be pointed out that the All-Level subtest contained only four questions. The control and experimental groups had mixed subtest scores on Tests 2C and 9D; the control group scored higher than the experimental group on several subtests.

In examining Tables 48 and 49 the large discrepancy in the number of cases between the two tests should be noted. For the control group eighty-three persons took Test 2C while only twenty-nine took Test 9D; in the experimental group sixty-five persons took Test 2C while
TABLE 48
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR
CONTROL AND EXPERIMENTAL GROUPS ON
PERSONAL PREFERENCE TEST 2C

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>22.494</td>
<td>22.133</td>
<td>27.602</td>
<td>3.663</td>
<td>7.229</td>
<td>83.121</td>
</tr>
<tr>
<td>83 cases</td>
<td>SD</td>
<td>0.755</td>
<td>0.658</td>
<td>1.473</td>
<td>0.476</td>
<td>2.115</td>
</tr>
<tr>
<td>1 - 7 Activities</td>
<td>M</td>
<td>22.585</td>
<td>22.062</td>
<td>27.400</td>
<td>3.815</td>
<td>7.400</td>
</tr>
<tr>
<td>65 cases</td>
<td>SD</td>
<td>0.682</td>
<td>0.609</td>
<td>1.445</td>
<td>0.497</td>
<td>1.910</td>
</tr>
<tr>
<td>F-Ratio (1,146; F .05 = 3.91)</td>
<td>0.571</td>
<td>0.435</td>
<td>0.700</td>
<td>3.615</td>
<td>0.259</td>
<td>0.088</td>
</tr>
</tbody>
</table>

*aSignificant at the 0.05 level*
TABLE 49
MEANS, STANDARD DEVIATIONS, AND F-RATIOS FOR
CONTROL AND EXPERIMENTAL GROUPS ON
PERSONAL PREFERENCE TEST 9D

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Activity</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22.586</td>
<td>22.138</td>
<td>27.483</td>
<td>3.655</td>
<td>7.103</td>
<td>82.966</td>
</tr>
<tr>
<td>29 cases</td>
<td>0.983</td>
<td>0.441</td>
<td>1.479</td>
<td>0.484</td>
<td>2.041</td>
<td>3.168</td>
</tr>
<tr>
<td>1 - 7 Activities M</td>
<td>22.696</td>
<td>22.087</td>
<td>27.261</td>
<td>3.652</td>
<td>8.348</td>
<td>84.043</td>
</tr>
<tr>
<td>23 cases</td>
<td>0.559</td>
<td>0.417</td>
<td>1.573</td>
<td>0.487</td>
<td>2.058</td>
<td>2.225</td>
</tr>
<tr>
<td>F-Ratio (1,50; F .05 = 4.03)</td>
<td>0.226</td>
<td>0.180</td>
<td>0.273</td>
<td>0.000</td>
<td>4.731&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.911</td>
</tr>
</tbody>
</table>

<sup>a</sup>Significant at the 0.05 level
Test 9D was taken by only twenty-three students. Consequently the students taking Test 9D did not represent the same sample as those who took Test 2C.

To determine if there were any significant changes in the Affective Domain from Test 2C to Test 9D, those control and experimental students who had not taken both tests were eliminated, and a correlated t-test was run on those individuals who had taken both tests. The results are shown in Table 50 on page 159. The data indicate that at the .05 level there is no significant change in scores on the subtests from Test 2C to Test 9D.

Based on the above sets of data as well as that used in Hypothesis 3, Hypothesis 5 cannot be adequately judged because the affective instrument was unable to discriminate among the various levels of the Affective Domain. Consequently Hypothesis 5 must be dismissed.

Summary

The rejection of Hypothesis 5 places the usefulness of the affective instrument in discriminating between levels of this domain in serious doubt. Tables 48 and 49 (pages 156 and 157) show that only on the All-Level subtest of Test 9D is there any significant difference between the control and experimental groups; the subtest scores are mixed with the control group scoring higher than the
### Table 50

**Correlated T-Ratios for All Students**

*Taking Both Test 2C and 9D*

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-ratio (50 cases, t .05 = 2.03)</td>
<td>-0.22</td>
<td>0.0</td>
<td>0.53</td>
<td>1.52</td>
<td>-0.70</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

*Significant at the 0.05 level*
experimental group in several cases. These tables also indicate that the number of persons taking Test 9D was a great deal smaller than the sample taking Test 2C; this reduction in number of cases throws some doubt on the results obtained. Table 50 (page 159) gives a correlated t-ratio for all students who took both affective tests; none of the subtest ratios are significant at the .05 level, indicating that there are no significant changes in scores from Test 2C to Test 9D.

Due to the questionable ability of the affective instrument to discriminate at various levels and to the above data, Hypothesis 5 cannot be adequately judged and must be dismissed.

Hypothesis 6. The multimedia approach in Biology 100 at The Ohio State University is able to develop the higher levels of the two domains in a significant number of students as measured by the instruments used in this study.

Cognitive Domain

In exploring this hypothesis in the Cognitive Domain only student group S5 was used, since only this control group took Pretest B and the B-Post-test series and participated in the regular Biology 100 program (A-Activity Unit series). During both quarters of this study, group S5
was taught by the same graduate associate. Of the thirty items on Pretest B, items 1-10 were also found on Post-test 4B; items 11-20 were also on Post-test 6B; and items 21-30 were on Post-test 8B. To determine if the control group gained significantly between the pretest and the post-tests, post-test scores on the same items which appeared on the pretest were compared with the pretest scores, and t-ratios of means were obtained. The results are shown in Table 51 on page 162.

Not all the pretest items were at the higher cognitive levels. Of the pretest items used on Post-test 4B and analyzed for this hypothesis, two items were at the Application level, three at the Analysis level, and one each at the Synthesis and Evaluation levels. These cognitive levels were grouped as in the previous hypotheses with the Application-Analysis (Ap-An) subtest containing five items, the Synthesis-Evaluation (S-E) subtest having two items, and the Analysis-Synthesis-Evaluation (An-S-E) subtest containing five items.

An examination of Table 51 shows that on all the higher level subtests of Post-test 4B the control group made gains which were significant at the .01 level. This indicates that between the pretest and Post-test 4B the control group gained the ability to answer questions at
**TABLE 51**

**t-RATIOS OF MEANS OF SUBTEST SCORES FOR IDENTICAL ITEMS ON PRETEST B AND B-POST-TESTS FOR CONTROL GROUP**

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Post-test</th>
<th>$\Sigma D$</th>
<th>$\Sigma D^2$</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4B</strong>: Ap-An</td>
<td>26</td>
<td>89</td>
<td>-63</td>
<td>170</td>
<td>$8.75^b$</td>
</tr>
<tr>
<td></td>
<td>S-E</td>
<td>24</td>
<td>39</td>
<td>-15</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>An-S-E</td>
<td>41</td>
<td>96</td>
<td>-55</td>
<td>163</td>
</tr>
<tr>
<td><strong>6B</strong>: Ap-An</td>
<td>61</td>
<td>76</td>
<td>-15</td>
<td>39</td>
<td>2.99$^b$</td>
</tr>
<tr>
<td></td>
<td>S-E</td>
<td>19</td>
<td>29</td>
<td>-10</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>An-S-E</td>
<td>58</td>
<td>75</td>
<td>-17</td>
<td>57</td>
</tr>
<tr>
<td><strong>8B</strong>: Ap-An</td>
<td>73</td>
<td>92</td>
<td>-19</td>
<td>37</td>
<td>3.80$^b$</td>
</tr>
<tr>
<td></td>
<td>S-E</td>
<td>33</td>
<td>35</td>
<td>-2</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>An-S-E</td>
<td>51</td>
<td>56</td>
<td>-5</td>
<td>19</td>
</tr>
</tbody>
</table>

*33 cases, $t_{.05} = 2.04$

**22 cases, $t_{.05} = 2.08$

***28 cases, $t_{.05} = 2.05$

$^a$Significant at the 0.05 level

$^b$Significant at the 0.01 level
the higher cognitive levels; this gain is probably closely linked to gains in content material.

In the analysis of gains between Pretest B and Post-test 6B, seven items were used; two items were at the Application level, three were at the Analysis level, and one each was at the Synthesis and Evaluation levels. When these items were combined into subtests, there were five items on the Application-Analysis (Ap-An) subtest, two items on the Synthesis-Evaluation (S-E) subtest, and five items on the Analysis-Synthesis-Evaluation (An-S-E) subtest.

The data in Table 51 show that for Post-test 6B the control group made significant score gains on all three subtests; the gains on the Application-Analysis and Synthesis-Evaluation subtests were at the .01 level. These results indicate that the ability of the control group to answer higher level cognitive questions was significantly increased between Pretest B and Post-test 6B. Some of this gain may be attributed to gains in the content area.

In analyzing gains in the control group between pre-test performance and Post-test 8B, six pretest items were used; three of these items were at the Application level, and one item each was at the Analysis, Synthesis, and Evaluation levels. When the cognitive levels were grouped
into subtests, the Application-Analysis (Ap-An) subtest had four items, the Synthesis-Evaluation (S-E) subtest had two items, and the Analysis-Synthesis-Evaluation (An-S-E) subtest had three items.

By examining Table 51 it can be seen that for Post-test 8B only the Application-Analysis subtest shows significant gains between Pretest B and Post-test 8B for the control group; this gain is significant at the .01 level. The Synthesis-Evaluation and Analysis-Synthesis-Evaluation subtests show only slight gains in subtest scores. The gains that were made can probably be partially contributed to an increase in content material.

The gain in scores between Pretest B and all three post-tests was further examined in terms of shifts in individual students. Sign test comparisons were made by examining the number of students who fell above the mean (positive scores) and below the mean (negative scores) on the pretest and the number who fell above the mean (positive scores) and below the mean (negative scores) on each post-test. The shifts in subtest scores—positive to positive, positive to negative, negative to positive, and negative to negative—were examined for each post-test using a chi square test.

The shifts in subtest scores between Pretest B and
Post-test 4B are shown in Table 52 on page 166. Table 52 shows that there are no significant shifts in student scores on the Application-Analysis subtest. On the Synthesis-Evaluation subtest there is a significant change at the .05 level; this significance is due almost totally to the failure of students with negative scores on the pretest to improve their scores on the post-test so that they fall above the mean. However this trend is reversed on the Analysis-Synthesis-Evaluation subtest. This subtest also shows a significance at the .05 level, but in this case the shift in scores occurs mostly among the students who had negative pretest scores but had positive post-test scores. There is also a small shift of scores from positive pretest scores to negative post-test scores.

Data for performance of the control group on Post-test 6B were analyzed in the same manner as that for Post-test 4B. The chi square tests performed on these data is shown in Table 53 on page 167. An examination of Table 53 shows that significant shifts in scores occurred on all three subtests. The score shift between Pretest B and Post-test 6B on the Application-Analysis subtest is significant at the .05 level, but the significance is due almost entirely to the large number of students who had negative scores on both tests and the small number who moved from negative pretest scores to positive post-test scores. The
TABLE 52

CHI SQUARE VALUES ON DISTRIBUTION OF SUBTEST SCORES FOR IDENTICAL ITEMS ON PRETEST B AND POST-TEST 4B FOR CONTROL GROUP*

<table>
<thead>
<tr>
<th>Quadrant**</th>
<th>Subtest</th>
<th>Post-Pretest Frequency</th>
<th>Observed Frequency</th>
<th>Expected Frequency</th>
<th>((O - E)^2/E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap-An</td>
<td>+ +</td>
<td>11</td>
<td>8.25</td>
<td>.9167</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ -</td>
<td>8</td>
<td>8.25</td>
<td>.0076</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- +</td>
<td>7</td>
<td>8.25</td>
<td>.1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- -</td>
<td>7</td>
<td>8.25</td>
<td>.1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33</td>
<td>33.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-E</td>
<td>+ +</td>
<td>10</td>
<td>8.25</td>
<td>.3712</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ -</td>
<td>10</td>
<td>8.25</td>
<td>.3712</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- +</td>
<td>2</td>
<td>8.25</td>
<td>4.3712</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- -</td>
<td>11</td>
<td>8.25</td>
<td>.9167</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33</td>
<td>33.00</td>
<td>(\chi^2 = 6.0303^a)</td>
<td></td>
</tr>
<tr>
<td>An-S-E</td>
<td>+ +</td>
<td>7</td>
<td>8.25</td>
<td>.1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ -</td>
<td>4</td>
<td>8.25</td>
<td>2.1894</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- +</td>
<td>14</td>
<td>8.25</td>
<td>4.0076</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- -</td>
<td>8</td>
<td>8.25</td>
<td>.0076</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>33</td>
<td>33.00</td>
<td>(\chi^2 = 6.3940^a)</td>
<td></td>
</tr>
</tbody>
</table>

* df = 1, \(\chi^2\) .05 = 3.84

** + = above the mean, - = below the mean

^aSignificant at the 0.05 level
TABLE 53
CHI SQUARE VALUES ON DISTRIBUTION OF SUBTEST
SCORES FOR IDENTICAL ITEMS ON PRETEST B
AND POST-TEST 6B FOR CONTROL GROUP*

<table>
<thead>
<tr>
<th>Quadrant**</th>
<th>Subtest</th>
<th>Post-Pretest Test</th>
<th>Observed Frequency</th>
<th>Expected Frequency</th>
<th>((O - E)^2 \div E)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ap-An</td>
<td>+</td>
<td>7</td>
<td>5.5</td>
<td>.4091</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>4</td>
<td>5.5</td>
<td>.4091</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>5.5</td>
<td>2.2273</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>9</td>
<td>5.5</td>
<td>2.2273</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(22)</td>
<td>(22.0)</td>
<td>(\chi^2 = 4.8728^a)</td>
</tr>
<tr>
<td></td>
<td>S-E</td>
<td>+</td>
<td>5</td>
<td>5.5</td>
<td>.0455</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>10</td>
<td>5.5</td>
<td>3.6818</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>5.5</td>
<td>2.2273</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>5</td>
<td>5.5</td>
<td>.0455</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(22)</td>
<td>(22.0)</td>
<td>(\chi^2 = 6.0001^a)</td>
</tr>
<tr>
<td></td>
<td>An-S-E</td>
<td>+</td>
<td>10</td>
<td>5.5</td>
<td>3.6818</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>3</td>
<td>5.5</td>
<td>1.1364</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>5.5</td>
<td>3.6818</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
<td>8</td>
<td>5.5</td>
<td>1.1364</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(22)</td>
<td>(22.0)</td>
<td>(\chi^2 = 9.6364^b)</td>
</tr>
</tbody>
</table>

* df = 1, \(\chi^2_{.05} = 3.84\)

** + = above the mean, - = below the mean

^aSignificant at the 0.05 level

^bSignificant at the 0.01 level
Synthesis-Evaluation subtest is significant at the .05 level; this significance is due to the large number of students who shifted from positive pretest scores to negative post-test scores and the small number of students who moved in the opposite direction. The Analysis-Synthesis-Evaluation subtest shows mixed results. Although the shifts in scores are significant at the .01 level, just as many students moved from positive or negative pretest scores to post-test scores that are positive as moved to post-test scores that are negative.

Data for student performance on Post-test 8B were analyzed in the same manner as for the other two post-tests. Table 54 on page 169 shows the data collected for this post-test. The data in this table indicates that there are no significant shifts in scores on the Application-Analysis subtest. On the Synthesis-Evaluation subtest the change in scores is significant at the .01 level; this is due almost entirely to the large number of students who had below-the-mean (negative) scores on both tests. Shifts in scores on the Analysis-Synthesis-Evaluation subtest are also significant at the .01 level; the major contributor to this chi square value is the small number of students who moved from negative pretest scores to positive post-test scores.

The data in Tables 52-54 indicate that for the control group those students who scored high at the higher cognitive
## TABLE 54

**CHI SQUARE VALUES ON DISTRIBUTION OF SUBTEST SCORES FOR IDENTICAL ITEMS ON PRETEST B AND POST-TEST 8B FOR CONTROL GROUP**

<table>
<thead>
<tr>
<th>Quadrant**</th>
<th>Subtest</th>
<th>Post-Pretest Test</th>
<th>Observed Frequency</th>
<th>Expected Frequency</th>
<th>( \frac{(O - E)^2}{E} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ap-An</td>
<td>+</td>
<td>+</td>
<td>10</td>
<td>7</td>
<td>1.2857</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>-</td>
<td>5</td>
<td>7</td>
<td>.5714</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>+</td>
<td>4</td>
<td>7</td>
<td>1.2857</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>9</td>
<td>7</td>
<td>.5714</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>28</td>
<td>( \chi^2 = \frac{3.7142}{3} )</td>
</tr>
<tr>
<td>S-E</td>
<td>+</td>
<td>+</td>
<td>6</td>
<td>7</td>
<td>.1429</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>-</td>
<td>3</td>
<td>7</td>
<td>2.2857</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>+</td>
<td>5</td>
<td>7</td>
<td>.5714</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>7</td>
<td>7.0000(^b)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>28</td>
<td>( \chi^2 = 10.0000(^b) )</td>
</tr>
<tr>
<td>An-S-E</td>
<td>+</td>
<td>+</td>
<td>10</td>
<td>7</td>
<td>1.2857</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>-</td>
<td>4</td>
<td>7</td>
<td>1.2857</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>+</td>
<td>1</td>
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<td>5.1429</td>
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<td>6</td>
<td>7</td>
<td>.1429</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td>28</td>
<td>( \chi^2 = 7.8572(^b) )</td>
</tr>
</tbody>
</table>

*df = 1

\( \chi^2 .05 = 3.84 \)

**+ = above the mean, - = below the mean

\(^a\)Significant at the 0.05 level

\(^b\)Significant at the 0.01 level
levels on the pretest also scored high at the same levels on the post-tests. Those who scored low on the higher cognitive levels on the pretest scored low on the post-tests. Very few shifts in scores from pretest to post-test were found. This suggests that the multimedia approach in Biology 100 is helping those students who do well on the pretest but is unable to affect a shift in the ranks of the other students on performance at the higher cognitive levels. However, the gain in scores from pretest to post-test was significant on all higher cognitive subtests of Post-tests 4B and 6B and on the Application-Analysis subtest for Post-test 8B. Consequently Hypothesis 6 is accepted for the Cognitive Domain.

Affective Domain

With the rejection of Hypothesis 3 the use of the Personal Preference Test in discriminating the various affective levels is doubtful. Table 55 on page 171 shows the mean scores for student groups S1, S2, and S5; these control groups took Tests 2C and 9D but performed the regular A-Activity Unit series at the Bio-Learning Center. These data show the close similarity between the scores on these two tests. Neither test consistently produced higher scores, and the maximum difference between subtest scores was less than two tenths of a point. The difference in
<table>
<thead>
<tr>
<th>Test</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>All-Level</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2C</td>
<td>22.494</td>
<td>22.133</td>
<td>27.602</td>
<td>3.663</td>
<td>7.229</td>
<td>83.121</td>
</tr>
<tr>
<td>Test 9D</td>
<td>22.586</td>
<td>22.138</td>
<td>27.483</td>
<td>3.655</td>
<td>7.103</td>
<td>82.966</td>
</tr>
<tr>
<td>(83 cases)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(29 cases)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
sample size between the two tests suggests that Test 9D no longer represented the same population as Test 2C.

Because of the inability of the affective instrument to discriminate between the levels of this domain and because of the data presented in Table 55, Hypothesis 6 cannot be tested for the Affective Domain.

**Summary**

This hypothesis examines the performance of the control group at the higher cognitive levels by obtaining t-ratios on gains on subtest scores between Pretest B and the various B-Post-tests (see Table 51, page 162). Except for two subtests on Post-test 8B all higher cognitive level subtests showed significant gains by the control group. Consequently Hypothesis 6 is accepted for the Cognitive Domain.

The pretest-post-test gains were also examined in terms of shifts in individual students from above-the-mean (positive) or below-the-mean (negative) pretest scores to above-the-mean (positive) or below-the-mean (negative) post-test scores (see Tables 52-54, pages 166, 167, and 169). Of the nine chi square tests performed in examining shifts in scores, seven were significant at either the .05 or .01 level. The Application-Analysis subtest on Post-tests 4B and 8B was not significant. The shifts in scores suggest
that the Biology 100 program is unable to effectively bring about a change in student rank from pretest performances to post-test performances.

The rejection of the affective test as being unable to discriminate levels of the Affective Domain (Hypothesis 3) makes the instrument not applicable for this hypothesis. The data in Table 54 (page 169) show that the control group performed similarly on both Tests 2C and 9D. Therefore Hypothesis 6 cannot be evaluated and must be dismissed for the Affective Domain.

**Summary of Analysis**

Three background variables—the effects of the cognitive pretests, the college class of each student, and the influence of the teacher—were examined as to their influence on post-test scores. For the first variable it is shown that neither Pretest A nor Pretest B affects student performance on any of the cognitive post-tests. The two remaining background variables—college class and teacher—show no significant correlation with either cognitive or affective subtests, except in a few isolated instances. Hypothesis 1 is therefore accepted.

When the influence of sex is examined, there are no significant correlations on cognitive post-tests, except on Review and Total Score subtests of Post-test 8B; in these
instances the females scored higher. On the affective post-test (Test 9D) the males scored significantly higher on Level 3 and Total Score subtests, and the males' score on Level 4 approaches the significant level. Consequently Hypothesis 2 is accepted for the Cognitive Domain but rejected for the Affective Domain.

Correlations of subtest scores on the cognitive instruments and a decrease in the number of correct responses from lower to higher cognitive levels show a significant hierarchical development indicating that these tests can discriminate student performance at the various cognitive levels. The subtests of the affective instrument show no such hierarchy on subtest correlations or percent of positive responses. Hypothesis 3 is therefore accepted for the Cognitive Domain and rejected for the Affective Domain.

No significant difference between the control and experimental groups is observed on the cognitive pretests at the higher levels of the Cognitive Domain. Comparing control and experimental groups on Post-tests 4B and 6B also shows no difference. On Post-test 8B students who had taken more than half of the special activities scored significantly higher than the control group on Review, Application-Analysis, Analysis-Synthesis-Evaluation, and Total Score subtests. In addition this same experimental
group scored significantly higher than the control group on the tests given as a regular part of the Biology 100 course --two midterm examinations, final examination, and total quarter score. Consequently Hypothesis 4 is accepted.

Since the affective instrument is not shown to be able to discriminate at various levels of the Affective Domain, a comparison of control and experimental groups in this domain cannot be undertaken. Hypothesis 5 cannot be tested.

An analysis of the performance of the control group on the cognitive tests shows that in a majority of cases the control post-test scores at the higher cognitive levels are significantly higher than pretest scores on the same items; however, only a few positive shifts are seen from the pre-test to the post-test. The affective instrument cannot be used in this hypothesis since it has been shown that this instrument does not discriminate student performance at the various affective levels. Hypothesis 6 is therefore accepted for the Cognitive Domain and dismissed for the Affective Domain.

The analysis of data can be summarized as follows:

Hypothesis 1 - Cognitive Domain - Accepted,
Affective Domain - Accepted,
Hypothesis 2 - Cognitive Domain - Accepted,
Affective Domain - Rejected,
Hypothesis 3 - Cognitive Domain - Accepted,
   Affective Domain - Rejected,
Hypothesis 4 - Cognitive Domain - Accepted,
Hypothesis 5 - Affective Domain - Cannot be tested,
Hypothesis 6 - Cognitive Domain - Accepted,
   Affective Domain - Cannot be tested.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The major problem of this study was the development of an effective scheme for evaluating the audio-tutorial science laboratory. Since the main objectives of many laboratories fall into the Cognitive and Affective Domains, sub-problems which were investigated include 1) The development of laboratory activities to specifically teach for the higher levels of the Cognitive and Affective Domains and 2) the construction of instruments to assess the various levels of these two domains.

The laboratory used in this investigation was the introductory biology laboratory (Biology 100) at The Ohio State University which is an innovative program using an audio-tutorial approach. The regular Biology 100 program consists of ten, one-week units of study (A-Activity Unit series) using an audio-tutorial approach; the control group in this study took the A-Activity Unit series. Seven additional activity units were constructed to teach for the higher levels of the Cognitive and Affective Domains. These activities were added, one each, to Units 2 - 8 of
the regular Biology 100 program; this activity series
(B-Activity Unit series) was undertaken by the experimental
group in this study.

For this investigation three of the ten units in
Biology 100 were selected for evaluation. Two types of
cognitive instruments were developed for this purpose.
The A-Post-test series consisted of three individual
post-tests, one for each of the three units, designed to
assess the lower three levels of the Cognitive Domain -
Knowledge, Comprehension, and Application; the last two
post-tests also contained review items from the previous
tests. The B-Post-test series also containing three
post-tests was designed to assess all six levels of the
Cognitive Domain - Knowledge, Comprehension, Application,
Analysis, Synthesis, and Evaluation; review items were
included on the last two post-tests. Pretests of the A-
and B-type were also administered.

One affective test - Personal Preference Test - was
developed for this investigation. This test contained
items to assess the first four levels of Krathwohl's Af­
fective Domain; the fifth level was deemed too difficult
to assess. The Personal Preference Test was given to all
participating students as a pretest (Test 2C) and a post-
test (Test 9D).
The population used in this study consisted of students at The Ohio State University who were registered for Biology 100 during the Autumn Quarter 1970 and Winter Quarter 1971. A random sample of five recitation classes was selected from each quarter, giving a total of ten classes which participated in the study. Each class was randomly assigned to take either the A- or B-Post-test series. Since the study required that students take part in tests and laboratory activities in addition to performing their regular work in Biology 100, volunteer participants were solicited from each of the ten classes; this resulted in a sample of 141 students during the Autumn Quarter and 86 students for the Winter Quarter.

Hypotheses involving the influence of college class, teacher, and sex on post-test performance were tested using correlation coefficients. Correlation coefficients were also used with the hypotheses determining the effectiveness of the cognitive and affective instruments in discriminating performances at various levels of the two domains. Means, standard deviations, and F-ratios of sub-test scores were used with hypotheses involving the influence of the type of pretest used with post-test performance and analysing differences between control and experimental groups on post-tests in the Cognitive and Affective Domains. Hypotheses concerning achievement of
the control group at the higher levels of the two domains made use of t-ratios, sign tests, and chi square values.

**Conclusions**

The conclusions drawn in this section are based on the sample of the population used in this study. Generalizations made to apply in similar areas should be done with care. For a detailed examination of the findings of this study, the reader is directed to Chapter IV.

**Cognitive Domain**

**Pretest Effects**

Student performances on the cognitive post-tests were not affected by the type of pretest given to the students (Tables 13 and 14, pages 95 and 97). There were no significant differences on any of the cognitive levels between students who took Pretest A with items at only the lower three levels and students who took Pretest B with items at all six cognitive levels.

**Post-test Performance**

The biology program for the control and experimental groups differed basically in that the experimental group performed additional laboratory activities which were designed to teach higher levels of cognitive thinking. Most of these activities involved presenting the student with raw data or having the student himself collect this information; the student was then to generate one or more
hypotheses which could be supported by the data which he had. In some activities additional information was provided, and the student had to accept, reject, or modify his hypotheses.

Three post-tests - 4B, 6B, and 8B - which contained items at all levels of the Cognitive Domain including review items, were given during the fifth, seventh, and ninth weeks of the quarter respectively. The data for Post-tests 4B (Tables 38 and 39, pages 138 and 139) and 6B (Tables 40 and 41, pages 140 and 141) indicate that the experimental group was scoring almost consistently higher than the control group, but by only a few points. By the end of the quarter the results of Post-test 8B (Tables 42 - 44, pages 143, 144, and 145) showed that the experimental group was scoring significantly higher than the control group on several higher cognitive levels as well as on the review items.

Based on these findings, the performance of the students at the higher cognitive levels can be increased by providing activities which allow the students to actively manipulate data and evaluate hypotheses. This learning process seems to require a period of time before the results can be seen. More substantial results can be obtained if the students are required to do a minimum of four such activities throughout the quarter; since each
activity takes approximately twenty to thirty minutes to perform, this would mean only approximately two hours of additional laboratory time over a ten week quarter to produce significant higher level thinking abilities.

These results support the conclusions drawn in the literature. Woodruff (1961), Gagné (1965), and Bruner (1968) point out the problem-solving activities can teach critical thinking abilities and permanently change the student's capabilities at the higher cognitive levels. Studies by Sorenson (1966), Rickert (1967), and Zingars and Collette (1968) used various cognitive measures to show that in high school and college science courses students can learn to develop high level thinking abilities through student-oriented laboratory activities; such activities should give the students opportunity to formulate solutions to problems. Several authors (Carey, 1968; Evan, 1968; Benson, 1970) have indicated that it is possible to construct instruments with test items at particular levels of Bloom's cognitive hierarchy and to measure high level thinking abilities; however the work by Pancelia (1971) shows that this practice is not wide spread.

Performance on Course Work

Three tests are normally given to the students in Biology 100 - two midterm examinations and a final examination. In addition a quarter score is obtained for each
student; this score combines the two midterm exams and the final exam with a score given by the recitation teacher for class performance and assignments. The three examinations consist of objective, lower-level cognitive questions with most of the items being above the memorization level and a large number at the Application level.

The experimental group as a whole consistently scored higher than the control group on all four scores (Table 45, page 148). Moreover when only those participants who took four or more of the specially designed activities were compared with the control group (Table 47, page 151), the differences between the two groups became significant. The level of significance increased from the first midterm to the second midterm and the final examination.

Based on these data, working with the specially designed activities increases the student's ability to perform in Biology 100 as measured by the course examinations. This is especially true if the student performs a minimum of four of the seven activities; this is also demonstrated by the increase in significance between Midterm I and Midterm II. These results agree with Bloom's description (1956) of the Cognitive Domain. If the cognitive levels are hierarchical, the development of the higher levels brings about refinement at the lower levels; this refinement would appear as higher scores on low level tests.
Affective Domain

The affective instruments used in this study - Personal Preference Tests 2C and 9D - were unable to discriminate among student performances at various levels of the Affective Domain (Table 32, page 129). These data indicate that the affective items were at various levels (Table 33, page 130), but the differences from level to level were not significant. Consequently no conclusions can be drawn concerning student performances in the Affective Domain; however, this area, should be pursued further. One interesting aspect which also needs further investigation is the high post-test performance (based on significant correlations) by the male participants.

Several studies (Mahan, 1963; Coulter, 1966; Sorenson, 1966) have shown that laboratory activities which allow the students to manipulate data and solve problems bring about positive attitudinal changes in students. However, only the work with "open-mindedness" by Sorenson produced data which were significant at the .05 level. Neidt and Hedlund (1965) concluded from their study of college students in a introductory psychology course that affective outcomes were independent of cognitive outcomes. However, the ability of paper-and-pencil instruments to measure attitudinal changes has been questioned (Howe and Ramsey,
1969); there are some indications that such instruments may be linked to intelligence (Howe, 1972). It is evident that further work is needed in this area.

**Evaluation Scheme**

For the Cognitive Domain the evaluation scheme used in this study appears to be a success. It was possible to construct instruments which contain items at all six levels and distinguish student performances at least at the lower, middle, and higher levels of this domain (Table 30, page 125). The evaluation of individual units of work, as was undertaken with Units 4, 6, and 8 in this study, can be done, and the combining of individual unit tests into mid-term and final examinations is certainly feasible.

The work of this study in the Affective Domain was unsuccessful. The affective instrument constructed for this study could not be shown to distinguish among student performances at the various levels of this domain (Table 32, page 129). Without an effective evaluative instrument, the attempt for assessing student performance in the Affective Domain had to be abandoned, although the scheme used in the evaluation appears to be useful.

**Recommendations**

Recommendations made in this section are based on the evidence collected for this study during the Autumn Quarter 1970 and Winter Quarter 1971 at The Ohio State
University. Generalizations can be made only to other science programs which have a similar population and approach as in the Biology 100 audio-tutorial program in the College of Biological Sciences' Bio-Learning Center on the Columbus campus. Areas of special interest and in need of further investigation are given below.

1. Since this study has indicated that laboratory activities which teach higher cognitive abilities can be constructed and used in a large laboratory situation, science programs which seek higher cognitive outcomes should look into the construction of such activities. The Bio-Learning Center at The Ohio State University especially lends itself for the adaptation of such activities, and concerted efforts should be made to develop high level cognitive activities for the Biology 100 program. These activities could follow the plan of those used in this study in which the students actively collect data and use the data in formulating hypotheses.

2. For this study a minimum number of four activities during the quarter was shown to best produce a significant difference in higher level cognitive performances; science programs should seek to determine an optimal number of special activities which achieve
the desired results for their students. Since some activities will be better than others in developing abilities at specific cognitive levels, the best activities should be selected for student use; these could be made available to the students on either a required or an optional basis. Data on the performance of students who work through these activities could be kept and evaluated continuously, so that further improvements could be made.

3. Since the special activities used in this study were self-contained and individually performed, the use of these activities for individualizing instruction should be investigated. The ways in which these activities could be used in an audio-tutorial program may include areas of required or optional material, special interests, research, and others. A continuous study of the progress made by students who use the special activities could provide valuable information for course improvement.

4. The development of activities which teach higher level cognitive abilities in all content areas of a science program should be investigated. Such activities could be used with an individualized approach as well as with the traditional class approach. The College
of Biological Sciences at The Ohio State University should provide additional support to the introductory biology program for the construction of these types of laboratory activities and their implementation into the Biology 100 program.

5. The evidence from this study shows that instruments can be constructed which assess the higher levels of the Cognitive Domain; the development and use of such instruments in other science programs should be investigated.

6. The use of instruments which evaluate all levels of the Cognitive Domain should be considered in developing individualized instruction. Such instruments could be taken by the students as they finish a unit of study rather than forcing the student to take class or departmental examinations. With the use of the computer such a testing program once begun could be maintained with a minimum amount of effort.

7. The use of high level cognitive tests as diagnostic instruments should be investigated. With individualized instruction the student who is weak in specific content areas at specific cognitive levels could be directed to those activities which develop that content area and that cognitive level.
8. The effect of the specially designed activities on the student's ability to retain content material needs further investigation. The performance of the experimental group in this study on review items on the final post-test suggests that the high level cognitive activities aid retention of content material, but further studies should be made. The program at the Bio-Learning Center offers an excellent opportunity for the collection of new data in this area; the College of Biological Sciences should provide support for an on-going program of evaluation of these activities and student performance.

9. Further work needs to be done toward the construction of affective instruments which can discriminate various levels of the Affective Domain. Although the data indicate that the instrument used in this study contained items at various affective levels, the differences among levels were not significant.

10. The use of specially designed activities in producing positive changes in the affective behavior of students should be examined. Because of the lack of sufficient instrumentation, the affective changes in students were not adequately measured in the present study.
It is hoped that the recommendations presented in this chapter will serve as a basis for implementing the audio-tutorial biology program at The Ohio State University. Since it is possible to construct laboratory activities which teach for the higher levels of the Cognitive and Affective Domains, concerted effort should be made for the development of such activities, and continuous research on the impact of these activities on students should be maintained.
APPENDIX A

DIAGRAM OF DEVELOPMENTAL DESIGN
For a discussion of the Developmental Design see pages 40 - 45.
APPENDIX B

PRETEST A

1. The Instrument
2. Key and Cognitive Level Designation
1. During DNA replication, pairing of bases occurs because of
   A) di-sulfide bonds
   B) adenosine triphosphate
   C) purine activation
   D) hydrogen bonds

2. There is a three nucleotide sequence found on DNA which codes for a specific amino acid; these three nucleotides are: ADENINE—THYMINE—GUANINE.
   The messenger-RNA formed from these three nucleotides would be
   A) Adenosine—Uracil—Guanine
   B) Thymine—Uracil—Cytosine
   C) Uracil—Adenine—Cytosine
   D) Thymine—Adenine—Cytosine

3. The function of Transfer-RNA is to
   A) transfer specific amino acids from the cytoplasm to the nucleus
   B) carry RNA from the nucleus to the cytoplasm
   C) bring specific amino acids into the cell
   D) carry specific amino acids to the ribosomes

4. Consider the following:
   I  = The number of different amino acids in a bacteria cell
   II = The number of different amino acids in a human cell
   How would you best categorize the relationship between I and II?
   A) Item I is greater than item II.
   B) Item I is less than item II.
   C) Item I is equal to item II.
   D) There is no way of comparing the two items.

5. The model of DNA most accepted today was proposed by
   A) Cohrs
   B) Linnaeus
   C) Watson and Crick
   D) Kornberg and Hirsenberg

6. We know that nucleotides occur in match pairs in DNA molecules because in every DNA helix
   A) the number of purine bases always equals the number of pyrimidine bases
   B) the number of purine bases is always the same
   C) the number of adenine bases always equals the number of guanine bases
   D) the number of purine bases is twice the number of pyrimidine bases

7. The diagram at the right represents
   A) chromosomes in mitosis
   B) TRNA and t-RNA at the ribosomes
   C) DNA replication
   D) DNA being created from RNA
8. Each nucleotide on a DNA contains
   A) phosphate, sugar, and protein
   B) ATP, amino acid, and protein
   C) phosphate, sugar, and base
   D) sugar, acid, and base

9. If Enzyme A which is involved in protein formation is removed from a human liver cell and placed in a human kidney cell, Enzyme A in the kidney would
   A) affect the same reaction that it did in the liver
   B) affect more reactions than it did in the liver
   C) require a different energy of activation than it did in the liver
   D) fail to function

10. Which of the following best describes why adenosine triphosphate (ATP) is considered to be the “monetary system of energy exchange” in living organisms?
    A) ATP is one of the organic bases found in the DNA of all organisms.
    B) Once formed, ATP is very stable and cannot be broken apart.
    C) The third phosphate bond contains more energy than the other chemical bonds.
    D) The third phosphate is easily transferred to other molecules, making them reactive.

11. To find the genotype of an unknown individual, a test cross should be made; this would mean mating the individual of unknown genotype with an individual who is
    A) homozygous dominant
    B) homozygous recessive
    C) heterozygous dominant
    D) heterozygous recessive

12. If a red bean with the genotype Rr is crossed with a white bean having the genotype rr, out of the progeny which they can produce you would expect
    A) all to be red
    B) all to be white
    C) half to be red
    D) one-fourth to be white

13. If a mutation were to occur in the skin cells of an animal, this mutation
    A) would be passed on to this animal’s offspring because mutations are changes in the chromosome structure.
    B) would be passed on to this animal’s offspring because skin cells divide often by mitosis.
    C) would not be passed on to this animal’s offspring because skin cells do not form gametes.
    D) would not be passed on to this animal’s offspring because chromosomes do not duplicate in mitosis.

14. Of what importance is the knowledge of cross-over percentages?
    A) It makes possible the mapping of genes of chromosomes.
    B) It neutralizes the effects of linkage.
    C) It provides evidence for the structure of DNA.
    D) It provides proof for the X-Y chromosome theory of sex determination.

15. The phenotype of an organism is its
    A) DNA structure
    B) progeny
    C) physical appearance
    D) chromosome count
Questions 16 - 18 involve the information below:

If two corn plants - each with yellow kernels and smooth seed coats (YySs) - are crossed, offspring are produced in the following ratio:

9 yellow-smooth
3 yellow-wrinkled
3 red-smooth
1 red-wrinkled

16. From this information you can say that
A) yellow is dominant over smooth
B) kernel color is dominant over seed coat texture
C) smooth is dominant over wrinkled
D) red is dominant over wrinkled

17. The parental plants (yellow-smooth) can produce which types of gametes?
A) Yy and Ss
B) YS, Ys, yS, and ys
C) YS, RY, RS, and RW
D) YS and yS

18. The red-wrinkled offspring are
A) homozygous recessive
B) heterozygous recessive
C) homozygous dominant
D) homozygous recessive

19. When a red-flowered plant is crossed with a white-flowered plant, the resulting offspring all have red flowers. This is probably because
A) red flowers are dominant over white flowers
B) the white flowers are heterozygous
C) red is a more vivid color than white
D) the white alleles do not form gametes

20. One of the main differences between soma (body) cells and germinai (sex or germ) cells is that soma cells undergo cell division by
A) mitosis only
B) meiosis only
C) both mitosis and meiosis
D) neither mitosis nor meiosis

21. Which one of the following best describes what Darwin meant when he wrote about the "survival of the fittest"?
A) The organisms which could run the fastest would survive.
B) The organisms that best fit into the environment would survive.
C) The organisms with the most genes would survive.
D) Only the strongest organisms would survive.

22. Structures on different organisms that have a similar function are
A) homologous
B) analogous
C) convergent
D) divergent
Questions 23 - 24 refer to the description below:
A population of antelope was threatened with over-population when a number of lions was imported into the area.

23. Some time after the lions had arrived, you would expect to find that
A) there were fewer deer and the running speed of the deer population had decreased.
B) there were fewer deer and the running speed of the deer population had increased.
C) there were fewer deer and the running speed of the deer population had not changed.
D) there were more deer and the running speed of the deer population had increased.

24. The statement and question above indicating a change in the characteristics of the deer population is an illustration of
A) induced mutation
B) hereditary transmission of the results of training
C) natural selection
D) genetic drift

25. According to Darwin, evolution is due to
A) mutation, crossing-over, and chromosome breakage
B) mutation, isolation, and selection
C) DNA, RNA, and protein synthesis
D) variation, competition, and selection

26. Two groups within one population will become distinct species when
A) their number of chromosomes change
B) they become genetically isolated
C) they demonstrate different characteristics
D) they no longer look like each other

27. Organisms that interbreed and potentially share the same gene pool belong to the same
A) class
B) kingdom
C) biome
D) species

28. Successful competition and natural selection occur because of
A) variations between organisms
B) homologous structures
C) large gene pools
D) physical isolation between groups

29. The lateral line system in fish is used to detect vibrations in the water and changes in water pressure. This system was lost as amphibians evolved from the fish. This loss of the lateral line system in amphibians is probably due to
A) loss of the tail
B) movement to a land habitat
C) development of eyelids
D) changes in reproductive habits

30. A "primitive" organism is one that
A) has changed little over a long period of time
B) has changed a great deal over a long period of time
C) is not well adapted to the environment
D) shows a low degree of intelligence
Pretest A

Key and Cognitive Level Designation

Total number of Knowledge questions: 6
Total number of Comprehension questions: 12
Total number of Application questions: 12

1. D Knowledge
2. C Application
3. D Comprehension
4. C Application
5. C Knowledge
6. A Comprehension
7. C Comprehension
8. C Knowledge
9. A Comprehension
10. D Comprehension
11. B Comprehension
12. C Application
13. C Application
14. A Comprehension
15. C Knowledge
16. C Application
17. B Application
Pretest A (continued)

18. A Application
19. A Comprehension
20. A Application
21. B Comprehension
22. B Knowledge
23. B Application
*24. C Application
25. D Comprehension
26. B Application
27. D Knowledge
28. A Comprehension
*29. B Application
30. A Comprehension

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX C

PRETEST B

1. The Instrument
2. Key and Cognitive Level Designation
1. The theory that the nucleotides of DNA always occur in matched pairs is best supported by which piece of evidence cited below?
   A) The number of adenine and thymine nucleotides always equals the number of guanine and cytosine nucleotides.
   B) The amount of ATP used in DNA replication is always the same.
   C) For every purine nucleotide there is a pyrimidine nucleotide.
   D) The lengths of both strands of DNA in a single helix are always the same.

2. The chromosomes are mostly made up of
   A) ATP
   B) sugar
   C) DNA
   D) enzymes

3. In protein synthesis a "triplet code" (with three nucleotides) is used for each amino acid. Since there are only four types of nucleotides in DNA and only twenty amino acids, this means that
   A) not all amino acids have a triplet code
   B) some amino acids have more than one triplet code
   C) all amino acids have only one triplet code
   D) several amino acids have the same triplet code

In questions 4 - 5 categorize the two items in each question by the following key:
   A) Item I is greater than item II.
   B) Item I is less than item II.
   C) Item I is equal to item II.
   D) there is no way of comparing the two items.

4. I - the number of purine nucleotides on one DNA strand
   II - the number of pyrimidine nucleotides on the same DNA strand

5. I - the number of different amino acids in a bacterial cell
   II - the number of different amino acids in a human cell

6. The diagram on the right represents
   A) chromosomes in mitosis
   B) t-RNA and m-RNA at ribosomes
   C) DNA replication
   D) DNA being created from RNA

7. Glucose is converted into carbon dioxide and water in the presence of oxygen. If the specific enzymes for this reaction are not present,
   A) the reaction will proceed but will require less energy.
   B) the reaction will proceed but will require more energy.
   C) the reaction will occur using the same amount of energy as when the enzymes are present.
   D) the reaction will not proceed.
6. It has been reported that in an enzyme catalyzed reaction, physical contact between the enzyme and the substrate occurs. This report
   A) is true and supports the lock-and-key theory of enzyme action
   B) is true but opposes the lock-and-key theory
   C) is true but has no bearing on the lock-and-key theory
   D) is false

9. Which of the following best describes why adenosine triphosphate (ATP) is considered to be the "monetary system of energy exchange" in living organisms?
   A) ATP is one of the organic base compounds found in the DNA of all organisms.
   B) Once formed, ATP is very stable and cannot be broken apart unless large amounts of energy are used.
   C) The third phosphate bond contains more energy than any other chemical bond.
   D) The third phosphate radical is easily transferred to other molecules, making them reactive.

10. Occasionally a mistake may be made in forming t-RNA from DNA (eg. the X-RNA may have a cytosine in place of a guanine base). As a result of this,
    A) DNA will probably pass the error on to other cells during mitosis
    B) no t-RNA will pair with the X-RNA
    C) the X-RNA will not be able to leave the nucleus
    D) an incorrect amino acid will be placed in the protein chain

11. To find the genotype of an unknown individual, a test cross should be made; this would mean mating the individual of unknown genotype with an individual who is
    A) homozygous dominant
    B) homozygous recessive
    C) heterozygous dominant
    D) heterozygous recessive

12. If a cell which has twenty-four (24) chromosomes undergoes meiosis, the daughter cells formed will contain
    A) 48 chromosomes
    B) 36 chromosomes
    C) 24 chromosomes
    D) 12 chromosomes

13. When two dihybrid individuals who are heterozygous for both traits (AaBb) are mated with each other, they produce 64 offspring. Approximately how many of those offspring would you expect to be homozygous recessive for both traits?
    A) 4
    B) 16
    C) 9
    D) 1

14. Slight differences in 10-year-old identical twins supports the hypothesis that
    A) dominance may be incomplete
    B) genetic traits are influenced by many genes
    C) single genes may produce multiple effects
    D) the environment affects the expression of genetic characteristics
15. A poultry farmer discovers that a recessive mutation which greatly increases egg production has occurred in his flock. He would like to distribute this characteristic throughout his flock as quickly as possible. Which one of the following would do this best?
   A) Use a high-production hen to sit on as many eggs as she can.
   B) Intercross both male and female offspring of a high-production hen.
   C) Breed sons of a high-production hen with heterozygous hens.
   D) Interbreed heterozygous hens and heterozygous roosters.

16. Many matings of two spotted guinea pigs resulted in the following data:

<table>
<thead>
<tr>
<th>Coat Color</th>
<th>Offspring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>21</td>
</tr>
<tr>
<td>Spotted</td>
<td>48</td>
</tr>
<tr>
<td>Tan</td>
<td>31</td>
</tr>
</tbody>
</table>

Which one of the following hypotheses best explains this data?

Coat color in guinea pigs is due to
   A) one pair of alleles with no dominance and no recessive.
   B) one pair of alleles with dominance and recessive.
   C) one pair of sex-linked alleles with dominance and recessive.
   D) two pairs of alleles with dominance and recessive.

17. Which one of the following constitutes a genetic change in an organism?
   A) Exposing a rat to radiation while taking a chest X-ray.
   B) Changes in a canary's feathers from yellow to orange from eating certain chemicals.
   C) Substitution of a guanine nucleotide for an adenine nucleotide in the DNA of a zygote nucleus.
   D) Infection of a rabbit with a virus.

18. The table below indicates the offspring produced from several matings of two cats - both cats having yellow eyes and brown fur:

<table>
<thead>
<tr>
<th>Number of Offspring</th>
<th>Eye Color</th>
<th>Fur Color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yellow</td>
<td>Gray</td>
</tr>
<tr>
<td>3</td>
<td>Yellow</td>
<td>Gray</td>
</tr>
<tr>
<td>11</td>
<td>Yellow</td>
<td>Brown</td>
</tr>
<tr>
<td>2</td>
<td>Black</td>
<td>Gray</td>
</tr>
<tr>
<td>4</td>
<td>Black</td>
<td>Brown</td>
</tr>
</tbody>
</table>

The data from the table indicates that this was
   A) a monohybrid cross involving simple dominant and recessive genes.
   B) a monohybrid cross with incomplete dominance (intermediate inheritance).
   C) a monohybrid cross with linked genes.
   D) a dihybrid cross involving simple dominant and recessive genes.

19. The following information is known about the genetics of eye color in man:
   Brown eye color is dominant over blue eye color.
   Many blue-eyed people marry brown-eyed people and have mostly brown-eyed children.
   The percentage of blue-eyed people in the human population has not decreased over the last several generations.

This data is best explained by which one of the following hypotheses?
   A) A blue-eyed individual must be homozygous for blue eye color.
   B) In human genetics, characteristics are seldom determined by a single gene.
   C) Many brown-eyed people are heterozygous for eye color.
   D) Having blue eyes is advantageous to an individual, so this characteristic will always remain in the population.
20. If a mutation were to occur in the skin cells of an animal, this mutation
   A) would be passed on to this animal's offspring because mutations are changes
      in the chromosome structure.
   B) would be passed on to this animal's offspring because skin cells divide often
      by mitosis.
   C) would not be passed on to this animal's offspring because skin cells do not
      form gametes.
   D) would not be passed on to this animal's offspring because chromosomes do
      not duplicate in meiosis.

21. Structures on different organisms that have a similar function are
   A) homologous
   B) analogous
   C) convergent
   D) divergent

22. A population of deer was threatened with over-population until a number of
    lions was imported; after a time, there were fewer deer, but the average
    running speed of the population of deer was increased. This is an illustration of
    A) induced mutation
    B) hereditary transmission of the results of training
    C) natural selection
    D) genetic drift

23. Which one of the following best describes what Darwin meant when he wrote
    about the "survival of the fittest"?
    A) The organism which could run the fastest would survive.
    B) The organisms that best fit into the environment would survive.
    C) The organisms with the most genes would survive.
    D) Only the strongest organisms would survive.

24. Which is most important in predicting the direction of evolution of an
    animal species?
    A) High mutation rate for certain traits
    B) Changes in the structure of the land
    C) Selection of certain traits by environmental conditions
    D) High rate of crossing over of chromosomes during meiosis

25. According to Darwin, evolution is due to
    A) mutation, crossing-over, and chromosome breakage
    B) mutation, isolation, and selection
    C) DNA, RNA, and protein synthesis
    D) variation, competition, and selection

26. Organisms that interbreed and potentially share the same gene pool belong
    to the same
    A) biome
    B) homologous group
    C) ecological niche
    D) species
27. Two groups of one population will become distinct species when
   A) their number of chromosomes change
   B) they become genetically isolated
   C) they demonstrate different characteristics
   D) they no longer look like each other

28. In a paper on evolution a student made the statement that "environmental
    changes are responsible for species changes." By this statement the student
    was referring to
   A) mutation
   B) genetic drift
   C) natural selection
   D) physical isolation

29. Which one of the following is an example of a mutation?
   A) The feathers of a canary turn pink when it eats certain chemicals.
   B) A snake causes its body temperature to increase by sitting in the sun.
   C) ADP is changed to ATP by adding a phosphate.
   D) A guanine nucleotide is substituted for an adenine nucleotide on RNA.

30. Below is a set of data concerning protein synthesis:

   Living organisms make particular proteins under the direction of
   particular nucleic acids, i.e. DNA and RNA.
   Nucleic acids are transmitted from one generation to another.
   Organisms of different species are unable to breed together.
   Closely related species have more proteins in common than less closely
   related species.

   Which one of the following hypotheses best explains this set of data?
   A) Closely related species probably had common ancestors that bred together.
   B) Closely related species may occasionally breed with one another, there-
      fore passing nucleic acids from one species to the other.
   C) Different species may have similar proteins because DNA passes genetic
      information to the next generation during fertilization.
   D) Closely related species will have similar protein because all protein
      is made from the same twenty amino acids.
Pretest B

Key and Cognitive Level Designation

Total number of Knowledge questions: 4
Total number of Comprehension questions: 6
Total number of Application questions: 7
Total number of Analysis questions: 7
Total number of Synthesis questions: 3
Total number of Evaluation questions: 3

1. C Analysis
2. C Knowledge
3. B Evaluation
4. D Analysis
5. C Application
6. C Comprehension
7. B Application
8. A Synthesis
9. D Comprehension
10. D Analysis
11. B Comprehension
12. D Knowledge
13. A Application
14. D Analysis
*15. B Analysis
*16. A Evaluation
*17. C Comprehension
18. D Analysis
19. C Synthesis
20. C Application
21. B Knowledge
*22. C Application
23. B Comprehension
*24. C Application
25. D Comprehension
26. D Knowledge
27. B Application
28. C Evaluation
29. D Analysis
30. A Synthesis

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX D

POST-TEST 4A

1. The Instrument
2. Key and Cognitive Level Designation
1. During DNA replication, pairing of bases occurs because of
   A) di-sulfide bonds
   B) adenosine triphosphate
   C) purine activation
   D) hydrogen bonds

2. An organ transplant from one human to another may be rejected because
   the body of the recipient reacts to the new organ as though it were
   "foreign protein". This reaction indicates that the two people involved
   (the donor and the recipient) had
   A) different DNA
   B) different number of chromosomes
   C) the same kind of RNA
   D) the same number of ribosomes

3. There is a three nucleotide sequence found on DNA which codes for a specific
   amino acid; these three nucleotides are: ADENINE-THYMINE-GUANINE.
   The **Messenger-RNA** formed from these three nucleotides would be
   A) Adenine-Thymine-Guanine
   B) Thymine-Uracil-Cytosine
   C) Uracil-Adenine-Cytosine
   D) Thymine-Adenine-Cytosine

4. The function of Transfer-RNA is to
   A) transfer specific amino acids from the cytoplasm to the nucleus
   B) carry RNA from the nucleus to the cytoplasm
   C) bring specific amino acids into the cell
   D) carry specific amino acids to the ribosomes

5. In a normally growing plant cell most of the **amino acids** can be found
   A) free in the cytoplasm
   B) inside the nucleus
   C) linked to T-RNA
   D) linked to H-RNA

6. It takes three nucleotides to code for one amino acid because
   A) amino acids are larger than nucleotides
   B) there are four nucleotides and twenty amino acids
   C) some amino acids have the same triplet code
   D) a DNA strand contains less than twenty nucleotides

7. The tertiary structure of many amino acid molecules is due to
   A) peptide bonds
   B) di-sulfide bonds
   C) phosphate bonds
   D) hydrogen bonds
The following experiment was performed; questions 8 - 11 on this page are related to this experiment. When amoebae were placed in water containing radioactive thymine (Thymine can be made radioactive by various methods.), this base was taken up by the cell (See Fig. IA below), and some of it was incorporated into duplicating DNA within the organism; both the cytoplasm and the nucleus became radioactive (See Fig. IB). By means of delicate micro-pipettes, it was possible to remove the radioactive nucleus of one amoeba (Fig. IB) and transfer it to a non-radioactive amoeba whose own nucleus had already been removed (Fig. IC and ID). After the transfer, the radiation remained within the nucleus of the second amoeba and did not move into the cytoplasm even after several days (Fig. IE).

8. The radioactive thymine is incorporated into the DNA because
   A) it forms part of the deoxyribose sugar
   B) it is one of the nitrogen bases needed by DNA
   C) it reacts with phosphate in forming a chain of nucleotides
   D) it forms di-ruthide bonds

9. In order for the thymine to be incorporated into DNA, it must base-pair with
   A) adenine
   B) cytosine
   C) guanine
   D) uracil

10. The thymine does not leave the nucleus because thymine
    A) is too large to pass through the nuclear membrane
    B) is manufactured only in the nucleus
    C) replaces nucleotides which are already a part of DNA
    D) never forms a part of RNA

11. Which one of the following bases is found only in RNA?
    A) adenine
    B) uracil
    C) thymine
    D) cytosine
12. Consider the following:

I. The number of different amino acids in a bacteria cell.
II. The number of different amino acids in a human cell.

How would you best categorize the relationship between I and II?

A) Item I is greater than item II.
B) Item I is less than item II.
C) Item I is equal to item II.
D) There is no way of comparing the two items.

13. The model of DNA most accepted today was proposed by

A) Ochoa
B) Linnaeus
C) Watson and Crick
D) Kornberg and Nirenberg

14. We know that nucleotides occur in matched pairs in DNA molecules because in every DNA helix

A) the number of purine bases always equals the number of pyrimidine bases
B) the number of purine bases is always the same
C) the number of adenine bases always equals the number of guanine bases
D) the number of purine bases is twice the number of pyrimidine bases

15. If the current theory of protein synthesis is correct, which one of the following cellular components need not be present in a newly formed cell?

A) amino acids
B) ribosomes
C) DNA
D) Messenger-RNA

16. The five events listed below are the steps necessary for protein synthesis:

1 - Messenger-RNA and Transfer-RNA pair together.
2 - Protein strands are formed.
3 - Messenger-RNA is formed.
4 - Transfer-RNA picks up amino acids.
5 - RNA moves to the ribosomes.

The correct order in which these events occur is:

A) 1 - 3 - 4 - 5 - 2
B) 3 - 1 - 4 - 5 - 2
C) 3 - 4 - 5 - 1 - 2
D) 4 - 3 - 1 - 5 - 2

17. In DNA, a purine base cannot pair with another purine base because

A) purine bases are found only in RNA
B) purines do not contain hydrogen bonds
C) two purine bases would be too large to fit within the DNA helix
D) uracil is not a purine
Questions 18 - 21 refer to the diagram on the right:

18. This diagram represents
   A) chromosomes in mitosis
   B) T-RNA and M-RNA at ribosomes
   C) DNA replication
   D) DNA being created from RNA

19. At all locations marked "X" we find
   A) ATP
   B) pyrimidines
   C) sugars
   D) phosphates

20. At all locations marked "Y" we find
   A) purines
   B) bases
   C) sugars
   D) phosphates

21. On the diagram, if I is guanine, then II is
   A) adenine
   B) thymine
   C) cytosine
   D) sugar

22. DNA and RNA differ from each other in that RNA
   A) has a sugar molecule with more oxygen
   B) has a 5-carbon sugar
   C) may have thymine on it
   D) All of the above answers are correct.

23. Each nucleotide on a DNA contains
   A) phosphate, sugar, and protein
   B) ATP, amino acid, and protein
   C) phosphate, sugar, and base
   D) sugar, acid, and base

24. In DNA replication
   A) RNA is not involved
   B) RNA contributes nitrogen bases
   C) purines pair together
   D) the amount of cytoplasm is doubled

25. Enzymes are necessary in living systems because enzymes
   A) make reactions occur that would never occur
   B) reduce the amount of energy necessary for a reaction
   C) limit the types of reactions that can occur
   D) produce energy that can be stored by the cell
26. Enzymes

A) may form part of the end product of the reaction
B) do not always have active sites
C) usually act as catalysts for several different reactions
D) may bring substances together so they can react

27. If Enzyme A which is involved in protein formation is removed from a human liver cell and placed in a human kidney cell, Enzyme A in the kidney would

A) affect the same reaction that it did in the liver
B) affect more reactions than it did in the liver
C) require a different energy of activation than it did in the liver
D) fail to function

28. An enzyme can be made inactive by

A) adding a substrate
B) reducing the enzyme concentration by half
C) blocking the enzyme's active site
D) removing the products as they are formed.

29. Which of the following is the best evidence for the lock-and-key theory of enzyme action?

A) All isolated enzymes have been identified as proteins.
B) Compounds similar in structure to the substrate inhibit the reaction.
C) Enzymes are found in living organisms and speed up certain reactions.
D) Enzymes speed up reactions by definite amounts.

30. The immediate source of energy for most reactions in an animal cell is

A) sunlight
B) DNA
C) ATP
D) amino acids

31. Which of the following best describes why adenosine triphosphate (ATP) is considered to be the "monetary system of energy exchange" in living organisms?

A) ATP is one of the organic bases found in the DNA of all organisms.
B) Once formed, ATP is very stable and cannot be broken apart.
C) The third phosphate bond contains more energy than the other chemical bonds.
D) The third phosphate is easily transferred to other molecules, making them reactive.

32. Energy + Glucose + Oxygen \[\rightarrow\] Carbon dioxide + Water

The above reaction needs energy to make it proceed; consequently it is known as an

A) energetic reaction
B) endergonic reaction
C) enzymatic reaction
D) exergonic reaction
Post-test 4A

Key and Cognitive Level Designation

Total number of Knowledge questions: 9
Total number of Comprehension questions: 17
Total number of Application questions: 6

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<td>Knowledge</td>
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<tr>
<td>2.</td>
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<td>Comprehension</td>
</tr>
<tr>
<td>3.</td>
<td>C</td>
<td>Application</td>
</tr>
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<td>Comprehension</td>
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<td>A</td>
<td>Application</td>
</tr>
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<td>Comprehension</td>
</tr>
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<td>7.</td>
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*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).*
APPENDIX E

POST-TEST 4B

1. The Instrument
2. Key and Cognitive Level Designation
1. An enzyme can be made inactive by
   A) adding a substrate  
   B) reducing the enzyme concentration by half  
   C) blocking the enzyme's active site  
   D) removing the products as they are formed

2. A radioactive nucleus from one amoeba is transferred to a non-radioactive amoeba which has had its nucleus removed. If, later on, the second amoeba is found to have radioactive ribosomes in its cytoplasm, this would be evidence in support of the
   A) functioning of Messenger-RNA  
   B) existence of the DNA code  
   C) function of chromosomes  
   D) existence of Transfer-RNA

3. An organ transplanted from one human to another may be rejected because the body of the recipient reacts to the new organ as though it were "foreign protein." This reaction indicates that the two people involved (the donor and the recipient) had
   A) different DNA  
   B) different number of chromosomes  
   C) the same kind of RNA  
   D) the same number of ribosomes

4. The theory that the nucleotides of DNA always occur in matched pairs is best supported by which piece of evidence cited below?
   A) The number of adenine and thymine nucleotides always equals the number of guanine and cytosine nucleotides. 
   B) The amount of ATP used in DNA replication is always the same. 
   C) For every purine nucleotide there is a pyrimidine nucleotide. 
   D) The lengths of both strands of DNA in a single helix are always the same.

5. In protein synthesis a "triplet code" (with three nucleotides) is used for each amino acid. Since there are only four types of nucleotides in DNA and only 20 amino acids, this means that
   A) not all amino acids have a triplet code  
   B) some amino acids have more than one triplet code  
   C) all amino acids have only one triplet code  
   D) several amino acids have the same triplet code

6. In a normally growing plant cell most of the amino acids can be found
   A) free in the cytoplasm  
   B) inside the nucleus  
   C) linked to T-RNA  
   D) linked to M-RNA
The following experiment was performed; questions 7 - 10 on this page are related to this experiment. When amoebae were placed in water containing radioactive thymine (Thymine can be made radioactive by various methods.), this base was taken up by the cell (See Fig. IA below), and some of it was incorporated into duplicating DNA within the organism; both the cytoplasm and the nucleus became radioactive (See Fig. IB). By means of delicate micropipettes, it was possible to remove the radioactive nucleus of one amoeba (Fig. IB) and transfer it to a non-radioactive amoeba whose own nucleus had already been removed (Fig. IC and ID). After the transfer, the radiation remained within the nucleus of the second amoeba and did not move into the cytoplasm even after several days (Fig. IE).

7. The radioactive thymine is incorporated into the DNA because
   A) it forms part of the deoxyribose sugar
   B) it is one of the nitrogen bases needed by DNA
   C) it reacts with phosphate in forming a chain of nucleotides
   D) it forms di-sulfide bonds

8. In order for the thymine to be incorporated into DNA, it must base-pair with
   A) adenine
   B) cytosine
   C) guanine
   D) uracil

9. The thymine does not leave the nucleus because thymine
   A) is too large to pass through the nuclear membrane
   B) is manufactured only in the nucleus
   C) replaces nucleotides which are already a part of DNA
   D) never forms a part of RNA

10. The results of this experiment with amoeba show that
    A) DNA never leaves the nucleus
    B) RNA moves out of the nucleus
    C) RNA is found at the ribosomes
    D) thymine is manufactured only in the nucleus
11. An investigator tries to find out what chemicals a chromosome starts with when it replicated DNA. In this research, he would most likely need which of the following?

A) a compound microscope  
B) an electron microscope  
C) a radioactive tag to mark chemicals  
D) an oscilloscope to watch for movement

12. The following ingredients were mixed together: ribosomes from rat cells, amino acids from guinea pigs, Transfer-RNA from bacterial cells, and Messenger-RNA from rabbit cells. When these ingredients were put together in the proper concentration with ATP, proteins were made. These proteins are most likely to resemble

A) rat proteins  
B) guinea pig proteins  
C) bacterial proteins  
D) rabbit proteins

13. Evaluate the following statement: "DNA base sequences control the formation of Messenger-RNA base sequences." This statement is

A) a fact  
B) a false statement  
C) based on unfounded evidence  
D) an assumption or theory

14. Which of the following statements best describes the function of Transfer-RNA?

A) T-RNA is responsible for enzyme manufacture.  
B) T-RNA carries amino acids in the cytoplasm to the ribosomes.  
C) T-RNA links with Messenger-RNA to put amino acids in a specific sequence in a protein chain.  
D) T-RNA carries amino acids to the Messenger-RNA on the ribosome.

15. Phenylalanine is an amino acid normally found in bacteria. Certain bacteria were placed in a solution containing the false amino acid fluorophenylalanine. Later the protein which was produced by the cell was chemically analyzed, and it was found that the false amino acid (fluorophenylalanine) had been substituted for the amino acid phenylalanine but not for other amino acids. The best conclusion from this observation is that the false amino acid (fluorophenylalanine) probably

A) blocked entry of phenylalanine into the cell  
B) became attached to phenylalanine's Transfer-RNA  
C) inhibited the enzymes involved in the formation of phenylalanine  
D) inhibited the activation of phenylalanine
16. The five events listed below occurred in algae cells in a cause-and-effect sequence. Arrange these events in their proper order of occurrence.

1 - An enzyme was manufactured at a ribosome.
2 - Cellulose, a carbohydrate, was deposited as a cell wall.
3 - Under the influence of DNA, a molecule of RNA was constructed.
4 - A carbohydrate strand was formed.
5 - A nucleic acid migrated from nucleus to cytoplasm.

The order in which these events occurred is:

A) 4 - 2 - 1 - 3 - 5
B) 5 - 3 - 4 - 1 - 2
C) 2 - 1 - 4 - 5 - 3
D) 3 - 5 - 1 - 4 - 2

In questions 17 - 19, categorize the two items in each question by the following key:

A) Item I is greater than item II.
B) Item I is less than item II.
C) Item I is equal to item II.
D) There is no way of comparing the two items.

17. I - the number of adenine nucleotides on one DNA strand
   II - the number of guanine nucleotides on the same DNA strand

18. I - the amount of energy required to change one molecule of glucose to carbon dioxide and water in a human liver cell
   II - the amount of energy required to change one molecule of glucose to carbon dioxide and water in a human muscle cell

19. I - the number of different amino acids in a bacterial cell
   II - the number of different amino acids in a human cell

20. If the current theory of protein synthesis is correct, which one of the following cellular components need not be present in a newly formed cell?

   A) amino acids
   B) ribosomes
   C) DNA
   D) Messenger-RNA

21. The chromosomes are mostly made up of

   A) ATP
   B) sugar
   C) DNA
   D) enzymes
Questions 22 - 23 refer to the diagram on the right:

22. This diagram represents
   A) chromosomes in mitosis
   B) T-RNA and H-RNA at ribosomes
   C) DNA replication
   D) DNA being created from RNA

23. At all locations marked "X" we find
   A) ATP
   B) pyrimidines
   C) sugars
   D) phosphates

24. Enzyme A has been isolated from a rat kidney cell; another enzyme B has been isolated from a rat muscle cell. Both A and B affect the same reaction. From what you know of enzyme activity, which of the following statements would most likely be true?
   A) A and B are the same enzyme.
   B) A and B are different enzymes which affect the same reaction and only this reaction.
   C) A and B are different enzymes which affect many different reactions.
   D) There is not enough evidence to make a statement about enzymes A and B.

25. Glucose is converted into carbon dioxide and water in the presence of oxygen. If the specific enzymes for this reaction are not present,
   A) the reaction will proceed but will require less energy
   B) the reaction will proceed but will require more energy
   C) the reaction will occur using the same amount of energy as when the enzymes are present
   D) the reaction will not proceed

26. Which of the following is the best evidence for the lock-and-key theory of enzyme action?
   A) All isolated enzymes have been identified as proteins.
   B) Compounds similar in structure to the substrate inhibit the reaction.
   C) Enzymes are found in living organisms and speed up certain reactions.
   D) Enzymes speed up reactions by definite amounts.

27. It has been reported that in an enzyme catalyzed reaction, physical contact between the enzyme and the substrate occurs. This report
   A) is true and supports the lock-and-key theory of enzyme action
   B) is true but opposes the lock-and-key theory
   C) is true but has no bearing on the lock-and-key theory
   D) is false
28. Which of the following best describes why adenosine triphosphate (ATP) is considered to be the "monetary system of energy exchange" in living organisms?

A) ATP is one of the organic base compounds found in the DNA of all organisms.
B) Once formed, ATP is very stable and cannot be broken apart unless large amounts of energy are used.
C) The third phosphate bond contains more energy than any other chemical bond.
D) The third phosphate radical is easily transferred to other molecules, making them reactive.

29. Occasionally a mistake may be made in forming M-RNA from DNA (eg, the M-RNA may have a cytosine in place of a guanine base). As a result of this,

A) DNA will probably pass the error on to other cells during mitosis
B) no T-RNA will pair with the M-RNA
C) the M-RNA will not be able to leave the nucleus
D) an incorrect amino acid will be placed in the protein chain

30. A reaction to which an enzyme has been added will require

A) less energy
B) an increase in temperature
C) more substrate
D) a different substrate

31. 

\[ A \xrightarrow{E_1} B \xrightarrow{E_2} C \xrightarrow{E_3} D \]

The above equation represents a chain reaction where A, B, C, and D are compounds found in the changing of Substance A to Substance D, and where \( E_1, E_2, \) and \( E_3 \) are the enzymes involved in the reactions. What would happen if \( E_3 \) were to be totally removed from the chain reaction?

A) Only half the amount of D would be formed.
B) The amount of Compound A would not be changed.
C) The reaction would proceed at a normal rate.
D) Compound C would accumulate.

32. An enzyme can be "fooled" into reacting with the wrong substrate instead of the proper one if

A) the wrong substrate is similar in physical shape to the proper substrate
B) the wrong substrate will form hydrogen bonds with the enzyme
C) the two substrates unite to form a new substrate
D) both substrates contain the same chemical elements
Post-test 4B

Key and Cognitive Level Designation

Total number of Knowledge questions: 4
Total number of Comprehension questions: 6
Total number of Application questions: 6
Total number of Analysis questions: 8
Total number of Synthesis questions: 4
Total number of Evaluation questions: 4

1. C Knowledge

*2. A Analysis

3. A Comprehension

4. C Analysis

5. B Evaluation

6. A Application

7. B Knowledge

8. A Knowledge

9. D Comprehension

10. A Synthesis

*11. C Analysis

*12. D Synthesis

13. D Evaluation

*14. C Evaluation
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*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).*
APPENDIX F

POST-TEST 6A

1. The Instrument
2. Key and Cognitive Level Designation
1. To find the genotype of an unknown individual, a test cross should be made; this would mean mating the individual of unknown genotype with an individual who is
A) homozygous dominant
B) homozygous recessive
C) heterozygous dominant
D) heterozygous recessive

2. The expected genotypic ratio of a simple, heterozygous monohybrid cross is
A) 9 : 3 : 3 : 1
B) 3 : 1
C) 1 : 2 : 1
D) 1 : 1

3. If a cell which has twenty-four (24) chromosomes undergoes meiosis, the daughter cells formed will contain
A) 48 chromosomes
B) 36 chromosomes
C) 24 chromosomes
D) 12 chromosomes

Questions 4 - 6 involve the following information:
If two corn plants - each with yellow kernels and smooth seed coats (YySs) - are crossed, offspring are produced in the following ratio:
9 yellow-smooth
3 yellow-wrinkled
3 red-smooth
1 red-wrinkled

4. From this information you can say that
A) yellow is dominant over smooth
B) kernel color is dominant over seed coat texture
C) smooth is dominant over wrinkled
D) red is dominant over wrinkled

5. The parental plants (yellow-smooth) can produce which types of gametes?
A) Yy and Ss
B) YS, Ys, yS, and yS
C) yS, rY, rS, and rW
D) YS and yS

6. The red-wrinkled offspring are
A) homozygous recessive
B) heterozygous recessive
C) heterozygous dominant
D) heterozygous recessive

7. Male honeybees develop from unfertilized eggs. This is an example of
A) sexual reproduction because the male honeybee is incapable of producing sperm.
B) sexual reproduction because the union of male and female gametes does not occur.
C) asexual reproduction because the individual is always a male.
D) asexual reproduction because the egg comes from the honeybee queen (female).
8. Many matings of two mice with spotted fur resulted in the following offspring:

- 23 with spotted coats
- 7 with solid coats
- 30 total offspring

The genotype of the parents was probably:

A) AA and AA  
B) AA and As  
C) As and As  
D) AaBb and AaBb

9. When two dihybrid individuals who are heterozygous for both traits (AaBb) are mated with each other, they produce 64 offspring. Approximately how many of these offspring would you expect to be homozygous recessive for both traits?

A) 4  
B) 16  
C) 9  
D) 1

10. Which one of the following is homozygous for all three traits represented?

A) AaBbCc  
B) aaBbCc  
C) AaBbCC  
D) AAbbCC

Questions 11 and 12 refer to the following information:

Color-blindness is a sex-linked characteristic found in humans; normal vision (C) is dominant over color-blindness (c). Alleles for this type of vision are found on the X-chromosome but not on the Y-chromosome. The following mating involving this characteristic occurred:

Heterozygous, Normal Female: Co - Color-blind Male: cX(-)

Offspring: Co Co  
cX(-) cX(-)

11. What types of gametes can the female produce?

A) X(-) only  
B) C only  
C) c only  
D) Both C and c

12. Of the offspring, approximately how many will be color-blind?

A) 1/4  
B) 1/2  
C) 3/4  
D) all

13. When you talk about linked genes, you mean genes that

A) affect the same characteristic  
B) are studied in dihybrid crosses  
C) are located in the same cell by chance  
D) are located on the same chromosome
14. Of what importance to the scientist is the knowledge of cross-over percentages?
   A) It makes possible the mapping of genes on chromosomes.
   B) It neutralizes the effects of linkage.
   C) It provides evidence for the structure of DNA.
   D) It provides proof for the X-Y chromosome theory of sex determination.

15. In certain species of birds we are interested in two characteristics:
   feather color - blue (B) is dominant over yellow (b), and
   tail length - long tail (L) is dominant over short tail (l).
   Each characteristic is controlled by a single gene and both are found on separate
   chromosomes. What is the probability of the offspring having yellow feathers,
   when a bird with genotype BBLL is mated with a bird of genotype bbll?
   A) 1
   B) 3/4
   C) 1/2
   D) 1/4

16. If a red bean with the genotype Rp is crossed with a white bean having the
    genotype rp, out of the progeny which they can produce you would expect
   A) all to be red.
   B) all to be white.
   C) half to be red.
   D) one-fourth to be white.

17. Meiosis in an animal cell occurs
   A) at the time gametes are produced.
   B) whenever a cell divides.
   C) during protein synthesis and ATP production.
   D) only at the time of fertilization.

18. If a mutation were to occur in the skin cells of an animal, this mutation
   A) would be passed on to this animal's offspring because mutations are changes
      in the chromosome structure.
   B) would be passed on to this animal's offspring because skin cells divide
      often by mitosis.
   C) would not be passed on to this animal's offspring because skin cells do not
      form gametes.
   D) would not be passed on to this animal's offspring because chromosomes do not
      duplicate in meiosis.

19. In cats, having a long tail (T) is dominant over having a short tail (t). To find
    out if a long-tailed cat is homozygous or heterozygous for this trait, you
    would mate that cat with one who has the following genotype:
   A) TT
   B) Tt
   C) tt
   D) There is no way to determine the genotype of the long-tailed cat.

20. A monohybrid cross usually involves
   A) one allele
   B) two alleles
   C) three alleles
   D) four alleles
21. The phenotype of an organism is its
   A) DNA structure
   B) progeny
   C) physical appearance
   D) chromosome count

22. One of the main differences between soma (body) cells and germinal (sex or germ) cells is that soma cells undergo cell division by
   A) mitosis only
   B) meiosis only
   C) both mitosis and meiosis
   D) neither mitosis nor meiosis

23. Sometimes during meiosis chromosomes may become twisted together and part of the chromosome break off. If the broken part reattaches in the wrong place, this will be an event known as
   A) synapsis
   B) crossing-over
   C) oogenesis
   D) intermediate breakage

24. When a black guinea pig is crossed with a white guinea pig, their offspring are all gray. If the gray offspring are mated with each other, their progeny will be black, gray, and white. Coat color in these guinea pigs is probably due to
   A) dominant and recessive genes
   B) multiple alleles
   C) test crossing
   D) intermediate inheritance

25. When a red-flowered plant is crossed with a white-flowered plant, the resulting offspring all have red flowers. This is probably because
   A) red flowers are dominant over white flowers
   B) the white flowers are heterozygous
   C) red is a more vivid color than white
   D) the white alleles do not form gametes

26. Which of the following constitutes a genetic change in an organism?
   A) Exposing a rat to radiation while taking a chest X-ray.
   B) Changes in a canary's feathers from yellow to orange from eating certain chemicals.
   C) Substitution of a guanine nucleotide for an adenine nucleotide in the DNA of a zygote nucleus.
   D) Infection of a rabbit with a virus.

27. An organ transplant from one human to another may be rejected because the body of the recipient reacts to the new organ as though it were "foreign protein". This reaction indicates that the two people involved (the donor and the recipient) had
   A) different DNA
   B) different number of chromosomes
   C) the same kind of DNA
   D) the same number of ribosomes

28. It takes three nucleotides to code for one amino acid because
   A) amino acids are larger than nucleotides
   B) there are four nucleotides and twenty amino acids
   C) some amino acids have the same triplet code
   D) a DNA strand contains less than twenty nucleotides
29. Which one of the following bases is found only in RNA?
   A) adenine
   B) uracil
   C) thymine
   D) cytosine

30. If the current theory of protein synthesis is correct, which one of the following cellular components need not be present in a newly formed cell?
   A) amino acids
   B) ribosomes
   C) DNA
   D) messenger-RNA

31. In DNA, a purine base cannot pair with another purine base because
   A) purine bases are found only in RNA
   B) purines do not contain hydrogen bonds
   C) two purine bases would be too large to fit within the DNA helix
   D) uracil is not a purine

32. On the diagram at the right, at all locations marked "X" we find
   A) ATP
   B) pyridines
   C) sugars
   D) phosphates

33. In DNA replication
   A) RNA is not involved
   B) DNA contributes nitrogen bases
   C) purines pair together
   D) the amount of cytoplasm is doubled

34. Enzymes are necessary in living systems because enzymes
   A) speed reactions occurring that would never occur
   B) reduce the amount of energy necessary for a reaction
   C) limit the types of reactions that can occur
   D) produce energy that can be stored by the cell

35. An enzyme can be made inactive by
   A) adding a substrate
   B) reducing the enzyme concentration by half
   C) blocking the enzyme's active site
   D) removing the products as they are formed
Post-test 6A

Key and Cognitive Level Designation

Total number of Knowledge questions: 5
Total number of Comprehension questions: 14
Total number of Application questions: 16
Total number of Review questions: 9

1. B Comprehension
2. C Application
3. D Knowledge
4. C Application
5. B Application
6. A Application
7. B Comprehension
8. C Application
9. A Application
10. D Knowledge
11. D Application
12. B Application
13. D Comprehension
14. A Comprehension
*15. C Application
16. C Application
Post-test 6A (continued)

17. A Comprehension
18. C Application
19. C Application
20. B Comprehension
21. C Knowledge
22. A Application
23. B Comprehension
24. D Application
25. A Comprehension
*26. C Comprehension
27. A Comprehension
28. B Comprehension
29. B Knowledge
*30. D Application
31. C Application
*32. C Comprehension
33. A Comprehension
34. B Comprehension
35. C Knowledge

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX G

POST-TEST 6B

1. The Instrument
2. Key and Cognitive Level Designation
1. A gene is primarily
   A) ATP
   B) sugar
   C) DNA
   D) protein

2. To find the genotype of an unknown individual, a test cross should be made; this would mean mating the individual of unknown genotype with an individual who is
   A) homozygous dominant
   B) homozygous recessive
   C) heterozygous dominant
   D) heterozygous recessive

3. If a cell which has twenty-four (24) chromosomes undergoes meiosis, the daughter cells formed will contain
   A) 48 chromosomes
   B) 36 chromosomes
   C) 24 chromosomes
   D) 12 chromosomes

4. Male honeybees develop from unfertilized eggs. This is an example of
   A) sexual reproduction because the male honeybee is incapable of producing sperm.
   B) sexual reproduction because the union of male and female gametes does not occur.
   C) sexual reproduction because the individual is always a male.
   D) sexual reproduction because the egg comes from the honeybee queen (female).

5. When two dihybrid individuals who are heterozygous for both traits (AaBb) are mated with each other, they produce 64 offspring. Approximately how many of these offspring would you expect to be homozygous recessive for both traits?
   A) 4
   B) 16
   C) 9
   D) 1

6. Slight differences in 10-year-old identical twins supports the hypothesis that
   A) dominance may be incomplete.
   B) genetic traits are influenced by many genes.
   C) single genes may produce multiple effects.
   D) the environment affects the expression of genetic characteristics.

7. Which of the following is homozygous for all three traits represented?
   A) AaBbCc
   B) AaBbCc
   C) AABBCc
   D) AAbbCC

8. A poultry farmer discovers that a recessive mutation which greatly increases egg production has occurred in his flock. He would like to distribute this characteristic throughout his flock as quickly as possible. Which one of the following would do this best?
   A) Use a high-production hen to sit on as many eggs as she can.
   B) Interbreed both male and female offspring of a high-production hen.
   C) Breed sons of a high-production hen with heterozygous hens.
   D) Interbreed heterozygous hens and heterozygous roosters.
9. By using a test cross one can determine whether an organism of unknown genotype is
A) homozygous recessive or homozygous dominant.
B) heterozygous or homozygous recessive.
C) heterozygous or homozygous dominant.
D) dominant or recessive.

10. Many matings of two spotted guinea pigs resulted in the following data:

<table>
<thead>
<tr>
<th>Coat Color</th>
<th>Offspring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>21</td>
</tr>
<tr>
<td>Spotted</td>
<td>48</td>
</tr>
<tr>
<td>Tan</td>
<td>31</td>
</tr>
</tbody>
</table>

Which one of the following hypotheses best explains this data?

Coat color in guinea pigs is due to
A) one pair of alleles with no dominance and no recessive.
B) one pair of alleles with dominance and recessive.
C) one pair of sex-linked alleles with dominance and recessive.
D) two pairs of alleles with dominance and recessive.

11. In a certain species of birds we are interested in two characteristics:
feather color - blue (B) is dominant over yellow (b)
and tail length - long tail (L) is dominant over short tail (l).
Each characteristic is controlled by a single gene and both are found on separate chromosomes. What is the probability of the offspring having yellow feathers, when a bird with genotype Bbll is mated with a bird of genotype bbll?
A) 1
B) 3/4
C) 1/2
D) 1/4

12. Of what importance to the scientist is the knowledge of cross-over percentages?
A) It makes possible the mapping of genes on chromosomes.
B) It neutralizes the effects of linkage.
C) It provides evidence for the structure of DNA.
D) It provides proof for the X-Y chromosome theory of sex determination.

13. Meiosis in an animal cell occurs
A) at the time gametes are produced.
B) whenever a cell divides.
C) during protein synthesis and ATP production.
D) only at the time of fertilization.

14. In a certain family there is a hair condition known as Streaking in which there is a strip of white hair running through the normal hair. The father has normal hair; the mother has streaked hair and is homozygous for this condition. Of their four children - 2 boys and 2 girls - one girl and one boy have the streaked condition. From the evidence it is most likely that which one of the following is true?

Streaking is probably due to
A) a sex-linked gene.
B) a recessive gene.
C) a dominant gene.
D) two or more genes.
The following experiment concerns questions 15 - 18.

A colony of the mold G. lusitanae grows normally on Food Source A, which is a complex food that is broken down to a simpler food by the cells. This colony was subjected to radiation for several hours; afterwards, reproductive spores from the colony were removed and grown on Food Source E, a simple food requiring no further breakdown before being used by the cells. From these irradiated spores, five (5) distinct types of mold arose, each type capable of growing successfully on a different food source. The most complex food that each type will grow on is shown in the chart below; each type will grow on the simple food E.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROWS ON</td>
<td>Food A</td>
<td>Food B</td>
<td>Food C</td>
<td>Food D</td>
<td>Food E</td>
</tr>
</tbody>
</table>

15. Which type(s) of mold resulted from mutation(s) in the original colony?
   A) I only.
   B) II, III, IV, and V only.
   C) I, II, III, IV, and V.
   D) None of the five types.

16. If A - E are compounds involved in a chemical pathway and the probable order in the sequence is A → B → C → D → E, then we would expect Type
   A) II to grow on Food C.
   B) III to grow on Food A.
   C) IV to grow on Food E.
   D) V to grow on Food D.

17. If the inability of the types of mold to grow on a more complex food resulted from lack of a single enzyme, then the enzyme lacking in Type
   A) V probably controls the reaction C → D.
   B) IV probably controls the reaction D → E.
   C) III probably controls the reaction C → D.
   D) II probably controls the reaction A → B.

18. If the DNA-RNA template hypothesis is correct, then we would expect Types I - V to possess
   A) identical DNA.
   B) identical proteins.
   C) different number of nuclei.
   D) different messenger-RNA.

19. Which of the following constitutes a genetic change in an organism?
   A) Exposing a man to radiation while taking a chest X-ray.
   B) Changes in a canary's feathers from yellow to orange from eating certain chemicals.
   C) Substitution of a guanine nucleotide for an adenine nucleotide in the DNA of a zygote nucleus.
   D) Infection of a rabbit with a virus.

20. If a red bean with the genotype Rr is crossed with a white bean having the genotype rr, out of the progeny which they can produce you would expect
   A) all to be red.
   B) all to be white.
   C) half to be red.
   D) one-fourth to be white.
Questions 21 - 23 refer to the following table.

The table below indicates the offspring produced from several matings of two cats - both cats having yellow eyes and brown fur.

<table>
<thead>
<tr>
<th>Number of Offspring</th>
<th>Eye Color</th>
<th>Fur Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Yellow</td>
<td>Gray</td>
</tr>
<tr>
<td>11</td>
<td>Yellow</td>
<td>Brown</td>
</tr>
<tr>
<td>2</td>
<td>Black</td>
<td>Gray</td>
</tr>
<tr>
<td>4</td>
<td>Black</td>
<td>Brown</td>
</tr>
</tbody>
</table>

21. The data from the table indicates that this was
   A) a monohybrid cross involving simple dominant and recessive genes.
   B) a monohybrid cross with incomplete dominance (intermediate inheritance).
   C) a monohybrid cross with linked genes.
   D) a dihybrid cross involving simple dominant and recessive genes.

22. What is the genotype of the two offspring with black eyes and gray fur?
   A) Aa
   B) aa
   C) aabb
   D) AaBa

23. If you wanted to find the genotype of one of the eleven offspring with yellow eyes and brown fur, you should cross this individual with
   A) the offspring with black eyes and gray fur.
   B) the offspring with black eyes and brown fur.
   C) the offspring with yellow eyes and gray fur.
   D) one of the parents.

24. The following information is known about the genetics of eye color in man:
   Brown eye color is dominant over blue eye color.
   Many blue-eyed people marry brown-eyed people and have mostly brown-eyed children.
   The percentage of blue-eyed people in the human population has not decreased over the last several generations.

   This data is best explained by which one of the following hypotheses?
   A) A blue-eyed individual must be homozygous for blue eye color.
   B) In human genetics, characteristics are seldom determined by a single gene.
   C) Many brown-eyed people are heterozygous for eye color.
   D) Having blue eyes is advantageous to an individual, so this characteristic will always remain in the population.

25. The phenotype of an organism is its
   A) DNA structure.
   B) progeny.
   C) physical appearance.
   D) chromosome count.

26. If a mutation were to occur in the skin cells of an animal, this mutation
   A) would be passed on to this animal's offspring because mutations are changes in the chromosome structure.
   B) would be passed on to this animal's offspring because skin cells divide often by mitosis.
   C) would not be passed on to this animal's offspring because skin cells do not form gametes.
   D) would not be passed on to this animal's offspring because chromosomes do not duplicate in mitosis.
27. If the current theory of protein synthesis is correct, which one of the following cellular components need not be present in a newly formed cell?
A) amino acids
B) ribosomes
C) DNA
D) Messenger-RNA

28. An organ transplanted from one human to another may be rejected because the body of the recipient reacts to the new organ as if it were "foreign protein". This reaction indicates that the two people involved (the donor and the recipient) had
A) different DNA,
B) different number of chromosomes,
C) the same kind of RNA,
D) the same number of ribosomes.

29. A radioactive nucleus from one amoeba is transferred to a non-radioactive amoeba which has had its nucleus removed. If, later on, the second amoeba is found to have radioactive ribosomes in its cytoplasm, this would be evidence in support of the
A) functioning of Messenger-RNA,
B) existence of the DNA code,
C) function of chromosomes,
D) existence of transfer-RNA.

30. An enzyme can be "fooled" into reacting with the wrong substrate instead of the proper one if
A) the wrong substrate is similar in physical shape to the proper substrate,
B) the wrong substrate will form hydrogen bonds with the enzyme,
C) the two substrates unite to form a new substance,
D) both substrates contain the same chemical elements.

31. An enzyme can be made inactive by
A) adding a substrate,
B) reducing the enzyme concentration by half,
C) blocking the enzyme's active site,
D) removing the products as they are formed.

32. The five events listed below occurred in algae cells in a cause-and-effect sequence. Arrange these events in their proper order of occurrence.

1 - An enzyme was manufactured at a ribosome.
2 - Cellulose, a carbohydrate, was deposited as a cell wall.
3 - Under the influence of DNA, a molecule of RNA was constructed.
4 - A carbohydrate strand was formed.
5 - A nucleic acid migrated from nucleus to cytoplasm.

The order in which these events occurred is:
A) 4-2-1-3-5
B) 5-3-4-1-2
C) 2-1-4-5-3
D) 3-5-1-4-2
33. Phenylyalanine is an amino acid normally found in bacteria. Certain bacteria were placed in a solution containing the false amino acid fluorophenylalanine. Later the protein which was produced by the cell was chemically analyzed, and it was found that the false amino acid (fluorophenylalanine) had been substituted for the amino acid phenylalanine but not for other amino acids. The best conclusion from this observation is that the false amino acid (fluorophenylalanine) probably
A) blocked the entry of phenylalanine into the cell.
B) became attached to phenylalanine's transfer-RNA.
C) inhibited the enzymes involved in the formation of phenylalanine.
D) inhibited the activation of phenylalanine.

34. The following ingredients were mixed together: ribosomes from rat cells, amino acids from guinea pig cells, transfer-RNA from bacterial cells, and messenger-RNA from rabbit cells. When these ingredients were put together in the proper concentration with ATP, proteins were made. These proteins are most likely to resemble
A) rat proteins.
B) guinea pig proteins.
C) bacterial proteins.
D) rabbit proteins.

35. Evaluate the following statement: "DNA base sequences control the formation of messenger-RNA base sequences."
This statement is
A) a fact.
B) a false statement.
C) based on unfounded evidence.
D) an assumption or theory.
Post-test 6B

Key and Cognitive Level Designation

Total number of Knowledge questions: 5
Total number of Comprehension questions: 6
Total number of Application questions: 7
Total number of Analysis questions: 8
Total number of Synthesis questions: 5
Total number of Evaluation questions: 4
Total number of Review questions: 9

1. C Knowledge
2. B Comprehension
3. D Knowledge
4. B Comprehension
5. A Application
6. D Analysis
7. D Knowledge
8. B Analysis
9. C Analysis
10. A Evaluation
11. C Application
12. A Comprehension
13. A Comprehension
14.  B  Evaluation
15.  B  Analysis
16.  A  Synthesis
17.  D  Synthesis
18.  D  Application
19.  C  Comprehension
20.  C  Application
21.  D  Analysis
22.  C  Analysis
23.  A  Evaluation
24.  C  Synthesis
25.  C  Knowledge
26.  C  Application
27.  D  Application
28.  A  Comprehension
29.  A  Analysis
30.  A  Application
31.  C  Knowledge
32.  D  Analysis
33.  B  Synthesis
34.  D  Synthesis
35.  D  Evaluation

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX H

POST-TEST 8A

1. The Instrument
2. Key and Cognitive Level Designation
1. The man who first presented strong evidence in support of the theory of evolution through natural selection was
   A) Lamarck
   B) Lyell
   C) Mendel
   D) Darwin

2. A "primitive" organism is one that
   A) has changed little over a long period of time
   B) has changed a great deal over a long period of time
   C) is not well adapted to the environment
   D) shows a low degree of intelligence

Questions 3 - 4 refer to the description below:
A population of antelope was threatened with over-population when a number of lions was imported into the area.

3. Some time after the lions had arrived, you would expect to find that
   A) there were fewer antelope and the running speed of the antelope population had decreased
   B) there were fewer antelope and the running speed of the antelope population had increased
   C) there were fewer antelope and the running speed of the antelope population had not changed
   D) there were more antelope and the running speed of the antelope population had increased

4. The statement and question above indicating a change in the antelope population is an illustration of
   A) induced mutation
   B) hereditary transmission of the results of training
   C) natural selection
   D) genetic drift

5. Which of the following best describes what Darwin meant when he wrote about the "survival of the fittest"?
   A) The organisms which could run the fastest would survive.
   B) The organisms that best fit into the environment would survive.
   C) The organisms with the most genes would survive.
   D) Only the strongest organisms would survive.

6. The lateral line system in fish is used to detect vibrations in the water and changes in water pressure. This system was lost as the amphibians evolved from the fish. This loss of the lateral line system in amphibians is probably due to
   A) loss of the tail
   B) movement to a land habitat
   C) development of eyelids
   D) changes in reproductive habits
7. In the theory of evolution by natural selection, variations among animals is due to the interaction of
   A) the organism and the environment
   B) gene pools and populations
   C) members of two different species
   D) an organism’s breeding habits and the number of offspring produced

8. In 1953 Urey and Miller performed a classic experiment at the University of Chicago. They made a mixture of gases believed to be similar to the earth’s atmosphere before life first appeared; this mixture was then exposed to electrical charges periodically for a week. After this time the residue of the gas mixture was found to contain certain organic compounds – amino acids; this was the first time organic compounds had been formed from inorganic gases.

   In order for the results to be valid, Urey and Miller must show that
   A) water vapor in the gas mixture was split into hydrogen and oxygen
   B) there were no amino acids present before the experiment began
   C) the nitrogen for the amino acids came from the ammonia gas in the mixture
   D) the pressure of the gas mixture increased to cause the ammonia gas to condense

9. Successful competition and natural selection occur because of
   A) variations between organisms
   B) homologous structures
   C) large gene pools
   D) physical isolation between groups

10. In the following examples all are homologous with the front legs of a horse except for
    A) wings of a bird
    B) arms of a human
    C) front legs of an insect
    D) front fins of a seal

11. In an experiment 250 mice had their tails cut off at the base immediately after birth. After reaching maturity, these tail-less mice were allowed to breed only among themselves to produce an F₁ generation.
    According to Darwin’s theory, what kind of tail characteristic would you expect to find in this F₁ when compared with normal mice?

    The F₁ would have
    A) shorter tails than normal mice
    B) longer tails than normal mice
    C) no tails
    D) normal tails

12. Structures on different organisms that have a similar function are
    A) homologous
    B) analogous
    C) convergent
    D) divergent
13. A species with a small gene pool has less chance of survival than a species with a large gene pool because the species with the small gene pool probably
A) cannot show as much variation
B) will have a lower mutation rate
C) cannot produce as many offspring
D) has fewer characteristics

14. Evolution is characterized by a branching pattern of descent, known as adaptive radiation. This type of pattern occurs because
A) most organisms spread out from the place where they are born
B) different organisms can cope with their environment differently
C) the environment remains relatively constant
D) organisms may become isolated from one another

15. According to Darwin, evolution is due to
A) mutation, crossing-over, and chromosome breakage
B) mutation, isolation, and selection
C) DNA, RNA, and protein synthesis
D) variation, competition, and selection

16. In his book on evolution, Kraus writes that "while mutation are generally detrimental to the individual organism, they are absolutely essential for the ultimate survival of the species." By this, Kraus means that although a mutant characteristic is usually harmful to the individual, a mutation also
A) adds new genes to the gene pool
B) makes an individual stronger
C) changes the structure of the DNA
D) becomes a dominant characteristic

17. Two groups within one population will become distinct species when
A) their number of chromosomes change
B) they become genetically isolated
C) they demonstrate different characteristics
D) they no longer look like each other

Questions 18 and 19 refer to the following statement:
Flying squirrels can glide through the air because of flaps of tissue which stretch from their front legs to their back legs. Ground squirrels have no such tissue and are unable to glide through the air.

18. The difference between these two closely related animals is an example of
A) divergent evolution
B) convergent evolution
C) analogous structure
D) homologous structure

19. The flap of tissue found in the flying squirrel is probably the result of
A) a mutation
B) speciation
C) natural selection
D) a common ancestor with the ground squirrel
20. Organisms that interbreed and potentially share the same gene pool belong to the same
   A) class
   B) kingdom
   C) biome
   D) species

21. While aboard the *Beagle*, Darwin observed similarities between animals in South America and animals he had seen in England. According to *Darwin*, these similarities were due to
   A) a common gene pool
   B) isolation by a physical barrier
   C) reproductive isolation
   D) common ancestors

22. Variation among organisms of the same species is due largely to
   A) the recombination of genes
   B) a high mutation rate
   C) reproductive isolation
   D) interbreeding with different species

23. The five events listed below are the steps necessary for protein synthesis:
   1 - Messenger-RNA and Transfer-RNA pair together
   2 - Protein strands are formed
   3 - Messenger-RNA is formed
   4 - Transfer-RNA picks up amino acids
   5 - RNA moves to the ribosomes

   The correct order in which these events occur is:
   A) 1 - 3 - 4 - 5 - 2
   B) 3 - 1 - 4 - 5 - 2
   C) 3 - 4 - 5 - 1 - 2
   D) 4 - 3 - 1 - 5 - 2

24. On the diagram at the right in all locations marked "Y" we find
   A) purines
   B) bases
   C) sugars
   D) phosphates

25. On the diagram at the right, if I is guanine, then II is
   A) adenine
   B) thymine
   C) cytosine
   D) sugar

26. DNA and RNA differ from each other in that RNA
   A) has a sugar molecule with more oxygen
   B) has a 5-carbon sugar
   C) may have thymine on it
   D) All of the above answers are correct.
27. Each nucleotide on DNA contains
   A) phosphate, sugar, and protein
   B) ATP, amino acid, and protein
   C) phosphate, sugar, and base
   D) sugar, acid and base

28. Which of the following is the best evidence for the lock-and-key theory of enzyme action?
   A) All isolated enzymes have been identified as proteins.
   B) Compounds similar in structure to the substrate inhibit the reaction.
   C) Enzymes are found in living organisms and speed up certain reactions.
   D) Enzymes speed up reactions by definite amounts.

29. Energy + Glucose + Oxygen → Carbon dioxide + Water
   The above reaction needs energy to make it proceed; consequently it is known as an
   A) energetic reaction
   B) endergonic reaction
   C) enzymatic reaction
   D) exergonic reaction

30. If a cell which has twenty-four (24) chromosome undergoes meiosis, the daughter cells formed will contain
   A) 48 chromosomes
   B) 24 chromosomes
   C) 24 chromosomes
   D) 12 chromosomes

31. Male honeybees develop from unfertilized eggs. This is an example of
   A) asexual reproduction because the male honeybee is incapable of producing sperm
   B) asexual reproduction because the union of male and female gametes does not occur
   C) sexual reproduction because the individual is always a male
   D) sexual reproduction because the egg comes from the honeybee queen (female)

32. When two dihybrid individuals who are heterozygous for both traits (AaBb) are mated with each other, they produce 64 offspring. Approximately how many of these offspring would you expect to be homozygous recessive for both traits?
   A) 4
   B) 16
   C) 9
   D) 1

33. Which one of the following is homozygous for all three traits represented?
   A) AaBbCc
   B) aaBbCc
   C) AAbbCc
   D) AAbbCc

34. Meiosis in an animal cell occurs
   A) at the time gametes are produced
   B) whenever a cell divides
   C) during protein synthesis and ATP production
   D) only at the time of fertilisation
35. In certain species of birds we are interested in two characteristics:

- Feather color - blue (B) is dominant over yellow (b), and
- Tail length - long tail (L) is dominant over short tail (l).

Each characteristic is controlled by a single gene and both are found on separate chromosomes. What is the probability of the offspring having yellow feathers, when a bird with genotype \( BbLl \) is mated with a bird of genotype \( bbLl \)?

A) 1
B) 3/4
C) 1/2
D) 1/4

36. In cats, having a long tail (T) is dominant over having a short tail (t). To find out if a long-tailed cat is homozygous or heterozygous for this trait, you would mate that cat with one who has the following genotype:

A) TT
B) Tt
C) tt
D) There is no way to determine the genotype of the long-tailed cat.

37. When a black guinea pig is crossed with a white guinea pig, their offspring are all gray. If the gray offspring are mated with each other, their progeny will be black, gray, and white. Coat color in these guinea pigs is probably due to

A) dominant and recessive genes
B) multiple alleles
C) test crossing
D) intermediate inheritance
Post-test 8A
Key and Cognitive Level Designation

Total number of Knowledge questions: 7
Total number of Comprehension questions: 15
Total number of Application questions: 15
Total number of Review questions: 15

1. D Knowledge
2. A Comprehension
3. B Application
4. C Application
5. B Comprehension
6. B Application
7. A Comprehension
8. B Application
9. A Comprehension
10. C Application
11. D Application
12. B Knowledge
13. A Application
14. B Application
15. D Comprehension
16. A Comprehension
Post-test 8A (continued)

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>17.</td>
<td>B</td>
<td>Application</td>
<td></td>
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<tr>
<td>18.</td>
<td>A</td>
<td>Comprehension</td>
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<tr>
<td>19.</td>
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<tr>
<td>20.</td>
<td>D</td>
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<tr>
<td>21.</td>
<td>D</td>
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<tr>
<td>22.</td>
<td>A</td>
<td>Comprehension</td>
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<td>23.</td>
<td>C</td>
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<td>24.*</td>
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<td>25.*</td>
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<td>26.</td>
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<td>28.*</td>
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<td>30.</td>
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<td>32.</td>
<td>A</td>
<td>Application</td>
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<td>33.</td>
<td>D</td>
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<tr>
<td>34.</td>
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<tr>
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<td>C</td>
<td>Application</td>
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<tr>
<td>36.</td>
<td>C</td>
<td>Application</td>
<td></td>
</tr>
<tr>
<td>37.</td>
<td>D</td>
<td>Application</td>
<td></td>
</tr>
</tbody>
</table>

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX I

POST-TEST 8B

1. The Instrument
2. Key and Cognitive Level Designation
1. The man who first presented strong evidence in support of the theory of evolution through natural selection was
   A) Lamarck
   B) Lyell
   C) Mendel
   D) Darwin

2. A “primitive” organism is one that
   A) has changed little over a long period of time
   B) has changed a great deal over a long period of time
   C) is not well adapted to the environment
   D) shows a low degree of intelligence

Questions 3 - 4 refer to the description below:
A population of antelope was threatened with over-population when a number of lions was imported into the area.

3. Some time after the lions had arrived, you would expect to find that
   A) there were fewer antelope and the running speed of the antelope population had decreased
   B) there were fewer antelope and the running speed of the antelope population had increased
   C) there were fewer antelope and the running speed of the antelope population had not changed
   D) there were more antelope and the running speed of the antelope population had increased

4. The statement and question above indicating a change in the antelope population is an illustration of
   A) induced mutation
   B) hereditary transmission of the results of training
   C) natural selection
   D) genetic drift

5. One hypothesis on the origin of life suggests that the first living things on earth evolved from non-living materials present in the environment. Recent experiments have shown that irradiation of a mixture of gases similar to those found in the original atmosphere resulted in the formation of adenine. This evidence supports the hypothesis that life evolved from non-living material because adenine is
   A) a nucleotide
   B) a protein
   C) an essential amino acid
   D) found in ATP, RNA, and DNA

6. Which of the following best describes what Darwin meant when he wrote about the “survival of the fittest”?
   A) The organisms which could run the fastest would survive.
   B) The organisms that best fit into the environment would survive.
   C) The organisms with the most genes would survive.
   D) Only the strongest organisms would survive.
Questions 7 - 10 on this page refer to the following experiment:

In 1953 Urey and Miller performed a classic experiment at the University of Chicago. They made a mixture of gases believed to be similar to the earth's atmosphere before life first appeared and which contained water vapor, methane, ammonia, and hydrogen gas. This mixture was exposed to electrical charges periodically for a week. After this time the residue of the gas mixture was found to contain certain organic compounds - amino acids. The following questions concern this experiment:

7. The source of energy for the chemical formation of amino acid in the experiment was
   A) methane gas
   B) sun light
   C) electrical charges
   D) ATP

8. In order for the results to be valid, Urey and Miller must show that
   A) the water was split into hydrogen and oxygen
   B) there were no amino acids present before the experiment began
   C) the nitrogen for the amino acids came from the ammonia
   D) the pressure of the gas mixture increased to cause the methane gas to condense

9. It is significant that amino acids were formed because amino acids
   A) can be made into protein strands
   B) are found in ATP
   C) are necessary for photosynthesis
   D) are found in DNA

10. The Miller-Urey experiment provides evidence in support of which of the following hypothesis?
    A) The original atmosphere of earth contained methane, water vapor, hydrogen gas, and ammonia
    B) Given a source of energy and the proper chemicals, amino acids can be formed
    C) When the earth was first formed, the atmosphere contained little oxygen
    D) The first living things on earth evolved from non-living materials present in the atmosphere

11. Which of the following is most important in predicting the direction of evolution of an animal species?
    A) high mutation rate for certain traits
    B) changes in the structure of the land
    C) selection of certain traits by environmental conditions
    D) high rate of crossing over of chromosomes
12. Structures on different organisms that have a similar function are
   A) homologous
   B) analogous
   C) convergent
   D) divergent

13. The evolution of the domestic dog from its common ancestor *Canis lupus* was most affected by which one of the following factors?
   A) mutations in its DNA
   B) frequent chromosome breakage
   C) selective breeding by man
   D) changes in its feeding habits

14. The following data concerns interbreeding among races of swallow-tail butterflies:

   - Three separate races of swallow-tail butterflies occur in the U.S. — an Eastern, a Mid-Western, and a Western race.
   - In the laboratory the races are capable of successfully interbreeding with each other.
   - In nature the territory of the Mid-Western race overlaps with both the Eastern and the Western races.
   - No interbreeding of these three races occurs in nature.

Which one of the following hypotheses best explains this set of data?

Breeding between the Mid-Western and the Eastern races does not occur in nature because
   A) the sex organs of the Eastern male are located in such a way that fertilization with a Mid-Western female is physically impossible
   B) the members of the Mid-Western race are night feeders whereas the Eastern race feeds during the day
   C) the gene pool of the Eastern race of butterflies is entirely separate from the Mid-Western gene pool.
   D) a physical barrier — the Appalachian Mountains — keeps the two races from interbreeding.

15. According to Darwin, evolution is due to
   A) mutation, crossing-over, and chromosome breakage
   B) mutation, isolation, and selection
   C) DNA, RNA, and protein synthesis
   D) variation, competition, and selection

16. In his book on evolution, Kraus writes that "while mutations are generally detrimental to the individual organism, they are absolutely essential for the ultimate survival of the species." By this, Kraus means that although a mutant characteristic is usually harmful to the individual, a mutation also
   A) adds new genes to the gene pool
   B) makes an individual stronger
   C) changes the structure of the DNA
   D) becomes a dominant characteristic
17. Two groups within one population will become distinct species when
   A) their number of chromosomes change
   B) they become genetically isolated
   C) they demonstrate different characteristics
   D) they no longer look like each other

18. In an experiment 250 mice had their tails cut off at the base immediately
    after birth. After reaching maturity, these mice were allowed to breed
    only among themselves.

    If both Lamarck and Darwin had performed this experiment, what kind
    of tail characteristic would each of them expect in the F₁ generation
    produced by these 250 tail-less mice as compared with normal mice?
    A) Lamarck would expect no tails; Darwin would expect shorter tails.
    B) Lamarck would expect normal tails; Darwin would expect longer tails.
    C) Lamarck would expect shorter tails; Darwin would expect normal tails.
    D) Lamarck would expect longer tails; Darwin would expect normal tails.

19. In a paper on evolution a student made the statement that "environmental
    changes are responsible for species changes." This statement best describes
    A) mutations
    B) genetic drift
    C) natural selection
    D) physical isolation

20. Organisms that interbreed and potentially share the same gene pool belong
    to the same
    A) class
    B) kingdom
    C) biome
    D) species

21. Which one of the following is an example of a mutation?
    A) The feathers of a canary turn pink when it eats certain chemicals
    B) A snake causes its body temperature to increase by sitting in the sun
    C) ADP is changed to ATP by adding a phosphate
    D) A guanine nucleotide is substituted for an adenine on DNA

22. Below is a set of data concerning protein synthesis:

    - Living organisms make particular proteins under the direction of
      particular nucleic acids, i.e., DNA and RNA.
    - Nucleic acids are transmitted from one generation to another.
    - Organisms of different species are unable to breed together.
    - Closely related species have more proteins in common than species
      that are less closely related.

    Which one of the following hypotheses best explains this set of data?
    A) Closely related species probably had common ancestors that bred together
    B) Closely related species may occasionally breed with one another, thus
      passing nucleic acids from one species to the other.
    C) Different species may have similar proteins because DNA passes genetic
      information to the next generation
    D) Closely related species will have similar protein because all proteins
      are made from the same 20 amino acids
23. Chromosomes are mostly made up of
   A) ATP
   B) sugar
   C) DNA
   D) enzymes

24. Consider the following:

   I = the number of adenine nucleotides on one DNA strand
   II = the number of guanine nucleotides on the same DNA strand

   How would you categorize the relationship between I and II?
   A) Item I is greater than item II
   B) Item I is less than item II
   C) Item I is equal to item II
   D) There is no way of comparing the two items

25. Which of the following is the best evidence for the lock-and-key theory of enzyme action?
   A) All isolated enzymes have been identified as proteins.
   B) Compounds similar in structure to the substrate inhibit the reaction
   C) Enzymes are found in living organisms and speed up certain reactions
   D) Enzymes speed up reactions by definite amounts

26. Phenylalanine is an amino acid normally found in bacteria. Certain bacteria were placed in a solution containing the false amino acid fluorophenylalanine. Later the protein which was produced by the cell was chemically analysed, and it was found that the false amino acid (fluorophenylalanine) had been substituted for the amino acid phenylalanine but not for other amino acids. The best conclusion from this observation is that the false amino acid (fluorophenylalanine) probably
   A) blocked entry of phenylalanine into the cell
   B) became attached to phenylalanine's Transfer-RNA
   C) inhibited the enzymes involved in the formation of phenylalanine
   D) inhibited the activation of phenylalanine

27. Glucose is converted into carbon dioxide and water in the presence of oxygen. If the specific enzymes for this reaction are not present,
   A) the reaction will proceed but will require less energy
   B) the reaction will proceed but will require more energy
   C) the reaction will occur using the same amount of energy as when the enzymes are present
   D) the reaction will not proceed

28. The theory that the nucleotides of DNA always occur in matched pairs is best supported by which piece of evidence cited below?
   A) The number of adenine and thymine nucleotides always equals the number of guanine and cytosine nucleotides
   B) The amount of ATP used in DNA replication is always the same
   C) For every purine nucleotide there is a pyrimidine nucleotide
   D) The lengths of both strands of DNA in a single helix are always the same
29. Which of the following statements best describes the function of transfer-RNA?
   A) T-RNA is responsible for enzyme manufacture
   B) T-RNA carries amino acids in the cytoplasm to the ribosomes
   C) T-RNA links with messenger-RNA to put amino acids in a specific sequence in a protein chain
   D) T-RNA carries amino acids to the messenger-RNA on the ribosome

30. The phenotype of an organism is its
   A) DNA structure
   B) progeny
   C) physical appearance
   D) chromosome count

31. A poultry farmer discovers that a recessive mutation which greatly increases egg production has occurred in his flock. He would like to distribute this characteristic throughout his flock as quickly as possible. Which one of the following would do this best?
   A) Use a high-production hen to sit on as many eggs as she can
   B) Interbreed both male and female offspring of a high-production hen
   C) Breed sons of a high-production hen with heterozygous hens
   D) Interbreed heterozygous hens and heterozygous roosters

32. If a red bean with the genotype Rr is crossed with a white bean having the genotype rr, out of the progeny which they can produce you would expect
   A) all to be red
   B) all to be white
   C) half to be red
   D) one-fourth to be white

33. The following information is known about the genetics of eye color in man:
   - Brown eye color is dominant over blue eye color
   - Many blue-eyed people marry brown-eyed people and have mostly brown-eyed children
   - The percentage of blue-eyed people in the human population has not decreased over the last several generations

This data is best explained by which one of the following hypotheses?
   A) A blue-eyed individual must be homozygous for blue eye color
   B) In human genetics, characteristics are seldom determined by a single gene
   C) Many brown-eyed people are heterozygous for eye color
   D) Having blue eyes is advantageous to an individual, so this characteristic will always remain in the population

34. Male honeybees develop from unfertilized eggs. This is an example of
   A) sexual reproduction because the male honeybee is incapable of producing sperm
   B) sexual reproduction because the union of male and female gametes does not occur
   C) sexual reproduction because the individual is always a male
   D) sexual reproduction because the egg comes from the honeybee queen (female)
35. By using a test cross one can determine whether an organism of unknown genotype is
   A) homozygous recessive or homozygous dominant
   B) heterozygous or homozygous recessive
   C) heterozygous or homozygous dominant
   D) dominant or recessive

36. In a certain species of birds we are interested in two characteristics:
   feather color - blue (B) is dominant over yellow (b)
   and tail length - long tail (L) is dominant over short tail (t).
   Each characteristic is controlled by a single gene and both are found on separate chromosomes. What is the probability of the offspring having yellow feathers, when a bird with genotype \( BbLl \) is mated with a bird of genotype \( bbll \)?
   A) 1
   B) 3/4
   C) 1/2
   D) 1/4

37. In a certain family there is a hair condition known as Streaking in which there is a strip of white hair running through the normal hair. The father has normal hair; the mother has streaked hair and is homozygous for this condition. Of their four children - 2 boys and 2 girls - one girl and one boy have the streaked condition. From the evidence it is most likely that which one of the following is true?

   Streaking is probably due to
   A) a sex-linked gene
   B) a recessive gene
   C) a dominant gene
   D) two or more genes
Post-test 8B

Key and Cognitive Level Designation

Total number of Knowledge questions: 5
Total number of Comprehension questions: 6
Total number of Application questions: 8
Total number of Analysis questions: 8
Total number of Synthesis questions: 5
Total number of Evaluation questions: 5
Total number of Review questions: 15

1. D Knowledge
2. A Comprehension
3. B Application
4. C Application
5. D Evaluation
6. B Comprehension
7. C Analysis
8. B Application
9. A Analysis
10. D Analysis
11. C Application
12. B Knowledge
13. C Evaluation
14. B Synthesis
Post-test 8B (continued)

15. D Comprehension
16. A Comprehension
17. B Application
18. C Synthesis
19. C Evaluation
20. D Knowledge
21. D Analysis
22. A Synthesis
23. C Knowledge
24. D Analysis
25. B Comprehension
26. B Synthesis
27. B Application
28. C Analysis
29. C Evaluation
30. C Knowledge
31. B Analysis
32. C Application
33. C Synthesis
34. B Comprehension
35. C Analysis
36. C Application
37. B Evaluation

*Modified from Commission on Undergraduate Education in the Biological Sciences (1967).
APPENDIX J

PERSONAL PREFERENCE TEST

1. The Instrument
2. Key and Affective Level Designation
PERSONAL PREFERENCE TEST

DIRECTIONS: For each item below mark the answer which BEST completes that item or which indicates how you feel toward that item. Mark all items; there are no right or wrong answers. Write only on the answer sheet, not on the test itself.

1. When making important decisions, a person should
   A) act according to the way he feels about the situation
   B) base his judgment entirely on the analysis of facts
   C) rely on the opinion of others who are involved
   D) make a decision that does not offend anyone

2. If I performed an experiment in lab and got results different from the students around me, I would
   A) perform the experiment again
   B) change my results
   C) work with the results that I had
   D) think that I had made an error

3. The "scientific attitude" of practicing scientists and science teachers can be seen when these people are
   A) facing a new situation at work or at home
   B) teaching a class or seminar
   C) actually engaged in research and study
   D) doing almost anything

4. When I go shopping for something, I ______ buy that item at the first place that I find it.
   A) always
   B) usually
   C) seldom
   D) I am uncertain as to what I do.

5. In performing lab experiments the best results are obtained when the student
   A) becomes emotionally involved in what he is doing
   B) is making good grades
   C) is objective
   D) persists to the end

6. I prefer discussion groups where the people involved
   A) give personal opinions
   B) become emotionally involved
   C) are willing to change their position
   D) "stick to their guns"

7. Scientific experiments can be conducted
   A) almost anywhere
   B) in the laboratory
   C) in or out of the school situation
   D) in the lab or classroom

8. When shopping for a car, a person
   A) should base his decision on an objective analysis of facts
   B) should look at several places before buying
   C) should be aware of the many choices available
   D) should seek out information about the quality of several cars
9. I prefer lab work when
   A) the directions are very detailed
   B) I am given only a few directions
   C) I am left pretty much on my own
   D) the work is fully explained

10. If the results of an experiment are not explained by an existing theory, most scientists would
   A) look for the source of error in his experiment
   B) change the theory and retest it
   C) discard the theory and start all over again
   D) show the theory to be in error

11. The most important human ingredient in interpreting the results of any lab experiment is
   A) knowledge
   B) curiosity
   C) patience
   D) open-mindedness

12. When doing a lab activity with a friend, it is best to perform the experiment together and then
   A) make separate observations but discuss your conclusions
   B) write the observations and conclusions together
   C) make observations together but draw separate conclusions
   D) both make separate observations and conclusions

13. When I go downtown to buy a large item, such as a suit,
   A) I shop for color and fashion
   B) I am interested in examining the quality of the merchandise
   C) I usually have a fixed idea in mind, and I shop until I find it
   D) I usually look in only one store

14. People should
   A) be willing to listen to other people
   B) stick firmly to their convictions
   C) change their minds less often
   D) be more skeptical of new ideas

15. The key to efficient studying is
   A) endurance
   B) advance planning
   C) quiet surroundings
   D) getting together with two or more friends

16. A scientist should
   A) work on a problem until he is satisfied with his results
   B) have the same attitude toward his personal life that he does in his job
   C) be objective in his approach
   D) only perform experiments that can be repeated and verified by others

17. Lab experiments should
   A) have one correct answer
   B) have a preferred solution
   C) give answers that are open to interpretation
   D) have answers that differ with every student
18. Working on a schedule  
   A) appeals to me  
   B) is something I never do  
   C) is all right sometimes  
   D) makes me frustrated

19. I prefer to listen to speakers who  
   A) have a clear knowledge of their subject  
   B) appeal to the emotions of the audience  
   C) have an unbiased approach to the topic  
   D) tell amusing stories during their talk  
   E) can make the audience get involved

20. In working on a lab experiment it is easiest to make errors in  
   A) setting up the experiment  
   B) performing the experiment  
   C) recording the results  
   D) drawing conclusions

21. A person who is "scientific" is usually  
   A) very smart  
   B) an introvert  
   C) impartial  
   D) quite busy

22. When a person has decided upon a course of action, he should  
   A) see it through to the end  
   B) remain open to suggestions  
   C) ignore people who try to interfere  
   D) check his progress regularly

23. I prefer to do my work  
   A) on the spur of the moment  
   B) at a regular time  
   C) when I am under pressure  
   D) when the mood hits me

24. In performing a lab experiment, the results should  
   A) have only one interpretation  
   B) be open to several interpretations  
   C) be the same for every student  
   D) depend upon one's opinion

25. I think that science has  
   A) had a positive effect on our lives  
   B) caused us to reorganize our way of living  
   C) changed our way of living  
   D) created a new set of values in our lives

26. What part of doing a lab experiment do you most enjoy?  
   A) Deciding from the instructions how to do the experiment  
   B) Performing the experiment  
   C) Interpreting the results  
   D) Explaining my conclusions to someone else
27. I prefer doing experiments
   A) where I know the kind of results to expect
   B) when I am uncertain as to what will happen
   C) in which the instructions suggest what is supposed to happen
   D) I don't like to do experiments.

28. The average person has little or no use for the methods of scientific research in his daily life.
   A) I strongly agree
   B) I agree
   C) I am uncertain
   D) I disagree
   E) I strongly disagree

29. The key to performing good experiments in the lab is
   A) advance planning
   B) working slowly
   C) good equipment
   D) endurance

30. It is difficult to make accurate observations because
   A) a person cannot see everything at once
   B) it is hard to separate observation from interpretation
   C) a person cannot always observe the small details
   D) an event will not occur the same way everytime

31. In most biology courses, it is important that the students should
   A) learn how certain biological processes work
   B) develop an open mind
   C) learn the basic facts of biology
   D) learn how to perform experiments

32. I would rather work with someone who
   A) is kind to everyone
   B) gives good directions
   C) is available when needed
   D) treats everyone fairly

33. A scientific approach to a subject
   A) is a personal approach
   B) takes a long time
   C) should be realistic
   D) requires scientific equipment

34. When I watch TV news programs and/or documentaries, I am _____ aware of it when they are slanted and biased.
   A) never
   B) seldom
   C) sometimes
   D) often

35. The methods of science can be used
   A) anywhere there is a choice to be made
   B) in the classroom and the science lab
   C) only rarely in the home
   D) in or out of the classroom
36. Suppose you had performed a lab experiment at one time, and you had gotten certain results and had drawn certain conclusions from these results. Later you performed the same experiment a second time, but this time you got different results. You would probably
   A) stick by your original conclusions
   B) propose a theory that would account for both results
   C) perform the experiment a third time
   D) recognize that you made an error

37. Problems can be solved scientifically if they
   A) require lab equipment
   B) concern science and math courses
   C) involve reasoning
   D) are solved in the classroom or lab
   E) if they result in a decision being made

38. I expect scientists and science teachers to
   A) treat everyone fairly
   B) be kind to everyone
   C) have strong personalities
   D) give good directions

39. When a scientist performs an experiment,
   A) he almost always knows what is going to happen
   B) he may use the work of other people as a starting place
   C) he is usually testing an hypothesis or a theory
   D) he is usually surprised by the results

40. I would think that most scientists
   A) enjoy investigating new areas of knowledge
   B) would be just as objective in their personal life as they are in the lab
   C) look at new problems objectively
   D) are seldom highly emotional
Personal Preference Test

Key and Affective Level Designation

Total number of Level 1 questions: 10
Total number of Level 2 questions: 11
Total number of Level 3 questions: 13
Total number of Level 4 questions: 2
Total number of All-Level questions: 4

1. Level 2
   A - Negative
   B - Positive
   C - Neutral
   D - Negative

2. Level 3
   A - Positive
   B - Negative
   C - Neutral
   D - Neutral

3. Level 3
   A - Positive
   B - Neutral
   C - Positive
   D - Neutral

4. Level 4
   A - Negative
   B - Neutral
   C - Positive
   D - Neutral
5. Level 1
   A - Neutral
   B - Neutral
   C - Positive
   D - Neutral

6. Level 3
   A - Neutral
   B - Neutral
   C - Positive
   D - Negative

7. Level 1
   A - Positive
   B - Positive
   C - Positive
   D - Positive

8. All-Level
   A - Level 4
   B - Level 2
   C - Level 1
   D - Level 3

9. Level 2
   A - Negative
   B - Positive
   C - Positive
   D - Neutral

10. Level 2
    A - Positive
    B - Positive
    C - Negative
    D - Neutral
Personal Preference Test (continued)

11. Level 1
   A - Positive
   B - Neutral
   C - Neutral
   D - Neutral

12. Level 3
   A - Positive
   B - Neutral
   C - Neutral
   D - Positive

13. Level 4
   A - Neutral
   B - Positive
   C - Neutral
   D - Negative

14. Level 3
   A - Positive
   B - Negative
   C - Neutral
   D - Neutral

15. Level 2
   A - Neutral
   B - Positive
   C - Neutral
   D - Neutral

16. All-Level
   A - Level 2
   B - Level 4
   C - Level 1
   D - Level 3
17. Level 2
A - Negative
B - Neutral
C - Positive
D - Neutral

18. Level 2
A - Positive
B - Negative
C - Neutral
D - Neutral

19. Level 3
A - Positive
B - Negative
C - Positive
D - Neutral
E - Positive

20. Level 1
A - Positive
B - Neutral
C - Neutral
D - Positive

21. Level 1
A - Neutral
B - Neutral
C - Positive
D - Neutral

22. Level 3
A - Neutral
B - Positive
C - Negative
D - Positive
23.  Level 3
   A - Negative
   B - Neutral
   C - Neutral
   D - Neutral

24.  Level 2
   A - Negative
   B - Positive
   C - Neutral
   D - Negative

25.  All-Level
   A - Level 2
   B - Level 4
   C - Level 1
   D - Level 3

26.  Level 2
   A - Neutral
   B - Neutral
   C - Positive
   D - Positive

27.  Level 3
   A - Negative
   B - Positive
   C - Neutral
   D - Negative

28.  Level 3
   A - Negative
   B - Negative
   C - Neutral
   D - Positive
   E - Positive
Personal Preference Test (continued)

29. Level 2
   A - Positive
   B - Neutral
   C - Neutral
   D - Neutral

30. Level 1
   A - Positive
   B - Positive
   C - Neutral
   D - Neutral

31. Level 3
   A - Positive
   B - Positive
   C - Positive
   D - Neutral

32. Level 3
   A - Neutral
   B - Neutral
   C - Neutral
   D - Positive

33. Level 1
   A - Neutral
   B - Neutral
   C - Positive
   D - Positive

34. Level 1
   A - Negative
   B - Negative
   C - Positive
   D - Positive
Personal Preference Test (continued)

35. Level 2
   A - Positive
   B - Positive
   C - Negative
   D - Positive

36. Level 2
   A - Negative
   B - Positive
   C - Positive
   D - Neutral

37. Level 1
   A - Negative
   B - Neutral
   C - Positive
   D - Neutral
   E - Positive

38. Level 3
   A - Positive
   B - Neutral
   C - Neutral
   D - Neutral

39. Level 1
   A - Negative
   B - Positive
   C - Positive
   D - Negative

40. All-Level
   A - Level 2
   B - Level 4
   C - Level 1
   D - Level 3
APPENDIX K

ADDITIONAL EXERCISES FOR B-ACTIVITY UNITS

1. Week 2 Activity Sheet
2. Week 3 Activity Sheet and Follow-up
3. Week 4 Activity Sheet and Follow-up
4. Week 5 Activity Sheet and Follow-up
5. Week 6 Activity Sheet and Follow-up
6. Week 7 Activity Sheet and Follow-up
7. Week 8 Activity Sheet and Follow-up
**This Activity REPLACES the prepared slide of plant mitosis.**

**WEEK 2**

**MITOSIS IN ONION ROOT TIP**

The process of cell division is known as mitosis. During this process the nucleus of the cell duplicates itself exactly (replication); this is followed by a division of the cytoplasm (cytokinesis). The result is two "daughter cells" with nuclei that are identical to each other and both identical to the original "parent" nucleus. Each daughter cell is half the size of the original cell, but with the production of new cytoplasm, the cell will grow in size.

Mitosis is best observed in living tissues that are growing rapidly - such as in the root tip of an onion. In a root the region of cellular growth (mitosis) is protected by a root cap (see the diagram at left) so that the new cells are not damaged as the root pushes through the soil. The root cap is 1mm or less in thickness, and the growing region is immediately behind it. Consequently the region of most mitotic activity is at the very end of the root - the last 2mm or so (less than 1/8 inch) from the tip.

You will now make a root slide and look for cells undergoing mitosis.

**Making an Onion Root Tip Slide**

**Materials:**
- Onion root
- Glass slide
- Coverslip
- Hydrochloric Acid (HCl)
- Toluidine blue (cellular stain)

**Procedures:**

1) Take one root from the white onions growing in the beakers on the demonstration table. Cut the root behind the root cap (1-2mm or 1/8 inch) onto a clean slide.

2) Cover the root tip with 3 or 4 drops of HCl and warm the slide gently several times over an open flame. Use the alcohol or bunson burners on the demonstration table. Do not allow the HCl to boil. Total HCl treatment should be about one minute.

3) Blot off the excess HCl and cover the root tip with toluidine blue. Warm the slide gently several times over an open flame without boiling. The stain will dye the chromosomes in the cell so they will be visible through the microscope. Total staining time is one minute.

* Modified from *Turtox News*, XLVI, No. 9 (September 1968).
4) Blot off excess stain, add a drop of fresh toluidine blue, and cover with a coverslip. Wrap the slide in a folded paper towel and squash the slide firmly with your thumb. This will spread the cells apart so they can be seen better. Try not to break the coverslip.

5) Now you can put the slide under the microscope. Use your scanning lens to locate the area of mitotic division - where the chromosomes are distinct structures.

Using your low and high power objectives, locate the various stages of mitosis on your slide. (When using your high power objective, check to see that your objective does not crush the slide.)

You will notice that not all cells undergo mitosis at the same time; many of the cells are in interphase. The dividing cells are in various stages of mitosis; you will have to look over several areas in order to find all the stages. Figure 2-18 on page 214 of your text will be of help to you in locating the stages of mitosis; remember that Figure 2-18 is animal mitosis and your slide is plant mitosis. Notice the differences between mitosis in animal cells and in plant cells.

If you have difficulty finding all the stages of plant mitosis, use the prepared slide to supplement your own slide.

6) When you have found and studied all the mitotic stages, clean your slide and coverslip thoroughly and return them to the demonstration table.

There is no follow-up for this activity.
ACTIVITY SHEET - WEEK 3

This week's lab contains several tests for chemical products commonly found in living organisms:

- Benedict test for sugar
- Iodine test for starch
- Biuret test for protein

These tests are frequently used by scientists in order to understand what chemical processes are taking place in an organism. In this special activity for week 3, you are to use the results of these tests in the same way that a scientist does. In the exercise below you should interpret the test results, draw conclusions, and formulate hypotheses as to what is taking place.

Studying the life-cycle of corn, a botanist was concerned with the distribution of starches, sugars, and proteins in certain tissues of the plant. He studied this by removing tissue from corn plants at various times while they were in the field; when the tissue was brought into the laboratory, he ran the Benedict, Iodine, and Biuret tests on them. Part of his results are shown in the chart on this page.

Our botanist was particularly interested in the changes that occurred 1) in the seeds at the time of germination and 2) in the leaves at various times during the day and night. The results of some of his tests are shown below:

<table>
<thead>
<tr>
<th>TISSUE SAMPLES</th>
<th>BENEDICT TEST</th>
<th>IODINE TEST</th>
<th>BIURET TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I - Corn Seeds</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - Dry seeds in the dark for 12 hours</td>
<td>blue</td>
<td>blue-black</td>
<td>purple</td>
</tr>
<tr>
<td>2 - Dry seeds in sunlight for 12 hours</td>
<td>blue</td>
<td>blue-black</td>
<td>purple</td>
</tr>
<tr>
<td>3 - Moist seeds in the dark for 12 hours</td>
<td>green</td>
<td>blue-black</td>
<td>purple</td>
</tr>
<tr>
<td>4 - Moist seeds in sunlight for 12 hours</td>
<td>green</td>
<td>blue-black</td>
<td>purple</td>
</tr>
<tr>
<td>5 - Moist seeds germinating - 72 hours</td>
<td>red</td>
<td>red-brown</td>
<td>purple</td>
</tr>
<tr>
<td><strong>II - Mature Corn Leaves</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 - Leaf tissue: sunny day early morning</td>
<td>red</td>
<td>red-brown</td>
<td>purple</td>
</tr>
<tr>
<td>7 - Leaf tissue: sunny day mid-afternoon</td>
<td>red</td>
<td>blue-black</td>
<td>purple</td>
</tr>
<tr>
<td>8 - Leaf tissue: cloudy day mid-afternoon</td>
<td>red</td>
<td>red-brown</td>
<td>purple</td>
</tr>
<tr>
<td>9 - Leaf tissue: at night</td>
<td>blue</td>
<td>red-brown</td>
<td>purple</td>
</tr>
</tbody>
</table>
From the chart you should be able to reach conclusions and formulate hypotheses which would explain the results of the two series of tests (on seeds and on loaves) performed by the botanist. The questions below will guide you; answer the questions in each section (I and II), and then write out your hypothesis for that section. Questions and hypotheses can be written out on this sheet.

When you have finished this activity, get a Follow-Up Sheet from the teaching assistant and compare your hypotheses with those of your botanist.

I. CORN SEEDS

Sugar is the source of energy for most cellular activities since it can be changed to carbon dioxide and water and helps the cell to form adenosine triphosphate (ATP) or chemical energy. Because sugar is soluble in water, it is not readily stored, but it can be converted to starch which is not soluble in water and is the usual storage product. When energy is needed the starch is broken down into sugar and the sugar into ATP.

A. Explain the results of test I 1 from the information above.
   Why is there no sugar in the dry seed?

B. From tests I 2 - I 4 can you determine which factor is most important in seed germination - water or sunlight?
   What tells you this?
   How much sunlight does a planted seed get?

C. What is the source of energy for the germinating seed?

D. What is the function of proteins in plant cells so that the Biuret tests are always positive?

Using the above questions (and your answers) as a guide, construct an hypothesis to explain the balance of sugar, starch, and protein in corn seeds before and during seed germination.

Corn Seed Hypothesis:
II. MATURE CORN LEAF TISSUE

Photosynthesis is the light-requiring process used by plants to produce a stable food from the raw materials of carbon dioxide and water. The food produced is in the form of sugar.

A. In what form is this food usually stored?

B. Why is there starch in the leaves in the mid-afternoon sample (II 7) but not in the morning sample (II 6)?
   When is there the most sunlight?

C. Why is there starch in the mid-afternoon leaf samples from a sunny day (II 7) but not on a cloudy day (II 8)?

D. What happens to the sugar in the leaves at night (II 9)?

E. Suggest some tests that might be used to demonstrate the importance of sunlight in photosynthesis.

F. What is the function of protein in the leaf cell?
   Is it always present?

Use your answers to the above questions to formulate a hypothesis on the factors affecting food formation and storage during photosynthesis.

Leaf Tissue Hypothesis:
In making hypotheses there is always a danger of going beyond the evidence given and assuming the hypotheses to be always "true". By its very nature an hypothesis is nothing more than an "educated guess" based on certain evidence; more tests will need to be made to show that the hypothesis is true in all cases.

I. CORN SEEDS

Sugar is the source of energy for seed germination (Question I C); the actual chemical energy used is the adenosine triphosphate (ATP) formed in the cell from the sugar. Sugar is not easily stored, but is changed to starch which can be stored. This is why the iodine test indicates starch is found in the dry seed while sugar is not (Test I 1; Question I A). When germination begins, the starch is converted to sugar (Test I 5) and the sugar is changed to help the cell form chemical energy (ATP).

Since the conversion of starch to sugar is indicative of the start of germination, this reaction can be used to show what factors are necessary for germination (Question I B). A dry seed in sunlight (Test I 2) does not show this chemical change; consequently we can surmise that sunlight is not needed to initiate the germination process. (A seed buried under the soil gets no sunlight.)

The Test I 3 shows that seeds in water for 12 hours begin to convert some of the starch to sugar; the test shows both starch and some sugar present. After 72 hours (Test I 5), the starch has been completely changed to sugar; then water must be the factor which causes seed germination to begin. Test I 4 with seeds in water and sunlight shows that although sunlight is not necessary for germination, it does no inhibit it either.

Possible Hypothesis: In corn seeds starch is converted to sugar during the process of germination; water is a necessary factor in germination whereas sunlight is not.

II. MATURE CORN LEAF TISSUE

Photosynthesis is the process whereby plants produce sugar (for use as energy). Sugar is found in the leaf tissue during the day time hours (Tests II 6-8) but not at night (Test II 9).

As the sugar is formed in the leaf, several things may happen to it: 1) some of it will be converted to energy (ATP) by the cells or 2) if there is more sugar produced than is needed, the excess will be stored as starch.
(Question II A). In the early morning (Test II 6) the sun is not very strong, and the amount of sugar produced at this time is relatively small; consequently the sugar is used by the cells rather than being stored as starch. By mid-
Mоmн (Test II 7) the strong sunlight allows the photosynthesis process to produce more sugar than can be used, and some of this is stored as starch (Question II B).

On cloudy days (Test II 8) a similar sort of situation exists. Because the amount of sunlight if reduced by the cloud cover, the rate of photosynthesis is also reduced. Consequently sugar production is reduced, and there is little stored as starch (Question II C).

Without sunlight there is no photosynthesis. This can be demonstrated in several ways (Question II E). One method might be to cover certain leaves of a plant growing in sunlight; you would expect these leaves to show no trace of sugar or starch after being in the sun. A second method would be to grow some plants in sunlight and others in the dark; the "dark" plants would not show starches or sugars in the leaf tissue whereas the "light" plants would. One problem comes up in this second method - where will the "dark" plants get their energy to live without photosynthesis? (How about the food stored in the seed.)

At night there is no photosynthesis (Test II 9). Sugar does not appear in the leaf tissue for two reasons: 1) some sugar is being converted to energy by the cell and 2) most of the sugar produced during the day has been transported to other parts of the plant for permanent storage (Question II D). (Although you would not have known the second answer, you could surmise the first answer from the information given you.) Storage may occur in the stems, roots, or seeds depending upon the plant and the time of year. But this would not be known from the data available in the chart.

Possible Hypothesis: Sugar is found in leaf tissue that is in sunlight; if excess sugar is produced, it may be stored in the form of starch. The amount of sugar produced and stored as starch depends upon the intensity of the sunlight; no sugar is produced at night.
ENZYMES IN LIVING TISSUE

Enzymes are very important proteins in living systems. They control nearly all chemical reactions in living organisms, causing these reactions to proceed far more rapidly than they otherwise could. In addition, the enzymes are not destroyed or consumed in the reaction, and they are specific for a particular reaction.

Today you will be working with the enzyme CATALASE found in plant tissue. Catalase is specific for the reaction which breaks down hydrogen peroxide by the following reactions:

\[ 2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \]

Hydrogen peroxide breaks down into water and oxygen gas.

This is the same hydrogen peroxide which is used for a bleach or for medicinal purposes and is a very toxic substance. In plant tissue it is continuously being formed by the cell, and unless it is broken down before it can accumulate, it will kill the cell. Catalase is the enzyme which speeds up the decomposition of hydrogen peroxide into its harmless components.

Objectives of Experiment:
1) to observe the effects of catalase upon hydrogen peroxide,
2) to determine the effects of various factors upon enzyme activity.

Materials Needed:
- wax pencil
- 7 small test tubes
- forceps
- test tube rack
- mortar and pestle
- celery stalk
- razor blade

Materials on Demonstration Table:
- Hydrogen peroxide
- Hydrochloric Acid
- Water bath

Procedure:
1) Using a wax pencil number five test tubes from 1-5 and fill each one-fourth full with hydrogen peroxide and place in the test tube rack.

2) Wash the celery stalk and with a razor blade cut four strips of celery all the same size — approximately 1/2" long and small enough in width to fit easily into a test tube.

Handle the strips of celery with forceps and place them on a clean, moist paper towel. Return the celery stalk to the demonstration table.
3) Using your forceps, place one strip of celery in test tube #1. Observe what occurs.

The small stream of bubbles coming from the tissue is the gas being given off as hydrogen peroxide is reduced to water and oxygen.

Save this test tube for comparison with others later on.

Write out brief answers to all the questions below. When you have finished, check your answers with the lab instructor's answer sheet.

4) Using a clean mortar and pestle, thoroughly crush a strip of celery. Dump the crushed tissue and its juices into test tube #2. Observe what occurs.

   a) Is there any difference between the reaction in #2 and that in #1?
   b) If so, how do you account for this difference?

5) Take a clean test tube and write the word "ACID" on the outside. Fill this test tube 1/4 full with hydrochloric acid from the demonstration table, and place a piece of celery in the acid. Let this sit for five minutes.

(You might prepare step 6 below while you are waiting.)

After five minutes, use forceps to remove the celery from the acid and place it in test tube #3. Observe what occurs.

   a) How do you account for any difference between test tube #3 and #1?
   b) What is the effect of acid on enzyme activity?
   c) Is this true of proteins in general? Think of what stomach acid does to meats (protein).

6) Write your initials on a clean test tube and fill it half full with water. Place a piece of celery in the test tube and put the test tube in the boiling water bath on the demonstration table; leave it for five minutes.

After five minutes, check the temperature of the water in your test tube using the thermometer beside the water bath. If the temperature of the water does not read 200°F (or 90°C), leave the test tube in the water bath a while longer; if the water in the test tube has reached 200°F (or 90°C), remove your test tube from the water bath with a test tube holder and allow it to cool. Remove the celery and place it in test tube #4. Observe what occurs.
6) (Continued)

   a) How do you account for the difference between test tube 11 and 112?
   b) What is the effect of high temperatures upon enzymes?
   c) Is this true of proteins in general? Think of what happens to egg protein (egg white) in boiling water.

7) Thoroughly clean your mortar and pestle. Obtain a piece of meat from the demonstration table and crush it in the mortar and pestle. Place the crushed meat and its juices in test tube 15. Observe what occurs.

   a) Is the enzyme catalase found in animal tissue as well as plant tissue?
   b) What characteristic of an enzyme supports the conclusion that catalase is responsible for the reaction that you observe?

Summary:
Enzymes are organic agents which
1) affect the rate of chemical reactions,
2) are not changed as the result of the reaction,
3) are specific for a particular reaction,
4) may be affected by acids and high temperatures.

When you have finished your observations:
Clean all equipment before returning it to the demonstration table.
Dispose of the acid carefully.
Do not put the pieces of celery down the sink.
FOLLOW-UP - WEEK 4

ANSWERS TO QUESTIONS FROM ENZYMES IN LIVING TISSUE

4- CRUSHED CELERY (42) VS WHOLE CELERY (41)
   a. 42 gives off more bubbles and at a greater rate than 41.
   b. The crushed cells (42) release more of the enzyme Catalase to
      break down more of the hydrogen peroxide.

5- ACID CELERY (43) VS WHOLE CELERY (41)
   a. No bubbles of gas are given off by 43; the hydrochloric acid has
      changed the structure of the enzyme and thus made it inactive.
   b. An acid may destroy enzymes.
   c. Strong acids destroy protein; for example, the action of some
      acids upon human skin, and the break down of meats by the acids
      secreted by the stomach during digestion.

6- BOILED CELERY (44) VS WHOLE CELERY (41)
   a. The boiling water has destroyed the enzyme in the celery;
      consequently no gas bubbles are observed.
   b. High temperatures make enzymes inactive.
   c. High temperatures change the structure of protein molecules;
      for example, the effects of boiling water on egg white (hard
      boiled eggs) and on commercial gelatins, such as Jello.

7- CRUSHED MEAT (43) VS WHOLE CELERY (41)
   a. Since the crushed meat causes hydrogen peroxide to be broken
      down into water and oxygen (observe the gas bubbles), you can
      assume that the enzyme Catalase is involved and is released
      from the crushed meat.
   b. Supportive enzyme characteristic:
      Enzymes are specific for a particular reaction.
ACTIVITY SHEET - WEEK 5

Diffusion and Osmosis

The movement of molecules across a cell membrane is of great interest to biologists — for this is the principle mechanism that cells have to get materials into or out of the cell. Molecules of a substance have a tendency to move from a region where they are highly concentrated to a region of lower concentration; this type of movement is known as diffusion and is brought about by the kinetic energy of the molecules. You observed the diffusion of molecules when you watched what happened to potassium permanganate crystals in a beaker of water in Exercise 1 (SSG p. 5.17).

The diffusion of molecules through a membrane (such as a cell membrane) may also take place provided the membrane has pores (holes) large enough for the molecules to pass through. Membranes often have pores large enough to allow some molecules to pass through, but these same pores may be too small for other molecules; consequently only the molecules of certain substances can pass through the membrane. This property of a membrane which allows the molecules of some substances to pass through but not those of others is known as Selective Permeability.

Like other substances, water molecules will diffuse from a region of high concentration to a region of lower concentration. Since water molecules are so small, they can diffuse through the pores of almost any membrane. Because the movement of water molecules through a membrane occurs so easily and is so important to the cell, this special type of diffusion is given its own name — Osmosis.

In this week’s activity you will be looking at the diffusion of materials through selectively permeable membranes (sometimes called semipermeable membrane). In each case that you study, you should decide what forces are at work in directing the movement of the molecules — permeability of membrane, kinds and size of molecules, concentration of each molecule, and so on. Once all this information is known, you can decide what mass movement of molecules is taking place.

EXERCISE 1 -

This exercise involves the three beakers on the demonstration cart which contain the three membrane sacs. The beakers are numbered I, II, and III. All three beakers contain a 1% sugar solution (1% sugar and 99% water). Of the three sacs, each contains one of the following solutions:
- 3% sugar solution
- 1% sugar solution
- Distilled water (0% sugar and 100% water)

The sugar molecules are too large to move through the membrane (the membrane is impermeable to sugar), but water molecules pass through easily. All three sacs were filled with their specific solution to the same amount of "fullness"; therefore any differences that you observe in the three sacs must be due to the movement of molecules through the membrane.
EXERCISE I (cont.)

For this exercise you are to hypothesize what would happen if any one of the three sacs—3% sugar solution, 1% sugar solution, and distilled water—were placed in a beaker containing a 1% sugar solution, observe the sacs in each of the three beakers, and conclude which solution must be in each sac.

The following questions may help you; answer the questions on this sheet:

A membrane sac containing a 3% sugar solution is placed in a beaker of 1% sugar solution.

1. Does the sac or the beaker have the higher concentration of sugar molecules?
2. Does the sac or the beaker have the higher concentration of water molecules?
3. Can the sugar diffuse through the membrane? Why or why not?
4. Can the water molecules diffuse through the membrane? Why or why not?
5. Will more molecules enter or leave the sac?
6. How will this movement of molecules change the shape of the sac?

Consider these questions and write your answers on the back.

Repeat the above line of reasoning with
1) a sac containing a 1% sugar solution in a beaker containing a 1% sugar solution
and 2) a sac containing distilled water in a beaker containing a 1% sugar solution.

In the space provided below, draw in the sacs as they appear in the three beakers. Note any differences in appearance between the three sacs—for example: "fullness" of each sac, is the sac floating in the beaker or has it sunk to the bottom (why would this be the case?), and so on—

POSSIBLE SAC CONTENTS
3% sugar solution
1% sugar solution
Distilled Water

BEAKER CONTENT
1% sugar solution

From your hypothesis and observations, what conclusions can you make?

The Sac in Beaker I contains—
The Sac in Beaker II contains—
The Sac in Beaker III contains—

When you have finished, check your Follow-Up Sheet for the correct answers.
EXERCISE II -

This exercise involves the two beakers (A and B) with test tubes on the demonstration cart.

When these two beakers were first set out, Beaker A contained a milky 1% solution while Test-tube A held a reddish-brown iodine solution. In the second set the solutions were reversed; Beaker B contained the iodine while the starch solution was in Test-tube B. Both test tubes were tightly covered with a selectively permeable membrane. Shake the test tubes (A and B) before you make your observations.

Observe the two beaker-test-tube sets; note any changes that have occurred by filling in the chart below:

<table>
<thead>
<tr>
<th>CONDITIONS AT START</th>
<th>PRESENT OBSERVATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OF EXPERIMENT</td>
<td>(Day: )</td>
</tr>
<tr>
<td>(Monday morning)</td>
<td></td>
</tr>
</tbody>
</table>

BEAKER A 1% starch solution - cloudy, white

TEST TUBE A Iodine solution - reddish-brown

BEAKER B Iodine solution - reddish-brown

TEST TUBE B 1% starch solution - cloudy, white

For this exercise you are to propose a hypothesis to explain the color changes you have observed. The following questions may help you - answer them on the back of this sheet:

1. What molecules are available in the two sets that might diffuse across the membrane?
2. How large are these molecules in relationship to each other?
3. What happens when iodine and starch are mixed together?
   Would the results depend upon whether the starch diffused into the iodine solution or the iodine diffused into the starch solution?
4. Which happened here? How can you tell?
5. Why did it not occur the other way?

Hypothesis:

When you have finished this exercise and formulated your own hypothesis, check your Follow-Up Sheet for the correct answer.
Follow-Up - Week 5

Both exercises this week involve the passage of molecules through a membrane.

Exercise I -

I. All beakers contain a 1% sugar solution (1% sugar and 99% water) and Sac I contains a 5% sugar solution (5% sugar and 97% water). Diffusion tends to move molecules from a place where they are highly concentrated to a place of lower concentration; consequently the water molecules would tend to migrate from the beaker (99% water) into the sac (97% water). Actually some water molecules would move in both directions, but the net flow of molecules would be into the sac.

The sugar molecules would tend to move from the sac (3% sugar) into the beaker (1%). But because sugar molecules are so large, they would be unable to pass through the membrane. Consequently there would be no movement of sugar molecules across the membrane.

The situation in Beaker I might be diagrammed as follows:

```
          SAC
            |
            |
         ---|---
          M     BEAKER
            |
            |
     3% sugar  1% sugar
    97% water  99% water
```

The end result would be that the sac would gain water molecules and increase in size (or "fullness"). Also this sac may tend to sink to the bottom of the beaker because it is heavier (3% sugar) than the surrounding solution (1% sugar).

II. Beaker II contains 1% sugar. Sac II contains distilled water (0% sugar and 100% water). Although the sugar would tend to move from the beaker (1% sugar) into the sac (0%), here again the sugar molecules are too large to cross the membrane. The water molecules would move from the sac (100% water) into the beaker (99% water); consequently the sac would decrease in size having lost some of its molecules. Also this sac may tend to float to the top of the beaker since it is lighter (0% sugar) than the surrounding solution (1% sugar).

III. Beaker III has a balanced situation. The beaker contains a 1% sugar solution (1% sugar and 99% water), and the sac contains the same thing. The water molecules would move across the membrane in both directions, but there is no mass movement of molecules in any one direction; just as many water molecules would tend to enter the sac as would tend to leave the sac. The result would be no change in the size of the sac in Beaker III.
EXERCISE II

Here we are dealing with the diffusion of three molecules - starch, iodine, and water. You already know that the starch molecule is too large to pass through the membrane, so we can discount the movement of starch. Water passes easily through a membrane but we do not know what concentrations of water are involved in the iodine solution. The big question concerns whether or not the iodine molecules can move through the membrane.

Your observations should show you that the milky starch solution in Beaker A and in Test-tube B have both turned blue-black, (Compare the color with the starch solutions in Beakers I, II, and III.) whereas the iodine solution is still reddish-brown. From your work during Week 3 you should remember that a solution of iodine turns blue-black in the presence of starch; in fact this is one of the tests for starch. And this is what has happened here. Since it is the starch solution in Beaker A and Test-tube B that has turned blue-black, rather than the iodine solution in Test-tube A and Beaker B, then the iodine must have moved into the starch solution. Therefore you can hypothesize that iodine molecules moved through the membrane at the end of the test tubes and diffused into the starch solution causing it to turn blue-black. (An alternate hypothesis might be that the membrane around the test-tube leaks, and iodine molecules are entering the starch solution in this way.)
Before reading this activity obtain one cup of peas from the Demonstration Table.

All of the peas in your beaker were taken from a single strain of peas. These peas have two characteristics which we are interested in - color and seed coat appearance.

Examine the peas that you have. You'll notice that they are of two colors - cream and pale green. At the same time you can see that the seed coat of each pea is either smooth or wrinkled. In this activity you are to determine how these two characteristics - color and seed coat - are inherited.

For all the steps below write out your answers in the space provided or on the back of this sheet. When you have finished, check your answers by obtaining a Follow-up sheet on this activity from the lab instructor.

1. Count the number of peas which have all the possible combinations of the two characteristics, e.g. the number of green peas with smooth seed coats. This is your "observed" number of peas of each kind. Enter these numbers in the chart below:

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>OBSERVED NUMBER</th>
<th>ACTUAL RATIO</th>
<th>EXPECTED RATIO</th>
<th>EXPECTED NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Number of Peas - __________

2. From the data you have observed and collected, calculate the actual ratio of the four pea types to each other:

   Actual Ratio = \[
   \frac{\text{Number of Peas of Each Type}}{\text{Smallest Number of Peas of Any One Type}}
   \]

Enter the actual ratio in the chart.

3. Is the actual ratio similar to any of the expected phenotypic ratios with which you are familiar?

   If so, enter this expected ratio on the chart.

   If not, skip to step 5.
4. From the expected ratio calculate how many of each of the four types of peas you would have expected from this same total number of peas, and enter these figures in the chart under "expected number".

For example: $9/16 \times$ Total Number of Peas

Why is there a difference between the observed and the expected number of peas of each type?

5. Of the peas that you have, how many are pale green in color? ______
   how many are cream in color? ______

The approximate ratio of green to cream is:

   _____ green : _____ cream

Of the peas that you have, how many have smooth seed coats? ______
   how many have wrinkled seed coats? ______

The approximate ratio of smooth to wrinkled is:

   _____ smooth : _____ wrinkled

6. From the data that you have, explain how color and seed coat appearance are inherited in peas. Think carefully before writing out your answer on the back of this sheet. When you finish, be sure to pick up your Follow-up Sheet and compare your answers.

Consider the following:
   Are the two characteristics determined by simple dominant and recessive alleles?

   How many genes are involved?
   How many alleles are involved?

   Are the characteristics linked to the same chromosome?
1. Inheritance chart: The number of peas may vary from beaker to beaker; consequently the numbers in your chart may be slightly different from those below.

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>OBSERVED NUMBER</th>
<th>ACTUAL RATIO</th>
<th>EXPECTED RATIO</th>
<th>EXPECTED NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cream - Wrinkled</td>
<td>115</td>
<td>11.5</td>
<td>9</td>
<td>112.5</td>
</tr>
<tr>
<td>2. Cream - Smooth</td>
<td>36</td>
<td>3.6</td>
<td>3</td>
<td>37.5</td>
</tr>
<tr>
<td>3. Green - Wrinkled</td>
<td>39</td>
<td>3.9</td>
<td>3</td>
<td>37.5</td>
</tr>
<tr>
<td>4. Green - Smooth</td>
<td>10</td>
<td>1.0</td>
<td>1</td>
<td>12.5</td>
</tr>
</tbody>
</table>

2. Actual Ratio = \[ \frac{\text{Number of Peas of Each Type}}{\text{Smallest Number of Peas of any One Type}} \]

\[ \frac{115}{10} = 11.5; \quad \frac{36}{10} = 3.6; \quad \frac{39}{10} = 3.9; \quad \frac{10}{10} = 1.0 \]

3. The actual ratio is similar to the dihybrid phenotypic ratio: 9:3:3:1

4. To calculate the expected number from the expected ratio:

   Add up the parts of the ratio - 9 + 3 + 3 + 1 = 16

   Divide this number into the Total Observed Number - 200/16 = 12.5

   Multiply this number by each part of the expected ratio -

   \[ 9 \times 12.5 = 112.5; \quad 3 \times 12.5 = 37.5; \quad 3 \times 12.5 = 37.5; \quad 1 \times 12.5 = 12.5 \]

   The expected ratio is a statistical, theoretical number rather than a real number. Differences between the observed number of peas and the expected number of peas will be due to this and to the fact that in this experiment we are dealing with a small number of peas. As the size of the sample increases, the observed number will come closer to the theoretical expected number.

5. 49 green: 151 cream or 1:3;\quad 46 smooth: 156 wrinkled or 1:3

6. Inheritance of color and seed coat in peas is due to:
   simple dominant and recessive alleles,
   two sets of genes,
   four alleles or two pairs of alleles,
   and non-linked characteristics. If the characteristics had been linked to the same chromosome, the peas would have been all green-wrinkled and green-smooth or all cream-wrinkled and green smooth (except for crossing-over) and not the four distinct types that we have here.
ACTIVITY - WEEK 7

During the embryonic development of a plant or animal, the maturing embryo is shielded from the outside world by several protective layers - the seed coat, endosperm, egg shell, membranes or others. However the embryo quickly reaches maturity and leaves its protection behind. The individual - plant or animal - is soon bombarded by environmental factors to which he must respond; these include light, food, heat, cold, moisture, gravity, oxygen, and so on. During this activity, you will take a look at three of these factors - light, gravity, and temperature.

I. LIGHT

Light is one of the environmental factors which affects plant growth. The response of an organism to light is called phototropism (photo = light, tropism = to turn). On the demonstration cart are several plants which are covered by a box with a window in the side; this window allows light to enter from only one direction.

Observe the effect of light upon plant growth by raising the lid of the box to see the plants. Replace the lid on the box after making your observation so that light will not enter from the top.

What do you observe to be the effect of light upon plant stems?

A certain growth hormone - auxin - is found in plant stems; this hormone causes the cells to enlarge and the tissue to grow. The production of auxin is inhibited by light.

Using this knowledge formulate an hypothesis that will explain the response of plant stems to light:

II. GRAVITY

Gravity also affects the growth of organisms; this is called geotropism (geo = earth or gravity). Observe the round petri dishes with corn seeds in them; each dish is standing on its edge and has four corn seeds in it.

A corn seed has a pointed end out of which will grow the new root (see diagram at right); the stem will come from the middle portion of the corn seed.

The seeds were placed in the petri dish so that the "root ends" were pointed toward the center. The dish was then made to stand on its edge as the seeds germinated.

Observe the petri dishes.

What is the response of the roots to gravity?

Of the stems?

Do not remove the petri dishes from the clay when you make your observations.
The growth hormone - auxin - is found in roots as well as stems where it causes cells to enlarge. Auxin occurs between and within the cells as a liquid; what do you think would be the effect of gravity on liquid auxin?

In the diagram to the right, shade in with your pencil that part of the germinating seed where the auxin is most likely to collect due to gravity.

Does the same thing happen to the auxin in both the stem and the root?

Is the response of the root tissue and stem tissue to gravity the same?

Formulate a hypothesis that would explain the response of stems and roots to gravity:

III. TEMPERATURE

Organisms will grow at a wide range of temperatures, but for each species or organism there is an optimum temperature at which it will grow best. You will be looking at three species of bacteria that have different optimum temperatures. They are all growing on agar slants (a type of gelatin material) that contains all the nutritional materials that the bacteria would need for growth.

A. Observe the bacteria Pseudomonas in test tubes IA, IB, and IC. All three test tubes were inoculated with Pseudomonas on Wednesday, November 11, 1970. Test tube IA was kept at 35° F for two days; Tube IB was kept at 68° F (room temperature); and Tube IC was kept at 122° F.

In what tube does Pseudomonas grow the best?
(Rate the growth as follows: greatest growth +++, ++, +, - no growth)

TEST TUBE IA: TEST TUBE IB: TEST TUBE IC:

What would you think is the optimum temperature for Pseudomonas?

Pseudomonas grows only at temperatures close to freezing and is usually found in the arctic regions. Few organisms can live permanently at temperatures below 32° F. Can you think of any reason why this is the case?

B. The bacteria Stearothermophilus is found in Test Tubes IIA, IIB, and IIC. As above these test tubes were inoculated on November 11; IIA was kept at 35° F for two days, IIB at 68° F, and IIC at 122° F.
Rate the growth of the tubes of *Stearophermophilus* just as you did with *Pseudomonas*. Observe the test tubes carefully.

Tube IIA:  
Tube IIB:  
Tube IIC:

What would you think is the optimum temperature for *Stearophermophilus*?

This bacteria is usually found in soil where full sunlight often brings the temperature to over 125° F or in hot springs where temperatures may reach even higher. Few organisms can grow at these temperatures. Can you think of what cellular materials might be most affected by these extreme temperatures?

C. Tube III contains your old friend *Escherichia coli*. *E. coli* grows in the intestinal tract of animals — including humans; it also grows at room temperatures. This tube of *E. coli* was inoculated at the same time as the other tubes.

Observe Tube III and classify the growth of *E. coli* as compared with *Pseudomonas* and *Stearophermophilus*:

Why does *E. coli* show more growth?

Like *E. coli*, most microorganisms have an optimum temperature range of about 50° F – 90° F.
FOLLOW-UP - WEEK 7

I. LIGHT

Light affects the stems of plants by slowing down the production of auxin and causing the stems to grow toward the light. Auxin is a growth hormone which, when present in the proper concentrations, causes cells to enlarge and tissue to grow.

A low concentration of auxin results in only a small amount of tissue growth; an extremely high concentration of auxin may actually retard cell growth.

Light inhibits the production of auxin; consequently the side of the stem away from the light will soon have a greater concentration of auxin than the side toward the light. (See the diagram below; the dots represent auxin concentration.) The extra auxin causes the cells on the "dark side" of the stem to grow faster than the cells on the "light side". This results in an elongation of the "dark side", and the stem bends toward the light.

PHOTOTROPISM in stems; the dots represent auxin concentration

II. GRAVITY

Auxin concentration is also affected by gravity resulting in the stems growing upward (away from gravity) and the roots growing downward (toward gravity). Gravity affects auxin just as it does any liquid - it collects at the lowest point. The diagram below shows how auxin would collect in a germinating corn seed lying on its side:

STEM: As in Section I the higher concentration of auxin in the lower side of the stem will cause those cells to elongate faster than the top cells. Consequently the lower side grows faster that the top side causing the stem to turn upward.

ROOT: In the root auxin also collects on the lower side. However the growing cells in the root are much more sensitive to auxin concentrations than are stem cells. Here the auxin concentration actually inhibits cell growth in the lower cells because the auxin is so strong whereas the reduced auxin concentration in the top cells stimulates cell growth. Consequently the root tissue on the top side grows faster than the lower side, and the root turns downward.
III. TEMPERATURES

Most organisms are limited to living at temperatures well above freezing and well below the boiling point. The reasons for this are simple:

1. Water is essential to life; if it is frozen or boiled away, then it cannot be or use to the cell. Only pure water freezes at 32°F; impure water may remain in a liquid state well below this temperature so that some organisms may grow below this temperature.

2. Most enzymes are affected by temperatures. Extremely cold or hot temperatures may cause enzymatic activities not to take place or to take place very slowly. Remember how the enzyme catalase was destroyed by being placed in boiling water in Activity 6.

3. Most proteins are destroyed (denatured) at high temperatures. Remember what happens to egg white when it is put in boiling water.

*Pseudomonas* grows best at cold temperatures because its chemical reactions occur best in the cold, and its enzymes are cold resistant. On the other hand *Streptophytophilus* has heat resistant proteins and enzymes, and grows best at temperatures above 100°F. Most organisms, like *E. coli*, favor a medium temperature range. This is why *E. coli* outgrew the other bacteria on the demonstration cart; all three have been at room temperature all week.
Man's ideas about evolution must be based mainly upon the observation and interpretation of the earth's past geological record and how this record relates to present day physical features and organisms that now occupy the earth. To help you understand how such observations and interpretations can be made, you will be performing two activities related to this aspect of scientific thinking. One activity - Evolution of the Four- Chambered Heart - allows you to interpret evidence for evolution which exists in present day animals; the second activity - Animal Tracks - deals with the type of record that may have been left as a part of geological history. In both cases you will be taking the part of the scientist in trying to find the best interpretation of the data with which you are presented.

**EVOLUTION OF THE FOUR-CHAMBERED HEART**

For the lung-breathing vertebrate the most efficient circulatory pump is the four-chambered heart with two auricles and two ventricles (see Fig. A below). With this type of heart, blood is pumped separately to the lungs - via the right auricle (RA) and right ventricle (RV) - and to the body cells - via the left auricle (LA) and the left ventricle (LV); in this manner the blood coming from the lungs and going to the body cells and which contains a high degree of oxygen is kept separated from the low oxygen blood going to the lungs. Also since the blood is pumped twice, it is traveling faster when it leaves the heart and goes to the cells of the body.

Look at the heart diagrams in Figures B, C, and D below, and compare these with Figure A. Figures B - D represent various steps in the evolutionary development of the four-chambered heart (Fig. A). Through your observations, what do you think would be the most logical order in the sequential development of the heart in Figure A?

Figure _____ —> Figure _____ —> Figure _____ —> Figure A (four-chambered)

Support your choice of stages of heart evolution by citing evidence from the diagrams. When you have finished this entire activity you can check your selected sequence against that accepted by most evolutionists.

![Heart Diagrams](Diagrams from Storer and Usinger)

All four hearts shown above (A-D) are found today in living representatives of the classes of the Vertebrates: Fish (perch, trout), Amphibians (frog, salamander), Reptiles (turtle, snake, lizard, alligator), Birds (robin, sparrow), and Mammals (dog, bear, cat). The four-chambered heart is especially adapted for lung-breathing organisms; the more active an organism is, the greater the necessity
for a more efficient heart. Knowing this can you infer which type of heart (A - D) is found in which of the five classes of vertebrates? (One heart type is found in two classes.)

Fish ____  Reptile ____  Mammal ____
Amphibian ____  Bird ____

Cite evidence for your selection. When you have finished, check your selection with the lab instructor.

**ANIMAL TRACKS ★**

In working with the evolutionary record of the earth, the scientist has to learn to interpret this record on the basis of what he can observe and what he can infer from his observations. From one's observations it should be possible to formulate one or more hypotheses; but these hypotheses should be tentative and subject to change whenever new evidence appears.

In a layer of sandstone in a mountain ridge a set of animal tracks was uncovered. Because of the difficulty of cutting through overlying layers, the sandstone could not be exposed all at once. The set of tracks was made available for observation by scientists in three separate excavation attempts; consequently, on each of the three occasions the scientists had more information to work with.

Like these scientists, you will have three opportunities to observe this set of animal tracks with each succeeding observation giving you additional information. Read all of the following instructions before you begin your observations.

Station #1 is located on the wall by the Black Board - These are the tracks that were first uncovered in the sandstone. Examine these tracks and propose several hypotheses which might explain them. For example - what kind of animals were involved? How many animals were there? Were the tracks made at the same time? How large were the animals? Write your hypotheses on the back of this page and give what evidence you have in support of these hypotheses.

Go on to Station #2 which is located on the wall near the Teaching Assistant's desk - Here are the same tracks you saw at Station #1 plus additional ones which have been uncovered more recently. Does this new evidence cause you to reformulate any of your hypotheses? Can you propose new hypotheses to cover all of the available evidence? Write out these hypotheses on the back of this page and give evidence to support them.

Station #3 is located on the exit door at the back of the lab. This is the complete set of animal tracks. Re-write new hypotheses based on this new evidence and support them with your observations. Which hypothesis do you prefer and why? Which ones have you had to abandon altogether?

When you have finished making your observations and writing your hypotheses, pick up a follow-up sheet from your lab instructor. This sheet will suggest some of the observations and hypotheses you might have made, and those you should not have made.

STATION #3
The developmental sequence accepted by most evolutionists is as follows:

Fig. D — Fig. B — Fig. C — Fig. A

These hearts represent the vertebrate classes of Fish (Fig. D), Amphibians (Fig. B), Reptiles (Fig. C), and Birds and Mammals (Fig. A).

The two-chambered heart of the fish (Fig. D) pumps the blood to the gill system where the blood becomes oxygenated, and then on to the body cells. However, the flow of blood is slowed down in the narrow capillaries of the gills. Consequently the blood is sluggish in reaching the body, and the oxygen reaches the cells at a relatively slow rate.

The three-chambered heart of the Amphibian (Fig. B) is a partial solution to the problems of the two-chambered. In the Amphibian the blood is pumped directly to the lungs and to the body cells at the same time by the single Ventricle. Thus the blood flows rapidly to the cells since it does not pass through a narrow capillary bed first. However because there is only one ventricle, the oxygenated blood from the lungs (entering the heart through the Left Auricle) and the deoxygenated blood from the body cells (entering through the Right Auricle), both come into the single ventricle at the same time, and the two types of blood mix together. Consequently the blood going to the body cells is a mixture of oxygenated and deoxygenated blood, rather than only oxygenated blood. To keep the two types of blood separated, most Amphibians have an elaborate set of grooves in the inner wall of the heart to help channel the blood in the proper direction.

The further separation of the oxygenated and deoxygenated blood is seen in the partially partitioned ventricle of the Reptilian heart (Fig. C). Although the heart has only one ventricle, this chamber is partially separated by a partition; this helps to direct the oxygenated blood coming in from the Left Auricle to the body cells (via the two blood vessels at the top right of the heart in the diagram on your Activity Sheet) and the deoxygenated blood coming in from the right Auricle to the lungs (via the single, branched vessel on the left). The partition is more prominent in some reptiles than in others.

The four-chambered heart of the birds and Mammals (Fig. A) provides a solution to both problems found in the previous hearts - the mixing of oxygenated and deoxygenated blood and keeping blood flowing rapidly to the body cells. The four-chambered heart is actually two separate pumps acting together; the Right Ventricle pumps deoxygenated blood to the lungs while the Left Ventricle pumps oxygenated blood to the body. The complete separation of the ventricle prevents any mixing of the two types of blood, and the pumping action of the Left Ventricle assures a rapid flow of blood to the cells.
ANIMAL TRACKS - FOLLOW-UP

Scientists must frequently attempt to reconstruct happenings in the geologic past. Keen observation must be combined with deductive reasoning. In this investigation you should form several defensible hypotheses and modify them as more evidence becomes available. Inferences that are made should be derived from the data presented. Your interpretation should be consistent with the evidence you observe.

Questions to consider:

1. What kinds of animals were involved?
2. Were the tracks made at the same time?
3. What incident does the picture show?
4. How many animals were involved?
5. In what directions did they move?
6. How many legs are involved?
7. Did they change their speed and direction?
8. What might have changed the footprint pattern?
9. Was the land level or quite irregular?
10. Was the soil moist or dry on the day those tracks were made?
11. In what kind of rock were the prints made?
12. Were the sediments coarse or fine where the tracks were made?

The environment or physical setting of the track area should also be included in the discussion. If we assume that dinosaurs made the tracks, then the presence of these cold-blooded creatures would suggest a warm, humid climate. If you propose that some sort of obstruction prevented the adversaries from seeing each other, this might suggest vegetation. Or, perhaps the widened pace might suggest a slope. The condition of the surface at the time the prints were made as well as the conditions necessary for their preservation should also be speculated on.

Range of results. An imaginative student should develop several defensible hypotheses. One of the most common is that two animals met and fought. There is no real reason to assume that these were natural enemies fighting to the death, although certain lines of evidence -- the quickened gaits, circular pattern, and disappearance of one set of tracks -- seem to bear this out. Perhaps some feel that a happier ending -- mother picking up baby -- is better. With the information given at Station #1, many explanations are possible. The description and temperament of the animals involved are open to question. Indeed, we lack the evidence to say that the tracks were made at the same time. The intermingling shown at Station #2 may be evidence that both tracks were made at one time but it could be only a coincidence. Perhaps one animal passed by and flew off, and then the other animal came along. We still cannot say whether the animals are friends, enemies, or just curious.

Station #3 reinforces the fight and the mother-baby hypotheses and introduces the possibility that one animal flew away. With all the available evidence there are still several defensible hypotheses that explain all the facts. Some are more likely than others but no reasonable and logical ideas can be totally ruled out.
APPENDIX L

SCHEDULE OF ACTIVITIES AND TESTS

DISTRIBUTED TO STUDENTS

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2. Winter Quarter 1971
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Schedule of Activities and Tests - Autumn Quarter 1970
### Schedule of Activities and Tests - Winter Quarter 1971

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**BIOLOGY 100**

**EXPERIMENTAL GROUPS**

**for Module** 3

**NAME**

**SECTION**
APPENDIX M

LETTER TO TEACHING ASSOCIATES IN MODULE 8
To All Teaching Assistants in Module 8:

In addition to the normal activities in the BLC, Module 8 will be the site of special testing and laboratory activities as a part of an evaluation of Biology 100 which is being undertaken by Dr. Keleca and me. Five recitation sections have been chosen to participate in this study; although Module 8 will be open to all students, only those in the specially designated sections (and they know who they are) will do the extra activities and/or tests. The five sections will not be doing all the same things; the students have a schedule of what they are supposed to do, and there is a schedule posted in the module.

The students will be doing two things: taking tests and/or performing lab activities. For the testing there will be test forms, answer sheets, and #2 pencils on your desk during the weeks that the testing takes place. There are several things that I would appreciate your doing to assist in the testing program:

1) When the student asks for a test, make sure he knows what test he should be taking; there may be several tests to be given - 2C or 4A or 4B.

2) If he does not know what test to take, have him check the schedule posted in the module.

3) When a student asks for a specific test, please give him that particular test plus an answer sheet and a #2 pencil.

4) Remind the student to return the test, answer sheet and pencil to you. The student does not have to remain in the module to take the test.

5) When the student finishes the test and returns the material, check the answer sheet for the student's name, section, and test form.

6) Put the returned test and pencil with the others, and place the answer sheet to one side.

Every week some students will be performing special lab activities. Each activity has a printed Activity Sheet with instructions telling the student what to do, a Follow-up Sheet, and a Time Record; the student will come to you for these materials. Do not give the Follow-up Sheet to the student until he has performed the activity. Special materials that the student will need to do the activity will be on the demonstration table. You can help in this part of the study in several ways:

1) Give the student the Activity Sheet and the Time Record only after he has finished the tape for that week.
2) Be sure the Activity Sheet corresponds to the BLC week — eg. Activity Sheet — Week 3.

3) After the student finishes the activity, give him the corresponding Follow-Up Sheet, eg. Follow-Up — Week 3.

4) The student must return the Time Record to you at the time that he picks up the Follow-Up Sheet. The student should keep the Activity Sheet and the Follow-Up Sheet.

5) If the student needs assistance in performing the activity, please feel free to help him as you would any other student.

I will pick up the returned Tests, Answer Sheets, and Time Records each Monday morning and will leave the Activity Sheets, Follow-Up Sheets, and Tests for the new week on your desk. I will also leave some of the old Tests and Activity Sheets for students who missed the previous week.

Thank you for your help in this evaluation. If you have any questions or would like to know more about the study, please feel free. Sincerely yours,

Jack Wheatley

Jack Wheatley
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