It was the intent of this investigation to compare the performance of community college students to four-year institutional students, both of whom were enrolled in a college general biology program (GS 101, 102, 103) during the 1967-68 academic year. During the week of May 27, 1968 measurements were taken of student performance in the two types of institutions in terms of the following important objectives of biology teaching: critical thinking; knowledge of facts and principles; comprehension; application; and a combination of analysis, synthesis, and evaluation. The criterion instruments used to measure these objectives were the Cornell Critical Thinking Test, Form Z, developed by R. Ennis and J. Millman, and a biology test developed by the researcher.

The population for this investigation consisted of full-time students enrolled in a general biology course at either of three
community colleges or two four-year institutions in Oregon. A total of 261 students were in the community college sample and 465 students were in the four-year institution sample.

**Findings**

The findings from this research were based on results of a Gauss-Markoff Setup for Multiple Measurements (analysis of dispersion) statistical design. The effects due to a difference in high school G. P. A. and sex among students in the samples were removed from the mean scores used in the statistical analysis. Resultant F values were tested at the 1 percent level.

1. There was a significant statistical difference among community colleges in terms of the behavioral objectives of knowledge of facts and principles and a combination of analysis, synthesis, and evaluation.

2. There was a significant statistical difference among four-year institutions in terms of all behavioral objectives of the biology criterion instrument. It was concluded that one of the major factors causing the difference among the four-year institutions was one additional hour per week spent in a discussion session with a biology instructor at university # 1.
3. Although significant statistical differences existed among community colleges and among four-year institutions, there was still a significant difference between community colleges and four-year institutions in terms of critical thinking ability and the behavioral objective of knowledge of facts and principles of biology. It was concluded that four-year institutional students received a superior educational experience to community college students in terms of the development of critical thinking ability. It was also concluded that a major cause of the significant statistical difference between community colleges and four-year institutions in terms of the behavioral objective of knowledge of facts and principles of biology was an overemphasis on memorization and factual recall by community college instructors.
Student Performance in Lower Division Collegiate
General Biology Programs in Selected
Community Colleges and Four-Year
Institutions in Oregon

by

Richard Robins Tolman

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I. INTRODUCTION

American higher education, with its roots in the educational institutions of Western Europe, has adapted itself in many ways to the peculiar social, economic, political, and cultural conditions and needs of its own society. Medsker (80, p. 5) notes that in this process, "... American Higher Education has created two unique institutions, found nowhere else in the world. They are the two-year college, increasingly called the community college, and the four-year liberal arts college."

Since its inception in the early years of the twentieth century, the two-year college has grown from an insignificant part of American Higher Education to a point where it can now be considered a major force in the dynamics of modern higher education. This growth is exemplified by Gleazer's (44, p. 3) report that one student in every four beginning his program of higher education during 1963 in America enrolled in a two-year college. In some parts of the country this proportion was much greater. In the 33 counties supporting two-year colleges in Florida, 64 percent of the Florida College freshmen were enrolled in community colleges. In several states, such as New York, Illinois, Michigan, and Mississippi, it is
expected that within a few years at least half of the beginning college students will go to community colleges. Moreover, Medsker (80, p. 7) showed an anticipation in California that about 80 percent of all college bound high school graduates will enroll in two-year colleges by 1970.

At present there are more than 700 two-year colleges operating in the United States enrolling nearly 1,000,000 students. In describing the current situation, Ruopp (105, p. 1) points out that one hundred and thirty new community colleges were organized between 1963 and 1966. He predicts that more than 250 additional community colleges will organize between 1967 and 1971. This growth indicates that eventually two-year college campuses will be within commuting distance of the total population.

Much of this recent growth of community colleges has resulted from a re-emphasis of the philosophy stated at the establishment of the first community college in Joliet, Illinois (96, p. 1). This philosophy of education stated the belief that:

The American way of life holds that all human beings are supreme, hence of equal moral worth and are, therefore, entitled to equal opportunities to develop to their fullest capacities. The basic function of public education then should be to provide educational opportunity by teaching whatever needs to be learned to whoever needs to learn it, whenever he needs to learn it.

In order to make this philosophy operational, an ideal image of the community college must also be stated. Gleazer (45, p. 1)
enunciates the concept of this ideal when he says:

A good community college will be honestly, gladly, and clearly a community institution. It is in and of the community. The community is used as an extension of classroom and laboratory. Drawing upon the history, traditions, personnel, problems, assets and liabilities of the community, it declares its role and finds this accepted and understood by faculty, administration, students, and the citizenry.

With an operational philosophy and an ideal image of the community college in mind, one can better appreciate the development of the present day purposes of the community college. The purposes of the community college have been restated many times during the last forty years. Such statements support the ideology of an ideal type of educational institution standing between secondary schools and four-year colleges and universities. One such statement by Crawford (19, p. 1-2) makes apparent the comprehensive view of the educational objectives of the community college in terms of the purposes it should serve:

... it is appropriate for community colleges to provide, for all persons above the twelfth-grade age levels, education consistent with the purposes of the individuals and the society of which they are a part, subject only to the restrictions in the state statutes... The educational needs appropriate for community colleges to fulfill at this time include:

1. The need for programs of liberal arts and science courses, usual to the first and second years of college, which will provide sound general and pre-professional education of such quality that credits may be transferred to a nationally or regionally accredited four-year college or university and applied toward degrees of the baccalaureate level or higher.
2. The need for vocational and technical programs in the trades, industrial, agricultural, and semi-professional fields. Such programs may be of long or short duration, depending on the amount of time needed by the student to complete the requirements for entrance into the occupation.

3. The need for programs of courses for adults and other community college students, for which credit may or may not be given, designed to provide general education and to improve self-government, healthful living, understanding (of) civic and public affairs, avocational growth, constructive use of leisure time, personal and family living satisfactions, cultural depth, and to facilitate occupational advancement.

4. The need for individual services to students including guidance and counseling, assistance in career selection, removal of deficiencies in preparation for college programs, personality and health improvement.

5. The need for programs and services for individuals and groups interested in cultural, civic, recreational or other community betterment projects.

This list of purposes concisely illustrates the uniqueness of the community college as compared with the secondary school and the university. Because the community college stands between these two segments of the public educational system, it must and does face simultaneously in both directions, serves the needs of students who intend to complete the requirements for a baccalaureate or higher degree and at the same time, provides other needed educational services to a complex society. These purposes can be viewed in a number of different ways. First, the college provides educational services for young people who will eventually transfer to four-year
colleges as well as for those who will terminate their formal studies at the end of one course, one term, or the two-year period. Second, the college makes available various adaptations of standard courses and sequences of study for specific individual and societal needs.

The two-year college is probably more diverse in defined functions, programs, clientele, and philosophical bases than any other educational institution in existence. Fields (37, p. 63-95), in his analysis of community and junior colleges, identified five fundamental characteristics which he thought clearly established the uniqueness of this institution.

1. Democratic - low tuition and other costs; nonselective admission policies; geographically and socially accessible; and popularized education for the largest number of people.

2. Comprehensive - a wide range of students with widely varying abilities, aptitudes, and interests; a comprehensive curriculum to meet the broad needs of such students.

3. Community centered - locally supported and controlled; local resources utilized for educational purposes; a community service improving the general level of the community.

4. Dedicated to life-long education - educational programs for individuals of all ages and educational needs.

5. Adaptable - to individual differences among students, differences in communities, and the changing needs of society.

Thus we see that the comprehensive community college is an organization of and for the people it serves. Its services are not
confined exclusively to the traditional functions of the four-year colleges, but include activities which contribute to the general upgrading of society as a whole. Therefore, this study was confined to an evaluation of programs in only one phase of community college activity; that of the lower division collegiate transfer education.

Development of Community Colleges in Oregon

Population growth and society's changing educational demands in Oregon and throughout the nation have brought new responsibilities to Oregon's educational system. Important and revolutionary developments have taken place in industry, business, and agriculture and various means by which men and women earn their livelihood. The success of individuals depends upon their receiving an adequate education.

A great deal of study was given to post-high school education in Oregon and considerable legislation, as shown in "Education Beyond the High School" (90, p. 7-13), was produced during the second quarter of the century. But the legislation, which contained excellent philosophy, provided little financial assistance to implement the fine intentions of its sponsors. Thus, after many years of consideration, the community college movement is relatively new in Oregon. The 1961 Oregon State legislature finally came to grasp with the persisting issue and provided substantial state financial assistance for operation
and building construction. The legislature passed Public Law ORS 341.510 establishing the comprehensive community college which was responsible to the State Board of Education, and was defined as (93, p. 1)

... a public secondary school established by a school district or by an area education district to provide terminal two-year programs for some, serve a transitional purpose for others who will continue college work, serve to determine future educational needs for other students, and provide means for adults to continue their academic education, vocational training, or attain entirely new skills as old occupations cease to exist and new technologies supplant them.

The comprehensive community college will carry an increasingly important role in the post-high school education of the youth and adults of Oregon's communities. The Oregon Community College Annual Report 1963-1964 (94, p. 33) states that in 1962 the total community college full time enrollment was 2884, or approximately 5 percent of all Oregon's post-high school students. This report predicts that by 1980 there will be nearly 50,000 community college students, or approximately 50 percent of all college students in Oregon. Various types of post-high school education are needed and desired. The community college has the resources and the capacity for flexible organization to fulfill these needs and desires and to do so at a low cost to the student.

Although Oregon's community colleges have developed from diverse backgrounds within their individual locales, and their
educational programs have been designed to meet the needs of given areas, every community college has the following structure for its program (93, p. 12):

1. Lower division collegiate

2. Vocational-technical and semi-professional programs for full-time and part-time students

3. General education for full-time and part-time students.

This study was concerned with lower division collegiate programs as designated by the Oregon State Department of Education (94, p. 11)

... as a transfer curriculum offering classes in the broad areas of fine arts, business, foreign languages, humanities, sciences, social sciences, and physical education. Students can complete freshman and sophomore requirements prior to pursuing a baccalaureate degree as a junior in a four-year institution.

The curricula for these as described in The Oregon Community College Annual Report 1963-1964 (94, p. 18) are

... primarily transfer programs directed towards the pursuit of a baccalaureate degree, prescribed by the Oregon State System of Higher Education and intended to be parallel in content to freshmen and sophomore courses in the state's four-year institutions of higher learning.

**Statement of Problem**

The purpose of this study was to compare the performance of community college students to four-year institutional students, both of which are enrolled in a general biology program consisting of three
hours of lecture and a two or three-hour laboratory period per week. The general biology sequence (General Science 101, 102, and 103) may not be taken for credit if the student has completed six or more hours in a college level course in a biological science.

After completion of the program, measurements of student performance from the two types of institutions were taken in terms of five important levels of behavioral objectives of biology teaching—critical thinking; knowledge of facts and principles; comprehension; application; and a combination of analysis, synthesis, and evaluation.

**Definition of Terms**

Many of the terms used in this study are defined as they are first introduced in the text of the dissertation. However, for purposes of clarity and emphasis, those terms which are cardinal to an understanding of the investigator's intent are here defined.

**Community College Collegiate Student**

Those students enrolled in the transfer program for twelve quarter hours or more per term at three selected Oregon Community Colleges—Lane Community College, Portland Community College, and Southwestern Oregon Community College.
Four-Year Institution College Student

Those students enrolled in a four-year undergraduate curriculum for twelve quarter hours or more per term at Oregon State University or Portland State College.

Critical Thinking

Good (46, p. 424) defines critical thinking as thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions cautiously through the consideration of all pertinent factors. This concept of critical thinking was more precisely defined by the author of the critical thinking test used in this study as, "... the ability to correctly assess statements" (35, p. 599). Statements on this test were designed to measure proficiency in:

1. **Induction**: ability to judge whether a simple generalization or hypothesis is warranted.

2. **Reliability**: ability to judge whether an observation statement is reliable.

3. **Deduction**: ability to judge whether a statement follows from the premises.

4. **Assumption-finding**: ability to judge whether a statement is an assumption.
Critical thinking, as used in this study, refers to student proficiency in these four abilities.

**Behavioral Objectives**

The instrument used to measure the students' knowledge of the principles of biology consisted of items which covered six behavioral objectives. These objectives are:

1. **Knowledge**: Knowledge as defined here involves **RECALL**. The knowledge objectives emphasize most the psychological processes of **REMEMBERING**. To use an analogy, if one thinks of the mind as a file, the problem in a knowledge test situation is that of finding in the problem or task the appropriate signals, cues, and clues which will most effectively bring out whatever knowledge, relevant to the situation, that is filed or stored in the mental file (16, p. 5-1).

2. **Comprehension**: Comprehension represents the basic level of understanding. It refers to a type of understanding or apprehension such that the individual knows what is being communicated and can make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implications. Comprehension is the ability to make use of materials or ideas (16, p. 5-2).

3. **Application**: Application involves the use of abstractions in particular and concrete situations. The abstractions may be in the form of general ideas, rules or procedures, or generalized methods. The abstractions may also be technical principles, ideas, and theories which must be remembered and applied (16, p. 5-2).

4. **Analysis**: Analysis involves the breakdown of a scientific report into its constituent elements or parts such that the relative hierarchy of ideas is made clear and/or the relations between the ideas expressed are made explicit. Such analyses are intended to clarify the communication, to indicate how the communication is organized, and the way
in which it manages to convey its effects, as well as its basis and arrangement. Analysis is the dissection of a scientific paper, abstract or problem solving procedure (16, p. 5-3).

5. Synthesis: Synthesis involves the putting together of elements and parts so as to form a whole. This involves the process of working with pieces, parts, elements, etc., and arranging and combining them in such a way as to constitute a pattern or structure not clearly there before. Synthesis is the putting together parts or elements so as to produce a new pattern or structure (16, p. 5-3).

6. Evaluation: Evaluation involves judgments about the value of material and methods for given purposes. Quantitative and qualitative judgments about the extent to which material and methods satisfy criteria. Use of a standard of appraisal. The criteria may be those determined by the student or those which are given to him (16, p. 5-4).

Basic Assumptions

In this study it was assumed that:

1. The high school composite G. P. A. is a valid and reliable measure of the student's general aptitude for college work.

2. Any significant statistical difference between the selected community colleges and four-year institutions on the tests are the result of real differences in the variables under comparison.

3. The Cornell Critical Thinking Test measures the students' ability to think critically.

4. The items in the instrument used to measure the students' knowledge of the principles of biology validly and reliably
measure the designated behavioral objectives.

5. The non-science major general biology programs at the four-year institutions used in this study are representative of those found at other four-year institutions in Oregon.

6. The non-science major general biology programs at the community colleges used in this study are representative of those found at other community colleges in Oregon.

Questions To Be Investigated

In order to determine the quality of student performance in non-science major general biology curricula at Oregon's community colleges, the following questions were tested:

1. Is there a significant statistical difference in student performance among four-year institutions or among community colleges as measured by the combined scores of the Cornell Critical Thinking Test; knowledge subtest; comprehension subtest; application subtest; and combined analysis, synthesis, and evaluation subtest when the effects of high school G. P. A. and sex are removed?

2. Is there a significant statistical difference in student performance between four-year institutions and community colleges as measured by the combined scores of the Cornell Critical Thinking Test; knowledge subtest;
comprehension subtest; application subtest; and combined analysis, synthesis, and evaluation subtest when the effects of high school G. P. A. and sex are removed?

Delimitations of the Study

This study was subjected to the following delimitations:

1. The population for this study was limited to a sample of those students enrolled in lower division general biology programs at Lane, Portland, and Southwestern Oregon Community Colleges, Oregon State University, and Portland State College during the 1967-68 academic year.

2. Critical thinking ability and ability to answer general biology questions at the behavioral levels of knowledge, comprehension, application, analysis, synthesis, and evaluation were the only factors of concern in this study.

3. The instrument used to measure critical thinking abilities was a 60 minute test limited to the following aspects of critical thinking:
   a. Induction: evaluation of evidence for or against a hypothesis.
   b. Reliability: evaluation of the reliability of information.
   c. Deduction: logical reasoning ability.
4. The instrument used to measure students' knowledge of the principles of biology was a 60 minute test limited to those topics presented in the general biology programs at the selected institutions. The items were chosen by the researcher and evaluated by a critique jury of experienced general biology teachers.

5. High school composite G. P. A. and sex were used as covariables to adjust for differences in native ability between students. The high school composite G. P. A. was obtained from the participating institutions.

Importance of the Study

Increasingly, the community college is the means by which states are equalizing and expanding educational opportunity beyond the high school. Many state universities and state colleges have raised their standards for admission as well as tuition rates, which means that students of lesser opportunities, either academically or economically, must turn to community colleges in the public educational system. Furthermore, according to Medsker and Knoell (66, p. 1), several heavily populated states such as California, New York, Ohio, and Illinois, are encouraging students to take the first two years of a four year program in the community college.

Although Oregon's young community college program is just
beginning to reflect these national trends, pressures will increasingly be placed on the community college to furnish a greater percentage of the lower division collegiates' education in the state and to maintain the principles of public post-high school education to which the people of Oregon subscribe. An example of this was seen in an October, 1966 address to the Oregon League of Women Voters by Milosh Popovich, Dean of Administration at Oregon State University, who predicted that by 1980 nearly 80 percent of the Oregon State University student body would be comprised of upper division and graduate students. This statement certainly indicates the significant role that the Oregon community college will play in lower division collegiate education. Therefore, if success in additional education beyond the fourteenth year is to be assured to students whose aptitude and achievement qualify them for it, it is critical that the community colleges, in addition to their several other functions, offer lower division collegiate programs that are comparable in content and quality to that of the four-year institutions.

This dissertation is a companion study to A Comparison of Student Performance in Lower Division Collegiate General Chemistry Programs Between Selected Community Colleges and Four-Year Institutions in Oregon, by C. O. Denney (24).
II. REVIEW OF RELATED RESEARCH

Objectives of Science Education

The Thirty-First Yearbook of the National Society for the Study of Education was one of the first attempts to help set the course of science education in the United States. Since this yearbook was published, a great deal of importance has been placed upon the role of science education in our society and upon the formulation of concrete statements of objectives for science education.

Publications by the Educational Policies Commission of the National Education Association (28), the National Society for the Study of Education (86), Nelson (89), McGrath (79), Richardson (102), Burnett (10), Hurd (58), the United States President's Scientific Research Board (119), the National Science Teachers Association (115), the Commission of Science of the American Association for the Advancement of Science (72), and Cohen (15), have all suggested possible objectives for science education.

In 1966, Tyler (118, p. 11-14) presented the report of a committee of science teachers, curriculum specialists, and scientists called together by the Educational Testing Service. They stated that students should come to:

1. Know the fundamental facts and principles of science.
2. Possess the abilities and skills needed to engage in the processes of science.
3. Understand the investigative nature of science.

4. Have attitudes about and appreciation of scientists, science, and the consequences of science that stem from adequate understanding.

Although the statements of objectives of the various scientists, science educators, committees, and associations are not exactly the same, some general areas of agreement emerge. These common areas are:

1. To be able to think critically and to evaluate facts and data.

2. To gain an understanding of the fundamental facts and principles of science.

3. To understand the investigative nature of science and its role in our society.

4. To have appreciation of science and scientists.

Studies in Critical Thinking

Burton, Kimball, and Wing (11), Dale (21), Dressel (27), Edwards (29), and many others have stated that one of the principle goals of education should be to teach students to think. Burnett (10), and Richardson (102), specify critical thinking as one of the major goals of science education.

The number of studies devoted to critical thinking is exceedingly large. To facilitate the review of this research, two categories were used; the nature of critical thinking and the teaching of critical thinking.
The Nature of Critical Thinking

Edwards (29, p. 269-270) stated:

The teaching of critical thinking in the schools is established as an objective by means of an authoritative, dogmatic statement. Accepting this objective there are many teachers who try hard to improve the critical thinking of their pupils. They are not content to assume that proof of the acquisition of knowledge is also proof that such knowledge will be rightly used.

It appears that ability to do critical thinking is a valid objective of the schools in that it is possible to isolate techniques of critical thinking and test for the acquisition of skill in the use of these techniques.

On the other hand, if pupils are to be taught to think they must first be given something to think about. Thinking is possible only with familiar concepts for most people. Pupils will not, in general, be able to think about materials to which they have been merely exposed.

Many factors seem to be related to critical thinking abilities, but there are conflicting reports in the literature. The Watson-Glaser Critical Thinking Appraisal was reported to have a correlation of .48 to .68 to several intelligence tests. In a study involving high school students, Teichman (116, p. 268-279) reported that intelligence was related to the students' ability to reach conclusions on items in science. Alpern (1, p. 220-226) reported a positive correlation between intelligence quotient and high school students' ability to devise or choose tests of scientific hypotheses. The studies by Alpern (1), and also Furst (40), seem to support the hypothesis that students have a critical thinking ability in much the same manner as they have intellectual ability. However, Sorenson (112), reported no
relationship between a student's mental ability and change in critical thinking ability, based on the results of the Watson-Glaser Critical Thinking Appraisal and the Cornell Critical Thinking Test, Form X.

In a more striking contrast, Mandell (76), reported a negative relationship between intelligence quotient and improvement in critical thinking ability. His subgroups having average or below-average intelligence scores showed a significant increase in critical thinking and achievement when compared to the sub-group having above average intelligence.

Kopans (69) stated that complex abilities, such as critical thinking, develop slowly. Using selected items from the Watson-Glaser Critical Thinking Appraisal, he found that when controlled by age and intelligence, social science majors showed significant improvement over science majors, but only on the controversial items on the appraisal form. There were no significant differences on the other aspects.

Fox (39, p. 357), in a discussion of the nature of critical thinking, stated:

Procedures which were reported to be most difficult to use require higher levels of critical thinking on the part of the students -- to analyze, interpret, and evaluate information; and to determine the most reasonable and logical conclusions. The procedures which were reported to be the least difficult to use are the procedures for gathering information, and most of them require only a passive type of thinking or learning on the part of the students -- to gain information from audio-visual aids, to gain information by listening to others. This doesn't mean that such activities are without value, on the
contrary, they are essential procedures for developing skill in critical thinking and for solving problems. However, they are only preliminary steps in critical thinking, not ends in themselves.

The Teaching of Critical Thinking

Edwards (29), reviewed studies by Fawcett in geometry, Glaser in language arts, and Thelen in Chemistry which concluded that pupils can be taught to think critically. He also reported that chemistry students in an experimental group showed significant gains over control groups after having been exposed to activities designed specifically to develop critical thinking abilities.

Hurd (59), in a review of several studies in science education, stated that Weisman found that students could be taught critical thinking skills when a course is structured about problems and problem-solving activities.

Brown (8) reported that chemistry students made greater gains in growth in critical thinking ability than non-chemistry students, as measured by the Cornell Critical Thinking Test, Form X.

Chenowith (13), and Herber (55) both reported that students made significant gains in critical thinking when exposed to materials which were specifically designed to improve this ability. Herber (55) also reported that sex, grade, and course effect the development of critical thinking ability.
In a study involving nineteen universities and colleges, Dressel and Mayhew (27, p. 390-391) stated that institutions offering critical thinking courses had no advantage over other institutions, since only small gains were recorded in critical thinking ability in a course of this type. These researchers found that the greatest gain in critical thinking ability occurred during the freshman year and that greater gains were registered when an entire curriculum was devoted to the development of critical thinking abilities. They concluded that the objective of critical thinking was frequently not attained because the activities only involved reading or studying about the thinking of others.

Mason (78, p. 283), in a study of scientific thinking in a college biological science course, concluded:

1. The ability to think scientifically can be a concomitant outcome of science education.

2. Ability to think scientifically can be taught more effectively when the students are given direct training in the methods of science than when they do not receive such training.

3. Problem-solving can be an effective method for teaching both facts and skills inherent in the methods of science.

Henderson (52) reported an experiment on the teaching of logical and critical thinking which involved approximately 1500 high school students in English, geometry, and social studies. Activities designed to foster critical thinking were used, and the mean gain during one school year was in favor of the experimental class when measured by
the **Watson-Glaser Critical Thinking Appraisal**. Mean gains on the **American Council on Education Test of Critical Thinking** were not significant at the five percent level.

Rust (107) reported an attempt to teach critical thinking which involved approximately three thousand students. About one-third served as a control, while the remainder were given activities involving critical thinking in connection with classes in English, mathematics, science, and social studies. Few significant differences were found between experimental and control groups, but the testing produced a low intercorrelation among the **Watson-Glaser Critical Thinking Appraisal**, the **American Council on Education Test of Critical Thinking**, and a test of critical thinking constructed by the investigator.

Wallen (120), in an investigation involving seven U. S. history teachers, found that the experimental groups, which had received a three week introduction involving critical thinking activities, registered a significant increase in critical thinking ability over the control group, which did not receive the introduction. These results were obtained with the **Induction, Deduction, Semantics Critical Thinking Test** constructed by Ennis (32), but when tested by the **Watson-Glaser Critical Thinking Appraisal**, no significant differences were recorded.

Howe (57, p. 202), in a study of biology teaching in Oregon, reported that positive gains in critical thinking were obtained in 44
of 51 biology classes studied. He used the Watson-Glaser Critical Thinking Appraisal in a pretest and post-test design. The majority of the high gains in critical thinking ability were obtained in classes using the problem-solving approach with instruction and practice in critical thinking.

Kastrinos (62) reported that two different levels of biology classes, which utilized a principles-critical thinking approach, produced significant improvements in critical thinking when compared to traditional courses taught by the same instructors. The results were obtained with the Watson-Glaser Critical Thinking Appraisal.

Sorenson (112) reported that students in laboratory-centered high school biology courses registered significant gains in critical thinking when mean scores on the Watson-Glaser Critical Thinking Appraisal and Cornell Critical Thinking Test, Form X were controlled by intelligence scores.

Crall (17), in a study of high school biology students, compared an experimental class involving learning and application of principles with a traditionally taught class. Both the control and experimental group registered gains in critical thinking ability as measured by written tests and teacher observation. He noted that a direct method of instruction produced a higher degree of gains in critical thinking ability.

Kemp (63), in a study involving students with "open" belief
systems and "closed" belief systems, reported that students with "open" belief systems registered significantly higher achievement in critical thinking. He also reported that small groups of students involved in direct instruction showed the greatest gains in critical thinking skills.

Yudin (124) found that an experimental college freshman group involved in a program designed to improve critical thinking showed no significant gains in critical thinking ability when comparing two methods of instruction.

Richert (103) reported that students involved in a one semester experimental physical science course which provided opportunities to analyze problems, to examine assumptions, to collect and organize data, and to test hypotheses, registered significantly greater gains on the American Council on Education Test of Critical Thinking than students in a physical science survey course and students in a physics course.

Lee (72), in a post-test only design, studied the effect of two methods of teaching high school chemistry upon critical thinking abilities. After an eleven-week period, there were no significant differences between the experimental group, which engaged in problem-solving activities, and the control group, as measured by the Watson-Glaser Critical Thinking Appraisal.

Anderson (3), in a comparative study involving Chemical
Education Materials Study and traditional chemistry, reported no significant differences between the two groups, as measured by the Watson-Glaser Critical Thinking Appraisal.

Boeck (7), Edwards (29), and Montague (81) conducted separate studies involving experimental chemistry classes emphasizing critical thinking processes, and in each case the experimental groups showed significant gains when compared to the control groups.

Fogg (38) evaluated the effect of two different testing techniques on the critical thinking ability of 551 university freshmen. In the experimental test, the student was required to indicate all alternatives which he felt were wrong. The control test was the standard five-choice multiple-choice type of examination. The gains registered by the experimental group were significantly greater than those of the control group, as measured by the Watson-Glaser Critical Thinking Appraisal.

Graham (47) investigated the effect of student-centered classes on critical thinking ability. Eighty students were matched using scores on the Otis Mental Ability Test and the Watson-Glaser Critical Thinking Appraisal as pre-tests. The experimental group registered significantly greater gains over the control group taught by the same instructor.

Dressel and Mayhew (26) concluded that minor changes in a course are not adequate to bring about changes in critical thinking
ability when the major emphasis of a course remains on the coverage of content.

Lehmann (73) studied changes in critical thinking abilities of 1,051 students at Michigan State University from the beginning of freshman orientation week until near the end of the senior year. Using the American Council on Education Critical Thinking Test, he found that the greatest change occurred during the freshman and sophomore years. He also found that males did not gain significantly in critical thinking abilities over females.

Craven (18), in a study involving teacher-candidates and in-service teachers at Oregon State University, reported that the critical thinking abilities of science teacher-candidates were significantly greater (at the five percent level) than those of freshmen in social science education, freshmen in science education, elementary teacher-candidates, and in-service science teachers.

Dressel and Mayhew (26, p. 180-181) summarized the nature of critical thinking research to date:

Much of the research accomplished to date has been divorced from teaching practice. In this same connection, there is a noticeable lack of suggestions and evidence as to how critical thinking can be taught. Still one further weakness in critical thinking research lies in the fact that the way it is presented too often suggests that emphasizing critical thinking can be a mechanical sort of operation tacked onto some particular college course.

Having pointed out the lack of adequate research to date, we are constrained to advance some ideas which we believe
might be fruitful in the area of critical thinking. Perhaps the first step in the development of major research in this area is for teachers to become concerned about the development of thinking on the part of their students. So long as teachers are unaware or unconcerned about the apparent fact that imparting information by means of class lectures or reading textbooks is relatively ineffective in the development of the higher mental processes, the importance of research in connection with critical thinking is likely to be overlooked.

To fulfill the major need of research in connection with critical thinking, it is essential for such research to be basically oriented toward and integrally related to classroom practice.

Glaser (43, p. 418), in discussing the objective of thinking, stated:

Such evidence as there is points to the development of critical thinking as a long term task in which but small gains will be shown for any particular course. It is, therefore, of the utmost importance that fostering the ability to think critically becomes the aim of all teachers for the entire period of a student's schooling . . . Critical thinking, then, is evidently the deserved goal of education in the achievement which promises that there will be a life-long interest in learning.

It appears, then, that critical thinking abilities can be developed in students when specific activities are directed toward this goal.

Critical thinking should be an essential objective of modern education, and not simply something that is hoped will be developed during the pursuit of other objectives.

Four-Year Institution - Community College Comparative Studies

The success of community or junior college students in upper division collegiate work has been reported by many investigators.
Grossman (48) and Koos (68) found over thirty years ago that junior college students were able to pursue junior and senior level course work at universities with equal or greater success than native university students. Eells (30) reported similar findings over thirty years ago at Stanford University. More recently, Henry (54), Klitzke (65), Martorana (77), and Medsker (80) reported similar findings.

Although the above studies indicate that junior college transfers are capable of success in upper division university work, Hennessy (53) reported that transfer students at the University of Michigan had lower grade point averages than native university students. He also noted that female transfer students were particularly deficient.

Nall (82) reported that junior college transfer students at the University of Colorado are academically less successful in both scholarship and persistency than are native university students. One notable exception emerged however--transfer students in the college of engineering equaled or excelled matched native students in scholastic average.

Hagie (49) reported that junior college students were different from university students in that they came from lower socio-economic families, were more interested in semi-professional preparation, were attracted by the lower cost junior colleges, and generally lived within short commuting distance of the junior college. Some of these findings were supported by Rice (101) who reported that white
Mississippi junior college students, when compared with similar white undergraduate lower division university students, came from the lower socio-economic levels, scored significantly lower on tests of academic aptitude, and indicated a lower educational level reached by their parents.

Howard (56, p. 97-98) reported the following:

The typical male freshman at Oregon State University was primarily oriented toward specific vocational goals in the scientific and technological areas. He attended high school in a relatively large community in Oregon, and obtained a B grade point average. Although practically self-supporting, he believed his family capable of paying his college expenses. His interest was in acquiring knowledge because it was useful, but he had relatively little concern for aesthetic or social values. The community college male, who was somewhat older because his schooling had been interrupted, believed that education had value in attaining economic success. The income of his family was not sufficient to provide for college training and he was expected to provide the financial cost himself. He expressed more concern for social welfare than his counterpart at Oregon State University, and the values most important to him were political and economic.

The female at Oregon State University came from a home in which economic level was high and the parents were college trained. She expressed more concern with maintenance of her high economic status and placed value on the activities which furthered this goal, in contrast to the community college female who placed less value on economic goals than on any other. The Oregon State University female was less religious than the community college female. However, there was no clear-cut differentiation between females at Oregon State University and the community college, other than the difference in socio-economic status and variables related to this status.
Fields (37), reporting in general terms, stated that average ability, as measured by college entrance tests, was lower for the junior college student than for the student attending a liberal arts college or university.

Iffert (61) obtained 2,661 classroom evaluations from former students at 170 two and four-year colleges. The results indicated a significant difference in favor of the two-year school, based on such items as teaching ability, assistance from instructors, and opportunity to confer with the teacher. It should be noted, however, that these results did not provide a qualitative measure of the actual learning which took place.

Only two investigations have been reported to date involving a comparison of student performance in similar community college and university courses. Kochersberger (67) investigated achievement in similar undergraduate biology courses and reported no significant difference between community college and university students as measured by a common test of principles of biology. He reported that more D and F grades were given to the university students, and concluded that low ability students performed better in the community college atmosphere.

Denney (24), in a companion study to this dissertation, reported no significant difference in critical thinking ability between community college students and university students in three different
college chemistry sequences. He also reported no significant difference between community college students and university students in academic achievement in two of the three chemistry sequences. He concluded that the significant difference in the third chemistry sequence was attributable to the timing of the offering of the fourth quarter of the sequence.

In summary, many studies have been carried out comparing the success of junior and community college transfer students with native upper division university students. The differences in attitude, socio-economic level, and ability have also been investigated. The presence of only two comparative studies involving community college students and university students in courses that are supposed to be equivalent in both types of institutions demonstrates the need for further research in this area.
III. DESIGN OF THE STUDY

The design of this study was directed toward investigating the performance of students who were completing a three-term sequence in general biology (GS 101, 102, 103) at three community colleges and two four-year institutions. Performance was measured in terms of five criteria: (1) critical thinking ability (CT); (2) knowledge of facts and principles (K); (3) comprehension (C); (4) application (A); (5) a combination of analysis, synthesis, and evaluation (S).

The Experimental Design

The research design was a Post-Test-Only Control Group model suggested by Campbell and Stanley (41, p. 195). They state that:

While the pretest is a concept deeply embedded in the thinking of research workers in education, it is not actually essential to true experimental designs . . . many problems exist for which pretests are unavailable, inconvenient, or likely to be reactive, and for which (this) design is greatly underused in educational and psychological research.

The research design described by Campbell and Stanley may be designated:

\[
\begin{align*}
R_{1, 2, 3} & \quad X \quad O_1 O_2 O_3 O_4 O_5 \\
R_{4, 5} & \quad O_1 O_2 O_3 O_4 O_5
\end{align*}
\]

Where \(R_{1, 2, 3}\) represent Portland, Lane, and Southwestern Oregon Community College students and \(R_{4, 5}\) represent Oregon State
University and Portland State College students. The experimental variable, X, was the community college instruction in college general biology. The four-year institution groups served as controls. \( O_1, O_2, O_3, O_4, \) and \( O_5 \) represent the Cornell Critical Thinking Test, Form Z and the subtests of the subject matter criterion instrument on knowledge of facts and principles; comprehension, application; and a combined analysis, synthesis, and evaluation.

To compensate for differences in native ability among students in the experimental and control groups, the effects attributable to the mean high school G. P. A. and sex were removed from the combined criterion test scores by the mathematical model (see Appendix 1).

**The Population**

The population for this investigation consisted of full-time freshman or sophomore students who had completed a three-term sequence of college general biology (GS 101, 102, 103) at either of three community colleges or two four-year institutions in Oregon. The samples used for statistical inference consisted of 261 community college students and 465 four-year institution students. The purpose of this section is to provide a description of these five participating institutions and the students matriculating them.
Community Colleges

Lane Community College. Lane Community College (LCC) located in Eugene, Oregon began operation as a legally constituted tax supported institution on July 1, 1965. During the 1967-68 academic year the college enrollment for full time students reached 2,100.

The college catalog (70, p. 7) states that the offerings... vary from single courses to those necessary for an Associate of Arts or an Associate of Science degree. The college maintains an open door policy, affording educational opportunity for all.

Lane provides two years of post-high school education in three broad areas (70, p. 8).

1. Liberal arts and pre-professional lower division collegiate education for transfer to higher institutions offering baccalaureate degrees.

2. Occupational education for preparation for employment in technical and vocational fields.

3. General education for personal growth, enrichment and advancement.

Portland Community College. Portland Community College (PCC), located in Portland, Oregon opened its doors for operation in September, 1961. During the 1967-68 academic year there were 5,400 full time students enrolled.

Portland Community College believes that (97, p. 17):

All individuals in a democracy, regardless of age or ability, should be provided the opportunity to develop to the maximum
of their potentials and interests.

Education is a lifelong process, and programs covering many facets of knowledge should be made available to all ages of the adult population.

Education should include the knowledge, skills, attitudes and understanding necessary for a rewarding and enriched life.

In keeping with their philosophy the college offers:

A. Liberal arts and pre-professional education (transfer programs)

B. Vocational-technical programs

C. Adult enrichment

Southwestern Oregon Community College. Southwestern Oregon Community College (SWOCC), located in Coos Bay, Oregon was officially voted into existence in December of 1960. During the 1967-68 academic year over 1,600 students were enrolled.

The philosophy of Southwestern Oregon Community College is (113, p. 12):

To serve college-bound youth, youth aspiring to a career in a technical field, adults seeking cultural or general education experiences, and workers desiring to keep abreast of new developments in their field or to gain new skills.

To implement this philosophy the institution offers the following programs:

A. Lower Division Collegiate

B. Occupational-Vocational

C. Continuing Education

D. Community Services
Four-Year Institutions

Oregon State University. Oregon State University (OSU) (91, p. 7), established in 1868 and located in Corvallis, Oregon, is a coeducational, land grant university operated under the Oregon State Board of Higher Education. University undergraduates are enrolled in the liberal arts and sciences and in seven professional schools; agriculture, business and technology, education, engineering, forestry, home economics, and pharmacy. During the 1967-68 academic year nearly 13,000 full-time students were enrolled at the university.

Portland State College. Portland State College (PSC) (92, p. 7), established in 1955 and located in Portland, Oregon, is a coeducational, state public college operated under the Oregon State Board of Higher Education. College undergraduates are enrolled in the liberal arts and sciences and in the professional schools of education and business administration. During the 1967-68 academic year over 10,000 full time students matriculated the college.

The Evaluation Instruments

Cornell Critical Thinking Test

The Cornell Critical Thinking Test, Form Z was selected to evaluate student critical thinking ability. Form Z, an experimental edition copyrighted in 1961, consists of 52 multiple choice items
designed to reveal how well the student was able to correctly assess statements. Four aspects of critical thinking were measured by this test: (1) Induction: evaluation of evidence for or against a hypothesis; (2) Reliability: evaluation of the reliability of information; (3) Deduction: logical reasoning ability; and (4) Assumption-finding: recognition of assumptions.

Ennis, author of the test, precisely defines critical thinking as follows (35, p. 599):

As a root notion, critical thinking is here taken to mean the correct assessing of statements . . . if we set about to find out what a statement means to determine whether to accept or reject it, we would be engaged in thinking, which, for lack of a better term, we shall call critical thinking.

A critical thinker is characterized by proficiency in judging whether:

1. A statement follows from the premises.
2. Something is an assumption.
3. An observation statement is reliable.
4. A simple generalization is warranted.
5. A theory is warranted.
6. An argument depends on an ambiguity.
7. A statement is overvague or overspecific.
8. An alleged authority is reliable.

In order to develop an operational definition of critical thinking for the purpose of designing a measuring instrument, the following important aspects of critical thinking were deliberately excluded (35, p. 600): (1) The judging of value statements; (2) Creative thinking; and (3) Judging whether a problem has been identified. Several aspects of critical thinking which are measured by the
Cornell Critical Thinking Test have been amplified by Ennis (35, p. 604) as follows:

Judging whether a hypothesis is warranted. A hypothesis is warranted to the extent that:

1. It explains a bulk and variety of reliable data.
2. It is itself explained by a satisfactory system of knowledge.
3. It is not inconsistent with any evidence.
4. Its competitors are inconsistent with the evidence. This is the basis of controlled experiments.
5. It is testable. It must be, or have been, possible to make predictions from it.

Judging whether an observation statement is reliable.

Observation statements tend to be more reliable if the observer:

1. Was skilled at observing the sort of thing observed.
2. Had good sensory equipment in good condition.
3. Has a reputation for veracity.
4. Used precise techniques.
5. Had no preconception about the way the observation would turn out.

The above statements provide examples of the preciseness with which aspects of critical thinking have been defined by the author of the Cornell Critical Thinking Test. Several of the preceding statements of aspects of critical thinking are consistent with generally accepted objectives of science education.

General agreement between concepts of critical thinking measured by this test and those measured by other critical thinking tests analyzed by Dressel (26) and Rust (107) supports the validity of the criterion instrument. The previously mentioned consistency between generally accepted objectives of science education and the
rather precisely defined aspects of critical thinking measured by the Cornell Critical Thinking Test, constitutes additional evidence of the validity of this test for use with science students.

The author of the CCTT supplied standardization data based upon administration of the test to graduate and undergraduate students at Cornell University. Although limited, the data relative to the split-half reliability estimate does indicate an acceptable reliability level (.84) for the CCTT, Form Z.

Biology Criterion Instrument

The subject matter test was developed by the researcher specifically for this investigation. The test consisted of 65 multiple choice items representing the nine general areas of biology identified by CUEBS (16). The topics were selected on the basis that they were common to all of the general biology course outlines of the participating institutions. The researcher selected 155 items from the 1,300 items listed in Testing and Evaluation in the Biological Sciences (16). The items were plotted on a matrix and classified according to the area of biology and the level of behavior designated in Testing and Evaluation in the Biological Sciences (16). These 155 items were then submitted to a critique jury which consisted of one biology instructor from each of the participating institutions. These instructors evaluated the items in terms of applicability to the program at their own institution. The
items were rated on the following scale:

0 = not applicable
1 = not desirable
2 = poor
3 = fair
4 = good
5 = excellent

The researcher summed the total ratings for each question. For the final 65 items, none was chosen with a total score of less than 18 (Maximum = 25), and most of the items scored above twenty. If any item received a 0 or a 1 rating from any jury member, it was automatically excluded. Table 1 lists the numbered items and their classification into subject matter areas and behavioral objectives. Items marked with an asterisk (*) were eliminated from the final analysis because of a low discrimination index (see Table 4, page 52).

Procedures Used in Collecting the Data

Criterion Test Scores

The Cornell Critical Thinking Test, Form Z and the subject matter criterion instrument were administered to the experimental (community college) and control (four-year institution) groups at their respective institutions during the week of May 27, 1968. Both criterion tests were given at the same session with 60 minutes allotted
Table 1. Content Area and Behavioral Objectives of Biology Test Items.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis Synthesis Evaluation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energetics &amp; Metabolism</td>
<td>1, 2</td>
<td>3</td>
<td>4, 5</td>
<td>6, 7</td>
<td>7</td>
</tr>
<tr>
<td>Form-Function</td>
<td>8, 9</td>
<td>10</td>
<td>11, 12, 13*</td>
<td>14, 15*</td>
<td>8</td>
</tr>
<tr>
<td>Behavior</td>
<td>- - - -</td>
<td>16</td>
<td>17</td>
<td>18*, 19</td>
<td>4</td>
</tr>
<tr>
<td>Genetics</td>
<td>20, 21, 23*</td>
<td>22, 24, 25</td>
<td>26</td>
<td>27, 28</td>
<td>9</td>
</tr>
<tr>
<td>Reproduction &amp; Development</td>
<td>29, 30</td>
<td>31, 32</td>
<td>33, 34</td>
<td>- - - -</td>
<td>6</td>
</tr>
<tr>
<td>Systematics</td>
<td>35*</td>
<td>36, 37</td>
<td>38, 39</td>
<td>40, 41</td>
<td>7</td>
</tr>
<tr>
<td>Evolution</td>
<td>42*, 43*</td>
<td>44, 45*</td>
<td>46, 47, 48</td>
<td>49, 50</td>
<td>9</td>
</tr>
<tr>
<td>Organism-Environment</td>
<td>51*, 52</td>
<td>53, 54</td>
<td>55, 56</td>
<td>57, 58*, 59*</td>
<td>9</td>
</tr>
<tr>
<td>History, Philosophy, Methodology</td>
<td>60, 61</td>
<td>62, 63</td>
<td>- - - -</td>
<td>64, 65*</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>65</td>
</tr>
</tbody>
</table>

*Eliminated because of low discrimination.
for each. Reusable test booklets were used and students recorded their responses on answer sheets prepared by the researcher. The answer sheets were scored and double-checked by the researcher. The formula for the raw score on the Cornell Critical Thinking Test was number right minus 1/2 the number wrong; the number of correct responses served as the raw score for each subtest in the subject matter criterion instrument.

Mean High School Grade Point Average

The mean high school G. P. A. records were acquired from high school transcripts located in the Registrar's office of the participating institutions during the summer of 1968.

Statistics Utilized in Analysis of Data

Mean high school G. P. A. was used as a covariable to adjust for differences in native ability among students in the participating institutions. This was necessary because the mean high school G. P. A. was the only measurement common to all groups in the population. Shamos (109) stated that the high school G. P. A. is still the best single guide to a student's probable success in college. Rice (101) also reported a high positive correlation between high school G. P. A. and success in university work.

Group sample means, with the effect of high school G. P. A. and
sex removed, were used as the unit of analysis. Individual student scores were not used because the participating groups, not the individual students, had been subjected to the instructional variations under comparison.

The reliability of the Cornell Critical Thinking Test was estimated by using the Kuder-Richardson formula (88, p. 92):

\[ r = \frac{K}{K - 1} \left( 1 - \frac{M - M^2/K}{S^2} \right) \]

where,

- \( r \) = reliability
- \( K \) = number of items in the test
- \( M \) = sample mean score
- \( S \) = standard deviation

Nedelsky states (88, p. 92):

This formula gives an excellent estimate of \( r \) if the items are objective and if they measure the same ability; otherwise the formula is likely to underestimate the test's reliability.

The reliability of the subject matter criterion instrument was estimated by computing an index of discrimination (\( D \)) for each individual item (88, p. 97):

\[ D = \frac{H - L}{N} \]

where,

- \( D \) = discrimination index
- \( H \) = average number of correct responses by members of high group
\[ L = \text{average number of correct responses by members of low group} \]

\[ N = \text{maximum possible score (} = 1 \text{ when using single items)} \]

A difficulty index \((d)\) was also computed for each individual item (88, p. 97):

\[ d = \frac{H + L}{2N} \]

where,

\[ d = \text{difficulty} \]

\[ H = \text{average number of correct responses by members of high group} \]

\[ L = \text{average number of correct responses by members of low group} \]

\[ N = \text{maximum possible score (} = 1 \text{ when using single items)} \]

In the tests of the questions being investigated, the Gauss-Markoff Setup for Multiple Measurements (analysis of dispersion) statistical design was used. Computational procedures for this model followed those outlined by Rao (99, p. 459-470). This design yielded a matrix of regression coefficients from which adjusted sample means, degrees of freedom, and F-distribution values were calculated. Since the five individual test scores used in this study are statistically dependent, they are treated simultaneously in the analysis of dispersion. The resulting F-scores are not equivalent to an F-score which would result from the treatment of statistically independent tests in the analysis of variance method. Computer output data also yielded
standard deviations for the regression coefficients. These standard deviations were provided to aid in the interpretation of possible significant differences in the F-scores. The mathematical expression for the full model, the matrix of regression coefficients, and the standard deviations for the regression coefficients are located in Appendix 1.

Processing of the Data

Data from the criterion tests were tabulated on index cards and then punched on I. B. M. cards for analysis. Using the statistical designs cited in the previous section, a program was written and punched for execution on the I. B. M. 1620 computer. The program was processed mostly at the Oregon State University Computer Center. High School G. P. A. means and criterion instrument reliability measures were computed by the investigator on an Olivetti-Underwood Programma 101 at Mount Hood Community College.
IV. PRESENTATION AND INTERPRETATION OF THE FINDINGS

The purpose of this study was to compare the performance of community college students to four-year institutional students, all of whom were completing a three term sequence of college general biology (GS 101, 102, 103). Therefore, near the completion of these programs, measurements of student performance from the two types of institutions were taken involving the following objectives of biology teaching: (1) critical thinking (CT); (2) knowledge of facts and principles (K); (3) comprehension (C); (4) application (A); (5) a combination of analysis, synthesis, and evaluation (S).

The investigation was conducted at Lane Community College, Portland Community College, Southwestern Oregon Community College, Oregon State University, and Portland State College during the 1967-68 academic year. All data were collected during the week of May 27, 1968. Data were obtained through: (1) analysis of student records located in the registrar's office at the participating institutions, and (2) single administrations of the instruments selected to measure the objectives of biology teaching as listed in the previous paragraph. Data from these sources were tabulated on index cards and then punched on I. B. M. cards for processing.

The data collected in this study were used in the following ways: (1) mean high school G. P. A. was used as a covariable to adjust
mean scores for differences occurring as a result of differences in
native ability; and (2) analysis of the criterion scores was used to
compute a matrix of regression coefficients from which mean scores,
with the effect of sex and high school G. P. A. removed, F-ratios
for testing the questions under investigation, and standard deviations
for the regression coefficients were computed.

In testing the questions under investigation, the statistical
model employed was the analysis of dispersion. Adjusted group
means, rather than individual student scores, were used as the unit
of analysis, since the effect of the participating institutions was
being investigated and not the individual students.

Presentation of the Data

The two criterion tests were administered to 344 community
college students. The size of the community college sample was
reduced to 261 because no high school G. P. A. could be obtained for
83 students. The two criterion tests were administered to 811
university students. The size of the university sample was reduced
to 465 for the following reasons: (1) all three terms of the sequence
had not been completed by some students; (2) some students had
attained a junior or senior standing; (3) no high school G. P. A. was
available for some students. The mean high school G. P. A. for
students entering the four-year institutions was higher than the G. P.
A. for students entering community colleges. This agrees with the findings of Kochersberger (67) who conducted a similar study in New York. Table 2 shows the number of students in the sample at each institution; sex distribution; high school G. P. A. range, mean, standard deviation.

Data From Criterion Instruments

The Cornell Critical Thinking Test, Form Z, as 52-item multiple choice examination and a 65-item multiple choice biology examination covering the behavioral objectives of knowledge of facts and principles; comprehension; application; and a combination of analysis, synthesis, and evaluation were the criterion instruments used in this investigation.

The reliability of the Cornell Critical Thinking Test was estimated by the Kuder-Richardson formula (88, p. 92):

\[ r = \frac{K}{K - 1} \left(1 - \frac{M - M^2/K}{S^2}\right) \]

where,

\[ r = \text{reliability} \]

\[ K = \text{number of items in the test} \]

\[ M = \text{mean score} \]

\[ S = \text{standard deviation} \]

The reliability of the Cornell Critical Thinking Test was within
Table 2. Summary of Students' High School G. P. A.'s and Sex Distribution for Participating Institutions.

<table>
<thead>
<tr>
<th>Institution</th>
<th>n</th>
<th>Males</th>
<th>Females</th>
<th>G. P. A. -Range</th>
<th>G. P. A. -Mean</th>
<th>Standard Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane C. C.</td>
<td>90</td>
<td>50</td>
<td>40</td>
<td>2.0 - 3.8</td>
<td>2.63</td>
<td>.40</td>
</tr>
<tr>
<td>Portland C. C.</td>
<td>143</td>
<td>89</td>
<td>54</td>
<td>1.2 - 3.8</td>
<td>2.48</td>
<td>.50</td>
</tr>
<tr>
<td>SWOCC</td>
<td>28</td>
<td>12</td>
<td>16</td>
<td>2.0 - 3.7</td>
<td>2.83</td>
<td>.46</td>
</tr>
<tr>
<td>OSU</td>
<td>231</td>
<td>91</td>
<td>140</td>
<td>1.7 - 4.0</td>
<td>3.22</td>
<td>.55</td>
</tr>
<tr>
<td>PSC</td>
<td>234</td>
<td>59</td>
<td>175</td>
<td>2.0 - 3.9</td>
<td>3.11</td>
<td>.35</td>
</tr>
</tbody>
</table>
acceptable limits at all institutions. Table 3 provides a summary of the reliability estimations for the Cornell Critical Thinking Test.

Table 3. Reliability Calculations for Cornell Critical Thinking Test.

<table>
<thead>
<tr>
<th>Institution</th>
<th>K</th>
<th>M</th>
<th>S</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane C. C.</td>
<td>52</td>
<td>16.70</td>
<td>6.41</td>
<td>.73</td>
</tr>
<tr>
<td>Portland C. C.</td>
<td>52</td>
<td>16.28</td>
<td>7.46</td>
<td>.82</td>
</tr>
<tr>
<td>Southwestern Oregon C. C.</td>
<td>52</td>
<td>18.00</td>
<td>7.04</td>
<td>.77</td>
</tr>
<tr>
<td>OSU</td>
<td>52</td>
<td>20.43</td>
<td>6.23</td>
<td>.69</td>
</tr>
<tr>
<td>PSC</td>
<td>52</td>
<td>19.47</td>
<td>6.89</td>
<td>.75</td>
</tr>
</tbody>
</table>

The reliability of the subject matter criterion instrument was estimated by computing an index of discrimination (D) for each individual item on the examination (88, p. 97):

\[ D = \frac{H - L}{N} \]

where,

- **D** = discrimination
- **H** = average number of correct responses by members of high group
- **L** = average number of correct responses by members of low group
- **N** = maximum possible score (= 1 when using single items)

An estimate of difficulty was also computed for each individual item on the examination (88, p. 97):
\[ d = \frac{H + L}{2N} \]

where,

- \( d \) = difficulty
- \( H \) = average number of correct responses by members of high group
- \( L \) = average number of correct responses by members of low group
- \( N \) = maximum possible score (= 1 when using single items)

All of the subject matter examination answer sheets were ranked from highest score to lowest score and divided into a high and a low group. Numbers were assigned to each examination and a random sample of 50 was chosen from the top 27 percent of the high group and from the bottom 27 percent of the low group, using a random numbers table constructed by Croxton and Cowden (20). The discrimination index and difficulty were then calculated in the manner prescribed by Nedelsky, who states (88, p. 97):

"The contribution of an item to the test's reliability is considered low if \( D \) is less than .2 and high if \( D \) is greater than .4 . . . a difficulty equal to 1 means a very easy test."

Table 4 provides a summary of the discrimination index and difficulty estimations for each item. Numbers marked with an asterisk (*) were eliminated from the final analysis due to low discrimination.

Table 5 gives the number and classification for the 53 items
Table 4. Discrimination Index (D) and Difficulty (d) Calculations for Biology Criterion Test Items.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>H</th>
<th>L</th>
<th>D</th>
<th>d</th>
<th>Item No.</th>
<th>H</th>
<th>L</th>
<th>D</th>
<th>d</th>
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<tr>
<td>1</td>
<td>43</td>
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<td>.30</td>
<td>.71</td>
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<td>33</td>
<td>.34</td>
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<td>.32</td>
<td>.76</td>
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<td>.10</td>
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<td>.25</td>
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<td>.22</td>
<td>.85</td>
<td>37</td>
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<td>10</td>
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<td>.22</td>
<td>.35</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Eliminated before final analysis.
<table>
<thead>
<tr>
<th>Objectives</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis Synthesis Evaluation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energetics &amp; Metabolism</td>
<td>1, 2</td>
<td>3</td>
<td>4, 5</td>
<td>6, 7</td>
<td>7</td>
</tr>
<tr>
<td>Form-Function</td>
<td>8, 9</td>
<td>10</td>
<td>11, 12</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Behavior</td>
<td>- - -</td>
<td>16</td>
<td>17</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Genetics</td>
<td>20, 21</td>
<td>22, 24, 25</td>
<td>26</td>
<td>27, 28</td>
<td>8</td>
</tr>
<tr>
<td>Reproduction &amp; Development</td>
<td>29, 30</td>
<td>31, 32</td>
<td>33, 34</td>
<td>- - -</td>
<td>6</td>
</tr>
<tr>
<td>Systematics</td>
<td>- - -</td>
<td>36, 37</td>
<td>38, 39</td>
<td>40, 41</td>
<td>6</td>
</tr>
<tr>
<td>Evolution</td>
<td>- - -</td>
<td>44</td>
<td>46, 47, 48</td>
<td>49, 50</td>
<td>6</td>
</tr>
<tr>
<td>Organism-Environment</td>
<td>51</td>
<td>53, 54</td>
<td>55, 56</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>History, Philosophy, Methodology</td>
<td>60, 61</td>
<td>62, 63</td>
<td>- - -</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>15</strong></td>
<td><strong>15</strong></td>
<td><strong>12</strong></td>
<td><strong>53</strong></td>
</tr>
</tbody>
</table>
used in the final analysis.

Table 6 summarizes the means of each test and subtest, with the effect of sex and high school G. P. A. removed, for each participating institution. No attempt was made to identify these institutions for the reader; they are simply designated with a number to avoid possible embarrassment.

Table 6. Summary of Mean Scores for Participating Institutions.

<table>
<thead>
<tr>
<th>Institution</th>
<th>CT</th>
<th>K</th>
<th>C</th>
<th>A</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community College #1</td>
<td>16.617</td>
<td>6.197</td>
<td>7.875</td>
<td>8.162</td>
<td>7.106</td>
</tr>
<tr>
<td>Community College #2</td>
<td>16.700</td>
<td>5.608</td>
<td>7.919</td>
<td>8.501</td>
<td>6.517</td>
</tr>
<tr>
<td>Community College #3</td>
<td>17.528</td>
<td>5.992</td>
<td>7.993</td>
<td>8.699</td>
<td>6.645</td>
</tr>
<tr>
<td>University #1</td>
<td>18.938</td>
<td>5.383</td>
<td>8.062</td>
<td>8.984</td>
<td>7.280</td>
</tr>
<tr>
<td>University #2</td>
<td>18.415</td>
<td>4.768</td>
<td>7.380</td>
<td>7.808</td>
<td>6.585</td>
</tr>
</tbody>
</table>

All criterion instruments used in this investigation are located in Appendices 2 and 3.

Tests of Questions Under Investigation

1. Is there a significant statistical difference in student performance among four-year institutions or among community colleges, as measured by the combined scores of the Cornell Critical Thinking Test; knowledge subtest; comprehension subtest; application subtest; and combined analysis, synthesis, and evaluation subtest when the effect of high school G. P. A. and sex are removed?

The individual F values for Test #1 are as follows:
Test | F Value  
--- | ---  
CT | 0.367  
K | 6.28  
C | 3.36  
A | 10.58  
S | 6.51  

The critical F value at the .01 level with 3 and 719 degrees of freedom is 3.78; the critical F value at the .05 level with 3 and 719 degrees of freedom is 2.60. The answer to question #1 is yes -- there is a significant statistical difference at the .01 level among community colleges or among four-year institutions, or among both groups, in every subtest of the subject matter criterion instrument except comprehension. At the .05 level there is a significant statistical difference among either or both sample groups in every subtest. There is no significant statistical difference among community colleges nor among four-year institutions on the Cornell Critical Thinking Test. The significant difference signifies that either the community colleges or four-year institutions, or both, cannot be treated as a homogeneous group.

Table 7 shows the comparison of the differences between the highest and lowest mean scores among the community colleges with the standard deviations of the regression coefficients. In this type of analysis, any difference under 2 standard deviations is considered
to be within acceptable limits, and any difference in excess of 2 standard deviations is considered significant.

Table 7. Comparison of the Difference Between High and Low Community College Means With the Standard Deviations of the Regression Coefficients.

<table>
<thead>
<tr>
<th></th>
<th>CT</th>
<th>K</th>
<th>C</th>
<th>A</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. C. High Mean Score</td>
<td>17.528</td>
<td>6.197</td>
<td>7.993</td>
<td>8.699</td>
<td>7.106</td>
</tr>
<tr>
<td>C. C. Low Mean Score</td>
<td>16.617</td>
<td>5.608</td>
<td>7.875</td>
<td>8.162</td>
<td>6.517</td>
</tr>
<tr>
<td>difference</td>
<td>0.911</td>
<td>0.589</td>
<td>0.118</td>
<td>0.537</td>
<td>0.589</td>
</tr>
<tr>
<td>S. D.</td>
<td>1.396</td>
<td>0.244</td>
<td>0.475</td>
<td>0.473</td>
<td>0.264</td>
</tr>
<tr>
<td>No. of S. D.'s from Mean</td>
<td>0.653</td>
<td>2.414</td>
<td>0.248</td>
<td>1.135</td>
<td>2.231</td>
</tr>
</tbody>
</table>

The difference among community colleges is mainly due to the difference between the high mean score and low mean score on the knowledge subtest (2.414 standard deviations from the mean) and to differences between the high mean score and the low mean score on the combined analysis, synthesis, and evaluation subtest (2.231 standard deviations from the mean).

Table 8 shows the comparison of the differences between the mean scores of the four-year institutions with the standard deviations of regression coefficients.

The difference among four-year institutions is due to the wide difference between the two institutions on the four subtests of the subject matter criterion instrument. The difference in scores on the
Table 8. Comparison of the Difference Between High and Low Four-Year Institution Means with the Standard Deviations of the Regression Coefficients.

<table>
<thead>
<tr>
<th>Test</th>
<th>CT</th>
<th>K</th>
<th>C</th>
<th>A</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Mean Score</td>
<td>18.938</td>
<td>5.383</td>
<td>8.062</td>
<td>8.984</td>
<td>7.280</td>
</tr>
<tr>
<td>Low Mean Score</td>
<td>18.415</td>
<td>4.768</td>
<td>7.380</td>
<td>7.808</td>
<td>6.585</td>
</tr>
<tr>
<td>difference</td>
<td>0.523</td>
<td>0.615</td>
<td>0.682</td>
<td>1.176</td>
<td>0.695</td>
</tr>
<tr>
<td>S. D.</td>
<td>0.635</td>
<td>0.171</td>
<td>0.216</td>
<td>0.215</td>
<td>0.185</td>
</tr>
<tr>
<td>No. of S. D.'s from Mean</td>
<td>0.824</td>
<td>3.596</td>
<td>3.157</td>
<td>5.470</td>
<td>3.757</td>
</tr>
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</table>

knowledge subtest amounts to 3.596 standard deviations, with 3.157 standard deviations on the comprehension subtest; 5.470 standard deviations on the application subtest; and 3.757 standard deviations on the combined analysis, synthesis, and evaluation subtest.

2. Is there a significant statistical difference in student performance between four-year institutions and community colleges as measured by the combined scores of the Cornell Critical Thinking Test; knowledge subtest; comprehension subtest; application subtest; and combined analysis, synthesis, and evaluation subtest when the effects of high school G. P. A. and sex are removed?

The individual F values for test #2 are as follows:

<table>
<thead>
<tr>
<th>Test</th>
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<td>K</td>
<td>29.89</td>
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<td>C</td>
<td>1.11</td>
</tr>
<tr>
<td>A</td>
<td>0.01</td>
</tr>
<tr>
<td>S</td>
<td>0.16</td>
</tr>
</tbody>
</table>
The critical F value at the .01 level with 1 and 719 degrees of freedom is 6.63. The answer to question #2 must be qualified. Although there is a significant statistical difference among community colleges and among four-year institutions, the difference between community colleges and four-year institutions is still large enough to be significant at the .01 level in the Cornell Critical Thinking Test and in the knowledge subtest of the subject matter criterion instrument. The difference is not statistically significant, however, in the case of the remaining three subtests.

A summary of the data indicates that there is a significant statistical difference among community colleges on the knowledge subtest and on the combined analysis, synthesis, and evaluation subtest. There is also a significant statistical difference among the four-year institutions on each subtest of the subject matter criterion instrument. Although these differences exist among both groups, there is still a significant statistical difference between the four-year institutions and community colleges on the Cornell Critical Thinking Test and on the knowledge subtest of the subject matter criterion instrument.
V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The objective of this investigation was to determine whether or not Oregon community college students enrolled in a college general biology course (GS 101, 102, 103) received comparable educational experiences to those students enrolled in a similar course in four-year institutions. This objective was accomplished by comparing the performance of community college students to students in four-year institutions in terms of five important objectives of biology teaching: critical thinking ability; knowledge of facts and principles; comprehension; application and a combination of analysis, synthesis, and evaluation. These comparisons were made by statistical analysis of group mean test scores, with the effect of high school G. P. A. and sex removed, calculated from student responses to the criterion instruments administered during the week of May 27, 1968. All of the students whose scores were used in the final analysis were either freshmen or sophomores, had completed all three terms of the general biology sequence during the 1967-68 school year, and had high school G. P. A. records on file at the registrar's office in the participating institutions.

The criterion instruments were the Cornell Critical Thinking Test, Form Z, developed by Robert Ennis of Cornell University, and
a test of the principles of biology, covering the behavioral objectives of knowledge of facts and principles; comprehension application; and a combination of analysis, synthesis, and evaluation. This instrument was developed by the researcher and evaluated by a critique jury consisting of one biology instructor from each of the participating institutions.

Since this investigation was a post-test only design, the criterion instruments were administered only once with 60 minutes of time allotted for each. Calculations of reliability estimations for the Cornell Critical Thinking Test, using the Kuder-Richardson formula, indicated that a reasonable reliability was achieved at each institution:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane C. C.</td>
<td>.73</td>
</tr>
<tr>
<td>Portland C. C.</td>
<td>.82</td>
</tr>
<tr>
<td>Southwestern Oregon C. C.</td>
<td>.77</td>
</tr>
<tr>
<td>Oregon State University</td>
<td>.69</td>
</tr>
<tr>
<td>Portland State College</td>
<td>.75</td>
</tr>
</tbody>
</table>

The reliability of the subject matter criterion test was estimated by computing a discrimination index and difficulty for each individual item. On the basis of a low discrimination index, 12 items were eliminated before the final analysis. This still left a sufficient number for statistical inference at each behavioral level:
<table>
<thead>
<tr>
<th>Behavioral Objective</th>
<th>No. of Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>11</td>
</tr>
<tr>
<td>Comprehension</td>
<td>15</td>
</tr>
<tr>
<td>Application</td>
<td>15</td>
</tr>
<tr>
<td>Combined analysis, synthesis and evaluation</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
</tr>
</tbody>
</table>

In the tests of the questions under investigation, the Gauss-Markoff Setup for Multiple Measurements (analysis of dispersion) statistical design was used. Computational procedures yielded a matrix of regression coefficients from which adjusted sample means, degrees of freedom, and F-distribution values were calculated. Computer output data also yielded standard deviations for the regression coefficients, which were used to aid in the interpretation of significant differences in the F values among the sample groups.

The F values at the 1 percent level for the first question under investigation indicated a significant statistical difference among community colleges or among four-year institutions, or among both groups, in every subtest of the subject matter criterion instrument except comprehension. At the 5 percent level there was a significant difference among either or both groups in every subtest. There was no significant difference among either group in terms of critical thinking ability. When the difference between the high and low mean scores among the community college biology subtests were compared
with the standard deviations of the regression coefficients, it was
determined that the difference among community colleges was due to
differences occurring in the knowledge subtest and in the combined
analysis, synthesis, and evaluation subtest. When the differences
between mean scores among the four-year institution biology sub-
tests were compared with the standard deviations of the regression
coefficients, it was determined that the difference among the four-
year institutions was due to large differences occurring in every
subtest of the subject matter criterion instrument.

The F values at the 1 percent level for the second question
under investigation indicated that even though significant differences
existed among community colleges and among four-year institutions,
the difference between community colleges and four-year institutions,
in terms of critical thinking ability and the knowledge subtest of the
subject matter criterion instrument was large enough to be
statistically significant at the 1 percent level.

Conclusions

The conclusions to be drawn from the results of this research
will be stated at the end of a review of each question under investiga-
tion.

1. Is there a significant statistical difference in student perform-
ance among four-year institutions or among community colleges,
as measured by the combined scores of the Cornell Critical
Thinking Test; knowledge subtest; comprehension subtest; application subtest; and combined analysis, synthesis, and evaluation subtest when the effects of high school G. P. A. and sex are removed?

The answer is yes. Under the assumptions of Chapter I, the general biology courses at the participating community colleges are representative of those found at other community colleges in Oregon. Therefore, the statistical inference can be made that community college students in Oregon, who are enrolled in a general biology course (GS 101, 102, 103), receive comparable educational experiences in terms of critical thinking, as measured by the Cornell Critical Thinking Test, Form Z, and the behavioral objectives of comprehension and application, as measured by the subject matter criterion instrument. The educational experiences at Oregon community colleges are not comparable, in general biology courses, in terms of the behavioral objective of knowledge and the combined objectives of analysis, synthesis, and evaluation, as measured by the subject matter criterion instrument.

Under the assumptions of Chapter I, the general biology courses at the participating four-year institutions are representative of those found at other four-year institutions in Oregon. Therefore, the statistical inference can be made that the four-year institutional students in Oregon, who are enrolled in a general biology course, receive comparable educational experiences in terms of critical thinking, as measured by the Cornell Critical Thinking Test, Form Z.
The educational experiences at four-year institutions in Oregon are not comparable, in a general biology course, in terms of the behavioral objectives of knowledge; comprehension, application; and a combination of analysis, synthesis, and evaluation, as measured by the subject matter criterion instrument.

It is the conclusion of the researcher that the large significant difference between the two four-year institutions may be due to the manner in which the course is conducted. At four-year institution #1, the general biology sequence (GS 101, 102, 103) is a 4 credit-hour course; two hours per week are spent in televised lecture sessions and two hours per week (1 credit-hour) are spent in the laboratory. In addition, one hour per week is spent in a "recitation" section; this time is used to give examinations, conduct discussions, answer student questions, etc.

At four-year institution #2, the general biology sequence (GS 101, 102, 103) is only a 3 credit-hour course; two hours per week are spent in lecture session and two hours per week (1 credit-hour) are spent in the laboratory. The additional one hour per week spent in a "recitation" section with a biology instructor in four-year institution #1 is probably a major factor in the difference in student achievement between the two four-year institutions.

2. Is there a significant statistical difference in student performance between four-year institutions and community colleges as measured by the combined scores of the Cornell Critical Thinking Test; knowledge subtest; comprehension subtest;
application subtest; and combined analysis, synthesis, and evaluation subtest when the effects of high school G. P. A. and sex are removed?

Although significant statistical differences existed among the community colleges and among the four-year institutions, the difference between community colleges and four-year institutions was statistically significant.

The statistical inference can be made that community college students in Oregon who are enrolled in a general biology course, receive comparable educational experiences to those received at four-year institutions, in terms of the behavioral objectives of comprehension; application; and a combination of analysis, synthesis, and evaluation, as measured by the subject matter criterion instrument.

The statistical inference can be made that community college students in Oregon, who are enrolled in a general biology course, do not receive comparable educational experiences to those received at four-year institutions, in terms of critical thinking, as measured by the Cornell Critical Thinking Test, Form Z, and in terms of the behavioral objective of knowledge, as measured by the subject matter criterion instrument.

In the case of critical thinking, the four-year institutional general biology student received a superior educational experience to the community college general biology student. The reason for this
is undoubtedly complex and further research will be necessary for a satisfactory explanation. The only explanation the researcher is able to suggest, based on the limited data available, is that the four-year institution may be attracting those students who have high critical thinking abilities. This seems reasonable considering the fact that neither of the two four-year institutions nor any of the three community colleges had as a stated objective the improvement of critical thinking abilities.

In the case of the behavioral objective of knowledge, the community college general biology student received a superior educational experience to the four-year institutional general biology student. Again, there undoubtedly are many factors involved in this difference, but it is the conclusion of the researcher that the major contributing cause is an overemphasis on memorization and factual recall in the general biology programs of the community colleges in Oregon. There is some concern among community college instructors that their courses be equivalent to those offered at the four-year institutions, and this concern could be a major underlying factor in the overemphasis on memorization and factual recall.

**Recommendations**

On the basis of the data presented in this study, the investigator recommends that:
1. Four-year institution #2 offer the general biology sequence (GS 101, 102, 103) in a manner similar to four-year institution #1.

2. Community college and university general biology instructors establish the goal of improving the critical thinking abilities of their students and work toward the achievement of this goal.

3. Community college general biology instructors deemphasize the memorization of facts and shift this emphasis to the achievement of other levels of behavioral objectives.

4. A study be conducted to determine why the students in general biology courses at four-year institutions in Oregon achieve the goal of critical thinking to a greater extent than students in general biology classes in Oregon community colleges.

5. Improved channels of communication be opened between community college general biology instructors and four-year institution general biology instructors to enable both institutions to keep abreast of improvements in the methods and techniques of biology instruction.

6. Other investigations in the areas of physics, physical science, and mathematics be conducted to determine the quality of science instruction in the community colleges of Oregon.

7. An investigation similar to this be conducted for the Biology
211, 212, 213 sequence which is in the process of being adopted by four-year institutions and community colleges in Oregon.


Appendix 1

MATHEMATICAL MODEL

\[ y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 \]

where

- \( \beta_0 \) = average score
- \( \beta_1 \) = community college average - university average
- \( \beta_2 \) = community college #2 average - community college average
- \( \beta_3 \) = community college #3 average - community college average
- \( \beta_4 \) = university #1 average - university average
- \( \beta_5 \) = male average - female average
- \( \beta_6 \) = slope of regression of score on high school G. P. A.

- \( x_0 \) = 1, always
- \( x_1 \) = 1, if a community college
  = 0, if a university
- \( x_2 \) = 1, if community college #2
  = 0, if not
- \( x_3 \) = 1, if community college #3
  = 0, if not
- \( x_4 \) = 1, if university #1
  = 0, if not
- \( x_5 \) = 1, if male
  = 0, if not
- \( x_6 \) = G. P. A.
### Appendix Table 1. Matrix of Regression Coefficients.

<table>
<thead>
<tr>
<th></th>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\beta_3$</th>
<th>$\beta_4$</th>
<th>$\beta_5$</th>
<th>$\beta_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_1$ (CT)</td>
<td>10.820</td>
<td>-1.798</td>
<td>0.083</td>
<td>0.911</td>
<td>0.523</td>
<td>0.832</td>
<td>2.705</td>
</tr>
<tr>
<td>$Y_2$ (K)</td>
<td>2.008</td>
<td>1.429</td>
<td>-0.589</td>
<td>-0.205</td>
<td>0.615</td>
<td>0.067</td>
<td>1.077</td>
</tr>
<tr>
<td>$Y_3$ (C)</td>
<td>4.700</td>
<td>0.495</td>
<td>0.044</td>
<td>0.118</td>
<td>0.682</td>
<td>0.105</td>
<td>1.030</td>
</tr>
<tr>
<td>$Y_4$ (A)</td>
<td>4.564</td>
<td>0.354</td>
<td>0.339</td>
<td>0.537</td>
<td>1.176</td>
<td>0.791</td>
<td>0.981</td>
</tr>
<tr>
<td>$Y_5$ (S)</td>
<td>3.779</td>
<td>0.521</td>
<td>-0.589</td>
<td>-0.461</td>
<td>0.695</td>
<td>0.568</td>
<td>0.895</td>
</tr>
</tbody>
</table>

### Appendix Table 2. Standard Deviations of the Regression Coefficients.

<table>
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<tr>
<th></th>
<th>$\beta_0$</th>
<th>$\beta_1$</th>
<th>$\beta_2$</th>
<th>$\beta_3$</th>
<th>$\beta_4$</th>
<th>$\beta_5$</th>
<th>$\beta_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_1$ (CT)</td>
<td>1.921</td>
<td>0.816</td>
<td>0.902</td>
<td>1.396</td>
<td>0.635</td>
<td>0.552</td>
<td>0.587</td>
</tr>
<tr>
<td>$Y_2$ (K)</td>
<td>0.519</td>
<td>0.221</td>
<td>0.244</td>
<td>0.378</td>
<td>0.171</td>
<td>0.150</td>
<td>0.159</td>
</tr>
<tr>
<td>$Y_3$ (C)</td>
<td>0.653</td>
<td>0.278</td>
<td>0.307</td>
<td>0.475</td>
<td>0.216</td>
<td>0.188</td>
<td>0.199</td>
</tr>
<tr>
<td>$Y_4$ (A)</td>
<td>0.651</td>
<td>0.277</td>
<td>0.306</td>
<td>0.473</td>
<td>0.215</td>
<td>0.187</td>
<td>0.199</td>
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<tr>
<td>$Y_5$ (S)</td>
<td>0.562</td>
<td>0.239</td>
<td>0.264</td>
<td>0.409</td>
<td>0.185</td>
<td>0.161</td>
<td>0.172</td>
</tr>
</tbody>
</table>
SECTION 1A: In the first five items, two men are debating about voting by eighteen-year olds. Mr. Pinder is speaker in the first three items, Mr. Wilstings in the last two. Each item presents a set of statements and a conclusion. In each item, the conclusion is underlined. Do not be concerned with whether the conclusion or statements are true.

Mark items 1 through 5 according to the following system:
A) The conclusion follows necessarily from the statement given.
B) The conclusion contradicts the statements given.
C) The conclusion neither follows necessarily nor contradicts the statement given.

If a conclusion follows necessarily, a person who accepts the statement is unavoidably committed to accepting the conclusion. When two things are contradictory, they can not both be true at the same time.

CONSIDER EACH ITEM INDEPENDENTLY OF THE OTHERS,

1. "Mr. Wilstings says that eighteen-year-olds haven't faced the problems of the world, and that anyone who hasn't faced these problems shouldn't vote. What he says is correct, but eighteen-year-olds still should be able to vote. They're mature human beings, aren't they?"

   A) Conclusion follows necessarily from the statements given.
   B) Conclusion contradicts the statements given.
   C) Neither.

2. "Furthermore, eighteen-year-olds should be allowed to vote because anyone who will suffer or gain from a decision made by the voters ought to be permitted to vote. It is clear that eighteen-year-olds will suffer or gain from the decision of the voters."

   A) Conclusion follows necessarily from the statements given.
3. "Many eighteen-year-olds are serving their country. Now there can be no doubt that many people serving their country ought to be allowed to vote. From this you can see that many eighteen-year-olds ought to be allowed to vote."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

4. "I agree with Mr. Pinder that anyone who will suffer or gain from a decision made by the voters ought to be permitted to vote. And it is true that eighteen-year-olds will suffer or gain from these decisions. But so will ten-year-olds. Therefore, eighteen-year-olds shouldn't be allowed to vote."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

5. "Most eighteen-year-olds don't know the difference between right and wrong. The right to vote should not be possessed by a group, if most of its members don't know this difference. It is obvious then that eighteen-year-olds shouldn't have the right to vote."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

SECTION IB: In the next five items, the two men are debating about immigration. Mr. Pinder is speaking in the first three items, Mr. Wilstings in the last two.

CONSIDER EACH ITEM INDEPENDENTLY OF THE OTHERS.

6. "Mr. Wilstings has proposed that we open our doors to all the foreigners who want to enter our beloved country. But foreigners always have made trouble and they always will.
Most of them can't even speak English. Since any group that makes trouble is bad, it follows that foreigners are a bad bunch."

A) Conclusion follows necessarily for the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

7. "You may not know it, but for the past ten years the Communists in our country have been supporting a policy of unrestricted immigration. It is obvious why they support this policy of opening our doors to the foreigners. Now I hate to say this, but Mr. Wilstings' support of this policy leaves us but one conclusion. Mr. Wilstings is a Communist."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

8. "Mr. Wilstings has said that most foreigners have made positive contributions to our country. This is true. I will also admit that a group is not bad, if most of its members do make positive contributions. But don't be deceived by Mr. Wilstings' fine-sounding language. Foreigners are a bad lot and shouldn't be admitted."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

9. "I'm sorry that Mr. Pinder feels that way about it. Sure, foreigners make trouble and most of them can't speak English. But even though it's true that groups that make trouble ought not be admitted, we still ought to admit foreigners to our country. You don't want to be selfish do you?"

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.
10. "All of you think it was all right to open our doors to all people from distant lands in the nineteenth century. Any person who thinks it was all right to do so at that time ought also to be in favor of doing so now. Thus, you ought to be in favor of opening our doors now to those from distant lands who are seeking admission to our country."

A) Conclusion follows necessarily from the statements given.
B) Conclusion contradicts the statements given.
C) Neither.

SECTION II: The discussion that follows is divided into parts to correspond to items 11 through 21. There is faulty thinking going on in each part. Your job for each item is to pick the one best reason why the thinking is faulty.

To take this part of the test you need not know anything about the chlorination of water supplies.

11. DOBER: I hear that you and some other crackpots are trying to get Gailton to chlorinate its water supply. You seem to think that this will do some good. There can be no doubt that either we should chlorinate or we shouldn't. Only a fool would be in favor of chlorinating the water, so we ought not do it.

ALGAN: You are correct at least in saying that we are trying to get the water chlorinated.

Pick the one best reason why some of this thinking is faulty.

A) Dobert is mistakenly assuming that there are only two alternatives.
B) Dobert is using a word in two ways.
C) Dobert is using emotional language which doesn't help to make his argument reasonable.

12. DOBER: I guess you know that to put chlorine in the water is to threaten the health of every one of Gailton's citizens, and that, you'll admit, is bad.

ALGAN: What right do you have to say that our health will be threatened?
DOBERT: "Healthy living" may be defined as living according to nature. Now we don't find chlorine added to water in nature. Therefore, everyone's health would be threatened if chlorine were added.

Pick the one best reason why some of this thinking is faulty.

A) Dobert is using emotional language which doesn't help to make his argument reasonable.
B) Dobert's thinking is in error.
C) Dobert is using a word in two different ways.

13. DOBERT: Furthermore, Gailton's water is pure already. I know this from the report, which you haven't seen yet, that will soon be released by the State Water Survey.

ALGAN: You can't know that Gailton's water is pure. The State Water Survey didn't test all the water that we have available to us. They only took samples. Furthermore, you can't know that they didn't make an error in their investigation, because there's always a chance for error in any investigation. Therefore, you could never know that Gailton's water is pure.

Pick the one best reason why some of this thinking is faulty.

A) Algan is not using "know" in its ordinary sense, yet he is expecting the effect that follows from its being used in the ordinary sense.
B) Dobert, in using secret evidence, is not being fair, since this evidence is not available to everyone for inspection.
C) Algan can't know that an error was made in the investigation.

14. DOBERT: I understand that you look on this thing as an experiment. I'm sure that the citizens of Gailton don't want to be guinea pigs in this matter.

ALGAN: This is a demonstration. Nobody ought to object to a demonstration, since the purpose of a demonstration is not to find out something, but rather to show us something that is already known. An additional value of this demonstration of chlorination is that its purpose is also to test for the long-range effects of chlorination of the human body. This objective of the demonstration is a worthy one.
Pick the best reason why some of this thinking is faulty.

A) Algan has not shown that testing for the long-range effects of chlorination is a worthy objective.
B) Algan is using a word in two ways.
C) There is an error in thinking in this part.

15. ALGAN: The question boils down to two alternatives. Either we want clean, chlorinated water or we want bad-smelling, disease-ridden water. The citizens of Gailton certainly don't want bad-smelling, disease-ridden water. What is left but to chlorinate?

Pick the one best reason why some of this thinking is faulty.

A) Algan hasn't shown that there are only two alternatives.
B) Algan is using emotional language which doesn't help to make the argument reasonable.
C) Algan is using the same word in two ways.

16. DOBERT: Laying aside the question of whether medication is bad or good, wouldn't you say that you are proposing a plan for medication?

ALGAN: Not at all. Is killing germs in the water supply the same as treating a disease of the human body? Certainly not. Therefore, my plan can not be called a plan for medication.

DOBERT: Oh, but it is medication. Isn't one of your stated goals the prevention of disease? Medication is the process of trying to restore or preserve health in any manner whatsoever. Whether your plan actually would result in preserving or restoring health doesn't matter. The point is that you would be trying to do so and thus would be medicating people.

Pick the one best reason why some of this thinking is faulty.

A) There is a serious mistake in the thinking in this part.
B) Dobert's conclusion doesn't necessarily follow from the reasons given.
C) Dobert and Algan are using the same word differently.

17. DOBERT: Can you prove that chlorination is useful in making water safe?
ALGAN: Yes, I can. Devon gets its water from the same place that we do. Three years ago, Devon had nine cases of typhoid fever. Two years ago they started to chlorinate and they had only two cases that year. That's enough proof.

Pick the one best reason why some of the thinking is faulty.

A) Algan is using the same word in two ways.
B) That's not a big enough reduction. If there were no typhoid at all the second year, then Algan would have proven his statement.
C) One such comparison is not enough to prove such a statement.

18. DOBERT: In reality you are proposing to poison our water supply when you propose to put chlorine gas in the water. Chlorine gas has been used in war to kill human beings. It is deadly poison. Nobody wants to be poisoned.

ALGAN: But when chlorine is mixed 3 1/2 parts per million nobody will be hurt at all.

DOBERT: That's not the point. You'd still be putting a deadly poison in the water. That's what it means to poison the water. So anyone drinking the water would necessarily be poisoned.

Pick the one best reason why some of the thinking is faulty.

A) Algan is missing the point.
B) Dobert is using the same word in two ways.
C) Dobert's thinking is in error.

19. DOBERT: Furthermore, Gailton's water is safe now.

ALGAN: That's not true. Nothing is safe as long as there's a conceivable chance for something to go wrong. From this it follows that Gailton's water is not safe.

Pick the one best reason why some of the thinking is faulty.

A) Algan has made the word "safe" useless for communicating information.
B) Algan hasn't said what he means by "safe".
C) There is a flaw in Algan's thinking about safety.
20. **DOBERT:** The citizens of Gailton will have to make a choice. Either we want absolutely pure water or we should keep our present set-up. Now any chemist can tell you that from a practical point of view it is impossible to remove all the impurities from a water supply. So we should leave things the way they are.

**Pick the one best reason why some of the thinking is faulty.**

A) Dobert hasn't shown that there are only two alternatives.
B) Dobert is using the same word in two ways.
C) The conclusion doesn't necessarily follow from the reasons given.

21. **DOBERT:** To add chlorine is to add a drug to Gailton's water supply. Obviously, we don't want our citizens to be drugged every time they take a drink of water.

**ALGAN:** What right do you have to say that chlorine is a drug?

**DOBERT:** The term "drug" is defined in section 201 (g) of the Federal Food, Drug and Cosmetic Act, as an article intended for use in the diagnosis, cure, treatment or prevention of disease in man or other animals. Now since chlorine is intended for use in the prevention of disease, it is a drug.

**Pick the one best reason why some of the thinking is faulty.**

A) Dobert's thinking is in error.
B) Algan should realize that a person has a right to use a word in a special way. The important thing is that there be understanding of what is said.
C) Dobert is using a word in two different ways.

**SECTIONS III, IV, AND V REFER TO THE FOLLOWING EXPERIMENT:**

An experiment was performed by Drs. E. E. Brown and M. R. Kolter in the veterinary laboratory of the British Ministry of Agriculture and Fisheries. The doctors were interested in what happens to ducklings that eat cabbage worms. Several cases had been reported to them in which ducklings had "mysteriously" died after being in cabbage patches containing cabbage worms.
Two broods of each of three types of ducklings were secured (Mallards, Pintails, and Canvas-backs). Each brood was split into two equal groups, as much alike as possible. For a one-week period they were fed an approved diet for ducklings. All had this diet, except that half of each brood had something more: two cabbage worms per duckling each day. The condition of the ducklings at the end of the week was observed and is reported in the following chart:

<table>
<thead>
<tr>
<th>Type of Duckling</th>
<th>Original Number In Brood</th>
<th>Regular Diet Healthy</th>
<th>Ill</th>
<th>Dead</th>
<th>Regular Diet Plus Worms Healthy</th>
<th>Ill</th>
<th>Dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mallard</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
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<td>3</td>
</tr>
<tr>
<td>Pintail</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Canvas-back</td>
<td>8</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>44</strong></td>
<td><strong>18</strong></td>
<td><strong>3</strong></td>
<td><strong>1</strong></td>
<td><strong>1</strong></td>
<td><strong>4</strong></td>
<td><strong>17</strong></td>
</tr>
</tbody>
</table>

The doctors draw this conclusion: CABBAGE WORMS ARE POISONOUS TO DUCKLINGS.

**SECTION III:** The experiment attracted a great deal of attention. Many statements were made about the experiment and about the protection of ducklings.

Each of items 22 through 25 contains a pair of such statements. Each statement is underlined. In each case you are to decide which one of the pair is probably more reliable than the other. In making your decisions, use the information provided in the experiment and the information given in parentheses after each statement.

Mark items 22 through 25 according to the following system:

A) The first statement is probably more reliable.
B) The second statement is probably more reliable.
C) Neither statement is probably more reliable than the other.

22. A) Cabbage worms are poisonous to ducklings. (said by Dr.
23. A) Six Pintails were healthy at the end of the experiment. (said by Dr. Brown)
B) Four worm-fed ducklings were ill at the end of the experiment. (said by Dr. Brown)
C) Neither.

24. A) Six Canvas-backs died during the week of the experiment. (said by Dr. Kolter)
B) Four worm-fed ducklings were ill at the end of the experiment. (said by Dr. Brown)
C) Neither.

25. A) During the week following the experiment, all of the ill ducklings died. (from an article in a magazine that is to be found on almost every newsstand. The author, a popular American writer, stated that he obtained his information from Drs. Brown and Kolter.)
B) During the week following the experiment, the rest of the worm-fed ducklings died. (from the report written by Drs. Brown and Kolter)
C) Neither.

SECTION IV: From the original experiment the doctors drew this conclusion: CABBAGE WORMS ARE POISONOUS TO DUCKLINGS.

Mark items 26 through 38 according to the following system:

A) If true, it would make the conclusion more certain.
B) If true, it would make the conclusion less certain.
C) It would do neither.

CONSIDER EACH ITEM INDEPENDENTLY OF THE OTHERS.

26. The experiment is repeated. The results are similar.
27. The experiment is repeated with three different varieties of ducklings, which are younger than the ones used in the original experiment. At the end of the week two of the regular-diet ducklings are dead and twenty of the worm-diet ducklings are dead.

28. At the time of the original experiment there was an apple tree shedding apples into the cages of both sets of ducklings. The experimenters did not expect this to happen. About the same number of apples fell into each cage. This kind of apple does not affect the health of ducklings.

29. The experiment is repeated in Canada with twice as many ducklings. None of the ducklings die. At the end of the week two of the regular-diet ducklings are ill and three of the worm-diet ducklings are ill.

30. The experiment is repeated in Scotland. At the end of the week all of the worm-diet ducklings are dead and all of the regular-diet ducklings are alive and healthy. But it is discovered that the man who handled the worms had been spraying fruit trees with arsenic and had carelessly transferred some arsenic to the feeding pan of the worm-fed ducklings. Arsenic is a deadly poison.

31. A team of expert biologists examines the body structure and processes of ten common varieties of ducklings including the three used in the experiment. The biologists can find no significant difference between the varieties examined except for coloring.

32. It is discovered that during the original experiment the regular-fed ducklings had less sunlight than the worm-fed ducklings. It is not known whether or not the difference in amount of sunshine would have an effect on the health of ducklings.

33. A group of well-known Canadian duck breeders report that they discovered long ago that it was dangerous to ducklings to let them run in a cabbage patch.

34. It is discovered that both sets of ducklings reached through their cages and drank water from a little ditch that ran past both cages. They drank practically no water out of the pans that were in the cages. The water in the ditch was ordinary water.
35. The experiment is repeated in Canada with three different varieties of ducklings. All of the ducklings die, whether worm-fed or not.

36. The experiment is repeated in the United States with twice as many ducklings. At the end of the week, 40 out of the 44 regular-fed ducklings are alive and healthy and 39 out of the 44 worm-fed ducklings are alive and healthy.

37. It turns out that at the time of the original experiment a large oak tree was dropping acorns into the cages of the worm-fed ducklings only. The effect of this kind of acorn on the health of ducklings is not known.

38. A similar experiment with young dogs is performed. Another is performed with young turtles. In both cases the results are similar to those of the original ducklings experiment.

SECTION V: A research worker sets out to test the truth of the statement: If any duckling eats a cabbage worm, the duckling will die within six hours.

The research worker has developed accurate stomach-examining methods of telling whether a duckling has eaten a cabbage worm during the previous twelve hours.

In planning his experiments he needs to make some "predictions" from the above underlined statement.

a. "PREDICTIONS" TELL WHAT WOULD BE TRUE, IF THE STATEMENT WERE TRUE.

b. "PREDICTIONS" SHOULD BE USEFUL IN GUIDING AN ACTUAL EXPERIMENT.

Remembering these two rules about "predictions" answer items 39 through 42. The items refer to the seven possible "predictions" listed after item 42.

39. Of j, k, and l, which is the best "prediction"? A) j B) k C) l

40. Of k, l, and m, which is the best "prediction"? A) k B) l C) m

41. Of m, n, and o, which is the best "prediction"? A) m B) n C) o

42. Of n, o, and p, which is the best "prediction"? A) n B) o C) p
Possible "predictions":

j. If any duckling eats a cabbage worm, the duckling will be dead within six hours; and if a stomach test is performed within twelve hours after eating the worm, the results of the stomach test will show that the duckling has eaten at least one cabbage worm.

k. If any duckling does not die within six hours after a given period, then it did not eat any cabbage worms during that period.

l. Suppose six hungry Pintail ducklings are put for one hour in a cabbage patch containing cabbage worms and then put in a clean cage for six hours; if any do not die during that period, the results of the stomach test will show that these ducklings did not eat any cabbage worms.

m. If one Mallard duckling is selected at random from each of ten different broods, and all ten ducklings are kept away from cabbage worms for a twelve-hour period; then none will die during the last six hours of the twelve-hour period.

n. If one Mallard duckling is selected at random from each of six different broods, and each selected duckling is fed a cabbage worm; all six ducklings will be dead within six hours.

o. If twelve hungry, randomly-selected Canvas-back ducklings are turned loose for one hour in a cabbage patch containing cabbage worms and then put in a clean cage for six hours; if each dies during that period, the results of the stomach test will show that each has eaten a cabbage worm.

p. If a group of ten healthy Canvas-back ducklings that would probably live if not fed cabbage worms is randomly split in half, and each half treated the same except that the five of one group eat cabbage worms; then the worm-fed ducklings will die within six hours and the other ducklings probably will not.

SECTION VI: Items 43 through 46 provide situations in which a definition of a word is called for. From the three choices after each description, pick the one definition that best gives the meaning.
43. "That's a nice stock car you have there, Bill," his mother remarks.

"Stock car!" exclaims Bill. "That's no stock car. Did you ever see a car in a dealer's showroom with bumpers made out of heavy pipe? Do the automobile manufacturers turn out cars with no fenders? Of course not."

Bill's mother then asks, "Just what do you mean by 'stock car'?"

Of the following, which is the best way to state Bill's notion of a stock car?

A) A stock car is an automobile that is for the most part made of standard parts put out by automobile manufacturers, but which might have missing fenders and special bumpers.

B) A stock car is an automobile that has fenders and doesn't have bumpers made out of pipe.

C) A stock car is a standard automobile, as turned out by the factory and sold to the public.

44. "It certainly is a stock car," says Jim. "It has an ordinary engine that hasn't been changed since it came off the assembly line. That alone makes it a stock car and that's all that matters.

Of the following, what is the best way to state Jim's notion of a stock car?

A) A stock car is an automobile that is for the most part made of standard parts put out by automobile manufacturers, but which might have the fenders missing and special type bumpers.

B) A stock car is an automobile with a standard engine.

C) A stock car is where the engine is standard.

45. "What are you making with that dough?" asked Mary's father.

"Dough!" exclaimed Mary. "Did you ever see anything made with yeast that was baked immediately after it was mixed? Naturally not," she said as she put the mixture into the oven immediately after mixing it. "Therefore, it's not dough."

"What do you mean by 'dough'?" her father asked.
Of the following, which is the best way to state Mary's notion of dough?

A) Dough is a mixture of flour and other ingredients, including yeast.
B) Dough is a mixture of flour and other ingredients, not baked immediately.
C) Dough is a mixture of flour and other ingredients, often baked in an oven.

46. "Why, of course that's dough," said Joan. "You're making cookies, aren't you? It's not even called dough, unless it's used for cookies."

Of the following, which is the best way to state Joan's notion of dough?

A) Dough is a mixture of flour and other ingredients not baked immediately unless it's used for cookies.
B) Dough is a mixture of flour and other ingredients which is used for cookies.
C) Dough is a mixture of flour and other ingredients, which is used for cookies, unless it's baked immediately.

SECTION VII: In items 47 through 52 someone is speaking, but in each case there is an unstated assumption. An assumption is a statement that is taken for granted. Select the one that is most probably the unstated assumption. Consider each item by itself.

47. MR DOBERT: The fact that Gailton's children have been forced to work explains their misbehavior.

A) Children who have never been forced to work behave properly.
B) Children who behave improperly have been forced to work.
C) Children who have been forced to work behave improperly.

48. MRS. DOBERT: What we should do is not make them work. Then they would be all right. I know it.

A) Children who are forced to work will misbehave.
B) Children who are forced to work will behave properly.
C) Children who behave properly have not been forced to
work.

49. MRS. ALGAN: We ought to make them work. That will cure them.

   A) Children who aren't forced to work will misbehave.
   B) Children who are forced to work will behave properly.
   C) Children who haven't been severely punished behave properly.

50. MR. ALGAN: The explanation of the misbehavior of Gailton's present-day crop of youngsters is a simple one. These children have been severely punished at some time or other. That's the trouble.

   A) Children who have been severely punished misbehave.
   B) Children who misbehave have been severely punished at some time.
   C) Children who haven't been severely punished behave properly.

51. MRS. DOBERT: Their behavior can be explained by realizing that most of these youngsters have never been punished.

   A) Children who are punished behave properly.
   B) Children who behave improperly have never been punished.
   C) Children who have never been punished behave improperly.

52. MR. DOBERT: What we should do is never punish them. That would take care of things.

   A) Children who behave badly have been punished at some time.
   B) Children who are punished will misbehave.
   C) Children who behave properly have never been punished.

THE END. GO BACK AND CHECK YOUR ANSWERS.
PRINCIPLES OF BIOLOGY

1. The "first step" in photosynthesis is the
   A. formation of ATP.
   B. ionization of water.
   C. Excitement of an electron of chlorophyll a by a photon of light.
   D. attachment of CO₂ to a 5-carbon sugar.
   E. joining of two 3-carbon compounds to form glucose.

2. Within the cell, the site of respiration is the
   A. Golgi bodies.
   B. ribosomes.
   C. mitochondria.
   D. nucleus.
   E. nucleolus.

3. The use of energy entering an organism from the outside is 100% efficient in
   A. unicellular green plants only.
   B. all green plants.
   C. unicellular animals.
   D. bacteria.
   E. no organisms.

4. A theater audience applauds following a performance. The room immediately seems to become warmer. Which is probably the major reason for this change?
   A. This is a psychological effect--during the performance the audience ignores the heat.
   B. Body temperatures are lower during the performance due to inactivity.
   C. Everyone puts on his coat.
   D. Heat is released as a result of muscular activity and increased glucose oxidation.
   E. The lights are turned on, giving off heat.

5. A biology teacher has sealed a balanced aquarium and a quantity of air into a large glass carboy. After three months, the plants and animals in the aquarium appear alive and healthy. Which of the following statements about the experiment is wrong?
A. No energy has entered the carboy from the outside during the three months.
B. Potential energy in one organism in the aquarium has entered another organism during the three months.
C. Some atoms from water molecules have become parts of organic molecules.
D. The air above the water in the carboy contains carbon dioxide.
E. During the three months, the biomass of plant life was greater than the biomass of animal life.

6. Which best supports the belief that CO₂ fixation does not require light?
   A. ATP is made from ADP by green plants in the light but CO₂ fixation doesn't require ATP.
   B. Motile aerobic bacteria move faster when placed with green algae in the dark than when placed with green algae in the light.
   C. Plants give off CO₂ in the dark.
   D. Radioactive C*O₂ can be traced to phosphoglyceric acid (PGA) in green plants.
   E. Radioactive (C*) carbon compounds are found in animals grown in darkness in an atmosphere containing radioactive C*O₂.

7. In a fairly deep body of water, there is apt to be more biomass on or near the bottom than at most other levels. Yet, the energy of sunlight, on which living organisms depend, diminishes rapidly in being passed through the water. The best of the following ways of accounting for this apparent paradox is
   A. all photosynthetic plants must be rooted in the bottom to obtain minerals.
   B. organic materials continually drop to the bottom of the water.
   C. the animal population on the bottom converts enough carbon dioxide to organic compounds to supply all nutritive needs.
   D. all organisms must have a solid substratum to support them.
   E. temperature is more uniform at the bottom than elsewhere.

8. Transpiration rate in a maple tree is controlled by
   A. mitochondria.
   B. stomata.
   C. meristem.
   D. phloem.
   E. cambium.
9. Seed plant leaves are known to carry on all of the following except
   A. nerve impulse conduction.
   B. asexual reproduction.
   C. transpiration.
   D. starch synthesis.
   E. mitotic spindle formation.

10. Compound X breaks down the mitotic spindle but does not interfere
    with growth or with duplication of cell organelles. An application
    of compound X should result in which of the following (assuming
    the cells are alive)?
    A. Haploids.
    B. Cells without nuclei.
    C. Identical daughter cells.
    D. Polyploids.
    E. Synchronous dividing cells.

11. If the Golgi apparatus functions in secretion, then we would expect
    to find the most abundant Golgi apparatus in
    A. muscle cells.
    B. egg cells.
    C. gland cells.
    D. bone cells.
    E. blood cells.

Items 12-13 are based on the following information about three new
species of animals which fit into our existing classification system.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat is:</td>
<td>terrestrial</td>
<td>marine</td>
<td>terrestrial</td>
</tr>
<tr>
<td>Embryo develops in:</td>
<td>water</td>
<td>mother</td>
<td>egg</td>
</tr>
<tr>
<td>Mates:</td>
<td>in water</td>
<td>in water</td>
<td>on land</td>
</tr>
<tr>
<td>Skeleton is:</td>
<td>internal</td>
<td>internal</td>
<td>internal</td>
</tr>
<tr>
<td>Epidermis covered with:</td>
<td>slime or mucus</td>
<td>hair</td>
<td>scales</td>
</tr>
</tbody>
</table>

12. If we arrange the animals according to the proportion of yolk in
    their eggs, the most likely sequence (least to most yolk) is
    A. I, II, III.
    B. I, III, II.
    C. II, III, I.
    D. II, I, III.
    E. III, II, I.
13. Which animal(s) most likely has (have) gills at some state in the life cycle?
   A. Species I only.
   B. Species II only.
   C. Species I and II only.
   D. Species I and III only.
   E. None of the above species.

14. If living cells similar to those found on earth were found on another planet where there was no \( \text{O}_2 \), which cell organelle would most likely be absent?
   A. Cell membrane.
   B. chromosomes (or DNA).
   C. Nucleus.
   D. Mitochondria.
   E. Ribosomes

15. Which of the following is not functionally analogous with the others in the list?
   A. Archegonium.
   B. Oogonium.
   C. Spermatogonium.
   D. Ovary.
   E. Ovule.

16. A biologist plans to study the group behavior of monkeys. In order to avoid generalizing from aberrant observations, he would do best to select for observation
   A. a group at the center of the region inhabited by monkeys.
   B. a group at the periphery of the region inhabited by monkeys.
   C. a group containing a small number of individuals.
   D. a group containing a large number of individuals.
   E. many groups of monkeys.

17. Population growth pressure is a probable cause of which of the following?
   A. Genetic drift.
   B. Production of sterile hybrids.
   C. Ecological isolation.
   D. Migration of Lemmings.
   E. Abiogenesis.

18. A sexually immature male chicken is given daily injections of a hormone. At the end of two weeks, the investigator finds that the bird exhibits premature sexual behavior and crowing, and that its comb and gonads are unduly enlarged. He concludes that the
hormone must have been extracted from adult
A. testes.
B. ovaries.
C. thyroids.
D. pituitaries.
E. adrenals.

19. Carnivorous species are found in which of the following phyla of animals?
1. Coelenterata
2. Platyhelminthes
3. Annelida
4. Mollusca
5. Arthropoda
6. Echinodermata
A. All six phyla.
B. 1, 2, and 5, but not 3, 4, and 6.
C. 1, 5, and 6, but not 2, 3, 4.
D. 2, 4, 5, and 6, but not 1 and 3.
E. 2, 4, and 6, but not 1, 3, and 5.

20. The Hardy-Weinberg law enables us to
A. predict genetic ratio from individual matings.
B. map chromosomes.
C. calculate gene frequencies in a population.
D. predict population growth.
E. measure the rate of evolutionary change.

21. Genetic drift is most apt to occur in
A. tropical climates.
B. marine habitats.
C. high elevations.
D. small populations.
E. bacteria.

22. Which of the following is characteristic of a mouse homozygous for albinism?
A. It produces a white pigment in cells of its hair follicles.
B. It has a deficient capillary distribution.
C. It cannot manufacture melanin.
D. It does not absorb iron from its diet.
E. It lacks vitamin E.

23. Why were pea plants more suitable than cattle for Mendel's experiments?
A. There were no breeding records on cattle.
B. Pea plants can be self-fertilized.
C. Cattle are not easy to raise.
D. All pea plants have 2X chromosomes.
E. Cattle have many genetic traits.

24. It is suggested that Queen Victoria of England possessed a gene for hemophilia. This would indicate that
   A. her father also possessed this gene.
   B. hemophilia would occur in more of her male descendants than of her female descendants.
   C. all of her daughters must have carried the gene for hemophilia.
   D. all of her sons must have had a gene for hemophilia.
   E. Victoria herself was hemophilic.

25. If some mutations are harmful, why are they not eliminated from a gene pool?
   A. They are dominant and show up more frequently.
   B. They are recessive and carried by heterozygous individuals.
   C. They may have future survival value, hence they are retained.
   D. The Hardy-Weinberg Law enables them to survive.
   E. The population size is usually so small that genetic drift occurs.

26. There is a breed of cats in which genes for black or white hair color do not show dominance or recessiveness. If a cat carrying only black hair color genes is bred to a cat carrying only white-hair genes all of the offspring have grey hair. If two of these grey cats reproduce, the theoretical progeny ratio would be
   A. all grey.
   B. either all black or all white.
   C. 1/2 black, 1/2 white.
   D. 1/2 grey, 1/4 white, 1/4 black.
   E. 1/3 each of black, white, and grey individuals.

27. A radioactive nucleus from one ameba is transferred to a non-radioactive ameba which has its nucleus removed. If, later on, the second ameba is found to have radioactive ribosomes in its cytoplasm, this would be evidence in support of the
   A. chromosomal theory of inheritance.
   B. existence of the DNA code.
   C. functioning of messenger RNA.
   D. single gene - single enzyme hypothesis.
   E. Watson-Crick model of the structure of DNA.
28. Slight differences in 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.
E. they developed from separate fertilized eggs.

29. Which of the following insects undergo complete metamorphosis?
A. Grasshoppers.
B. Mayflies.
C. Fruitflies.
D. Termites.
E. Bugs.

30. If the pituitary stimulates the development of the follicles within the ovaries which in turn stimulate the growth of the uterine lining, then how can we best explain the periodical return of the uterine lining to the resting stage?
A. The pituitary alternately secretes a stimulating and inhibiting hormone.
B. The follicle produces a hormone which stimulates the uterine lining and inhibits the pituitary hormone.
C. The uterus produces a hormone which inhibits the follicle development which inhibits the pituitary.
D. The hypothalamus controls the development of the uterine lining which feeds back to the pituitary.
E. The ovary periodically changes its function because of an internal "clock".

31. What do the growth of a single cell, an organism, and a population have in common?
A. They are influenced by the environment.
B. They require energy and materials.
C. They result in an S-shaped curve if size is plotted versus time.
D. They involve chemical reactions catalyzed by enzymes.
E. All of the above.

32. A fern differs from a moss in having
A. an independent gametophyte.
B. an independent sporophyte.
C. swimming sperms.
D. archegonia.
E. haploid spores.
33. "Year after year, men cruising timber or hunting deer in the Blue Mountains of Eastern Oregon had come back with the same story. Near the little hamlet of Kamela, they had often heard a faraway tinkling, a ghostly bell ringing. No one was ever able to track down the strange sound. It would fade away in the sighs of the wind through the big pines. Skeptics accused the men of hearing things."

"Last week, slashing a right-of-way for a power line from Bonneville Dam, lumberjacks brought down a ponderosa pine. Tied by a shriveled leather thong high in the treetop was the answer to the mystery of Kamela: a bronze cattle bell, inscribed with the date 1878... The people of Kamela guessed that a pioneer had tied it to a sapling that grew into a towering pine." (TIME Magazine.) Which of the following is the best appraisal of the concluding sentence in this report?

A. Logical - because a tree elongates from the ground up.
B. Logical - because this particular tree could have attained great height since 1878.
C. Illogical - because no one knows with certainty when the bell was tied to the sapling.
D. Illogical - because elongation occurs only in the region of meristematic cells.
E. There is no basis for appraising the concluding sentence of this report.

34. Which will probably happen if fertilized eggs of toads and frogs are placed in the same container, assuming external conditions are suitable to both?

A. The environment will determine which RNA will direct the development and all frogs or all toads will result.
B. If given conditions are more favorable to a frog, the toad embryo will show the characteristics of a frog.
C. The frog embryo will assume toad features.
D. Fertilized frog eggs will become frogs; fertilized toad eggs will become toads.
E. No embryo will develop.

35. The class Sporozoa of the phylum Protozoa can be most easily characterized by

A. flagella.
B. chlorophyll.
C. parasitism.
D. cilia.
E. ameboid movement.
36. Blue-green algae may be distinguished from green algae by
   A. lack of the filament-forming habit.
   B. the presence of centrioles during mitosis.
   C. the absence of sexual reproduction.
   D. the absence of discrete nuclei.
   E. the absence of chlorophyll.

37. The characteristics defining a genus are more general than those defining
   A. a family
   B. a species.
   C. an order.
   D. a phylum.
   E. a class.

38. Nicotiana sylvestris flowers only during long days and Nicotiana tabacum flowers only during short days. If raised in the laboratory under different photoperiods, they can be induced to flower at the same time and can be cross-fertilized to produce self-fertile offspring. What is the best reason for considering N. sylvestris and N. tabacum separate species?
   A. They cannot interbreed in nature.
   B. They are reproductively distinct.
   C. They are physiologically distinct.
   D. They are morphologically distinct.
   E. They will probably not occur together in nature.

39. If our classification system represents evolutionary relationships, then which organisms probably would have the most similar antigens?
   A. Chlamydomonas eugametos and Sagittaria sagittifolia.
   B. Porcellio scaber and Daphnia pulex.
   C. Paramecium caudatum and Chlamydomonas eugametos.

Item 39 is based on the following abbreviated classification chart:

<table>
<thead>
<tr>
<th>Kingdom</th>
<th>Protista</th>
<th>Protista</th>
<th>Animal</th>
<th>Animal</th>
<th>Plant</th>
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<tbody>
<tr>
<td>Phylum</td>
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<td>Volvocales</td>
<td>Isopoda</td>
<td>Diplostraca</td>
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<tr>
<td>Family</td>
<td>Parameciidae</td>
<td>Chlamydomonadidae</td>
<td>Porcellionidae</td>
<td>Daphniidae</td>
<td>Alismaceae</td>
</tr>
<tr>
<td>Genus</td>
<td>Paramecium</td>
<td>Chlamydomonas</td>
<td>Porcellio</td>
<td>Daphnia</td>
<td>Sagittaria</td>
</tr>
<tr>
<td>Species</td>
<td>caudatum</td>
<td>eugametos</td>
<td>scaber</td>
<td>pulex</td>
<td>sagittifolia</td>
</tr>
</tbody>
</table>

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D. Paramecium caudatum and Porcellio scaber.
E. Sagittaria sagittifolia and Porcellio scaber.

40. A biologist classifies chemical substances according to their contribution to the life of a cell. Which of the following categories would chlorophyll best fit?
   A. Nutrition.
   B. Movement.
   C. Reproduction.
   D. Secretion.
   E. Energy transformation.

41. You are asked to classify cell organelles on the basis of their principal functions. One category you erect is for organelles whose chief function concerns cell division. Which of the following is the most likely representative of this category?
   A. Lysosome.
   B. Mitochondrion.
   C. Centriole.
   D. Ribosome.
   E. Golgi body.

42. A living organism most like the postulated common ancestor of plants and animals is a/an
   A. diatom.
   B. flagellate.
   C. ameba.
   D. blue-green algae.
   E. ciliate.

43. On the phylogenetic "tree" of animal life, which of the following is assumed to be more primitive than a dinosaur but more advanced than a shark?
   A. Crayfish.
   B. Starfish.
   C. Amphioxus.
   D. Salamander.
   E. None of the foregoing.

44. Which is most important in determining the direction of evolution of an animal species?
   A. High mutation rate for certain traits.
   B. Independent assortment and recombination of certain traits.
   C. Selection of certain traits by environmental conditions.
   D. The gradual change of certain traits by environmental conditions.
E. "An inner desire to survive in the face of change."

45. Which of the following best states the evolution theory?
   A. Evolution is the maintenance of life under changing conditions.
   B. Evolution is the survival of the fittest.
   C. Evolution is the descent of humans from lower animals.
   D. Evolution is goal-directed change.
   E. Evolution is variation.

46. Which of the following is the best example of an evolutionary change in a species of organisms?
   A. Formation of a callus on the stem of a lilac bush.
   B. Change of color of a canary's feathers due to feeding the bird pepper.
   C. "Whitening" of bean seedlings grown in the dark.
   D. Alteration of molecular structure of DNA by radiation.
   E. Development of thicker fur on a rabbit in winter.

47. The development of large size in land plants in especially correlated with
   A. increased efficiency in asexual reproduction.
   B. insect pollination.
   C. specialization of vascular tissues.
   D. appearance of an electron transport system.
   E. development of a cambium.

48. A population of deer was threatened with overpopulation until a number of cheetahs 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. population explosion.
   E. genetic drift.

49. Which of the following events probably contributed the most to the formation of the first living entity on this planet?
   A. Appearance in an ocean of the first soluble carbonates.
   B. Occurrence in a warm, shallow bay of a medium with a pH of 7.0.
   C. Synthesis of the first functional nucleic acid molecule.
   D. Development of a limiting membrane.
   E. Occurrence of the first mitotic cell division.
50. Humans have achieved evolutionary success without the speed of deer, the teeth of wolves, or the skin thickness of rhinoceroses. Of the following, the evolutionary development which has probably contributed most to success of the human species in competition with other mammals is
   A. the bi-ocular vision.
   B. upright posture.
   C. long gestation period.
   D. loss of body hair and tail.
   E. increased brain development.

51. Freshwater amebas are commonly protected from desiccation by
   A. attaching to the gills of fishes.
   B. encystment.
   C. sexual reproduction.
   D. burrowing into the lake bottom.
   E. entering the alimentary canal of an invertebrate host.

52. British moths living in soot-drenched areas tend to be darkly colored, in contrast to their light-colored relatives in regions relatively free from soot. The increased prevalence of the dark color is referred to as
   A. chromocenter.
   B. protective coloration.
   C. chromotrophy.
   D. industrial melanism.
   E. warning coloration.

53. Competition for food, light, space, etc. is probably most severe between two
   A. closely related species occupying the same niche.
   B. closely related species occupying different niches.
   C. unrelated species occupying the same niche.
   D. unrelated species occupying different niches.
   E. species in different overlapping ecosystems.

54. In a certain ecosystem, field mice are preyed upon by snakes and hawks. The entrance of wild dogs into the system adds another predator on the mice. Of the following, the most likely short-term result of this addition is
   A. increase in snake population.
   B. tendency for hawks to prey on the dogs.
   C. extinction of the hawks.
   D. reduction in numbers of mice.
   E. migration of the hawks to another ecosystem.
55. Compared to the Texas jack rabbit, the Arctic hare would be expected to have
   A. longer legs.
   B. longer ears.
   C. shorter appendages.
   D. more sensitive whiskers.
   E. more frequent breeding seasons.

56. Which of the following is a result of ecological isolation?
   A. The variation among Darwin's finches on the Galapagos Islands.
   B. The development of the amniote egg in reptiles.
   C. The dominance of the sporophyte generation in ferns.
   D. The formation of cellulose walls in blue-green algae.
   E. The development of autotrophy in green plants.

57. The chief advantage of encystment to an ameba is
   A. the ability to live for a time without ingesting food.
   B. the cessation of most metabolic activity so that available energy may be used for reproduction.
   C. protection from parasitic invasion.
   D. the opportunity to get rid of accumulated waste products.
   E. the ability to survive during unfavorable physical conditions.

58. A crocodile has just eaten a lamb. A plover accommodately picks the crocodile's teeth. By this act, the plover, in ecological terms, is a
   A. producer.
   B. primary consumer.
   C. secondary consumer.
   D. tertiary consumer.
   E. reducer.

59. Which of the following is the best experimental procedure to determine the effectiveness of a vaccine in preventing influenza in parakeets?
   A. Expose 100 parakeets to the disease and inoculate 50 with the vaccine.
   B. Inoculate 100 parakeets with the vaccine and expose all 100 to the disease.
   C. Inoculate 50 with the vaccine and expose all 100 to the disease.
   D. Inoculate 50 with the vaccine and expose those to the disease.
E. Inoculate 50 with the vaccine and 50 with sterile saline and then expose all 100 to the disease.

60. The helical structure of the DNA molecule was established by
   A. Watson and Crick.
   B. Jacob and Monod.
   C. Beadle and Tatum.
   D. Briggs and King.
   E. Hardy and Weinberg.

61. Which of the following was most influential upon Darwin's formulation of the theory of natural selection?
   A. DeVries' concept of mutations.
   B. Lamarck's ideas on inheritance of acquired characteristics.
   C. Malthus' essay on population.
   D. Mendel's genetic studies on peas.
   E. Wallace's paper on survival.

62. The "cell theory" of Schleiden and Schwann states that
   A. all cells have nuclei.
   B. cells use ATP as the immediate source of energy.
   C. cells arise only from preexisting cells.
   D. cells reproduce by mitosis or meiosis.
   E. cells are the fundamental structural units of plants and animals.

63. Molecular biologists generally maintain that
   A. the kinds of atoms an organism possesses differentiate it best from other kinds of organisms.
   B. there are in living organisms no higher levels of organization than the molecule.
   C. all significant biological phenomena are intramolecular.
   D. organisms are more alike in their chemical reactions than in their morphological characteristics.
   E. only molecules in the first two rows of the periodic table occur normally in living organisms.

64. It is hypothesized that owl species X is the major factor in controlling rabbit species Z. The most workable yet valid procedure for the investigator would be to study
   A. examples of all species of rabbits and owls.
   B. samples from representative populations of owl X and rabbit Z.
   C. all individuals of a representative population of owl X and rabbit Z.
D. representative individuals of rabbit Z.
E. samples of all major ecosystems.

65. If our hypothesis is correct, then
   A. a decrease in the population of X owls should decrease the population of Z rabbits.
   B. a decrease in the population of Z rabbits should increase the population of X owls.
   C. an increase of Z rabbits diseases should not change the population of X owls.
   D. an increase in food for Z rabbits should not change the population of X owls.
   E. an increase in X owls should decrease the population of Z rabbits.