ASSESSMENT OF CONTENT AREA KNOWLEDGE, WRITING SKILLS, AND HIGHER ORDER THINKING SKILLS OF STUDENTS PARTICIPATING IN AN ENTRY-LEVEL BIOLOGY MAJOR'S COURSE

THESIS

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WRITING SKILLS, AND HIGHER ORDER THINKING SKILLS OF STUDENTS

PARTICIPATING IN AN ENTRY-LEVEL BIOLOGY MAJOR'S COURSE

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August 2002

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Current curriculum reform trends in science education have led many institutions to revamp their programs from those incorporating traditional direct teaching style lectures and labs to those integrating inquiry driven, problem based learning in lectures and labs. In response to poor performance in mixed majors'/non majors' biology courses and low retention rate of biology students at Southwest Texas State University (SWT) a new program entitled the Biology 2000 Curriculum was implemented in the fall of 2000. A major portion of the new curriculum is the addition of two new entry-level majors' only courses. The new curriculum replaced the traditional entry-level zoology and botany courses with a two-semester Functional and Organismal Biology sequence. The entry-level courses were designed to introduce inquiry-based learning at the first phase of the biology program. Program evaluation of two entry-level biology major's courses was implemented in the fall semester of 2000 as part of the total assessment strategy of the Biology Program at SWT. The goal of the assessment was to assess change in entry-level students' content area knowledge, writing skills, and higher order thinking skills over the course of a semester. A "homemade" instrument of assessment was designed and used in a pre-post semester format on all students enrolled in the entry-level courses. Content areas reflective of course syllabi were chosen and assessed. A paired t-test was used to determine significant change over the course of a semester. Four semesters of data were aggregated and a total of 708 students were assessed. Results of assessments in Functional Biology indicate a significant increase in the content areas of genetics only. Results of assessments in Organismal Biology indicate a significant increase in the content areas of cells, metabolism, plants, and genetics. Students in Functional Biology had an average increase of 10.3% from pre semester to post semester with a maximum score of 54% while students in Organismal Biology had an average increase of 6.6% with a maximum score of 41%. Results indicate that students are not learning sufficient content area knowledge, but showed marked improvement in writing skills and higher order thinking skills. An assessment protocol was established and groundwork laid for continuing assessment of entry-level biology classes at SWT.

INTRODUCTION

Sixty-five percent of students enrolled in the Southwest Texas State University (SWT) Biology curriculum in mixed majors/non-majors entry-level courses in the 1998 – 1999 academic year earned D, F or W grades and twenty percent of students enrolling in these courses dropped them. According to data generated in 1999 by the SWT Institutional Research and Planning Department, the Biology Department retains close to 37% of biology majors to the BA or BS degree (Koke 1999). This, compared to the four year SWT average retention rate of 46% indicates that students are leaving the biology curriculum at a disturbing rate. It was hypothesized by the biology faculty, that biology students who were taking upper division courses "out of sequence" to avoid taking cellular biology and genetics, was resulting in the poor grades and the high withdrawal rates in addition to a prolonged advancement through the curriculum. These quantitative lines of evidence along with qualitative input from professors in upper division courses indicating low performance by students in the areas of writing skills, presentation skills and inquiry-based hypothesis driven thinking skills were the driving force in the creation of a new curriculum designed to address these issues.

Specifically, the Biology Department at SWT implemented a new program in the fall of 2000 entitled the "Biology 2000 Curriculum" which implements, among other changes: (1) two newly designed separate entry-level courses for biology majors and non-majors, (2) a more streamlined and diverse core curriculum for biology majors, (3) and an assessment plan that includes formative and summative assessment of both cognitive and affective effects of the Biology 2000 Curriculum.

The SWT Biology 2000 Curriculum was designed to achieve the following goals: (1) improve the majors' and non-majors' understanding of life sciences, (2) increase students' enthusiasm for science, (3) improve the retention of students in the Biology program for majors and in the University for non-majors, (4) development a long term relationships among the Biology department and its present and former students, (5) have a positive impact on students' appreciation and understanding of life science; and (6) increase the number of students choosing to become Biology majors at SWT (Koke 1999).

A major element of the Biology 2000 Curriculum is the addition of the two new entry-level courses that replace the traditional first year botany and zoology courses. The two new courses are Functional Biology and Organismal Biology. Functional Biology provides the science major with a strong foundation in cellular and molecular biology and physiology. Content areas covered in Functional Biology include biological chemistry, metabolism, the molecular bases of cellular functions and genetics, the molecular biology of reproduction and development, cell signaling, neurobiology and the special senses, and human physiology and the immune system (Koke 2002). Organismal Biology provides the science major with a strong foundation in organismal biology, Mendelian and population genetics, evolution, and ecology. Content areas covered in Organismal Biology include taxonomy, patterns of diversity, ecosystems and human biology, behavior, reproductive biology, and comparative physiology (Koke 2002).

It is hoped that these courses may act as a catalyst for first year students in their journey toward a biology degree and have a positive effect on their performance in upper division courses. Improved performance in upper division courses will reflect well on the

whole biology program and will aid in meeting the six departmental goals established in the Biology 2000 Curriculum documentation.

The change in the SWT Biology program follows a worldwide trend, not only in science education, but education as a whole. This thesis is written not to defend previous or current curriculum changes worldwide or in the SWT Biology program. The purpose of this thesis is to describe the methods and materials used to assess the Biology 2000 Program at SWT in the entry-level courses, to discuss the results of the assessment, and to make recommendations for future assessment strategies. It is imperative though, that one understands the driving forces and the history behind curriculum reform before discussing the curricular change and subsequent assessment strategy implemented in the SWT Biology Department.

Reform of educational programs, curricula and pedagogy has reoccurred in decade long cycles beginning in the 1920's and again in the 1940's and reached a fevered pitch with the launch of Sputnik by the Soviet Union in 1957 (Shymansky 1992). For the first time, Americans felt they might be technologically behind the rest of the world. The American education system, specifically the science and math educational program, was the first to be blamed. There now exist over 4,000 articles and books declaring the educational system as a whole in the United States in disarray (Gibbs 1999), including Hyman Rickover's 1963 *American Education: A National Failure* which predicted a Russian technological dominance over the U.S. due to Soviet superiority in science and math curriculums (Rickover 1963), and the 1983 text *A Nation at Risk: The imperative for educational reform*, which warned that our failure in the classroom would lead to Japan's and other countries technological dominance over the U.S. (United States. National Commission on Excellence in Education. 1983). The results of the 1995 Third

International Mathematics and Science Study confirmed these predictions when it was shown that America's high school seniors had placed near last (Gibbs 1999).

As part of a response, curricular reform plans in the subjects of chemistry, physics and biology sprang up almost overnight around the country including the Biological Sciences Curriculum Study (BSCS) in biology, the Physical Science Study Committee (PSSC) in physics, and the Chemical Bond Approach (CBA) in chemistry, to name a few. These curricula are now known as the "alphabet-soup" science curricula and have a common theme of inquiry-based student learning (Leonard 1983; (Shymansky 1990).

In 1980 the BSCS inquiry-based approach to teaching biology was first compared, experimentally, against a well-established commercial program that was viewed as highly directive in nature. Inquiry-based teaching focuses on the process of actually "doing" science and not just reading, memorizing and repeating vocabulary. The independent variable tested was the method of laboratory instructions whereas the dependant variable was a sixty question multiple-choice test covering concepts and principles usually taught in university entry-level biology courses. Results indicated significantly higher scores (6%) on post assessments by BSCS students (Leonard 1983). A meta-analysis, using the methodology described by Glass (Glass 1976), of the results of the "alphabet soup" curricula indicated that they were more effective in enhancing student performance and attitudes toward science than traditional textbook-based programs of the time. Other studies have shown that BSCS style programs, and their subsequent Problem Based Learning (PBL) pedagogy, at least equivalent or superior to traditional instruction for some variables of interest (Greenfeld 1996). PBL courses mirror the philosophy of the "alphabet soup" curriculum of the 60's and 70's in that they focus on inquiry based learning and student understanding and ownership of their

knowledge instead of rote memorization and regurgitation of facts and figures. Overall, PBL programs have been found significantly effective in secondary and post-secondary institutions for outcomes related to critical thinking, research skills, positive attitudes toward learning, and long-term retention, all of which are desirable outcomes in the Biology Program at SWT.

Implementing a curriculum designed to improve student's inquiry-based skills requires introduction of problem-based learning (PBL) courses into the program. PBL is an instructional format requiring students to participate actively in their own learning by researching and working through a series of real-life problems to arrive at a "best" solution (Greenfeld 1996). In the past, PBL courses have been implemented primarily in medical schools to help develop the diagnostic skills of future physicians (Gardiner 1999). Results of comparison of PBL courses to traditional courses are mixed at best due mainly to the fact that their growth and implementation are so new (Hall 1990). As with any major curriculum change, initiating PBL requires time, research, resources, risk-taking and some trial and error. All of these factors have been observed during the curriculum change at SWT. Educators must develop PBL research problems for students to work on and then support the student in his or her endeavors rather than "spoon feed" the information to them as in traditional directed learning environments. Studies have identified some of the reasons behind the lack of enthusiasm among teachers in implementing a new biology curriculum. The reasons included: (1) The high expectations set at the ideal level regarding the inquiry approach to teaching, (2) the greater role given to verbalization in a biology curriculum, and (3) dull implementation which occurs when teachers are too faithful to the teaching text (Banta 1963). Implementation of PBL courses is difficult for some educators who are set in their ways

and especially difficult for lab instructors who have no experience how to teach PBL courses. Inconsistency in lab instruction across sections is a result of untrained lab instructors or constant lab instructor turnover due to either dissatisfaction with the assignment or graduation (Sundberg 1994).

No complete set of goals was ever established for these new science curricula, although a common thread running through them was that the "process" objective of actually learning how to "do" science was stressed. This contrasts dramatically with the traditional curricula that stressed facts, laws, theories and some application. The consensus began to grow among science professionals that schools should produce more scientifically literate citizens instead of more candidates for the academic elite, i.e. "science for all." A myriad of definitions of scientific literacy exist in the literature, but it has been more concisely summarized by Frank Sutman of Temple University: "A person is science literate when that person is able and willing to continue to learn science content, to develop science processes on his or her own, and is able to communicate the results of this learning to others" (Sutman 1996). The late John Moore of the University of California added to this concept in his thesis "Science as a Way of Knowing" where he describes ways to improve entry-level science courses at the university level by creating a "framework of knowledge" from which to work (Moore 1993).

It is, therefore, becoming widely recognized and accepted throughout the educational community that implementation of these type curricula improve levels of student learning and attitudes toward science. Universities that have implemented PBL courses have discovered, via their assessment programs, that students enrolled in these courses have a more positive learning experience, an improved attitude toward science, and that enrollment, retention and achievement improved over time (Hall 1990).

Comparison of inquiry-based BSCS style laboratory approach to a more traditional direct teaching approach on student outcomes in cognitive and affective domains of learning of students enrolled in introductory, majors biology courses was measured at St. Cloud State University, St. Cloud, Minnesota and at The University of Nebraska-Lincoln. Administration of a researcher-generated instrument of assessment indicated that students participating in the BSCS-style laboratory approach scored significantly higher than the comparison group in levels of performance on biology content area achievement (Hall 1990). A study in the biology department at Skyline College, San Bruno, California, indicated that the implementation of a BSCS style biology laboratory induced significant increases in enrollment, retention, and achievement as opposed to students participating in conventional direct teaching format biology labs (Case 1980).

The University of Oregon developed and assessed an inquiry-based "Workshop Biology" course that is designed to have a positive effect on students' learning, their perceptions of their learning, their involvement in learning activities and the retention of students. Results of three years of comparing students participating in Workshop Biology courses to students participating in more traditional direct teaching methodologies indicate significant increases in Workshop Biology students' understanding of basic biology concepts and their ability to apply them to novel situations, an increases in the estimations of the course's effect on their learning and their motivation to learn, as well as a higher retention rate from one semester to the next (Udovic 1993).

Quantitative synthesis via a meta-analysis (Glass 1976) of primary research of the results of 105 experimental studies on more than 45,000 students in 27 different PBL

curricula, at the university level, reveal definite positive patterns of student performance. Students participating in the new curricula performed better than students in traditional courses in general achievement, analytical skills, process skills, and related skills of reading, mathematics, social studies and communication, as well as developing a more positive attitude toward science. On average, students participating in new science curricula outperformed 63% of students in traditional science classes (Shymansky 1983).

These examples are but a few of the proven, research based of curricular reform involving implementation of university biology PBL type courses at the entry-level. The majority of universities undertaking similar curriculum reforms point out that a huge investment of time and energy is required to start and maintain the new curriculum, but the benefits for both students and instructors far outweigh any negative aspects of the reform.

It has been estimated by some that 10 years is a reasonable estimate of the minimum time required to change the undergraduate science teaching culture at a university (Wyckoff 2001). Similar changes and time frame can be expected as SWT moves forward in its Biology 2000 Curriculum reform and assessment efforts.

The path to science curricula reform is wide and varies because each institution and academic program differs in its individual needs. The assessments of programs initiated as part of a curriculum reform are as varied as the programs and institutions themselves, but should have common outcomes of determining whether the goals of the instructional programs are being met, whether the assumptions being made are accurate, and whether and where gaps exist (Diamond 1998). A descriptive statement from the American Association for Higher Education (AAHE) provides a starting place for the discussion of assessment:

> "Assessment is an ongoing process aimed at understanding and improving student learning. It involves making our expectations explicit and public; setting appropriate criteria and high standards for learning quality: systematically gathering, analyzing, and interpreting evidence to determine how well performance matched those expectations and standards: and using the resulting information to document, explain, and improve performance. When it is embedded effectively within larger institutional systems, assessments can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education" (Angelo 1992).

Academic programs are evaluated to determine their quality and to provide direction for improving them. Many guidelines and methodologies have been established for carrying out assessment programs in both the academic and corporate world. To that end, many methods and instruments have been designed and validated to assess academic achievement at the national, state and local levels (Champagne 1992). *The Program Evaluation Standards 2nd Edition* contains a set of standards designed to assist the needs of assessors in all arenas (Sanders 1994) as does the *Guiding Principles for Evaluators* and *Classroom Assessment Techniques: A Handbook for College Teachers 2nd Edition* (Angelo 1992) .

While guidelines are important and useful in establishing assessment protocols for individual programs, they cannot create a valid and reliable instrument for each institution's needs by following prescribed steps alone. Assessments ought to be oriented toward what each institution values, be epistemologically sound, have the richness of the

learning experience embedded in the assessment protocols, and have the quality and value of the total education and science experiences be evident (Kyle 1997). Assessments should not rely solely on quantitative high stakes testing (Maybry 2002) or on qualitative feedback, but should be comprised of multiple lines of evidence. Though few studies have documented increased student learning associated with assessments, three other outcomes related to assessment practices have been noted: (1) Changes in the classroom that were linked with positive outcomes. (2) Changes in curricula in response to varying assessments, and (3) improvements in assessment types so that the intended target was actually measured (Banta 1996).

To ensure that the "target was actually measured" assessment instruments must be both valid and reliable. Validity and reliability of assessment instruments are important factors in determining if a test measures what is designed to measure. A test is considered valid "if it measures what it purports to measure" (Scriven 1991) and is reliable "to the extent to which an assessment consistently assesses whatever it is assessing" (Airasian 2001).

An analysis of "homemade" achievement instruments indicated that reliability estimates and the procedure for selecting items were often omitted when reporting results from assessments (Hastings 1983). These must be reported if any significant links are to be made between assessment results and course specific goals. In his article "How to construct achievement tests to assess comprehension" (Anderson 1972), Anderson stated that,

"procedures currently in use for constructing and describing achievement tests

> are a mess. Conclusions about methods, variables or procedures can hardly be taken seriously when you don't know what the test measures. Drastic action is indicated. Journal editors are admonished forthwith to reject papers unless they contain (1) a documented rational for selecting the questions to be asked, and (2) a fully-explained analysis of the relationship between the questions and the preceding instruction."

Anderson identified eight categories that should be included when reporting results from homemade achievement tests including, (1) the number of items indicated, (2) response mode of the test, (3) the number of alternatives in multiple choice items indicated, (4) the reliability estimates of the instrument, (5) the empirical test development procedure, (6) the procedure for selecting questions, (7) the control for preexperimental knowledge, and (8) the relation of test items to instruction.

There are numerous "homemade" instruments of assessment that have been developed in biology, chemistry and physics that illustrate the difficulty of establishing both reliability and validity (Maynes 1983; Lawrenz 2000; Scantlebury 2001), but it should be realized that these instruments provide a better means of measuring student performance in domains of central interest to individual institutions than can competing instruments, and that they do so at little costs. Data comparing the costs of administering different types of assessments, time spent by faculty administering tests, and the time spent by students taking different forms of assessment were compounded as part of a cost analysis for policy considerations in large scale science assessments (Lawrenz 2000). Results of this study show that multiple choice items cost the least, and that it is approximately 80 times as much for an open ended item, 300 times as much for a content station, and 500 times as much for a full investigation item. A meta-analysis (Glass 1976)

of standardized tests in the areas of biology, chemistry, earth science, and physics indicated that these tests have little significant interest in measuring whether or not science students have developed an ability to use rational powers of thinking (Morgenstern 1984). It is for these reasons that an internally developed, or "homemade" instrument of assessment, including multiple choice and essay questions will be utilized in this study of the assessment of students' content area knowledge, writing skills and higher order thinking skills in the entry-level biology major's program at SWT.

A classroom achievement instrument designed to measure course specific content areas, student writing skills, and higher order thinking skills will provide feedback to the Biology Department of the change in entry-level student's understanding of course specific concepts, writing skills and higher order thinking skills over the course of a semester. Data will also provide information about the students' ability to apply PBL approach to answering new and unique questions using information gleaned from lecture, lab, textbook and other resources. Data from each semester will be aggregated to indicate total entry-level program performance as opposed to "data mining" from individual semesters. Analysis of demographic variables obtained from test instruments allow for future pairing of change in student scores with independent variables of interest. Independent, unbiased assessment of the entry-level biology curriculum as a whole, as opposed to individual assessment provided by teaching faculty members is necessary and valuable to the Biology Department as a whole, and to the University.

The goals of this study were to (1) assess students' gain in course specific content area knowledge in entry-level Functional and Organismal Biology courses at SWT using a "homemade" instrument of assessment, (2) assess students' writing skills via an essay question designed around course specific content area knowledge, (3) assess students'

higher order thinking skills using questions designed around Bloom's taxonomy of higher order thinking skills (Bloom 1956), and (4) establish a protocol for continued assessment of the entry-level biology courses at SWT. Specifically, my research hypothesis is that there will be no statistically significant change in entry-level course students' performance in the areas of course specific content knowledge, writing skills and higher order thinking skills due to participation in the new entry-level courses.

METHODS/MATERIALS

Change in entry-level biology students' performance in the areas of content knowledge, writing skills, and higher order thinking skills was measured via the administration of an internally designed, or "homemade", instrument of assessment. Assessments were administered in a pre–post semester format to all students enrolled in entry-level biology courses at SWT. The research, or null hypothesis that there will be no change in content area knowledge, writing skills and higher order thinking skills due to participation in new entry-level biology courses was tested using a paired t-test to determine if significant change occurred over the course of a semester. Data from each semester will be aggregated to aid in determining longitudinal change over time in the entry-level biology courses at SWT. It is hypothesized by the biology faculty that the change in performance will be a positive one that reflects the course content and inquiry based pedagogy of the Biology 2000 Curriculum.

An assessment instrument approved by the entry-level teaching faculty was administered in a pre-semester, post-semester format, in all laboratory sections to all students enrolled in Functional and Organismal Biology classes at SWT during the fall 2000, spring 2001, fall 2001, and spring 2002 semesters. Assessments were administered to students in classroom lecture settings in fall 2000 and spring 2001 and in laboratory settings in fall 2001 and spring 2002 semesters. Students' social security numbers were used to compare pre and post assessment scores. Any results without both a pre and post semester assessment were not used. Cognitive achievement, higher order thinking ability, and writing skills were assessed. The cognitive areas assessed in both entry-level courses reflect the content areas in the course syllabi (Tables 1 and 2). Content area

questions were gleaned from validated test banks (Germann 1989; Udovic 1993; Service 1994; Schrock 1997; Martin 1999) and reflected material that was addressed in lab and lecture in both Functional and Organismal Biology courses at SWT. Pre validated questions were chosen to eliminate the validation process involved with creating "homemade" achievement tests. The criteria of content-related validity was achieved by ensuring that the test represents the domain of tasks to be measured as recommended by Gronlund (Gronlund 1990). Criterion validity was not achieved, as there are no definitive criterions established for student outcomes in entry-level biology courses at SWT. It is for this reason that the instrument of assessment is labeled a classroom achievement test as opposed to a criterion referenced measurement device. There are 41 test items included in the Functional Biology test (Appendix A). All of the multiple-choice items have either four or five possible responses. There is one question that requires students to draw the chromosomes as they appear at certain times during mitosis and meiosis. The last question is an essay question (Appendix B). There are 51 test items included in the Organismal Biology test (Appendix C). Fifty of these items are multiple choice with either four or five possible responses. The last question is an essay question (Appendix D). Each content area has items that assess the levels of higher order thinking skills as defined by Bloom's taxonomy of learning (Bloom 1956) and will be used as a measure of knowledge, understanding, application and analysis and synthesis (Tables 3 and 4). Analyses of these results indicate students' ability to perform higher order thinking skills. Student's writing skills were assessed using a response to an essay question designed around course specific content areas in both Functional and

Organismal Biology. An internally designed rubric (Tables 5 and 6) was used to score essay questions and pre-post semester scores on all assessments were analyzed using a paired t-test. A paired t-test was used to analyze individual dependant variables within each instrument of assessment. Dependant variables include each content area of interest, student writing skills, and each level of Bloom's taxonomy of higher order thinking, while the independent variable tested was participation in the new curriculum.

The null hypothesis is that there are no differences ($\overline{D} = \mu_{post} - \mu_{pre}$), between mean scores of pre and post semester assessment scores: Ho: $\overline{D} = 0$. The alternate hypothesis is that there is a difference between pre and post semester assessment scores: Ha: $\overline{D} \neq 0$. The test statistic will be: $t = \frac{\overline{d} - Do}{Sd/\sqrt{n}}$ where $\overline{d}$ and Sd are the sample means and sample standard deviation, respectively. The distribution of the test statistic will be t with $v = n - 1$ degrees of freedom. The test will be performed with $\alpha = 0.05$. Significance levels throughout are denoted as: * = $p < 0.05$; ** = $p < 0.01$; *** $p < 0.001$. Critical significance values were from Winer (Winer 1991). The probability of committing a Type I Error decreased below 5% for each independent variable analyzed, as the paired t-tests were calculated for dependant variables within each test instrument as described by the Dunn-Bonferroni Procedure (Winer 1991) where α for each subsequent dependent variable within the assessment was adjusted according to the formula $\alpha_{ind} = 1 - (1 - \alpha_{exp})^{1/m}$, where $\alpha_{exp} = 0.05$, m = independent tests of dependent variables and α_{ind} = level of significance of each dependant variable tested. The Functional Biology instrument of assessment contains five concept areas (Table 6). Therefore $m = 5$ and $\alpha_{ind} = 0.010$ for each concept area. The Organismal Biology instrument of assessment contains seven

concept areas (Table 7). Therefore m = 7 and $\alpha = 0.007$ for each concept area. All other statistical analysis will be calculated with a level of significance of 0.05 unless otherwise noted. t-test data will be calculated using Microsoft® Excel© software.

Included in each instrument is a demographic survey designed to identify students' educational background in high school and college (Appendix E). The demographic survey will provide data for comparison of change within each classification (freshman, sophomore, junior, senior and other) of student participating in the entry-level biology classes at SWT. This survey will also provide information at a later date to correlate student performance against previous science experiences as well as providing descriptive statistical information of the student population in the entry-level biology classes at SWT.

Scores were tracked in all content areas as well as levels of Bloom's taxonomy. Significant changes in Bloom's taxonomy scores were used as an indicator of student's higher order thinking skills. Any statistically significant change in student's scores will result in a failure to reject the null hypothesis that there will be no change between student's pre and posttest scores. Teaching faculty have the option of changing either content materials and/or pedagogy in response to the results.

Assessment instrument reliability indices were calculated after the administration of each test using the coefficient α formula which is the ratio of the true score variance to the observed score variance and is expressed symbolically as $\rho_{xx' \geq \alpha} = \frac{[N]}{[N-1]}\left[\frac{\sigma_x^2 - \sum_{i=1}^{n}\sigma_{yi}^2}{\sigma_x^2}\right]$, where X = the observed score for a test formed from

combining N components, $X = \sum_{i=1} Ny_i$, σ_x^2 = the population variance of X, σ_{yi}^2 = the population variance of the *i*th item, Y_i, and N = number of content areas in each instrument and/or the number of areas of Bloom's taxonomy. Typical classroom reliability indices range from 0.60 to 0.80, with standardized tests usually above 0.80.

Item discrimination analysis was also performed after each assessment administration. Item discrimination is a correlation between points awarded on an item and the total test score. When the item discrimination is *positive*, it indicates that the students who answered the item correctly performed better on the rest of the test than the students who answered the item incorrectly. A *negative* item discrimination means that the student who missed the item did better on the rest of the test than the students who got the item correct. Item discrimination analysis allows for poorly worded or ambiguous items, items that do not assess what other items are assessing, and dissimilar items to be removed and replaced in the instrument. Test items that were found to be low for two continuous administration of the test were removed and replaced with questions of identical content area and Bloom's taxonomy level in an attempt to improve overall instrument reliability. Item discrimination data was generated by the Testing Center at SWT.

The results of statistical analysis of the paired t-test indicate either a change or no change in scores from a pre to post semester assessments. A statistically significant positive change in content area scores over the course of a semester indicates an increase in content area knowledge, while a significantly significant decrease in scores is an indicator that students are not learning course specific content knowledge. Reliability indices are examined after each test administration to determine the instrument's

reliability. Item discrimination analysis enables reliability indices to be increased over time. Results of the descriptive statistics of the nineteen demographic variables provide a tracking mechanism for the demographics of students who enrolled in entry-level biology classes and provide data, which can be analyzed to answer other research questions in the evaluation of the entry-level Biology program at SWT.

A control group of students' performance in the "old" curriculum was obtained using the instruments of assessment used in the Biology 2000 Curriculum assessment. The data from the old curriculum was gleaned from two summer semesters in 2000. The classes assessed were introductory botany and zoology. There has been no data produced from a summer semester in the Biology 2000 Curriculum, therefore the comparisons between the control group in the "old" curriculum and students in the Biology 2000 Curriculum would not be statistically significant and the data were, therefore, not used.

Table 1. Content areas assessed in Functional Biology at Southwest Texas State University, as part of the assessment of the entry-level biology major's program.

Content Area
Animal Cells
Metabolism Energy and Enzymes
Plants and Photosynthesis
Animal Physiology
Genetics

Table 2. Content areas assessed in Organismal Biology at Southwest Texas State University, as part of the assessment of the entry-level biology major's program.

Content Area
Behavior
Diversity
Ecology
Evolution
Genetics
Organismal Biology
Scientific Reasoning

Table 3. Assessment questions for Functional Biology based on concept area vs. cognitive level as described by Bloom's taxonomy of higher learning.

Concept Area	**Cognitive Level**			
	Knowledge	Understanding	Application	Analysis /Synthesis
Animal Cells	20, 21, 24,	25, 28	22	23, 26
Metabolism	34	30, 31, 35	32, 33	29, 36
Plants	39	38, 40, 43, 44	42	37, 41, 61
Animal Physiology	45	47	46, 48	49, 62
Genetics	52, 53, 58, 60	56, 59	54, 57	50, 51, 55

Table 4. Assessment questions for Organismal Biology based on concept area vs. cognitive level as described by Bloom's taxonomy of higher learning.

Concept Area	**Cognitive Level**			
	Knowledge	Understanding	Application	Analysis /Synthesis
Behavior	22	20	23	21
Diversity	24, 25, 27	28, 30	29	26
Ecology	31, 32, 34, 37	35, 39	33, 38	36
Evolution	44	41, 43	46	40, 42, 45, 47
Genetics	48, 49, 51, 54, 56	50, 53, 55, 57	58	52
Organismal Biology	61, 63	59, 60, 62, 65, 67	64	66
Scientific Reasoning	69	68		70

Table 5. Scoring rubric for aerobic cellular respiration – photosynthesis essay question used in Functional Biology at SWT.

TOPICS	POINTS AWARDED		
	2	**1**	**0**
CELLULAR ORGANELLE	Mitochondria in ACR and Chloroplast in PS	Only one organelle is listed.	Nothing stated about organelles
GLUCOSE	PS involves the making of glucose. ACR involves the breakdown of glucose.	Glucose listed in only one pathway.	Nothing stated about glucose.
PATHWAYS	PS and ACR are pathways that use electron transport system in a cellular membrane to generate ATP via H+ as a carrier. ACR uses NAD+ and PS uses NADP+ as coenzymes.	Only one pathway listed.	Nothing stated about pathways.
PRODUCTS / REACTANTS	ACR uses glucose and oxygen as reactants with CO_2 and H_2O as products. PS uses CO_2 and H_2O as reactants with glucose and Oxygen as products.	Any one of the four molecules listed as a product or reactant.	Nothing stated about products or reactants.
TIME OF REACTIONS	Both reactions occur in daylight, but only ACR occurs at night. Rate of PS > ACR in daylight, results in net increase in glucose storage.	Only one pathway listed.	Nothing stated about time of reactions.

Note: Response must be in appropriate paragraph format with complete sentences or no points are awarded. Ten total points are possible.

Table 6. Scoring rubric used for evolution essay question in Organismal Biology at SWT

Topics	**POINTS AWARDED**	
	1	**0**
Definition	Change in Allele frequencies…	Allele frequencies not mentioned
Genetic Drift	Included in discussion	Not included in discussion
Mutation	Included in discussion	Not included in discussion
Migration	Included in discussion	Not included in discussion
Natural Selection	Included in discussion	Not included in discussion

Note: Response must be in appropriate paragraph format with complete sentences or no points are awarded. Five total possible points.

RESULTS

Assessments of student performance in the areas of course specific content areas, writing skills, and higher order thinking skills was performed in fall 2000, spring 2001, fall 2001 and spring 2002. A total of 468 students were assessed in Functional Biology and 244 students in Organismal Biology. Of the 468 students assessed in Functional Biology, 190 were freshmen, 121 were sophomores, 97 were juniors, 55 were seniors and 5 were "others". Of the 244 students assessed in Organismal Biology, 100 were freshmen, 58 were sophomores, 64 were juniors, 18 were seniors and 4 were "others". Analysis of total percentages of student classifications during the four semesters assessed revealed that in the fall 2000 semester there were 42% freshman, 28 % sophomores, 21% juniors and 9% seniors who took the pre-post semester assessments. In the spring 2001 semester there were 25% freshman, 25% sophomores, 29% juniors and 10% seniors. In the fall 2001 semester there were 54% freshman, 21% sophomores, 15% juniors, and 10% seniors. In the spring 2002 semester there were 38% freshman, 23% sophomores, 26% juniors and 13 % seniors. (Table 7)

Results of assessments of student performance in the areas of interest in Organismal Biology showed that there were statistically significant increases in pre to post semester percentages of questions answered correctly in the content areas of cells (40% to 54%, **), metabolism (35% to 44%, **), plants (36% to 45%, **), and genetics (30% to 43%, ***). There was no significant increase in the content area of animal physiology (31% to 35 %, $p > 0.01$) (Figure 1). The results of Bloom's taxonomy of higher learning areas showed a significant increase in knowledge (39% to 60%, **), understanding (34% to 44%, *), application (38% to 49%, *), and analysis and synthesis

(29% to 43%, **) (Figure 2). Assessments of students' writing skills in Functional Biology showed a significant increase from pre to post semester assessments (6.2 % to 19.3%, *) (Figure 3). Assessment of students performance in Functional Biology showed a statistically significant increase in pre to post semester percentages in the content area of genetics (34% to 45%, **), whereas there were no significant increases in the areas of behavior (53% to 54%), diversity (46% to 50%), ecology (43% to 49%), evolution (53% to 61%), organismal biology (37% to 44%) and scientific reasoning (70% to 69%) (Figure 4). The results of analysis of Bloom's taxonomy of higher learning areas showed a significant increase knowledge (43% to 61%, **), understanding 39% to 59%, **), application (41% to 52%, **), and analysis and synthesis (35% to 64%. **) Assessments of students' writing skills in Organismal Biology showed a significant increase for pre to post semester assessments (17% to 49%, ***) (Figure 3).

Reliability indices for each test indicate an increase, from pre semester to post semester, of reliability for each administration of the instrument. In Functional Biology, reliability indices increased from 0.7184 to 0.7199 in fall 2000, from 0.0.6600 to 0.7300 in spring 2001, from 0.7220 to 0.0.7610 in fall 2001, and from 0.7560 to 0.8801 in spring 2002. In Organismal Biology, reliability indices increased from 0.6994 to 0.8170 in fall 2000, from 0.7150 to 0.7970 in spring 2001, from 0.6240 to 0.8260 in fall 2001, and from 0.7023 to 0.8950 in spring 2001(Table 8).

Table 7. Percentages of students enrolled in entry-level courses during the four semesters of assessment at SWT.

	Freshmen	Sophomores	Juniors	Seniors
Fall 2000	42	28	21	9
Spring 2001	25	25	29	21
Fall 2001	54	21	15	10
Spring 2002	38	23	26	13

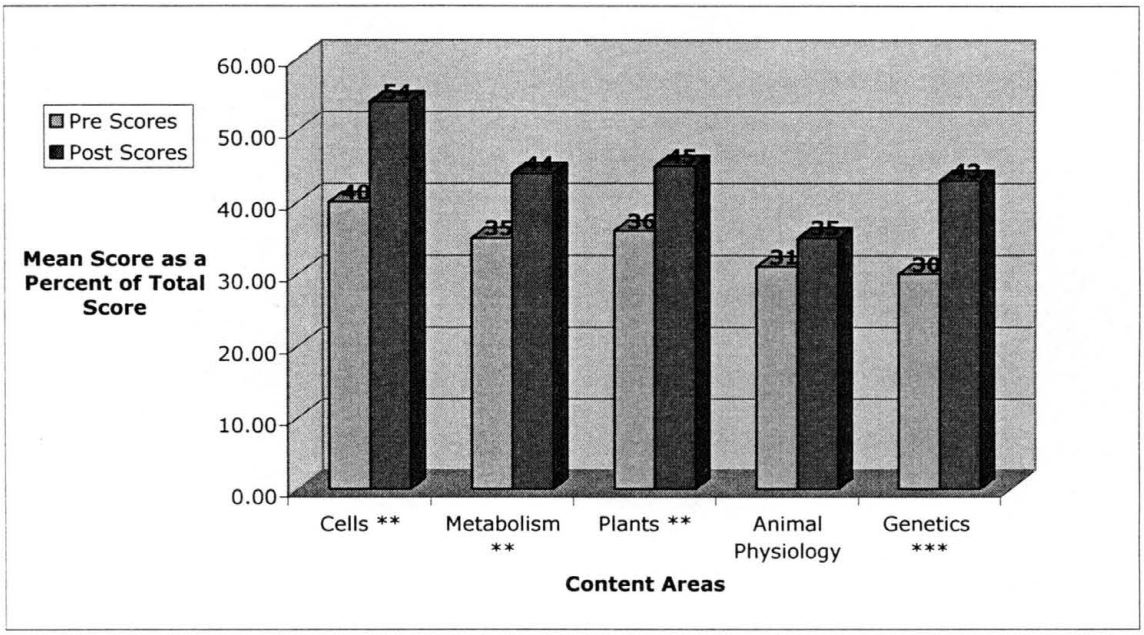


Figure 1. Change in content area scores in Functional Biology from four semesters of assessment of entry-level biology classes at SWT. Content areas of cells, metabolism, animal plants and genetics show significant increases.

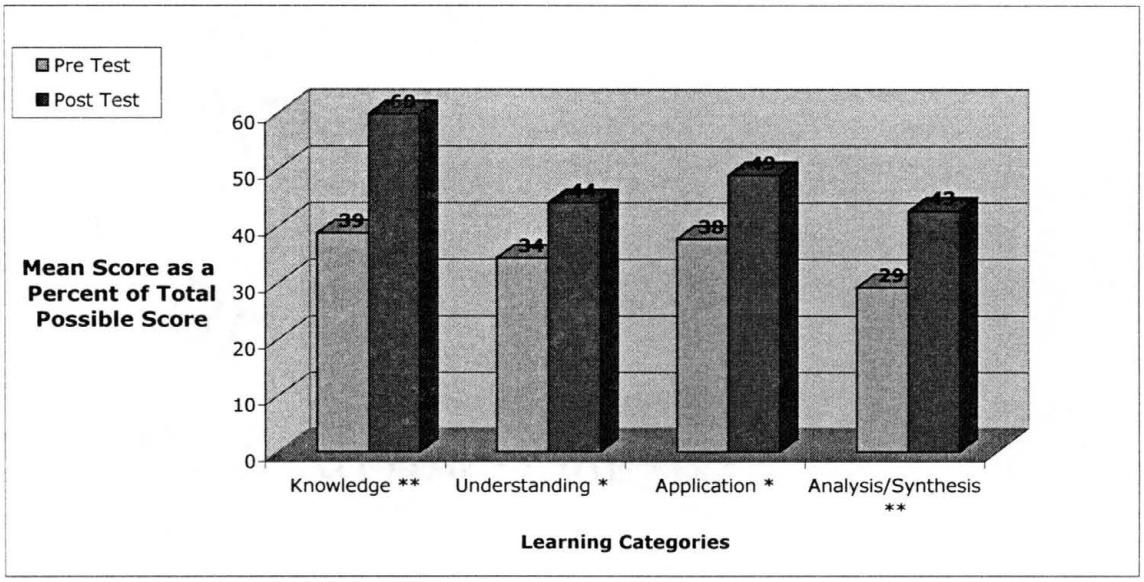


Figure 2. Change in areas of Bloom's taxonomy of higher learning in Functional Biology from four semesters of assessment of entry-level biology classes at SWT. Areas of knowledge, understanding, application and analysis and synthesis show significant increases.

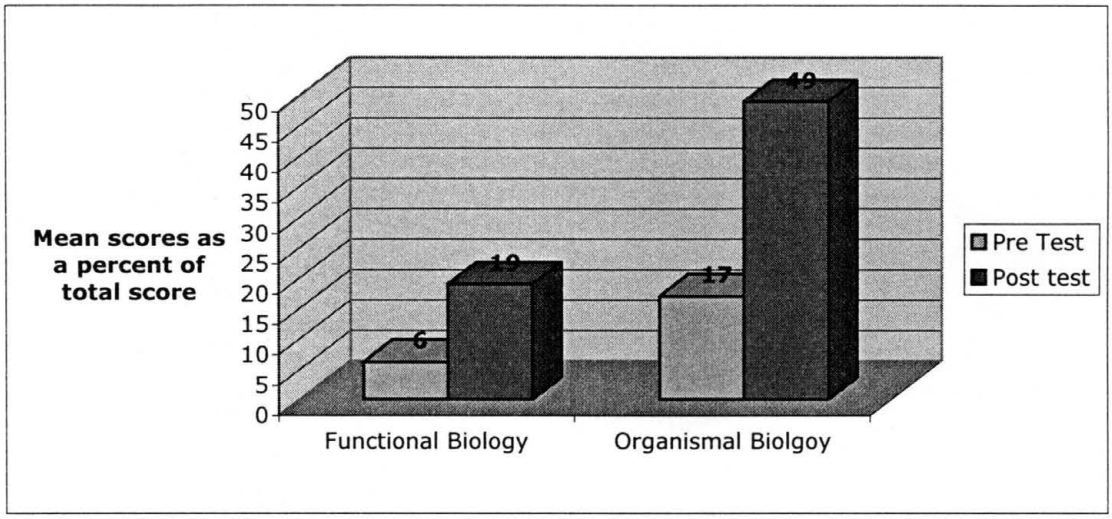


Figure 3. Change as a percent of total score, of students' writing skills in Functional and Organismal Biology over a four-semester assessment period at SWT.

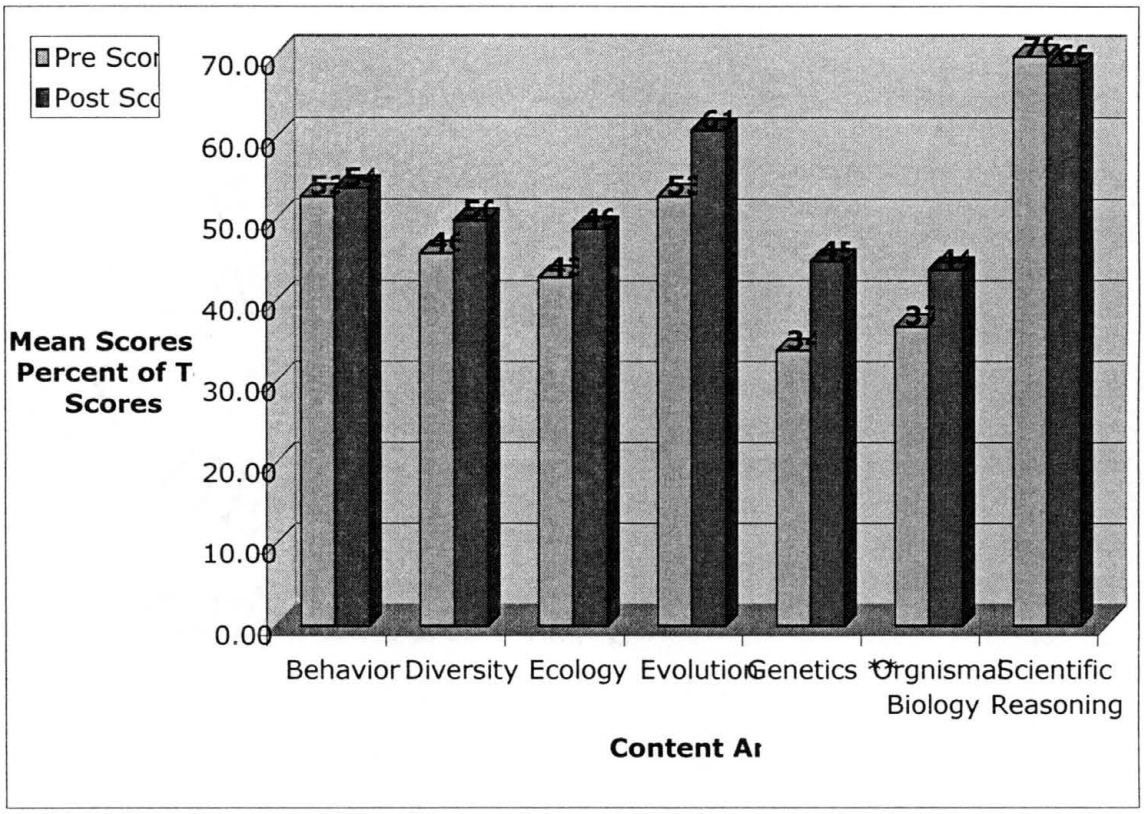


Figure 4. Change in content area scores in Organismal Biology from four semesters of assessment of entry-level biology classes at SWT. The content area of Genetics is the only area that shows significant increase.

Table 8. Assessment instrument reliability indices from four semesters of assessments in Functional (1430) and Organismal (1431) Biology at SWT.

Semester / Course	Pre Test	Post Test
Fall 2000 1430	0.7184	0.7199
Fall 2000 1431	0.6944	0.8170
Spring 2001 1430	0.6600	0.7300
Spring 2001 1431	0.7150	0.7970
Fall 2001 1430	0.7220	0.7610
Fall 2001 1431	0.6240	0.8260
Spring 2002 1430	0.7560	0.8801
Spring 2002 1431	0.7023	0.8950

DISCUSSION

Results of four semesters of assessment of entry-level biology students at SWT have shown that students have a range of improvement in course specific content areas. As a whole content knowledge showed improvement, but not all individual content areas showed statistically significant improvement. It is clear that students significantly improve their understanding in the areas of cells, metabolism, plants, and genetics over the course of study, while the areas of animal physiology, behavior, diversity, ecology, evolution, organismal biology and scientific reasoning show no significant increases during the four semester study. The range of test scores (Figures 1 and 4) is strikingly low for biology majors who must receive at least a 70% grade to pass an entry-level course. If assessment instruments truly reflect the content area knowledge that students are exposed to in entry-level courses, the upper range scores should be indicative of scores received in actual course work. It is for this reason that it is recommended the assessment instrument have a criteria associated with it that students should score at least a 70% to be considered successful in their assessment outcome. "A good test will tell the teacher what the students learn from a course and do not, and this is the beginning of wisdom" (Nedelsky 1965).

Results of assessments of the writing skills of entry-level biology students at SWT have shown an increase over the four semesters they have been measured. Over the course of four semesters, instructional assistants and this researcher have observed that as students' realize how important their writing skills are in biology courses, they seem to put more of an effort into the assessment question. Students are required to write two research papers over the course of a semester in both entry-level courses and

are required to purchase the text A Short Guide to Writing About Biology (Pechenik 2001) during their first semester. What was once left to English and technical writing classes is now being addressed in the entry-level biology labs at SWT. Although students might not answer the content area portions of the essay questions correctly, their writing skills improve from pre to posttest. Some students even write succinct answers explaining that they do not know the answer at the moment, but are looking forward to learning the material and answering the essay correctly at the end of the semester while some students express their opinions of the course (both good and bad), but do it in proper written format. Portfolio assessment of student writing, where several representative pieces written over a semester, is a good indicator of progress of writing skills (Brand 1992). The pre–post semester writing assessment included with students' reports would be a good indicator of students' writing progress. It is suggested that the writing assessment be embedded into the laboratory session. It is believed that student will put more of an effort into completing the essay question in class for a grade than completing it after taking a 40 to 50 question multiple-choice assessment.

Results of analysis of the classification demographics of students participating in the entry-level courses showed that there were, at the most, only 54% freshman enrolled at any one time in both courses. This is due mainly to juniors and seniors taking Functional Biology as a substitute for their cellular biology course, as mentioned earlier. It will be interesting to track student performance in areas of interest as a cohort of mostly freshman participate in these courses.

The outcome of assessing entry-level students' higher order thinking skills via Bloom's taxonomy of higher learning indicated a significant increase in higher order

thinking skills in both courses assessed. Assessments revealed increases in the domains of (1) knowledge: where students must remember previously learned material, (2) understanding: where students must understand the meaning of remembered material, (3) application: where students use information in new context to solve a problem, answer questions, or perform another task, and (4) analysis and synthesis: where students explain the relationship between content areas and put ideas together to form a whole new understanding or structure (Bloom 1956). It is believed that the new inquiry-based labs drive the increase in this area of interest. Students participating in the labs are required to design their own lab protocols and take ownership of their knowledge by understanding what they are doing. It usually takes a couple of weeks for the students to get the idea that teaching instructors are not going to "spoon feed" the information to them. An important comparison to observe, however statistically insignificant it might be, is the comparison between students' enrolled in the "old" curriculums' increase in areas of Bloom's taxonomy vs. students in the Biology 2000 Curriculum. Students in the old curriculum showed an increase in only the areas of knowledge and understanding, indicating more a rote memorization of facts. It was not until the implementation of the Biology 2000 Curriculum that an increase in the areas of understanding and analysis and synthesis was observed.

The assessment of content area knowledge, writing skills, and higher order thinking skills of students enrolled in entry-level biology courses is a small part of the overall assessment strategy employed by the Biology Department at SWT. Results should be used as an indicator as to how entry-level students are performing in areas of interest and should not be confused with the overall performance of the program. The

assessment at the entry-level should, as stated earlier should lead to, (1) changes in the classroom that are linked to assessment outcomes, (2) curriculum changes in response to varying assessments, and (3) improved and modified assessment types that more accurately measure the intended target (Banta 1996).

As part of an effort to establish some measurable goals for the entry-level biology courses, a suggested mission statement was created by the researcher, using information from the entry-level course web sites (Ott 2000) (Appendix F). It could be used as a starting point for the implementation of goals and course specific criterion references in the future.

A protocol of implementation should be established to ensure constant, reliable and valid assessment continues at not only the entry-level, but at all levels of the Biology Department at SWT. The protocol that was used during the entry-level assessment included: (1) the development of goals for assessment, i.e. areas to be assessed, 2) creation of an instrument to assess these goals, (3) administration of the instrument in a pre-post semester format, (4) analysis of data, (5) dissemination of information, (6) faculty review of data and instrument, (7) modification of instrument to increase reliability. These steps incorporate both the formative and summative feedback steps associated with assessment. It is this researchers' opinion, however, that one never reaches the final summative portion of assessment, rather each ending is, in effect, a new beginning on the dynamic stage of assessment. This protocol is a good starting point for subsequent assessors to use in their quest to maintain and improve the assessment program in the entry-level biology program at SWT.

APPENDICES

APPENDIX A

Biology 2000 Program Assessment

Biology 1430
Functional Biology

Use a number 2 pencil and the supplied scan-tron answer sheet to record your responses to questions 1 – 19 of the demographic survey and questions 20 – 60 of the test. Make no marks on the test itself unless indicated to do so.

Cells

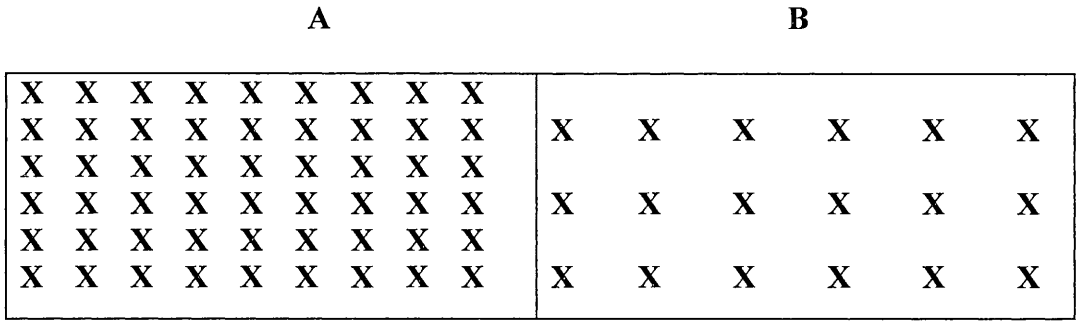
20. Place the list of cellular components in order of size from smallest to largest.

Nucleus **Chromosome** **Cell** **Nucleotide** **Gene**

A. nucleotide, nucleus, gene, chromosome, cell
B. nucleotide, gene, chromosome, nucleus, cell

C. gene, nucleotide, nucleus, cell, chromosome
D. chromosome, nucleus, nucleotide, cell, gene
E. gene, nucleotide, chromosome, nucleus, cell

Refer to the following diagram. The X's represent solutes dissolved in water and separated by a semi-permeable membrane.



21. What side of the membrane contains the hypotonic solution?

A. A
A. B
B. Both
D. Neither

22. An animal cell placed in a hypotonic solution will

A. lose water.
B. gain water.
C. neither gain nor lose water.
D. both gain and lose water equally.
E. gain water initially and then lose water.

23. Each time water in a cell freezes slowly, long sharp water crystals spear through the membrane structures of the cell. The most reasonable explanation for the bad taste of meat that has "freezer burn" from repeated freezing is the destruction of

A. the nuclear membrane, causing mixing of nucleoplasm and cytoplasm.
B. ribosomes, causing them to break into subunits.
C. lysosomes, and the resultant self-digestion of the cell
D. rough endoplasmic reticulum causing the release of ribosomes.
E. the Golgi apparatus and vesicles.

24. Which sequence in the cell cycle is correct?

A. prophase, metaphase, interphase, telophase, anaphase
B. metaphase, anaphase, prophase, telophase, interphase
C. anaphase, interphase, telophase, prophase, metaphase
D. interphase, prophase, metaphase, anaphase telophase
E. interphase, metaphase, prophase, anaphase, telophase

25. Meiosis results in a change in chromosomal ploidy number indicated by

A. 2N to 2N
B. 2N to N
C. N to 2N
D. N to N
E. 2N to 2N in diploid organisms, N to N in haploid organisms.

26. Why are cells small?

A. Small structures have a much higher ratio of surface area to volume than large structures.
B. Cells must be small to fit inside an organism.
C. Plant and animal cells have cell walls, whereas bacterial cells do not.
D. Diffusion is too slow a process to work well at a large spatial scale
E. Both A and D are correct.

27. All of the following are typical components of the plasma membrane of a eukaryotic cell EXCEPT

A. glycoproteins
B. cytochromes
C. cholesterol
C. phospholipids
D. Integral proteins

28. Which of the following is NOT true of cell signaling?

A. The key to a cell's continuing receptiveness to regulation is the reversibility of the changes that signals produce.
B. Ligand binding is critical to a signal response.
C. Cell signaling has been shown to be important in animals, fungi, and bacteria but less so in plants.
D. Animal cells communicate with nearby cells by secreting local regulators or neurotransmitters at synapses.
E. Both C and D are correct.

Metabolism: Energy and Enzymes

29. In some living systems, the hydrolysis of ATP to ADP and P is virtually the sole supply of energy. However, ATP does not release this energy spontaneously but only in cell machinery where some work is being carried out. In such cases, special enzymes (ATPases) are necessary for the hydrolysis of ATP.

A. Therefore, relatively small quantities of ATP molecules can be re-used to sustain many days' cellular energy.
B. The fact that ATP is universal but there is a diversity of enzyme systems indicates ATP is an ancient system and the various enzymatic pathways show diversity of life through evolution.
C. If ATP underwent hydrolysis spontaneously at a fast rate without enzymes, life as we know it, would not be possible.
D. All of the above are true.
E. None of the above are true.

30. A metabolic reaction that involves two parts:
1) a reaction that releases energy which will provide the energy for,
2) a reaction that requires energy
This type of reaction is called
A. an endergonic reaction.
B. an exergonic reaction.
C. a coupled reaction.
D. a reversible reaction.
E. antimetabolism.

31. If 12 different intermediate products are created within a cell during production of a molecule, we can expect that there:

A. is one enzyme that carries this process through to the end product.
B. are about 12 enzymes, at least one responsible for each step in the metabolic pathway.
C. is one enzyme for degradation and another enzyme for synthesis.
D. there may not be any enzymes involved if this is a natural cell product.
E. must be 12 different raw materials combined in one cell by one enzyme.

32. While eating a portion of yogurt, you have to leave, so you store the yogurt in the refrigerator. A day later you return and find the surface of the yogurt is no longer smooth but has broken into several liquefied products. You correctly guess that enzymes from

your saliva, via the spoon, have continued digesting the yogurt in your absence. What will happen over time?

A. The reaction has probably stopped because the amount of saliva is small and you would have to add more saliva to continue the degradation.
B. The reaction will continue indefinitely since the enzyme is not consumed by the reaction.
C. The reaction will continue until half is digested and then stop because the reaction between substrate and product will be balanced.
D. Absolutely no degradation of the yogurt would have occurred naturally unless in the presence of this enzyme.

33. Lactose is milk sugar, and humans produce substantial lactase enzyme to digest it when we are infants. However, we soon lose some or even all of our lactase after childhood. In such cases, undigested lactose passes to the lower intestine where bacteria break it down into lactic acid and CO_2, causing painful gas bloating. This problem could be avoided by

A. avoiding all dairy products containing lactose.
B. taking lactase enzyme tablets when consuming lactose products.
C. taking any enzyme tablets when consuming dairy products.
D. consuming lactose in tablet form.
E. Both A and B are correct.

34. The $C_6H_{12}O_6 + 6O_2 \longrightarrow 38\ ATP + 6\ CO_2 + 6\ H_2O$ reaction represents

A. glycolysis
B. electron transport system.
C. Krebs cycle
D. photosynthesis
E. aerobic cellular respiration

35. Large numbers of ATP molecules are produced by mitochondria, and are needed throughout the cell. Therefore, the ATP molecules are

A. embedded in the inner mitochondrial membrane and diffuse in both directions.
B. inside the mitochondrial matrix and diffuse out through the phospholipid bilayer of the outer mitochondrial membrane.
C. outside the mitochondria and diffuse in through the mitochondrial membrane.
D. inside the mitochondrial matrix and leave through a channel protein located in the mitochondrial membrane.
E. outside the mitochondria and enter through a channel protein.

36. Why would glycolysis and fermentation be considered older processes in the history of life than the electron transport system and the Krebs cycle?

A. The early earth lacked an oxygen atmosphere.
B. The first reactions in these complex equations are always the most primitive.
C. The fossil record directly shows that these reactions came first.

D. Bacteria, fungi, and protists only carry on anaerobic respiration, not aerobic.
E. The electron transport system and the Krebs cycle only occur in mammals.

Plants and Photosynthesis

37. The heavy oxygen isotope (O^{18}) could be provided to plants either in the CO_2 or in H_2O or in both. Today, we know from experimental results that O_2 released from chloroplasts comes from H_2O and not from CO_2. Which experimental result would have proved this?

A. When heavy oxygen is part of H_2O given the plant, the plant produces heavy O_2.
B. When heavy oxygen is part of CO_2 given the plant, the plant produces heavy O_2.
C. When heavy oxygen is part of both H_2O and CO_2 given a plant, the plant produces heavy O_2.
D. When no heavy oxygen is part of H_2O given to the plant, the plant produces no heavy O_2.
E. When no heavy oxygen is part of CO_2 given the plant, the plant produces no heavy O_2.

38. At the cellular level in eukaryotes, photosynthesis occurs within
A. the chloroplast
B. the christae of the mitochondria
C. both chloroplast and the mitochondria
D. all plant cell organelles
E. the nucleus of plant cells but not but not of animal cells

39. The raw materials or reactants of the photosynthetic process include
A. glucose and oxygen.
B. carbon dioxide and glucose.
C. carbon dioxide and water.
D. carbon dioxide and oxygen.
E. glucose and water.

40. Which of the following statements is FALSE?
A. During cellular respiration, some carbohydrate energy is recovered as ATP.
B. During cellular respiration, mitochondria release carbon dioxide.
C. During photosynthesis, oxygen is used as the final electron acceptor in the electron transport chain.
D. During photosynthesis, energy from the sun is used to form carbohydrates.
E. During photosynthesis, carbon dioxide is used as a reactant.

41. A scientist observes that the chloroplasts in a *Hydrilla* leaf begin to stream through the cytoplasm when observed with a light microscope. The scientist then adds cytochalasin, a chemical that prevents the formation of microfilaments in cells, to the leaf preparation. After a few minutes the scientist observes the cells and notes that the cytoplasmic streaming has:

A. sped up.
B. remained the same.
C. slowed down.
D. stopped completely.

42. You have just discovered a new flower species that has a unique photosynthetic pigment. The leaves of this plant appear to be reddish yellow. What wavelengths of visible light are NOT being absorbed by this pigment?

A. red and yellow
B. blue and violet
C. green and yellow
D. blue, green and red
E. green, blue and violet

43. Oxidative phosphorylation in mitochondria

A. has been show to prevent carbon fixation in chloroplasts.
B. is identical to photophosphorylation in chloroplasts.
C. and photophosphorylation in chloroplasts produce ATP in plants.
D. generates light that drives photophosphorylation in chloroplasts.
E. does not happen in plants because they have chloroplasts but no mitochondria.

44. Which of the following statements BEST describes the relationship between photosynthesis and cellular respiration?

A. Respiration is the exact reversal of the biochemical pathways of photosynthesis.
B. Photosynthesis stores energy in complex organic molecules and respiration releases it.
C. Photosynthesis occurs only in planets and respiration occurs only in animals.
D. ATP molecules are produced in photosynthesis and used up in respiration.
E. Respiration is anabolic and photosynthesis is catabolic.

Animal Physiology

45. Which of the following statements is FALSE about homeostasis?

A. Homeostasis is achieved in part, by the actions of hormones.
B. Homeostasis is primarily controlled by the circulatory system.
C. Homeostasis maintains all metabolic fluctuations near the body's average levels.
D. Homeostasis requires coordination between internal organs.
E. Homeostasis is often controlled by negative feedback.

46. You spray an insect with a common insecticide that destroys the ability of acetylcholinesterase to recycle acetylcholine. What then happens?

A. This kills the neuron directly.
B. The lack of recycled acetylcholine brings the cell metabolism to a halt.
C. The insect loses control of body functions as nerve impulses flow continuously.
D. This prevents the synapse from restoring its ability to "reset" itself for the next impulse.
E. The insecticide has no effect on the insect .

47. Which of these is true of all receptors?

A. Each receptor is sensitive to all stimuli.
B. They are stimulated by a change in the external environment only.
C. They are found at the end of dendrites and initiate a nerve impulse that is carried to the brain.
D. They not only receive stimuli but also interpret them.
E. The nerve impulse generated from the organ of Corti is different than one generated from the retina

48. Which of the following assertions about regulation of body temperature is CORRECT?

A. Most animals are endotherms.
B. Endothermy involves production of heat through metabolism.
C. Ectothermic animals are cold-blooded.
D. Mammals are always ectothermic.
E. Insects are always ectothermic.

49. If a person's bone marrow were destroyed by radiation, which of the following cells could NOT be produced?
A. B cells
B. T cells
C. erythrocytes
D. neutrophils
E. All of the above

Genetics

50. A tobacco plant can be made to express a gene from fireflies, resulting in the emission of light. Which of the following is the basis for phenomenon?

A. Chloroplasts can be made to produce light if firefly proteins are injected into plant cells.
B. Fireflies and tobacco plants share a recent common ancestor.
C. Fireflies and tobacco plants are infected by the same kinds of bacteria.
D. Transcription and translation are fundamentally similar in both fireflies and tobacco.

E. Most enzymes in fireflies have the same amino acid sequence as the enzymes in tobacco plants.

51. When a double-stranded DNA molecule is heated, it denatures into two single-stranded molecules. The reason for this is that

A. the proteins associated with the double helix are denatured and can no longer hold the DNA strands together.
B. the heat causes the helix to straighten, breaking the connections between the bases.
C. the heat breaks the hydrogen bonds holding the bases together in the center of the molecule but does not affect the covalent bonds of the backbone.
D. the heat denatures the bases, preventing them from hydrogen-bonding with each other.
E. the heat causes the phosphate groups to ionize, preventing them from hydrogen bonding to the bases.

52. What is the relationship among DNA, a gene and a chromosome?

A. A chromosome contains hundreds of genes, which are composed of protein.
B. A chromosome contains hundreds of genes, which are composed of DNA.
C. A gene contains hundreds of chromosomes, which are composed of protein.
D. A gene is composed of DNA, but there is no relationship to a chromosome.
E. A gene contains hundreds of chromosomes, which are composed of DNA.

53. If a diploid organism has 200 total chromosomes in its somatic cells

A. any 100 could have been from its father and any 100 from its mother.
B. they would consist of 100 pairs with one of each pair from the father and one of each pair from the mother.
C. as many as none-to-200 came from the father and conversely, from 200-to-none would
have come from the mother.
D. 50 pairs or 100 total would come from the father and 50 pairs from the mother.
E. all 200 come from the mother in a female offspring and all 200 come from the father in a male offspring.

54. The coat of a virus is labeled with radioactive sulfur and the DNA of the virus is labeled with radioactive phosphorous. If the virus then attacks a bacterium,
A. both the sulfur and the phosphorous will be found inside the bacterium.
B. only the sulfur will be found inside the bacterium.
C. only the phosphorous will be found inside the bacterium.
D. neither the sulfur nor the phosphorus will be found inside the bacterium.

55. The "central dogma" of modern biochemical genetics, pertaining to the flow of inherited information, states that information moves as diagramed here:
A. protein→RNA→DNA.
B. DNA→RNA→protein.

C. DNA→protein→RNA.
D. RNA→DNA→protein.
E. RNA→protein→DNA.

56. The "central dogma" is thought to be a one-way path. The exception could be
A. retroviruses
B. temperate phages
C. herpes viruses
D. tumor viruses
E. all viruses

57. What percentage of the DNA in a typical eukaryotic cell is expressed at any given time?
A. 3 - 5%
B. 5 – 20%
C. 20 – 40-%
D. 40 – 60%
E. 60 – 90%

58. The polymerase chain reaction is important because it allows us to
A. insert prokaryotic genes into eukaryotic plasmids.
B. incorporate genes into viruses.
C. make DNA from RNA transcripts.
D. make many copies of DNA.
E. insert regulatory sequences into eukaryotic genes.

59. If a person inherits two X chromosomes, this individual will be
A. female.
B. male.
C. color blind.
D. sterile.
E. a metafemale.

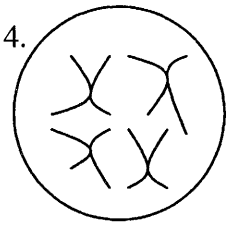
APPENDIX B

SS# _____

60. Answer this question in **essay** format. Use complete sentences to describe your ideas.

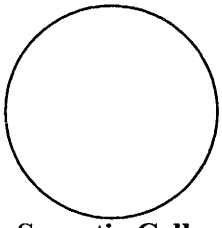
What are some major differences and similarities between **photosynthesis** and **cellular respiration**?
Topics to include in your essay are: A) Cellular Organelles involved B) the role of Glucose C) Pathways D) Products and Reactants involved E) Time of reactions (day/night)

61. The eukaryotic cell shown at right has a diploid number 2N= 4.



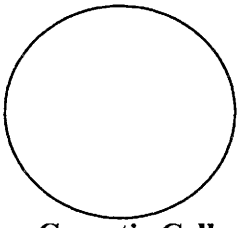
Draw the chromosomes as they would appear at the metaphase plate of:

Mitosis



Somatic Cell

Meiosis I



Gametic Cell

APPENDIX C

Biology 2000 Program Assessment

Biology 1431
Organismal Biology

Use a number 2 pencil and the supplied scan-tron answer sheet to record your responses to questions 1 – 19 of the demographic survey and questions 20 – 70 of the test. Make no marks on the test itself unless indicated to do so.

Behavior

20. The presence of altruistic behavior in animals is most likely due to kin selection, a theory that maintains that

A. genes enhance survival of copies of themselves by directing organisms to assist others who share those genes.
B. companionship is advantageous to animals because in the future they can help each other.
C. critical thinking abilities are normal traits for animals and they have arisen, like other traits, through natural selection.
D. natural selection has generally favored the evolution of exaggerated aggressive and submissive behaviors to resolve conflict without grave harm to participants.
E. aggression between sexes promotes the survival of the fittest individuals.

21. Your friend Jim comes to you with a problem: His dog barks too much. He tells you that it is getting worse and the only way he can get his dog to stop barking is to give it a treat. Which of the following might you use to explain what has happened to your friend?

A. The dog is displaying an instinctive fixed action pattern of barking that is triggered by a specific releaser. Somehow, Jim is doing something that serves as the releaser.
B. The dog's behavior is a result of operant conditioning. Every time the dog barks, Jim rewards it with a treat. Thus, the dog will bark more to get more treats.
C. The dog has been classically conditioned, in that some inappropriate stimulus has become associated with barking.
D. The dog is performing a social behavior and is considering Jim a potential rival dog. Jim needs to roll on his back as an appeasement display.
E. The dog is trying to protect Jim from something that it perceives as being harmful. Jim needs to identify what it is and get rid of it.

22. Although different species of warblers often migrate together and use the same habitats for mating and feeding, they rarely hybridize. The isolating mechanism most likely to be operating is

A. temporal isolation.
B. gametic isolation.
C. mechanical isolation.
D. behavioral isolation.
E. ecological isolation.

23. When the environment of an animal changes, the animal may respond in several ways. Which of the following represents a correct sequence (from most rapid to slowest) of potential animal responses?
A. migration, acclimation, morphological change, evolution
B. acclimation, morphological change, migration, evolution
C. migration, evolution, morphological change, acclimation
D. acclimation, migration, evolution, morphological change
E. migration, evolution, acclimation, morphological change

Diversity

24. Which factor is the most important in producing the variability, and resulting diversity that occurs in each generation of humans?
A. nonrandom mating
B. genetic drift
C. genetic recombination
E. diploidy
F. natural selection

25. The only way that two populations can assure their integrity as distinct biological species is by
A. allopatry.
B. introgression.
C. sympatry.
D. geographic isolation from one another.
E. reproductive isolation from one another.

26. Which of the following statements about biological species is (are) CORRECT?
I. Biological species are defined by reproductive isolation.
II. Biological species are the model used for grouping extinct forms of life.
III. The biological species is the largest unit of population in which gene flow is possible.

A. I, II, and III
B. I and III
C. II and III
D. II only
E. I only

27. The taxonomic system developed by Linnaeus is best described as a
A. decimal plan for sorting all living organisms.
B. branching diagram of interrelationships.
C. hierarchy of increasingly general categories.
D. binary scheme of groupings.
E. map that distinguishes kinship among animals.
28. Which of the following pieces of evidence most strongly supports the common origin of all life?

A. All organisms have undergone evolution.
B. All organisms require energy.
C. All organisms reproduce.
D. All organisms have the same genetic code.
E. All organisms show heritable variation.

29. Australia and New Zealand are very close together geographically, yet the wide variety of marsupials indigenous to Australia is not evident in New Zealand. This is probably because

A. marsupials are unable to survive well in New Zealand.
B. Australia is larger than New Zealand.
C. many marsupials have gone extinct in New Zealand.
D. most marsupials have left New Zealand for Australia over a recent land bridge.
E. Australia and New Zealand have different biogeographic origins.

30. Which of these statements about classification systems is true?

A. Similarities of structure that indicate related ancestry are not used in classification.
B. The addition of domains is advocated by only a few biologists and shouldn't be taken seriously.
C. Classification systems are open to modification on the basis of new information.
D. Classification systems never change because of the confusion it would cause.
E. The five-kingdom system of classification is used by all biologists.

Ecology

31. Which of the following causes the Earth's seasons?

A. ocean currents
B. changes in the Earth's distance from the sun
C. the tilt of the Earth's axis
D. global wind patterns
E. global air circulation

32. Which of the following would be most helpful in solving the world's environmental problems?

A. decreased human birth rates
B. new energy sources
C. more food from the oceans
D. increased agricultural productivity
E. increased life expectancy

33. Which of the following statements about the evolution of life histories is CORRECT?

A. The reproductive efforts of r-selected populations are directed at producing just a few offspring with good competitive abilities.
B. Stable environments with limited resources favor r-selected populations.
C. K-selected populations rarely approach carrying capacity.
D. K-selected populations are most often found in environments where density-independent factors are important regulators of population size.
E. Most populations have both r- and K-selected characteristics that vary under different environmental conditions.

34. According to the competitive exclusion principle, two species cannot continue to occupy the same

A. territory
B. range
C. biome
D. niche
E. habitat.

35. All of the following statements about community interactions are correct EXCEPT:

A. Mutualism is an important biotic interaction that occurs in communities.
B. Closely related species may be able to coexist if there is at least one significant difference in their niches.
C. Keystone predators reduce diversity in a community by holding down or wiping out prey populations.
D. Some predators use mimicry to attract prey.
E. Plants can defend themselves against herbivores by the production of compounds that are irritating or toxic.

36. Dwarf mistletoes are flowering plants that grow on certain forest trees. They obtain nutrients and water from the vascular tissues of the trees. The trees derive no known benefits from the dwarf mistletoes. Which of the following best describes the interactions between dwarf mistletoes and trees?

A. Parasitism
B. mutualism
C. facilitation
D. commensalism
E. symbiosis

37. In general, the total biomass in a terrestrial ecosystem will be greatest for which trophic level?

A. producers

B. tertiary consumers
C. herbivores
D. primary consumers
E. secondary consumers

38. For most terrestrial ecosystems, pyramids of numbers, biomass, and energy are essentially the same: they have a broad base and a narrow top. The primary reason for this pattern is that

A. top carnivores and secondary consumers have a more general diet than primary producers.
B. at each step, energy is lost from the system as a result of keeping the organisms alive.
C. biomagnification of toxic materials limits the secondary consumers and top carnivores.
D. as materials pass through ecosystems, some of them are lost to the environment.
E. secondary consumers and top carnivores require less energy than producers.

39. Which of the following statements is (are) consistent with current concepts of conservation biology?

A. As much area as possible should be set aside to remain unchanged forever.
B. Extraction of natural resources for human use must not be decreased because, ultimately, humans must solve the biodiversity crisis.
C. Without fire suppression by humans, vast forest fires are likely to produce the next mass extinction.
D. All of the above are true.
E. None of the above are true

Evolution

40. Evolution is "the biological theme that ties together all the others." This is because the process of evolution

A. explains the diversity of organisms.
B. explains why all organisms have characteristics in common.
C. explains why distantly related organisms sometimes resemble one another.
D. explains how organisms become adapted to their environment.
E. All of the below are appropriate answers.

41. Which of the following observations and ideas are incorporated into Darwin's concept of natural selection?

A. A change in the environment will create an appropriate, heritable adaptation during the lifetime of individuals coping with that environment.
B. Reproductive potential equals what the environment can support.
C. Individuals of a population do not vary.
D. Members of a population in a particular environment are equal in their potential for leaving offspring.
E. Through natural selection, a population may adapt to the environment over many generations.

42. During a study session about evolution, one of your fellow students remarks, "The giraffe stretched its neck while reaching for higher leaves; its offspring inherited longer necks as a result." To correct your fellow student's misconception, what would you say?

A. Characteristics acquired during an organism's life are not passed on through genes.
B. Overproduction of offspring leads to a struggle for survival.
C. Only favorable adaptations have survival value.
D. Spontaneous mutations can result in the appearance of new traits.
E. Disuse of an organ may lead to its eventual disappearance.

43. Through time, the movement of people on Earth has steadily increased. This has altered the course of human evolution by increasing

A. geographical isolation.
B. gene flow.
C. mutations.
D. nonrandom reproduction.
E. genetic drift.

44. Which of the following statements is consistent with the punctuated equilibrium interpretation of speciation?

A. There is an equilibrium between living and extinct species.
B. Evolution proceeds at a slow, steady pace.
C. Large populations evolve more quickly than small ones.
D. Long periods of minor change are interrupted by short bursts of significant change.
E. Rapid speciation is caused by population explosions.

45. With which of the following statements would a biologist be MOST inclined to agree?

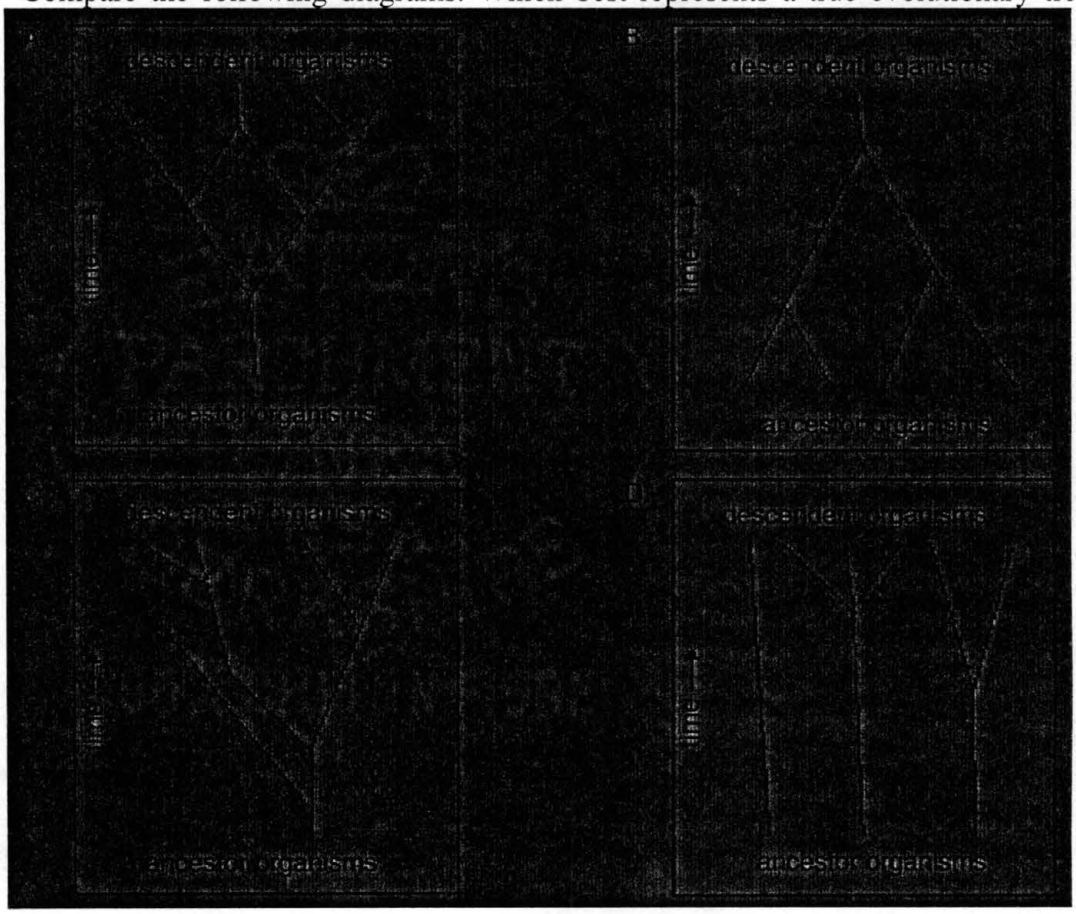
A. Humans and apes probably represent divergent lines of evolution from common ancestors.
B. Humans have stopped evolving and now represent the pinnacle of evolution.
C. Humans and apes are the result of disruptive selection in a species of Gorilla.
D. Humans evolved from New World monkeys.
E. Apes evolved from humans.

46. The formation of a land bridge between North and South America about three million years ago resulted in which of the following?

I. allopatry of marine populations that were previously sympatric
II. sympatry of marine populations that were previously allopatric
III. sympatry of terrestrial populations that were previously allopatric

A. I and III
B. II only
C. III only
D. I and II
E. I only

47. Compare the following diagrams. Which best represents a true evolutionary tree?



Genetics

48. What is a genetic cross called between an individual of unknown genotype and a homozygous recessive?

A. an F1 cross
B. a testcross
C. a hybrid cross
D. a self-cross
E. a dihybrid cross

49. What was the most significant conclusion that Gregor Mendel drew from his research?

A. An organism that is homozygous for many recessive traits is at a disadvantage.
B. Traits are inherited in discrete units, one from each parent.
C. Genes are composed of DNA.
D. Dominant genes occur more frequently than recessive ones.
E. There is considerable genetic variation in garden peas.

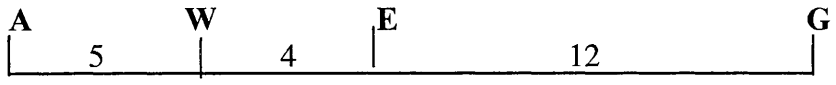
50. Blueprints contain specific instructions for constructing a building. The room you are sitting in now was constructed by using the instructions on a set of blueprints. The relationship between blueprint and building is analogous to the relationship between

A. genotype and phenotype.
B. dominant and recessive alleles.
C. chromosomes and genes.
D. genes and alleles.
E. segregation and independent assortment.

51. What does independent assortment refer to?

A. the separation of alleles in anaphase I
B. the separation of chromatids at anaphase II
C. the fact that any pair of chromatids in a tetrad can cross over
D. the random arrangement of chromosomal tetrads at metaphase I
E. the random arrangement of gene loci on a chromosome

52. The following is a map of four genes on a chromosome. The numbers represent map units between the genes



Between which two genes would you expect the highest frequency of recombination?

A. W and E
B. A and G
C. A and W
D. E and G
E. A and E

53. The statement, "The X and Y chromosomes determine sex" is inaccurate and misleading. Which of the following statements is MOST accurate?

A. Genes on the X and Y chromosomes determine sex.
B. Genes on the X chromosome that are not present on the Y determine sex.
C. Genes on the Y chromosome that are not present on the X determine sex.
E. A variety of genes on the X and/or Y chromosomes play various roles in determining sex, and the activity of those genes is controlled by a small number of genes on other chromosomes.
F. A variety of genes on other chromosomes play various roles in determining sex, and the activity of those genes is controlled by a small number of genes on the X and/or Y chromosomes.

54. What is the relationship among DNA, a gene, and a chromosome?

A. A gene contains hundreds of chromosomes, which are composed of protein.
B. A gene contains hundreds of chromosomes, which are composed of DNA.
C. A chromosome contains hundreds of genes, which are composed of protein.
D. A gene is composed of DNA, but there is no relationship to a chromosome.
E. A chromosome contains hundreds of genes, which are composed of DNA.

55. The gene pool can best be described as the

A. group of genes not described by the Hardy-Weinberg theorem.
B. genes only found in isolated populations.
C. total number of gene loci that occur in each species.
D. group of genes responsible for polygenic traits.
E. total aggregate of genes in a population at any time.

56. The Darwinian fitness of an individual is measured by

A. its physical strength.
B. the number of its offspring that survive to reproduce.
C. the number of supergenes in the genotype.
D. the number of mates it attracts.
E. how long it lives.

57. Which of the following is NOT a criterion for a Hardy-Weinberg equilibrium involving two alleles?

A. The relative fitness of all genotypes must be equal.
B. Populations must be large.
C. The frequency of all genotypes must be equal.
D. Gene flow from other populations must be zero.
E. Matings must be random.

58. Which of the following statements related to genetic variation is TRUE?

A. Recent increases in population size of the northern sea elephant are probably related to high levels of genetic variation.
B. Populations with low Ne are relatively susceptible to effects of bottlenecking and genetic drift.
C. Genetic variation does not contribute to biodiversity.
D. Population size is always positively correlated with genetic variation.

Organismal Biology

59. The strongest evidence for the endosymbiotic origin of eukaryotic organelles is the similarity between extant prokaryotes and

A. mitochondria and chloroplasts.
B. ribosomes and cilia.
C. ribosomes and nuclei.
D. cilia and mitochondria.
E. nuclei and chloroplasts.

60. In plants, which of the following could be an advantage of sexual reproduction as opposed to asexual reproduction?

A. genetic variation
B. greater longevity
C. rapid population increase
D. mitosis
E. stable populations

61. Which of the following is an example of countercurrent flow?

A. the flow of water across the skin of a frog and the flow of blood within the ventricle of its heart
B. the flow of water across the gills of a fish and the flow of blood within those gills
A. the flow of fluid out of the arterial end of a capillary and the flow of fluid back into the venous end of that same capillary
B. the flow of blood in the dorsal vessel of an insect and the flow of air within its tracheae

C. the flow of air within the primary bronchi of a human and the flow of blood within the pulmonary veins

62. Which of the following are modes of asexual reproduction found in animals?
A. fission and budding
B. fragmentation and gemmule production
C. regeneration
D. Only A and B are correct.

63. Which of the following are possible advantages of asexual reproduction?

A. It enables the species to rapidly colonize new regions.
B. It allows the species to endure periods of fluctuating or unstable environmental conditions.
C. It enhances genetic variability in the species.
D. Both A and B are advantages.

64. You observe an organism with the following characteristics: parthenogenetic reproduction, internal development of embryos, presence of an amnion, lack of parental care of young. Of the following, the organism is probably a (an)

A. mammal
B. frog
C. earthworm
D. lizard
E. bird.

65. In vertebrate animals, spermatogenesis and oogenesis differ, in that

A. spermatogenesis begins before birth.
B. oogenesis begins at the onset of sexual maturity.
C. oogenesis produces one functional gamete, whereas spermatogenesis produces four functional spermatozoan.
D.oogenesis produces four haploid cells, whereas spermatogenesis produces only one functional spermatozoon.
E. spermatogenesis is not complete until fertilization occurs.

66. Why is sexual reproduction important?

A. The resulting diverse phenotypes may enhance survival of a population in a changing environment.
B. It enables isolated animals to colonize a habitat rapidly.
C. It allows animals to conserve resources and reproduce only during optimal conditions.
D. It can result in numerous offspring in a short amount of time.

67. In which of the following ways are ALL living things alike?

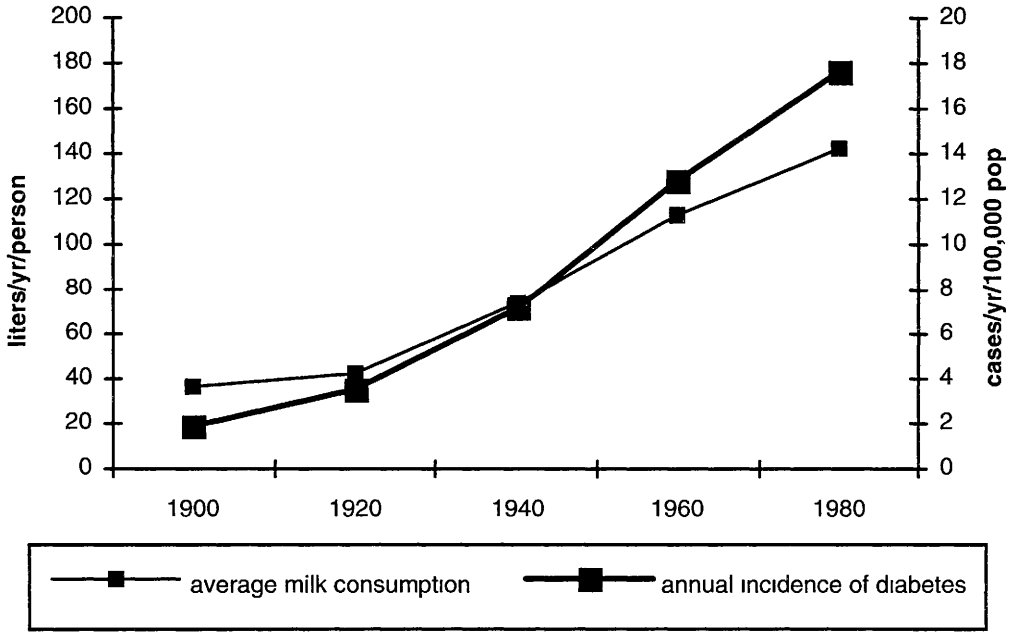
They all breathe.
A. They all undergo mitosis.
B. They are all composed of cells with nuclei.
C. They all contain complex, reduced molecules.
D. They all have circulatory systems.

Scientific Reasoning

68. Which of the following is a correct statement about the scientific method?
A. It distinguishes between good and bad.
B. It can only be done by someone with a Ph.D. degree or advanced training.
C. It organizes evidence and helps us predict what will happen in our environment.
D. It requires expensive laboratory equipment.
E. Its methods are substantially different from the way people normally process information from and about their environment.

69. Which of the following are properties of ALL life forms?
A. heritable programs in the form of DNA
B. photosynthesis
C. the ability to transform energy from one form to another
D. Only A and C are correct.
E. A, B, and C are correct.

70. The following graph shows trends in milk consumption and the incidence of juvenile diabetes in the US over the past century



What is the best conclusion that can be drawn from this graph?
A. Increased milk consumption may be partially responsible for the increase in many health problems in the US, including obesity, heart disease, and diabetes.
B. Drinking milk causes juvenile diabetes.

C. Children who drink a lot of milk are more likely to get diabetes.
D. Both milk consumption and the incidence of juvenile diabetes have increased in the US in the last century.
E. The graph is meaningless because drinking milk doesn't have anything to do with diabetes.

APPENDIX D

Social Security Number_____

Answer this question in **essay** format. Use complete sentences to express your thoughts.

Define evolution. Be as precise as possible. Include in your discussion, the four fundamental forces that act to produce evolutionary change within and between populations of living organisms.

APPENDIX E

Background and Demographic Survey

If you are not sure of an answer, do not enter a response.

1. Gender
   A. Female B. Male
2. Age
   A. 16 - 17 B. 18 - 19 C. 20 - 21 D. 22 and above

E. Classification
   A. Freshman B. Sophomore C. Junior D. Senior E. Graduate

4. Race / Ethnicity
   A. Caucasian B. African American C. Hispanic D. Asian E. Other
5. Number of college hours completed.
   A. 0 - 12 B. 13 - 24 C. 25 – 48 D. 49 and over
6. SAT score (verbal - math combined)
   A. 800 - 899 B. 900 - 1099 C. 1100 – 1200 D. 1200 and over
7. Number of Biology hours completed at the college level.
   A. 0 - 4 B. 5- 8 C. 9 – 12 D. 13 – 16 E. Above 16

Indicate if you have completed the following college science courses.

8. Freshman Chemistry I
   A. Yes B. No
9. Freshman Chemistry II
   A. Yes B. No
10. Organic Chemistry I
    A. Yes B. No
11. Organic Chemistry II
    A. Yes B. No
12. Biology 1430 (Functional)
    A. Yes B. No
13. Biology 1431 (Organismal)
    A. Yes B. No

Indicate if you have completed the following high school science courses.

14. Biology
    A. Yes B. No
15. AP Biology
    A. Yes B. No
16. Chemistry
    A. Yes B. No
17. AP Chemistry
    A. Yes B. No
18. Physics
    A. Yes B. No
19. AP Physics
    A. Yes B. No

APPENDIX F

MISSION STATEMENT
BIOLOGY 2000 CURRICULUM

The Biology Department at Southwest Texas State University has implemented a new program entitled the "Biology 2000 Curriculum", which is designed to provide a strong background of basic principles in biology to entry-level students. This program will provide the entry-level biology major with a foundation for all subsequent core and advanced courses offered by the SWT Department of Biology. At the entry, or freshman level, the Biology 2000 Curriculum consists of two courses for Biology majors: Functional Biology and Organismal Biology. Functional Biology will provide the student with a strong background in cellular and molecular biology and physiology while Organismal Biology will provide the student with a strong background in evolution, ecology, genetics, behavior and diversity.

The goals for both the Functional and Organismal Biology courses offered within the Biology 2000 Curriculum are to: 1) provide students a foundation for all subsequent core and advanced courses offered by the SWT Department of Biology; 2) provide students with a conceptual framework within which all other biological experiences can be integrated; 3) provide students opportunities to experience science as an investigative process; 4) increase understanding of how the process of scientific inquiry works; 5) encourage understanding science as a way of knowing; 6) foster the ability to think creatively and formulate questions about nature; 7) attain the ability to reason logically and critically evaluate information; 8) promote understanding of the logic involved in the design, analysis, and interpretation of scientific investigations; 9) help students develop and explore new areas of interest.

In the broadest sense, the overall goal of the Biology 2000 Curriculum is to help students attain scientific literacy in Biology. Attaining scientific literacy is an important component of a well-rounded university education. A scientifically literate person is described in "Science for All Americans" by Rutherford and Ahlgren as one who ...is aware that science, mathematics and technology are interdependent human enterprises with strengths and limitations: understands key concepts and principles of science: is familiar with the natural world and recognizes both its unity and diversity; and uses scientific knowledge and ways of thinking for individual and social purposes. Furthermore, the National Science Education Standards consider a scientifically literate individual one who can...ask, find, or determine answers derived from curiosity about everyday experiences...describe, explain, and predict natural phenomenon...read with understanding articles about science in the popular press and...engage in social conversations about the validity of the conclusions...identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed...evaluate the quality of scientific information on the basis of its source and the methods used to generate it...pose and evaluate arguments based on evidence and...apply conclusions from such arguments.

The goal of attaining scientific literacy requires both mastery of course content, and applying what is learned to novel situations. Toward these ends, both course content and pedagogy of the entry-level majors' program will reflect this goal. Students will focus their efforts more on understanding the ideas and concepts presented and less so on memorizing lists and minutia. Laboratory sections will consist of open-ended investigations where students are required to work in groups, design their own

investigations, accumulate, tabulate and analyze their data and report their findings in formal seminars settings.

To determine whether the goals of the Biology 2000 Curriculum are being met, whether the assumptions being made are accurate, and whether and where gaps exist, we will perform formative and summative evaluation of both cognitive and affective effects of the Biology 2000 Curriculum. The assessment of the program will be clearly distinguished from other forms of assessment such as the assessment of individual students or of faculty and staff. The conclusions drawn will feed back into our development and assessment process, in which we review our goals, our methods to achieve and measure these goals, and our continual effort to improve the Biology 2000 Curriculum at the entry-level.

LITERATURE CITED

Airasian, P. W. (2001). Classroom Assessments: Concepts and Applications. New York, McGraw Hill.

Anderson, R. C. (1972). "How to construct achievement tests to assess comprehension." Educational Resources **42**: 145-170.

Angelo, T. A. (1992). Classroom Assessment Techniques: A Handbook for College Teachers. San Francisco.

Banta, T. W., Lund, J.P., Black, K.E. and Oblander. F.W. (1996). Assessment in Practice: Putting Principles to Work on College Campuses. San Francisco.

Bloom, B. S. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals. New York, Longmans, Green.

Brand, A. G. (1992). Writing Assessment at the College Level. Blomington, IN., ERIC Clearinghouse on Reading and Communication Skills.

Case, C. L. (1980). "The Influence of Modified Laboratory Instruction on College Student Biology Achievement." Journal of Research in Science Teaching **17**(1): 1-6.

Champagne, A. B., Newell, S.T. (1992). "Directions for Research and Development: Alternate Methods of Assessing Scientific Literacy." Journal of Research in Science Teaching **29**(8): 841-860.

Diamond, R. M. (1998). Designing and Assessing Course and Curricula: A Practical Guide, Jossey-Bass.

Gardiner, L. F. (1999). "Why We Must Change: The Research Evidence." National Education Association Higher Education Journal: 71-81.

Germann, P. J. (1989). "The Processes of Biological Investigations Test." Journal of Research in Science Teaching **26**(7): 609-625.

Gibbs, W. W., Fox, D. (1999). "The False Crisis in Science Education." Scientific American: 87-93.

Glass, G. V. (1976). "Primary, secondary, and meta-analysis of research." Educational Researcher **5**: 3-8.

Greenfeld, T. A. (1996). "Implementing Problem-Based Learning in a College Science Class." Journal of College Science Teaching: 26-30.

Gronlund, N. E., et.al. (1990). Measurement and Evaluation in Teaching. New York, Macmillan Publishing Company.

Hall, D. A., McUrdy, D.W. (1990). "A Comparison of a Biological Science Curriculum Study (BSCS) Laboratory and a Traditional Laboratory on student Achievement at Two Private Liberal Arts Colleges." Journal of Research in Science Teaching **27**(7): 625-636.

Hastings, J., Stewart, J. (1983). "An analysis of Research Studies in which "Homemade" Achievement Instruments were Utilized." Journal of Research in Science Teaching **20**(7): 697-703.

Koke, J. R. (1999). Biology 2000 Curriculum-Executive Summary. San Marcos, Southwest Texas State University: 1-1.

Koke, J. R. (2002). Functional Biology 1430 Homepage. **2002**.

Koke, J. R. (2002). Organismal Biology 1431 Homepage. **2002**.

Kyle, W. C. (1997). "Assessing Student's Understanding of Science." Journal of Research in Science Teaching **34**(9): 851-852.

Lawrenz, F., Huffman, D., Welch, W. (2000). "Policy Considerations based on a Cost Analysis of Alternative Test Formats in Large Scale Science Assessments." Journal of Research in Science Teaching **37**(6): 615-626.

Leonard, W. H. (1983). "An Experimental Study of a BSCS-Style Laboratory Approach for University General Biology." Journal of Research in Science Teaching **20**(9): 807-813.

Martin, et. al. (1999). Biology. Fort Worth, Harcourt Brace College.

Maybry, L. et. al. (2002). High Stakes Testing. American Evaluation Association.

Maynes, F. J., Ross, J.A. (1983). "Development of a Test of Experimental Problem-Solving Skills." Journal of Research in Science Teaching **20**(1): 63-75.

Moore, J. A. (1993). Science as a way of knowing: the foundations of modern biology. Cambridge, Mass., Harvard University Press.

Morgenstern, C. F., Renner, J.W. (1984). "Measuring Thinking with Standardized Science Tests." Journal of Research in Science Teaching **21**(6): 639-648.

Nedelsky, L. (1965). Science Teaching and Testing. New York, Harcourt Brace and World.

Ott, J. (2000). Scientific literacy statement, **2000**.

Pechenik, J. A. (2001). A Short Guide to Writing About Biology. New York, Addison-Wesley.

Rickover, H. G. (1963). American education, a national failure; the problem of our schools and what we can learn from England. New York, Dutton.

Sanders, J. R., et. al. (1994). The Program Evaluation Standards, SAGE Publications.

Scantlebury, K., Boone, W., Kaahle, J.B., Frasier, B.J. (2001). "Design, Validation and Use of an Evaluation Instrument for Monitoring Systematic Reform." Journal of Research in Science Teaching **38** (646-662).

Schrock, J. R. (1997). Inquiry into Life. Dubuque, Brown, W.C.

Scriven, M. (1991). Evaluation Thesaurus, Fourth Edition, SAGE Publications.

Service, E. T. (1994). 1994 AP Biology: Free response Scoring Guide with Multiple-Choice Section. New York, The College Board.

Shymansky, J. A., Hedges, L.V., Woodworth, G. (1990). "A Reassessment of the Effects of Inquiry-Based Science Curricula of the 60's on Student Performance." Journal of Research in Science Teaching **27**(2): 127-144.

Shymansky, J. A., Kyle, W.C. (1992). "Overview: Science Curriculum Reform." Journal of Research in Science Teaching **29**(8): 745-747.

Shymansky, J. A., Kyle, W.C., Alport, J.M. (1983). "The Effects of New Science Curricula on Student Performance." Journal of Research in Science Teaching **20**(5): 387-404.

Sundberg, M. D., Dini, M.L., Li, E. (1994). "Decreasing Course Content Improves Student Comprehension of Science and Attitudes towards Science in Freshman Biology." Journal of Research in Science Teaching **31**(6): 679-693.

Sutman, F. X. (1996). "Science Literacy: A Functional Definition." Journal of Research in Science Teaching **33**(5): 459-460.

Udovic, D., et. al. (1993). What Matters in Nonmajors' Biology? **2000**.

United States. National Commission on Excellence in Education. (1983). A nation at risk: the imperative for educational reform: a report to the Nation and the Secretary of Education, United States Department of Education. Washington, D.C.

Winer, B., J., et. al. (1991). Statistical Principles in Experimental Design, 3rd Edition. Boston, McGraw Hill.

Wyckoff, S. (2001). "Changing the Culture of Undergraduate Science Teaching." Journal of College Science Teaching **30**(5): 306-312.

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