TESTING AND EVALUATION IN THE BIOLOGICAL SCIENCES
This book is a wonderful resource but had only a limited distribution back around 1967. Thanks to GWU for permission to put it in digital form so that it can be shared widely. It is still under copyright, so please read the permission letter.

Biology has changed quite a bit since 1967, so many of the example questions are dated and this book doesn’t serve as a simple question bank. Yet the questions can be very useful as exemplars of questions pointed at different topics and at different cognitive levels. Since you have the digital version, it is fairly easy to copy/paste them and then update/modify as you find appropriate and useful.

While I did a lot of proofreading, I’m sure I’ve missed many details, so the scanned pages in jpg format are also available. Feel free to check them if anything puzzling is found.

To me, the question bank emphasizes the value of the earlier discussion in the book about assessment and evaluation methods. While most of the items given are multiple choice questions, there is also presentation and discussion about essay and matching questions. Each question, of all types, has an associated cognitive level (using Bloom’s Taxonomy). This significantly assists the instructor in assessing the progress of the students, and there is also discussion of evaluating the validity of the questions.

For courses in other areas than Biology, this book can also be valuable. The discussion about question construction is broadly applicable, and the questions can still serve as examplars for question construction in other fields.

I hope everyone finds this book as valuable as I have.

--henry schaffer
Professor Emeritus of Genetics and Biomathematics
Member of the Academy of Outstanding Teachers
N. C. State University

P.S. To get the book into digital form, I scanned each page and then submitted each page to a very nice, free OCR site http://www.onlineocr.net/ which produced a Word document (.doc). I was amazed at how accurately the OCR worked, but sometimes it was too accurate as it tried to get every aspect of character and word spacing exact, usually over-complicating what was supposed to be a simple page in two columns. Additionally, while it tried to handle diagrams and formulas, that part worked poorly and so I cut/pasted most of the diagrams from the scanned material into the .doc using Insert Picture.
Testing and Evaluation in the Biological Sciences

November, 1967

Publication No. 20

COMMISSION ON UNDERGRADUATE EDUCATION
IN THE BIOLOGICAL SCIENCES

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The CUEBS Panel on Evaluation and Testing, established in 1965, created this document to serve as a resource for the instructor preparing course examinations. The test items included represent a broad spectrum of both subject matter and behavioral objectives. While some of the items may be suitable for use verbatim, others may require modification to adapt them to particular situations. The ultimate aim is to encourage the development and use of better evaluation and testing instruments in biology.

This volume is not intended to represent any "official" prescription of course content or to set any national patterns. The number of items in the various categories do not in any way reflect their relative weights or values in a biology course or curriculum. The fact that more items are included in some areas merely reflects the rapid increase in new content in these areas in recent years. Since a supply of items in some of the more traditional areas already exists, fewer of these items are included.

CUEBS would welcome any comments, criticisms, or contributions of new test items. A large pool of good items, together with feedback information concerning the present items, will form the basis for possible revision of this volume in the future. If item analysis data on tests are obtained, CUEBS would appreciate receiving copies.

A compendium of this sort represents the combined efforts of a number of people. Certainly the leadership and industry of the Panel itself must be recognized. In addition, valuable ideas and guidance were offered at various stages by Garland E. Allen, Ted F. Andrews, Jeffrey J. W. Baker, Richard V. Bovbjerg, Frank M. Child, Earl D. Hanson, J. Thomas Hastings, Charles E. Holt III, Johns Hopkins III, Willis H. Johnson, Ray Koppelman, Ariel G. Loewy, Gairdner B. Moment, Thomas G. Overmire, and Alfred S. Sussman. The test items themselves were created by the individual Panel members and by Paul H. Barrett, Mary Alice Burmester, Kenneth F. Jerkins, Auley A. McAuley, Frederick C. Neidhardt, C. Francis Shutts, Roy E. Snyder, Bruce Stewart, and Joseph W. Vanable, Jr. To all these people, and to others who contributed so markedly to the formulation of this volume, CUEBS is indeed grateful; without the contributions of their various talents, this task could not have been completed.

Martin W. Schein
Director, CUEBS
November, 1967
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SECTION 1. INTRODUCTION

Problems of evaluation are always with us. The person who first discovered fire probably critically clocked his tongue over the technique used by his pupils as they rubbed sticks together. In this case, the evaluation was personal and subjective. It is more difficult today, however. With the ever-burgeoning enrollments in our institutions, where classes of 500 or more are becoming common, evaluation is a very different matter. Techniques possible in small classes become impractical in large ones. As informal subjective evaluation of student performance becomes more difficult, other more structured procedures must be used.

Instructors teach many things; some planned, others unplanned; some directly, others indirectly; some invoking attitudes, skills and techniques (the spirit of inquiry, skepticism, problem solving techniques), others oriented toward subject matter mastery. All these and many more constitute in varying proportions the goals and objectives of science instruction. Some teachers believe their responsibility has been satisfactorily discharged when students have learned the "basic facts" in a course. Others accept responsibility for changing the attitudes and thinking skills of their students. Many biology instructors wish to know when and to what extent their students have attained instructional objectives, whether in a subject matter unit, an experiment in the laboratory, an excursion to the field, or in the subtle areas of attitude and outlook on life.

Most biology teachers would agree that students should gain from the study of biology a better understanding of the nature and structure of science. Many would probably include attainment of problem-solving abilities and attitudes as an important aspect of acquiring this understanding. The following abilities are certainly important:

1. to identify and define problems to be solved;
2. to reduce problems to their simplest form and to formulate hypotheses;
3. to design experiments to test hypotheses (e.g., the selection of the simplest procedure, the reduction of variables, the selection of proper organisms, valid and reliable sampling techniques, and proper selection and use of controls);
4. to carry out experiments and gather reliable data;
5. to organize and present qualitative and quantitative data so that relationships can be determined (e.g., skill in selecting and using appropriate pictorial, graphic, or statistical techniques);
6. to make valid tentative interpretations or to draw conclusions based on the data and other knowledge; this ability includes skill in recognizing the importance of variables, errors and limitations in the experimental design and data;
7. to generalize from the experimental results, to formulate new hypotheses based on these results, and to state the predictions which lead to more experiments;
8. to communicate effectively.  

Suitable evaluation techniques must be designed to measure these abilities. Many biology instructors who believe they concentrate on principles, concepts and major ideas in their courses, actually test for specific recall of information such as the names of bones, orders of insects and chemical formulae. Students soon learn that in order to earn a favorable grade in Professor Blank’s class it is more important to memorize the underlined words in the text than to gain a thorough understanding of the major ideas. If large numbers of students do poorly on an examination it may be not so much a reflection on the capabilities of the students as it is a testimony to the instructor's failure either to present the material successfully or to measure attainment of those goals which he believes are important.

Basically, teachers desire to bring about changes in student behavior. Since these changes vary greatly in level of importance, it is essential to determine which changes will be most significant and then plan to structure the course offerings to induce these desirable changes. Concurrently, it is also essential to consider how the extent of change will be evaluated. The wider the range anticipated, the greater may be the variety of evaluative procedures and techniques required.

The most important goal of evaluation in the minds of many students and instructors is that of grade determination. Examinations are the most common means of evaluation. They largely determine student attitudes toward both courses and instructors. Furthermore, standardized examinations influence curricular content and teacher attitudes. Because of the magnitude of their impact, examinations should be of the highest quality.

Inadequate training in examination techniques is sometimes correlated with a lack of appreciation of the value of tests. The fixation on examinations solely as a grading technique tends to lessen their importance as a learning experience. The lack of time available makes construction of good examinations unlikely. When properly constructed and used, examinations can be a valuable adjunct to the educational program. Many instructors feel that student interest in their courses is highest just before and immediately after examinations. If this is true, it should be capitalized upon. Good examinations, coupled with good discussions, can stimulate the faculty and illuminate material for the student because of the high motivation level which is engendered.

Instruction begins and ends with evaluation. Course construction requires the selection of goals and outcomes. Techniques chosen for measuring student achievement are determined largely by the goals and outcomes initially selected. Ideally, a sort of bench mark should be established by pre-testing the students at the outset to determine their level of attainment in course content and objectives. Without pre-testing, the instructor may be tempted to assume that the student's initial knowledge must be near zero, and that practically all progress as revealed by the final examination can be attributed to the exposure the students have received in his course. This may, indeed, be true in a very unique and esoteric course. In the typical biology course, however, the initial level of achievement may be far higher than suspected.

Having made this initial assessment, the instructor has a basis for structuring his course. In order to get feedback helpful in structuring the course procedures as the term progresses, he would do well to obtain periodic assessments of how the students are progressing. These may take many forms: e.g., chance observations of spontaneous behavior in response to fortuitous unplanned occurrences in the laboratory, oral quizzes or interviews, laboratory practical examinations, objective pencil-and-paper tests, short-answer essay questions, single-concept essay questions, and seminar reports on topics students have studied in the laboratory or library.

It is desirable that evaluation be broad and comprehensive. The final evaluation should be a composite of many different techniques and not simply a multiple-choice test. When instruction and evaluation both receive their impetus and direction from the same carefully formulated objectives, the evaluation is likely to be in phase with the instruction and to have high validity. The goal of the biology instructor should be to bring about this relationship, for only through a program of systematic evaluation can he determine whether his instructional objectives have been attained.
In this section a number of testing procedures are discussed. No attempt has been made, however, to be all-inclusive. Regardless of the type of examination used, the purpose of testing in the biological sciences is to assess the extent to which desirable changes in the student's knowledge, intellectual abilities, attitudes and values have occurred as a consequence of his educational experiences. These educational experiences include the laboratory, lecture, discussion, reading, problem solving, field work and other related activities.

**Essay Examinations**

Essay testing is perhaps an outgrowth of individual oral testing. Each has unique characteristics and advantages under certain conditions. Students can be tested individually with a series of related oral questions, each probing to successively greater depths. The responses can provide a feedback to serve as a basis for structuring subsequent questions. A skillful interrogator would give direction and focus to the guiding the reducing irrelevancies and successively probing toward the limits of the individual student's knowledge and comprehension. Unless the group being tested is very small — less than 10 perhaps — this procedure is quite time consuming and somewhat unwieldy. In the future, however, the use of a computer with an individual procedure is quite time consuming and somewhat unwieldy. In the future, however, the use of a computer with an individual console for each member of a class of 30 or more may make it possible to give this type of individualized test to all of the students in a class simultaneously.

Though it does not lend itself to structuring successive questions on the basis of feedback, the essay examination, if composed of carefully framed questions, can provide latitude for the student to respond in ways characteristic of his own thinking. It will allow him to demonstrate skill in written expression and in the organization of his thoughts. When the primary emphasis is upon originality and creativity involving synthesis and organization of ideas as well as a demonstration of language facility, the essay type examination can best yield the kinds of results that are being sought.

The essay examination should be formulated so as to elicit from the student a response which requires him to assemble pertinent information and ideas, to organize and present these logically in an integrated arrangement, and to state them in carefully chosen, imaginative and expressive language. Sometimes an essay question introduces a real learning experience — the student generates relationships and insights he has not before appreciated.

In assembling the information and ideas, the student may demonstrate his command of the material and his ability to determine relevance, or he may compare and contrast different areas of knowledge. For example, consider the following:

938. * Discuss whether there is a common mechanistic basis for the biological clocks determining flowering times in angiosperms and breeding seasons in vertebrates.

In organizing and presenting his answer, the student should show a coherent, logical arrangement of the points he makes and present appropriate illustrations of these points. A question which calls for this skill is:

1298. Over a period of many years an abandoned 240 acre cornfield becomes an oak-hickory forest. Outline the factors which bring this about.

The use of ingenuity can be elicited in several ways. The student may be asked to account for certain experimental results, suggest an original hypothesis to answer a biological problem, propose a research procedure, develop a tool, or formulate a new way of considering phenomena. Examples of such questions are:

324. A guinea pig intestine is washed out, then filled with an aqueous solution of glucose of a concentration half that of the cells lining the intestinal lumen. The intestine absorbs glucose from this solution. How can this be explained?

506. Describe a cat as if you were an engineer discussing a new invention.

507. How would you go about determining whether the geometric form of a parametium is the most efficient one for its path and mode of locomotion?

1381. Devise an apparatus for measuring the fluid pressure in a muscle cell during contraction and relaxation such that the apparatus will not itself affect either the pressure or the state of contraction.

1382. Account for the fact that infection with malaria is used as a therapeutic method in treating certain diseases.

The student may also be called upon to translate sensory data into ideas. He may be asked to demonstrate his judgement, his evaluations, and the bases for his beliefs. Consider these questions:

1026. Compare the relative importance of morphology and biochemistry in the classification of plants ten years from now.

1387. Look out of the window for five minutes. Then describe what you saw in terms of biological phenomena. How would your description have been different if you observed only those phenomena which are of primary importance to a biochemist? A plant physiologist? A student of animal behavior? An ecologist?

1388. One writer suggests that biology is a science only insofar as it is quantitative. Do you agree or disagree, and why?

Scoring of essay examinations is frequently unreliable. A question too loosely structured may elicit a response difficult to judge. A reader may very well judge such a paper as failing one day and passing the next. He may judge the last paper in a set by a standard entirely different from that used for the first paper. He may be influenced by extraneous factors — handwriting, prior work of the student, image of the student, or even by reader fatigue or boredom as he is nearing the bottom of a stack of papers. There is also considerable variability among readers. In cases on record, papers regarded as deserving A by some readers received F from other readers. Variations of as much as two letter grades from one reader to another were quite frequent.

Greater consistency in scoring can be achieved if essay questions are brought into sharp focus. Loosely worded questions beginning with "Tell all you know about — " "Elaborate on — " "What about — " and the like, tend to elicit widely ranging answers that are difficult to score. By contrast, questions, such as the following, which require a fairly precise answer from the student, make it possible to judge successive papers with greater consistency:

1305. An oasis in the Sahara desert, fifty miles from the nearest source of neighboring life, is devastated by the explosion of a nuclear bomb, whose radiations kill all life in the oasis. In time, the radioactivity falls below the lethal level, but no human beings return to the oasis. Describe the development of a new biota by natural means in this oasis.

1331. This question refers to regulatory devices.

a. In general, what is meant by the engineering term "negative feedback"?

b. Give an example of an intracellular ("within one") regulatory device that operates on the principle of negative feedback. Briefly show how it is a negative feedback device.

c. Give an example of an intercellular ("between two or more") regulatory device that operates on the principle of negative feedback. Briefly show how it operates.

These questions give the student a much clearer indication of what is expected, with the consequence that the adequacy of his responses can probably be judged much more precisely and the papers scored more reliably.
In scoring a set of 40-50 papers the reader could also enhance the consistency of his scoring if he would postpone the final decision on each paper until all the papers had been read. One way to accomplish this is to put each paper that is read into one of three piles: High — Middle — Low. The High group can then be further subdivided into Superior and High, and the Low group can be separated into Low and Inferior. After a quick check again and perhaps a little shifting of papers from one group to another, grades can be assigned to the papers — perhaps A for Superior, B for High, C for Middle, D for Low and F for Inferior. If only three grades are desired, the original High, Middle and Low groups, after a quick review and slight shifting of papers, can be used as the basis for three different grades.

Another procedure for increasing reliability in scoring essay answers involves judging the answer to question one on all the papers, then to question two on all the papers, and so on until the questions have all been read and scored. It is well to shuffle the papers between questions.

When several readers are working on a common set of papers, one reader could score the responses to question one on all the papers, a second reader could score the answers of question two, etc. Thus, if there are four or five questions in all, each student's paper will have had the benefit of the judgement of several different readers. This procedure reduces the effects of extremes in severity or leniency in grading and increases the consistency or reliability of the scores.

Multiple-Choice Examinations

When constructing an objective type examination the judgment as to what constitutes the right answer to each item is made in advance, and each item is so formulated that ordinarily no decision regarding the correctness of the answer has to be made at the time the scoring is in progress. Many decisions and judgments of the kind that have to be made while scoring an essay examination paper are made many weeks earlier when the objective items are being written and the examination is being put together. Ambiguities and other flaws in objective items can be largely eliminated if the items are subjected to critical review in the early stages of item writing by a group of individuals, all of whom are either teaching sections of the course or who are competent to judge the accuracy, relevance and validity of the test items in relation to the course for which they are being written. If each instructor will go through the proof copy of the examination as though he were a student taking the examination, many ambiguities or otherwise unclear phraseology and irrelevant clues to the answers can be discovered and eliminated or corrected before the test is reproduced. The students, when they are taking the test, will find most of the remaining flaws. Item analysis data may indicate any other ineptitudes. These are perhaps the most cogent reasons for using previously tried and subsequently refined items in important examinations for large groups.

If an instructor is writing objective items for use in his own class examination, review by others is not feasible, he would do well to set his items aside for a week and then come back to them to see if their meaning is still clear. He may then feel that some revision or refinement is in order.

In writing multiple-choice items, the goal should be to make sure that the stem (i.e., the part of the item that contains the question to be answered) presents a clearly stated premise or problem so that there is no uncertainty as to what the student is being asked to do. To achieve this, the stem should contain a verb — something that is often overlooked when instructors are writing multiple-choice items. The stem should be followed by a set of four or five options or responses from which the student is expected to select the answer. Each response should be a plausible answer. This requires that the set of responses be homogeneous, grammatically consistent and free from verbal associations or specific determiners that may serve as irrelevant clues to the correct answer. Ideally, most of the questions in the examination should require the student to demonstrate profound understandings rather than merely to select memorized pat answers. While it is true that multiple-choice items are often used to test for insignificant trivia and self-evident verbal associations, they can be created to measure attainment of complex abilities and fundamental understandings.

An example of testing for mere verbal association would be:

Who wrote Origin of Species?
A. Mendel
B. Lamarck
C. De Vries
D. Darwin
E. Weismann

Biology students probably ought to know who wrote Origin of Species, but this knowledge per se is no indication of a larger understanding. To ask a question about the main theme of the book or the ideas of the book or man's thinking or how certain people reacted to the ideas set forth would be more fruitful. Following is an item which calls for more profound understandings.

1097. If carbon deposits in rocks were produced by living organisms, and if such carbon deposits occur in rocks that are calculated to be older than any known fossil-bearing rocks, then life existed upon the earth prior to the time that any now known fossil-bearing rocks were formed. How would the underlined portion of the foregoing statement be categorized?
A. It is an assumption upon which the validity of the concept of evolution depends.
B. It is a deduction from postulates or premises.
C. It is a generalization based upon empirical observations.
D. It is a conclusion that is not supported by empirical evidence.
E. It is an analogy comparing an unknown with something that is known.

The previous example has the following characteristics that a satisfactory multiple-choice item should possess:

a. the stem sets forth a single precise unambiguous task for the student to do;
b. the stem is followed by a homogeneous set of responses, parallel in construction;
c. no response can be eliminated because of grammatical inconsistency with the stem;
d. the responses contain no verbal associations that provide irrelevant clues to the answer;
e. the correct response is not more elaborate in phraseology than the incorrect ones;
f. to the student who does not perceive the problem or know the answer, each response may appear to be a plausible answer.

On occasion it may be desirable to write objective type items using some common misconceptions as foils (wrong responses). One way that this can be done is by asking a question in open-ended form before the students have studied the concept under consideration. Some of the more plausible sounding wrong responses can then be used in the student's own words as foil for tests given to the students after they have studied the new concept. For example, prior to the study of the effect of auxins, a class was given this unfinished statement to complete:

When young seedlings are exposed to a bright light source on only one side, they tend to bend toward that light source as they grow because ...

Here are a few of the completions:

- the part nearest the light grows faster and thus seems to bend.
- light is needed for photosynthesis and the plant is responding to the light of the sun.
- plants need light in order to make food.
- the side of the plant in the dark grows faster and therefore makes the plant bend towards the light.
- the young seedlings seek the light because they are phototropic.

There were 43 such completions, many of which were variations of the above. Selecting from these, it was possible to construct the following multiple-choice item:

833. Which of the following constitutes the best explanation of what causes a green plant, exposed to the light on only one side, to bend toward the light as it grows?
A. Green plants need light to carry on photosynthesis.
B. Green plants seek the light because they are phototropic.

* The correct answer, according to the item writer.
While it is possible to use the above procedure to construct items at almost any level of sophistication, this is a very time-consuming way to get multiple-choice items written. However, a less time-consuming adaptation could be applied. While the test writer is attempting to think of suitable foils, he might try to recall some of the misconceptions that students revealed in questions they raised or statements they made in class. The ideas in some of these may lend themselves to use as foils.

Words or phrases used out-of-context are another source of foils. These tend to distract the superficial learners who have memorized a great many terms or phrases but have not gained a thorough understanding of the context in which each is applicable. A good test item should reward the student who quickly detects out-of-context phraseology and recognizes the correct answer.

In composing a test item based upon computational operations, greater discriminating power can be obtained if the foils are the answers one would obtain if he used alternative, but incorrect, computational procedures. Use of this technique gives greater plausibility to the foils and makes them more attractive to the students who almost know how to work the exercise, but whose preparation is lacking in thoroughness.

A multiple-choice item that stands by itself and is not part of a series is called a self-contained item. One of the advantages of this type of item lies in its independence. Great flexibility accrues from putting such items on cards — one to a card. The sequence of items for a test can easily be established by arranging the cards in the desired order. Any time before the test is typed, a particular item can easily be replaced or changed in sequence by readjusting the cards. Multiple-choice items can also be written in a series or constellation to involve the students in a comprehensive analysis of a more extensive topic, such as a research report.

Interpretive Items

Significant testing can be done by using variations of the matching-test format, known as interpretive or master-list items. In general, these are constellations of items based upon a situation such as (a) a description of a research project (b) a set of data in the form of a table, graph, chart or diagram (c) a pedigree chart showing the inheritance pattern of a certain trait, etc. The items frequently have a common key from which answers are to be selected. The structuring of the set of items requires all the students to perform the same task, resulting in a high degree of comparability of student scores. The amount of pertinent information given to the students can be controlled; i.e., as much or as little as deemed necessary can be given to measure satisfactorily the attainment of the particular objective under consideration.

In the creation of interpretive test items be sure that the key is homogeneous and that the key categories are mutually exclusive. For example:

**KEY: A. Assumption**
B. Postulate
C. Inference
D. Prediction
E. Deduction

A and B are not mutually exclusive, and C, D, and E tend to mean nearly the same thing. Key categories should be chosen that are separate and distinct, with no overlap or duplication in meaning.

Interpretive test items can be used to measure application, analysis and evaluation. However, they are not well suited to measuring synthesis or creativity, these outcomes being best measured by essay examinations or student projects. The following example illustrates the interpretive type of test item set. (For additional examples see items 191-197 and 612-015.)

Items 237-243 are concerned with the following experiment:

A student placed 5cc of distilled water in a test tube. After heating the water he then added 2cc of Fehling's solution. Nothing happened. In another test tube, the student placed 5cc of distilled water and added some grapes. After heating, he added 2cc of Fehling's solution. The water in the test tube turned reddish in color. The student concluded that the grapes tested contained glucose.

In drawing this conclusion the student had to make certain assumptions. Based only on the information given here, decide items 237-245 according to the following key.

**KEY: A. A justifiable and necessary assumption**
B. An unjustifiable but necessary assumption
C. An unjustified or irrelevant assumption
D. Not an assumption but a mere restatement of results
E. Not an assumption but a mere restatement of the conclusion

237. The water did not contain glucose until the grapes were added.  
(A)

238. The glucose in grapes turns to alcohol by fermentation.  
(C)

239. Fehling's solution will cause a reddish color in the presence of glucose.  
(B)

240. Glucose is found most abundantly in grape leaves during photosynthesis.  
(C)

241. The addition of Fehling's solution caused the mixture in the second test tube to turn reddish in color.  
(D)

242. Fehling's solution will cause a reddish color only in the presence of glucose.  
(B)

243. Only ripe grapes will give the test for glucose.  
(C)

Reading Passages

The use of reading passages is not limited to interpretive items, of course, and has application in most multiple-choice testing situations.

The subject matter of a reading passage used as the basis of any kind of test item should be both timely and relevant to what has been learned in the classroom and laboratory. It can introduce recent investigations in the subject being studied and can thus contribute to learning as well as evaluation. An ideal passage has the following attributes:

1. It describes a problem and presents one or more proposed solutions.
2. It contains evidence relating to the problem, accompanied by some description of how the evidence was obtained.
3. It requires interpretation or analysis of the material and not mere recognition of what the passage says.
4. It is not too complex and lends itself to condensation or simplification in a way which clearly differentiates the basic assumptions, observations and deductions.
5. It is relatively brief — one or two paragraphs — and gives rise to six or more items.
6. It has interest to the student and particular relevance to the subject under study.

Passages of this kind are to be found in recent books and in various scientific publications ranging from specialized journals to the more popular periodicals. Scientific American has been a very fruitful source. Sometimes the entire article can be abstracted to suitable length. In other instances, a few paragraphs can be excerpted. Slight editing may be necessary to retain some of the context.

Test items pertaining to the passage may be designed to evaluate the student's (1) background of knowledge and understanding of the subject matter relevant to the passage, (2) ability to read the passage perceptively enough to discern what problem is being investigated and what steps are being proposed for its solution, and (3) capacity to follow the experimental methodology and reasoning to the conclusion. The test items may ask the student to decide such things as: which of several choices constitutes the best formula-
1113. Which of the following defines most precisely the problem under investigation in this experiment?
A. Are all species of bacteria found in nature equally susceptible to antibiotics?
B. Do bacteria grow better in a flask culture or on a plate culture?
C. What precautions must be taken in transferring bacteria from a flask culture to a plate culture?
D. How is bacterial resistance to antibiotics acquired and maintained?
E. Why are susceptible bacteria killed by the antibiotic?
(D)

1114. Why did Lederberg begin the experiment with susceptible bacteria?
A. Most bacteria in nature are susceptible to antibiotics.
B. This was the control in his experiment.
C. He was concerned with acquisition, not loss, of resistance.
D. The appearance of a mutant could easily be demonstrated.
E. He wished to show the degree of susceptibility of the bacteria and the potency of the drug.
(D)

1115. Which of the following would be true about the velv?
A. It was assumed to be sterile.
B. It made colony location identifiable on Plate II.
C. It was a vehicle for precise transfer.
D. Both A and C above, but not B.
E. A, B and C above.
(E)

1116. Which of the following served as a control?
A. Plate I
B. Plate II'
C. Plate III
D. Plate IV
E. The flask
(D)

1117. What is the major hypothesis being tested here?
A. Mutation is the source of resistance.
B. Mutations for resistance are hereditary.
C. Resistance, once acquired, will eventually be lost.
D. Resistance results from something other than contact with antibiotics.
E. Over half of the colonies contained resistant bacteria.
(D)

1118. We can deduce that a mutation must have occurred in
A. the stock culture.
B. Plate I.
C. Plate II.
D. Plate II'.
E. Plates III and IV.
(A)

For additional examples in this same series see items 1119-1126.

Matching Tests
Most instructors are familiar with the matching-test format. One list of phrases or statements (the entry list) appears in one column. A list of terms (the reference list) is placed in a parallel column. The student is directed to select the response from the reference list which is properly associated with each item in the entry list. This kind of exercise can be reasonably effective if properly constructed. The following example, which typifies prevailing practice in far too many institutions, illustrates how NOT to write matching exercises:

**DIRECTIONS:** In the blank space at the right of each item in Column B write the letter of the corresponding term in Column A.

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. cellulose</td>
<td>1. Macroscopic single-celled plant</td>
</tr>
<tr>
<td>B. nitrogen</td>
<td>2. Stage in meiosis</td>
</tr>
<tr>
<td>C. ornithology</td>
<td>3. Enzyme capable of digesting wood</td>
</tr>
<tr>
<td>D. tetrads</td>
<td>4. Life processes related to release and utilization of energy</td>
</tr>
<tr>
<td>E. glycolysis</td>
<td>5. Land habitat</td>
</tr>
<tr>
<td>F. mushroom</td>
<td>6. Belong to the respiratory system</td>
</tr>
<tr>
<td>G. barriers</td>
<td>7. Electron acceptor molecule</td>
</tr>
<tr>
<td>H. terrestrial</td>
<td>8. ATP production</td>
</tr>
<tr>
<td>I. Darwin</td>
<td>9. Bearer of the genetic code</td>
</tr>
<tr>
<td>J. metabolism</td>
<td>10. A saprophyte</td>
</tr>
<tr>
<td>K. dendrology</td>
<td>11. Internal parasites of man</td>
</tr>
<tr>
<td>L. lungs</td>
<td>12. A sauropteryx</td>
</tr>
<tr>
<td>M. NAD</td>
<td>13. Named the cell</td>
</tr>
<tr>
<td>N. mutation</td>
<td>14. Growth movement in plants</td>
</tr>
<tr>
<td>O. DNA</td>
<td>15. Living substance that surrounds cell nucleus</td>
</tr>
<tr>
<td>P. herpetology</td>
<td>16. Study of trees</td>
</tr>
<tr>
<td>Q. hookworms</td>
<td>17. Study of reptiles</td>
</tr>
</tbody>
</table>

*Items with underlined numbers are not included in the test item pool (sections 6-14).*
Every response listed in Column A should be a plausible answer to each item in Column B. Is this the case?

Item 3 calls for the name of an enzyme. If the student knows that words ending in -ase usually denote enzymes, he has the answer immediately because there is only one such word in the list.

Item 11 calls for a plural as the answer. Three plurals are listed in Column A (barriers, lungs, hookworms). Grammatical consistency dictates that the answer has to be one of these three. The proper answers are then self-evident.

Item 13 apparently calls for the name of a person. In all of Column A there are only two names of people listed (Darwin and Hooke). By simple elimination one of these two names could be settled upon as the answer.

Items 16 and 17 call for areas of science, of which only three are listed in Column A (ornithology, dendrology and herpetology). The student has at least one chance in three, rather than one chance in 21, of guessing the right answer for each of these two items.

For the majority of the items in Column B, most of the responses in Column A can be eliminated as possible answers because of sheer mechanics of grammar. Column A is too heterogeneous. It consists of too many kinds of entries, such as common nouns and proper names, singulars and plurals, names of processes, names of organisms, names of people and names of substances. This heterogeneity weakens the exercise and reduces the discrimination power of the entries by giving irrelevant clues to the answers.

How can the foregoing matching items be rewritten to eliminate most or all of these flaws?

1. Divide Column A into several sets, each of which centers around one idea. That is, make one set that includes only areas of science, another that includes only names of scientists, etc.

2. Limit each set to three items in Column B and, five responses in Column A. Or, if the same responses can be used more than once, put seven or eight items in Column B, the answers to which are to be selected from the five responses in Column A. In any event, avoid an even match, that is, do not have five items in Column B to be matched with five responses in Column A.

3. Explain clearly the basis on which the matching is to be done.

4. Include only homogeneous material in a single set.

5. Maintain grammatical consistency. Use all plurals or all singulars, all proper names or all common nouns. Do not mix adjectives, nouns, proper names, etc., in the same list.

The following example constitutes one new set that could be made from ideas in the previous example, incorporating some of these recommendations:

DIRECTIONS: In the blank space at the right of each item in Column B write the letter of the category from Column A to which the organism described or alluded to belongs.

It is possible to write a matching test item set covering a situation involving a longer list (e.g., names of classification categories in one column and a list of names or descriptions of organisms to be categorized in the other column) providing the principles of homogeneity and grammatical consistency are observed. When a long reference list is used, as in Column A of the following example, the terms should be put in alphabetic order.

DIRECTIONS: Items 1-10 constitute a matching test exercise. Column B below consists of descriptions of organisms. In the blank space at the right of each item write the letter of the category from Column A to which the organism described or alluded to belongs.

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. ornithology</td>
<td>1. Ross Allen operates a reptile ranch. In what field of work is Mr. Allen involved?</td>
</tr>
<tr>
<td>B. entomology</td>
<td>2. M. H. Macintosh bands birds and keeps records of their migratory habits. This requires competence in which branch of biology?</td>
</tr>
<tr>
<td>C. ichthyology</td>
<td>3. M. J. Michaels spends his time isolating and breeding resistant mutant strains of insects that ordinary insecticides won't kill. In what field does he work?</td>
</tr>
<tr>
<td>D. herpetology</td>
<td>4. __</td>
</tr>
<tr>
<td>E. mycology</td>
<td>5. __</td>
</tr>
</tbody>
</table>

Every response listed in Column A should be a plausible answer to each item in Column B. Is this the case?
Open-Book Tests

Open-book tests are most commonly of the essay type, where answers to the questions are not simply a matter of reproducing certain facts from the textbook or lecture notes. Objective-type tests can be used equally well with books and notes accessible. Obviously, multiple-choice items must demand more than mere recall; they should involve the student in making deductions from and seeing relationships between the premises and facts of text, lecture and laboratory findings. It is, of course, more difficult to create questions of this type than questions that merely ask for factual recall.

Open-book tests may have certain advantages over closed-book tests since they permit the student to look up necessary details, just as he does in everyday situations. This parallels actual experimental procedure and de-emphasizes the memorization of facts. On the other hand, the open-book tests may tend to discourage adequate preparation. Memorization, in many cases necessary and valuable, is slighted. As a result, open-book tests are likely to encourage superficial knowledge of the subject.

The first student reaction to the idea of open-book objective tests is one of surprised overconfidence, usually followed by second thoughts about how excessively long or difficult they must be. Fifty multiple-choice items can occupy most students for one class period. Some students are able to organize their reference materials more systematically and thus make a relative gain in rank. Others succumb to an exaggerated belief about how many answers they can look up during an hour test. As a result, open-book tests tend to encourage a more realistic attitude in the student toward the subject.

The net effect of using books and notes on biology tests can perhaps be illustrated by considering the experiment in which the same 50-point objective test was administered to two different classes (one with books and the other without) assumed to be approximately equal in ability. The class average was 3-4 points higher for the group with books. A slightly higher scale was used in assigning the grades to the book class, but the final grade distribution was about the same for both groups. There were no perfect papers in either group.

If the open-book test is to be optimally effective, the questions should require the student to work with his newly gained knowledge and see its logical consequences, interrelationships and philosophical meanings. To illustrate briefly, suppose the lecture has presented the basic postulates of the main theories of evolution developed by different biologists, accompanied by appropriate examples and historical background. Rather than reproducing these postulates and examples on the examination, the student might be presented with a group of items based upon a common key such as the following:

Items 1127-1132 pertain to evolution. Categorize each item according to the following key:

KEY: A. Ectogenetic theory of evolution
     B. Theory of natural selection
     C. Autogenetic theory of evolution
     D. Mutation theory of evolution
     E. None of these

1127. Does not consider the source of the variant forms upon which the environment acts. (B)
1128. Ignores the role of gametic genes in evolution and how they are influenced by structural changes. (A)
1129. Proposes no interaction of the organism with its environment, even though it does consider the source of change. (C)
1130. Postulates that eyes in the fish originally entering the cave would have been a point of easy injury and infection. (B)
1131. Does not deal with interaction between changes in gene structure and the selection pressures acting on them. (E)
1132. Attributes no role to the environment in producing or preserving evolutionary changes. (C)
1133. Postulates that eyes in the fish originally entering the cave would have been a point of easy injury and infection. (B)
1134. Postulates that sudden hereditary changes occurred, tending to eliminate eyes. (D)
1135. Postulates that pangenes travel from the eyes to the germ cells, influencing the latter toward a beneficial reduction of the units of eye heredity. (E)
1136. Postulates that lack of stimulation of eyes in the inky blackness of the cave would have caused them to degenerate. (A)
1137. Postulates an inherent trend toward eye reduction in this fish population. (C)
SECTION 3. OTHER EVALUATION PROCEDURES

The types of examinations described in the previous section offer flexibility for evaluating a variety of objectives. Even so, many of the skills, abilities and attitudes that are said to be desirable outcomes are still extremely difficult to evaluate. In actual practice the result is that some objectives may tend to be ignored. If they are ignored, however, they cease to be valid objectives. In this section, two additional approaches to the problem of evaluating student achievement are discussed.

Laboratory Practical Examinations

The laboratory practical as commonly used consists of a series of stations where specimens are located. A particular part of the specimen is often indicated by a microscope pointer or by a labelled pin. The student is directed to write the proper identification of each numbered specimen as he passes from one to another. Used in this way, the practical is nearly a pure recall examination, testing only how well the student can remember what he saw, drew or dissected.

If the class is small enough the students may be quizzed one at a time or in small groups and given questions over laboratory material on display. With many such tests during a semester, a student will presumably have answered a large enough number of questions to constitute a typical sample. This procedure can lend itself to a somewhat greater emphasis on factors other than memory of simple structures.

There is no reason, however, why practical examinations may not introduce and evaluate broader understandings. Questions can call not only for identification of structures but for functions or relationships to other parts as well. If, for example, a pin were placed in a pancreas, the following questions might be asked:

1. What would be the effects of the removal of this organ?
2. What substance(s) does this organ secrete?
3. If the nerve to this organ is cut the organ still secretes enzymes at the appropriate time; however, if the blood supply is cut off no enzymatic effects can be detected. Explain.

The following will illustrate other ways in which the laboratory practical can be used to evaluate abilities other than pure recall:

1. Following laboratories stressing taxonomy, the students might be asked to use a key to identify some unknowns not previously studied.
2. Following an investigation of respiration, students might be shown a respirometer and asked to state the purpose of the ascarite (or other CO₂ absorber) and how this aspect of the experimental design might introduce a variable as the experiment progresses. Or, students could be shown three laboratory set-ups showing "before," "before, with CO₂ absorbed" and "after, with O₂ removed" and asked to determine the RQ and predict what type of compound is being oxidized.
3. An experimental set-up with a deliberate error or omission could be shown and the students required to criticize the set-up.
4. Following photosynthesis exercises, students might be shown a paper chromatogram of pigments from red algae and an action spectrum of photosynthetic activity in the plant. They could then be asked to identify which pigment band is probably most active in photosynthesis and to give reasons for their answers.
5. After students have completed a study involving microorganisms, the instructor might demonstrate the transfer of a bacterial culture and ask the students to evaluate his technique.

Laboratory Practical Examinations

After a study of enzymes, students might be shown a series of fermentation tubes with different amounts of yeast cultures at different temperatures. After briefly describing the experimental design, the teacher might ask the students to relate the results to Q₁₀ or to Arrhenius' equation. Or, students might be asked to predict the amount of gas collected at "lower," "higher" or "in-between" temperatures.

Field trips might include stations where students are asked questions involving their ability to observe, make scientific guesses and make meaningful associations of principles, processes or previously learned relationships.

All of the examples would require considerable thought; hence an examination might consist of only a few questions in contrast to the usual 20-40 items.

In addition to the practical examination, laboratory work can be evaluated in other ways. Check lists can be used; formal tests can be given; workbooks can be required; informal observations can be made; etc. An interesting procedure would be to assign term problems which would require students to design experiments, collect data and make observations (e.g., determine the effects of an unknown crystalline enzyme, the optimal growing conditions for a seedling, the dominant plants in a quadrat). In all of these evaluation devices the important criteria are those if ingenuity, perception, powers of deduction, and ability to interrelate and organize the observational data gathered during experimentation.

Behavioral Rating Scales

Observations can be effective as an evaluation device. Random undirected observation, however, is not as useful as directed systematic observation. One way of directing observation of student attitudes, abilities and skills is to place students in a structured situation. This may reduce spontaneity and validity, but it does enable the instructor to make more objective comparisons since all students may be placed in similar situations. An example of a structured situation which might be used in smaller classes is the seminar-type presentation where a student reports on a laboratory or library investigation and then defends his presentation.

One way of directing an instructor's observation of student behavior is to use a rating scale, consisting of a list of behavioral traits which are indicators of certain desirable attitudes, abilities, and skills. An instructor can base a certain portion of a student's grade on this scale. Although any evaluation of student behavior is subjective, the scale can provide some degree of objectivity. For example, in one informal laboratory-type biology course, the instructor and an assistant independently rate the students from 0-10 at the end of each semester. The independent ratings are identical in about 75% of the cases.

The use of a rating scale is time-consuming and not entirely reliable or objective, but it is of value in small classes or laboratory sections. Even if the instructor does not attempt to rate students on all categories, it does remind the instructor that these attitudes and behaviors are important, thus affecting his teaching.

Total evaluation of a student's progress and development should encompass, insofar as possible, a broad spectrum of changes he has undergone in knowledge, intellectual abilities and skills, and the concomitant acquisition of attitudes befitting an educated person in the truest sense of the word. The procedures described are by no means prescriptive. Some readers may indeed have devised other equally effective approaches.
SECION 4. PREPARING AN ACHIEVEMENT EXAMINATION

An all-too-common way to prepare an objective examination is to just start writing items and stop after a sufficient number have been produced. Unfortunately, tests produced in this way sometimes have a lopsided distribution of items, with some areas being covered thoroughly and others ignored. To avoid such results it is helpful if a specification chart listing the major content areas and educational objectives being tested is prepared in advance to serve as a guide (see Figure 1).

<table>
<thead>
<tr>
<th>CONTENT AREAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Energetics and Metabolism</td>
</tr>
<tr>
<td>2. Form-Function</td>
</tr>
<tr>
<td>3. Behavior</td>
</tr>
<tr>
<td>4. Genetics</td>
</tr>
<tr>
<td>5. Reproduction and Development</td>
</tr>
<tr>
<td>6. Systematics</td>
</tr>
<tr>
<td>7. Evolution</td>
</tr>
<tr>
<td>8. Organism-Environment</td>
</tr>
<tr>
<td>9. History-Philosophy-Methodology</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

Figure 1. A chart such as this can be used to categorize and tally items during test construction. Reference to the chart as item selection or writing proceeds will indicate which areas still require emphasis. The specific Content Areas and Behavioral Objectives headings in the chart are discussed in detail in Section 5.

A temporary tally mark may be entered in the appropriate cell of the chart for each item that is written or selected for the examination. Checking the chart periodically will indicate which areas are too sparsely represented. Subsequent item writing or selection can then be directed toward giving these shortage areas proportionate representation in the examination. Later, when the examination has been assembled and the items sequenced and given numbers, the actual item numbers can replace the tally marks in the cells. This will serve as a record of categorization for each item in the examination, which, in turn, may be valuable for reference after the examination has been given, particularly if item analysis data will be filed on cards along with the items for subsequent reference and use. Figure 2 illustrates one style of 5" x 8" card that may be used for filing items and item analysis data. If machine scoring service is available, faculty members can usually obtain item analysis data which will give some indication as to how well each item functioned in the examination. Such data can provide very helpful information for use in constructing future examinations.

A distinction as to kinds of tests and their purposes should be made here. On some quizzes and tests given during the early weeks of the semester, the chief purpose may be to ascertain whether all students have thoroughly mastered certain fundamentals. On such a mastery test, the expected level of performance by every student would be at or near 100 percent. Those who fall short of 100 percent would be required to do remedial work until 100 percent performance is attained. Obviously, a mastery test does not serve as a ranking device for the purpose of assigning grades (except perhaps in a negative way in that students who attain less than 100 percent are in the unsatisfactory category until 100 percent performance is attained).

At the end of the semester, a substantial achievement...
ment examination is usually administered for the deliberate purpose of distributing students as widely as possible on a score continuum, ranging perhaps from a 20 percent to a 95 percent performance. Each test item is designed to separate some students from others — those who know or are able to perform from those who do not know or cannot perform. The rigor with which an item achieves this separation is expressed as the discrimination index for the item and can be computed in the process of machine-scor ing the answer sheets. (The formula used for determining the discrimination index is discussed in several of the publications listed in section 15.) If the entire test is constructed so that every item will separate some students from others, so that no item in the test will be answered correctly by all the students, and so that no item in the test will be missed by all the students, then the test as a whole should produce a range of scores along a continuum. An item usually has a high discrimination index if all or nearly all the upper quarter (actually 27 percent is optimum) of the students answer it correctly and if nearly all of the lowest quarter (or 27 percent) answer it incorrectly. If the item also pertains to something that is truly significant in the course in addition to its high discrimination index, it is considered to have high validity, a quality for which perceptive test writers are constantly striving.

The difficulty index is simply a measure of the proportion of students who missed an item. Conversely, the level of success refers to the proportion of students who answer an item correctly. A composite of any one index for the individual items gives the index for the test as a whole.

Experience with testing involving thousands of students has shown that for the typical college or university situation at the introductory level, an average of about 55-60 percent success is about optimum when no correction for guessing is applied. If the average level of success is 50 percent or less, students and their instructors may begin to show signs of frustration and wonder why the classroom and laboratory experience has culminated in such a "poor showing" on the examination. On the other hand, if the average level of success is substantially above 70 percent, the test will be looked upon as being too easy and the scores may tend to cluster near the top of the range, making separation between scores at the upper end less sharp.

If indices are recorded for each item and a rigorous culling of items is made, eventually a high-level testing program can be established. It is sometimes possible to salvage items with only minor flaws. For example, a foil that was not chosen by either the high or low group can sometimes be revised to sound more attractive and still be a foil. Conversely, a foil that is too attractive can often be toned down a bit or replaced.

No hard and fast criteria govern precisely what difficulty and discrimination indices are acceptable or unacceptable. In general, the higher the discrimination index the better. An item with an index of .20 may be worth keeping if it measures something of significance. It would be better if most items had higher indices than this. Indices of .30 to .40 are quite common. On occasion, one may obtain an index of .60 and, in rare cases, an index of .70 or higher.

If more than 80 percent of the students answer an item correctly it is probably too easy, though a few items of this level may be included in the test if they embody something that is significant in the course. Conversely, if more than 80 percent of the students miss an item, the content of that item would bear close scrutiny, for it may have dealt with an obscure or insignificant point. More likely, however, the item does not have a clear-cut answer. One or more of the foils may have as much merit as the keyed response and may therefore be attracting the students. Such an item should be looked at closely, for it may be a good item and the keyed answer may be indisputably right in spite of what the majority of the students think. If the students who chose the keyed response were predominantly high ranking students, the item will probably still have a satisfactory discrimination index and may be worth reusing in a subsequent examination. However, if the keyed response is chosen equally by both high and low ranking students, the item is probably ambiguous and will very likely have a low discrimination index. If more low ranking than high ranking students chose the keyed answer, the item has serious flaws (or may have been miskeyed) and will have a negative index of discrimination.

If the foregoing criteria for item selection are observed, it is not improper to think in terms of "70 percent for passing" if, for example, the level of success on the examination is 58 percent, application of the 70 percent for passing standard would result in nearly two-thirds of the students failing. The decision as to what are appropriate grade equivalents for various score intervals will have to be determined on the basis of many factors, including the institution's admission policy and standards, the purpose(s) of the course, the selection of students taking the course, etc. In terms of percentage, perhaps the following might be realistic for an introductory course where F is failing and a C average is required for graduation: 10 percent A, 25 percent B, 40 percent C, 20 percent D, 5 percent F. The foregoing is by no means prescriptive and does not constitute a recommendation. This does come close, however, to prevailing practice in a few large public institutions which have very heterogeneous student populations and where nearly everyone is required to take the particular introductory course.
SECTION 5. CATEGORIZATION AND CODING OF TEST ITEMS

As suggested in the previous chapter, categorization of test items can help the instructor to see (1) how well the items reflect the goals of a course as well as the material covered in the lecture and laboratory, and (2) which items can best be used to construct achievement examinations that are meaningful and representative.

The remainder of this publication consists of test items that have been categorized and coded according to the criteria in the three-dimensional grid shown in Figure 3. The grid is divided into three categories: Content (x-axis), Organizational Levels, (y-axis), and Behavioral Objectives (z-axis). Each category has subdivisions (e.g., x-1. Energetics and Metabolism; y-1. Molecular; z-1. Knowledge) and each item is coded according to its characteristics as they pertain to these subdivisions. For example, an item dealing with evolution (x-7) at the population level (y-4) devoted to analyzing (z-4) a research paper on industrial melanism in moths is coded 7-4-4 to indicate its categorization on the x-, y-, and z-axes of the grid.

The intellectual abilities and skills included under behavioral objectives (z-axis) are of a hierarchical character. When an item relates to several of these subdivisions it is assigned to the highest one. For example, an item that requires the student to make an analysis will also require him to utilize knowledge and to demonstrate comprehension. Such an item will be assigned to the highest subdivision (i.e., z-4, analysis). The z-axis category may not be as familiar to biologists generally as the categories represented on the x- and y-axes. The following amplifications and examples are therefore offered.*

Behavioral Objective: z-1. Knowledge.

Knowledge as defined here involves recall. The knowledge objectives emphasize most the psychological processes of remembering. To use an analogy, if one thinks of the mind as a file, the problem in a knowledge test situation is that of finding in the problem or task the appropriate signals, cues and clues which will most effectively bring out whatever knowledge, relevant to the situation, is filed or stored in the mental file.

z -1.00 Knowledge
1.10 Knowledge of specifics
1.11 Knowledge of terminology
1.12 Knowledge of specific facts
1.20 Knowledge of ways and means of dealing with specifics
1.21 Knowledge of conventions

1.22 Knowledge of trends and sequences
1.23 Knowledge of classifications and categories
1.24 Knowledge of criteria
1.25 Knowledge of methodology
1.30 Knowledge of the universals and abstractions in a field
1.31 Knowledge of principles and generalizations
1.32 Knowledge of theories and structures

The following nine examples are test items that measure knowledge:

1316. The viewpoint that the human body is directed by a vital force not amenable to scientific investigation is vitalism. This directing force is commonly called
A. typhlosole.
B. entelechy.
C. chiasma.
D. stroma.
E. nous.

(B) 9-3-1 (1.11 - Knowledge of terminology)

1317. Charles Darwin published a book on changes in soils which concerned especially the influence of
A. trace elements.
B. grass roots.
C. burrowing insects.
D. moles.
E. earthworms.

(E) 9-4-1 (1.12 - Knowledge of specific facts)

946. The scientific name of the American elm is *Ulmus americana* L. Which of the following is correct concerning the way this name is written?
A. The L. means that this particular name is from the Latin language.
B. The L. means that the Swedish botanist, Linnaeus, gave this tree its scientific name.
C. The L. actually has nothing to do with assigning this name to this tree.
D. The name is not written properly - the first letter in americana ought to be capitalized.
E. The words *Ulmus* and *americana* are underlined to give them emphasis.

(B) 6-3-1 (1.21 - Knowledge of conventions)

*The organizational outline used in the Behavioral Objectives category, and the descriptive excerpts which follow, have been adapted with permission from the Taxonomy of Educational Objectives, by B. S. Bloom, et al. (see Selected References, section 15).
9. The "first step" in photosynthesis is the
A. formation of ATP.
B. ionization of water.
C. excitation of an electron of chlorophyll a by a photon of light.
D. attachment of CO₂ to a 5-carbon sugar.
E. joining of two 3-carbon compounds to form glucose.

(C) 1-1-1 (1.22 — Knowledge of trends and sequences)

1033. On the phylogenetic "tree" of animal life, which of the following is assumed to be more primitive than a dinosaur but more complex than a shark?
A. Crayfish
B. Starfish
C. Amphioxus
D. Salamander
E. None of the foregoing

(D) 7-3-1 (1.23 — Knowledge of classification and categories)

1312. Gametes are reproductive cells produced by individual organisms. There are two kinds of gametes: one kind, the sperm, is produced by the male; the other kind, the egg, is produced by the female. The sperm and the egg unite to form a new organism. This union is called fertilization. The new cell formed by the union of gametes is called a zygote.

In the context of the foregoing passage on sexual reproduction, which one of the following is a primary term?
A. Gametes
B. Cells
C. Fertilization
D. Zygote
E. None of these

(B) 9-2-1 (1.24 — Knowledge of criteria)

1313. Which of the following developments was most instrumental in enabling us to determine the function of mitochondria?
A. Techniques of cell disruption and ultracentrifugation
B. Techniques of culturing bacteria
C. Techniques of plastic imbedding and ultrathin sectioning
D. The electron microscope
E. The phase microscope

(A) 9-1-1 (1.25 — Knowledge of methodology)

1314. In 1838, Schwann, on the basis of his own observations as well as the observations of others, advanced the tentative conclusion that all living things are composed of cells. This statement, when first made in 1838, was
A. an assumption.
B. an observation.
C. a generalization.
D. an analogy.
E. a law.

(C) 9-2-1 (1.31 — Knowledge of principles and generalizations)

1315. Which of the following was most influential upon Darwin's formulation of the theory of natural selection?
A. De Vries' concept of mutations
B. Lamarck's ideas on inheritance of acquired characteristics
C. Malthus' essay on population
D. Mendel's genetic studies on peas
E. Wallace's paper on survival

(C) 9-3-1 (1.32 — Knowledge of theories and structures)

Comprehension represents the basic level of understanding. It refers to a type of understanding or apprehension such that the individual knows what is being communicated and can make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implications.

2.00 Comprehension — ability to make use of materials or ideas.

2.10 Translation — ability to deal with an idea when expressed in different phraseology from that in which it was originally encountered.

2.20 Interpretation — ability to deal with materials or ideas that have been reordered, rearranged or organized into a different format, such as graphs, tables of data, charts, diagrams, and the like, depicting data that were originally in descriptive paragraph format.

2.30 Extrapolation — the extension of trends or tendencies beyond the given data to determine implications, consequences, corollaries, effects, etc., which are in accordance with the conditions described in the original communication. Skill in predicting continuation of trends.

The following three examples are test items that measure comprehension.

829. Which of the following best illustrates feedback in development?
A. As tissue X develops it secretes something that inhibits the development of tissue Y.
B. As tissue X develops it secretes something that induces tissue Y to develop.
C. Tissue X secretes RNA which changes the development of tissue Y.
D. As tissue X develops it secretes something which slows down growth of tissue X.
E. Rates of development in tissue X and tissue Y are controlled by the pituitary.

(E) 5-2-2 (2.10 — Translation)

169. Consider the following graph.

The above graph of research data indicates that
A. ATP is produced by green cells only when there is light present.
B. most of the ATP of green cells comes from photosynthetic activity.
C. chlorophyll is essential for photosynthesis.
D. water is the source of the oxygen by-product of photosynthesis.
E. promotion of ATP production is vital to the world's economy.

(B) 1-1-2 (2.20 — Interpretation)

124. Consider the following reaction:

In this reaction, what has occurred?
A. An important coenzyme has been oxidized.
B. A three-carbon compound has been reduced.
C. A high energy phosphate bond has been formed.
D. More than one of the above.
E. None of the first three above.

(C) 1-1-2 (2.30 — Extrapolation)

Behavioral Objective: z-3. Application
Application involves the use of abstractions in particular and concrete situations. The abstractions may be in the form of general ideas, rules or procedures, or generalized methods. The abstractions may also be technical principles, ideas, and theories which must be re-
Year after year, men cruising timber or hunting ponderosa pine. Tied by a shriveled leather thong, high in the treetop was the answer to the mystery of the strange sound. It would fade away in the night and come back with the same story. Near the little hamlet of Kamela, they had often heard a faraway tinkling, a faint sound of metal. Skeptics accused the men of hearing things. Last week, lumberjacks brought down a false claim of a legend.

Kamela: a bronze cattle bell, inscribed with the date 1878. The people of Kamela guessed that a region of meristematic cells had become gametes. Weismann's germ plasm theory was the experiment most likely designed to investigate. Darwin's theory of pangenesis was not valid but is unrelated to the results. Embryonic induction theory was not valid and is not supported by the results. Theory of inheritance of acquired characteristics was valid but is supported by the results.

881. Which theory was the experiment most likely designed to investigate?
A. Darwin's theory of pangenesis
B. Embryonic induction theory
C. Theory of epigenesis
D. Theory of inheritance of acquired characteristics
E. Weismann's germ plasm theory

882. How is the conclusion related to the experimental results? It is probably
A. valid but is not supported by the results.
B. valid and is supported by the results.
C. not valid but is supported by the results.
D. not valid and is not supported by the results.
E. not valid but is unrelated to the results.

883. Which theory was the experiment most likely designed to investigate?
A. Darwin's theory of pangenesis
B. Embryonic induction theory
C. Theory of epigenesis
D. Theory of inheritance of acquired characteristics
E. Weismann's germ plasm theory

The vital stain does not affect the cells' function. The location of the stained cells was recorded. No stained cells appeared within the gonads. It was concluded that endoderm cells do not become germinal cells.

Behavioral Objective: z-5. Synthesis
Synthesis involves the putting together of elements and parts so as to form a whole. This involves the process of working with pieces, parts, elements, etc., and arranging and combining them in such a way as to constitute a pattern or structure not clearly there before.

z-5.00 Synthesis — Putting together parts or elements so as to produce a new pattern or structure.
5.10 Production of a unique communication or experiment, reflecting excellent organization of ideas.
5.20 Production of a plan, or proposed set of operations. Ability to propose ways of testing hypotheses, of designing experiments to solve specific problems.
5.30 Derivation of a set of abstract relations. The development of a set of abstract relations either to classify or explain particular data or phenomena, or the deduction of propositions and relations from hypotheses.

4.10 Analysis of elements. The ability to recognize unstated assumptions. Skill in distinguishing facts from hypotheses.

4.20 Analysis of relationships. Interaction and interplay of ideas. Ability to check the consistency of hypotheses with given information and assumptions. Skill in comprehending interrelationships among ideas.

4.30 Analysis of organizational principles. What holds this report together? Ability to recognize the relevance and significance of this report to the larger context of the scientific discipline. How the deductions or inferences of this report relate to the postulates or premises of a broader theory, e.g., heredity or evolution.
a set of basic propositions or symbolic representations. Ability to formulate appropriate hypotheses based upon an analysis of factors involved, and to modify such hypotheses in the light of new factors and considerations. Ability to make generalizations. The following three examples are test items that measure synthesis:

439. A new ultramicroscopic (< 0.14u long) cell organelle is reported by an electron microscopist. Another biologist challenges the report and claims the organelle is an artifact formed by the deposition of the chemical compounds used in the preparation of the cells. Which experimental procedure would provide the best test of this hypothesis?
A. Analyze the cells chemically to see if they contain the chemical compound in question.
B. Look at living cells with a phase contrast microscope.
C. See if any other report of the organelle exists in previous literature.
D. Use different electron microscopic preparation procedures on similar cells and see if the organelle is present.
E. Use the same procedure as the electron microscopist used on many different cells to see if they have the organelle.
(D) 2-2-5 (5.20 — Production of a proposed set of operations)

1143. Charles Darwin's presentation of the theory of evolution by natural selection may be expressed in a set of propositions:
1. Organisms of the same species compete with each other for the necessities of existence.
2. As environments change, selective factors will be different.
3. More offspring are produced than the ecologic niche can support.
4. The best adapted forms tend to survive and reproduce in greater numbers than the less well adapted.
5. Members of any species vary widely, some being well adapted, others poorly adapted, to their environments.
6. Adaptive characteristics are passed from generation to generation by heredity.
7. Mutations produce new characteristics (post-Darwinian).
8. New species are produced when new selective factors preserve different characteristics.
The best sequencing of these propositions in a logical construction of the natural selection theory is:

(C) 7-3-5 (5.30 — Derivation of a set of abstract relations)

Many aspects of synthesis can better be examined by the use of open-ended essay questions, of which the following is an example:

566. Propose a procedure to determine what the mechanisms are for "playing possum" in opossums.
3-3-5 (5.10 — Production of a unique communication or experiment)

Behavioral Objective: z-6. Evaluation

Evaluation involves qualitative and quantitative judgments about the value of material and methods for given purposes, the extent to which material and methods satisfy criteria, or the use of a standard of appraisal. The criteria may be those determined by the student or those which are given to him.

z-6.00 Evaluation — making judgments in relation to criteria.
6.10 Judgments in terms of internal evidence such as logical accuracy, consistency, and other internal criteria. Ability to indicate fallacies in logic in a statement or sequence of statements offered as support of a proposition or hypothesis.
6.20 Judgments in terms of external criteria such as comparison of major theories, generalizations and facts that relate to certain phenomena. Using external standards to compare a procedure or product with another of recognized excellence in the field.
The following three examples are test items that measure evaluation:

902. The biologist Dr. Fritz Went found that if coleoptile tips were removed and placed on agar for one hour the agar would produce a bending when placed on one side of freshly-cut coleoptile stumps. Of what significance is this experiment?
A. It is the basis for quantitative determination of small amounts of growth-promoting substances.
B. It made possible the isolation and exact identification of auxin.
C. It is the basis for the experimental support for the hypothesis that IAA is auxin.
D. It demonstrated polar movement of auxins.
E. It made possible the discovery that roots respond differently than do shoots to different quantities of IAA.
(A) 5-1-6 (6.10 — Judgment in terms of internal evidence)

Items 1154 and 1152 are concerned with the following: A biology test included the question: "Show that communities, as well as species, evolve." A student wrote an answer which included the following: "The essence of evolution is permanent change. When a species evolves, its characteristics change. These characteristics are outwardly phenotypic changes, but behind every phenotypic change is a genotypic change, also called a mutation. Environmental changes are responsible for species changes.

"When a community evolves, its characteristics change. These characteristics are kinds of plants and animals, their relative numbers, and their interrelations. When the kinds of organisms and their numbers and interrelations change, these are environmental changes in the sense of the previous paragraph, and bring about species changes. So, communities evolve not only in the sense of changing their faunal and floral composition but also in changing their species characteristics."

1154. The second sentence of the second paragraph is
A. an acceptable statement for his purposes.
B. unacceptable because the kinds of organisms it contains are not characteristics of a community.
C. unacceptable because the interrelations of different species are not characteristics of a community.
D. unacceptable because relative numbers are not characteristics of a community.
E. unacceptable because there are other characteristics of a community which are not mentioned by the student.
(A) 7-4-6 (6.10 — Judgment in terms of internal evidence)

1152. The student's statement about evolution is
A. adequate for the use he makes of it.
B. inadequate because not all evolutionary changes are permanent.
C. inadequate because some phenotypic changes occur without corresponding genotypic changes.
D. inadequate because not all genotypic changes are mutations.
E. inadequate because it does not state the mechanism of evolution.
(A) 7-3-6 (6.20 — Judgments in terms of external criteria)
SECTION 6. EXAMPLES: ENERGETICS AND METABOLISM

Objective Items

1. The common immediate source of energy in cellular activity is
   A. DNA
   B. RNA
   C. ATP
   D. NAD
   E. FAD. (C) 1-1-1

2. An enzyme may be rendered inoperative by
   A. removing its product as fast as it appears.
   B. blocking its active site.
   C. halving its concentration.
   D. doubling its concentration.
   E. adding apoenzyme (B) 1-1-1

3. Which best describes the relationship between photosynthesis and protein synthesis in a plant?
   Photosynthesis provides
   A. glucose which can be broken down to provide energy for protein synthesis.
   B. ATP as an energy source, but it needs amino acids from nitrogen-fixing bacteria.
   C. carbohydrates as a carbon and energy source and ATP and TPNH2 (FADH2) as energy and electron sources.
   D. amino acids for protein synthesis by aminoacylation of tRNA with them.
   E. oxygen to oxidize the acid groups on the amino acids so they will hook together. (C) 1-1-1

4. Which is the immediate energy source for the "dark reaction" of photosynthesis?
   A. Phosphoglyceraldehyde (PGAL)
   B. ATP and TPNH2
   C. ADP and TPN
   D. Light
   E. CO2 and H2O (B) 1-1-1

5. During Priestley's day it was believed that the main function of photosynthesis was to purify the air. Our present-day view regarding the significance of photosynthesis is that it
   A. converts light energy into chemical energy.
   B. creates usable energy.
   C. "fixes" CO2 into carbohydrates.
   D. reverses the action of respiration.
   E. splits water, releasing O2. (A) 1-1-1

6. Which one of the following was not present in free form at the time life originated?
   A. Methane
   B. Hydrogen
   C. Ammonia
   D. Oxygen
   E. Water (D) 1-1-1

7. The type of RNA specifically responsible for directing the proper sequence of amino acids in protein synthesis is
   A. ribosomal RNA.
   B. messenger RNA.
   C. transfer RNA.
   D. nucleolar RNA.
   E. chromosomal RNA. (B) 1-1-1

8. The synthesis of ATP in both photosynthesis and respiration is essentially an oxidation process involving the "removal" of energy from
   A. carbon dioxide.
   B. water.
   C. electrons.
   D. oxygen.
   E. cytochromes. (C) 1-1-1

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

10. The ornithine cycle removes two waste products from the blood and transforms them to a relatively harmless compound. Which two waste products does it remove?
    A. Carbon dioxide and urea
    B. Carbon dioxide and ammonia
    C. Ammonia and urea
    D. Ammonia and urine
    E. Urine and urea (B) 1-1-1

11. Photosynthesis consists of essentially two biological reaction systems following in sequence. The second of these systems does which of the following?
    A. Traps light energy
    B. Synthesizes starch
    C. Fixes carbon dioxide
    D. Occurs in the nucleus
    E. Works only in the presence of light (C) 1-1-1

12. We often speak of "limiting factors" in biology; that is, conditions or substances which limit the processes of a biological system by absence or inappropriate amount. Which of the following "factors" would not limit photosynthesis, regardless of presence, absence, or quantity?
    A. Oxygen
    B. Carbon dioxide
    C. Chlorophyll
    D. Water
    E. Light (A) 1-1-1

13. From available evidence it is probably true that CO2 fixation occurs in the
    A. lipid layer of the lamellae.
    B. chlorophyll layer of the grana.
    C. protein layer of the grana.
    D. stroma.
    E. chloroplast membrane. (D) 1-1-1

14. From electron photomicrography and biochemistry it seems probable that the cytochrome system is located on the
    A. chromosomes.
    B. inner side of the nuclear membrane.
    C. inner side of the mitochondrial membrane.
    D. plasma membrane.
    E. ribosomes. (C) 1-1-1

15. Experimental evidence has shown that the site of the first part of photosynthesis (within the chloroplast) is the
    A. stroma.
    B. grana.
    C. double membrane.
    D. lamellae.
    E. inner surface of the inner membrane. (B) 1-1-1

16. Within the cell, the site of respiration is the
    A. Golgi bodies.
    B. ribosomes.
    C. mitochondria.
    D. nucleus.
    E. nucleolus. (C) 1-1-1

17. Respiration and photosynthesis both require which one of the following?
    A. Organic fuel
    B. Green cells
    C. Cytochromes
    D. Energy from carbon bonds
    E. Sunlight (C) 1-1-1

18. Phosphorylated compounds are important to us because
    A. a phosphate bond is capable of holding more available energy than is needed to simply hold -P to a molecule.
    B. they store phosphates in the body.
    C. they neutralize H+ in the blood.
    D. they maintain phosphorus in the blood.
    E. they play a significant role in the formation of erythrocytes. (A) 1-1-1
19. The oxygen liberated in photosynthesis results from the decomposition of
   A. carbon dioxide.
   B. carbohydrates.
   C. PGAL.
   D. TPN.
   E. water.  (E) 1-1-1

20. The main function of cyclic electron transfer in photosynthesis is to
   A. produce glucose.
   B. produce hydrogen which in turn will be used in carbon dioxide fixation.
   C. produce PGAL.
   D. decompose the water molecule.
   E. produce ATP.  (E) 1-1-1

21. The main role of non-cyclic electron transfer in photosynthesis is to
   A. produce glucose.
   B. produce oxygen.
   C. split the carbon dioxide molecule.
   D. produce hydrogen which is then released as a gas.
   E. produce hydrogen from the decomposition of water, which will in turn be used in carbon dioxide fixation. (A) 1-1-1

22. The step in photosynthesis that directly requires light is the
   A. excitation of chlorophyll.
   B. transfer of hydrogen to TPN.
   C. regeneration of chlorophyll.
   D. transfer of energy from chlorophyll to water.
   E. fixation of carbon dioxide. (A) 1-1-1

23. Before amino acids can yield energy in respiration they must be converted into
   A. glucose.
   B. protein.
   C. glycogen.
   D. phosphorylated compounds in the chloroplasts.
   E. some intermediate product of glucose decomposition. (E) 1-1-1

24. In respiration, pyruvic acid is
   A. one of the products in the citric acid cycle or Krebs cycle.
   B. formed only if oxygen is not available.
   C. broken down into a two-carbon fragment and CO₂.
   D. the result of peptide breakdown.
   E. a precursor in glycogen formation. (C) 1-1-1

25. One of the first steps in the utilization of glucose in metabolism consists of the formation of
   A. ATP.
   B. glycogen.
   C. pyruvic acid.
   D. a disaccharide.
   E. high energy bonds. (C) 1-1-1

26. Zinc is commonly used by organisms in
   A. exoskeleton.
   B. blood pigments.
   C. chlorophyll synthesis.
   D. enzyme composition.
   E. flower nectar. (D) 1-1-1

27. Starch and cellulose are compounds consisting of many units of
   A. amino acid.
   B. fatty acid.
   C. glycerol.
   D. protein.
   E. simple sugar. (E) 1-1-1

28. That the synthesis of DNA in cells is actually catalyzed by the enzyme DNA polymerase has been made virtually certain by which of the following findings?
   A. A mutant which lacks this enzyme must be supplied with DNA in its growth medium.
   B. The product made in a test tube has approximately the same molecular weight as natural DNA.
   C. The product made in a test tube always has the same biological properties (ability to direct enzyme synthesis, to transform bacteria, or to infect cells) as the "primer" DNA.
   D. All of the above
   E. None of the first three above (E) 1-1-1

29. A method of choice in many cases to determine where a certain compound is localized in a cell is
   A. phase contrast microscopy.
   B. autoradiography.
   C. electron microscopy.
   D. light microscopy.
   E. microdissection. (B) 1-1-1

30. "Endproduct inhibition" regulates cell activity by controlling
   A. structural citron transcription.
   B. regulatory citron transcription.
   C. mRNA production in general.
   D. mRNA translation.
   E. enzyme action. (E) 1-1-1

31. How does the Kornberg enzyme differ from that described by Weiss and Hurwitz?
   A. One uses DNA as a template, the other uses RNA.
   B. One uses nucleoside triphosphates, the other uses nucleoside diphosphates as substrates.
   C. One forms pyrophosphate, the other forms orthophosphate as a byproduct.
   D. More than one of the above
   E. None of the first three above (E) 1-1-1

32. The structure below represents
   A. a tripeptide.
   B. a nucleoside triphosphate.
   C. a trinucleotide.
   D. more than one of the above.
   E. none of the first three above (B) 1-1-1

33. What type of compound is cellulose?
   A. globulin
   B. lipid
   C. steroid
   D. polysaccharide
   E. fibrous protein (D) 1-1-1

Items 34-84. Categorize the pair of entities in each item according to the following key.

KEY:  A. I is greater than
      B. I is less than II
      C. I is exactly or approximately equal to II
      D. I may stand in more than one of the above relations to II

34. (I) The number of repressible biosynthetic enzymes in a bacterial cell  
   (II) The number of inducible biosynthetic enzymes in a bacterial cell  
   A. I may stand in more than one of the above relations to II  
   B. I is greater than II
   C. I is exactly or approximately equal to II
   D. I may stand in more than one of the above relations to II  
   E. II is greater than I

35. (I) The necessity for ATP in protein synthesis  
   (II) The necessity for ATP in mRNA synthesis  
   A. I may stand in more than one of the above relations to II  
   B. I is greater than II
   C. I is exactly or approximately equal to II
   D. I may stand in more than one of the above relations to II  
   E. II is greater than I

36. (I) The effect of enzyme concentration on the velocity of a reaction  
   (II) The effect of enzyme concentration on the equilibrium of a reaction  
   A. I may stand in more than one of the above relations to II  
   B. I is greater than II
   C. I is exactly or approximately equal to II
   D. I may stand in more than one of the above relations to II  
   E. II is greater than I

37. (I) The effect of temperature on the activation energy required for a given reaction  
   (II) The effect of a catalyst on the activation energy required for a given reaction  
   A. I may stand in more than one of the above relations to II  
   B. I is greater than II
   C. I is exactly or approximately equal to II
   D. I may stand in more than one of the above relations to II  
   E. II is greater than I
38. (I) The importance of ester bonds in the primary structure of RNA
   (II) The importance of ester bonds in the primary structure of DNA
   (C) 1-1-2
39. (I) The importance of the biological source of DNA polymerase in specifying the chemical structure of newly made DNA in a test tube
   (II) The importance of the biological source of primer DNA in specifying the chemical structure of newly made DNA in a test tube
   (B) 1-1-2
40. (I) The number of molecules of pyrophosphate released when a certain number of appropriate nucleotides are polymerized by DNA polymerase.
   (II) The number of molecules of pyrophosphate released when the same number of appropriate nucleotides are polymerized by RNA polymerase.
   (C) 1-1-2
41. (I) The probable ability of proline activating enzyme to attach proline to alanine's sRNA.
   (II) The probable ability of proline activating enzyme to attach proline to proline's sRNA.
   (B) 1-1-2
42. (I) The importance of an activating enzyme in insuring that the proper amino acid will become attached to a particular sRNA molecule.
   The importance of mRNA in insuring that the proper amino acid will become attached to a particular sRNA molecule.
   (A) 1-1-2
43. (I) The role of molecular oxygen in aerobic respiration.
   (II) The role of molecular oxygen in anaerobic respiration.
   (A) 1-1-2
44. (I) The amount of ornithine transcarbamylase in an average E. coli cell growing in glucose-Werkman's.
   (II) The amount of ornithine transcarbamylase in an average E. coli cell growing in lactose-Werkman's.
   (C) 1-1-2
45. (I) The overall rate of synthesis of RNA in the nucleus of a thyroid cell.
   (II) The overall rate of synthesis of RNA in the cytoplasm of a thyroid cell.
   (A) 1-1-2
46. (I) The energy in an ATP molecule formed by oxidative phosphorylation.
   (I) The energy in an ATP molecule formed by substrate phosphorylation.
   (C) 1-1-2
47. (I) The percentage of a thyroid cell's cytochrome oxidase which is likely to reside in the mitochondria.
   (II) The percentage of a thyroid cell's cytochrome oxidase which is likely to reside in the nucleus.
   (A) 1-2-2
48. (I) The approximate size of an E. coli ribosome.
   (II) The approximate size of a thyroid cell ribosome.
   (C) 1-2-2
49. (I) The amount of free amino acids in an average, growing E. coli cell.
   The amount of peptide-linked amino acids in an average, growing E. coli cell.
   (B) 1-1-3
50. (I) The number (not weight) of ribosomes in an E. coli cell.
   (II) The number of molecules (not weight) of transfer RNA in the same cell.
   (B) 1-1-3
51. (I) The number of free carboxyl groups in a single peptide chain containing three leucine, two alanine, one phenylalanine, and five glycine residues.
   (II) The number of free amino groups in the same chain.
   (C) 1-1-3
52. (I) The importance of NADPH in the biosynthesis of arginine from glutamic acid.
   (II) The importance of NADPH in the activation of arginine preparatory to protein synthesis.
   (A) 1-1-3
53. (I) The number of ATP molecules usually formed when five grams of glucose are converted to lactic acid by way of pyruvate and the Embden-Meyerhoff glycolytic pathway.
   (II) The number of ATP molecules usually formed when one gram of glucose is converted to CO₂ and H₂O via glycolysis and the Krebs cycle.
   (B) 1-1-3
54. (I) The total number of protein molecules in an average E. coli cell.
   (II) The total number of protein molecules in an average thyroid follicular cell.
   (B) 1-1-3
55. (I) The probability of isolating a mutant strain of cells which lack the first enzyme in the biosynthesis of histidine.
   (II) The probability of isolating a mutant strain of cells which lack RNA polymerase.
   (A) 1-1-3
56. (I) The amount of the enzyme ornithine transcarbamylase being produced by a normal wild strain of E. coli while growing in glucose-Werkman's medium.
   The amount of this enzyme being produced by a normal wild strain of E. coli while growing in glucose-Werkman's medium plus arginine.
   (A) 1-1-3
57. (I) The ability of lactose to induce the synthesis of β-galactosidase in E. coli.
   (II) The ability of glycerol (another good carbon source) to induce the synthesis of β-galactosidase in E. coli.
   (A) 1-1-3
58. (I) The biosynthetic capacity (i.e., the ability to synthesize a variety of building blocks) of a cell whose minimal medium is glucose-Werkman's.
   (II) The biosynthetic capacity of a cell whose minimal medium is glucose-Werkman's plus eight amino acids plus biotin plus thiamine.
   (A) 1-1-3
59. (I) The probable importance of RNA polymerase for the growth of a bacterial cell.
   (II) The probable importance of RNA polymerase for the growth of a liver cell.
   (C) 1-1-3
60. (I) The ratio of adenine to guanine in a molecule of DNA used as "primer" for the Kornberg enzyme in a test tube.
   (II) The ratio of adenine to guanine in a molecule of DNA produced in response to that "primer" in a test tube.
   (C) 1-1-3
61. (I) The total number of protein molecules in an average E. coli cell.
   (II) The total number of protein molecules in an average thyroid follicular cell.
   (B) 1-1-3
62. (I) The probable importance of amino acid activating enzymes for an E. coli cell to make proteins.
   (II) The probable importance of amino acid activating enzymes for a thyroid cell to make proteins.
   (C) 1-1-3
63. (I) The probable similarity in the reaction pathway leading to adenine formation in E. coli and in a thyroid cell.
   (II) The probable similarity in the reaction pathway leading to adenine breakdown in E. coli and in a thyroid cell.
   (A) 1-1-3
64. (I) The number of kinds of amino acids in an average E. coli enzyme.
   (II) The number of kinds of amino acids in an average thyroid cell enzyme.

65. (I) According to the "messenger theory," the number of kinds of 70S ribosomes in an E. coli cell.
   (II) According to the "messenger theory," the number of kinds of 70S ribosomes in a thyroid cell.

66. (I) The number of kinds of amino acids used in an E. coli cell to make protoplasm.
   (II) The number of kinds of amino acids used in a thyroid cell to make protoplasm.

67. (I) The amount of arginine incorporated into polypeptides by an E. coli cell during ten minutes of balanced growth in a medium containing arginine.
   (II) The amount of arginine synthesized by that cell in that time.

68. (I) The amount of arginine incorporated into polypeptides by an E. coli cell during ten minutes of balanced growth in a medium containing arginine.
   (II) The amount of arginine synthesized by that cell in that time.

69. (I) The number of ATP molecules consumed by an A. aerogenes cell in manufacturing one molecule of arginine during aerobic growth in minimal medium.
   (II) The number consumed for the same purpose during anaerobic growth.

70. (I) The degree to which ribosomes are membrane-bound in an eucaryotic cell.
   (II) The degree to which ribosomes are membrane-bound in a thyroid cell.

71. (I) The probable number of mitochondria in an eucaryotic cell chosen at random.
   (II) The probable number of mitochondria in a prokaryotic cell chosen at random.

72. (I) The mass of A. aerogenes protoplasm that can be formed aerobically from 1 mg of glucose.
   (II) The mass of A. aerogenes protoplasm that can be formed aerobically from 1 mg of glucose.

73. (I) The amount of protein in an average E. coli cell in balanced growth at a k of 1.15.
   (II) The amount of DNA in an average E. coli cell in balanced growth at a k of 1.15.

74. (I) The number of ways that cells throughout the biological world have of making ATP from glucose.
   (II) The number of ways that cells throughout the biological world have of making ATP from glucose.

75. (I) The probable rate of incorporation of [H3] -thymidine into macromolecules in a thyroid cell in a normal adult animal.
   (II) The probable rate of incorporation of [H3] -thymidine into macromolecules in a thyroid cell in an adult animal shortly after administration of thyroid-stimulating hormone (TSH).

76. (I) The probable level of protein-bound iodine circulating in the blood of a normal adult rat.
   (II) The probable level of protein-bound iodine circulating in the blood of a normal adult rat.

77. (I) The probable level of protein-bound iodine circulating in the blood of a normal adult rat.
   (II) The probable level of protein-bound iodine circulating in the blood of an adult rat whose anterior pituitary has been destroyed.

78. (I) The probable level of TSH in the blood of a normal adult rat.
   (II) The probable level of TSH in the blood of a rat receiving thyroxine for long periods.

79. (I) The ability of a bacterial mutant lacking NAD (and NADP) to grow anaerobically in glucose-Werkman's media.
   (II) The ability of a bacterial mutant lacking NAD (and NADP) to grow aerobically in glucose-Werkman's media.

80. (I) The diversity of pathways of catabolism through the biological world.
   (II) The diversity of pathways of biosynthesis through the biological world.

81. (I) The amount of RNA in an average A. aerogenes cell in balanced growth at a k of 1.15.
   (II) The amount of DNA in the same cell under the same conditions.

82. (I) The probable importance of H-bonds in the primary structure of a polypeptide chain.
   (II) The probable importance of H-bonds in the secondary structure of a polypeptide chain.

83. (I) The probable number of ATP molecules consumed in the biosynthesis of one molecule of tryptophan by an A. aerogenes cell.
   (II) The probable number of ATP molecules consumed in the biosynthesis of one molecule of tryptophan by a Chlorella pyrenoidosa cell.

84. (I) The effect of lactose on β-galactosidase synthesis in a normal E. coli cell growing on succinate.
   (II) The effect of lactose on β-galactosidase synthesis in a constitutive (r-) mutant growing on succinate.

85. A cytochrome system is present.
86. Phospholipids are present.
87. A rigid cell wall is present.
88. DNA polymerase is present.
89. Share(s) with plant leaf cells the property of being functionally and structurally in intimate relation to other cells.
90. RNA polymerase is present.
91. One or more organic compounds required as an energy source.
92. Can synthesize 20 different amino acids.
93. Leucyl sRNA synthetase is present.
94. Polysomes are present.
95. Characterized as a cell but not as an organism.
96. Can make ATP from ADP by oxidative phosphorylation.
97. One or more centrioles is/are present.
98. **Which releases the greatest amount of usable energy per molecule of glucose broken down?**
   A. Aerobic respiration in an ameba
   B. Fermentation by a yeast cell
   C. Glycolysis in a liver cell
   D. Lactic acid formation in a muscle cell
   E. Oxidation of glucose in a fire
   (A) 1-3-1

99. **Every ecosystem must have a continual external source of**
   A. living adult organisms.
   B. plant spores.
   C. bacteria.
   D. oxygen.
   E. energy.
   (E) 1-4-1

100. **Undergo(s) mitosis.**
    (B) 5-2-1

101. **Sensitive to penicillin.**
    (A) 8-3-1

102. **In nature, its/their metabolism is externally regulated.**
    (D) 4-3-1

103. **To determine the ultrastructure of a cell organelle, the most likely method to be used would be**
    A. phase contrast microscopy.
    B. autoradiography.
    C. electron microscopy.
    D. light microscopy.
    E. microdissection.
    (C) 1-1-1

104. **In an oak tree, metabolic energy is most extensively used in the**
    A. cambium.
    B. cork.
    C. xylem vessels.
    D. root parenchyma.
    E. medullary rays.
    (A) 1-2-1

105. **Which of the following requires no expenditure of energy?**
    A. Passage of a nerve impulse across a synapse
    B. Synthesis of thyroxin
    C. Contraction of visceral muscle
    D. Diffusion of sodium chloride through blood plasma
    E. Passage of a nerve impulse along an axon
    (D) 1-2-1

106. **Phosphorylation in a cell is thought to occur within which organelle?**
    A. Endoplasmic reticulum
    B. Golgi apparatus
    C. Lysosome
    D. Mitochondrion
    E. Ribosome
    (D) 1-2-1

107. **Which of the following structures is thought to be exceptionally rich in hydrolytic enzymes (nucleases, phosphatases and peptidases)?**
    A. Lysosomes
    B. Microsomes
    C. Chromosomes
    D. Nucleoli
    E. Microvilli
    (A) 1-2-1

108. **The rate at which a human being expends energy is influenced most by the activity of the**
    A. diencephalon.
    B. thyroid gland.
    C. liver.
    D. adrenal cortex.
    E. neurohypophysis
    (B) 1-3-1

109. **The use of energy in muscular movement by vertebrates is positively correlated with the size of the animal's**
    A. red blood cells.
    B. spinal ganglia.
    C. stomach.
    D. notochord.
    E. cerebellum.
    (E) 1-3-1

110. **Which releases the greatest amount of usable energy per molecule of glucose broken down?**
    A. Aerobic respiration in an ameba
    B. Fermentation by a yeast cell
    C. Glycolysis in a liver cell
    D. Lactic acid formation in a muscle cell
    E. Oxidation of glucose in a fire
    (A) 1-3-1

111. **Every ecosystem must have a continual external source of**
    A. living adult organisms.
    B. plant spores.
    C. bacteria.
    D. oxygen.
    E. energy.
    (E) 1-4-1

112. **Most of the photosynthesis in the ocean is performed by**
    A. algae.
    B. fungi.
    C. bacteria.
    D. psilophytes.
    E. angiosperms.
    (A) 1-4-1

113. **Absorption of solutes against a concentration gradient by intestinal epithelium is accomplished by**
    A. osmotic pressure.
    B. chemical combination.
    C. Brownian movement.
    D. Donnan equilibrium.
    E. electron transport.
    (B) 1-1-2

114. **Assuming that the heterotrophs arose in a reducing atmosphere, which type of respiration probably arose first and why?**
    A. Aerobic because it releases more energy
    B. Aerobic because it is more complex
    C. Aerobic because the early atmosphere contained oxygen
    D. Anaerobic because it releases more energy
    E. Anaerobic because the early atmosphere contained little or no oxygen
    (E) 1-1-2

115. **In the metabolism of carbohydrates, most of the energy is released by change from**
    A. starch to maltose.
    B. maltose to glucose.
    C. glucose to phosphoglyceraldehyde.
    D. phosphoglyceraldehyde to pyruvic acid.
    E. pyruvic acid to CO₂ and H₂O.
    (E) 1-1-2

116. **Which best describes why adenosine triphosphate (ATP) is considered to be a "monetary system of energy exchange" in organisms?**
    A. ATP is one of the organic base compounds found in the DNA of all organisms.
    B. Once formed, ATP is very stable and can not be broken apart unless large amounts of energy are applied.
    C. Phosphate is used in all organic chemical reactions.
    D. The third phosphate bond contains more energy than any other chemical bond.
    E. The third phosphate radical is easily transferred to other molecules making transfer feasible.
    (E) 1-1-2

117. **Which of the following kinds of RNA is least like the others?**
    A. Soluble
    B. Acceptor
    C. Messenger
    D. Adaptor
    E. Transfer
    (C) 1-1-2

118. **Which of the following sequences best arranges the compounds named in order of increasing molecular weight?**
    A. Ribosomal RNA; AMP; ADP; ATP
    B. ATP; ADP; AMP; ribosomal RNA
    C. AMP; ATP; ADP; ribosomal RNA
    D. AMP; ADP; ATP; ribosomal RNA
    E. Ribosomal RNA; ATP; AMP; ADP
    (D) 1-1-2

119. **From the following list, select the one factor which seems most important in assuring that amino acid X will be placed where the mRNA directs it to be placed.**
    A. ATP
    B. The sRNA for X
    C. The ribosome making the protein
    D. DNA polymerase
    E. The concentration of X in the cell
    (B) 1-1-2
120. Which of the following sequences best arranges the compounds in order of increasing molecular weight?

A. Alanine; ATP; DNA; NAD
B. ATP; alanine; DNA; NAD
C. DNA; NAD; ATP; alanine
D. ATP; NAD; alanine; DNA
E. Alanine; ATP; NAD; DNA

121. The primary structure of a polypeptide is defined by a specific sequence of amino acids linked together by peptide bonds. In general, which of the following is true of primary structure?
A. It can be determined simply by the use of a device known as an amino acid analyzer.
B. It is unknowable by present-day analytical methods.
C. It can be ascertained today, but only by methods which include hydrolysis of the polypeptide to various degrees, analysis of the composition of the peptides formed, and identification of the N-terminal groups of these peptides.
D. It is of little interest to enzymologists.
E. None of the above.

122. Which of the following sequences best arranges the compounds in order of increasing molecular weight?
A. Leucine; transfer RNA; DNA; ATP; ribosomal RNA
B. ATP; leucine; ribosomal RNA; DNA; transfer RNA
C. Leucine; ATP; transfer RNA; ribosomal RNA; DNA
D. Leucine; ATP; DNA; transfer RNA; ribosomal RNA
E. Leucine; ATP; transfer RNA; DNA; ribosomal RNA

123. Anfinsen's investigation of the structure and biological activity of ribonuclease led him to conclude that:
A. A three-carbon compound has been reduced.
B. A high energy phosphate bond has been formed.
C. More than one of the above.
D. None of the above.

124. Consider the following reaction:

In this reaction what has occurred?
A. An important coenzyme has been oxidized.
B. A high energy phosphate bond has been formed.
C. All of the above.
D. None of the above.

Items 125-131 are concerned with the following situation:
According to Oparin's hypothesis, during the early history of the earth, evolution leading up to and including the formation of living matter is believed to have occurred. Judge the relative time of the following pairs of events according to the key.

125. Formation of free oxygen and in the original atmosphere of earth
Event I
Event II

126. Formation of water, methane and ammonia

127. Formation of green organisms

128. Formation of nucleotide

129. Formation of protein shells

130. Appearance of aerobic respiration

131. Formation of nucleic acids

Items 132-142.
Examine the following quotation from Stern and Nanezy,

The Biology of Cells (Wiley, 1965, pp. 113-115), then answer the questions which follow. Note that you are to complete the blanks in the quoted passage by selecting the correct responses from the items that follow.

"Proteins, like polysaccharides, yield molecular subunits on (1). Unlike most polysaccharides, the subunits consist of many kinds of molecules. By the close of the century Emil Fischer had clarified exactly how these subunits were linked together in the intact protein molecule. The principal fact which Fischer had at his disposal was that all the subunits of protein had one feature in common, though they differed in most other respects. This feature is best seen in the structural formulas of the subunits; the subunits are called (2) because each contains a/an (3) and a/an (4). Fischer concentrated his attention on the last two carbon atoms of the (5) all of which had the structure (6). He therefore pictured (7) linking in the following way (Fig. 1). Fischer called such bonds (8), and to prove that his hypothesis was correct he synthesized small chains of (9) to one another by (10). His interpretations of protein structure were not universally accepted at the time, but gradually criticism thinned and today we accept the fact that proteins are long chains of (11) linked to one another by (12)."

E. Amino acids (B) 1-1-2
D. Purines
C. Purines
B. Pyrimidines
A. Nucleotides

133. Which term best represents the word or phrase denoted by the blank labeled II?
A. Hydrolysis
B. Simple decomposition
C. Polymerization
D. Fractionation
E. Decarboxylation

134. What terms best represent the words or phrases denoted by the blanks labeled III-1 and 111-2?
A. Purine; pyrimidine
B. Amino group; carboxyl group
C. Adenine-thymine; cytosine-guanine
D. Nicotinamide adenine dinucleotide; cytochrome
E. ATP; ADP

135. What term best represents the word or phrase denoted by the blank labeled III?
A. Hydrolysis
B. Simple decomposition
C. Polymerization
D. Fractionation
E. Decarboxylation

136. Which term best represents the word or phrase denoted by the blank labeled III-1?
A. Nucleotides
B. Pyrimidines
C. Purines
D. Bases
E. Amino acids

137. What terms best represent the words or phrases denoted by the blanks labeled III-1 and 111-2?
A. Purine; pyrimidine
B. Amino group; carboxyl group
C. Adenine-thymine; cytosine-guanine
D. Nicotinamide adenine dinucleotide; cytochrome
E. ATP; ADP

138. What terms best represent the words or phrases denoted by the blanks labeled III-1 and 111-2?
A. Purine; pyrimidine
B. Amino group; carboxyl group
C. Adenine-thymine; cytosine-guanine
D. Nicotinamide adenine dinucleotide; cytochrome
E. ATP; ADP
135. What formula best denotes the missing symbols for blank IV?
(D) 1-1-2

136. What terms (or term) best denotes the missing symbols for blank V?
A. Van der Waal's forces
B. Hydrogen bonds
C. Electron exchanges
D. Ionic attraction
E. Peptide bonds
(E) 1-1-2

137. Which of the following diagrams best represents Figure 1 referred to in the passage?

138. In what way did Fischer postulate proteins and polysaccharides to be similar?
A. Each is composed of hydroxyl, methyl and carboxyl groups.
B. Each is composed of methyl, phosphate and nucleic acid groups.
C. Upon separating into subgroups, each combines with water at the rate of one molecule of water per subgroup.
D. Each divides into subunits of two types, acid and base.
E. Upon separating into subunits, each releases water at the rate of one molecule of water per subunit.
(C) 1-1-2

139. According to the passage, Fischer attempted to explain certain empirical information about proteins. He did this by postulating certain invisible characteristics of protein molecules. What was this empirical knowledge?
A. X-ray diffraction data showed regular patterns of linked subgroups.
B. Chromatographic data showed identical scatter "fingerprints" of basic subunits.
C. DPN, NAD, and cytochrome were common components of each polymerized molecule.
D. A purine and a pyrimidine were common to each subunit.
E. An amino acid and a carboxyl group were common to each subgroup.

140. Which of the following is a postulate invented by Fischer to explain the common characteristics of all proteins?
A. The electrophoretic dispersion of fractionated subunits produces similar chromatographic patterns.
B. The ratio of gram-molecular weights of adenine + thymine to cytosine + guanine remains constant for the individuals of a species.
C. The ratio of gram-molecular weights of adenine + guanine to cytosine + thymine remains constant for the individuals of a species.
D. A hydrogen atom of a terminal amino group of one subunit unites with an OH radical of the terminal carboxyl group of another subunit to form water and a peptide bond.
E. By hydrogen bonding a pyrimidine of one nucleic acid chain combines with a purine of a complementary nucleic acid chain to form a polymerized giant molecule with the formation of one molecule of water per bond.

141. What kind of scientific method convinced Fischer of the soundness of his postulates?
A. The similarity between his expected experimental results and the actual experimental results.
B. The verification of his premises by the collection of nearly identical data in repeated experiments.
C. The delayed but enthusiastic acceptance of his theory by a few respected colleagues whose principal researches were also in biochemistry.
D. The experimental data of his predecessors furnished confirmatory evidence of both his premises and conclusions.
E. Like his original discovery, another "happy accident" led him to conduct a second experiment, the results of which fortuitously included unexpected long chains of polymerized nucleic acids.
(A) 1-1-2

142. Following Fischer's original discoveries about proteins, the number of different kinds of subunits of which proteins are composed has been found to be
A. four.
B. six.
C. between 20 and 60.
D. between 100 and 100,000.
E. infinite.
(C) 1-1-2

Items 143-147 are to be interpreted in relation to the following graphs. For each item select the graph which best represents the data presented in the item.

143. If an enzyme-catalyzed reaction requires molecular contact between enzyme and substrate, then which figure best represents the relation between the initial rate of a reaction and substrate concentration? (Let X-axis represent reaction rate and Y-axis represent substrate concentration.)
(B) 1-1-2

144. Which figure best represents the total amount of product in a catalyzed reaction over a long period of time? (Let X-axis represent time and Y-axis represent amount of product.)
(B) 1-1-2
145. Which figure best represents the general relation of temperature increase to rate of uncatalyzed chemical reaction between two inorganic compounds? (Let X-axis represent temperature change and Y-axis represent, on an exponential scale, reaction rate.)

(A) 1-1-2

146. Which figure best represents the rate of osmosis, as a function of time, into a semipermeable bag containing a strong solution of large molecules, such as starch? (Let X-axis represent time and Y-axis represent rate of osmosis.)

(B) 1-1-2

147. Which figure best represents photosynthetic rates (O₂ production) under increasing concentrations of CO2? (Let X-axis represent rate of O₂ production and Y-axis represent CO₂ concentration.)

(B) 1-1-2

148. Where does deamination occur?

A. I → III
B. II → I
C. I → IV
D. I → VIII
E. Not shown

(B) 1-1-2

149. Where does actinomyosin function?

A. III → V
B. V → VI
C. VI → VII
D. III → VII
E. More than one of these

(C) 1-1-2

150. The greatest amount of oxidative phosphorylation takes place

A. in I
B. in III
C. in I V f f 1
D. in I → VIII
E. in VIII → V

(E) 1-1-2

151. Creatin is produced by which reaction?

A. II → IV
B. I → IV
C. III → IV
D. VI → VII
E. V → VI

(D) 1-1-2

152. The compounds DPN and TPN play leading roles at which location?

A. I
B. II
C. III
D. VI
E. VIII

(E) 1-1-2

153. Which arrow represents the transmission of acetic acid?

A. I → III
B. I → VIII
C. III → IV
D. III → V
E. III → VII

(A) 1-1-2

154. The anaerobic process of changing pyruvic to lactic acid is best represented by

A. III → IV
B. I → IV
C. II → I
D. I → III
E. III → V

(B) 1-1-2

155. Which of the features in this diagram would be missing in plant cells?

A. I
B. II
C. III
D. VI
E. VIII

(E) 1-1-2

156. Where do the cytochromes accept hydrogen?

A. I
B. II
C. III
D. V
E. VIII

(E) 1-1-2

157. The major decarboxylation occurs where?

A. I
B. III
C. IV
D. VI
E. VIII

(B) 1-1-2

158. Where are most high energy bonds created?

A. I → III
B. III → VIII
C. II → I
D. III → V
E. VIII → V

(D) 1-1-2

159. Which arrow represents the phosphorylation of arginine in invertebrates?

A. VI → VII
B. V → VI
C. III → VII
D. III → IV
E. III → V

(B) 1-1-2

160. Which is equivalent to glycolysis?

A. I
B. II
C. III
D. V
E. VIII

(A) 1-1-2

Items 161-168 are concerned with aerobic combustion of fuels in cellular respiration.

161. The above diagram shows the aerobic combustion of fuels in cellular metabolism. The main stem represents the principal stages of breakdown, with the number of carbon atoms in each molecule of that stage. Branches represent classes of compounds which feed into the main stages. Each arrow connects a step in the sequence, in order of its occurrence.
a substance I is converted by a series of reactions to CH₃COCOOH. During this particular series of reactions, a net production of two molecules of ATP result. Thirty-four additional ATP molecules result, however, as a consequence of the actions of block V and the reactions between I and II. Examine the remainder of the diagram, and then proceed to answer the questions which follow.

162. Starch or glycogen would best be represented by which position?
A. Four
B. Five
C. Six
D. Seven
E. More than one of these (D)

163. A disaccharide should be located at which position?
A. One
B. Two
C. Three
D. Four
E. More than one of these (A)

164. Lactic acid is properly represented by which number?
A. One
B. Two
C. Three
D. Four
E. More than one of these (C)

165. Amino acids should be placed in which position?
A. One
B. Five
C. Six
D. Seven
E. More than one of these (E)

166. Decarboxylation occurs at which number?
A. Six
B. Eight
C. Nine
D. Ten
E. More than one of these (E)

167. Acetic acid occurs at which number?
A. Six
B. Seven
C. Eight
D. Nine
E. Ten (D)

168. Fatty acids would be found at which position?
A. One
B. Two
C. Three
D. Four
E. Seven (D)

169. Consider the following graph:

The above graph of research data indicates that
A. ATP is produced by green cells only when there is light present.
B. most of the ATP of green cells comes from photosynthetic activity.
C. chlorophyll is essential for photosynthesis.
D. water is the source of the oxygen by-product of photosynthesis.
E. promotion of ATP production is vital to the world’s economy. (B)

Items 170-185.

The diagram below is a schematic illustration of certain metabolic pathways by which ATP is produced in living cells. Each labeled block in the diagram represents either a particular substance or several substances and the interactions between them. Note, for example, that
177. Which of the following is known as the electron (or hydrogen) transport system?
A. I  
B. II  
C. III  
D. IV  
E. V (E) 1-1-2

178. During which steps does decarboxylation occur?
A. I to II, and IV  
B. II to III, and IV  
C. II to III, and V  
D. V only  
E. I to II, only (B) 1-1-2

179. The entire diagram is a schematic representation of certain reactions of
A. photophosphorylation.  
B. glycolysis and aerobic respiration.  
C. carbon fixation.  
D. cyclic phosphorylation.  
E. pinocytosis. (B) 1-1-2

180. In what cell organelles do the metabolic pathways II, III, IV, and V occur?
A. Chloroplasts  
B. Leucoplasts  
C. Ribosomes  
D. Mitochondria  
E. Lysosomes (D) 1-2-2

181. Within which area of the diagram do the following reactions occur?
\[ \text{Cytochrome } 3 \rightarrow \text{Cytochrome } 1 \; \; ; \; \; \text{Cytochrome } 3 \rightarrow \text{Cytochrome } 1 \; \; ; \; \text{Cytochrome } 3 \rightarrow \text{Cytochrome } 1 \; \; ; \; \text{Cytochrome } 3 \rightarrow \text{Cytochrome } 1 \; \; \]
A. I → II  
B. II → III  
C. III → IV  
D. IV → V  
E. V (E) 1-1-2

182. The production of ATP in the series of reactions diagrammed is accompanied by the reduction of free oxygen. What substance is produced as a result of this reduction?
A. CO₂  
B. H₂O  
C. C₆H₁₂O₆  
D. Pyruvic acid  
E. Acetyl CoA (B) 1-1-2

183. The conversion of one mole of ATP to ADP releases approximately 7,000 calories. The combustion of 180 grams of glucose produces approximately 686,000 calories. From these data we can compute the percent efficiency of the conversion of the energy of glucose to ATP by the living cell. What percent of the combustible energy of glucose is converted to ATP under the conditions illustrated by the diagram?
A. 5  
B. 10  
C. 20  
D. 40  
E. 95 (D) 1-1-3

184. What is the percent efficiency of the conversion of the energy of glucose to ATP under anaerobic conditions?
A. Less than 1  
B. About 2  
C. Between 5 and 10  
D. Between 10 and 50  
E. Between 50 and 90 (B) 1-1-3

185. How many molecules of ATP are produced upon the transfer of two electrons and/or hydrogens to NAD (DPN) during the processes illustrated in the diagram?
A. 2  
B. 3  
C. 4  
D. 6 (C) 1-1-2

186. Certain yeast mutants lack “normal” mitochondria. They probably also lack
A. the ability to grow.  
B. a cell membrane.  
C. the ability to form ATP by oxidative phosphorylation.  
D. the enzyme which synthesizes RNA on a DNA template.  
E. the enzyme which synthesizes glutamic acid (an amino acid) from m-ketobutyric acid. (C) 1-2-2

187. The greatest amount of energy used by a single type of human tissue is used by
A. epithelial tissue.  
B. muscular tissue.  
C. nervous tissue.  
D. connective tissue.  
E. vascular tissue. (B) 1-2-2

188. Which of the following structures would probably have the highest ratio of nitrogen content to phosphorus content in its overall composition?
A. A nucleus  
B. A ribosome  
C. A mitochondrion  
D. An enzyme  
E. A cytoplasmic membrane (D) 1-2-2

189. The use of energy entering an organism from the outside is 100% efficient in
A. unicellular green plants only.  
B. all green plants.  
C. unicellular animals.  
D. bacteria.  
E. no organisms. (E) 1-3-2

190. It is possible for a red bud tree to produce flowers in the spring before it produces leaves because
A. no energy is required for the production of flowers.  
B. redbud petals photosynthesize enough to furnish all the energy needed in flower formation.  
C. the redbud trees metabolize insects which are attracted to the flowers.  
D. photosynthesis in the new growth of redbud stems furnishes enough energy for flowering.  
E. stored food from the year before is metabolized to provide energy for flowering. (E) 1-3-2

Items 191-197 are concerned with the following experiment.

The following experiment was designed to determine whether the .03 percent of CO₂ in the atmosphere is the most satisfactory (optimum) amount for the synthesis of carbohydrate in a plant.

A weighed geranium plant was placed in each of 10 containers. The containers were sealed and each 24 hours. The plants were well watered at the beginning with .03 percent and at intervals of 1 percent (i.e., .03, .03 up to 9.03 percent) twice each 24 hours. The plants were well watered at the outset and each container was kept on a greenhouse bench for three days. At the end of this period each plant was weighed.

Categorize each statement according to the following key.

**KEY:**
A. This change is unimportant in the revision of this experiment.
B. This change would improve the experiment because it would provide a control of one of the presently uncontrolled variables.
C. This change would improve the experiment because it would permit more inclusive conclusions to be drawn.
D. This change would improve the experiment because it would aid in verifying the results.
E. This change would improve the experiment because it would permit expression of results in quantitative terms.

The following experiment was designed to determine whether the .03 percent of CO₂ in the atmosphere is the most satisfactory (optimum) amount for the synthesis of carbohydrate in a plant.

A weighed geranium plant was placed in each of 10 containers. The containers were sealed and the CO₂ removed. CO₂ was then introduced, beginning with .03 percent and at intervals of 1 percent (i.e., .03, .03 up to 9.03 percent) twice each 24 hours. The plants were well watered at the outset and each container was kept on a greenhouse bench for three days. At the end of this period each plant was weighed.

Categorize each statement according to the following key.

**KEY:**
A. This change is unimportant in the revision of this experiment.
B. This change would improve the experiment because it would provide a control of one of the presently uncontrolled variables.
C. This change would improve the experiment because it would permit more inclusive conclusions to be drawn.
D. This change would improve the experiment because it would aid in verifying the results.
E. This change would improve the experiment because it would permit expression of results in quantitative terms.
191. If only ten containers were available it would have been better to have kept five in continuous dark and five in continuous light. (A) 1-3-2

192. The intervals of CO₂ should have been increased to allow certain containers to contain less than .03 percent and others more than 9.03 percent. (C) 1-3-2

193. The CO₂ content in each container should have been kept constant. (A) 1-3-2

194. The containers should have been kept in the same relative humidity. (B) 1-3-2

195. The experiment should have been started with weighed cuttings from the same plant. (B) 1-3-2

196. The containers should all be made of pyrex glass. (A) 1-3-2

197. The heights of the plants should have been measured at the beginning and at the end of the experiment. (A) 1-3-2

198. Which of the following characterizes the biomass in an ecosystem?
   A. The biomass of secondary consumers is generally greater than the biomass of primary consumers.
   B. The biomass of producers is generally greater than the biomass of primary consumers.
   C. The biomass of reducers is generally greater than the combined biomass of producers and consumers.
   D. The biomass of producers is generally less than the combined biomass of consumers and reducers.
   E. No general statement can be made about relative biomass of different ecologic groups. (B) 1-4-2

199. If precise quantitative measurements are made on a confined ecosystem in a laboratory we will find amounts of which of the following to be a one-way flow rather than cyclic?
   A. Carbon
   B. Free energy
   C. Nitrogen
   D. Oxygen
   E. Potassium (B) 1-4-2

200. If CO₂ is given off in respiration, why does the amount of CO₂ in the atmosphere remain relatively constant?
   A. CO₂ is converted in photosynthesis to carbohydrates.
   B. CO₂ is split apart during photosynthesis.
   C. CO₂ forms carbonate rocks.
   D. CO₂ is trapped in dead organisms’ bodies.
   E. CO₂ is a buffer. (A) 1-4-2

201. To a living organism, which of the following has the greatest amount of available energy per molecule?
   A. ATP
   B. ADP
   C. AMP
   D. H₂O
   E. CO₂ (A) 1-1-3

202. Which of the following is not a direct result of solar radiation reaching a lake and its contents?
   A. Conversion of phytochrome 660 to phytochrome 735 in pond lilies
   B. Breaking of rhodopsin in a fish retina
   C. Activation of chlorophyll in a diatom
   D. Orientation of euglenas toward the lake surface
   E. Transformation of phosphoglyceric acid into phosphoglyceraldehyde in an Elodea plant. (E) 1-1-3

203. If it is assumed that the primary gene action is to produce proteins, and that our current concepts of how proteins are produced are correct, which of the following cellular components need not be present in a spore?
   A. DNA
   B. Messenger RNA
   C. Ribosomes
   D. ATP, or a means of producing it
   E. Enzymes (B) 1-1-3

204. Which of the following is/are true of the analytical procedures used by Sanger to deduce the primary structure of the protein insulin?
   A. They are, in theory, applicable to almost any protein, though the analysis becomes more difficult with proteins of very high molecular weight.
   B. They established the linear order of the amino acids in the chain, but could not establish the polarity of the chain.
   C. They are of great usefulness because the protein being analyzed need not be extensively purified.
   D. Both B and C above, but not A
   E. A, B, and C above. (A) 1-1-3

For items 205-206:
   X-sRNA₅ = an sRNA which is specific for amino acid X.
   Y-sRNA₅ = an sRNA which is specific for amino acid Y.

205. Which of the following cell-free systems is most likely to result in the synthesis of a polypeptide, assuming UUU is the codon for phenylalanine?
   A. poly U + "polypeptide polymerase" + ribosomes + phenylalanine + GTP + ATP
   B. poly U + "polypeptide polymerase" + ribosomes + phenylalanyl-sRNA₅ + GTP
   C. poly U + "polypeptide polymerase" + ribosomes + phenylalanine + sRNA₅ + ATP + GTP
   D. poly U + "polypeptide polymerase" + ribosomes + phenylalanine + sRNA₅ + GTP
   E. poly U + "polypeptide polymerase" + ribosomes + phenylalanine + sRNA₅ + phenylalanine's activating enzyme (B) 1-1-3

206. Assume that poly UG contains codons for alanine but not for tyrosine, and that poly UAC contains codons for tyrosine but not for alanine. Under otherwise appropriate conditions for polypeptide synthesis which of the following pairs of reagents will lead to some kind of polypeptide?
   A. poly UG + alanyl-sRNA₅
   B. poly UG + tyroaryl-sRNA₅
   C. poly UG + alanyl-sRNA₅
   D. More than one of the above
   E. None of the first three above (E) 1-1-3

Questions 207 and 208 are based on the diagram below representing a simplified cycle.

207. If A represents H₂O and CO₂, then
   A. I is respiration, II is photosynthesis and B is CH₂O and O₂.
   B. I is photosynthesis, II is respiration and B is CO₂ and H₂O.
   C. I is respiration, II is photosynthesis and B is CO₂ and O₂.
   D. I is respiration, II is photosynthesis and B is CO₂ and H₂O.
   E. I is respiration, II is photosynthesis and B is CO₂ and O₂. (C) 1-1-3
208. If A represents atmospheric nitrogen and B represents nitrates, then:
   A. I could be denitrifying bacteria and II could be lightning.
   B. I could be nitrifying bacteria and II could be denitrifying bacteria.
   C. I could be lightning and II could be denitrifying bacteria.
   D. I could be nitrifying bacteria and II could be denitrifying bacteria.
   E. I could be decay bacteria and II could be nitrifying bacteria. \(\text{(A) 1-1-3}\)

209. During mitosis in a rat epidermal cell, the greatest amount of energy is used in:
   A. dividing the centriole in early prophase.
   B. disintegrating the nuclear membrane in late prophase.
   C. aligning the chromosomes at metaphase.
   D. movement of the chromosomes to the poles during anaphase.
   E. rebuilding nuclear membranes during telophase. \(\text{(D) 1-2-3}\)

210. The greatest amount of energy used by a Chlorella is in:
   A. locomotion.
   B. defensive reactions.
   C. chemical reactions.
   D. mitosis.
   E. gamete formation. \(\text{(C) 1-2-3}\)

211. A mammalian cell grown in a culture medium containing all of its phosphorus-containing compounds tagged with \(P\) would be found upon fractionation to possess:
   A. radioactive chromosomes.
   B. radioactive nuclear membrane.
   C. radioactive endoplasmic reticulum.
   D. all of the above.
   E. none of the first three above. \(\text{(D) 1-2-3}\)

212. A theater audience applauds following a performance. The room immediately seems to become warmer. Which is probably the major reason for this change?
   A. This is a psychological effect—during the performance the audience ignores the heat.
   B. Body temperatures are lower during the performance due to inactivity.
   C. Everyone puts on his coat.
   D. Heat is released as a result of muscular activity and increased glucose oxidation.
   E. The lights are turned on, giving off heat. \(\text{(D) 1-3-3}\)

213. Which of the following events in a vegetable garden is never directly affected by light?
   A. Seed germination
   B. Flowering
   C. Food manufacture
   D. Fertilization
   E. Transpiration \(\text{(D) 1-3-3}\)

214. That system originating from the embryonic ectoderm is the
   A. digestive system.
   B. muscular system.
   C. nervous system.
   D. circulatory system.
   E. endocrine system. \(\text{(C) 1-3-3}\)

215. Equal masses of paramecia, mice, and bean plants are placed in respirometers at 20°C in continuous darkness with O2 in excess. Which is the most likely arrangement of respiration rates — slowest to fastest?
   A. Paramecia, mice, bean plants
   B. Mice, paramecia, bean plants
   C. Mice, bean plants, paramecia
   D. Bean plants, mice, paramecia
   E. Bean plants, paramecia, mice \(\text{(D) 1-4-3}\)

216. In an oak forest, the greatest amount of energy turnover is accomplished by the
   A. oaks.
   B. squirrels.
   C. hawks.
   D. fungi.
   E. bacteria. \(\text{(A) 1-4-3}\)

217. A biology teacher has sealed a balanced aquarium and a quantity of air into a large glass carboy. After three months, the plants and animals in the aquarium appear alive and healthy. Which of the following statements about the experiment is wrong?
   A. No energy has entered the carboy from the outside during the three months.
   B. Potential energy in one organism in the aquarium has entered another organism during the three months.
   C. Some atoms from water molecules have become parts of organic molecules.
   D. The air above the water in the carboy contains carbon dioxide.
   E. During the three months, the biomass of plant life was greater than the biomass of animal life. \(\text{(A) 1-4-3}\)

218. Which of the following is the best evidence for the lock and key (or template) theory of enzyme action?
   A. All isolated enzymes have been identified as proteins.
   B. Compounds similar in structure to the substrate inhibit the reaction.
   C. Enzymes are found in living organisms and speed up certain reactions.
   D. Enzymes speed up reactions by definite amounts.
   E. Enzymes determine the direction of a reaction. \(\text{(B) 1-1-4}\)

219. Which is evidence for the belief that O2 given off in photosynthesis comes from water?
   A. Photosynthetic bacteria use H2S and CO2 to make carbohydrates, H2O and sulfur.
   B. Isolated chloroplasts in water release O2 if supplied ferric oxalate or some other reducing agent.
   C. Isotopic oxygen supplied as H2O appears in the O2 released during photosynthesis.
   D. All of the above.
   E. None of the first three above. \(\text{(D) 1-1-4}\)

220. A hypothesis states that mitochondria contain electron-transfer enzymes collected into compact associations. Which observation most cogently supports this hypothesis?
   A. Mitochondria have a highly folded inner wall.
   B. Droplets of material have been seen on the inner walls of mitochondria.
   C. Ultrasonic disruption of mitochondria yields membrane fragments which can synthesize ATP.
   D. A contractile protein capable of utilizing ATP has been isolated from mitochondria.
   E. Mitochondria in animal embryos tend to concentrate in cells destined to become parts of the locomotor systems. \(\text{(C) 1-1-4}\)

221. A red pigment is extracted from marine algae. Which best supports the hypothesis that the pigment is involved in photosynthesis? The red pigment
   A. has an absorption spectrum similar to that for chlorophyll.
   B. has an absorption spectrum similar to the photosynthesis action spectrum for the algae.
   C. has a molecular structure similar to chlorophyll.
   D. contains iron which is a transition element similar to magnesium which has a variable valence.
   E. is also found in land plants. \(\text{(B) 1-1-4}\)
222. A student studies a textbook table of the reactions in the tricarboxylic acid cycle. He is looking for the particular reactions which release energy. Which of the following clues is the most helpful in recognizing these reactions?
A. The appearance of inorganic phosphate as one of the reagents.
B. The combination of a two-carbon compound and a four-carbon compound to make a six-carbon compound.
C. The appearance of carbon dioxide as one of the products.
D. The saturation of a double bond.
E. The appearance of water as one of the reagents.

Items 223-226 are based on an experiment in which a mouse is placed in a special chamber which confines all movement and can measure the heat given off by the mouse, the mouse's mass and the relative concentration of gases in the chamber.

223. If the energy source in the mouse is glucose (C₆H₁₂O₆) and then is suddenly changed to a specific fat (C₅₇H₁₁₀O₇) the amount of CO₂ given off per O₂ taken in should
A. decrease because the fat has a lower ratio of oxygen to carbon.
B. decrease because the fat has a lower ratio of hydrogen to carbon.
C. increase because the fat has a lower ratio of oxygen to carbon.
D. increase because the fat has a lower ratio of hydrogen to carbon.
E. stay the same because the same number of C atoms will be released.

224. If the temperature of the chamber is lowered from 30° to 5°C the amount of heat given off by the mouse should
A. decrease because the mouse will use heat given off in respiration in regulating its temperature.
B. decrease because the mouse will move less thus using less energy and releasing less heat.
C. increase because the mouse will burn more stored energy in order to regulate its temperature by shivering.
D. increase because the mouse will move less thus having less heat available.
E. remain the same, since the mouse regulates its temperature and thus the rate of respiration remains the same.

225. If the mouse uses glucose as an energy source and does not gain or lose any liquids or solids during the experiment, its mass should (Note: At. weight of C=12, O=16)
A. decrease because the carbon dioxide given off weighs more than the oxygen taken in.
B. decrease because mass is converted to energy.
C. increase because the oxygen taken in weighs more than the carbon given off.
D. increase because water is a waste product and weighs more than the carbon-dioxide given off.
E. remain the same since the weight of carbon dioxide given off will equal the oxygen taken in.

226. If the mouse is replaced with another mouse (same sex, etc.), which is smaller, the O₂ consumption and CO₂ output per gram body mass will
A. decrease because smaller animals use less energy.
B. decrease because more glucose than fat is respired.
C. increase because more energy is required to regulate body temperature.
D. increase because small animals are less efficient.
E. remain the same because O₂ and CO₂ exchange is independent of body mass.

227. Consider the data in the following table:

<table>
<thead>
<tr>
<th>Exp't.</th>
<th>% O¹⁸ in raw materials</th>
<th>% O¹⁸ in resultant glucose</th>
<th>% O¹⁸ in resultant oxygen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.20%</td>
<td>0.01%</td>
<td>0.19%</td>
</tr>
<tr>
<td>2</td>
<td>0.20%</td>
<td>0.19%</td>
<td>0.01%</td>
</tr>
</tbody>
</table>

The most significant conclusion to be drawn is that
A. glucose usually contains some O¹⁸.
B. water is changed into glucose.
C. the hydrogen in glucose comes from water.
D. the oxygen from photosynthesis comes from water.
E. carbon dioxide is a product of photosynthesis.

Items 228-233 are based on the following:
The reaction A + B ⇌ AB takes place slowly at 20°C unless either compound x or y is present. Compound x is a metallic catalyst for the reaction and y is an enzyme which catalyzes the reaction. Ten ml. of a solution of A and B is placed in each of four test tubes to which varying amounts of x or y are added.

228. At 20°C the rate of reactions is probably
A. greatest in tube # I.
B. greatest in tube # II.
C. greatest in tube # III.
D. greatest in tube # IV.
E. equal in all tubes.

229. If A and B are heat stable at 100°C the rate of reaction is probably
A. greatest in tube # I.
B. greatest in tube # II.
C. greatest in tube # III.
D. greatest in tube # IV.
E. equal in all tubes.

230. Increasing the temperature from 20° to 30°C will probably double the rate of reaction in
A. tube #I but have no effect on the rate of reaction in tube # II.
B. tube #II but have no effect on the rate of reaction in tube # I.
C. tube # I and increase slightly the rate of reaction in tube # II.
D. tube #II and increase slightly the rate of reaction in tube # I.
E. both tubes # I and #II.

231. If the reaction is allowed to reach equilibrium in all tubes then the amount of AB will be
A. greatest in tube # I.
B. greatest in tube # II.
C. greatest in tube # III.
D. greatest in tube # IV.
E. equal in all tubes.

232. If after two days at 40°C more A and B are added to all tubes, the rate of reaction should increase in
A. tube # I only.
B. tube #II only.
C. tube #III only.
D. tube #IV only.
E. all tubes.
233. The contents of tubes #I, #II, #III, and #IV are poured into separate dialyzing sacks made from cellophane. The sacks are placed in separate containers of distilled water. The reaction slows down in sacks #I and #III but continues at a previous rate in sacks #I and #IV. Distilled water containing sacks #I and #IV did not carry out the reaction. When water from containers #II and #III is added to the contents of sacks #I and #II, the reaction occurs at the previous rate. This indicates that
A. enzyme y has a cofactor which diffuses out.
B. the structure of enzyme y is unstable.
C. the enzyme y molecule is not small enough to pass through the membrane pores.
D. x can act as a cofactor for enzyme y.
E. the dialyzing membrane allows enzyme y to pass only in one direction.
(A) 1-1-4

Items 234-235 are concerned with the following situation.

Two identical cultures of HeLa cells (a human cancer cell line) were infected with equal numbers of polio virus. At the same time, actinomycin D was added to one of the cultures, and radioactive uridine was added to both. Actinomycin D is known to inhibit DNA-dependent RNA synthesis in HeLa cells. Uridine is a precursor of RNA and becomes incorporated primarily into RNA. After two hours of incubation at 37° C, two measurements were made on each culture: (1) the amount of radioactivity that had been incorporated into RNA, and (2) the number of new virus particles that had been produced. The following data were obtained.

<table>
<thead>
<tr>
<th>Culture number</th>
<th>Actinomycin D added</th>
<th>Amount of radioactivity in RNA counts/minute</th>
<th>Number of new virus particles in millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>no</td>
<td>530</td>
<td>111</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>23</td>
<td>102</td>
</tr>
</tbody>
</table>

234. If it is assumed that only a small fraction of the cells were infected, then one can possibly conclude
A. actinomycin D inhibits RNA synthesis in polio-infected HeLa cells.
B. that RNA synthesis is required for the production of polio viruses.
C. that polio virus can be produced in the presence of actinomycin D.
D. that uridine incorporation is unaffected by actinomycin D.
E. none of the above.
(C) 1-1-4

235. If it is assumed that all cells were infected, then the data can best be interpreted in which of the following ways?
A. The addition of actinomycin D significantly decreases the number of viruses produced.
B. DNA-dependent RNA synthesis is required for the production of polio virus.
C. The protein coat of polio virus is required for successful infection.
D. Actinomycin D does not act in polio-infected cells.
E. None of the above.
(E) 1-1-4

236. Aerobic organisms differ from anaerobic organisms in the use of
A. nucleoli.
B. centrioles.
C. mitochondria.
D. lysozymes.
E. vacuoles.
(C) 1-2-4

Items 237-243 are concerned with the following experiment.

A student added 5cc of distilled water to a test tube. After heating the water he then added 2cc of Fehling's solution. Nothing happened. In another test tube, the student placed 5cc of distilled water and added some grapes. After heating, he added 2cc of Fehling's solution. The water in the first test tube turned reddish in color. The student concluded that the grapes tested contained glucose.

In drawing this conclusion the student had to make certain assumptions. Based only on the information given here, classify items 237-243 according to the following key.

KEY:  A. A justifiable and necessary assumption
B. An unjustifiable but necessary assumption
C. An unjustified or irrelevant assumption
D. Not an assumption but a mere restatement of results
E. Not an assumption but a mere restatement of the conclusion

237. The water did not contain glucose until the grapes were added.
(A) 1-1-4

238. The glucose in grapes turns to alcohol by fermentation.
(C) 1-1-4

239. Fehling's solution will cause a reddish color in the presence of glucose.
(B) 1-1-4

240. Glucose is found most abundantly in grape leaves during photosynthesis.
(C) 1-2-4

241. The addition of Fehling's solution caused the mixture in the second test tube to turn reddish in color.
(D) 1-1-4

242. Fehling's solution will cause a reddish color only in the presence of glucose.
(B) 1-1-4

243. Only ripe grapes will give the test for glucose.
(C) 1-1-4

244. Which of the following contributes most to the transport of water from the ground to the leaves of a sequoia?
A. Breakdown of ATP
B. Oxidation of glucose
C. Secretion of root epidermal cells
D. Countercurrent pressure in phloem cells
E. Cohesion of water molecules
(C) 1-3-4

Items 245-248 are based on an experiment in which equal amounts of ground liver cells, with the ATP removed, are placed in respirometers I, II, and III. Flask I contains glucose. ATP is added to flask II. Flask III contains a glucose solution and ATP. Flask IV contains no liver — only glucose and ATP. All flasks are placed in a water bath at 20° C. The following figures represent the respirometers after one hour.

245. Which is the best interpretation from these data?
A. ATP and glucose interact to produce CO2.
B. ATP is necessary to start the respiratory breakdown of glucose
C. Respiration cannot take place outside of living cells.
D. The Krebs cycle is not operating since no ATP is given off.
(A) 1-2-4
246. What is the main function of flask #IV?
A. To measure gas changes due to temperature changes.
B. To measure gas changes due to temperature and air pressure changes.
C. To control changes in gas pressures.
D. To determine how glucose and ATP function.
E. To account for cell enzymes. (B) 1-3-4

247. If the experiment is repeated, but at 30°C, the time required for the drop to move the same distance would probably be about
A. one-half hour.
B. one hour.
C. two hours.
D. four hours.
E. There is no way of predicting. (A) 1-2-4

248. The reaction in tube III stops after two hours. Which is the most likely explanation?
A. All the ATP is used up.
B. All the CO₂ is used up.
C. Enzymes cannot function outside of living cells.
D. Alcohol produced in fermentation denaturizes the enzyme. (B) 1-2-4

249. Human blood passes from the inferior vena cava into the diastolic right atrium of the heart because of
A. the pushing of venous valves.
B. a pressure differential between the atrium and the vena cava.
C. the beating of the sinoatrial node.
D. gravitational pull.
E. phagocytosis. (B) 1-3-4

Items 250-255 are concerned with the following situation.

Respiration in germinating pea seeds was measured with a respirometer. Four setups and the average value for each from ten repetitions is as follows:

250. Which is the best estimate of O₂ consumption in germinating pea seeds?
A. 20 ml/hr
B. 30 ml/hr
C. 70 ml/hr
D. 80 ml/hr
E. 100 ml/hr (E) 1-3-4

251. What is the purpose of respirometer IV?
A. To measure temperature and atmospheric pressure changes.
B. To control temperature and atmospheric pressure.
C. To show that rocks don't respire.
D. To compare respiration in living and dead things.
E. It has no purpose since the water droplet never moved. (A) 1-3-4

252. What is the best general interpretation of these data?
A. Dry pea seeds have a higher respiration rate than germinating seeds.
B. Germinating pea seeds have a higher respiration rate than dry seeds.
C. Dry and germinating pea seeds use O₂ at about the same rate.
D. Dry seeds do not use very much O₂.
E. Rocks absorb CO₂. (B) 1-3-2

253. What is the approximate ratio of CO₂ output to O₂ intake in germinating pea seeds?
A. 2 : 10
B. 2 : 3
C. 8 : 10
D. 10 : 10
E. Cannot be determined from the data. (C) 1-3-4

254. What is the approximate RQ of germinating pea seeds?
A. .2
B. .6
C. .8
D. 1.0
E. 2.0 (C) 1-3-4

255. Which is the best assumption regarding respiration of germinating pea seeds based on the above information?
A. Fermentation is taking place.
B. Glucose alone is being oxidized.
C. Compounds other than glucose are also being oxidized.
D. Respiration is not occurring — photosynthesis is.
E. No assumption can be made. (C) 1-3-4

Items 256-258 are based on an observation that illuminated Elodea leaves give off bubbles of gas at 20°C.

256. Which could result in a four fold (4X) increase in the volume of gas within a given time if light is the limiting factor?
A. Double the distance between plant and light
B. Decrease by one-half the distance between plant and light
C. Decrease by one-quarter the distance between plant and light
D. Increase the temperature 10°C
E. None of the above (B) 1-3-4

257. A plot of the volume of gas emitted in given time interval versus CO₂ concentration gives the following curve:

If the hypothesis principle of “limiting factors” is valid, then the volume should increase at point I if
A. more CO₂ is added.
B. the temperature is decreased.
C. the light intensity is increased.
D. more water is added.
E. less O₂ is present. (C) 1-3-4

258. If the CO₂ concentration is not limiting and photosynthesis consists of a light and dark reaction, then under “normal environmental conditions” a 10°C increase in temperature will
A. drastically increase the number of bubbles at high light intensities but will have little effect at low light intensities.
B. drastically increase the number of bubbles at very low light intensities but will have little effect at high light intensities.
C. drastically increase the number of bubbles regardless of light intensity.
D. have little effect on the number of bubbles released regardless of light intensity.
E. increase the number of bubbles at high light intensity but decrease the number at low light intensity. (A) 1-3-4
Items 259-261 are based upon the following experiment. Elodea shoots were placed upside down in water and illuminated. Bubbles of constant size which were emitted from the leaves and stem were counted. Illumination was varied by moving the light source. Results are shown in the following figure:

259. What is the best interpretation of these data alone?
A. Light is the limiting factor.
B. Light is limiting up to X when some other factor becomes limiting.
C. CO2 is the limiting factor.
D. Light is limiting up to X but darkness limits beyond Y.
E. Temperature would increase the rate. (B) 1-3-4

The above experiment was repeated except that a strong bicarbonate solution was added to provide an excess of CO2. Results are shown in the following figure:

260. Which is the best interpretation of these data when compared to the previous experiment?
A. CO2 is the limiting factor at X in experiment 1.
B. Light can be made to be limiting by decreasing other factors.
C. Temperature is limiting at Y in experiment 2.
D. CO2 is limiting at X in experiment 2.
E. Light was limiting at X in experiment 2. (A) 1-3-4

261. The foregoing experiments led to which of the following hypotheses?
A. Photosynthesis consists of a light and dark reaction.
B. Photosynthesis is cyclic and temperature dependent.
C. Photosynthesis is not cyclic and not temperature dependent.
D. CO2 and light are necessary factors in photosynthesis. (A) 1-3-4

262. Carbon monoxide (CO) is a "cell poison" which affects various cytochrome oxidase enzymes. If CO is added to a sealed aquarium, which organism is most likely to survive? (Assume CO is soluble in water.)
A. Anaerobic bacteria living in the mud.
B. Elodea which can make enough ATP during daylight and store it for use during night.
C. Green algae which carry on photosynthesis thus making their own oxygen.
D. Small animals called rotifers.
E. Snails which can come up for air. (A) 1-4-4

263. Chemical analysis of protein made by normal E. coli cells exposed to p-fluorophenylalanine reveals that the analogue has substituted for phenylalanine and not for other amino acids. The best conclusion from this observation is that
A. the false amino acid probably blocks entry of phenylalanine into the cell.
B. the false amino acid is probably an inhibitor of the first enzyme involved in phenylalanine synthesis.
C. the false amino acid is probably a repressor of the pathway leading to phenylalanine.
D. the false amino acid probably gets attached to phenylalanine's sRNA.
E. the false amino acid probably inhibits the activation of phenylalanine. (D) 1-1-5

264. The reactions catalyzed by RNA polymerase and DNA polymerase are similar in
A. that a large molecular weight product is formed.
B. that nucleotides at the triphosphate level serve as substrates.
C. that for each mole of nucleotide incorporated into polymer, one mole of pyrophosphate is produced.
D. all of the above respects.
E. none of the first three respects listed above. (D) 1-1-5

265. Which of the following would characterize the chemical composition of A. aerogenes' living material?
A. It is essentially constant during balanced growth.
B. It depends on the growth rate at which it was formed.
C. It is determined in large part by cellular regulatory devices.
D. All of the above.
E. None of the first three above. (D) 1-1-5

266. If an E. coli cell were to be grown in a medium containing (N15H4)2SO4 as the sole source of nitrogen, then N15 could be reasonably expected in
A. the ribosomes.
B. the DNA.
C. the pilus.
D. the enzymatic proteins.
E. all of the above. (E) 1-1-5

267. If mammalian cells utilize leucine exclusively for protein synthesis, then feeding radioactive leucine to a growing cell culture will eventually label
A. the ribosomes.
B. the mitochondria.
C. the mRNA.
D. more than one of the above.
E. None of the first three above. (D) 1-2-5

268. Anfinsen took purified bovine pancreatic ribonuclease (R) and denatured it by chemical means to yield a primary polypeptide chain (DR). He then allowed this molecule to reform H-bonds and S-S bridges yielding another product (RR). He measured the ability of R, DR, and RR to hydrolyze RNA and found
A. only DR had activity.
B. only R had activity.
C. only RR had activity.
D. only R and DR had activity.
E. none of the above. (E) 1-1-5

269. From the experiment described above Anfinsen could conclude
A. that the enzymatic activity of ribonuclease depends on an intact secondary and tertiary structure.
B. that the primary structure of ribonuclease determines to a large extent the secondary and tertiary structure which it assumes.
C. that ribosomes are important sites of cellular protein synthesis.
D. more than one of the above.
E. none of the above. (D) 1-1-5
270. A chemical derivative of the natural amino acid, L-phenylalanine, can be prepared in the laboratory. The false amino acid, p-fluorophenylalanine, when added to a growing culture of normal *E. coli* cells in minimal medium, gets incorporated into newly made protein. From what is known about the mechanism of protein synthesis, it would be reasonable to suspect that
A. normal *E. coli* can admit the false amino acid into the cell.
B. normal *E. coli* cells probably contain at least one enzyme that can "activate" the false amino acid.
C. normal *E. coli* cells probably possess at least one tRNA species that can accept the false amino acid and adapt it to some one or more codons.
D. all of the above occur.
E. none of the first three above occur.

271. A biologist supposes that a hummingbird gets part of its body heat from radiation from the sun and the earth and another part from chemical reactions within its body. He graphs the ratio of these two values against environmental temperature on a graph such as this:
The line he will get will approximate
A. a straight line with positive slope.
B. a straight line with negative slope.
C. a logarithmic curve bending up.
D. a parabola approaching a horizontal asymptote.
E. a circular arc with the origin at the center.

272. What color is the plant?
A. Blue
B. Green
C. Yellow
D. Red
E. Yellow green

273. What is the best conclusion from these data and previous photosynthetic studies on common green plants? The extracted pigments in this plant are given below. The action spectrum for photosynthesis in this plant is also given below:
A. the major light-receptor pigments in photosynthesis.
B. the only light-receptor pigments in photosynthesis.
C. are not involved in photosynthesis.
D. may be chlorophyll a and b.
E. may or may not be involved along with other pigments which are the major receptors.

274. A pound of butter contains more usable energy than a pound of sugar for a human because
A. the butter is an animal product whereas the sugar is a plant product.
B. a fat molecule has more carbon-hydrogen bonds than a sugar molecule.
C. sugar contains much more water than does butter.
D. there is more waste in digestion and absorption of sugar than of butter.
E. it requires fewer enzymes to oxidize butter than to oxidize sugar.

275. It is hypothesized that chemicals are produced and accumulate in vesicles within nerve cells. These vesicles move to the synaptic membrane and release their contents into the synaptic space when the nerve cell is stimulated. Which of the following observations provide the strongest support for this hypothesis?
A. It is observed under the electron microscope that more vesicles appear near the synaptic membranes of stimulated nerve cells than appear near the synaptic membranes of unstimulated nerve cells.
B. The application of lysosomes to the nerve cell causes an inhibition of the transmission of nerve impulses across the synapse.
C. The injection of an enzyme which breaks down the stimulatory chemical in the synaptic space inhibits the transmission of the nerve impulse.
D. The injection of an enzyme which breaks down the stimulatory chemical in the synaptic space, followed by electron microscope examination, reveals fewer vesicles in the nerve cell.
E. Electron microscope examination reveals a difference in the number of vesicles in nerve cells when compared with the number in gland cells.

276. Which best supports the belief that CO₂ fixation does not require light?
A. ATP is made from ADP by green plants in the light but CO₂ fixation doesn't require ATP.
B. Motile aerobic bacteria move faster when placed with green algae in the dark than when placed with green algae in the light.
C. Plants give off CO₂ in the dark.
D. Radioactive C₄O₂ can be traced to phosphoglyceric acid (PGA) in green plants.
E. Radioactive C₄ carbon compounds are found in animals grown in darkness in an atmosphere containing radioactive C₄O₂.

Items 277-292 are concerned with energy conversion in photosynthesis.
The conversion by green plants of radiant light energy to the chemical energy of organic compounds is a complex process, parts of which occur in the light, and parts of which may occur in the dark. The preceding diagrams represent certain aspects of this conversion. Examine the diagrams and answer the questions which follow.

Categorize items 277-292 according to the following key.

KEY: A. A reaction of I but not II.
B. A reaction of II but not I.
C. A reaction of both I and II.
D. Not a reaction of either I or II, but necessary if either I or II or both are to occur.
E. Not a reaction of either I or II, but occurs as a result of I or II or both.

277. Fixation of carbon, i.e., the conversion of carbon from an inorganic to an organic state (B) 1-1-6
278. Oxidation (C) 1-1-6
279. Photophosphorylation (A) 1-1-6
280. Production of phosphoglyceraldehyde (B) 1-1-6
281. Glycolysis (E) 1-1-6
282. Photolytic splitting of water (A) 1-1-6
283. Reduction (C) 1-1-6
284. Grana formation (D) 1-1-6
285. Glucose formation (E) 1-1-6
286. Reduction of triphosphopyridine nucleotide (nicotinamide dinucleotide phosphate) (A) 1-1-6
287. Cyclic phosphorylation (A) 1-1-6
288. Photon production (D) 1-1-6
289. Conversion of the energy of photons to the energy of chlorophyll (A) 1-1-6
290. Free oxygen produced (A) 1-1-6
291. Oxidative phosphorylation (E) 1-1-6
292. Water formation (C) 1-1-6

Categorize items 293-305 according to the following key.

293. The source of electrons in photophosphorylation is water (C) 1-1-6
294. Carbohydrate concentrations increase in plants placed in the sunlight. (A) 1-1-6
295. Greater quantities of adenosine triphosphate are formed during the dark phase of photosynthesis than during the light phase. (A) 1-1-6
296. In the replication of DNA molecules the geometric configuration of each pyrimidine permits the attachment of a purine only. (D) 1-1-6
297. The conversion of the energy of photons to the energy of adenosine triphosphate depends upon the transfer of electrons from carrier to carrier. (C) 1-1-6
298. The Krebs cycle requires free oxygen or some other hydrogen acceptor. (B) 1-1-6
299. Phosphoglyceraldehyde is a precursor to the production of ribulose-diphosphate. (A) 1-1-6
300. Carboxydismutase is an enzyme necessary for the conversion of CO₂ and RuDP to phosphoglyceric acid. (A) 1-1-6
301. The quantaosome is that portion of a chlorophyll molecule which traps the photons. (E) 1-1-6
302. DNA base sequences control the formation of messenger and transfer RNA base sequences. (D) 1-1-6
303. Mitochondria and plastids have self-replicating nucleic acid molecules independent of chromosomal DNA. (B) 1-1-6
304. Crossover of chromatids between homologues occurs at the chiasmata. (D) 1-1-6
305. During exposure to light, electrons emerging from chlorophyll engage in formation of high-energy bonds. (C) 1-1-6
306. Nerve cells require some energy for impulse transmission. Much of this energy is used in A. operating the sodium pump; B. extending and withdrawing dendrite and axon endings; C. rebuilding the myelin sheath after each impulse transmission; D. building mitotic spindles; E. movements of chromosomes. (A) 1-2-6
307. Mitochondria are called the powerhouses of the cell because they make energy readily available to the cell's metabolism. Which of the following observations is most cogent in supporting this concept of mitochondrial function? A. ATP occurs at the mitochondria; B. Mitochondria have a double membrane construction; C. The enzymes of the Krebs cycle and the cytochromes are found in mitochondria; D. Mitochondria abound in muscle tissue; E. Mitochondria are found in almost all kinds of plant and animal cells. (C) 1-2-6
308. Energy consumption of the heart is very much greater than that of the brain in vertebrates. One significant reason for this is A. a muscle cell is much longer than a nerve cell; B. muscle contraction is much faster than nervous transmission; C. muscle activity involves movements of much more mass than does nervous activity; D. muscles contain much more lipid material than nerve tissues; E. muscle activity invariably follows nerve activity in time. (C) 1-3-6
309. Many members of a cave ecosystem never leave the cave. The provision of sufficient energy to maintain the flora and fauna in a cave is made chiefly by which of the following? A. Photosynthesizers using the light of luminescent organisms; B. An energy cycle involving only consumers and reducers; C. Influx of food materials from outside the cave; D. Heightened background radioactivity; E. Organisms coming up from deep underground wells. (C) 1-4-6
310. In a fairly deep body of water, there is apt to be more biomass on or near the bottom than at most other levels. Yet, the energy of sunlight, on which living organisms depend, diminishes rapidly in being passed through water. The best of the following ways of accounting for this apparent paradox is
A. all photosynthesizing plants must be rooted in the bottom to obtain minerals.
B. organic materials continually drop to the bottom of the water.
C. the animal population on the bottom converts enough carbon dioxide to organic compounds to supply all nutritive needs.
D. all organisms must have a solid substratum to support them.
E. temperature is more uniform at the bottom than elsewhere. (B) 1-4-6

311. Which of the following supports the idea that mutations may have been more frequent when living cells first evolved?
A. DNA was simpler, hence mutations were easier to induce.
B. Early cells did not have DNA, which is a stable compound, hence changes were frequent.
C. Early cells reproduced asexually, hence mutations appeared.
D. Less ozone (O₃) was present, thus permitting more radiation to penetrate the earth's atmosphere.
E. More ozone (O₃) was present, thus permitting more radiation to penetrate the earth's atmosphere. (D) 1-4-6

312. Arrange the following components of *A. aerogenes* cell in order of their size (calling the smallest No. 1, etc.), ignoring molecular shapes and just considering molecular or particle weights:
A. NAD 1. (G) (smallest)
B. L-valine 2. (B)
C. 70s ribosome 3. (D)
D. ATP 4. (A)
E. valyl sRNA 5. (E)
F. DNA 6. (D)
G. Mg²⁺ 7. (C)
H. DNA polymerase 8. (F) (largest) 1-1-2

**Essay Questions**

Questions 313-317. Propose a research program which will determine

313. whether a bacterium can derive energy more efficiently by oxidizing cholesterol or by oxidizing stearin. 1-1-5

314. whether *P. aerogenes* or rose leaves are more efficient at using solar energy for photosynthesis. 1-2-5

315. whether an amoeba or a paramecium is more efficient in the use of energy for locomotion. 1-2-5

316. which uses more energy during twenty-four hours: an oyster or a kelp of the same mass of living tissue. 1-3-5

317. the proportion of the total energy a bear uses in a year which is derived from plants in his diet as compared to the proportion derived from animals in his diet. 1-4-5

318. Propose a procedure to determine how many photons are required to photolyse one molecule of water in photosynthesis. 1-1-5

319. A gardener buries a ton of dead oak leaves in a pit, covered by a two-inch layer of soil. A scientist wants to compute the amount of heat produced by decay in this compost heap during the next five years. What data will the scientist need to make a reasonably accurate prediction of this amount? 1-2-4

320. A scientist is trying to evaluate the efficiency of biological processes by computing the amount of energy represented by the sunlight falling on an acre of corn during the growing season and the amount of energy humans can derive from eating the meat of the cattle fed on that corn. What measurements will this scientist need to make to accomplish his aim? 1-4-4

321. Describe the passage of a photon of energy through a producer, a consumer, and a reducer in a freshwater pond. 1-4-5

322. Birds and mammals require more energy to maintain thermal homeostasis than do cold-blooded organisms of the same mass. This would seem to be a handicap. How can you account for the fact that it was favorably selected? 1-3-6

323. With a crude cell-free extract as starting material, cite in outline form the general steps that should be followed to find out the primary structure of a particular enzyme. 1-1-5

324. A guinea pig intestine is washed out and then filled with an aqueous solution of glucose of a concentration half that of the cells lining the intestinal lumen. The intestine absorbs glucose from this solution. How can it do this? 1-2-2

325. Propose a procedure to determine the turnover number of the liver-extract enzyme catalase, acting on hydrogen peroxide (H₂O₂). 1-1-5
SECTION 7. EXAMPLES: FORM - FUNCTION

Objective Items

326. An antibody is a
A. compound specifically inactivating an antigen.
B. white corpuscle which phagocytizes invading bacteria.
C. secretion of mammalian erythrocytes.
D. nonreproductive segment of a polychete worm.
E. member of a symbiotic association.

327. Which of the following show the least constancy of shape?
A. Red blood corpuscles.
B. White blood corpuscles.
C. Visceral muscle cells.
D. Neurons.
E. Cartilage cells.

328. Transpiration rate in a maple tree is controlled by
A. mitochondria.
B. stomata.
C. meristem.
D. pit vessels.
E. resin ducts.

329. Rapid, irreversible cell elongation is common in plants but not in animals. What plant cell structures account for this difference?
A. Absence of centrioles and Golgi bodies.
B. Absence of endoplasmic reticulum and presence of large vacuoles.
C. Absence of Golgi bodies and presence of cell walls.
D. Presence of large vacuoles and cell walls.
E. Presence of cytoplasmic RNA and chloroplasts.

332. Blood which leaves the liver and moves to the heart has a higher than usual concentration of which of the following?
A. Urea
B. Salts
C. Water
D. Red blood cells
E. White blood cells

333. Considering that a functional kidney consists of healthy living cells, which of the following processes does not occur in the kidneys?
A. Deamination
B. Respiration
C. Pressure filtration
D. Tubular resorption
E. Tubular excretion

334. The liquid which collects in the cavity of Bowman's capsule is
A. concentrated urine.
B. blood plasma minus blood proteins.
C. used bile ready for excretion.
D. glycoprotein and water.
E. sulfates and water.

335. A man had both kidneys removed surgically and died shortly thereafter. Based on what is known about the kidney, what would be the best explanation as to the cause of death?
A. No hemoglobin was produced.
B. No urea was excreted.
C. No urea was produced.
D. The water backed up and drowned all the body cells.
E. Too much water was excreted.

336. Seed plant leaves are known to carry on all of the following except
A. nerve impulse conduction.
B. asexual reproduction.
C. transpiration.
D. starch synthesis.
E. mitotic spindle formation.

337. A function of the human spleen is
A. induction of sleep.
B. stimulation to anger.
C. stimulation of reverse peristalsis in the intestine.
D. secretion of a steroid hormone.
E. control of blood volume in blood vessels.

338. Streamlined organisms occur
A. only in water.
B. only in air.
C. only in soil.
D. only in water and air.
E. in water, air, and soil.

339. On the upper surface of a pond move organisms whose
A. bodies are highly porous.
B. surface layer is miscible with water.
C. base of support is large in relation to their mass.
D. lower surfaces decrease the surface tension of water.
E. lower surface is planar.

340. The ribonucleotide triplet "ACC" is said to "code for the amino acid threonine." This means that
A. the ribonucleotides adenosine and cytidine are required for the biosynthesis of threonine.
B. ACC is a shorthand way of writing the covalent structure of threonine.
C. addition of the trinucleotide ACC to certain cells causes them to produce threonine.
D. the transfer RNA for threonine probably contains the complementary codeword, UUU.
E. when the nucleotides TGG appear together in a strand of DNA, threonine appears in a particular location in the corresponding protein.

341. An increase in thyrotrophin in the blood of a mammal causes
A. proliferation of cells in the thyroid gland.
B. accumulation of thyroglobulin in follicles.
C. release of thyroxin by the thyroid gland into the blood.
D. flow of nerve impulses into the thyroid follicles.
E. cessation of thyroxin secretion.

342. Niacin prevents pellagra by
A. transforming succinic acid to fumaric acid.
B. acting as an enzyme in the manufacture of acetylcholine.
C. synthesizing hemoglobin.
D. being a component of TPN and DPN, which help oxidize carbohydrates.
E. acting as an antibiotic against the pellagra virus.
343. (I) The size of an average mRNA molecule  
   (II) The size of an average sRNA molecule
   (A) 2-1-2

344. (I) The size of an average enzyme molecule  
   (II) The size of an average DNA molecule  
   (B) 2-1-2

345. (I) The size of an average bacterial DNA molecule  
   (II) The size of an average bacterial mRNA molecule
   (A) 1-1-2

346. (I) According to current ideas, the presumed size of an average codon  
   (II) The size of an average trinucleotide  
   (C) 2-1-2

347. (I) The length of an average DNA molecule  
   (I) The length of an average ribosome  
   (A) 2-2-2

348. (I) The importance of the mitochondria as sites of protein synthesis  
   (II) The importance of membrane-bound ribosomes as sites of protein synthesis  
   (B) 2-2-2

349. (I) The size of an average ribosome  
   (II) The size of an average protein molecule  
   (A) 2-2-2

350. (I) The compositional and structural complexity of bacterial capsule  
   (II) The compositional and structural complexity of a bacterial wall  
   (B) 2-2-3

351. (I) The approximate dimensions of an E. coli ribosome  
   (II) The approximate dimensions of a thyroid cell ribosome  
   (C) 2-2-3

352. (I) The amount (by weight) of protein in an A. aerogenes cell  
   (II) The amount (by weight) of water in the same cell  
   (B) 2-1-3

353. (I) The weight of one football defensive guard (280 lbs.)  
   (II) The weight of 1015 A. aerogenes cells  
   (A) 2-3-3

354. (I) The structural similarity between a human thyroid cell and an ameba  
   (II) The structural similarity between a bacterial cell and an ameba  
   (A) 2-2-5

Items 355-361 are concerned with the following: Below are statements about the makeup of essential life and determines its truth or falsity. Evaluate the statements and conditions according to the key.

**Key:**
A. Statement is true if condition holds.
B. Statement is true regardless of condition.
C. Statement is false if condition holds.
D. Statement is false regardless of condition.
E. Truth or falsity of the statement and condition is indeterminate.

**Statement** | **Condition**
---|---
355. A cell can be called primitive if its nucleoprotein is dispersed  
   (A) 2-2-2  
   (B) 2-1-2

356. A nucleoprotein may be a virus if it lacks a protein shell  
   (A) 2-2-2  
   (C) 2-1-2

357. A protein is an enzyme if it contains amino acids  
   (E) 2-1-2  
   (C) 2-1-2

358. A primitive proto-virus was a parasite if it was chemosynthetic  
   (C) 2-1-2

359. A compound containing purines and pyrimidines is a nucleotide if it also contains phosphate and ribose sugar in the proper chemical combination  
   (B) 2-1-2

360. A nucleoprotein contains nucleic acids if nucleotides are found in it.  
   (B) 2-1-2

361. A cell is chemosynthetic only if it can combine the molecules from its environment to make its substance.  
   (E) 2-2-2

Items 362-378 refer to the partially labeled diagram which illustrates a segment of a particular giant molecule produced in living cells. Examine the diagram and then answer the questions. It will be helpful if you recall that cytosine and thymine are pyrimidines and that adenine and guanine are purines. You can distinguish pyrimidines from purines by the single ring structural formula of the former, and the double ring structural formula of the latter. A methyl group is attached to the thymine molecule, an amino group is attached to the cytosine molecule, and an oxygen atom is attached to the guanine molecule.

362. The diagram illustrates a segment of a  
   A. DNA molecule.  
   B. ribosomal RNA molecule.  
   C. transfer RNA molecule.  
   D. messenger RNA molecule.  
   E. polypeptide molecule.  
   (A) 2-1-2

363. The structure represented by I in the diagram is  
   A. a base; a pyrimidine; thymine.  
   B. a sugar; ribose; thymine.  
   C. a nucleotide; an enzyme; a lipid.  
   D. a peptide; an amino acid; thymine.  
   E. a base; a purine; adenosine.  
   (A) 2-1-2

364. Label II represents a  
   A. strong hydrogen bond.  
   B. weak hydrogen bond.  
   C. polymerase  
   D. GTP bond.  
   E. peptide bond.  
   (A) 2-1-2

365. Structure III represents  
   A. deoxyribose.  
   B. ribose.  
   C. adenine.  
   D. guanine.  
   E. cytosine.  
   (C) 2-1-2

7-2
366. Structure IV represents
A. part of a lipid.
B. a molecule present also in ATP.
C. a sugar.
D. an amino acid.
E. pyruvic acid.  (B)  2-1-2

367. Structure V represents
A. a base; a pyrimidine; cytosine.
B. an amino acid.
C. a phosphate.
D. part of a nucleotide; a sugar; deoxyribose.
E. ribose.   (D)  2-1-2

368. Structure VI is a bond between
A. a purine and a pyrimidine.
B. a sugar and a base.
C. an enzyme and a substrate.
D. a phosphate and a base.
E. a sugar and a phosphate.  (E)  2-1-2

369. The structures labeled VII and VIII are, respectively,
A. a pyrimidine and a purine.
B. a purine and pyrimidine.
C. ribose and deoxyribose.
D. an enzyme and a substrate.
E. a substrate and an enzyme.  (A)  2-1-2

370. Which of the following are "complementary" to each other?
A. The sugar and the phosphate
B. Thymine and cytosine
C. The members of a base pair
D. Adenine and guanine
E. Deoxyribose and ribose  (C)  2-1-2

371. If one were to reason from the data given in the diagram, the structures labeled XI and IX ought to be, respectively,
A. a pyrimidine and purine.
B. a purine and pyrimidine.
C. ribose and deoxyribose.
D. an enzyme and a substrate.
E. a substrate and an enzyme.  (A)  2-1-3

372. According to the Watson-Crick theory, if the structure labeled XI were adenine, then IX would be
A. a purine.
B. ribose.
C. deoxyribose.
D. phosphate.
E. thymine.   (E)  2-1-2

373. The distance between structures I and III is
A. the same as between VII and VIII and XI and IX.
B. greater than between VII and VIII but the same as between XI and IX.
C. greater than between VII and VIII, which in turn is greater than between XI and IX.
D. less than between VII and VIII but the same as between XI and IX.
E. less than between VII and VIII, which in turn is less than between XI and IX.  (A)  2-1-2

374. If XI were guanine, then X would represent
A. two strong hydrogen bonds.
B. two peptide bonds.
C. three weak hydrogen bonds.
D. three strong hydrogen bonds.
E. two weak hydrogen bonds.  (D)  1-1-2

375. The structures I, XII, and XIII, together constitute
A. an amino acid.
B. a nucleotide.
C. a deoxyribonucleic acid.
D. a ribonucleic acid.
E. a peptide.  (B)  2-1-5

376. The entire structure as shown in the diagram
A. is a triplet.
B. is two triplets.
C. forms a triplet by template replication.
D. forms a peptide by template replication.
E. transfers an amino acid to a ribosome.  (C)  2-1-2

377. In the molecule, of which only a segment is represented in the diagram, the number of adenine molecules equals the number of (______) molecules.
A. cytosine
B. adenine
C. deoxyribose
D. thymine
E. guanine  (D)  2-1-1

378. In the molecule diagrammed, the number of purine molecules equals the number of (______) molecules.
A. phosphate
B. uracil
C. ribose
D. deoxyribose
E. pyrimidine  (E)  2-1-1

379. Which of the following is true of uracil?
A. It is present in RNA but not DNA, and is a pyrimidine complementary to adenine.
B. It is present in messenger RNA but not in transfer RNA and is a pyrimidine complementary to cytosine.
C. It is present in transfer RNA but not messenger RNA and is a purine complementary to guanine.
D. It is present in ribosomal RNA but not messenger RNA and is a purine complementary to thymine.
E. It is present in messenger and transfer RNA but not ribosomal RNA and is a pyrimidine complementary to guanine.  (A)  2-1-2

380. Which of the following would be a false assumption if a biologist were to attempt to distinguish fragmented chromosomes of a cell from the ribosomes?
A. Proteins are present in chromosomes but not in ribosomes.
B. Sugars of ribosomes are more highly oxygenated.
C. Most RNA is a single helix and most DNA is a double helix.
D. In DNA, thymine complements adenine while, in RNA, uracil complements adenine.
E. DNA concentrations are constant in different tissues of an individual organism but RNA concentrations are not.  (A)  2-1-1

381. Which ratio is constant for the members of a species but varies widely between species?
A. Adenine + thymine / cytosine + guanine
B. Adenine + cytosine / thymine + guanine
C. Adenine + guanine / cytosine + thymine
D. Ribose + purine / deoxyribose + pyrimidine
E. Purine + pyrimidine / ribose + deoxyribose  (A)  6-1-1

382. The principal nucleic acid of which chromosomes are composed is
A. DNA.
B. ribosomal RNA.
C. transfer RNA.
D. messenger RNA.
E. uracil.  (A)  4-2-1

383. The presence of DNA in mitochondria and in chloroplasts supports the hypothesis proposing that
A. glycolysis occurs in both the mitochondria and in the chloroplasts.
B. ATP is produced in both the mitochondria and in the chloroplasts.
C. mitochondria and chloroplasts originated as independent free-living organisms.
D. ribosomal RNA is produced in mitochondria and in chloroplasts.
E. mitochondria and chloroplasts undergo mitosis and meiosis independently of the nucleus.  (C)  2-2-2

384. Compound X breaks down the mitotic spindle but does not interfere with growth or with duplication of cell organelles. An application of compound X should result in which of the following (assuming the cells are alive)?
A. Cancerous cells
B. Cells without nuclei
C. Identical daughter cells
D. Polypliods
E. Synchronous dividing cells  (D)  2-2-2
385. Which does not demonstrate the interrelationship between form and function?  
   A. Spherical shape of the nucleus and storage of DNA  
   B. Infolding of inner mitochondrial membrane and arrangement of enzymes  
   C. Chloroplast lamellae and photosynthesis  
   D. Muscle fibrils and contraction  
   E. Extension of nerve cell (axons and dendrites) and impulse conduction  
   (A) 2-2-3

386. The muscles of the human intestine contract upon  
   A. hormonal stimulation and relax upon nervous stimulation.  
   B. nervous stimulation and relax upon hormonal stimulation.  
   C. nervous stimulation and relax in the absence of nervous stimulation.  
   D. hormonal stimulation and relax in the absence of hormonal stimulation.  
   E. nervous stimulation and relax upon nervous stimulation.  
   (E) 2-3-3

387. A termite colony and a pack of wolves differ in that in the termite colony  
   A. food-gathering and defense are carried on by individuals of different structure.  
   B. the members do not collaborate in a common enterprise.  
   C. the members never leave the nest.  
   D. every member participates in reproduction.  
   E. association is temporary, occurring only in the warm season.  
   (A) 2-4-2

388. An example of the dependence of function on form is  
   A. diffusion of musk in air.  
   B. Brownian movement.  
   C. the deliquescent shape of a maple tree.  
   D. hardness of tooth enamel.  
   E. catalytic activity at the active site of an enzyme molecule.  
   (E) 2-1-3

389. The formation of phosphoglyceraldehyde from phosphoglyceric acid in carbohydrate manufacture by a green plant is an example of  
   A. polymerization.  
   B. isomerism.  
   C. tautomerism.  
   D. reduction.  
   E. plasmosisysis.  
   (D) 2-1-3

For items 390-399 if an increase in  
   I causes an increase in II, mark A.  
   II causes an increase in I, mark B.  
   I causes a decrease in II, mark C.  
   II causes a decrease in I, mark D.  
   either causes no change in the other, mark E.

390. Thyroxin level in blood  
   Carbon dioxide release in tissues  
   (A) 2-1-3

391. Peristaltic rate in intestine  
   Blood adrenalin concentration  
   (D) 2-2-3

392. Transpiration rate  
   Light intensity  
   (B) 2-3-3

393. Contraction of the diaphragm  
   Flow of blood into the right atrium  
   (A) 2-3-3

394. Auxin concentration  
   Phosphoglyceraldehyde manufacture in a chloroplast  
   (E) 2-1-3

395. Production of lipases  
   Amount of amino acids in In a cell  
   (C) 2-1-3

396. Impulses over the vagus nerve  
   Heartbeat  
   (C) 2-3-3

397. Humidity in the atmosphere  
   Size of stomates  
   (A) 2-2-3

398. Deaths from malaria  
   Incidence of sickle-cell anemia  
   (D) 2-3-3

399. Urea production in the liver  
   Protein content of the diet  
   (B) 2-1-3

400. A difference between humans living at sea level and those living at an altitude of 10,000 feet is that the latter would have  
   A. a higher rate of secretion of gland cells of the stomach.  
   B. more active sweat glands.  
   C. higher blood pressure.  
   D. more active bone marrow.  
   E. larger semicircular canals of the ear.  
   (D) 2-2-3

401. During a spring flood, a paramecium is carried downstream into an estuary of the Atlantic Ocean. A change resulting from this would be  
   A. loss of some of its cilia.  
   B. gamete formation.  
   C. decrease in contraction frequency of the contractile vacuoles.  
   D. acceleration of feeding reactions.  
   E. development of fin-like extensions along the sides of the body.  
   (C) 2-2-3

402. If the Golgi apparatus functions in secretion, then we would expect to find the most abundant Golgi apparatus in  
   A. muscle cells.  
   B. egg cells.  
   C. gland cells.  
   D. bone cells.  
   E. blood cells.  
   (C) 2-2-3

403. Which of the following structures would probably be least damaged by a lipid-dissolving solvent?  
   A. A mitochondrion  
   B. An endoplasmic reticulum  
   C. A polysome  
   D. A protoplast  
   E. A nucleus  
   (C) 2-2-3

Items 404-409 are based on the paragraphs below.  
When the 43X objective is in position, the diameter of the field of view is approximately 0.1 mm. and the area of the field of view is approximately 0.075 mm². The diameter of the field of view is inversely proportional to the magnification of the objective.

Counting left to right, one observes 15 rectangular onion epidermal cells across the field of view when there is high power magnification (43X). Also, counting from top to bottom it can be observed that 4 cells span the diameter of the field of view.

404. What is the best estimate of the average width of the onion cells?  
   A. 0.005 mm  
   B. 0.023 mm  
   C. 0.035 mm  
   D. 0.100 mm  
   E. 0.370 mm  
   (B) 2-2-3

405. What is the best estimate of the average length of the onion cells?  
   A. 0.023 mm  
   B. 0.035 mm  
   C. 0.037 mm  
   D. 0.075 mm  
   E. 0.087 mm  
   (E) 2-2-3

406. What is the best estimate of the average area of each of the onion cells?  
   A. 0.002 mm²  
   B. 0.003 mm²  
   C. 0.004 mm²  
   D. 0.008 mm²  
   E. 0.037 mm²  
   (A) 2-2-3

407. If a 10X objective were used under the same conditions one would probably observe how many cells counting from bottom to top?  
   A. 64  
   B. 48  
   C. 35  
   D. 17  
   E. Less than 1  
   (D) 2-2-3
408. Using a 50X objective, the area of the field of view is approximately 0.07 sq. mm. and one sees on the average 8 stomates on the lower surface of leaf "Z". What is the density of stomates per square millimeter? Note: Density = (1/area) (average count per field of view)
A. 6-50
B. 51-100
C. 101-125
D. 126-135
E. 136-150 (C) 2-2-2

409. When using the 43X objective one sees on the average 18 stomates in the field of view. What is the best estimate of the density of stomates per square mm?
A. Less than 125
B. 125-150
C. 151-200
D. 201-239
E. 240-300 (C) 2-2-3

Items 410-412 are based on the following information about three new species of animals which fit into our existing classification system.

<table>
<thead>
<tr>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Habitat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>terrestrial</td>
<td>marine</td>
</tr>
<tr>
<td></td>
<td>Embryo develops in</td>
<td>water</td>
</tr>
<tr>
<td></td>
<td>Skeleton is internal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epidermis covered with</td>
<td>slime or mucus</td>
</tr>
</tbody>
</table>

410. If we arrange the animals according to the proportion of yolk in their eggs, the most likely sequence (least to most yolk) is
A. I, II, III
B. I, III, II
C. II, III, I
D. II, I, III
E. III, I, II (D) 2-3-3

411. Which animal(s) most likely has (have) gills at some stage in the life cycle?
A. Species I only
B. Species II only
C. Species I and II only
D. Species I and III only
E. None of the above species (A) 2-3-3

412. Which animal(s) is (are) probably dormant when the air temperature is below freezing?
A. Species I only
B. Species II only
C. Species I and II only
D. Species I and III only
E. None of the above species (D) 2-3-3

413. The principle of division of labor among members of a population is best illustrated by which of the following?
A. A school of herring
B. A nest of termites
C. A pack of wolves
D. A herd of elephants
E. A grove of poplars (B) 2-4-3

414. If a hydrogen atom loses one electron in a chemical reaction and if H2O, KOH, KMnO4, and MnO2 are all stable molecules, then we can assume that
A. KMn may have a valence of 1+ or 4+.
B. Mn can be either + or -.
C. Mn may have a valence of 7+ or 4+.
D. Oxygen can be either + or -.
E. the formula for either MnO2 or KMnO4 is incorrect. (C) 2-1-4

415. The Golgi apparatus was for some time under debate as to whether it really existed or was an artifact of preparation of cells for microscopic study. The most convincing of the following five observations on behalf of the genuineness of the apparatus is
A. appearance of the apparatus in live cells under phase contrast microscopy.
B. occurrence of the apparatus in sections of tissues from many species of organisms.
C. appearance of the apparatus after staining with three different stains.
D. nonappearance of the apparatus after treatment with certain fat solvents.
E. more frequent appearance of the apparatus in secretory cells than in nonsecretory cells. (A) 2-2-4

416. Five events occurred in an algal cell:
P. An enzyme was manufactured at a ribosome.
Q. Cellulose was deposited as a cell wall.
R. Under the influence of DNA, a molecule of RNA was constructed.
S. A carbohydrate polymer was formed.
T. A nucleic acid migrated from nucleus to cytoplasm.

It is discovered that these five events constitute a cause-and-effect sequence. The order in which these events occurred is therefore
A. S-Q-P-R-T.
B. T-R-S-P-Q.
C. Q-P-S-T-R.
D. P-R-T-S-Q.
E. R-T-P-S-Q. (E) 2-2-4

417. If living cells similar to those found on earth were found on another planet where there was no O2, which cell organelle would most likely be absent?
A. Cell membrane
B. Chromosomes (or DNA)
C. Nucleus
D. Mitochondria
E. Ribosomes (D) 2-2-4

418. Examination of thin sections of pancreas cells with an electron microscope reveals many small, dark, round structures not found in non-glandular cells. It is hypothesized that the structures are associated with secretion. To test this hypothesis one might
A. compare actively secreting glandular cells with some which are no longer secreting.
B. stimulate muscle cells and look for the structures.
C. examine plant cells since they seldom secrete substances.
D. collect the secretion and look at it with an electron microscope.
E. determine if ATP is used. (A) 2-2-4

419. A just criticism of the above study might be that
A. the dark bodies might not exist in living cells.
B. not all glandular cells were examined before the hypothesis was formed.
C. not all glandular cells secrete.
D. ATP is used in many cellular functions. (E) the dark structures might also have other functions. (A) 2-2-4

420. That the mammalian thymus is associated with the development of immunity is most strongly supported by its
A. large number of leucocytes.
B. extensive vascularization.
C. location close to the bronchi, a port of entry of infectious organisms.
D. derivation from the walls of embryonic gill pouches.
E. close proximity to the heart. (A) 2-3-4

421. Which of the following approaches gives the best promise of determining whether plant sap goes into the digestive tracts of aphids because of some characteristic of protoplasm, or of the sap itself, or because of aphid suction?
A. Applying a manometer to the cut surface of a phloem tube in the plant stem
B. Studying the anatomy of the stomach muscles of aphids
C. Measuring the osmotic pressures of root cells and leaf cells at the ends of columns of phloem cells
D. Measuring rates of transpiration and food manufacture in leaves
E. Allowing the aphid to pierce the plant stem, then cutting off the aphid from the proboscis and observing whether sap flows through the proboscis (E) 2-3-5
440. A new ultramicroscopic (<0.01 µ long) cell organelle is reported by an electron microscopist. Another biologist challenges the report and claims the organelle is an artifact formed by the deposit of the chemical compounds used in the preparation of the cells. Which experimental procedure would provide the best test of this hypothesis?

A. Analyze the cells chemically to see if they contain the chemical compound in question.
B. Look at living cells with a phase contrast microscope.
C. Use different electron microscopic preparation procedures on similar cells and see if the organelle is present.
D. Use the same procedure as the electron microscopist used on many different cells to see if they have the organelle.
E. Use the same procedure as the electron microscopist used on many different cells to see if they have the organelle.

441. It is hypothesized that chemicals are produced and accumulate in vesicles within nerve cells. When a nerve cell is stimulated, these vesicles move to the synaptic membrane and release their contents into the synaptic space. Which is the best test for this hypothesis?

A. Stimulate nerve cells and using the electron microscope determine if more vesicles appear near the synaptic membrane than in non-stimulated nerves.
B. Apply lysosomes to the nerve cell and determine if the transmission of nerve impulses across the synapse is inhibited.
C. Inject into the synaptic space an enzyme which breaks down the stimulatory chemical and determine if the transmission of the impulse is inhibited.
D. Inject into the synaptic space an enzyme which breaks down the stimulatory chemical and, using an electron microscope, determine if fewer vesicles appear in the nerve cell.
E. Using an electron microscope, compare the number of vesicles in nerve cells and gland cells.

442. The electron microscope yields information unobtainable with the light microscope because

A. it accepts ultrathin specimens.
B. it is possible to obtain much greater magnification than with the light microscope.
C. the resolution of fine detail is much greater than with the light microscope.
D. it is not necessary to use colored stains to obtain contrast.
E. the specimen always contains electrons.

(2-2-6)

443. The light microscope yields information unobtainable with the electron microscope because

A. only killed and fixed cells can be examined with present electron microscopes.
B. better resolution can be achieved using the light microscope.
C. better contrast can be achieved using the light microscope.
D. not all specimens emit electrons.
E. only ultrathin sections can be examined using the electron microscope.

(2-2-6)

444. In a laboratory test, peptides from the fractionated hemoglobin of sickle-cells and of normal cells took different positions on chromatographic paper.

A. Involves an expectation, an anticipated observation to be made as a result of experimentation or investigation.
B. An empirical generalization (a conclusion formulated by inductive reasoning from a particular set of observations; it is an assumption which is believed to be true in most or all instances).
C. A postulate or a theory (an imaginary set of conditions which is proposed for the purpose of explaining large sets of facts and empirical generalizations).
D. A hypothesis or prediction (formulated by deductive reasoning from facts and postulates; it is an expectation, an anticipated observation to be made as a result of experimentation or investigation).
E. A statement known to be false, or an illogical conclusion from the known facts.

(2-1-6)

445. Certain patterns of light and dark areas on X-ray photographs of positive-Feulgen staining organelles are the same for all cells.

A. Constant for all such molecules and are terminal, whereas the adaptor nucleotide triplets which are at the "nub" or bend and which code particular amino acids to particular mRNA triplets, are variable.
B. Involves giving the plant the appearance of a tall cone.
C. The effect of auxins on growth of stem tips.
D. The electron microscope. (A) 2-2-6
E. The shape of cellulose molecules.

(2-3-6)

446. The geometric configuration of the deoxyribonucleic acid is a double helix.

A. The nucleotides of RNA which bond amino acids are constant for all such molecules and are terminal, whereas the adaptor nucleotide triplets which are at the "nub" or bend and which code particular amino acids to particular mRNA triplets, are variable.
B. Involves giving the plant the appearance of a tall cone.
C. The effect of auxins on growth of stem tips.
D. The electron microscope. (A) 2-2-6
E. The shape of cellulose molecules.

(2-3-6)

447. During template replication of RNA by DNA, the uracil nucleotide forms as a complement of the adenine nucleotide.

A. Involves giving the plant the appearance of a tall cone.
B. The effect of auxins on growth of stem tips.
C. The shape of cellulose molecules.
D. The electron microscope. (A) 2-2-6
E. The shape of cellulose molecules.

(2-3-6)

448. The nucleotides of RNA which bond amino acids are constant for all such molecules and are terminal, whereas the adaptor nucleotide triplets which are at the "nub" or bend and which code particular amino acids to particular mRNA triplets, are variable.

A. Involves giving the plant the appearance of a tall cone.
B. The effect of auxins on growth of stem tips.
C. The shape of cellulose molecules.
D. The electron microscope. (A) 2-2-6
E. The shape of cellulose molecules.

(2-3-6)

449. In most plants, the number of stomates on the underside of leaves exceeds the number of stomates on the upper surface.

A. Involves giving the plant the appearance of a tall cone.
B. The effect of auxins on growth of stem tips.
C. The shape of cellulose molecules.
D. The electron microscope. (A) 2-2-6
E. The shape of cellulose molecules.

(2-3-6)

450. The shape of a pine tree is excurrent, the branches giving the plant the appearance of a tall cone. The best explanation of the development of this form involves

A. competition among adjoining trees for sunlight.
B. the effect of auxins on growth of stem tips.
C. efficiency of water transport from ground to leaves.
D. adaptation for wind pollination.
E. the shape of cellulose molecules.

(2-3-6)
451. In many metazoan intestines, the lining epithelium is made of very tall columnar cells. The efficiency of this arrangement is correlated with which of the following?
A. The maximum area of exposure of each to the lumen
B. The most extensive blood vessel supply to each cell
C. The largest number of mitochondria per cell
D. The largest possible enzyme-secreting organelles
E. The largest number of cells exposed to the lumen

452. Chromosomes occasionally “break”. Sometimes the chromosome fragment is attached to another chromosome, other times it is not. If the fragment is not attached to another chromosome or does not contain a centromere, it fails to orient on the metaphase plate, lags during anaphase, and does not enter the reforming daughter nuclei. The above paragraph supports the view that the centromere functions in:
A. chromosome replication.
B. chromosome movement.
C. nucleolar formation.
D. chromosomal control of the cell.
E. spindle apparatus formation.

453. Which of the following is not functionally analogous with the others in its group?
A. Green gland
B. Laurer's canal
C. Malpighian tubule
D. Kidney tubule
E. Nephridium

Items 454-460.

Which of the following plant structures is functionally most analogous to the human structures listed below: (A) Cork (B) Embryo sac (C) Ovary (D) Phloem tube (E) Pollen grain (F) Root hairs (G) Stem tip (H) Stoma (I) Style (J) Xylem.

454. Vein
455. Hypophysis
456. Mouth
457. Nostril
458. Stratum corneum
459. Vagina
460. Vertebral column

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

462. Epithelial cells from an adult mammal, when grown in tissue culture, often do not differentiate unless some other tissue such as mesenchyme is present. The most likely of the following explanations of this is
A. there is no possibility of epithelial cells alone making a complete mammal
B. epithelial cells must ingest food but do not ingest their own kind.
C. mesenchyme cells release a substance which stimulates epithelial cells to differentiate.
D. epithelial cells alone are immobile, but move when pushed by differentiating muscle cells.
E. mesenchyme cells can differentiate into many tissues including epithelium.

463. Chromosomal spindle fibers and continuous spindle fibers have different internal molecular structures. (E) 2-2-4

464. Spindle fibers contribute to the conversion of messenger RNA nucleotide sequences to DNA nucleotide sequences. (E) 2-2-6

465. Chromosomal fibers extend from the centromeres toward the poles. (A) 2-2-6

466. ADP concentrations in the region of the spindle increase as the spindle contracts. (D) 2-2-6

467. Following metaphase, the two sets of daughter chromosomes are pushed apart by the elongation of the spindle fibers. (C) 2-2-6

468. Fibers connecting centromeres with centriole regions are produced from the centromere (C) 2-2-6

469. Nucleolar RNA base sequences are complements of the chromosomal DNA base sequences. (B) 2-1-6

467. Separation and migration of centrioles toward opposite poles begins during prophase. (B) 2-2-1

471. Radioactive phosphate is present along spindle fibers during mitosis in cells which have been treated with ATP prepared from radioactive phosphorus. (D) 2-2-6

472. Fragments of chromosomes lacking centromeres do not move toward the poles during anaphase. (A) 2-2-6

473. If and how the spindle apparatus contributes to the movement of chromosomes is unknown. (A) 2-2-12

475. Contraction of spindle fibers in early mitosis requires a high source of quick energy which is supplied by a particular organic compound containing three high energy phosphate bonds. (C) 2-2-1

476. Pairing of homologues during metaphase is requisite to the onset of mitotic anaphase. (E) 2-2-2

477. Anaphase II of meiosis is initiated by the duplication of the centromere into sister centromeres and the separation of these sister centromeres as their respective chromatids move toward opposite poles. (B) 2-2-1

“There are thus two types of anaphase movements, each probably having a different molecular mechanism. One concerns the chromosomal fibers and the other the spindle proper. These two types of movements may participate in more or less proportion according to the cell type.

"The problem of the actual attachment of the spindle fibers to the centromeres is an important point in this discussion. This has been confirmed by electron microscopy... and it has been postulated that the chromosomal spindle fibers are developed from the centromere of each chromosome and grow toward the poles of the cell. The fact that chromosomal fragments that have no centromere do not undergo anaphase movements confirms the importance of these spindle fibers in chromosomal movement." -- from CELL BIOLOGY by DeRobertis, Nowinski and Saez (Saunders)

For items 463-480 use the following key.

KEY: A. A fact about mitosis presented in the passage; or a restatement of a fact given in the passage
B. A fact, or a true statement, but not presented in the passage
C. An hypothesis, or assumption, which is presented in the passage
D. An hypothesis, or deduction which is not presented in the passage, but which is logical and is directly deducible from material in the passage
E. A false statement, or an illogical conclusion
The arrangement and the number of internal rod-like structures of centrioles are essentially the same as those in cilia and flagella. (B) 2-2-1

The contraction and thickening of the respiratory chain (i.e., the electron transport chain) is associated with the migration of the sister chromatids toward opposite poles. (E) 2-2-6

The comparative degree of participation of the fibers attached, and the fibers unattached, to centromeres during separation and migration of sister chromatids is related to cell type. (C) 2-2-6

For items 481-488 use the following key.
KEY: A. I is numerically greater than II.
B. II is numerically greater than I.
C. I and II are numerically equal.
D. Either I or II can vary numerically.
E. Both I and II can vary numerically.
The number of --

481. I. cilia on a Paramecium aurelia
   II. pseudopodia on an Amoeba proteus
   (A) 2-2-6

482. I. metanemes in an earthworm.
   II. metanemes in a human being. (A) 2-3-6

483. I. atoms in a chlorophyll molecule.
   II. atoms in an acetylcholine molecule.
   (A) 2-1-6

484. I. kinds of amino acids normally absorbed by the human intestine.
   II. kinds of fatty acids normally absorbed by the human intestine.
   (A) 2-1-6

485. I. paramecium contractile vacuole contractions per minute in 3% aqueous solution of sodium chloride.
   II. paramecium contractile vacuole contractions per minute in fresh water.
   (A) 2-2-6

486. I. peripheral filaments in a cilium.
   II. peripheral filaments in a centriole.
   (C) 2-2-6

487. I. paired locomotor appendages on a crayfish.
   II. paired locomotor appendages on a centipede.
   (B) 2-3-6

488. I. paired locomotor appendages on a mosquito.
   II. paired locomotor appendages on a grasshopper.
   (B) 2-3-6

For items 489-491 use the following key.
KEY: A. I is quantitatively greater than II.
B. II is quantitatively greater than I.
C. I and II are quantitatively equal.
D. Either I or II can vary quantitatively.
E. Both I and II can vary quantitatively.

489. I. Speed of contraction of visceral muscle.
   II. Speed of contraction of skeletal muscle.
   (B) 2-2-6

490. I. Speed of contraction of visceral muscle.
   II. Speed of contraction of cardiac muscle.
   (B) 2-2-6

491. I. Greatest dimension of a bacterium.
   II. Greatest dimension of a human erythrocyte.
   (D) 2-2-6

Essay Questions
Questions 492-495. Propose a research program which will determine

492. what influence the shape of a protein molecule has on its role in metabolism.
   2-1-5

493. why human neurons and human fibroblasts resemble each other in shape.
   2-2-5

494. whether differences in mitochondrion structure reflect differences in reaction sequences they perform.
   2-2-5

495. whether a large territory such as a continent can be usefully divided up into carefully plotted ecosystems with contiguous borders.
   2-4-5

496. A Portuguese man-of-war colony includes many individuals of diverse forms and different contributions to the welfare of the colony. Discuss the evidence bearing on whether the forms of the individuals are determined by their functions, or their functions are determined by their forms.
   2-4-4

497. Propose a hypothesis which will satisfactorily explain the following set of data:
1. Dibenanthracene has both carcinogenic and embryonic organizer properties.
2. Pleiotropic genes occur capable of producing more than one phenotypic character.
3. Several different chemical substances act as lactic dehydrogenases.
   2-1-5

498. Propose a procedure to determine to what extent the pineal eye of a tuatara functions as a visual organ.
   2-3-5

499. Describe the structure and physiology of a biome in terms comparable to those used in describing the structure and physiology of a single organism.
   2-4-5

500. What special properties possessed by water are important factors in the properties of biological systems at the cellular and subcellular level?
   2-2-1

501. Diagram a short segment of a polypeptide chain and indicate the bonds that will tend to stabilize an α-helical configuration.
   2-1-2

502. What two things could be done to bring about the aggregation of dissociated sponge cells that are in cold, but otherwise normal sea water? (None of the original conditions in which the cells are found need prevail.)
   2-2-2

503. What would have to occur at the chromosomal level in order for a cell to shift from the production of LDH that is inhibited by high amounts of pyruvate to an LDH that is not greatly inhibited by high amounts of pyruvate?
   2-2-2

504. This question refers to regulatory devices.
(a) In general, what is meant by the engineering term "negative feedback"?
(b) Give an example of an intracellular (intra: "within one") regulatory device that operates on this principle. Briefly show how it is a negative feedback device.
(c) Give an example of an intercellular (inter: "between two or more") regulatory device that operates on the same principle. Briefly show how it does so operate.
   2-1-3

505. Propose a procedure for determining to what degree the olfactory sacs of migrating salmon may enable the fish to return to their home streams to spawn.
   2-3-5

506. Describe a cat as if you were an engineer discussing a mouse-catching machine.
   2-3-5

507. How would you go about determining whether the geometric form of a paramecium is the most efficient one for its path and mode of locomotion?
   2-3-5
508. The behavior of an ameba indicates that it can distinguish a distance between
A. moving and stationary organisms.
B. yellow and green objects.
C. round and elongated algae.
D. black and white objects.
E. radioactive and non-radioactive substances. (A) 3-2-1

509. Muscle tissue may be stimulated to contract by all of the following except
A. the touch of a needle.
B. contact with 1% hydrochloric acid.
C. the odor of clove oil.
D. a summation of subliminal nerve stimuli.
E. stretching of the muscle. (C) 3-2-1

510. Bird song commonly expresses
A. hunger.
B. pugnacity.
C. euphoria.
D. territoriality.
E. courthship. (D) 3-3-1

511. According to recent findings, what appears to be the main purpose that motivates the male robin to sing?
A. He thereby attracts the female of his choice.
B. He consciously provides aesthetic beauty of sound in the world of nature.
C. He proclaims to the world that he is happy.
D. He thereby attempts to frighten away cats and other enemy species.
E. He thereby warns other male robins to keep off his domain. (E) 3-3-1

512. According to recent research findings, the female robin appears to be attracted to a particular male for which of the following reasons?
A. The aesthetic beauty of his plumage
B. The enchantment of his song
C. His manifest sexual virility
D. His attentiveness to her
E. His dominance of a specific territory

513. The return of salmon to the river of their origin is due to
A. racial memory.
B. chemotaxis.
C. thigmotropism.
D. recognition of visual landmarks.
E. geomagnetic sense. (B) 3-3-1

514. The social structure of a bird flock concerned with relative dominance of its members is called the
A. peck order.
B. rassenkreis.
C. overburden.
D. rasate.
E. axial gradient. (A) 3-4-1

515. Which of the following classes of vertebrates has no known representative which glides through the air on modified appendages and/or skin folds?
A. Osteichthyes
B. Amphibia
C. Reptilia
D. Aves
E. Mammalia

516. Social hierarchy results in
A. increased competition for mates.
B. increased competition for food.
C. reduced energy expenditure.
D. reduced dominance.
E. reduced gene frequencies. (C) 3-4-1

517. By selective breeding, it has been possible to shift levels of
A. aggressive behavior in chickens.
B. sexual behavior in guinea pigs.
C. docility (to man) in dogs.
D. all of the above.
E. A and B above, but not C. (D) 3-3-3

518. The rank position of a dairy cow is largely a function of
A. her seniority in the herd.
B. the acreage allotted to the herd.
C. the quality of the available forage.
D. the number of cows in the herd.
E. the breeds of cattle in the herd. (A) 3-4-2

519. A Vorticella responds to vibration by quick contraction of its stalk. However, repeated vibrations produce less and less response. This is the phenomenon of
A. compensation.
B. discrimination.
C. instinct.
D. habituation.
E. thigmotropism. (D) 3-2-2

520. The behavior of a vine in climbing a tree is best described as
A. tropic.
B. agonistic.
C. mimetic.
D. conditioned.
E. compensatory. (A) 3-3-2

521. When a spider spins an orb-web, the spacing of the strands is a function of the
A. size of the intended prey.
B. altitude as represented by atmospheric pressure.
C. length of parts of the spider's body.
D. diameter of the spinnerets.
E. specific gravity of the spider's silk. (B) 3-3-2

522. A biologist plans to study the group behavior of monkeys. In order to avoid generalizing from aberrant observations, he would do best to select for observation
A. a group at the center of the region inhabited by monkeys.
B. a group at the periphery of the region inhabited by monkeys.
C. a group containing a small number of individuals.
D. a group containing a large number of individuals.
E. many groups of monkeys. (E) 3-4-2

523. A trained planarian, fed to an untrained planarian, transmits some of its behavioral characteristics. The mechanism of this transmission centers around a
A. nucleic acid.
B. protein.
C. polysaccharide.
D. lipoid.
E. steroid. (A) 3-1-3

524. Which of the following will be most likely to occur when an oak leaf stoma is opening more widely?
A. Water molecules enter the adjacent guard cells.
B. The atmosphere outside the stoma is becoming less humid.
C. Salt molecules are being excreted by the adjacent guard cells.
D. Auxins are accumulating in the guard cells.
E. A cool night is setting in. (A) 3-1-3

525. Seasonal changes bring on display of breeding behavior in some birds and mammals. The mechanism of this effect involves especially
A. thymic corpuscles.
B. gustatory epithelium.
C. Malphigian corpuscles.
D. Islets of Langerhans. (E) 3-2-3
E. retinal rod cells.
526. A freshwater ameba lives in a pond which has become quite stagnant and is about to dry up. A likely response of the ameba is: 
A. gamete formation. 
B. encystment. 
C. development of pyrenoids. 
D. change to a parasitic phase. 
E. elimination of a large part of its DNA. (B) 3-2-3

527. An Obelia polyp responds to the close passage of a crustacean by a quick withdrawal into its exoskeleton. After repeated passages of such crustacean, however, the polyp withdraws less and less completely, and finally remains fully extended. This is an example of: 
A. habituation. 
B. agonistic behavior. 
C. investigative behavior. 
D. territoriality. 
E. thigmotropism. (A) 3-3-3

528. Cow A consistently threatens Cow B with impunity; Cow B always retreats without a fight. This is an example of: 
A. dependent assortment. 
B. homozygous dominance. 
C. habituation. 
D. epimeletic behavior. 
E. dominance hierarchy. (E) 3-4-3

529. Population growth pressure is a probable cause of which of the following? 
A. Genetic drift 
B. Production of sterile hybrids 
C. Ecological isolation 
D. Migration of lemmings 
E. Abiogenesis (D) 3-4-3

530. Which is the most likely function of fighting between two adult male deer during mating season? 
A. Reduction of testosterone levels in the male deer. 
B. Competition over a female. 
C. Elimination of the weak from the breeding population. 
D. Identification of sex. 
E. Species identification (B) 3-4-3

531. A male turkey was imprint ed to humans and subsequently reared with a flock of "normal" turkeys. When sexually mature, it directed its courtship to: 
A. other turkeys in preference to humans. 
B. inanimate objects in preference to other turkeys. 
C. humans in preference to turkeys. 
D. only female turkeys but not males. 
E. only male turkeys but not females. (C) 3-3-4

532. A sexually immature male chicken is given daily injections of a hormone. At the end of two weeks, the investigator finds that the bird exhibits pre-mature sexual behavior and crowing, and that its comb and gonads are unduly enlarged. He concludes that the hormone must have been extracted from adult: 
A. testes. 
B. ovaries. 
C. thyroids. 
D. pituitaries. 
E. adrenals. (D) 3-3-4

533. The stigma of a swimming euglena travels in a helical path, yet the euglena will move directly toward a source of illumination. The best of the following ways to account for this is: 
A. The base of the flagellum, rather than the stigma, is the light-receptor organelle. 
B. The basal body of the flagellum acts as a brain, translating sensory impulses from the stigma with interpretations as if the basal body were the light receptor. 
C. The helical path pointed toward the light source submits the stigma to uniform illumination and if the euglena departs from this path, the stigma will receive uneven quantities of light, stimulating a return to uniformity. 
D. The helical path, with the stigma moving on the outside of the euglena with respect to the axis, keeps the stigma in the euglena's own shadow, and hence dark; if the stigma were directly exposed to the light, the euglena would alter its course. 
E. The helical course submits the stigma to a rhythmic alternation of increasing and decreasing illumination so long as it is headed toward the light source; departure from this rhythm stimulates a return to the optimum path. (D) 3-2-4

534. A mature female and a mature male dove are separated in adjoining cages. The male displays. The female builds a nest and lays infertile eggs. What function of courtship is demonstrated? 
A. Orientation or bringing together of individuals. 
B. Synchronization of release of gametes. 
C. Identification of sex. 
D. Reproductive isolation or species identification. 
E. Reduction of aggressive behavior (B) 3-3-4

Items 535-543 are concerned with animal behavior. Accounts 1-5 below summarize some research findings on animal navigation. Read each of these, then answer the questions involving them which follow. 

1. Storks from West Germany migrate to the Nile River around the west side of the Mediterranean Sea, while storks from East Germany migrate to the Nile around the east side. West German stork eggs were hatched and raised by East German storks. At migration time, the fledglings left their foster parents and flew to the Nile by the western route. 
2. Night migrating warblers were raised in confinement so they could never see the heavens. At migration time the birds were taken to a planetarium, the dome illuminated and the cage uncovered. The birds faced south. The cage was covered and the dome was rotated 90 degrees. When the cover was removed, the birds shifted 90 degrees and promptly faced toward artificial south. 
3. Bees are known to receive directions from the sun; however, it was found that they could still get their bearings if the sun were covered by clouds, so long as some blue sky remained. Using polaroid sheeting, von Frisch was able to show that polarized light from the sky was being used as a compass. 
4. The sandhopper, a nocturnal inhabitant of the Italian coast, if taken some distance back from the sea will return. East coast hoppers will turn eastward and west coast hoppers will turn westward. If a west coast hopper is taken to the east coast, it will orient westward and hop to its destruction. The same will be true of eastern sandhoppers taken to the west coast—they will hop eastward. 
5. Bees shipped from the northern to the southern hemisphere and vice versa are unable to navigate successfully. Apriarists believe that navigational ability is due to a mutation, one which is useful only in the northern hemisphere and another which functions only in the southern hemisphere. 

—— Reported by Drs. Lorus & Margery Milne in AUDUBON ENCYCLOPEDIA

535. In which of the above situations does the evidence clearly indicate that the behavior in question was not learned by observing the parents? 
A. #1 
B. #2 
C. #3 
D. #4 
E. #5 (A) 3-3-4
536. The most convincing evidence that the ability to navigate is probably hereditary is provided by
A. #1.  
B. #2.  
C. #3.  
D. #4.  
E. #5.  (A) 3-3-4

537. Which part of the brain probably plays the major role in the above cases of navigation which involve vertebrates?
A. Olfactory lobe  
B. Corpus striatum  
C. Medulla  
D. Hypophysis  
E. Infundibulum  (B) 3-3-4

538. It has been discovered that ommatidia are sensitive to directional orientation of light waves. In which of the above cases could this have some bearing on the organism's ability to navigate?
A. #1 only  
B. #2 only  
C. #1 and #2 but none of the others  
D. #3, #4, and #5, but not #1 and #2  
E. None of the five described  (D) 3-3-4

539. Which of the above described research situations provides evidence that celestial cues are necessary to navigation?
A. #1 only  
B. #4 only  
C. #1 and #4 but none of the others  
D. #2 and #3 but none of the others  
E. All of the five situations described  (D) 3-3-4

540. In which of the organisms studied are we uncertain as to the mechanism used to navigate?
A. #2 only  
B. #1, #4  
C. #2, #3  
D. #2, #5  
E. #3, #5  (B) 3-3-4

541. The migration of cowbirds is most similar to which of the above?
A. #1  
B. #2  
C. #3  
D. #4  
E. #5  (A) 3-3-5

542. Salamanders return to their home pool from as far as three miles away even over ridges 1000 feet high and even when deprived of sight. This is most similar to
A. #1  
B. #2  
C. #3  
D. #4.  
E. #5.  (D) 3-3-4

543. Cases such as the storks and warblers cause us to wonder about the validity of a fundamental assumption of science. Which of the following is it?
A. All events have causes.  
B. Objects exist independently of the observer.  
C. The universe is orderly and operates according to natural law.  
D. Presently recognized sense organs are the only means of contact with the external world.  
E. None of the above.  (D) 3-3-4

544. A dog is gnawing on a bone. Suddenly he grips the bone hard with his teeth and growls. The most likely stimulus for this behavior is
A. the strident call of a crow in a nearby tree.  
B. the odor of a horse wafted to him on the wind.  
C. the sight of the approach of another dog.  
D. the sound of his master's voice calling him home.  
E. a knob on the bone which caught his canine tooth.  (C) 3-3-4

545. Geese over much of Canada tend to fly south at about the same time of year. This may be due to an environmental effect on their endocrine system. The most likely of the following environmental factors to bring this about is
A. increase in atmospheric pressure.  
B. dropping of the maximum daily temperature below a certain figure.  
C. snowfall of a certain depth.  
D. shortening of daylight hours.  
E. dark of the moon.  (D) 3-4-4

546. Appearance of a bat flying about is followed by the immediate altering of flight patterns in a population of moths, which drop to the ground. The most likely way the moths have of sensing the bat's presence is
A. the sense of smell.  
B. vibration sense.  
C. kinesthetic sense.  
D. warning cries of birds.  
E. temperature sense.  (B) 3-4-4

547. Different species of jungle fowl, thought to be ancestral to our domestic chickens, show a variety of social hierarchies ranging from no peck order to a linear peck right. This might be best interpreted as evidence for which of the following?
A. Social hierarchies are variable in nature.  
B. There is an age relationship to social hierarchy.  
C. Hierarchies are social on genetic endowment.  
D. Chickens have no behavior.  
E. None of these.  (C) 3-4-4

Items 548-552 are based on the following observations:
A certain species of marine mammals feeds on fish and breeds on rocky coasts. Mature males establish territories on the coasts by physical combat which often results in death of the loser. Females live within the territories in "harems." Social status in the harems is established by vocalization and aggressive positions (bluff). The number of females within a harem depends upon the size of the male's territory. The male mates with all females in his harem. Immature males are relegated to small isolated "bachelor" areas. These males do not have harems and sometimes challenge the mature males for possession of their territory by vocalization, bluff, and occasional "fights."

548. What is the main function of the territory?
A. To make certain that males have mates  
B. To make certain that all individuals have food  
C. To keep the population size constant by limiting feeding areas  
D. To provide a place for the harem  
E. To eliminate the poorest fighters from the breeding population  (D) 3-4-4

549. Which of the following is the major factor involved in the determination of size and number of territories?
A. Number of nesting sites  
B. Size of breeding grounds  
C. Size of feeding area  
D. Social order  
E. Violence of the combats  (B) 3-4-6

550. What function might the "bachelor" areas serve?
A. A reservoir of expendable reproductive animals  
B. A strengthening of the potential mating stock by making the young males more aggressive  
C. A strengthening of the present mating stock by constantly subjecting the mature males to physical combat  
D. Inhibitory feedback which prevents overbreeding by the mature males  
E. Selective mating of males and females  (A) 3-4-4
551. Which is probably the most important function of the social hierarchy among the cows?
   A. To divide the available food evenly
   B. To establish some mating order
   C. To establish territories
   D. To reduce energy expenditures from fighting
   E. To select only the strongest females for mating

   (D) 3-4-4

552. How might the territory and harem system be related to evolution of the species? It will
   A. enable the population to increase to its maximum
   B. decrease the aggressive nature of the species
   C. increase variation within the population
   D. keep the population small, permitting genetic drift.
   E. reduce variation within the population.

   (E) 3-4-6

553. Carnivorous species are found in which of the following phyla of animals?
   1. Coelenterata
   2. Platyhelminthes
   3. Annelida
   4. Mollusca
   5. Arthropoda
   6. Echinodermata

   A. All six phyla
   B. 1, 2, and 5, but not 3, 4, and 6
   C. 1, 5, and 6, but not 2, 3, and 4
   D. 2, 4, 5 and 6, but not 1 and 3
   E. 2, 4, and 6, but not 1, 3, and 5

   (A) 3-3-5

554. A stickleback fish vigorously attacks other sticklebacks near its nest, but the strength of the attack diminishes the further the fish is from its nest. This phenomenon is in accordance with
   A. heterozygosity
   B. dominance hierarchies
   C. social integration
   D. territorial behavior
   E. maintenance behavior

   (D) 3-3-3

555. The behavior pattern of a certain kind of crab is cyclic and concurrent with tidal cycles. If the crab is kept in a refrigerator for six hours, then restored to its usual temperature, its behavioral pattern is six hours out of phase with tidal cycles. The most likely of the following explanations of this is that
   A. cold anesthetizes a crab's central nervous system.
   B. complete darkness stops a crab's biological clock.
   C. crabs respond to no other external stimuli except light and heat.
   D. in winter, the moon is slightly slower in changing phases than in the summer.
   E. enzyme manufacture is at a standstill while the crab is being refrigerated.

   (E) 3-1-6

Items 556-557 are concerned with the following situation. In the "Chimpomat" experiment, chimpanzees were shown how to insert coins in a machine and obtain grapes. After they had learned this, coins of different kinds were introduced, some of which would deliver more grapes than others. The chimpanzees soon learned to prefer the coins which produced more grapes. Then a work machine was installed. If the chimpanzee would work on the machine for a time, it would deliver a coin. In the second part of the experiment, chimpanzees were permitted at the work machine only occasionally. Between times they got no food. When exposed to the machine, some chimpanzees would work vigorously for coins, go immediately to the grape machine and use them all. Others would take their coins and hide some of them. During the intervals when not permitted at the work machine they would return and get their hidden coins to obtain grapes.

556. The most significant conclusion to be drawn from the first part of this experiment is that chimpanzees
   A. can copy human procedures.
   B. like to work.
   C. can distinguish one coin from another if the coins are observably different.
   D. can recognize different values of coins.
   E. realize that work is essential for survival.

   (D) 3-3-6

557. The most significant conclusion to be drawn from the second part of the experiment is that
   A. all chimpanzees will work if they must.
   B. chimpanzees have an instinct for hoarding.
   C. some chimpanzees are loafers while others are diligent.
   D. some chimpanzees have a more intense hunger drive than others.
   E. some chimpanzees can plan for the future.

   (C) 3-3-6

558. The protist Stentor was sprayed with a jet of red dye. It first waved about trying to avoid the dye. At first many jets of dye were played upon the Stentor before it would finally detach itself and move to a new location. If it were followed up immediately and again squirted with dye, it would move more promptly. Finally it would move at the first jet of dye. If a minute were allowed to pass before the dye hit the Stentor, it would react just as it did when first exposed.

   The most significant conclusion to be drawn from this experiment is that
   A. there is a short term biochemical state.
   B. Stentors have short memories.
   C. Stentors develop short term immunity to dye.
   D. the conditioning of Stentor lasts only a short time.
   E. Stentor will tolerate dye better if given a short rest.

   (D) 3-3-6

559. A vast migration of lemmings occurs periodically in the Scandinavian peninsula. The most likely cause is
   A. increase in population pressure.
   B. an unusually cold winter.
   C. mutation affecting cells of the cerebral.
   D. widespread decrease in thyroid secretion among the lemmings.
   E. an epidemic of ectoparasites.

   (A) 3-4-6

560. Which of the following variables would be expected to correlate most highly with the peck order of a flock of chickens?
   A. Proportion of vitamins in the diet
   B. Color of the bird
   C. Quantity of certain endocrine secretions
   D. Thickness of the skin
   E. Deployment of nerve endings in the skin

   (C) 3-4-6

Essay Questions

Questions 561-565. Propose a research program which will determine

561. whether the movement of RNA molecules through nuclear membranes is accomplished by a form of phagocytosis.

   3-1-5

562. whether negatively charged molecules diffuse into red blood cells more readily than positively charged molecules of the same size and shape.

   3-1-5

563. whether the movements of chromosomes during meiotic diakinesis are a function of electrostatic charges.

   3-2-5

564. whether Didinium attacks paramecia rather than other ciliates because of the particular proteins of the paramecium membrane.

   3-2-5
565. Whether the behavior of an ameba in capturing a motile protozoan differs from the behavior of the same ameba in ingesting a nonmotile alga as the result of the vibrations in the water set up by the moving prey in contrast to the absence of such vibrations in the nonmotile organism.

566. Propose a procedure to determine the mechanisms for "playing possum" in opossums.

567. An experimenter has a square glass container ten feet long and ten feet wide. He fills it to a depth of two inches with pond water, and adds a large population of euglenas evenly distributed through the medium. He arranges an illumination gradient such that the north side of the container receives a foot candle of light, the south side is dark, and the intermediate regions display an even gradation between the two. Positive electrodes are set up along the east side and negative electrodes along the west side with a potential difference of 1 volt between the two sets. A heating device at the northeast corner maintains the water at this corner at a temperature of 50°C and a cooling device at the southwest corner maintains the temperature there at 0°C. The temperature grades regularly between these two corners. If the euglenas are allowed to move freely under these circumstances, what is likely to be their equilibrium distribution?

568. Devise an appropriate research program to test this hypothesis. Acute food shortage in the range normally occupied by a pack of wolves results in migration of the pack to areas of more abundant food.

569. Devise an experiment to show that rats can or cannot detect a lethal radioactive field.
SECTION 9. EXAMPLES: GENETICS

Objective Items

570. With respect to the type of hemoglobin produced, the gene for sickle-cell trait in human beings is
A. dominant in both sexes.
B. recessive in both sexes.
C. dominant in males only.
D. dominant in females only.
E. neither dominant nor recessive. (E) 4-1-1

571. The transformation experiments using pneumococcus bacteria gave evidence for the hypothesis that
A. bacteria have sexual reproduction.
B. chromosomes are made up of DNA.
C. DNA is the genetic substance.
D. RNA is the transfer link between DNA and protein synthesis.
E. the genetic code lies in the arrangement of amino acids in the protein in the nucleus. (C) 4-1-1

572. An example of a triploid tissue is
A. human placenta.
B. lily endosperm.
C. fern prothallus.
D. sea urchin pluteus.
E. oak gall. (B) 4-2-1

573. A student read a newspaper report of a study of nonchromosomal inheritance. Which of the following publications would be his best first source for locating studies on the same topic?
A. Scientific American.
C. Hereditas.
D. Biological Abstracts.
E. The Newspaper (D) 4-2-1

574. Which of the following is a sex-linked characteristic?
A. White eyes in Drosophila.
B. Adenine absence in Neurospora.
C. AB blood type in humans.
D. Albinism in maize.
E. Dark ears in Himalayan rabbits. (A) 4-3-1

575. The Hardy-Weinberg law enables us to
A. predict genetic ratio from individual matings.
B. map chromosomes.
C. calculate gene frequencies in a population.
D. predict population growth.
E. measure the rate of evolutionary change. (C) 4-4-1

576. The Hardy-Weinberg law is chiefly concerned with
A. gene frequencies.
B. osmotic phenomena.
C. electron transport.
D. prey-predator relationships.
E. geographic distribution. (A) 4-4-1

577. Genetic drift is most apt to occur in
A. tropical climates.
B. marine habitats.
C. high elevations.
D. small populations.
E. bacteria. (D) 4-4-1

578. Both transfer RNA and DNA are believed to be characterized by which of the following?
A. Both are composed of purine, pyrimidine, sugar and phosphate groups.
B. Both are unbranched linear macromolecules.
C. Both exist at least partially in a helical configuration.
D. All of the above.
E. None of the above. (D) 4-1-1

579. The best evidence available at present that the sequence of bases in a DNA molecule made by the Kornberg enzyme is a faithful replica of the sequence of bases in the "primer" is
A. the nearly identical base composition of primer and product.
B. the dependence of nearest neighbor frequencies on the kind of primer used.
C. the ability of strands of the product to combine with primer strands to form "hybrid" double-stranded molecules.
D. the requirement of the enzyme specifically for the deoxyribose triphosphates of the purine and pyrimidine bases.
E. not given in any of the above. (C) 4-1-1

580. The strongest evidence that DNA is the genetic material comes from
A. cytological examination of the behavior of DNA during cell division.
B. the absence in the cell of any other polymer capable of bearing information.
C. studies on the transformation of bacterial cells.
D. measurements of recombination frequencies to establish a genetic map.
E. studies on the specificity of the Kornberg enzyme. (C) 4-1-2

581. Which of the following is characteristic of a mouse homozygous for albinism?
A. It produces a white pigment in cells of its hair follicles.
B. It has a deficient capillary distribution.
C. It cannot manufacture melanin.
D. It does not absorb iron from its diet.
E. It lacks vitamin E. (C) 4-1-2

582. In order for a chemical to serve as a code for heredity, it is essential that the chemical be
A. able to form itself into long spiral chains.
B. subject to duplication.
C. composed of pyrimidines and purines.
D. easily changed.
E. transferable to different strains of organisms. (B) 4-1-2

583. An albino rat differs from a gray rat in that the albino rat
A. produces a white substance due to certain enzymes.
B. produces enzymes which digest pigment.
C. cannot produce enzymes used in a pigment-manufacturing reaction.
D. was raised in total darkness until weaning time.
E. has a different molecular structure in its hemoglobin. (C) 4-1-2

584. Which technique is most valuable in determining the genetic code?
A. Determine frequencies of crossing-over among genetic characteristics which are linked and map the genes.
B. Inject synthetic DNA of known composition into pneumococcus bacterial cultures and observe what biochemical changes occur.
C. Irradiate Neurospora ascospores and observe what biochemical mutants occur.
D. Mix ATP, enzymes, amino acids, ribosomes and synthetic RNA of known composition and observe what kind of polypeptides occur.
E. Mix different purines and pyrimidines (organic bases) together with viruses and observe what changes occur in the viruses. (D) 4-1-2

Items 585-597. Categorize the pair of entities in each item according to the following key.

**KEY:**
A. I is greater than II.
B. is less than II.
C. I is exactly or approximately equal to II.
D. I may stand in more than one of the above relations to II.
585. (I) The total number of phosphate residues in a single strand of DNA
   (II) The total number of deoxyribose residues in the same strand
   (C) 4-1-1

586. (I) The total number of adenine plus thymine residues in a native, double-stranded DNA molecule
   (II) The total number of guanine plus cytosine residues in the same structure
   (D) 4-1-1

587. (I) The total number of adenine residues in a native, double-stranded DNA molecule
   (II) The total number of thymine residues in the same structure
   (C) 4-1-1

588. (I) The total number of guanine residues in a single strand of DNA
   (II) The total number of cytosine residues in the same structure
   (D) 4-1-1

589. (I) The importance of cell contact for the transfer of genes from one bacterial cell to another by means of transformation
   (II) The importance of cell contact for the transfer of genes from one bacterial cell to another by means of transduction
   (C) 4-2-2

590. (I) The total number of purine plus pyrimidine bases in a molecule of double-stranded DNA
   (II) The total number of phosphate groups in the same molecule
   (C) 4-1-2

591. (I) The probable mass of DNA in a cell chosen at random
   (II) The probable mass of protein in the same cell
   (B) 4-1-2

592. (I) The number of genetic linkage groups (and "chromosomes") in an E. coli cell
   (II) The number of genetic linkage groups (and "chromosomes") in a thyroid cell
   (B) 4-3-2

593. (I) The size of an average DNA molecule
   (II) The size of an average protein molecule
   (A) 4-1-2

594. (I) The ability of thyroid cell DNA to bind thyroid cell mRNA in a hybridization experiment
   (II) The ability of thyroid cell DNA to bind E. coli mRNA in a hybridization experiment
   (A) 4-1-3

595. (I) The number of genetic linkage groups in a eukaryotic cell
   (II) The number of genetic linkage groups in a prokaryotic cell
   (A) 4-2-3

596. (I) The number of genes in an E. coli cell growing in minimal medium
   (II) The number of genes in the same cell growing in a rich medium
   (C) 4-4-3

597. (I) The probable number of cistrons in an A. aerogenes genome
   (II) The probable number of cistrons in a thyroid cell genome
   (B) 4-1-3

Items 598-611 involve interpretation of the following diagram:

598. This diagram represents
   A. synapsing chromosomes in meiosis.
   B. DNA replication.
   C. crossing over of genes at reduction.
   D. ganglia of a flatworm.
   E. DNA being created from RNA. (B) 4-1-2

599. In locations identified with X we find
   A. genes.
   B. DNA.
   C. phosphates.
   D. sugars.
   E. bases. (D) 4-1-2

600. In locations marked with Y we find
   A. phosphates.
   B. sugars.
   C. genes.
   D. purines.
   E. pyrimidines. (A) 4-1-2

601. In locations marked with I, II, III, or IV we find
   A. ATP.
   B. DNA.
   C. sugars.
   D. phosphates.
   E. bases. (E) 4-1-2

602. If I is adenine, then II is
   A. thymine.
   B. guanine.
   C. cytosine.
   D. sugar.
   E. phosphate. (A) 4-1-2

603. If III is guanine, then IV is
   A. thymine.
   B. adenine.
   C. cytosine.
   D. phosphate.
   E. sugar. (C) 4-1-2

604. At location #10, we would find
   A. I and II respectively.
   B. III and IV respectively.
   C. II and I respectively.
   D. V and III respectively.
   E. Cannot be determined. (E) 4-1-2

605. At location #1 must be
   A. I
   B. II
   C. III
   D. IV
   E. Unknown (D) 4-1-2

606. At location #2 must be
   A. I
   B. II
   C. III
   D. IV
   E. Unknown (C) 4-1-2

607. At location #3 must be
   A. I
   B. II
   C. III
   D. IV
   E. Unknown (C) 4-1-2

608. On O or P, adenine will appear at position
   A. #4.
   B. #5.
   C. #6.
   D. #7.
   E. #8. (E) 4-1-2

609. Thymine will appear at
   A. #5.
   B. #6.
   C. #8.
   D. #5 and #8.
   E. #6 and #8. (A) 4-1-2
610. Cytosine will appear at
A. #4.
B. #6.
C. #7.
D. #4 and #6.
E. #6 and #7.  (E)  4-1-2

611. Guanine will appear at
A. #1.
B. #2.
C. #3.
D. #9.
E. None of the above.  (D)  4-1-2

Items 612-615 are based upon the following situation.

In a certain variety of peppers --

(1) Brown x Yellow

↓

All Red offspring

(2) Red x Red

↓

182 Red 59 Brown 61 Yellow 20 Green

For each item select the best response from the following key.

KEY:   A.   The statement is an empirical generalization or an observation.
B.   The statement can be deduced from theory plus observations, but cannot be established by empiricism alone.
C.   The statement can be refuted by observation alone.
D.   The statement cannot be refuted by observation alone, but can be refuted by deduction from theory plus observation.
E.   There is insufficient evidence to judge this statement.

612. Red is the result of a homozygous combination of a single pair of dominant genes.  (D)  4-1-2

613. Brown is the result of being homozygous or heterozygous for a dominant gene; the other genes affecting color must be recessive.  (B)  4-1-2

614. Green is the result of the presence of a single dominant gene, regardless of what other genes are present.  (D)  4-1-2

615. Yellow is the result of being homozygous or heterozygous for a dominant gene; the other genes affecting color must be recessive.  (B)  4-1-2

616. Of what importance to scientists is the knowledge of cross-over percentage?
A. It makes possible the mapping of chromosomes.
B. It neutralizes the effect of linkage.
C. It enables certain gene frequencies to increase in a population.
D. It proves that genes are the DNA in chromosomes.
E. It provides proof for the X-Y chromosome theory of sex determination.  (A)  4-2-2

617. Paramecium aurelia has a macronucleus and two micronuclei. Genetic material occurs in
A. the macronucleus only.
B. one micronucleus only.
C. both micronuclei but not the macronucleus.
D. all three nuclei.
E. none of the nuclei.  (D)  4-2-2

618. Animal X reproduced parthenogenetically for two generations. What must be assumed about the chromosome number of the second generation?
A. It was abnormal.
B. It was doubled.
C. It was not reduced during meiosis.
D. It was reduced by one-fourth.
E. It was reduced by one-half.  (C)  4-2-2

619. A technician studying a human blood smear notes that several of the white corpuscles have a small mass of chromatin close to the nuclear membrane. This indicates that the blood came from
A. a diabetic.
B. a hemophiliac.
C. a negro.
D. a male.
E. a female.  (E)  4-2-2

620. A man is hemophilic. This indicates that he
A. has an abnormal craving for drinking blood.
B. is afraid of the sight of blood.
C. is carrying a parasitic organism in his blood.
D. inherited the condition from his father.
E. inherited the condition from his mother.  (E)  4-3-2

Items 621-623 are based on the following:

One of Mendel's experiments was repeated. A plant heterozygous for green pod (Gg) was self-fertilized, resulting in 724 plants with green pods and 276 with yellow pods

\[ X^2 = \sum (\text{expected} - \text{observed})^2 \]

621. What is the most likely expected ratio?
A. 1 : 1
B. 2 : 1
C. 3 : 1
D. 4 : 1
E. 9 : 3 : 3 : 1  (C)  4-3-1

622. What is the approximate chi-square value for the results?
A. 0.5
B. 1.2
C. 2.4
D. 3.6
E. 4.8  (D)  4-3-2

623. How many degrees of freedom are there in this situation?
A. 1
B. 2
C. 3
D. 4
E. 15  (A)  4-3-2

624. Why were pea plants more suitable than cattle for Mendel's experiments?
A. There were no breeding records on cattle.
B. Pea plants can be self-fertilized.
C. Cattle are not easy to raise.
D. All pea plants have 2X chromosomes.
E. Cattle have many genetic traits.  (B)  4-3-1

Items 625-628 list genotypes of organisms with respect to four pairs of alleles. For each item select from the key the number of gametes that can be produced by an individual of the genotype listed in the item.

KEY:   A.   1
B.   2
C.   3
D.   4
E.   8

625. CCDDGgRR  (B)  4-3-2
626. CcDDGgRr  (D)  4-3-2
627. CCDDGGRR  (A)  4-3-2
628. CcDdGgRR  (E)  4-3-2
629. Based on the answers to the previous four questions, which formula best represents the relationship of number of kinds of gametes (X) to the number of heterozygous traits (n)?
A. \( X = 2^n \)
B. \( X = n \)
C. \( X = n^2 \)
D. \( X = n^2 + 1 \)
E. \( X = n^2 - 1 \)  
(C) 4-3-5

630. It is suggested that Queen Victoria of England possessed a gene for hemophilia. This would indicate that:
A. her father also possessed this gene.
B. hemophilia would occur in more of her male descendants than of her female descendants.
C. all of her daughters must have carried the gene for hemophilia.
D. all of her sons must have had a gene for hemophilia.
E. Victoria herself was hemophilic.  
(B) 4-3-2

631. A population of wild rats obeying the Hardy-Weinberg Law with respect to coat color would be expected to:
A. increase the proportion of dominant phenotypes.
B. increase the proportion of heterozygotes.
C. increase the proportion of homozygous recessives.
D. maintain a constant proportion of dominant to recessive genes.
E. eliminate heterozygosity.  
(D) 4-4-2

632. The frequency of a mutant gene in a population is expected to increase if that gene is:
A. dominant.
B. recessive.
C. sex-linked.
D. favorably selected.
E. cytoplasmic.  
(D) 4-4-2

633. Which would probably result in random genetic drift in a population?
A. Constant low mutation rate
B. Small population size
C. Interbreeding within this population
D. Selective reproduction
E. Large population size  
(B) 4-4-2

634. If some mutations are harmful, why are they not eliminated from a gene pool?
A. They are dominant and show up more frequently.
B. They are recessive and carried by heterozygous individuals.
C. They may have future survival value, hence are retained.
D. The Hardy-Weinberg Law enables them to survive.
E. The population size is usually so small that genetic drift occurs.  
(B) 4-4-2

635. The genetics of Neurospora has been extensively investigated. The type of genetic character commonly studied is represented by a mutant form which:
A. possesses purple spores.
B. does not synthesize methionine.
C. produces an elliptical mycelium.
D. fails to produce septa.
E. manufactures a deadly toxin.  
(B) 4-1-3

636. A biochemist compared base ratios of two compounds. To which of the following problems was his research most applicable?
A. Determining whether a certain DNA molecule produced a certain RNA molecule
B. Determining whether a certain enzyme catalyzed the synthesis of a certain protein
C. Finding the particular cells responsible for secreting a certain hormone
D. Comparing the effectiveness of two inhibitors of seed production in tomato fruits
E. Determining which substance in blood plasma was an antibody for a certain antigen  
(A) 4-1-3

637. Which would lead one to expect linkage of genes if we assume genes are on chromosomes?
A. The number of hereditary traits always exceeds the number of chromosomes.
B. Chromosomes physically cross over during nuclear divisions.
C. Mendelian ratios are not always observed.
D. Multiple alleles sometimes occur.
E. The most complex organism does not always have the most chromosomes.  
(A) 4-2-3

638. A geneticist wishes to study the production of phenotypic differences in organisms in which dominance plays no role. Which of the following conform to this specification?
A. Petals of a lily
B. Sporophytic filaments of a red alga
C. Spore capsules of a moss
D. Redias of a liver fluke
E. Ameboid stages of a slime mold  
(E) 4-2-3

639. Weismann's germplasm concept is particularly appropriate in discussions of:
A. relationships among the finches of the Galapagos Islands.
B. dominance of gametophytes in liverwort life cycles.
C. reproduction in endamebas.
D. near extinction of ginkgoes.
E. chromosome diminution in Ascaris embryology.  
(E) 4-2-3

640. Which best describes the relationship between auxins and a plant's developmental heredity? The addition of auxins from species x to developing seedlings of species y will probably:
A. change species y into species x which will give x offspring.
B. change species y to resemble species x but offspring will be one-half x and one-half y.
C. change growth and development in species y within species y's limitation but offspring will be y.
D. not affect growth and development in species y but offspring will be x.
E. not affect growth and development but offspring will be one-half x and one-half y.  
(C) 4-3-3

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

642. A bright red male cardinal possessed a genetic character of webbing of the toes. His mate, of a duller color, did not show this trait. It was noted that their offspring were peculiar in that the bright red male birds lacked the webbing, whereas the duller-colored female birds were web-footed. The most likely explanation of this phenomenon involves:
A. sex-linkage.
B. dominant epistasis.
C. recessive epistasis.
D. autosomal linkage.
E. sex influence.  
(A) 4-3-3
Items 643-651 refer to Table B and the following paragraph.
The Punnett square shown in Table B represents possible patterns of inheritance in dihybrid crosses where black (B) is dominant to white (b), and straight hair (S) is dominant to curly hair (s).

<table>
<thead>
<tr>
<th></th>
<th>BS</th>
<th>bS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS</td>
<td>Q</td>
<td>U</td>
</tr>
<tr>
<td>Bb</td>
<td>V</td>
<td>Z</td>
</tr>
<tr>
<td>bb</td>
<td>W</td>
<td>F</td>
</tr>
<tr>
<td>bs</td>
<td>T</td>
<td>X</td>
</tr>
<tr>
<td>Bb</td>
<td>Y</td>
<td>H</td>
</tr>
<tr>
<td>bb</td>
<td>S</td>
<td>K</td>
</tr>
<tr>
<td>bs</td>
<td>G</td>
<td>L</td>
</tr>
</tbody>
</table>

643. The genotype for organisms of type "J" is
A. Bbss.
B. bbSs.
C. BBss.
D. bbSS.
E. black and curly.

644. The phenotype for organisms of type "K" is
A. black, straight hair.
B. black, curly hair.
C. white, curly hair.
D. white, straight hair.
E. just like organism "U".

645. Which organism will show both recessive traits?
A. Type Q_
B. Type Z
C. Type V
D. Type G
E. Type L

646. Which organism will be white and homozygous for straight hair?
A. Type V
B. Type F
C. Type W
D. Type P
E. Type Q

647. An organism of type S has the same (identical) genotype as which organism?
A. Type X
B. Type U
C. Type Y
D. Type K
E. Type F

648. If organisms of type T and type H are crossed, what proportion of the offspring will show at least one recessive trait?
A. 9/16
B. 7/16
C. 6/16
D. 3/16
E. 1/16

649. Organisms of type V can produce how many genetically different gametes?
A. Zero
B. Two
C. Four
D. Five
E. Six

650. If organisms of type W and type G are crossed, what proportion of the offspring are expected to have curly hair?
A. 100%
B. 75%
C. 50%
D. 37.5%
E. 25%

651. If organisms of type W and type G are crossed, what proportion of the offspring are expected to be homozygous for both traits?
A. p = 62.5%
B. p = 50%
C. p = 37.5%
D. p = 25%
E. p = 12.5%

652. It has been estimated that 9 percent of the American Negro population are "non-tasters." On the basis of the Hardy-Weinberg principle, what part of the population is heterozygous for the taster trait?
A. 49%
B. 42%
C. 36%
D. 30%
E. None of alternatives A-D is correct.

Items 653-657 are based on the paragraph below.
Kenneth has blood type "B". His genotype is I b I°• His girlfriend Ann has blood type "A". Her genotype is I a I °. They plan to marry and have at least three children.

653. What is the probability that their first child will have blood type "AB"?
A. p = 1.00
B. p = 0.75
C. p = 0.50
D. p = 0.25
E. p = 0.125

654. What is the probability that their second child will be a girl with "O" blood?
A. p = 1.00
B. p = 0.75
C. p = 0.50
D. p = 0.25
E. p = 0.125

655. What are the chances that their first three children will have the same blood type?
A. 1/125
B. 1/64
C. 1/32
D. 1/16
E. 1/8

656. What are the chances that none of the above three children will have type "B" blood?
A. 32/64
B. 30/64
C. 27/64
D. 24/64
E. 21/64

657. What are the chances that only one child of the above three will have type "A" blood?
A. 9/64
B. 21/64
C. 27/64
D. 30/64
E. 37/64

658. What are the chances of a dark-haired couple having a red-haired child if each had a red-haired parent?
A. 0
B. 1/4
C. 1/2
D. 3/4
E. 1/1

9-5
659. What are the chances of this couple (item 658) having identical, red-haired twin boys?
A. 0
B. 1/600
C. 1/1200
D. 1/2400
E. 1/216,000

660. What are the chances of this couple (item 658) having red-haired twins (either identical or fraternal)?
A. 1/780
B. 7/3600
C. 13/1800
D. 13/3600
E. 119/450

Items 661-665 are based on inheritance in a certain species of bird. Eye color is controlled by one gene on a non-sex chromosome (autosome). Pink eye (P) is autosomal dominant to blue eye (p). Tail length is also controlled by an autosomal gene. Long tail (L) is dominant over short (l). Beak shape is also controlled by an autosomal gene. Sharp (S) is dominant over blunt (s). Assume the genes are on separate chromosomes.

661. A bird with genotype PpLlss mates with a ppL1Ss.
A. 100%
B. 75%
C. 50%
D. 33%
E. 25%

662. What is the chance of an offspring from the previous mating having pink eyes and long tail?
A. 9/16
B. 3/8
C. 1/4
D. 1/8
E. 1/16

663. What is the chance of an offspring from the previous mating having blue eyes, short tail, and blunt beak?
A. 27/64
B. 1/4
C. 3/32
D. 1/16
E. 0

664. A bird heterozygous for three traits is bred to a similar bird of opposite sex. What is the expected phenotypic ratio for the offspring?
A. 3 : 1
B. 9 : 3 : 3 : 1
C. 1 : 4 : 5 : 4 : 1
D. 1 : 7 : 21 : 35 : 21 : 7 : 1
E. 27 : 9 : 9 : 3 : 3 : 3 : 1

665. A homozygous pink-eyed, long-tailed bird is bred to a blue-eyed, short-tailed bird. What will the F1 phenotype (s) and ratio be?
A. 3/4 pink eye, long tail; 1/4 blue eye, short tail
B. 9/16 pink eye, long tail; 3/16 blue eye, long tail; 3/16 pink eye, short tail; 1/16 blue eye, short tail.
C. 1/2 pink eye, long tail; 1/2 blue eye, long tail
D. All blue eye, short tail
E. All pink eye, long tail

666. Which of the following best illustrates the Hardy-Weinberg Principle?
A. The coats of Arctic hares are white in winter and brown in summer.
B. Jurassic dinosaurs tended to be larger than Triassic dinosaurs.
C. Native amphibians do not occur on many Pacific islands.
D. The proportion of blue-eyed to brown-eyed people in the world has not greatly changed in the last ten generations.
E. The populations of hawks and mice go through similar cyclic changes with the hawks slightly later in phase.

667. How could one determine if variations of a trait in a population were genetically controlled?
A. Count chromosomes and see if the number varies in the population.
B. Examine the DNA and see if it varies in the population.
C. Use the Hardy-Weinberg Law and then test the results with chi-square.
D. Measure the variation and see if it is continuous or discontinuous.
E. Mate individuals of both extremes with each other and see if their offspring show the same range of variation as that represented by their parents. [may not be correct] (E) 4-4-3

Items 668-669 are based upon the following situation:
In rabbits a certain color results from a recessive gene. This color occurs in 9% of a population.

668. The frequency of a recessive gene in this population is
A. 3%
B. 9%
C. 25%
D. 30%
E. 50% (D) 4-4-3

669. What percentage of the population have one or more recessive genes for this color?
A. 3%
B. 9%
C. 30%
D. 51%
E. 75% (D) 4-4-3

670. If 1/3 of hemophilia genes in a population are eliminated by death of males, then why does the incidence of hemophilia remain constant?
A. Recessive genes in carrier females replace the lost genes.
B. Mating is not random and hemophiliacs marry carriers.
C. Mutant genes replace the lost genes.
D. Recombination of recessive genes enable them to appear.
E. The population is large and mating is random. (C) 4-4-3

Items 671-672 are based on a study of a specific inherited trait with only two alleles. Individuals who can digest protein Z have the genotype dd.

671. Which additional information will enable us to calculate the frequency of allele d in the population if used alone?
A. The ratio of sample size to population size is 1 : 100.
B. Sixteen percent of the individuals in the sample can digest protein Z.
C. Thirty percent of the individuals in the sample are of mating age.
D. The number of individuals in the sample who can digest protein is 160.
E. The sample consisted of 1000 individuals. (B) 4-4-2

672. Assume it is discovered that 640 individuals in a population of 1000 cannot digest protein Z. The frequency of allele d in the population is
A. 6%
B. 8%
C. 36%
D. 60%
E. 80% (D) 4-4-3

673. Genetic drift is most apt to be significant in which of the following?
A. English sparrows in Canada
B. Trumpeter swans in Texas
C. Rabbits in Australia
D. Starlings in central U.S.A.
E. Banyan trees in southern Asia (B) 4-4-3
674. Some viruses have RNA but no DNA. This would indicate that
A. these viruses cannot replicate.
B. these viruses have no inheritable information.
C. RNA can act to transmit hereditary information in these viruses.
D. their nucleic acids must combine with host DNA for virus replication.
E. they can direct the manufacture of proteins but not of nucleic acids.  
(C) 4-1-4

675. A radioactive nucleus from one ameba is transferred to a non-radioactive ameba which has its nucleus removed. If, later on, the second ameba is found to have radioactive ribosomes in its cytoplasm, this would be evidence in support of the
A. chromosomal theory of inheritance.
B. existence of the DNA code.
C. functioning of messenger RNA.
D. single gene - single enzyme hypothesis.
E. Watson-Crick model of the structure of DNA.  
(C) 4-1-4

676. The occurrence of DNA in mitochondria most convincingly suggests which of the following functions for this molecule in that location?
A. It substitutes for ATP in energy release.
B. It manufactures enzymes as does RNA on ribosomes.
C. It transmits hereditary characters of these structures.
D. It contributes phosphate for the reconstitution of ATP from ADP.
E. It is a substitute for creatine phosphate in respiratory reactions.  
(C) 4-1-4

677. Which is evidence that genes are carried on chromosomes?
A. Mutant strains of the baker's mold Neurospora result from the change of single genes which controlled single enzymes.
B. Bacteriophages will change bacterial metabolic machinery so more bacteriophages are produced.
C. DNA extracted from disease-causing (virulent) pneumococcus bacteria change nonvirulent strains into virulent bacteria.
D. Microscopic observation of abnormal chromosomes shows that chromosome crossing-over occurs when genetic crossing-over occurs.
E. All of the above.  
(C) 4-1-4

678. Irradiation with X-rays causes mutations; therefore, the X-rays must
A. dissolve the nuclear membrane.
B. change the tricarboxylic acid cycle.
C. prevent the formation of mitotic spindles.
D. depolymerize complex carbohydrates.
E. alter the chemical structure of chromosomal constituents.  
(E) 4-2-4

Items 679-683 are based on the following experiment and diagram of the procedure

**Gelasinospora**

Colony growing on simple medium is irradiated. Spores formed.

Spores separated

Placed on complete medium. Haploid colony forms from each spore.

Portions of colony transferred to five media

Colonies transferred to five media each strain will grow on is shown below. (They will grow on more complex media.)

<table>
<thead>
<tr>
<th>Strain</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grows on Simple</td>
<td>Simple</td>
<td>Simple</td>
<td>Simple</td>
<td>Simple</td>
<td>Simple</td>
</tr>
<tr>
<td>medium medium medium</td>
<td>medium medium medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+A</td>
<td>+B</td>
<td>+C</td>
<td>+D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

679. Which strain(s) show(s) that a mutation occurred [i.e., the strain(s) have resulted from mutation(s)]
A. I only
B. I and IV only
C. II, III, IV, V Only
D. I, II, III, IV and V
E. None of the above strains  
(C) 4-1-4

680. If A-D are compounds involved in a metabolic pathway and the hypothesized sequential order is D → C → B → A, then we would expect strain(s)
A. If to grow on a simple medium + D.
B. III to grow on a simple medium + C.
C. IV to grow on a simple medium + D.
D. V to grow on a simple medium + A.
E. If and V to grow on a simple medium + B.  
(D) 5-1-5

681. If the inability to grow resulted from lack of only one enzyme, then the enzyme lacking in strain
A. V probably controls reaction D → C.
B. IV probably controls D → A.
C. III probably controls B → A.
D. II probably controls C → B.
E. I probably controls B → A.  
(B) 4-1-4

682. Which of the following scientists are known for their pioneering work on experiments similar to that described above?
A. Avery, MacLeod and McCarthy
B. Beadle and Tatum
C. Lederberg and Tatum
D. Ochoa and Nirenberg
E. Watson and Crick  
(B) 9-1-1

683. If the DNA-RNA code-messenger-transfer system hypothesis is correct, then we would expect strains I-V to possess
A. identical DNA.
B. identical ribosomal RNA.
C. identical proteins.
D. different number of chromosomes.
E. different ribosomal RNA.  
(E) 4-1-3

684. Genetic studies on corn, which has 20 chromosomes, have revealed over 100 different inherited traits. How is this related to Mendel's original work?
A. It supports his one gene-one enzyme theory.
B. It supports his ideas on linkage and crossing over.
C. It supports his ideas on mutations.
D. It does not support his ideas on independent assortment.
E. It does not support his ideas on linkage.  
(D) 4-2-4

685. The work of Briggs and King, Moore, and others has shown that early developmental phenomena reflect the genetics of the mother rather than of the zygote. The same point is illustrated by the
A. determination of sex in honeybees.
B. lack of crossing-over in male fruit flies.
C. inheritance of hemophilia in humans.
D. inheritance of sinistral and dextral coiling in snails.
E. expression of sickle-cell hemoglobin genes in humans.  
(D) 4-2-4
Items 686–687 are based on a study of a bug in which hairy legs (H) are dominant over hairless (h) and large mouth (M) is dominant over small mouth (m). Crosses between HhMm bugs result in the following offspring:

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>male</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy, large mouth</td>
<td>204</td>
<td>202</td>
</tr>
<tr>
<td>Hairless, small mouth</td>
<td>199</td>
<td>207</td>
</tr>
</tbody>
</table>

686. This best illustrates
A. autosomal linkage.
B. crossing-over.
C. independent assortment.
D. mutations.
E. sex linkage.  (A) 4-2-4

A series of matings between HhMm and hhmm results in:

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>male</th>
<th>female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy, large mouth</td>
<td>272</td>
<td>267</td>
</tr>
<tr>
<td>Hairy, small mouth</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Hairless, large mouth</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Hairless, small mouth</td>
<td>281</td>
<td>258</td>
</tr>
</tbody>
</table>

687. Which is illustrated by this mating but not by the previous mating?
A. Autosomal linkage.
B. Crossing-over.
C. Independent assortment.
D. Mutations.
E. Sex linkage.  (B) 4-2-4

Items 688–690 are based on the following map of a beetle's chromosomes.

<table>
<thead>
<tr>
<th>centromere</th>
<th>o-----------------</th>
<th>----------------------------------</th>
</tr>
</thead>
<tbody>
<tr>
<td>light body</td>
<td>short legs</td>
<td>black eyes</td>
</tr>
<tr>
<td>dark body</td>
<td>long legs</td>
<td>pink eyes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>small head</td>
</tr>
</tbody>
</table>

688. Crossing-over would probably be most frequent between loci of genes
A. body and legs.
B. body and head.
C. eyes and head.
D. eyes and legs.
E. legs and head.  (B) 4-2-4

689. Which information would be most valuable in making a chromosome map?
A. Light body beetles bred with dark body beetles result in all dark body offspring.
B. Twenty percent of beetles in a population have big heads and 36% have light bodies.
C. One hundred twenty-five beetles have black eyes and big heads while nine have pink eyes and small heads.
D. There is 16% crossing-over between light body and black eyes and 4% crossing-over between short legs and black eyes.
E. There is 9% crossing-over between light body and dark body and 3% crossing-over between light body and pink eyes.  (D) 4-2-4

690. Assume crossing-over between dark body and small head was expected to be 50% yet experimental results were only 42%. Which best explains this?
A. The traits are not always linked.
B. Double cross-over occurred.
C. Dark body is dominant over small head.
D. Cross-over between body and head already occurred.
E. Cross-overs are more viable.  (B) 4-2-4

691. Which of the following research programs produced results most like those of Mendel's study on peas?
A. Darwin's work on earthworms
B. Morgan's work on the fruit fly
C. Spemann's work on the newt
D. Salk's work on the rhesus monkey
E. Stanley's work on the tobacco mosaic virus  (B) 4-3-4

692-695 are concerned with the following situation:

Pete and Repete were identical twins.

Pete married a brown-eyed brunette. They had two children: a daughter with eye color and hair color just like her mother’s, and a son who was blud-eyed and sandy-haired.

Repete married a brown-eyed blonde. They had two children: a daughter with eye color and hair color just like her mother’s, and a blue-eyed, dark-haired son.

Using these symbols to designate the two pairs of allele genes —

- H = gene for dark hair
- h = gene for light hair
- E = gene for brown eyes
- e = gene for blue eyes.

Select the most likely genotype for each of the individuals named in items 692-695.

692. Pete's genotype —
A. hhEe
B. HhEe
C. HhEE
D. HHee
E. Hhee  (E) 4-3-4

693. Genotype of Pete's wife —
A. HHEe
B. HhEe
C. hhee
D. HHee
E. HHEE  (B) 4-3-4

694. Repete's genotype —
A. Hhee
B. HHee
C. HhEE
D. HHee
E. hHee  (A) 4-3-4

695. Genotype of Repete's wife —
A. hHee
B. HHee
C. HhEE
D. HHee
E. hHee  (A) 4-3-4

Items 696–697 are based on an experiment in which phages labeled with either radioactive P or S and allowed to infect bacteria. Possible results are as follows:

I. P * enters bacterial cell.
II. S * enters bacterial cell.
III. P * remains outside bacterial cell.
IV. S * remains outside bacterial cell.

696. Which would be evidence that only DNA from a phage enters a bacterial cell? Result(s)
I. P only
II. II only
III. I and II
IV. I and IV
V. II and III  (D) 4-3-4

697. Recombination of T2 phage characteristics could occur only if several strains infect bacteria and
A. result 1 occurred.
B. result II occurred.
C. result III occurred.
D. result IV occurred.
E. results I and II occurred.  (A) 4-3-4

Items 698-701 are based on inheritance in wild house mice.

698. A biologist noted spotted coats in a population of wild house mice. He bred two spotted mice re-peatedly, and obtained 52 offspring, all spotted. The best interpretation is that the trait is
A. a blend.
B. dominant.
C. inherited.
D. recessive.
E. sex-linked.  (C) 4-3-4
The biologist then sampled the wild population and found 91 solid color and 9 spotted mice. What is the approximate frequency of the spotted gene in that population?
A. 3%  
B. 9%  
C. 30%  
D. 90%  
E. 95%  

The biologist then repeatedly bred spotted offspring to solid color mice and obtained 46 solid color and 17 spotted mice. The best interpretation is that the characteristic "spotted" is
A. an autosomal dominant  
B. an autosomal recessive  
C. a sex linked dominant  
D. a sex linked recessive  
E. a blend with the homozygous condition lethal.

About how many heterozygous individuals were there in that population?
A. 0  
B. 6  
C. 16  
D. 21  
E. 42

NOTE: Items 702-720 are based on a situation suggested by an article by Ruth Sager in the January, 1965 issue of Scientific American.

Recent evidence suggests that in addition to the chromosomal or nuclear genes on which the classical gene theory has been based, there are certain genetic systems that depend on non-chromosomal, or cytoplasmic, genes. Consider the following comparative diagrams:

Most significant in accounting for the foregoing differences, you will note, is the process of meiosis, which assures numerical equality of chromosomes in all sex cells of either sex, but proportions to egg cells large amounts of cytoplasm, while to sperm almost none. Non-chromosomal genes, being cytoplasmic, are accordingly transmitted only via egg cells, and hence we say that they show a maternal pattern of inheritance. This contrasts with a bi-parental pattern for chromosomal genes, which are contributed equally by sperm and egg. The possibility that nuclear and cytoplasmic genes may exist in the same cell suggests that at least some inheritable traits may be determined by an interaction between the two genetic systems. Now consider the following information on the inheritance of pollen-sterility in corn.

Each corn plant is normally monoecious, with both male (tassel) and female (ear) flower parts appearing on the same individual. However some genetically stable strains are known to produce sterile pollen, though ears of these same plants can be fertilized by normal pollen from another strain which is pollen-fertile. The results of several experimental matings involving such strains are recorded diagrammatically.

In working through items 702-713, assume that each of the individuals of strains 1, 2, and 3 is a member of a pure line. Assume further that all individuals, parents, and progeny, have inherited a single pair of nuclear genes for the pollen-sterile or pollen-fertile condition. On these assumptions, and in the light of other characteristics of nuclear genes, as postulated in the classical (Mendelian) theory of the mechanisms of inheritance, answer each of the following, by choosing the most appropriate response from those listed.

702. Which of the following would characterize Mating I?
A. Each of the progeny must have received one gene for pollen-fertility from each of its parents.  
B. The gene for pollen-fertility is dominant.  
C. Each one of the progeny must have the same combination of genes as each of the other progeny.  
D. Both statements B and C are equally consistent with Mendelian principles.  
E. All of the first three of the foregoing statements are equally consistent with Mendelian principles.

703. Which of the following would characterize Mating II?
A. Only pollen-fertile offspring.  
B. More pollen-sterile than pollen-fertile offspring.  
C. Equal numbers of sterile and fertile offspring.  
D. Only hybrid offspring.  
E. Equal numbers of heterozygous and homozygous offspring.

704. If we were to self-cross all the progeny from Mating III, we would expect to obtain
A. Only pollen-fertile offspring.  
B. More pollen-sterile than pollen-fertile offspring.  
C. Equal numbers of sterile and fertile offspring.  
D. Only hybrid offspring.  
E. Equal numbers of heterozygous and homozygous offspring.

705. In which of the following matings is there evidence of dominance?
A. Number I  
B. Number II  
C. Number III  
D. Number IV  
E. All four matings

706. Which mating or matings yielded only hybrid progeny?
A. Number I  
B. Numbers I and III  
C. Numbers I and IV  
D. Numbers I, II, III and IV  
E. Number III

707. Which mating can we classify as an example of a monohybrid cross?
A. Number I  
B. Number II  
C. Number III  
D. Number IV  
E. None of them

708. Which of the matings, of and by itself, gives evidence that requires us to assume that non-chromosomal genes are involved in the inheritance of pollen-fertility or sterility in corn?
A. Number I  
B. Number II  
C. Number III  
D. Number IV  
E. None of them
710. Which of the following facts provides the best evidence that pollen-fertility strain 3 is genetically different from pollen-fertile strain 3?

A. In Mating I only one kind of progeny appeared, while in Mating II both kinds were produced.
B. In Mating I all progeny were pollen-fertile, while in Mating IV all were sterile.
C. In Mating II both progeny types were equally numerous, while in Mating III they were not.
D. Facts A and B are both equally pertinent as evidence of genetic difference.
E. Facts A, B, and C are all equally pertinent as evidence.

(B) 4-3-4

711. In terms of the nuclear gene hypothesis (see introductory comments) it appears from Mating IV that the gene for pollen-sterility in strain 3 is recessive to its pollen-sterility allele, presumably present in strain 1. If so, this implies that a test-cross of the progeny from Mating IV to their strain 3 parent would yield

A. two kinds of offspring.
B. only homozygous offspring.
C. only heterozygous offspring.
D. a 3:1 ratio in the offspring.
E. only pollen-sterile offspring. (A)

4-3-2

712. When such a test-cross was performed (see item 711) the resulting offspring were found to be pollen-sterile without exception. These results suggest that

A. the principle of dominance, in its usual Mendelian sense, does not apply here.
B. all individuals involved in Mating IV and the test-cross are homozygous for their nuclear genes.
C. some mechanism in addition to nuclear genes is necessary to account for the fact that strain A is pollen-sterile while strain C is pollen-fertile.
D. fertility and sterility may be a consequence of an interaction of nuclear and non-nuclear (i.e., cytoplasmic) genes.
E. all of the foregoing statements are applicable to this situation.

(E) 4-3-4

713. If nuclear genes only were involved in the inheritance of pollen-sterility or fertility, which of the following would we not expect to find in populations of corn?

A. The same characteristic (fertility or sterility) being represented in some strains by a dominant gene, and in others by a recessive gene
B. Changes in progeny phenotypes and ratios resulting from reciprocal crosses (i.e., strain X male x strain Y-female giving different progeny from Y-male x X-female)
C. Variations in the actual numbers of progeny resulting from each of a series of matings of parents with the same genotypes
D. Appearance of recessive progeny in matings of hybrid dominant parent plants
E. Equal genetic contributions to the progeny by each parent involved in any particular mating

(B) 4-3-4

In items 702-713 you found that a nuclear gene hypothesis can account for many but not all of the facts developed in the four matings diagrammed previously. In items 714-720 we shall consider a modification of this hypothesis, involving interaction of nuclear and cytoplasmic genes.

Let us now propose that pollen-sterility or fertility depends on the following conditions within the cell:

a. the presence or absence of genes for sterility in the cytoplasm; and
b. the presence or absence of a dominant sterility-suppressing gene in the nucleus.

We can now undertake to visualize a model representing various specific patterns of distribution of nuclear and cytoplasmic genes, according to the above hypothesis, and then apply these to an interpretation of Matings I to IV. We shall use the following symbols:

- a single nuclear gene for sterility-suppression (dominant)
- a single nuclear gene for non-suppression of sterility
- a single cytoplasmic gene

Answer items 714-720 by choosing from the key a cell model that is correct in terms of the above hypothesis.

714. A strain 1, pollen-sterile female (see mating diagrams) (B) 4-3-4

715. A strain 2, pollen-fertile male (see diagrams) (A) 4-3-4

716. A strain 3, pollen-sterile male (D) 4-3-4

717. Any one of the pollen-sterile offspring of Mating II (C) 4-3-4

718. Any one of the offspring of Mating I (C) 4-3-4

719. One-third of the pollen-fertile offspring of Mating III (E) 4-3-4

720. Any one of the progeny that we would expect from a mating of a strain 2 male and a strain 3 female (E) 4-3-4

Items 721-744 are concerned with two fruit fly crosses involving three traits: body size, body color, and wing length. All three of these traits show complete dominance and are not sex-linked.

CROSS I: giant, ebony body, short winged male x normal size, grey body, long winged male offspring: Females: all normal size, grey body, long winged
Males: all giant size, grey body, long wing

CROSS II giant, ebony body, short wing x normal size, grey body, long wing - grand total below = 399

<table>
<thead>
<tr>
<th>size</th>
<th>Color</th>
<th>Wing</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>normal</td>
<td>grey</td>
<td>long</td>
<td>45</td>
<td>50</td>
<td>94</td>
</tr>
<tr>
<td>normal</td>
<td>grey</td>
<td>short</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>normal</td>
<td>ebony</td>
<td>long</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>normal</td>
<td>ebony</td>
<td>short</td>
<td>80</td>
<td>44</td>
<td>124</td>
</tr>
<tr>
<td>giant</td>
<td>grey</td>
<td>long</td>
<td>48</td>
<td>22</td>
<td>70</td>
</tr>
<tr>
<td>giant</td>
<td>grey</td>
<td>short</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>giant</td>
<td>ebony</td>
<td>long</td>
<td>3</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>giant</td>
<td>ebony</td>
<td>short</td>
<td>45</td>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

399
721. Grey body is dominant to ebony body.  
722. Genes for ebony body and for short wing are located on autosomes.  
723. Genes for ebony body and for short wing assort independently.  
724. Genes for giant size and for ebony body assort independently.  
725. Giant size is a sex-linked characteristic.  
726. The female parent in Cross II was of normal size.  
727. Normal size is dominant to giant size.  
728. The locus of the gene for giant size is not on the same chromosome as the locus of the gene for ebony body.  
729. Short wing is dominant to long wing.  
730. The locus of the gene for ebony body is on the same chromosome as the locus of the gene for short wing.  
731. The female parent in Cross II had a genotype heterozygous for three traits.  
732. The cross-over percent between the loci of ebony body and short wing is about 6%.  
733. The normal size female offspring of Cross II all had genes heterozygous for size.  
734. Giant size males have only one gene for giant size.  
735. The cross-over percent between the loci of grey body and long wing is about 3%.  
736. The male parent in Cross I was a supermale.  
737. Genes for grey body and normal size are linked.  
738. Genes for grey body and for long wing are about 6 "map units" apart.  
739. In the somatic cells of the female parent in Cross II, genes for grey body and for long wing were on one chromosome, while genes for ebony body and for short wing were on the homologous chromosomes.  
740. The male parent in Cross I had two genes for each trait.  
741. The female parent in Cross II had the same genotype as the female offspring of Cross I.  
742. The female parent in Cross I had the same phenotype as the female parent in Cross II.

743. The gene for normal size is located on an X chromosome.  
744. The gene for giant is located on a Y chromosome.  
745. A poultry farmer discovers that a recessive mutation has occurred in his flock, greatly increasing egg production. He would like to distribute this throughout his flock as quickly as possible. Which of the following would do this best?  
A. Use a high-production hen as a brooder to hatch as many eggs as she can.  
B. Interbreed both male and female offspring of high-production hen  
C. Breed sons of a high-production hen with heterozygous cocks.  
D. Interbreed heterozygous hens and heterozygous cocks.  
E. Submit the unfertilized eggs of a high-production hen to artificial parthenogenesis.

746. If the homozygous recessive condition known as sickle-cell anemia is often fatal, then why has the incidence of "sickle cell" reached 40% in certain African Negro tribes while the incidence is under 10% in the U. S. Negro?  
A. Mutation rates are higher in Africa than in U. S.  
B. African populations are small and do not interbreed.  
C. Sickle cell has a selective advantage in malaria country.  
D. The American Negro interbreeds with white Americans.  
E. Heterozygosity is more common in Africa.

747. Slight differences in identical twins supports the hypothesis that  
A. dominance may be incomplete.  
B. genetic traits are influenced by many genes.  
C. single genes may produce multiple effects.  
D. the environment affects the expression of genetic characteristics.  
E. they developed from separate fertilized eggs.

748. The frequency of B blood in a small isolated population is 20% compared to 10% in the white U. S. population. Which best explains this difference?  
A. There has been random gene drift in a small population.  
B. Natural selection has reduced the frequency of the other alleles because B blood individuals are resistant to malaria.  
C. The "B" allele originated in the population.  
D. B is dominant to A and 0.  
E. All members of the population received B blood transfusions.

749. A small group from a closely intermarrying sect immigrated from what is now West Germany into central Mexico and established a community. After about 150 years, their blood type was determined. In the following table, the frequency of the "B" allele is compared with its frequency in other populations.  

<table>
<thead>
<tr>
<th>German community</th>
<th>Central Mexican Population</th>
<th>Parent German Population</th>
<th>Russian Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Mexico</td>
<td>25%</td>
<td>13%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Which best explains the high frequency of "B" allele in the German community in central Mexico?  
A. The "B" allele has some selective advantage for Germans.  
B. The "B" allele has some selective advantage in central Mexico.  
C. Genetic drift probably occurred.  
D. Russians recently married into the community.  
E. Their ancestors really came from Russia.
Items 750-780 concern the use of a statistical procedure, the Chi-square test, in an analysis of data from experimental matings, with a view to testing various hypotheses as to the underlying gene mechanism that are presumably reflected in the data. Each experiment involves the inheritance of seed-coat color in Adzuki beans.

Experiment I, conducted by an investigator whom we shall call Hodges, was a mating of two plants which germinated from seeds with spotted coats. When the resulting seed pods were opened (i.e., the progeny from this mating), three types of seed-coat were identified: brown, tan, and spotted. There was a total of 100 seeds. Hodges recorded his data and the necessary Chi-square calculations, in Table A. Note that certain of Hodges’ figures are omitted.

Table A

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Observed Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>21.0</td>
</tr>
<tr>
<td>Tan</td>
<td>36.0</td>
</tr>
<tr>
<td>Spotted</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Items 750-755. Applying your knowledge of the Chi-square method, determine the number value of each missing entry, and choose an appropriate response from the key.

Key: A. 21.0
     B. 36.0
     C. 0.08
     D. None of the above

750. Value of I (B) 4-4-4
751. Value of II (E) 4-4-4
752. Value of III (E) 4-4-4
753. Value of IV (D) 4-4-4
754. Value of V (C) 4-4-4
755. Value of VI (A) 4-4-4

756. The phenotypic ratio on which the data analysis (Table A) is based, can be most readily deduced from the three values listed in which column?
A. the O column
B. the E column
C. the (O-E) column
D. the (O-E)/E column

757. The actual count of specimens belonging to each phenotype, among the progeny resulting from Experiment I, is indicated in which column?
A. the O column
B. the E column
C. the (O-E) column
D. the (O-E)/E column

758. From which column do we obtain, by a summation of the entries in that column, our value for Chi-square?
A. the O column
B. the E column
C. the (O-E) column
D. the (O-E)/E column

759. Which column best expresses the relative size of the presumed sampling error for each phenotype?
A. the O column
B. the E column
C. the (O-E) column
D. the (O-E)/E column

760. Which column represents a mathematical device adopted in order to avoid having the various values for the difference between observation and prediction add up to zero?
A. the O column
B. the E column
C. the (O-E) column
D. the (O-E)/E column

Table B. Chi-square Probabilities

<table>
<thead>
<tr>
<th>d.f.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>0.025</td>
</tr>
<tr>
<td>3</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>0.10</td>
</tr>
</tbody>
</table>

761. As interpreted from Table B, the Chi-square value for the data from Experiment I has a probability value of
A. between 0.50 and 0.20.
B. between 0.50 and 0.80.
C. between 0.20 and 0.05.
D. less than 0.05.

762. The hypothesis from which we can deduce phenotypes and ratios that conform most closely to those implied in Table A proposes a mechanism involving
A. one pair of autosomal alleles, with no dominance.
B. one pair of autosomal alleles, with dominance.
C. one pair of sex-linked alleles, with dominance.
D. two pairs of non-linked autosomal alleles, with epistasis.
E. two pairs of linked autosomal alleles, with crossing-over.

763. Which of the following is most probably the alternative hypothesis that Wilkins has decided to test?
A. Three allelic autosomal pairs, with independent assortment, and dominance in each pair
B. Two linked autosomal pairs, with crossing-over, and with dominance in each pair
C. Two non-linked autosomal pairs, with dominance in each pair, and epistasis
D. Two allelic pairs, one autosomal and the other sex-linked, with dominance in the autosomal pair
E. One allelic autosomal pair, with dominance influenced by sex

764. From this hypothesis (item 763) we would predict that each spotted parental plant in Experiment I should have one dominant gene in each pair of alleles and that the phenotypes should appear in some approximation of a 9:3:4 ratio. On this basis, we predict that 9 out of every 16 progeny should be spotted, and that the percentages of brown and tan progeny should be
A. 19 and 25 respectively.
B. 30 and 40 respectively.
C. 25 and 19 respectively.
D. either Answer A or C above.
E. any of the three answers. (D) 4-4-4
765. Let us assume that our hypothesis leads us to expect 3/16 of the progeny to have brown seeds, while 4/16 should have tan seeds. Substituting these values into Table A, and performing all necessary calculations, we will obtain a Chi-square value of between A. 0.001 and 0.5. B. 0.5 and 1.5. C. 1.5 and 2.5. D. 2.5 and 3.0. E. 3.5 and 5.0. (D) 4-4-4

766. From Table B we learn that the probability value of the Chi-square calculated in item 765 is A. between 0.50 and 0.20. B. between 0.20 and 0.05. C. between 0.80 and 0.50. D. less than 0.05. E. greater than 0.95. (A) 4-4-4

767. Let us now assume that our hypothesis leads us to expect 3/16 of the progeny in Experiment I to have tan seeds, while 4/16 will have brown seeds. Substituting these values into Table A, and performing all necessary calculations, we will obtain a Chi-square value of A. greater than 10.0. B. between 8.0 and 10.0. C. between 5.0 and 8.0. D. between 3.0 and 5.0. E. between 1.0 and 3.0. (B) 4-4-4

768. Again, consulting Table B, we find that the value of Chi-square as determined in item 767, has a probability of A. between 0.50 and 0.20. B. between 0.20 and 0.05. C. between 0.80 and 0.50. D. less than 0.05. E. greater than 0.95. (D) 4-4-4

769. We interpret the probability obtained in item 766 as indicating which of the following? A. The discrepancy between observation and prediction is too large to have occurred entirely by chance. B. The discrepancy between observation and prediction could have occurred entirely as a result of sampling error. C. Some factor other than those implied in the hypothesis is operating to cause the discrepancy between observation and prediction. D. There is a statistical justification to reject the hypothesis. E. Both answers A and D above are indicated. (B) 4-4-4

770. We interpret the probability obtained in item 768 as indicating which of the following? A. There are statistical grounds for rejecting the hypothesis. B. The discrepancy between observation and prediction is unlikely to have occurred by chance. C. There are statistical grounds for regarding the hypothesis as supported by the data obtained in Experiment I. D. Both answers A and B, above, are indicated. E. None of the first three answers is indicated. (A) 4-4-4

771. In view of these findings, Wilkins is now justified in drawing which of the following conclusions as to the inheritance of seed-coat color? A. Coat color must depend on two pairs of autosomal alleles, with epistasis. B. Coat color cannot be determined by a single allelic gene pair, either with or without dominance. C. Coat color inheritance may involve epistasis. D. Both conclusion A and conclusion B are now justified. E. Some other statistical procedure than Chi-square should now be tried, since Chi-square results are ambiguous. (C) 4-4-4

Items 772-777. Pursuing the implications of items 762, 769, and 770, you are now in a position to deduce genotypes for each category of bean plant, using either the original hypothesis tested by Hodges (item 762) or the alternative suggested and tested by Wilkins.

772. According to Hodges, what is the genotype of any of the spotted plants? A. SS B. ss C. Either SS or Ss D. Either Ss or ss E. Ss (E) 4-3-4

773. What is the genotype, according to Hodges, of any one of the tan-seeded plants? (Let S = 1 tan gene.) A. SS B. ss C. Either SS or Ss D. Either Ss or ss E. Ss (A) 4-3-4

774. What is the genotype of any of the brown-seeded plants, according to Hodges? A. SS B. ss C. Either SS or Ss D. Either Ss or ss E. Ss (B) 4-3-4

775. According to Wilkins' alternative hypothesis (see items 769 and 770) what is the genotype of any one of the brown-seeded plants? A. AABB B. A-B- C. aabb D. aa- E. A-bb (E) 4-3-4

776. According to Wilkins, what is the genotype of any one of the tan-seeded plants? A. AABB B. A-B- C. aabb D. aa- E. A-bb (B) 4-3-4

777. According to Wilkins, what is the genotype of any one of the spotted plants? A. AABB B. A-B- C. aabb D. aa- E. A-bb (D) 4-3-4

Items 778-780. Wilkins at this point decided to obtain some additional data in the hope of reaching a decision among the various hypotheses. He secured two plants from the same spotted population as that used for Experiment I, and transferred pollen from one plant to the pistils of the other. This he called Experiment II. Progeny resulting from this experiment were: 30 brown, 53 spotted, 17 tan. To obtain an indication of the goodness of fit of these data to the two variant 9:3:4 hypotheses, he made a Chi-square analysis and obtained values as follows:

a) Using an hypothesis that predicts 9 spotted : 4 brown : 3 tan = 0.853
b) Using an hypothesis that predicts 9 spotted : 3 tan : 4 brown = 0.853

778. If Wilkins were to limit himself to his own experimental data (Experiment II) and ignore those of Hodges (Experiment I) he would be justified in concluding that there is a sufficient basis statistically for rejecting hypothesis a) above.

779. If Wilkins were to consider the experimental data of both Hodges (Experiment I) and Wilkins (Experiment II), he would be justified in concluding that there is a sufficient basis statistically for rejecting both hypotheses a) and b) above.
779. Wilkins, however, recognized that his obligation to the traditions of scientific inquiry required him to account for the data from both Experiments I and II. His attempt to explain these data on the basis of a 9:3:4 hypothesis was unsuccessful for which of the following reasons?
   A. The percentages of brown and tan in the two experiments differed.
   B. The two experiments yielded different values for Chi-square.
   C. Data from the two experiments did not fit the same variant of the 9:3:4 hypothesis [i.e., a or b above].
   D. The probabilities for the Chi-square values of Experiments I and II were different.
   E. The variations in the observed numbers of brown, spotted, and tan for Experiment I and II were entirely due to chance.  
   (C) 4-4-4

780. At this point Wilkins was on the verge of undertaking yet another experimental mating of spotted bean plants. It occurred to him, however, that by pooling the counts of each phenotype from Experiment I with those of corresponding phenotypes from Experiment II, some clarification might result. The combined count was as follows:
   brown (I and II) = 51
   spotted (I and II) = 101
   tan (I and II) = 48

These results impressed Wilkins as a very close approximation to a well-known genetic ratio. Testing the pooled data against the hypothesis from which this ratio can be deduced, he obtained a Chi-square value of 0.11. Which of the following hypotheses now affords the most probable explanation for the inheritance of seed coat color in Adzuki beans?
   A. One pair of sex-linked alleles, with dominance
   B. One pair of autosomal alleles, with dominance
   C. One pair of autosomal alleles, with lack of dominance
   D. Two pairs of non-linked autosomal alleles, with epistasis
   E. Two pairs of linked autosomal alleles, with crossing-over.  
   (D) 4-4-4

For items 781-792 use the following information. The frequencies of ABO blood types in a certain area of Egypt are: 31% Type A, 31% Type B, 13% Type AB and 25% Type O.

For items 781-792 use the following information. The frequencies of ABO blood types in a certain area of Egypt are: 31% Type A, 31% Type B, 13% Type AB and 25%

781. Which of the following equations could be used to express the gene frequencies of the A, B, and O genes in the given population? (Let q represent the frequency of the O gene.)
   A. \( p + q = 1 \)
   B. \( (p + q)^2 = 1 \)
   C. \( p^2 + q^2 = 1 \)
   D. \( 2p + q = 1 \)
   E. \( p + 2q = 1 \)

782. The percent of individuals in this population who are Type A.  
   (A) 4-4-4

783. The percent of individuals in this population who are Type O.  
   (A) 4-4-4

784. The percent of individuals in this population who are Type AB.  
   (B) 4-4-4

785. The frequency of the O gene in this population.  
   (C) 4-4-4

786. The frequency of the B gene in this population.  
   (D) 4-4-4

787. Whether the gene for Type A is dominant to the gene for Type O.  
   (E) 4-4-4

788. The percent of individuals in this population with genotypes heterozygous for Type A.  
   (D) 4-4-4

789. The percent of individuals in this population with genotypes homozygous for Type B.  
   (D) 4-4-4

For items 790-792 use the following key.
   KEY:  
   A. .13  
   B. .25  
   C. .31  
   D. .50  
   E. .55

790. What is the frequency of the O gene in this population?  
   (D) 4-4-4

791. What is the frequency of the B gene in this population?  
   (B) 4-4-4

792. What is the frequency of the A gene in this population?  
   (B) 4-4-4

793. In the African clawed toad (Xenopus) a mutation occurs which gives rise to cells that have no nucleolus if the mutated gene is present in duplicate (homozygous). Homozygotes for this mutation never produce new ribosomes and die at an early stage. Heterozygotes have one nucleolus per cell and grow and reproduce normally. Which of the following is a relevant hypothesis, not inconsistent with the data, that might serve as a fruitful basis for further experimental investigation?
   A. A mating between a normal animal and a heterozygote will give a maximum of 50% viable progeny.
   B. Two nucleoli are required for the production of ribosomes.
   C. Genes that are physically associated with the nucleolus control the production of ribosomes.
   D. The presence of a nucleolus is not under genetic control.
   E. None of the above.  
   (B) 4-4-4

794. Which of the following constitutes a genetic change in an organism?
   A. X-ray photography of a human chest.
   B. Change of a canary's feathers from yellow to orange on ingestion of pepper.
   C. Substitution of a guanine nucleotide for an adenine nucleotide in the DNA of a zygote nucleus.
   D. Infection of a rabbit with tularemia.
   E. Changing of a bacterium from aerobic to anaerobic respiration.  
   (C) 4-1-6

795. Consider the following:
   I. The number of nucleotides in a unit of the genetic code
   II. The number of strands in a DNA molecule
   How can the relationship of I and II best be categorized?
   A. I is quantitatively greater than II.
   B. II is quantitatively greater than I.
   C. I and II are quantitatively equal.
   D. Either I or II can vary quantitatively.
   E. Both I and II can vary quantitatively.  
   (D) 4-2-6

796. Which of Mendel's procedures differed from those of his predecessors and contributed most to his success?
   A. He kept breeding records.
   B. He observed distinct inherited traits.
   C. He observed many characteristics for each trait.
   D. He quantitatively analyzed his data.
   E. He used one of the few organisms which can be grown in a laboratory.  
   (D) 4-3-6
797. In which of the following conditions can a physician most surely pinpoint the specific cause from the data given?
A. A boy has never formed pigment in his skin, hair, or irises.
B. A woman has a fever of 104 degrees F.
C. A dog is shedding much of its hair.
D. A girl shows an unusually flushed face.
E. A man limps badly with his left leg.  
(A) 4-3-6

798. Which of the following would contribute least to the computation of the frequency of the gene for brown eye color in the human population of North America?
A. Choosing a random sample of the human population
B. Recording the number of blue-eyed people in the chosen sample
C. Noting the sex of each brown-eyed person in the chosen sample
D. Determining the ratio of the number of blue-eyed people to the number of all people in the sample
E. Extracting the square root of the ratio of the number of blue-eyed people to total number of people in the chosen sample  (C) 4-4-6

Questions 799-804. Devise an appropriate research program to test each of these hypotheses:

Essay Questions

Questions 799-804. Devise an appropriate research program to test each of these hypotheses:

799. Viruses cannot replicate outside of a living host.  
4-1-5

800. The two alleles of a heterozygote showing incomplete dominance produce different phenotypic results because their molecular shapes are different.  
4-1-5

801. In the differentiation of a frog embryo, cells of the intestinal lining come to have different genomes from cells of the cerebellum.  
4-2-5

802. Cestodes possess nonfunctioning genes for the formation of endodermal tissues.  
4-3-5

803. Pogonophores possess genes for development of a digestive tract, but those genes are prevented from expressing themselves by repressor substances.  
4-3-5

804. The palmate pattern of venation in the leaves of silver maples is due to the action of DNA in nuclei of leaf bud cells.  
4-3-5

805. Propose a procedure to determine where on the human X-chromosome the gene for normal blood clotting, or the gene for hemophilia, is located.  
4-2-5

Questions 806-807. Answer each of the following and defend your answers.

806. A species of flowering plant develops three new mutations in three places in its population range. These three places soon come to overlap, as the mutations at first spread through the population. No linkage is involved. One mutation makes the pollen oilier and heavier than before; another produces more conspicuous yellow petals than were present before; the third develops nectaries at the bases of the petals. Predict the change in frequencies of these genes with time in this population.  
4-4-5

807. A population of organisms acquires two mutations. Each mutation appears in different members of the population. Through random mating, the mutation is propagated until each is possessed by a large percentage of the population, some members having both. Each mutation is dominant. One mutation causes a coloration which makes individuals possessing the mutation vulnerable to predators. The other produces a variation which makes the organism better able to procure food. Predict (a) the trend in population frequency of each of the genes and (b) the effect on numbers of members of the population over many generations. 4-4-5

808. What evidence suggests that
(a) E. coli possesses a regulatory gene, R, for the enzyme β-galactosidase?
(b) this regulatory gene makes a product that can block β-galactosidase synthesis when inducer is absent?

809. Give your estimate of the number of different kinds of RNA molecules in an A. aerogenes cell. (It should help your calculation to know that the genome of this cell can potentially code for 2,000 different protein molecules.) Important: State your assumptions in making the estimates.

Number of kinds of sRNA = ____________
Assumptions: ______________________________

Number of kinds of rRNA = ____________
Assumptions: ______________________________

Number of kinds of mRNA = ____________
Assumptions: ______________________________

Total number of kinds of RNA = ____________ 4-1-3

810. (a) Assume that a mutant cell were to arise that has a normal isoleucine activating enzyme in all respects except that it cannot distinguish between isoleucine and valine, and now attaches either equally well to isoleucine's sRNA. If this cell were to make a small amount of protein, what, if anything, might be wrong about this protein?

(b) Assume that a mutant cell were to arise that has a normal phenylalanine activating enzyme except that it cannot distinguish between phenylalanine's sRNA and tyrosine's sRNA, and now attaches phenylalanine equally well to both kinds of sRNA. Any small amount of protein made by this cell would be abnormal in what, if any, respects?

811. Propose a procedure to determine whether or not red hair and freckles are genetically linked characteristics. 4-2-5

9-15
SECTION 10. EXAMPLES: REPRODUCTION AND DEVELOPMENT

Objective Items

812. Failure of an organism to develop pigment may be due to the absence of an enzyme for one of the sequence of reactions which produces the pigment. Such a condition is
A. melanoma
B. melanin
C. albinism
D. piebaldness
E. chromophobia. (C) 5-1-1

813. The amphibian central nervous system develops under the influence of an organizer which is a pituitary hormone.
A. histone
B. mucopolysaccharide
C. nucleoprotein
D. glycolipid
E. glycoprotein. (D) 5-1-1

814. At different stages during the normal sequence of events in the menstrual cycle there is an increase in progesterone, FSH, and estrogen. Which one of the following shows the correct sequence of increases in each substance beginning with menstruation?
A. Estrogen, FSH, progesterone
B. Estrogen, progesterone, FSH
C. FSH, estrogen, progesterone
D. FSH, progesterone, estrogen
E. Progesterone, estrogen, FSH. (C) 5-1-1

815. Certain molecules are concentrated in the blood of a mammalian fetus to a higher degree than in the blood of the fetus’ mother. Among these molecules is
A. ATP
B. RNA
C. prothrombin
D. sodium bicarbonate
E. fructose. (E) 5-1-1

816. The development of a worker honeybee differs from that of a drone honeybee in having
A. a syncytal blastula
B. inversion
C. fertilization
D. a gastrula stage
E. a pupal stage. (C) 5-2-1

817. Chlorenchyma develops in the
A. cytoplasm of a Chlorella
B. stem of an Indian pipe plant
C. mycelium of a green mold
D. spore capsule of a moss
E. pollen tube of a pine. (D) 5-2-1

818. Acetabularia nuclear transplant experiments support the
A. DNA transfer messenger hypothesis
B. induction hypothesis
C. epigenesis hypothesis
D. Mendelian concept of heredity
E. belief that the nucleus alone controls development. (A) - 5-2-1

819. Which of the following insects undergo complete metamorphosis?
A. Grasshoppers
B. Mayflies
C. Fruitflies
D. Termites
E. Bugs (C) 5-3-1

820. If the pituitary stimulates the development of the follicles within the ovaries which in turn stimulate the growth of the uterine lining, then how can we best explain the periodical return of the uterine lining to the resting stage?
A. The pituitary alternately secretes a stimulating and inhibiting hormone.
B. The follicle produces a hormone which stimulates the uterine lining and inhibits the pituitary hormone.
C. The uterus produces a hormone which inhibits the follicle development which inhibits the pituitary.
D. The hypothalamus controls the development of the uterine lining which feeds back to the pituitary.
E. The ovary periodically changes its function because of an internal “clock.” (B) 5-3-1

821. Roux killed one of the cells of a frog two-celled embryo and found that the remaining living cell produced only part of a later embryo. Driesch separated the two cells of a sea urchin two-celled embryo and found that each cell produced a complete, though small, larva. Which of the following is the most acceptable explanation of the difference in results?
A. Frogs evolved later than sea urchins.
B. Differences in the techniques used probably account for the differences in results.
C. The sea urchin larva is not as complex as the frog larva.
D. Frogs are bilaterally symmetrical whereas sea urchins are radially symmetrical.
E. Differentiation occurs at the two-cell stage in sea urchins. (B) 5-3-1

822. Which of the following is derived from both ectodermal and mesodermal cells in amphibians?
A. Heart
B. Skull
C. Larynx
D. Kidney
E. Brain. (B) 5-3-1

823. In which of the following do both larvae and adults live in the same medium?
A. Ascidian
B. Mayfly
C. Leopard frog
D. Dragonfly
E. Mosquito. (A) 5-4-1

824. Which of the following occurs as a free-swimming developmental stage of some duration in fresh water?
A. Ascidian tailedpole
B. Red alga alga endocyst
C. Clam glochidium
D. Fluke cercaria
E. Bryozoa avicularium. (D) 5-4-1

825. The fact that mammalian embryonic development is an orderly sequence of events and not a crowded jumble of random processes is due to
A. the principle of Clerk-Maxwell’s demon.
B. secretions of the thymus.
C. activity of the pituitary gland.
D. the action of gene repressors.
E. the cleavage pattern. (D) 5-1-2

826. Part of a bean seedling starts to manufacture chlorophyll. This suggests that part has been stimulated by
A. gibberellin
B. naphthoxyacetic acid
C. indoleacetic acid
D. kinin
E. light. (E) 5-1-2

827. identical auxins control growth of both the root and shoot, then we can explain the upward growth of the shoot and downward growth of the root only if we assume that
A. different growth processes (cell division and cell enlargement) are involved in each.
B. exposure to light makes the difference.
C. identical growth processes are involved in each.
D. they respond differently to the same concentration of auxins.
E. they respond identically to the same concentration of auxins. (D) 5-1-2

828. In a chick embryo, white blood cells are derived from
A. the lining of the pharynx
B. the walls of blood vessels
C. the myocardium of the heart
D. neuroglia
E. paronephric tubules. (B) 5-2-2
829. Which of the following best illustrates feedback in development?
   A. As tissue X develops it secretes something that inhibits the development of tissue Y.
   B. As tissue X develops it secretes something that induces tissue Y to develop.
   C. Tissue X secretes RNA which changes the development of tissue Y.
   D. As tissue X develops it secretes something which slows down growth of tissue X.
   E. Rates of development in tissue X and tissue Y are controlled by the pituitary.
   (D) 5-2-2

830. The human humerus differs from the human parietal bones in that the humerus
   A. contains calcium phosphate.
   B. retains living osteocytes throughout life.
   C. has a blood supply.
   D. articulates with other bones.
   E. is preformed in cartilage.
   (E) 5-2-2

831. Briggs and King injected nuclei from frog embryos into enucleated frog eggs. The later the embryonic stage from which the nuclei were obtained the more abnormal the development of the eggs. This shows that
   A. nuclei do not control development since all nuclei should have the same gene complement.
   B. nuclei can differentiate.
   C. nuclei alone control development.
   D. the embryo is preformed.
   E. DNA is the hereditary material.
   (B) 5-2-2

832. What do the growth of a single cell, an organism, and a population have in common?
   A. They are influenced by the environment.
   B. They require energy and mass.
   C. They result in an S-shaped curve if size is plotted versus time.
   D. They involve chemical reactions catalyzed by enzymes.
   E. All of the above.
   (E) 5-4-2

833. Which of the following constitutes the best explanation of what causes a green plant, exposed to the light on only one side, to bend toward the light as it grows?
   A. Green plants need light to carry on photosynthesis.
   B. Green plants seek the light because they are phototropic.
   C. Light stimulates plant cells on the lighted side to grow faster.
   D. Auxin accumulates on the shaded side stimulating greater cell elongation there.
   E. Light stimulates the plant nerves on the lighted side more than those on the shaded side.
   (D) 5-3-2

Use the following generalized life cycles as responses for questions 834-837.

834. Which would most likely result in a population of genetically identical individuals (assume interspecies sexual reproduction can occur)?
   A. I
   B. II
   C. III
   D. IV
   E. V
   (A) 4-3-2

835. Which would involve meiosis?
   A. I only
   B. land II only
   C. I, II, and III only
   D. II, III, and IV only
   E. II, III, IV, and V only
   (E) 5-3-2

836. Which best represents the life cycle in moss?
   A. I
   B. II
   C. III
   D. IV
   E. V
   (E) 5-3-2

837. Which involves an alternation of generations with different chromosome number?
   A. I only
   B. II and IV
   C. III only
   D. IV and V
   E. V and III
   (E) 5-3-2

Items 838-841 are based on the following information about three new species of animals which fit into our existing classification system.

Habitat: terrestrial marine terrestrial
Embryo develops in: water mother egg
Mates: in water in water on land
Skeleton is: internal internal internal
Epidermis covered with: mucus slime or hair scales

838. Which specimen(s) probably has (have) internal fertilization?
   A. I only
   B. II only
   C. III only
   D. I and II only
   E. II and III only
   (E) 5-3-3

839. If all three animals are about equal in volume, weight and surface area, which is the most likely arrangement based on egg size (smallest to largest)?
   A. I, II, III
   B. I, III, II
   C. II, III, I
   D. II, I, III
   E. III, II, I
   (D) 5-3-3

840. Which would be the most likely sequence based on number of eggs released at one time (least to most)?
   A. I, II, III
   B. I, III, II
   C. II, III, I
   D. II, I, III
   E. III, II, I
   (C) 5-3-3

841. Which specimen(s) may have gills during a part or all of its (their) life-time?
   A. I only
   B. II only
   C. III only
   D. II and III, but not I
   E. I, II, and III
   (A) 5-3-3

842. Which of the following effects of auxins are the basis for commercial application?
   A. Induction of fruit development
   B. Induction of root formation
   C. Prevention of leaf abscission
   D. Synergistic effects on growth by certain compounds when auxin is present
   E. All of the above
   (E) 5-3-2

843. The root of species A and the shoot of species B are grafted together. If the “grafted” plant grows, which of the following will probably happen?
   A. Because of the presence of A and B hormones, the seed will have characteristics of both A and B if the flower is self-fertilized.
   B. Because of the B hormones produced in the shoot, the root will assume B characteristics.
   C. Since auxins are the same for species A and species B, the shoot will retain A characteristics and the shoot will retain B characteristics.
   D. Because of the interaction of A and B hormones, the characteristics of both root and shoot will change slightly.
   E. Since both species will contribute equally, half of the resulting seeds will be A and half will be B if the flower is self-fertilized.
   (C) 5-3-2
844. The formation of which of the following occurs during gastrulation in the frog?
A. Gill slits
B. Heart
C. Archenteron
D. Pericardial and peritoneal cavities from the coelom
E. Dermatome, myotome and sclerotome from the epimere (C) 5-3-2

845. Distinction of root, stem and leaf primordia in a developing fern occurs in the
A. zygote.
B. four-cell stage of the embryo.
C. antheridium.
D. sporangium.
E. fiddlehead stage. (B) 5-3-2

846. One of the constituents of beef fat is glyceryl stearate. When a cow builds a molecule of this fat, one of the most likely reagents in the series of synthetic reactions is which of the following?
A. Cysteine
B. Mannose
C. Lauryl sulfate
D. Pyruvic acid
E. Sodium taurocholate (D) 5-1-3

847. It is thought that the first living organisms to establish themselves on Krakatau after the volcanic eruption of 1883 were lichens. Lichens were able to do this because they
A. are the most primitive forms of life.
B. can obtain and keep adequate supplies of water from the atmosphere.
C. reproduce by gemmules.
D. are not subject to predation.
E. secrete substances which repel insects. (B) 5-4-2

848. One of the constituents of beef fat is glyceryl stearate. A fern differs from a moss in having
A. an independent gametophyte.
B. an independent sporophyte.
C. swimming sperms.
D. archegonia.
E. haploid spores. (B) 5-4-2

849. It is thought that the first living organisms to establish themselves on Krakatau after the volcanic eruption of 1883 were lichens. Lichens were able to do this because they
A. are the most primitive forms of life.
B. can obtain and keep adequate supplies of water from the atmosphere.
C. reproduce by gemmules.
D. are not subject to predation.
E. secrete substances which repel insects. (B) 5-4-2

850. An example of such an event?
A. Cysteine
B. Mannose
C. Lauryl sulfate
D. Pyruvic acid
E. Sodium taurocholate (D) 5-1-3

851. A certain embryonic event in a rat takes about five minutes. Of the following, which is the most likely example of such an event?
A. Gastrulation
B. Migration of the heart from the pharyngeal region to the thorax
C. Descent of the testes
D. Manufacture of a synthesizing enzyme
E. Involution of the neural plate, forming a neural tube (D) 5-1-3

852. The basic 2n chromosome number of species x is probably
A. 3
B. 6
C. 16'
D. 12
E. not determinable from the drawings (B) 5-2-3

853. Which supports the claim that the cell division shown above is meiosis?
A. All of the following observations.
B. In II, the chromatids are doubled.
C. In III, the chromosomes are paired.
D. In IV, crossing-over is occurring.
E. None of the above observations (C) 5-2-3

854. Which of the following would be derived from mesoderm?
A. Nerve cords of a tapeworm
B. Intestine of a nematode
C. Nephridia of an earthworm
D. Tympanic membrane of a seal's ear
E. Lateral line organ of a shark's head (C) 5-2-3

855. In a vertebrate, most of the organs of special sense are located in the head. This is an example of
A. bilateral symmetry.
B. radial symmetry.
C. cephalization.
D. homeostasis.
E. preformation. (C) 5-3-3

856. If we consider the life history of a liver fluke as passing from egg to adult it includes the stages listed below. Arrange them in the proper temporal sequence.
1. Cercaria
2. Metacercaria
3. Miracidium
4. Redia
5. Sporocyst
A. 1-2-3-4-5
B. 5-4-3-2-1
C. 4-5-3-2-1
D. 3-5-4-1-2
E. 2-1-4-5-3 (D) 5-3-3

857. "Year after year, men cruising timber or hunting deer in the Blue Mountains of eastern Oregon had come back with the same story. Near the little hamlet of Kamela, they had often heard a faraway tinkling, a ghostly bell ringing. No one was ever able to track down the strange sound. It would fade away in the sighs of the wind through the big pines. Skeptics accused the men of hearing things.

"Last week, slashing a right-of-way for a power line from Bonneville Dam, lumberjacks brought down a ponderosa pine. Tied by a shriveled leather thong, high from Bonneville Dam, lumberjacks brought down a ponderosa pine. Tied by a shriveled leather thong, high in the treetop was the answer to the mystery of Kamela: a bronze cattle bell, inscribed with the date 1878... The people of Kamela guessed that a pioneer had tied it to a sapling that grew in to a towering pine." (TIME Magazine) Which of the following is the best appraisal of the concluding sentence in this report?
A. Logical — because a tree elongates from the ground up.
B. Logical — because this particular tree could not determinable from the drawings.
C. Illogical — because one knows with certainty when the bell was tied to the sapling.
D. Illogical — because elongation occurs only in the region of meristematic cells.
E. There is no basis for appraising the concluding sentence of the report. (D) 5-3-3

851. The nucleic acids are thought to replicate during phase
A. I
B. II
C. III
D. IV
E. V (A) 5-1-1
Coleoptile X is briefly exposed to light from the left then placed in the dark. Coleoptile Y is briefly exposed to light from the right then placed in the dark. Immediately their tips are cut off. Tip Y is placed on stump X without being rotated and tip Y is placed on stump X without being rotated. Which of the following best shows the probable growth of the coleoptiles?

858.

(A) 5-3-3

859. The sequence: willow—spruce—birch—maple represents a
A. phylogenetic trend.
B. food pyramid.
C. plant succession.
D. genetic drift.
E. homeostatic community. (C) 5-4-3

860. If the generation time of a certain species of bacteria is 20 minutes, how many bacteria will be present after two hours, if we start with one bacterium?
A. 12
B. 32
C. 40
D. 64
E. 128 (D) 5-4-3

861. Which will probably happen if fertilized eggs of toads and frogs are placed in the same container, assuming external conditions are suitable to both?
A. The environment will determine which RNA will direct the development and all frogs or all toads will result.
B. If given conditions more favorable to a frog, the toad embryo will show the characteristics of a frog.
C. The frog embryo will assume toad features because of influence of the enzymes from the toad.
D. Fertilized frog eggs will become frogs; fertilized toad eggs will become toads.
E. No embryo will develop. (D) 5-4-3

862. During development several different enzymes may appear in an embryo at different stages, all performing the same function. From this we may appropriately conclude:
A. Enzymes that perform a certain function may evolve several times in one kind of organism.
B. It often takes more than one enzyme to make a given reaction go.
C. Once a cell makes an enzyme it uses up its DNA for that function and cannot make that same enzyme again.
D. Secreting cells do not live long, and must be replaced often by other kinds of cells with other secretions.
E. Enzymes are not specific; they catalyze many kinds of reactions. (A) 5-1-4

863. In snail development, the histones of cleavage cells are rich in arginine; in gastrula cells the histones are rich in lysine. An acceptable conclusion from this is
A. the food preferences of snail embryos change during development.
B. the yolk of a snail’s egg is stratified as to chemical content.
C. different waste materials are given off at different stages of development.
D. in snails, endocrine glands appear quite early in embryology.
E. different enzymes are manufactured at different stages of development. (E) 5-1-4

864. Thin sheets of mica were inserted beneath the tips of two oat coleoptiles which were then exposed to unilateral light. The following figures represent the results after six hours.

If curvature results from substances which are produced in the tip and transported downward then the above results show that the substances are:
A. transported down the dark side and stimulate growth.
B. transported down the light side and inhibit growth.
C. transported laterally from the light side to the dark side.
D. auxins, namely indoleacetic acid (IAA).
E. unequally distributed due to their destruction by light. (A) 5-1-4

865. The mitotic spindle was once the subject of an argument as to whether the apparent fibers were really fibers or were channels more liquid than their immediate surroundings. Exposure of a living cell in mitosis to a strongly hypertonic medium resulted in a shrinking of the cell cytoplasm, but the spindle did not shorten; instead, it bent into a crescentic arc. This phenomenon best supports which of the following hypotheses?
A. The fibers did not shorten for salt water is denser than fresh water, and resists distortion of the “fibers.”
B. The spindle is protected from osmotic damage by a resistant membrane.
C. The “fibers” are more solid and contain less water than the surrounding cytoplasm.
D. The fibers are always present in the cytoplasm, but are more apparent during mitosis than at other times.
E. Spindle fibers cannot form if a cell is placed in a hypertonic medium. (C) 5-2-4

866. Which of the following best explains the results of the various experiments that show a direct correlation between the stage of cell development and the loss of a nucleus' ability to form a complete embryo?
A. Certain chromosomes are lost as the nuclei divide.
B. Compounds formed in the cytoplasm change the DNA structure resulting in the formation of new cytoplasmic enzymes.
C. Cytoplasmic feedback regulates the operation of genes which, in turn, regulate cytoplasmic operation.
D. Messenger RNA from the ribosomes tells the proper DNA code to operate.
E. The cytoplasm is self-regulating through RNA. (C) 5-2-4
This was repeated on 100 eggs. Scientist B used a similar egg. The development in the laboratory was observed. Scientist A used a laser to destroy half of a fertilized frog.

Items 872-877 are concerned with the following experiments:

872. Which best accounts for the difference in number of abnormal embryos?
   A. The eggs did not heal properly.
   B. Scientist A destroyed more ectoderm.
   C. Scientist A used eggs fertilized by “bad” sperm.
   D. Scientist B did not destroy the gray crescents.
   E. Scientist B used a solution more favorable for embryo survival. (D) 5-3-4

873. The results of scientist A best support which of the following hypotheses?
   A. Epigenesis
   B. Feedback by RNA
   C. Induction
   D. One gene, one enzyme
   E. Preformation (E) 5-3-4

874. Which of the following is the best control for scientist A’s experiment?
   A. 100 fertilized frog eggs allowed to develop under similar laboratory conditions
   B. 100 fertilized frog eggs allowed to develop in the natural environment
   C. 100 fertilized frog eggs cut in half and allowed to develop under similar laboratory conditions
   D. 100 unfertilized frog eggs exposed to the laser and then placed under similar laboratory conditions
   E. 100 fertilized eggs from a different animal exposed to the laser and then allowed to develop under similar laboratory conditions (A) 5-3-5

875. Which of the following hypotheses was scientist A most likely testing?
   A. A fertilized frog egg can develop normally only if it has a complete complement of cytoplasm.
   B. In developing frog embryos the nuclei can differentiate.
   C. Laser emissions inhibit RNA production in developing frog embryos.
   D. The destruction of half of a fertilized frog egg inhibits development.
   E. The grey crescent is necessary for development of fertilized frog eggs. (A) 5-3-4

876. Which of the following hypotheses was scientist B most likely testing?
   A. A fertilized frog egg can develop normally only if it has a complete complement of cytoplasm.
   B. In developing frog embryos the nuclei can differentiate.
   C. Laser emissions inhibit RNA production in developing frog embryos.
   D. The destruction of half of a fertilized frog egg inhibits development.
   E. The grey crescent is necessary for development of fertilized frog eggs. (E) 5-3-4

877. Which best explains why more eggs healed in scientist A’s experiment than in scientist B’s experiment?
   A. Chance
   B. Experimental error
   C. It takes more energy for normal embryos to develop, hence fewer eggs have enough energy to heal.
   D. Scientist A used 110-volt current; scientist B used 220-volt current.
   E. The frogs used in the two experiments were of different species. (A) 5-3-6

Items 867-869 represent phases in cell division.

867. Which happens between phases V and I?
   A. The chromosomes move to the poles.
   B. The chromosomes split.
   C. The DNA replicates.
   D. The RNA in the nucleolus replicates.
   E. The spindle is formed. (C) 5-2-2

868. Does the figure most likely represent division of a plant or of an animal cell and why?
   A. An animal cell because a spindle and nucleolus are present.
   B. An animal cell because centrioles are shown and the cell pinches in.
   C. A plant cell because centrioles are shown and a cell wall forms.
   D. A plant cell because a spindle and nucleolus are present.
   E. Either an animal or a plant cell because both have spindles, centrioles and nucleoli and the cell divides similarly. (B) 5-2-4

869. Could the figure represent division in bacteria and why?
   A. Yes, because the process in bacteria is identical to that in other organisms.
   B. Yes, because bacteria have DNA, nuclei and cell walls.
   C. No, because bacteria do not have DNA or cell walls.
   D. No, because bacteria do not have definite nuclei or nucleoli.
   E. No, because bacterial cells do not divide. (D) 5-2-4

Items 870-871 are based on an experiment with a Triton which has balancers on its head and an Axolotl which has suckers on its head. Side skin, which does not develop suckers, was transplanted from an Axolotl embryo to a Triton embryo head, the area where balancers develop. The Triton embryo developed suckers instead of balancers. Head skin from an Axolotl embryo transplanted on the side of a Triton embryo failed to develop balancers or suckers.

870. The best explanation of these results is that
   A. The Axolotl cells are preformed.
   B. Ectoderm cells become gametes.
   C. Although cells are induced to differentiate they are limited by their heredity.
   D. Skin from different organisms can not be transplanted successfully.
   E. Development is directed by a guiding principle known as entelechy. (C) 5-2-4

871. Which would probably develop if Triton side skin were transplanted to Axolotl head?
   A. Balancers
   B. Suckers
   C. Both balancers and suckers
   D. A Triton head
   E. Nothing, since a tissue transplant from one organism to another will not grow. (A) 5-2-4

Items 872-877 are concerned with the following experiments: Scientist A used a laser to destroy half of a fertilized frog egg. The development in the laboratory was observed. This was repeated on 100 eggs. Scientist B used a similar technique on 100 fertilized frog eggs. Their results are given below:

<table>
<thead>
<tr>
<th></th>
<th>Scientist A</th>
<th>Scientist B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of eggs which healed</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Number of normal embryos</td>
<td>15</td>
<td>55</td>
</tr>
<tr>
<td>Number of abnormal embryos</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>
878. if the diagram represents the menstrual cycle, then
A. 1 represents the pituitary, II the ovary, I the egg, and IV the uterus.
B. 1 represents the brain, II the thyroid, III the uterus and IV the ovary.
C. 1 represents the hypothalamus, II the ovary, III the uterus, and IV the pituitary.
D. 1 represents the hypothalamus, II the pituitary, III the ovary, and IV the uterus.
E. 1 represents the pituitary, II the uterus, III the ovary and IV the hypothalamus.

(D) 5-3-4

879. If organ IV periodically changes from one state (IVa) to another (IVb) and back - then what is the best explanation for this change? Assume that 1, 2, and 3 are secretions from I, II and III.
A. A built-in block mechanism makes organ IV responsive and then not responsive to secretion 3.
B. Organ IV secretes a substance which feeds back to organ I inhibiting secretion 1.
C. Secretion 3 causes state IVb, but inhibits the secretion of 1 or 2, thus stopping its own secretion, hence organ IV goes back to IVa.
D. Secretion 3 causes state IVb but inhibits organ III's secretion 3, hence organ IV goes to state IVa.
E. Secretion 3 consists of 3a, which stimulates organ IV to go to state IVb, and 3b, which stimulates organ IV to revert back to IVa.

(C) 5-3-4

880. If the above diagram represents the formation of an amino acid (IV) in the mold Neurospora, then 1 2 and 3 represent
A. enzymes, and II and III represent intermediate chemical compounds.
B. genes, and II and III represent enzymes.
C. intermediate chemical compounds, and I, II, and III represent enzymes.
D. intermediate chemical compounds, and I, II, and III represent genes.
E. enzymes, and II, III, and IV represent genes.

(A) 5-1-4

Items 881-885 are based upon the following experiment performed to determine the origin of germinal cells which become gametes. Endoderm cells in 10 three-day old chick embryos were marked with a vital stain (i.e., one which does not kill the cells). One embryo was killed and the stained cells were recorded. No stained cells appeared within the gonads. It was concluded that endoderm cells do not become germinal cells.

881. What must be assumed if the results of this experiment are to be considered valid?
A. Endoderm cells usually form the gonads.
B. Ectoderm cells become gametes.
C. Gonads are comprised of cells from various parts of the embryo.
D. The presence of stained cells indicates that they actively move.
E. The vital stain does not affect the cells' functions.

(E) 5-3-4

882. How is the conclusion related to the experimental results? It is probably
A. valid but is not supported by the results.
B. valid and is supported by the results.
C. not valid but is supported by the results.
D. not valid and is not supported by the results.
E. not valid but is unrelated to the results.

(C) 5-3-4

883. Which theory was the experiment most likely designed to investigate?
A. Darwin's pangenesis
B. Embryonic induction
C. Epigenesis
D. Inheritance of acquired characteristics
E. Weismann's germ plasm

(E) 5-3-4

884. Which is the most justifiable criticism of the experimental technique?
A. Since their development is abnormal, chick embryos should not be used.
B. The sample was taken at too widely spaced intervals because if cells move they do so rapidly.
C. The samples were taken at too widely spaced intervals because if cells move they do so rapidly.
D. The sample was inadequate, and the experiment may not have continued long enough.
E. Killing and preservation changes cells, hence only living cells should be examined.

(D) 5-3-6

885. What might be the best experimental procedure to follow next if the results are valid?
A. Use radioactive tracers on similar embryos because they are less harmful.
B. Repeat the experiment with other kinds of embryos which are more representative.
C. Repeat the experiment but mark other groups of endodermal cells.
D. Graft two embryos together and see if stained endodermal cells will move from one embryo to another.
E. Remove endodermal cells from developing chick embryos and see if gonads form.

(C) 5-3-5

886. The intercostal muscles of a human are supplied by nerves from the thoracic region of the spinal cord. The diaphragm muscles, posterior to the intercostal muscles, are supplied by nerves from the cervical region of the spinal cord, anterior to the thoracic region. The best explanation of this involves the statement that the intercostal muscles are supplied by sympathetic nerves, whereas the diaphragm is supplied by parasympathetic nerves.

(C) 5-3-4
An investigator tries to find out with what precursors a chromosome starts when it replicates its DNA. In this research, he would most need which of the following? 

A. A phase-contrast microscope 
B. A radioactive marker 
C. A pH-meter 
D. An oscilloscope 
E. A calorimeter

The best way to determine relative amounts of auxin in a plant organ is to 

A. extract the auxin and chemically analyze it. 
B. remove the plant organ and measure its effect on the plant. 
C. place the organ on top of a coleoptile. 
D. extract the auxin, apply it to one side of detached coleoptiles and measure the bending. 
E. place the organ on agar, remove it, then grow seedlings on the agar and measure their growth.

The biologist Dr. Fritz Went found that if coleoptile tips were removed and placed on agar blocks for one hour, the agar blocks would then produce a bending when placed on one side of freshly-cut coleoptile stumps. Of what significance is this experiment? 

A. It is the basis for quantitative determination of small amounts of growth-promoting substances. 
B. It made possible the isolation and exact identification of auxin. 
C. It is the basis for the experimental support for the hypothesis that IAA is auxin. 
D. It demonstrated polar movement of auxins. 
E. It made possible the discovery that roots respond differently than do shoots to different quantities of IAA.

Which provides evidence that the action of 2,4-D is synergistic rather than a direct auxin effect? 

A. 2,4-D has no effect on split sections of pea stems, whereas IAA does. 
B. 2,4-D curls split sections of pea stems if applied immediately but not if applied after soaking the stems for four hours in water. 
C. 2,4-D curls split sections of pea stems if applied after soaking the stems for four hours in water but not if applied immediately. 
D. 2,4-D curls split sections of pea stems but IAA does not. 
E. 2,4-D will not cause elongation of oat coleoptiles but IAA will.

A cytologist wants to know the details of the changes in form undergone by the chloroplast of a Spirogyra cell from zygospore to vegetative cell. Which of the following tools will be most useful in this research? 

A. An electron microscope 
B. An oscilloscope 
C. A spectrophotometer 
D. An ultracentrifuge 
E. A chromatographic column

Assume chromosome movement during mitosis results from contraction of fibers attached to the centromere and to the pole region. Then if the centromere is located very near the end of a chromosome, which best represents the chromosome during anaphase?

If the left front limb of an adult rat is grafted to the lateral chest wall of an adult chicken, it will develop into a wing. 

If the left front limb of an adult rat is grafted to the lateral chest wall of an adult chicken, it will develop into a wing. 

If phytochrome promotes internodal elongation in plant species X, then exposure to 

A. red light should inhibit, and exposure to far red light should stimulate elongation. 
B. far red light should inhibit, and red light should stimulate elongation. 
C. red and far red light should stimulate elongation. 
D. red and far red light should inhibit elongation. 
E. red and far red light should have no effect on elongation.

The particular nature of the organ into which the graft developed reflects its genetic endowment. 

The transplanted frog tissue developed a structure in harmony with its new location.

If phytochrome promotes internodal elongation in population #1. elongation in population #2.

The hormone affects only one sex in species X. His results are shown in Figure 1.

If phytochrome promotes internodal elongation in plant species X, then it 

A. will inhibit internodal elongation in Y. 
B. will inhibit flowering in Y. 
C. will stimulate flowering in Y. 
D. will stimulate internodal elongation in Y. 
E. may have no effect or it may stimulate flowering in Y.

The action spectrum for promoting internodal elongation in plant species X is similar to the action spectrum for initiation of flowering in "long day" species Y. If gibberellin promotes internodal elongation in X then it 

A. will inhibit internodal elongation in Y. 
B. will inhibit flowering in Y. 
C. will stimulate flowering in Y. 
D. will stimulate internodal elongation in Y. 
E. may have no effect or it may stimulate flowering in Y.

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B. will inhibit flowering in Y. 
C. will stimulate flowering in Y. 
D. will stimulate internodal elongation in Y. 
E. may have no effect or it may stimulate flowering in Y.

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C. red and far red light should stimulate elongation. 
D. red and far red light should inhibit elongation. 
E. red and far red light should have no effect on elongation.
For items 906-908 use the following diagrams representing models which explain development or aspects of development.

906. If \( a \) represents raw materials, \( b \) represents increase in cell size and \( c \) represents cell division, then which diagram best shows the relationship found in most cells?

A. I  
B. II  
C. III  
D. IV  
E. V  

907. Which diagram shows a feedback mechanism?

A. I  
B. II  
C. III  
D. IV  
E. V  

908. If diagram II represents development of a fruiting body from a spore in a cellular slime mold then which is possible?

A. \( a \) represents cell movement (aggregation); \( b \), cell division; and \( c \), cell differentiation.  
B. \( a \) represents cell division; \( b \), cell movement (aggregation); and \( c \), cell differentiation.  
C. \( a \) represents cell division; vision \( b \) cell differentiation; and \( c \), cell movement (aggregation).  
D. \( a \) represents cell differentiation; \( b \), cell division; and \( c \), cell movement (aggregation).  
E. \( a \) represents cell differentiation; \( b \), cell movement (aggregation); and \( c \), cell division.  

909. If development consists of cell growth, differentiation and movement, why is the cellular slime mold of interest to scientists studying development?

A. Cell growth, differentiation and movement occur independently and can be studied separately.  
B. Cell growth, differentiation and movement occur independently and can all occur together and can be studied as a whole.  
C.  

910. As a slug is formed it is cut in half. Both the head and tail halves form complete but abnormal spore bodies with stalks and discs. Spores from those bodies will each give rise to amebae which form normal spore bodies. This shows that

A. a cell’s fate is controlled by genes only.  
B. each half contains the potential to form all spore body parts.  
C. tail and head cells are genetically different.  
D. the environment alone controls development.  
E. development can occur without cell differentiation.  

911. It is hypothesized that a chemical attractant is involved in aggregation of amebae. Which experimental procedure will best demonstrate the presence of such an attractant?

A. Add a combination of chemicals found in the laboratory and observe if single amebae are attracted.  
B. Add respiratory toxins and note whether aggregation is inhibited.  
C. Place amebae in gravitational, magnetic and electric fields and observe if aggregation is affected.  
D. Observe if single amebae are attracted to an extract from aggregating amebae.  
E. None of the above procedures will demonstrate the presence of an attractant.  

912. Which experiment(s) demonstrate(s) that the procedure for nuclear removal was effective?

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

913. What is the best modern explanation for the results from experiment III?

A. Cytoplasmic RNA controlled early cleavage.  
B. DNA from species \( x \) and \( y \) was incompatible.  
C. DNA from species \( y \) was incompatible with cytoplasmic, RNA in \( x \) egg.  
D. DNA from \( y \) sperm doubled and prevented the haploid syndrome.  
E. Without DNA, mitosis did not occur hence cell division was impossible.  

914. If the \( x \) egg nucleus in experiment III were replaced with a nucleus from a “normal” \( x \) early blastula, which would probably have resulted?

A. A neurula showing the “haploid syndrome”  
B. A normal diploid embryo  
C. A normal-sized embryo with fewer but larger polyploid cells  
D. An abnormal triploid hybrid embryo  
E. An embryo stopped in gastrulation due to nuclear cytoplasmic incompatibility
915. Which best supports the hypothesis that differentiation depends upon inhibitions rather than stimulations?
A. A transplanted optic cup will cause lens formation in a salamander embryo.
B. Frog embryos grow in solutions with pieces of mature organs failed to develop these organs.
C. If frog embryo belly skin is transplanted to the head of a salamander embryo, external gills are formed instead of balancers.
D. Mouse and chick liver cells will reaggregate if mixed.
E. Removal of the gray crescent will result in an abnormal embryo lacking a neural tube.
(B) 5-3-6

For items 916-919 use the following key:
KEY: A. I is quantitatively greater than H.
B. II is quantitatively greater than I.
C. I and II are quantitatively equal.
D. Either I or II can vary quantitatively.
E. Both I and II can vary quantitatively.

916. I. sepals in an apple flower.
II. styles in an apple flower.
(C) 5-3-6

917. I. cells in a sea urchin blastula.
II. cells in a frog blastula.
(B) 5-2-6

918. I. chromosomes in a corn egg nucleus.
II. chromosomes in a corn pollen tube nucleus.
(C) 5-2-6

919. I. chromosomes in corn embryo.
II. chromosomes in corn endosperm nucleus.
(B) 5-2-6

For items 920-921 use the following key:
KEY: A. I is quantitatively greater than II.
B. II is quantitatively greater than I.
C. I and II are quantitatively equal.
D. Either I or II can vary quantitatively.
E. Both I and II can vary quantitatively.

920. I. Cell division rate during cleavage in a frog embryo.
II. Cell division rate in Escherichia coli in a human intestine.
(B) 5-2-6

921. I. Usual number of young per litter in the armadillo.
II. Usual number of young per litter in the hamster.
(D) 5-3-6

Essay Questions
Questions 922-927. Answer each of the following, and defend your answer.

922. In the development of fatty acid molecules, organisms add two-carbon increments until a chain of 16 or 18 carbons is formed. What brings about the stoppage of increment additions at this point?
5-1-5

923. It has been said that it takes about five seconds for a bacterium to manufacture a protein molecule and about five minutes for a mammalian liver cell to manufacture a protein molecule of comparable size. How do you account for the time difference?
5-1-5

924. What evidence can you suggest to apply to the question whether mitochondria are self-replicating?
5-2-5

925. When a human skin wound involves the dermis, healing may result in development of a denser mat of connective tissue fibers than was present before the wound occurred. What set of factors accounts for this?
5-2-5

926. Assuming that life first arose on this planet by chemical evolution, describe the first truly living organism.
5-3-5

927. Two lizards of the same species, a male and a female, are carried on a tree limb by a typhoon to an island in the Pacific Ocean isolated from the nearest adjacent mainland by fifty miles. No lizards of this species have lived on the island before. Food is present in abundance and for ten years no natural enemies seriously threat the success of these lizards and their offspring. Describe the growth of the population of this species of lizards on the island during the first ten years.
5-3-5

928. A pond on a Civil War battlefield is described in a soldier's diary. Yet a visit to the same spot described by the soldier reveals only a forest. Give in detail a biological explanation which might account for this discrepancy.
5-4-5

Questions 929-930. Answer each of the following, and defend your answers.

929. The Florida Everglades suffered from a combination of diminished rainfall and diversion of ground water. Many plant and animal populations decreased markedly as a result of the water shortage.

a. Which kinds of natural inhabitants of the Everglades probably showed the most rapid diminution in numbers? Why?
5-4-5
b. Which kinds probably showed the most extensive diminution in numbers? Why? Why?
5-4-5
c. What factors would make your answers to the two preceding questions different? Why? Why?
5-4-4
d. If water in abundance were restored to the Everglades, which kinds of organisms would stage the most rapid comeback to normality of population numbers? Why?
5-4-5
e. Which kinds would be the slowest at restoring normal numbers? Why?
5-4-5

930. Propose a procedure to determine what is the first measurable indication of the differentiation of an endoderm cell from a totipotent blastomere in an amphibian embryo.
5-3-5

931. Briefly, but specifically, predict the developmental consequences of

a. tying off the ductus arteriosus of an unhatched chick embryo.

b. grafting two eye fields together.

c. tying off the right IVth aortic arch of a 96-hour chick embryo.

5-2-2

932. Contrast or compare

a. the chief means of morphogenesis in the formation of Capsella cotyledons and the chief means of morphogenesis in the formation of the chick primitive streak.

b. the means by which Pteridium spermatozoa locate Pteridium ova, and the means by which Cynthia spermatozoa locate Cynthia ova.

c. the developmental flexibility of I; and of P.

5-2-2

933. Cite two consequences of destroying I that would be apparent three plastochrones later.
5-2-2

934. Cite three different developmental consequences that might be expected in a frog embryo homozygous for the hypothetical recessive mutant "bottle cell-less."
5-3-2

935. Cite evidence to indicate whether the information acquired from an inducing tissue can be transmitted to the progeny of the cells originally induced.
5-2-5

936. Suppose that a biologist is interested in learning more about the nature of tissue invasiveness by studying blastocyst invasion of uterine tissues. Assuming that there would be no problems with immune reactions to a foreign blastocyst, outline two experiments he might try that would tell him whether the uterine tissues stop the blastocyst's invasion, or whether the blastocyst stops of its own accord. Be sure to include

(a) what type of fetal-maternal relationships are characteristic of the blastocysts(s) and uterus (or uteri) that are chosen, and

(b) what results could be expected and what these would indicate.
5-2-5
937. Assume that you are able to graft small pieces of grey crescent cortex to various locations on the surface of host eggs and you find that although transplants to the ventral margin result in a secondary point of gastrulation at that place, transplants to a location between the animal pole and the ventral margin (say, at 10 or 11 o’clock, looking at the egg sideways) do not result in a point of gastrulation at the place of grafting.

(a) Describe briefly an experiment that might explain this second result. Include a few labelled sketches.
(b) Where might a second point of gastrulation be expected in this latter experiment? 5-2-5

938. Discuss whether there is a common mechanistic basis for the biological clocks determining flowering times in angiosperms and breeding seasons in vertebrates. 5-3-3

939. Propose a procedure to determine the final fate of a cell on the outer surface of a frog blastula. 5-3-5
SECTION 11. EXAMPLES: SYSTEMATICS

Objective Items

940. Classification of algae, protozoa, fungi and bacteria poses a major taxonomic problem. Haeckel proposed to settle this problem by saying that these organisms
A. are all plants.
B. are all animals.
C. include some plants and some animals.
D. are neither plants nor animals.
E. should be of no concern to biologists.

(D) 6-3-1

941. The class Sporozoa of the phylum Protozoa can be most easily characterized by
A. flagella.
B. chlorophyll.
C. parasitism.
D. cilia.
E. ameboid movement.

(C) 6-2-1

942. A criterion commonly used to differentiate paramecia into species is
A. number of micronuclei.
B. position of the oral groove.
C. number of contractile vacuoles.
D. number of cilia.
E. presence or absence of a cytopyge.

(A) 6-2-1

943. The genera Euglena and Astasia differ in that Euglena possesses
A. mitochondria.
B. Golgi bodies.
C. chloroplasts.
D. ribosomes.
E. centrioles.

(E) 6-2-1

944. Which genus has more than one living species?
A. Ginkgo
B. Limulus
C. Spirogyra
D. Planaxa
E. Homo

(C) 6-3-1

945. An animal phylum having radially symmetrical adults but bilaterally symmetrical larvae is
A. Porifera.
B. Cnidaria (Coelenterata).
C. Echinodermata.
D. Annelida.
E. Arthropoda.

(C) 6-3-1

946. The scientific name of the American elm is Ulmus americana. L. Which of the following is correct concerning the way this name is written?
A. The L. means that this particular name is from the Latin language.
B. The L. means that the Swedish botanist, Linneaus, gave this tree its scientific name.
C. The L. actually has nothing to do with assigning this name to this tree.
D. The name is not written properly -- the first letter in americana ought to be capitalized.
E. The words Ulmus and americana are underlined to give them emphasis.

(B) 6-3-1

947. All roundworms differ from all flatworms in having a
A. longitudinal nerve cord.
B. segmented body.
C. pseudocoel.
D. metamorphosis in the life history.
E. blood circulatory system.

(C) 6-4-1

948. Consider the following phyla of animals:
1. Cnidaria (Coelenterata).
2. Platyhelminthes.
3. Annelida.
5. Arthropoda.

A blood circulatory system is characteristic of
A. 2, 3, 4, and 5, but not 1 and 6.
B. 3, 5, and 6, but not 1, 2, 4, and 6.
C. 2, 3, 5, but not 1, 2, 4, and 6.
D. 3, 4, 5, and 6, but not 1 and 2.
E. 2, 3, 4, 5, and 6, but not 1.

(D) 6-3-1

949. Carnivorous species are found in which of the phyla listed in the previous item?
A. all six phyla
B. 1, 2, 3, 5, but not 4, 6, and 6.
C. 1, 5, and 6, but not 2, 3, and 4.
D. 2, 4, 5, and 6, but not land 3
E. 2, 4, 6, and 6, but not land 3 and 5

(E) 6-1-2

950. Biologists use the biochemical activity of bacterial enzymes as a
A. basis for classifying the bacteria.
B. means of acclimating the bacteria to new natural habitats.
C. method of identifying viruses.
D. mechanism for refining crude petroleum.
E. technique for transferring nuclei among amphibian embryos.

(A) 6-1-2

951. Two organisms are thought to be taxonomically closely related if
A. they store carbohydrates in the same kind of molecule.
B. both possess pinately-veined leaves.
C. both possess red blood.
D. both obtain energy by changing ATP to ADP.
E. each builds antibodies to few if any of the other's proteins.

(E) 6-1-2

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

(D) 6-2-2

953. A freshwater ameba and an intestinal ameba are alike in
A. possession of a single contractile vacuole.
B. their mechanisms of dispersal.
C. the absence of cilia.
D. cyst structure.
E. kinds of predators.

(C) 6-2-2

954. The shape of which of the following is commonly used taxonomic criterion in fossil mammals?
A. Heart
B. External ear
C. Molar tooth
D. Knee joint
E. Blood corpuscles

(A) 6-3-2

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

(B) 6-3-2

Items 956-966 are descriptions of fossils, on the basis of which the specimens are classified and dated on the geological time scale. Evaluate the classification and dating of each according to the following key:

KEY: A. The classification is correct and the time is possible.
B. The classification is wrong but the time is possible.
C. The classification is correct but the time is impossible.
D. The classification is wrong and the time is impossible.
E. The evidence is insufficient for proper classification and/or dating.

956. A tree showing regular unbranched stems was classified as a gymnosperm and was believed to be carboniferous in age.

(B) 6-3-2
957. A straight shell with chambers was classified as an ammonite and was thought to have lived in the early Tertiary.  
958. A skeleton with teeth, a long tail and feathers was alleged to have come from Jurassic rocks and was called a bird.  
959. A plant fossil showing roots, stems and seeds was definitively classified as an angiosperm and was concluded to be necessarily post-carboniferous.  
960. A fossil skeleton with pillar-like legs and incisor teeth five inches long was called a reptile and was assumed to have been Mesozoic in age.  
961. From deposits dated Devonian an impression revealed a creature with external skeleton, paired appendages and three longitudinal divisions of the body. It was called a crustacean. (B) 6-3-2  
962. A plant with no leaves, no roots, but having stems and spores was called a Psilopsid. It was associated with rocks believed to have been Silurian in age. (A) 6-3-2  
963. From rocks thought to be Cretaceous came an animal 40 feet long with scales on the skin. It was called a dinosaur. (E) 6-3-2  
964. A fish with radiating bones in the fin region was called a lungfish and was assumed to have been dead only a few centuries. (B) 6-3-2  
965. Some branches of a plant were found showing flowers with three sepals and a few seeds. It was concluded to have been a dicot and to have come from the Permian. (D) 6-3-2  
966. A skull with eye sockets both directed forward was alleged to be a primate and was thought to come from rocks late Mesozoic in age. (C) 6-3-2  
967. Which of the following is not an essential in a permanently closed balanced aquarium?  
A. An external energy source  
B. A producer  
C. A primary consumer  
D. A secondary consumer  
E. A reducer  
(D) 6-4-2  
968. Morphological characteristics are commonly used as taxonomic criteria. A more fundamental basis for classification would use as criteria  
A. the nature of the native biome.  
B. factors of sexual selection.  
C. types of food molecules ingested.  
D. nucleic acid chemistry.  
E. typical behavior patterns. (D) 6-1-3  
969. Presence or absence of chloroplasts can be used to distinguish among different genera of  
A. rotifers.  
B. flagellates.  
C. blue-green algae.  
D. bacteria.  
E. slime molds. (B) 6-2-3  
970. The difference between diploid and tetraploid kinds of organisms is sufficient to distinguish them as separate species if the organisms are  
A. laboratory rats.  
B. water molds.  
C. earthworms.  
D. sea anemones.  
E. evening primroses. (E) 6-2-3  
971. Nicotiana sylvestris flowers only during long days and Nicotiana tabacum flowers only during short days. If raised in the laboratory under different photoperiods, they can be induced to flower at the same time and can be cross-fertilized to produce self-fertile offspring. What is the best reason for considering N. sylvestris and N. tabacum separate species?  
A. They can not interbreed in nature.  
B. They are reproductively distinct.  
C. They are physiologically distinct.  
D. They are morphologically distinct.  
E. They will probably not occur together in nature. (A) 6-3-3  
972. An explorer has found a new kind of buttercup in a remote habitat. He describes it as a new species. The one of the following characteristics most suitable to distinguish it from previously established species is its  
A. pungent odor.  
B. root branching pattern.  
C. leaf size.  
D. soil type preference.  
E. floral structure. (E) 6-3-3  
973. The most likely criteria for differentiating taxonomically between two kinds of mosquitoes would be  
A. one prefers human blood, one prefers plant juices.  
B. one transmits yellow fever, one transmits malaria.  
C. one has antennae differently formed from those of the other.  
D. one lays an average of 60 eggs, one an average of 75 eggs.  
E. one metamorphoses twelve days after egg-laying, one in ten days. (C) 6-3-3  
974. Two habitats, one in Asia and one in South America, are very much alike as to physical and chemical characteristics. The organisms living in these two habitats are most likely to be of the same  
A. variety.  
B. species but different varieties.  
C. genus but different species.  
D. family but different genera.  
E. order but different families. (E) 6-4-3  
975. If our classification system represents evolutionary relationships, then which organisms probably would have the most similar antigens?  
A. Chlamydomonas eugametos and Sagittaria sagittifolia  
B. Porcellio scaber and Daphnia pulex.  
C. Paramecium caudatum and Chlamydomonas eugametos  
D. Paramecium caudatum and Porcellio scaber  
E. Sagittaria sagittifolia and Porcellio scaber  
(B) 6-3-3  
976. Which organisms can be identified as aquatic?  
A. All of them  
B. Paramecium, Daphnia and Chlamydomonas only  
C. Paramecium, Daphnia, Porcellio and Chlamydomonas only  
D. Paramecium and Chlamydomonas only  
E. They cannot be determined from the above chart (E) 2-4-3  
977. Which organisms probably possess DNA?  
A. Chlamydomonas and Sagittaria only  
B. Paramecium and Chlamydomonas only  
C. Paramecium, Chlamydomonas, Porcellio, Daphnia and Sagittaria.  
D. Porcellio and Daphnia only  
E. Porcellio, Daphnia and Sagittaria only  
(C) 4-1-2
978. Which organisms would probably contain chlorophyll a?
   A. Chlamydomonas and Sagittaria only
   B. Paramecium and Chlamydomonas only
   C. Paramecium, Chlamydomonas, Porcellio, Daphnia and Sagittaria
   D. Porcellio and Daphnia only
   E. Porcellio, Daphnia and Sagittaria only  
   Items 979-981 are concerned with an island which supports isolated populations of two types of frogs. The following information is known about the frogs.
   A. The frogs have a different appearance.
   B. The frogs have a common fossil ancestor.
   C. The frogs have similar nutrient requirements but excrete different products.
   D. The frogs live in different, isolated habitats.
   E. The frogs will interbreed, producing fertile offspring.

979. Which is the most important in a useful (to the average citizen) classification system of these frogs?
   (A) 6-3-3

980. Which is the best evidence for the hypothesis that the frogs are all one species?
   (E) 6-3-3

981. Which suggests that the frogs may be evolving into two separate species?
   (D) 6-3-3

982. Morphological characters are most commonly used as criteria in metaphyte taxonomy. Which of the following reasons is the least appropriate for this practice?
   A. Structure reflects the processes that nucleic acids control.
   B. Structure is more readily determined than nucleic acid biochemistry.
   C. Organisms with similar genotypes have similar morphologies.
   D. Variation in structure is multifarious.
   E. Differences in structure can be determined by several means — sight, touch, photography, etc.  
   Items 983-984. Viruses are now classified according to the hosts they infect and the effects they cause. It has been suggested that a more satisfactory taxonomy would use as criteria the chemistry of the viruses.

983. The present criteria are used because
   A. nothing is known of the chemistry of viruses.
   B. the hosts are more of an economic liability to man than the viruses.
   C. virology is more of an applied science than a pure science.
   D. only medical research workers are interested in viruses.
   E. the hosts and effects are more easily determined than the chemistry of viruses.  
   Items 985-994. Each item lists two categories, numbered I and II. Select the answers from the following key.  
   KEY: A. All the members of I are also members of II, but not all members of II are members of I.
   B. All the members of II are also members of I, but not all members of I are members of II.
   C. All members of I are members of II, and all members of II are members of I.
   D. No member of I is also a member of II.
   E. Some members of I are members of II and some are not, and some members of II are members of I and some are not.

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995. If two species of snails whose distribution ranges and ecological niches overlap are competing then
   A. a new species will arise in the overlapping zone because of hybridization.
   B. both species will coexist in the overlapping zone if the environment is different from either species' "specific zone."
   C. both species will coexist in the overlapping zone if the environment is like one "specific zone."
   D. each species' distribution will end abruptly in the middle of the overlapping zone.
   E. one species will eventually "take over" the overlapping zone.  
   Items 986-994. Each item lists two categories, numbered I and II. Select the answers from the following key.  
   KEY: A. All the members of I are also members of II, but not all members of II are members of I.
   B. All the members of II are also members of I, but not all members of I are members of II.
   C. All members of I are members of II, and all members of II are members of I.
   D. No member of I is also a member of II.
   E. Some members of I are members of II and some are not, and some members of II are members of I and some are not.

996. Geographic races of a species are recognized because they
   A. live in different media.
   B. differ from each other in morphological characteristics.
   C. are capable of interbreeding when brought together.
   D. have narrow tolerances for environmental conditions.
   E. compete with each other for the same ecological niche.  
   Items 986-994. Each item lists two categories, numbered I and II. Select the answers from the following key.  
   KEY: A. All the members of I are also members of II, but not all members of II are members of I.
   B. All the members of II are also members of I, but not all members of I are members of II.
   C. All members of I are members of II, and all members of II are members of I.
   D. No member of I is also a member of II.
   E. Some members of I are members of II and some are not, and some members of II are members of I and some are not.

997. Which of the following comparisons of biome taxonomy and organism taxonomy is invalid? In both
   A. there are hierarchies of classification comparable to phyla, classes, orders, etc.
   B. visible criteria are used in classifying.
   C. taxonomy helps point up evolutionary changes.
   D. physical factors such as temperature, pressure, and physical state are prime factors in determining taxonomic status.
   E. the taxonomy is an arbitrary human construct.  
   Items 986-994. Each item lists two categories, numbered I and II. Select the answers from the following key.  
   KEY: A. All the members of I are also members of II, but not all members of II are members of I.
   B. All the members of II are also members of I, but not all members of I are members of II.
   C. All members of I are members of II, and all members of II are members of I.
   D. No member of I is also a member of II.
   E. Some members of I are members of II and some are not, and some members of II are members of I and some are not.
998. When ribosomes from rat cells, activating enzymes from guinea pig, polypeptide polymerizing enzymes from mouse cells, sRNA from E. coli cells, and mRNA from rabbit cells are incubated together in the proper concentration and with ATP and GTP, proteins are made. These proteins are likely to resemble
   A. rat proteins.  
   B. guinea pig proteins.  
   C. mouse proteins.  
   D. E. coli proteins.  
   E. rabbit proteins.  
   (E) 6-1-5  

999. The ranges of grass species I and II overlap, yet hybrids are not usually found in nature. Species I and II will interbreed in the laboratory resulting in fertile hybrids. Which is the best explanation?  
   A. I and II are different species.  
   B. I and II are the same species.  
   C. Species I and II can not interbreed.  
   D. The hybrids cannot compete in the naturally existing habitats.  
   E. Breeding is genetically controlled in species I or II.  
   (D) 6-3-4  

1000. Which would probably be the best place to look for naturally occurring hybrids between species I and II?  
   A. Disturbed areas in the overlapping range  
   B. Habitats elsewhere but similar to that in which species I is found  
   C. An entirely different part of the country where neither I nor II is found  
   D. An environment containing high quantities of x-rays, ultraviolet light or radioactive elements  
   E. A habitat intermediate between habitats occupied by species I and II but outside the range of both  
   (A) 6-3-5  

1001. A biologist classifies chemical substances as to their contribution to the life of a cell. Which of the following categories would chlorophyll best fit?  
   A. Nutrition  
   B. Movement  
   C. Reproduction  
   D. Secretion  
   E. Energy transformation  
   (E) 6-1-6  

1002. Consider the following:  
   I. The number of kinds of nucleotides in an RNA molecule  
   II. The number of kinds of nucleotides in a DNA molecule  
   How can the relationship of I and II best be categorized?  
   A. I is qualitatively greater than II.  
   B. II is qualitatively greater than I.  
   C. I and II are qualitatively equal.  
   D. Either I or II can vary quantitatively.  
   E. Both I and II can vary quantitatively.  
   (A) 6-1-6  

1003. You are asked to classify cell organelles on the basis of their principal functions. One category you erect is for organelles whose chief function concerns cell division. Which of the following is the most likely representative of this category?  
   A. Lysosome  
   B. Mitochondrion  
   C. Centriole  
   D. Ribosome  
   E. Golgi body  
   (C) 6-2-6  

Essay Questions  
1004. Formulate criteria for classifying all kinds of proteins according to the role they play in the metabolism of organisms.  
   (A) 6-1-5  

1005. Viruses are frequently divided into bacterial, plant, and animal viruses according to the nature of their hosts. Devise a useful classification of viruses into major groups without using the nature of the host as a criterion.  
   (A) 6-1-5  

1006. A bacteriologist wishes to develop a taxonomy of bacteria based entirely on biochemical criteria with no reference to morphological characters. Propose the criteria and divisions which represent the best scheme for assorting all kinds of bacteria into major groups.  
   (B) 6-2-5  

Questions 1007-1011. A biologist is convinced that all organisms which are not multicellular can best be called noncellular rather than unicellular.  

1007. Assemble a set of arguments supporting his contention.  
   (6-2-4  

1008. He wishes to develop a classification of these noncellular organisms. What criteria will best break them up into major groups and what will these groups include?  
   (6-2-4  

1009. He realizes that in the life cycles of many multicellular organisms there are nonmulticellular stages. Should these be included in his group of noncellular organisms? Why or why not?  
   (6-2-6  

1010. He realizes also that some organisms are syncytial with many nuclei but no partitioning membranes or walls. Should these be included in his group of noncellular organisms? Why or why not?  
   (6-2-6  

1011. What arguments support the unicellularity of these other-than-multicellular organisms?  
   (6-2-4  

1012. Propose a procedure to determine what characteristics are the best to use in classifying members of the genus Quercus into separate species.  
   (6-3-5  

1013. Zoologists set aside a major taxon for unicellular animals, but botanists do not put all unicellular plants in one major taxon. What are the reasons for this? Are these reasons valid and sufficient for the practice?  
   (6-3-6  

Questions 1014-1023. A biologist attempts to classify ecosystems. He thinks of five schemes.  

1014. One of these schemes classifies ecosystems according to variant sets of physical factors such as average temperatures, temperature ranges, pressure (elevation), fluid currents, and so forth. Outline the major groups of ecosystems according to these criteria.  
   (6-4-5  

1015. Another of these schemes uses chemical factors such as concentrations of water, inorganic salts, hydrogen ions, and organic compounds as a basis for classification. Outline the major groups of ecosystems according to these criteria.  
   (6-4-5  

1016. A third scheme uses the most abundant types of plant life as criteria. Outline the major groups of ecosystems here.  
   (6-4-5  

1017. A fourth scheme uses the most abundant types of animal life as criteria. Outline the major groups of ecosystems here.  
   (6-4-5  

1018. The fifth scheme uses the combinations of plant and animal life in nutritional relationships as criteria. Outline the major groups of ecosystems here.  
   (6-4-5  

1019. Of the above five systems, which two are most nearly alike in the resulting classification schemes?  
   (6-4-6  

1020. Which two are most different?  
   (6-4-6  

1021. Which one do you think would be most useful to a contemporary ecologist? Why?  
   (6-4-6  

1022. Which one would be least useful to the ecologist? Why?  
   (6-4-6  

1023. Can you combine features of several or all of the five systems into a scheme which is better than any one for use by ecologists? If so, what would be that scheme?  
   (6-4-5  

1024. An ecologist seeks a classification of habitats on earth into phyla, classes, orders, families, genera, and species in a manner comparable to the classifications of organisms. Suggest and defend a classification he can well use.  
   (6-4-6  

1025. Propose a procedure to construct an hypothetical phylogenetic tree showing the relationships between members of the order Primata.  
   (6-3-5  

1026. Compare the relative importance of morphology and biochemistry to the classification of plants ten years from now.  
   (6-3-6
SECTION 12. EXAMPLES: EVOLUTION

Objective Items

1027. To be evolutionarily successful, a mutation must occur in
   A. germplasm DNA.
   B. somatoplasm RNA.
   C. plasma proteins.
   D. centrioles.
   E. endoplasmic reticulum.  (A) 7-1

1028. Sickle-cell hemoglobin differs from normal hemoglobin in
   A. an amino acid residue.
   B. its site of manufacture.
   C. the species of organisms possessing it.
   D. its effects on transportation of urea.
   E. its measurable sedimentation velocity.  (A) 7-1

1029. If the early earth's atmosphere contained little or no free O₂, then where did most of the 20% O₂ in our modern atmosphere come from?
   A. Oxidation of metals
   B. Photosynthesis
   C. The breakdown of CO₂
   D. A byproduct of aerobic respiration
   E. The splitting of water by sunlight  (B) 7-1

1030. An advantage allowing the seed plants to greatly surpass the ferns in colonizing the land is the evolution of the
   A. fibrous root system.
   B. woody stem.
   C. resin duct.
   D. nonswimming sperm.
   E. tetraploid genome.  (D) 7-2

1031. A living organism most like the postulated common ancestor of plants and animals is a/an
   A. diatom.
   B. flagellate.
   C. ameba.
   D. blue-green alga.
   E. ciliate.  (B) 7-2

1032. Isolation of varieties resulting in speciation can involve differences in
   A. environmental requirements.
   B. geographical distribution.
   C. seasonal or physiological aspects of sexual reproduction.
   D. sexual structures.
   E. all of the above.  (E) 7-3

1033. On the phylogenetic "tree" of animal life, which of the following is assumed to be more primitive than a dinosaur but more complex than a shark?
   A. Crayfish
   B. Starfish
   C. Amphioxus
   D. Salamander
   E. None of the foregoing  (D) 7-3

1034. The dodo and the passenger pigeon had a common cause of extinction, namely
   A. egg-eating snakes.
   B. prolonged drought.
   C. avian malaria.
   D. parasitism by a blood fluke.
   E. human predation.  (E) 7-3

1035. The human species first appeared in the
   A. Jurassic Period.
   B. Cretaceous Period.
   C. Eocene Period.
   D. Miocene Period.
   E. Pliocene Period.  (E) 7-3

1036. The flowering plants rose to great prominence in the
   A. Cambrian Period.
   B. Devonian Period.
   C. Permian Period.
   D. Cretaceous Period.
   E. Eocene Period.  (D) 7-4

1037. The "Age of Dinosaurs" was the
   A. Archeozoic Era.
   B. Cenozoic Era.
   C. Mesozoic Era.
   D. Paleozoic Era.
   E. Proterozoic Era.  (C) 7-4

1038. That radiation can seriously increase the rate of mutation in man is best shown by studies pointing out a higher rate of congenital abnormalities among children of
   A. radio operators on board ship.
   B. radio technicians.
   C. radiologists.
   D. TV announcers.
   E. garbage collectors  (C) 7-4

1039. Which of the following would characterize the exponential phase of cell growth?
   A. The number of cells produced per unit of time (hours) remains constant.
   B. The growth rate constant, k, increases exponentially.
   C. The generation time of the culture remains virtually constant.
   D. All of the above.
   E. None of the first three above.  (C) 7-4

Items 1040-1048 are concerned with evolutionary development.

Certain developments have occurred in ontogeny and in phylogeny. These developments occur in a certain sequence and may or may not be in the direct and immediate line of change. Evaluate the following pairs of developments according to this key.

Key: A. Development I preceded and gave rise to development II.
   B. Development II preceded but did not give rise to development I.
   C. Development I preceded but did not give rise to development II.
   D. Development II preceded and gave rise to development I.
   E. Either time sequence or structural relationship of the two developments is unknown.

<table>
<thead>
<tr>
<th>Development I</th>
<th>Development II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1040. Development of the monocot</td>
<td>Development of the dicot (E) 7-3</td>
</tr>
<tr>
<td>1041. Development of cycadoids</td>
<td>Development of gymnosperms (C) 7-3</td>
</tr>
<tr>
<td>1042. Appearance of pterosaurs</td>
<td>Appearance of Archeopteryx (C) 7-3</td>
</tr>
<tr>
<td>1043. Zygote of algae</td>
<td>Sporangium of lower liverworts (A) 7-3</td>
</tr>
<tr>
<td>1044. Appearance of seed fern</td>
<td>Appearance of gymnosperms (C) 7-3</td>
</tr>
<tr>
<td>1045. Development of swim bladder</td>
<td>Development of lung (A) 7-3</td>
</tr>
<tr>
<td>1046. Development of feathers</td>
<td>Development of scales (B) 7-3</td>
</tr>
<tr>
<td>1047. Development of seeds</td>
<td>Development of spores (D) 7-3</td>
</tr>
<tr>
<td>1048. Development of the plant embryo</td>
<td>Development of the suspensor in club moss (B) 7-3</td>
</tr>
</tbody>
</table>
1049. Which curve best describes the value of k as a function of time during balanced exponential growth?  
(A) 7-4-1
1050. Which curve best describes the protein/ml as a function of time in a culture during balanced exponential growth?  
(B) 7-4-1
1051. Which curve best describes the logarithm of the optical density of a culture during balanced exponential growth?  
(D) 7-4-1
1052. Which curve best describes the logarithm of cell number/ml of a culture during balanced exponential growth?  
(D) 7-4-1
1053. Which curve best describes the logarithm of the bacterial dry weight/ml as a function of time in a culture in the accelerating phase of growth?  
(B) 7-4-2
1054. Which curve best describes the logarithm of the optical density as a function of time for a culture in a decelerating phase of growth?  
(E) 7-4-2
1055. Which theory was suggested by its original proponents on the basis of the implications of the invariable tendency of populations of organisms to grow to sizes that exceed the capacity of their environments to support them?  
A. The modern synthetic theory of evolution  
B. The theory of natural selection  
C. The autogenetic theory  
D. The mutation theory  
E. The theory of inheritance of acquired characteristics  
(B) 7-4-1
1056. If the Hardy-Weinberg Law is valid, then how can evolution occur?  
A. Gene migration can occur, thus maintaining genetic variability.  
B. Mutations are unidirectional: that is, back mutations never occur.  
C. Populations of organisms are seldom large.  
D. Populations are continually changing because of inheritance of acquired characteristics.  
E. Subpopulations can be reproductively isolated.  
(E) 7-4-2
1057. Based on its phyletic-distribution, we conclude the oldest of the following porphyrin derivatives to be  
A. chlorophyll.  
B. bacteriopurpurin.  
C. cytochrome.  
D. hemocyanin.  
E. hemoglobin  
(C) 7-1-2
1058. Phylogenetic variation occurs fundamentally in the chemistry of  
A. polysaccharides.  
B. lipid.  
C. chlorophylls.  
D. amino acids.  
E. nucleic acids.  
(E) 7-1-2
1059. The tissue type which contributed most to the adaptive radiation of land plants is  
A. meristematic.  
B. vascular.  
C. sporogenous.  
D. parenchymatous.  
E. epidermal.  
(B) 7-2-2
1060. Both sea squirts and lampreys have the pharynx perforated, a notochord at some stage of development, and a ventral heart. This similarity of two different kinds of animals is explained by postulating  
A. similar adaptations to the same predators.  
B. a likeness of dietary habit.  
C. the same environmental pressures.  
D. the same type of cleavage pattern of the fertilized egg.  
E. a common ancestry.  
(E) 7-3-2
1061. The most primitive living vascular plants are the  
A. brown algae.  
B. sphenophytes.  
C. horsetail rushes.  
D. psilophytes.  
E. cycads.  
(D) 7-3-2
1062-1065 are based on the following events.  
I. Change in nucleic acid at a gene locus  
II. Deletion or addition of portions of chromosomes  
III. Inversion or translocation of portion of chromosomes  
IV. Addition of single chromosomes  
V. Addition of entire set of chromosomes  
1062. Which is most apt to give immediate rise to a new species?  
A. I only  
B. II only  
C. III only  
D. IV only  
E. V only  
(E) 7-3-2
1063. Which is considered a mutation?  
A. I only  
B. I and II only  
C. I, II and III only  
D. I, II, III, IV, and V  
E. I, II, IV, and V  
(E) 7-3-2
1064. Which is most likely to be passed on to progeny in a sexually reproducing organism?  
A. I only  
B. II only  
C. III only  
D. IV only  
E. V only  
(A) 4-2-2
1065. Which has been used to produce giant commercial plants and is thought to have occurred in nature giving rise to evolutionary changes?  
A. I only  
B. II only  
C. III only  
D. IV only  
E. V only  
(E) 7-3-3
1066. Which is most important in determining the direction of evolution of an animal species?  
A. High mutation rate for certain traits  
B. Independent assortment and recombination of certain traits  
C. Selection of certain traits by environmental conditions  
D. The gradual change of certain traits by environmental conditions  
E. "An inner desire to survive in the face of change"  
(C) 7-3-2
1067. Which of the following best states the evolution theory?  
A. Evolution is the maintenance of life under changing conditions.  
B. Evolution is the survival of the fittest.  
C. Evolution is the descent of humans from lower animals.  
D. Evolution is goal-directed change.  
E. Evolution is variation.  
(A) 7-4-2
1068. The resemblance of the monarch and viceroy butterflies is explained as an instance of
A. genetic drift.
B. natural selection.
C. adaptive radiation.
D. polymorphism.
E. industrial melanism.

(B) 7-4-2

Items 1069-1074 are concerned with levels of organization in the evolution of life.

There are different levels of organization which occur in the evolution of life. These range from molecules to communities. The following key lists some transitions from one level to the next. Below are changes which are most characteristic of the transitions listed in the key.

KEY: A. Molecular aggregates to cells
B. Unicells to colonies
C. Colonies to tissues
D. Tissues to organ systems
E. Organisms to species

1069. First great change of specialization

(C) 7-3-2

1070. Earliest stage at which competition occurs

(A) 7-1-2

1071. First appearance of natural death by parents

(B) 7-2-2

1072. Stage of maximum organization and instability

(E) 7-3-2

1073. Last great change producing the integrated individual

(D) 7-5-2

1074. Transition during which chloroplasts appeared

(A) 7-1-2

1075. If two different cultures have the same growth rate constant (k) then which of the following must also be true of these two cultures?

A. They must at any one time contain the same number of cells.
B. They must contain the same organism.
C. They must have the same generation time.
D. More than one of the above.
E. None of the first three above.

(C) 7-4-2

1076. Which of the following is the best example of an evolutionary change in a species of organisms?

A. Formation of a callus on the stem of a lilac bush
B. Change of color of a canary's feathers due to feeding the bird pepper
C. Etiolation of bean seedlings grown in the dark
D. Alteration of molecular structure of DNA by radiation
E. Development of thicker fur on a rabbit in winter

(E) 7-3-2

1077. Evolution occurs at the molecular level as well as at the organism level: An example of this would be

A. difference in color pattern on the wings of different species of moths
B. storage of starch by some algae, paramylum by others.
C. presence of ATP in a wide variety of organisms.
D. appearance of blood in nemertines.
E. development of a shell in some sarcodinians.

(B) 7-1-3

1078. The development of large size in land plants is especially correlated with

A. increased efficiency in asexual reproduction.
B. insect pollination.
C. specialization of vascular tissues.
D. appearance of an electron transport system.
E. development of a cambium.

(C) 7-2-3

1079. Assume that a new method is found to remove continuous cores 1 ft. in diameter and 2,000 ft. long from the earth. Examination of thousands of cores would probably reveal that as one goes from top (surface) to bottom (inward) the

A. species of fossils decrease.
B. species of fossils remain constant.
C. species of fossils increase.
D. number of fossils decreases but the kinds increase.
E. number of fossils increases but the kinds decrease.

(A) 7-3-3

1080. The loss of the lateral line system in the evolution of amphibians is most closely associated with which of the following?

A. Assumption of a land habitat
B. Herbivorous diet
C. Development of legs in place of fins
D. Loss of the tail
E. Disappearance of a scaly exoskeleton

(A) 7-3-3

Items 1081-1086. Categorize the pair of entities in each item according to the following key.

KEY: A. I is greater than II
B. I is less than II
C. I is exactly or approximately equal to II
D. I may stand in more than one of the above relations to II

1081. (I) The number of cells in a culture three hours after inoculating it with 10^6 cells which have a generation time of 90 minutes in that medium. The number of cells in a culture three hours after inoculating it with 10^6 cells which have a generation time of 30 minutes in that medium

(B) 7-4-3

1082. (I) The growth rate of a culture in balanced growth which increases from 2 x 10^9 cells/ml to 8 x 10^9 cells/ml in two hours

(II) The growth rate of a culture in balanced growth which increases from 50 cells/ml to 200 cells/ml in two hours

(C) 7-4-3

1083. (I) The number of cells in a culture four hours after inoculating it with 1,000 cells which have a generation time of one hour

(II) The number of cells in a culture four hours after inoculating it with 10,000 cells which have a generation time of four hours

(B) 7-4-3

1084. (I) The growth rate of a culture in balanced growth which increases from 28,000,000 cells to 56,000,000 cells in three hours

(II) The growth rate of a culture in balanced growth which increases from 360 cells to 950 cells in three hours

(B) 7-4-3

1085. (I) The growth rate of a bacterial culture in balanced growth which increases from 500 cells to 2,000 cells in 16 hours

(II) The growth rate of a thyroid cell culture in balanced growth which increases from 500 cells to 2,000 cells in 16 hours

(C) 7-4-3

1086. (I) The number of cells in a culture four hours after inoculating it with 10^7 cells which have a generation time of one hour

(II) The number of cells in a culture four hours after inoculating it with 8 x 10^7 cells which have a generation time of four hours

(D) 7-4-3
1087. A fresh medium is inoculated with $8.1 \times 10^9$ A. aerogenes cells which begin exponential growth immediately. Three generations later how many will there be?

A. $24.3 \times 10^9$
B. $6.48 \times 10^9$
C. $64.8 \times 10^9$
D. $648 \times 10^9$
E. None of the above (B) 7-4-3

1088. The invasion of land by arthropods in the middle Paleozoic Era had to wait for the
A. evolution of predatory vertebrates.
B. invasion of land by green plants.
C. appearance of decay microorganisms.
D. development of a method of internal fertilization.
E. appearance of a chitinous exoskeleton. (B) 7-4-3

1089. A population of deer was threatened with over-population until a number of cheetahs was imported; after a time, there were fewer deer, but the average running speed of the population of deer was increased. This is an illustration of
A. induced mutation.
B. hereditary transmission of the results of training.
C. natural selection.
D. population explosion.
E. genetic drift. (C) 7-4-3

1090. Consider the following:
I. The number of ventricles in a frog heart
II. The number of ventricles in a chicken heart

How can the relationship of I and II best be categorized?
A. I is quantitatively greater than II.
B. II is quantitatively greater than I.
C. I and II are quantitatively equal.
D. Either I or II can vary quantitatively.
E. Both I and II can vary quantitatively. (B) 7-4-3

1091. Which of the following events probably contributed the most to the formation of the first living entity on this planet?
A. Appearance in an ocean of the first soluble carbonates
B. Occurrence in a warm, shallow bay of a medium with a pH of 7.0
C. Synthesis of the first functional nucleic acid molecule
D. Development of a limiting membrane
E. Occurrence of the first mitotic cell division

(C) 7-1-4

1092. Which of the following is the most satisfactory argument for the thesis that RNA developed before DNA in biological organisms?
A. Some viruses have RNA, but no DNA.
B. Some viruses have DNA but no RNA.
C. RNA contains one more oxygen atom per nucleotide than DNA.
D. RNA acts in the cytoplasm, whereas DNA acts in the nucleus.
E. RNA is the immediate participant in enzyme manufacture, with DNA one step removed. (E) 7-1-4

Items 1093-1095 are based on Miller's experiment on the origin of life.

1093. Why was an electrical discharge used as a source of energy?
A. Electricity breaks water into oxygen and hydrogen.
B. Electricity is used in many present-day chemical experiments.
C. Electrical storms were thought to have been common in the early atmosphere.
D. Electrical storms commonly occur today in the atmosphere of the Earth and Venus.
E. Ultraviolet light or radioactivity could not be used. (C) 7-1-2

1094. Chemical analysis of the solution after one week revealed the presence of amino acids. Where did the nitrogen in the amino acids come from?
A. Ammonia
B. Methane
C. Nitrogen gas
D. DNA
E. Proteins (A) 7-1-4

1095. Which best describes the hypothesis tested in the Miller-Urey experiment?
A. Organic compounds can arise spontaneously.
B. Organisms can arise spontaneously.
C. Organic compounds can arise abiogenically under conditions thought to be present in the earth's early atmosphere.
D. The heterotroph arose first in a reducing atmosphere on the early earth.
E. None of the above has any relevance to the Miller-Urey experiment. (C) 7-1-4

1096. Which of the following would indicate a probable change in a clone of paramecia?
A. Disappearance of the contractile vacuoles when the paramecia are in brackish water
B. Establishment, after exposure to ultraviolet radiation, of two micronuclei per individual in a strain where only one had occurred before
C. Reversal of the direction of ciliary beat with a change in pH of the medium
D. Acceleration of the movement of food vacuoles with a rise in temperature
E. Swelling and changing of shape of the body after exposure to sulfur dioxide (B) 7-2-4

1097. If carbon deposits in rocks were produced by living organisms and if such carbon deposits occur in rocks that are calculated to be older than any known fossil-bearing rocks, then life existed upon the earth prior to the time that any now known fossil-bearing rocks were formed. How would the underlined portion of the foregoing statement be categorized?
A. It is an assumption upon which the validity of the concept of evolution depends.
B. It is a deduction from postulates or premises.
C. It is a generalization based upon empirical observations.
D. It is a conclusion that is not supported by empirical evidence.
E. It is an analogy comparing an unknown with something that is known. (B) 7-3-4

Items 1098-1099 are based on the following descriptions of four different isolated populations of a plant species.
I. 20 plants vegetative reproduction only
II. 100 plants unisexual flowers borne on different plants
III. 1000 plants bisexual self-fertilized flowers
IV. 500 plants bisexual self-sterile flowers

1098. Which would be most likely to survive in the event of a drastic environmental change?
A. I
B. II
C. III
D. IV
E. All would survive equally well. (D) 7-3-4

1099. Which population would probably show the most variation?
A. I
B. II
C. III
D. IV
E. All would have equal amount of variation. (D) 7-3-4
1100. The turtle egg has a leathery shell; the chicken egg has a calcareous shell. (B) 7-3-4

1101. Wings characterize honeybees, pterodactyls, eagles, and bats. (C) 7-3-4

1102. Adult monotremes and birds are toothless. (C) 7-3-4

1103. The Jurassic Archeopteryx had many reptilian characteristics but also had feathers and birdlike appendages. (A) 7-3-4

1104. The larynxes of reptiles and of mammals are well developed and complex; the larynxes of birds are simple and not used as vocal organs. (D) 7-3-4

1105. The tails of pigeons and humans are much reduced in contrast to those of crocodiles and lizards. (D) 7-3-4

1106. Indicate whether each of the following supports, opposes, or is indifferent to the hypothesis that birds are phylogenetically intermediate between reptiles and mammals.

(A) supports
(B) opposes
(C) is indifferent

1106. The pleuroperitoneal cavity of turtles is continuous, in birds is divided by a connective-tissue septum, in mammals is divided by a connective-tissue septum invaded by muscle. (A) 7-3-4

1107. Paleontologically, the first fossil mammals preceded the first fossil birds. (B) 7-3-4

1108. The principal exoskeletal structure of reptiles is scales, of birds is feathers, of mammals is hair. (C) 7-3-4

1109. Reptiles are poikilothermic, birds and mammals homoiothermic. (C) 7-3-4

1110. Reptile and bird erythrocytes are nucleated, mammal's anucleate. (C) 7-3-4

1111. The size of the cerebrum relative to the sizes of other parts of the brain is larger in birds than in reptiles and larger in mammals than in birds. (A) 7-3-4

1112. The esophagus and stomach have: no specialized parts in alligators; crop, proventriculus and gizzard in pigeons; rumen, reticulum, omasum, and abomasum in cows. (C) 7-3-4

Items 1100-1105. It is hypothesized that reptiles were the immediate evolutionary ancestors of birds. For each of the following observations, state whether it
A. supports the hypothesis strongly.
B. supports the hypothesis weakly.
C. has no bearing on the hypothesis.
D. opposes the hypothesis weakly.
E. opposes the hypothesis strongly.

1113. Which of the following defines most precisely the problem under investigation in this experiment?
A. Are all species of bacteria found in nature equally susceptible to antibiotics?
B. Do bacteria grow better in a flask culture or on a plate culture?
C. What precautions must be taken in transferring bacteria from a flask culture to a plate culture?
D. How is bacterial resistance to antibiotics acquired and maintained?
E. Why are susceptible bacteria killed by the antibiotic? (D) 7-4-4

1114. Why did Lederberg begin the experiment with susceptible bacteria?
A. Most bacteria in nature are susceptible to antibiotics.
B. This was the control in his experiment.
C. He was concerned with acquisition, not loss of resistance.
D. The appearance of a mutant could be easily demonstrated.
E. He wished to show the degree of susceptibility of the bacteria and the potency of the drug. (D) 7-4-4

1115. Which of the following would be true about the velvet? (Select the best answer.)
A. It was assumed to be sterile.
B. It made colony location identifiable on Plate II'
C. It was a vehicle for precise transfer.
D. Both A and C above, but not B.
E. A, B and C above. (E) 7-4-4

1116. Which of the following served as a control?
A. Plate I
B. Plate II
C. Plate III
D. Plate IV
E. The flask (D) 7-4-4

1117. What is the major hypothesis being tested here?
A. Mutation is the source of resistance.
B. Mutations for resistance are hereditary.
C. Resistance, once acquired, will eventually be lost.
D. Resistance results from something other than contact with antibiotics.
E. Over half of the colonies contained resistant bacteria. (D) 7-4-4

1118. We can deduce that a mutation must have occurred in A. the stock culture.
B. Plate I
C. Plate II
D. Plate III
E. Plate IV. (A) 7-4-4
1119. From the data a reasonable prediction would be that bacteria would grow in:
A. Plate IV, but not in Plate III.
B. Plate III, but not in Plate IV.
C. both Plate III and Plate IV.
D. neither Plate III nor Plate IV.
E. no plate with antibiotic concentration greater than in Plate II.
(B) 7-4-4

1120. Critical evidence which serves as the basis for the prediction in the previous item would be obtained from observing plates:
A. III and IV.
B. I and II.
C. II and III.
D. I and III.
E. I and IV.
(B) 7-4-4

1121. If cells had been transferred from Plate II to a Plate IV with highly higher concentration of antibiotic, then to a Plate II" which had still higher concentration and so on for five transfers, and if some colonies should still survive after five such exposures to increasing concentration, then a reasonable explanation would be that:
A. multiple mutations had occurred.
B. the increase in resistance was due to autogenesis.
C. the bacteria became conditioned to the antibiotic.
D. bacteria grew to depend on antibiotics.
E. once a bacterium becomes resistant it is permanently and completely resistant. (A) 7-4-4

1122. Suppose that after 24 hours of incubation some of the resistant bacteria from Plate II were to be grown for 20 generations without exposure to antibiotics. It is probable that after 20 generations of non-exposure to antibiotics the surviving cells would have:
A. no resistance to the antibiotic.
B. more resistance to the antibiotic.
C. about the same resistance as those in Plate II.
D. some resistance, but considerably less than those in Plate II.
E. have become noticeably larger in size than they were 20 generations earlier. (C) 7-4-4

1123. If a mutation for resistance to antibiotics were to occur in the generation indicated for each of five cultures as follows:

<table>
<thead>
<tr>
<th>Culture No.</th>
<th>Mutation Occurred in Generation No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
</tr>
</tbody>
</table>

then which culture would be likely to have the greatest greatest number of resistant individuals among its descendants in the 40th generation?
A. Culture No. 1
B. Culture No. 2
C. Culture No. 3
D. Culture No. 4
E. Culture No. 5 (A) 7-4-4

1124. Which of the following would be an observable fact?
A. We can determine that there are six colonies on Plate II'.
B. Bacterial cells from each colony in Plate I were transferred to Plate II.
C. The degree of resistance to antibiotics of each of the Plate II colonies would be the same.
D. Cells in all the colonies on Plate I are resistant.
E. Cells that were transferred from Plate I to Plate II were typical of the population from which they came (A) 7-4-4

1125. If Lamarkian postulates were correct, then more mutations for resistance would have occurred in Plate I.
A. no cells would have survived in Plate II.
B. no cells would have survived in Plate II'.
C. more mutations for resistance would have occurred in the stock culture.
D. no cells should have survived in Plate III.
E. all cells transferred to Plate IV should have survived. (E) 7-4-4

1126. If we were to use the results and conclusions of this experiment to explain the development of the giraffe's long neck through natural selection, we would be:
A. reasoning by analogy.
B. formulating an empirical generalization about Lamarckism.
C. speculating on the role of autogenesis in evolution.
D. making an ad hoc hypothesis about genetic drift.
E. drawing an inference about the significance of pleiotropy. (A) 7-4-4

Items 1127-1132 pertain to evolution. Categorize each item according to the following key:

KEY: A. Ectogenetic theory of evolution
B. Theory of natural selection
C. Autogenetic theory of evolution
D. Mutation theory of evolution
E. None of these

1127. Does not consider the source of the variant forms upon which the environment acts. (B) 7-3-4

1128. Ignores the role of gametic genes in evolution and how they are influenced by structural changes. (A) 7-2-4

1129. Suggests no mechanism to explain the successive changes in an organism or the direction they take. (C) 7-3-4

1130. Proposes no interaction of the organism with its environment, even though it does consider the source of change. (D) 7-4-4

1131. Does not deal with interaction between changes in gene structure and the selection pressures acting on them. (E) 7-2-4

1132. Attributes no role to the environment in producing or preserving evolutionary changes. (C) 7-4-4

Items 1133-1137 pertain to evolution in a species of sightless cave fish. Categorize each item according to the following key:

KEY: A. Ectogenetic theory of evolution
B. Theory of natural selection
C. Autogenetic theory of evolution
D. Mutation theory of evolution
E. None of these

1133. Postulates that eyes in the fish originally entering the cave would have been a point of easy injury and infection. (B) 7-3-4

1134. Postulates that sudden hereditary changes occurred, tending to eliminate eyes. (D) 7-1-4

1135. Postulates that pangenues travel from the eyes to the germ cells, influencing the latter toward a beneficial reduction of the units of eye heredity. (E) 7-2-4

1136. Postulates that lack of stimulation of eyes in the inky blackness of the cave would have caused them to degenerate. (A) 7-3-4

1137. Postulates an inherent trend toward eye reduction in this fish population. (C) 7-1-4
During the third period of the Paleozoic Era, the eventual production of oxygen by aquatic photosynthetic forms and its diffusion into the atmosphere (to about 1/100 of present-day concentration) would have enabled the invasion of most aquatic environments by living forms. Thus, nearly all lethal ultraviolet radiation was eliminated from the atmosphere, making land habitats available for newly evolving forms. Consequently, which of the following major events in the evolution of plants and animals probably occurred at this time?

A. Remains of Cycadeoids, Gymnosperms and Angiosperms were left in the great coal deposits.
B. The major groups of Pisces and Angiosperms first appeared.
C. Primitive Psilopsids, Lycopsids, Arachnids and Myriapods first appeared.
D. The first Osteichthyes, Graptolites and Eurypterids appeared.
E. None of the above.  

1142. During the Devonian period certain fishes appeared for the first time. Which is a correct list of these fishes?
A. Labyrinthodontia, Cotylosauria, Pelycosauria, Synapsida
B. Chondrichthyes, Osteichthyes, Dipnoi, Crossopterygii
C. Ostracoderms, Placoderms, Chondrichthyes, Dipnoi
D. Placoderms, Osteichthyes, Dipnoi, Labyrinthodontia
E. Actinopterygii, Chondrichthyes, Cephalochorda, Ascidians

1143. Charles Darwin's presentation of the theory of evolution by natural selection may be expressed in a set of propositions:

1. Organisms of the same species compete with each other for the necessities of existence.
2. As environments change, selective factors will be different.
3. More offspring are produced than the ecologic niche can support.
4. The best adapted forms tend to survive and reproduce in greater numbers than the less well adapted.
5. Members of any species vary widely, some being well adapted, others poorly adapted to their environments.
6. Adaptive characteristics are passed from generation to generation by heredity.
7. Mutations produce new characteristics.
8. New species are produced when new selective factors preserve different characteristics.

The best sequencing of these propositions in a logical construction of the natural selection theory is:

A. New species are produced when new selective factors preserve different characteristics.
B. As environments change, selective factors will be different.
C. Organisms of the same species compete with each other for the necessities of existence.
D. More offspring are produced than the ecologic niche can support.
E. Adaptive characteristics are passed from generation to generation by heredity.

1144. Chromosomes occasionally "break." Sometimes the chromosome fragment is attached to another chromosome; other times it is not. If the fragment is not attached to another chromosome or does not contain a centromere, it fails to orient on the metaphase plate, lags during anaphase and does not enter the reforming daughter nuclei.

How would the phenomenon described above most likely affect evolution of the species if it occurred in gamete formation? It would probably

A. cause polyploidy and a new species.
B. decrease the number of genes and reduce species variation.
C. increase the number of genes and increase species variation.
D. result in an individual which would have one less chromosome and might be a new species.
E. result in an abnormal gamete which would be lost and have no effect on the species.
1145. According to current thought in biology, which of the following could be said of autocatalytic systems having sufficient organization to be considered as cells?
A. They probably could not have formed on earth until extensive chemical evolution had occurred.
B. They are not now springing into existence on our planet.
C. They have arisen by an evolutionary process which violates neither the Second Law of Thermodynamics nor any other known property of our physical universe.
D. All of the above.
E. None of the first three above. (D) 7-4-5

1146. The exponential phase of bacterial growth can be characterized by which of the following?
A. It is difficult to maintain in a culture for very long period.
B. It can be prolonged by repeated and frequent subculture of portions into fresh medium.
C. It can be prolonged by the use of a chemostat.
D. All of the above.
E. None of the first three above. (D) 7-4-5

1147. Disregarding relative feasibility of the following procedures, which of these lines of research is likely to provide us with the most valid and direct evidence as to phylogenetic relations among different species?
A. Analysis of the chemistry of stored food in female gametes
B. Spectrophotometry of the enzymes of the tricarboxylic acid cycle
C. Observation of the form and arrangement of the endoplasmic reticulum
D. Comparison of details of molecular structure DNA
E. Serological study of immune reactions against characteristic proteins (D) 7-1-6

1148. Recent NASA experiments have shown that irradiation of a mixture of NH₃, CH₄, H₂, and H₂O resulted in the formation of adenine. This is important evidence supporting Oparin's hypothesis on the origin of life because adenine is
A. a nucleotide.
B. a protein.
C. a respiratory enzyme.
D. an essential amino acid.
E. found in ATP, RNA and DNA. (E) 7-1-6

1149. In spontaneous generation of life on the earth, the most likely temporal sequence of appearance of molecular types among the following choices would be
A. amino acid—protein—chlorophyll.
B. succinic acid—ascorbic acid—amino acid.
C. hemoglobin—echinochrome—xanthophyll.
D. chlorophyll—starch—adenine.
E. starch—glycogen—phosphoglyceraldehyde. (A) 7-1-6

1150. Which of the following is the least likely result of an evolutionary change in a species? A change in
A. a parasitic species affecting the altered species.
B. a predator of the species.
C. another species of the same genus.
D. the embryonic development of individuals of the species.
E. the physiology of individuals of the species. (C) 7-4-6

1151. Cell organelles probably evolved. From which of the following is it most likely that cilia were derived?
A. Mitochondria
B. Microvilli
C. Ribosomes
D. Nucleoli
E. Centrioles (E) 7-2-6

Items 1152-1156 are concerned with the following:
A biology test included the question: "Show that communities, as well as species, evolve." A student wrote an answer which included the following:

"The essence of evolution is permanent change. When a species evolves, its characteristics change. These characteristics are outwardly phenotypic changes, but behind every phenotypic change is a genotypic change, also called a mutation. Environmental changes are responsible for species changes.

"When a community evolves, its characteristics change. These characteristics are kinds of plants and animals, their relative numbers and their interrelations. When the kinds of organisms and their numbers and interrelations change, these are environmental changes in the sense of the previous paragraph, and bring about species changes. So, communities evolve not only in the sense of changing their faunal and floral composition but also in changing their species characteristics."

1152. The student's statement concerning evolution is
A. adequate for the use he makes of it.
B. inadequate because not all evolutionary changes are permanent.
C. inadequate because some phenotypic changes occur without corresponding genotypic changes.
D. inadequate because not all genotypic changes are mutations.
E. inadequate because it does not state the mechanism of evolution. (A) 7-3-6

1153. By the statement, "Environmental changes are responsible for species changes," the student most probably referred to
A. ortogenesis.
B. genetic drift.
C. mutations brought about by irradiation or mutagenic chemicals.
D. natural selection.
E. abiogenesis. (D) 7-3-4

1154. The second sentence of the second paragraph is
A. an acceptable statement for his purposes.
B. unacceptable because the kinds of organisms it contains are not characteristics of a community.
C. unacceptable because relative numbers are not characteristics of a community.
D. unacceptable because the interrelations of different species are not characteristics of a community.
E. unacceptable because there are other characteristics of a community which are not mentioned by the student. (A) 7-4-6

1155. Which of the following should not be considered community evolution? A change from
A. predominant aspen-birch flora to predominant maple-basswood flora.
B. a marsh to a meadow.
C. a prairie to a forest.
D. a freshwater lake to a saltwater bay.
E. summer fauna and flora to winter fauna and flora. (E) 7-4-4

1156. The student's second paragraph says all of the following except one; which one?
A. A change in some of the inhabitants of a community affects the lives of other inhabitants of the community.
B. Changes in the constitution of a community may cause single species to evolve.
C. If some of its members evolve, a community evolves.
D. A change in interrelationships causes mutations.
E. A change in species genotypes is not the only way a community evolves. (D) 7-4-4
1157. Which of the following events would have the most direct and immediate effect on the evolutionary changes of the biota of a large lake?
A. An increase of 5°C in the mean annual temperature
B. A disappearance of 5% of the species at the base of the food pyramid
C. An increase of 5% in the incidence of parasitic worms
D. A decrease of 5% in the mean annual rainfall
E. An increase of 5% in reproductive rate in each uninculturated species present  (B) 7-4-6

1158. Humans have achieved evolutionary success without the speed of deer, the teeth of wolves, or the skin thickness of rhinoceroses. Of the following, the evolutionary development which has probably contributed most to success of the human species in competition with other mammals is:
A. the bi-ocular vision.
B. upright posture.
C. long gestation period.
D. loss of body hair and tail.
E. increased brain development. (E) 7-3-6

For items 1159-1168 categorize each statement according to the following key. Note that in this set of questions you must classify the types of scientific knowledge that each item represents.

KEY: A. A particular fact (i.e., an observation or set of observations, made empirically at a particular place and time by a certain person, or persons)
B. An empirical generalization (a conclusion formulated by inductive reasoning from a particular set of observations; it is an assumption which is believed to be true in most or all instances)
C. A postulate of a theory (an imaginary set of conditions which is proposed for the purpose of explaining large sets of facts and empirical generalizations)
D. An hypothesis or prediction (formulated by deductive reasoning from facts and postulates; it is an expectation, an anticipated observation to be made as a result of experimentation or continued investigation)
E. A statement known to be false, or an illogical conclusion from the known facts

1159. Different varieties of finch-like birds have been found in the Galapagos Islands. (A) 7-4-6

1160. The more isolated a region, and/or the smaller that region, and/or the younger the geological age of that region, the fewer endemic species have evolved there. (B) 7-4-6

1161. Combined action of genetic mutations, biotic potentials, geometric increases in populations result in differential selective pressures, differential survival, and the formation of incipient species. (C) 7-4-6

1162. The geographical distribution of Marsupalia is restricted to the Australasian sub-continent. (E) 7-4-6

1163. Fossil skulls found in Jurassic rocks (i.e., the Middle Mesozoic) are likely to contain molars, premolars, canines, incisors, and the incus, stapes and malleus. (D) 7-3-6

1164. Fossil skulls found in Devonian rocks (i.e., the Middle Paleozoic) lack operculae, otic notches, intertemporal bones, but possess nasals, frontal, parietals, and molar, canine and incisor teeth. (E) 7-3-6

1165. In undisturbed layers, the rocks containing dinosaur fossils are usually stratigraphically superimposed over rocks containing trilobite fossils. (B) 7-3-6

1166. Vertebrate fossil skulls which have a mandible composed exclusively of the dentary-bone are found in Permian rocks. (E) 7-3-6

1167. A certain Pleistocene deposit was found to contain vertebrate fossils lacking tails, but having fingernails and toenails rather than claws or hooves, and having opposable digits, chin bones, and molar teeth with flat grinding surfaces. (A) 7-3-6

1168. Archaeopteryx fossils were present in certain Jurassic rocks excavated by a paleontologist in Bavaria. (A) 7-3-6

Items 1169-1180 consist of statements and a conclusion. Each statement is identified by a Roman numeral. The statements may be true or false, and the conclusion may be illogical or logical. To be logical, the conclusion must be a necessary consequence of the statements. If the statements are postulates or principles of the theory of evolution, then select your answer from A-D in the key; if the statements are from some other theory, such as a cell theory or molecular biology, Mendelian genetics, or some other non-organismal, non-evolutionary topic, then select key answer E.

1169. I The greater the adaptive value of a genetic trait the greater will be the probability of its frequency being increased in successive generations.
II In malarial-endemic centers the heterozygote for sickle-cell has a greater adaptive value than the normal individual.

Therefore, in successive generations the gene for sickle-cell, which in the homozygote is lethal, will probably increase in frequency in successive generations in malarial endemic centers. (A) 7-4-6

1170. I All populations tend to increase at a geometric rate.
II Food supplies for all populations remain, on the average, constant.
III Struggles for survival occur among individuals of populations for which food supplies are constant and which increase at a geometric rate.

Therefore, struggles for survival occur among individuals of all populations. (A) 7-4-6

1171. I An increase in rate of speciation is caused by an increase in intensity of selective pressure.
II The mammoth, the mastodon and Megatherium were exposed to abrupt and marked increases in selective pressure at the close of the Pleistocene.

Thus, the rate of speciation of these animals increased abruptly and markedly at the close of the Pleistocene. (D) 7-3-6
1172. I Speciation is the formation of new species by the geographical isolation of separated segments of a population.
II Phylectic modification is the formation of new species by the gradual modification of descendants through many successive generations.

Therefore, natural selection is the formation of new species by the gradual change in gene pool compositions through differential genic adaptive values. (B) 7-4-6

1173. I The nucleolus is composed, in part, of RNA.
II Ribosomes are composed, in part, of RNA.

Therefore, the nucleolus is composed, in part, of ribosomes. (E) 2-2-6

1174. I The younger the geological age of a region, the greater the barriers to immigration into that region, and the smaller the area of that region, the fewer will be the number of species which occupy the region.
II A volcanic island formed during the Pleistocene in an ocean 1,000 miles away from a continent is younger in geological age, is effectively separated by barriers to immigration of many land animals, and is smaller in area than a continental land mass.

Thus, a small volcanic island formed during the Pleistocene in an ocean 1,000 miles away from a continental land mass will have fewer species than a large continental land mass formed during the Paleozoic. (A) 7-4-6

1175. I The beneficial characteristics acquired during the life of an individual are transmitted by heredity to successive generations.
II The transmission of new characteristics to successive generations results in the gradual formation of new taxa.

Therefore, the beneficial characteristics acquired during the gradual formation during successive generations of new taxa.

1180. I ATP is produced by the Krebs cycle in the mitochondria.
II ATP is produced by photophosphorylation.

Therefore, photophosphorylation occurs in the mitochondria. (E) 1-2-6

1177. I Within a particular family, individuals of a single species have evolved more characteristics in common than have individuals of separate species.
II Within a particular family, the species of a single genus have evolved more characteristics in common than have species of different genera.

Therefore, within the family Hominidae individuals of the species Homo sapiens have more characteristics in common than do individuals of Homo and of Pithecanthropus. (A) 7-3-6

1178. I Most gametes are haploid cells.
II Meiosis produces haploid cells.

Therefore, most gametes are produced by meiosis. (E) 2-2-6

1179. I In the Pongidae the coccyx has evolved as a vestigial organ.
II In the Hominidae the coccyx is a vestigial organ.

Therefore, the Hominidae are members of the Pongidae. (D) 7-3-6

generational distributions of the species which comprise a genus are restricted to a particular geographical region.
II The geographical regions occupied by most genera are circumscribed from other geographically distinct regions by effective geographical barriers to migration.

Thus, the geographical distribution of the species which comprise a genus are circumscribed from other geographically distinct regions by effective geographical barriers to migration.

(A) 8-4-6

Essay Questions

1181. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Living organisms make particular proteins under the direction of particular nucleic acids.
   b. Taxonomically closely related organisms have more proteins in common than less closely related organisms.
   c. Nucleic acids are transmitted from one generation to another.

Propose a critical test for your hypothesis. 7-1-5

1182. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Sickle-cell hemoglobin differs from normal hemoglobin in one of about three hundred amino acid components.
   b. Sickle-cell hemoglobin results in deformation of red blood corpuscles in situations of low oxygen tension.
   c. Blood corpuscles containing sickle-cell hemoglobin are not as susceptible to invasion by malarial organisms as blood corpuscles containing normal hemoglobin.

Propose a critical test for your hypothesis. 7-1-5

1183. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Cnidaria (coelenterata) have epitheliomuscular cells, mesenchyme cells, and netlike nervous systems.
   b. Flatworms have separate epithelial and muscular cells, fibroblasts, and centralized nervous systems.

Propose a critical test for your hypothesis. 7-2-5

1184. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. In seed plants, the gametophyte generation is specialized for water conduction.
   b. In mosses the gametophyte has elongated cells specialized for water conduction.
   c. In seed plants, the sporophyte has elongated cells specialized for water conduction.

Propose a critical test for your hypothesis. 7-2-5

1185. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Striated muscle occurs only among arthropods and chordates.
   b. Jointed appendages characterize only arthropods and chordates.
   c. The speediest land animals are arthropods and chordates.

Propose a critical test for your hypothesis. 7-3-5

1186. Propose an procedure to determine what kinds of plants were the immediate ancestors of the first tracheophytes. 7-3-5
1187. Propose an hypothesis which will satisfactorily explain the following set of data:

a. Three races of swallowtail butterflies occur in the United States—an eastern, a mid-western, and a western.
b. The races are capable of successfully interbreeding with each other in laboratory experiments.
c. The native territory of the midwestern race overlaps those of the eastern and western races.
d. No interbreeding of these three races occurs in the wild.

Propose a critical test for your hypothesis. 7-4-5

1188. Propose an hypothesis which will satisfactorily explain the following set of data: Brown eye color is dominant over blue eye color in humans.

a. Many blue-eyed people marry brown-eyed people and have brown-eyed children.
b. The percentage of blue-eyed people in human populations does not decrease over several generations. 7-4-5

1189. Given the information that the total proportion of the amino-acid hydroxyproline in the protein collagen is directly proportional to body temperature, suggest how this information might be used to determine an extinct animal's body temperature. 7-3-5
1190. In Himalayan rabbits, the development of black pigment depends upon
A. lower temperature.
B. a pituitary hormone.
C. manganese in the diet.
D. higher atmospheric pressure.
E. presence of a parasite.
(A) 8-1-1

1191. Freshwater amebas are commonly protected from desiccation by
A. attaching to the gills of fishes.
B. encystment.
C. sexual reproduction.
D. burrowing into the lake bottom.
E. entering the alimentary canal of an invertebrate host.
(B) 8-2-1

1192. The greatest biomass of living diatoms is to be found in
A. marine pelagic habitats.
B. marine benthic habitats.
C. swamps.
D. moist soil.
E. salt lakes.
(A) 8-2-1

1193. The human intestinal fluke enters the human body
A. by the bite of a mosquito.
B. by the bite of the Oriental flea.
C. when the human eats uncooked fish.
D. by a free-swimming cercaria when the human is wading in water.
E. when the human eats aquatic plants.
(E) 8-3-1

1194. An organism characteristic of the tundra in the United States is the
A. sequoia.
B. hummingbird.
C. horned toad.
D. willow.
E. cactus.
(D) 8-3-1

1195. British moths living in soot-drenched areas tend to be darkly colored, in contrast to their light-colored relatives in regions relatively free from soot. The increased prevalence of the dark color is referred to as
A. chromocenter.
B. nictalopia.
C. penumbra.
D. industrial melanism.
E. warning coloration.
(D) 8-4-1

1196. Allen's Rule states that
A. organisms increase in size with evolutionary advance.
B. warm-blooded organisms living in cold regions are larger than those of the same genus living in warmer regions.
C. animals living in cold regions have relatively smaller extremities than those living in warmer regions.
D. animals living in dry areas are lighter in color than those in damp areas.
E. animals tend to adapt their color to that of their surroundings.
(C) 8-4-1

1197. According to Lamont Cole, which one of the following mineral elements is the critical limiting factor in the function of the ecosystem because of its irretrievable loss into the oceans?
A. Calcium
B. Iron
C. Magnesium
D. Phosphorus
E. Potassium
(D) 8-4-1

1198. A scientist changed the pH of a culture medium from 3 to 6. This change would
A. double the concentration of hydrogen ions.
B. eliminate all ammonium ions present.
C. precipitate all the proteins in the medium.
D. disperse any colloidal particles not previously dispersed.
E. increase the number of hydroxyl ions a thousandfold.
(E) 8-1-2

1199. A biologist kept euglenas in various experimental situations. In one of these, the euglenas lost their stigmas. This situation was
A. three atmospheres of pressure.
B. pH 7.5.
C. constant temperature of 30°C.
D. magnesium-free pond water.
E. total darkness.
(E) 8-2-2

1200. A biologist obtains specimens of a parasitic ameba from a human intestine. He wishes to keep them in a medium which will not cause injury to the amebas by osmotic effects. Which of the following would best serve his purpose?
A. Distilled water
B. Pond water
C. Sea water
D. A 10% solution of sodium chloride in water
E. A 10% solution of human blood plasma in water
(C) 8-2-2

1201. Competition for food, light, space, etc. is probably most severe between two
A. closely related species occupying the same niche.
B. closely related species occupying different niches.
C. unrelated species occupying the same niche.
D. unrelated species occupying different niches.
E. species in different overlapping ecosystems.
(A) 8-3-2

1202. A dog was kept in a room at a temperature of 40°C. for two weeks. At the end of that time, it was determined that the dog was sterile. The investigator proposed the hypothesis that the high temperature had caused the animal's sterility. In order to defend the hypothesis, the investigator should be able to show that
A. the dog was homozygous for temperature sensitivity.
B. the high temperature did not alter the dog's blood pressure.
C. the dog was sterile before the experimental period began.
D. a cat kept in the same room did not become sterile.
E. the dog's pituitary gland had not degenerated.
(C) 8-3-2

1203. Which of the following is an ecological principle?
A. Double limbs are mirror images of each other.
B. Evolution is irreversible.
C. All life arises from pre-existing life.
D. Ontogeny recapitulates phylogeny.
E. Animals living in colder climates have relatively smaller appendages than those living in warmer climates.
(E) 8-4-2

1204. In a certain ecosystem, field mice are preyed upon by snakes and hawks. The entrance of wild dogs into the system adds another predator on the mice. Of the following, the most likely short-term result of this addition is
A. increase in snake population.
B. tendency for hawks to prey on the dogs.
C. extinction of the hawks.
D. reduction in numbers of mice.
E. migration of the hawks to another ecosystem.
(D) 8-4-2
At which portion of the curve does the unchecked rate \( R_u = k_u N \) equal the environmental resistance \( R_c = k_c N^2 \) where \( R_u \) is the rate of increase, \( R_c \) is the rate of death and \( k_u \) and \( k_c \) are constants?

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

Items 1206-1207 are to be interpreted in relation to the following graphs. For each item select the graph which best represents the data presented in the item.

1206. Which figure best represents the population growth (total number) for an organism that reproduces by splitting in constant time intervals and without any death? (Let X-axis represent time and Y-axis represent population numbers on an exponential scale.)

(C) 8-4-2

1207. Which figure best represents actual population growth (total number) of fruit flies in a jar closed with cheese cloth and well stocked with food? (Let X-axis represent time in days and Y-axis represent number of flies.)

(D) 8-4-2

1208. Which best describes a self-contained spacecraft?

A. Organ system  
B. Population  
C. Community  
D. Ecosystem  
E. Biosphere  

(D) 8-4-2

1209. A man is surface-sterilized and placed in a lighted, germ-free capsule with a tank containing only green algae \( (Chlamydomonas \text{ sp.}) \) and sterile distilled water. The man’s wastes are placed in the tank and he drinks only filtered water from the tank and eats only compressed algae. The man is not likely to survive. Why?

A. He contracts disease from the contaminated water.  
B. The algae are unable to use the nitrogen in the air or in the man’s wastes.  
C. The algae supply only carbohydrates.  
D. Man can not live without a wide variety of organisms around him.  
E. Man can not evolve so that he can use atmospheric nitrogen.  
F.  

(B) 8-4-5

Items 1210-1222 are concerned with relationships of organisms to each other.

All organisms have certain relations to each other. These relations may be classified in two ways: first on a benefit-harm scale, according to whether the relationship is mutually beneficial, benefit to one and indifferent to the other; second, we may classify the relationship according to whether it is necessary for the existence of both organisms, necessary for one but not the other, or not necessary for the existence of either. This can be shown in tabular form as follows:

<table>
<thead>
<tr>
<th></th>
<th>Not necessary</th>
<th>Necessary for both</th>
<th>Necessary for one but not other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mutual benefit</td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>Benefit- indifferent</td>
<td>IV</td>
<td>V</td>
<td>VI</td>
</tr>
<tr>
<td>Benefit-harm</td>
<td>VII</td>
<td>VIII</td>
<td>IX</td>
</tr>
</tbody>
</table>

1210. The relationship between a predator and his prey (e. g. whale and plankton) will be categorized as

A. VII  
B. VIII  
C. IX  
D. VII and VIII.  
E. VII and IX.  

(C) 8-4-2

1211. The tickbird on a rhinoceros or the sea anemone on a hermit crab would exemplify

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

(A) 8-4-2

1212. A termite and the protozoan flagellate in its gut

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

(B) 8-4-2

1213. A suckerfish on a shark would be

A. IV  
B. V  
C. VI  
D. IV and V.  
E. V and VI.  

(C) 8-4-2

1214. A barnacle on a whale

A. IV  
B. V  
C. VI  
D. IV and V.  
E. V and VI.  

(A) 8-4-2

1215. The relationship between bacteria and bacteriophage

A. VII  
B. VIII  
C. IX  
D. VII and VIII  
E. VII and IX  

(C) 8-4-2

1216. Scale insect and ladybird beetle

A. VII  
B. VIII  
C. IX  
D. VII and VIII  
E. VII and IX  

(A) 8-4-2

1217. Bumblebee and clover

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

(B) 8-4-2
Facultative symbiosis would be categorized as
A. I.
B. II.
C. III.
D. I and II.
E. I and III. (A) 8-4-2

Obligate parasitism would be categorized as
A. I.
B. II.
C. III.
D. I and II.
E. I and III. (B) 8-4-2

Facultative parasitism would be categorized as
A. VII.
B. VIII.
C. IX.
D. VII and VIII.
E. VII and IX. (A) 8-4-2

Obligate parasitism would be categorized as
A. VII.
B. VIII.
C. IX.
D. VII and VIII.
E. VII and IX. (C) 8-4-2

Commensalism would be categorized as
A. II.
B. IV.
C. V.
D. VI.
E. IX. (B) 8-4-2

Items 1223-1228. Categorize the pair of entities in each item according to the following key.
KEY: A. I is greater than II.
B. I is less than II.
C. I is exactly or approximately equal to II.
D. I may stand in more than one of the above relations to II.

The number of ATP molecules required to produce a protein from amino acids in a cell growing aerobically.
The number of ATP molecules required to produce the same protein from the same amino acids in the same cell growing anaerobically.
(C) 8-1-3

The probable number of different amino acid biosynthesizing enzymes in an average E. coli cell growing in its minimal medium.
The probable number of different amino acid biosynthesizing enzymes in an average thyroid follicular cell growing in cell culture in its minimal medium.
(A) 8-1-3

The probable effect of penicillin on a growing A. aerogenes cell.
The probable effect of penicillin on a growing thyroid cell.
(A) 8-2-3

The probable duration of the lag phase when E. coli cells grown in glucose-Werkman's medium are transferred to fresh glucose-Werkman's medium.
The probable duration of the lag phase when E. coli cells grown in glucose-Werkman's plus many amino acids are transferred to fresh glucose-Werkman's medium.
(B) 8-4-3

The effect of penicillin on the wall of a non-growing bacterial cell.
The effect of lysozyme on the wall of a non-growing bacterial cell.
(B) 8-2-3

The time it takes to label all of the free leucine in a bacterial cell fed radioactive glucose.
The time it takes to label all of the peptide-bound leucine in the same cell.
(B) 8-1-5

All heterotrophs require environments which can furnish
A. nitrates in solution.
B. organic compounds.
C. free halogens.
D. ammonium salts.
E. vitamin A. (B) 8-1-3

All autotrophs require environments which can furnish
A. free hydrogen.
B. combined hydrogen.
C. carbohydrates.
D. free halogens.
E. vitamin A. (B) 8-1-3

A biologist was experimenting with a protozoan, and noticed that the animal's contractile vacuole stopped contracting although the other parts of the organism seemed to be in good health and normal activity. Which of the following experiments was the one which might have produced this result?
A. Cooling the medium from 20° C to 10° C.
B. Changing the pH of the medium from 7.0 to 6.5.
C. Moving the protozoan from a Syracuse dish to a ten-gallon aquarium.
D. Transferring the protozoan from a lighted environment to a dark environment.
E. Transferring the protozoan from pond water to sea water.
(E) 8-2-3

To obtain a pure culture of bacterium X from an environment which contains, per ml, 5,000 X cells and 10° other cells, the quickest useful method would be based on
A. micromanipulation.
B. serial dilution into tubes of liquid medium.
C. plating directly on solid nutrient medium.
D. serial liquid selective cultures.
E. one of the above. (C) 8-2-3

Which of the following is/are characteristic in general of the elemental composition of an Aerobacter aerogenes cell?
A. It closely matches the elemental composition of the earth's crust.
B. It is strikingly different from the elemental composition of animal cells.
C. It shows that only 1% (by weight) of this cell consists of atoms other than O, C, H and N.
D. More than one of the above.
E. None of the first three above. (C) 8-3-3

Two similar flasks of media are inoculated at the same time. Flask S receives 8,000 cells of organism S and flask T receives 20 cells of organism T. Exponential growth proceeds immediately in both flasks. After 10 hours there are 32,000 S cells in flask S and 640 T cells in flask T. Which of the following is/are true?
A. Organism S grows faster than organism T.
B. Fewer cells were produced in flask S than flask T.
C. Under these conditions, S cells have a generation time of 2.5 hours.
D. All of the above are true.
E. None of the first three above are true. (E) 8-4-3

Timberline occurs at certain levels in the Rocky Mountains, measurable in distance above sea level. A similar timberline occurs on a horizontal land surface, measurable in
A. distance inland from the seashore.
B. British thermal units.
C. isobars.
D. isochrones.
E. degrees of latitude. (E) 8-3-3

Compared to a Texas jack rabbit, the Arctic hare would be expected to have
A. longer legs.
B. longer ears.
C. shorter appendages.
D. more sensitive whiskers.
E. more frequent breeding seasons. (C) 8-3-3
31237. Which of the following is a result of ecological isolation?
A. The variations among Darwin's finches on the Galapagos Islands
B. The development of the amniote egg in reptiles
C. The dominance of the sporophyte generation in ferns
D. The formation of cellulose walls in blue-green algae
E. The development of autotrophy in green plants

1238. Which of the following is the most likely result of destroying all the coyotes in Colorado?
A. Great overdevelopment of sagebrush
B. Increased drainage runoff into the rivers
C. Great increase in the rabbit population
D. Disappearance of the cattle tick
E. Disappearance of elk

For items 1239-1242 use the information in the following paragraph:
When bacterial cells multiply maximally during the logarithmic phase, the total number of cells \( b \) after some time interval \( t \) is equal to the original number of cells \( B \) multiplied by \( 2^n \), where \( n \) is the number of generations formed during the time interval; \( n = t/g \) and \( b = B \times 2^n \). The generation time for type A cells is 28 minutes.

1239. If type A cells are multiplying maximally, how many generations would be produced during a five-hour time interval?
A. Approximately 11
B. Approximately 12
C. Approximately 15
D. Approximately 19
E. Approximately 20

1240. If a population of \( 10^7 \) (1,000) cells of type A undergoes four successive generations, how many cells will be present after the fourth generation?
A. Approximately \( 10^{10} \) cells
B. Between 20,000 and 22,000 cells
C. Between 18,000 and 20,000 cells
D. Between 16,000 and 18,000 cells
E. Between 14,000 and 16,000 cells

1241. Estimate the least amount of time required for a population of type A cells to increase by 300 per cent. (Note: This means to add on three times as many as were present originally)
A. More than 60 minutes
B. Approximately 55 minutes
C. Approximately 50 minutes
D. Approximately 45 minutes
E. Approximately 40 minutes

1242. When type A cells are multiplying synchronously and maximally, how much time is required to form a population of at least 2,000 cells from one type A cell?
A. Approximately 3 hours and 40 minutes
B. Approximately 4 hours and 25 minutes
C. Approximately 5 hours and 10 minutes
D. Approximately 5 hours and 30 minutes
E. None of the alternatives A-D is correct

Items 1243-1245 are based on a preliminary study of a terrestrial ecosystem.

1243. Which technique(s) would probably give an estimate of the number and kinds of insects?
A. Capture, mark, recapture
B. Removal by sweeping
C. Light traps
D. Fumigation of a known enclosed area
E. All of the above

1244. Which technique would probably give the best estimate of net photosynthesis?
A. Counting oxygen bubbles from plants immersed in water
B. Weighing standing crop of plants plus litter
C. Use of light and dark chambers
D. Use of radioactive carbon tracers
E. Necessary amount of \( \text{CO}_2 \) given off in a definite volume

1245. Which describes a community?
A. A list of species present (species structure)
B. Biomass of consumers and producers
C. Autotrophic and heterotrophic measurements
D. Diversity indices
E. All of the above

Items 1246-1250 refer to the following graphs:

1246. Which best represents growth of a bacterial colony on a nutrient agar plate over one week (time is abscissa or horizontal axis)?
(A) 8-4-3
1247. Which best represents homeostasis in a population?
(C) 8-4-3
1248. Which best represents the growth of world human population beginning with prehistoric man as food gatherer?
(C) 8-4-3
1249. Which best represents the growth of a Drosophila population in a closed jar containing agar medium over two months time?
(B) 8-4-3
1250. Which best represents \( \text{O}_2 \) consumption and \( \text{CO}_2 \) output in an organism with an RQ of .8
(E) 8-4-3

Items 1251-1260 are concerned with a high grassland in the mountains. This grassland has a moderate slope and forests are found above it. Five elements are present in the area: grass, the herbivores and rodents which feed upon the grass, small carnivores such as the fox and weasel that feed on rodents, large carnivores such as pumas and wolves who feed on the herbivores, and the soil which contains worms, bacteria, etc.

Let us assume that in the beginning this area is in balance and the five elements can be represented by a food pyramid as shown in Fig. I. Fig. II shows a growth curve for a population. It is divided into five parts. These must be used in answering the questions below.

1251. Under normal conditions of balance, the populations could be represented by what part of the growth curve?
A. I
B. II
C. III
D. IV
E. V
1252. If a drought occurred, which animal group would be first affected?
A. 5
B. 4
C. 5
D. 2 and 3
E. 4 and 5  (A) 8-4-3

1253. Which would be last affected?
A. 3
B. 4
C. 5
D. 3 and 4
E. 4 and 5  (C) 8-4-3

1254. Which part of the curve represents the effect described in the two previous questions?
A. I
B. II
C. III
D. IV
E. V  (E) 8-4-3

1255. Suppose that an epidemic strikes and kills all the herbivores. That part of the growth curve which best represents the short-range effect on the herbivore population is
A. I
B. II
C. III
D. IV
E. V  (B) 8-4-3

1256. As a result of this change in the herbivores, which population would be most adversely affected immediately?
A. 1
B. 2
C. 3
D. 4
E. 5  (B) 8-4-3

1257. As a result of the adverse effect in question 1256 the population curve of the herbivores would resemble
A. I
B. II
C. III
D. IV
E. V  (C) 8-4-3

1258. After the grassland recovered, along with the small carnivores that eat herbivores, suppose a few new large carnivores entered the area. What part of the population curve would best represent the new carnivores during the first two years?
A. I
B. II
C. III
D. IV
E. V  (A) 8-4-3

1259. What part of the population curve would best represent the large carnivores during years 3-5, assuming conditions, remain about the same?
A. I
B. II
C. III
D. IV
E. V  (B) 8-4-3

1260. The ranchers wish to increase the deer and sheep, so they greatly reduce the numbers of coyotes and foxes. The ultimate long-range effect of this program on the deer and sheep is represented by what part of the curve?
A. I
B. II
C. III
D. IV
E. V  (E) 8-4-3

Items 1261-1263 are based on the following measurements.

The concentration of ions inside an ameba is expressed below as ion-units per milliliter. The composition of the extracellular environment (ECE) is given for comparison.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Cl⁻</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ameba</td>
<td>42</td>
<td>3</td>
<td>119</td>
<td></td>
</tr>
<tr>
<td>ECE</td>
<td>21</td>
<td>16</td>
<td>41</td>
<td>119</td>
</tr>
</tbody>
</table>

1261. The differences in concentrations of K⁺ and Na⁺ indicate that
A. diffusion is not occurring.
B. free energy has been increased.
C. free energy has been expended.
D. osmosis has occurred.
E. the amebae are dead.  (C) 8-1-4

1262. Free diffusion alone could account for which ionic strength inside the amebae? (Assume membrane is permeable to all of the above ions.)
A. Na⁺
B. HCO₃⁻
C. Na⁺, K⁺, Cl⁻, and HCO₃⁻
D. Na⁺, Cl⁻, and HCO₃⁻
E. None of the above ions  (B) 8-1-4

1263. Since the number of + and - ions in the amebae and the ECE are not equal, one might assume that
A. a mistake in measurement has been made.
B. other ions are also involved.
C. either K or Na has a different valence.
D. the ameba and the ECE are very acidic.
E. the ameba and the ECE are very basic. (B)8-1-4

1264. The chief advantage of encystment to an ameba is
A. the ability to live for a time without ingesting food.
B. the cessation of most metabolic activity so that available energy may be used for reproduction.
C. protection from parasitic invasion.
D. the opportunity to get rid of accumulated waste products.
E. the ability to survive during unfavorable physical conditions.  (E) 8-2-4

1265. Antarctic penguins are much larger than penguins living in more temperate regions. A satisfying explanation of this would most likely invoke which one of the following factors?
A. Breeding seasons are short in Antarctica; hence penguins there lay fewer and larger eggs than penguins in warmer latitudes.
B. The fishes on which penguins feed are larger in cold water than in warmer water.
C. Cold air contains a larger percentage of oxygen than warm air.
D. Large bodies have a smaller surface-to-volume ratio than small bodies.
E. Fewer parasites live in Antarctic regions than in temperate regions. (D) 8-3-4

1266. A crocodile has just eaten a lamb. A plover accommodatingly picks the crocodile's teeth. By this act, the plover, in ecological terms, is a
A. producer.
B. primary consumer.
C. secondary consumer.
D. tertiary consumer.
E. reducer. (C) 8-3-4

1267. It is said that the spiders of the Himalayas are native to the highest territory of any animals on earth. Spiders are carnivores. Therefore they must thrive by
A. making daily forays to lower altitudes.
B. eating each other.
C. eating insects blown up the mountains by the winds.
D. becoming herbivorous.
E. adapting to manufacture of organic materials from inorganic substances. (C) 8-3-4
1268. Fossil spores of magnolias have been found in Scotland. Magnolias are not native to Scotland today. The most likely reason for this discrepancy is
A. early settlers cut down all the trees for firewood.
B. the Scotch pine is more resistant to insect infestation than the magnolia.
C. Glaciers uprooted all the magnolias in the Pleistocene.
D. Magnolias cannot survive the salt spray that sweeps across Scotland.
E. The mean temperature of Scotland was formerly much higher than it is now. (E) 8-4-4

1269. At the end of the Paleozoic Era, many kinds of marine organisms such as trilobites, blastoids, and tetracorals became extinct. Other kinds of marine organisms in the same environment, such as brachiopods, clams, and crustaceans, survived. This can best be explained on the basis of the differences between the two groups in
A. the incidence of lethal mutations.
B. the nature of their predators.
C. their adaptability to environmental changes.
D. the ratio of sexual to asexual reproduction.
E. their feeding habits. (C) 8-4-4

1270. Which is evidence that man no longer has biological (as opposed to cultural) self-regulation of his population?
A. The birth rate has remained high despite insufficient food and a decrease in death rate.
B. War has been practically eliminated.
C. Outbreaks of serious diseases failed to reduce the population.
D. Man has no predators and few parasites which he can’t control.
E. Population growth has been constant for centuries. (A) 8-4-4

Items 1271-1273 refer to the following graphs:

1271. In which population is homeostasis most evident?
(C) 8-4-4

1272. Which population is probably dependent on external factors?
(D) 8-4-4

1273. If the graphs represent predator populations then which probably has the most varied prey requirements?
(C) 8-4-4

1274. A cell which has i+ z+ genes can make \( \beta \)-galactosidase only if an inducer is added to the growth medium. A cell which has i' z genes makes \( \beta \)-galactosidase in any growth medium. A cell which has both i' z and i' genes can make \( \beta \)-galactosidase only if an inducer is added to the growth medium. Which of the following logically follows?
A. Constitutive production of this enzyme is genetically dominant to inducible production.
B. i' z cells most likely make their own inducer.
C. i' most likely governs the synthesis of an endogenous inducer.
D. i' most likely governs the synthesis of an endogenous repressor.
E. The i' gene must be unrelated to the regulation of \( \beta \)-galactosidase synthesis. (D) 8-1-5

1275. Cells of strain A require methionine, leucine and histidine to grow in a glucose-salts medium. Cells of strain B require biotin, adenine and tryptophan to grow in a glucose-salts medium. If \( 10^6 \) cells of each of the two strains are incubated together in a liquid medium for two hours, then approximately \( 10^6 \) cells are found to be able to grow in a glucose-salts medium. Therefore, the likely reason for this discrepancy is
A. both strains are probably \( F^+ \).
B. one strain is probably \( F^- \), while the other is \( Hfr \).
C. both strains are probably \( Hfr \).
D. No conclusion about mating type can be drawn, because the data are compatible with normal mutation rates yielding the wild type cells.
E. none of the above is a reasonable conclusion. (B) 8-1-5

1276. Cells of E. coli strain B are grown in a minimal medium (glucose-Werkman’s). They are harvested during balanced growth and analyzed. Cells of the same strain are grown in a rich medium (glucose-Werkman’s + amino acids, nucleosides, vitamins, etc.). They also are harvested during balanced growth and analyzed. Assuming no mutants have been selected, the average cell from the minimal medium will probably be found to have
A. far fewer ribosomes than the average cell from the rich medium.
B. fewer nuclear bodies than the average cell from the rich medium.
C. more biosynthetic enzymes than the average cell from the rich medium.
D. all of the above.
E. none of the first three above. (C) 8-1-5

1277. Which one of the following groups contains a structure or component which would not be radioactive if a bacterial cell were grown in a medium containing
\( K_2HPO_4 \) as the sole source of phosphorus?
A. Ribosomes; transfer RNA; nuclear region
B. NAD; sRNA; acid-soluble nucleotide pool
C. Flagellum; ATP; DNA
D. Transfer RNA; membrane-wall complex; pool of inorganic ions
E. All of the above would be radioactive. (C) 8-1-5

1278. If an Aerobacter aerogenes cell were to be grown in a glucose-Werkman’s medium containing \( \text{NH}_4\text{Cl} \), \( S\text{O}_4 \) as the sole source of sulfur, then radioactivity would be found in
A. glycine.
B. ATP.
C. DNA.
D. ribosomal RNA.
E. none of the above. (E) 8-1-5

1279. If an Aerobacter aerogenes cell were to be grown in a glucose-Werkman’s medium containing \( \text{NH}_4\text{Cl} \), \( \text{SO}_4 \) as the sole source of nitrogen, then \( \text{N}_2 \) could reasonably be expected in
A. ATP.
B. sRNA.
C. glucose-6-phosphate.
D. more than one of the above.
E. none of the first three above. (D) 8-1-5
A culture of normal E. coli is grown in a Werkman's medium which initially has no sugar present except that added later. The Werkman's medium contains the following compounds: lactose + tryptophan + leucine + adenine. The culture is harvested during balanced growth and by suitable means four enzymes are measured: (1) β-galactosidase; (2) ornithine transcarbamylase (in the path leading to arginine); (3) tryptophan synthetase (in the path leading to tryptophan); and (4) DNA polymerase.

+ means enzyme activity was found
0 means little or no activity found

1280. Based upon our knowledge of how cells regulate enzyme synthesis, which line in the table below represents the best prediction of the results?

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(D)  8-1-5

1281. Which of the following could be expected if, instead of lactose, succinate has been present?

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(E)  8-1-5

1282. Assume that poly UG directs the synthesis of poly-alanine but not of poly-lysine. Also assume that poly UAC directs the synthesis of poly-lysine but not of poly-alanine. Under otherwise appropriate conditions for polypeptide synthesis, which of the following pairs of reagents will lead to any kind of polypeptide?

A. Poly UG + lysine attached to lysine sRNA
B. Poly UAC + lysine attached to lysine sRNA
C. Poly UG + alanine attached to lysine sRNA
D. More than one of the above
E. None of the above

(B)  8-1-5

1283. Which of the following is the best experimental procedure to determine the effectiveness of a vaccine in preventing influenza in parakeets?

A. Expose 100 parakeets to the disease and inoculate 50 with the vaccine.
B. Inoculate 100 parakeets with the vaccine and expose all 100 to the disease.
C. Inoculate 50 with the vaccine and expose all 100 to the disease.
D. Inoculate 50 with the vaccine and expose those to the disease.
E. Inoculate 50 with the vaccine and 50 with sterile saline and then expose all 100 to the disease. (E)

8-4-5

1284. Why could sterilized male screw worm flies be used to eliminate screw worms in Florida but not in California?

A. California is too warm and the flies can overwinter.
B. California is not isolated from large areas such as Mexico, which can not be controlled.
C. California doesn't have any screw worms because cattle are not raised there.
D. California is too dry and the screw worm flies mate repeatedly.
E. California flies are stronger and more resistant to sterilization. (B)

8-4-5

1285. 5-Methyltryptophan (5-MT) is structurally very similar to the natural amino acid, tryptophan. 5-MT has been used unsuccessfully in cancer chemotherapy, but it does inhibit the growth of many bacterial cells, including E. coli. 5-MT is not incorporated into protein, nor does it prevent tryptophan from being incorporated. Rather, it is believed to act by preventing a cell from making tryptophan. To determine whether it does this by acting as a false repressor it would be best to measure the

A. ability of E. coli to degrade 5-MT.
B. effect of 5-MT on the amount of tryptophan synthetase in inhibited cells.
C. effect of 5-MT on ATP formation.
D. amount of β-galactosidase in inhibited cells.
E. effect of 5-MT on the action of tryptophan synthetase in a test tube. (B)

8-4-5

1286. Some algae live in hot springs, but fish cannot survive there principally because

A. the high temperature may denature many of the fish proteins and may create lipid problems.
B. there is nothing there on which the fish may feed.
C. metabolic activity in the fish would be so rapid it could not store food reserves.
D. nerve impulses in the fish would travel too rapidly for efficient function.
E. bacterial growth would be so rapid as to foul the water. (A)

8-1-6

1287. By the use of a valid assay system, an investigator determines that there is no detectable enzyme X activity in a given organism grown in glucose-Werkman's medium. He therefore has a valid basis for concluding

A. that this organism lacks an appropriate intact structural gene to make X.
B. that this organism may or may not possess an appropriate intact structural gene to make X.
C. that glucose most likely represses the synthesis of enzyme X.
D. all of the above.
E. none of the first three above. (B)

8-1-6

1288. Pleurococcus can grow on terrestrial tree trunks whereas Euglena cannot, because

A. Pleurococcus has no flagellum, and is sessile.
B. the cell wall of Pleurococcus prevents desiccation.
C. Pleurococcus stores starch.
D. Euglena does not reproduce sexually.
E. Euglena has a stigma and requires an aqueous medium for its use. (B)

8-2-6

1289. Life is said to be improbable, but it does occur on the earth. Which of the following changes would be most likely to make terrestrial life on this planet impossible?

A. Decrease in mean annual temperature of 10°C
B. Change in the atmosphere permitting all of the solar radiation reaching the upper atmosphere to penetrate to the lithosphere
C. Change in the orbit of the earth from an ellipse to a circle
D. Disappearance of the moon
E. Increase of the angle of inclination of the axis of the earth to 45° away from a perpendicular to the plane of the orbit (B)

8-4-6

1290. Which of the following kinds of organisms could perhaps most readily become adapted to living in a pool of crude petroleum?

A. A kind of bacterium
B. A kind of unicellular green alga
C. A kind of yeast
D. A kind of ciliate
E. A kind of amoeba (A)

8-3-6
1291. Which of the following situations is most conducting to growth of a human white blood cell?  
A. A healthy human spleen  
B. An infected human tonsil  
C. A blood agar medium sterile except for the white blood corpuscles  
D. A tissue culture medium containing an abundance of antibiotics  
E. A dilute aqueous solution of sucrose, gelatin and selected inorganic salts  

1292. In some cultivated plants which a gardener has been growing for years, one specimen shows irregular, meandering patches of a yellow-white color in otherwise green leaves. With no further evidence available, which of the following is the most likely explanation?  
A. A mutation to albino has occured.  
B. Aphids have attacked the leaves.  
C. Lepidopterous larvae have been perforating the leaves.  
D. A virus infection has attacked the leaves.  
E. A lens of water on the leaves.  

1293. Although populations remain relatively constant over long periods, they fluctuate or oscillate about the constant or average. The regulation of populations has been called a form of homeostasis. Which best describes the relation of the oscillations (or fluctuations) to homeostasis?  
A. The larger the oscillations, the more efficient the homeostatic mechanism.  
B. The smaller the oscillations, the more efficient the homeostatic mechanism.  
C. The more frequent the oscillations, the more efficient the homeostatic mechanism.  
D. The less frequent the oscillations, the more efficient the homeostatic mechanism.  
E. There is no relationship between oscillations and homeostasis.  

Essay Questions  

1294. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. According to one computation, the ten most abundant chemical elements in the universe are carbon, helium, hydrogen, iron, magnesium, neon, nitrogen, oxygen, silicon and sulfur.  
b. Of these, seven are essential to most living organisms, one (silicon) is used by a few organisms such as diatoms and sponges, and two (helium and neon) are not part of living matter.  
c. None of the forty least abundant elements is an essential or common component of living matter.  

1295. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. A diatom requires the oxides of hydrogen, carbon, and silicon.  
b. The diatom obtains all of these in solution in the medium in which it lives.  
c. Of the three substances, hydrogen has the lowest atomic weight, carbon next, and silicon the highest.  
d. In the temperature range at which diatoms live, the oxide of carbon is gaseous, of hydrogen is liquid, and of silicon is solid.  

1296. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. Many kinds of freshwater amebas possess contractile vacuoles.  
b. Many kinds of marine amebas have no contractile vacuoles.  
c. A marine ameba gradually adapted to fresh water acquires a contractile vacuole.  
d. A freshwater ameba gradually adapted to salt water loses its contractile vacuole.  

Propose a critical test for your hypothesis.  

1297. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. Plasmodium vivax, a malaria-causing protozoan, successfully adapts to life in a mammal, Homo.  
b. Plasmodium vivax successfully adapts to life in an insect, Anopheles.  
c. Plasmodium vivax does not successfully adapt to life in other mammals, other insects, or other kinds of animals.  

1298. Over a period of many years an abandoned 240-acre cornfield becomes an oak-hickory forest. Outline the factors which bring this about.  

1299. Propose a procedure to determine how the metacercaria of a human liver fluke is protected against the acid and enzymes of the human stomach.  

1300. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. Onychophora are land animals requiring moist, shady environments.  
b. Onychophora are destroyed by moderate exposure to salt water.  
c. Onychophora occur in some of the islands of the West Indies, in South America, in South Africa, in the East Indies, in Australia, and in New Zealand.  

1301. Propose a procedure to determine whether mutations in bacteria causing immunity to phage occur spontaneously or in response to exposure to the phage.  

1302. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. Magnolias and water lilies occur in warm, temperate and sub-tropical habitats at the present time.  
b. The Jurassic rocks of Greenland and northern Scotland contain fossil pollen of magnolias and water lilies.  

1303. Propose an hypothesis which will satisfactorily explain the following set of data:  
a. In the Arctic oceans there are not many species of planktonic organisms, but there are tremendous numbers of individuals of some of these species.  
b. In the tropical oceans, there are very many species of planktonic organisms, but not such large numbers of individuals of any one species.  

1304. A population of cells consists of 10⁶ unwanted parental cells and 10 desired mutant cells. Indicate the steps that should be employed to isolate a pure culture of the mutant cell.  

1305. An oasis in the Sahara desert, fifty miles from the nearest source of neighboring life, is devasted by the explosion of a nuclear bomb, whose radiation kills all life in the oasis. In time, the radioactivity falls below the lethal level, but no human beings return to the oasis. Describe the development of a new biota by natural means in this oasis.
SECTION 14. EXAMPLES: HISTORY - PHILOSOPHY - METHODOLOGY

Objective Items

1306. "A tentative statement, or supposition adopted provisionally as a working tool to explain certain facts and to guide investigations of the problem" describes a
A. law.
B. conclusion.
C. hypothesis.
D. purpose.
E. principle. (C) 9-1-1

1307. The helical structure of the DNA molecule was established by
A. Watson and Crick.
B. Jacob and Monod.
C. Beadle and Tatum.
D. Briggs and King.
E. Hardy and Weinberg. (A) 9-1-1

1308. Linus Pauling established the chemical differences between
A. FSH and LH.
B. estrogen and testosterone.
C. plant viruses and bacteriophages.
D. DNA and RNA.
E. normal and sickle-cell hemoglobins. (E) 9-1-1

1309. Which of the following techniques contributed the most to nineteenth century advances in bacteriology?
A. Chromatography.
B. Oscilloscopy.
C. Photography.
D. Spectroscopy.
E. Microscopy. (E) 9-2-1

1310. Unicellular animals such as paramecium were first described by
A. Linnaeus.
B. Malpighi.
C. Hooke.
D. Leeuwenhoek.
E. Swammerdam. (D) 9-2-1

1311. Credit for establishing the nucleus as an important biological entity belongs to the scientist for whom is named
A. Rathke's pocket.
B. Malpighian corporules.
C. the loop of Henle.
D. Brownian movement.
E. the Golgi apparatus. (D) 9-2-1

1312. Gametes are reproductive cells produced by individuals organisms. There are two kinds of gametes; one kind, the sperm, is produced by the male, the other kind, the egg, is produced by the female. The sperm and the egg unite to form a new organism. This union is called fertilization. The new cell formed by the union of gametes is called the zygote.

In the context of the foregoing passage on sexual reproduction, which one of the following is a primitive term?
A. Gametes
B. Cells
C. Fertilization
D. Zygote
E. None of these (B) 9-2-1

1313. Which of the following developments was most instrumental in enabling us to determine the function of mitochondria?
A. Techniques of cell disruption and ultracentrifugation
B. Techniques of culturing bacteria
C. Techniques of plastic embedding and ultrathin sectioning
D. The electron microscope
E. The phase microscope (A) 9-1-1

1314. In 1838, Schwann, on the basis of his own observations as well as the observations of others, advanced the tentative conclusion that all living things are composed of cells. This statement, when first made in 1838, was
A. an assumption.
B. an observation.
C. a generalization.
D. an analogy.
E. a law. (C) 9-2-1

1315. Which of the following was most influential upon Darwin's formulation of the Theory of Natural Selection?
A. DeVries' concept of mutations
B. Lamarck's ideas on inheritance of acquired characteristics
C. Malthus' essay on population
D. Mendel's genetic studies on peas
E. Wallace's paper on survival (C) 9-3-1

1316. The viewpoint that the human body is directed by a vital force not amenable to scientific investigation is vitalism. This directing force is commonly called
A. typhlosole.
B. entelechy.
C. chiasma.
D. stroma.
E. nous. (B) 9-3-1

1317. Charles Darwin published a book on changes in soils which concerned especially the influence of
A. trace elements.
B. grass roots.
C. burrowing insects.
D. moles.
E. earthworms. (E) 9-4-1

Items 1318-1320 are based on the following excerpt from Biological Abstracts:


1318. Under what name would one locate this abstract in the Biological Abstracts author index?
A. Alfred
B. Arch
C. Deficience
D. Jacques
E. Legrand (E) 9-1-2

1319. Under what key words would this title probably be listed in the Biological Abstracts, subject index?
A. Cerebellum, maturation.
B. Deficience, thyroidienne, cervelet, rat.
C. Thyroid deficiency.
D. Thyroid, cerebellum, rat.
E. Thyroid, deficiency, maturing, cerebellum, rat. (D) 9-1-2

1320. What does 50(4) stand for?
A. April, 1950
B. 50 pages, 4 illustrations
C. 1950, page 4
D. Volume 50, page 4
E. Volume 50, number 4 (E) 9-1-2

1321. It is theorized that cytoplasmic as well as nuclear organelles are concerned with the transmission of hereditary information, because
A. centrioles divide whenever an animal cell divides.
B. mitochondria and chloroplasts contain DNA.
C. particular kinds of cells have particular shapes of chloroplasts.
D. centrioles are equally distributed to the daughter cells at cell division.
E. some cells are not nucleated. (B) 9-2-2
1322. If Mendel had studied his seven traits using a plant with 6 chromosomes instead of 14, how might his interpretation have changed?
A. He would have discovered blending or incomplete dominance.
B. He would not have proposed that genes are carried on chromosomes.
C. He might not have discovered the law of independent assortment.
D. He would have discovered sex-linkage.
E. He could have mapped the chromosomes.  (C) 9-2-2

1323. The "cell theory" of Schleiden and Schwann states that
A. all cells have nuclei.
B. cells use ATP as the immediate source of energy.
C. cells arise only from preexisting cells.
D. cells reproduce by mitosis or meiosis.
E. cells are the fundamental structural units of plants and animals.  (E) 9-2-2

1324. The theory of abiogenesis held that
A. spores of organisms were originally transmitted through space from another planet to the earth.
B. bacteria gave rise to plants and plants to animals.
C. each species of living organisms has been separately created.
D. each fertilized egg contains in miniature all future generations to be descended from that individual.
E. living organisms arise from nonliving matter.  (E) 9-2-2

1325. Which of the following gave the original impetus to the development of modern human physiology?
A. Harvey's work on the circulation of the blood
B. Pasteur's work on the germ theory of disease
C. Darwin's work on the theory of natural selection
D. Mendel's work on the transference of hereditary information
E. Watson and Crick's work on the structure of the DNA molecule  (A) 9-3-2

1326. Which of the following is a teleological statement?
A. A deer herd will increase numbers just to the point that the environment will support it adequately.
B. A mutation in mosses that allows them to manufacture food more efficiently will be favorably selected.
C. Humans are mortal.
D. Some fishes are herbivorous and some are carnivorous.
E. The presence of gill markings in mammal embryos suggests an aquatic ancestry of mammals.  (A) 9-4-2

1327. What is the best reason for using mathematics in a study of populations? It enables us to
A. define the limits of a population.
B. quantify and predict growth in populations.
C. regulate populations.
D. determine when we are working with a population.
E. isolate populations.  (B) 9-4-2

1328. An example of the biochemical similarity of all living organisms is the
A. derivation of metabolic energy from chemical reactions.
B. manufacture of all hormones from steroids.
C. form of carbohydrate used for food storage.
D. ultimate waste product from the denitrification of proteins.
E. use of molecular oxygen in oxidation reactions.  (A) 9-1-2

1329. Molecular biologists generally maintain that
A. the kinds of atoms an organism possesses differentiate it best from other kinds of organisms.
B. there are in living organisms no higher levels of organization than the molecular.
C. all significant biological phenomena are intracellular.
D. organisms are more alike in their chemical reactions than in their morphological characteristics.
E. only molecules in the first two rows of the periodic table occur normally in living organisms.  (D) 9-1-2

1330. The "cell theory" credited to Schleiden and Schwann is often written in quotes to signify that it is not a theory, but actually a (an)
A. law.
B. hypothesis.
C. certainty.
D. generalization.
E. lemma.  (D) 9-2-3

1331. Belief that a mother bird cares for her young out of affection is an example of
A. teleonomy.
B. anthropomorphism.
C. entelechy.
D. charisma.
E. none of the above.  (B) 9-4-2

1332. The existence of the planet Neptune was predicted before it was discovered. A comparable example from biology was the prediction followed by the discovery of
A. egg-laying mammals.
B. plant cell nuclei.
C. living psilophytes.
D. bacteria.
E. blood capillaries.  (E) 9-2-3

1333. A vitalist would say of himself,
A. I am the product of the interaction of genes and environment.
B. I am not the captain of my soul, but the pawn of fate.
C. I am one of those works of God which no man can understand.
D. I differ from a rock because of my superior level of organization.
E. My brain development sets me apart from other species of animals.  (C) 9-3-3

1334. Which of the following is the most holistic comment on the attempt of a student to set up a balanced aquarium with distilled water, pickeral weed, and tadpoles?
A. He needs to add a little salt to prevent plasmolysis.
B. As a community, it needs reducers such as bacteria.
C. He should put it in the sunlight.
D. He should be careful that the plant mass exceeds the animal mass.
E. Humans cannot set up a completely balanced aquarium.  (B) 9-4-3

1335. The most mechanistic of the following explanations of the origin of life on earth is
A. the first life was a fortuitous association of atoms.
B. a chain of causally connected events brought about a self-replicating molecule.
C. God created the earth and all that is in it.
D. given the physical and chemical nature of the earth, the origin of life was inescapable.
E. when conditions were right, life happened.  (B) 9-4-2
1341. Living organisms are built of carbon compounds. It has been suggested that organisms built of silicon compounds are imaginable. Silicon is mentioned as a possible alternate to carbon because
A. silicon atoms combine with each other into chains as do carbon atoms.
B. silicon, like carbon, is one of the most abundant elements in the universe.
C. silicon, like carbon, is a relatively light element. silicon dioxide, like carbon dioxide, occurs in solution in water.
D. silicon dioxide, like carbon dioxide, occurs in solution in water
E. silicon, like carbon, has a valence of 4.

1342. In 1828, Wohler synthesized urea in his laboratory. Why was this significant?
A. It refuted spontaneous generation.
B. It provided support for a mechanistic interpretation of living matter.
C. It demonstrated the similarity between plants and animals.
D. It enabled man to create life in the laboratory.
E. It demonstrated that organic compounds can be synthesized without living organisms.

1343. Robert Brown announced the presence of the nucleus in cells about ten years before Schleiden and Schwann enunciated the "cell theory." Which of the following best explains the priority of the nucleus announcement?
A. The nucleus is a more important entity than the cytoplasm.
B. The English had better microscopes than the Germans.
C. Nuclei take a darker stain than other parts of cells.
D. The nucleus is a morphological entity while the "cell theory" is an abstract generalization.
E. In cell division, the behavior of chromosomes is the most conspicuous cytological phenomenon.

1344. The most important advantage of using litter-mates in a nutritional study on rats is that they
A. are more apt to be genetically similar than individuals which are not litter mates.
B. are more apt to be genetically different than individuals which are not litter mates.
C. will all be the same age while non-litter mates cannot be.
D. will show the effects of nutrition better because of inbreeding.
E. are more apt to have mutant genes.

1345. Of the organ systems of the human body, the endocrine was the last to be recognized as a system because endocrine glands
A. have nothing to do with locomotion.
B. are the smallest of the body's organs.
C. are not essential for human life.
D. arise from all three embryonic germ layers, not just one.
E. do not constitute a morphological continuity.

1346. Van Belmont added only water to a willow tree and found that the tree gained 164 lbs. in weight over 5 years but the soil lost only 2 oz. in weight. E.
A. Water and CO2 caused the increase in plant mass.
B. Water is necessary for the light reaction.
C. Water is necessary for the light reaction.
D. Plants gain in mass by the addition of water.
E. Plants use water in photosynthesis.

1347. Priestley (1771) demonstrated that a sprig of green mint plant enabled a mouse to live within a closed bell jar.
A. O2 is liberated from the "light reaction."
B. O2 comes from "decomposed" H2O.
C. O2 comes from CO2 decomposed in the "light reaction."
D. Plants give off O2 in the presence of light and CO2.
E. Plants purify the putrified air breathed out by animals.

Items 1336-1339 are based on the following experiment: Bacterium X is grown in liquid medium. It is diluted and pipetted over the surface of neomycin-nutrient agar so that each bacterium gives rise to a colony. Three cultures are exposed to three different intensities of ultraviolet light. Two plates are left in the dark. Colony counts are as follows:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II 100</th>
<th>III 200</th>
<th>IV 400</th>
<th>V dark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colonies per culture</td>
<td>5</td>
<td>10</td>
<td>25</td>
<td>50</td>
<td>10,000</td>
</tr>
<tr>
<td>Neomycin in medium</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

1336. What is the natural occurring rate of mutation for the neomycin resistance trait in bacterium X? Assume no neomycin-resistant bacteria are in the original population.
A. .005%
B. .10%
C. .25%
D. .50%
E. Cannot tell from the above data.

1337. How much does 400 ergs ultraviolet change the natural occurring mutation rate for neomycin resistance in bacterium X?
A. It doubles the rate.
B. It increases it 5 times.
C. It increases it 10 times.
D. It increases it 50 times.
E. It does not change the rate.

1338. Which test tube served as the control for intensity of ultraviolet light exposure?
A. I
B. V
C. I and V
D. II and III
E. There was no control.

1339. Which test tube served as the control for effect of the antibiotic?
A. I
B. II
C. III
D. IV
E. V

1340. Molecular biology came to be the most active field of biology in the 1960's. The most cogent of the following reasons for this is
A. it wasn't until the 1950's that chemistry developed active concern about molecules.
B. new and useful techniques for study of biological phenomena at the molecular level were developed in the 1950's.
C. instruments required for the study of molecular biology are very expensive, and biologists had to wait for extensive governmental support of biology.
D. the major problems at the population and organismic levels had all been solved and only molecular problems remained.
E. in universities and research institutes most of the positions in other kinds of biology were filled, and most of the vacancies were in molecular biology.
1348. DeSaussure's (1804) quantitative measurements showed that the CO$_2$ taken in by an illuminated plant was related to the O$_2$ given off.
A. The O$_2$ released in photosynthesis comes from CO$_2$.
B. The O$_2$ released in photosynthesis comes from H$_2$O.
C. CO$_2$ is converted to phosphoglyceraldehyde (PGAL).
D. CO$_2$ is reduced by hydrogen ions to a simple sugar.
E. Light is necessary for "carbon fixation." (A) 9-3-4

1349. Engelmann (1882) found motile aerobic bacteria accumulated near areas of a strand of green algae which were illuminated by red or blue light but they did not accumulate near a strand of green algae illuminated by green light.
A. Chlorophyll is involved in photosynthesis.
B. Chlorophyll absorbs green light.
C. O$_2$ is released from CO$_2$ in the light reaction.
D. O$_2$ is released from H$_2$O in the light reaction.
E. Red and blue light are most effective in photosynthesis. (E) 9-3-4

1350. Blackman (1905) demonstrated that increasing illumination increased the photosynthetic rate up to a point when CO$_2$ became limiting. If light was not limiting then temperature became limiting. Emerson found that maximum CO$_2$ fixation could be obtained with brief flashes of light.
A. Only one factor can be limiting in photosynthesis.
B. Photosynthesis consists of a "light" and a "dark" reaction.
C. Photosynthesis consists of the reduction of CO$_2$ to form carbohydrates.
D. The "trapping" of light by chloroplasts can occur only if CO$_2$ is present.
E. The "trapping" of light by chloroplasts is temperature dependent. (B) 9-3-4

1351. Van Niel (1929) found purple sulfur bacteria used hydrogen sulfide (H$_2$S) and released sulfur (S) but no O$_2$.
A. The hydrogen which reduces CO$_2$ in photosynthesis comes from H$_2$O which liberates O$_2$.
B. The sulfur which reduces CO$_2$ comes from H$_2$S which liberates H$_2$.
C. Photosynthesis does not require chlorophyll.
D. Photosynthesis consists of a "light" and a "dark" reaction.
E. Bacterial photosynthesis is not comparable to that occurring in green plants. (A) 9-3-4

1352. Robin Hill (1939) obtained O$_2$ from isolated chloroplasts when an oxidizing agent like ferric iron salts is added.
A. The O$_2$ liberated in photosynthesis comes from H$_2$O.
B. The O$_2$ liberated in photosynthesis comes from CO$_2$.
C. Photosynthesis consists of a "light" and a "dark" reaction.
D. Iron is necessary for continuation of photosynthesis.
E. The plant is not necessary for photosynthesis. (A) 9-2-4

1353. Calvin exposed green algae to C$^{14}$O$_2$ and light for a fraction of a second. Chromatography and autoradiography revealed the C$^{14}$ in a 3-carbon compound. A shorter exposure showed the C$^{14}$ in a 5-carbon compound. A longer exposure showed the C$^{14}$ in a 6-carbon compound and in starch.
A. A 6-carbon compound is synthesized from a 5-carbon compound which comes from a 3-carbon compound.
B. The 5-carbon compound is broken down from a 6-carbon compound which is synthesized from two 3-carbon compounds.
C. CO$_2$ is added to a 5-carbon compound forming a 6-carbon compound which is split.
D. Starch is the end product of photosynthesis.
E. Only a brief exposure to light is necessary for starch formation. (C) 9-3-4

1354. Which of the following does not represent a way in which a single white oak tree is like a population of white oaks?
A. It may increase in mass with time.
B. It is subject to genetic drift.
C. It is sensitive to temperature changes in the environment.
D. It is subject to parasitism.
E. It may have a cyclical pattern of growth. (B) 9-4-4

1355. It is hypothesized that owl species X is the major factor in controlling rabbit species Z. The best preliminary step in the study might be to determine
A. if the rabbits are first order consumers and the owls are second order consumers.
B. if the owls eat the rabbits.
C. which kind of diseases rabbits can contract.
D. what food the rabbits eat.
E. what type habitats the rabbits and owls occupy. (B) 9-4-5

1356. The most workable yet valid procedure for the investigator would be to study
A. examples of all species of rabbits and owls.
B. samples from representative populations of owl X and rabbit Z.
C. all individuals of a representative population of owl X and rabbit Z.
D. representative individuals of rabbit Z.
E. samples of all major ecosystems. (B) 9-4-5

1357. If our hypothesis is correct, then
A. a decrease in the population of X owls should decrease the population of Z rabbits.
B. a decrease in the population of Z rabbits should increase the population of X owls.
C. an increase of Z rabbits diseases should not change the population of X owls.
D. an increase in food for Z rabbits should not change the population of X owls.
E. an increase in X owls should decrease the population of Z rabbits. (E) 9-4-4

Items 1358-1364 are based on the following description:
Edward Buchner was the first to obtain fermentation without yeast cells. He ground up yeast cells and water and squeezed out a yellow liquid which was capable of fermenting glucose, fructose, sucrose, and maltose but not lactose or mannitose. This fermenting power was not destroyed when chloroform was added or the liquid was passed through a fine filter but after five days in ice the solution no longer fermented sucrose. Buchner obtained a fermenting power from yeast cells which had been killed by heating (65°C for 1 hr.) the liquid would change (invert) sucrose to glucose and fructose but would not ferment it.

1358. What was the significance of the experiment described above?
A. It proved the idea that living things contained a "vital spirit."
B. It proved the idea that life functions conformed to physical laws.
C. It disproved spontaneous generation.
D. It made possible wine and beer production without organisms.
E. It showed that organic compounds could be produced in the laboratory. (D) 9-1-6

1359. The fact that Buchner's solution fermented different mono-and disaccharide sugars indicates that the solution probably contained
A. an energy source.
B. an organizing principle.
C. living cells.
D. one enzyme which could break apart compound sugars and ferment the products.
E. several enzymes. (E) 9-1-4
1360. The fact that Buchner could filter his solution or add chloroform without destroying the fermenting power indicates that
A. living cells were not affected by these treatments.
B. living cells were not present.
C. the enzyme was very small.
D. the organizing principle was not affected by these treatments.
E. the solution was a protein.  (B) 9-1-4

1361. How could the observation that "heating stopped fermentation but not the change of sucrose to glucose and fructose" be best explained?
A. An organizing principle is not involved in changing sucrose.
B. Energy is not needed to change sucrose.
C. Only living cells can ferment but sucrose can be changed without living cells.
D. The enzyme's separate functions could be separated.
E. The several enzymes have separate characteristics.  (E) 9-1-4

1362. Which best explains why fermentation did not occur when the alcoholic precipitate was dissolved in a sucrose solution? The alcohol
A. changed the protein structure.
B. destroyed the organizing principle.
C. killed the cells.
D. precipitated only the sugar.
E. removed the energy source.  (A) 9-1-6

1363. Which experimental design would probably provide the most information about the nature of Buchner's solution?
A. Add different kinds of energy and sugars to measure the amount of fermentation.
B. Hydrolyze the enzyme and analyze the amino acids by paper chromatography.
C. Identify the living cells.
D. Philosophically discuss what an organizing principle is.
E. Use different solvents to separate and purify the different components.  (E) 9-1-6

1364. Why did Buchner filter his solution?
A. To remove cells.
B. To inactivate the organizing principle.
C. To remove the energy source.
D. To separate the enzymes.
E. To distill the enzyme.  (A) 9-1-6

1365. It is most significant in a causal sense that the establishment of the "cell theory" came at about the time that
A. Pasteur developed the germ theory of disease.
B. embryologists built the biogenetic theory.
C. taxonomy was dethroned as the principal interest of biologists.
D. the optics of the microscope were radically improved.
E. Cuvier disappeared as the dominant figure of French biology.  (D) 9-2-6

1366. Toward the end of his life, Linnaeus wavered in his belief in the fixity of species. The most likely cause of his doubts was
A. Lamarck's ideas on evolution by the inheritance of acquired characters.
B. the stand of the Lutheran Church on the story of creation.
C. observation of specimens apparently intermediate between two of his species.
D. the very great number of species known at that time.
E. the impossibility of getting two of every kind of animal on a vessel of the stated size of Noah's Ark.  (C) 9-3-6

1367. Which one of the following aspects of William Harvey's "On the Motion of the Heart and the Blood" was the most helpful contribution to biology of the seventeenth century?
A. The use of the human as an object of biological study.
B. The introduction of Italian anatomical knowledge into England.
C. The proper respect and reverence for authoritarian beliefs.
D. The use of quantitative experimentation in physiology.
E. The combining of physics and biology.  (D) 9-3-6

For items 1368-1373 compare Mendel's theory with Darwin's theory with respect to the attributes described in the following questions. Use this key.

KEY: A. True of Mendel's theory but not true of Darwin's theory
B. True of Darwin's theory but not true of Mendel's theory
C. True of both Mendel's and Darwin's theories
D. True of neither Mendel's nor Darwin's theories but true of some other theory of biology
E. True of no theory in biology

1368. Clearly defined laws were developed during the early stages of the theory.  (A) 9-3-6

1369. The original theory was modified subsequently by addition of ad hoc postulates.  (C) 9-3-6

1370. Mathematics played a part in the early development of the theory.  (A) 9-3-6

1371. The theory originated from studies of pathology.  (D) 9-3-6

1372. The theory had great immediate impact on other areas of human knowledge.  (B) 9-3-6

1373. While the theory originally made no mention of chemical change, its modern version is very much concerned about chemical change.  (C) 9-3-6

1374. Teleology is generally rejected by mechanistic biologists because
A. these biologists find no evidence for a mechanism for a final state influencing the processes leading to that state.
B. teleology is an outdated explanation characteristic of the Middle Ages and early Renaissance.
C. physicists have shown that causes of all natural events can be expressed in terms of atomic and subatomic processes.
D. living organisms are so variable that no single explanation is suitable for biological phenomena.
E. no living organisms can be conscious of purpose.  (A) 9-4-6

Essay Questions

1375. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Biologists have long maintained that only photosynthetic and chemosynthetic plants can make organic compounds out of carbon dioxide and water.
   b. Recently, it has been shown that many kinds of animals can incorporate carbon dioxide into succinic acid and malic acid.
   c. Biologists still maintain that photosynthetic plants are the essential basis for the food chain on this planet.  9-1-5

1376. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Statistical studies of heredity were advancing rapidly in the first decade of this century.
   b. Cytological studies of heredity were advancing rapidly in the first decade of this century.
   c. Molecular studies of heredity did not begin to advance rapidly until the sixth decade of this century.  9-1-5
1377. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. A prominent biologist of the early nineteenth century maintained that the microscope was a handicap to biologists, and refused to use it.
   b. A prominent biologist of the early twentieth century maintained that the microtome was a handicap to biologists, and refused to use it.

1378. Propose a procedure to determine whether vitalism or mechanism is a better basis for explaining the adaptive differentiation of the cell of a metazoan organism.

1379. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. Satisfactory biochemical explanations have been provided for the energy transformations in living organisms.
   b. Satisfactory biochemical explanations have been provided for protoplasm synthesis in living organisms.
   c. Satisfactory biochemical explanations have not been provided for the efficient coordination of metabolic processes in living organisms.

1380. Using examples such as the sliding filament hypothesis of muscle contraction, the Watson-Crick hypothesis of DNA structure, the construction of phylogenetic charts, or some other example which may occur to you, show how deductive logic and hypothetical models play a role in scientific investigations.

1381. Devise an apparatus for measuring the fluid pressure in a muscle cell during contraction and relaxation such that the apparatus will not itself affect either pressure or the state of contraction.

1382. Account for the fact that infection with malaria is used as a therapeutic method in treating certain diseases.

1383. The idea of evolution by natural selection is widely credited to Charles Darwin, although it had been discussed by several forerunners including Charles’ grandfather. The “cell theory” is commonly attributed to Schleiden and Schwann, although it had been previously described by Wolff and others. The use of binomial nomenclature in taxonomy of living organisms is not original with Linnaeus, although he is often given the credit for it. What common feature in these cases accounts for the attribution of fame to Charles Darwin, Schleiden and Schwann, and Linnaeus for developments in which they had been preceded?

1384. Propose an hypothesis which will satisfactorily explain the following set of data:
   a. A concerted attack on problems of plant and animal morphology characterized the eighteenth century.
   b. A concerted attack on problems of plant and animal chemistry did not get under way until the nineteenth century.
   c. A concerted attack on problems of plant and animal ecology did not get under way until the twentieth century.

1385. Propose a procedure to determine who first stated the presently accepted concept of an ecosystem.

1386. Bichat held that tissues were the fundamental structural and functional units of a human body. Schleiden and Schwann maintained that cells were such fundamental units. Which position is, in your opinion, better? Why?

1387. Look out of the window for five minutes. Then describe what you saw in terms of biological phenomena. How would your description have been different if you observed only those phenomena which are of primary interest to a biochemist? A plant physiologist? A student of animal behavior? An ecologist?

1388. One writer suggests that biology is a science only insofar as it is quantitative. Do you agree or disagree, and why?


May 2, 2013

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