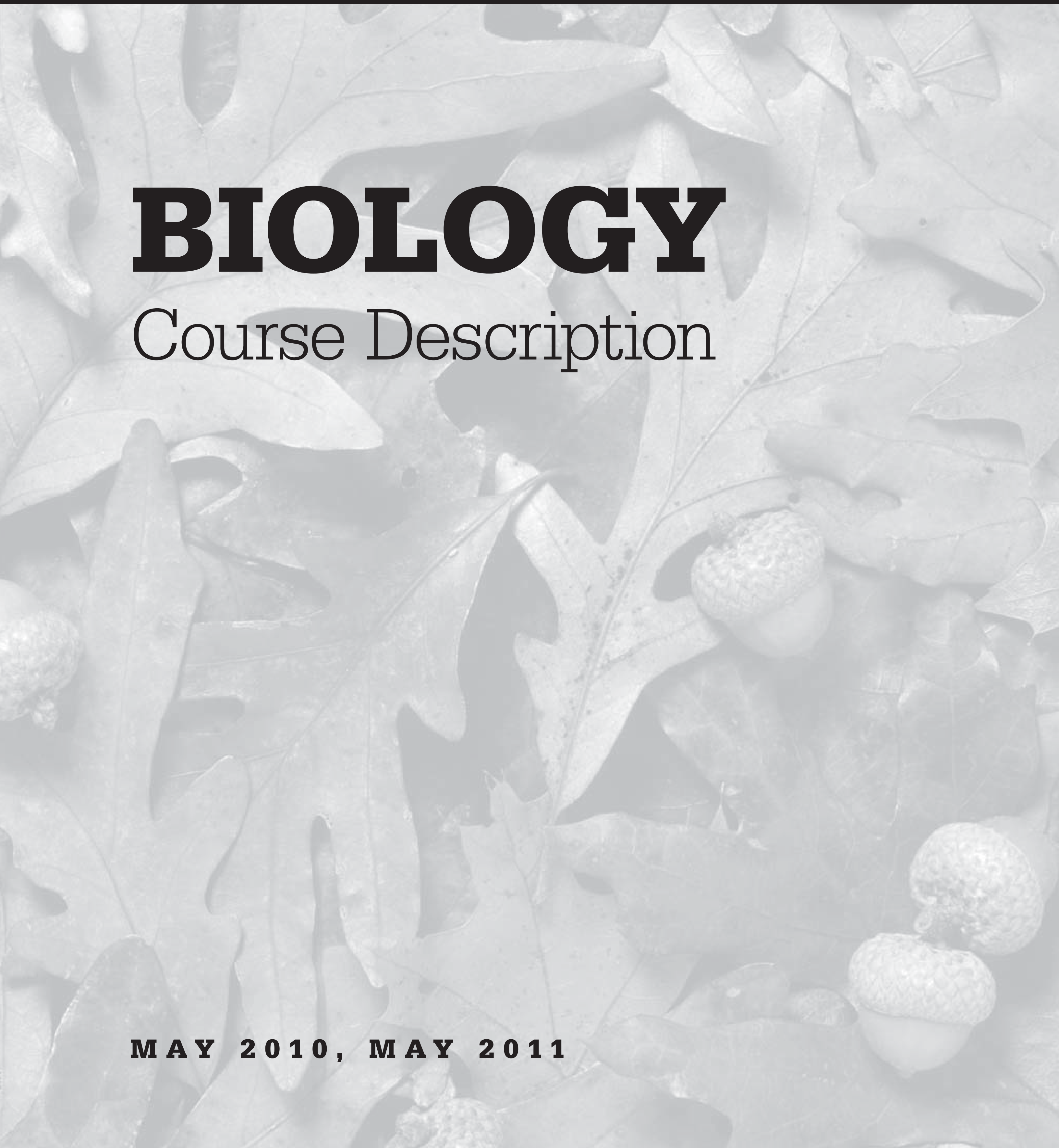
CollegeBoard AP



BIOLOGY

Course Description

MAY 2010, MAY 2011

The College Board

The College Board is a not-for-profit membership association whose mission is to connect students to college success and opportunity. Founded in 1900, the association is composed of more than 5,600 schools, colleges, universities, and other educational organizations. Each year, the College Board serves seven million students and their parents, 23,000 high schools, and 3,800 colleges through major programs and services in college admissions, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT®, and the Advanced Placement Program® (AP®). The College Board is committed to the principles of excellence and equity, and that commitment is embodied in all of its programs, services, activities, and concerns.

For further information visit www.collegeboard.com.

The College Board and the Advanced Placement Program encourage teachers, AP Coordinators, and school administrators to make equitable access a guiding principle for their AP programs. The College Board is committed to the principle that all students deserve an opportunity to participate in rigorous and academically challenging courses and programs. All students who are willing to accept the challenge of a rigorous academic curriculum should be considered for admission to AP courses. The Board encourages the elimination of barriers that restrict access to AP courses for students from ethnic, racial, and socioeconomic groups that have been traditionally underrepresented in the AP Program. Schools should make every effort to ensure that their AP classes reflect the diversity of their student population.

Contents

Welcome to the AP® Program

For over 50 years, the College Board's Advanced Placement Program (AP) has partnered with colleges, universities, and high schools to provide students with the opportunity to take college-level course work and exams while still in high school. Offering more than 30 different subjects, each culminating in a rigorous exam, AP provides motivated and academically prepared students with the opportunity to earn college credit or placement and helps them stand out in the college admissions process. Taught by dedicated, passionate AP teachers who bring cutting-edge content knowledge and expert teaching skills to the classroom, AP courses help students develop the study skills, habits of mind, and critical thinking skills that they will need in college.

AP is accepted by more than 3,600 colleges and universities worldwide for college credit, advanced placement, or both on the basis of successful AP Exam grades. This includes over 90 percent of four-year institutions in the United States.

More information about the AP Program is available at the back of this Course Description and at AP Central®, the College Board's online home for AP teachers (apcentral.collegeboard.com). Students can find more information at the AP student site (www.collegeboard.com/apstudents).

AP Courses

More than 30 AP courses in a wide variety of subject areas are now available. A committee of college faculty and master AP teachers designs each AP course to cover the information, skills, and assignments found in the corresponding college course.

AP Exams

Each AP course has a corresponding exam that participating schools worldwide administer in May. Except for AP Studio Art, which is a portfolio assessment, each AP Exam contains a free-response section (essays, problem solving, oral responses, etc.) as well as multiple-choice questions.

Written by a committee of college and university faculty and experienced AP teachers, the AP Exam is the culmination of the AP course and provides students with the opportunity to earn credit and/or placement in college. Exams are scored by college professors and experienced AP teachers using scoring standards developed by the committee.

AP Course Audit

The intent of the AP Course Audit is to provide secondary and higher education constituents with the assurance that an "AP" designation on a student's transcript is credible, meaning the AP Program has authorized a course that has met or exceeded the curricular requirements and classroom resources that demonstrate the academic rigor of a comparable college course. To receive authorization from the College Board to label a course "AP," teachers must participate in the AP Course Audit. Courses authorized to use the "AP" designation are listed in the AP Course Ledger made available to colleges and universities each fall. It is the school's responsibility to ensure that its AP Course Ledger entry accurately reflects the AP courses offered within each academic year.

The AP Program unequivocally supports the principle that each individual school must develop its own curriculum for courses labeled "AP." Rather than mandating any one curriculum for AP courses, the AP Course Audit instead provides each AP teacher with a set of expectations that college and secondary school faculty nationwide have established for college-level courses. AP teachers are encouraged to develop or maintain their own curriculum that either includes or exceeds each of these expectations; such courses will be authorized to use the "AP" designation. Credit for the success of AP courses belongs to the individual schools and teachers that create powerful, locally designed AP curricula.

Complete information about the AP Course Audit is available at www.collegeboard.com/apcourseaudit.

AP Reading

AP Exams—with the exception of AP Studio Art, which is a portfolio assessment—consist of dozens of multiple-choice questions scored by machine, and free-response questions scored at the annual AP Reading by thousands of college faculty and expert AP teachers. AP Readers use scoring standards developed by college and university faculty who teach the corresponding college course. The AP Reading offers educators both significant professional development and the opportunity to network with colleagues. For more information about the AP Reading, or to apply to serve as a Reader, visit apcentral.collegeboard.com/readers.

AP Exam Grades

The Readers' scores on the free-response questions are combined with the results of the computer-scored multiple-choice questions; the weighted raw scores are summed to give a composite score. The composite score is then converted to a grade on AP's 5-point scale:

AP GRADE	QUALIFICATION
5	Extremely well qualified
4	Well qualified
3	Qualified
2	Possibly qualified
1	No recommendation

AP Exam grades of 5 are equivalent to A grades in the corresponding college course. AP Exam grades of 4 are equivalent to grades of A–, B+, and B in college. AP Exam grades of 3 are equivalent to grades of B–, C+, and C in college.

Credit and Placement for AP Grades

Thousands of four-year colleges grant credit, placement, or both for qualifying AP Exam grades because these grades represent a level of achievement equivalent to that of students who have taken the corresponding college course. This college-level equivalency is ensured through several AP Program processes:

- College faculty are involved in course and exam development and other AP activities. Currently, college faculty:
  - Serve as chairs and members of the committees that develop the Course Descriptions and exams in each AP course.
  - Are responsible for standard setting and are involved in the evaluation of student responses at the AP Reading. The Chief Reader for each AP subject is a college faculty member.
  - Lead professional development seminars for new and experienced AP teachers.
  - Serve as the senior reviewers in the annual AP Course Audit, ensuring AP teachers' syllabi meet the curriculum guidelines of college-level courses.
- AP courses and exams are reviewed and updated regularly based on the results of curriculum surveys at up to 200 colleges and universities, collaborations among the College Board and key educational and disciplinary organizations, and the interactions of committee members with professional organizations in their discipline.
- Periodic college comparability studies are undertaken in which the performance of college students on AP Exams is compared with that of AP students to confirm that the AP grade scale of 1 to 5 is properly aligned with current college standards.

For more information about the role of colleges and universities in the AP Program, visit the Higher Ed Services section of the College Board Web site at professionals.collegeboard.com/higher-ed.

Setting Credit and Placement Policies for AP Grades

The College Board Web site for education professionals has a section specifically for colleges and universities that provides guidance in setting AP credit and placement policies. Additional resources, including links to AP research studies, released exam questions, and sample student responses at varying levels of achievement for each AP Exam are also available. Visit professionals.collegeboard.com/higher-ed/placement/ap.

The "AP Credit Policy Info" online search tool provides links to credit and placement policies at more than 1,000 colleges and universities. This tool helps students find the credit hours and/or advanced placement they may receive for qualifying exam grades within each AP subject at a specified institution. AP Credit Policy Info is available at www.collegeboard.com/ap/creditpolicy.

AP Biology

INTRODUCTION

The AP Biology course is designed to be the equivalent of a two-semester college introductory biology course usually taken by biology majors during their first year. After showing themselves to be qualified on the AP Exam, some students, in their first year of college, are permitted to take upper-level courses in biology or register for courses for which biology is a prerequisite. Other students may have fulfilled a basic requirement for a laboratory-science course and will be able to undertake other courses to pursue their majors.

AP Biology should include those topics regularly covered in a college biology course for majors. The college course in biology differs significantly from the usual first high school course in biology with respect to the kind of textbook used, the range and depth of topics covered, the type of laboratory work done by students, and the time and effort required of students. The textbooks used for AP Biology should be those used by college biology majors. The kinds of labs done by AP students must be the equivalent of those done by college students.

The AP Biology course is designed to be taken by students after the successful completion of a first course in high school biology and one in high school chemistry as well. It aims to provide students with the conceptual framework, factual knowledge, and analytical skills necessary to deal critically with the rapidly changing science of biology.

GOALS OF THE COURSE

The AP Biology Development Committee conducts surveys in which professors at colleges regularly receiving the most AP students respond to a questionnaire asking them to describe the content of their introductory biology courses for biology majors. The AP Course Description that follows was developed by the committee after a thorough analysis of survey results.

The AP Biology Exam seeks to be representative of the topics covered by the survey group. Accordingly, goals have been set for percentage coverage of three general areas:

I. Molecules and Cells, 25%
II. Heredity and Evolution, 25%
III. Organisms and Populations, 50%

These three areas have been subdivided into major categories with percentage goals specified for each. The percentage goals should serve as a guide for designing an AP Biology course and may be used to apportion the time devoted to each category. The exam is constructed using the percentage goals as guidelines for question distribution.

The two main goals of AP Biology are to help students develop a conceptual framework for modern biology and an appreciation of science as a process. The ongoing knowledge explosion in biology makes these goals even more challenging.

Primary emphasis in an AP Biology course should be on developing an understanding of concepts rather than on memorizing terms and technical details. Essential to this conceptual understanding are a grasp of science as a process rather than as an accumulation of facts; personal experience in scientific inquiry; recognition of unifying themes that integrate the major topics of biology; and application of biological knowledge and critical thinking to environmental and social concerns.

The following guidelines are offered to help teachers and their students focus on unifying themes and key concepts.

THEMES, TOPICS, AND CONCEPTS

Themes, topics, and concepts all give structure to an AP Biology course. This book defines *themes* as overarching features of biology that apply throughout the curriculum. *Topics* are the subject areas in biology, and *concepts* are the most important ideas that form our current understanding of a particular topic.

An example of a topic is "cellular respiration." In a conceptual approach to this topic, for example, it is important to understand how membranes couple ATP synthesis to the energy released by electron transport. This key concept stands above discrete "facts," such as the role of a particular cytochrome in electron transport.

Emphasizing concepts over facts makes the content of a biology course more meaningful and less overwhelming. A biology course has more structure and meaning when the key concepts for each topic are placed in the broader context of unifying themes. As an example, the theme of "energy transfer" helps students connect topics as diverse as cellular respiration and ecosystem dynamics. Concepts are the key ideas, restricted in scope to a certain topic. Themes cut across the topics. Increasingly, the AP Biology Exam will emphasize the themes and concepts of biology and place less weight on specific facts.

The next few sections of this book reinforce the relationships of themes and concepts to the topics in an AP Biology course. First is a suggested list of themes. Following this list is a topic outline that organizes biology into subject areas. Then there are explanations of the items in the suggested list of themes with a specific example for each one.

MAJOR THEMES

I. Science as a Process
II. Evolution
III. Energy Transfer
IV. Continuity and Change
V. Relationship of Structure to Function
VI. Regulation
VII. Interdependence in Nature
VIII. Science, Technology, and Society

TOPIC OUTLINE

Topic		*Percentage of Course*
I. Molecules and Cells		25%
A. Chemistry of Life	7%	
Water		
Organic molecules in organisms		
Free energy changes		
Enzymes		
B. Cells	10%	
Prokaryotic and eukaryotic cells		
Membranes		
Subcellular organization		
Cell cycle and its regulation		
C. Cellular Energetics	8%	
Coupled reactions		
Fermentation and cellular respiration		
Photosynthesis		
II. Heredity and Evolution		25%
A. Heredity	8%	
Meiosis and gametogenesis		
Eukaryotic chromosomes		
Inheritance patterns		
B. Molecular Genetics	9%	
RNA and DNA structure and function		
Gene regulation		
Mutation		
Viral structure and replication		
Nucleic acid technology and applications		
C. Evolutionary Biology	8%	
Early evolution of life		
Evidence for evolution		
Mechanisms of evolution		
III. Organisms and Populations		50%
A. Diversity of Organisms	8%	
Evolutionary patterns		
Survey of the diversity of life		
Phylogenetic classification		
Evolutionary relationships		
B. Structure and Function of Plants and Animals	32%	
Reproduction, growth, and development		
Structural, physiological, and behavioral adaptations		
Response to the environment		
C. Ecology	10%	
Population dynamics		
Communities and ecosystems		
Global issues		

EXPLANATION OF THE MAJOR THEMES

The AP Biology Development Committee has identified eight major themes that recur throughout the course (see page 5). AP Biology teachers should emphasize the pervasiveness of the themes to assist students in organizing concepts and topics into a coherent conceptual framework.

I. **Science as a Process—**Science is a way of knowing. It can involve a discovery process using inductive reasoning, or it can be a process of hypothesis testing.

Example: The theory of evolution was developed based on observation and experimentation.

II. **Evolution—**Evolution is the biological change of organisms that occurs over time and is driven by the process of natural selection. Evolution accounts for the diversity of life on Earth.

Example: Widespread use of antibiotics has selected for antibiotic resistance in disease-causing bacteria.

III. **Energy Transfer—**Energy is the capacity to do work. All living organisms are active (living) because of their abilities to link energy reactions to the biochemical reactions that take place within their cells.

Example: The energy of sunlight, along with carbon dioxide and water, allows plant cells to make organic materials, synthesize chemical energy molecules, and ultimately release oxygen to the environment.

IV. **Continuity and Change—**All species tend to maintain themselves from generation to generation using the same genetic code. However, there are genetic mechanisms that lead to change over time, or evolution.

Example: Mitosis consistently replicates cells in an organism; meiosis (and hence sexual reproduction) results in genetic variability.

V. **Relationship of Structure to Function—**The structural levels from molecules to organisms ensure successful functioning in all living organisms and living systems.

Example: Aerodynamics of a bird's wing permits flight.

VI. **Regulation—**Everything from cells to organisms to ecosystems is in a state of dynamic balance that must be controlled by positive or negative feedback mechanisms.

Example: Body temperature is regulated by the brain via feedback mechanisms.

VII. **Interdependence in Nature—**Living organisms rarely exist alone in nature.

Example: Microscopic organisms can live in a symbiotic relationship in the intestinal tract of another organism; the host provides shelter and nutrients, and the microorganisms digest the food.

VIII. **Science, Technology, and Society—**Scientific research often leads to technological advances that can have positive and/or negative impacts upon society as a whole.

Example: Biotechnology has allowed the development of genetically modified plants.

TEXTBOOKS

A number of recently published textbooks are appropriate for college students enrolled in introductory courses for biology majors. The AP Biology teacher should examine a variety of textbooks and use one that will adequately cover the suggested AP syllabus in a manner and style satisfactory to the teacher and students. Among the major considerations to be used in choosing a text are: depth and breadth of coverage, quality of illustrations, level and attractiveness of writing, clarity of presentation, value of end-of-chapter questions, availability of other teaching aids, and capacity to stimulate the student's interest. Whenever possible, a recently published textbook should be chosen so as to ensure that the information it contains is current and accurate. School systems should recognize that the rapidly changing nature of biology requires frequent purchasing of new textbooks for AP Biology. While textbooks serve as valuable references, they cannot always be exhaustive and up to date. Professional development—especially remaining current with new discoveries and conceptual trends—is a responsibility of any AP instructor.

The Teachers' Resources section of AP Central (apcentral.collegeboard.com) also offers reviews of textbooks, articles, Web sites, and other teaching resources.

THE LABORATORY

Laboratory experience must be included in all AP Biology courses. Since one-fourth to one-third of the credit in most college introductory biology courses is derived from laboratory work, it follows that approximately the same degree of emphasis should be placed on laboratory experience in an AP course. Descriptive and experimental laboratory exercises should be assigned that will provide the maximum opportunity for students to learn a variety of skills and those facts, principles, and concepts of general biology covered in lectures, reading, and discussion. In addition, good laboratory exercises can present novel material not covered in other parts of the course. Laboratory work should encourage the development of important skills such as detailed observation, accurate recording, experimental design, manual manipulation, data interpretation, statistical analysis, and operation of technical equipment. Laboratory assignments offer the opportunity for students to learn about problem solving, the scientific method, the techniques of research, and the use of scientific literature. Laboratory investigations also encourage higher-order thinking, which may include evaluating and monitoring progress through an investigation, generating ideas, and formulating hypotheses.

Surveys confirmed that most colleges and universities have a laboratory component in their general biology courses that are taken by majors or by a combination of majors and nonmajors. In teaching AP Biology, teachers are challenged to teach a course that is equivalent to a college-level course in both quality and sophistication. In order to reflect these aspects, every AP Biology course should therefore have a substantial laboratory component. The AP Biology Development Committee has produced a set of 12 laboratories to provide a standard with which teachers can begin integrating laboratories more efficiently into the AP Biology curriculum.

School administrators should be aware that an AP college-level laboratory is significantly more expensive to operate than a typical high school biology laboratory and requires more time than nonlaboratory courses. The first-level college course consists of approximately 40 to 50 hours of lecture and 30 to 40 hours of laboratory work per quarter or semester. Proportional allocations of time for laboratory work should be accorded an AP Biology course. School administrators should provide the equivalent of two double periods a week for laboratory work.

Some of the laboratories will require equipment that schools may not have; alternative ways of conducting the laboratories are therefore offered. Schools should try to purchase college-level laboratory equipment eventually. Many teachers have indicated that their administrations do not fully realize the implications, in both cost and time, of incorporating serious laboratories into their programs. An AP course is a college course, and the equipment and time allotted to laboratories should be similar to that in a college course.

Many laboratories that teachers are already conducting are worthwhile and important. The laboratory section in this book describes the objectives of 12 laboratories that have been developed by the AP Biology Development Committee. The laboratories are not "perfect" or "ultimate" but exemplify experimental and quantitative, rather than descriptive, laboratory exercises. They are intended to challenge students' abilities to understand problems, develop and implement appropriate experimental designs, manipulate data, draw conclusions, think analytically, and develop hypotheses. In these laboratories, students are challenged to perform experiments drawn from some of the more important areas within modern biology, including biological chemistry, cell structure and function, energy transformation, molecular genetics, heredity, plant structure and physiology, animal structure and physiology, behavior, and ecology.

The laboratories should be considered basic introductions to, or springboards into, further experiments, studies, or independent projects. They are not intended to be ends in themselves. The AP Biology Development Committee thanks the countless AP Biology teachers who have supported and encouraged the committee's commitment to introduce and maintain a laboratory component in the AP Biology curriculum. The field testing and "hands-on" experiences of AP teachers have generated many of the suggestions that are incorporated into these laboratories. The committee welcomes feedback as to how effectively the laboratories work and how they have been integrated into a school's program. Such contributions and suggestions will be used to fine-tune or replace the laboratories over the coming years.

To allow students to show their mastery of laboratory science skills and knowledge, each year some questions on the objective portion of the AP Biology Exam and/or one or more of the four mandatory essay questions may reflect the topics and objectives associated with the 12 AP Biology laboratories. *This should not preclude AP Biology teachers from using their own existing laboratory exercises as long as they encompass the same topics and objectives.*

12 RECOMMENDED BIOLOGY LABORATORIES

Laboratory Topic

1. Diffusion and Osmosis
2. Enzyme Catalysis
3. Mitosis and Meiosis
4. Plant Pigments and Photosynthesis
5. Cell Respiration
6. Molecular Biology
7. Genetics of Organisms
8. Population Genetics and Evolution
9. Transpiration
10. Physiology of the Circulatory System
11. Animal Behavior
12. Dissolved Oxygen and Aquatic Primary Productivity

An overview and objectives are presented for each laboratory on the pages that follow. Teachers can use this information in conjunction with their own laboratories that address these topics and objectives, or in conjunction with the *AP Biology Laboratory Manual for Students* and the *AP Biology Laboratory Manual for Teachers* (go to AP Central for ordering information).

Laboratory 1. Diffusion and Osmosis

Overview

In this laboratory, students will investigate the processes of diffusion and osmosis in a model of a membrane system. They will also investigate the effect of solute concentration on water potential as it relates to living plant tissues.

Objectives

Before doing this laboratory, students should understand:

- the mechanisms of diffusion and osmosis and their importance to cells;
- the effects of solute size and concentration gradients on diffusion across selectively permeable membranes;
- the effects of a selectively permeable membrane on diffusion and osmosis between two solutions separated by the membrane;
- the concept of water potential;

- the relationship between solute concentration and pressure potential and the water potential of a solution; and
- the concept of molarity and its relationship to osmotic concentration.

After doing this laboratory, students should be able to:

- measure the water potential of a solution in a controlled experiment;
- determine the osmotic concentration of living tissue or an unknown solution from experimental data;
- describe the effects of water gain or loss in animal and plant cells; and
- relate osmotic potential to solute concentration and water potential.

Laboratory 2. Enzyme Catalysis

Overview

In this laboratory, students will observe the conversion of hydrogen peroxide (H_2O_2) to water and oxygen gas by the enzyme catalase. They will then measure the amount of oxygen generated and calculate the rate of the enzyme-catalyzed reaction.

Objectives

Before doing this laboratory, students should understand:

- the general functions and activities of enzymes;
- the relationship between the structure and function of enzymes;
- the concept of initial reaction rates of enzymes;
- how the concept of free energy relates to enzyme activity; and
- that changes in temperature, pH, enzyme concentration, and substrate concentration can affect the initial reaction rates of enzyme-catalyzed reactions.

After doing this laboratory, students should be able to:

- measure the effects of changes of temperature, pH, enzyme concentration, and substrate concentration on reaction rates of an enzyme-catalyzed reaction in a controlled experiment; and
- explain how environmental factors affect the rate of enzyme-catalyzed reactions.

Laboratory 3. Mitosis and Meiosis

Overview

In this laboratory, students will investigate the process of mitosis and meiosis. The first part is a study of mitosis. They will use prepared slides of onion root tips to study plant mitosis and to calculate the relative duration of the phases of mitosis in the meristem of root tissue. Prepared slides of the whitefish blastula will be used to study mitosis in animal cells and to compare animal mitosis with plant mitosis.

The second part is a study of meiosis. Students will simulate the stages of meiosis by using chromosome models. They will study the crossing over and recombination that occurs during meiosis. They will observe the arrangements of ascospores in the asci from a cross between wild type *Sordaria fimicola* and mutants for tan spore coat color in the fungus. These arrangements will be used to estimate the percentage of crossing over that occurs between the centromere and the gene that controls the tan spore color.

Objectives

Before doing this laboratory, students should understand:

- the events of mitosis in animal and plant cells;
- the events of meiosis (gametogenesis) in animal and plant cells; and
- the key mechanical and genetic differences between meiosis and mitosis.

After doing this laboratory, students should be able to:

- recognize the stages of mitosis in a plant or animal cell;
- calculate the relative duration of the cell cycle stages;
- describe how independent assortment and crossing over can generate genetic variation among the products of meiosis;
- use chromosome models to demonstrate the activity of chromosomes during meiosis I and meiosis II;
- relate chromosome activity to Mendelian segregation and independent assortment;
- demonstrate the role of meiosis in the formation of gametes in a controlled experiment, using a model organism;
- calculate the map distance of a particular gene from a chromosome's center or between two genes, using a model organism;
- compare and contrast the results of meiosis and mitosis in plant cells; and
- compare and contrast the results of meiosis and mitosis in animal cells.

Laboratory 4. Plant Pigments and Photosynthesis

Overview

In this laboratory, students will separate plant pigments using chromatography. They will also measure the rate of photosynthesis in isolated chloroplasts. The measurement technique involves the reduction of the dye, DPIP. The transfer of electrons during the light-dependent reactions of photosynthesis reduces DPIP, and it changes from blue to colorless.

Objectives

Before doing this laboratory, students should understand:

- how chromatography separates two or more compounds that are initially present in a mixture;
- the process of photosynthesis;
- the function of plant pigments;
- the relationship between light wavelength and photosynthetic rate; and
- the relationship between light intensity and photosynthetic rate.

After doing this laboratory, students should be able to:

- separate pigments and calculate their Rf values;
- describe a technique to determine photosynthetic rates;
- compare photosynthetic rates at different temperatures, or different light intensities, or different wavelengths of light using controlled experiments; and
- explain why the rate of photosynthesis varies under different environmental conditions.

Laboratory 5. Cell Respiration

Overview

In this experiment, students will work with seeds that are living but dormant. A seed contains an embryo plant and a food supply surrounded by a seed coat. When the necessary conditions are met, germination occurs, and the rate of cellular respiration greatly increases. In this laboratory, students will measure oxygen consumption during germination. They will measure the change in gas volume in respirometers containing either germinating or nongerminating peas. In addition, they will measure the respiration of these peas at two different temperatures.

Objectives

Before doing this laboratory, students should understand:

- how a respirometer works in terms of the gas laws; and
- the general processes of metabolism in living organisms.

After doing this laboratory, students should be able to:

- calculate the rate of cell respiration from experimental data;
- relate gas production to respiration rate; and
- test the effects of temperature on the rate of cell respiration in ungerminated versus germinated seeds in a controlled experiment.

Laboratory 6. Molecular Biology

Overview

In this laboratory, students will investigate some basic principles of genetic engineering. Plasmids containing specific fragments of foreign DNA will be used to transform *Escherichia coli* cells, conferring antibiotic (ampicillin) resistance. Restriction enzyme digests of phage lambda DNA will also be used to demonstrate techniques for separating and identifying DNA fragments using gel electrophoresis.

Objectives

Before doing this laboratory, students should understand:

- how gel electrophoresis separates DNA molecules present in a mixture;
- the principles of bacterial transformation;
- the conditions under which cells can be transformed;
- the process of competent cell preparation;
- how a plasmid can be engineered to include a piece of foreign DNA;
- how plasmid vectors are used to transfer genes;
- how antibiotic resistance is transferred between cells;
- how restriction endonucleases function; and
- the importance of restriction enzymes to genetic engineering experiments.

After doing this laboratory, students should be able to:

- use plasmids as vectors to transform bacteria with a gene for antibiotic resistance in a controlled experiment;
- demonstrate how restriction enzymes are used in genetic engineering;
- use electrophoresis to separate DNA fragments;
- describe the biological process of transformation in bacteria;
- calculate transformation efficiency;
- be able to use multiple experimental controls;
- design a procedure to select positively for antibiotic resistant transformed cells; and
- determine unknown DNA fragment sizes when given DNA fragments of known size.

Laboratory 7. Genetics of Organisms

Overview

In this laboratory, students will use living organisms to do genetic crosses. They will learn how to collect and manipulate the organisms, collect data from F1 and F2 generations, and analyze the results from a monohybrid, dihybrid, or sex-linked cross. The procedures that follow apply to fruit flies; teachers may substitute other procedures using different organisms.

Objectives

Before doing this laboratory, students should understand:

- chi-square analysis of data; and
- the life cycle of diploid organisms useful in genetics studies.

After doing this laboratory, students should be able to:

- investigate the independent assortment of two genes and determine whether the two genes are autosomal or sex-linked using a multigeneration experiment; and
- analyze the data from their genetic crosses using chi-square analysis techniques.

Laboratory 8. Population Genetics and Evolution

Overview

In this activity, students will learn about the Hardy–Weinberg law of genetic equilibrium and study the relationship between evolution and changes in allele frequency by using their class to represent a sample population.

Objectives

Before doing this laboratory, students should understand:

- how natural selection can alter allelic frequencies in a population;
- the Hardy–Weinberg equation and its use in determining the frequency of alleles in a population; and
- the effects on allelic frequencies of selection against the homozygous recessive or other genotypes.

After doing this laboratory, students should be able to:

- calculate the frequencies of alleles and genotypes in the gene pool of a population using the Hardy–Weinberg formula; and
- discuss natural selection and other causes of microevolution as deviations from the conditions required to maintain Hardy–Weinberg equilibrium.

Laboratory 9. Transpiration

Overview

In this laboratory, students will apply what they learned about water potential from Laboratory 1 (Diffusion and Osmosis) to the movement of water within the plant. They will measure transpiration under different laboratory conditions. They will also study the organization of the plant stem and leaf as it relates to these processes by observing sections of tissue.

Objectives

Before doing this laboratory, students should understand:

- how water moves from roots to leaves in terms of the physical/chemical properties of water and the forces provided by differences in water potential;
- the role of transpiration in the transport of water within a plant; and
- the structures used by plants to transport water and regulate water movement.

After doing this laboratory, students should be able to:

- test the effects of environmental variables on rates of transpiration using a controlled experiment; and
- make thin sections of stem, identify xylem and phloem cells, and relate the function of these vascular tissues to the structures of their cells.

Laboratory 10. Physiology of the Circulatory System

Overview

In Exercise 10A, students will learn how to measure blood pressure. In Exercise 10B, they will measure pulse rate under different conditions: standing, reclining, after the baroreceptor reflex, and during and immediately after exercise. The blood pressure and pulse rate will be analyzed and related to an index of relative fitness. In Exercise 10C, they will measure the effect of temperature on the heart rate of the water flea, *Daphnia magna.*

Objectives

Before doing this laboratory, students should understand:

- the relationship between temperature and the rates of physiological processes; and
- basic anatomy of various circulatory systems.

After doing this laboratory, students should be able to:

- measure heart rate and blood pressure in a human volunteer;
- describe the effect of changing body position on heart rate and blood pressure;
- explain how exercise changes heart rate;
- determine a human's fitness index;
- analyze cardiovascular data collected by the entire class; and
- discuss and explain the relationship between heart rate and temperature.

Laboratory 11. Animal Behavior

Overview

In this laboratory, students will observe some aspects of animal behavior. In Exercise 11A, they will observe pillbugs and design an experiment to investigate their responses to environmental variables. In Exercise 11B, they will also observe and investigate mating behavior in fruit flies. You may suggest other organisms or other types of animal behavior to study.

Objectives

Before doing this laboratory, students should understand:

- the concept of distribution of organisms in a resource gradient; and
- the difference between kinesis and taxis.

After doing this laboratory, students should be able to:

- describe some aspects of animal behavior, such as orientation behavior, agonistic behavior, dominance display, or mating behavior; and
- understand the adaptiveness of the behaviors they studied.

Laboratory 12. Dissolved Oxygen and Aquatic Primary Productivity

Overview

In Exercise 12A, students will measure and analyze the dissolved oxygen (DO) concentration in water samples at varying temperatures. In Exercise 12B, they will measure and analyze the primary productivity of natural waters or laboratory cultures using screens to simulate the attenuation of light with increasing depth.

Objectives

Before doing this laboratory, students should understand:

- the biological importance of carbon and oxygen cycling in ecosystems;
- how primary productivity relates to the metabolism of organisms in an ecosystem;
- the physical and biological factors that affect the solubility of gasses in aquatic ecosystems; and
- the relationship between dissolved oxygen and the process of photosynthesis and respiration and how these processes affect primary productivity.

After doing this laboratory, students should be able to:

- measure primary productivity based on changes in dissolved oxygen in a controlled experiment; and
- investigate the effects of changing light intensity and/or inorganic nutrient concentrations on primary productivity in a controlled experiment.

THE EXAM

The AP Biology Exam is three hours in length and is designed to measure a student's knowledge and understanding of modern biology. The exam consists of an 80-minute, 100-item multiple-choice section, which examines the student's understanding of representative content and concepts drawn from across the entire course; a 10-minute reading period; and a 90-minute free-response section, consisting of four mandatory questions that encompass broader topics. The number of multiple-choice questions taken from each major subset of biology reflects the approximate percentage of the course as designated in the Course Description (see the Topic Outline on page 6). In the free-response portion of the exam, usually one essay question is taken from Area I of the outline (Molecules and Cells), and another question focuses on Area II (Heredity and Evolution). Two questions generally focus on Area III of the outline (Organisms and Populations). Any of these four questions may require the student to analyze and interpret data or information drawn from laboratory experience, as well as from lecture material, and may require students to integrate material from different areas of the course.

The multiple-choice section counts for 60 percent of the student's exam grade, and the free-response section counts for 40 percent. Within the free-response section, each of the four questions is weighted equally. The answers to the free-response questions must be in essay form; outlines alone or unlabeled and unexplained diagrams alone are not acceptable. The students should read each question carefully, organize their material neatly, and compose answers that are as comprehensive and precise as time permits.

To provide the maximum information about differences in students' achievements in biology, the exams are intended to have average scores of about 50 percent of the maximum possible score for the multiple-choice section and for the free-response section. Thus, students should be aware that they may find these exams more difficult than most classroom exams. However, it is possible for students who have studied most but not all of the topics in the outline to obtain acceptable grades.

To be broad enough in scope to give every student who has covered an adequate amount of material an opportunity to perform well, the multiple-choice section must be so comprehensive that no student should be expected to attain a perfect or near-perfect score. Thought-provoking problems and questions based on fundamental ideas from biology are included, along with questions based on the recall of basic facts and major concepts. In this section of the exam, as a correction for haphazard guessing, one-fourth of the number of questions answered incorrectly will be subtracted from the number of questions answered correctly.

The free-response section asks the students to organize answers to broad questions, thereby demonstrating reasoning and analytical skills as well as an ability to synthesize material from several sources into a cogent and coherent essay. To prepare for such questions, students should practice writing free-response answers whenever appropriate during the course.

Sample Multiple-Choice Questions

Examples of the kinds of objective questions that may be used in the exam follow. This is NOT a complete exam. (Answers are given on page 32.) Additional sample questions can be found at AP Central.

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

1. Which of the following best describes an intimate ecological association in which an organism benefits from living on or within a host, but which generally has a negative effect on that host?

   (A) Mutualism
   (B) Saprophytism
   (C) Commensalism
   (D) Parasitism
   (E) Predation

2. While studying a cell with the electron microscope, a scientist notes the following: numerous ribosomes, a well-developed endoplasmic reticulum, chloroplasts, and a cell wall. Which of the following could be the source of this cell?

   (A) A fungus
   (B) An animal
   (C) A bacterium
   (D) A plant
   (E) A virus

3. Which of the following statements best summarizes organic evolution as it is viewed by modern evolutionists?

   (A) It is goal directed.
   (B) It represents the results of selection for acquired characteristics.
   (C) It is synonymous with the process of gene flow.
   (D) It is the descent of humans from the present-day great apes.
   (E) It is the differential survival and reproduction of certain phenotypes.

4. If a segment of DNA is 5′-TAC GAT TAG-3′, the RNA that results from the transcription of this segment will be

   (A) 3′-TAC GAT TAU-5′
   (B) 3′-ATG CTA ATA-5′
   (C) 3′-UAC GAU UAG-5′
   (D) 3′-AAC GAU UAA-5′
   (E) 3′-AUG CUA AUC-5′

5. The bones of a human arm are homologous to structures in all of the following EXCEPT a

   (A) whale flipper
   (B) bat wing
   (C) butterfly wing
   (D) bird wing
   (E) frog forelimb

6. Regarding mitosis and cytokinesis, one difference between higher plants and animals is that in plants

   (A) the spindles contain cellulose microfibrils in addition to microtubules, whereas animal spindles do not contain microfibrils
   (B) sister chromatids are identical, whereas in animals they differ from one another
   (C) a cell plate begins to form at telophase, whereas in animals a cleavage furrow is initiated at that stage
   (D) chromosomes become attached to the spindle at prophase, whereas in animals chromosomes do not become attached until anaphase
   (E) spindle poles contain centrioles, whereas spindle poles in animals do not

7. A common feature of starch and glycogen is that molecules of both

   (A) form microfibrils that give support to connective tissue fibers
   (B) contain repeated monomers of glucose and galactose
   (C) are important structural components of plant cell walls
   (D) are polymers of glucose
   (E) are water-soluble disaccharides

8. The ancestors of land plants most likely resembled modern-day members of the

   (A) Cyanobacteria (blue-green algae)
   (B) Rhodophyta (red algae)
   (C) Chlorophyta (green algae)
   (D) Phaeophyta (brown algae)
   (E) Chrysophyta (diatoms and golden-brown algae)

9. Which of the following offers the best description of neural transmission across a mammalian synaptic gap?

   (A) Neural impulses involve the flow of K^+ and Na^+ across the gap.
   (B) Neural impulses travel across the gap as electrical currents.
   (C) Neural impulses cause the release of chemicals that diffuse across the gap.
   (D) Neural impulses travel across the gap in both directions.
   (E) The calcium within the axons and dendrites of nerves adjacent to a synapse acts as the neurotransmitter.

10. Which of the following statements is true about the Krebs (citric acid) cycle and the Calvin (light-independent) cycle?

    (A) They both result in a net production of ATP and NADH.
    (B) They both require a net input of ATP.
    (C) They both result in a release of oxygen.
    (D) They both take place within the cytoplasmic matrix.
    (E) They both are carried out by enzymes located within an organelle matrix.

11. Two fossil vertebrates, each representing a different class, are found in the undisturbed rock layers of a cliff. One fossil is a representative of the earliest amphibians. The other fossil, found in an older rock layer below the amphibian, is most likely to be

    (A) a dinosaur
    (B) a fish
    (C) an insectivorous mammal
    (D) a snake
    (E) a bird

12. The bonding of two amino acid molecules to form a larger molecule requires

    (A) the release of a water molecule
    (B) the release of a carbon dioxide molecule
    (C) the addition of a nitrogen atom
    (D) the addition of a water molecule
    (E) an increase in activation energy

13. If young male zebra finches are raised by foster parents of another species, the Bengalese finch, they will court female Bengalese finches instead of females of their own species. This behavior results from which of the following?

    (A) Imprinting
    (B) Habituation
    (C) Conditioning
    (D) Reinforcement
    (E) Pheromones

14. The relative location of four genes on a chromosome can be mapped from the following data on crossover frequencies

Genes	*Frequency of Crossover*
B and *D*	5%
C and *A*	15%
A and *B*	30%
C and *B*	45%
C and *D*	50%

Which of the following represents the relative positions of these four genes on the chromosome?

(A) *ABCD*
(B) *ADCB*
(C) *CABD*
(D) *CBAD*
(E) *DBCA*

15. When hydrogen ions are pumped out of the mitochondrial matrix, across the inner mitochondrial membrane, and into the space between the inner and outer membranes, the result is

(A) damage to the mitochondrion
(B) the reduction of NAD
(C) the restoration of the Na-K balance across the membrane
(D) the creation of a proton gradient
(E) the lowering of pH in the mitochondrial matrix

16. Once transcribed, eukaryotic mRNA typically undergoes substantial alteration that results primarily from

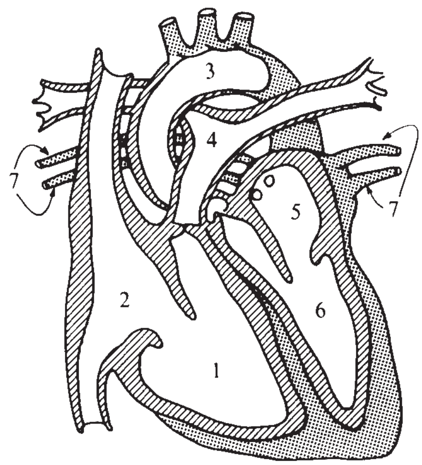
(A) excision of introns
(B) fusion into circular forms known as plasmids
(C) linkage to histone molecules
(D) union with ribosomes
(E) fusion with other newly transcribed mRNA molecules to form larger translatable units

17. The function of water in photosynthesis is to

(A) combine with CO_2
(B) absorb light energy
(C) supply electrons in the light-dependent reactions
(D) transport H^+ ions in the light-independent (dark) reactions
(E) provide O_2 for the light-independent (dark) reactions

Questions 18–19

Questions 18–19 refer to the diagram below of the adult human heart.



18. Chambers or vessels that carry oxygenated blood include which of the following?

    (A) 3 only
    (B) 1 and 2 only
    (C) 5 and 6 only
    (D) 1, 2, and 3
    (E) 3, 5, and 6

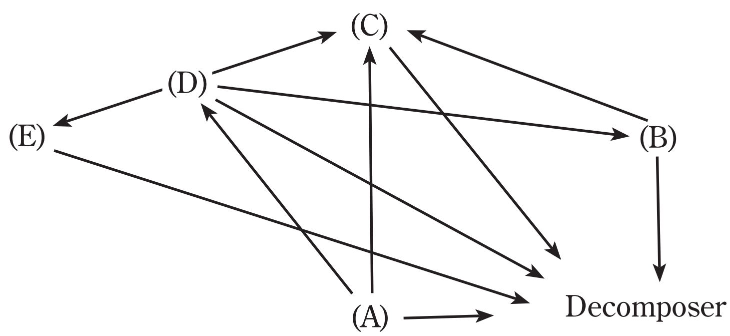
19. The correct sequence of blood flow beginning at the pulmonary arteries and passing through the lungs and the systemic circulation is

    (A) 2 - 1 - 4 - systemic - 3 - 6 - 5 - 7 - lungs
    (B) 3 - 6 - 5 - 7 - systemic - 4 - 1 - 2 - lungs
    (C) 4 - lungs - 7 - 5 - 6 - 3 - systemic - 2 - 1
    (D) 6 - 4 - lungs - 3 - systemic - 2 - 1 - 5 - 7
    (E) 7 - 5 - 6 - systemic - 2 - 1 - 4 - lungs - 3

Directions: Each set of lettered choices below refers to the numbered words or statements immediately following it. Select the one lettered choice that best fits each word or statement. A choice may be used once, more than once, or not at all in each set.

Questions 20–23

The figure below represents a food web in a particular ecosystem. Each letter represents a species. The arrows indicate the direction of energy flow.



20. Which species would most likely represent humans if they were part of this ecosystem?

21. A photosynthetic organism would be represented by which species?

22. Members of which species are herbivores?

23. Members of which species are most likely to be omnivorous?

Questions 24–27

(A) Centriole
(B) Lysosome
(C) Nucleolus
(D) Peroxisome
(E) Ribosome

24. Found in both prokaryotic and eukaryotic cells

25. Possesses a microtubular structure similar in form to a basal body

26. Assembles ribosomal precursors

27. Contains hydrolytic enzymes associated with the intracellular digestion of macromolecules

Questions 28–30

(A) Grassland
(B) Taiga
(C) Deciduous forest
(D) Tundra
(E) Tropical rain forest

28. This biome exhibits the greatest diversity in plant species.

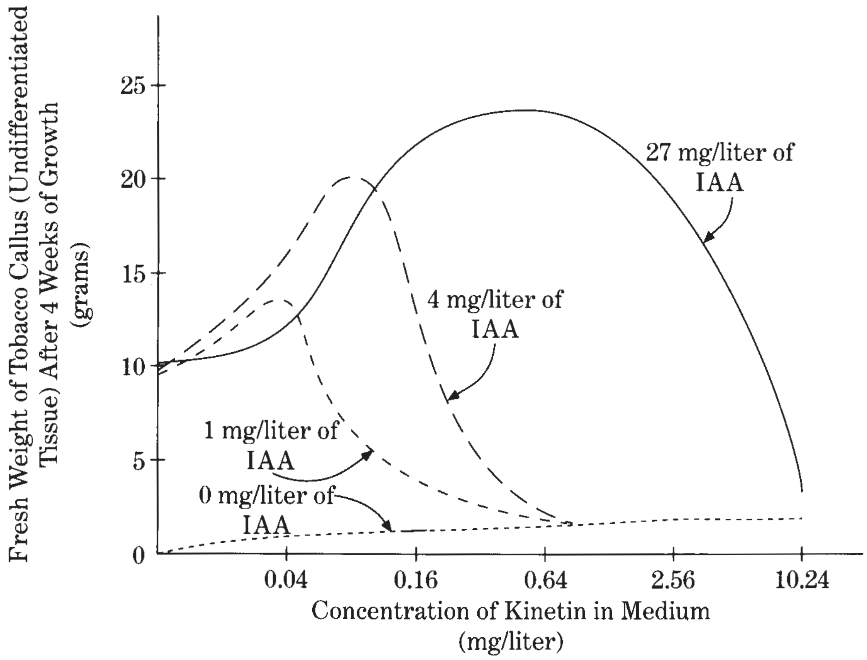
29. In this biome, agriculture is commonly practiced in a "cut-burn-cultivate-abandon" mode.

30. This biome can be recognized by its coniferous forests and relatively infertile, acidic soil.

Directions: Each group of questions below concerns an experimental or a laboratory situation. In each case, first study the description of the situation. Then choose the one best answer to each question following it.

Questions 31–32

Questions 31–32 refer to the data presented in the graph below of tobacco cells grown in tissue culture. The numbers on the curves indicate the concentrations of indoleacetic acid (IAA) in milligrams per liter.



31. The optimum concentrations of hormones for promoting maximum tobacco cell growth are

    (A) 27 mg/liter of IAA alone
    (B) 27 mg/liter of IAA and 2.56 mg/liter of kinetin
    (C) 27 mg/liter of IAA and 0.64 mg/liter of kinetin
    (D) 4 mg/liter of IAA and 0.64 mg/liter of kinetin
    (E) 1 mg/liter of IAA and 0.64 mg/liter of kinetin

32. The purpose of the experiment is primarily to determine the

    (A) effect of IAA on the growth of tobacco cells
    (B) amount of hormone normally released by tobacco cells in tissue culture
    (C) response of tobacco cells in tissue culture to synthetic hormones
    (D) response of kinetin to various concentrations of IAA only
    (E) response of tobacco cells in tissue culture to combinations of IAA and kinetin

Questions 33–34

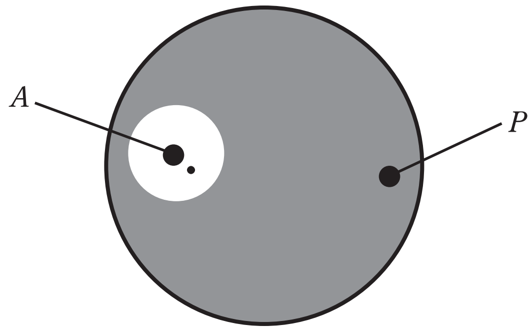


Plate I

A sterile agar plate, I, is streaked with a pure culture of bacteria by means of aseptic techniques. Paper discs treated with the antibiotics Aureomycin (*A*) and penicillin (*P*) are placed at opposite sides of the plate, as shown in the diagram above. The plate is examined after a 24-hour incubation period, and a clear ring is discovered around disc *A*, but not around disc *P*. Within the clear ring around disc *A*, a single bacterial colony with physical characteristics like those of the pure culture is observed. A second sterile agar plate, II, is then streaked with this single colony and also incubated with antibiotics.

33. The single colony found within the clear ring in plate I is most likely made up of the descendants of a bacterial cell that

    (A) contaminated the agar plate
    (B) contained information conferring resistance to Aureomycin
    (C) changed its response to Aureomycin as a result of being exposed to the antibiotic
    (D) was susceptible to both penicillin and Aureomycin
    (E) emigrated from another area of the agar plate

34. Which of the following would most likely be observed in plate II after 24 hours?

    (A) A clear ring larger than that around disc *A* in plate I would appear around disc *A* only.
    (B) A clear ring larger than that around disc *A* in plate I would appear around disc *P* only.
    (C) A clear ring smaller than that around disc *A* in plate I would appear around disc *P* only.
    (D) There would be a clear ring around both disc *A* and disc *P*.
    (E) There would not be a clear ring around either disc *A* or disc *P*.

Questions 35–37

In dogs, one pair of alleles determines coat color (dark and albino). Another pair of alleles determines hair length (short and long). Thus, each gamete will contain one of the coat-color alleles, *C* or *c,* and one of the hair-length alleles, *B* or *b*. In repeated crosses of a specific dark, short-haired dog with an albino, long-haired dog, all the offspring were dark with short hair, as shown in cross I. However, in subsequent crosses of another dark, short-haired dog with a dark, long-haired dog, the ratios shown in cross II below were obtained.

Cross	*Parents*	*Offspring*
I.	Dark, short hair x Albino, long hair	All dark, short hair
II.	Dark, short hair x Dark, long hair	3 dark, short hair 3 dark, long hair 1 albino, short hair 1 albino, long hair

35. In cross II, the genotype of the dark, short-haired parent is

    (A) *CcBb*
    (B) *ccbb*
    (C) *CCBB*
    (D) *CCbb*
    (E) *ccBB*

36. Which of the following is probably the genotype of the dark, short-haired parent in cross I?

    (A) *CcBb*
    (B) *ccbb*
    (C) *CCBB*
    (D) *CCbb*
    (E) *ccBB*

37. Which of the following correctly describes the relationship of the dark-coat-color allele to the albino condition?

    (A) It is dominant.
    (B) It is recessive.
    (C) It is codominant.
    (D) It is a polygenic inheritance pattern.
    (E) The alleles are linked.

Questions 38–40

A large population of laboratory animals has been allowed to breed randomly for a number of generations. After several generations, 49 percent of the animals display a recessive trait (*bb*), the same percentage as at the beginning of the breeding program. The rest of the animals show the dominant phenotype, with heterozygotes indistinguishable from the homozygous dominants.

38. What is the most reasonable conclusion that can be drawn from the fact that the frequency of allele *b* has not changed over time?

    (A) The population is undergoing genetic drift.
    (B) The two phenotypes are equally adaptive under laboratory conditions.
    (C) The genotype *BB* is lethal.
    (D) There has been a high rate of mutation of allele *B* to allele *b*.
    (E) There has been sexual selection favoring allele *b*.

39. What is the frequency of allele *b* in the gene pool?

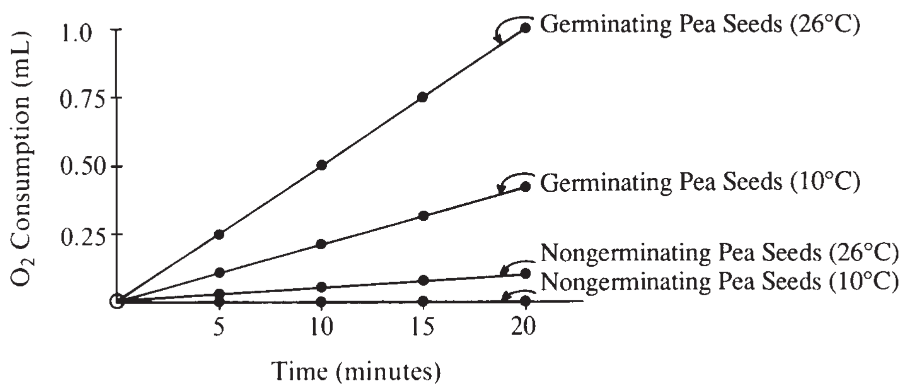
    (A) 0.70
    (B) 0.51
    (C) 0.49
    (D) 0.30
    (E) 0.07

40. What proportion of the population is heterozygous (*Bb*) for this trait?

    (A) 0.51
    (B) 0.42
    (C) 0.21
    (D) 0.09
    (E) 0.07

Questions 41–42

Questions 41–42 refer to an experiment that is set up to determine the relative volume of O_2 consumed by germinating and nongerminating (dry) pea seeds at two different temperatures. The change in volume is detected by using a respirometer over a given period of time. The data are given below.



41. The rate of oxygen consumption in germinating pea seeds at 26°C is

    (A) 0.05 mL / min
    (B) 0.25 mL / min
    (C) 0.50 mL / min
    (D) 0.75 mL / min
    (E) 1.00 mL / min

42. Which of the following conclusions is best supported by the data?

    (A) Nongerminating pea seeds have a higher rate of respiration than germinating pea seeds do.
    (B) Light is required for pea seed germination.
    (C) In the nongerminating pea seeds, oxygen consumption is directly proportional to oxygen concentration.
    (D) Less carbon dioxide is produced by germinating pea seeds at 26°C than at 10°C.
    (E) In pea seeds an increase in temperature results in an increase in oxygen consumption.

Questions 43–45

Individuals of a particular species of ground beetle are either light tan or dark brown. Light-tan beetles are predominant in habitats with light-colored sandy soils, and dark-brown beetles are predominant in habitats with dark-colored loam soils. In an experiment designed to determine the survival rates of light-tan beetles and dark-brown beetles in different habitats, 500 light-tan beetles and 500 dark-brown beetles were released in each of four habitats. Each beetle had been marked with a small spot of red paint on the underside of its abdomen before it was released. One week after the beetles had been released, any marked beetles that could be found were recaptured. The results are presented in the table below. It is assumed that differences in the numbers of beetles recaptured are directly related to differences in survival rates.

	Habitat 1 Sandy soil, no insectivorous birds present		Habitat 2 Sandy soil, insectivorous birds present		Habitat 3 Loam soil, no insectivorous birds present		Habitat 4 Loam soil, insectivorous birds present	
Color of Beetle	Light tan	Dark brown	Light tan	Dark brown	Light tan	Dark brown	Light tan	Dark brown
Number Released	500	500	500	500	500	500	500	500
Number Recaptured	130	114	123	22	65	74	13	87

43. Which of the following processes best explains why fewer light-tan beetles than dark-brown beetles were recaptured in habitat 4?

    (A) Immigration
    (B) Genetic drift
    (C) Mutation
    (D) Adaptive radiation
    (E) Predation

44. If all insectivorous birds and remaining beetles were removed from habitat 2 and 500 additional dark-brown beetles and 500 additional light-tan beetles were then released into habitat 2, which of the following is the best estimate of the number of additional dark-brown beetles that would be expected to be recaptured in habitat 2 after one more week?

(A) 0
(B) 22
(C) 120
(D) 220
(E) 500

45. Which of the following can be inferred from the data in the table?

(A) Ground beetles do not emigrate from the habitat in which they live.
(B) Insectivorous birds prefer to eat light-tan beetles rather than dark-brown beetles.
(C) Ground beetles have higher rates of survival in habitats with loam soil.
(D) Insectivorous birds are predators of this species of ground beetle.
(E) The reproductive success of beetles in habitats with sandy soils is greater than that of beetles in habitats with loam soils.

Answers to Multiple-Choice Questions

1 – D	9 – C	17 – C	25 – A	33 – B	41 – A
2 – D	10 – E	18 – E	26 – C	34 – E	42 – E
3 – E	11 – B	19 – C	27 – B	35 – A	43 – E
4 – E	12 – A	20 – C	28 – E	36 – C	44 – C
5 – C	13 – A	21 – A	29 – E	37 – A	45 – D
6 – C	14 – C	22 – D	30 – B	38 – B	
7 – D	15 – D	23 – C	31 – C	39 – A	
8 – C	16 – A	24 – E	32 – E	40 – B	

Sample Free-Response Questions

Four mandatory questions will be asked. In general, there will be one on molecules and cells, one on genetics and evolution, and two on organisms and populations. Some questions may cover more than one of these areas. One or more of the four questions may be designed to test analytical and reasoning skills. The laboratory experiences may be reflected in these questions.

Questions from the 2006 exam are presented here. Additional sample questions can be found at AP Central.

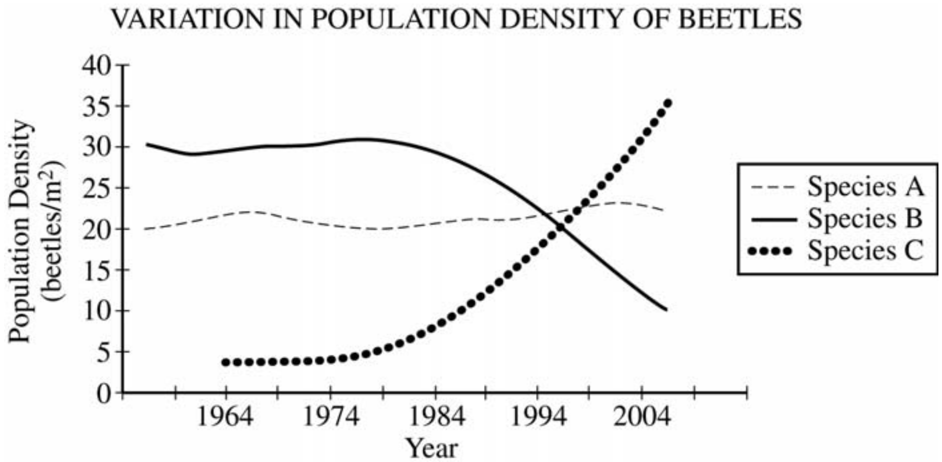
1. A major distinction between prokaryotes and eukaryotes is the presence of membrane-bound organelles in eukaryotes.

   (a) **Describe** the structure and function of TWO eukaryotic membrane-bound organelles other than the nucleus.

   (b) Prokaryotic and eukaryotic cells have some non-membrane-bound components in common. **Describe** the function of TWO of the following and **discuss** how each differs in prokaryotes and eukaryotes.

   - DNA
   - Cell wall
   - Ribosomes

   (c) **Explain** the endosymbiotic theory of the origin of eukaryotic cells and **discuss** an example of evidence supporting this theory.



2. According to fossil records and recent published observations, two species of leaf-eating beetles (species A and B) have existed on an isolated island in the Pacific Ocean for over 100,000 years. In 1964 a third species of leaf-eating beetle (species C) was accidentally introduced on the island. The population size of each species has been regularly monitored as shown in the graph above.

   (a) **Propose** an explanation for the pattern of population density observed in species C.

   (b) **Describe** the effect that the introduction of beetle species C has had on the population density of species A and species B. **Propose** an explanation for the patterns of population density observed in species A and in species B.

   (c) **Predict** the population density of species C in 2014. Provide a biological explanation for your prediction.

   (d) **Explain** why invasive species are often successful in colonizing new habitats.

3. The movement of water through vascular plants is important to their survival.

   (a) **Explain** the mechanism of water movement through vascular plants during transpiration. Include a discussion of how the anatomy of vascular plants and the properties of water contribute to this process.

   (b) **Explain** how gas exchange affects transpiration.

   (c) **Describe** TWO adaptations that affect the rate of transpiration in desert plants.

4. The evolution of circulatory systems allowed larger and more-complex animals to arise.

   (a) **Describe** the respiratory and digestive systems' specialized structures that facilitate the movement of oxygen and glucose into the circulatory system of mammals.

   (b) **Explain** how oxygen and glucose are transported within the circulatory system of mammals.

   (c) **Explain** the transfer of oxygen and glucose from the blood and into the active cells of mammals.

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You can find the following Web resources at AP Central:

- AP Course Descriptions, AP Exam questions and scoring guidelines, sample syllabi, and feature articles.
- A searchable Institutes and Workshops database, providing information about professional development events.
- The Course Home Pages (apcentral.collegeboard.com/coursehomepages), which contain articles, teaching tips, activities, lab ideas, and other course-specific content contributed by colleagues in the AP community.
- Moderated electronic discussion groups (EDGs) for each AP course, provided to facilitate the exchange of ideas and practices.

AP Publications and Other Resources

Free AP resources are available to help students, parents, AP Coordinators, and high school and college faculty learn more about the AP Program and its courses and exams. Visit www.collegeboard.com/apfreepubs.

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Teacher's Guides

For those about to teach an AP course for the first time, or for experienced AP teachers who would like to get some fresh ideas for the classroom, the Teacher's Guide is an excellent resource. Each Teacher's Guide contains syllabi developed by high school teachers currently teaching the AP course and college faculty who teach the equivalent course at colleges and universities. Along with detailed course outlines and innovative teaching tips, you'll also find extensive lists of suggested teaching resources.

Course Descriptions

Course Descriptions are available for each AP subject. They provide an outline of each AP course's content, explain the kinds of skills students are expected to demonstrate in the corresponding introductory college-level course, and describe the AP Exam. Sample multiple-choice questions with an answer key and sample free-response questions are included. (The Course Description for AP Computer Science is available in PDF format only.)

Released Exams

Periodically the AP Program releases a complete copy of each exam. In addition to providing the multiple-choice questions and answers, the publication describes the process of scoring the free-response questions and includes examples of students' actual responses, the scoring standards, and commentary that explains why the responses received the scores they did.

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2099 Gateway Place, Suite 550
San Jose, CA 95110-1051
866 392-4078
E-mail: wro@collegeboard.org

2008-09 Development Committee and Chief Reader

apcentral.collegeboard.com

I.N. 080082745