SAT* II SUCCESS

Biology E/M

TEST PREP

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RED ALERT

ABOUT THIS BOOK

Almost a quarter of a million students take SAT II Subject Tests (previously known as the College Board Achievement Tests) every year. Many colleges require SAT II Subject Test scores. The purpose of these tests is to measure and demonstrate your knowledge and/or skills in specific subjects and to test your ability to apply that knowledge on each particular examination. The better your score is, the better your application will look to the colleges of your choice.

If you're reading this book, it's likely that you are preparing for one of the SAT II Biology exams. We have tried to make this a "workable" book. In other words, the book is set up so that, regardless of the level exam you're taking, you will be able to find the material necessary to study and to take those tests that are most applicable to your level.

Divided into sections, the book begins with a diagnostic biology exam. The purpose of this diagnostic test is to help you get a handle on what you know and what needs more work. Take this exam (and all of the tests) under simulated exam conditions, if you can. What this means is that you should find a quiet place in which to work, set up a clock, and take the test without stopping. When you are finished, take a break and then go back and check your answers. Always reread those questions you got wrong, since sometimes an error can come from merely misreading the question. Again, double-check your answers, and if they're still not clear, read the appropriate section in the review material.

Once you've completed your Diagnostic Test, it's time to move on to the biology review section. Study the material carefully, but feel free to skim those portions of the review section that are easiest for you.

Then, take the Practice Tests. There are three simulated exams designed to give you a broad spectrum of question-types, similar to those you will find on the actual SAT II Biology test. We suggest that regardless of whether you plan to take the E (ecological) or M (molecular) version of the test, it would be extremely helpful to *take all of the tests in the book*. In this way you will have a much broader perspective of the exam and may even surprise yourself as to how much you actually know about each level.

As you complete each exam, take some time to review your answers. We think you'll find a marked improvement as you work through the Diagnostic Test and complete all of the full-length practice tests. Always take the time to check the review section for clarification, and if you still don't understand the material, go to your teacher for help.

ABOUT THE TEST

The Biology E/M test contains 60 general biology questions followed by 20 questions in each of the special sections: Biology E or Biology M. You can select the area in which you feel most confident, and, after completing the 60 core questions, you can then take either the Ecological or Molecular sections. That selection can be made when you take the test by filling in the appropriate code for the section you wish to take. You cannot take both sections on the same test date.

The test covers the following areas.

Cellular and Molecular Biology — 12%
Ecology — 12%
Classical Genetics — 10%
Organismal Biology — 30%
Evolution and Diversity — 11%
Ecology/Evolution (Biology E Test) — 25%
Molecular/Evolution (Biology M Test) — 25%

In order to take this test and do well, you should have completed at least a one-year course in biology. In addition, it would be helpful to have also taken algebra, in order for you to understand basic algebraic concepts. Since you will not be allowed to use a calculator while taking this test, it is also important to have basic mathematical skills, although the calculations you will encounter will be fairly simple. In addition, you will encounter some questions utilizing the metric system, so you should brush up on this topic.

TAKING THE TEST

Since you will have 60 minutes in which to complete the exam, it is important that you pace yourself. One important item to remember is to be thoroughly familiar with the directions for the tests so that you don't waste time trying to understand them once you've opened your test booklet.

Work through the easy questions first. The faster you can complete those questions, the more time you'll have for those that are more difficult. You may use your test book for scratch paper, but keep your answer sheet clean; since they are machine-readable, any stray marks might be misconstrued as an answer.

The questions are all multiple choice, with five lettered choices. As with any multiple-choice test, you should approach each question by first trying to select the correct answer. If the answer is clear to you, select it at once. If you're unsure, the first technique is the process of elimination. Try to cross off any answers that don't seem to make sense or that you know are completely wrong. This improves your odds of guessing the correct answer. If, for example, you can eliminate three choices, you have a 50/50 chance of guessing the correct answer. Otherwise, if you can't eliminate any choices, you have only a 20 percent rather than a 50 percent chance of getting the answer correct.

Scoring

While it's not imperative that you completely understand how the test is scored, since the process shouldn't deter you from trying to do your best, you are probably aware that the scores are reported on the 200–800 point range.

Each question answered correctly receives one point. You will lose a fraction of a point for each wrong answer. However, you will not lose points if you *don't* answer a question. (Make sure that if you skip any answers, the next question you answer is filled in on your answer page in the correct space.) Thus, it makes sense to guess at those questions that you don't know, and of course, as with most multiple-choice questions, you should use the process of elimination to increase the odds of guessing correctly. The more choices you eliminate, the better are your odds for choosing the correct answer.

SAT II BIOLOGY STUDY PLAN

The most important thing you should have when preparing for the SAT II Biology exam is a plan. To start, you should estimate how much time you have before the exam. If you have enough time to prepare completely, you'll be okay. If, however, you're somewhat short on time, this plan will be even more valuable for you. We offer you these different study plans to help maximize your time and studying. The first is a 9-Week Plan, which involves concentrated studying and a focus on the practice test results. The second is the more leisurely 18-Week Plan, one that's favored by schools. Finally, if time is running short, you should use the Panic Plan. We don't want you to panic, however—this plan is supposed to help you conquer that panic and help you organize your studying so that you can get the most out of your review work and still be as prepared as possible when it is time to take the test.

These plans are supposed to be flexible and are only suggestions. Feel free to modify them to suit your needs and your own study habits. But start immediately, because the more you study and review, the better your results will be.

THE 9-WEEK PLAN—TWO LESSONS PER WEEK

Week 1

- **Lesson 1—Diagnostic Test**. The diagnostic SAT II Biology test is designed to help you determine what you need to know and where to focus your studying. Take this test under simulated test conditions in a quiet room, and keep track of the time it takes to complete the test. The diagnostic test has only 50 questions (30 general biology, 10 M-level, and 10 E-level). Regardless of which specific test (E or M) you intend to take, you should answer all of the questions on the diagnostic test to get an idea of the areas in which you're weakest.
- **Lesson 2—Diagnostic Test Answers**. Once you have completed the test, spend this lesson carefully checking all of your answers and reading through the explanations. This may take a bit of time, but it will enable you to select those subject areas that you should focus on and the areas on which you should spend the most amount of time studying. Armed with this information, you can start reviewing the chapters in the rest of the book.

Week 2

- **Lesson 1—Chapter One: Chemistry—Atoms and Compounds.** Take your time to read through the first chapter. Note that the style of the review material is in an outline format. It should be similar to your classroom notes. Underline or use a marker to highlight those areas that are unclear to you.
- **Lesson 2—Chapter Two: Cells—Organization and Regulation**. Again, read through this chapter, mark whatever is unclear, and go back and reread the material if necessary.

Week 3

- **Lesson 1—Chapter Three: Energy for Life—Anabolism and Catabolism**. As you continue your lessons, try to study in a quiet room, uninterrupted by others in your house or the TV, radio, or any other noises.
- **Lesson 2—Chapter Four: Genetics—Mendel and Heredity**. Again, read through this chapter, mark whatever is unclear, and go back and reread the material if necessary.

Week 4

- **Lesson 1—Chapter Five: Molecular Genetics—DNA and Evolution**. You're approaching the halfway point in the content chapters of this book now, so continue reading and taking notes. You can, of course, break these lessons into sections. Work on half the chapter in the morning and the other half in the afternoon.
- **Lesson 2—Chapter Six: Organisms and Populations**. Read through this chapter, mark whatever is unclear, and then go back and reread the material if necessary. You can always ask your teacher for additional information if you're having difficulty.

Week 5

- **Lesson 1—Chapter Seven: Animals—Structure and Function**. Chapters 7 and 8 are the last ones that cover the subject matter that will be on the test. By now, you should have a strong understanding of the material.
- **Lesson 2—Chapter Eight: Behavior and Ecology**. This is the final part of your journey into the subject review of SAT II Biology. All that's left is one more chapter that can help you improve your scores on the actual exam.

Week 6

- **Lesson 1—Chapter Nine: The Laboratory**. While laboratory exercises are not on the test itself, you must have a working knowledge of lab techniques in order to do well on this exam. This chapter will cover most of what you have already practiced in your classroom.
- **Lesson 2—Review.** This is the time to take a breather and go back and look over the content chapters of the book in order to find anything that might have slipped by. Look at the illustrations. Do you understand them? Try to answer some questions from earlier chapters. How did you do? You still have some time before taking the practice tests.

Week 7

- **Lesson 1—Practice Test 1.** Answer as many of the questions as you can, and then guess at those you don't know. Circle those questions that you guessed at so you can zero in on those specific answers and so you don't delude yourself into thinking that you really knew those answers in the first place. Answer the questions in the General Biology section first, and then answer all of the questions in each of the E and M portions of the exam. It's important to evaluate what you know.
- **Lesson 2—Practice Test 1 Answers.** Check all of your answers to both parts of the test.

Week 8

- **Lesson 1—Practice Test 2**. Take this test and answer as many of the questions as you can. By now, you will have noticed how much you have improved since you took the diagnostic test.
- **Lesson 2—Practice Test 2 Answers**. Check your answers to both parts of the test.

Week 9

- **Lesson 1—Practice Test 3**. This is the final test. After taking this test you will have answered 300 multiple-choice questions on these three practice tests as well as 50 more on the diagnostic test. Although there may be some new material on the actual test that you haven't encountered here, you should be very well prepared.
- **Lesson 2—Practice Test 3 Answers.** Check your answers to both parts of the test, and then relax!

THE 18-WEEK PLAN—1 LESSON PER WEEK

If you're lucky enough to have the extra time, the 18-Week Plan will enable you to better utilize your study time. You will now be able to spread out your plan into one lesson a week. This plan is ideal because you are not under any pressure and you can take more time to review the material in each of the chapters. You will also have enough time to double-check the answers to those questions that might have given you problems. Keep in mind that the basis for all test success is practice, practice, practice.

THE PANIC PLAN

We hate using this term, and while we hope you don't fall into this category, not everyone has the luxury of extra time to prepare for the SAT II Biology test. Perhaps, however, we can offer you a few helpful hints to get you through this difficult and stressful period.

Read through the official SAT II Biology bulletin and this *SAT II Success: Biology* book, and memorize the directions. One way of saving time on any test is to be familiar with the directions so you can maximize the time you have to work on the questions. On this test, they're pretty simple.

Read the introduction to this book. It will be helpful in preparing for the test and will give you an understanding of what you can expect on the exam and how much time you will have to complete both sections of the test.

Take the diagnostic test as well as the practice tests.

Focus whatever time you have left on those specific areas that gave you the most difficulty when you took the practice tests.

Whatever time you have before the exam, keep in mind that the more you practice, the better you will do on the final exam.

Good luck!

SYSTEMS OF MEASUREMENT

Some of the questions you will encounter on the SAT II Biology E/M test will involve measurements in both the English and the metric systems. Following is a brief review of the material. We suggest you review these few pages and answer the practice questions we've provided before you take the diagnostic and practice tests or begin studying the biology review chapters in this book.

THE ENGLISH SYSTEM

When taking the SAT II Biology exam, you will need to be able to compute using both the English system of measurement and the metric system. It may also be necessary for you to convert measurements from one system to the other, but in such cases, you will be given the appropriate conversion factors.

Make sure you have the following relationships within the English system memorized:

Conversion Factors for Length

36 inches = 3 feet = 1 yard

12 inches = 1 foot

5,280 feet = 1,760 yards = 1 mile

Conversion Factors for Volume

2 pints = 1 quart

16 fluid ounces = 1 pint

8 pints = 4 quarts = 1 gallon

Conversion Factors for Weight

16 ounces = 1 pound

2,000 pounds = 1 ton

These conversion factors enable you to change units within the English system.

Examples

1. How many feet are in 5 miles?

5 miles × (5,280 feet/1 mile) = 26,400 feet

Notice how the unit of "miles" cancels out of the numerator and denominator.

2. How many ounces are in 2 tons?

   2 tons × (2,000 pounds/1 ton) × (16 ounces/1 pound) = 64,000 ounces

   Notice how the units of "tons" and "pounds" cancel out of the numerator and denominator.

The Metric System

In the metric system, distance or length is measured in meters. Similarly, volume is measured in liters, and mass is measured in grams. The prefixes below are appended to the beginning of these basic units to indicate other units of measure with sizes equal to each basic unit multiplied or divided by powers of 10.

giga $= 10^9$
mega $= 10^6$
kilo $= 10^3$
hecto $= 10^2$
deka $= 10^1$
deci $= 10^{-1}$
centi $= 10^{-2}$
milli $= 10^{-3}$
micro $= 10^{-6}$
nano $= 10^{-9}$
pico $= 10^{-12}$

From the table above, we can see, for example, that a kilometer is 1,000 times as long as a meter, 100,000 times as long as a centimeter, and 1,000,000 times as a long as a millimeter. Similarly, a centigram is $\frac{1}{100}$ the size of a gram.

Conversions among metric units can be made quickly by moving decimal points.

Examples

1. Convert 9.43 kilometers to meters.

   Since meters are smaller than kilometers, our answer will be larger than 9.43. There are 1,000 meters in a kilometer, so we move the decimal point three places over to the right. 9.43 kilometers is equal to 9,430 meters.

2. Convert 512 grams to kilograms.

   Since kilograms are more massive than grams, our answer must be less than 512. There are 10^{-3} kilograms in a gram, so we move the decimal point three places to the left. 512 grams are equal to .512 kilograms.

Conversions between the English and the Metric Systems

Conversions between the English and metric systems are accomplished in the same way as conversions within the English system. Recall that any problem that requires you to make such a conversion will include the necessary conversion factors.

Examples

1. If 1 meter is equivalent to 1.09 yards, how many yards are in 10 meters?

   10 meters × (1.09 yards/1 meter) = 10.9 yards

2. If 1 yard is equivalent to .914 meters, how many meters are there in 24 yards?

   24 yards × (.914 meters/1 yard) = 21.936 meters

Systems of Measurement Problems

1. Express 38 meters in millimeters.
2. Express 871 millimeters in centimeters.
3. Which measurement is greater, 8,000 millimeters or 7 meters?
4. Arrange the following from smallest to biggest: 6,700 meters, 672,000 centimeters, and 6.6 kilometers.
5. Express 49 milligrams in centigrams.
6. 4.6 liters is how many milliliters?
7. A package weighing 32.5 kilograms is shipped to the U.S. What is its weight in pounds? There are 2.2 pounds in a kilogram.
8. A line drawn on a blueprint measures 1.5 yards. What is its length in meters? There are .914 meters in a yard.
9. If the distance between two exits on a highway is 40 kilometers, what is the distance in miles? There are .62 miles in a kilometer.
10. A particular brand of bottled water is available in two different bottle sizes—a 2.25 quart bottle and a 2.1 liter bottle. Which bottle contains more water? There are 1.06 quarts in a liter.

SOLUTIONS

1. Since meters are larger than millimeters, our answer will be larger than 38. There are 1,000 millimeters in a meter, so we move the decimal point three places over to the right. 38 meters is equal to 38,000 millimeters.
2. Since millimeters are smaller than centimeters, our answer will be smaller than 871. There are 10 millimeters in a centimeter, so we move the decimal point one place over to the left. 871 millimeters is equal to 87.1 centimeters.
3. In order to answer this question, we must express both measures in the same units. Since, for example, 8,000 millimeters is equal to 8 meters, we can see that 8,000 millimeters is larger than 7 meters.
4. Let's start by expressing all measurements in meters.

   672,000 centimeters=6,720 meters
   6.6 kilometers=6,600 meters
   6,700 meters=6,700 meters

   Thus, from smallest to largest, we have 6.6 kilometers, 6,700 meters, and 672,000 centimeters.
5. Since there are 10 milligrams in a centigram, 49 milligrams is equal to 4.9 centigrams.
6. Since there are 1,000 milliliters in a liter, there are 4,600 milliliters in 4.6 liters.
7. 32.5 kgs = 32.5 kgs × (2.2 lbs/1 kg) = 71.5 lbs
8. 1.5 yards = 1.5 yards × (.914 meters/1 yard) = 1.371 meters
9. 40 kilometers = 40 kilometers × (.62 miles/1 kilometer) = 24.8 miles
10. Express 2.1 liters in quarts.

    2.1 liters = 2.1 liters × (1.06 quarts/1 liter) = 2.226 quarts. Thus, the quart bottle holds more.

DIAGNOSTIC TEST

While you have taken many standardized tests and know to blacken completely the ovals on the answer sheets and to erase completely any errors, the instructions for the SAT II exam in Biology differs from the directions for other standardized tests you have taken. You need to indicate on the answer key whether you are taking the SAT II Biology with Ecological Emphasis (Biology-E) or Molecular Emphasis (Biology-M).

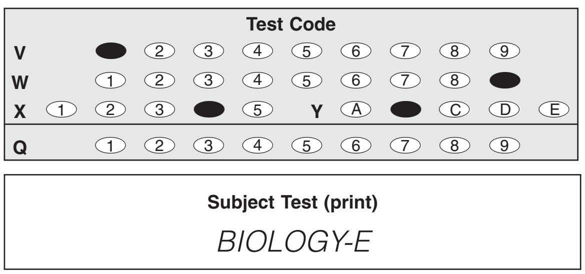
The instructions on the answer sheet will tell you to fill out the top portion of the answer sheet exactly as shown.

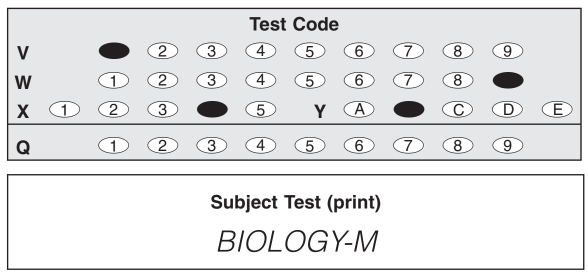
1. Print *BIOLOGY-E or BIOLOGY-M on the line to the right under the words Subject Test (print).*

2. In the shaded box labeled *Test Code* fill in four ovals:

For BIOLOGY-E
—Fill in oval 1 in the row labeled V.

For BIOLOGY-M
—Fill in oval 1 in the row labeled V.





—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

3. When everyone has completed filling in this portion of the answer sheet, the supervisor will tell you to turn the page and begin. The answer sheet has 100 numbered ovals on the sheet, but there are only 90 (or 95) multiple-choice questions in the test, so be sure to use only ovals 1 to 90 (or 95) to record your answers.

DIAGNOSTIC TEST—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

1. Which of the following statements about mitochondria is NOT correct?

(A) They serve as sites for cellular respiration.

(B) They are enclosed by a double membrane.

(C) They are the sites where most of the cell's ATP is produced.

(D) They are found in animal cells only; plant cells have chloroplasts instead.

(E) They are found in eukaryotic cells but not in prokaryotic cells.

2. Which of the following statements about cell structure is NOT correct?

(A) Plant cells have cell walls, whereas animal cells do not.

(B) Ribosomes are the main sites of energy production for the cell.

(C) Plant cells have chloroplasts, whereas animal cells do not.

(D) Lysosomes function in the digestion of cellular waste products.

(E) Many cellular organelles are interrelated through an endomembrane system.

3. What would happen to a human red blood cell if it was placed in distilled water?

(A) It would shrivel.

(B) It would plasmolyze.

(C) It would lyse.

(D) It would dehydrate.

(E) It would not be affected.

4. Which of the following pairs does NOT represent a correct relationship?

(A) fat; lipid

(B) starch; polysaccharide

(C) starch; carbohydrate

(D) sugar; carbohydrate

(E) enzyme; lipid

5. Which of the following statements is correct?

(A) The product of transcription is DNA.

(B) The product of transcription is mRNA.

(C) The product of transcription is a polypeptide.

(D) The product of translation is mRNA.

(E) The product of translation is DNA.

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DIAGNOSTIC TEST—*Continued*

6. Which of the following is responsible for changes in the Earth's seasons?

(A) The tilt of the Earth's axis toward or away from the sun.
(B) The distance between the Earth and the sun at different times of the year.
(C) The movement of the oceans' currents.
(D) The annual cycles of temperature and rainfall.
(E) The variation in the amount of energy released by the sun from month to month.

7. The two fundamental processes that govern the dynamics of an ecosystem are

(A) solar radiation and the carbon cycle.
(B) photosynthesis and respiration.
(C) the carbon cycle and photosynthesis.
(D) energy flow and chemical/nutrient cycling.
(E) the nitrogen cycle and the phosphorous cycle.

8. A host plant produces a toxin that is lethal to aphids feeding on its leaves. Over time, some of the aphids become immune to the toxin. In response, the host plant begins to produce a different toxin that is lethal to aphids. This is an example of

(A) parasitism.
(B) commensalism.
(C) predation.
(D) mutualism.
(E) coevolution.

9. The use of specially bred strains of bacteria to clean up oil spills along beaches is an example of

(A) primary succession.
(B) bioremediation.
(C) decomposition.
(D) coevolution.
(E) eutrophication.

10. In the food chain illustrated below, which trophic level is represented by the earthworm?

sunflower — caterpillar —bluejay — tom cat — earthworm

(A) primary consumer
(B) secondary consumer
(C) tertiary consumer
(D) quaternary consumer
(E) decomposer

11. Which of the following statements about meiosis is correct?

(A) The result of meiosis is a zygote.
(B) Only somatic cells undergo meiosis.
(C) Meiosis restores the original diploid condition of a population.
(D) Meiosis typically results in genetic variation among the gametes produced.
(E) The products of meiosis are always four cells identical to the parent cell.

DIAGNOSTIC TEST—*Continued*

12. An animal organism with a diploid number of chromosomes equal to 30 would normally

(A) not be able to undergo meiosis because gametes would end up with an odd number of chromosomes.
(B) produce two gametes with 30 chromosomes each during meiosis.
(C) produce four gametes with 30 chromosomes each during meiosis.
(D) produce two gametes with 15 chromosomes each during meiosis.
(E) produce four gametes with 15 chromosomes each during meiosis.

Questions 13–14 refer to the following breeding experiment. The researcher's goal was to develop white mice with short tails.

P	brown mice with short tails	x	white mice with long tails
F_1	all offspring are brown and have long tails	F_2	292 mice are brown with long tails 97 mice are brown with short tails 103 mice are white with long tails 36 mice are white with short tails

13. The results of the above cross indicate that among the original parents (P-generation)

(A) both were heterozygous for coat color and tail length.
(B) one was homozygous dominant for coat color and tail length, whereas the other was homozygous recessive for both traits.
(C) one was homozygous dominant for coat color and homozygous recessive for tail length, whereas the other was homozygous recessive for coat color and homozygous dominant for tail length.
(D) one was homozygous dominant for both traits, whereas the other was heterozygous for both traits.
(E) one was homozygous recessive for both traits, whereas the other was heterozygous for both traits.

14. Based on the results, how many genes control the four traits observed among the F_2 progeny (brown coat color, white coat color, short tail, long tail)?

(A) one
(B) two
(C) four
(D) eight
(E) sixteen

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DIAGNOSTIC TEST—*Continued*

15. A cooperative unit of many cells with similar form and function is known as a(n)

(A) tissue.
(B) tissue system.
(C) organ.
(D) organ system.
(E) cell system.

16. Which of the following is NOT one of the stages involved in the processing of food?

(A) ingestion
(B) digestion
(C) acid processing
(D) absorption
(E) elimination

17. Which of the following statements best describes the process of gas exchange in living organisms?

(A) Plants take in oxygen and give off carbon dioxide during photosynthesis.
(B) Animals take in carbon dioxide and give off oxygen during respiration.
(C) Animals take in oxygen and give off carbon dioxide during respiration.
(D) Aquatic organisms cannot undergo gas exchange with their environment.
(E) True gas exchange only occurs in organisms with lungs.

18. Homeostasis refers to

(A) an animal maintaining a home range.
(B) a population maintaining a constant population size.
(C) females remaining in their parents' territory.
(D) plants ceasing to grow at a maximum height.
(E) maintaining a steady state of internal conditions.

19. The human skin contains all of the following receptors EXCEPT

(A) pain receptors.
(B) pressure receptors.
(C) thermoreceptors.
(D) chemoreceptors.
(E) touch receptors.

DIAGNOSTIC TEST—*Continued*

20. Which of the following types of learning behavior is responsible for allowing you to ignore the constant sensation to your body caused by the clothes you are wearing?

(A) habituation
(B) association
(C) imprinting
(D) imitation
(E) innovation

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

Questions 21–23 refer to the following pairs of organisms:

(A) monocot and dicot
(B) algae and fungi
(C) mosses and ferns
(D) ferns and gymnosperms
(E) gymnosperms and angiosperms

21. One produces spores, whereas the other produces seeds.

22. One is photosynthetic, whereas the other is saprophylic.

23. One contains xylem and phloem, whereas the other does not.

Questions 24–26 refer to the following terms:

(A) vascular cambium
(B) ground tissue
(C) apical meristem
(D) phloem
(E) xylem

24. Responsible for movement of water and dissolved nutrients from the roots upward in the plant.

25. Responsible for the movement of sugars made in the leaves downward through the plant.

26. Responsible for primary growth (growth in length) of the plant body.

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DIAGNOSTIC TEST—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

27. Which of the following represents the correct order of appearance of different vertebrate groups in the fossil record?

(A) fish, birds, reptiles, mammals
(B) amphibians, reptiles, fish, mammals
(C) fish, reptiles, amphibians, mammals
(D) fish, amphibians, reptiles, mammals
(E) fish, amphibians, mammals, reptiles

28. Evidence validating the theory of evolution based on the study of structures that appear during the development of different organisms is known as

(A) comparative homology.
(B) comparative endocrinology.
(C) comparative morphology.
(D) comparative anatomy.
(E) comparative embryology.

29. The concept that the gene pool of an idealized, non-evolving population remains constant over generations forms the basis of

(A) Mendel's principle of segregation.
(B) Mendel's principle of independent assortment.
(C) Darwin's theory of natural selection.
(D) Darwin's theory of survival of the fittest.
(E) the principle of Hardy-Weinberg equilibrium.

30. The process by which species from different evolutionary lineages come to resemble each other as a result of living in very similar environments is known as

(A) adaptive radiation.
(B) convergent evolution.
(C) sympatric speciation.
(D) allopatric speciation.
(E) punctuated equilibrium.

S T O P

IF YOU ARE TAKING THE BIOLOGY-E TEST, CONTINUE WITH QUESTIONS 31–40.
IF YOU ARE TAKING THE BIOLOGY-M TEST, GO TO QUESTION 41 NOW.

DIAGNOSTIC TEST—*Continued*

BIOLOGY-E TEST

Directions: Each of the questions or statements below is accompanied by five choices. Some questions refer to a laboratory or experimental situation. For each question, select the best of the answer choices given.

31. Which of the following statements is correct?

(A) A species is one type of population.
(B) A species is a local subset of a population.
(C) A population is a local subset of a species.
(D) A population encompasses many different species.
(E) The terms population and species are interchangeable.

32. Which of the following best describes a pattern of idealized population growth that is restricted by limiting factors?

(A) logistic growth model
(B) carrying capacity model
(C) dispersion model
(D) habitat cap model
(E) exponential growth model

33. Which of the following terms best encompasses all of the populations of organisms living together and potentially interacting in an area?

(A) carrying capacity
(B) biome
(C) ecosystem
(D) biological community
(E) geographical community

34. The human population, from Stone Age times to the present, is best represented by

(A) an exponential growth curve.
(B) a logistic growth curve.
(C) a bimodel distribution curve.
(D) a normal distribution curve.
(E) a random growth curve.

35. Which of the following would NOT be considered a density-dependent factor affecting population size?

(A) competition
(B) parasitism
(C) predation
(D) tornado
(E) disease epidemic

36. If a population exceeds the carrying capacity of the ecosystem, the most likely outcome would be

(A) an increase in resources to meet its needs.
(B) extinction of the species.
(C) an eventual decline in population size.
(D) a steady increase in population size.
(E) maintenance of the current population size indefinitely.

GO ON TO THE NEXT PAGE

DIAGNOSTIC TEST—*Continued*

37. The role of a particular species within an ecosystem, including all of its interactions with both biotic and abiotic factors, is known as the species'

(A) ecological niche.
(B) habitat.
(C) carrying capacity.
(D) dispersion pattern.
(E) density pattern.

38. Mutualistic interactions among species in an ecosystem would be characterized as

(A) −/−.
(B) −/0.
(C) +/0.
(D) +/+.
(E) +/−.

Questions 39–40 refer to the following population in Hardy-Weinberg equilibrium:

Approximately 4% of the turtle population in the local pond shows the recessive phenotype—long nose (nn).

39. What is the frequency of the dominant allele (N) in the population?

(A) 0.16
(B) 0.20
(C) 0.40
(D) 0.32
(E) 0.80

40. What is the frequency of heterozygotes in the population?

(A) 0.08
(B) 0.24
(C) 0.32
(D) 0.48
(E) 0.64

S T O P

If you answered the first 40 questions STOP HERE.
If you are taking the Biology-M test CONTINUE HERE.

DIAGNOSTIC TEST—*Continued*

BIOLOGY-M TEST

Directions: Each of the questions or statements below is accompanied by five choices. Some questions refer to a laboratory or experimental situation. For each question, select the best of the answer choices given.

41. If a molecule of DNA is composed of approximately 16.2% adenine (A) and 33.4% guanine (G), the percentages of thymine (T) and cytosine (C) must be approximately

(A) 16.3% T and 16.3% C.
(B) 34.1% T and 34.1% C.
(C) 34.1% T and 16.3% C.
(D) 16.3% T and 34.1% C.
(E) 33.4% T and 16.2% C.

42. The primary building blocks of a DNA molecule are

(A) nitrogenous bases, phosphates, and ribose sugar.
(B) nitrogenous bases, phosphates, and deoxyribose sugar.
(C) phosphorous bases, nitrogen, and ribose sugar.
(D) phosphorous bases, nitrogen, and deoxyribose sugar.
(E) carbon, nitrogen, oxygen, phosphorous, and deoxyribose sugar.

43. Which of the following procedures would NOT be likely to lead to the production of recombinant DNA?

(A) transformation of bacterial cells with plasmid DNA from another strain of bacteria
(B) transformation of bacterial cells with naked DNA from human cells
(C) transduction of bacteria using phage particles (bacterial viruses)
(D) projectile bombardment of cells with DNA-coated particles from a 'gene gun'
(E) the removal of a single somatic cell from a carrot and regenerating an entire plant from the cell through tissue culture

GO ON TO THE NEXT PAGE

DIAGNOSTIC TEST—*Continued*

44. Which of the following statements does NOT contribute to the evidence in support of evolution?

(A) Sequences of fossils have been found that show a gradual series of changes in form among organisms.

(B) Species thought to be related through evolution from a common ancestor show many anatomical similarities.

(C) The stages of embryological development in animals are quite similar among highly diverse types of organisms.

(D) Similarities in chromosome structure, DNA sequence, and amino acid sequence suggest relationships among organisms descending through evolution from a common ancestor.

(E) The most well adapted individuals do not always produce the most fit offspring.

45. Which of the following statements suggests that all organisms descended through evolution from a common ancestor?

(A) There is much evidence for the occurrence of convergent evolution.

(B) It is widely accepted that natural selection leads to evolution.

(C) Despite the diversity of organisms on Earth, all share the same genetic code.

(D) All populations experience mutation and natural selection.

(E) Selection acts on individuals, but only populations evolve.

46. Which of the following pairs represents homologous structures?

(A) human arm and octopus tentacle

(B) human arm and sea star arm

(C) human arm and bird wing

(D) bird wing and fly wing

(E) fly wing and bat wing

47. The relative fitness of an organism in a population is best measured by

(A) the number of times it mates during its lifetime.

(B) the size of the offspring it produces.

(C) the number of offspring it produces each year.

(D) the number of offspring it produces during its lifetime.

(E) the number of offspring it produces during its lifetime that survive and successfully reproduce.

48. According to the biological species concept, the main criterion for identifying a species is

(A) morphological distinctiveness.

(B) behavioral distinctiveness.

(C) physiological distinctiveness.

(D) geographical isolation.

(E) reproductive isolation.

DIAGNOSTIC TEST—*Continued*

49. Which of the following is NOT considered a potential cause of extinction?

(A) introduction of a new predator
(B) introduction of a new parasite
(C) introduction of a new mutation
(D) interspecific competition for limited resources
(E) habitat destruction

50. Which of the following statements is NOT a feature of restriction fragment length polymorphisms?

(A) They can be used to detect single gene mutations in human DNA.
(B) They can be used prenatally to analyze fetal cells for genetic disorders.
(C) They can be used to amplify large quantities of a single gene through use of the polymerase chain reaction.
(D) They can be used to detect variation in DNA sequences among individuals.
(E) They can be separated by electrophoresis according to fragment size.

S T O P

If you finish before the hour is up, you may review your work on this test only. You may not turn to any other test in this book.

ANSWERS AND EXPLANATIONS

QUICK-SCORE ANSWERS				
1. D	11. D	21. D	31. C	41. D
2. B	12. E	22. B	32. A	42. B
3. C	13. C	23. C	33. D	43. E
4. E	14. B	24. E	34. A	44. E
5. B	15. A	25. D	35. D	45. C
6. A	16. C	26. C	36. C	46. C
7. D	17. C	27. D	37. A	47. E
8. E	18. E	28. E	38. D	48. E
9. B	19. D	29. E	39. E	49. C
10. E	20. A	30. B	40. C	50. C

1. **The correct answer is (D).** Mitochondria are cellular organelles bound by double membranes. They are the sites where respiration occurs, resulting in the production of ATP. Therefore, they are the main sites of energy production for the cell. Both plant and animal cells contain mitochondria, as do most eukaryotic cells. Prokaryotic cells lack membrane-bound organelles and an organized nucleus.
2. **The correct answer is (B).** Ribosomes serve as sites for protein synthesis in the cell. Mitochondria are the main sites of cellular energy production.
3. **The correct answer is (C).** The solute concentration inside a human red blood cell is greater than that of distilled water. If such a cell was placed in distilled water, the water concentration outside the cell would be greater than the water concentration inside the cell, and the cell would take up water by osmosis. Animal cells do not have cell walls to prevent unlimited expansion, thus the cell would lyse (swell until it burst).
4. **The correct answer is (E).** Enzymes are one type of protein. Lipids include fats, waxes, phospholipids, and steroids that are insoluble in water. Both sugar and starch are carbohydrates. Simple, single-unit sugars such as glucose are monosaccharides. Starch is composed of long chains of glucose molecules and, thus, forms a more complex carbohydrate known as a polysaccharide.
5. **The correct answer is (B).** Transcription is the synthesis of RNA from a DNA template. Translation is the synthesis of a polypeptide using the genetic information encoded in an mRNA

molecule. It involves the conversion of a nucleotide "language" to an amino acid "language."

6. **The correct answer is (A).** The change of seasons that occurs throughout the year results from changes in the tilt of the Earth's axis toward or away from the sun during its annual orbit.
7. **The correct answer is (D).** The two fundamental processes that govern the dynamics of an ecosystem are energy flow and chemical cycling. Energy flow involves the passage of energy through the components of an ecosystem. Energy enters an ecosystem as sunlight and leaves the ecosystem as heat (a byproduct of the use of various forms of chemical energy by the organisms present). Energy is not recycled through the system and must be continually replaced in the form of sunlight. Thus, energy is said to flow through a system rather than cycle through it. Chemical cycling involves the circular movement of materials within an ecosystem. Chemical elements (such as carbon, nitrogen, and phosphorous) are cycled between abiotic components (air, water, soil) and biotic components (plants, animals, microorganisms) of an ecosystem.
8. **The correct answer is (E).** Coevolution involves evolutionary change in which adaptations in one species act as a selective force on a second species, including adaptations that in turn act as a selective force on the first species.
9. **The correct answer is (B).** Bioremediation involves the use of living organisms to detoxify polluted areas of an ecosystem.
10. **The correct answer is (E).** The earthworm represents a decomposer—an organism that obtains energy from organic wastes and dead organisms. In this example, the earthworm might feed on decaying organic matter formed by any of the other organisms in the food chain. The sunflower represents a producer (an autotrophic organism). The consumption of the sunflower by the caterpillar makes it a primary consumer (feeding directly on a producer). The bluejay, feeding on a primary consumer, represents a secondary consumer while the tomcat represents a tertiary consumer. The earthworm would not represent a quaternary consumer because it does not consume the living tomcat, although it may feed off organic matter from the decaying carcass of the tomcat once it dies.
11. **The correct answer is (D).** Events that occur during the process of meiosis (crossing over, independent assortment) result in the production of gametes that are genetically variable. The two separate divisions that occur during meiosis lead to the formation of four genetically variable gametes, each with half the number of chromosomes as the original parent cell (haploid

condition). When two gametes unite at fertilization, the diploid condition is restored in the resulting zygote.

12. The correct answer is (E). The products of meiosis are four gametes, each with half the number of chromosomes as the original parent cell.

13. The correct answer is (C). Questions 13–14 pertain to Mendelian inheritance of traits. You are asked to draw conclusions about the inheritance of two traits from the results of the breeding experiment presented in the introductory material. First, you should observe that the only traits occurring in the F_1 generation are brown coat color and long tails, whereas all four traits show up among the F_2 progeny. This suggests that brown coat color and long tails are dominant over white coat color and short tails, respectively. The parents must have been homozygous for each trait, as only the dominant traits were present among their offspring. Thus, the parent with a brown coat and short tail must have been homozygous dominant for coat color and homozygous recessive for tail length, whereas the parent with a white coat and long tail must have been homozygous recessive for coat color and homozygous dominant for tail length.

14. The correct answer is (B). This question tests your knowledge of inheritance patterns. The ratio produced in the F_2 (9:3:3:1) could only have occurred if two different genes control the inheritance of coat color and tail length, and those genes reside on separate chromosomes (i.e., they are not linked). A simple Punnet square derived from intermating the F_1 generation would reveal the 9 genotypes represented by the four phenotypic classes found among the F_2 progeny.

15. The correct answer is (A). Tissues are composed of many cells with similar structure and function working cooperatively as a unit to carry out a specific role. An organ is usually composed of two or more tissues (e.g., the heart contains muscle tissue, epithelial tissue, connective tissue, and nervous tissue). An organ system is composed of several organs that work together to carry out a particular body function (e.g., the cardiovascular system includes the heart, which pumps the blood, and the blood vessels that transport the blood throughout the body).

16. The correct answer is (C). Food is ingested (eaten), then enzymes in saliva and stomach secretions digest the food particles (break them down) so they can be absorbed. Non-digested food particles are eliminated as waste.

17. The correct answer is (C). During gas exchange, animals take in oxygen and give off carbon dioxide as respiration occurs, whereas plants take in carbon dioxide and release oxygen to the atmosphere as a byproduct of photosynthesis. Plants also release a small amount of carbon dioxide through respiration.

18. **The correct answer is (E).** Homeostasis involves the regulation of bodily functions.

19. **The correct answer is (D).** Humans have chemoreceptors in their noses and mouths.

20. **The correct answer is (A).** Habituation is a learning behavior in which the individual learns not to respond to a repeated stimulus that conveys little or no information. Association, choice (B), is a learning behavior in which the individual learns that a particular stimulus or response is linked to a reward or punishment. Imprinting, choice (C), is a learning behavior that is limited to a certain period in an organism's life and is irreversible. Imitation, choice (D), is a learning behavior in which the individual learns by observing and mimicking (imitating) others. Innovation, choice (E), is a learning behavior in which the individual uses inventive behavior in response to a new situation without trial and error or imitation.

21. **The correct answer is (D).** This question asks you to distinguish between plants that reproduce by spores (ferns) and those that reproduce by seeds (gymnosperms) and thus are more advanced on an evolutionary scale.

22. **The correct answer is (B).** This question asks you to recognize the difference between two organisms that were once thought to be members of the plant kingdom but that are now classified separately. The algae (in kingdom Protista) contain chlorophyll and various accessory pigments and are able to carry out photosynthesis. Fungi are currently classified in their own kingdom (kingdom Fungi). These organisms lack photosynthetic pigments and are typically saprobic (absorbing nutrients from nonliving material) or parasitic (absorbing nutrients from a living host organism).

23. **The correct answer is (C).** This question asks you to recognize the difference between plants lacking vascular tissue (xylem and phloem), which are quite restricted in size (mosses), and those that contain vascular tissue and which are able to obtain considerable height (ferns).

24. **The correct answer is (E).** Xylem tissue consists of several cell types, most of which are nonliving at maturity, and is responsible for conducting water and dissolved minerals upward from the roots where they are absorbed.

25. **The correct answer is (D).** Phloem tissue consists of several types of food-conducting cells and is responsible for transporting sugars made in the leaves during photosynthesis, along with

those stored in other parts of the plant body, to regions of the plant requiring energy.

26. **The correct answer is (C).** Apical meristems are regions of actively dividing tissue in plants that give rise to growth in length. They are typically found in shoot tips and root tips.
27. **The correct answer is (D).**
28. **The correct answer is (E).** Comparative embryology is the study of structures that appear during the development of different organisms.
29. **The correct answer is (E).**
30. **The correct answer is (B).** Convergent evolution occurs when species from different evolutionary lineages come to resemble each other as a result of living in very similar environments. Adaptive radiation, choice (A), is the emergence of numerous species from a common ancestor introduced into new and different environments. Sympatric speciation, choice (C), is the formation of a new species as a result of genetic change that produces a reproductive barrier between the changed (mutant) population and the original population. Allopatric speciation, choice (D), is the formation of a new species as a result of an ancestral population's becoming isolated by a geographical barrier. Punctuated equilibrium, choice (E), is the concept that species formation occurs in spurts followed by long periods of little or no speciation.

BIOLOGY-E TEST

31. **The correct answer is (C).** A population is a group of interacting individuals belonging to the same species and living in the same geographic area.
32. **The correct answer is (A).** A logistic growth model depicts the pattern of idealized population growth that is restricted by limiting factors. The other common growth model listed, an exponential growth model, choice (E), depicts the pattern of idealized population growth that is unregulated.
33. **The correct answer is (D).**
34. **The correct answer is (A).** Human population growth is occurring at a continuously accelerating rate that is characteristic of an exponential growth curve. This exponential growth rate has been possible because humans have overcome much environmental resistance and have increased the carrying capacity of the Earth.

35. The correct answer is (D). Density-dependent factors have an increased effect on population size as the density of the population increases (e.g., predation, parasitism, disease, and competition). The affect of weather phenomena and natural disasters (e.g., tornadoes) are independent of population density and, thus, are referred to as density-independent factors.

36. The correct answer is (C). The carrying capacity of an ecosystem is the maximum population size it can support indefinitely; it is usually based on the availability of resources. If a population exceeds the carrying capacity of the ecosystem, it will eventually decline in size until it returns to a size that can be sustained indefinitely (carrying capacity).

37. The correct answer is (A).

38. The correct answer is (D). In mutualistic interactions among species, both species gain some benefit from the interaction (e.g., the mutualistic interaction between termites and the particular strains of bacteria that live in their gut; the bacteria find food and shelter while helping the termite breakdown the wood material it ingests).

39. The correct answer is (E). By definition, p is used to reflect the frequency of the dominant allele for a given gene in a population, whereas q is used to reflect the frequency of the corresponding recessive allele. p^2 reflects the union of two gametes, each carrying the dominant allele, and, thus, reflects the frequency of the homozygous dominant genotype in the population. q^2 reflects the union of two gametes, each carrying the recessive allele and, thus, reflects the frequency of the homozygous recessive genotype in the population. If we know that 4 percent of the population has the recessive genotype, then the frequency of the recessive allele must be the square root of 0.04 = 0.20. Since $p + q = 1$, then $p = 1 - q = 0.80$. If the trait in question is governed by co-dominance or incomplete dominance, such that heterozygotes can be distinguished phenotypically from homozygous dominant individuals, then, by default, p^2 may also reflect the frequency of individuals in the population with the dominant phenotype; however, that is not always the case.

40. The correct answer is (C). A heterozygous individual may result from the union of a dominant allele from the maternal parent and a recessive allele from the paternal parent, or it may result from the union of a recessive allele from the maternal parent and a dominant allele from the paternal parent. Both possibilities must be considered when determining the frequency with which a heterozygous individual could be produced in a given population. Thus, the frequency of heterozygotes in this population would be equal to $2pq = 2(0.80)(0.20) = 0.32$.

BIOLOGY-M TEST

41. **The correct answer is (D).** In the DNA molecule, base pairing occurs between adenine and thymine, which are held together by two hydrogen bonds, and base pairing occurs between guanine and cytosine, which are held together by three hydrogen bonds. Therefore, the percentages of adenine and thymine would be similar, as would the percentages of guanine and cytosine.
42. **The correct answer is (B).** The DNA molecule is composed of double strands of a sugar-phosphate backbone (with deoxyribose sugar molecules alternating with phosphate groups) held together by hydrogen bonds between nitrogenous bases (specifically, two hydrogen bonds between adenine and thymine; and three hydrogen bonds between guanine and cytosine).
43. **The correct answer is (E).** Removing a single cell from an organism and using it to regenerate an entire new individual through tissue culture would produce a clone of the original organism. No genetic recombination would take place. The other procedures listed can each be used in the production of recombinant DNA.
44. **The correct answer is (E).** Natural selection is a primary driving force in evolution. The concept of natural selection is based on the inheritance of traits over generations that confer adaptation to the environment. Those individuals that are best adapted to their environment are more likely to produce offspring showing the adaptation and will subsequently survive to successfully reproduce. All of the other choices are areas of study that have provided (and continue to provide) significant evidence in support of evolution.
45. **The correct answer is (C).** The fact that all organisms share a universal genetic code suggests the code evolved once early in evolutionary history.
46. **The correct answer is (C).** The human arm and the wing of a bird are homologous structures—structures that differ in function but have similar anatomy, presumably because the organisms that possess them have a common ancestor.
47. **The correct answer is (E).** Fitness is the degree to which an organism is adapted to survive and perpetuate its genes in a given environment.
48. **The correct answer is (E).** According to the biological species concept, a species is a population or group of populations whose

members have the potential in nature to interbreed and produce fertile offspring. Thus, reproductive isolation between groups would not fit the biological species concept.

49. **The correct answer is (C).** The introduction of a mutation into a population allows for genetic variation within the population and the potential for particular genotypes to be selected for or against. As such, mutation is an important contributor to evolution. Introduction of a parasite or predator into a population that did not exist there previously could wipe out an entire population or species. Interspecific competition could lead to the displacement or extinction of the less competitive species. Habitat destruction is a significant contributor to extinction of species.

50. **The correct answer is (C).**

Unit I—Molecules and Cells

Key:

element name **atomic number** element symbol 1997 atomic weight (mean relative mass)

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
hydrogen 1 H 1.00794(7)																		helium 2 He 4.002602(2)
lithium 3 Li 6.941(2)	beryllium 4 Be 9.012182(3)												boron 5 B 10.811(7)	carbon 6 C 12.0107(8)	nitrogen 7 N 14.00674(7)	oxygen 8 O 15.9994(3)	fluorine 9 F 18.9984032(5)	neon 10 Ne 20.1797(6)
sodium 11 Na 22.989770(2)	magnesium 12 Mg 24.3050(6)												aluminium 13 Al 26.981538(2)	silicon 14 Si 28.0855(3)	phosphorus 15 P 30.973761(2)	sulfur 16 S 32.066(6)	chlorine 17 Cl 35.4527(9)	argon 18 Ar 39.948(1)
potassium 19 K 39.0983(1)	calcium 20 Ca 40.078(4)		scandium 21 Sc 44.955910(8)	titanium 22 Ti 47.867(1)	vanadium 23 V 50.9415(1)	chromium 24 Cr 51.9961(6)	manganese 25 Mn 54.938049(9)	iron 26 Fe 55.845(2)	cobalt 27 Co 58.933200(9)	nickel 28 Ni 58.6934(2)	copper 29 Cu 63.546(3)	zinc 30 Zn 65.39(2)	gallium 31 Ga 69.723(1)	germanium 32 Ge 72.61(2)	arsenic 33 As 74.92160(2)	selenium 34 Se 78.96(3)	bromine 35 Br 79.904(1)	krypton 36 Kr 83.80(1)
rubidium 37 Rb 85.4678(3)	strontium 38 Sr 87.62(1)		yttrium 39 Y 88.90585(2)	zirconium 40 Zr 91.224(2)	niobium 41 Nb 92.90638(2)	molybdenum 42 Mo 95.94(1)	technetium 43 Tc [98.9063]	ruthenium 44 Ru 101.07(2)	rhodium 45 Rh 102.90550(2)	palladium 46 Pd 106.42(1)	silver 47 Ag 107.8682(2)	cadmium 48 Cd 112.411(8)	indium 49 In 114.818(3)	tin 50 Sn 118.710(7)	antimony 51 Sb 121.760(1)	tellurium 52 Te 127.60(3)	iodine 53 I 126.90447(3)	xenon 54 Xe 131.29(2)
caesium 55 Cs 132.90545(2)	barium 56 Ba 137.327(7)	57-70 *	lutetium 71 Lu 174.967(1)	hafnium 72 Hf 178.49(2)	tantalum 73 Ta 180.9479(1)	tungsten 74 W 183.84(1)	rhenium 75 Re 186.207(1)	osmium 76 Os 190.23(3)	iridium 77 Ir 192.217(3)	platinum 78 Pt 195.078(2)	gold 79 Au 196.96655(2)	mercury 80 Hg 200.59(2)	thallium 81 Tl 204.3833(2)	lead 82 Pb 207.2(1)	bismuth 83 Bi 208.98038(2)	polonium 84 Po [208.9824]	astatine 85 At [209.9871]	radon 86 Rn [222.0176]
francium 87 Fr [223.0197]	radium 88 Ra [226.0254]	89-102 **	lawrencium 103 Lr [262.110]	rutherfordium 104 Rf [261.1089]	dubnium 105 Db [262.1144]	seaborgium 106 Sg [263.1186]	bohrium 107 Bh [264.12]	hassium 108 Hs [265.1306]	meitnerium 109 Mt [268]	ununnilium 110 Uun [269]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]		ununhexium 116 Uuh [289]		ununoctium 118 Uuo [293]

*lanthanides	lanthanum 57 La 138.9055(2)	cerium 58 Ce 140.116(1)	praseodymium 59 Pr 140.90765(2)	neodymium 60 Nd 144.24(3)	promethium 61 Pm [144.9127]	samarium 62 Sm 150.36(3)	europium 63 Eu 151.964(1)	gadolinium 64 Gd 157.25(3)	terbium 65 Tb 158.92534(2)	dysprosium 66 Dy 162.50(3)	holmium 67 Ho 164.93032(2)	erbium 68 Er 167.26(3)	thulium 69 Tm 168.93421(2)	ytterbium 70 Yb 173.04(3)
**actinides	actinium 89 Ac [227.0277]	thorium 90 Th 232.0381(1)	protactinium 91 Pa 231.03588(2)	uranium 92 U 238.0289(1)	neptunium 93 Np [237.0482]	plutonium 94 Pu [244.0642]	americium 95 Am [243.0614]	curium 96 Cm [247.0703]	berkelium 97 Bk [247.0703]	californium 98 Cf [251.0796]	einsteinium 99 Es [252.0830]	fermium 100 Fm [257.0951]	mendelevium 101 Md [258.0984]	nobelium 102 No [259.1011]

Chapter 1

CHEMISTRY—ATOMS AND COMPOUNDS

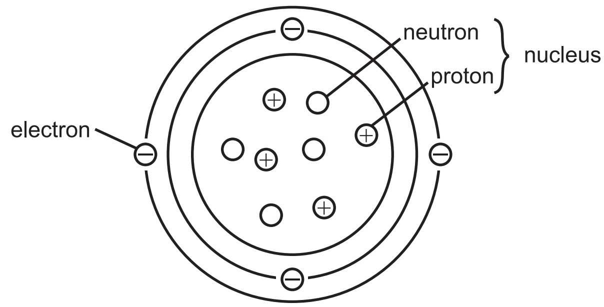
OVERVIEW

Appreciation for the **unity** of life on earth must begin with an understanding of the **diversity** of the building blocks, beginning at the atomic level. More than 90 naturally occurring elements combine in what seems to be an infinite number of ways to produce surprisingly similar classes of chemical compounds, both inorganic and organic. In addition to composition, these substances bond their elements together in a variety of ways. Organisms and organic molecules are complex. Complexity derives from using atoms, information, and energy. On the SAT II Biology test, the student should expect a detailed assessment of the properties, structures, formation, and breakdown of these substances. In addition, the student is expected to know the role and the effect of energy in the interactions between elements and compounds, particularly in the anabolism and catabolism of the chemicals of life. We begin, then, at the atomic level.

CHEMISTRY

ELEMENTS

Elements are forms of matter that cannot be broken down into any simpler form by ordinary means. The more than 100 elements on the periodic chart are distinctly different from one another in discreet ways.



Typical atom (Beryllium)

Atoms

An atom is the smallest part of an element that is still that element and is composed of more than 40 subatomic particles. The three main subatomic particles are the proton, neutron, and electron.

A. Nucleus

Dense center of the atom where most of the mass is concentrated.

1. *Proton*—Positive particle in the nucleus of an atom; its mass is arbitrarily set as 1 for the purpose of calculating the mass of an atom.
2. *Neutron*—Neutral particle in the nucleus of the atom, generally agreed to be a proton and an electron combined. Its mass number is also considered to be equal to 1 for the purpose of calculating the mass of an atom, since the electron is 1/1837 the mass of a proton and is, therefore, not significant in mass calculations.

B. Orbital(s)

1. *Electron*—Negative particle that remains some distance from the nucleus while still being a part of the atom.
2. *Atomic Models*
   - *Planetary*—Abandoned theory that had electrons orbiting the nucleus as the planets in a solar system orbit a central star. For the purpose of writing structural formulae of atoms and compounds, we usually use this model.
   - *Bohr*—Indicated that electrons were discreet packets of energy placed outside the nucleus, depending on their present quantum or energy state.
   - *Electron Cloud Model*—Current theory that states, as best we can determine, the location of the electron is a

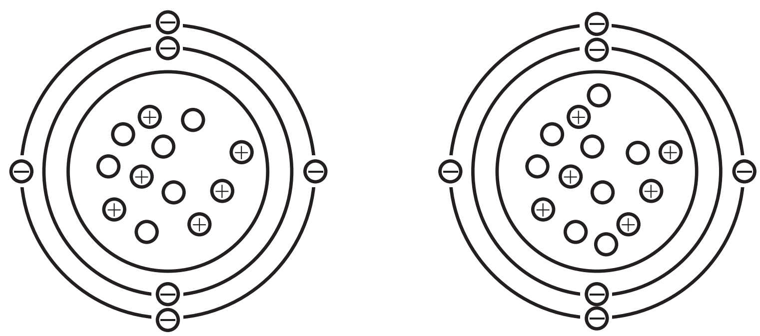
statistical statement, placing it somewhere in a "cloud" surrounding the nucleus, depending on its energy state.

C. Atomic Number

The number of protons in an atom.

D. Atomic Mass

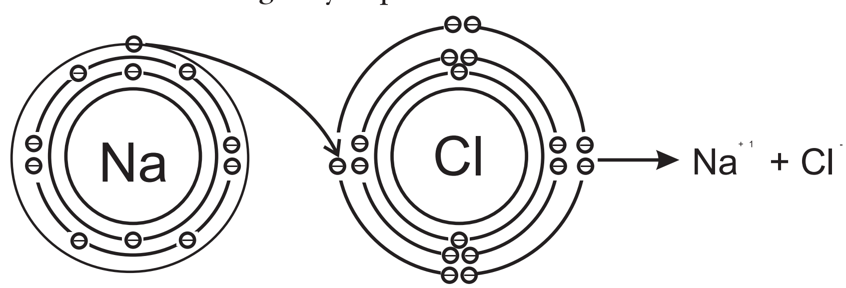
The number of protons and neutrons in the nucleus of an atom. Electrons are not considered in this number. The actual number on the periodic table is an average of the abundance of all the isotopes of each element.



Isotopes of Carbon

E. Isotope

Different form of an atom due to a different number of neutrons. Carbon 12 has six neutrons, while Carbon 14 has eight neutrons. Different isotopes of an element have slightly different properties that are sometimes biologically important.



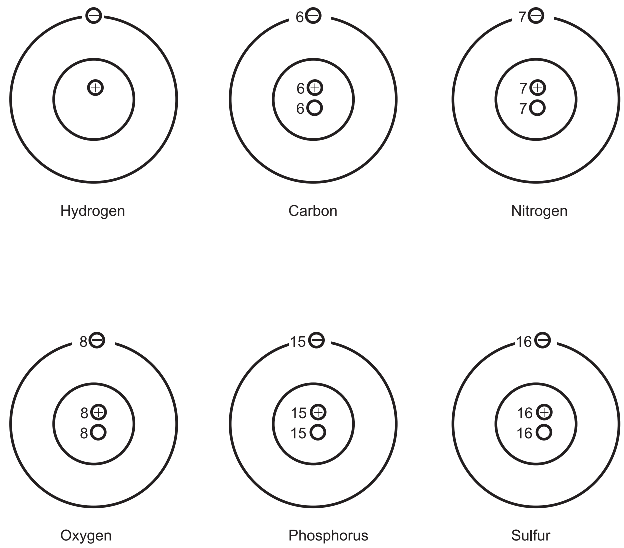
Formation of Ions

F. Ion

Electrically charged atom due to a loss (+ ion) or gain (– ion) of electrons. An ionic bond is an attractive force of oppositely charged ions by virtue of the loss/gain of electrons that takes place between them. As atoms lose electrons and thus become positive, attraction occurs with the atoms that gain electrons and thus become negative.

Some essential atoms

A. Hydrogen
Simplest element that has one proton and one neutron. It combines with oxygen to form water, an essential abiotic substance for living things.



Atoms of Life

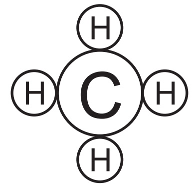
B. Carbon
Ubiquitous element on this planet that forms the basis for all living things. It can form the most number of bonds in chemical combinations.

C. Nitrogen
Essential component of proteins and nucleic acids.

D. Oxygen
Necessary for aerobic respiration to take place and in the formation of many organic molecules.

E. Phosphorous
Necessary for nucleic acid structure and in energy transformations. Also important in membrane structure.

F. Sulfur
Forms sulfide bridges that are found in proteins.



Methane molecule

MOLECULES

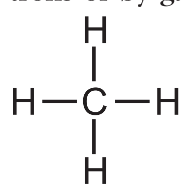
Molecules are a group of chemically combined atoms that are the smallest form of a compound and have the properties of that compound.

Compounds

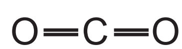
Compounds are chemically combined atoms that form discreet particles in which the atoms lose their individual physical properties, and the compound, as a combined unit, takes on new properties.

Molecular bonds

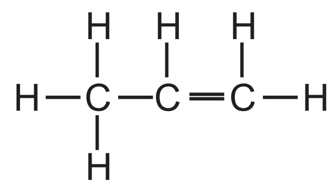
Molecular bonds are the attractive forces of atoms by sharing electrons or by gaining or losing electrons.



Methane



Carbon Dioxide



Propane

A. Covalent

Sharing of pairs of electrons between atoms that may result in single, double, or triple bonds. A single bond, for example, results from the sharing of one pair, thus the reference to "single."

1. *Nonpolar covalent*—Covalent sharing is distributed symmetrically within the molecule.
2. *Polar covalent*—Covalent sharing is distributed nonsymmetrically within the molecule, resulting in weak positive and weak negative charges.

B. Hydrogen bonds

Caused by polar covalent bonding, hydrogen bonds are the weak attractions between slightly positive hydrogen atoms of a molecule and slightly negative atoms, such as oxygen and nitrogen, of another molecule.

C. Ionic bonds
Caused by electrons being pulled off one atom and bonded to the atom that was attracting them.

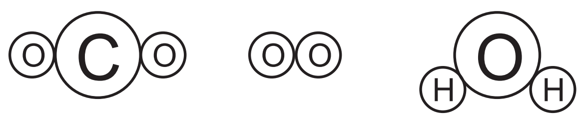
Molecular forces

Molecular forces are forces that affect molecules, including the following:

A. Van der Waals
Attractive forces that occur between electrically neutral molecules because they are so close to each other.

B. Hydrophobic
Clumping together of molecules that are insoluble in water because they are nonpolar.

Some molecules essential to life



Carbon Dioxide Oxygen Water

A. Carbon Dioxide
Carbon and two oxygens bonded in a nonpolar, covalent orientation. This is a highly oxidized, low energy form of carbon.

B. Oxygen molecule
Two atoms of oxygen bonded covalently. Molecular oxygen allows a maximum oxidation of organic molecules in aerobic respiration.

C. Water
One oxygen and two hydrogen atoms bonded polar covalently. Supplies the hydrogen and electrons to initiate the photosynthesis process.

WATER

Water is the essential abiotic molecule for sustaining life. It is essential in photosynthesis, in the maintenance of membranes, and as the solvent for all of life's molecules.

Structure

Two hydrogens with two single, covalent bonds with an oxygen atom forming a polar molecule.

A. Shape

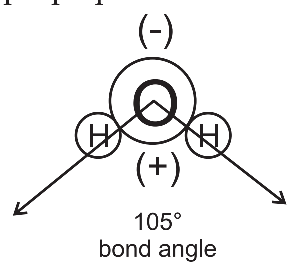
Orientation of the unbonded electrons in the oxygen and the protons in the hydrogen orient them on "opposite sides of the molecule with respect to each other." The bond angles are approximately 105 degrees.

B. H+ bonds

Weak associations between the negative side of the water molecule oxygen and the positive side that the hydrogens create; bonds that hold water molecules together and result in high specific heat; good solvent properties and cohesion that results in a substantial surface tension.

Properties

Water has several unique properties.



Water molecule

A. Polar

The covalent bond orientation results in the slightly positive hydrogens being on one side of the molecule and the unequally unshared electrons from oxygen more often on the other side of the molecule.

B. Cohesion

The dipole nature of the molecule produces bonds between the positive hydrogens and the negative oxygen that, in sum, can be substantial. The result is that water molecules tend to stick together, resulting in a very high surface tension.

C. High Specific Heat

Because of the hydrogen bonds, water absorbs a large amount of heat before it vaporizes.

D. Weak acid/base

Water has a neutral pH of 7.0 and normally dissociates into equal amounts of H+ ions and OH^- ions. It can, therefore, be a weak proton donor (an acid) or a weak proton acceptor (a base).

Acids/Bases

$$\underset{\text{metal}}{H^+} + \underset{\text{nonmetal}}{Cl^-} \longrightarrow \underset{\text{Hydrochloric Acid}}{HCl}$$

Formation of an acid

Acids

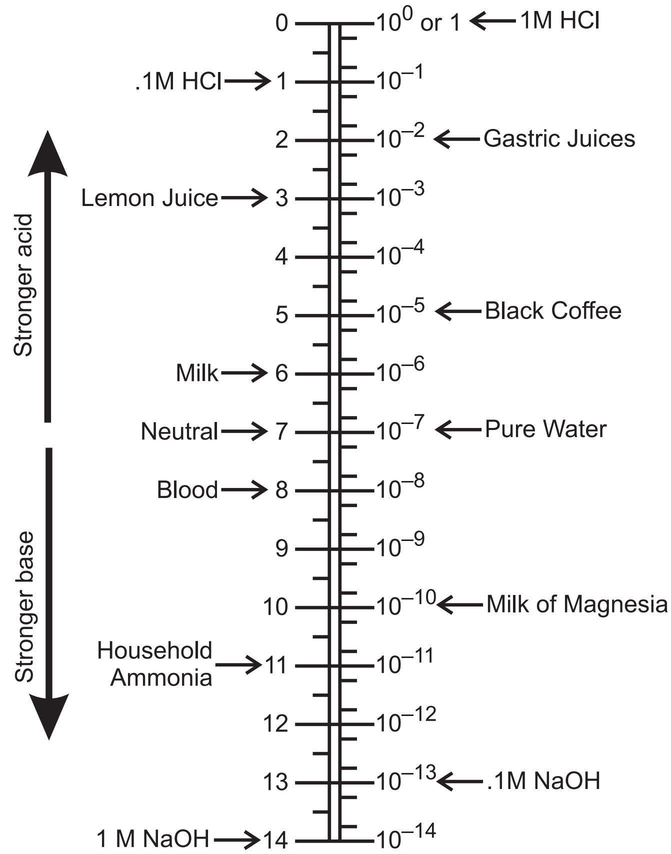
Proton donor; when dissociated in aqueous solutions, acids become sources of protons donated to the reaction.

$$\underset{\text{water}}{H_2O} + \underset{\text{metal}}{Na_2O} \longrightarrow \underset{\text{Base}}{2NaOH}$$

Formation of a base

Bases

Proton acceptor; when dissociated in aqueous solutions, bases become proton acceptors in a reaction.

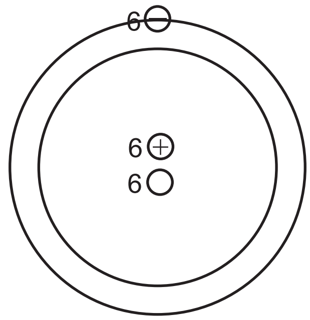


pH Scale

pH

pH is the measure of concentration of hydrogen ions in a solution. The term stands for the *percent concentration of hydrogen ions* and is the negative log of the concentration of hydrogen ions. Thus a lower pH means a higher concentration of H+. (NOTE: Hydrogen ions (H+) and protons are the same thing.) One may also take the inverse of this concentration and thereby arrive at the concentration of hydroxyl ions in solution.

BIOCHEMISTRY



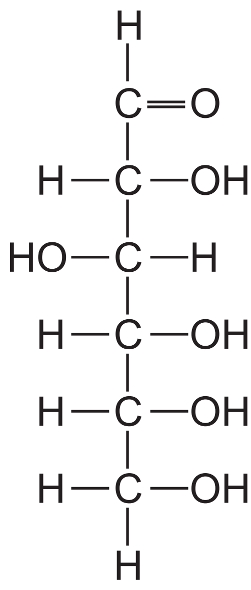
Carbon Atom

CARBON

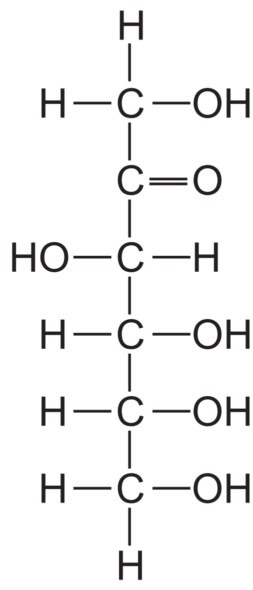
Carbon is the atom that is the basis for life on earth, owing to its versatility. Carbon has four bonding electrons that make it capable of forming many complex molecules. The *chemistry* of life is the chemistry of carbon. The *macro molecules* of life are carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates

Carbohydrates are macro molecules that organisms create for energy storage, such as glycogen, or as structural components, such as cellulose. Their basis is carbon, hydrogen, and oxygen in a 1:2:1 ratio, thus the original term of hydrated carbon or carbohydrate.



Glucose



Fructose

A. Monosaccharides

Simple sugars made up of a backbone of usually three to seven carbons with the formula of CH_2O. When combined to produce polysaccharides, they give off water at each bonding site in a reaction known as dehydration synthesis.

1. *Glucose*—Preferred energy molecule of life. It is produced in chloroplasts in the process of photosynthesis that stores energy from the sun in organic molecules and is broken down in the process of aerobic respiration that releases energy.
2. *Fructose*—Fruit sugar with the same molecular formula as glucose but different structural formula. When combined with glucose in a dehydration synthesis reaction, the two form sucrose.

B. Disaccharide

Complex sugars formed from the union of two monosaccharides in a condensation reaction.

Condensation

Condensation is also called dehydration synthesis. When two monosaccharides bond together to form a disaccharide and a water molecule is produced, then two hydrogens and one oxygen are removed from the two simple sugars and form into a water molecule in the process. Complex organic molecules are created by assembling a small number of simple subunits in many different ways, analogous to forming many words from the 26 letters of the alphabet. The assembly of complex molecules from simple subunits is by so-called "dehydration synthesis" or "condensation reactions" (the same thing). When the small subunits are combined, a hydrogen atom (H) is removed from one and a hydroxyl group (OH) from the next. These atoms combine to make a water molecule (HOH), and the subunits become covalently bonded. The opposite process is called hydrolysis (water splitting) and releases the simple subunits from the molecule. This occurs, for example, during digestion.

Hydrolysis

Hydrolysis is the opposite of condensation; it occurs when carbohydrates, for example, are metabolized. Two hydrogens and one oxygen are ultimately inserted into the polysaccharide to cleave it into two simpler carbohydrates. For each cleavage, one water molecule is needed.

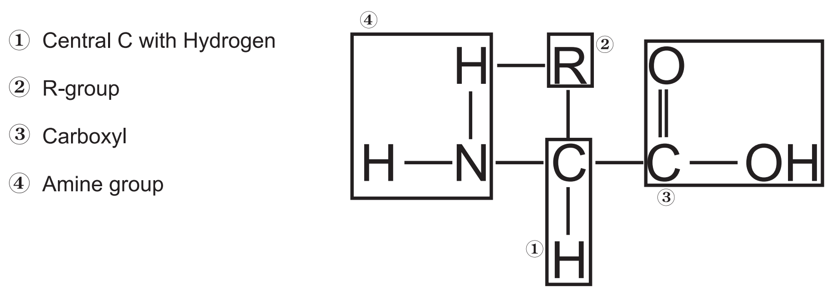
A. Polysaccharide

Carbohydrate formed from a number of simple sugars; the typical storage and structural form of carbohydrate in autotrophs. Polysaccharides are less diverse than DNA or proteins and are often long chains of a single monosaccharide, such as glucose (e.g., starch, cellulose, and glycogen).

1. *Starch*—Plant polysaccharide that is almost insoluble in water. In autotrophs, glucose may be quickly converted to starch in order to conserve glucose, which is soluble in water.
2. *Cellulose*—Largest carbohydrate molecule is insoluble in water and can be metabolized primarily by bacteria and fungi. An autotroph structural molecule, it is nonetheless important to heterotrophs in that it aids in digestion.
3. *Glycogen*—The heterotroph analog to starch, it is used to store energy in animals.

Proteins

One of the main structural as well as functional molecules in living systems, protein comes from chains of amino acids bonded together. It is found embedded in plasma membranes, acting as a catalyst, or as part of the structural integrity of many parts of living systems. In addition to the C, H, N, and O mix of living systems, they also contain S. Proteins are assembled from 20 different amino acids.



Amino acid

A. Amino acids

Main building block of polypeptides.

1. *Backbone*—Amino acids are built around a carbon center that has a hydrogen attached to one of the four covalent bonds of the central carbon.
2. *R-group*—Occupies a second of the four covalent bonds of the central carbon and can be as simple as a hydrogen or a complex ringed structure. There are 20 R-groups on the 20 amino acids that combine to form proteins.

3. *Carboxyl group*—COOH complex attached to a third spot on the central carbon.
4. *Amine group*—NH complex attached to the fourth covalent bond on the central carbon.

B. Polypeptides

Built up of strings of two or more amino acids that are bonded together as a result of condensation.

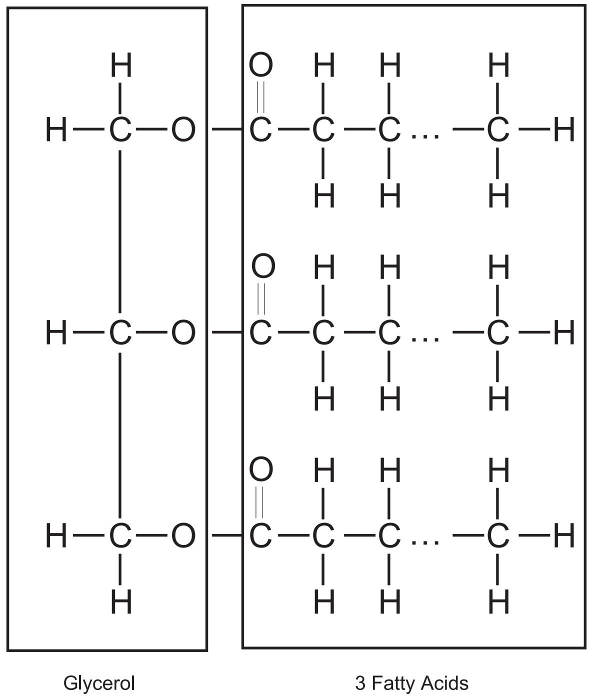
C. Protein structures

Four different ways in which proteins are structured:

1. *Primary*—The number, type, and sequence of amino acids forming a linear structure.
2. *Secondary*—Repetition of amino acid sequences and, therefore, bond angles that give the linear primary structure molecule a repeating structural pattern.
3. *Tertiary*—Folding pattern of the chain that relates to the underlying secondary structure and gives the molecule a three-dimensional shape.
4. *Quaternary*—Fitting together of two or more independently folded polypeptides that conform to each other to provide a functional protein.

Lipids

Lipids are molecules that store the most energy for living systems; also made up of C, H, and O that are not in a 1:2:1 ratio. Lipids are insoluble in water but soluble in nonpolar substances. Fats are examples that have three fatty acid residues attached to a glycerol backbone. Lipids are often assembled from fatty acids and an alcohol.



Fat Molecule

A. Fats

Three fatty acids bonded at their carboxyl site to the hydroxyl site in a molecule of glycerol and often referred to as a triglyceride. They are either saturated and contain all single covalent bonds between carbon atoms in the fatty acids or are unsaturated and contain at least one double covalent bond.

B. Oils

Esters of open-chain hydrocarbons that are liquid at room temperature. An ester is usually formed by the reaction between an acid and an alcohol with elimination of water.

C. Waxes

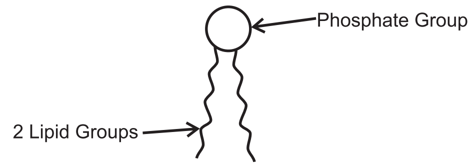
Esters of long chain fatty acids and long chain alcohols. They have low melting points but are solids at room temperature.

D. Steroids

Fashioned on a backbone of four linked carbon rings and include cholesterol and hormones.

E. Phospholipids

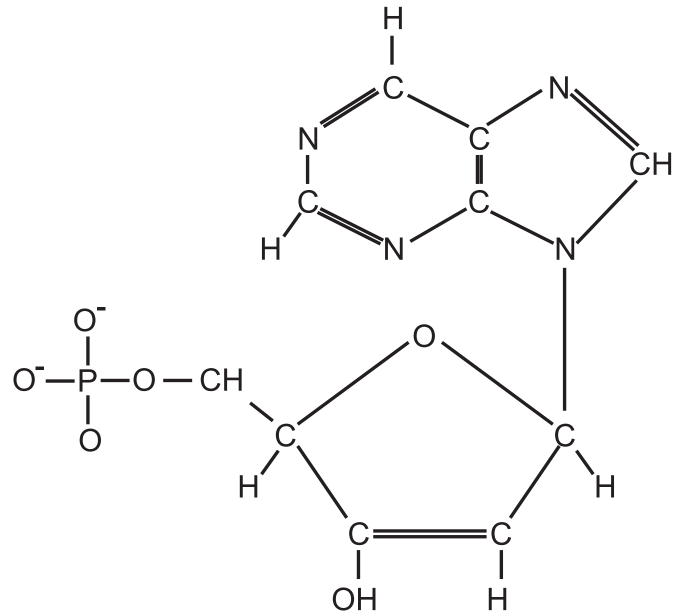
Composed of two fatty acids (the hydrophobic side of the molecule) and a phosphate group (the hydrophilic side of the molecule). Found in plasma membranes of cells as two layers of molecules (bilayer) where the hydrophobic ends are oriented to both the inside of the bilayer and the outside of the bilayer.



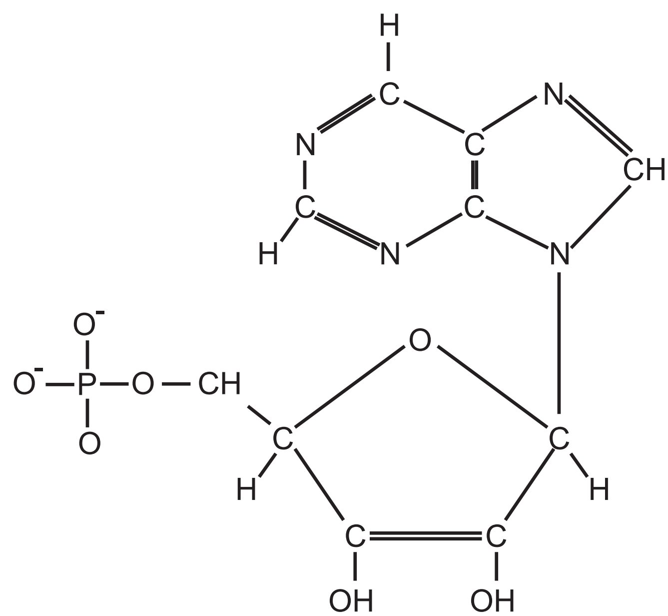
Phospholipid Molecule

Nucleic Acids

Nucleic acids control molecules of life that contain or carry the codes for all the molecules that a particular cell needs. In addition, they carry the code for making new cells of a like kind—the key to heredity. Their building blocks are known as nucleotides and are composed of a 5-carbon sugar, a phosphate group, and a nitrogenous base. Their almost infinite variability lies in the unique sequences of their nucleotides. RNA and DNA are two types of nucleic acids.



Deoxyribonucleic Acid



Ribonucleic Acid

A. DNA (double helix)

Nucleic acid that contains the 5-carbon sugar known as deoxyribose, which denotes less oxygen than the ribose sugar. This molecule is the basis for genes and chromosomes. DNA is assembled from only four nucleotides (adenine, thymine, cytosine, guanine), but the code is millions of nucleotides long.

B. RNA (single stranded)
Nucleic acid that contains the 5-carbon sugar known as ribose, which denotes more oxygen than the deoxyribose sugar. It is the molecule that carries the DNA code to the ribosome in cells and helps in fashioning proteins. In the code, uracil replaces thymine in RNA.

Chemical reactions

Interactions among chemicals fall into five categories and are characterized by an alteration of the structures involved as well as their energy levels. An organism that is properly nourished has the atoms/molecules it needs. The information for its complexity comes from DNA. The energy comes from manipulating oxidation/reduction reactions. Oxidation is the loss of electrons and, therefore, the loss of the energy of those electrons. In biological systems, this is usually the result of adding oxygen to a molecule or removing hydrogen. In cellular respiration, energy is removed from organic molecules by removing hydrogen atoms. Carbon is discarded in its most oxidized form, CO_2. Reduction is the opposite of oxidation. Thus, every chemical reaction oxidizes something and reduces something else. Reduction can be the loss of oxygen or the gain of hydrogen. Biological molecules are highly reduced and, therefore, have lots of hydrogens and are complex. The business of being alive is to maintain reduced molecules in an oxidizing environment. In other words, we eat to stay reduced.

Synthesis
The combination of two or more substances (atoms or molecules) that results in the making of another substance unlike the original components.

Decomposition
Breakdown of a substance into its component parts; it is the opposite of synthesis.

Single replacement
One part of a substance is replaced by another.

Double replacement
Similar to single replacement, except the exchange results in two new compounds as a result of the replacement in two substances, not one.

Equilibrium

Results when conditions produce no net changes in amounts of reactants and products. This can be altered by the addition of reactants, products, or any one of a number of physical aspects of the reaction, such as temperature or acidity.

Free energy

Becomes available for work as a result of a reaction.

A. Exergonic

Release of energy during a reaction that is spontaneous.

B. Endergonic

Absorption of energy during a reaction that is nonspontaneous.

Enzyme

Organic catalysts (completely or partially proteins) that alter the amount of energy needed to initiate a reaction, usually accelerating a reaction. They take part in the reaction but are not altered by it.

Coenzyme

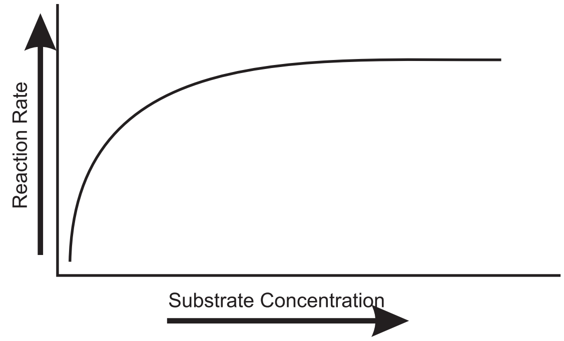
Works with an enzyme to complete the catalytic reaction and consists of either a metal or nonprotein organic molecules. Vitamins can be coenzymes.

Co-factor

Any organic or inorganic substance that is needed for the operation of an enzyme.

MULTIPLE-CHOICE QUESTIONS

1. In the reaction rate versus substrate concentration graph below, the curve plateaus because



Energy curve for Reaction Rate
versus Substrate Concentration

(A) a noncompetitive inhibitor is present.
(B) a competitive inhibitor is present.
(C) all the substrate has been converted to product.
(D) the active site is saturated with substrate.
(E) the cofactor is locked in an inactive conformation.

2. Which of the following terms does NOT refer to an example of a weak force of interaction between two molecules?

(A) covalent bond
(B) Van der Waals bond
(C) hydrophobic bond
(D) electrostatic bond
(E) hydrogen bond

3. The element found in all amino acids that is NOT found in carbohydrates is

(A) sulfur.
(B) carbon.
(C) oxygen.
(D) hydrogen.
(E) nitrogen.

4. Which of the following would NOT have hydrophilic properties?

(A) OH
(B) molecules in aqueous solution
(C) long hydrocarbon chains
(D) ionized molecules
(E) polar molecules

5. Which if the following is NOT found in DNA?

(A) uracil
(B) thymine
(C) phosphate
(D) adenine
(E) deoxyribose sugar

6. Elements used for making molecules found in living systems must

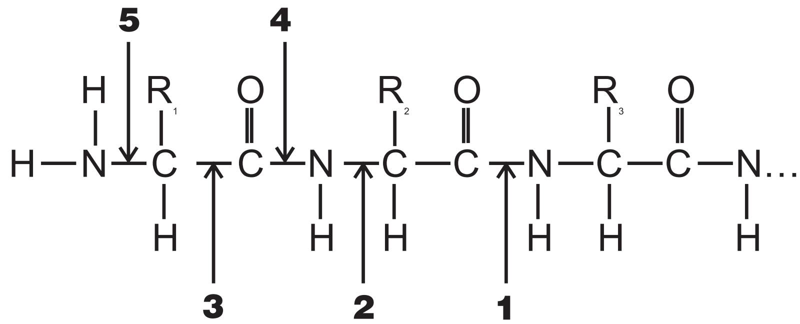
(A) contain nitrogen and sulfur.
(B) be hydrophilic.
(C) be covalent.
(D) be water soluble and ionic.
(E) be suitable and available.

7. Which of the following is NOT a property of water?

(A) hydrophilic properties
(B) hydrophobic properties
(C) very good solvent
(D) density as a solid is less than that as a liquid
(E) strong surface tension

8. Which of the following are weak forces usually associated with biological molecules?

(A) hydrogen bonds
(B) electrostatic interactions
(C) covalent bonds
(D) ionic bonds
(E) both (A) and (B)



9. Which arrow(s) point to a peptide bond?

(A) 1

(B) 1 and 4

(C) 2

(D) 3

(E) 2 and 5

10. A polypeptide that is ten amino acid units long is split into several small fragments, and the sequences of some of the fragments are discovered. The fragments are lys-trp-arg, lys-asp-ala-gly, pro-gln-his-lys, and arg-pro-gln. What was the primary source of the polypeptide?

(A) ala-gly-ser-gln-lys-trp-arg-pro-gln-his

(B) asp-ala-gln-ser-gln-his-lys-trp-arg-pro

(C) ala-gly-pro-gln-his-lys-trp-arg-pro-asp

(D) lys-trp-arg-pro-gln-his-lys-asp-ala-gly

(E) gly-ala-asp-lys-his-gln-pro-arg-trp-lys

Explanation of Answers for Multiple-Choice Questions

1. The correct answer is (D). A reaction in which the enzyme is the catalyst may be written as follows:

Enzyme + Substrate ↔ Enzyme-Substrate complex ↔ Enzyme + Product

The substrate binds to a specific site on the surface of the enzyme, known as the active site, after which product and enzyme are released. The enzyme is then available to bind another substrate. At low substrate concentration, the reaction rate increases sharply with increasing substrate concentration because there are abundant free enzyme molecules available to bind to an added substrate. At high substrate concentration, the reaction rate reaches a plateau as the enzyme active sites become saturated with substrate. The enzyme-substrate complex and no free enzymes are available to bind the added substrate.

2. **The correct answer is (A).** All of the choices except choice (A) are weak forces in biological systems. Covalent bonds involve a sharing of electrons, which leads to a strong interaction between molecules. In large numbers, some of the forces listed can produce strong binding in molecules, but taken individually, they cannot compare to the strength of a covalent bond.
3. **The correct answer is (E).** Amino acids derive their name from the amine group that bonds to one of the four covalent bonds of the central carbon atom. The amine group consists of one nitrogen and two hydrogens and is found in all molecules known as amino acids. The amine group forms a peptide bond with the COOH complex of an adjoining amino acid in the construction of a polypeptide.
4. **The correct answer is (C).** Any substance with electrical charges will exhibit hydrophilic or "water loving" properties and interact with water forming hydrogen bonds. Ionized molecules are charged molecules, as are polar molecules. The long hydrocarbon chains on molecules of that nature distribute any charge they might have uniformly over the chain, thus rendering the chain nonpolar and thus nonresponsive to the polar nature of water necessary for hydrophilic properties in the molecule.
5. **The correct answer is (A).** Choices (B) through (E) are all present in DNA. Thymine and adenine are two DNA bases and make up one of the three components of nucleic acids, namely nucleotides. These consist of a base, a 5-carbon sugar, and a phosphate group. The sugar in DNA lacks an oxygen and is called deoxyribose sugar. Uracil is unique to RNA, as is the 5-carbon ribose sugar not listed here.
6. **The correct answer is (E).** All of the choices listed are found in one or more biologically significant molecules, but choice (E) must be true of all biologically significant molecules. They must be correct for the "job," and they must be within reach of the living system that needs them. Not all molecules contain nitrogen and sulfur, nor are they attracted to water. In addition, they are not all covalent substances.
7. **The correct answer is (B).** Choice (B) translates to "water fearing" and, therefore, is a logical impossibility since it would describe water as not binding with water. The hydrophobic as well as the hydrophilic nature of a molecule is used to describe the interaction another molecule has with water. More importantly, it describes a situation that would not have a polar nature, which water does. Hydrophilic *would* be explained by the

polar nature of water and refer to the fact that it attracts polar substances. Choices (C) through (E) also reflect interactions that result from the polar nature of water.

8. **The correct answer is (E).** The hydrogen bonds formed in biological molecules refers to the positive nature of available hydrogens, such as those found in the bases of nucleic acids, that promote the nucleotide base pairing. In addition, electrostatic forces are often associated with molecule-molecule binding, such as that found in enzyme substrate complexes. Finally, choices (C) and (D) represent large forces and, therefore, do not fit the nature of the question posed.

9. **The correct answer is (B).** A peptide bond, formed when two amino acids are joined, occurs at the site where the amino group—NH_2—of one amino acid and the carboxyl group—COOH—are bonded. One H^+ of the amino group is removed and coupled with an OH^- from the carboxyl group to form water, which is removed from the molecule, leaving two amino acids bonded together. Choice (B) indicates the arrows that show these bonding situations.

10. **The correct answer is (D).** Assembling the four fragments in the following way:

```
lys-trp-arg
        arg-pro-gln
            pro-gln-his-lys
                        lys-asp-ala-gly
```

lys-trp-arg-pro-gln-his-lys-asp-ala-gly

indicates that choice (D) is the correct answer.

VOCABULARY

acidic
adhesion
amino acids
atom
basic
carbohydrates
cellulose
chemical reaction
cohesion
compound
condensation
dehydration synthesis
deoxyribonucleic acid
dipeptide
disaccharides
electron
elements
fat
glucose
glycogen
hydrogen bonds
hydrolysis
hydrophilic
hydrophobic
lipids
monosaccharides
neutron
nucleic acids
nucleotides
nucleus
organic compounds
oxidation
peptide bond
phospholipids
pH scale
polypeptide
polysaccharides
protein
proton
reactants
reduction
ribonucleic acid
specific heat
starch
synthesis

Chapter 2

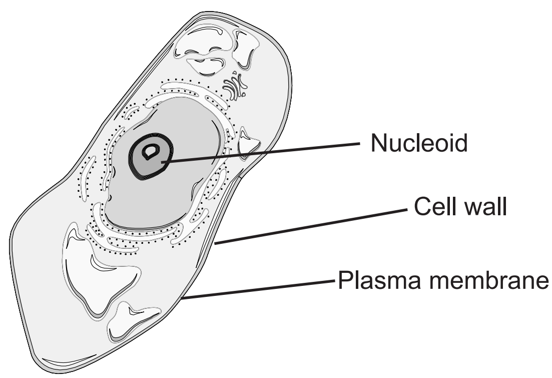
CELLS—ORGANIZATION AND REGULATION

OVERVIEW

Cells are the basic unit of living things. The student should demonstrate a knowledge of the structure and function of cells as well as a detailed knowledge of the cell organelles. This area includes the way that cells divide and produce the next generation of cells. The student should be able to compare and contrast mitosis and meiosis with ease, including the phases of the cell cycle. A brief discussion of the regulatory mechanisms involved in the life of the cell is included. To begin with, we define the cell and discuss the cell organelles.

CELL TYPES

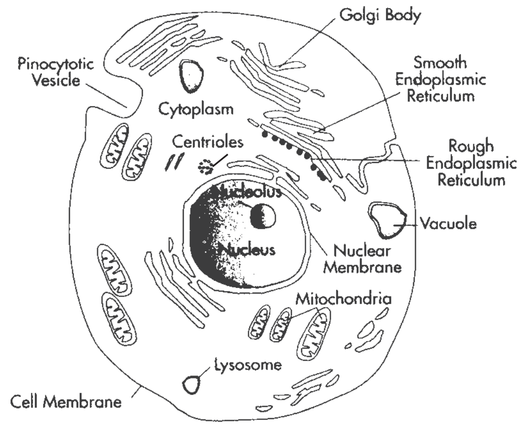
The principle types of cells on earth are the prokaryotic and eukaryotic. Viruses are not considered living things by many scientists.



Prokaryotic Cell

PROKARYOTIC

Prokaryotic cells lack the membrane-bound organelles found in eukaryotic cells and consist of the Archaebacteria and Eubacteria. They generally have a plasma membrane, a single DNA molecule not coupled with protein molecules, small ribosomes, cytoplasm, and a cell wall. If they possess flagella, they are different from the eukaryotic flagella and cilia. There are two very different kinds of prokaryotic cells, those called bacterial (including cyanobacteria or blue-green algae) and those called Archaea. Many Archaea can tolerate extremes of temperature, pressure, pH, and salinity. Prokaryotes have a much simpler structure than eukaryotes.



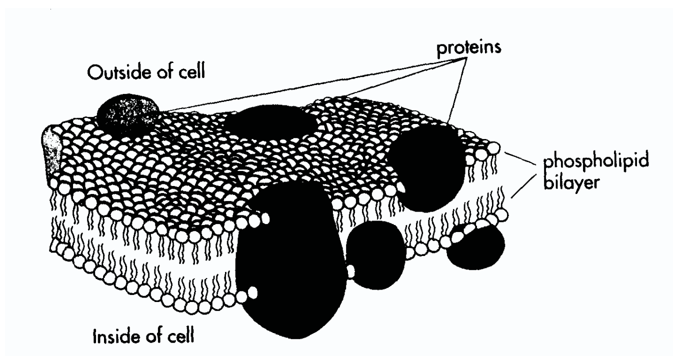
Eukaryotic cell

EUKARYOTIC

Eukaryotic cells contain some or all of the components listed below and are found in or compose all of the non-prokaryotic living things. Evolutionarily, they are "younger" than the prokaryotes.

Membrane

Encloses the material in the cell and regulates the passage of material into the cell from the surrounding environment.



Cross-section of cell membrane
showing fluid-mosaic nature

A. Fluid mosaic model

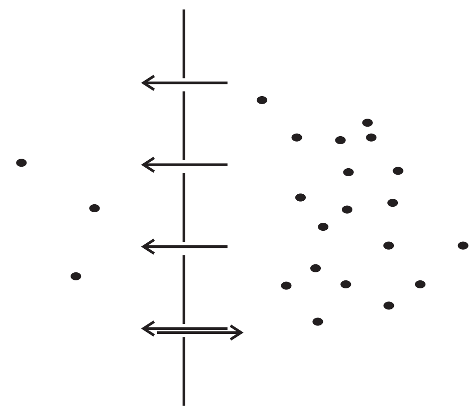
Describes a phospholipid bilayer as the foundation of a plasma membrane. The polar, hydrophilic end lies on the outside of the bilayer, and the nonpolar, hydrophobic end lies on the inside. Embedded in the bilayer are cholesterol and a variety of protein molecules, and carbohydrates are located on the outside of the membrane.

1. *Channel (transmembrane) proteins*—provide for the passage of certain water-soluble substances across the membrane.
2. *Electron transfer proteins*—transfer electrons from one molecule to another.
3. *Receptor proteins*—sites that act as receptors for trigger molecules that cause a cell response within the cell.
4. *Recognition proteins*—recognize and help in some cells sticking to other cells.
5. *Transport proteins*—use energy from ATP to transfer material across the membrane in a process called active transport.

B. Transport across the membrane

There are a variety of instances in which substances need to be transported across the membrane, both in and out. Some molecules diffuse through the membrane, and others require special transport proteins.

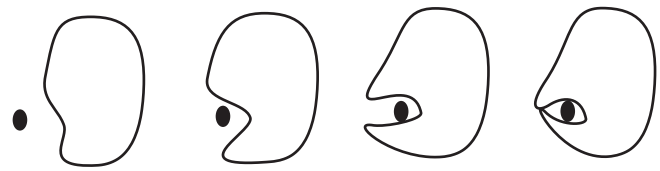
1. *Selectively permeable membrane*—any membrane through which only certain substances can pass. This process is dictated by several factors as explained below.



Diffusion

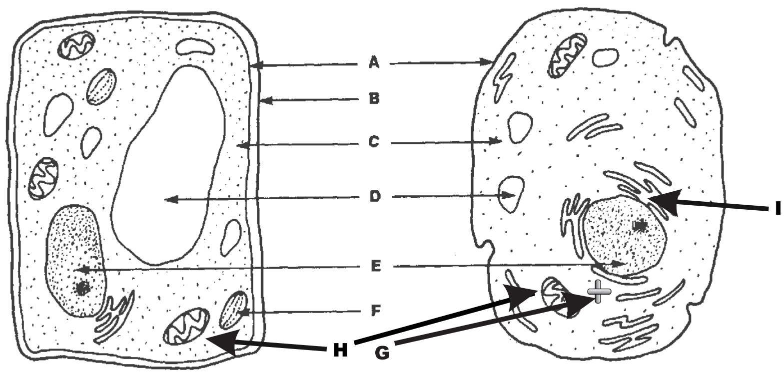
2. *Diffusion*—random movement of particles from an area of greater concentration to an area of lesser concentration, producing a diffusion gradient
3. *Osmosis*—diffusion of water
4. *Plasmolysis*—osmosis directed outward from the cell and leads to cell collapse

5. *Facilitated diffusion*—diffusion of water-soluble substances aided by channel proteins
6. *Active transport*—energy aided transport using ATP and transport proteins in the membrane
7. *Exocytosis*—movement of substances out of the cells within membrane vesicles, which release to the exterior of the cell
8. *Endocytosis*—movement of substances into the cell within the cell membrane



Phagocytosis

- Phagocytosis—plasma membrane engulfs an undissolved substance (usually whole cells or cell parts) too large to pass through the membrane.
- Pinocytosis—plasma membrane engulfs a dissolved substance—and therefore water as well—too large to pass through the membrane.



A - cell membrane
B - cell wall
C - cytoplasm
D - vacuole
E - nucleus
F - chloroplast
G - centrioles
H - mitochondria
I - endoplasmic reticulum

Typical Cell Organelles

Cell organelles

Cell organelles are specialized structures within the cell that house specialized functions.

A. Cell walls

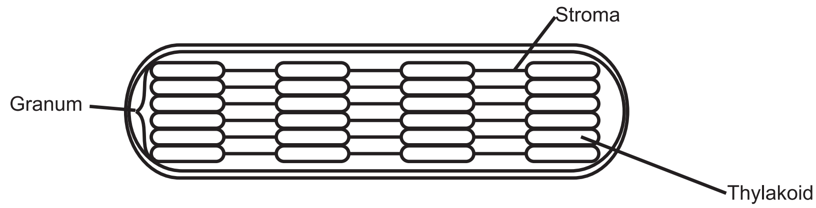
While not strictly an organelle, cell walls are found only in plants, fungi, some protists, and some bacteria; they consist mainly of cellulose in plants and help control osmotic uptake of water.

B. Centrioles

Give rise to spindle fibers that aid in mitosis. Almost exclusively found in animal cells.

C. Chloroplasts

The site for photosynthesis in plants cells, they contain photosynthetic pigments, including chlorophyll.



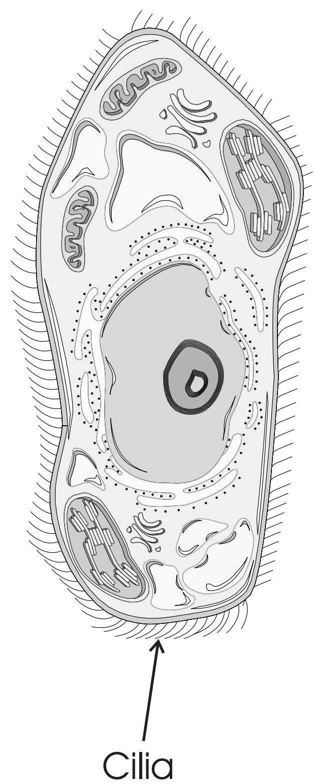
Chloroplast

D. Chromosomes

Genetic material in the nucleus of the cell, they pass on hereditary information and regulate the cell through the production of proteins.

E. Cilia and flagella

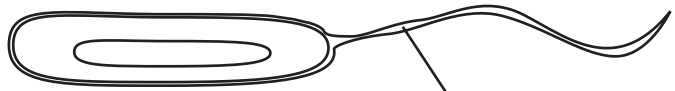
Have the same construction and aid in the movement of individual cells or movement of water past cells that are part of tissues, like lung epithelium.



F. Endoplasmic reticulum (ER)

Both smooth (no ribosomes embedded) and rough (ribosomes embedded) ER. The rough ER is the site where ribosomes make proteins for use in the cell and for export from the cell with the aid of the various RNAs. Smooth ER makes lipids and detoxifies enzymes.

G. Flagella
Longer than cilia but of the same material, they aid the cell in movement with a wave-like motion.



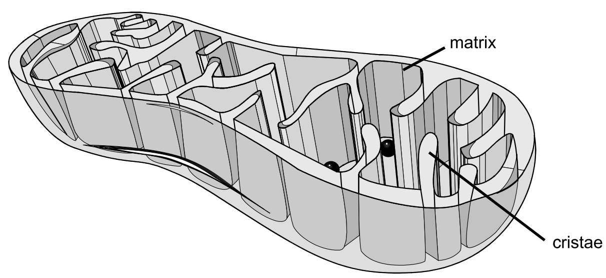
H. Golgi bodies
Also known as Golgi complex or apparatus, they are the site where proteins are modified and other proteins are packaged for release from the cell.

I. Lysosomes
Contain digestive enzymes that metabolize substances for the cell, and even the cell itself, if it ages too much.

J. Microfilaments
Aid in the movement of substances in the cells as well as helping cells that change shape to move.

K. Microtubules
Provide support for the cell. Microtubules and microfilaments comprise the cytoskeleton of eukaryotic cells.

L. Mitochondria
The "powerhouse" of the cell, it is the site of ATP synthesis only in aerobic respiration on the enfolded, inner membranes, which are known as cristae.



Mitochondrion

M. Nucleolus
A densely staining region of the nucleus where there are multiple copies of genes for making ribosomes. It contains rRNA.

N. Nucleus
A double-phospholipid-bilayer-bounded control center of the cell. It contains DNA, proteins known as histones, and the nucleoli.

O. Peroxisomes
Organelles that break down substances in cells, usually toxins.

P. Ribosomes
The site of protein synthesis in the cell, they are composed of ribosomal RNA.

Q. Vacuoles
Usually found only in plant cells in the form of large storage areas.

Plant cells

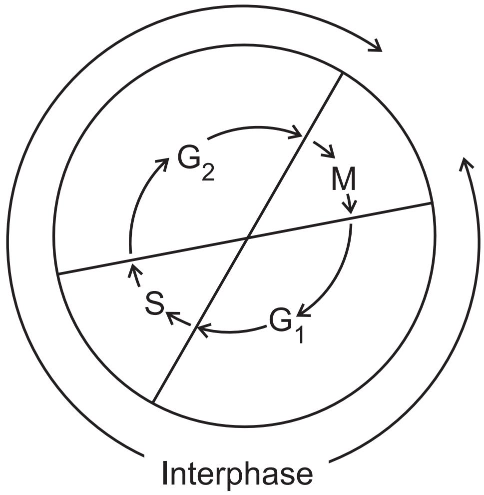
Plant cells have an outermost cell wall that provides support but is primarily for osmotic control, chloroplasts where photosynthesis takes place, and a large vacuole filled with cell sap that contributes to the rigid nature of plant cells.

Animal cells

Animal cells have centrioles that take part in cell division; some have flagella or cilia, as do some plant cells, and some are able to engulf solid matter.

Cell cycles

There are three stages in the reproductive cycle of every eukaryotic cell: interphase, karyokinesis, and cytokinesis. Interphase and karyokinesis comprise a sequence of events called the cell cycle that includes growth and replication of DNA. When cells divide to make other cells, it is necessary for them to copy their DNA so that daughter cells will each have a full set of information for controlling the cells' activities. The replication of eukaryotic cells is described by the cell cycle. In a typical multicellular eukaryotic organism, some cells will be actively dividing (in the cell cycle), such as skin cells in humans, and some will not. During the cell cycle, cells grow, replicate their DNA, grow some more, and then direct equal copies of their DNA (chromosomes) into two groups that will become the two nuclei of the daughter cells. Usually, the cell divides immediately (cytokinesis), but that process is not connected to mitosis. Often, mitosis occurs without cytokinesis, resulting in cells with more than one nucleus.

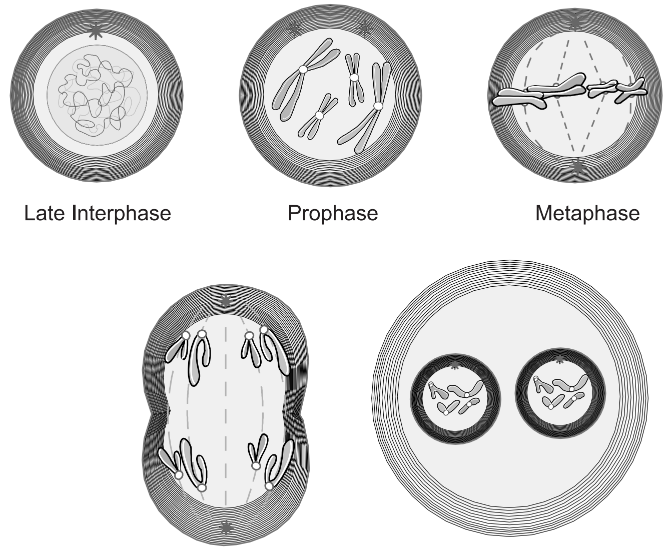


Cell cycle

A. Interphase

Formerly thought to be the resting phase of mitosis since little could be seen happening, it is actually a very active phase in the life of the cell. It includes two growth phases, known as G1 and G2, and an S phase. Following these phases, the cell undergoes mitosis, or an M phase, when karyokinesis occurs, followed soon thereafter by cytokinesis.

1. *G1*—primarily a growth phase of the cell.
2. *S*—growth and duplication of DNA.
3. *G2*—growth and preparation for karyokinesis (mitosis).
4. *M*—the four stages of mitosis (karyokinesis) followed by cytokinesis.

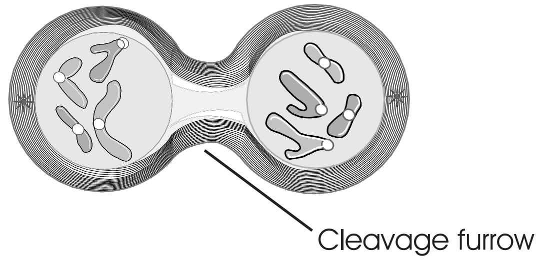


Mitosis

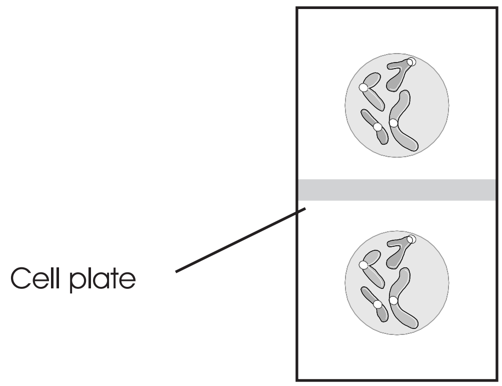
B. Mitosis

Division of the nucleus of a cell that is identifiable in the life of the cell as four visible phases that take place: prophase, metaphase, anaphase, and telophase.

1. *Prophase*—activity in the cell is indicated by a disappearance of the nuclear membrane and the nucleolus, and condensation of the chromosomes begins and is completed by the end of prophase. The spindle, which is composed of microtubules, then forms.
2. *Metaphase*—the chromosomes line up along the metaphase plate of the cell and become attached to the spindles at their central location, known as the centromere.
3. *Anaphase*—sister chromatids of each chromosome separate at their centromeres as the spindles begin to pull them to opposite poles of the cell.
4. *Telophase*—appears almost as the reverse of prophase. The chromosomes begin to unravel and become less visible in the two new daughter cells as the nuclear membrane reappears around them. The nucleolus also reappears. The spindle disappears.



Telophase in animal cell



Telophase in plant cell

C. Cytokinesis

Following the stages of karyokinesis—during telophase specifically—in animal cells, the equator pinches at the cleavage furrow of the two new cells. In plant cells, a cell plate is formed between the two new daughter cells, ultimately producing a new cell wall between the new daughter cells.

MULTIPLE-CHOICE QUESTIONS

1. Identify the correct eukaryotic cell cycle.

(A) G1 to S to G2 to M to cytokinesis
(B) G1 to G2 to M to S to mitosis
(C) G1 to G2 to S to M to karyokinesis
(D) S to G1 to G2 to M to cytokinesis
(E) G2 to M to S to G1 to cytokinesis

2. Which of the following is NOT involved in the synthesis of proteins?

(A) rough ER
(B) smooth ER
(C) Golgi body
(D) ribosomes
(E) RNA

3. Which of the following stages of the cell cycle occurs immediately prior to mitosis?

(A) G1
(B) G2
(C) S
(D) M
(E) cytokinesis

Questions 4–6 refer to the following choices. Decide which best matches the descriptions below.

(A) interphase
(B) prophase
(C) metaphase
(D) anaphase
(E) telophase

4. Chromosomes replicate.

5. Cytokinesis begins.

6. Chromosomes are pulled to opposite poles of the cell.

7. Which of the following produces ATP during aerobic respiration?

(A) chloroplast
(B) nucleus
(C) ER
(D) mitochondrion
(E) ribosomes

8. If the concentration of a solute differs across a membrane permeable only to water, water will move across the membrane by

(A) facilitated transport.
(B) osmosis.
(C) phagocytosis.
(D) active transport.
(E) exocytosis.

9. The ______________ is a rigid structure that gives the cell support in plants.

(A) vacuole
(B) cell wall
(C) microfilament
(D) nucleus
(E) centriole

10. Which of the following often distinguishes plant cells from animal cells?

(A) centrioles
(B) nucleus
(C) chromatin
(D) rough ER
(E) bilayer plasma membrane

Explanation of Answers for Multiple-Choice Questions

1. The correct answer is (A). Following cytokinesis, the cell that continues in the cell cycle immediately goes through a growth phase (G1), followed by a phase that involves continued growth as well as replication of the DNA (S), followed by continued growth and preparation for mitosis (G2) after which mitosis—karyokinesis—occurs (M), often (but not always) ending with cytokinesis or dividing off of the cytoplasm between the two new daughter cells.

2. **The correct answer is (B).** Rough ER is the site for protein synthesis and has ribosomes embedded, which is why it appears "rough" in electron photomicrographs. The ribosomes, mainly composed of RNA, utilize other RNA—mRNA and tRNA—to synthesize proteins. Ribosomes on the rough ER produce proteins that are passed from the cell; the Golgi body then packages them for this purpose. Smooth ER is used mainly in the making of lipids and detoxifying enzymes.
3. **The correct answer is (B).** Referring back to the answer for question number 1, it is noted that G2 is the phase just prior to the mitosis (M) phase. S is the phase where replication of DNA occurs. G1 phase occurs immediately *after* mitosis, and cytokinesis occurs at the end of mitosis, prior to G1, not mitosis.
4. **The correct answer is (A).** During interphase, which would include phases G1 to S to G2, the cell replicates its chromosomes. Specifically, it prepares for this in G1, it follows through with the replication in S, and it prepares for mitosis in G2. Choices (B) through (E) are the phases of mitosis. By this time, the chromosomes must have already been replicated.
5. **The correct answer is (E).** Of all the phases of mitosis—choices (B) through (E)—telophase, which is at the end, is the end of karyokinesis and marks the imminent division of the cell, or cytokinesis. Interphase is the growth and DNA replication phase. Chromosomes become visible during prophase, line up along the equator of the cell in metaphase (Metaphase—Middle), and begin migrating toward the poles in anaphase.
6. **The correct answer is (D).** As is noted in answer number 5, the chromosomes are pulled, or migrate, to opposite poles during anaphase.
7. **The correct answer is (D).** The site for ATP production, of course, is on the inner membranes of a mitochondrion, known as the cristae. The ER houses the ribosomes and plays a role in protein synthesis, not ATP production. The nucleus is the site that houses the nucleic acids and is also where they are replicated. Chloroplast captures sunlight and traps it in high-energy carbon molecules, the energy of which is then released in the mitochondria to make ATP.
8. **The correct answer is (B).** The movement of water, by definition, across a selectively permeable membrane is by osmosis. Facilitated transport is the movement of substances—sometimes water and a solute—through channel proteins embedded in specific sites in the plasma membrane. Phagocytosis is the wholesale infolding of the plasma membrane to engulf particles too large to pass through the membrane. Active

transport, of course, is the use of energy to facilitate the movement of a substance across the membrane, where the substance, without the addition of energy, would not normally be transported across the membrane. Finally, if the membrane is permeable only to water, the solute will not be transported across the membrane.

9. **The correct answer is (B).** The danger in picking vacuole for the answer is that it is the vacuole and the water in it that create turgor pressure, which does indeed provide for cell support in plant cells. However, taken alone—meaning specifically without water in it—the vacuole actually collapses (the typical wilting of some plants not watered for some time). Microfilaments don't provide for support; they aid in movement. Microtubules have a role in support as a cytoskeleton. Rough ER and the nucleus have no rigidity to them. The cell wall is the constant source of rigidity in plant cells.

10. **The correct answer is (A).** Plant and animal cells both have the structures listed in choices (B) through (E). It is the almost total absence of the centriole in plant cells that distinguishes them from animal cells. The centriole plays a role in animal mitosis, and while plants lack this structure, they nonetheless also go through mitosis.

VOCABULARY

active transport
adenosine triphosphate
anaphase
carrier proteins
cell
cell cycle
cell division
cell sap
cell wall
centrioles
chloroplasts
chromatids
chromatin
chromosomes
cilia
cleavage furrow
cytokinesis
cytoplasm
cytoskeleton
diffusion
endocytosis
endoplasmic reticulum
eukaryotic
facilitated transport
flagella
fluid-mosaic model
G1 phase
G2 phase
Golgi bodies
homologues
interphase
karyokinesis
lysosomes
M phase
metaphase
microfilaments
microtubules
mitochondria
mitosis
nucleolus
nucleus
organelles
osmosis
passive transport
peroxisomes
phagocytosis
phospholipid bilayer
pinocytosis
plasma membrane
prokaryotic
prophase
ribosomes
sodium-potassium pump
S phase
spindle fibers
telophase
vacuoles
vesicles

Chapter 3

ENERGY FOR LIFE—ANABOLISM AND CATABOLISM

OVERVIEW

The currency of the cell is ATP (adenosine triphosphate), and a study in bioenergetics must involve a substantial knowledge of how this molecule—and by default ADP (adenosine diphosphate)—works. The student should study this chapter to achieve an understanding of the importance of coupled reactions: energy released from one is used to drive another reaction. ATP as a source of activation energy in many reactions is a good example. Oxidation as a source of energy to pump H+ ions across a membrane is another. This section briefly describes the formation and breakdown of biological substances, and then it launches into discussions of anabolism and catabolism. You should not fall into the trap that portrays autotrophs as carrying on photosynthesis only and heterotrophs as carrying on respiration only. Autotroph translates roughly into "makes own food." Use of the word "food" indicates that they use the food they make as well; heterotrophs are just fortunate enough to be able to use it also. Autotrophs carry on photosynthesis and respiration—they still need energy when the sun goes down—and heterotrophs carry on respiration only. If there is a group of organisms dependent on another, it is the heterotrophs. To begin our discussion, we start with the building of energy-rich (energy-stored) molecules.

Glucose + Glucose ... + Glucose + energy ⟶ Starch

Starch polymerization (synthesis)

ANABOLISM

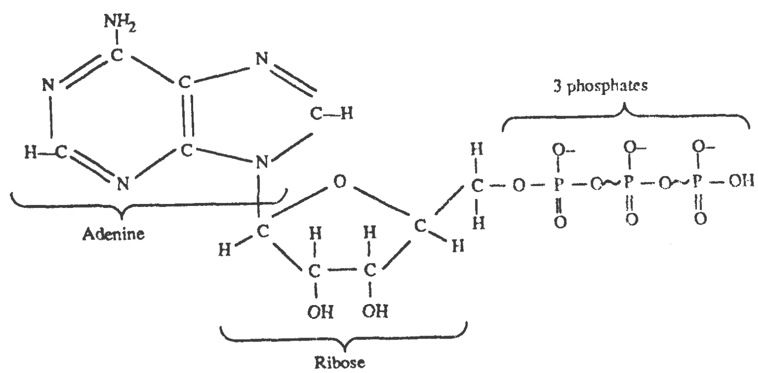
Anabolism is the constructive part of metabolism during which larger molecules are formed. Photosynthesis is one of the primary anabolic series of reactions that result in energy-rich molecules assembled to yield glucose. This occurs in many autotrophs, paving the way for formation of all of the organic molecules of the organism. Any reaction that builds a substance with higher chemical organization than its component parts is anabolic, such as the formation of macromolecules in the production of cell parts and in the production of larger biological molecules from elements such as C, H, N, O, P, and S. Many large biological molecules are the result of the breakdown of even larger molecules, so the student should distinguish between the molecule and the process.

$$C_{20}H_{40} + 60O_{2} \longrightarrow 20CO_{2} + 20H_{2}0 + \text{energy}$$

Catabolism

CATABOLISM

Catabolism is the breakdown phase of metabolism during which energy is released and complex molecules are broken down. Respiration, both aerobic and anaerobic, is one of the primary series of catabolic reactions that result in the release of raw materials that can again be used to supply anabolism and the release of free energy to do work. One example would be the storing of free energy in ATP. The reactions of respiration—catabolic in nature—are coupled with the production of ATPs in the system—anabolic in nature.



Adenosine Triphosphate (ATP)

ATP: THE ENERGY MOLECULE

ATP provides the energy for many biological chemical reactions. It is composed of three distinct parts: a 5-carbon sugar called ribose, an adenine base, and three phosphate groups aligned in a linear fashion, extending from the central, ribose sugar. The three phosphate groups are linked by two easily broken covalent bonds that, when broken, yield the energy for the metabolic processes that occur in the cell. When ATP loses a phosphate group, it becomes adenosine diphosphate, ADP.

Phosphorylation

Phosphorylation is the process by which ADP returns to the high-energy molecule ATP. In an endergonic reaction, energy and a free phosphate are added to ADP to reform ATP.

Sources

It is the formation of these bonds that occurs in the catabolism of energy-rich carbon molecules during respiration. The ATP that is formed in respiration is primarily a carrier molecule for energy.

PHOTOSYNTHESIS

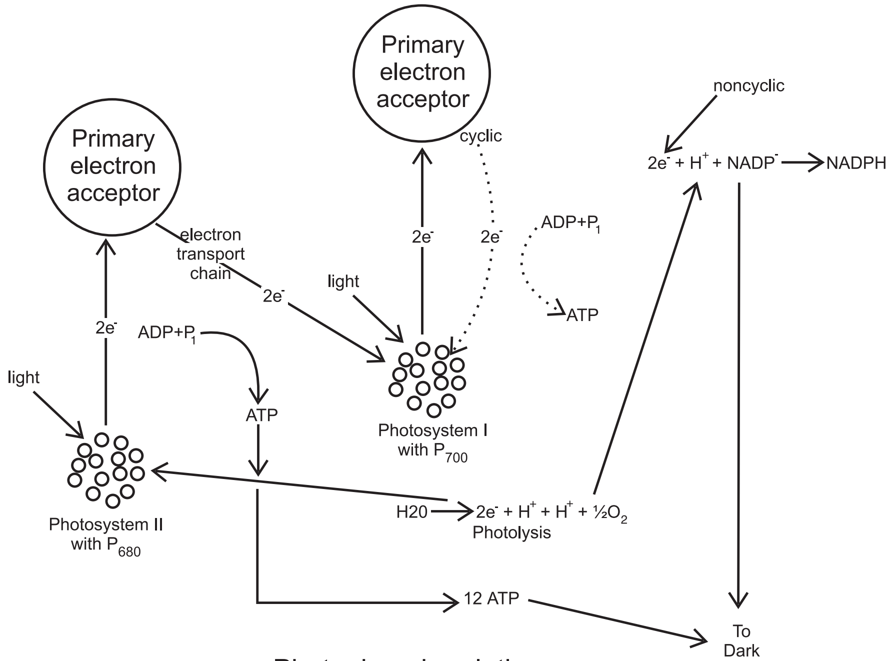
Photosynthesis is the production of high-energy molecules in the presence of light, using carbon dioxide, water, chlorophylls, ATP, NADP, and enzymes. A change in any of these ingredients will, of course, change the rate of the reaction. The overall reaction is given by

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{enzymes}} C_6H_{12}0_6 + 60_2 + 6H_20$$

Summary of Photosynthesis

Chlorophyll

Chlorophyll is actually several light-absorbing pigments—including chlorophylls a and b—found in chloroplasts that are involved in absorbing light energy, which is then passed on to the reaction centers of the photosystems through the use of antenna chlorophylls.



Photophosphorylation

Light Reactions

Light reactions are comprised of reactions that occur in the presence of light in what are called photosystem I and photosystem II. These reactions carry on the phosphorylation that produces ATP. The LR take place in the thylakoids located in the grana of the chloroplasts.

Photosystems I (PS I)

This reaction center contains a chlorophyll molecule, known as P700, which absorbs light energy in the 700-nanometer range and reactivates energy-drained electrons from PS II. These activated electrons reduce $NADP^+$ to NADPH, a carrier molecule that transports both energy and hydrogen to the carbon fixation reactions in what are sometimes known as the dark reactions. It takes part in both cyclic and noncyclic photophosphorylation.

Photosystems II (PS II)

In this reaction center, the chlorophyll molecule known as P680, which has an absorption peak in the 680-nanometer range, is a system by which electrons are activated to help form ATP in the process known as photophosphorylation. The P680 center also takes part in photolysis, which splits water into hydrogen and oxygen ions and replaces the missing electrons from PS I.

Photophosphorylation

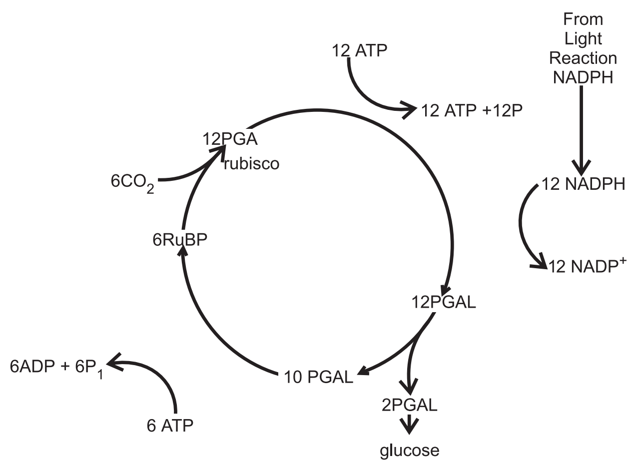
Photophosphorylation is the addition of a phosphate to an ADP molecule making it an ATP molecule. ATP then transports this energy from the light reactions to the dark reactions—the fixation of carbon. As the name suggests, it takes place in the presence of light.

A. Noncyclic

Drives an activated electron to the dark reactions using the energy-carrying molecule ATP and the energy- and hydrogen-carrying molecule of NADP, utilizing both the PS II and the PS I reactions. The electron is not recycled but is replaced by another electron from the ionization of water in PS II photolysis, which produces the hydrogen ions used to make $NADPH_2$ and releases free-oxygen molecules. Thus the electrons are passed from the light reactions to the dark reactions using $NADPH_2$.

B. Cyclic

Involves only the PS I reactions, wherein the electrons leave the reaction center and are passed through a system of carrier molecules and eventually are returned to PS I. ATP is produced at the very end of this cycle.



Calvin-Benson cycle

Dark Reactions

Dark reactions do not utilize the energy directly from light but rather use the energy-rich molecules formed during the light reactions (hence “dark”). Atmospheric carbon dioxide is the source of carbon for the ultimate formation of the energy-rich carbohydrate molecules at the end of the dark reactions known as carbon-fixation.

Calvin-Benson (C_3) cycle

Carbon dioxide enters the Calvin-Benson cycle by combining with a 5-carbon sugar known as ribulose biphosphate (RuBP, see previous page). RuBP and the "fixed" CO_2 form an unstable compound and thus the cycle continues with the splitting of RuBP into two 3-carbon—thus the C_3 pathway—molecules known as phosphoglyceric acid (PGA), which converts eventually to phosphoglyceraldeyde (PGAL) that is ultimately converted to the 6-carbon molecule glucose.

C_4 pathway

In hot, dry climates, plants have evolved a very efficient method of sugar production called the C_4 pathway, since it initially involves fixing CO_2 by forming a 4-carbon molecule before entering the Calvin cycle.

CAM pathway

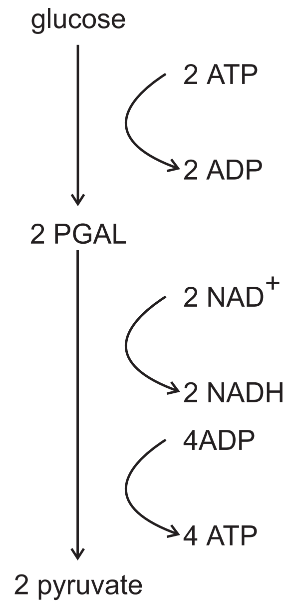
Another efficient method of fixing carbon in some climates with hot, dry days and cool nights, the CAM pathway is almost identical to the C_4 pathway. CAM plants fix CO_2 at night, forming a C_4 molecule that is stored in large vacuoles until the next day. The stomata are open at night and closed during the day, thus conserving water.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{cytochromes}]{\text{enzymes}} 6CO_2 + 6H_2O + ATP$$

Summary of Aerobic respiration

CELLULAR RESPIRATION

Cellular respiration is a catabolic (breakdown) reaction that releases the stored energy in glucose so that it might be stored in ATP. In many ways cellular respiration and photosynthesis are parallel yet are opposite reactions. Cellular respiration starts with the high-energy, multicarbon molecule glucose and breaks it down to carbon dioxide, water, and ATP, using oxygen, some ATPs to prime the pump, and enzymes. It, too, uses electron transport chains and ends with a substantial production of ATPs and water. There are three stages in cellular respiration: glycolysis, the Krebs (citric acid) cycle, and the electron transport system.



Glycolysis

Glycolysis

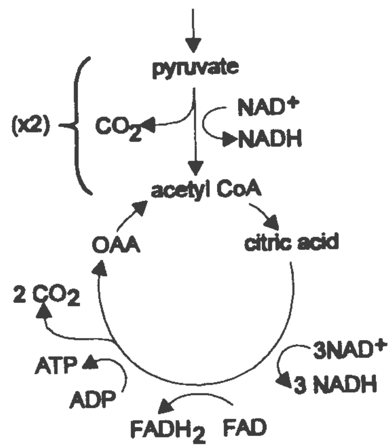
After passing across the plasma membrane with the help of several proteins in the membrane, glucose is activated in the cytoplasm and transformed into a sugar diphosphate, which degrades to two PGAL molecules that are the next step in the formation of pyruvic acid. This is the beginning of anaerobic respiration since no oxygen is invested and it results in a net gain of two ATPs—two ATPs start glycolysis and four are produced. If oxygen is available at this time, the pyruvic acid enters the mitochondrion, where it continues degradation until the final result is the bulk of the ATP production, water, and $FADH_2$. If oxygen is not available, aerobic respiration soon comes to a halt, resulting in a multicarbon molecule still rich in energy.

Aerobic processes

Aerobic processes are the continued breakdown of glucose to completion, fueled by the presence of oxygen. This phase is carried out on the enfolded membranes of the mitochondrion called cristae. The net result is a large amount of energy in the form of ATP for the cell to carry on its work.

Acetyl-CoA

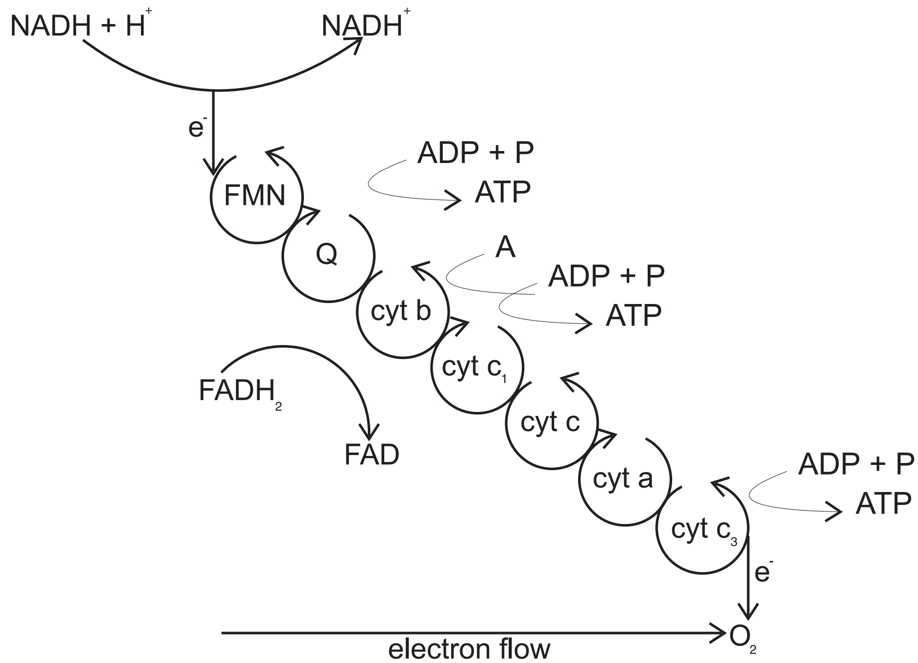
Upon entering the mitochondrion, the 3-carbon pyruvic acid is converted to Acetyl Coenzyme A by forming a substrate complex with Coenzyme A. Essentially, this delivers the degraded pyruvate to the Kreb's—citric acid—Cycle, where it undergoes a series of reactions that result in the production of some ATP, $FADH_2$, and NADH.



Kreb's (citric acid) Cycle

Kreb's (citric acid) cycle (or TCA)

Coupling the end product of the last turn of the Kreb's cycle, a 4-carbon molecule known as oxaloacetate, the 2-carbon Acetyl-CoA enters the Kreb's cycle. A chain of reactions results in the formation and then degradation of various multicarbon molecules (see above), the formation of NADH and $FADH_2$, and the release of two carbons as carbon dioxide. The end result of this turn of the cycle is the above-mentioned substances and oxaloacetate, which is precisely where the cycle began. The next Acetyl-CoA couples with this oxaloacetate and the cycle turns again. The resulting NADH and $FADH_2$, still rich in energy and hydrogen, now enter the electron transport chain, with the result being the bulk of the ATP production.



Cytochrome system

Electron transport

Hydrogen and its energy are transferred to carrier molecules. They are then shuttled to the inner membranes of the mitochondrion, where the electrons undergo a series of reactions. Traveling down the electron transport chain, their energy is coupled with the final electron acceptor, oxygen, which, along with the hydrogen from oxidative phosphorylation, forms the bulk of the water from cellular respiration.

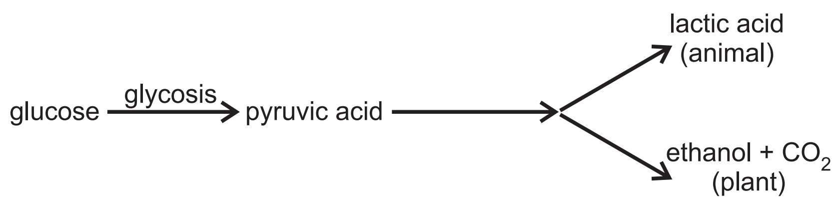
Oxidative phosphorylation

Energy from the electron transport chain is used to pump the hydrogen ions across the inner membranes of the mitochondrion creating a hydrogen (proton) gradient. This causes the hydrogen (proton) to eventually cross back over the membrane, resulting in a large production of ATP and providing the hydrogen ions needed to form water with the activated oxygen ions from the electron transport chain

ANAEROBIC PROCESSES

An aerobic process results when no oxygen is available, either by an accident of nature or by design, as in brewing of alcoholic beverages.

When cells enter anaerobic respiration, the result is a molecule still very high in energy and some carbon dioxide, depending on the fermentation schema. This takes place entirely in the cytoplasm, and the cell releases alcohol in plant tissue and lactic acid in mammalian tissue, both generally considered toxins for the cells.



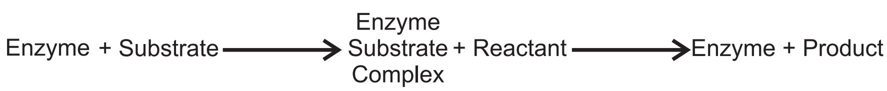
Anaerobic respiration
(fermentation)

Plant

Results in the production of alcohol in plant tissues and the release of carbon dioxide.

Animal

Results in the production of lactic acid, for example, in human tissue.



Enzyme-Substrate action

ENZYMES

Catalysts, both inorganic and organic, change the rate of a chemical reaction without changing as a result of the reaction. Organic catalysts are seen as organic facilitators that most often speed up a chemical reaction. Enzymes are protein molecules that do just such a thing in biological systems and are, therefore, seen as organic catalysts. They are very specific, work with other chemicals that they bring changes in, are affected by a variety of environmental factors, and often work with a coenzyme.

SPECIFICITY

Enzymes are very specific to the chemical that they are helping to undergo a change. Enzymes only act on one chemical.

SUBSTRATES

Enzymes work with substrate(s) to form a needed product. The substrate(s) can be seen as the reactants in the reaction that, as a result of the enzyme-substrate complex formed, most often have their activation energy lowered so the reaction will more easily and rapidly take place. The end result is the enzyme and the product. The enzyme is now free to carry out the reaction again, unless an inhibiting molecule attaches to it and prevents it from doing so (see Chapter 1).

Coenzymes

Coenzymes couple with the enzyme to aid in the job of the enzyme. Vitamins are often coenzymes in some reaction vital to the system. Inorganic substances, such as several metallic ions, also serve as coenzymes.

Affecting Factors

An enzyme is affected by several environmental factors that speed up its action, slow it down, or stop it altogether. Some of the factors, in the extremes, effectively cause irreversible reactions.

Temperature

Since temperature increases the motion of particles leading to the increased potential of collisions, this factor will increase the reaction as the temperature increases and slow it down as the temperature decreases. For example, refrigeration helps slow down the enzymatic reactions in microbes that can lead to food spoilage.

pH

Most enzymes work best around a neutral pH of 7. An exception would be the enzymes in the stomach, which, aided by gastric juices, work best around a pH of 2 to 3.

Substrate concentration

The amount of available substrate controls the rate of an enzyme-driven reaction. As the amount of substrate increases, the number of enzyme-substrate collisions increases, driving the rate of the reaction to occur faster. If enough substrate binds to the active site of an enzyme, the reaction will plateau (reach equilibrium).

MULTIPLE-CHOICE QUESTIONS

1. Which of the following is true about enzymes?

(A) They always work alone.
(B) They are consumed in a reaction.
(C) They are amino acid polymers.
(D) They always require a coenzyme.
(E) They are classified as inorganic catalysts.

2. Which of the following has a vitamin as a building block?

(A) apoenzyme
(B) alloenzyme
(C) metallic ion
(D) lipoprotein
(E) coenzyme

3. Which enzyme would the microbes in the gut of a termite need to have in order to metabolize the cell walls of the wood that termites eat?

(A) cellulase
(B) esterase
(C) protease
(D) pepsin
(E) trypsin

4. The reds, oranges, and yellows of the leaves of deciduous trees that become evident in the fall are from

(A) carotenoids.
(B) ATP.
(C) leaf decay.
(D) chlorophylls.
(E) overabundance of water.

5. Which of the following is a product of cyclic photophosphorylation?

(A) carbon dioxide
(B) oxygen
(C) ATP
(D) NAD^+
(E) Acetyl CoA

6. The role of oxygen in aerobic respiration is
   (A) to couple with C to form CO_2 in chemiosmosis.
   (B) to form ATP.
   (C) to contribute H^+ to the Kreb's cycle.
   (D) to make PGAL.
   (E) to accept electrons from the Electron Support Chain (ETC).
7. Photosynthesis is
   (A) light driven.
   (B) photo driven.
   (C) anabolic.
   (D) enzyme moderated.
   (E) all of the above.

Questions 8–10 refer to the following choices. Decide which best matches the description below.

(A) stroma
(B) thylakoid
(C) vacuole
(D) stomates
(E) lamella

8. The light reactions of photosynthesis take place here.
9. The Calvin cycle of photosynthesis takes place here.
10. The site of carbon fixation.

EXPLANATION OF ANSWERS FOR MULTIPLE-CHOICE QUESTIONS

1. **The correct answer is (C).** If choice (A) excluded the word "always," it might be an attractive choice. Enzymes, as has been noted, are not changed by the reaction they facilitate, which excludes choice (B). Very often, they do require a coenzyme, but, once again, the word "always" excludes some enzyme-mitigated reactions. The definition of enzymes calls them organic catalysts. Inorganic catalysts are an entirely different class of catalysts with different physical properties, although they still affect the rate of a reaction.
2. **The correct answer is (E).** All enzymes are composed of proteins that form one of two binding sites. One is for the allosteric binder and one is for the substrate, and this enzyme is

known as an allosteric enzyme. Also, the more complex the enzyme, the more cofactors—nonprotein parts—it has. If the cofactor is an easily removable cofactor, it is a coenzyme. Vitamins qualify for this designation, but metallic ions do not since they bond quite securely. If the enzyme is without the coenzyme, it ceases to function. Apoenzymes do not exist. Apoenzyme merely refers to the protein portion of the enzyme.

3. **The correct answer is (A).** The enzyme in the gut of a termite has to metabolize the cell wall of the wood cells, and those walls are composed of cellulose. Enzymes that break down substances have the suffix *-ase* attached to them, so the enzyme for metabolizing cellulose would be cellulase. Proteases metabolize proteins; pepsin and trypsin are proteases.
4. **The correct answer is (A).** Chlorophylls are active during the growing season and are eventually dismantled at the end of that period in the life of deciduous trees. This paves the way for the red, orange, and yellow carotenoids to be seen. Leaf decay, as in a dead leaf, would take on a brown appearance, and ATP is certainly not responsible for any colors in a plant. An overabundance of water might lead to bursting of the cells, but this would not be accompanied by the wholesale color changes we see in deciduous trees in the fall. It is important to note that the carotenoids are not produced in the fall; they are there for the life of the leaf.
5. **The correct answer is (C).** Cyclic photophosphorylation occurs only when there are not enough NADPH molecules around to accept electrons. It is fairly inefficient and doesn't occur often; the abundance of water would obviously have an effect on this process. With little or no NADP available, NAD^+ is not produced or even used in cyclic photophosphorylation. Acetyl-CoA is involved in the Kreb's cycle of cellular respiration where no phosphorylation due to light occurs. The release of oxygen occurs in the photolysis of water during the several reactions that make up non-cyclic photophosphorylation. Carbon dioxide is not produced during photosynthesis; it is consumed to produce carbohydrates. ATP is the only thing produced in this reaction.
6. **The correct answer is (E).** The primary role of free oxygen in respiration is to accept electrons at the end of the ETC following, which it couples with H^+ to produce water at the end of aerobic respiration. Chemiosmosis involves the pumping of hydrogens across the thylakoid membranes in the production of ATP in photosynthesis. Oxygen does not play a role in contributing H^+,

nor does it contribute to the synthesis of PGAL, the molecule in the Calvin-Benson cycle of photosynthesis.

7. **The correct answer is (E).** Photosynthesis is all of the choices (A) through (D). It is first and foremost driven by the photons that are the energy packets given off by a source of light. It is anabolic since it produces a higher energy state, which is composed of energy-rich molecules that represent more ordered systems of energy and, therefore, have higher free energy. Enzymes are, of course, crucial to this process and are, as a whole, non-cyclic in nature, proceeding from CO_2 and H_2O to $C_6H_{12}O_6$, a sequence that does not cycle. There are cycles within photosynthesis, but the reaction as a whole is non-cyclic.
8. **The correct answer is (B).** The oxidation-reduction reactions involved in oxidation of water, reduction of $NADP^+$, and synthesis of ATP via a chemiosmotic mechanism are located in the thylakoid membranes of the chloroplast. The soluble enzymes that are involved in the synthesis of glucose from carbon dioxide and water and utilize the ATP and NADPH produced during the light reactions are in the stroma compartment of the chloroplast.
9. **The correct answer is (A).** When ATP and $NADPH_2$ are produced in the thylakoids at the end of the light reactions, they proceed to the stroma, where they drive the C_3 cycle.
10. **The correct answer is (A).** Carbon fixation occurs during the Calvin-Benson cycle of the dark reactions, which means this also occurs in the stroma.

VOCABULARY

acetyl coenzyme A
activation energy
active site
aerobic respiration
allosteric site
anaerobic respiration
antenna pigments
ATP
ATP-synthase
autotrophs
bioenergetics
C4 pathway
Calvin-Benson cycle
carbon fixation (C3 pathway)
carotenoids
cellular respiration
chlorophyll a
chlorophyll b
chloroplasts
citric acid cycle
coenzyme
cofactor
competitive inhibition
conducting tissue
cuticle
cyclic photophosphorylation
cytochromes
electron transport chain
entropy
enzymes
enzyme specificity
enzyme-substrate complex
ethanol
feedback inhibition
fermentation
glyceraldehyde-3-phosphate (G3P)
glycolysis
grana
guard cell
heterotrophs
hydrogen ion gradient
induced fit
Kreb's cycle
lactic acid
light reaction
lock-and-key theory
lower epidermis
metabolic cascade
mitochondria
NADPH
noncompetitive inhibition
noncyclic photophosphorylation
nonspontaneous reaction
organic catalyst
oxaloacetate
oxidative phosphorylation
p680
p700
palisade cells
phosphoglyceric acid (PGA)
phosphophenolpyruvate (PEP)
photolysis
photon
photophosphorylation
photosynthesis
photosystem I
photosystem II
pyruvic acid
reaction center
ribulose biphosphate (RuBP)
spongy mesophyll cells
spontaneous reaction
stomate
stroma
substrate
thermodynamics—first law
thermodynamics—second law
thylakoids
upper epidermis

Unit II—Heredity and Evolution

Chapter 4

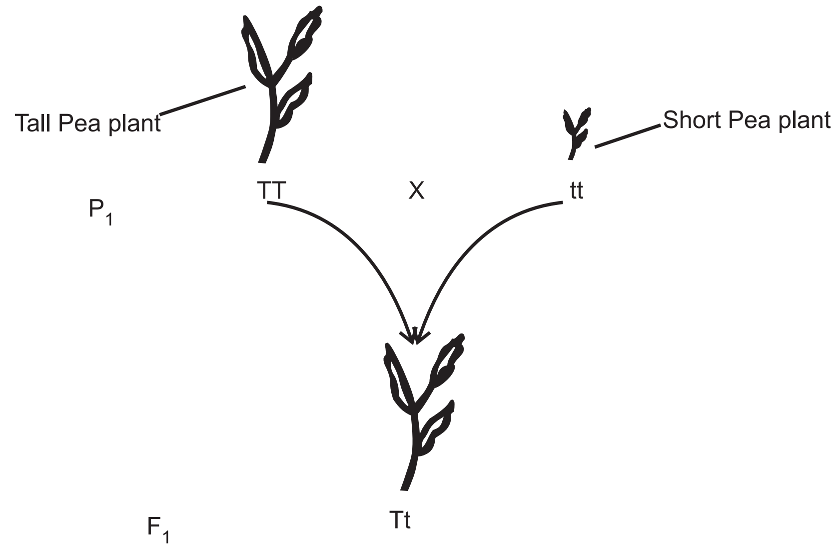
GENETICS—MENDEL AND HEREDITY

OVERVIEW

Since Mendel's time, scientists have added to his fundamentals and have linked such processes as meiosis as well as mitosis to his findings. Modern genetics has explored crossing over, nondisjunction, incomplete dominance, linkage, and the like. Our current knowledge of these areas has even engendered the field of genetic counseling. Use of the Punnett square is assessed on the exam, and you should know how to utilize this tool in calculating answers in genetics, particularly Mendelian genetics. The student should know these processes and Mendel's laws in detail, be capable of comparing and contrasting mitosis and meiosis (a favorite essay question), know the differences between spermatogenesis and oogenesis, and be able to perform monohybrid crosses, test crosses, and dihybrid crosses. The student should also be comfortable with the basics of Mendel's work and be able to transition to modern genetics—the subject of Chapter 5—with confidence. Finally, the study of the patterns of inheritance will be discussed from a variety of levels and is a theme that actually runs through most of the study of this area.

MENDEL

The "father" of genetics and a nineteenth-century monk trained in mathematics, Mendel conducted years of studies on the traits of pea plants as a hobby. He theorized that certain factors—known today as genes—controlled the passing on of these traits from one generation to the next. His laws are the foundation of genetics and are the principles upon which we base our current knowledge of inheritance. His techniques were precise, and his knowledge of mathematics was an essential asset to his conclusions. In discussing terminology, you should be aware that not all terms listed emanated from Mendel's original work. A large measure of them are "post-Mendelian" but involve either clarification of his work or the discovery of new principles that dictated new terms. We begin with a discussion of his laws; meiosis is treated separately but is obviously an integral part of these laws and, in fact, embodies what Mendel discovered.



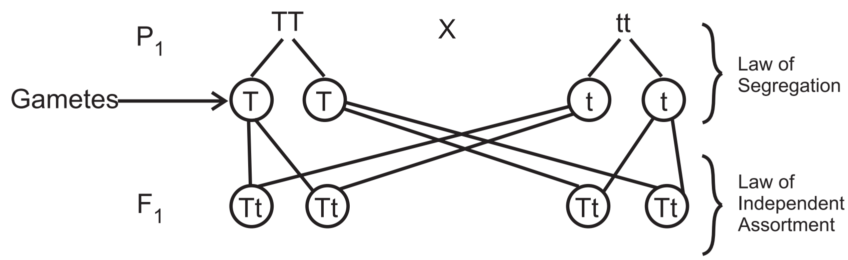
Mendel's Law of Dominance

LAW OF DOMINANCE

First and foremost, Mendel noticed that certain traits did not have a halfway point or a blending affect (see Incomplete Dominance). Such was the case with the trait for height in peas in a monohybrid cross or mating for one trait. Mendel's conclusion was that in the expression of the trait for height in peas, tall pea plants dominate over short pea plants; Mendel called them factors, and we now call them genes or alleles. When a pea plant that is homozygous, or pure, for tallness is crossed with a pea plant that is homozygous for shortness, it appears that the offspring produced in the F_1, or first filial generation, have lost the recessive allele. This is an indication that one trait is dominant, and the other (seemingly vanished) trait is recessive. Eventually, Mendel came to conclude that the recessive trait was being masked. In truth we know today that, although each offspring receives one gene from each parent (the P_1 generation) for a trait, only one gene works to express that trait. In the case of a homozygous individual, it doesn't matter which one because they are identical. In a heterozygous individual, it will be the dominant allele. Thus, the effect of the Law of Dominance was a powerful one, illuminating the relationship between dominant and recessive alleles. It should be noted that farmers and agriculturists were aware of this relationship to a certain extent before Mendel but used it informally in a hit-or-miss manner. Mendel codified the relationship, and, although his work sat on a library shelf for more than three decades, it nonetheless had a powerful effect on the world when it was rediscovered.

Law of Segregation

Prior to the potential for mating, certain cells go through a process we now know as meiosis. During this time, the alleles ultimately separate from each other and end up in separate gametes or sex cells. Mendel saw this as a mathematical construct and realized that anything else would be mathematically impossible. If all the genes of an individual were passed on each time mating occurred, the number of genes each successive generation receives would double. If instead, as we now know occurs in meiosis, the number of alleles is halved through segregation from each other before they are "doubled" at mating, the number of alleles in each generation remains constant. In using the Punnett square, we put one allele above each column or on each row to signify that the genes must separate from each other before they can reunite in sexual reproduction.



Mendel's Law of Segregation and Law of Independent Assortment

Law of Independent Assortment

Simply stated, this law says that the way that alleles for a trait are "coupled" to each other in sexual reproduction is random and, with every mating, all recombinations are possible. For example, we cross two F_1 offspring from the mating of a homozygous tall and a homozygous short. (NOTE: When referring to the recessive trait, it is not necessary to use the term homozygous: a recessively expressed phenotype (physical appearance as a result of possessing certain alleles) means that the individual *has* to be homozygous.) The presence of a dominant allele means that the individual will not express the recessive trait due to the presence of that dominant trait. A favorite ruse of the test maker is to appear to be giving less information about the genotype (the exact nature of the alleles, TT, Tt, or tt) than is needed when referring to the individual whose phenotype expresses the recessive trait. Indicating that the individual's phenotype is short, as in the case of peas, without indicating homozygous or heterozygous short, does this. In order for a recessive trait to appear, it must be homozygous; thus the term homozygous is irrelevant when referring to the recessive phenotype, and the use of the term heterozygous would be incorrect. In the case of peas, a phenotype of tall, on the other hand, must be accompanied by a description of the genotype—either homozygous {TT} or heterozygous {Tt}. In that cross, the possible offspring could be {TT}, {Tt}, {Tt}, or {tt}. A better illustration of independent assortment is found in a dihybrid cross where, for example, if the alleles are A, a, B, and b, the possible matings are {AB}, {Ab}, {aB}, or {ab}.

	T	t
T	TT	Tt
t	Tt	tt

Monohybrid Cross

Punnett Square

A Punnett square is used to better organize the crosses and their possible outcomes between two individuals. The use of capital letters in the illustrations represents the law of dominance. Placing each allele in a separate column or row represents the law of segregation. The inner squares of the Punnett square represent the law of independent assortment. All three of Mendel's laws can be illustrated in a Punnett square.

Monohybrid Crosses

Monohybrid crosses are the mating of individuals that are the P_1 hybrid for one trait. This is originally a reference to the dominant/recessive state between individuals within a species and does not hold for incomplete dominance, although the laws of Mendel hold true for both. Several monohybrid crosses are indicated below, including a test cross. (NOTE: The only way a test cross can successfully reveal the presence of a recessive gene in a dominantly expressing individual is to cross that individual with a recessively expressing individual. If there is a recessive gene being masked in the dominant individual, it will only be expressed if that individual is mated with a recessive individual for that trait. Three test crosses are illustrated below.)

	T	t
T	TT	Tt
If T?	TT?	Tt?

100% Tall

	T	t
T	TT	Tt
If t?	Tt?	t?t

75%Tall

Monohybrid Cross
(Incorrect Test Crosses)

	t	t
T	Tt	Tt
T or t ?	T?t t?t	T?t t?t

If TT → 100% Tall

If Tt → 50% Tall

Monohybrid Cross
(Correct Test Crosses)

Test Crosses in Monohybrids

Monohybrid does not refer to the fact that each member involved in the cross need be hybrid. It refers to the fact that individuals homozygous for both the dominant and the recessive trait, when crossed, will result in hybrids. Another way to say it is that monohybrid crosses reflect one of each trait, the dominant and the recessive. We also use this to refer to a hybrid individual who has one dominant allele and one recessive allele. The classic monohybrid results of a phenotypic ratio of 3:1 and genotypic ratio of 1:2:1 are noted below.

	T	t
T	TT	Tt
t	Tt	tt

Genotype: 1:2:1
1 – TT
2 – Tt
1 – tt

Phenotype: 3:1
Tall – 3
Short – 1

Monohybrid Cross Results

	AB	Ab	aB	ab
AB	AA BB	AA Bb	Aa BB	Aa Bb
Ab	AA Bb	AA bb	Aa Bb	Aa bb
aB	Aa BB	Aa Bb	aa BB	aa Bb
ab	Aa Bb	Aa bb	aa Bb	aa bb

Genotype
AABB: 1
AABb: 2
AaBB: 2
AaBb: 4
AAbb: 1
Aabb: 2
aaBB: 1
aaBb: 2
aabb: 1

Phenotype
A+B trait: 9
A+b trait: 3
a+B trait: 3
a+b trait: 1

Dihybrid Cross

Dihybrid Crosses

A cross potentially hybrid for two traits, dihybrid crosses still hold true to Mendel's laws; there are simply more gametes possible and more offspring (illustrated above). The typical true genotypic ratio is cumbersome to note here, although it is illustrated, and the typical true dihybrid phenotype ratio is the classic 9:3:3:1. If the traits are ***A*** or ***a*** and ***B*** or ***b***, the phenotypic nine would produce all ***AB*** appearing, the first three might be ***Ab*** appearing, making the second three ***aB*** appearing, and the one would be represented by ***ab*** appearing individuals.

RR (red) × WW (white)
↓
RW (pink) 100%

RW (pink) × RW (pink)
↓
RR (red) 25% — RW (pink) 50% — WW (white) 25%

Incomplete Dominance

Incomplete Dominance

Characteristics intermediate between parental extremes are shown; the traits combine to produce an intermediate form indicating that neither is dominant, thus the name. Instead of making up a new symbol to indicate the third trait, it is illustrated by showing it as being made up of one each of the two alleles in question, as illustrated. Care should be taken on questions referring to incomplete dominance. The greater number of “blended” offspring would be given not by a cross between two of these individuals but by crossing individuals pure for the component alleles. If ***R*** represents red in four-o’clock flowers, ***W*** represents white, and ***RW*** represents pink, the largest number of pink flowers would come from mating a red [***RR***] and a white [***WW***] four-o’clock flower plant. By Mendel’s laws, all of the offspring would be ***RW***.

MEIOSIS

Meiosis refers to stages in the life of cells as they prepare to pass on their traits to the next generation. Meiosis has two divisions in contrast to the one division of mitosis. Meiosis is often referred to as a reduction division. Meiosis is the embodiment of Mendel’s Law of Segregation. As will be seen, this is where crossing over, nondisjunction, and the like do matter. A chromosome is composed of two identical “sister” chromatids. They are identical to each other and are in fact duplicates. Only one half is present in the normal workings of the cells. An exact copy is made and attached to its “sister” half during interphase in order to prepare for the division about to occur.

CELL TYPES

When referring to cells and their division in meiosis, we use two terms, depending on how many of the necessary compliment of chromosomes each cell has. One refers to the number we typically find in body, or somatic, cells, and the other is used to refer to the number of chromosomes found in the sex cells located in the primary sex organs, or gonads, of the female (the ovaries) or the male (the testes).

Haploid

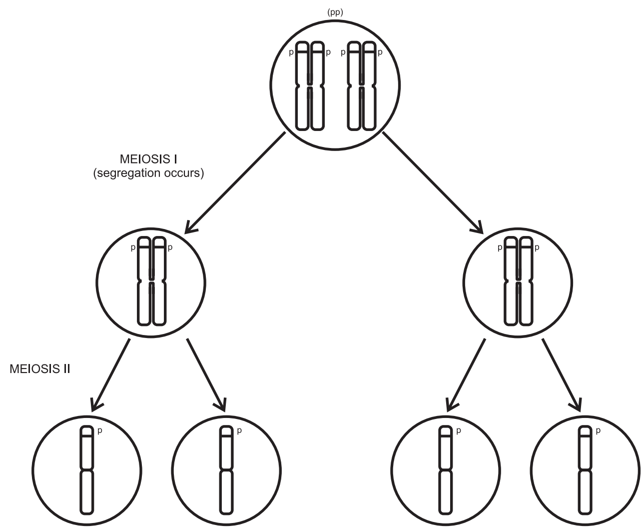
Haploid refers to half the number of chromosomes normally found in the body cells of an individual. This number is achieved through meiosis and occurs mainly in all cells, with the exception of plants, that are ready for reproduction. Sexual reproduction brings the cell back to the diploid number.

Diploid cells

Diploid refers to the normal chromosomal number found in the body cells of individuals capable of sexual reproduction. Also found in the sex cells prior to meiosis.

STAGES

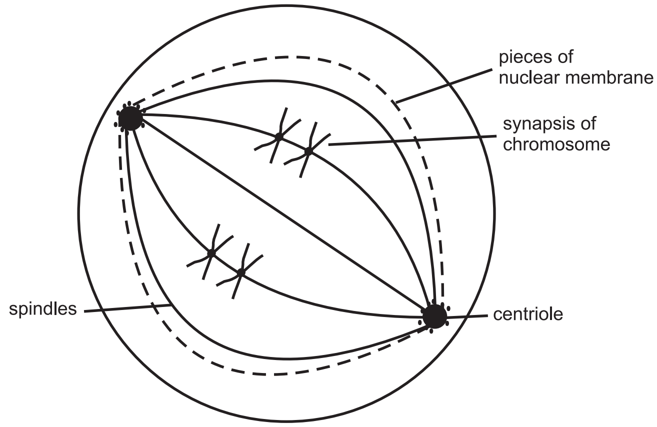
Meiosis goes through two divisions, with the stages named after similar stages found in mitosis but labeled with a I or II. Condensation of the chromosomes occurs and they migrate to the middle of the cell, are separated, and migrate to opposite ends of the cell. This is where the similarity ends between mitosis and meiosis.



Meiosis Summary

Meiosis I

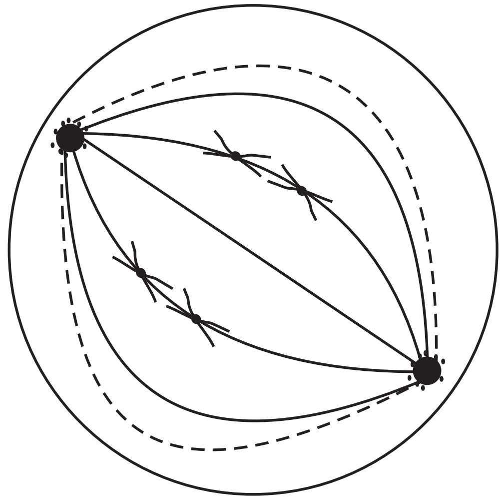
Following the disappearance of the nuclear envelope, chromosomes begin to condense, and homologous pairs lie next to each other in a manner similar to mitosis. The way in which they line up and what can happen to them, however, is very different in meiosis I.



Prophase I

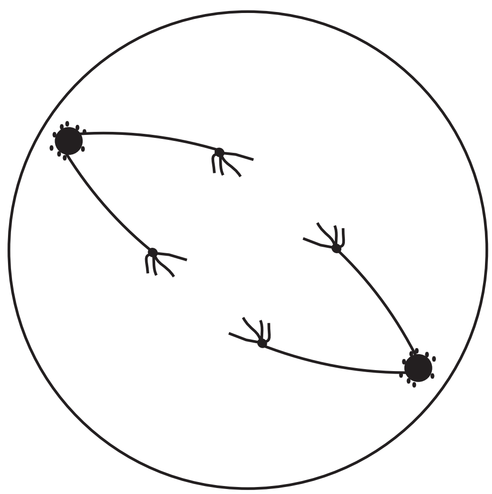
A. Prophase I

Homologous pairs begin to line up next to each other as pairs—not as individuals as in mitosis—in a process called synapsis. This makes four entities, which explains why they are called tetrads at this point. Homologous pairs are biochemically very similar: the genetic code for blue eyes versus brown eyes starts in exactly the same way, although the code for those colors is chemically different beyond those starting points. If these closely associated segments, by virtue of their chemistry, happen to intertwine in close proximity, they may exchange parts in a process called crossing over. Occasionally, homologous pairs do not separate, or they separate inconsistently in a process know as nondisjunction. This will most likely cause more information to be passed on in one or more of the resulting sex cells.



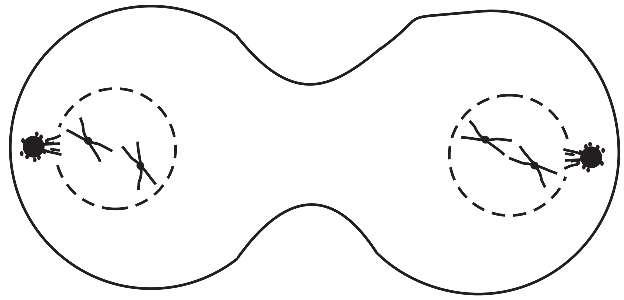
Metaphase I

B. Metaphase I
Tetrads line up along the equator in the middle of the cell as in mitotic metaphase. Once again, they are lined up as pairs, not as individual chromosomes as in mitosis. Spindles are attached to the centromeres, and the homologous pairs are about to be separated, which provides the basis for the variation noted in the Law of Independent Assortment.



Anaphase I

C. Anaphase I
The homologous pairs of each tetrad begin migrating to opposite ends of the cell, similar to mitosis. At this point, the number of chromosomes in each forming cell is reduced by half.



Telophase I

D. Telophase I
The nuclear envelope reforms around each set of chromosomes and the cells divide (cytokinesis).

Meiosis II

This part of meiosis is almost identical to mitosis, except it uses only one half of the tetrad.

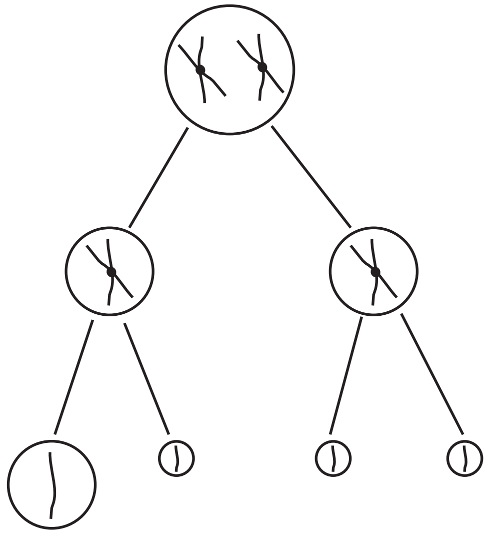
A. Prophase II
Chromosomes condense and become visible as sister chromatids attached at the centromere, but only as half the number of normal homologous pairs.

B. Metaphase II
The chromosomes line up along the equator of the cell.

C. Anaphase II
The chromosomes split at the centromeres and begin migrating to opposite ends of the cell.

D. Telophase II
The nuclear envelope reforms, and the result is four haploid cells.

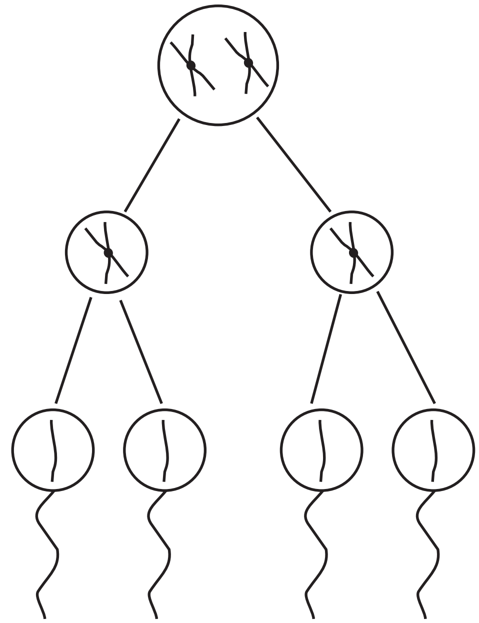
Gametogenesis



Oogenesis

Oogenesis

In females, gametogenesis produces eggs, or ova, and is called oogenesis. For every diploid cell that undergoes gametogenesis in females, one egg is produced. In oogenesis, the other three cells receive very little cytoplasm and eventually degenerate in a move that conserves cytoplasm for the surviving cell.



Spermatogenesis

Spermatogenesis

In males, gametogenesis produces sperm and is called spermatogenesis. For every diploid cell that undergoes gametogenesis in males, four sperm are produced.

CHROMOSOME INTERACTIONS

During the course of both mitosis and meiosis, the chromosomes come in proximity and, since they are composed of similar chemical material, they may interact. The bulk of this section is spent on the matter at hand, namely meiosis.

Mitosis

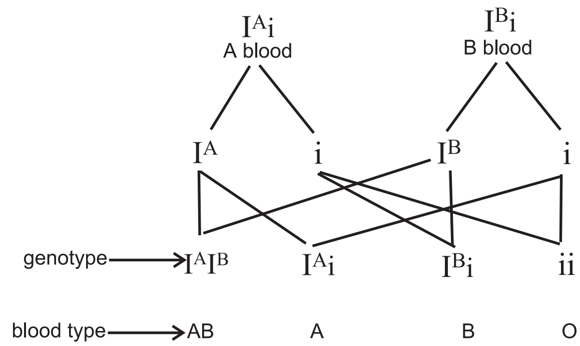
In body cells, there is no risk of what the next generation of individuals will receive as genetic information. Any interaction of chromosomes in mitosis, other than what usually should happen, will lead the cells to die off or pass on the anomaly, called a mutation, which is usually negative. (NOTE: If a cell is currently functioning properly, any change will most likely result in a problem with that functioning.) If the cell survives the interaction, it will most likely be the result of a mutation that makes it different than the surrounding cells and thus, in all likelihood, a competitor. If the new anomalous cell is better at surviving than the surrounding cells, it will crowd them out, becoming what is known as cancerous.

Meiosis

In meiotic chromosomal interactions, the danger is that negative interactions may be passed on to future generations. The mutations result in a variety of well-known conditions. The future may hold more or fewer, and it is anybody's guess.

A. Epistasis

When one gene masks the expression of another gene (e.g., if the first gene codes for the absence of a trait), as in no pigmentation, then the expression of the second gene, which may code for the kind of pigmentation, has no effect.



Hybrid A and Hybrid B Cross

B. Multiple alleles

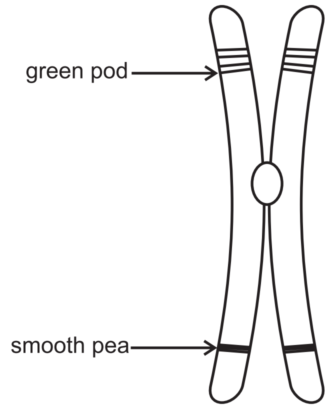
Expression of a trait is controlled by the presence of more than two alleles, as in the case of blood types A, B, AB, and O. The alleles for blood types A and B (represented by I^A and I^B, respectively) are separately dominant. Together they are incompletely dominant as in AB (represented only by $I^A I^B$) blood type. Blood type O (represented by i) is recessive. If the two alleles are $I^A I^A$ or $I^A i$, then the dominate blood type will be A. If the two alleles are $I^B I^B$ or $I^B i$, then the dominate blood type will be B. Type O blood can only be ii. The interactions of these alleles, which produce an easily identifiable trait, is the first line of investigation in verifying the parents of a baby, if it actually comes into question, as has occurred in the past in hospital mix-ups.

C. Pleiotropy

Occurs when a gene has more than one phenotypic expression.

D. Polygenic inheritance

Rather than producing clearly defined phenotypes, polygenic inheritance involves a continuum of genetic variation that is controlled by many genes, as the name suggests.



Linkage

E. Linked genes

If two genes are on the same chromosome, they are linked. The mapping of (or the percent probability of spacing between and even the sequence of) these genes on the chromosome can be determined through the frequency with which crossing over occurs. One well-known instance of linkage is the universe of traits that is known as sex-linked. While these show up, as a rule, in a higher percentage of males, the sex-linked trait resides on the sex cell (gamete). In essence, the gene on the X chromosome has no counterpart on the male or Y chromosome, making the gene on the X chromosome dominant by default. Sex linkage is illustrated by, as in the case of hemophilia, $\boldsymbol{X^N}$ where the $\boldsymbol{N}$ represents the allele for normal blood and $\boldsymbol{X^n}$ would represent an $\boldsymbol{X}$ chromosome with the $\boldsymbol{n}$ allele for hemophilia. Thus $\boldsymbol{X^N X^N}$ and $\boldsymbol{X^N X^n}$ would represent two females with normal blood, and the latter would be known as a carrier, able to pass on the gene but as a phenotype. A female with the genotype $\boldsymbol{X^n X^n}$ would be a hemophiliac. A male with the genotype $\boldsymbol{X^N Y}$ would be expressing a normal blood phenotype, and a male inheriting $\boldsymbol{X^n Y}$ would be a hemophiliac, which is a rare condition. Several Punnett squares illustrating these interactions are noted on the next page. Note that females are likely to be color blind 33 percent of the time while males are likely to be color blind 50 percent of the time in these interactions. This is also illustrated on the following page.

$X^N X^N$ (normal female) × $X^n Y$ (color-blind male) → All females carriers $X^N X^n$
All males normal $X^N Y$

$X^N X^n$ (carrier female) × $X^n Y$ (color-blind male) → 25% females carriers $X^N X^n$
25% females color-blind $X^n X^n$
25% males color-blind $X^n Y$
25% males normal $X^N Y$

$X^n X^n$ (color-blind female) × $X^N Y$ (normal male) → all females carriers $X^N X^n$
all males color-blind $X^n Y$

$X^n X^n$ (color-blind female) × $X^n Y$ (color-blind male) → all offspring color-blind $X^n X^n$ or $X^n Y$

All possible sex-linked trait crosses
except color blindness

F. Nondisjunction

Occurs when chromosomes do not properly separate during meiosis as they migrate to opposite poles. Down's syndrome or Trisomy 21 is an example of this and is easily identified through amniocentesis, an examination of the baby's cells—the only ones present—in the amniotic fluid.

MULTIPLE-CHOICE QUESTIONS

1. Which of the following is NOT indicated by Mendel's experiments?

(A) incomplete dominance
(B) segregation
(C) recessive
(D) dominant
(E) independent assortment

2. A ratio of 3:1 in the phenotype of an organism occurs when

(A) the alleles are incompletely dominant.
(B) only recessive traits are involved.
(C) only dominant traits are involved.
(D) alleles segregate during meiosis.
(E) crossing over has occurred in Anaphase II.

3. Colorblindness in humans is

(A) caused by a recessive allele.
(B) in equal proportion in both sexes.
(C) caused in females by a heterozygous genotype.
(D) inherited by males from their male parent.
(E) caused in males by a homozygous genotype.

4. Trisomy 21 in humans is the result of

(A) pleiotropy.
(B) polygenic inheritance.
(C) epistasis.
(D) x-inactivation.
(E) nondisjunction.

5. Homologous chromosomes line up in pairs in

(A) metaphase of mitosis.
(B) metaphase I.
(C) metaphase II.
(D) interphase.
(E) prophase of mitosis.

6. In a heterozygous monohybrid cross, the dominant trait can be expressed in the phenotype of the F1 ________ of the time.

(A) 0 percent
(B) 25 percent
(C) 33 percent
(D) 75 percent
(E) 100 percent

7. Which of the following would be the result of a true dihybrid cross?

(A) AABB
(B) AABb
(C) AaBb
(D) AaBB
(E) aaBb

8. Which of the following would indicate a test cross, where **T** represents the dominant, tall, trait and **t** represents the recessive, short, trait?

(A) Tall × TT
(B) Tall × Tt
(C) Tall × tt
(D) TT × Tt
(E) short × tt

9. __________ refers to one gene affecting many traits.

(A) Polygenesis
(B) Pleiotropy
(C) Linkage
(D) Epistasis
(E) Nondisjunction

10. Which of the following blood types are possible if the parents are A and O blood types?

(A) A and O
(B) B and O
(C) AB only
(D) O only
(E) A, B, and O

Explanation of Answers for Multiple-Choice Questions

1. **The correct answer is (A).** The only choice that represents non-Mendelian genetics would be choice (A). The interaction of traits that blend would have been much harder to delineate without first knowing the laws that Mendel proposed. Being the mathematician that he was, Mendel reduced the number of variables to easily interpretable parameters. Choices (B) through (E), of course, reflect his laws: choice (B) represents the Law of Segregation, choices (C) and (D) represent the Law of Dominance, and choice (E) represents the Law of Independent Assortment.
2. **The correct answer is (D).** A phenotypic ratio of 3:1 is expressed only where there is the presence of a dominant allele in both individuals and a recessive allele in both individuals; they are hybrids. More important, though, is the fact that these alleles, in order to produce all possible combinations, must segregate in a process we now know as meiosis. This results in offspring with 1-TT genotype, 2-Tt genotypes, and 1-tt genotype. It produces a phenotype ratio of three dominant-expressing individuals and one recessive-expressing individual for every four offspring. A 3:1 ratio cannot occur in incomplete dominance. If only recessive or only dominant alleles are involved, the ratios would respectively be 100 percent and 100 percent. Crossing over cannot be detected using this ratio.
3. **The correct answer is (A).** Colorblindness is caused by a recessive allele on the X chromosome. It is not found in equal proportion in both sexes: Females are 33 percent likely to be colorblind and must inherit a colorblind–carrying X chromosome from both parents, but males are 50 percent likely to be colorblind as they only need to inherit one colorblind–carrying X chromosome from their mothers. A heterozygous female will be a carrier; she possesses one of the genes and has no colorblindness, but in order to be colorblind, she must be homozygous for the recessive trait. Since the male inherits only a Y chromosome from his father, he cannot inherit colorblindness from his father. Finally, males do not have homozygous sex chromosomes; therefore, colorblindness is not a male-only trait. The homozygous genotype would only be in the female.
4. **The correct answer is (E).** Pleiotropy is one gene controlling many traits, and polygenic inheritance is the opposite of this. Epistasis is one gene affecting one other gene in its expression. X-inactivation occurs in mammals when one X chromosome stays coiled up and is known as a Barr body. The other one functions as the active chromosome. The coiled up autosome has become

inactive. Trisomy 21 occurs when the twenty-first pair of chromosomes separates incorrectly during meiosis, which is known as nondisjunction.

5. **The correct answer is (B).** In meiosis, the homologous pairs line up as individuals in meiosis I in preparation for final segregation in meiosis II. Meiosis simply needs to ensure the pairs end up in opposite daughter cells in meiosis I. It is in mitosis that the homologous pairs line up as pairs, and interphase, of course, is not a phase where the chromosomes even appear.
6. **The correct answer is (D).** In a heterozygous cross—height, for example, when **T** represents the dominant, tall, trait and **t** represents the recessive, short, trait—the following genotype would represent both parents: **Tt**. Following Mendelian procedures and using a Punnett square to ensure accuracy, the following genotypes would result: **TT**, **Tt**, **Tt**, and **tt**. This would produce an occurrence of the dominant trait 75 percent of the time.

	T	t
T	TT	Tt
t	Tt	tt

Tall: 3 (75%)
Short: 1 (25%)

7. **The correct answer is (C).** The use of the word "true" dihybrid indicates that the test maker wants hybrid expression for both traits, which means the presence of all possible alleles in the genotype; this only appears in choice (C). Choices (B) and (D) are dihybrids, but not true dihybrids for both traits.
8. **The correct answer is (C).** A test cross occurs where a recessively expressed phenotype (which is therefore homozygous in genotype) is used to detect the likelihood of a recessive allele being masked by a dominant allele. If the recessive is crossed with a pure dominant, there is no chance of the recessive trait in the phenotype of the F1. If, on the other hand, there is a recessive allele being masked by a dominant allele, it has the potential of showing up no less than 50 percent of the time in the phenotype of the F1.
9. **The correct answer is (B).** Our definition of one gene affecting many traits is, of course, called pleiotropy and occurs in instances such as several disease-causing alleles. Sickle-cell anemia is one such condition. The "sickling" or collapse of the RBCs results in effects in other parts of the body. Polygenesis is the opposite and would be found in such instances as height in humans, where a group of genes results in a continuum of heights. Epistasis is one gene affecting one other gene in its

expression. Nondisjunction occurs when a pair of chromosomes separate incorrectly during meiosis.

10. **The correct answer is (A).** This is a case of multiple alleles controlling a trait (not to be confused with polygenesis). The alleles for blood types A and B (represented by I^A and I^B, respectively) are separately dominant, when one is present but the other is not. Taken together, they are incompletely dominant as in AB (represented only by $I^A I^B$) blood type. Blood type O (represented by i) is recessive. If the two alleles are $I^A I^A$ or $I^A i$, then the blood type will be A. If the two alleles are $I^B I^B$ or $I^B i$, then the blood type will be B. Type O blood can only be ii.

VOCABULARY

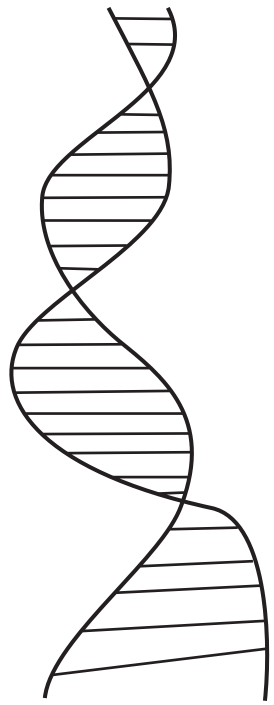
alleles
autosomes
carrier
chromatin
codominance
color blindness
crossing over
dihybrid cross
diploid cell
dominant
F2 generation
filial (F) generation
gametes
gametogenesis
genes
genotype
germ cells
gonads
Gregor Mendel
haploid cell
hemophilia
heterozygous
homologous chromosomes
homozygous
incomplete dominance
Law of Dominance
Law of Independent Assortment
Law of Segregation
meiosis
monohybrid cross
oogenesis
ovaries
parent (P1) generation
phenotype
polygenic inheritance
Punnett square
recessive
sex cells
sex chromosomes
sex-linked traits
sister chromatids
spermatogenesis
spindle fibers
synapsis
test cross
testes
tetrad
trait

Chapter 5

MOLECULAR GENETICS—DNA AND EVOLUTION

OVERVIEW

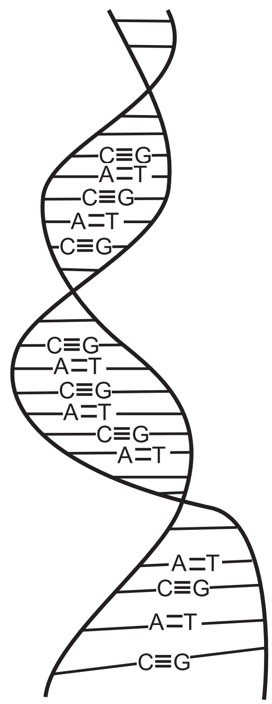
DNA controls the life of the cell by controlling the manufacture of proteins and is the material of the genes that are integral parts of the chromosomes. These proteins are used either to make other molecules or to form part of the structural network of the cell. DNA even makes the proteins that control the functions of DNA itself as well as controlling heredity. Watson and Crick are credited with first expressing the structure of DNA. You will find test questions on both the structure and function of DNA as well as RNA and the molecules involved in protein synthesis. DNA is now known to be a double helix in its non-replicating state.



DNA double helix

The code for life resides in the sequence of nucleotides along the length of the molecule. The foundation of evolution is change that comes about through the interaction of an organism's unique cellular

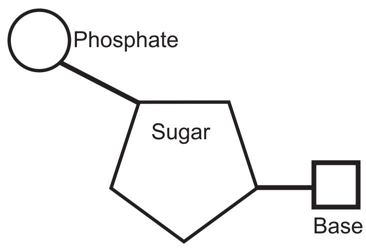
DNA with the organism's environment. For this reason, we include material on evolution coupled with the material on DNA. Since the function of DNA is to pass on traits from generation to generation, and we have explored heredity, we now explore the *details* of how this information is passed on. As we have stated before, the student should be familiar with the material outlined in this book and related material as well. We begin with the structure of DNA.



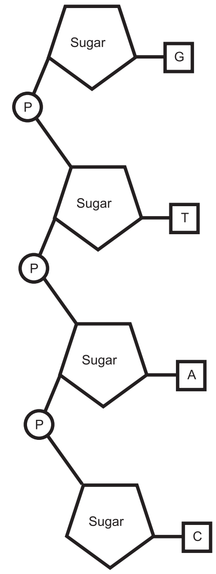
DNA: sample base-pairing

DNA

DNA is a biochemical molecule responsible for passing on the traits of an organism, which include controlling the biochemical nature and function of that organism. DNA is a double helix molecule that achieves a great deal of compacting in the nucleus by coiling in on itself many times. DNA makes RNA, which carries the code to the cytoplasm. There, ribosomes are utilized in making polypeptide chains that are proteins. Both the lack of an oxygen on the ribose sugar—thus the name deoxyribose nucleic acid—and the presence of the base thymine serve to prevent DNA from leaving the nucleus.



Nucleotide



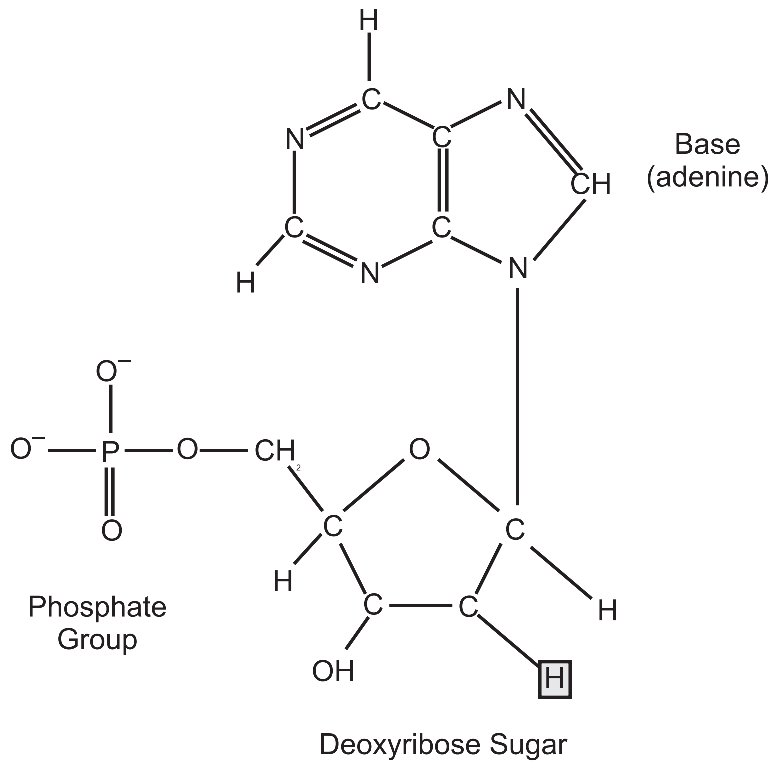
DNA backbone

NUCLEOTIDES

The building blocks of DNA, nucleotides are used to make up the repeating units in the strands of DNA that represent the genetic code. A nucleotide consists of a sugar, a phosphate, and a nitrogen base. Since there are only four bases, researchers postulated that the enormous amount of genetic variation on the planet had to be in the sequence of the nucleotides within the DNA molecule. This sequence then controls the synthesis of precise proteins in the sequence of amino acids. On one end of the DNA molecule, the 5-carbon sugar has a phosphate attached and is known as the 5′ end. On the other end of the sugar is an OH that is identified as the 3′ end of the DNA molecule.

Bases

Four nitrogenous bases make up the bonding sites along the center of the DNA molecule and are bonded to a carbon on the sugar molecule. There are two purines and two pyrimidines. The purine names end in *-nine*.



DNA Nucleotide

A. Adenine
A purine, double-ring base with two bonding sites

B. Thymine
A pyrimidine, single-ring base with two bonding sites

C. Cytosine
A pyrimidine, single-ring base with three bonding sites

D. Guanine
A purine, double-ring base with three bonding sites

Ribose

A 5-carbon sugar, as signified by the *-ose* ending, ribose is considered the central part of the nucleotide, as the bases and the phosphate bond to it.

Phosphate

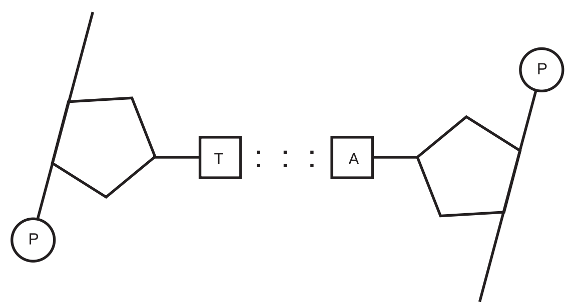
Bonded to another carbon on the ribose sugar, the last phosphate on the molecule is the 5′ end.

HISTONES

Histones are proteins that help protect the DNA molecule. The DNA molecule is surrounded by eight or nine histones to help it form a protective DNA-histone complex in a tight space in the nucleus.

BASE-PAIRING

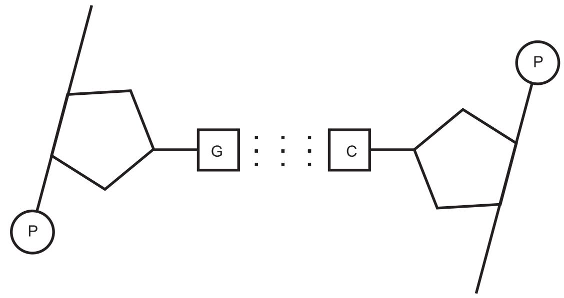
Base-pairing is the pairing of complimentary bases along the DNA strand. The sum of the bonds and the coiling of DNA makes the molecule securely attached along its entire length. Analysis of the assays of the DNA from a variety of organisms caused Erwin Chargaff to note that the percentage of adenine was almost identical to the percentage of thymine in the DNA of a cell. A similar relationship was discovered for cytosine and guanine. This was later referred to as Chargaff's rule and led Watson and Crick to the ultimate conclusion that the molecule was directed inward—the result of which was their proposal that DNA was a double helix. Linus Pauling, who did so much work with proteins, wrestled with the molecule being directed outward; many others did as well, based on the strength of Dr. Pauling's reputation.



Thymine-Adenine base-pairing

Adenine-Thymine

This purine-pyrimidine bonding is the result of each base having two hydrogen bonding sites. Adenine and thymine can bond only with each other in DNA.



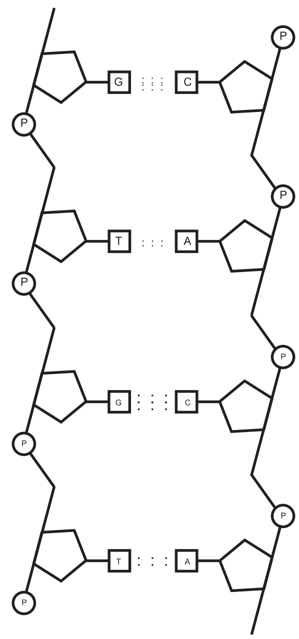
Guanine-cytosine base-pairing

Cytosine-Guanine

This purine-pyrimidine bonding in the DNA molecule is the result of these bases having three sites for hydrogen bonds. Cytosine and guanine can only bond with each other.

H+ bonds

The bonds between the adenine-thymine and cytosine-guanine classes of chemicals that form the base sequences in DNA, in addition to other places where we find hydrogen bonds.



DNA base-pairing

COMPLIMENTARY STRANDS

Since adenine always bonds with thymine and guanine always bonds with cytosine, if one strand of the DNA molecule is known, then the other, complimentary strand can be known. This means that if you have one half of the molecule, you can construct the other half, which is exactly what DNA does during replication. The main strand is used as a template to produce its complement. The nature of the bonds along the strand make the adenines on one strand line up in the opposite direction of the adenines on the other strand. As a result, the molecule is said to be anti-parallel.

5′ end

"Hanging out" on one end of the base pairs is the phosphate group, which is the end that starts the "reading" of the molecule when it is being replicated. The direction of replication along the master strand then is from 5′ end to 3′ end.

3′ end

Opposite the base on the master strand with its 5′ end is the complimentary strand with its 3′ end oriented outward at the "beginning" of this strand, in an anti-parallel way.

REPLICATION

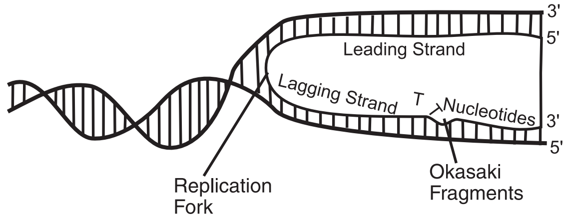
A combination of the words "***rep***roduce" and "dup***licate***," replication refers to the act of DNA making a copy of itself. This precedes mitosis or meiosis. Mitigated by enzymes, it proceeds as two concurrent events, one from the 5′ end of what is called the leading strand and the other from the 3′ end of the lagging strand. The result of replication is said to be semi-conservative, since we end up with half the original DNA in each of the resulting new strands.

DNA helicase

DNA helicase is an enzyme that begins the unraveling of the DNA molecule at the sites of the hydrogen bonds.

DNA polymerase

This enzyme arranges the new nucleotides next to their complimentary base to make the new strand of DNA. As the name suggests, it makes a polymer out of individual nucleotides.



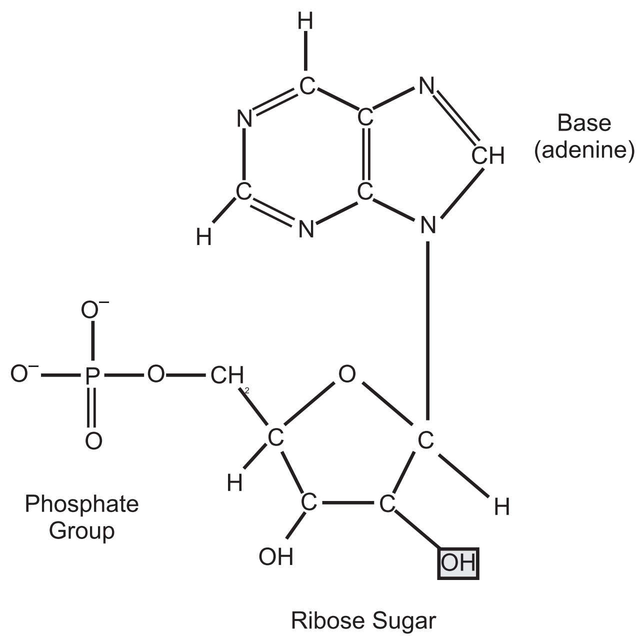
DNA replication

Leading strand

A leading strand is a strand of DNA that starts at the 5′ end and is made continuously. It is not named for the fact that it starts first, but for the fact that, since it is made continuously, the construction of it proceeds faster.

Lagging strand

A strand of DNA that starts at the 3′ end. Its production proceeds slower than the leading strand because it is made in pieces that are then bonded to the template to which it will be complimentary. These pieces, known as Okasaki fragments, are bonded into place by DNA ligases.



RNA nucleotide

RNA-RNA

RNA-RNA is a 5-carbon sugar that possesses an extra oxygen atom [compared with DNA] and replaces thymine with the base uracil, thus enabling it to pass through the nuclear envelope and take the code of DNA to the cytoplasm. Three types of RNA are made in the nucleus and reunite in the cytoplasm in the process known as protein synthesis.

TYPES

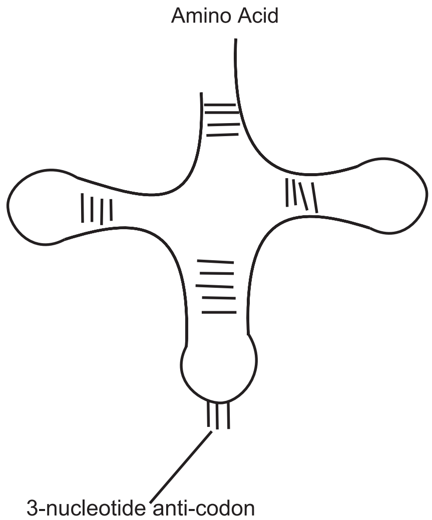
RNA, the carrier of the DNA code from the nucleus to the rough ER in the cytoplasm, has three forms that play a key role in the synthesis of proteins. These molecules, acting in concert, ultimately produce the proteins that control the life of the cell, even the production of RNA.

rRNA

Stored in the nucleolus, rRNA helps make up ribosomes that reside on the rough ER. Ribosomes are composed of rRNA and proteins. The mRNA attaches to the ribosomes and thus begins the making of a protein.

mRNA

mRNA is the lengthy form of RNA that is coded by the DNA molecule and carries that code for synthesis of a particular protein. This sequence will be “read” in the ribosome and serves as the blueprint for the precise sequence of amino acids that will make up the protein coded for in the mRNA. The codon is three consecutive nucleotides on the mRNA that code for a particular amino acid carried by the tRNA.



tRNA

tRNA

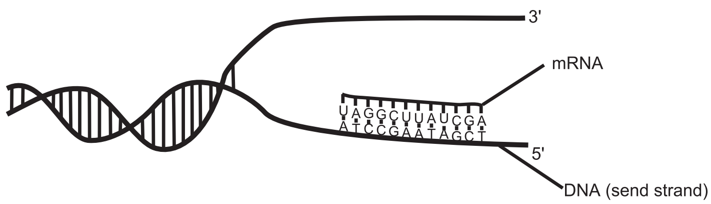
tRNA contains the anticodon to the mRNA's codon, just three nucleotides long; the nature of this molecule was hypothesized before the structure was actually known. The tRNA carries an amino acid to the ribosome, where it bonds to the codon on the mRNA. There are 20 amino acids that make up proteins. The sequence of these amino acids, like the sequence of nucleotide bases in the DNA, is critical. If there was one base pair for every one amino acid, this would result in only four amino acids ever being utilized to make proteins. Two base pairs for every amino acid will code for a maximum of 16 amino acids, four short of the needed 20 to transport all of the amino acids needed for life. It is now known that the tRNA molecules are, in fact, three bases long, providing more than enough variations to code for 20 amino acids as well as stop, start, and some duplication.

First Letter	Second Letter U	C	A	G	Third Letter
U	phenylalanine	serine	tyrosine	cysteine	U
	phenylalanine	serine	tyrosine	cysteine	C
	leucine	serine	STOP	STOP	A
	leucine	serine	STOP	tryptophan	G
C	leucine	proline	histidine	arginine	U
	leucine	proline	histidine	arginine	C
	leucine	proline	glutamine	arginine	A
	leucine	proline	glutamine	arginine	G
A	isoleucine	theonine	asparagine	serine	U
	isoleucine	theonine	asparagine	serine	C
	isoleucine	theonine	lysine	arginine	A
	methionine & START	theonine	lysine	arginine	G
G	valine	alanine	aspartate	glycine	U
	valine	alanine	aspartate	glycine	C
	valine	alanine	glutamate	glycine	A
	valine	alanine	glutamate	glycine	G

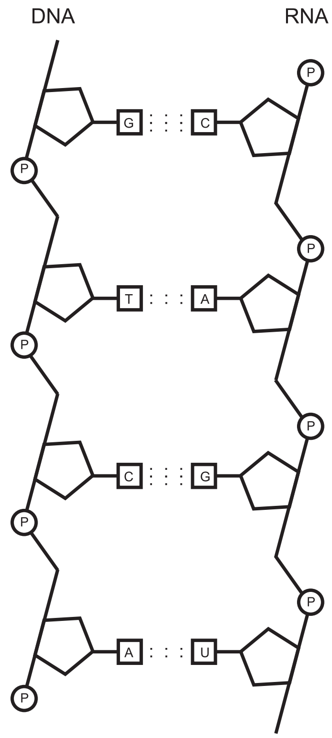
mRNA codons and accompanying amino acids

TRANSCRIPTION

Transcription takes place in the nucleus of eukaryotic cells. It is the first step in protein synthesis, wherein DNA's information is copied on RNA. Three RNA molecules, rRNA, mRNA, and tRNA, are made during this phase, each from the separate complementary strands of original DNA. They are then transported to the cytoplasm, where the next step is performed—*translation.* During translation, the sequence of codons on mRNA orders the sequence of amino acids in the protein. Transcription can be likened to what occurs in, say, a court setting, where the court reporter transcribes the spoken word into the written word—same language, different form.



mRNA transcription



DNA-RNA base-pairing

Bases

In RNA, uracil replaces the thymine found in DNA. The uracil, like the thymine it replaces, still bonds opposite adenine. Students should be careful not to associate uracil with thymine in a way that the uracil *replaces* the adenine. It doesn't; like thymine, it will bond *opposite* adenine as thymine does in DNA. In RNA, we will get A-U pairing, whereas in DNA, we get A-T pairing.

Sugar

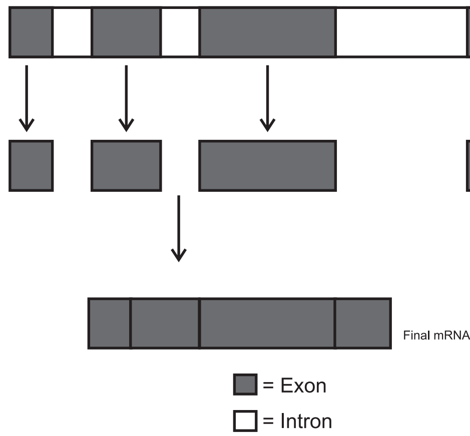
The 5-carbon sugar, along with the phosphate, is part of the backbone of nucleotides and is different in RNA. The RNA sugar has one more oxygen than the amount found in the DNA sugar. This makes this site possess an OH radical with no electrical activity. Alternatively, DNA possesses an H+ at that site, making its activity different than RNA.

Promoters

The site on DNA where transcription of RNA is begun, using only one of the DNA strands, the sense strand. The other strand—called the missense strand—is not used during this process.

RNA Polymerase

As the name of this enzyme suggests, its role is to bring RNA nucleotides into proper position on the sense strand ending in an mRNA strand.



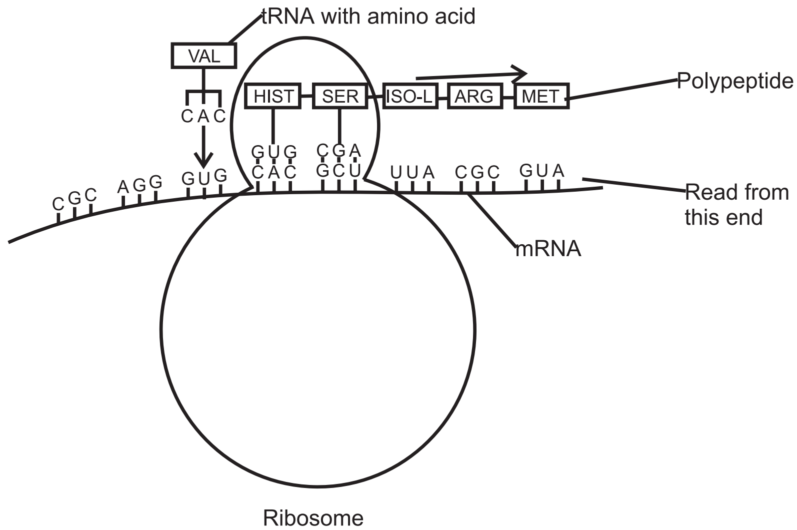
Final processing of mRNA

RNA modification

The mRNA molecule is not ready to be transported to the cytoplasm yet. It undergoes a final processing stage where the nonsense sequences, called *introns,* are excised, leaving the meaningful sequences known as *exons* to make up the final mRNA. A tail, called the poly(A) tail, is added to the 3′ end, a cap—5′ cap—is added to the 5′ end, and the molecule is ready to take part in the making of polypeptides.

TRANSLATION

Continuing the court reporter analogy, this stage of protein synthesis is like translating words from one language into another. In the case of the cell, we will be translating from the language of the nucleus into the language of the cytoplasm or cell on a larger scale. DNA has been replicated, it has transcribed its message into RNA, and a nucleic acid can safely leave the nucleus without having the original code compromised if anything should happen to this RNA. Finally, we translate the nucleotide sequences into polypeptide sequences.



Translation of RNA into proteins

mRNA

This is known as the codon and reflects the statement of the original code in the DNA. This will be placed along the ribosomes for "reading," the sequential passing of the base sequence over ribosome and subsequent bonding of tRNAs in proper places on the mRNA.

tRNA–tRNA molecules

tRNA–tRNA molecules transfer amino acids to the ribosomes. There is at least one tRNA for each of the 20 amino acids. Amino acids bond to one end of the tRNA. The other end contains a three-base anticodon sequence form of RNA, which codes for specific amino acids. While their nucleotide end anticodon bonds with the next sequence on the mRNA, their amino acid form lines up with the next amino acid.

A. Start

The mRNA sequence that initiates the construction of all polypeptides is A-U-G, which is bonded with the tRNA sequence of U-A-C that carries the amino acid methionine.

B. Stop

There are several stop codons on the mRNA, namely U-A-A, U-A-G, and U-G-A, which bond opposite the tRNA anticodons of A-U-U, A-U-C, and A-C-U, respectively.

Polypeptides

The chains of amino acids that make up the polypeptides are, in sum, formed in the following way. Once the mRNA is attached to the rRNA in the ribosomes, the tRNA anticodon, with its accompanying amino acids, moves into position on the codon of mRNA. The mRNA is then shifted by three bases along the rRNA and makes room for another tRNA-amino acid complex to move into position. Once this occurs, the two adjacent amino acids are bonded to each other in a peptide bond at the amine and the carboxyl groups. Once again, mRNA is shifted, and another tRNA-amino acid moves into place. Another peptide bond is formed between this third amino acid in the sequence and the second amino acid. As the process continues, the tRNAs are immediately rejected from the mRNA—the tRNA-amino acid complex is the substance that was moved into position on the mRNA, *not* the tRNA by itself. It is now available to leave the area and pick up another amino acid specific to itself. In addition, the molecule is continually moved along the rRNA sites, and, thus the polypeptide elongates. When codons U-A-A, U-A-G, or U-G-A are encountered, the process stops and a polypeptide is formed. The formation of a protein may not be complete and depends on the interaction among the amino acids as to what form this protein will take. Some, like insulin, are actually shortened in order to become active. Not all proteins will become enzymes—some will be structural, as in the proteins in the plasma membrane or those that make up part of other biological molecules. Originally, the thinking was characterized as "one gene—one enzyme," but is now thought to be more accurate with the phrase "one gene—one polypeptide chain."

MUTATIONS

Characterized as "errors" in the genetic code, these cause a change in the functioning of the cell, either as a structural anomaly—as in the case of sickle cell anemia—or as a functioning anomaly, such as a defective enzyme. There are so-called micro-mutations and macro-mutations. Both form the basis for much of our evidence for evolution. The causes of mutations can be almost anything from radiation to physical disruption of the cell—a rare one—to environmental factors to chemicals. Pollution is feared to be the potential cause of many mutations.

Point

Point mutations are those that occur at a specific site along the DNA molecule, specifically a change in a single nucleotide. One type of point mutation is base substitution, during which one base along the original DNA sequence is replaced by another base.

Frame shift

The entire sequence is shifted one or more frames along the DNA sequence. Two types of mutations that cause a frame shift mutation are insertion (a base is added into the original DNA sequence) and deletion (a base is deleted from the original DNA sequence.)

MACRO-MUTATIONS

These mutations tend to affect larger numbers of DNA sequences, even up to whole chromosomes, as in the case of the first type discussed below.

Non-disjunction

Chromosomes fail to separate properly during the process of meiosis, as in the cases of Down's, Turner's or Klinefelter's syndromes.

Translocation

A segment breaks off of one chromosome and moves to another chromosome.

Inversion

A segment of a chromosome breaks off and is inserted in reverse order.

Deletion

A segment of a chromosome breaks off and is lost.

Duplication

An extra copy of a segment of a chromosome is produced along the chromosome.

RECOMBINANT DNA

Recombinant DNA is the transferring of DNA segments from one entity to another, whether it is DNA molecules or chromosomes. Recent technology uses restriction enzymes from bacteria to slice DNA in very specific places for the purposes of recombining sequences or assaying the nature of a sequence.

BACTERIAL GENETICS

Variation is introduced into bacteria cells in several ways. One is by conjugation, the exchange of DNA between bacteria. Another, transduction, occurs when DNA is introduced into the bacteria by a virus. Transformation occurs when bacteria absorb free pieces of DNA from their environment.

VIRAL GENETICS

Non-living substances, viruses can nonetheless take over a living cell in two stages. The first, called the lytic stage, is when the virus penetrates the cell, uses cellular enzymes to duplicate viral particles, transcribes the DNA into RNA, and then uses the RNA to make proteins. The second, called the lysogenic stage, occurs when an infected bacterium does not immediately duplicate viral particles. The viral DNA is temporarily incorporated into the cellular DNA.

EVOLUTION

Evolution is the changes in the frequencies of certain genes in a population over a period of time; 11 percent of the SAT II Biology exam has questions on this subject. Genetic variation is what drives evolution. Much of what involves evolution also involves knowledge of several fields of geology, as will be seen. We will provide the highlights of this concept and make reference to areas that the student will want to be conversant with outside the specific area of biology, such as paleobiology or biogeography.

JEAN-BAPTISTE DE LAMARCK

Lamarck popularized the notion that acquired traits were passed on to future generations. Changes in the body cells are not capable of being passed on. Only sex cell changes achieve this. Lamarck's theory became known as the use-disuse theory and was soon seen by many as fruitless. If one loses a finger prior to having children, those children will not be missing a finger as a result of the parent losing a finger. Especially with our knowledge of the nature of mutations, we can reject this idea outright. Darwin did also.

CHARLES DARWIN

The nineteenth-century naturalist who advanced the notion of Natural Selection, which became the foundation of his theory that led him to conclude how species came to be so varied on the planet. Basically, he stated that nature selects those organisms that will survive and pass on their survivability traits.

Natural Selection

Natural Selection is Darwin's idea that species could not simply acquire the trait that allowed them to survive. Like the culling of a herd that predators achieve, the ability to survive better than other members of the species led him to conclude that nature was bringing about the changes—we now know the level on which this proceeds. Changes in DNA, and/or DNA combinations provide the variation; nature selects the fittest.

A. Number of offspring

Species produce more offspring than the environment can support.

B. Competition

As a result of overproduction, these offspring are led to compete with each other for survival: food, shelter, water, etc.

C. Variation

Within every population, there is the potential of having variation among the members. Students will note that this is the place that modern molecular genetics has provided evidence that this happens.

D. Survival of the fittest

Those in the population who are more fit will survive to mate.

E. Evidence

Evidence comes from a variety of scientific areas of study, as was mentioned before. The areas include, but are not limited to, biogeography, comparative anatomy, embryology, molecular biology (which is the main subject of this chapter) and paleontology.

F. Types

There are three ways in which nature "selects" the fittest to survive, and they have significance in terms of how evolution will proceed.

1. *Directional*—phenotypes that are at the extremes of a range of traits are selected against those at the opposite end of the range.
2. *Stabilizing*—selects out individuals with extreme traits, favoring those with more common traits. Those with the extreme traits have fewer means to survive.
3. *Disruptive*—favors the extremes mainly when the environmental changes favor these extreme traits.
4. *Sexual*—differential mating of a sex in a species that ensures their survivability. For example, if a female mates with a superior male and produces superior offspring, she will more likely be able to survive now through that male's protective attachment.

5. *Artificial*—directional selection mediated by humans.

Speciation

Speciation is the process by which a new species originates. The emergence of a new species as a result of the interactions within molecular and environmental parameters producing what is known as divergent evolution: two closely related species emerge from a common predecessor. Members of the same species look alike, behave alike, and can mate and produce offspring that can mate.

A. Types

There are two known types of speciation that center around the variation that can occur when a barrier arises between members of a species or when no barrier arises, species simply diverge on their own—caused by the "usual" factors, of course.

1. *Allopatric*—a geographical barrier separates parts of a population and, over time, the two diverge to become two distinctly different species.
2. *Sympatric*—a geographical barrier does *not* separate members of a population yet, over time, the two diverge to become two distinctly different species. This occurs often in the plant kingdom.

B. Sources

Speciation of variation within a population can be caused by a variety of factors acting alone or in concert.

1. *Mutations*—many mutations or mistakes in the DNA makeup are lethal and do not get passed on. Alleles never before present in the population can arise, however, by mutations to the gene pool.
2. *Diploidy*—the production of two copies of each chromosome in a cell.
3. *Sexual reproduction*—during meiosis, events can emerge, such as independent assortment, random gamete selection, and crossing over.
4. *Outbreeding*—mating that occurs between unrelated partners.
5. *Balanced polymorphism*—the maintenance of a variety of phenotypes in a population, the most advantageous of which possess survival value. The non-advantageous alleles decrease in frequency.

C. Allele Frequency

Darwin proposed natural selection as the means by which evolution proceeded. With the advent of modern genetics, we have discovered other factors that obviously impact the nature and direction of evolution. Basically, these factors change the frequency of allele availability and thus have the effect of advancing evolution. Besides mutations and natural selection itself, other factors are briefly outlined below.

1. *Gene flow*—changes that occur in the population when individuals enter or leave the population.
2. *Genetic drift*—random increase or decrease in alleles.
3. *Nonrandom mating*—when individuals choose with whom to mate, including inbreeding (the mating with relatives) and sexual selection (the selection by females of a particular male).

D. Genetic equilibrium

Genetic equilibrium, also called the Hardy-Weinberg equilibrium, is a favorite subject of SAT II Biology test-makers. Genetic equilibrium occurs when allele frequency remains unchanged, meaning there is no evolution: factors—mentioned above as affecting allele frequency—are held constant. The frequency for each allele is given by p and q, the frequency of homozygous individuals is given by p^2 and q^2, and the frequency of heterozygous individuals is given by $pq + qp = 2pq$. The following equations hold: (1) $p + q = 1$ (the sum of the alleles is 100 percent) and (2) $p^2 + 2pq + q^2 = 1$ (the sum of all the individuals is 100 percent). This equation holds true if

1. no natural selection occurs.
2. no mutations occur.
3. the population is isolated from other populations.
4. the population is large.
5. mating is random.

The Hardy-Weinberg equilibrium formula is a baseline used to judge if evolution has occurred. If there is a change in allele frequencies in a population, then evolution has occurred.

Patterns of evolution

Four patterns emerge in evolutionary studies.

A. Convergent evolution

When two unrelated species share similar traits through adaptation to similar environmental conditions.

B. Divergent evolution
Allopatric or sympatric speciation lead to the emergence of two species from a common ancestor.

C. Parallel evolution
After diverging from a common ancestor, two unrelated species make similar evolutionary changes.

D. Co-evolution
An almost leap-frogging of traits where one species adapts to a new set of conditions and another species adapts to new conditions brought about by the new species.

MULTIPLE-CHOICE QUESTIONS

1. Which of the bonding examples below is NOT possible?

(A) a DNA adenine to a DNA thymine
(B) a DNA adenine to an RNA thymine
(C) a DNA guanine to an RNA cytosine
(D) a DNA adenine to an RNA uracil
(E) a DNA guanine to a DNA cytosine

2. Which of the following replaces guanine in RNA?

(A) adenine
(B) thymine
(C) cytosine
(D) uracil
(E) none of the above

3. Which of the following statements is true about mutations?

(A) Rates tend to be very high in most populations.
(B) generally lethal
(C) irreversible
(D) Only certain gene locations are affected.
(E) source of genetic variation

4. For the DNA strand 5′-A-C-C-G-T-G-A-C-A-T-T-G-3′, the correct compliment DNA would be

(A) 3′-T-G-G-C-A-C-T-G-T-A-A-C-5′.
(B) 5′-T-G-G-C-A-C-T-G-T-A-A-C-3′.
(C) 3′-U-G-G-C-A-G-U-G-U-A-A-C-5′.
(D) 5′-A-C-C-G-U-G-A-C-A-U-U-G-3′.
(E) 3′-T-C-C-G-A-G-T-G-T-A-A-C-5′.

5. The portion of the DNA molecule that can vary is its

(A) sugar.
(B) base.
(C) deoxyribose.
(D) ribose.
(E) phosphate.

6. An mRNA is 429 nucleotides long. The number of amino acids in the polypeptide chain formed from this mRNA is

(A) 143.
(B) 142.
(C) 141.
(D) 429.
(E) 428.

7. Which of the following is NOT consistent with Griffith's experiments?

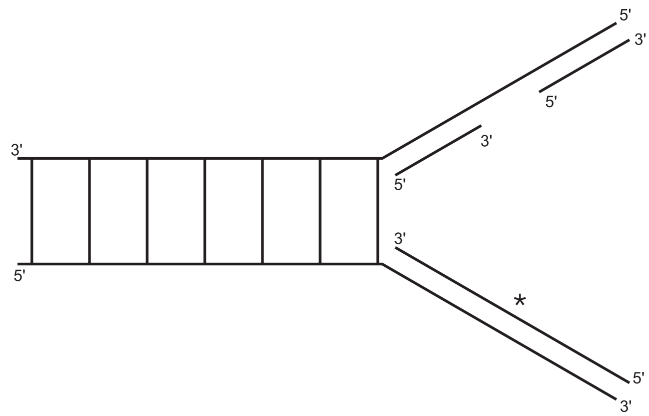
(A) injected mixture of R-strain and live S-strain: mouse dies
(B) injected mixture of heat-killed S-strain and live R-strain: mouse lives
(C) injected heat-killed S-strain: mouse lives
(D) injected R-strain: mouse lives
(E) injected S-strain: mouse dies

8. Which of the following is a semi-conservative process?

(A) DNA replication
(B) non-disjunction
(C) translation
(D) transcription
(E) crossing over

9. In the illustration below, the strand with an (*) is the

(A) promoter.
(B) Okasaki fragment.
(C) template.
(D) lagging strand.
(E) leading strand.



10. Darwin's Natural Selection includes all of the following EXCEPT

(A) Variation can be due to mutations.
(B) The difference in survivability between organisms may be due to variation.
(C) Not all organisms may survive, due to competition.
(D) Organisms produce more offspring than can survive.
(E) Some organisms will be more fit to survive than others.

Explanation of Answers for Multiple-Choice Questions

1. The correct answer is (B). In RNA, thymine is replaced by uracil, so the correct choice is (B), where DNA adenine is said to bond to an RNA thymine. All the other choices are incorrect, including the DNA guanine to an RNA cytosine. The testmaker may depend on the student vaguely remembering that a certain base-pairing between DNA and RNA is not possible and may choose choice (C) as being correct. This is not the case.

2. The correct answer is (E). Guanine is not replaced in RNA. It is found in both DNA and RNA. The trick here, once again, is the vague recollection of something being replaced. Of course, thymine in DNA is replaced by uracil in RNA, and uracil is on the list. However, the question here asks about the replacement of guanine, which does not occur. The bases listed in choices (A) and (C) also are found in RNA.

3. **The correct answer is (C).** These recent conclusions about mutations—recall that Darwin did not know of mutations—are all the reverse of those listed in the choices, with the exception of choice (C), the correct answer. Rates, in fact, tend to be below in populations, mutations are generally not lethal, any gene location can be affected, and they are felt to be the source of genetic variation. Darwin felt over-production of offspring was the source of potential variation.
4. **The correct answer is (A).** The complimentary strand for the indicated DNA strand would begin at the 3′ end, not at the 5′ end. In addition, it would also have thymine—T. Finally, opposite A would be T, and vice-versa, and opposite G would be C, also vice-versa.
5. **The correct answer is (B).** Choices (A), (C), and (E) are all places on the DNA that are constant and form the sides of the DNA "ladder." The place at which the molecule differs is in the bases that form the rungs of this ladder, providing DNA with a virtually infinite number of variations. Ribose, of course, refers to RNA and should not be on the list when discussing DNA.
6. **The correct answer is (B).** tRNA, which contains 3 anti-codon bases for every amino acid it carries, matches up opposite the mRNA codons that are also three bases long. This means that the mRNA in question potentially codes for 429/3 amino acids. This gives us a potential of 143 amino acids or choice (A). However, the stop sequence does not code for an amino acid, so this gives us 142 amino acids coded for. Care should be exercised when considering the start sequence. While not a part of the resulting protein, that site does code for the amino acid methionine in the translation process.
7. **The correct answer is (B).** The foundation of Griffith's work was that the mice that received the killed Smooth-coat strain/Rough-coat strain mix, in fact, died. This suggested that the inheritable trait of producing a lethal substance to mice could be inherited by the R-strain bacteria. All the other choices are true and led to the experiment outline briefly in choice (B), but the conclusion of that experiment, once again, was that all the mice died.
8. **The correct answer is (A).** In DNA replication, each new strand receives half of the original DNA, a process said to be semi-conservative—it conserves only half of the original DNA for each new strand produced. Crossing over and non-disjunction are macro-genetic events that occur during meiosis and pass on all of the genetic information for the event. Crossing over exchanges whole parts—however long—of one chromosome with whole

parts of a homologous chromosome. Non-disjunction causes an entire chromosome to be incorrectly separated. Translation and transcription pass along the entire code for a protein from RNA to polypeptide and DNA to RNA, respectively.

9. **The correct answer is (E).** The strand with a (*) is being replicated from the 5′ end onward and will proceed without delay. The strand with the 3′ end as a start—opposite the 5′ end on its compliment, the sense strand—makes this strand the anti-sense strand and is fashioned piece by piece from Okasaki fragments. These fragments are bonded onto the anti-sense strand with DNA ligases. The construction of the 3′ strand then proceeds slower than the construction of the 5′ end and is said to lag behind. Since the strand with a (*) is the 5′ end, it is not an Okasaki fragment, nor is it a template; the sense strand is the template and a promoter is a molecule that starts the process: it is not a DNA molecule, but a protein.

10. **The correct answer is (A).** Darwin did not know of mutations, so choice (A) is the correct answer. Fundamental to his idea of natural selection was that, in order, (1) organisms produce more offspring than can survive and, (2) due to competition, not all organisms will survive, which means, (3) some organisms will be more fit to survive than others, and (4) variation may be the reason for the difference in survivability.

VOCABULARY

adenine
anticodon
base pairing
base substitutions
codons
complementary
cytosine
deletions
deoxyribonucleic acid (DNA)
deoxyribose
DNA polymerase
DNA replication
double helix
Down's syndrome
duplication
exons
guanine
hydrogen bonds
insertions
introns
inversion
mRNA
mutation
nitrogenous base
nondisjunction
nucelotides
peptide bond
point mutation
promoters
proteins
protein synthesis
ribonucleic acid (RNA)
ribose
RNA polymerase
RNA primer
rRNA
template
thymine
transcription
translation
translocation
tRNA
uracil

Unit III—Organizations and Populations

Chapter 6

ORGANISMS AND POPULATIONS

OVERVIEW

This material constitutes about 30 percent of the SAT II Biology exam. This part of the study of biology, then, contains the bulk of the material on the scale of entire organisms. Previous chapters have dealt basically with how the organisms function mostly at the molecular level. We now explore organism-level structure—and, therefore, function—and on a grander scale, the biology of the organism and how organisms as populations interact with one another and with other organisms, as well as with their environment. Carolus Linnaeus is credited with organizing living things into understandable groups based on their structures and giving them a two-part name. Today, we use many characteristics, including behavior and, more recently, DNA analysis. Since the earliest times, humans have attempted to understand their world, and one of the ways to start the process is to organize it. The way humans have done this has changed over time. This chapter is about the grouping of organisms. Some of the vocabulary at the end of the chapter will not be detailed here, but we suggest that the student know all of those terms; this holds true for all the chapters in this book.

CLASSIFICATION

Taxonomy, or the science of classifying organisms, groups organisms into categories based on various characteristics.

SCHEMA

Just as we find in grocery stores, the organisms are placed in specific categories. Imagine trying to find an item in the store if all of the delivery vehicles dumped their goods at the front door. In a like manner, grouping organisms has many benefits. Imagine proposing that a predator of a parasite be introduced into the local environment in an attempt to control the parasite population, but instead, the organism you believe to be the predator is actually a slight variation of that predator and has no interest whatsoever in the parasite you are trying to eliminate. You may now have two problems to deal with, and at the very least, you haven't done anything to help control the parasite.

Aristotle

Aristotle's classification system proposed that if something moves, it is an animal, and if it doesn't, it is a plant. Of course, sponges were mistakenly taken for plants, and when they threatened the shellfish industry centuries ago, were "killed" by being cut up and tossed back into the sea. To the surprise of the shellfish harvesters, the next year, the number of sponges had increased; the shellfishers were actually helping the sponges reproduce (asexually) by their actions.

Aristotle's Taxonomy

Motile … Animal
Non-Motile … Plant

Linnaeus

Linnaeus proposed naming organisms by a two-name system that we call *binomial nomenclature.* These were very specific names based on the organism's characteristics and are the genus and species of today. Note that the genus is always capitalized and the species is not, as in Terrestris americanus, and the entire name is underlined or italicized.

Modern

The modern system of classification now contains five major groups called *kingdoms.* Life on the planet could be seen as analogous to a grocery store. The major consumer item areas, such as produce, dairy, and canned goods, would be analogous to the kingdoms of living things. As with the grocery store, the sub-categories get more and more specific until it is possible to name an item exclusive of all other items in the store. You should know the categories, starting with the largest (the kingdom) and continuing to narrower and narrower groups in the sequence: Kingdom, Phylum, Class, Order, Family, Genus, and Species. In plants, the word "phylum" is replaced with the word "division." Modern day study has become so detailed that we will now find such categories as sub-genus and super-species. The student is responsible only for the above schema. Most beginning biology students become familiar with the mnemonic—memory device—in a variety of expressions, one being *K*ing *P*hillip *C*ome *O*ut *F*or *G*oodness *S*akes. The first letter of each word, in the order given, is the first letter of each of the major categories in taxonomy.

Modern Taxonomy

Kingdom
Phylum
Class
Order
Family
Genus
Species

Examples of Genus and species

Canis familiarus
domesticated dog

Felis feline
domesticated cats

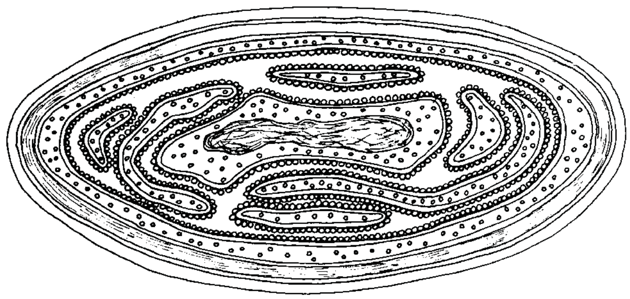
Homo sapiens
modern humans

MODERN TAXONOMY

Today, scientists generally agree on five major categories of living things, or kingdoms, although there are several classification systems. Students may want to become familiar with how these categories came to be agreed upon. You should recall that some of these organisms were mentioned in other chapters and at other levels. The good news is that the SAT II Biology exam does not test for information as detailed as how the phylogenic categories arose. A brief word about viruses seems appropriate at the beginning of a discussion on the taxonomy of living things. Viruses, while not considered a living thing, can, nonetheless, take over the cell chemistry of a living thing to reproduce. We will now outline the schema of living things.

Prokaryote (Moneran)

Prokaryotes are single-celled, microscopic prokaryotic (see Chapter 2) cells with no distinct nucleus or other membrane-enclosed organelles.



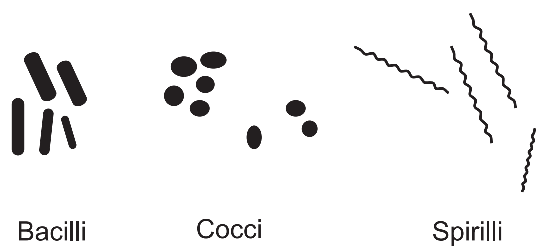
Typical Prokaryotic cell

Bacteria

Bacteria have cell walls composed of peptidoglycan, an amino acid–sugar complex, and circular DNA. Composition of the cell wall provides us with the Gram staining means of identifying certain types of bacteria. Reproduction of bacteria was outlined in an earlier chapter. Some bacteria possess flagella. While many bacteria are decomposers, some fix nitrogen and other elements in a form usable by organisms, and some are pathogenic.

A. Shapes

Bacteria can be found in three shapes: coccus (round-shaped), bacillus (rod-shaped)—the one the SAT II Biology exam commonly refers to when asking a question about bacteria—and spirillus (spiral-shaped).



Bacteria Types

B. Types

Aerobic (oxygen-needing) bacteria are the largest group of bacteria. Anaerobic (not needing oxygen) bacteria are found in two groups: those that need an oxygen-free environment (obligate) and those that do not need a lack of oxygen, but a small amount of oxygen will not kill them (facultative).

C. Significance

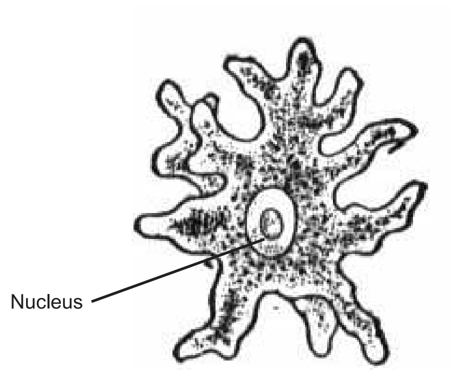
Bacteria are the most populous organisms on earth—they can be useful for things like making pickles from cucumbers, or they can be lethal, as in the case of pneumococcus and several STDs.

Cyanobacteria

Producer prokaryotes, their numbers can "explode" under the right conditions and are the cause of water pollution associated with algal blooms. They are photosynthesizers that sometimes fix nitrogen. They, in symbiotic association with fungi, form lichens.

PROTISTA

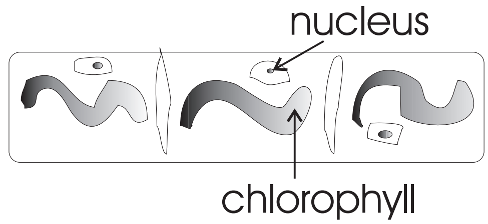
Protista (also called protoctist) are single-celled eukaryotes. This kingdom is a composite for organisms that do not fit in other kingdoms.



Amoeba

Protozoan

Protozoan are classified by their mode of locomotion. Amoeba and paramecium are two of the Protists about which test questions are asked. The amoeba is a heterotrophic, shapeless organism that moves by pseudopods and engulfs its food by the endocytotic method known as phagocytosis. The paramecium, also a heterotroph, moves about using tiny hair-like projections known as cilia. Cilia also help the paramecium in engulfing food.



Algae

Eukaryotic algae

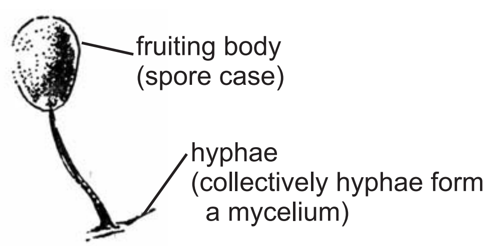
The plant-like protists, they include green algae, brown algae, golden algae, diatoms, dinoflagellates, red algae, and the euglena. The euglena, heterotrophic in the absence of light, possess chlorophyll and from one to three flagella. Green algae, in association with fungi, also form lichens.

Slime molds

Fungi-like protists that resemble fungi because at one point in their life cycle they come together as a unit—looking like a multicelled organism—and form spores.

FUNGI

Formerly classed as plants, fungi do not possess chlorophyll—making them heterotrophs. The fungi are structurally different from plants, so they have been placed in their own kingdom. For example, they have no cell membrane. Some fungi are unicellular, while others are multicellular. Fungi are predominantly haploid, becoming diploid for the purpose of reproduction through the production of spores.



Reproductive body of Fungus

Types

Fungi are classed into three groups based on how they obtain nutrients.

A. Saprophytic

Live off dead organisms

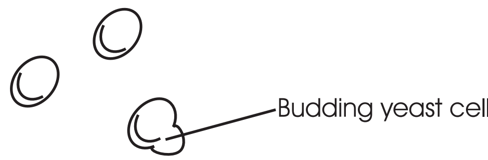
B. Parasites
Live off live organisms

C. Symbiotic
Work in concert with other organisms

Members

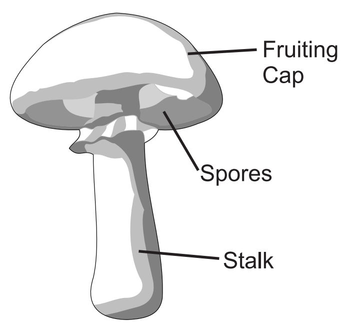
The following are the major groups of fungi covered on the SAT II Biology Exam.

A. Molds (the zygospore fungi)
Molds invade hosts through root-like hyphae, which they also use for reproduction. Bread molds are an example of this group.



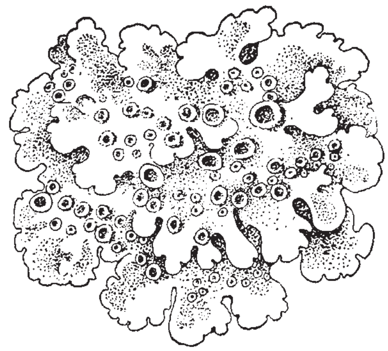
Yeast

B. Yeast (the sac fungi that form ascospores)
Along with mildews, they are primarily unicellular but form fruiting bodies containing ascospores for reproduction. This group also includes the much sought after truffle.



Mushroom

C. Mushroom (the club fungi that form basidiospores)
Multicellular fungi include the well-known mushroom.

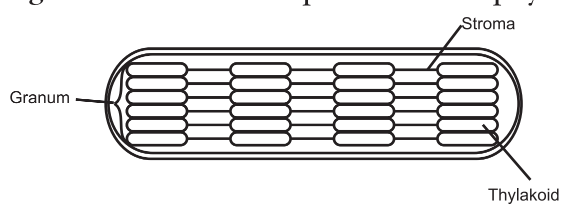


Lichen

D. Lichens
A symbiotic union between fungi and either a chlorophyta [eukaryotic algae] or a cyanobacteria.

Plants

Multicellular and autotrophs, these organisms contain chlorophyll bound in organelles called chloroplasts—***chloro***phyll ***plast***ids.



Chloroplast

The dominant generation in most plants is diploid, most have vascular tissue, and they reduce desiccation with a cuticle—a waxy coating on all aerial parts. Advanced forms possess ovaries and have adapted to seasonal changes, as in the case of the deciduous trees. You will want to use this outline as a guide to studying plants. We start with bryophytes despite the fact that the nonvascular bryophytes are very different from the vascular plants.

Bryophytes

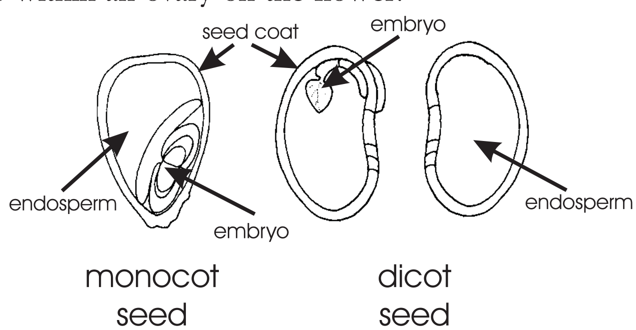
The simplest plants, these plants do not have true roots, stems, or leaves. This fact limits the movement of water through the organisms and therefore is a major limitation to the plants, mostly in size, but also in storage of water and in the process of reproduction, so their habitat is very moist. In reproduction, for example, the sperm must swim to the egg. Adult bryophytes are haploid, entering the diploid stage when the sperm fertilizes the egg. Following this, spores are produced by meiosis and *alternation of generation* has once again brought about the haploid generation, which dominates the cycle. This division of plants includes the mosses, liverworts, and hornworts.

Vascular plants

More typical of the plants are the vascular members of the kingdom, some of which are extinct but are included in the schema. Vascular plants are predominantly diploid throughout their life cycle, producing haploid sperm and egg for the purposes of reproduction. Eggs are produced in an ovary and sperm in the pollen grains.

A. Seedless vascular plants

1. *Lycophytes*—one group of lycophytes includes the extinct woody trees of the carboniferous period, and the second includes epiphytic plants that live off other plants, such as the so-called club mosses because of their club-shaped, spore-producing cones.
2. *Sphenophytes*—includes another group of extinct trees from the carboniferous period and herbaceous plants known as horsetails because they produce filamentous leaves that resemble horsetails.
3. *Pterophytes*—this group includes the ferns and has spore-bearing capsules on the underside of the leaves, called sori.
4. *Gymnosperms*—the first group of seed plants, some "naked seed" conifers take up to three years to complete reproduction, with the result being an unprotected seed. Gymnosperms bear pollen-producing male cones and ovule-bearing female cones all on the same tree.
5. *Angiosperms*—include the flowering plants, a major evolutionary adaptation for the angiosperms, and produce coated or covered seeds within an ovary on the flower.



6. *Classification*

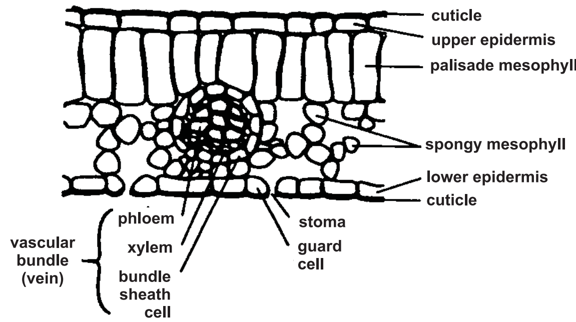
- *Monocots*—In seeded plants, the structure that stores the next generation's embryo, as well as a good amount of nutrients to get the embryo started, is contained in cotyledons. These are not seed halves, although the dicots contain two. Monocots only contain one.
- *Dicots*—so-called because they have two seed-bearing structures.

7. *Tissues*—there are three different types of plant tissues based on their function.

- *Ground tissue*—these tissues serve as support tissues for storage, photosynthesis, and secretion. Examples are collenchyme, sclerenchyme, and parenchyme tissues.
- *Dermal*—covers the outer portion of plants and includes the guard cells, hair cells, stinging cells, and glandular tissue. The aerial tissues secrete the cuticle, a waxy coating that acts to prevent water loss.
- *Vascular*—for transporting material throughout the plant, which includes xylem and phloem. These tissues, respectively, carry water and minerals up the plant and distribute photosynthetic products throughout the plant. Xylem cells are perforated specialized cells producing, in effect, one long tube. These tissues play a vital role in the transpiration-tension theory that explains how through adhesive and cohesive forces—hydrogen bonding, surface tension, capillary action—and the loss of water through the stomata, a plant moves water, in some cases, over considerable distances. Phloem tissue is made up of sieve-tube cells and companion cells and is likewise "connected," helping to pass on nutrients.

8. *Organs*—vegetative organs are roots, stems, and leaves. Reproductive organs are flowers, fruits, and seeds.

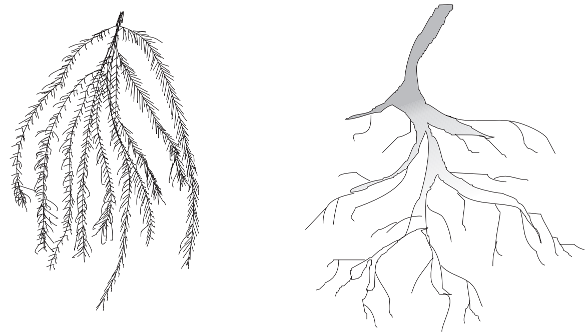
- *Seeds*—contain the next generation's embryo as well as stored nutrients. Under the right conditions and with the absorption of water, the seed germinates. The seed then goes through a primary and a secondary growth on the way to maturing into the next generation of adult plant.



Cross section of typical leaf

- *Leaves*—leaves are the main photosynthetic structure in plants and contain five distinct parts, each with their own function.
    - ▷ *Epidermis*—the outer layer of cells, like the skin of an animal, it serves to protect and prevent desiccation. A waxy substance called a cuticle may be secreted.
    - ▷ *Palisades layer*—so-called because it contains a layer of closely packed vertical photosynthetic cells. The arrangement allows the maximum exposure to the light of the sun. The cells are photosynthetic.
    - ▷ *Spongy layer*—contains photosynthetic cells more loosely connected than those in the palisade layer. The spaces provide room for CO_2, O_2, and H_2O vapor to circulate.
    - ▷ *Guard cells*—found on the exterior side of leaves, these are specialized epidermal cells that change shape as the amount of water in the leaf changes. The opening that results when they swell up with water is called the stomate. It provides for passage of gases in and out of the leaf, including water vapor.
    - ▷ *Vascular bundles*—made up primarily of xylem and phloem tissues bundled together.
- *Stems*—the main support of the plant, they also contain tissues for storage of materials as well as vascular tissue and, in some cases, cells with chloroplasts.

- *Roots*—are the extensions of the stem, in a manner of speaking, into the ground and provide for water transportation, anchorage, some support, and possibly storage.



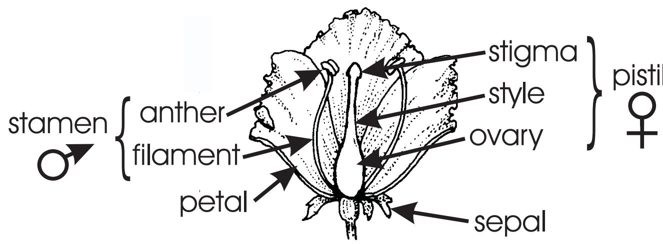
- *Flowers*—the reproductive organ of flowering plants, students should know the parts and their function.
    - ▷ *Pistil*—the female reproductive organ, it consists of a stigma, where pollen lands, and provides connection between the style and the ovary where the egg is fertilized. The ovary turns into the fruit containing the seed. The seed includes the embryo and all stored food for the embryo.
    - ▷ *Stamen*—the male reproductive organ, it consists of the anther and the stalk, or filament. The anther produces pollen that contains a generative cell and a tube cell. The pollen develops into a pollen tube, which grows down the style to the ovary. During the growth of the pollen tube, the generative cell develops into two sperm cells. In the ovary, one sperm fertilizes the egg, and the nucleus of the other sperm fuses with the polar nuclei.
    - ▷ *Sepals*—sepals protect the unopened flower.
    - ▷ *Petals*—petals in most cases aid in pollination by attracting pollinators.

Plant Growth and Development

Plants respond to interval stimuli, such as hormones and external environmental stimuli, by tropisms and photoperiodism.

1. *Hormones*—plants produce hormones that can pass from one cell to the other and affect the growth and differentiation of plant tissues.

- *Auxins*—promotes the elongation of certain cells and helps in the growth of the plant, mainly in the tips of shoots and roots.
- *Gibberellins*—these promote cell growth and fruit and seed development.
- *Cytokinins*—as the name suggests, these stimulate cell division.
- *Ethylene*—in the form of a gas, ethylene promotes the ripening of fruit, the production of flowers, and the promotion of leaf abscission.
- *Abscissic Acid*—a growth inhibitor that delays seed germination and bud development. It also may play a role in abscission.



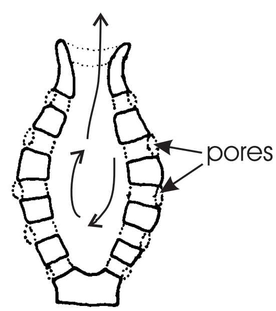
Flower

2. *Tropisms*—Plants are capable, under the influence of hormones, of growing toward or away from certain influences in the environment as they meet their needs in such an action. The name suggests a moving toward, but it is a growth process.
    - *Phototropisms*—growth toward light that is mediated by auxins.
    - *Gravitropism*—response by roots to the field of gravity and appears also to be mediated by auxins, although the classic role of light is absent—gravity being the influence that affects the concentration of auxins in certain cells.
    - *Thigmotropism*—response to touch.
    - *Chemotropism*—response to chemical.
3. *Photoperiodism*—the response by plants to varying amounts of light over time, particularly the length of day and night.
    - *Long-day plants*—are stimulated to bloom by increasing amount of daylight or, conversely, a decreasing amount of dark.

- *Short-day plants*—are stimulated by decreasing amount of light to enter their growth stage or an increasing amount of dark.
- *Day-neutral plants*—do not respond to changes in daylight but to some other environmental factor.

ANIMALS

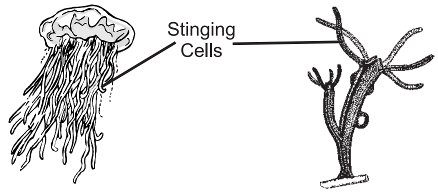
In this section, we will briefly outline the organisms that students should be familiar with. The schema used should be noted for the evidence it provides for evolution. The student should be familiar with these evolutionary connections. In an outline such as this, a biology text is indispensable and provides the detail that would make this a text on zoology or comparative anatomy if it were included. The SAT II Biology exam tests more on the related systems found in organisms, with comparisons to humans, than it does on the taxa of the individuals. Ancillary material to this subject would include the following: animals are multicellular heterotrophs, predominantly diploid; embryologically, most have three cell layers with increasing complexity as we go through the taxonomy; body symmetry is radial—a circular body plan—in the lower phyla or bilateral where organisms possess a top (head), bottom (tail), front (ventral), and back (dorsal), and many organisms are segmented, which is a key evolutionary stage.



Sponge

Porifera

The sponges. While some look cigar-shaped, they have no symmetry and contain a loose association of spicules that form a support—not skeletal—system. As the name suggests, they contain pores through which water and food pass.



Jellyfish Hydra

Cnidaria

Cnidaria include the sea anemone, hydra, jellyfish, and corals, which secrete a hard coating around themselves for protection. There are two morphological forms, the medusa and the polyp. The medusa is free-floating. In some cnidaria, the two stages alternate throughout their life cycle, with the polyp form producing the motile medusae which produce the sperm and egg. Cnidarians are radially symmetrical, have a digestive cavity with only one opening, and have a two-layered body wall.

Planaria

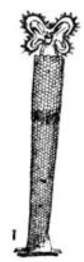
Platyhelminthes

Platyhelminthes are planarians, flukes, and tapeworms. Planarians are free-living carnivores, flukes are either internally or externally parasitic and live off the fluids of the host, and tapeworms are internal parasites in the digestive tract of vertebrates. Tapeworms lack their own digestive system. Platyhelminthes are radially symmetrical, the digestive cavity has only one opening, and it is not a coelom or pseudocoelom. There is no circulatory system. The body wall is composed of three layers.

Roundworm

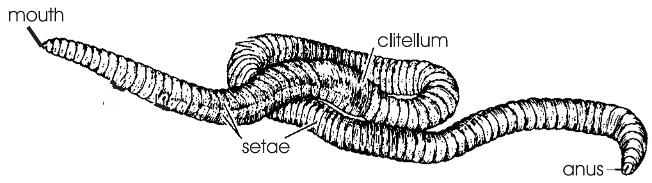
Nematodes

Roundworms are the first organism with a complete digestive tract; many are free-living and help recycle nutrients, and several are parasitic, such as the trichina worm. They are bilaterally symmetrical, have a pseudocoelom, and have three tissue layers in their body wall. They have a sac-body plan. They do have an organ level of organization.



Rotifer

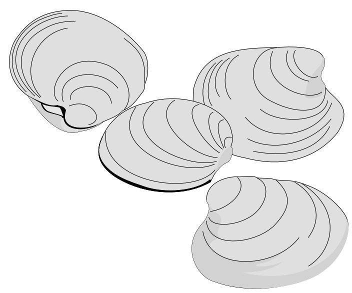
- *Rotifer*—microscopic with several specialized organs. They are primarily filter feeders.



Earthworm

Annelid

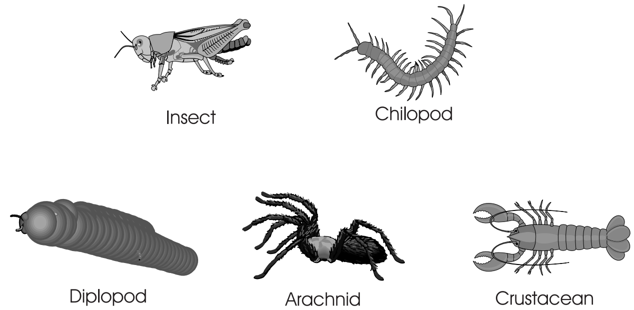
The segmented worms include the leeches, a blood-sucking parasite; the earthworms; and the polychaete worms, which occupy a mostly marine environment. At this point in the taxa, the organisms are becoming more and more complex by either possessing an entire organ system or by one or more organ systems attaining significant complexity. They are bilaterally symmetrical, have a true coelom and are protostomes and have a complete digestive system and well-defined nervous and circulatory systems.



Clams

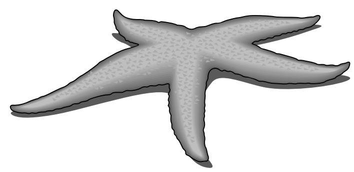
Mollusk

Soft-bodied—although some possess a shell—this group includes the snail, bivalve, octopus, and squid. Molluscans are unsegmented, have a true coelom, and are protostomes. They are bilaterally symmetrical. They have a head, a mantle, a 3-chambered heart, and a muscular foot. All but bivalves have a radula.



Arthropod

The jointed-legged animals, they possess exoskeletons and include the spiders, insects, crustaceans, the so-called “centipedes” or chilopods, and millipedes or diplopods. Arthropoda is the largest animal phylum. Arthropods are segmented and have paired, jointed appendages and a complete digestive tract. They are protostomes. Arthropods have cephalization with a ventral nerve cord and ganglia in each segment.



Sea star

Echinoderms

Echinoderms include the sea stars, sea cucumbers, and sand dollars, all of which have radial symmetry, although larval body shapes are bilateral. Echinoderms have well developed coeloms. They are deuterostomes. Echinoderms have an *endoskeleton* of calcareous ossicles and a water vascular system with tube feet.

Chordate and Mammal

Chordates

These animals, the highest in the taxa and on the evolutionary scale, all share the three following characteristics: (1) A flexible notochord (rod) at some time in their development that provides support for the nervous system and is located dorsally. The notochord is generally replaced by a vertebral column. (2) Dorsal, hollow, nerve cord that in some differentiates into a brain and spinal cord. (3) Pharyngeal gill slits that allow oxygen-carbon dioxide exchange. In the higher organisms, the pharyngeal gill slits appear mainly as pharyngeal folds. There is also a muscular tail at some point in their development that some lose as early as the embryonic stage. Chordates are deuterostomes.

Subphylum—Vertebrate Classes

Vertebrates have a complete digestive system, a large coelom, and a closed circulatory system. The sexes are generally separate. They have an endoskeleton, paired appendages, and cephalization.

A. Pisces

Fishes are aquatic gill breathers. They usually have an air bladder. Evidence indicates that the first vertebrates were fish-like.

B. Amphibian

Amphibians have four appendages. They usually have gills in the larval stages and lungs in the adult. They undergo metamorphosis. Amphibians are thought to have evolved from the lobe-finned fishes. They have incomplete double circulation; a smooth, moist skin; and a 3-chambered heart. Amphibians were the first animals to live on land and are ancestors of the reptiles.

C. Reptiles
Reptiles include turtles, lizards, snakes, crocodiles, and the extinct dinosaurs. Reptiles have lungs; incomplete double circulation; a shelled egg; dry, scaly skin; and are ectotherms.

D. Aves
Birds are homeotherms and have complete double circulation and a skin covered with feathers. Their forelimbs are wings. They have air sacs, a 4-chambered heart, and a hard-shelled egg.

E. Mammalian
Mammals include the oviparous animals, such as the duckbill platypus; the marsupials, including the kangaroo; and the mammals that have placentas. Placental mammals are homeotherms with body hair, differentiated teeth, mammary glands, a diaphragm used in respiration, and almost always seven vertebrae in the neck.

MULTIPLE-CHOICE QUESTIONS

1. The plant hormone responsible for fruit ripening is

(A) abscissic acid.
(B) auxin.
(C) cytokinin.
(D) ethylene.
(E) gibberellin.

2. Which of the following is found in all viruses?

(A) protein coat
(B) cell membrane
(C) membrane-bound organelles
(D) ER
(E) mitochondrial DNA

3. Which of the following categories includes the most distantly related organisms?

(A) family
(B) species
(C) class
(D) genus
(E) order

4. In flowering plants, sperm are produced by the

(A) ovary.
(B) anther.
(C) microsporangium.
(D) sporophyte.
(E) generative nucleus.

5. Which of the following is not a type of plant stem?

(A) corm
(B) node
(C) rhizome
(D) tendril
(E) tuber

6. Gymnosperms are NOT

(A) seed plants.
(B) predominantly diploid.
(C) flowering plants.
(D) conifers.
(E) naked seed plants.

7. Viruses are

(A) always viewed with a light microscope.
(B) are an enzyme-nucleus mix.
(C) obligate, intracellular parasites.
(D) cellular.
(E) host independent.

8. An invertebrate is found in a freshwater setting and studies show it to have three developmental body layers and a cuticle covering its outer body. It belongs in the same phylum as the

(A) hydra.
(B) leeches.
(C) sea stars.
(D) sponges.
(E) crustaceans.

9. Which of the following have a visceral mass and a muscular foot?

   (A) Medusoids
   (B) Annelida
   (C) Aschelminthes
   (D) Mollusca
   (E) Arthropoda

10. Which of the following is radially symmetrical and possesses nematocysts?

   (A) Porifera
   (B) Coelenterates
   (C) Mollusca
   (D) Amphibians
   (E) Polychaetes

Explanations of Answers for Multiple-Choice Questions

1. **The correct answer is (D)**. Ethylene promotes the ripening of fruit and the production of flowers. Auxins promote the elongation of certain cells and helps in the growth of the plant, mainly in the tips of shoots and roots. Gibberellins promote cell growth and fruit development—not ripening—and seed development. Cytokinins stimulate cell division. Abscissic acid delays seed germination and bud development.
2. **The correct answer is (A).** Of the structures listed, all viruses are found within a protective protein coat. All of the other structures are found in eukaryotic cells: a cell membrane to act as a barrier to things entering the cell; ER, which refers to the endoplasmic reticulum, the canal system of the cell, and the site where protein synthesis takes place; membrane-bound organelles is self-explanatory; and mitochondrial DNA is found in the mitochondria.
3. **The correct answer is (C).** The most specific group listed is the species and includes organisms that are virtually identical to each other, with slight variations. They have the same structures, act alike, and can mate and produce offspring that can mate. This group has the most closely related organisms. The next group, less specific than the species, is the Genus. The genus *Canus*, for example, includes all the dog-like organisms—wolf, coyote, and the domesticated dog. The family level is one up from the Genus and lies several levels below class, which means it has more widely varied examples than the Genus level but far fewer than the class level. Class is the group with the most widely varied

organisms. For example, the class Mammalia of the phylum Chordates includes elephants, tigers, bears, cats, dolphins, and humans.

4. **The correct answer is (B).** The anther is associated with the production of sperm in flowering plants, but, more specifically, the structure more closely identified with sperm production in the anther is the generative nucleus. Sporophyte refers to the dominant generation among the plant kingdom species and involves the entire organism. All other parts are associated with the female structures. The ovary is where the egg is produced and fertilized and will become the embryo; the megasporangium produces the mother spore cell in tracheophytes that leads to the production of the four haploid cells, one of which will become the egg; and the stigma is the place where pollen grains fall and ultimately grow a pollen tube to the ovary. It is supported by the stigma; both are female reproductive structures.
5. **The correct answer is (B).** A node is a site on the stem where leaves attach—and unattach—at the end of the growing season. They are *not*, therefore, an example of a stem. Of the other items in the question, all of which are a type of stem, tendrils assist climbing plants as attachment points and tubers; rhizomes and corms are all examples of underground stems. Tubers store large amounts of starch, as in the potato; rhizomes are found in ferns and are involved in vegetative propagation; and corms are specialized leaves that can store food.
6. **The correct answer is (C).** Gymnosperms have what are often referred to as "naked seeds," but they are seeds nonetheless. Like all tracheophytes, they are predominantly diploid and they bear—both the smaller male and the larger female—cones. However, a gymnosperm is not an angiosperm or a flowering plant.
7. **The correct answer is (C).** In order to reproduce, viruses need cells that they can invade. These two facts make them obligate and parasites. In addition, they are found intracellularly, taking over the cell only for the purposes of reproduction. In order to see viruses, they must be viewed with an electron microscope since they are smaller than bacteria. It is also well known that they contain a protein coat and a piece of DNA, not enzymes and certainly not a nucleus. They are also not cellular entities, and since they are not free living, they are definitely host dependent. Host dependent can mean they need a host to survive, or it can mean they need a host to reproduce. In the case of this question and the choices given, the latter is taken to mean host dependent here.

8. **The correct answer is (E).** The organism in question cannot be an echinoderm, as they are exclusively marine, so it is not a sea star. Sponges and coelenterates do not have a middle body layer, and annelids do not have an outer cuticle. Crustaceans match the description given in the question.

9. **The correct answer is (D).** Mollusks include the bi-valves, which possess considerable visceral mass, and a muscular foot with which they burrow and use for movement. Medusoids include the very simple body planned coelenterates, such as hydra and jellyfish, and lack significant visceral mass—if what they possess can be called that. Annelids do not have a muscular foot, and their viscera, while well developed, is not as substantial as a bi-valve's. Aschelminthes is a roundworm with more viscera than the cnidarians, but still considerably less than even the annelids. Finally, the arthropods are jointed-legged creatures and do not possess a single, muscular foot.

10. **The correct answer is (B).** Coelenterates, such as the jellyfish and the sea anemone, are well known for their radial symmetry and their stinging cells. Porifera have no symmetry. All the rest of the choices have bilateral symmetry—polychaetes are segmented worms that are predominantly marine; molluscs include octopuses and squid, neither of which have stinging cells; and amphibians are chordates with neither radial symmetry nor stinging cells. Some frogs secrete powerful toxins through their skin, but none of the cells in their skin has the ability to sting.

VOCABULARY

abdomen
abscissic acid
aerobes
algae
alternation of generations
amoeba
angiosperm
animal
animalia
annelid
anterior
anther
apical
arachnida
auxins
bacillus
bacteria
basidium
bilateral
binomial nomenclature
blastospore
bread mold
bryophyte
budding
bulbs
cambium
cephalization
chilopoda
chitin
chordata
cilia
class
cnidaria
coccus
coelenterate
coelom
crustacean
cyanobacteria
cytokinins
day-neutral
deuterostome
dicots
diploid
diplopoda
dorsal
echinoderm
ectoderm
egg nucleus
endoderm
endosperm
ethylene
euglena
facultative anaerobes
family
filament
flagellum
fruiting body
fungi
gametophyte
genus
gibberellins
grafting
gravitropism
gymnosperm
haploid
hyphae
insecta
kingdom
legumes
lenticels
lichen
Linnaeus
liverworts
long-day plant
mantle
meristem
mesoderm
mildew
mollusca
monera
monocots
mosses
mycelium
mycorrhizae
N2-fixing bacteria
nematode

obligate anaerobes
order
ovary
ovule
paramecium
parasite
penicillin
petals
phagocytosis
phloem
photoperiodism
phototropism
phylogeny
phylum
pilli
pistil
plantae
platyhelminthes
polar nuclei
pollen
porifera
posterior
protista
protostome
pseudocoelom
radial
roots
rotifer
runners
saprophytes
segmentation
sepals
short-day plant
sieve tubes
species
sperm nucleus
spirillus
spores
sporophyte
stamen
stigma
style
symbionts
symmetry
taxonomy
thigmotropism
thorax
tracheids
tracheophyte
tropisms
truffle
tubers
vascular
ventral
viruses
xylem
yeast

Chapter 7

ANIMALS—STRUCTURE AND FUNCTION

OVERVIEW

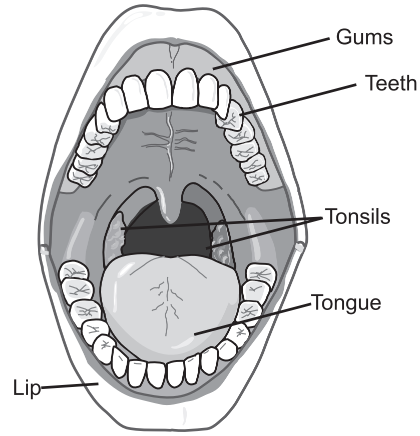
In Chapter 6 we mentioned that the material you will encounter in each chapter of this book will relate to material you will find in other chapters. In biology, everything is interrelated. To this end, you may find that some of this material is repetitious, but repetition is never a detriment to learning. In this chapter we will outline the animal systems, focusing on human systems. A broad area not discussed in this outline is that of hormones in heterotrophs other than humans.

You should be familiar with the area dealing with pheromones, sex attractants, and territorial marking. A word about cell differentiation—or specialization—in multicellular organisms is appropriate here: The good news is that cells are specialized to do what they do very well. The bad news is that all those specialized cells have become interdependent, thus the discovery of increasingly complex systems in increasingly complex organisms. Students should also be familiar with the sequence from cell—tissue—organ—system—organism and homeostasis.

DIGESTIVE SYSTEM

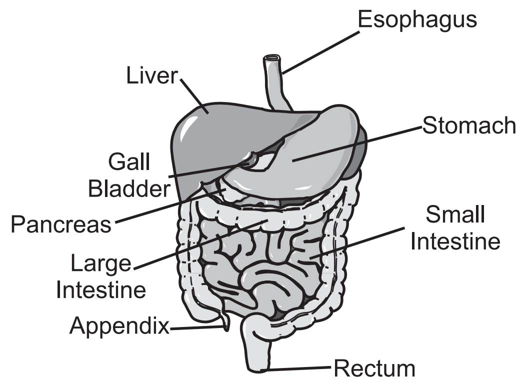
Humans

Large nutrient molecules are not usable by heterotrophs; they must be broken down into smaller molecules that are capable of being used by cells. This is the part of digestion called catabolism, which includes two main types: mechanical and chemical. For the most part, mechanical starts the process in most organisms, with chemical becoming increasingly prevalent as the process proceeds. Digestion—more specifically catabolism—replaces the water molecule in a process called hydrolysis, which is the reverse of dehydration synthesis—an anabolic reaction—where water is removed from molecules as polymers are formed. Digestion also includes the making of smaller pieces of nutrients from larger pieces to facilitate absorption, as in the case of fat molecules. The second process discussed here, of course, is absorption of the catabolized nutrients. In humans, mechanical and chemical digestion both start in the mouth or oral cavity. Chewing is aided by the teeth, the tongue, and even the cheeks and lips as they help position the food. The teeth help to tear, shred, and grind the nutrients, which increases the surface area. For example, the surface area of a cube that is 1cm on a side is $6cm^2$. If we cut it into 1,000 pieces—each having a .1cm on a side—the surface increases tenfold to $60cm^2$. Thus, mechanical digestion clearly aids chemical digestion.



Mouth

In the mouth, the carbohydrates are acted on with amylase, an enzyme secreted by the salivary glands, that breaks the starch into smaller polysaccharides. The pharynx is a connection between the mouth and the esophagus. It houses, among other things, the flap of skin called the epiglottis, which should close over the larynx and trachea each time we swallow. Swallowed items will get tangled in this area if one is breathing and swallowing at the same time. The connection between the mouth and the stomach is the esophagus. Nutrients are passed from the mouth to the stomach by peristalsis, a series of alternate muscle contractions along the esophagus. One set of smooth muscles rings the length of the esophagus and another set runs vertically along its length. Each set of muscles has the capability of alternately contracting. The effect is an opening and closing of a section of the esophagus as food passes along its length. Contrary to popular belief, this *does* allow humans to drink water upside down and even in space.



Digestive System

At the entrance to the stomach, we find a sphincter muscle that closes to keep materials in the stomach and to very briefly allow for the slow passing of materials into the stomach. As it is anatomically positioned so near the heart, it is called the cardiac sphincter. Irritation and illness sometimes cause this sphincter to allow for the reverse movement of material. In the stomach, proteins are acted upon for the first time and physical breakdown continues. Pepsin, an enzyme activated by the acid environment in the stomach, acts on peptide bonds to begin the breakdown of proteins. Both substances are secreted under the influence of hormones as well as by nerve impulses. The lining of the stomach is protected by a balanced secretion of mucus. The partially digested material, now known as chyme, is gradually allowed to exit the stomach through the pyloric sphincter in small amounts for further digestion in the upper portion of the small intestine, where bile from the gall bladder and digestive enzymes from the pancreas are secreted. As chyme leaves the stomach, it is, of course, very acidic. As a digestive organ, the pancreas secretes no less than four digestive enzymes that act on proteins and lipids: trypsin, chymotrypsin, pancreatic amylase, and pancreatic lipase, all packaged in an alkaline solution to neutralize the acid from the stomach. The pancreatic fluid contains sodium bicarbonate, which changes PH into base. The digestive enzymes act to continue the digestion of sugars and proteins. The pancreatic lipases are aided by bile in acting on lipids. The liver produces bile—manufactured from recycled RBCs—which helps to emulsify fat molecules to promote absorption of certain fat molecules into the lymph system in the villi of the small intestine. Beyond the one section immediately distal to the stomach, the small intestine is divided into two more distinct sections: Digestion as just described will occur in the upper section and absorption of catabolized nutrients will occur in the lower section through structures called villi that resemble finger-like structures that project inward along the length of the lower small intestine. The upper section continues the digestion of all three major classes of nutrients. Peristalsis moves material from the small intestine to the large intestine. The large intestine is involved mostly in absorption of water and minerals. Species of bacteria also reside in the large intestine and help manufacture vitamin K, a component necessary for the clotting of blood. The remaining material, called feces, is stored in the rectum for a short time, and then exits the body through the anus.

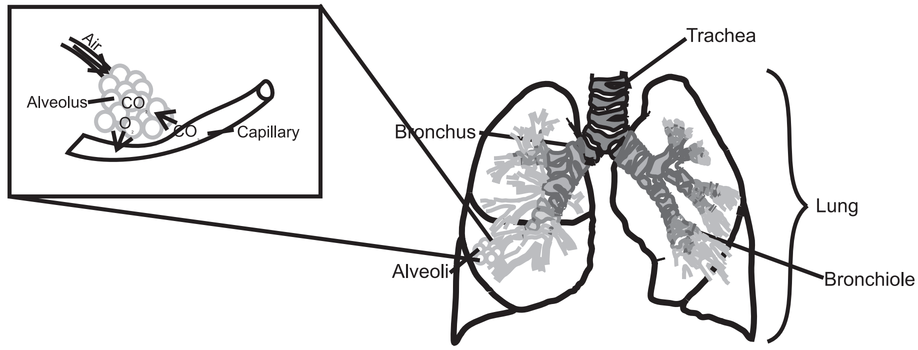
COMPARATIVE

Most coelenterates subdue their prey with stinging cells and digest through intracellular and extracellular digestion. As they burrow through the soil, earthworms grind food mixed with soil in their gizzards and pass it on to be absorbed in the intestines; the undigested material then passes out of the body. Although not the same structurally as earthworms, insects also possess a crop and a gizzard. Gastric glands secrete digestive enzymes; absorption takes place mainly in the stomach, after which undigested material is passed to the intestine and exits through the rectum.

RESPIRATORY SYSTEM

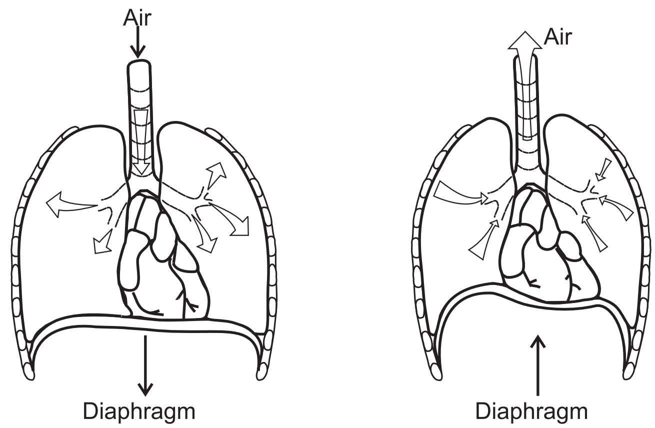
HUMANS

Cellular respiration, a key energy-releasing reaction in living organisms, requires oxygen and produces carbon dioxide. Carbon dioxide is the gas that, through the production of HCO_3, regulates breathing. These two gases must be exchanged by way of the respiratory system and the circulatory system. Air is filtered, warmed, and moistened as it enters the nasal passage through the nose and then passes through the pharynx on its way to the trachea. Air passes through the vocal cords, which are housed in the larynx, on its way through the trachea to the lungs. Ringed with C-shaped cartilage, the trachea has structural integrity while at the same time being flexible. If it were bony material, almost any blow that would strike this area could be disastrous.



Lungs

The trachea branches into two tubes called the bronchi, each of which passes into the lungs through even smaller and more numerous tubes called bronchioles. The main area for gaseous exchange is the alveoli of the lung. Each lung consists of several lobes or sections. The chest muscles, both inner and outer along with the diaphragm, create volume changes in the lungs, which establish pressure gradients between the outside air and the lung cavity.



Inhalation Exhalation

The changes in pressure alternately force air in and out of the lungs. Small sacs called alveoli form clusters like grapes and are surrounded by capillaries, where gas exchange actually takes place. Arriving at the alveoli, the blood contains large amounts of carbohemoglobin. This facilitates the diffusion of carbon dioxide into the alveoli through a single cell layer separating the open area of the air sacs and the capillaries. Housed in the air sacs is a large quantity of oxygen that diffuses out of the air sacs into the capillaries. The oxygen meets up with hemoglobin that recently dumped its carbon dioxide to form oxyhemoglobin, which is then transported to the cells that carry on cellular respiration. The reverse of this process occurs in the cells.

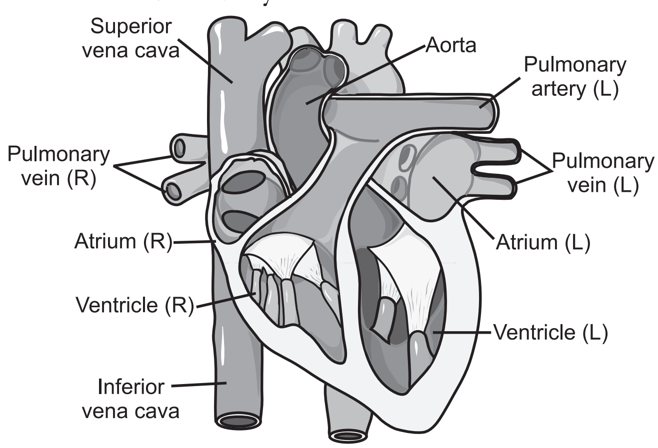
COMPARATIVE

Protists achieve the proper gas exchange through simple diffusion of gases with their immediate environment. Coelenterates achieve gas exchange by diffusion through two cell layers. Annelids exchange gases through a moist skin. Large numbers of the members of this group flee their burrows during large amounts of rainfall since the oxygen supply in the water that enters their burrows is soon depleted. Insects flex their abdomen, causing oxygen and carbon dioxide to be exchanged through openings called spiracles.

CIRCULATORY SYSTEM

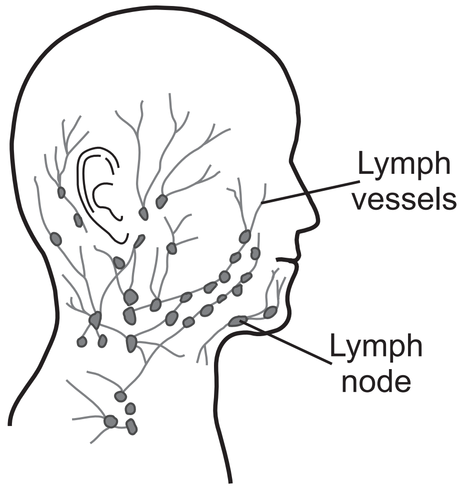
HUMANS

Many substances need to be moved around the body, and the circulatory system achieves it through the use of muscles. Humans possess a closed circulatory system where the fluid for transport is kept within transport vessels. Some leakage of the fluid portion of the blood does occur, but it is picked up by the lymph system and returned to the closed system. (Note: Leakage is a normal function that allows nutrients to leave the capillaries and arrive at the cells.) In the veins, we find valves every few centimeters that point in the direction of the heart, so that when they close, blood is prevented from back-flowing away from the heart. Muscle contractions in the skeletal muscles push the blood forward, helping the blood to return to the heart in the venous system.



Heart and associated vessels

Blood is transported away—***A***rteries ***A***way—from the heart by the action of the cardiac muscle in vessels called arteries. Blood is returned to the heart with the aid of skeletal muscles in vessels called veins and a series of valves in the veins. The veins and arteries connect through the smallest vessels of all, called capillaries, the sequence being heart—arteries—arteriole—capillaries—venule—veins—heart. The heart, the main pumping organ in the circulatory system, is actually two pumps in one. More accurately, one half beats in concert with the other half, delivering blood to two separate areas of the body. The right side of the heart receives low-oxygen blood in the upper part, known as the atrium, and uses the lower part to pump it through pulmonary arteries to the lungs in what is known as pulmonary circulation. The left side of the heart receives high-oxygen blood in the upper part, known as the atrium, and uses the lower part to pump it first through the aorta—the largest artery in the body—and then through arteries to the body.



A portion of the lymph systems

Blood is a fluid that circulates oxygen, carbon dioxide, nutrients, waste materials, hormones, vitamins, and anything else that the body needs to transport. It is composed of about 55 percent liquid, known as plasma; the rest consists of solid parts and includes erythrocytes, leukocytes, and platelets. Blood types were discussed in an earlier chapter.

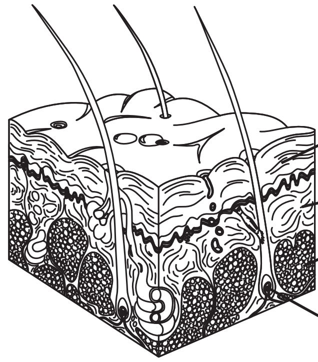
Comparative

Protists "swim" in an environment that includes nutrients and oxygen. This allows anything to diffuse in or out quite easily. Coelenterates, like the protists, exchange materials with their environment simply by diffusion. Annelids possess closed circulatory systems that contain a simple muscular loop.

IMMUNE SYSTEM

HUMANS

The basic functions of the human immune system include recognition of an invading entity as well as abnormal body cells, and the attempt to eliminate them. Lines of defense against attack include the skin, anti-microbial proteins, competing bacteria, cilia, and gastric juices.



Cross section of Human skin

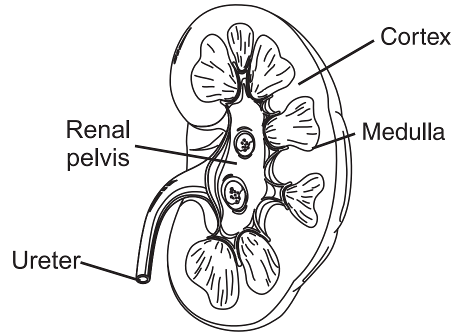
In addition, humans have developed means of augmenting the immune system through the use of vaccines, antibiotics, or the passing of antibodies from one person to the next. In addition, interferon has been identified as help in the invasion of viruses. Macrophages and neutrophils engulf and digest invaders while the B-cells and T-cells work in concert in both the interstitial areas, as well as within cells, to eliminate the antigens. The organs involved in human immune responses include the bone marrow and the thymus, where interaction between B-cells and T-cells is mediated; lymph nodes; the spleen; adenoids; and tonsils. Tissues in the appendix may also have a role similar to the tonsils.

COMPARATIVE

The invertebrate phyla have various types of immune reactions; among them is phagocytosis. Humans, on the other hand, modify their immune system with augmentation.

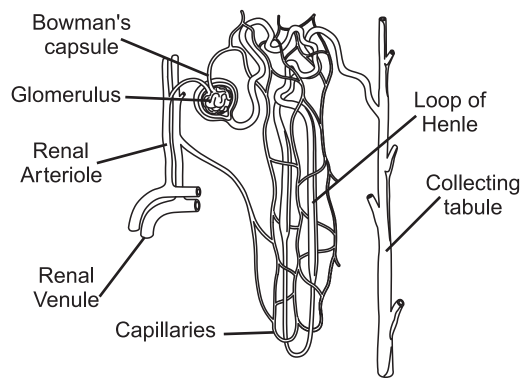
EXCRETORY SYSTEM

Waste must not be allowed to accumulate in or around cells, so it is gathered and eliminated by an excretory system. Homeostasis, maintaining a steady state in humans, is a critical role of this system.



Kidney

The metabolism of proteins, for example, produces toxic substances harmful to body tissues and must be gotten rid of. It is important to distinguish between the elimination that is achieved in the digestive system and the excretion done in this system. Material that passes entirely through the system is finally eliminated from the body as a passive act. What ends up in the lower large intestine is material that is left over after all the other nutrients have been acted on. It is not gathered and deposited there as an active process of excretion performed on materials, such as proteins and carbohydrates; it just happens to end up there. On the other hand, excretion is a homeostatic event with several systems working in concert to actively gather the substances necessary to maintain homeostasis and excrete those harmful substances from the body. The metabolism of proteins produces nitrogen wastes, most predominantly ammonia. This is coupled with carbon dioxide in the liver and is "neutralized," or made less harmful, in the form of urea.



Nephron

Transported to the kidneys, blood is filtered out in units called nephrons that house the main filtering structure, Bowman's capsule and tubules. In the nephrons, substances needed by the body are reabsorbed into the vascular system. Substances not needed by the body are excreted. Mediated by hormones and other chemical factors, the resulting mix that has been selectively separated is passed to the bladder through the ureters, where it is stored until it will be excreted from the body through the urethra.

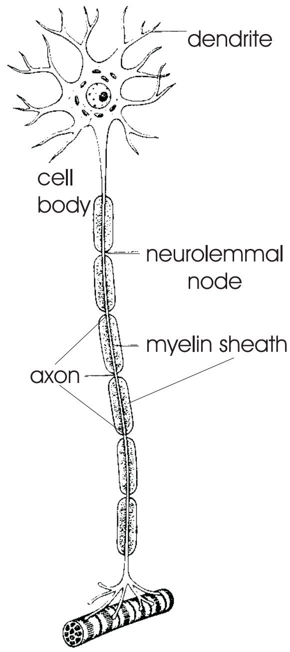
Comparative

Unicellular organisms simply pass their nitrogenous wastes through their plasma membrane by diffusion and maintain water balance by osmosis. Annelids filter and collect these wastes in nephridia that connect to the outside environment. Arthropods collect nitrogenous wastes in structures called Malpighian tubules and then pass the wastes to the environment. Aquatic organisms, for the most part, excrete ammonia directly into the water, and birds produce uric acid, a largely insoluble substance that precipitates in their systems, which they then excrete.

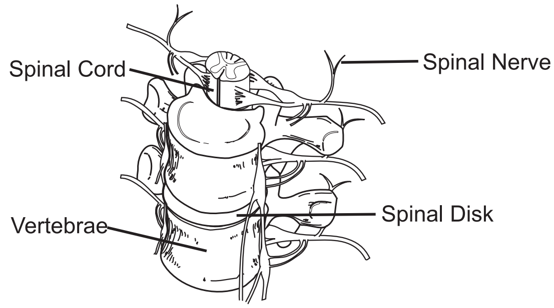
NERVOUS SYSTEM (NS)

Human

The basic unit of the nervous system is the neuron. Three principal neurons are the sensory (afferent—move information toward central nervous system), motor (efferent—move information away from central nervous system), and interneuron (association), which, respectively, receive signals, activate muscles, and connect the two and make up the neurons found in the spinal cord and brain.

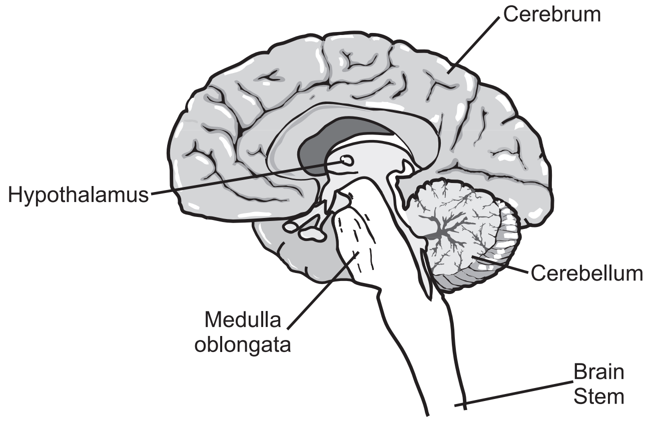


Motor neuron



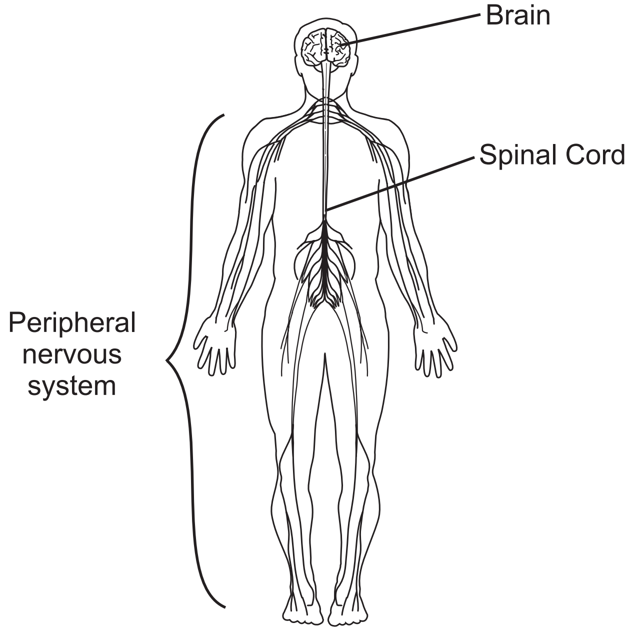
Segment of Human Spinal Column

Nerve cell axons are covered by a protective sheath called the myelin sheath, which is also where the segments of sheath connect exposed areas known as the Nodes of Ranvier's. Communication within the nervous system proceeds by way of an electrochemical event called a nerve impulse. As the nerve impulse proceeds along the nerve, an action potential is created by the interaction between ions inside and outside, the result of which is an electrical impulse. When the nerve impulse reaches the gap between two nerve cells, called the synapse, a neurotransmitter manufactured in sacs or vesicles at the end of a one-nerve ending is dumped into the synapse, which causes the next nerve to "fire." One of the neurotransmitters, acetylcholine, is then broken down almost immediately—lest the next nerve keep firing without an impulse from the preceding nerve—by an enzyme called acetycholinesterase.



Cross section of Human brain

The central nervous system (CNS) is composed of the brain and the spinal cord. The main parts of the brain are the cerebrum (the largest), which controls all voluntary action and interprets sensory information; the cerebellum, or "little cerebrum," which coordinates muscle activity; the hypothalamus, which regulates homeostasis and secretes hormones; the pituitary, part of the hypothalamus, which is the "master" controlling gland of the body that controls hormone activity; and the medulla, which controls involuntary actions.

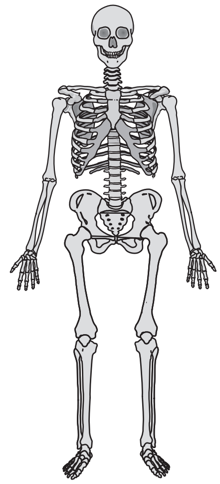


Peripheral nervous system

The peripheral nervous system (PNS) connects the CNS with all the outlying organs from the brain, skin, and all blood vessels. It is broken down into the somatic functions or voluntary functions and the autonomic functions or involuntary ones. The autonomic nervous system is further broken down into the sympathetic and parasympathetic portions of this system. The former prepares the body for action and the latter brings the body back to homeostasis. Finally, a rapid response, which initially goes from sensory neuron to an association neuron in the spinal cord and directly to a motor neuron, is called a reflex arc. Eventually—milliseconds later—the information reaches the brain.

COMPARATIVE

Single-celled organisms act mostly by moving away from irritants and toward attractants. Food attracts them, and toxins irritate them. Some even move according to the amount of light, but they possess no nerve structures. Coelenterates have a simple internal nerve net that covers their body. Annelids have a rudimentary nervous system consisting of a group of nerve cells called a ganglion and a nerve net that is the length of their body. This makes them capable of sensing their environment, but on a very primitive level, much like the protists. Arthropods, similarly, have a rudimentary system that is different in some structures from the annelids but similar in the resulting action. They have several specialized organs, such as eyes.



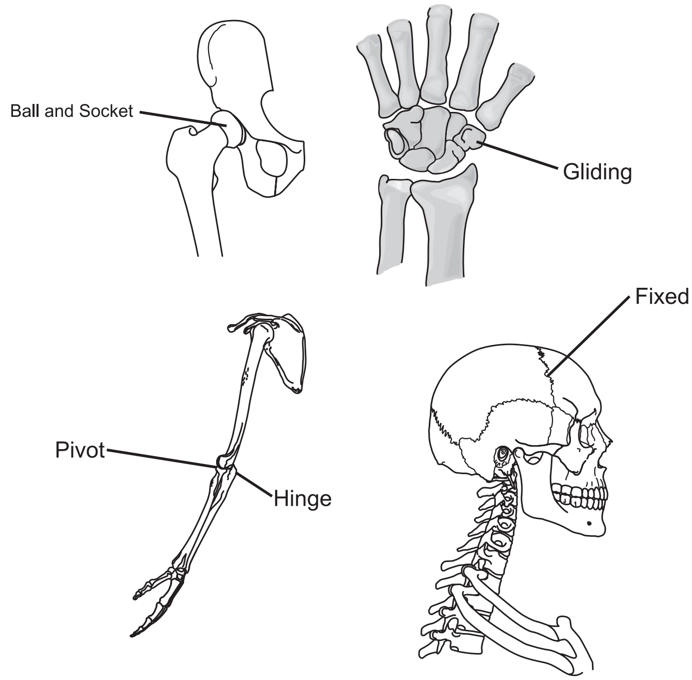
Skeleton

SKELETAL SYSTEM

HUMANS

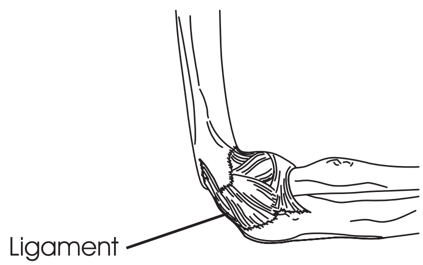
Humans have an endoskeleton made of hard tissue called bones. Bones act to support, protect, make blood cells, store minerals, and aid—along with the muscle system—in movement. Students should be familiar with the process of ossification, Haversian canals, and the spongy and hard bony areas of a typical bone.

The skeleton, consisting of 206 bones, has two main divisions; the axial skeleton and the appendicular skeleton. The axial skeleton has 80 bones located in the skull, the vertebral column, and the rib cage. The appendicular skeleton consists of the arms, legs, and pelvic and pectoral girdles.

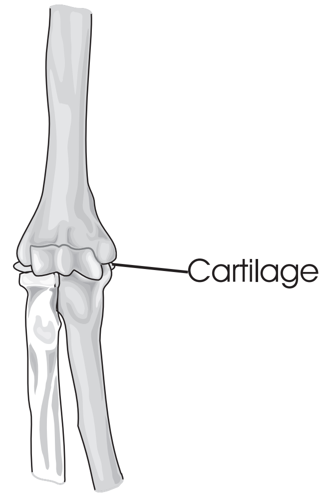


Human joints

The place where bones meet is called a joint or suture, and humans have joints described by names that suggest their action, such as pivot, gliding, saddle, hinge, ball-and-socket, and even fixed joints.



Bones are held in place by ligaments that, in concert with muscles, help maintain the structural integrity of the body under normal conditions.



In between many joints is a smooth, cushioning material called cartilage; some other body structures are composed of cartilage, such as the nose and the outer ear.

COMPARATIVE

Protists, coelenterates, and annelids have no skeletal structures but possess a hydrostatic skeleton (support comes from internal water pressure), and arthropods have an exoskeleton made of chitin. Echinoderms, contrary to what you might think, have an endoskeleton composed of ossicles.

MUSCULAR SYSTEM

HUMAN

Humans have muscle tissue that is capable of contracting and relaxing. Skeletal muscle tissue is composed of elongated cells called muscle fibers.

Muscle system

The primary function of this tissue is to aid in movement. Striated muscle, known also as skeletal or voluntary muscle, aids in moving the body along with the help of the skeleton—thus the name skeletal. Skeletal muscles are capable of very fast action, although they fatigue over a relatively short time. They are attached to the skeleton in opposing pairs: when one contracts, the opposite "partner" relaxes, and vice versa. Humans also have a muscle type, known as smooth muscles that comprise internal organs and blood vessels capable of much slower action but that rarely fatigue. The third type of muscle that humans have is exclusively in the heart and is therefore called cardiac muscle. In cardiac muscle, we find a combination of striated and smooth muscle tissue all in one. The best of both of these two worlds then is achieved in cardiac muscle, which acts fast and does not fatigue under normal conditions. Muscles are attached to the bones of the skeletal system by connective tissue extensions of the muscles called tendons.

COMPARATIVE

Protists do not have muscles but are capable of changing the shape of the plasma membrane to achieve a variety of movements. Coelenterates have a simple network of tissue that can contract. Annelids have simple muscle tissue that can provide them with more directed movement—one set of muscle tissue rings their body, and another set runs the length of it. Arthropods, with their exoskeleton, have muscles internal to that skeleton, which means that those muscles work in an opposite fashion to human muscles, as the “lever” system is opposite to that of humans.

ENDOCRINE SYSTEM

Human

The other system in humans that acts to control the internal environment is the endocrine system. Composed of a series of ductless glands—they use the blood vessels as their tubes—these glands secrete a class of chemicals known as hormones. These chemicals have specific effects on specific tissues, known as target tissues, in the body. Once again, as in the nervous system, the basic need is to maintain a steady state or homeostasis. The so-called master gland that releases many hormones that affect other endocrine glands as well as significant areas of the body—bones and muscles in mediating growth—is the pituitary gland. The anterior pituitary secretes no less than six hormones that control growth (GH), the adrenal cortex (ACTH), the thyroid (TSH), the ovaries (FSH and LH), and production of milk (Prolactin). The posterior pituitary stores another two hormones, called vasopressin, that control the balance of water in the body and oxytocin, a key hormone in parturition. A list of the glands and what they control is offered in the following chart:

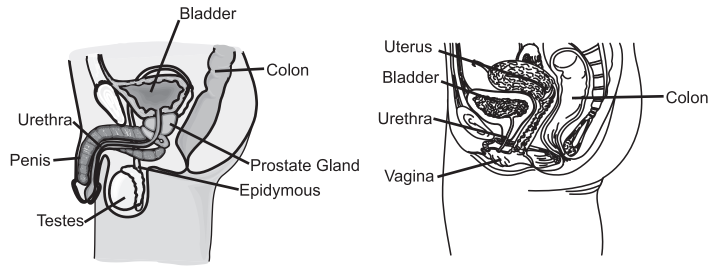
Gland →	Secretes →	Which Stimulate
Pituitary	TSH	Thyroid gland
anterior	ACTH	Kidney to secrete glucocorticoids
	FSH	Oogenesis and Spermatogenesis
	LH	Oogenesis and Spermatogenesis
	PRL	Production of Milk
	GH	Growth
posterior	ADH	Reabsorption of water
	Oxytocin	Release of Milk
Pancreas	Glucagon	Increases blood sugar
	Insulin	Decreases blood sugar
Adrenal medula	Epinephrine	Increases blood sugar, stimulates fight or flight reactions
	Norepinephrine	Increases blood sugar, stimulates fight or flight reactions
cortex	Glucocorticoids	Increases blood sugar
	Mineral corticoids	Reabsorption of Na^+ and excretion of K^+
Thyroid	Thyroxin	Increases cellular metabolism
	Calcitonin	Decreases blood Ca^+
Parathyroid	PTH	Increases blood Ca^+

Selected Human glands and their secretions

REPRODUCTIVE SYSTEM

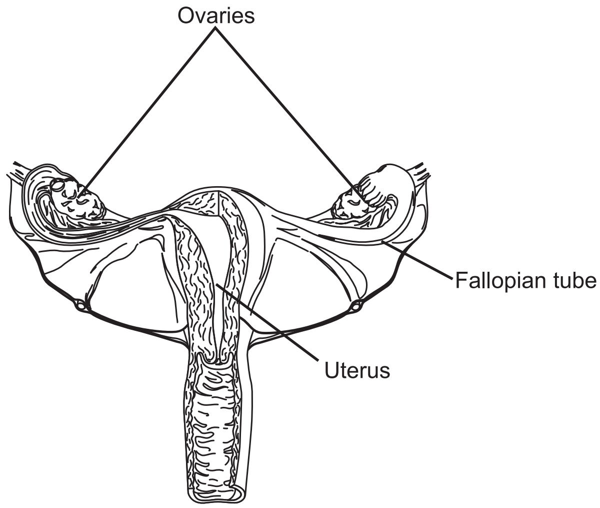
HUMAN

The system given to the process of continuing the species is, of course, the reproductive system, and students should be conversant with where the events take place in both male and female, when they take place, and under the influence of what hormones.



Human reproductive systems
(side view)

You should understand both the male and the female parts and their functions. In addition, students are tested on critical events, such as gastrulation, blastulation, and general morphogenesis of the embryo to fetus.



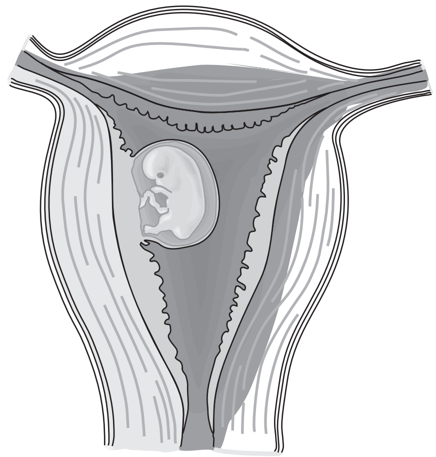
Female reproductive system
(front view)

Females manufacture an ova in a structure called the ovaries. The cyclic secretions of hormones normally causes the release of one egg approximately every month. Generally, the process, called menses, is started with the production of an egg under the influence of FSH. The follicle, in turn, produces estrogen that triggers an increase in LH from the pituitary, turning the follicle into a body known as a corpus luteum, which continues to produce estrogen and a new hormone called progesterone. Progesterone readies the body for pregnancy by mainly increasing the number of blood vessels in the uterus. As the follicle ruptures under the influence of LH, it releases the egg in a process called ovulation. If the egg is not fertilized, the corpus luteum eventually shuts down, and the unfertilized egg, along with the now unnecessary, newly manufactured blood tissues in the uterus, are sloughed off and exit the body. This signals menstruation, and the process begins all over again as the level of FSH rises in the other ovary. Thus the cycle repeats.

Fertilized egg | 2 cell stage | Multi-cell stage

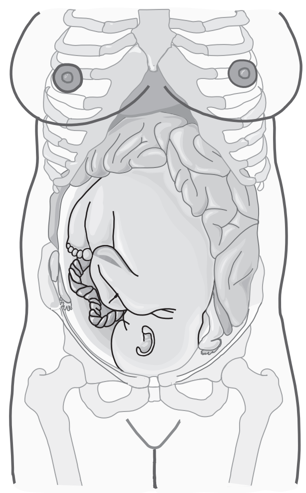
If the egg is fertilized, the embryo itself produces a hormone that continues the LH hormone to be secreted and suppresses FSH until birth. The fertilized egg or zygote goes through the developmental stages of the blastula and gastrula during which three germ layers develop. The ectoderm will develop into the epidermis and nervous system, the mesoderm develops in the most other systems, while the endoderm will form the lining of the digestive, respiratory tracts, and urinary bladder.

In addition to the development of the embryo, the organism undergoes growth differentiation and morphogenesis.



Embryo

At the age of three months, it is referred to as the fetus until the birth process or parturition is initiated.



Fetus

Human males produce sperm in a process described in Chapter 4 on meiosis. This process is not cyclic but continual and is initiated and maintained by the hormone testosterone.

COMPARATIVE

Heterotrophs can reproduce asexually, which several phyla are capable of, but most can reproduce sexually, too.

MULTIPLE-CHOICE QUESTIONS

1. Which of the following is the specialized absorptive structure in the intestine?

(A) alveoli
(B) villi
(C) Bowman's capsule
(D) salivary glands
(E) pyloric sphincter

2. Which of the following tissues contains the highest number of mitochondria?

(A) nervous
(B) skin
(C) connective
(D) muscle
(E) bone

3. Select the correct sequence for human circulation.

(A) heart—vein—capillary—artery—heart
(B) heart—artery—lung—vein—body systems—heart
(C) heart—artery—lungs—vein—heart—body systems
(D) body system—lungs—heart—vein—capillary—artery
(E) heart—artery—lungs—body systems—vein—heart

4. The skeletal system does all of the following EXCEPT

(A) support.
(B) transport.
(C) protect.
(D) digest.
(E) store.

5. Endocrine glands

(A) secrete vitamins.
(B) cease functioning after adolescence.
(C) begin functioning in adolescence.
(D) have ducts.
(E) have no ducts.

6. Bile

(A) activates pancreatic lipases.
(B) emulsifies fat droplets.
(C) congeals fat droplets.
(D) digests fats.
(E) is produced in the pancreas.

7. Which of the following enzymes acts on protein?

(A) pepsin
(B) ptyalin
(C) amylase
(D) maltase
(E) sucrase

8. Digestion in protozoans is

(A) extracellular.
(B) intracellular.
(C) intercellular.
(D) dorsal.
(E) none of the above.

9. Which of the following is true about the blood?

(A) Arteries carry oxygen-rich blood.
(B) Arteries carry oxygen-poor blood.
(C) Veins carry oxygen-rich blood.
(D) Veins carry oxygen-poor blood.
(E) None of the above is true.

10. Chemical digestion begins in the

(A) mouth.
(B) esophagus.
(C) stomach.
(D) gall bladder.
(E) small intestine.

EXPLANATION OF ANSWERS FOR MULTIPLE-CHOICE QUESTIONS

1. The correct answer is (B). The alveoli are structures that allow the passage, not absorption, of carbon dioxide and oxygen into the lungs. Bowman's capsule is where the filtration of the blood occurs in the nephrons of the kidney. Salivary glands produce amylase that helps begin the breakdown of carbohydrates in the mouth, and the pyloric sphincter is the valve-like structure at the end of the stomach that allows the passage of chyme. The villi are specialized, finger-shaped structures in the lower intestine that are designed for absorption of digested nutrients.

2. **The correct answer is (D).** One would expect that the cells with the highest potential for activity would have the highest number of mitochondria, the powerhouse of the cell, which would be muscles, choice (D). Connective tissue has very little need for such a high level of activity, and bone cells reach the point of utility as fairly sanguine cells. The only choice that comes close to muscles would be nerve cells, but, while they may achieve a high level of activity from time to time, they certainly do not need to fire nearly as often as muscle cells. In addition, muscle cells need the energy when they contract and to reconstruct the actin and myosin complexes when they relax to be ready to function again.
3. **The correct answer is (C).** While presented with a veritable hodgepodge of choices here—which just *may* occur on the exam—the only one that makes sense is choice (C), where the blood leaves the heart through an artery—***A***rteries ***A***way—to the lungs, back to the heart through a vein, and from the heart, out to the body systems. Choice (A) looks good on the surface, except a vein is leaving the heart, not an artery. In choice (B), once the blood goes to the lungs, it goes right to the body systems, which erroneously bypasses the heart. Choice (D) also bypasses the heart as the blood returns from the body systems, and choice (E), like choice (B), bypasses the heart.
4. **The correct answer is (D).** The skeletal system does not digest anything for the body. It stores minerals, such as calcium and phosphorous; it supports the body mass and also helps with transport of the body in concert with the muscles; and its cells reproduce and make more bone cells.
5. **The corrrect answer is (E).** It is important to define endocrine glands as ductless—they offer a separate delivery system from gland to target area. The endocrine glands use the “ducts” of the circulatory system, also known as blood vessels. The exocrine glands, such as the salivary glands and the pancreas, have ducts. The endocrine glands begin functioning at parturition and continue to function throughout life. Finally, endocrine glands do not secrete vitamins.
6. **The correct answer is (B).** Bile is produced in the liver, and its main function is to emulsify fat droplets into smaller fat droplets, contrary to congealing—which it does *not* do. Congealing is the

gathering of small droplets into bigger ones. Pancreatic lipases come in an activated form, and bile certainly does not digest fats; it emulsifies them.

7. **The correct choice is (A).** Choices (B) through (E) represent enzymes that act on carbohydrates, ptyalin being another name for amylase. Maltase and sucrase, as their names suggest, are enzymes that act, respectively, on maltose and sucrose. Choice (A) is a protease that arises from a precursor, pepsinogen, that is activated by hydrochloric acid, which is the acid found in gastric juices.
8. **The correct answer is (B).** Unicellular protists take their food into the cell that is the entire organism and digest it entirely intracellularly. Humans, for example, digest their nutrients extracellularly and absorb them into cells only after they are digested. Since protists are unicellular, the suggestion of *inter*cellular digestion is meaningless. The reference to dorsal is a certain orientation or place on multicellular organisms.
9. **The correct answer is (E).** A favorite trap of the test makers is to determine how solid the students are in their knowledge of the circulatory system by presenting questions that suggest that the movement of blood through the various vessels is wholesale. For example, they may suggest that arteries always carry oxygenated blood. While the bulk of blood carried in arteries is oxygenated, the blood in the pulmonary arteries is oxygen-poor—thus the reason for the trip to the lungs. Likewise, one can make a confusing statement about veins, but it would also be false. Veins that carry the blood back to the heart from the lungs are the only ones that carry oxygen-rich blood.
10. **The correct answer is (A).** Chemical digestion in humans can begin as soon as a nutrient enters the mouth, of course, if it has carbohydrate in it. So no matter what the nutrient is, it *could* begin in the mouth. The stomach is the second place that chemical digestion occurs when proteins are acted upon by pepsin. The esophagus is a tube that connects the pharynx with the stomach, so no digestion occurs there. No digestion takes place in the gall bladder—it is just a storage place for bile—and the small intestine is too general an answer. Digestion takes place in the upper portion of the small intestine and absorption takes placer in the lower portion. It doesn't matter, actually, since the question asks where digestion *begins*.

Vocabulary

acetylcholine
acetylcholinesterase
ACTH
action potential
adrenal cortex
adrenal medulla
AIDS
alveolus
ammonia
amnion
antibody
antigen
anus
aorta
aortic valve
arterioles
artery
autonomic nervous system
axons
bile
bladder
blastula
B-lymphocytes
bolus
bone
Bowman's capsule
bronchi
bronchioles
capillaries
cardiac muscle
cartilage
cell body
cerebellum
cerebrum
chorion
chyme
cleavage
CNS
collagen
collecting duct
corpus luteum
dendrites
deoxygenated
dermis
digestion
emulsify
endocrine
epidermis
epiglottis
epinephrine
erythrocytes
esophagus
estrogen
expiration
fallopian tube
feces
feedback
fertilization
fetus
filtrate
FSH
gastrula
glomerulus
glucagon
glycogen
growth hormone
homeostasis
hormones
hyperthyroidism
hypothalamus
hypothyroidism
immune
inferior vena cava
inspiration
insulin
integument
interneurons
involuntary muscles
islet of Langerhans
joints
kidney
large intestine
larynx
left atrium
left ventricle
leukocytes

LH
ligaments
loop of henle
lungs
lymph
lymphocytes
marrow
mastication
medulla
menstruation
morphogenesis
motor neurons
mouth
myelin
nephridia
nephrons
neurons
neurotransmitter
notochord
ova
ovaries
oviduct
ovulation
oxygenated
pancreas
parathyroids
pepsin
peristalsis
pharynx
pituitary
plasma
platelets
PNS
polarized
progesterone
puberty
pulmonary
pyloris
reabsorb
rectum
renal
right atrium
right ventricle
saliva
Schwann cells
secretion
sensory neurons
sinuses
skin
small intestine
sodium-potassium pump
sperm
steroid
striated
subcutaneous
superior vena cava
sympathetic nervous system
synapse
systemic circulation
tendons
testosterone
T-helper cells
thyroid
thyroxin
T-killer cells
T-lymphocytes
trachea
trypsin
urea
ureters
urethra
uterine walls
uterus
vasopressin
veins
venules
villi
vitamin K
voluntary muscles
yolk sac
zygote

Chapter 8

BEHAVIOR AND ECOLOGY

OVERVIEW

The two areas included in this chapter take an even broader view of living things. Starting with animal behavior, we explore the way that animals interact with their environment as an individual behavioral matter, and specifically how they learn and react to their surroundings. Following this, we outline what we know about how animals communicate, move, feed, and interact socially. Finally, we look at circadian rhythms. The second section is involved with an even broader view than the individual behaviors covered in the first section. Taking a worldview, we outline what the student may be tested on, beginning with the relationships between members of a population and their involvement with other species at a community level. We outline the different kinds of communities within the biosphere and, by including the abiotic factors, we study the interactions between the biosphere, the hydrosphere, the lithosphere, and the atmosphere on this planet in different regions and climes called biomes. From there, a worldview, literally, is outlined in summing up the relationships of all living things to each other and the planet and the changes they—living things and the planet—undergo.

ANIMAL BEHAVIOR

This is an area not specifically covered in any of the other areas in this book, but it actually brings together several factors in describing the way life expresses itself, given the interaction of all those other factors. In addition to learning, the areas covered alternately relate to the individual, groups, and their interactions. Some of the areas covered involve the study of influences outside the individual; others involve those that "come with the package." The argument persists as to whether nature or nurture dominates life. Do we come with a prepackaged set of formative influences, or do the environment and our response to it shape everything?

LEARNING

This is usually defined as acquiring information or a behavior that was not previously a part of the organism and tends to be brought about by experience. We now know that behavior has a genetic component that influences the individual's relations with the environment and with other individuals. An example is the case of reproductive success or survival fitness. Evolution and natural selection are seen to enhance these genetically conferred traits.

Conditioning

Conditioning is defined as exhibiting a behavior as a result of a response to a particular set of conditions, known or unknown, usually called a stimulus. Care should be taken not to "run around in circles" on the matter of stimulus/response. A stimulus is anything that results in activity; a response is the result produced.

A. Classical

Classical conditioning, or associative behavior, is of course, given in Pavlov's classical "salivating dog" experiment and is taken as responding to a substitute stimulus rather than the original or expected stimulus.

B. Operant

Operant conditioning is more of a trial-and-error kind of conditioning. The closer an individual gets to the desired response with positive reinforcement, the more the individual will repeat the response. This occurs in animal training, but it can also be seen in an animal that spends initial energy on revisiting a feeding site that has yielded success in the recent past.

Imprinting

This behavior is an example of one that appears to involve a "critical period." It occurs only if the right stimulus occurs during a particular time. Examples would be salmon returning to the precise site of their birth or, as in Lorenz's studies, with goslings.

Habituation

Habituation involves a behavior in which unproductive results are soon disregarded, and the stimulus that causes them is also disregarded eventually.

Insight

Without any previous experience with a situation, an animal performs a successful behavior, most likely influenced by previous behaviors.

Observational

Individuals copy the behavior of another without having previously experienced the stimulus that produces that behavior.

INNATE

Behaviors, or the potential for them, that already exist inside the individual are called innate.

Fixed action pattern

These follow a regular, unwavering pattern that is initiated by a specific stimulus and carried out even in the absence of the ability to complete the original intent.

Instinct

Instinct is the classic innate behavior that has no other explanation other than that it is inherited. One such behavior appears to deal with time and is known as circadian rhythm. Internal clocks or cycles appear in part to have a genetic basis to an organism's interaction between the environment and chemical promoters in the individual.

MOVEMENT

Animals have particular ways in which they move. Three specific ways have been identified, and they involve very specific actions according to the organisms and the environment in which they reside.

Kinesis

Kinesis is a random change in speed and/or direction of an organism in response to a stimulus. It will, for example, speed up in an unfavorable environment and slow down in a favorable one.

Taxis

Taxis is a very specific, directed response to a stimulus, in the direction of the stimulus if it is favorable and away from the stimulus if it is unfavorable.

Group

Group movement, better known as migration, is the wholesale movement of animals that is usually brought on by seasonal influences, in particular the availability of food.

COMMUNICATION

Communication is usually observed within a species to recognize one's own kind for mating, for social behavior, or for the avoidance of a nearby predator.

Chemical

Chemical communication uses pheromones, which trigger a response when smelled or, in some cases, when eaten. In the case of bees, the workers eat a pheromone, and it prevents them from developing reproductive ability.

Visual

Visual communication is usually observed during courtship or aggressive behavior when defending territory or establishing pecking order. In some, visual displays by males are releasers for reproductive behavior in females.

Auditory

Auditory communication may be for definition of territory; for species recognition, as in the case of a mating behavior; or for alerting behavior, as when a predator is nearby.

Tactile

Tactile communication is a common behavior in bonding, infant care, and mating. In bees, it is even used to locate successful food sources.

FEEDING

Feeding behaviors that organize the search for food have been observed and appear to impact the survival of the species and have, therefore, great impact and importance for the individual, even as the individual may relate to a group.

Groups

Groups of individuals have evolved several successful means of feeding or finding food.

A. Herds

Herds use this kind of group behavior when feeding as a means of defending against predators by shielding each other, when attempting to avoid a predator by becoming hidden from view, or simply by being alert to the presence of a predator. A member on one end of the herd may not be aware of a predator approaching the other end of the herd.

B. Packs

Packs engage in group hunting, which is most often observed when smaller species attack a larger one.

Search image

Animals will seek food based on the success previously experienced or on images they possess, however limited, of the target previously experienced. A measure of habituation obviously contributes to the success of this feeding behavior.

Social

Individuals behave in two different settings: in a group or on their own. Eventually, they will make contact with other organisms within their species or outside their species. The most successful interactions survive, as do the individuals or the groups that exhibit them.

Agonistic

Agonistic behavior is aggressive/submissive behavior that actually has great survival value, since it is most often quite ritualized and, therefore, actually reduces negative aspects of aggression.

Dominance

Dominance establishes hierarchies, or "pecking order," and also minimizes conflict within the group.

Territoriality

Territoriality is a behavior that ensures a food supply, a place for reproductive activities, and successful rearing of infants.

Altruistic

Altruism is seemingly unselfish behavior that is not beneficial to, or may be harmful to, an individual but that actually increases the fitness of the group by ensuring survival of the species and parental genes.

ECOLOGY

The word ecology comes from the root *ecce,* meaning home or place. If, in several instances, we have talked about the big picture, this is the biggest of all. All of the material discussed so far culminates in the study of our environment or ecology, the study of "this place."

Biosphere

The biosphere is the realm of living things, along with the hydrosphere, lithosphere, and atmosphere, that make up our world.

The Earth

The earth includes the four “spheres” and the ways in which they interact.

Major Biomes

Under the influence of latitude or elevation and various abiotic, nonliving factors, the earth is divided into large areas known as biomes, areas of distinctly different living things. Beginning with the most inhospitable, because it is the coldest, we begin at the “top” of the world. While reference will be made only to latitude as we progress toward the equator, one can also find similar conditions when descending a mountain.

A. Tundra

The northernmost biome is tundra, which contains rapidly maturing plants, a permanent layer of ice under the soil, and mostly small homeotherms.

B. Taiga

Taiga is less forbidding. It nonetheless has long cold winters; larger plants, such as stunted conifers, exist; and there are more large animals.

C. Temperate deciduous forests

Temperate deciduous forests contain larger trees that lose their leaves in dry—usually winter—seasons, proliferate heterotrophs and autotrophs, and have warm summers and colder winters.

D. Grasslands

Grasslands feature hot summers, cold winters, unpredictable rainfall, mostly grassy autotrophs, and a fairly wide variety of wildlife.

E. Deserts

Deserts contain drought-resistant plants, low rainfall, a very dry climate, small homeotherms, and proliferate reptilia.

F. Tropical rain forests

The tropical rain forests are the most proliferate of all biomes for living things, containing high rainfall and temperatures and poor soil.

ECOSYSTEM

An ecosystem is smaller than a biome and is most often a self-contained area, such as a lake or a tidal pool.

Abiotic factors

Abiotic factors are nonliving factors that include air, water, topography, geology, and sun. The interactions of these include things like temperature, humidity, wind, and erosion.

Biotic factors

Biotic factors are living things in an ecosystem and the way they interact.

A. Producers

Autotrophs are known as producers since, in the presence of the ultimate source of energy—the sun—they provide most of the biomass.

B. Consumers

As the name suggests, these consume biomass but are not capable of producing or using sunlight directly to create a food source, as the autotrophs are. Consumers are usually divided into at least primary consumers, whose primary source of nutrition is producers, and secondary consumers, whose primary source of nutrition is another consumer.

1. Herbivore—designed to metabolize producers exclusively
2. Carnivore—designed to metabolize other consumers exclusively
3. Omnivore—designed to metabolize both producers and consumers

C. Decomposers

At some point, the complex molecules that living things construct from their nutrients must be broken down lest the environment run out of raw materials that some organisms need to carry on life. This is the role of the decomposers.

FUNCTIONING

The biotic world functions at several levels, which are outlined here.

Food chain

The food chain consists of a linear interaction between organisms in which the starting point is usually a plant, which is consumed by the next organism, which is consumed by the next organism, and so on, until the chain ends. It can be portrayed vertically in what is called a food pyramid that more accurately portrays the amount of biomass at each level in the chain (called a trophic level).

Food web

The food web is several food chains interacting. For example, a mouse might not just eat corn; it might also eat nuts or grains.

Community

A community is a group of populations living in the same area.

A. Habitat

A habitat is the place where organisms usually live.

B. Niche

A niche consists of all the living and nonliving sources that contribute to an animal's survival—or, more accurately, a species survival—as a result of successful achieving of equilibrium with these factors by the animal (species). A niche is an organism's "job," or what it does in an ecosystem.

C. Biodiversity

Biodiversity is the variety of living things, their ecological functions, and the variety of genes they contain.

SYMBIOSIS

Symbiosis refers to relationships where animals are in proximity to each other and interact as a result. Literally, it means "living together."

Camouflage

Camouflage is the successful concealment from view of an organism, usually from its predator.

Commensalism

Commensalism is an interaction between organisms where one benefits and the other is not harmed or benefited.

Mimicry

Mimicry is similar to camouflage in that a protective appearance has evolved, but this might be displayed rather than concealed, since it might resemble a predator of an attacker or, at the very least, a more aggressive or distasteful organism than the attacker planned on encountering.

Mutualism

Unlike commensalism, both organisms benefit in mutualistic interaction.

Parasitism

Parasitism must strike a delicate balance between the parasite and the organism off of which it lives, mainly the host. The parasite-host relationship is one in which one organism is helped; the other—the host—is harmed but not killed.

Predator/Prey

The killing of the prey benefits the predator.

POPULATION STUDIES

This very important area of science is applied primarily to the study of human populations, although the principles relate to all lines of living things. Generally, the areas of study seek to determine the nature of the population, particularly its health or equilibrium with the environment.

Size

The number (N) of individuals in a population.

Density

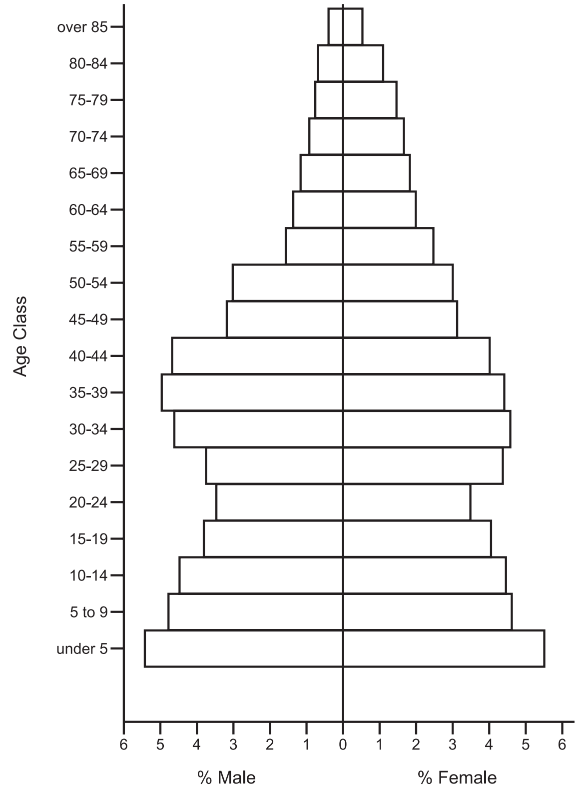
N per unit of volume—not area since some organisms occupy a three-dimensional cross-section of the niche.

Dispersion

How the population is distributed.

Age structure

The N of each age group, diagrammed along a vertical line that separates male and female members of the population on either side, results in specific shapes that can be interpreted as population trends.



Mortality

Mortality is the survival of individuals throughout their lifetime.

Growth

Two organisms and their life strategies emerge from our studies of populations. Their growth is the result of these strategies as they impact the environment, and vice versa. The r-selected species have a lifestyle of rapid invasion, rapid increase—from birth rates that involve many small offspring that mature quickly—and rapid decline. On the other hand, K-selected species' numbers remain at the carrying capacity and have few, relatively large offspring who require much care.

A. Biotic potential

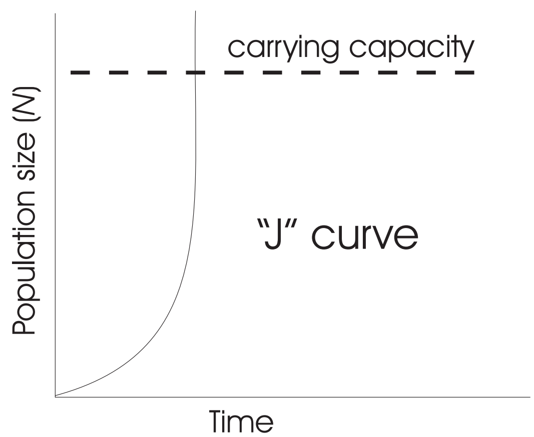
Maximum growth rate of a population under ideal conditions for all the factors just discussed, always, however, tempered by environmental resistance.

B. Carrying capacity
Indicated by the use of K, it is the maximum N that can be sustained by a particular ecosystem.

C. Limiting factors
Those factors in a habitat that prevent a population from reaching its maximum N or biotic potential.

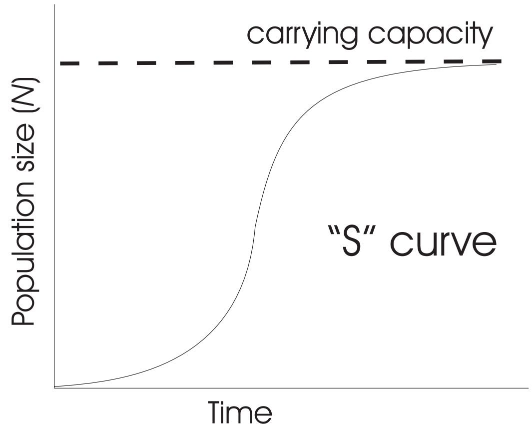
1. *Density dependent*—limiting factors that depend on the size of the population and have greater and greater effect on the population as the population grows, such as competition for food, dispersal of wastes, and reproductive behaviors.
2. *Density independent*—those factors that do not have a differential effect on the population, depending on the size of the population. Natural disasters and weather/climate extremes are among the density-independent limiting factors.

D. Exponential
Exponential growth occurs when the birth rate is >0, making the increase in population exponential. When graphed it typically follows a J-shape as the slope continues to increase towards a 90° incline.



E. Logistic
Logistic growth occurs when limiting factors restrict the growth rate to the available resources (carrying capacity). It is represented by an

S-shaped, or sigmoid, curve that typically plateaus when the population reaches equilibrium with the carrying capacity.



SUCCESSION

As the name suggests, it is the change in the make-up of populations in a community over time, ending with a climax community for that biome.

Primary

Primary succession is the first instance where an area will experience succession; the area has never before experienced living things, as in immediately after a lava flow cools.

Secondary

Secondary succession occurs when an area previously occupied by living things is completely destroyed, as in a forest fire or a flood that complete washes out an area.

EVOLUTION

Evolution involves the process by which species (not individuals) change over time. Members of a species show random inherited variations. For example, dogs show variations in height, weight, fur color, type of ears, and other traits. Changes in the environment will favor organisms with certain variations (the fit) that permit them to survive and reproduce more than members of the population that are less fit. This is called natural selection and is an important mechanism in evolution.

Evolution contains the hypothesis that all living species are derived from other species; that all life shares a common ancestor; and that all life is constantly changing. Evidence for this hypothesis is far reaching and substantial. It includes fossil records, comparative anatomy and biochemistry, and biogeography. Evolution also has been experimentally demonstrated in the laboratory and in nature.

The evolutionary aspects of comparative anatomy can be followed by a review of the phylas discussed in Chapter 6.

Charles Darwin

Receives primary credit for developing the Theory of Evolution after taking a trip around the world as a naturalist on the HMS *Beagle.*

Alfred Russel Wallace

Independently co-discovered natural selection as a mechanism in evolution.

Jean-Baptiste de Lamarck

In the late 1700s had proposed descent with modification, but erroneously thought characteristics acquired in one generation could be inherited by succeeding generations.

The Theory of Evolution

Now considered one of the basic theories of biology.

MULTIPLE-CHOICE QUESTIONS

Questions 1–4 refer to the following relationships:

(A) predator-prey
(B) commensalism
(C) mutualism
(D) parasitism
(E) camouflage

1. A cow produces milk daily after grazing in a large pasture owned and maintained by the farmer.

2. Remora fish attach themselves to the underside of a shark, and while the shark feeds, the remora darts out for shreds of the shark's food that are left floating in the water.

3. A walking stick resembles the branches it resides on.

4. Lacking a digestive system, tapeworms live in the intestines of their host.

5. Which of the following organisms in the food chain has the largest biomass?

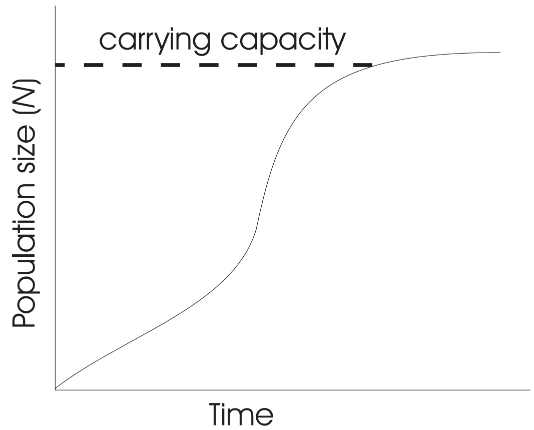
(A) plants
(B) grasshopper
(C) mouse
(D) owl
(E) snake

6. Which of the following is an instinct?

(A) caring for offspring
(B) habituation
(C) operant conditioning
(D) associative behavior
(E) observational learning

7. In the graph below, the curve indicates the

(A) biotic potential.
(B) carrying capacity.
(C) density-dependent effect.
(D) density-independent effect.
(E) sigmoid curve.



8. All of the following are associated with mating behavior EXCEPT

(A) aggressive behavior.
(B) releaser pheromones.
(C) search image.
(D) territoriality.
(E) visual communication.

9. Which of the following biomes is characterized by the driest conditions?

(A) tundra
(B) taiga
(C) temperate deciduous forest
(D) grasslands
(E) tropical rain forest

10. Which of the following is NOT a means of animal communication?

(A) auditory
(B) chemical
(C) instinctual
(D) tactile
(E) visual

Explanations of Answers for Multiple-Choice Questions

1. **The correct answer is (C).** The relationship indicated in this question benefits both individuals and so would be a case of mutualism. The next closest would be commensalism, but, in this case, both, not one, are benefited.
2. **The correct answer is (B).** This relationship is the case where commensalism is illustrated. While the shark is not harmed by the relationship, neither is it benefited. Only the remora benefits from the free transportation and the ready supply of food.
3. **The correct answer is (E).** Since the walking stick resembles the branch on which it lives, it is hidden from the view of predators as it camouflages itself by such an adaptation.
4. **The correct answer is (D).** Using another species for its survival by taking some part of its host's means of survival, the tapeworm is acting like a parasite. Due in part to its own lack of a digestive system, the tapeworm must achieve a balance, through its reproductive behavior, with the host lest the tapeworm kill the host, which would mark the demise of the tapeworm itself. In a parasite-host relationship, the parasite must reach a balance with the host that does not kill the host.
5. **The correct answer is (A).** If we construct the food chain with the members we are given as a food pyramid, we see that it must begin with the plants in a position at the bottom and widest part of the pyramid, which indicates that it represents the largest biomass. As we continue up the pyramid, or chain, the amount of material—which houses the main ingredient in the picture, that of energy—decreases dramatically between levels. The end result is that 10 percent of the energy, on average, of any one level is passed on to the next level. The owl, which we might find at the top of this food pyramid, has the least amount of biomass. Next comes the snakes the owl consumes with more biomass, just below the owl on the pyramid. More so the mouse,

even more so the grasshopper, until we reach the bottom, where the largest amount of biomass is found in the plants.

6. **The correct answer is (A).** Choices (B) through (E) are all forms of learned behavior and involve a necessary interaction with the environment to take place. Caring for an infant seems to be one of those behaviors that is instinctual in most species. Habituation is the active disregarding of unnecessary stimuli. Operant conditioning is the trial and error kind of learning associated with acts such as training. Associative behavior is the classical form of conditioning where an animal associates a set of behaviors with a successful result, usually after repeated encounters. Observational learning is associated with mimicking another's behavior after close observation.
7. **The correct answer is (E).** The entire graph is known as a sigmoid graph and represents changes in a population over time. The plateau indicates equilibrium between the organisms and the environment. A drop in the graph would indicate increasing mortality; a rise would indicate increasing birth rate. While biotic potential is a seemingly attractive choice, this graph is an indication of the reality of the population. Another line would be needed to indicate density relations, such as the relation between r-selected species and K-selected species.
8. **The correct answer is (C).** Search image has to do with a feeding or foraging behavior in an organism as it seeks food sources of which it has retained a somewhat abbreviated image. All of the other behaviors impact mating behavior by establishing dominance, triggering a behavior by chemical means, establishing a territory of ownership, or by a display that the opposite sex recognizes or which triggers reproductive behavior in the opposite sex.
9. **The correct answer is (A).** From the list of biomes given, the tundra classifies as the driest. Although it is covered with water, this water is frozen and therefore unavailable in the way we would hope water would be available for any plant or animal use. The taiga, with a period during which the water is frozen, also has a time when it is liquid and available for use. Temperate deciduous forests are more wet, and tropical rain forests are the wettest of all. Grasslands fall somewhere in between the taiga and temperate biomes. If there were more moisture in the grassland biome, it could support larger plants. On the other hand, it must have enough moisture to support the grassy plants throughout a growing season.
10. **The correct answer is (C).** Animals communicate through a variety of means. Sound, chemical, touch, and sight are all ways

that animals communicate with each other. Instinctual is not a means of communicating; rather, it is how the organism responds to environmental needs without appearing to learn these responses.

VOCABULARY

associative learning
autotroph
behavior
biomes
biosphere
carrying capacity
circadian rhythms
classical conditioning
climax community
commensalism
community
consumer
critical period
decomposer
density-dependent factors
density-independent factors
ecology
ecosystem
exponential growth
fauna
flora
food chain
food pyramid
food web
herbivore
heterotroph
imprinting
insight
instinct
K-strategists
learning
logistic growth
mutualism
niche
operant conditioning
parasitism
pioneer community
population
population density
primary consumer
producer
reasoning
r-strategists
secondary consumer
sere
succession
trophic

Chapter 9

LABORATORY

OVERVIEW

Testing laboratory skills on a multiple-choice test is almost impossible. However, some lab experience will be helpful in preparing for and actually taking the SAT II Biology exam. Therefore, you may find our review book helpful in providing as much information in this chapter and others as you should reasonably be expected to know in order to be successful on this part of the test. We will outline what the lab is about, what you need to know to successfully deal with the lab, and any tips that might be helpful. In the "First Things" section, we briefly describe what the student will do in the lab, despite the fact that the student may not actually have the opportunity to do the lab. In "The Basics," we indicate what the student should know before doing the lab and what the expected outcomes are; finally, in the "Last Things" section, we provide any additional information the student should know.

LABORATORY 1—DIFFUSION AND OSMOSIS

FIRST THINGS

The student will demonstrate a competency in investigating the processes of diffusion and osmosis and the effect of solute concentration on water potential in plants.

THE BASICS

In order to be successful on this lab, the student should understand (a) the mechanisms of both processes, (b) water potential, (c) differentially (selectively) permeable membranes and their effect on the two processes, (d) molarity, and (e) the relationship between water potential and solute concentration. Following this lab, the student will be able to (a) measure water potential of a solution, (b) determine the osmotic concentration in living plant tissue, (c) relate the effects of water gain or loss in living tissue, and (d) relate osmotic pressure to solute concentration and water potential.

Last Things

The student should be familiar with the fact that the free energy in water is known as its water potential. The terms *hypotonic* and *hypertonic* should be well known, as well as *turgor pressure.* Finally, the student should be familiar with the basics of the movement of water across a membrane and its effect in animal and plant tissue.

LABORATORY 2—ENZYME CATALYSIS

First Things

The student will measure the action of the enzyme catalase on hydrogen peroxide and the rate at which it is converted to water and oxygen gas.

The Basics

In order to be successful on this lab, the student should understand (a) enzymes, their structure, and how they act; (b) free energy; and (c) initial reaction rates of enzymes and the conditions that affect them. After performing this lab, the student should understand how to (a) measure the effects of temperature, pH, and enzyme/substrate concentration on enzyme-mediated catalysis and (b) explain the effect that environmental factors have on enzyme-catalyzed reactions.

Last Things

The student should be familiar with enzymes and how they act and how, if they become denatured, they change their shape and thus their ability to work.

LABORATORY 3—MITOSIS AND MEIOSIS

First Things

The student will perform two labs, one on mitosis and one on meiosis.

A. Mitosis
The student will calculate how long a cell spends in the various phases of mitosis and will compare animal mitosis with plant mitosis.

B. Meiosis
The student will investigate the stages of meiosis using chromosome models. This includes crossing over and recombination. The student

will investigate the life cycle of the fungus *Sordaria fimicola,* the arrangement of ascospores, crossing over, and the gene control of spore color.

The Basics

In order to be successful on this lab, the student should understand (a) the events in mitosis, (b) the differences between mitosis and meiosis, and (c) the events in gametogenesis. After performing this lab, the student should understand (a) the relative duration of cell cycles; (b) the mechanisms of crossing over, segregation, and independent assortment; and (c) how to calculate the distance of a gene from the centromere.

Last Things

The student should be familiar with mitosis and meiosis and how it leads to genetic variability.

LABORATORY 4—PLANT PIGMENTS AND PHOTOSYNTHESIS

First Things

The student will separate pigments using chromatography and measure the rate of photosynthesis through the reduction of the dye DPIP.

The Basics

In order to be successful on this lab, the student should understand (a) chromatography, (b) photosynthesis, (c) function of plant pigments, and (d) the effect of light on photosynthesis. After performing this lab, the student should understand (a) how to separate plant pigments, (b) how to measure photosynthetic rates, (c) the effect of temperature and light on the rate of photosynthesis, and (d) how to explain the variability of photosynthetic rates.

Last Things

The student should be familiar with paper chromatography, how to calculate the rate of pigment migration, how light and temperature affect photosynthesis, and how to design an experiment to test these three variables.

LABORATORY 5—CELL RESPIRATION

FIRST THINGS

The student will measure oxygen consumption during respiration in germinating or nongerminating peas.

THE BASICS

In order to be successful on this lab, the student should understand (a) how a respirometer works and (b) the process of metabolism in a living organism. After performing this lab, the student should understand how to (a) test the effects of temperature on peas in a controlled experiment, (b) calculate the rate of respiration, and (c) relate gas consumption and production to the respiration rate.

LAST THINGS

The student should be familiar with the formula for cellular respiration and how a respirometer works.

LABORATORY 6—MOLECULAR BIOLOGY

FIRST THINGS

The student will investigate some basic principles of genetic engineering.

THE BASICS

In order to be successful on this lab, the student should understand (a) gel electrophoresis, (b) principles of bacterial transformation, (c) proper cell preparation, (d) the role of plasmids in genetic engineering, (e) how restriction enzymes function, and (f) transfer of antibiotic resistance. After performing this lab, the student should understand how to (a) use plasmids in genetic research, (b) use restriction enzymes, (c) calculate transformation efficiency, (d) use multiple experimental controls, and (e) use DNA fragments of known size to calculate the size of unknown fragments.

LAST THINGS

The student should be familiar with how bacteria incorporate foreign DNA, how restriction enzymes function and electrophoresis, and how bacteria are "transformed."

LABORATORY 7—GENETICS OF DROSOPHILA

First Things

The student will use fruit flies to investigate genetic crosses.

The Basics

In order to be successful on this lab, the student should understand (a) chi-square analysis and (b) the life cycle of diploid organisms. After performing this lab, the student should understand how to (a) investigate independent assortment of two genes, (b) use a multi-generational study to investigate the interactions between the two genes, and (c) analyze the data from chi-square analyses.

Last Things

The student should be familiar with Punnett squares and multigenerational study techniques.

LABORATORY 8—POPULATION GENETICS AND EVOLUTION

First Things

The student will learn the Hardy–Weinberg law and the relationship between evolution and gene frequency.

The Basics

In order to be successful on this lab, the student should understand (a) how natural selection alters gene frequency, (b) the Hardy–Weinberg equation, and (c) the effects of allele frequency on natural selection. After performing this lab, the student should understand how to (a) calculate the frequency of alleles in the gene pool, (b) use the Hardy–Weinberg law to do this, and (c) discuss deviations from Hardy–Weinberg.

Last Things

The student should be familiar with the Hardy–Weinberg law and know how to calculate allele frequencies and evolution.

LABORATORY 9—TRANSPIRATION

First Things

The student will measure transpiration under varying laboratory conditions and how the structures in the plant stem and leaf relate to this.

The Basics

In order to be successful on this lab, the student should understand (a) how water moves in plants, (b) the role of transpiration in moving water in a plant, and (c) plant physiology. After performing this lab, the student should understand how to (a) test the role that environmental variables play in the rate of transpiration, (b) make a thin section of tissue, and (c) identify the cells in plant vascular tissue.

Last Things

The student should be familiar with transpiration, plant physiology, and how to make thin sections of tissues.

LABORATORY 10—PHYSIOLOGY AND THE CIRCULATORY SYSTEM

First Things

The student will, under a variety of conditions, learn how to measure and analyze blood pressure, measure pulse rate, and determine the effect of temperature on the heart beat of a water flea.

The Basics

In order to be successful on this lab, the student should understand the relationship between temperature and the rates of physiological activities. After performing this lab, the student should understand how to (a) measure heart rate and blood pressure, (b) describe the effect of body position on heart rate and blood pressure, (c) analyze cardiovascular data, (d) explain how exercise changes heart rate, and (e) discuss the effect temperature has on heart rate.

Last Things

The student should be familiar with how to measure pulse and blood pressure and should know that heat increases physiological activity.

LABORATORY 11—HABITAT SELECTION

First Things

The student will observe the behavior of an insect and design an experiment to investigate its responses to changing environments. The student will also observe mating behavior.

The Basics

In order to be successful on this lab, the student should understand (a) organism distribution with respect to resources, (b) kinesis and taxis, (c) how environmental factors affect habitat selection among organisms, and (d) how to describe different mating behaviors. After performing this lab, the student should be able to (a) design an experiment to investigate an organism's responses to environmental variables, (b) measure the effects of various environmental variables on habitat selection in a controlled experiment, and (c) describe the different types of insect mating behavior.

Last Things

The student should be familiar with the variables that affect an organism's habitat selection.

LABORATORY 12—DISSOLVED OXYGEN AND AQUATIC PRIMARY PRODUCTIVITY

First Things

The student will analyze the dissolved oxygen content in water and the productivity of laboratory cultures relative to the intensity of light.

The Basics

In order to be successful on this lab, the student should understand (a) the carbon and oxygen cycles in nature, (b) primary productivity in an ecosystem, (c) solubility of gases in water, and (d) how photosynthesis, respiration, and dissolved oxygen affect primary productivity. After performing this lab, the student should understand (a) how to measure primary productivity and (b) the effect that light and inorganic nutrients have on primary productivity.

Last Things

The student should be familiar with the carbon and oxygen cycle; the effect that temperature, salinity, and photorespiration have on the solubility of dissolved gases; primary production; and the difference between gross and net productivity.

FINAL TIPS

Here, finally, are a few things to be aware of. In this area, students will be tested either on experimental design or analysis. If you must construct a graph, don't forget labels—use the *x*-axis for independent variables and the *y*-axis for dependent ones. Where appropriate, connect the dots and provide values along the axes clearly and regularly. When you design an experiment, you want to distinguish between the dependent and the independent variables. Identify the experimental values and the control values, and remember that every experiment tests only one independent variable at a time. Organisms must be the result of a random sample. Describe the procedure, the expected results, and why you expected those results based on applicable biological principles.

PRACTICE TEST 1

While you have taken many standardized tests and know to blacken completely the ovals on the answer sheets and to erase completely any errors, the instructions for the SAT II exam in Biology differs from the directions for other standardized tests you have taken. You need to indicate on the answer key whether you are taking the SAT II Biology with Ecological Emphasis (Biology-E) or Molecular Emphasis (Biology-M).

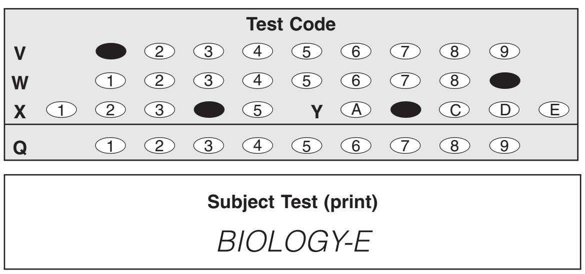
The instructions on the answer sheet will tell you to fill out the top portion of the answer sheet exactly as shown.

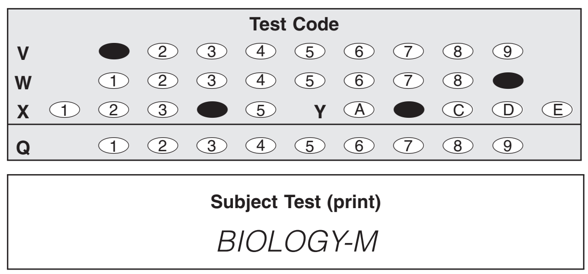
1. Print *BIOLOGY-E or BIOLOGY-M on the line to the right under the words Subject Test (print).*

2. In the shaded box labeled *Test Code* fill in four ovals:

For BIOLOGY-E
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.

For BIOLOGY-M
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.





For BIOLOGY-E
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

For BIOLOGY-M
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

3. When everyone has completed filling in this portion of the answer sheet, the supervisor will tell you to turn the page and begin. The answer sheet has 100 numbered ovals on the sheet, but there are only 90 (or 95) multiple-choice questions in the test, so be sure to use only ovals 1 to 90 (or 95) to record your answers.

TEST 1—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

Questions 1–3 refer to the following cellular structures:

(A) ribosome
(B) nucleus
(C) chloroplast
(D) mitochondria
(E) endoplasmic reticulum

1. Structure found in plant cells but not animal cells.
2. Structure that functions as the site of protein synthesis in cells.
3. Structure that contains the codes for the specific proteins produced by a cell.

Questions 4–6 refer to the following processes:

(A) protein synthesis
(B) respiration
(C) digestion
(D) photosynthesis
(E) fermentation

4. The process by which both plants and animals obtain energy for cellular function.
5. The process that allows higher plants to be autotrophic (able to manufacture their own food).
6. The process that leads to the production of ethyl alcohol or lactic acid.

TEST 1—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. Some questions refer to a laboratory or experimental situation. For each question, select the best of the answer choices given.

7. Which of the groups below represents the correct relationship in order from smallest (or simplest) to largest (or more complex)?

(A) matter — element — compound — electron — atom

(B) electron — element — atom — compound — matter

(C) electron — atom — element — matter — compound

(D) electron — atom — element — compound — matter

(E) atom — electron — element — compound — matter

8. Which of the following pairs does NOT represent a correct relationship?

(A) glucose; polysaccharide

(B) starch; polysaccharide

(C) starch; carbohydrate

(D) glucose; carbohydrate

(E) glucose; monosaccharide

9. Which of the following statements is correct?

(A) The product of transcription is DNA.

(B) The product of transcription is mRNA.

(C) The product of transcription is a protein.

(D) The product of translation is mRNA.

(E) The product of translation is DNA.

10. Which of the following descriptions of a DNA molecule is NOT correct?

(A) Synthesis is semiconservative.

(B) Opposite strands are antiparallel.

(C) It contains the sugar deoxyribose.

(D) The number of adenines present is roughly equal to the number of thymines.

(E) The number of cytosines present is roughly equal to the number of uracils.

11. What defines the Sahara Desert as a desert?

(A) It is characterized by very hot temperatures.

(B) The growing season is very short.

(C) Cacti make up the dominant form of vegetation.

(D) It is very dry.

(E) The average temperature fluctuates very little between winter and summer.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

12. Which of the following represents the correct sequence, from simplest to most complex?

(A) population — organism — community — ecosystem — biosphere
(B) organism — population — community — ecosystem — biosphere
(C) organism — population — community — biosphere — ecosystem
(D) population — organism — community — biosphere — ecosystem
(E) organism — community — population — ecosystem — biosphere

13. Lichens are composed of both fungal and algal (or cyanobacterial) components. The fungal component absorbs water and nutrients for both organisms, while the algal component manufactures food for both organisms through photosynthesis. This type of symbiotic relationship is referred to as

(A) parasitism.
(B) commensalism.
(C) predation.
(D) mutualism.
(E) interspecific competition.

14. In the Eastern United States, many forested areas were cleared for agricultural purposes. If cultivation was abandoned in those areas, they would eventually return to forests. This is an example of

(A) primary succession.
(B) secondary succession.
(C) decomposition.
(D) interspecific competition.
(E) eutrophication.

Questions 15–17 refer to the food chain illustrated below:

rose bush — grasshopper — mouse — snake — hawk — earthworm

15. What trophic level is represented by the snake?

(A) producer
(B) primary consumer
(C) secondary consumer
(D) tertiary consumer
(E) detritivore

16. The hawk could eat either the snake or the mouse and, thus, could represent which two different levels of the food chain?

(A) producer and primary consumer.
(B) primary and secondary consumer.
(C) secondary and tertiary consumer.
(D) tertiary and quaternary consumer.
(E) quaternary consumer and detritivore.

17. Which organism in the food chain represents a detritivore?

(A) earthworm
(B) hawk
(C) snake
(D) mouse
(E) grasshopper

TEST 1—*Continued*

18. The amount of nitrogen and phosphorous cycling through an ecosystem is greatly affected by local environmental conditions, such as heavy rainfall or the removal of large numbers of plants. The amount of carbon in an ecosystem is seldom significantly affected by such factors because

(A) plants make their own carbon compounds through photosynthesis.
(B) plants absorb large amounts of carbon from the soil.
(C) bacteria in the soil absorb large amounts of carbon.
(D) the primary source of carbon is the atmosphere, whereas much nitrogen and phosphorous come from the soil.
(E) organisms need only minute levels of carbon.

19. Which of the following represents an example of Mullerian mimicry?

(A) The coloration of the canyon tree frog allows it to blend in with the granite rocks among which it lives.
(B) When disturbed, the larva of the hawkmoth puffs up its head and thorax such that it resembles the head of a small poisonous snake.
(C) In some orchid species, the flowers resemble female moths and attract male moths that attempt to mate with them, contributing to pollination in the process.
(D) The conspicuous coloration of the blue-ringed octopus, which inhabits the coastal waters off Australia, serves to warn predators that it is extremely venomous.
(E) Two unrelated poisonous frog species that share the same habitat also resemble each other in coloration.

20. A human cell that contains 22 autosomes and a Y chromosome must be

(A) a zygote.
(B) a somatic cell of a male.
(C) a somatic cell of a female.
(D) a sperm cell.
(E) an egg cell.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

21. Which of the following events does NOT lead to genetic variation in a population?

(A) independent assortment of chromosomes during meiosis
(B) crossing over between homologous chromosomes during meiosis I
(C) crossing over between homologous chromosomes during meiosis II
(D) random union of an egg with a sperm
(E) random mutation

Questions 22–25 refer to the following breeding experiment, the purpose of which was to develop petunia plants with flowers expressing a new combination of form and shape: double (form) ruffled (shape) flowers.

P	plants with single ruffled flowers	x	plants with double plain flowers
F_1	all offspring have single plain flowers	F_2	290 plants have single plain flowers 99 plants have single ruffled flowers 101 plants have double plain flowers 32 plants have double ruffled flowers

22. The results of the cross indicate which of the following for the original parents (P-generation)?

(A) Both were heterozygous for flower form and flower shape.
(B) One was homozygous dominant for flower form and flower shape, whereas the other was homozygous recessive for both traits.
(C) One was homozygous dominant for flower form and homozygous recessive for flower shape, whereas the other was homozygous recessive for form and homozygous dominant for shape.
(D) One was homozygous dominant for both traits, whereas the other was heterozygous for both traits.
(E) One was homozygous recessive for both traits, whereas the other was heterozygous for both traits.

23. Based on the results, how many genes control the four traits observed among the plants (single, double, plain, and ruffled)?

(A) one
(B) two
(C) four
(D) eight
(E) sixteen

24. How many different genotypes are represented by the four phenotypic classes observed among the F_2 progeny?

(A) four
(B) eight
(C) nine
(D) thirty-two
(E) sixty-four

TEST 1—*Continued*

25. The results suggest that the inheritance of flower form and flower shape are controlled by

(A) different alleles of the same gene.
(B) two different genes on the same chromosome.
(C) four different genes on the same chromosome.
(D) two different genes on different chromosomes.
(E) four different genes on different chromosomes.

26. There are three alleles of the gene that controls the inheritance of the ABO blood groups; the A and B alleles are co-dominant, and O is recessive to both the A and B alleles. A man with type B blood and a women with type A blood could have children showing which of the following phenotype(s)?

(A) A only
(B) B only
(C) AB only
(D) A, B, or AB
(E) A, B, AB, or O

27. Most recessive sex-linked traits, such as colorblindness, show up more frequently in males than females because

(A) males have no corresponding allele on their X chromosome to mask the allele carried on their Y chromosome.
(B) males have no corresponding allele on their Y chromosome to mask the allele carried on their X chromosome.
(C) males carry all sex-linked traits on their Y chromosome.
(D) females always carry at least one dominant allele for sex-linked traits because they have two X chromosomes.
(E) females compensate by "turning" off the recessive allele through dosage compensation.

Questions 28–32 relate to various tissue types found in the human body. For each question, choose the term that corresponds to the definition given and fill in the corresponding oval on your answer sheet.

28. A special form of loose connective tissue that pads and insulates the body and stores fuel reserves is known as

(A) epithelial tissue.
(B) adipose tissue.
(C) fibrous connective tissue.
(D) nervous tissue.
(E) muscle tissue.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

29. The tissue that consists of long contractile cells (fibers) that are packed with microfilaments of actin and myosin is known as

(A) epithelial tissue.
(B) adipose tissue.
(C) fibrous connective tissue.
(D) nervous tissue.
(E) muscle tissue.

30. Tissue that lines the outer and inner surfaces of the body in protective sheets of tightly packed cells is known as

(A) epithelial tissue.
(B) adipose tissue.
(C) fibrous connective tissue.
(D) nervous tissue.
(E) muscle tissue.

31. The tissue that senses stimuli and transmits electrical signals to the brain and other parts of the body is known as

(A) epithelial tissue.
(B) adipose tissue.
(C) fibrous connective tissue.
(D) nervous tissue.
(E) muscle tissue.

32. Tissue consisting of a dense arrangement of parallel collagenous fibers found in tendons and ligaments is known as

(A) epithelial tissue.
(B) adipose tissue.
(C) fibrous connective tissue.
(D) nervous tissue.
(E) muscle tissue.

33. Which of the following correctly describes the relationship, from simplest to most complex, among the terms listed?

(A) cell — tissue — organ — organism
(B) organism — organ — tissue — cell
(C) cell — tissue — organism — organ
(D) tissue — cell — organ — organism
(E) tissue — organ — organism — cell

Questions 34–38 relate to various organ systems found in animals. For each question, choose the term that corresponds to the definition given and fill in the corresponding oval on your answer sheet.

34. The organ system that transports materials, such as nutrients, oxygen, and hormones, to body cells and transports carbon dioxide and various waste products away from cells is known as the

(A) digestive system.
(B) respiratory system.
(C) circulatory system.
(D) endocrine system.
(E) nervous system.

35. The organ system that forms a communication and coordination network throughout all parts of an animal's body is known as the

(A) digestive system.
(B) respiratory system.
(C) circulatory system.
(D) skeletal system.
(E) nervous system.

TEST 1—*Continued*

36. The organ system that functions in exchanging gases with the environment is known as the

(A) digestive system.
(B) respiratory system.
(C) circulatory system.
(D) endocrine system.
(E) nervous system.

37. The organ system that takes in food, breaks it down into smaller chemical units, and absorbs the nutrient molecules is known as the

(A) digestive system.
(B) respiratory system.
(C) circulatory system.
(D) endocrine system.
(E) nervous system.

38. The organ system that consists of ductless glands that secrete hormones and the molecular receptors on target cells that respond to the hormones is known as the

(A) digestive system.
(B) respiratory system.
(C) circulatory system.
(D) endocrine system.
(E) nervous system.

39. Which of the following best describes how a salmon is able to regulate its internal water and salt concentrations when it is swimming in the ocean and when it migrates into fresh water to spawn?

(A) In salt water, the salmon loses water by osmosis; it drinks salt water and disposes of excess salt through its gills. In fresh water, the salmon gains water by osmosis; its kidneys excrete large quantities of urine along with some salts, and it replenishes the lost salts through uptake by its gills and digestive system.
(B) In salt water, the salmon gains water by osmosis; it drinks salt water and disposes of excess salt through its gills. In fresh water, the salmon loses water by osmosis; its kidneys excrete large quantities of urine along with some salts, and it replenishes the lost salts through uptake by its gills and digestive system.
(C) In salt water, the salmon loses water by osmosis; it drinks salt water and stores excess salt in its body cavity. In fresh water, the salmon gains water by osmosis; its kidneys excrete large quantities of urine and salts.
(D) In salt water, the salmon gains water by osmosis; it drinks salt water and stores excess salt in its body cavity. In fresh water, the salmon loses water by osmosis; its kidneys excrete large quantities of urine and salt.
(E) In salt water, the salmon gains water by osmosis and loses salt by diffusion. In fresh water, the salmon loses water by osmosis and gains salt through diffusion.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

<u>Directions</u>: Each of the lettered choices below refers to the statements immediately following it. Select the lettered choice that best fits each statement. A choice may be used once, more than once, or not at all.

Questions 40–45 refer to the following pairs of organisms:

(A) cyanobacteria and algae
(B) algae and fungi
(C) mosses and ferns
(D) ferns and gymnosperms
(E) gymnosperms and angiosperms

40. One produces seeds, whereas the other does not.

41. One produces fruits, whereas the other does not.

42. One has vascular tissue, whereas the other does not.

43. One is a prokaryote, whereas the other is a eukaryote.

44. One photosynthesizes, whereas the other does not.

45. One produces naked seeds, whereas the other produces seeds enclosed in maternally derived tissue.

Questions 46–48 refer to the following terms:

(A) xylem
(B) phloem
(C) vascular cambium
(D) mesophyll
(E) pith

46. Responsible for secondary growth in woody plants.

47. Responsible for conducting water and dissolved minerals throughout the plant body.

48. Responsible for transporting food (mainly sugars) made during photosynthesis throughout the plant body.

TEST 1—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

49. Which of the following statements most accurately describes the process of double fertilization in angiosperms?

(A) Two pollen grains land on each stigma; thus, two ovules are fertilized.

(B) Two sperm cells produced by a single pollen grain fertilize two separate ovules, resulting in the formation of two seeds.

(C) One sperm cell from a single pollen grain fertilizes an egg cell to form a diploid zygote, while a second sperm cell from the same pollen grain combines with two fused nuclei in the embryo sac, resulting in the formation of a triploid endosperm nucleus.

(D) One sperm cell from a single pollen grain fertilizes an egg cell to form a haploid zygote, while a second sperm cell from the same pollen grain combines with a single nucleus in the embryo sac, resulting in the formation of a diploid endosperm nucleus.

(E) Two sperm cells from a single pollen grain fertilize the same egg cell to double the chance that fertilization will be successful.

Questions 50–51 refer to the following terms:

(A) integument

(B) cotyledon

(C) ovule

(D) ovary

(E) endosperm

50. Which of the above structures develops into the seed once fertilization has occurred?

51. Which of the above structures develops into the fruit once fertilization has occurred?

Questions 52–55 refer to the following terms:

(A) biogeography

(B) natural selection

(C) comparative anatomy

(D) comparative embryology

(E) molecular biology

52. Evidence validating the theory of evolution based on the study of similarities and differences in body structure among various species is known as ____________.

53. Evidence validating the theory of evolution based on the study of local, regional, and global distributions of species is known as ____________.

54. Evidence validating the theory of evolution based on the study of structures that appear during the development of different organisms is known as ____________.

55. Evidence validating the theory of evolution based on the study of the genetic makeup of species at the DNA level is known as ____________.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

56. Which of the following statements is NOT part of Darwin's theory of natural selection?

(A) Genetic variation exists among individuals in a population.

(B) The size of most populations remains relatively constant, despite the fact that more offspring are produced than are needed to maintain it.

(C) Early settlers saved seed only from the most productive crop plants to plant the following year.

(D) Disease, competition, and other environmental forces tend to eliminate the individuals in a population that are less adapted to their environment.

(E) Individuals that are best adapted to their environment tend to pass on heritable advantageous characteristics to their offspring.

57. Several accepted definitions of a species exist in the scientific literature. One of those definitions is of a biological species, defined as a population or group of populations whose members have the potential in nature to interbreed and produce fertile offspring. In other words, different species are reproductively isolated from one another. This definition can only be applied to

(A) species that reproduce sexually.

(B) species that reproduce asexually only.

(C) species that form sterile hybrids upon mating.

(D) extinct forms of life, based on fossil evidence.

(E) species living on separate continents.

Questions 58–59 refer to the Hardy-Weinberg equation used to reflect genotypic frequencies in a population, as given below.

$$p^2 + 2pq + q^2 = 1$$

58. Which of the following is reflected by the value of p^2 ?

(A) the frequency of individuals in the population with the dominant phenotype

(B) the frequency of individuals in the population with the homozygous dominant genotype

(C) the frequency of the dominant allele in the population

(D) the frequency of individuals in the population with the homozygous recessive genotype

(E) the frequency of individuals in the population that are heterozygous

59. The term $2pq$ indicates that

(A) there are two alleles for that gene in the population.

(B) there are two genes in the population.

(C) there are twice as many dominant alleles as recessive alleles in the population.

(D) there are twice as many heterozygotes as homozygotes in the population.

(E) there are two separate reproductive combinations that can result in the formation of a heterozygous individual.

TEST 1—*Continued*

60. A tetraploid individual would have

(A) one copy of each chromosome.
(B) two copies of each chromosome.
(C) four copies of each chromosome.
(D) two copies of a single chromosome.
(E) four copies of a single chromosome.

S T O P

IF YOU ARE TAKING THE BIOLOGY-E TEST, CONTINUE WITH QUESTIONS 61–80.
IF YOU ARE TAKING THE BIOLOGY-M TEST, GO TO QUESTION 81 NOW.

TEST 1—*Continued*

BIOLOGY-E TEST

Directions: Each of the questions or statements below is accompanied by five choices. Some questions refer to a laboratory or experimental situation. For each question, select the best of the answer choices given.

61. Which of the following best describes the relationship between a population and a species?

(A) A species is one type of population.

(B) A species is a local subset of a population.

(C) A population is a group of organisms occupying a specific area.

(D) A population encompasses many different species.

(E) The terms population and species are interchangeable.

62. The number of individuals in a population that the environment can just maintain with no net increase or decrease from generation to generation is known as

(A) the logistic growth curve.

(B) the carrying capacity.

(C) the dispersion pattern.

(D) the habitat cap.

(E) the exponential growth curve.

63. Which of the following pairs of figures would you need to know to determine the population density of elk living in Rocky Mountain National Park?

(A) the birth rate of the elk population and whether population growth is logistic or exponential

(B) the birth rate of the elk population and the area of land encompassed by the park

(C) the number of elk living in the park and the dispersion pattern of the elk population

(D) the number of elk living in the park and the area of land encompassed by the park

(E) the number of elk living in the park and the birth rate of the elk population

64. A small isolated population found on a remote island is more likely to undergo speciation than a large widespread population because a small isolated population

(A) is more susceptible to genetic drift.

(B) inherently contains much greater genetic diversity.

(C) is more readily adaptable to extreme environmental changes.

(D) is more likely to migrate to other islands or the nearest mainland.

(E) has a greater likelihood of containing sterile hybrid individuals.

TEST 1—*Continued*

65. Which of the following represents the correct order of eras, from most ancient to most recent, along the geological time scale?

(A) paleozoic — precambrian — mesozoic — cenozoic
(B) precambrian — cenozoic — paleozoic — mesozoic
(C) precambrian — mesozoic — paleozoic — cenozoic
(D) precambrian — paleozoic — mesozoic — cenozoic
(E) cenozoic — mesozoic — paleozoic — precambrian

66. Two snails in the same class must also be in the same

(A) order.
(B) species.
(C) genus.
(D) family.
(E) phylum.

67. As development continues to encroach on natural areas, individuals in local hawk populations must increasingly compete for a limited number of nesting sites. This type of behavior is likely to result in

(A) a convergent dispersion pattern within the population.
(B) a uniform dispersion pattern within the population.
(C) a random dispersion pattern within the population.
(D) a clumped dispersion pattern within the population.
(E) multiple individuals simultaneously occupying the same nest.

68. Interactions among species in an ecosystem defined as +/− would be characteristic of

(A) predation only.
(B) parasitism only.
(C) mutualism only.
(D) both predation and mutualism.
(E) both predation and parasitism.

69. Which of the following organisms would NOT be considered a primary producer?

(A) phytoplankton
(B) algae
(C) moss
(D) fungi
(E) cyanobacteria

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

Questions 70–71 refer to the following population in Hardy-Weinberg equilibrium:

Within the squirrel population at City Park, 16% show the recessive phenotype of a curled tail (tt).

70. What is the frequency of the dominant allele (T) in the population?

(A) 0.40
(B) 0.16
(C) 0.26
(D) 0.60
(E) 0.32

71. What is the frequency of heterozygotes in the population?

(A) 0.08
(B) 0.24
(C) 0.36
(D) 0.48
(E) 0.64

72. Which of the following is NOT a requirement for a population to be maintained in Hardy-Weinberg equilibrium through several generations of intermating?

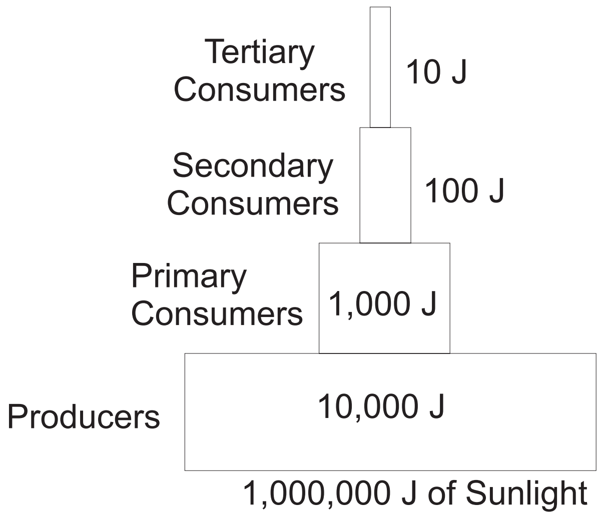
(A) nonrandom mating among individuals
(B) no net mutations
(C) large population size
(D) isolation from other populations (no migration into or out of the population)
(E) no natural selection occurring

73. Kingdom Monera in the traditional five-kingdom classification system has been divided into two separate kingdoms in the alternative eight-kingdom system of classification, the

(A) Bacteria and Archaea.
(B) Bacteria and Protista.
(C) Archaea and Protista.
(D) Archaea and Euarchaea.
(E) Euarchaea and Protista.

TEST 1—*Continued*

Questions 74–77 refer to the diagram below that shows a hypothetical pyramid of net productivity that depicts the multiplicative loss of energy in a food chain. Each trophic level in the food chain is represented by a block in the pyramid, with primary producers forming the foundation of the pyramid. The size of each block is proportional to the productivity at each trophic level per unit of time.



74. In the above example, approximately how much energy available in each trophic level is converted into new biomass in the trophic level above it?

(A) 1%

(B) 5%

(C) 10%

(D) 50%

(E) 100%

75. The percentage of energy transferred from one trophic level to the next (the ratio of net productivity at one trophic level to net productivity at the level below) is known as

(A) ecological efficiency.

(B) biomass.

(C) gross productivity.

(D) turnover.

(E) transformation.

76. In terms of the decline in productivity with energy transfer from one trophic level to the next higher trophic level, which of the following would be the most efficient means of trapping the energy produced in photosynthesis?

(A) a human eating beef that was raised on meat by-products

(B) a human eating beef that was raised on a combination of grain and meat by-products

(C) a human eating grain-fed beef

(D) a human eating grain along with grain-fed beef

(E) a human eating grain along with soybeans

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

77. Which of the following would likely remove the most energy from the food chain (so that it cannot be passed on to the next trophic level through the biomass of the organism) at the primary consumer level?

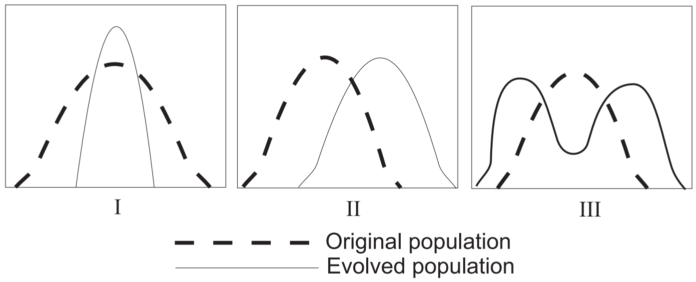
(A) photosynthesis
(B) excretion
(C) metabolism
(D) growth
(E) respiration

78. Which of the following statements is NOT one of the principle observations upon which Darwin based his theory of natural selection?

(A) The population size of a species would increase exponentially if all individuals that were born reproduced successfully.
(B) Populations tend to remain stable in size, aside from seasonal fluctuations.
(C) Environmental resources are limited.
(D) Individuals in a population vary extensively in their characteristics.
(E) Most of the variation observed among individuals in a population is due to environmental causes; thus, very little variation is heritable (passed on from parent to offspring).

TEST 1—*Continued*

Questions 79–80 refer to the series of graphs below.



79. Which of the above graphs best illustrates the concept of stabilizing selection (selection that favors intermediate variants by acting against individuals with extreme phenotypes)?

(A) Graph I only
(B) Graph II only
(C) both Graph I and Graph II
(D) Graph III only
(E) both Graph II and Graph III

80. Which of the above graphs best illustrates the concept of diversifying selection (selection that favors extreme phenotypes over intermediate phenotypes)?

(A) Graph I only
(B) Graph II only
(C) both Graph I and Graph II
(D) Graph III only
(E) both Graph II and Graph III

S T O P

If you answered the first 80 questions STOP HERE.
If you are taking the Biology-M test CONTINUE HERE.

TEST 1—*Continued*

BIOLOGY-M TEST

Directions: Each of the questions or statements below is accompanied by five choices. Some questions refer to a laboratory or experimental situation. For each question, select the best of the answer choices given.

81. In human DNA, adenine (A) makes up approximately 30.9% of the bases, and guanine (G) makes up approximately 19.9% of the bases; therefore the percentage thymine (T) and cytosine (C) are

(A) 19.8% T and 19.8% C.
(B) 19.8% T and 29.4% C.
(C) 29.4% T and 19.8% C.
(D) 29.8% T and 29.8% C.
(E) 19.9% T and 30.9% C.

82. If the chromosomes of a eukaryotic cell were lacking telomerase, the cell would

(A) have a greater potential to become cancerous than one with telomerase.
(B) would be able to repair mismatched base pairs during replication.
(C) not produce okazaki fragments.
(D) become increasingly shorter with each cycle of replication.
(E) be unable to take up extraneous DNA from the surrounding solution.

83. Which of the following statements concerning transcription and translation in eukaryotic cells is NOT correct?

(A) Transcription results in the production of mRNA, whereas translation results in the production of polypeptides.
(B) Transcription results in the production of polypeptides, whereas translation results in the production of mRNA.
(C) Transcription occurs in the nucleus, whereas translation occurs in the cytoplasm.
(D) Transcription uses a nucleotide "language," whereas translation uses an amino acid "language."
(E) Transcription uses DNA as a template, whereas translation uses mRNA as a template.

84. The open, less compacted form of DNA that is available for transcription is known as the

(A) promoter.
(B) enhancer.
(C) operator.
(D) euchromatin.
(E) heterochromatin.

TEST 1—*Continued*

85. A sequence on a DNA molecule that recognizes specific transcription factors that can stimulate transcription of nearby genes is known as the

(A) promoter.
(B) enhancer.
(C) operator.
(D) euchromatin.
(E) heterochromatin.

86. The tightly coiled, condensed form of DNA that is not transcribed is known as the

(A) promoter.
(B) enhancer.
(C) operator.
(D) euchromatin.
(E) heterochromatin.

Questions 87–90 refer to the following steps involved in cloning a eukaryotic gene in a bacterial plasmid vector.

I. Introduction of cloning vector into cells.
II. Insertion of eukaryotic DNA into the vector.
III. Identification of cell clones that carry the inserted eukaryotic gene.
IV. Isolation of the vector and the eukaryotic gene-source DNA.
V. Cloning of cells (and foreign DNA).

87. Which of the following depicts the correct sequence of the steps (from first to last) involved in cloning a eukaryotic gene in a bacterial plasmid described above?

(A) I — II — III — IV — V
(B) V — IV — III — II — I
(C) III — V — II — IV — I
(D) IV — II — I — V — III
(E) II — IV — I — III — V

88. During the stage in which insertion of eukaryotic DNA into the plasmid vector occurs, the sticky ends formed by digestion of both DNA types with the same restriction enzyme may join in a recombinant molecule because

(A) the eukaryotic DNA and plasmid DNA will have the same sequence.
(B) the eukaryotic DNA and plasmid DNA will have complementary sequences.
(C) the eukaryotic DNA can join with any plasmid DNA, regardless of sequence.
(D) the plasmid DNA can join with any eukaryotic DNA, regardless of sequence.
(E) the plasmid DNA and the eukaryotic DNA cannot join together due to differences in the structure of their DNA molecules.

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

89. Which of the following statements is NOT true of restriction enzymes?

(A) Each restriction enzyme recognizes a specific sequence of bases on the DNA molecule.

(B) Each restriction enzyme cuts at random locations along the DNA molecule.

(C) Most restriction enzymes are named after the bacterial organism from which they were first isolated.

(D) Restriction enzymes protect their bacterial host against intruding foreign DNA from viruses or other bacterial cells.

(E) When a particular sequence of DNA is digested with a specific restriction enzyme, the resulting set of restriction fragments will usually be the same.

90. The uptake of naked DNA from solution by bacterial cells is known as

(A) transpiration.

(B) electroporation.

(C) translation.

(D) transduction.

(E) transformation.

91. The classification of organisms into kingdoms has come under debate in recent years, with most of the debate focused on the

(A) algae and fungi.

(B) algae and plants.

(C) fungi and plants

(D) fungi and animals.

(E) prokaryotes and simple eukaryotes.

92. In the steps leading up to the origin of life on earth, early protobionts could not have evolved into living cells without both

(A) a semipermeable membrane and a nucleus.

(B) competition for resources and the development of hereditary mechanisms.

(C) a semipermeable membrane and the ability to catalyze chemical reactions.

(D) a nucleus and the ability to catalyze chemical reactions.

(E) a mechanism for growth and a mechanism for asexual reproduction.

TEST 1—*Continued*

93. One goal of phylogenetic systematics is to make classification of organisms more objective and consistent with evolutionary history. Which of the following statements regarding this important area of study is NOT correct?

(A) The two main analytical approaches to the study of phylogenetic systematics are phenetics and cladistics.

(B) Phenetic analysis compares as many characters as possible without distinguishing between homologous and analogous characters.

(C) Cladistic analysis classifies organisms according to the order in time that branches arose along a dichotomous phylogenetic tree.

(D) Cladistic analysis relies on analogous characters among organisms while ignoring novel homologies unique to the various organisms on a branch.

(E) The most accurate phylogenetic trees are those in which molecular data agree with other forms of evidence for phylogenetic relationships (such as morphology, fossil records, and biochemical analysis)

Questions 94–95 refer to the genetic codon table below:

First Base (5′ end)	Second Base: U	Second Base: C	Second Base: A	Second Base: G	Third Base (3′ end)
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
U	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
U	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
C	CUC Leu	CCC Pro	CAC His	CGC Arg	C
C	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
C	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
A	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
A	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
A	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
G	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
G	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
G	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

94. Which of the following partial polypeptides is coded for by the series of codons below?
— UUC — CCA — CAG — GGU — ACA —

(A) Start — Thr — Phe — Ala — Stop

(B) Met — Thr — Phe — Ala — Stop

(C) Leu — Lys — Ser — Arg — Val

(D) Phe — Pro — Gln — Gly — Thr

(E) Phe — Ser — Pro — Trp — Stop

GO ON TO THE NEXT PAGE

TEST 1—*Continued*

95. Which of the following base substitution mutations in the mRNA above would have the least effect on the resulting polypeptide?

(A) substitution of U**C**C for UUC in Phe

(B) substitution of C**A**A for CCA in Pro

(C) substitution of CA**C** for CAG in Gln

(D) substitution of GG**A** for GGU in Gly

(E) substitution of **C**CA for ACA in Thr

96. The pattern of DNA fragments resulting from restriction enzyme digestion of genomic DNA from two species of skunk with EcoRI show extensive similarities. This suggests that

(A) the two skunks must be the same species, not different species.

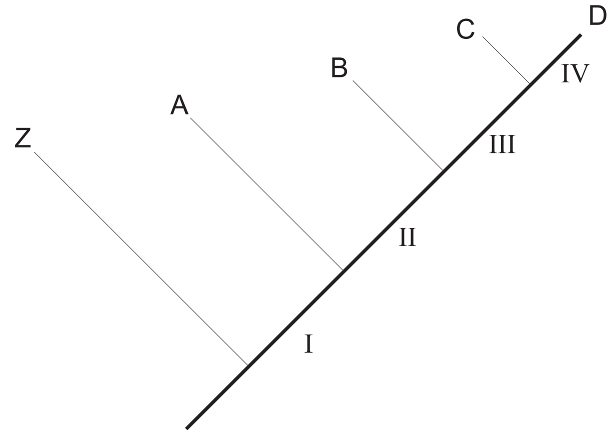
(B) most of the restrictions sites recognized by EcoRI are found at approximately the same distances apart in the DNA from both skunk species.

(C) restriction enzyme digestion with EcoRI produces the same pattern of DNA fragments in all organisms.

(D) restriction enzyme digestion with EcoRI produces the same pattern of DNA fragments in all species of skunks.

(E) the genetic makeup of the two skunk species is identical.

Questions 97–98 refer to the hypothetical phylogenetic tree below:



97. Which organism depicted on the phylogenetic tree above represents the outgroup?

(A) Z

(B) A

(C) B

(D) C

(E) D

98. Which pair of organisms on the phylogenetic tree depicted above represents the most closely related taxa?

(A) Z and A

(B) A and B

(C) B and C

(D) C and D

(E) Z and D

TEST 1—*Continued*

99. Restriction enzyme digestion with HindIII of genomic DNA from three toad species (A, B, and C) revealed that species A and B each produced unique fragment patterns, whereas species C shared fragments with both species A and species B. These results suggest that

(A) species C served as an outgroup for the study.

(B) restriction enzyme analysis should not be used in the comparison of more than two species simultaneously.

(C) species C is the most recent living ancestor of both species A and species B.

(D) the DNA sample from species C must have been contaminated.

(E) species C is a hybrid between species A and species B.

100. One of the earliest theories pertaining to the origin of life on earth suggested that life began in shallow pools. Recent studies have led to extensive debate regarding the origin of life, with some researchers suggesting that life may have originated

(A) near deep sea vents.

(B) as viral particles.

(C) in mudflats.

(D) from debris left behind when meteorites crashed to earth.

(E) from naked strands of RNA.

S T O P

If you finish before the hour is up, you may review your work on this test only. You may not turn to any other test in this book.

ANSWERS AND EXPLANATIONS

QUICK-SCORE ANSWERS									
1. C	11. D	21. C	31. D	41. E	51. D	61. C	71. D	81. C	91. E
2. A	12. B	22. C	32. C	42. C	52. C	62. B	72. A	82. D	92. B
3. B	13. D	23. B	33. A	43. A	53. A	63. D	73. A	83. B	93. D
4. B	14. B	24. C	34. C	44. B	54. D	64. A	74. C	84. D	94. D
5. D	15. D	25. D	35. E	45. E	55. E	65. D	75. A	85. B	95. D
6. E	16. D	26. E	36. B	46. C	56. C	66. E	76. E	86. E	96. B
7. D	17. A	27. B	37. A	47. A	57. A	67. B	77. E	87. D	97. A
8. A	18. D	28. B	38. D	48. B	58. B	68. E	78. E	88. B	98. D
9. B	19. E	29. E	39. A	49. C	59. E	69. D	79. A	89. B	99. E
10. E	20. D	30. A	40. D	50. C	60. C	70. D	80. D	90. E	100. A

1. **The correct answer is (C).** Chloroplasts are the site of photosynthesis, a process that occurs in plants but not in animals.
2. **The correct answer is (A).** Ribosomes function as the sites for protein synthesis.
3. **The correct answer is (B).** The nucleus contains DNA, which is packaged into chromosomes. The base sequence on the DNA molecule provides the code for the specific proteins to be manufactured by the cell.
4. **The correct answer is (B).** Respiration utilizes oxygen in the breakdown of organic compounds (such as glucose) to produce energy (in the form of ATP) for the function of cellular processes.
5. **The correct answer is (D).** Photosynthesis utilizes carbon dioxide and water from the atmosphere and light energy produced by the sun in the formation of chemical energy that is stored as glucose, starch, or other organic compounds in plant cells.
6. **The correct answer is (E).** Fermentation (sometimes referred to as anaerobic respiration) allows for the production of ATP in the absence of oxygen. Certain fungi and bacteria (for example, brewer's yeast) produce alcohol as a result of fermentation, while human muscle cells produce lactic acid.
7. **The correct answer is (D).** An electron is a subatomic particle with a negative charge; an atom (composed of electrons, protons, and neutrons) is the smallest part of an element that retains the properties of that element; a compound is a substance

composed of two or more elements in a fixed ratio; matter is anything that takes up space and has mass.

8. **The correct answer is (A).** Glucose is a monosaccharide—a simple, single-unit sugar molecule. Starch is a polysaccharide composed of numerous glucose molecules. Both starch and glucose are classified as carbohydrates.
9. **The correct answer is (B).** Transcription involves the synthesis of mRNA from a DNA template. Translation involves the synthesis of proteins encoded on mRNA molecules.
10. **The correct answer is (E).** The number of cytosines is equal to the number of guanines. Uracil is found in RNA, not DNA.
11. **The correct answer is (D).** Desert regions are defined by their dryness, usually the result of a minimal amount of rainfall combined with rapid evaporation.
12. **The correct answer is (B).** The biosphere consists of the global ecosystem—all life on earth and where it lives. An ecosystem consists of all the organisms in a given area along with all nonliving (abiotic) factors with which they may interact. A community is an assemblage of populations of different species living close enough together for potential interaction among them. A population is a group of individuals of a single species that live in a particular area. An organism is an individual living entity.
13. **The correct answer is (D).** Mutualism involves a symbiotic relationship in which both organisms benefit from their association. In commensalism, one organism benefits while the other is not significantly affected by the relationship. Neither parasitism nor predation are symbiotic relationships; in both cases, the association is detrimental to one of the organisms involved.
14. **The correct answer is (B).** The example illustrates secondary succession, in which a disturbance (clearing the forest for agriculture) destroys the existing community (forest) but leaves the soil intact. Primary succession takes place when a community arises in a virtually lifeless area with little or no soil, such as the colonization of newly formed volcanic islands.
15. **The correct answer is (D).**
16. **The correct answer is (D).**
17. **The correct answer is (A).** This set of questions involves the trophic structure (a pattern of feeding relationships with multiple levels) of a terrestrial ecosystem. The base of most food chains consists of autotrophic organisms referred to as producers (the rose bush). Primary consumers are herbivores that feed directly on the producers (the grasshopper). Secondary consumers are

carnivores that feed on organisms in the trophic level below (the mouse). Tertiary consumers (the snake) typically feed on secondary consumers, and quaternary consumers (the hawk) feed on tertiary consumers. An organism can occupy more than one trophic level in an ecosystem. In the above example, if the hawk consumed the mouse, it would be considered a tertiary consumer rather than a quaternary consumer. Detritivores derive their energy from detritus, the dead material left behind by the other trophic levels. The earthworm might feed on decaying matter from the hawk when it dies or from any of the other organisms in the food chain.

18. **The correct answer is (D).** The primary source of carbon in an ecosytem comes from CO_2 in the atmosphere. The return of CO_2 to the atmosphere through respiration is largely balanced by its removal through photosynthesis; thus, carbon is less subject to large fluctuations in quantity as a result of changes in local environmental conditions than other nutrients, such as nitrogen and phosphorous.

19. **The correct answer is (E).** Mullerian mimicry involves a mutual mimicry between two unpalatable or venomous species. Choice (A) is an example of cryptic coloration; choice (B) is an example of Batesian mimicry; choice (C) is an example of plant-pollinator interaction; and choice (D) is an example of aposematic coloration.

20. **The correct answer is (D).** The normal chromosomal complement of a human being is 46 chromosomes—22 pairs of autosomes plus a pair of sex chromosomes (either XX or XY). Thus, a cell with 22 autosomes and one sex chromosome must be a gamete. Females can only produce gametes (eggs) containing the 'X' sex chromosome, whereas, males can produce gametes (sperm cells) containing either of the sex chromosomes—'X' or 'Y'.

21. **The correct answer is (C).** Crossing over occurs during meiosis I only; it does not occur during meiosis II. All of the other events contribute to genetic variation in a population.

22. **The correct answer is (C).** First, you should observe that the only traits occurring in the F_1 generation are single flower form and ruffled flower shape, whereas all four traits show up among the F_2 progeny. This suggests that single flower form and plain flower shape are dominant over double flower form and ruffled flower shape, respectively. The parents must have been homozygous for each trait, as only the dominant traits were present among their offspring. Thus, the parent with single ruffled flowers must have been homozygous dominant for flower form

and homozygous recessive for flower shape, whereas the other parent with double plain flowers must have been homozygous recessive for flower form and homozygous dominant for flower shape.

23. **The correct answer is (B).** The ratios produced in the F_2 could have occurred only if two different genes control the inheritance of flower form and flower shape; and those genes reside on separate chromosomes (i.e., they are not linked). A simple Punnet square derived from intermating the F_1 generation would reveal the 9 genotypes represented by the four phenotypic classes found among the F_2 progeny.
24. **The correct answer is (C).** See the explanation for question 23.
25. **The correct answer is (D).** See the explanation for question 23.
26. **The correct answer is (E).** If the father with type B blood is heterozygous (BO) and the mother with type A blood is also heterozygous (AO), their children could inherit the B allele from the father and the O allele from the mother, producing type B blood; they could inherit the O allele from the father and the A allele from the mother, producing type A blood; they could inherit the B allele from the father and the A allele from the mother, producing type AB blood; or they could inherit an O allele from each parent, resulting in type O blood.
27. **The correct answer is (B).** Females have two X chromosomes, whereas males have one X and one Y chromosome. The Y chromosome typically lacks alleles for the corresponding genes along the X chromosome. Therefore, when a recessive allele is present on the X chromosome, it will automatically be expressed in males, while females have a high probability of masking a recessive allele on one X chromosome with a dominant allele on the other X chromosome.
28. **The correct answer is (B).**
29. **The correct answer is (E).**
30. **The correct answer is (A).**
31. **The correct answer is (D)**
32. **The correct answer is (C).**
33. **The correct answer is (A).** Tissue are collections of cells with a common structure and function (e.g., muscle tissue is composed of muscle cells), organs are made up of several types of tissue (e.g., the heart contains muscle tissue, nervous tissue, and connective tissue), and organisms have multiple organs (e.g., humans have a heart, liver, and kidneys).
34. **The correct answer is (C).**

35. **The correct answer is (E).**

36. **The correct answer is (B).**

37. **The correct answer is (A).**

38. **The correct answer is (D).**

39. **The correct answer is (A).** In salt water, the concentration of water inside the salmon is greater than that of the surrounding water; therefore, it loses water by osmosis (the movement of water from a region of high concentration to a region of low concentration). Because it must drink salt water, it disposes of salt through its gills while the kidneys conserve water and excrete excess salts. In fresh water, the salmon will gain water by osmosis, resulting in an increase in urine production by the kidneys. Salt lost through the urine is replenished by increasing the uptake of salts through both the gills and the digestive system.

40. **The correct answer is (D).** This question asks you to distinguish between plants that reproduce by spores (ferns) and those that reproduce by seeds (gymnosperms), which are thus more advanced on an evolutionary scale.

41. **The correct answer is (E).** The distinction is made between plants that produce exposed ("naked") seeds (gymnosperms) and those that produce seeds enclosed in a protective covering of maternal tissue—the fruit (angiosperms).

42. **The correct answer is (C).** Question 42 asks you to recognize the difference between plants lacking vascular tissue (xylem and phloem) and which are, thus, quite restricted in size (mosses) and those that contain vascular tissue and can obtain considerable height (ferns).

43. **The correct answer is (A).** This question asks you to make the distinction between prokaryotic photosynthetic organisms lacking a distinct nucleus (cyanobacteria—kingdom Monera) and eukaryotic photosynthetic organisms having a distinct nucleus and other cellular organelles (algae—kingdom Protista).

44. **The correct answer is (B).** Question 44 asks you to recognize the difference between two organisms that were once thought to be members of the plant kingdom but that are now classified separately. The algae (in kingdom Protista) contain chlorophyll and various accessory pigments and are able to carry out photosynthesis. Fungi are currently classified in their own kingdom (kingdom Fungi). These organisms lack photosynthetic pigments and are typically saprobic (absorbing nutrients from nonliving material) or parasitic (absorbing nutrients from a living host organism).

45. The correct answer is (E). The distinction is made between plants that produce exposed ("naked") seeds (gymnosperms) and those that produce seeds enclosed in a protective covering of maternal tissue—the fruit (angiosperms).

46. The correct answer is (C). The vascular cambium consists of meristematic tissue that divides laterally to increase growth in width of woody plants (secondary growth).

47. The correct answer is (A). Xylem tissue consists of several cell types, most of which are nonliving at maturity, and is responsible for conducting water and dissolved minerals upward from the roots where they are absorbed.

48. The correct answer is (B). Phloem tissue consists of several types of food-conducting cells and is responsible for transporting sugars made in the leaves during photosynthesis, along with those stored in other parts of the plant body, to regions of the plant that require energy.

49. The correct answer is (C). When a pollen grain lands on the stigma of a compatible flower, it germinates to form a pollen tube that grows down through the style until it reaches the ovary. Two (haploid) sperm cells travel down the pollen tube and enter the ovule through an opening called the micropyle. One sperm cell fuses with the (haploid) egg cell to form a diploid zygote that divides mitotically and grows into the embryo. The other sperm cell fuses with the central cell of the embryo sac. The central cell is formed by the fusion of two haploid nuclei and is, therefore, diploid. Fusion of a sperm cell with the central cell results in the formation of a triploid cell, referred to as the endosperm nucleus, that divides mitotically to form triploid endosperm tissue, which serves as a nutritive source for the developing embryo.

50. The correct answer is (C). Following double fertilization, the ovule containing the fertilized egg cell (now a zygote) and the fertilized central cell (now the endosperm nucleus) divide mitotically to form the embryo and endosperm, respectively. The tissue surrounding the ovule hardens to form a seed coat.

51. The correct answer is (D). Once fertilization has taken place and the seed begins developing, the tissues of the ovary swell and develop into a fruit. Some fruits are fleshy upon maturity (e.g., a tomato) while others are dry at maturity (e.g., a peanut). In some fruits (e.g., apples), other tissues in addition to the ovary tissue develop into part of the fruit; these are often referred to as accessory fruits.

52. The correct answer is (C).

53. The correct answer is (A).

54. The correct answer is (D).

55. The correct answer is (E).

56. The correct answer is (C). This would be an example of artificial selection, not natural selection. Selecting only the most productive plants leads to the favoring of characteristics desired by those individuals making the selection, but these characteristics may not be the most beneficial to the species as a whole in its natural environment. Choosing only those plants that are most productive often leads to loss of other favorable characteristics, such as disease resistance and drought tolerance.

57. The correct answer is (A). The biological species concept requires that individuals can mate with others of the same species (reproduce sexually) and produce fertile offspring. For species that reproduce only by asexual means, it cannot be determined whether reproductive isolation would occur upon mating with other individuals, and reproductive isolation is a key component of the biological species concept. If an organism is extinct, existing only in the fossil record, its reproductive potential upon intermating cannot be determined. Species living on separate continents also cannot intermate in nature unless one or both are artificially moved, such that they share a common habitat.

58. The correct answer is (B). By definition, p is used to reflect the frequency of the dominant allele for a given gene in a population, whereas q is used to reflect the frequency of the corresponding recessive allele. Thus, p^2 reflects the union of two gametes, each carrying the dominant allele and, thus, reflects the frequency of the homozygous dominant genotype in the population. If the trait in question is governed by codominance or incomplete dominance, such that heterozygotes can be distinguished phenotypically from homozygous dominant individuals, then, by default, p^2 may also reflect the frequency of individuals in the population with the dominant phenotype; however, that is not always the case.

59. The correct answer is (E). A heterozygous individual may result from the union of a dominant allele from the maternal parent and a recessive allele from the paternal parent, or it may result from the union of a recessive allele from the maternal parent and a dominant allele from the paternal parent. Both possibilities must be considered when determining the frequency with which a heterozygous individual could be produced in a given population.

60. **The correct answer is (C).** An individual with multiple copies of its entire set of chromosomes is referred to as polyploid: three sets = triploid; four sets = tetraploid; 5 sets = pentaploid, etc. An individual with extra copies of a single chromosome is referred to as anueploid.

BIOLOGY-E TEST

61. **The correct answer is (C).** A population refers to an interacting group of individuals of the same species occupying the same habitat and, therefore, could be thought of as a local subset of a species with a much wider distribution.
62. **The correct answer is (B).**
63. **The correct answer is (D).** Population density refers to the number of individuals of a species per unit area or volume.
64. **The correct answer is (A).** Genetic drift refers to a change in the gene pool of a population by chance. The smaller the population, the more likely it will lose alleles simply by random chance.
65. **The correct answer is (D).** Precambrian is the division of geologic time from the formation of the earth 4,600 million years ago (mya) to approximately 570 mya. Paleozoic (ancient animal) is the era from approximately 570 mya to 245 mya. Mesozoic (middle animal) is the era from approximately 245 mya to 65 mya. Cenozoic (recent animal) is the era beginning approximately 65 mya and continuing to modern times.
66. **The correct answer is (E).** The correct hierarchical classification of organisms is: kingdom — phylum — class — order — family — genus — species
67. **The correct answer is (B).** A uniform, evenly spaced pattern of dispersion is characteristic of direct competition among individuals within a population for a limited supply of one or more resources.
68. **The correct answer is (E).** A +/− interaction indicates that one organism benefits from the interaction while the relationship is detrimental to the other organism. Predation is where one organism, the predator, seeks out and usually destroys another organism, the prey. Parasitism is where one organism, the parasite, lives on or in another organism, the host, from which it obtains its nutrients, usually with some degree of damage to the host. Both are examples of +/− relationships.
69. **The correct answer is (D).** Fungi are detritivores, feeding on decaying matter. All of the other organisms listed are photosyn-

thetic autotrophs and, therefore, make up the base of the food chain—the producers.

70. The correct answer is (D). If 16 percent (.16) of the population shows the recessive phenotype (q^2), then the square root of .16 (0.40) would equal the frequency of the recessive allele, q. Because $p + q = 1$, then $p = 1 - q = 0.60$.

71. The correct answer is (D). The frequency of heterozygotes in the population is equal to two times the product of the frequencies of the recessive (q) and dominant (p) alleles. Thus, the frequency of heterozygotes is $2pq = 2(0.6)(0.4) = 0.48$.

72. The correct answer is (A). For a population to remain in Hardy-Weinberg equilibrium, the individuals must be randomly mating; nonrandom mating (e.g., positive or negative assortative mating) leads to changes in allelic and genotypic frequencies within the population. All of the other conditions listed above must be met for Hardy-Weinberg equilibrium to be maintained in a population. Failure to meet any of the conditions leads to microevolution and changes in allelic and genotypic frequencies in the population.

73. The correct answer is (A). Also in the eight-kingdom system, the kingdom Protista, of the traditional five-kingdom system, has been divided into three separate kingdoms (Archaezoa, Protista, Chromista); the remaining kingdoms (Plantae, Fungi, Animalia) are the same in both the five- and eight-kingdom systems. Another system of classification, the three-domain system, uses a "domain" as a superkingdom taxa to emphasize the significance to the evolutionary split between the Bacteria and Archaea. In this system, the Bacteria and Archaea are each assigned a domain, with the third domain (Eukarya) encompassing all eukaryotic organisms. Also, the three-domain system further subdivides the kingdom Protista into five separate groups (Archaeazoa, Euglenozoa, Alveolata, Stramenopila, and Rhodophyta).

74. The correct answer is (C). In this example, 10 percent of the energy is transferred from each trophic level to the next higher level. In actual ecosystems, the decline in productivity with the transfer of energy between trophic levels varies according to the species present, usually ranging from approximately 5 to 20 percent.

75. The correct answer is (A).

76. The correct answer is (E). The consumption of primary producers is the most energy-efficient form of consumption. The higher up on the food chain consumption takes place, the less energy-efficient it becomes.

77. The correct answer is (E). Primary consumers do not photosynthesize (only producers carry out photosynthesis). Excretion provides some metabolic waste materials that can be utilized by detritivores and, thus, are not lost from the ecosystem. Energy that goes into the metabolism and growth of an organism contributes to the biomass of the organism and is subsequently passed on to the next higher trophic level. The energy used in respiration results in the production of inorganic molecules and heat; it is largely lost from the flow of energy in the ecosystem.

78. The correct answer is (E). The heritability of variation is a key component to the theory of natural selection and is necessary for evolution to occur. Those individuals that are most adapted to their environment are most likely to survive and successfully reproduce, passing on favorable genes to their offspring. As long as the selection forces remain in place, the number of individuals in the population with favorable genes will continue to increase, possibly leading to the development of a new species after many generations.

79. The correct answer is (A).

80. The correct answer is (D).

BIOLOGY-M TEST

81. The correct answer is (C). In the DNA molecule, base pairing occurs between adenine and thymine, which are held together by two hydrogen bonds, and base pairing occurs between guanine and cytosine, which are held together by three hydrogen bonds.

82. The correct answer is (D). Under normal conditions of DNA replication, telomeres that are present on the end of each chromosome in eukaryotic cells become shorter and shorter with each cycle of replication. The length of the telomeres typically predetermines the life span of the cell by controlling the number of possible cycles of DNA replication. Telomerase, an enzyme that catalyzes the lengthening of telomeres, is not present in the cells of most multicellular organisms other than those giving rise to gametes. Telomerase has been found to occur in cells that become cancerous, suggesting a possible link between "uncontrolled" cell division and the cancerous nature of the cell.

83. The correct answer is (B). The process of transcription takes place in the nucleus of eukaryotic cells. The nucleotide sequence on the DNA molecule is transcribed into an RNA replica (messenger RNA, or mRNA). The mRNA transcript moves out of the nucleus through pores in the nuclear envelope and attaches to a ribosome complex. The mRNA is then translated into a polypeptide chain consisting of amino acids in the sequence that is coded for by the sequence of base triplets on the mRNA molecule.

84. **The correct answer is (D).**

85. **The correct answer is (B).**

86. **The correct answer is (E).**

87. **The correct answer is (D).** First, one must isolate the bacterial plasmid that is to be the cloning vector from its bacterial host and isolate the region of DNA that contains the gene of interest to be cloned from eukaryotic tissue cells. Next, both the plasmid and the eukaryotic DNA are digested with the same restriction enzyme, creating sticky ends. When the two cell types are mixed together in the presence of DNA ligase, the plasmid DNA and eukaryotic DNA may bind together (also, the eukaryotic DNA may reassociate and the plasmid DNA may reassociate; thus, the mixture will contain both recombinant molecules and molecules like the originals). Bacteria that are bathed in a solution of the naked DNA mixture will take up the plasmid vector by transformation. As the bacterial cells replicate, so, too, will any plasmids that they contain. If the plasmid(s) are recombinant, the eukaryotic gene of interest also will be replicated many times. Finally, the eukaryotic gene insert can be detected using either nucleic acid hybridization or a similar method.

88. **The correct answer is (B).** The union of the sticky ends of eukaryotic DNA and plasmid DNA is similar to the formation of the DNA double helix, relying on pairing between complementary bases (A with T; G with C).

89. **The correct answer is (B).** Each restriction enzyme recognizes a specific sequence of bases (usually four to six nucleotides in length), known as the restriction site (or target site), on a DNA molecule; it does not cleave DNA at random sites.

90. **The correct answer is (E).** Transpiration, choice (A), is the loss of water vapor by plants to the atmosphere. Electroporation, choice (B), is the application of electrical impulses to animal cells or plant protoplasts. This increases the permeability of their membranes that aid the uptake of foreign DNA by transformation, choice (E), the uptake by cells of soluble fragments of foreign DNA in solution. Translation, choice (C), is the process by which the genetic information in living cells encoded in the form of base triplets in mRNA is converted to a sequence of amino acids in a polypeptide chain. Transduction, choice (D), is the transfer of genetic material from one bacterial cell to another using a phage as a vector.

91. **The correct answer is (E).** Evidence from molecular genetic studies suggests earlier evolutionary splits among prokaryotic organisms and relatively simple eukaryotic organisms (primarily those organisms classified as Protists in the five-kingdom system) than was previously thought. Such evidence has led many researchers to further subdivide these groups of organisms into separate kingdoms, based on their ancient evolutionary lineages.

92. **The correct answer is (B).** Competition for a limited supply of resources and a mechanism for passing on traits that confer an advantage for adaptation to environmental conditions from parents to offspring are necessary for evolution to occur at any level. Protobionts (aggregates of abiotic molecules that maintain an internal environment that is different from their surroundings) could not have evolved into early living cells (with semipermeable membranes, the ability to reproduce, the ability to catalyze chemical reactions, or any other characteristics typically associated with living cells) without competition among individuals for limited resources and the ability to pass favorable traits on to offspring.

93. **The correct answer is (D).** Cladistic analysis relies on homology (similarity of characteristics among species due to a shared ancestry) in the construction of phylogenetic trees while avoiding analogous characters (similarity of characteristics among species that are not closely related; these characteristics are usually attributed to convergent evolution).

94. **The correct answer is (D).** Each triplet of bases on the mRNA molecule (codon) codes for a specific amino acid. The code has been deciphered and is represented in the table of genetic codons, with the first base along the left side, the second base across the top, and the third base along the right side of the table. More than one codon may code for the same amino acid. The codon AUG may code for methionine or it may code for a start site, signaling ribosomes to begin translating the mRNA at that site. Three "stop" codons (UAA, UAG, UGA), when present within a genetic message, signal the end of the message and termination of translation in that region.

95. **The correct answer is (D).** The substitution of an "A" for a "U" in the third base position of the codon for Gly results in a codon that also codes for Gly; thus, the resulting polypeptide should function normally. All of the other substitutions described above result in the replacement of the 'correct' amino acid with an 'incorrect' amino acid in the polypeptide chain produced in translation. The relative effects of such substitutions on an individual depend on the degree to which the incorrect amino acid changes the function of the polypeptide. For example, a single base substitution (U for A)

results in the incorporation of Val in place of Glu in the sixth position of the polypeptide coding for the primary structure of hemoglobin, resulting in the abnormally shaped cells that are characteristic of sickle cell anemia.

96. **The correct answer is (B).** Restriction enzymes recognize specific base sequences along the DNA molecule (usually 4 to 6 bases long) and cleave the molecule at each of these sites. When the fragments of DNA that are produced are separated electrophoretically, a characteristic pattern is produced. If two species share a similar pattern, they must share a similar number of restriction sites at equivalent distances along the DNA molecule. This suggests that the genomes of the two species are similar and that they most likely diverged in relatively recent history.

97. **The correct answer is (A).** In the figure, taxon Z represents the outgroup—a species or group of species that is closely related to the other taxa being studied, but not as closely related as each of the study taxa are to each other. The position of taxon Z on the phylogenetic tree suggests that it possesses the primitive condition shared by all of the taxa depicted and from which the other taxa have diverged.

98. **The correct answer is (D).** The change from a primitive to a derived state of character I separates taxon Z (the outgroup) from the remaining species. Taxa B, C, and D share two derived characters and, thus, are more closely related to each other than each is to taxon A. Following this reasoning, taxa C and D appear to be the most closely related pair of taxa depicted. These two taxa share three derived characters (I, II, and III), suggesting that they are more closely related to each other than either is to taxon B.

99. **The correct answer is (E).** The results suggest that species C shares genetic information with species A as well as with species B, whereas species A and B are genetically distinct from one another. The most likely explanation is that species C inherited genetic material from both species A and B, suggesting that it is a hybrid between the two.

100. **The correct answer is (A).** Some scientists suggest that the earth's surface was inhospitable during the period in which life began. Recent molecular studies suggest that the ancestors of modern-day prokaryotes thrived in very hot conditions and possibly utilized inorganic sulfur compounds. These conditions are common in deep sea vent environments, and the location also would have reduced exposure of early life forms to the inhospitable conditions that were present on the earth's surface.

PRACTICE TEST 2

While you have taken many standardized tests and know to blacken completely the ovals on the answer sheets and to erase completely any errors, the instructions for the SAT II exam in Biology differs from the directions for other standardized tests you have taken. You need to indicate on the answer key whether you are taking the SAT II Biology with Ecological Emphasis (Biology-E) or Molecular Emphasis (Biology-M).

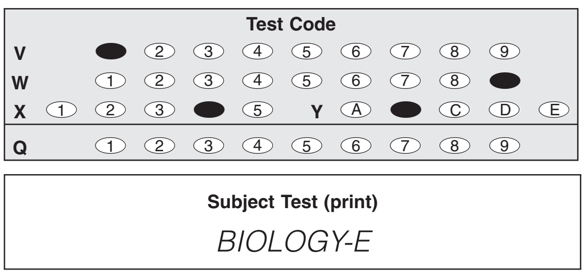
The instructions on the answer sheet will tell you to fill out the top portion of the answer sheet exactly as shown.

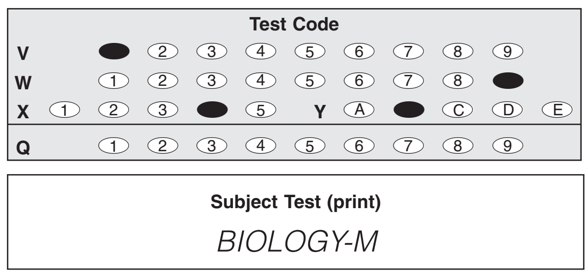
1. Print *BIOLOGY-E or BIOLOGY-M on the line to the right under the words Subject Test (print).*

2. In the shaded box labeled *Test Code* fill in four ovals:

For BIOLOGY-E
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.

For BIOLOGY-M
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.





For BIOLOGY-E:
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

For BIOLOGY-M:
—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

3. When everyone has completed filling in this portion of the answer sheet, the supervisor will tell you to turn the page and begin. The answer sheet has 100 numbered ovals on the sheet, but there are only 90 (or 95) multiple-choice questions in the test, so be sure to use only ovals 1 to 90 (or 95) to record your answers.

TEST 2—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

1. All of the following ideas are essential to Charles Darwin's theory of natural selection EXCEPT

(A) individuals tend to produce more offspring than can survive.

(B) variation is present in all populations.

(C) characteristics acquired by one parent can be passed on to their offspring.

(D) resources are usually limited.

(E) those individuals who produce the most fertile offspring are the most fit.

2. Consider a solution whose pH has a value of 4. Choose the correct statement from the following:

(A) It has a hydrogen ion concentration of 1×10^{-4}.

(B) It has a hydroxide ion concentration of 1×10^{-10}.

(C) It contains a thousand times more hydrogen ions than a neutral solution.

(D) It is acidic in nature.

(E) All of the above are true.

3. The secondary structure of proteins whose conformation may be an alpha helix is due to

(A) the hydrogen bonds between a carbonyl group of one amino acid and the amino group of another.

(B) the hydrogen bonds between variable groups.

(C) the interactions between hydrophobic and hydrophilic variable groups.

(D) the interactions between the positively and negatively charged variable groups.

(E) all of the above.

4. A student cut a 2 cm^3 block out of a potato and massed the block. She then placed the block in distilled water and waited an hour. If she remassed the block she could expect which of the following?

(A) the mass to increase due to plasmolysis

(B) the mass to increase because the potato is hypertonic to the water

(C) the mass to decrease because the potato will loose its water

(D) the mass to decrease because of the higher water potential in the potato

(E) the mass to remain the same because there are no living components in this system

TEST 2—*Continued*

5. Radioactively labeled amino acids introduced into a growing cell culture would be incorporated by the cells. If the cells were involved in protein synthesis and secretion, the labeled amino acids would appear in the following organelles in which order over a given time period?

(A) smooth endoplasmic reticulum — rough endoplasmic reticulum — golgi apparatus — nucleus

(B) rough endoplasmic reticulum — smooth endoplasmic reticulum — golgi apparatus — plasma membrane

(C) rough endoplasmic reticulum — golgi apparatus — smooth endoplasmic reticulum — plasma membrane

(D) smooth endoplasmic reticulum — rough endoplasmic reticulum — golgi apparatus — plasma membrane

(E) smooth endoplasmic reticulum — rough endoplasmic reticulum — golgi apparatus — lysosome

6. A student using a compound microscope with a 10× ocular lens and a 4× objective lens measured his field of view with a plastic ruler and found it to be 4 mm. He then placed some of his cheek cells on a slide, found them using the 4× objective lens and switched to the 40× objective lens. He counted twelve cells, side by side, that stretched from one side of the field of view to the other. What is the best estimate for the diameter of a cheek cell?

(A) 0.033 mm

(B) 0.132 mm

(C) 0.0132 mm

(D) 0.0033 mm

(E) 1.32 mm

7. In fruit flies, the gray body color is dominant to the black, and long wings are dominant to short. If you crossed a gray, short-winged fly to a black, long-winged fly and got 25 percent gray, long wing; 25 percent gray, short wing; 25 percent black, short wing; and 25 percent black, long wing, what were the genotypes of the parental flies?

(A) Ggll and GgLl

(B) Ggll and ggLl

(C) GGll and ggLl

(D) GGll and GgLl

(E) Ggll and ggLL

8. In fruit flies, red eyes are dominant to green eyes. In a cross between a short-winged, green-eyed fly and a long-winged, red-eyed fly, the results were as follows:
40 percent short winged and red eyed
10 percent short winged and green eyed
10 percent long winged and red eyed
40 percent long winged and green eyed

Which of the following reflects the chromosome makeup of the parents?

(A) LlRr × Llrr

(B) Llrr × llrr

(C) LlRr × llrr

(D) LLRR × llrr

(E) LlRR × llRr

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

9. In the above example the red-eyed, long-winged fly had chromosomes best represented as

(A)

(A) L R
l r

(B)

(B) l L
R r

(C)

(C) L l
R r

(D)

(D) L R
l r

(E)

(E) l r
R L

10. One can find naturally occurring plasmids in

(A) viruses.

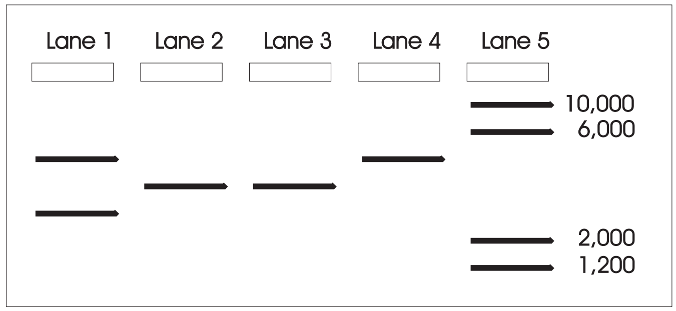
(B) bacteria.

(C) algae.

(D) people.

(E) all of the above.

11. A group of students tried to insert a small gene into a plasmid that was 4,500 bp in size. They then attempted to insert the plasmids into bacteria by transformation. Several days later, they chose four small colonies and grew them up in a broth culture. They extracted the DNA from the bacteria in each tube and loaded them onto a gel (lanes 1 to 4).



The plasmids shown in lanes 2 and 3 are the same size as the original plasmid. Which of the following statements is (are) true?

(A) The plasmids in lane 1 could be the result of cutting the original plasmid with restriction enzymes.

(B) The plasmids in lane 1 can be the same size but different configurations.

(C) The plasmids in lane 4 are smaller than the original plasmids.

(D) The students were probably successful in their genetic engineering attempt.

(E) Both (B) and (D) are correct.

12. The plasmids were separated according to

(A) their size.

(B) their charge.

(C) their A-T:G-C composition.

(D) both (A) and (B).

(E) all of the above.

TEST 2—*Continued*

13. Red-green colorblindness in humans is a sex-linked trait. If a woman with normal vision, whose father was colorblind, married a man whose mother was colorblind, what would be the probability of their first child being a colorblind girl?

(A) 0 percent
(B) 12.5 percent
(C) 25 percent
(D) 50 percent
(E) 100 percent

14. What are the number of different types of gametes that can be produced by an organism whose genotype is *AaBbCcDd*?

(A) 4
(B) 8
(C) 12
(D) 16
(E) 20

15. The number of chromosomes in normal humans is 46. After meiosis in sperm production, the number of chromosomes I would be ____________ and the number of resulting cells would be ____________ .

(A) 46, 2
(B) 23, 2
(C) 46, 1
(D) 23, 1
(E) 23, 4

16. Which of the following statements about mitochondria is (are) true?

(A) Mitochondria exist in all eukaryotes.
(B) Mitochondria exist in bacteria and plants.
(C) Mitochondria exist in animals, plants, and fungi.
(D) Both (B) and (C) are true.
(E) Both (A) and (C) are true.

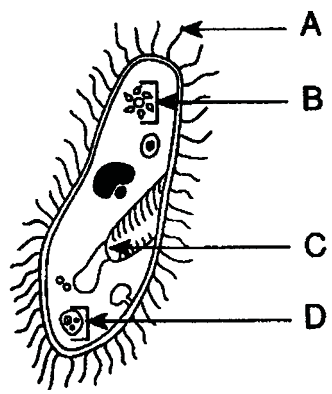
17. The flowing cytoplasm of an active amoeba is

(A) propelled by microfilaments for lipid synthesis.
(B) an adaptation for extracellular digestion.
(C) composed of microtubules and extracellular matrix.
(D) dependent on microfilaments for intracellular circulation.
(E) required for nerve transmission.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

1. Questions 18–19 refer to the following diagram.



2. The diagram above represents a freshwater protist. Which letter indicates a structure that prevents the accumulation of excess water?

(A) A

(B) B

(C) C

(D) D

(E) none of the above

3. The organism depicted above is both a

(A) ciliate and a prokaryote.

(B) flagellate and a protozoan.

(C) ciliate and a protozoan.

(D) sporozoan and a ciliate.

(E) zoospore and a sporozoan.

4. In chordates, locomotion is accomplished by the action of

(A) jointed chitinous appendages attached to muscles.

(B) muscles attached to an exoskeleton.

(C) paired muscles attached to an endoskeleton.

(D) all of the above.

(E) none of the above.

5. In the earthworm, the efficiency of food absorption is increased by the presence of

(A) the liver, which stores extra food in addition to making metabolic enzymes.

(B) the cecum, which stores unsuitable intake for excretion.

(C) infolds, which add surface area to the intestine.

(D) malphigian tubules, which increase the density of the food.

(E) the liver, which absorbs excess sugar and stores it as glycogen.

6. Which statement is NOT true of ferns?

(A) The gametophyte is larger than the sporophyte.

(B) The sori give rise to the gametophytes.

(C) Eggs are fertilized by sperm in the archegonia.

(D) Ferns possess vascular tissue for the transport of water and minerals.

(E) Male gametes depend on water for fertilization.

TEST 2—*Continued*

7. Monocotyledons and dicotyledons are the two subdivisions of flowering plants. Monocotyledons are distinguished from dicotyledons because monocots possess

(A) floral structures in multiples of fours and fives.
(B) long taproots and parallel venation in their leaves.
(C) netted leaf venation and floral structures in multiples of three.
(D) parallel leaf venation and fibrous roots.
(E) floral structures in multiples of three and long taproots.

8. Which of the following statements is true concerning plants that utilize C4 photosynthesis?

(A) They only open their stomates at night.
(B) They use bundle sheath cells to separate the Calvin cycle from the atmosphere.
(C) They use rubisco (ribulose bisphosphate carboxylase oxygenase) to capture carbon dioxide from the atmosphere.
(D) They use lenticels exclusively for gaseous exchange in order to conserve water.
(E) All of the above are true.

9. Neurotransmitters have as their effectors cells such as

(A) nerves.
(B) muscles.
(C) glands.
(D) all of the above.
(E) none of the above.

10. Neurotransmitters cross the synapse after being released from the

(A) dendrites.
(B) axons.
(C) cell bodies.
(D) all of the above.
(E) none of the above.

11. Insulin is an important hormone that serves to decrease one's blood sugar. Glucagon has the opposite effect through

(A) the conversion of glycogen to glucose.
(B) the secretion of glucose by cells.
(C) causing gluconeogenesis.
(D) all of the above.
(E) none of the above.

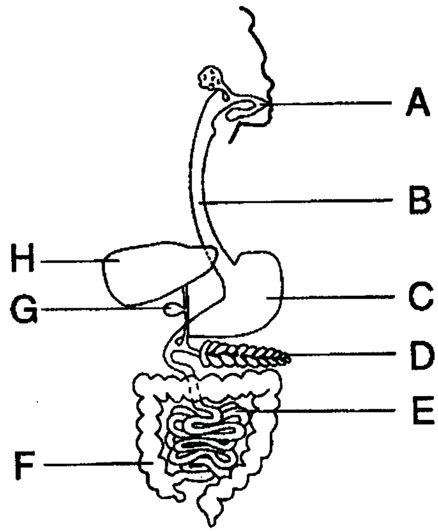
12. In humans, the structure that receives blood from the lungs is the

(A) aorta.
(B) pulmonary artery.
(C) pulmonary vein.
(D) renal vein.
(E) femoral artery.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

1. Questions 29–30 refer to the following diagram.



2. The initial digestion of carbohydrates takes place in

(A) A.
(B) C.
(C) D.
(D) F.
(E) H.

3. Glucose is normally absorbed by structure ______, and protein is mostly digested in _______.

(A) A, C
(B) A, E
(C) C, E
(D) E, C
(E) E, A

4. Which of the following statements about antibodies is false?

(A) Antibodies are produced by different combinations of soluble proteins in the blood called complement.
(B) When antibodies bind to a bacterial cell, it may keep that cell from adhering to host cells.
(C) The specific receptors on T cells that would interact with a specific antigen are the same shape as antibodies that will interact with that antigen.
(D) By binding to antigens, antibodies mark those antigens for destruction by macrophages.
(E) By binding to an invader, antibodies attract proteins that lyse the target membrane.

5. Which of the following statements about the menstrual cycle is false?

(A) Luteinizing hormone is produced by the pituitary in response to GNRH from the hypothalamus.
(B) Luteinizing hormone acts on the follicle, causing ovulation.
(C) Birth control pills that contain estrogen and progesterone would inhibit the secretion of FSH by the pituitary.
(D) The endometrium builds up to its maximum thickness soon after the release of FSH.
(E) Progesterone helps maintain the corpus luteum after ovulation.

TEST 2—*Continued*

6. Which of the following statements about muscle contraction is (are) true?

(A) Calcium ions combine with troponin to cause a conformational change in tropomyosin.

(B) Myosin and actin slide together because of the binding and contraction of actin filaments.

(C) Tropomyosin wraps around myosin and blocks the binding sites between actin and myosin.

(D) Both (A) and (B) are true.

(E) Both (B) and (C) are true.

7. Viruses are an exception to the cell theory because they

(A) normally reproduce by binary fission.

(B) normally reproduce by forming spores.

(C) lack either DNA or RNA.

(D) have no cell organelles.

(E) normally reproduce only in host cells.

8. Classification relies on arranging organisms that are most alike into groups. Choose from the lists below the correct arrangement of groups, from most to least inclusive.

(A) kingdom — class — phylum — order — family — genus

(B) kingdom — phylum — class — order — family — genus

(C) domain — kingdom — class — family — genus — phylum

(D) domain — kingdom — class — phylum — family — genus

(E) species — family — phylum — class — kingdom

9. Which of the following factors does not favor a change in gene frequency and, therefore, evolution?

(A) large populations

(B) mutations

(C) emigration

(D) genetic drift

(E) all of the above

10. The number of people in certain regions of Africa that suffer from sickle cell anemia is 16 percent. This genetic disorder is caused by a mutation in which homozygous recessive results in sickle cell anemia, but in the heterozygote condition causes the sickle cell trait. The gene frequency for that allele is _________, and the percentage of people that are heterozygotes is _________.

(A) 0.6, 24

(B) 0.4, 24

(C) 0.6, 48

(D) 0.4, 48

(E) 0.6, 72

11. All of the following could be considered evidences of evolution EXCEPT

(A) the structural homology between the forearms of bats and humans.

(B) the DNA sequence of the cytochrome-*c* gene for bats and birds.

(C) the dorsal nerve chord of crayfish and birds.

(D) fossils of dinosaurs.

(E) a wasp embedded in amber.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

12. In symbiotic relationships, groups of two or more organisms live in physical proximity. Which of the following types of symbiosis depicts commensalism?

(A) An egret riding on the back of a cow, looking for food in cow patties.
(B) A little bird riding on the back of a rhino, picking parasites off the back of the rhino.
(C) Undertaker bees removing dead bees from the hive of worker bees.
(D) A wrasse cleaning the parasites off the gills of a bigger fish.
(E) All of the above are commensalistic.

13. Competition between members of a prairie dog population could be expected to increase as a result of an increase in the

(A) prairie dog intrinsic reproductive rate.
(B) spread of disease among the prairie dogs.
(C) mortality rate of prairie dogs.
(D) natality rate of prairie dog predators.
(E) number of secondary consumers.

14. The rain shadow effect is used to describe rainfall around certain mountain ranges. Which of the following statements is true?

(A) The northern hemisphere and the southern hemisphere have the same prevailing winds.
(B) Cool air can hold more moisture than warm air.
(C) In the northern hemisphere, there is more rainfall on the eastern slopes.
(D) You would expect deserts to form on the western side of mountain ranges in the northern hemisphere.
(E) None of the above statements are true.

15. Which of the following biomes is correctly paired with its description?

(A) tundra—coniferous trees in a cold, dry climate
(B) taiga—cold areas with low, mat-like vegetation
(C) tropical deciduous forests—the biome with the most precipitation
(D) savanna—grassland with three distinct climates, based mainly on rain
(E) chaparral—wetlands with many shrubs and ruminants

16. Mimicry always involves a model and a mimic as well as a dupe or signal receiver (the organism the mimic is trying to fool). Which of the following depicts Batesian mimicry?

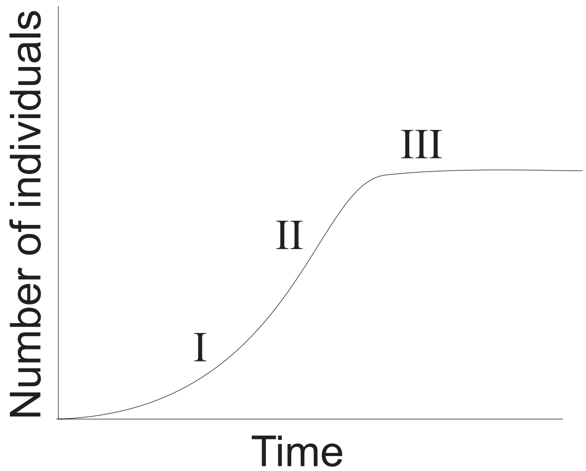
(A) a walking stick (a herbivore) sitting on a branch of a tree
(B) a rat snake (nonpoisonous) that looks like a poisonous species
(C) an oppossum playing possum
(D) a spider that looks like an ant
(E) a flounder that blends in with the bottom to avoid being eaten

17. Two organisms that occupy many of the same niches are most likely

(A) mutualistic partners.
(B) predator-prey.
(C) host-parasite.
(D) competitors.
(E) commensalistic partners.

TEST 2—*Continued*

1. Questions 45–47 refer to the following graph.



2. The carrying capacity of the population is

(A) I.
(B) II.
(C) III.
(D) I, II, and III.
(E) not shown.

3. The exponential growth phase is

(A) I.
(B) II.
(C) III.
(D) I, II, and III.
(E) not shown.

4. The formula for the line would best be written as

(A) dN/dT = r (N-K/N) N.
(B) dN/dT = r (K-N/N) K.
(C) dN/dT = r (N-K/K) N.
(D) dN/dT = r (K-N/K) N.
(E) dN/dT = r (K-N/K) K.

5. Which of the following statements about succession is correct?

(A) All farm ponds will eventually fill in and dry up.
(B) Secondary succession involves the formation of dirt and soil.
(C) Climax communities are not subject to change.
(D) Random events play little, if any, part in succession.
(E) In temperate deciduous forests, oaks and hickories are replaced by pines and furs.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

1.

Questions 49–50 refer to the following information.

Three sets of parents in the hospital had babies whose blood types are given.

Parents	Children
Mr. & Mrs. White Type B and O	BABY 1 Type A
Mr. & Mrs. Black Type AB and O	BABY 2 Type B
Mr. & Mrs. Brown Type A and B	BABY 3 Type O
	BABY 4 Type AB

2. The parents of Baby 4 could have been
   - (A) the Whites.
   - (B) the Blacks.
   - (C) the Browns.
   - (D) the Browns or the Whites.
   - (E) the Blacks or the Whites.

3. The Blacks could be the parents of
   - (A) Baby 1.
   - (B) Baby 2.
   - (C) Baby 4.
   - (D) Babies 1 and 2.
   - (E) any of the babies.

4. The gas that was least present in the atmosphere of the Earth over 2 billion years ago was
   - (A) methane.
   - (B) oxygen.
   - (C) nitrogen.
   - (D) carbon dioxide.
   - (E) carbon monoxide.

5. Prokaryotes, like bacteria, are very different from eukaryotes, like amoeba. The similarities they share are
   - (A) they both have endoplasmic reticulum.
   - (B) they both have DNA.
   - (C) they both have ribosomes.
   - (D) they have both endoplasmic reticulum and ribosomes.
   - (E) they have both DNA and ribosomes.

TEST 2—*Continued*

1.

Questions 53–54 refer to the following chart and information.

	SAND	SILT	CORAL
Daylight	15	10	13
Night	5	30	3

1. A student wanted to know where a particular type of fish was most likely to be found during a 24-hour period. He observed a total of 76 fish over several days.

2. He could rightly conclude that

(A) the fish don't have a preference for substrate.
(B) the fish are more active at night.
(C) the fish prefer coral to silt during the day.
(D) the fish prefer silt at night.
(E) all of the above are true.

3. The student wanted to present the data to his fishing club. The data would best be presented as

(A) a line graph, with time of day on the independent axis.
(B) a line graph, with type of substrate on the dependent axis.
(C) a bar graph, with one bar for sand, one for silt, and one for coral, each subdivided by daylight versus night.
(D) a bar graph, with one bar for daylight and one for night, each subdivided by substrate type.
(E) two different graphs, with light/dark on one axis and substrate on the other.

4. Choose the correct letter from among the following. One or more advantages of social dominance hierarchies is that they

(A) I. keep those lower on the pecking order from being abused.
(B) II. reduce interference competition.
(C) III. keep organisms that are closely related closer together.

(A) I is true.
(B) II is true.
(C) III is true.
(D) I and II are both true.
(E) I and III are both true.

5. Glucose levels in the human body are under the influence of

(A) insulin produced in the liver.
(B) glucagon produced in the kidneys.
(C) insulin produced in the kidneys.
(D) both insulin and glucagon.
(E) parathyroid hormone.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

6. Lynn Margulis's endosymbiotant theory is supported by the fact(s) that

(A) mitochondrial DNA is more like that of bacteria than the nuclear DNA in human cells.
(B) chloroplasts replicate on their own time schedule, not under nuclear control.
(C) mitochondria and chloroplasts are about the same size as prokaryotes.
(D) all of the above.
(E) none of the above.

7. Bryophytes, like mosses, are small because they

(A) I. lack vascular tissue.
(B) II. depend on water as a medium for their sperm transfer.
(C) III. evolved before other land plants.

(A) I is true.
(B) II is true.
(C) III is true.
(D) I and II are both true.
(E) I and III are both true.

8. People who suffer from meningitis are having an inflammation around their

(A) coronary arteries.
(B) pleural cavities.
(C) kidneys.
(D) membranes of the spinal cord.
(E) vas deferens.

9. Which is the correct sequence of events during embryonic development?

(A) cleavage — differentiation — fertilization — gastrulation
(B) differentiation — fertilization — gastrulation — cleavage
(C) fertilization — cleavage — gastrulation — differentiation
(D) fertilization — differentiation — cleavage — gastrulation
(E) fertilization — gastrulation — differentiation — cleavage

1.

1.

S T O P

1. IF YOU ARE TAKING THE BIOLOGY-E TEST, CONTINUE WITH QUESTIONS 61–80.
IF YOU ARE TAKING THE BIOLOGY-M TEST, GO TO QUESTION 81 NOW.

TEST 2—*Continued*

BIOLOGY-E TEST

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

2. Among social birds, like the Florida scrub jay, there are more male helpers at the nest than female because

(A) males are more numerous than females.
(B) males make better helpers than females.
(C) males are better foragers than females.
(D) males need to wait for a territory to become available elsewhere.
(E) all of the above.

3. A larger, more aggressive blackbird sees a younger, smaller blackbird discover a food resource. He flies down, taking the food from the younger bird. This is an example of

(A) a selfish act.
(B) an altruistic act.
(C) a spiteful act.
(D) a cooperative act.
(E) an unsocial act.

4. Two dogs fighting for one bone would be an example of

(A) exploitative and interspecific competition.
(B) interference and intraspecific competition.
(C) exploitative and intraspecific competition.
(D) exploitative and interference competition.
(E) interference and interspecific competition.

5. The difference between gross primary production and net primary production is

(A) respiration.
(B) the difference in photosynthetic rates between morning and afternoon.
(C) the amount of energy transferred between trophic levels.
(D) negligible in C4 plants.
(E) none of the above.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

6. The most pressing ecological problem facing the world today is

(A) the greenhouse effect.
(B) human population growth.
(C) the ozone problem.
(D) limited resources to feed, clothe, and house individuals.
(E) the amount of garbage created daily.

1. **Questions 66–69 refer to the following diagram.**

2. The primary consumers in this pyramid are the

(A) phytoplankton.
(B) small fish.
(C) large fish.
(D) seals.
(E) polar bears.

3. The build-up of DDT in this system would most likely affect the

(A) phytoplankton.
(B) small fish.
(C) large fish.
(D) seals.
(E) polar bears.

4. The reduction in the number of polar bears would probably cause

(A) an increase in the number of large fish.
(B) a decrease in the number of large fish.
(C) phytoplankton to reproduce more rapidly.
(D) a decrease in the biomass of the community.
(E) none of the above.

5. If the amount of biomass in the phytoplankton was 1,500 kg/hectare, the amount of seal biomass would be

(A) indeterminable from the data given.
(B) 150 kg/hectare.
(C) 100 kg/hectare.
(D) 15 kg/hectare.
(E) 1.5 kg/hectare.

TEST 2—*Continued*

6. Which of the following is true for freshwater ecosystems?

(A) I. There is a seasonal mixing of materials.

(B) II. During the year, oxygen concentrations are vertically uniform.

(C) III. Materials are recycled more quickly than in ocean ecosystems.

(A) I only
(B) II only
(C) III only
(D) I and III are both true.
(E) II and III are both true.

7. Midlatitude lakes undergo mixing more than equatorial lakes because

(A) the midlatitude lakes turn over twice a year.
(B) midlatitude lakes develop a thermocline.
(C) water is densest at 4^{o}C.
(D) all of the above.
(E) they don't—equatorial lakes have more mixing.

8. Which of the following statements about eutrophication is NOT true?

(A) It is caused by acid rain.
(B) It is caused by the addition of nutrients to a water system.
(C) It is most harmful when there is little flow through in the system.
(D) Phosphorus is the main causal agent.
(E) Humans are responsible for most eutrophication.

9. Which of the following statements about acid rain is true?

(A) I. Acid rain is caused by nitric acid and sulfuric acid.

(B) II. Acid rain can damage plants directly.

(C) III. Acid rain can cause magnesium and calcium to be leached from the soil.

(A) I only
(B) II only
(C) III only
(D) II and III are both true.
(E) I, II, and III are all true.

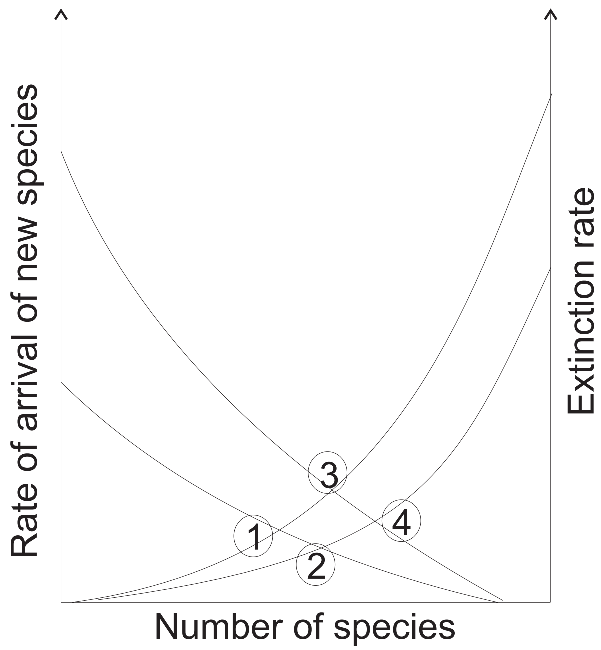
10. Which of the following statements about the carbon cycle is NOT true?

(A) Carbon dioxide levels fluctuate during the year.
(B) Carbon dioxide levels are rising because of consumption of fossil fuels.
(C) Atmospheric carbon dioxide will eventually be transferred to the oceans.
(D) Carbon dioxide levels are up because of the burning of forests.
(E) Carbon dioxide levels can be reduced by cleaning the gases that leave the smokestacks of power generating facilities.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

11. Consider the following diagram, illustrative of the species richness equilibrium.



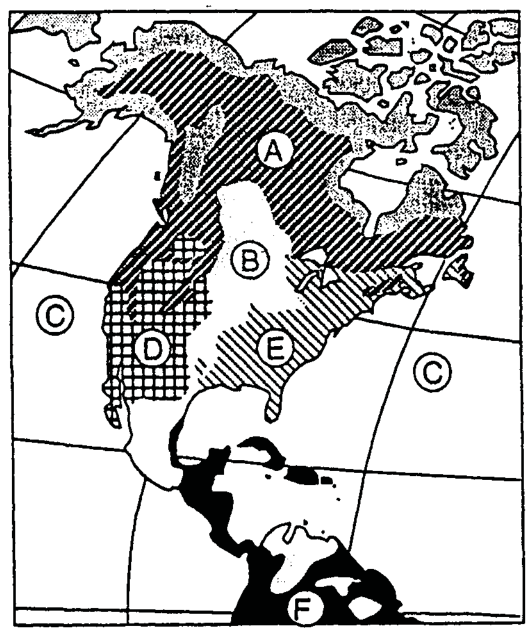
1. Circle number 3 represents the equilibrium of

(A) a small island far from the mainland.
(B) a small island close to the mainland.
(C) a large island far from the mainland.
(D) a large island close to the mainland.
(E) the natality and mortality rates on any island.

2. A fungus living on a dead tree is a

(A) saprophyte.
(B) heterotroph.
(C) consumer.
(D) all of the above.
(E) none of the above.

1. Questions 77–79 refer to the diagram below, which shows the general location of some major biomes of the Western Hemisphere.



2. The most stable biome is represented by letter

(A) A.
(B) B.
(C) C.
(D) D.
(E) E.

3. Which type of biome is indicated by letter E?

(A) tundra
(B) taiga
(C) grassland
(D) deciduous forest
(E) chaparral

TEST 2—*Continued*

4. The biome indicated by letter F is characterized by

(A) heavy rainfall, broad-leaved plants, and monkeys.
(B) sparse rainfall, grasses, and leopards.
(C) variable rainfall, mosses, and caribou.
(D) heavy rainfall, conifers, and snakes.
(E) variable rainfall, moderate temperatures, and low humidity.

5. The return of salmon to their own birthplace to breed is an example of

(A) habituation.
(B) a stimulus.
(C) operant conditioning.
(D) reasoned behavior.
(E) imprinting.

1.

If you answered the first 80 questions STOP HERE.
If you are taking the Biology-M test CONTINUE HERE.

TEST 2—*Continued*

BIOLOGY-M TEST

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

2. Alfred Hershey and Martha Chase performed a famous experiment that has been dubbed the "blender experiment." In it, they attempted to prove that the hereditary material was DNA. It is named the blender experiment because

(A) I. they blended viruses and bacteria into agar slants.

(B) II. they blended bacteria and viruses together after infection to rid the bacteria of their virus coats.

(C) III. they found that by blending viruses and bacteria together, the viruses could be trapped on the sides of the blender.

(A) I only
(B) II only
(C) III only
(D) II and III are both true.
(E) I, II, and III are all true.

3. Which of the following statements about the "blender experiment" is NOT true?

(A) The experiment preceded Watson's and Crick's elucidation of DNA structure.
(B) Hershey and Chase used radioactive sulfur to follow the protein in their experiment.
(C) Hershey and Chase used radioactive phosphorus to follow the nucleotides in their experiment.
(D) It was discovered by them that while different strains of bacteria have different percentages of nitrogen bases, the percent of adenine and the percent of thymine are equal, as are the percents of guanine and cytosine.
(E) Hershey and Chase's experiment lent strong credence to the idea that DNA is the hereditary material, at least for viruses.

4. The number of base pairs in a typical bacterium is about __________, while the number in human cells is around __________.

(A) 3 million, 3 billion
(B) 1 million, 1 billion
(C) 3,000, 3 million
(D) 1,000, 1 million
(E) 1 billion, 12 trillion

TEST 2—*Continued*

5. The proteins around which human DNA is wound are

(A) cyclins.
(B) cyclin-dependent kinases.
(C) histones.
(D) heat-shock proteins.
(E) G proteins.

6. The proteins that come together to form "maturation promoting factors," or "M phase factors," are

(A) cyclins.
(B) cyclin-dependent kinases.
(C) G proteins.
(D) cyclins and cyclin-dependent kinases.
(E) cyclin-dependent kinases and G proteins.

7. Restriction enzymes were originally isolated from

(A) viruses, which use them to cut bacterial DNA.
(B) bacteria, which use them to cut viral DNA.
(C) viruses, which use them to turn off their host bacterial DNA.
(D) protists, which use them to organize themselves into colonial life-forms.
(E) injured tissue, where they restrict the movement of molecules across the plasma membrane.

8. If a restriction enzyme has as its recognition sequence "ATCCTA," how many restriction sites would appear in the lambda genome, which is approximately 54,000 bp?

(A) 13
(B) 9,000
(C) 2,250
(D) 7
(E) 10,000

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

1. **Questions 88–90 refer to the following information about genetic engineering.**

1. Bacterial plasmid sequence: ATCCCA...1000 more nucleotides..... ..ATTAAGGCCTTACAG GACCCCGGAATGAGAGTA ATGGGCTAT-TCAGGTA... 2000 more nucleotides

   Human DNA sequence: ATATCGTAATGT-TGGTG..500 more nucleotides.. ..GTGT-CAGGACGGGTGAAAGCCAGGACGC-CGAATCG...5000 more nucleotides

The underlined DNA signifies the gene of interest we're trying to clone
Restriction enzyme sequences:

ERA I GTAATG
CRO I CAGGAC
MEM II GCCG

2. How many restriction sites appear in the bacterial plasmid sequence?

(A) none
(B) 1
(C) 2
(D) 3
(E) more than 3

3. Which enzyme(s) should be used to insert the human sequence into the plasmid?

(A) ERA I
(B) CRO I
(C) MEM II
(D) CRO I and ERA I
(E) ERA I, CRO I, and MEM II

4. How many bands would show up on a 1 percent agarose gel if the plasmid was cut with both ERA I and CRO I?

(A) 1
(B) 2
(C) 3
(D) 100
(E) 1,000

5. A gene that is 1,500 nucleotides long codes for a metabolic protein that is composed of 400 amino acids. The number of nucleotides in exons are ____________ and the number of nucleotides in introns are ____________.

(A) 1,200; 300
(B) 300; 1,200
(C) 1,500; 0
(D) 0; 1,500
(E) 400; 1,100

6. Which of the following statement(s) about RNA polymerases is (are) true?

(A) I. pry the two strands of DNA apart
(B) II. add RNA nucleotides together
(C) III. bind to promoter regions of the DNA to begin transcription

(A) I only
(B) II only
(C) III only
(D) II and III are both true.
(E) All of the above are true.

TEST 2—*Continued*

7. Which of the following statements about the *lac* operon is NOT true?

(A) RNA polymerase can be blocked by an active repressor protein attached to the operator.

(B) RNA polymerase attaches at a site on the DNA strand, known as the promoter.

(C) There is a regulatory gene that is downstream from the structural genes that can inhibit transcription.

(D) The regulatory gene produces the active repressor.

(E) The repressor protein can be activated by a substance like lactose, called the inducer.

8. Which of the following statements about the HIV virus is NOT true?

(A) The viral nucleotides contain ribose.

(B) HIV contains uracil, not thymine.

(C) HIV infection begins with the entrance of the virus into the host when the gp 120 and gp 41 function to pull the virus across the plasma membrane.

(D) HIV makes the host cell produce reverse transcriptase.

(E) Immunization against HIV has proven difficult because the virus mutates so rapidly.

9. All of the following are means of post-transcriptional control in eukaryotes EXCEPT

(A) the capping of the 5′ end with a modified guanosine triphosphate.

(B) the addition of a poly-A tail to the 3′ end.

(C) the cutting out of introns by a spliceosome.

(D) the ligation of exons by DNA polymerase.

(E) the attachment of signal sequences for direction to specific destinations.

10. Which of the following statements is NOT true concerning restriction fragment length polymorphisms (RFLPs)?

(A) Suspects whose fragments do not match any other fragments at a crime scene can be vindicated.

(B) The polymerase chain reaction can be used to produce more copies of DNA obtained at a crime scene before RFLP analysis.

(C) Most RFLPs use radioactive probes.

(D) Most RFLPs occur because of the repetitive nature of DNA.

(E) With the advent of PCR technology, restriction enzymes are no longer needed to perform RFLP analysis.

GO ON TO THE NEXT PAGE

TEST 2—*Continued*

1. Questions 97–100 refer to the following diagram.

First Base (5´ end)	Second Base: U	C	A	G	Third Base (3´ end)
U	phynyl-alanine leucine	serine	tyrosine stop stop	cysteine stop tryptophan	U C A G
C	leucine	proline	histidine glutamine	arginine	U C A G
A	isoleucine *methionine	threonine	asparagine lysine	serine arginine	U C A G
G	valine	alanine	aspartic acid glutamic acid	glycine	U C A G

* and start

2. Consider the following DNA nucleotides, where A, C, G, and T represent adenine, cytosine, guanine, and thymine:

TAC TTT TTG CTC ATC

The mRNA that would be transcribed from that would be

(A) TUC TTT TTG CTC ATC.
(B) CGT CCC CCA TCT GCT.
(C) ATG AAA AAC GAG TAG.
(D) AUG AAA AAC GAG UAG.
(E) CGU CCC CCA UCU GCU.

3. The amino acids coded for are, in order,

(A) tyrosine, phenylalanine, leucine, leucine, isoleucine.
(B) histidine, phenylalanine, valine, leucine, leucine.
(C) leucine, phenylalanine, methionine, leucine, stop.
(D) arginine, proline, proline, serine, alanine.
(E) methionine, lysine, asparagine, glutamic acid, stop.

4. Below is a list of the DNA coding sequence for a metabolic enzyme. Which of the four is most closely related to the first?

TAC TTT TTG CTC ATC

(A) ATC TTT TTG CTC ATC
(B) TAC TTC TTA CTT ATC
(C) TAC TTC TTG CTG ATC
(D) TAC TTC TAG CTC ATC
(E) Not enough information is given.

5. The number of tRNA molecules required by eukaryotic organisms to ferry around the amino acids is

(A) 64.
(B) 63.
(C) 45.
(D) 23.
(E) 20

S T O P

If you finish before the hour is up, you may review your work on this test only. You may not turn to any other test in this book.

ANSWERS AND EXPLANATIONS

QUICK-SCORE ANSWERS									
1. C	11. D	21. C	31. A	41. E	51. B	61. D	71. C	81. B	91. A
2. E	12. D	22. A	32. D	42. D	52. E	62. A	72. A	82. D	92. E
3. A	13. C	23. D	33. A	43. B	53. D	63. B	73. E	83. A	93. C
4. B	14. D	24. B	34. E	44. D	54. D	64. A	74. E	84. C	94. D
5. A	15. A	25. D	35. B	45. C	55. B	65. B	75. B	85. D	95. D
6. A	16. E	26. B	36. A	46. A	56. D	66. B	76. D	86. B	96. E
7. B	17. D	27. D	37. D	47. D	57. D	67. E	77. C	87. A	97. D
8. C	18. B	28. C	38. C	48. A	58. D	68. B	78. D	88. C	98. E
9. B	19. C	29. A	39. A	49. C	59. D	69. E	79. A	89. A	99. B
10. B	20. C	30. D	40. A	50. D	60. D	70. D	80. E	90. A	100. C

1. **The correct answer is (C).** The theory of acquired characteristics, proposed by Lamarck, plays no part in the theory of natural selection. It is not an accepted theory in biology.
2. **The correct answer is (E).** pH is defined as the negative log of the hydrogen ion concentration. Therefore, the negative log, choice (A), is 4. The pH and the pOH always add up to 14. And since it is a logarithmic scale, the difference in concentration between 4 and 7 is 1,000 times as strong.
3. **The correct answer is (A).** While the other interactions are important, they give rise to tertiary structure.
4. **The correct answer is (B).** The water molecules will move from a greater to a lesser concentration. The potato is hypertonic to the water because it has a greater solute concentration. Plasmolysis is the loss of water.
5. **The correct answer is (A).** Review the endomembrane system, which is responsible for packaging molecules for transport. The SER comes before the RER, and the golgi apparatus usually attaches a carbohydrate or modifies the protein in some manner.
6. **The correct answer is (A).** The field of view is 4 mm at 40 magnifications (ocular lens × objective lens gives total magnification). If he went to 400 magnifications, he would be looking at $\frac{1}{10}$ as much, or 0.4mm. If 12 cells line up and cover 0.4mm, then by division we get 0.033mm/cell.
7. **The correct answer is (B).** When doing dihybrid genetics problems, think about the traits as a monohybrid cross. The only way to have half gray and half black is hybrid × homozygous

recessive. Since the first fly is gray, he must be Gg. The second fly must be hybrid for wing length.

8. **The correct answer is (C).** The short-winged, green-eyed fly is llrr, and the other parent is LlRr. Being hybrid for both traits is necessary to produce the offspring that are non-parental types and are the result of crossing over during meiosis.
9. **The correct answer is (B).** The question relates to question 8 and the recombinants produced by the LlRr fly. The diagram below shows the results of crossing over that produced the short-winged, green-eyed flies and the long-winged, red-eyed flies.

   l L
   R r

10. **The correct answer is (B).** One of the major differences between prokaryotes and eukaryotes is the presence of plasmids.
11. **The correct answer is (D).** Choices (A) and (C) are incorrect because there are larger bands present than the original plasmid. While the same size plasmids can travel at different rates based on their conformation (relaxed, coiled, or supercoiled), there is no reason to believe one would not see the band shown in lanes 2 and 3 in lane 1.
12. **The correct answer is (D).** Gel electrophoresis draws negatively charged DNA to the positive pole. The smaller molecules will migrate faster through the gel.
13. **The correct answer is (C).** The mother is a carrier, and the father is colorblind. Their genotypes could be represented as $X^C X^c$ and $X^c Y$.
14. **The correct answer is (D).** 2^4 is 16, AaBb could make 4, or CcDd could make 4, so by multiplication, the probability of both events is the product of their individual probabilities.
15. **The correct answer is (A).** Meiosis I results in two cells, but there is no chromosome reduction at this point. During interphase, the DNA had been synthesized, doubling the amount of chromosomes. When divided into two cells, the number is 2N.
16. **The correct answer is (E).** Mitochondria are membrane-bound organelles and, as such, exist in all eukaryotic cells but not in prokaryotic (bacteria) cells.
17. **The correct answer is (D).** Actin and myosin are used for movement in many cells.
18. **The correct answer is (B).** The contractile vacuole is used to regulate water or tonicity.
19. **The correct answer is (C).** The protozoans are divided into groups relative to their mode of locomotion. The paramecia are

ciliates. Sporozoans do not move about by cilia, flagella, or pseudopods but are parasitic and move from host to host.

20. **The correct answer is (C).** Chordates lack both chitin (a substance found in fungal cell walls and the exoskeletons of arthropods) and an exoskeleton.
21. **The correct answer is (C).** The increase of surface area increases many physiological responses, including food absorption. Earthworms lack livers, ceca, and malphigian tubules.
22. **The correct answer is (A).** The gametophyte, large in both mosses and liverworts, is much reduced in the fern (and all other vascular plants).
23. **The correct answer is (D).** Monocots have parallel leaf venation, floral structures in multiples of 3, and fibrous taproots.
24. **The correct answer is (B).** CAM plants open their stomates at night. C4 plants use PEP carboxylase to capture carbon dioxide from the atmosphere.
25. **The correct answer is (D).** Effectors are the cells that neurons act upon.
26. **The correct answer is (B).** Dendrites are the receptors for nerves. The neurotransmitters are produced in the cell bodies.
27. **The correct answer is (D).** Insulin lowers blood sugar by making cells more permeable to glucose.
28. **The correct answer is (C).** Structures that carry blood toward the heart are veins, and those that carry it away are arteries. Blood circulation is divided into the pulmonary system (lungs) and the systemic system (everything else).
29. **The correct answer is (A).** Salivary amylase begins the digestion of carbohydrates in the mouth.
30. **The correct answer is (D).** Most food is absorbed in the small intestine. Protein digestion begins in the stomach and continues in the small intestine.
31. **The correct answer is (A).** Antibodies are produced by plasma cells and are released (as receptors) from the membranes of white blood cells.
32. **The correct answer is (D).** FSH is secreted early in the cycle. The endometrium builds to its thickest around the third week of the cycle.
33. **The correct answer is (A).** Myosin, not actin, is the filament that binds and contracts. Tropomyosin wraps around actin, not myosin.
34. **The correct answer is (E).** Not only are viruses not cellular, but they can not reproduce without being in a host cell.

35. **The correct answer is (B).** Some people use the following mnemonic to help them remember the order: King Phillip Came Over For Good Spaghetti.

36. **The correct answer is (A).** Small populations would favor a change in the gene frequency.

37. **The correct answer is (D).** The frequency of two alleles in the population (*p* and *q*) must add up to 1. The gene frequency is the square root of the homozygous recessive genotypic frequency. If 0.16 are homozygous recessive (q^2), 0.4 is the gene frequency (q). The carriers are the heterozygotes or $2pq$ (2*0.6*0.4).

38. **The correct answer is (C).** The first two are considered homologies. The last two are physical evidences of evolution. Crayfish have ventral nerve chords, not dorsal; nor are the nerve chords homologous.

39. **The correct answer is (A).** The commensalistic relationship depicts the egret benefiting from his relationship with the cow, but the cow is neither harmed nor helped by this relationship. On the other hand, the relationships in choices (B), (C), and (D) are mutualistic because both parties benefit.

40. **The correct answer is (A).** The reproductive rate will make more dogs, while the other factors will decrease both the number of dogs and the competition.

41. **The correct answer is (E).** The prevailing winds in the northern hemisphere are westerlies, which drive moisture-laden warm air up mountain sides until the air cools, reducing its ability to hold as much moisture. Precipitation falls on the eastern side, frequently creating deserts on the western sides.

42. **The correct answer is (D).** The taiga is coniferous forests; the temperate deciduous forests lose their leaves due to lack of moisture; and the chaparral is represented by coastal California, with few ruminants.

43. **The correct answer is (B).** By mimicking a dangerous or unpalatable prey, the rat snake hopes not to be viewed as easy prey. Other types of mimicry are crypsis, choices (A) and (E), and aggressive mimicry, choice (D).

44. **The correct answer is (D).** Niches are not only where an organism lives (habitat) but are multidimensional descriptions of everything about organisms.

45. **The correct answer is (C).** The carrying capacity is the number of organisms that can be supported in an environment.

46. **The correct answer is (A).** The early growth is exponential, followed by logistic growth. During exponential growth, the

factors that determine the carrying capacity are not yet influential.

47. **The correct answer is (D).** K is the carrying capacity, and each generation depends on the previous generation (N).

48. **The correct answer is (A).** The organisms that line the edge of the pond eventually die and displace the water from the outside toward the middle. Run-off and erosion help speed the process.

49. **The correct answer is (C).** By Mendel's Law of Segregation, the principles of meiosis, each parent gives one of their two alleles for blood type. Therefore, neither the Whites nor the Blacks could provide an A from one parent and a B from the other.

50. **The correct answer is (D).** As above, the Blacks can offer either an A or a B from the AB parent, and the other parent will give an O (nothing).

51. **The correct answer is (B).** Oxygen, produced by photosynthetic organisms, was not prevalent in the atmosphere until 2 billion years ago.

52. **The correct answer is (E).** Prokaryotes lack membrane-bound organelles (like ER) but do have ribosomes, which lack membranes. Don't forget to read all the choices in a multiple-choice test!

53. **The correct answer is (D).** While the fish don't have a preference for substrate during the day, they certainly do at night.

54. **The correct answer is (D).** The resulting graph has six bars, 2 groups of three. The other choice is 3 groups of two, which is harder to read and doesn't portray the information as clearly.

55. **The correct answer is (B).** Interference competition is direct aggression toward another, which is costly to both parties.

56. **The correct answer is (D).** Both insulin and glucagon are produced in the pancreas.

57. **The correct answer is (D).** The endosymbiotant theory states that eukaryotic cells evolved from the inclusion of one prokaryotic cell in another. Those early cells supplied energy to the other cells and were protected from the environment. The DNA evidence strongly supports the theory.

58. **The correct answer is (D).** Bryophytes lack vascular tissue and the ability to send water up long stems. The sperm must actually swim from the antheridia to the archegonia to fertilize the egg. It is a common misconception that vascular plants evolved from bryophytes.

59. The correct answer is (D). The meninges are the linings of the central nervous system.

60. The correct answer is (D). Gastrulation is the last event, which is an invagination of the blastula, creating three cell layers.

BIOLOGY-E TEST

61. The correct answer is (D). There is no indication that males are better at any of those tasks, but more importantly, it is to their selective advantage to mate if they can or help their own fitness through kin selection if they can't.

62. The correct answer is (A). It is selfish because it helps him at some cost to the younger bird. If it helped neither it would be considered a spiteful act. An altruistic act would help the young bird at some cost to the older bird, an event that must be viewed skeptically in the animal world.

63. The correct answer is (B). Interference competition is direct contact, as opposed to exploitative, an example of which would be the changing beak shapes on Darwin's finches. Intraspecific means "within the species," while interspecific means "between species."

64. The correct answer is (A). Respiration includes the costs of metabolism that plants, as well as animals, must meet.

65. The correct answer is (B). Human population growth exacerbates the other problems.

66. The correct answer is (B). Primary consumers eat producers, the phytoplankton.

67. The correct answer is (E). Biological magnification is the name given to this process, wherein a poison that is not metabolized but is stored builds up in the tissues of organisms. Those that feed at the top of the food chain are most at risk.

68. The correct answer is (B). We know that the biomass is supported by the number of producers, which will remain relatively constant with respect to upper-level consumers. We know that the number of seals will increase as the polar bears' numbers decrease. Therefore, the number of large fish will go down.

69. The correct answer is (E). The amount of biomass that can be supported in a system is approximately 10 percent of the preceding trophic level biomass, or 90 percent of the preceding level is lost—therefore, 150 in the small fish, 15 in the large fish, and 1.5 in the seals.

70. The correct answer is (D). The spring and fall turnover that occurs in most lakes mixes both nutrients and oxygen into the water column uniformly. At other times, the oxygen concentration falls as depth increases.

71. The correct answer is (C). Because water is densest at 4 degrees, there is a point (the thermocline) below which water temperature will not decline. This characteristic property of water enables the mixing that lakes go through. In the spring, as the water warms, the whole water column will be 4 degrees, enabling even slight winds to mix the water.

72. The correct answer is (A). Eutrophication is the loss of oxygen in a freshwater system to the decomposers in that system. It is caused by too much productivity.

73. The correct answer is (E). The acidic gases mix with moisture in the air to make nitric and sulfuric acids.

74. The correct answer is (E). The reason that carbon dioxide levels fluctuate is photosynthetic activity.

75. The correct answer is (B). Small islands have the highest extinction rates. The highest arrival rates occur closest to the mainlands.

76. The correct answer is (D). All fungi are heterotrophs and, as such, are consumers. The dead tree makes it a saprophyte, as opposed to a parasite.

77. The correct answer is (C). Oceans are the most stable biome.

78. The correct answer is (D). The temperate deciduous forest covers much of the eastern United States. There are regions like the Smokies and upstate New York that are much like taiga, with their coniferous trees, because of the altitude.

79. The correct answer is (A). The tropical evergreen forest is represented by choice (A).

80. The correct answer is (E). Imprinting is an event that takes place early in the life of an organism and that fixes a certain place or organism in its memory. There is a short-lived time or window in which these events can take place. Konrad Lorenz had some greylag geese imprint on him as their mother, and as such, they followed him around daily.

BIOLOGY-M TEST

81. The correct answer is (B). The viruses were labeled with both radioactive sulfur and radioactive phosphorus. The sulfur would stay with the protein coat on the virus and the phosphorus with the viral DNA. The blender knocked off the virus particles from the bacteria.

82. The correct answer is (D). See above.

83. The correct answer is (A). In addition, a typical plasmid would contain 3,000 DNA bp.

84. The correct answer is (C). While both prokaryotes and eukaryotes have proteins associated with their DNA, only eukaryotes use histones. Some people use a thread and spool analogy for DNA that is wound around the histones.

85. The correct answer is (D). Cyclins (as their name implies) cycle up and down during the cell cycle. There are several different types of combinations between cyclins and other cdk's.

86. The correct answer is (B). While these enzymes were originally found in bacteria, almost all are synthetically produced today.

87. The correct answer is (A). The calculation depends on the number of times that any base will be encountered. The probability that an A will be first is $\frac{1}{4}$, then $\frac{1}{4}$ for the T, *etc*. or $(\frac{1}{4})^6$ or $\frac{1}{4096}$. Since there are 54,000 bases, $54{,}000 \times \frac{1}{4096}$ or 13.

88. The correct answer is (C). There is one site that CRO I will cut and one that ERA I will cut.

89. The correct answer is (A). One should use the same restriction endonuclease to cut both the human gene and the bacterial plasmid. Since there is not a site for MEM II in the plasmid, it is not a suitable candidate. Since CRO I cuts within the gene of interest, it is unsuitable. The ERA I cuts both.

90. The correct answer is (A). When a bacterial plasmid, which is circular, is cut once, the result is one linear band. This plasmid will be cut twice, resulting in 2 bands, but one is so small (12 nucleotides) that it can not be seen (it will run off the gel).

91. The correct answer is (A). 400 amino acids require 1,200 nucleotides. The 300 leftover are introns.

92. The correct answer is (E). There may be other molecules involved, but most texts give those functions to RNA polymerase.

93. The correct answer is (C). The regulatory gene is upstream, making the active repressor.

94. The correct answer is (D). HIV, and all retroviruses, have to carry their own reverse transciptase with them since the host cell does not produce it or code for it.

95. The correct answer is (D). The spliceosome does the ligating.

96. The correct answer is (E). One can't produce a restriction fragment without using a restriction enzyme.

97. The correct answer is (D). Use Watson-Crick base-pairing rules and remember that RNA uses uracil, not thymine.

98. The correct answer is (E). The table is a messenger RNA codon table. Read from left to top to right.

99. The correct answer is (B). The answer cannot be obtained by examination of just the DNA nucleotides. One must transcribe and translate the sequences. By doing so, silent mutations, those which do not change the amino acid sequence, are not nearly important as missense mutations, choices (C) or (D) , which change an amino acid, or nonsense mutations, which introduce a stop codon, choice (A).

100. The correct answer is (C). Because of wobble, only about 45 different tRNAs are required. The relaxation is at the third base, with the use of inosine.

PRACTICE TEST 3

While you have taken many standardized tests and know to blacken completely the ovals on the answer sheets and to erase completely any errors, the instructions for the SAT II exam in Biology differs from the directions for other standardized tests you have taken. You need to indicate on the answer key whether you are taking the SAT II Biology with Ecological Emphasis (Biology-E) or Molecular Emphasis (Biology-M).

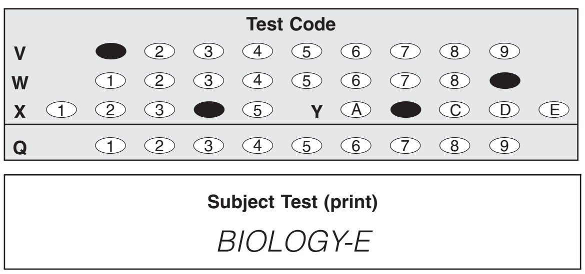
The instructions on the answer sheet will tell you to fill out the top portion of the answer sheet exactly as shown.

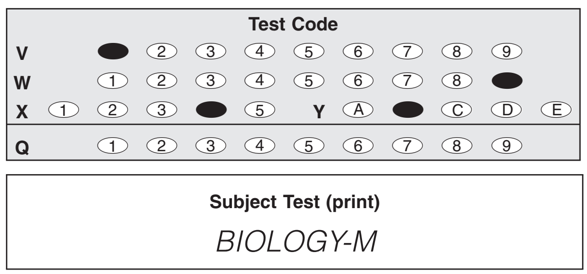
1. Print *BIOLOGY-E or BIOLOGY-M on the line to the right under the words Subject Test (print).*

2. In the shaded box labeled *Test Code* fill in four ovals:

For BIOLOGY-E
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.

For BIOLOGY-M
—Fill in oval 1 in the row labeled V.
—Fill in oval 9 in the row labeled W.
—Fill in oval 4 in the row labeled X.





—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

—Fill in oval B in the row labeled Y.
—Leave the ovals in row Q blank.

3. When everyone has completed filling in this portion of the answer sheet, the supervisor will tell you to turn the page and begin. The answer sheet has 100 numbered ovals on the sheet, but there are only 90 (or 95) multiple-choice questions in the test, so be sure to use only ovals 1 to 90 (or 95) to record your answers.

TEST 3—*Continued*

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

Questions 1–4 refer to the following information.

A student studying respiration decided to test the following hypothesis: "If yeasts use glucose for energy, then the more glucose I add to their medium, the more the population will grow."

To test this hypothesis, she filled four tubes with 5 ml of minimal growth media and added no glucose to the first, 5 ml to the second, 10 ml to the third, and 20 ml to the fourth. After 1 day she recorded the following data:

tube # 1	tube # 2	tube # 3	tube # 4
20 yeasts/mm^3	200 yeasts/mm^3	60 yeasts/mm^3	0 yeasts/mm^3
pH = 7.0	pH = 6.5	pH = 6.8	pH = 7.2

1. The data suggest which of the following?

(A) Yeasts need glucose to grow.

(B) The more glucose given to yeasts, the better they will grow.

(C) pH can be used to measure the rate of growth.

(D) Yeasts give off hydrochloric acid when they grow.

(E) None of the above

2. If she wanted to graph the data, she should put

(A) # of yeast on the *X* or independent axis and pH on the *Y* or dependent axis.

(B) pH on the *Y* axis and time on the *X* axis.

(C) # of yeasts on the *Y* axis and amount of glucose on the *X* axis.

(D) # of yeasts on the *Y* axis and pH on the *X* axis.

(E) (C) on one graph and (D) on another.

3. Reasons why the last tube didn't grow any yeast could be

(A) that the yeasts lost water through osmosis.

(B) that the mitochondria of the yeasts were overwhelmed.

(C) that fermentation killed the yeasts.

(D) that the high pH was bad for the yeasts.

(E) all of the above.

4. The student added no glucose to the first tube because

(A) she was testing the minimal media.

(B) she was using it for a control.

(C) she had to prove that yeasts need glucose to survive.

(D) all of the above.

(E) none of the above.

TEST 3—*Continued*

5. The hydrogen bonds in water are a result of

(A) the hydrogen of one molecule bonding to the hydrogen of another molecule.

(B) the oxygen of one molecule bonding to one of the hydrogens of that molecule.

(C) the hydrogen of a water molecule bonding to the nitrogen of another.

(D) the hydrogen of one molecule bonding to the oxygen of another molecule.

(E) none of the above.

6. Which of the following describe the physical dimensions for DNA?

I. The nitrogen bases are 0.34 nm from one another, moving 5′ to 3′.

II. The diameter of the strand is 20 nm.

III. The two strands run antiparallel.

(A) I only

(B) II only

(C) III only

(D) I and II

(E) I and III

Questions 7–8 refer to the following table.

First Base (5′ end)	Second Base: U	Second Base: C	Second Base: A	Second Base: G	Third Base (3′ end)
U	phynyl-alanine leucine	serine	tyrosine stop stop	cysteine stop tryptophan	U C A G
C	leucine	proline	histidine glutamine	arginine	U C A G
A	isoleucine *methionine	threonine	asparagine lysine	serine arginine	U C A G
G	valine	alanine	aspartic acid glutamic acid	glycine	U C A G

* and start

7. Which of the following DNA sequences would code for the polypeptide glutamine, lysine, histidine?

(A) CAG AAA CAU

(B) ACT CCC ACG

(C) GUC UUU GUA

(D) GTC TTT GTA

(E) none of the above

8. If a DNA strand contained the sequence ATG AGT CGT, what one base substitution could keep the translation from being completed?

(A) A to G

(B) T to A

(C) G to C

(D) C to G

(E) G to A

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

9. A consensus sequence is associated with __________, while a signal sequence is part of __________.

(A) translation, hnRNAs

(B) DNA, translation

(C) transcription, a snurp

(D) hnRNA, a snurp

(E) spliceosomes, translation

10. Plants produce energy in their

I. cytosol.
II. mitochondria.
III. chloroplasts.

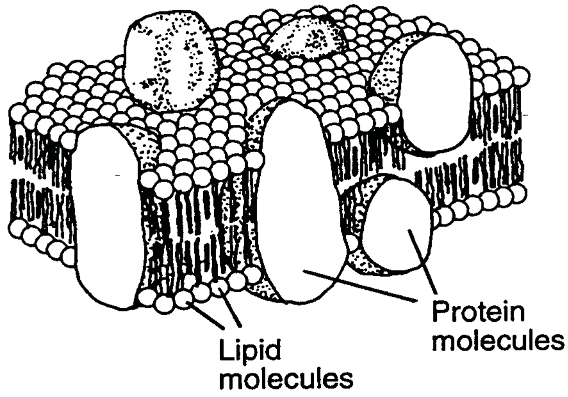
(A) I only

(B) II only

(C) III only

(D) II and III

(E) I, II, and III



11. Which cell structure is represented in the drawing above?

(A) plasma membrane

(B) chloroplast

(C) endoplasmic reticulum

(D) golgi apparatus

(E) mitochondrion

12. One would expect to find steroid hormone receptors in the

(A) plasma membrane.

(B) endoplasmic reticulum.

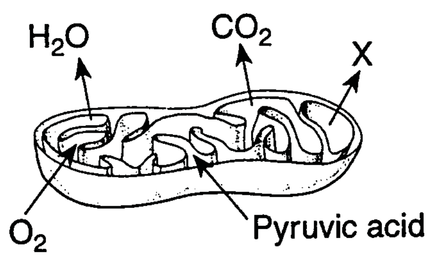
(C) nucleus.

(D) cytosol.

(E) none of the above.

TEST 3—*Continued*

Questions 13–14 refer to the following diagram.



13. All the arrows are associated with the process of

(A) carbon fixation.
(B) photochemical reactions.
(C) anaerobic respiration.
(D) aerobic respiration.
(E) oxygen fixation.

14. Letter X most likely represents

(A) the stroma.
(B) the matrix.
(C) the thylakoid space.
(D) the grana.
(E) none of the above.

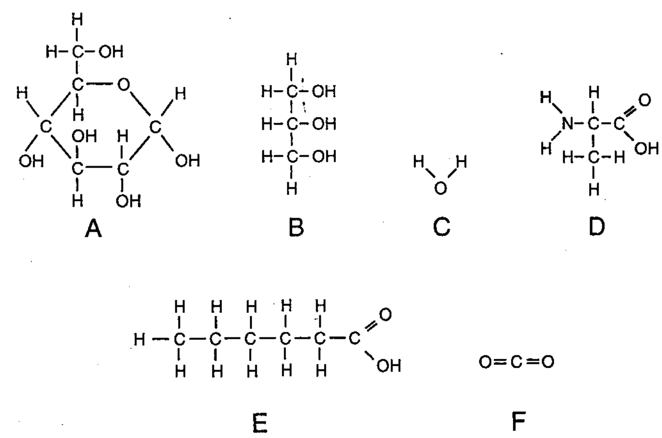
15. The enzyme that assimilates carbon dioxide into the Calvin cycle is known as

(A) rubisco.
(B) pepco.
(C) catalase.
(D) PEP carboxylase.
(E) malate hydrogenase.

16. Which element acts as a hydrogen acceptor during aerobic respiration?

(A) hydrogen
(B) carbon
(C) oxygen
(D) nitrogen
(E) phosphorus

Questions 17–19 refer to the following information.



17. Which molecule is the primary energy source for animals?

(A) A
(B) B
(C) C
(D) D
(E) E

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

18. Which molecule is an amino acid?

(A) A
(B) B
(C) C
(D) D
(E) E

19. What molecule is a product of the Kreb's cycle?

(A) B
(B) C
(C) D
(D) E
(E) F

20. The separation of plant pigments using paper chromatography is based on

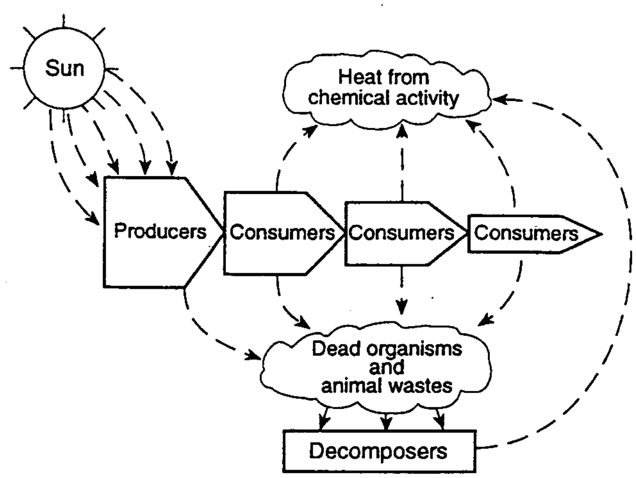
(A) the non-polarity of the solvents and pigments.
(B) the polarity of the paper.
(C) the polarity of the pigments.
(D) all of the above.
(E) none of the above.

21. The enzyme that charges tRNA molecules has as it substrate(s)

I. an amino acid.
II. ATP.
III. tRNA.
IV. snRNA.

(A) I only
(B) II only
(C) III only
(D) I, II, and III
(E) I, II, III, and IV

Questions 22–23 refer to the following diagram.



TEST 3—*Continued*

22. The diagram above illustrates __________ and shows that most energy is lost as __________.

(A) the first law of thermodynamics, fast as it arrives
(B) the second law of thermodynamics, heat
(C) the second law of thermodynamics, fast as it arrives
(D) the first law of thermodynamics, decomposition
(E) the second law of thermodynamics, decomposition

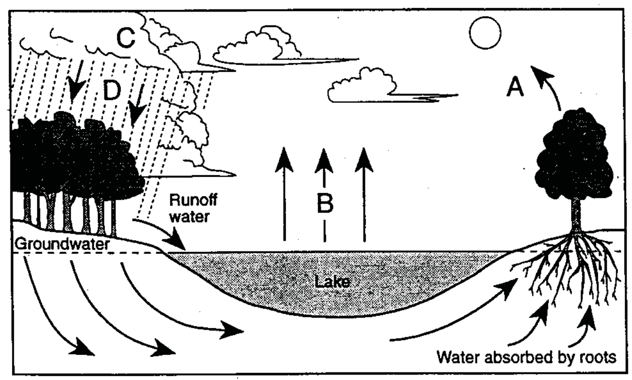
23. The amount of energy bound up in the second consumer's level is approximately __________ of the radiant energy falling on the system.

(A) 5 percent
(B) 0.5 percent
(C) 0.1 percent
(D) 0.01 percent
(E) 0.05 percent

24. Organisms are placed in different trophic levels according to how they obtain their energy. Another name for primary consumer is

(A) green plant.
(B) herbivore.
(C) carnivore.
(D) omnivore.
(E) decomposer.

Questions 25–26 refer to the drawing below.



25. Which letter represents the process of transpiration?

(A) A
(B) B
(C) C
(D) D
(E) none of the above

26. Over time, according to the theories of succession,

(A) the lake will get deeper and the trees more numerous.
(B) the lake will get shallower and the trees will be replaced by grass.
(C) the lake will dry up.
(D) the trees will become coniferous types.
(E) there is no fixed order to the replacement of species.

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

27. Some organisms living in a vacant lot include grass, dandelions, mice, grasshoppers, and slugs. Collectively these organisms represent

(A) an ecosystem.
(B) a community.
(C) a population.
(D) a mutualism.
(E) a biome.

28. Darwin's finches are a group of about twelve species of birds that live on the Galapagos Islands. The fact that they have different size beaks is regarded as a consequence of

(A) genetic drift.
(B) coevolution.
(C) competition.
(D) chance.
(E) behavioral modification.

29. Predators in an ecosystem

(A) help the community by keeping the number of prey from outstripping their resources.
(B) help the prey population by removing the sick and less fit individuals.
(C) enhance species diversity.
(D) reduce the possibility of competitive exclusion.
(E) all of the above.

30. A walking stick, a type of insect that is a primary consumer, is an example of an organism using

(A) aggressive mimicry.
(B) Batesian mimicry.
(C) camouflage.
(D) Mullerian mimicry.
(E) none of the above.

31. The buildup of pesticides in ospreys is known as

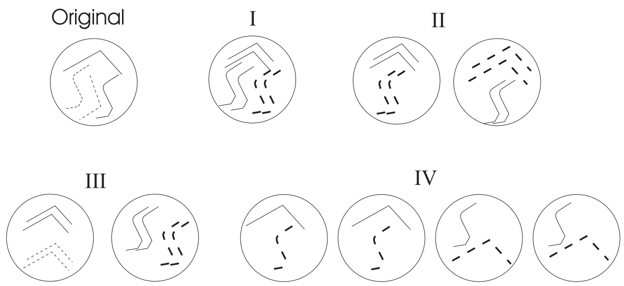
(A) biological magnification.
(B) food web dynamics.
(C) succession.
(D) keystone predation.
(E) none of the above.

32. An organism with the genotype AaVv can produce how many different types of gametes?

(A) 1
(B) 2
(C) 4
(D) 6
(E) 8

TEST 3—*Continued*

Questions 33–34 refer to the following diagram.



33. A cell has four chromosomes, which are represented in the original cell drawing. At the end of meiosis I, which of the other four drawings represents a possible outcome?

(A) I only
(B) II only
(C) III only
(D) IV only
(E) none of the above

34. At the end of meiosis II, which of the drawings represent(s) possible outcomes?

(A) I only
(B) II only
(C) II and III
(D) III and IV
(E) IV only

35. In minks, the gene for brown fur (B) is dominant to the gene for silver fur (b). Which set of genotypes represents a cross that could produce offspring with silver fur from parents that both have brown fur?

(A) Bb × Bb
(B) BB × Bb
(C) BB × bb
(D) Bb × bb
(E) none of the above

36. In four-o-clocks, pink flowers are the result of a red allele and a white allele for the color gene. If you crossed a white with a pink, what would be the most likely result?

(A) 20 red and 20 pink
(B) 40 pink
(C) 20 pink and 20 white
(D) 20 red and 20 white
(E) 40 white

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

37. In four-o-clocks, in addition to the flower color above, some plants may be tall (dominant) while others are short (recessive), based on a gene that is not on the same chromosome as the gene for flower color. A pure bred tall, red four-o-clock was bred to a pure bred white, short four-o-clock. Then the resulting F1 was crossed to get the F2. Approximately how many of the F2 will be short and pink?

(A) $\frac{1}{16}$

(B) $\frac{2}{16}$

(C) $\frac{3}{16}$

(D) $\frac{4}{16}$

(E) $\frac{6}{16}$

38. A colorblind man married a woman who wasn't colorblind, but her father had been. What is the possibility that their first child will be a colorblind girl?

(A) 0 percent

(B) 25 percent

(C) 50 percent

(D) 75 percent

(E) 100 percent

39. A man with type O positive blood married a woman with type B negative blood. What is (are) the types of blood that their children can have?

(A) B positive

(B) O positive

(C) B negative and B positive

(D) O negative and O positive

(E) B negative and positive and O negative and positive

40. People who have an extra X chromosome could have gotten it through

(A) nondisjunction.

(B) transposition.

(C) transduction.

(D) crossing over.

(E) all of the above.

41. The HIV virus infects mostly

(A) complement cells.

(B) red blood cells.

(C) T-killer cells.

(D) T-helper cells.

(E) all of the above.

42. Select the correct order of events in a person's response to a bacterial infection:

(A) macrophage ingestion → Helper T cell activation → B cell activation → clonal formation

(B) clonal formation → Helper T cell activation → B cell activation → macrophage ingestion

(C) macrophage ingestion → B cell activation → T helper cell activation → clonal formation

(D) Helper T cell activation → B cell activation → macrophage ingestion → clonal formation

(E) B cell activation → T helper cell activation → clonal formation → macrophage ingestion

TEST 3—*Continued*

43. Blood entering the dorsal aorta has most recently been in the

(A) right atria.
(B) right ventricle.
(C) left atria.
(D) left ventricle.
(E) pulmonary vein.

44. Carbon dioxide that is leaving the body is carried in

I. the plasma.
II. erythrocytes.
III. hemoglobin molecules.

(A) I only
(B) II only
(C) III only
(D) I and II
(E) I, II, and III

45. Carbohydrate digestion begins in the __________ with the action of the enzyme __________.

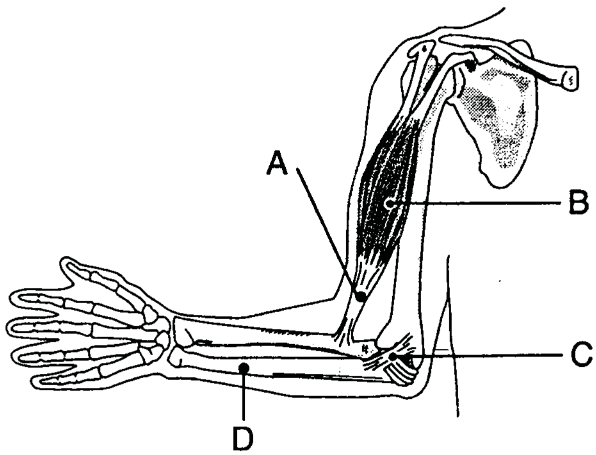
(A) mouth, amylase
(B) stomach, pepsin
(C) stomach, chymotrypsin
(D) small intestine, amylase
(E) small intestine, cholecystokinin (CCK)

46. The function of ATP in voluntary muscle movement is to supply the energy for

(A) myosin to bind to actin.
(B) myosin to become separated from actin.
(C) tropomyosin to bind to troponin.
(D) tropomyosin to become separated from troponin.
(E) tropomyosin to become separated from actin.

GO ON TO THE NEXT PAGE

TEST 3—*Continued*



Question 47 refers to the above drawing.

47. Choose the one correct statement from the following.

(A) A = muscle; B = tendon; C = ligament; D = ulna

(B) A = ligament; B = muscle; C = radius; D = tendon

(C) A = ligament; B = muscle; C = tendon; D = radius

(D) A = tendon; B = muscle; C = ligament; D = radius

(E) A = tendon; B = muscle; C = ligament; D = ulna

48. Curare acts on the same receptors as acetylcholine but does not cause the effect of acetylcholine, nor is it easily decomposed or cleaved by cholinesterases. Injection of curare into a person could result in

I. epileptic seizures.
II. muscle relaxation.
III. suffocation.

(A) I only

(B) II only

(C) III only

(D) I and II

(E) II and III

49. The undershoot during an action potential is the result of

(A) the sodium gates being closed and the potassium gate open.

(B) the sodium gates being closed and the potassium gate closed.

(C) the sodium gates being open and the potassium gate closed.

(D) the sodium gates being open and the potassium gate open.

(E) one of the sodium gates being open, one closed, and the potassium gate open.

50. In the development of a frog embryo, Speman's primary organizer was found to be the

(A) dorsal ectoderm.

(B) dorsal lip of the blastopore.

(C) archenteron.

(D) neural tube.

(E) notochord.

TEST 3—*Continued*

51. Choose the one statement that is true from among the following.

(A) FSH is produced in the ovaries and causes maturation of the follicle.

(B) LH is produced in the pituitary gland and causes ovulation.

(C) Estrogen is produced in the anterior pituitary gland and causes the endometrium to thicken.

(D) Progesterone is produced in the posterior pituitary gland and causes the endometrium to thicken.

(E) None of the above statements are true.

52. If 9 percent of all cicadas exhibit the homozygous recessive condition known as "flippant wings," what is the gene frequency for that gene in the general population?

(A) cannot be determined

(B) 91 percent

(C) 0.9

(D) 0.3

(E) 0.03

53. The wings of a bird and those of an insect are a good example of

(A) adaptive radiation.

(B) coevolution.

(C) convergent evolution.

(D) all of the above.

(E) none of the above.

54. Which one of the following lists contains an organism that does NOT belong in that phylum?

(A) jellyfish, coral, anemone, starfish

(B) tunicates, birds, sharks, man

(C) bats, dogs, cats, sloths

(D) liver fluke, planaria, tapeworm, flatworms

(E) clam, squid, nautilus, snail

55. Choose the most Darwinian reason to describe how camels came to have flat, broad hooves.

(A) The camels that ventured further into the desert acquired broader feet, which were passed along to their offspring.

(B) Those animals that had the broadest hooves were the most attractive to the opposite sex.

(C) The animals that had the broadest hooves were able to travel farther and find water more easily than those that couldn't and subsequently perished.

(D) Those animals with the broadest feet are descended from the camels that got broad feet from stomping out the forest fires that created the desert in the first place.

(E) In the game of life, random events will move evolution toward the most successful adaptations possible.

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

56. The age of the Earth is about __________ years, and life has existed on the Earth for __________ years.

(A) 3.5 billion, 2.5 billion
(B) 3.5 billion, 1.5 billion
(C) 15 billion, 3.5 billion
(D) 4.5 billion, 600 million
(E) 4.5 billion, 3.5 billion

57. Which of the following could be used to study evolution?

(A) DNA hybridization
(B) RFLPs
(C) structural homologies
(D) fossils
(E) all of the above

58. Which of the following is (are) a domain(s)?

I. Eukaryota
II. Archaebacteria
III. Eubacteria

(A) I only
(B) II only
(C) III only
(D) I and III
(E) I, II, and III

59. Which of the following organisms lacks a coelom?

(A) roundworms
(B) segmented worms
(C) clams
(D) grasshoppers
(E) people

60. Donald Johanson, Tom Gray, and others discovered a hominid that lived in East Africa__________ million years ago and nicknamed her Lucy, whose scientific name they gave as __________.

(A) 35, *Homo habilis*
(B) 3.5, *Homo africanus*
(C) 5.5, *Australopithecus africanus*
(D) 3.0, *Australopithecus afarensis*
(E) 5.5, *Australopithecus boisei*

S T O P

IF YOU ARE TAKING THE BIOLOGY-E TEST, CONTINUE WITH QUESTIONS 61–80.
IF YOU ARE TAKING THE BIOLOGY-M TEST, GO TO QUESTION 81 NOW.

TEST 3—*Continued*

BIOLOGY-E TEST

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

61. Ammonia is released from dead plants by

(A) denitrifying bacteria.
(B) nitrogen-fixing bacteria.
(C) bacteria of decay.
(D) nitrifying bacteria.
(E) none of the above.

Questions 62–65 refer to the following information.

Large Climatic Areas	Column 1	Column 2
Desert	Cacti	Rats and snakes
A	Deciduous trees	Deer and foxes
Taiga	*B*	Moose and lynx
Tundra	Lichens	*C*

62. Which statement correctly describes a relationship between the species of columns 1 and 2?

(A) The species in column 1 help to determine which species are in column 2.
(B) The species in column 2 help to determine which species are in column 1.
(C) The species in column 1 are dependent on the species in column 2.
(D) The species in both columns 1 and 2 help to determine the climate of the area.
(E) None of the above is true.

63. Letter A most likely represents

(A) a biosphere.
(B) a biome.
(C) a bathysphere.
(D) an ecosystem.
(E) a community.

64. Letter B most likely represents

(A) black bears.
(B) beavers.
(C) sugar maples.
(D) conifers.
(E) foxes.

65. Letter C most likely represents

(A) squirrels and deer.
(B) antelope and bison.
(C) monkeys and leopards.
(D) caribou and snowy owls.
(E) fungi and algae.

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

Questions 66–68 refer to the following information.

An investigator went to Central America to study oropendulas, which are communal nesting birds. Another species of bird, the cowbird, sometimes lay its eggs in the nests of oropendulas. Some of the populations of oropendulas throw the cowbird eggs out of the nest, and some don't. The investigator was interested in finding out why some birds would raise other species as their own but others would toss them out. By watching the nests closely, he found that blowflies lay their eggs in the nests of oropendulas, and that the young larvae, maggots, feed on the young birds. If young cowbirds are in the nest, the precocious cowbirds eat the blowfly larvae, protecting the young oropendulas. In colonies of oropendulas that discriminate against cowbirds, throwing them from the nest, the blowflies are not eaten by cowbirds. These colonies of oropendulas build their nests close to a particular wasp colony, and the wasps eat the blowflies.

66. The relationship between the oropendulas that don't discriminate against cowbirds and the cowbirds is one of

(A) commensalism.
(B) predation.
(C) mutualism.
(D) competition.
(E) annilism.

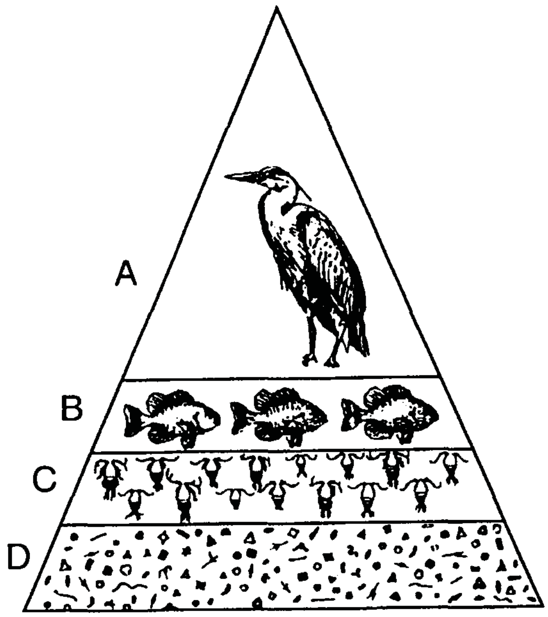
67. The relationship between the blowfly and the cowbirds that are associated with the non-discriminating oropendulas is one of

(A) commensalism.
(B) predation.
(C) mutualism.
(D) competition.
(E) annilism.

68. The relationship between the oropendulas that discriminate against cowbirds and the cowbirds is one of

(A) commensalism.
(B) predation.
(C) mutualism.
(D) competition.
(E) annilism.

TEST 3—*Continued*



Questions 69–70 refer to the above drawing.

69. Which statement best describes one of the levels of this pyramid?

(A) Level A contains the largest producers in the pyramid.
(B) The organisms in level B obtain food directly from level A.
(C) Level C contains the largest group of consumers in the pyramid.
(D) Level D contains the greatest number of heterotrophs in the pyramid.
(E) Levels C and D both contain producers.

70. Which of these levels would be most susceptible to biological magnification?

(A) A
(B) B
(C) C
(D) D
(E) They would all be equally affected.

71. In a natural community, all the living things that directly or indirectly affect the environment are known as

(A) pioneer organisms.
(B) keystone species.
(C) secondary consumers.
(D) climatic factors.
(E) biotic factors.

72. In order to preserve the biosphere for future generations, humans must

(A) make use of technology to develop new herbicides.
(B) put all wild animals in game preserves.
(C) explore ways to drain and fill wetlands along the seacoast.
(D) understand how living things interact with their environment.
(E) settle more people inland, away from the coasts.

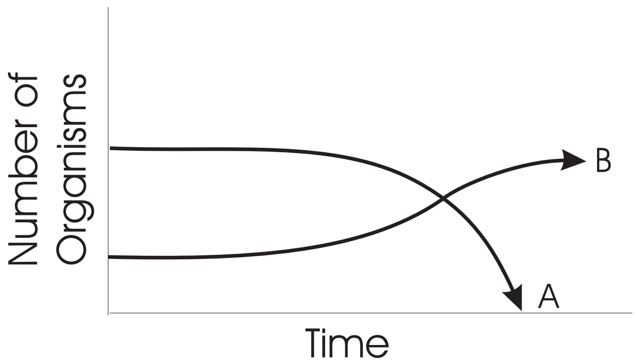
GO ON TO THE NEXT PAGE

TEST 3—*Continued*

73. Which group can best be described as a population?

(A) all the honeybees in an orchard in one spring
(B) all the plants and animals in a forest
(C) the living and nonliving factors in a meadow
(D) the life in Earth's atmosphere
(E) all the buffalo in 1840

Questions 74–75 refer to the following graph.



74. Assume first that the graph above shows the changes in two populations of herbivores in a grassy field. A possible reason for these changes is that

(A) all of the plant populations in this habitat decreased.
(B) population B competed more successfully for food than did population A.
(C) population A produced more offspring than population B did.
(D) population A consumed the members of population B.
(E) over time, both populations will have the same average number.

75. Assume now that the graph above shows the changes in any two populations in a grassy field. Choose which of the following statements are true.

I. A could represent predators and B prey.
II. A could represent prey and B predators.
III. A could be a host infested by the pathogen B.

(A) I only
(B) II only
(C) III only
(D) I and II
(E) II and III

76. Competition between the members of a woodchuck population in a large field could be expected to increase as a result of an increase in the

(A) woodchuck reproduction rate.
(B) spread of disease among the woodchucks.
(C) number of woodchucks killed by cars.
(D) number of secondary consumers.
(E) natality rate of their predators.

77. Let r stand for the intrinsic rate of growth, N for the number of organisms in a population, and K for the carrying capacity. A good formula for logistic growth would be

(A) $rN\,(N-K)/K$
(B) $rN\,(N-r)/rK$
(C) $rK\,(K-N)/rN$
(D) $rK\,(r-N)/K$
(E) $rN\,(K-N)/K$

TEST 3—*Continued*

78. Mimicry is an important biotic factor in communities all over the world. For instance, viceroy butterflies closely resemble (mimic) monarch butterflies. Birds that eat viceroys enjoy a good meal, but those that eat monarchs retch right away. What type of mimicry does this describe?

(A) Mullerian
(B) aggressive
(C) crypsis
(D) Batesian
(E) deflection

79. Probably the world's most pressing ecological problem is

(A) destruction of the rain forests.
(B) global warming.
(C) depletion of natural resources.
(D) over-fishing the oceans.
(E) human overpopulation.

80. Predators are beneficial to communities because

(A) they control the prey population growth.
(B) they practice predation harvest.
(C) predators enhance species diversity.
(D) Both (A) and (B).
(E) (A), (B), and (C).

S T O P

If you answered the first 80 questions STOP HERE.
If you are taking the Biology-M test CONTINUE HERE.

TEST 3—*Continued*

BIOLOGY-M TEST

Directions: Each of the questions or statements below is accompanied by five choices. For each question, select the best of the answer choices given.

Questions 81–82 refer to the following table.

Messenger RNA (mRNA) Codes for Selected Amino Acids	
Amino Acid	**mRNA Code**
Leucine	C–C–A
Arginine	C–G–A
Phenylalanine	U–U–U
Valine	G–U–U
Lysine	A–A–A

81. What would be the DNA triplet that would code for the addition of arginine to a polypeptide?

(A) C–G–A

(B) G–C–T

(C) C–C–T

(D) T–A–C

(E) G–C–U

82. Which amino acid would be attached to a polypeptide chain if the amino acid was attached to the anticodon A–A–A?

(A) phenylalanine

(B) lysine

(C) valine

(D) a stop codon

(E) cannot be determined from the information given

83. Which of the following functions can be attributed to DNA polymerase?

(A) It replaces RNA nucleotides with DNA nucleotides.

(B) It fixes errors in the replication of DNA.

(C) It ads nucleotides to the growing chain at the 3' end.

(D) It is used in the polymerase chain reaction.

(E) All of the above are true.

84. During translation, the first amino acid

(A) occupies the aminyl site first, then the peptidyl site.

(B) occupies the aminyl site before the attachment of the large portion of the ribosome.

(C) of the polypeptide chain is methionine.

(D) all of the above

(E) none of the above

TEST 3—*Continued*

85. A signal sequence

(A) is a sequence of DNA that begins transcription.

(B) is a sequence of RNA that is spliced out in the nucleus.

(C) is a sequence of DNA that directs a protein to certain organelles.

(D) is a sequence of DNA that attracts transcription factors.

(E) is the sequence of tRNA that bonds with the codon of mRNA at the ribosome.

86. Which of the following substances would NOT be present in a typical procedure for separating proteins by gel electrophoresis?

(A) water

(B) bromophenol blue

(C) Tris buffer

(D) agarose

(E) polyacrylamide

87. Northern blotting is used with

(A) DNA.

(B) RNA.

(C) hnRNA.

(D) ssDNA.

(E) all of the above.

88. You are trying to measure mRNA synthesis with animal cells growing in a tissue culture. Which radioactive nucleotide should you provide to the cells to measure RNA synthesis?

(A) adenine

(B) cytosine

(C) guanine

(D) thymine

(E) uracil

89. Splicing of hnRNA is done in the nucleus by "snurps." Of what are these "snurps" composed?

(A) RNA

(B) DNA

(C) proteins

(D) RNA and proteins

(E) DNA and proteins

90. Peter Mitchell was able to demonstrate chemiosmosis by getting ______________ to go down their concentration gradient by using two different ___________.

(A) potassium ions, light frequencies

(B) hydrogen ions, light frequencies

(C) potassium ions, pH solutions

(D) hydrogen ions, pH solutions

(E) potassium ions, electromagnetic frequencies

GO ON TO THE NEXT PAGE

TEST 3—*Continued*

91. One would expect to find reverse transcriptase in

(A) the plasmids of competent cells.
(B) retrovisuses.
(C) purple sulfur bacteria.
(D) plasmodia.
(E) archaebacteria.

92. The target tissue for parathyroid hormone is (are) the

(A) kidneys.
(B) bones.
(C) small intestine.
(D) all of the above.
(E) none of the above.

93. The products of oxidative phosphorylation are

(A) oxygen and water.
(B) NADH and ATP.
(C) pyruvate and NADPH.
(D) water and ATP.
(E) oxygen and NADH.

94. A major difference between gram positive and gram negative bacteria is that the former has

(A) a liposaccharide outer covering with a small peptidoglycan component in the cell wall.
(B) a small peptidoglycan component covering a large liposaccharide base.
(C) a large peptidoglycan component in the cell wall.
(D) a cell wall composed of liposaccharide and chitin.
(E) a cell wall composed of chitin over peptidoglycan.

95. Let X represent an atom and X^* its radioactive isotope. Assume both are taken up by living organisms. If the half-life of X^* is 4,000 years, how much X^* will be present in the remains of an organism that is 16,000 years old?

(A) as much as a living organism
(B) 4 times as much
(C) ¼ as much
(D) 1⁄16
(E) indeterminate given the lack of climatic data

TEST 3—*Continued*

96. All of our cells contain protooncogenes that may turn into oncogenes, which are cancer genes. The best explanation for proto-oncogenes is that they

(A) came into our cells from a viral infection of our ancestors.
(B) arose from plasmids that have been inserted into bacteria and now reside in us.
(C) are DNA "junk" with no known function.
(D) turn into oncogenes as we age.
(E) help regulate cell division.

97. In genetic engineering, it is necessary to cut DNA out of bacteria and eukaryotes. To insert the human insulin gene into a bacteria, one should use

(A) two different restriction enzymes so that the pieces won't reanneal.
(B) the same restriction enzyme so that both pieces will have the same sticky ends.
(C) methylated bacterial DNA so that only some of it will be spliced.
(D) two different ligases to reanneal the DNA.
(E) a hot water bath at 55 degrees centigrade so that the reaction will happen faster.

98. Watson and Crick used all of the following information in elucidating the physical structure of DNA EXCEPT

(A) X-ray crystallography.
(B) the Meselson-Stahl experiment.
(C) Chargoff's rules.
(D) the different sizes of purines and pyrimidines.
(E) the transforming principle of Avery *et al.*

99. Which of the following organelles is out of order from an endomembrane point of view?

(A) nucleus
(B) vesicles
(C) golgi apparatus
(D) endoplasmic reticulum
(E) plasma membrane

100. The products of the light reactions, or photophosphorylation, in photosynthesis are

(A) oxygen and water.
(B) oxygen and ATP.
(C) oxygen, ATP, and NADPH.
(D) water, ATP, and NADPH.
(E) water, ATP, and $NADP^+ + H^+$.

S T O P

If you finish before the hour is up, you may review your work on this test only. You may not turn to any other test in this book.

ANSWERS AND EXPLANATIONS

QUICK-SCORE ANSWERS									
1. C	11. A	21. D	31. A	41. D	51. B	61. C	71. E	81. B	91. B
2. C	12. C	22. B	32. C	42. A	52. D	62. A	72. D	82. A	92. D
3. A	13. D	23. D	33. B	43. D	53. C	63. B	73. A	83. E	93. D
4. B	14. B	24. B	34. E	44. E	54. A	64. D	74. B	84. C	94. C
5. D	15. A	25. A	35. A	45. A	55. C	65. D	75. E	85. C	95. D
6. E	16. C	26. C	36. C	46. B	56. E	66. C	76. A	86. D	96. E
7. D	17. A	27. B	37. B	47. E	57. E	67. B	77. E	87. B	97. B
8. C	18. D	28. C	38. B	48. E	58. E	68. D	78. D	88. E	98. B
9. E	19. E	29. E	39. E	49. A	59. A	69. C	79. E	89. D	99. D
10. E	20. D	30. C	40. A	50. B	60. D	70. A	80. E	90. D	100. C

1. **The correct answer is (C).** While the data may not be linear, the pH does go down as the number of yeasts goes up.
2. **The correct answer is (C).** The number of yeasts was related to the amount of glucose. It can't be choice (D); the pH changed in response to the yeast because the minimal media with the addition of glucose would have had the same pH in the beginning.
3. **The correct answer is (A).** The yeasts would be expected to lose water in such a difference of water potential.
4. **The correct answer is (B).** A control can be thought of as the experiment without the independent variable.
5. **The correct answer is (D).** Choice (B) is incorrect because the bonds between hydrogen and oxygen of the same water molecule are polar covalent bonds. Hydrogen bonds can form between the hydrogen of one molecule and any more electronegative atom of another molecule, such as oxygen.
6. **The correct answer is (E).** The diameter of the strand is 2 nm.
7. **The correct answer is (D).** Use the codon table to get the mRNA code and take the complement of each codon. Remember that uracil (U) is the RNA complement to adenine (A). Choices (A) and (C) are not DNA sequences because they contain uracil.
8. **The correct answer is (C).** In the first triplet, G goes to C, resulting in the RNA codon UAG, one of three stop codons. The second triplet would also give the stop codon if G goes to C.

9. **The correct answer is (E).** Splicesomes attach at the consensus sequences. Blobel won the 1999 Nobel Prize in Physiology for his discovery of signal sequences.
10. **The correct answer is (E).** Plants use cellular respiration and, as such, produce energy in the cytosol. They have both mitochondria and chloroplasts for energy production.
11. **The correct answer is (A).** The model of the PM is a phospholipid bilayer containing proteins and modified proteins.
12. **The correct answer is (C).** Steroid hormone receptors are in the nucleus and respond to steroid hormones that penetrate the cell membrane (because of their lipid nature).
13. **The correct answer is (D).** The picture denotes a mitochondrion. Cellular respiration culminates in oxidative phosphorylation, resulting in the formation of water when oxygen accepts the hydrogen ions and electrons at the end.
14. **The correct answer is (B).** The other structures are associated with chloroplasts.
15. **The correct answer is (A).** Rubisco is another name for ribulose bisphophate carboxylase-oxygenase. No wonder people use acronyms!
16. **The correct answer is (C).** See question 13.
17. **The correct answer is (A).** Choice (A) represents a glucose molecule.
18. **The correct answer is (D).** Amino acids are composed of an amine (NH_2), a central carbon with a variable group (in this case a methyl, CH_3), and a carboxyl group (COOH).
19. **The correct answer is (E).** Two carbon dioxide molecules are given off for each turn of the Kreb's cycle.
20. **The correct answer is (D).** The polar paper attracts the polar substances, and they travel less slowly than the nonpolar substances dissolved in the nonpolar solvents.
21. **The correct answer is (D).** The ATP molecule is actually a participant in the joining of the amino acid to the tRNA molecule.
22. **The correct answer is (B).** Ninety percent of the energy coming into a typical system is dissipated, much of it as heat.
23. **The correct answer is (D).** Plants capture about 1 percent of the radiant energy available to them. Consumers capture, on the average, 10 percent from what is available in the preceding trophic level. Therefore (0.01) (0.1) (0.1) = 0.0001 or 0.01 percent.

24. **The correct answer is (B).** All primary consumers are herbivores, and all secondary consumers are carnivores (because they eat the primary consumers). Omnivores can be either, depending on where they are feeding on the food chain.
25. **The correct answer is (A).** Transpiration is the loss of water by plants. Choice (B) illustrates evaporation.
26. **The correct answer is (C).** Ponds and lakes will dry up over time because plant detritus will fill in and replace some of the water, and solid matter (from run-off and dead organisms) will go to the bottom and displace water.
27. **The correct answer is (B).** A community is made up only of organisms. An ecosystem is the organisms and their abiotic surroundings.
28. **The correct answer is (C).** Competition for food sources has been shown to cause the beak sizes to diverge when the animals live sympatrically (together) versus allopatrically (apart).
29. **The correct answer is (E).** Predators can increase biodiversity by keeping one species from dominating competitors. For instance, assume that there are three types of mice living in the same area. One might be a superior competitor and drive the others to extinction if owls didn't feed on that particular type of mouse.
30. **The correct answer is (C).** The walking stick, as a herbivore, uses camouflage to avoid predation. His relative, the preying mantis, as a consumer, uses aggressive mimicry to capture its prey.
31. **The correct answer is (A).** Biological magnification is the buildup of a nonbiodegradable poison in the tissues of organisms. It is magnified because those organisms that feed higher on the food chain eat more organisms that have these poisons stored in their tissues.
32. **The correct answer is (C).** The types would be AV, Av, aV, and av.
33. **The correct answer is (B).** At the end of meiosis I, there will be two cells formed from the original 2N cell. It must be II, not III, because the distribution requires homologous pairs to separate.
34. **The correct answer is (E).** Meiosis takes an original 2N cell and makes it N. In this case, 2N = 4; therefore, each gamete would be N or have two chromosomes. In addition, the number of cells produced in meiosis is four.

35. The correct answer is (A). One fourth of their offspring, on the average, will have silver fur. Choice (D) is not a possibility because the parents don't both have brown fur.

36. The correct answer is (C). The pink plant will give the red allele to half of its gametes and the white to the other half. Therefore, since the white will always contribute white, the ratio is half white and half pink.

37. The correct answer is (B). Dihybrid crosses, involving two traits, should be solved one trait at a time. Since the F1 is Tt × Tt, ¼ of all offspring will be short. The F1 color cross is rw × rw, resulting in ½ pink. The number of offspring that will be short and pink is therefore the product of ½ and ¼ or ⅛, the same as 2⁄16.

38. The correct answer is (B). The woman is a carrier for color-blindness, meaning that she has an allele for it, but it is not expressed. The man is colorblind and will give all his daughters the colorblind gene.

39. The correct answer is (E). A person who has the B phenotype can be heterozygous (BO) or homozygous (BB). A person who has the O phenotype has only one genotype (OO). Therefore, their children, assuming the heterozygote condition, could be either B or O. The positive and negative refer to the Rhesus factor, a simple dominant trait reflecting the presence of a particular marker on some people's blood. If one assumes the man is a heterozygote (Pos/neg), then half of their children will be positive and half negative, on average.

40. The correct answer is (A). Nondisjunction results from an incomplete separation of chromosomes or chromatids during meiosis.

41. The correct answer is (D). While the HIV virus is known to infect nerve tissue, most of the time the T-helper (T4) cells are the ones infected.

42. The correct answer is (A). The first event is macrophage ingestion. Helper T cells act almost as the brain of the immune system, turning other cells off and on.

43. The correct answer is (D). The left side of the heart serves the systemic portion, the right side, the pulmonary. Blood is received in the atria and pumped out of the ventricles.

44. The correct answer is (E). About 7 percent of the carbon dioxide molecules are carried in the plasma as bicarbonate ions. The remainder is carried by erythrocytes, either bound to hemoglobin molecules carried therein as carbonic acid or bicarbonate ions.

45. The correct answer is (A). Salivary amylase breaks starches into sugars, which is why holding a cracker in your mouth for a short time makes it seem sweeter.

46. The correct answer is (B). Without this ATP, rigor mortis sets in.

47. The correct answer is (E). The bone above D is the radius, which one can feel rotate over the more stationary ulna. The letter C represents the connective tissue that holds bones together, which is a ligament. Muscles are held to bone by tendons.

48. The correct answer is (E). Since there will be fewer contractions, the diaphragm (the muscle that causes the chest cavity to increase) will not move as much, so suffocation is a possibility.

49. The correct answer is (A). The undershoot is a lower negative potential than the resting state. This occurs because the sodium gates are closed, keeping sodium from passing in, and the potassium channels, which are slower, are still open from the repolarizing phase, allowing potassium to move out of the cell.

50. The correct answer is (B). The gray crescent, which moves early in development, becomes the dorsal lip of the blastopore and is responsible, in part, for gastrulation.

51. The correct answer is (B). FSH and LH are produced in the pituitary. Estrogen and progesterone are produced in the ovaries.

52. The correct answer is (D). Using Hardy-Weinberg equilibrium conditions, the frequency for the recessive allele (q) can be found by taking the square root of q^2. The square root of 0.09 is 0.3.

53. The correct answer is (C). Convergent evolution describes conditions where organisms appear to have homologous structures that are, in fact, analogous. They are analogous because the organisms are not closely related, and the wings evolved from different basal structures.

54. The correct answer is (A). All the organisms here are Cnidarians, with the exception of the Echinoderm starfish.

55. The correct answer is (C). Darwinian selection is about reproductive success, not the Lamarckian reasons cited in choices (A) and (D).

56. The correct answer is (E). The earliest prokaryotic fossils date to about 3.5 billion years ago. The 600 million date refers to the Cambrian explosion, which refers to the rapid evolution of animal forms.

57. The correct answer is (E). The more data that can be collected about a time period or taxon, the better.

58. **The correct answer is (E).** These three groups have been proposed as domains based on the rRNA analysis of Carl Woese.
59. **The correct answer is (A).** Roundworms lack a true coelom.
60. **The correct answer is (D).** Currently, there are no hominids that date back to 5.5 million years ago. *A. afarensis* was a newly described species.

BIOLOGY-E TEST

61. **The correct answer is (C).** Nitrifying bacteria convert ammonium to nitrites and nitrates. Denitrifying bacteria convert nitrates to atmospheric nitrogen.
62. **The correct answer is (A).** Consumers usually are associated with certain types of producers or vegetation.
63. **The correct answer is (B).** Biomes are listed in the first column.
64. **The correct answer is (D).** Coniferous trees are the dominant life forms in the taiga.
65. **The correct answer is (D).** See question 62. Fungi and algae won't work here, even though they exist there, because they are not consumers.
66. **The correct answer is (C).** Mutualistic relationships are good for both parties (+ +). The cowbirds are being raised by the oropendulas (which have no genetic stake in cowbirds), which is positive for them. The oropendulas are being helped by the cowbirds as they rid them of their parasites.
67. **The correct answer is (B).** The cowbirds prey on the blowflies.
68. **The correct answer is (D).** Competition relationships are bad for both parties (––). The cowbird parents are wasting their resources as they lay in the discriminating nests, and the oropendulas are wasting their resources as they have less space and take time and energy to remove the cowbirds. It can't be predation because one would have to eat the other.
69. **The correct answer is (C).** Level D is producers. Organisms in level B obtain food directly from level C. Level A contains the largest consumer in the pyramid.
70. **The correct answer is (A).** Since poisons build up in the tissues of organisms in the food chain, and since each successive trophic level feeds on the one beneath it, most nonbiodegradable poisons will be found in the organisms at the top of the food chain.

71. The correct answer is (E). Biotic factors include symbiotic relationships, disease, mimicry, food, and the like.

72. The correct answer is (D). Education is the key to preserving the biosphere and is required for good decision making.

73. The correct answer is (A). A population must be a particular group of like individuals in a particular place at a particular time.

74. The correct answer is (B). Populations that are competitors either coexist or one goes extinct. This coextinction can take several forms, including resource partitioning, or character displacement.

75. The correct answer is (E). Predators cannot outnumber prey in normal situations. In this case, the predators and pathogen would both have to have switched to another prey or host species when population A crashed.

76. The correct answer is (A). All other effects would decrease the number of woodchucks and, therefore, reduce competition.

77. The correct answer is (E). As *N* approaches *K*, the numerator will become smaller.

78. The correct answer is (D). Batesian mimicry has the mimic fooling the predator (signal receiver) by mimicking an undesirable model.

79. The correct answer is (E). The world's human population is causing most of the other items in the list.

80. The correct answer is (E). This is especially true for keystone predators.

BIOLOGY-M TEST

81. The correct answer is (B). The table is mRNA codons, therefore the DNA that would be complementary to C-G-A would be G-C-T using Watson-Crick base-pairing rules (A with T and G with C).

82. The correct answer is (A). Phenylalanine is the amino acid attached to the tRNA molecule with AAA as its anticodon. Using Watson-Crick base-pairing rules, U bonds with A. Because anticodons are complementary to mRNA codons, which are complementary to DNA triplets, the anticodons are essentially the DNA triplet sequence, with the exception that uracil (U) is the RNA base that substitutes for thymine (T).

83. The correct answer is (E). DNA polymerase exists in three different forms in eukaryotic cells and performs all those functions as well as adding nucleotides to the lagging strand.

84. **The correct answer is (C).** The initiator tRNA is in the P site. The large portion of the ribosome joins after the initiator tRNA is docked on the mRNA with the small ribosomal subunit.

85. **The correct answer is (C).** Signal sequences are used to code for polypeptides that will be attracted to receptor sites on organelles.

86. **The correct answer is (D).** Agarose is the gel matrix normally used to separate DNA, while polyacrylamide is used for proteins.

87. **The correct answer is (B).** The original transfer of DNA from agarose gel to nitrocellulose or paper was named after its originator, Southern. The Northern blot, which uses RNA, is a take-off on both the procedure and his name. Western blots use proteins.

88. **The correct answer is (E).** Uracil is the only nucleotide found in RNA but not in DNA.

89. **The correct answer is (D).** Snurps are small nuclear riboproteins. When combined with other proteins, they form the spliceosome.

90. **The correct answer is (D).** Hydrogen ions are normally concentrated in either the thylakoid space in chloroplasts or the inner membrane space in mitochondria by the electromotive force of electron transport and transfer. He mimicked this action by using different acidic conditions, causing the hydrogen ions to flow from inside (placed there by a pH 4 solution) to the outside (moved to a pH 8 solution).

91. **The correct answer is (B).** Retroviruses carry RNA as their nucleic acid component. In order to successfully infect a cell, they must (reverse) transcribe their RNA to DNA.

92. **The correct answer is (D).** PTH controls calcium ions levels in the body by either having them conserved in the intestine or not passed in urine or by removing calcium from the bones.

93. **The correct answer is (D).** Oxygen serves as the final electron and hydrogen acceptor to form water. The end goal of cellular respiration and oxidative phosphorylation is the production of ATP.

94. **The correct answer is (C).** While both types have some peptidoglycan, the gram negative bacteria have less and are covered with a liposaccharide layer.

95. **The correct answer is (D).** Every 4,000 years, the amount is reduced by half.

96. **The correct answer is (E).** Cancer usually results from cells that handle signaling incorrectly. The analogy of overreactive cell division being like an accelerator in a car and improper control

of cell division being poor brakes was put forth by Bishop and Varmus. Physiologically, the acceleration problems could be the overproduction of cell division signals or oversensitive receptors, perhaps locked in the on position.

97. **The correct answer is (B).** Sticky ends are the uneven ends of a strand that will base pair with sticky ends of another strand. For example,

GATTCNNNNNNNN....
NNNNNNN....

would base pair with another strand

NNNNCTAAG
NNNN

98. **The correct answer is (B).** Meselson-Stahl came later and proved the semiconservative nature of the replication of DNA.

99. **The correct answer is (D).** Proteins that are produced in the ER are sent to the Golgi for modifications.

100. **The correct answer is (C).** Oxygen is given off as water molecules are split.

ANSWER SHEETS

Leave any unused answer spaces blank.

Test Code										
V		1	2	3	4	5	6	7	8	9
W		1	2	3	4	5	6	7	8	9
X	1	2	3	4	5	Y	A	B	C	D	E
Q		1	2	3	4	5	6	7	8	9

Subject Test (print)					
FOR ETS USE ONLY	R/C	W/S1	FS/S2	CS/S3	WS

1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	21 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	41 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	61 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	81 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	22 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	42 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	62 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	82 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
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7 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	27 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	47 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	67 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	87 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
8 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	28 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	48 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	68 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	88 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
9 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	29 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	49 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	69 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	89 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
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12 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	32 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	52 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	72 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	92 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
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14 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	34 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	54 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	74 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	94 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
15 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	35 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	55 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	75 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	95 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
16 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	36 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	56 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	76 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	96 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
17 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	37 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	57 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	77 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	97 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
18 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	38 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	58 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	78 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	98 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
19 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	39 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	59 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	79 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	99 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
20 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	40 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	60 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	80 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	100 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

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Test Code											
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Subject Test (print)					
FOR ETS USE ONLY	R/C	W/S1	FS/S2	CS/S3	WS

1	A B C D E	21	A B C D E	41	A B C D E	61	A B C D E	81	A B C D E
2	A B C D E	22	A B C D E	42	A B C D E	62	A B C D E	82	A B C D E
3	A B C D E	23	A B C D E	43	A B C D E	63	A B C D E	83	A B C D E
4	A B C D E	24	A B C D E	44	A B C D E	64	A B C D E	84	A B C D E
5	A B C D E	25	A B C D E	45	A B C D E	65	A B C D E	85	A B C D E
6	A B C D E	26	A B C D E	46	A B C D E	66	A B C D E	86	A B C D E
7	A B C D E	27	A B C D E	47	A B C D E	67	A B C D E	87	A B C D E
8	A B C D E	28	A B C D E	48	A B C D E	68	A B C D E	88	A B C D E
9	A B C D E	29	A B C D E	49	A B C D E	69	A B C D E	89	A B C D E
10	A B C D E	30	A B C D E	50	A B C D E	70	A B C D E	90	A B C D E
11	A B C D E	31	A B C D E	51	A B C D E	71	A B C D E	91	A B C D E
12	A B C D E	32	A B C D E	52	A B C D E	72	A B C D E	92	A B C D E
13	A B C D E	33	A B C D E	53	A B C D E	73	A B C D E	93	A B C D E
14	A B C D E	34	A B C D E	54	A B C D E	74	A B C D E	94	A B C D E
15	A B C D E	35	A B C D E	55	A B C D E	75	A B C D E	95	A B C D E
16	A B C D E	36	A B C D E	56	A B C D E	76	A B C D E	96	A B C D E
17	A B C D E	37	A B C D E	57	A B C D E	77	A B C D E	97	A B C D E
18	A B C D E	38	A B C D E	58	A B C D E	78	A B C D E	98	A B C D E
19	A B C D E	39	A B C D E	59	A B C D E	79	A B C D E	99	A B C D E
20	A B C D E	40	A B C D E	60	A B C D E	80	A B C D E	100	A B C D E

Leave any unused answer spaces blank.

Test Code											
V		1	2	3	4	5	6	7	8	9	
W		1	2	3	4	5	6	7	8	9	
X	1	2	3	4	5	Y	A	B	C	D	E
Q		1	2	3	4	5	6	7	8	9	

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13	A B C D E	33	A B C D E	53	A B C D E	73	A B C D E	93	A B C D E
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16	A B C D E	36	A B C D E	56	A B C D E	76	A B C D E	96	A B C D E
17	A B C D E	37	A B C D E	57	A B C D E	77	A B C D E	97	A B C D E
18	A B C D E	38	A B C D E	58	A B C D E	78	A B C D E	98	A B C D E
19	A B C D E	39	A B C D E	59	A B C D E	79	A B C D E	99	A B C D E
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X	1	2	3	4	5	Y	A	B	C	D	E
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