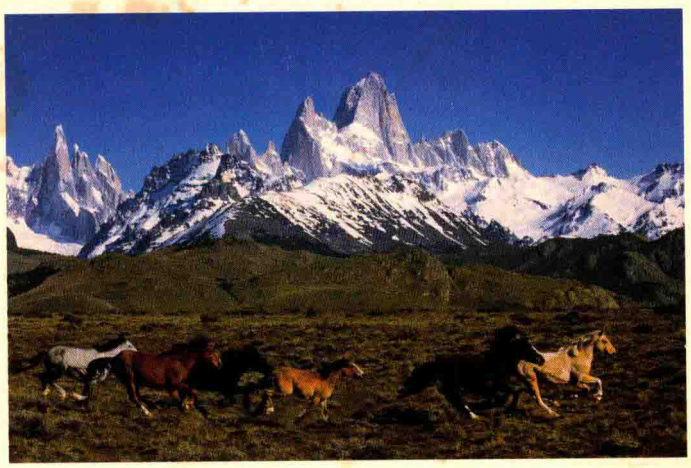
BIOLOGY

Fourth Edition

Sylvia S. Mader

BIOLOGY



Wild horses gallop across the Patagonian plains of South America's Argentine coast at the foot of the Fitzroy Mountains. In 1832, Charles Darwin came here aboard the HMS Beagle, captained by Robert Fitzroy. During his 5-year, around-the-world voyage on the Beagle, Darwin gathered data that would later support his theory of evolution.

Much has been learned since Darwin's day about the 65-million-year evolution of the horse, which began with a much smaller ancestor that had many toes and teeth with low crowns. As grasslands replaced a forestlike environment, the horse evolved into a much larger animal with fewer toes and teeth with high crowns. Today, the horse has only one toe and is highly adapted for running fast and far, allowing it to seek new sources of food and water when needed.

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Kevin Kane
Executive Editor
Life Sciences

BRIEF CONTENTS

READINGS

BOXED READINGS OF GENERAL INTEREST

HOW DO YOU DO THAT?

THE BIOLOGY LEARNING SYSTEM

3

Basic Chemistry

A hippopotamus keeps cool by remaining in water. Water has many biological functions, both without and within organisms. Cells are largely composed of this inorganic molecule, which facilitates chemical reactions and helps maintain a normal body temperature because it is slow to heat.

Your study of this chapter will be complete when you can

1. name and describe the subatomic particles of an atom, indicating which one accounts for the occurrence of isotopes;
2. describe and discuss the energy levels (electron shells) of an atom, including the orbitals of the first 2 levels;
3. draw a simplified atomic structure of any atom with an atomic number less than 20;
4. distinguish between ionic and covalent reactions, and draw representative atomic structures for ionic and covalent molecules;
5. tell which atom has been reduced and which has been oxidized in a particular reaction;
6. describe the chemical properties of water, and explain their importance for living things;
7. define an acid and a base; describe the pH scale, and state the significance of buffers.

24

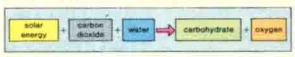
Behavioral Objectives

Each chapter begins with a list of behavioral objectives designed to help students identify the major concepts of the chapter. Their study of the chapter is complete when they can satisfy these objectives.

Text Line Art

Graphic diagrams placed within textual passages help clarify difficult concepts and enhance learning.

HAVE YOU THANKED A GREEN PLANT TODAY? Plants dominate our environment, but most of us spend little time thinking about the various services they perform for us and for all living things. Chief among these is their ability to carry on photosynthesis, during which they use sunlight (*photo*) as a source of solar energy to produce food (*synthesis*):



Other organisms, called algae, are also photosynthetic. Algae (chap. 24) are a diverse group, but many are water dwelling, microscopic organisms related to plants.

The organic food produced by photosynthesis is not only used by plants themselves, it is also the ultimate source of food for all other living things (fig. 8.1). Also, when organisms convert carbohydrate energy into ATP energy they make use of the oxygen (O_2) given off by photosynthesis. Nearly all living things are dependent on atmospheric oxygen derived from photosynthesis.

At one time in the distant past, plant and animal matter accumulated without decomposing. This matter became the fossil fuels (e.g., coal, oil, and gas) that we burn today for energy. This source of energy, too, is the product of photosynthesis.

Photosynthesis is absolutely essential for the continuance of life because it is the source of food and oxygen for nearly all living things.

Sunlight

Photosynthesis is an energy transformation in which solar energy in the form of light is converted to chemical energy within carbohydrate molecules. Therefore, we will begin our discussion of photosynthesis with the energy source—sunlight.

Solar radiation can be described in terms of its energy content and its wavelength. The energy comes in discrete packets called **photons.** So, in other words, you can think of radiation as photons that travel in waves:

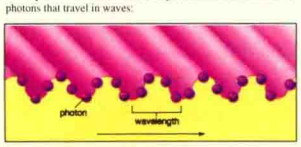


Figure 8.2*a* illustrates that solar radiation, or the **electromagnetic spectrum,** can be divided on the basis of wavelength—gamma rays have the shortest wavelength and radio waves have the longest wavelength. The energy content of photons is inversely proportional to the wavelength of the particular type of radiation; that is, short-wavelength radiation has photons of a higher energy content than long-wavelength radiation. High-energy photons, such as those of short-wavelength ultraviolet radiation, are dangerous to cells because they can break down organic molecules. Low-energy photons, such as those of infrared radiation, do not damage cells because they only increase the vibrational or rotational energy of molecules; they do not break bonds. But photosynthesis utilizes only the portion of the electromagnetic spectrum known as **visible light.** (It is called visible light because it is the part of the spectrum that allows us to see.) Photons of visible light have just the right amount of energy to promote electrons to a higher electron shell in atoms without harming cells.

We have mentioned previously that only about 42% of the solar radiation that hits the earth's atmosphere ever reaches the surface, and most of this radiation is within the visible-light range.

Figure 8.1
This squirrel is a herbivore. It feeds directly on plant material produced by a photosynthesizer. Carnivores, such as a hawk that may feed on this squirrel, are also dependent, although indirectly, on food produced by photosynthesizers.

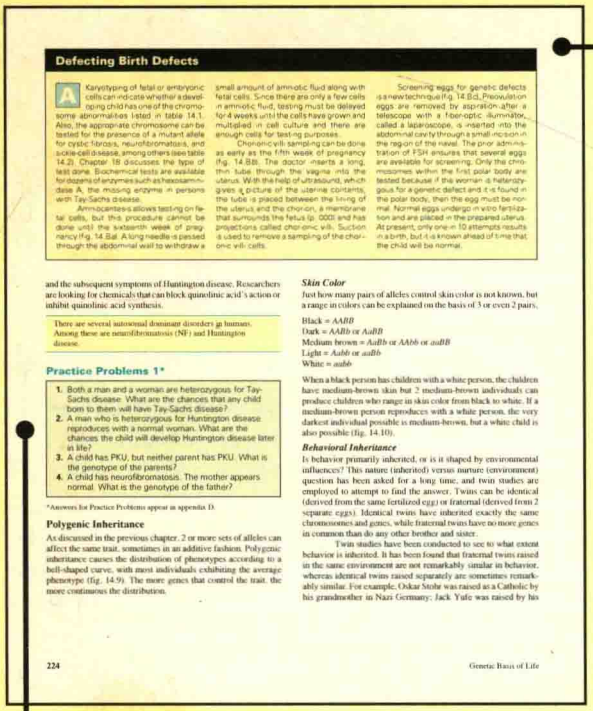
122 The Cell

Concept Summaries

At the ends of major sections within each chapter, concept summaries briefly highlight key concepts in the section, helping students focus their study efforts on the basics.

Bold-Faced Key Terms

Important terms are boldfaced and defined on first mention.



Defecting Birth Defects

Karyotyping of fetal or embryonic cells can indicate whether a developing child has one of the chromosome abnormalities listed in table 14.1. Also, the appropriate chromosome can be tested for the presence of a mutant allele for cystic fibrosis, neurofibromatosis, and sickle-cell disease, among others (see table 14.2). Chapter 18 discusses the type of test done. Biochemical tests are available for dozens of enzymes such as hexosaminidase A, the missing enzyme in persons with Tay-Sachs disease.

Amniocentesis allows testing on fetal cells, but this procedure cannot be done until the sixteenth week of pregnancy (fig. 14.8a). A long needle is passed through the abdominal wall to withdraw a small amount of amniotic fluid along with fetal cells. Since there are only a few cells in amniotic fluid, testing must be delayed for 4 weeks until the cells have grown and multiplied in cell culture and there are enough cells for testing purposes.

Chorionic villi sampling can be done as early as the fifth week of pregnancy (fig. 14.8b). The doctor inserts a long, thin tube through the vagina into the uterus. With the help of ultrasound, which gives a picture of the uterine contents, the tube is placed between the lining of the uterus and the chorion, a membrane that surrounds the fetus (p. 000) and has projections called chorionic villi. Suction is used to remove a sampling of the chorionic villi cells.

Screening eggs for genetic defects is a new technique (fig. 14.8c). Presolution eggs are removed by aspiration after a telescope with a fiber-optic illuminator, called a laparoscope, is inserted into the abdominal cavity through a small incision in the region of the navel. The prior administration of FSH ensures that several eggs are available for removal. Only the chromosomes within the first polar body are tested because if the woman is heterozygous for a genetic defect and it is found in the polar body, then the egg must be normal. Normal eggs undergo in vitro fertilization and are placed in the woman's uterus. At present, only one in 10 attempts results in a birth, but it is known ahead of time that the child will be normal.

and the subsequent symptoms of Huntington disease. Researchers are looking for chemicals that can block quinolinic acid's action or inhibit quinolinic acid synthesis.

There are several autosomal dominant disorders in humans. Among these are neurofibromatosis (NF) and Huntington disease.

Practice Problems 1*

1. Both a man and a woman are heterozygous for Tay-Sachs disease. What are the chances that any child born to them will have Tay-Sachs disease?
2. A man who is heterozygous for Huntington disease reproduces with a normal woman. What are the chances the child will develop Huntington disease later in life?
3. A child has PKU, but neither parent has PKU. What is the genotype of the parents?
4. A child has neurofibromatosis. The mother appears normal. What is the genotype of the father?

*Answers for Practice Problems appear in appendix D.

Polygenic Inheritance

As discussed in the previous chapter, 2 or more sets of alleles can affect the same trait, sometimes in an additive fashion. Polygenic inheritance causes the distribution of phenotypes according to a bell-shaped curve, with most individuals exhibiting the average phenotype (fig. 14.9). The more genes that control the trait, the more continuous the distribution.

Skin Color

Just how many pairs of alleles control skin color is not known, but a range in colors can be explained on the basis of 3 or even 2 pairs.

Black = *AABB*
Dark = *AABb* or *AaBB*
Medium brown = *AaBb* or *AAbb* or *aaBB*
Light = *Aabb* or *aaBb*
White = *aabb*

When a black person has children with a white person, the children have medium-brown skin but 2 medium-brown individuals can produce children who range in skin color from black to white. If a medium-brown person reproduces with a white person, the very darkest individual possible is medium-brown, but a white child is also possible (fig. 14.10).

Behavioral Inheritance

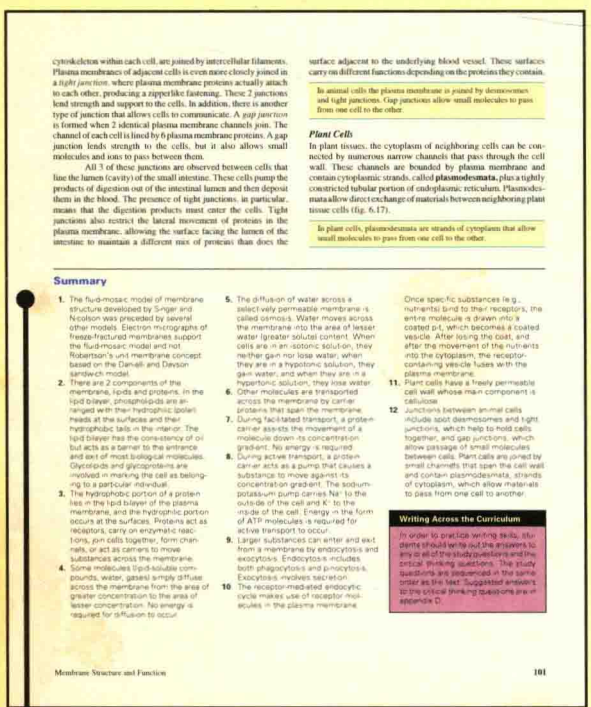
Is behavior primarily inherited, or is it shaped by environmental influences? This nature (inherited) versus nurture (environment) question has been asked for a long time, and twin studies are employed to attempt to find the answer. Twins can be identical (derived from the same fertilized egg) or fraternal (derived from 2 separate eggs). Identical twins have inherited exactly the same chromosomes and genes, while fraternal twins have no more genes in common than do any other brother and sister.

Twin studies have been conducted to see to what extent behavior is inherited. It has been found that fraternal twins raised in the same environment are not remarkably similar in behavior, whereas identical twins raised separately are sometimes remarkably similar. For example, Oskar Stohr was raised as a Catholic by his grandmother in Nazi Germany; Jack Yufe was raised by his

224 Genetic Basis of Life

Practice Problems

Practice problems at the end of passages in the genetics chapters help students master basic genetic quantifications. Answers to these problems are in appendix D.



cytoskeleton within each cell, are joined by intercellular filaments. Plasma membranes of adjacent cells is even more closely joined in a *tight junction*, where plasma membrane proteins actually attach to each other, producing a zipperlike fastening. These 2 junctions lend strength and support to the cells. In addition, there is another type of junction that allows cells to communicate. A *gap junction* is formed when 2 identical plasma membrane channels join. The channel of each cell is lined by 6 plasma membrane proteins. A gap junction lends strength to the cells, but it also allows small molecules and ions to pass between them.

All 3 of these junctions are observed between cells that line the lumen (cavity) of the small intestine. These cells pump the products of digestion out of the intestinal lumen and then deposit them in the blood. The presence of tight junctions, in particular, means that the digestion products must enter the cells. Tight junctions also restrict the lateral movement of proteins in the plasma membrane, allowing the surface facing the lumen of the intestine to maintain a different mix of proteins than does the surface adjacent to the underlying blood vessel. These surfaces carry on different functions depending on the proteins they contain.

In animal cells the plasma membrane is joined by desmosomes and tight junctions. Gap junctions allow small molecules to pass from one cell to the other.

Plant Cells

In plant tissues, the cytoplasm of neighboring cells can be connected by numerous narrow channels that pass through the cell wall. These channels are bounded by plasma membrane and contain cytoplasmic strands, called **plasmodesmata**, plus a tightly constricted tubular portion of endoplasmic reticulum. Plasmodesmata allow direct exchange of materials between neighboring plant tissue cells (fig. 6.17).

In plant cells, plasmodesmata are strands of cytoplasm that allow small molecules to pass from one cell to the other.

Summary

1. The fluid-mosaic model of membrane structure developed by Singer and Nicolson was preceded by several other models. Electron micrographs of freeze-fractured membranes support the fluid-mosaic model and not Robertson's unit membrane concept based on the Danielli and Davson sandwich model.
2. There are 2 components of the membrane, lipids and proteins. In the lipid bilayer, phospholipids are arranged with their hydrophilic (polar) heads at the surfaces and their hydrophobic tails in the interior. The lipid bilayer has the consistency of oil but acts as a barrier to the entrance and exit of most biological molecules. Glycolipids and glycoproteins are involved in marking the cell as belonging to a particular individual.
3. The hydrophobic portion of a protein lies in the lipid bilayer of the plasma membrane, and the hydrophilic portion occurs at the surfaces. Proteins act as receptors, carry on enzymatic reactions, join cells together, form channels, or act as carriers to move substances across the membrane.
4. Some molecules (lipid-soluble compounds, water, gases) simply diffuse across the membrane from the area of greater concentration to the area of lesser concentration. No energy is required for diffusion to occur.
5. The diffusion of water across a selectively permeable membrane is called osmosis. Water moves across the membrane into the area of lesser water (greater solute) content. When cells are in isotonic solution, they neither gain nor lose water; when they are in a hypotonic solution, they gain water; and when they are in a hypertonic solution, they lose water.
6. Other molecules are transported across the membrane by carrier proteins that span the membrane.
7. During facilitated transport, a protein carrier assists the movement of a molecule down its concentration gradient. No energy is required.
8. During active transport, a protein carrier acts as a pump that causes a substance to move against its concentration gradient. The sodium-potassium pump carries Na^+ to the outside of the cell and K^+ to the inside of the cell. Energy in the form of ATP molecules is required for active transport to occur.
9. Larger substances can enter and exit from a membrane by endocytosis and exocytosis. Endocytosis includes both phagocytosis and pinocytosis. Exocytosis involves secretion.
10. The receptor-mediated endocytic cycle makes use of receptor molecules in the plasma membrane. Once specific substances (e.g., nutrients) bind to their receptors, the entire molecule is drawn into a coated pit, which becomes a coated vesicle. After losing the coat, and after the movement of the nutrients into the cytoplasm, the receptor-containing vesicle fuses with the plasma membrane.
11. Plant cells have a freely permeable cell wall whose main component is cellulose.
12. Junctions between animal cells include spot desmosomes and tight junctions, which help to hold cells together, and gap junctions, which allow passage of small molecules between cells. Plant cells are joined by small channels that span the cell wall and contain plasmodesmata, strands of cytoplasm, which allow materials to pass from one cell to another.

Writing Across the Curriculum

In order to practice writing skills, students should write out the answers to any or all of the study questions and the critical thinking questions. The study questions are sequenced in the same order as the text. Suggested answers to the critical thinking questions are in appendix D.

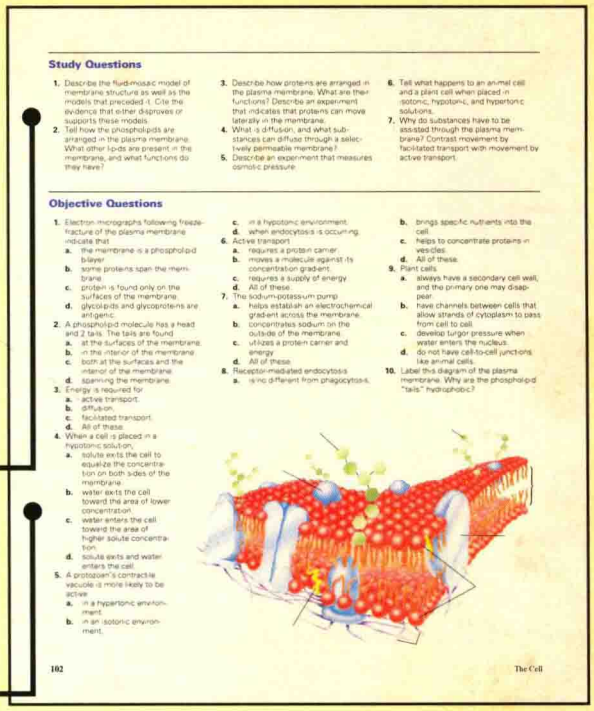
Membrane Structure and Function 101

Chapter Summaries

At the end of each chapter is a summary. This listing of important points should help students more readily identify important concepts and better facilitate their learning of chapter content.

Readings

Throughout *Biology*, selected readings reinforce major concepts in the book. Most readings are written by the author, but a few are excerpted from popular magazines. A reading may provide insight into the process of science or show how a particular kind of scientific knowledge is applicable to the students' everyday lives.



Study Questions

1. Describe the fluid-mosaic model of membrane structure as well as the models that preceded it. Cite the evidence that either disproves or supports these models.
2. Tell how the phospholipids are arranged in the plasma membrane. What other lipids are present in the membrane, and what functions do they have?
3. Describe how proteins are arranged in the plasma membrane. What are their functions? Describe an experiment that indicates that proteins can move laterally in the membrane.
4. What is diffusion, and what substances can diffuse through a selectively permeable membrane?
5. Describe an experiment that measures osmotic pressure.
6. Tell what happens to an animal cell and a plant cell when placed in isotonic, hypotonic, and hypertonic solutions.
7. Why do substances have to be assisted through the plasma membrane? Contrast movement by facilitated transport with movement by active transport.

Objective Questions

1. Electron micrographs following freeze-fracture of the plasma membrane indicate that
   a. the membrane is a phospholipid bilayer.
   b. some proteins span the membrane.
   c. protein is found only on the surfaces of the membrane.
   d. glycolipids and glycoproteins are antigenic.
2. A phospholipid molecule has a head and 2 tails. The tails are found
   a. at the surfaces of the membrane.
   b. in the interior of the membrane.
   c. both at the surfaces and the interior of the membrane.
   d. spanning the membrane.
3. Energy is required for
   a. active transport.
   b. diffusion.
   c. facilitated transport.
   d. All of these.
4. When a cell is placed in a hypotonic solution,
   a. solute exits the cell to equalize the concentration on both sides of the membrane.
   b. water exits the cell toward the area of lower concentration.
   c. water enters the cell toward the area of higher solute concentration.
   d. solute exits and water enters the cell.
5. A protozoan's contractile vacuole is more likely to be active
   a. in a hypertonic environment.
   b. in an isotonic environment.
   c. in a hypotonic environment.
   d. when endocytosis is occurring.
6. Active transport
   a. requires a protein carrier.
   b. moves a molecule against its concentration gradient.
   c. requires a supply of energy.
   d. All of these.
7. The sodium-potassium pump
   a. helps establish an electrochemical gradient across the membrane.
   b. concentrates sodium on the outside of the membrane.
   c. utilizes a protein carrier and energy.
   d. All of these.
8. Receptor-mediated endocytosis
   a. is no different from phagocytosis.
   b. brings specific nutrients into the cell.
   c. helps to concentrate proteins in vesicles.
   d. All of these.
9. Plant cells
   a. always have a secondary cell wall, and the primary one may disappear.
   b. have channels between cells that allow strands of cytoplasm to pass from cell to cell.
   c. develop turgor pressure when water enters the nucleus.
   d. do not have cell-to-cell junctions like animal cells.
10. Label this diagram of the plasma membrane. Why are the phospholipid "tails" hydrophobic?

102 The Cell

Study Questions

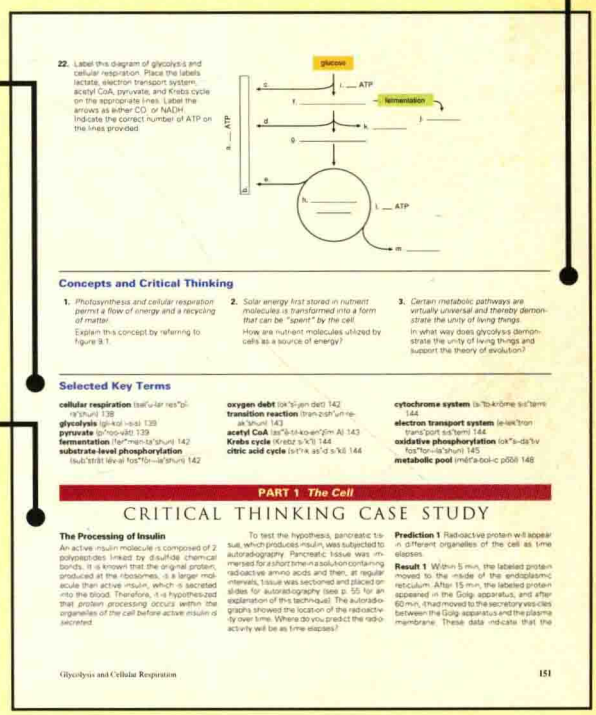
These questions appear at the end of each chapter. They call for specific, short essay answers that challenge students' mastery of the chapter's basic concepts.

Objective Questions

Multiple-choice questions at the end of each chapter test basic recall of the chapter's key points. The answers to the objective questions are listed in appendix D.

Concepts and Critical Thinking

These end-of-chapter questions require students to apply the chapter's basic concepts to biological concerns. Writing the answers to these or the Study Questions fulfills any Writing-Across-the-Curriculum requirement.



22. Label this diagram of glycolysis and cellular respiration. Place the labels lactate, electron transport system, acetyl CoA, pyruvate, and Krebs cycle on the appropriate lines. Label the arrows as either CO_2 or NADH. Indicate the correct number of ATP on the lines provided.

glucose
fermentation
a. ___ ATP
c. ___ ATP
h. ___ ATP

Concepts and Critical Thinking

1. *Photosynthesis and cellular respiration permit a flow of energy and a recycling of matter.*
   Explain this concept by referring to figure 9.1.
2. *Solar energy first stored in nutrient molecules is transformed into a form that can be "spent" by the cell.*
   How are nutrient molecules utilized by cells as a source of energy?
3. *Certain metabolic pathways are virtually universal and thereby demonstrate the unity of living things.*
   In what way does glycolysis demonstrate the unity of living things and support the theory of evolution?

Selected Key Terms

cellular respiration (sel'yū-lar res"pi-rā'shun) 138
glycolysis (glī-kol'i-sis) 139
pyruvate (pī'rō-vāt) 139
fermentation (fer"men-tā'shun) 142
substrate-level phosphorylation (sub'strāt lēv'el fos"fōr-i-lā'shun) 142
oxygen debt (ok'si-jen det) 142
transition reaction (tran-zish'un re-ak'shun) 143
acetyl CoA (as'ē-til-kō-en'zīm A) 143
Krebs cycle (Krebz sī'kl) 144
citric acid cycle (sit'rik as'id sī'kl) 144
cytochrome system (sī'tō-krōme sis'tem) 144
electron transport system (e-lek'tron trans'port sis'tem) 144
oxidative phosphorylation (ok"si-dā'tiv fos"fōr-i-lā'shun) 145
metabolic pool (met'a-bol-ic pōōl) 148

PART 1 *The Cell*

CRITICAL THINKING CASE STUDY

The Processing of Insulin

An active insulin molecule is composed of 2 polypeptides linked by disulfide chemical bonds. It is known that the original protein, produced at the ribosomes, is a larger molecule (not active insulin, which is secreted into the blood. Therefore, it is hypothesized that protein processing occurs within the organelles of the cell before active insulin is secreted.

To test the hypothesis, pancreatic tissue, which produces insulin, was subjected to autoradiography. Pancreatic tissue was immersed for a short time in a solution containing radioactive amino acids and then, at regular intervals, tissue was sectioned and placed on slides for autoradiography (see p. 55 for an explanation of this technique). The autoradiographs showed the location of the radioactivity over time. Where do you predict the radioactivity will be as time elapses?

Prediction 1 Radioactive protein will appear in different organelles of the cell as time elapses.

Result 1 Within 5 min, the labeled protein moved to the inside of the endoplasmic reticulum. After 15 min, the labeled protein appeared in the Golgi apparatus, and after 60 min, it had moved to the secretory vesicles between the Golgi apparatus and the plasma membrane. These data indicate that the

Glycolysis and Cellular Respiration 151

Selected Key Terms

A selected list of boldfaced, key terms from the chapter appears at the end of each chapter. Each term is accompanied by its phonetic spelling and a page number indicating where the term is introduced and defined in the chapter.

Critical Thinking Case Studies

Each part ends with a case study designed to help students think critically by participating in the process of science. At many institutions, instructors are encouraged to develop the writing skills of their students. In such cases, instructors could require students to write out their answers to the questions in each case study. Suggested answers for each of these questions appear in the Instructor's Manual for the text.

Further Readings

A list of readings at the end of each part suggests references that can be used for further study of topics covered in the chapters of that part. The items listed in this section were carefully chosen for readability and accessibility.

PREFACE

Biology is an introductory college text that covers the basic concepts and principles of general biology. While the text is clear and straightforward enough to be read by liberal arts students, it is also comprehensive and authoritative, so it can just as easily be read by science majors. The text strives to use other forms of life, in addition to humans, as examples, making frequent reference to plants and invertebrates. The text takes a hierarchical approach, proceeding from the chemistry of the cell up to the organization of the biosphere.

Science Process and Critical Thinking

Biology stresses the process of science in many ways. Chapter 2 is entirely devoted to describing the scientific method with examples. And throughout the text, experiments that have led us to our present level of knowledge are described. *New to this edition are the "How Do You Do That?" boxes, which help to emphasize technological literacy.* The boxes are meant to take the mystery out of laboratory procedures and show students that everyone is capable of utilizing the methods by which data are collected.

Understanding the concepts of biology and engaging in the process of science encourages one to think critically. *New to this edition, each chapter ends with a list of the major concepts within the chapter and asks critical thinking questions based on those concepts.* Those questions allow students to see that thinking conceptually leads to predictions and deductions concerning particular aspects of biology. Suggested answers to the end-of-chapter critical thinking questions appear in appendix D. Each major part in the text ends with a critical thinking case study. As before, the case studies were written by Dr. Robert Allen and myself. They provide students with an opportunity to use scientific methodology as they think critically. Suggested answers to the case study questions appear in the Instructor's Manual for the text.

Writing Across the Curriculum

Students need a chance to practice their writing skills and at the same time test their ability to fulfill the behavioral objectives that begin each chapter. *This is provided by the "Writing Across the Curriculum Study Questions" at the close of the chapter,* which is based on an educational approach to improving the skills of students. Instructors who have their students write out the answers to the study questions and critical thinking questions will have answered the challenge of this new approach.

The objective questions prepare students to take examinations that contain recall-based questions. These, too, have been improved, and instructors will appreciate the addition of questions that require students to complete and/or label diagrams.

Organization of the Text

Each chapter in *Biology* introduces particular concepts and describes biological experiments that have contributed to our present level of knowledge. As in the third edition, the chapters are of a suitable length to be read in one sitting. *A new chapter on animal organization and homeostasis has been added to part 5.* This chapter includes a discussion of animal tissues. The text has the following parts, which have been revised as discussed.

Introduction

Chapter 1, which concerns the characteristics of life and introduces important biological concepts, was completely rewritten to increase student interest. The chapter shows that the unity of life is due to descent from a common ancestor and that diversity is due to adaptations to particular ways of life in an ecosystem.

Chapter 2 thoroughly explains scientific methods and gives examples of both experimental and observational biological research. The biological understanding of the word *theory* is also fully explained.

Part 1 The Cell

Part 1 concerns cell structure and function including energy metabolism. *Membrane protein diversity is more thoroughly discussed and illustrated in this edition.* The first of the 3 chapters devoted to energetics gives an overview. Instructors can use just this one chapter or proceed on to cellular respiration and/or photosynthesis.

Part 2 Genetic Basis of Life

There is a strong historical emphasis in this part, but practical aspects are not neglected. Students are given an opportunity to test their ability to do problems as they proceed. New advances in the field of genetics appear daily, and this part has been thoroughly updated to reflect our changing knowledge. *The very latest that is known about human genetic disorders is included. The biotechnology chapter includes a discussion of new techniques in gene therapy in humans and the human genome project.* The presentation is at an appropriate level for the beginning student.

Part 3 Evolution and Diversity

The evolution chapters were completely reorganized and rewritten with the valuable help of many instructors and scholars who specialize in this area. The geological time scale was completely updated. Chapter 22, concerning the origin of life, was also rewritten and now includes several hypotheses on this topic. The diversity chapters were revised and the most up-to-date classification system is used. Instructors will appreciate a new expanded table that compares the major features of the plant divisions.

Part 4 Plant Structure and Function

Four chapters are devoted to flowering plant anatomy and physiology. The first chapter provides a foundation for the others on nutrition and transport, reproduction, and growth and development.

Part 5 Animal Structure and Function

This part begins with a new chapter on animal organization and homeostasis. There is a discussion of animal tissues and organ systems before homeostasis is discussed in some detail. *The comparative section that begins each of the animal physiology chapters has been rewritten for clarity and improvement. A new extended section on AIDS is included in the reproduction chapter.*

Part 6 Behavior and Ecology

A new animal behavior chapter takes a more modern approach to this topic. The ecology chapters have a logical sequence from populations to communities to the biosphere. Environmental concerns are emphasized in the last 2 chapters. Some instructors may wish to begin the year's work with this part, which is certainly a workable alternative.

Aids to the Reader

Biology was written so that students can enjoy, appreciate, and come to understand the concepts of biology and the scientific process. The following text features are especially designed to assist student learning.

Text Introduction

The introduction section (chapters 1 and 2) lays a foundation upon which the rest of the text depends. The first chapter reviews the characteristics of life and presents the fundamental concepts of biology. The second chapter explains the scientific process in detail and gives examples of studies done by biologists. Various other experiments are described throughout the text.

Study Objectives

Each chapter begins with a list of objectives designed to guide students as they study the chapter. Their study of the chapter is complete when they can satisfy these objectives, therefore, they help students prepare for an examination.

Boxed Readings

Throughout *Biology,* selected boxed readings reinforce major concepts in the book. Most readings are of general interest and heighten student involvement by expanding on a topic discussed in the chapter.

"How Do You Do That?" Boxes

New to this edition are the "How Do You Do That?" boxes, which describe laboratory methods. They are designed to take the mystery out of the manner in which biological data are collected.

Drawings, Photographs, and Tables

The drawings, photographs, and tables in *Biology* have been designed to help students learn basic biological concepts as well as the specific content of the chapters, and are consistent with multicultural educational goals. Often it is easier to understand a given process by studying a drawing, especially when it is carefully coordinated with the text, as is the case here. The photographs were selected not only to please the eye but also to emphasize specific points in the text. The tables summarize and list important information, making it readily available for efficient study.

Chapter Summaries

The summary is a numbered series of statements that follow the organization of the chapter. The summary helps students identify the concepts of the chapter and facilitates their learning of chapter content.

Chapter Questions

Three kinds of questions—study questions, objective questions, and critical thinking questions—appear at the close of each chapter. They allow students to test their ability to fulfill the study objectives. *Writing across the curriculum* recognizes that students need an opportunity to practice writing in all courses. The study questions review the chapter, and their sequence follows that of the chapter. When students write out the answers to the study questions, they are writing while studying biology. The critical thinking questions are based on biological concepts that pertain to the chapter. They show that knowledge of a biological concept allows one to reason about some particular aspect of biology. Writing out the answers to the critical thinking questions also fulfills any writing across the curriculum requirements. The objective questions allow students to test their ability to answer recall-based, multiple choice questions. The objective questions have been

expanded in this edition to include questions that require the completing or labeling of diagrams. Answers to the objective questions and critical thinking questions appear in appendix D.

Selected Key Terms

Each chapter ends with a selected key term list. Key terms are boldfaced in the chapter, defined in context, and also appear in the glossary. Especially significant key terms appear in the selected key term list. Each term is accompanied by its phonetic spelling and is referenced to the page on which it is introduced and defined.

Further Readings

The list of readings at the end of each part suggests references that can be used for further study of the topics covered in the chapters of that part. The items listed in this section were carefully chosen for readability and accessibility.

Critical Thinking Case Studies

Each part ends with a case study designed to help students think critically by participating in the process of science. At many institutions, instructors are encouraged to develop the writing skills of their students. In such cases, instructors could require students to write out their answers to the questions in each case study. Suggested answers for each of these questions appear in the Instructor's Manual.

Glossary

The glossary contains the terms that are boldfaced in the text. Many of the glossary entries are accompanied by a phonetic spelling and a definition, and each is referenced to the page on which it was first introduced and defined in the text.

ADDITIONAL AIDS

Instructor's Manual/Test Item File

Revised by Jean Helgeson, the Instructor's Manual/Test Item File is designed to assist instructors as they plan and prepare for classes using *Biology*. For each chapter in the text, the Instructor's Manual provides a chapter outline, key terms, an extended lecture outline, enrichment ideas, and a listing of selected films. The Test Item File contains approximately 40 multiple choice, true/false, and critical thinking essay questions per text chapter.

Suggested answers for the critical thinking case studies that appear at the end of each part in the text are placed at the end of the corresponding parts in the Instructor's Manual.

In addition, the Instructor's Manual includes an answer key for the Critical Thinking Case Study Workbook by Robert Allen, along with listings of the transparencies and micrograph slides available to instructors using *Biology*, fourth edition.

Student Study Guide

The Student Study Guide that accompanies the text was revised by Jay Templin. For each text chapter, there is a corresponding study guide chapter that includes a list of study objectives, a chapter review, vocabulary terms that are page-referenced to the text, learning activities with text page references that correlate to the study objectives and require students to apply textual information, critical thinking questions, and chapter test questions with an answer key providing the student immediate feedback.

Micrograph Slides

A boxed set of 99 slides includes all photomicrographs and electron micrographs printed in the text.

Laboratory Manual

The Laboratory Manual that accompanies *Biology* was thoroughly revised by Kenneth Kilborn and myself. Its 34 exercises provide enough variety to meet the needs of a broad spectrum of class designs. Student aids include a list of learning objectives at the beginning of each exercise and numerous full-color illustrations throughout. Each exercise includes an introduction, and ample space is provided for students to record their observations as the lab proceeds. A laboratory review, consisting of a series of questions, ends each exercise. Answers to the review questions are provided in an appendix.

Customized Laboratory Manual

The Laboratory Manual's 34 exercises are available as individual "lab separates," so instructors can custom-tailor the manual to their particular course needs. The separates, which are published in one color, can be individually selected at a greatly reduced price and will be collated and bound by WCB on request.

Laboratory Resource Guide

Helpful and thorough information regarding each lab preparation can be found in the Laboratory Resource Guide. Completely revised by Kenneth Kilborn, the guide is designed to help instructors make the laboratory experience a more meaningful one for the student. For handy reference, a list of suppliers is printed on the inside front cover. The Resource Guide is now divided into 3 parts. They are Laboratory Preparation and Instructions; Laboratory Exercises and Expected Results; and Answers to the Laboratory Review Questions.

Transparencies and Lecture Enrichment Kit

A full set of transparency acetates also accompanies the text. These feature key illustrations from the text in both 2 and full color. They are accompanied by a Lecture Enrichment Kit, which is a set of lecture notes featuring additional high-interest information about the pictured process or concept and not presented in the text.

Critical Thinking Case Study Workbook

Written by Robert Allen, this ancillary includes 30 additional critical thinking case studies of the type found in the text. Like the text case studies, they are designed to immerse students in the "process of science" and challenge them to solve problems in the same way biologists do. The case studies here are divided into 3 levels of difficulty (introductory, intermediate, and advanced) to afford instructors greater choice and flexibility. An answer key is printed in the Instructor's Manual.

Extended Lecture Outline Software

This instructor software features extensive outlines of each text chapter with a brief synopsis of each subtopic to assist in lecture preparation. Written in ASCII files for maximum utility, it is available in IBM, Apple, or Mac formats. It is free to all adopters, upon request.

Biology Art Masters

A set of 150 art masters consisting of one-color line art with labels can be used for additional transparencies or can be copied and used for student hand-outs.

The 7 packages include the following titles: Cell Biology, Genetics, Diversity, Plant Biology, Animal Biology, Ecology and Behavior, and Evolution.

Adopters of *Biology* can order one or all 7 packages for free.

WCB TestPak with Enhanced QuizPak and GradePak

WCB TestPak, a computerized testing service, provides instructions with either a mail-in/call-in testing program or the complete test item file on diskette for use with the IBM PC, Apple, or Macintosh computer. WCB TestPak requires no programming experience.

WCB QuizPak, a part of TestPak, provides students with true/false, multiple choice, and matching questions for each chapter in the text. Using this portion of the program will help students to prepare for examinations. Also included with the QuizPak is an on-line testing option to allow professors to prepare tests for students to take on the computer. The computer will automatically grade the test and update a gradebook file.

WCB GradePak, also a part of TestPak, is a computerized grade management system for instructors. This program tracks student performance on examinations and assignments. It will compute each student's percentage and corresponding letter grade, as well as the class average. Printouts can be made utilizing both text and graphics.

Other Titles of Related Interest from Wm. C. Brown Publishing

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by Judith Getis
This short, inexpensive supplement offers students practical guidelines for recycling, conserving energy, disposing of hazardous wastes, and other pollution controls. It can be shrink wrapped with the text, at minimal additional cost (ISBN 0-697-13923-9)

How to Study Science
by Fred Drewes, Suffolk County Community College
This excellent new workbook offers students helpful suggestions for meeting the considerable challenges of a college science course. It offers tips on how to take notes; how to get the most out of laboratories; as well as how to overcome science anxiety. The book's unique design helps students develop critical thinking skills, while facilitating careful note-taking. (ISBN 0-697-14474-7)

The Life Science Lexicon
by William N. Marchuk, Red Deer College
This portable, inexpensive reference helps introductory-level students quickly master the vocabulary of the life sciences. Not a dictionary, it carefully explains the rules of word construction and derivation, in addition to giving complete definitions of all important terms. (ISBN 0-697-12133-X)

Biology Study Cards
by Kent Van De Graaff, R. Ward Rhees, and Christopher H. Creek, Brigham Young University
This boxed set of 300, 2-sided study cards provides a quick yet thorough visual synopsis of all key biological terms and concepts in the general biology curriculum. Each card features a masterful illustration, pronunciation guide, definition, and description in context. (ISBN 0-697-03069-5)

The Gundy-Weber Knowledge Map of the Human Body
by G. Craig Gundy, Weber State University
This 13-disk, Mac-Hypercard program is for use by instructors and students alike. It features carefully prepared computer graphics, animations, labeling exercises, self-tests, and practice questions to help students examine the systems of the human body. Contact your local Wm. C. Brown representative or call 1-800-351-7671.

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GenPak: A Computer Assisted Guide to Genetics
by Tully Turney, Hampden-Sydney College
This Mac-Hypercard program features numerous interactive/tutorial (problem-solving) exercises in Mendelian, molecular, and population genetics at the introductory level. (ISBN 0-697-13760-0)

Acknowledgments

Many persons have contributed to the success of previous editions and helped me make this edition our very best effort. My editor, Kevin Kane, directed the efforts of all. Carol Mills, my developmental editor, served as a liaison between the editor, me, and many

other people. I especially want to mention Susan Murray and Anne Packard of Plymouth State College, who carefully read the galleys and made many helpful suggestions.

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The Contributors

With this edition, as with the last edition, there were several contributors to various sections of the book. They critically reviewed my revised chapters and told me how they could be improved. With their help, it was easier to make sure the content was sufficient, accurate, and up to date. The contributors were:

W. Dennis Clark (Ph.D. University of Texas), professor of botany at Arizona State University. Dr. Clark's expertise in the areas of chemistry, evolution, and physiology of plants was extremely helpful in the revision of the plant and energy chapters.

Thomas C. Emmel (Ph.D. Stanford University), professor of zoology at the University of Florida. He assisted invaluably by providing updated information in ecology, where he has published numerous articles and 2 books.

Robert M. Kitchin (Ph.D. University of California-Berkeley), professor of genetics at the University of Wyoming. He reviewed the genetics chapters and outlined new information and events taking place in this rapidly changing and expanding field.

The Ancillary Contributors

The ancillary package that accompanies *Biology* also involved the efforts of many instructors currently teaching biology.

Critical Thinking Case Study Book: Robert Allen (Ph.D. University of California-Los Angeles) is vice-president for instruction at Victor Valley College, whose special interests include research on the development of critical thinking skills in science. He is a frequent presenter on the subject for the National Science Foundation Chatauqua series.

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Laboratory Manual and Laboratory Resource Guide: Kenneth Kilborn (M. A. San Jose State University) has been teaching general biology and general botany in addition to 20 years of teaching in the biology laboratory at Shasta College.

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Reviewers

Many instructors of introductory biology courses around the country reviewed portions of the manuscript. Others assisted by taking the time to fill out survey forms that helped us make important decisions about content. With many thanks, we list their names here.

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