Cell Biology and Genetics

STARR AND TAGGART

BIOLOGY: THE UNITY AND DIVERSITY OF LIFE / EIGHTH EDITION

CELL BIOLOGY AND GENETICS

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BIOLOGY
THE UNITY AND DIVERSITY OF LIFE
EIGHTH EDITION

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PREFACE

Not too long from now we will cross the threshold of a new millennium, a rite of passage that invites reflection on where biology has been and where it might be heading. About 500 years ago, during an age of global exploration, naturalists first started to systematically catalog and think about the staggering diversity of organisms all around the world. Less than 150 years ago, just before the start of a civil war that would shred the fabric of a new nation, the naturalist Charles Darwin shredded preconceived notions about life's diversity. It was only about 50 years ago that biologists caught their first glimpse of life's unity at the molecular level. Until that happened a biologist could still hope to be a generalist—someone who viewed life as Darwin did, without detailed knowledge of mechanisms that created it, that perpetuate it, that change it.

No more. Biology grew to encompass hundreds of specialized fields, each focused on one narrow aspect of life and yielding volumes of information about it. Twenty years ago I wondered whether introductory textbooks could possibly keep up with the rapid and divergent splintering of biological inquiry. James Bonner, a teacher and researcher at the California Institute of Technology, turned my thinking around on this. He foresaw that authors and instructors for introductory courses must become the new generalists, the ones who give each generation of students broad perspective on what we know about life and what we have yet to learn.

And we must do this, for the biological perspective remains one of the most powerful of education's gifts. With it, students who travel down specialized roads can sense intuitively that their research and its applications may have repercussions in unexpected places in the world of life. With that perspective, students in general might cut their own intellectual paths through social, medical, and environmental thickets. And they might come to understand the past and to predict possible futures for ourselves and all other organisms.

CONCERNING THE EIGHTH EDITION

Like earlier editions, this book starts with an overview of the basic concepts and scientific methods. Three units on the principles of biochemistry, inheritance, and evolution follow. The principles provide the conceptual background necessary for deeper probes into life's unity and diversity, starting with a richly illustrated evolutionary survey of each kingdom. Units on the comparative anatomy and physiology of plants, then animals, follow. The last unit focuses on the patterns and consequences of organisms interacting with one another and with their environment. Thus the organization parallels the levels of biological organization, from cells through the biosphere. We adhere to this traditional approach for good reason: it works.

As before, we identify and highlight the key concepts, current understandings, and research trends for the major fields of inquiry. Through examples of problem solving and experiments, we give ample evidence of "how we know what we know" and thus demonstrate the power of critical thinking. We explain the structure and functioning of a broad sampling of organisms in enough detail so that students can develop a working vocabulary about life's parts and processes. We also updated the glossary.

CONCEPT SPREADS

In the first chapter, an overview of the levels of biological organization kicks off a story that continues through the rest of the book. Telling such a big, complex story might be daunting unless you remind yourself of the question *"How do you eat an elephant?"* and its answer, *"One bite at a time."* We who have told the story again and again know how the parts fit together, but many students need help to keep the story line in focus within and between chapters. And they need to chew on concepts one at a time.

In every chapter we present each concept on its own table, so to speak. That is, we organize the descriptions, art, and supporting evidence for it on two facing pages, at most. Think of this as a concept spread, as in Figure *A*. Each starts with a numbered tab and ends with boldface statements to summarize the key points. Students can use these cues as reminders to digest one topic before starting on another. Well-crafted transitions between spreads help students focus on where topics fit in the larger story and gently discourage memorization for its own sake. The clear demarcation also gives instructors greater flexibility in assigning or skipping topics within a chapter.

By restricting the space available for each concept, we force ourselves to clear away the clutter of superfluous detail. Within each concept spread, we block out headings and subheadings to rank the importance of its various parts. Any good story has such a hierarchy of information, with background settings, major and minor characters, and high points and an ending where everything comes together. Without a hierarchy, a story has all the excitement, flow, and drama of an encyclopedia. Where details are useful as expansions of concepts, we integrate them into suitable illustrations to keep them from disrupting the text flow.

Not all students are biology majors, and many of them approach biology textbooks with apprehension. If the words don't engage them, they sometimes end up hating the book, and the subject. It comes down to line-by-line judgment calls. During twenty-two years of authorship, we developed a sense of when to leave core material alone and when to loosen it up to give students breathing room. Interrupting, say, an account of mitotic cell division with a distracting anecdote does no good. Plunking a humorous aside into a chapter that ties together the evolution of the Earth and life trivializes a magnificent story. Including an entertaining story is fine, provided that doing so reinforces a key concept. Thus, for example, we include the story of a misguided species introduction that resulted in wild European rabbits running amok through Australia.

BALANCING CONCEPTS WITH APPLICATIONS

Each chapter starts with a lively or sobering application that leads into an adjoining list of key concepts. The list is an advance organizer for the chapter as a whole. At strategic points, examples of applications parallel the core material—not so many as to be distracting, but enough to keep minds perking along with the conceptual development. Many brief applications are integrated in the text. Others are in *Focus* essays, which give more depth on medical, environmental, and social issues but do not interrupt the text flow.

FOUNDATIONS FOR CRITICAL THINKING

To help students develop a capacity for critical thinking, we walk them through experiments that yielded evidence in favor of or against hypotheses being discussed. The main index for the book will give you a sense of the number and types of experiments used (see the entry *Experiments*).

We use certain chapter introductions as well as entire chapters to show students some of the productive results of critical thinking. Among these are the introductions to the chapters on Mendelian genetics (11), DNA structure and function (14), and speciation (19).

Many *Focus on Science* essays provide more detailed, optional examples of how biologists apply critical thinking to problem solving. For example, one of these describes RFLP analysis (Section 16.3) and a few of its more jarring applications. Another essay helps convey to students that biology is not a closed book. Even when new research brings a sweeping story into sharp focus, it also opens up new roads of inquiry.

This edition has *Critical Thinking* questions at the end of chapters. Katherine Denniston of Towson State University developed these thought-provoking questions. Chapters 11 and 12 also include a large selection of *Genetics Problems* that help students grasp the principles of inheritance.

To keep readers focused, we cover each concept on one or two facing pages, starting with a numbered tab . . .

5.1 MEMBRANE STRUCTURE AND FUNCTION

Earlier chapters provided you with a brief look at the structure of cell membranes and the general functions of their component parts. Here, we incorporate some of the background information in a more detailed picture.

The Lipid Bilayer of Cell Membranes

Fluid bathes the two surfaces of a cell membrane and is vital for its functioning. The membrane, too, has a fluid quality; it is not a solid, static wall between cytoplasmic and extracellular fluids. For instance, puncture a cell with a fine needle, and its cytoplasm will not ooze out. The membrane will flow over the puncture site and seal it!

How does a fluid membrane remain distinct from its fluid surroundings? To arrive at the answer, start by reviewing what we have already learned about its most abundant components, the phospholipids. Recall that a **phospholipid** has a phosphate-containing head and two fatty acid tails attached to a glycerol backbone (Figure 5.2*a*). The head is hydrophilic; it easily dissolves in water. Its tails are hydrophobic; water repels them. Immerse a number of phospholipid molecules in water, and they will interact with water molecules and with one another until they spontaneously cluster in a sheet or film at the water's surface. Their jostlings may even force them to become organized in two layers, with all fatty acid tails sandwiched between all hydrophilic heads. This **lipid bilayer** arrangement, remember, is the structural basis of cell membranes (Section 4.1 and Figure 5.2*c*).

The organization of each lipid bilayer minimizes the total number of hydrophobic groups exposed to water, so the fatty acid tails do not have to spend a lot of energy fighting water molecules, so to speak. A "punctured" membrane exhibits sealing behavior precisely because a puncture is energetically unfavorable. It leaves far too many hydrophobic groups exposed to the surrounding fluid.

Ordinarily, few cells get jabbed by fine needles. But the self-sealing behavior of membrane phospholipids is good for more than damage control. Among other things, it functions in vesicle formation. For example, as vesicles bud away from ER or Golgi membranes, phospholipids interact hydrophobically with cytoplasmic water. They get pushed together, and the rupture seals. You will read more about vesicle formation later in the chapter.

Fluid Mosaic Model of Membrane Structure

Figure 5.3 shows a bit of membrane that corresponds to the **fluid mosaic model**. By this model, cell membranes are a mixed composition—a "mosaic"—of phospholipids, glycolipids, sterols, and proteins. The phospholipid heads as well as the length and saturation of the tails are not all the same. (Recall that unsaturated fatty acids have one or more double bonds in their backbone and fully saturated ones have none.) The glycolipids are structurally similar to phospholipids, but their head incorporates one or more sugar monomers. In animal cell membranes, cholesterol is the most abundant sterol (Figure 5.2*b*). Phytosterols are their equivalent in plant cell membranes.

Also by this model, the membrane is "fluid" owing to the motions and interactions of its component parts.

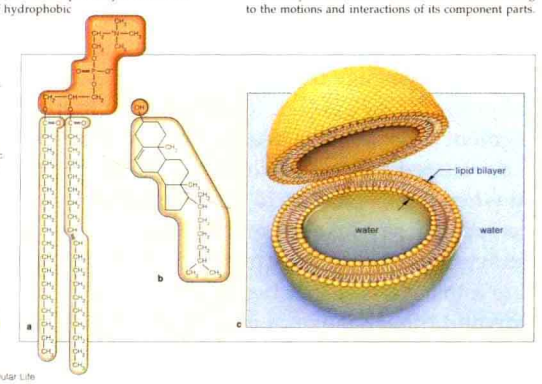


Figure 5.2
(**a**) Structural formula of phosphatidylcholine, a phospholipid that is one of the most common components of the membranes of animal cells. *Orange* indicates its hydrophilic head, *yellow* indicates its hydrophobic tails.
(**b**) Structural formula of cholesterol, the major sterol in animal tissues.
(**c**) Diagram showing how lipids that are placed in liquid water may spontaneously organize themselves into a bilayer structure.

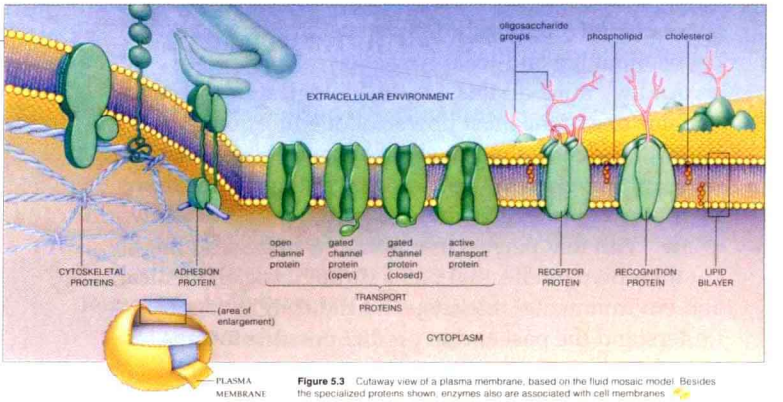


Figure 5.3 Cutaway view of a plasma membrane, based on the fluid mosaic model. Besides the specialized proteins shown, enzymes also are associated with cell membranes.

The hydrophobic interactions that give rise to most of a membrane's structure are weaker than covalent bonds. This means most phospholipids and some proteins are free to drift sideways. Also, the phospholipids can spin about their long axis and flex their tails, which keeps neighboring molecules from packing together in a solid layer. Short or kinked (unsaturated) fatty acid tails also contribute to membrane fluidity.

The fluid mosaic model is a good starting point for exploring cell membranes. But bear in mind, membranes differ in the details of their molecular composition and arrangements, and they are not even the same on both surfaces of their bilayer. For example, oligosaccharides and other carbohydrates are covalently bonded to protein and lipid components of a plasma membrane, but only on its outward-facing surface (Figure 5.3). Moreover, they differ in number and kind from one species to the next, even among the different cells of the same individual.

Overview of Membrane Proteins

The proteins embedded in a lipid bilayer or attached to one of its surfaces carry out most membrane functions. Many are enzyme components of metabolic machinery. Others are **transport proteins** that allow water-soluble substances to move through their interior, which spans the bilayer. They bind molecules or ions on one side of the membrane, then release them on the other side.

The **receptor proteins** bind extracellular substances, such as hormones, that trigger changes in cell activities. For example, certain enzymes that crank up machinery for cell growth and division become switched on when somatotropin, a hormone, binds with receptors for it. Different cells have different combinations of receptors.

Diverse **recognition proteins** at the cell surface are like molecular fingerprints; their oligosaccharide chains identify a cell as being of a specific type. For example, "self" proteins pepper the plasma membrane of your cells. Certain white blood cells chemically recognize the proteins and leave your own cells alone, but they attack invading bacterial cells having "nonself" proteins at their surface. Finally, **adhesion proteins** of multicelled organisms help cells of the same type locate and stick to one another and stay positioned in the proper tissues. They are glycoproteins with oligosaccharides attached. After tissues form, the sites of adhesion may become a type of cell junction, as described earlier in Section 4.10.

A cell membrane has two layers composed mainly of lipids, phospholipids especially. This lipid bilayer is the structural foundation for the membrane and also serves as a barrier to water-soluble substances.

Hydrophilic heads of the phospholipids are dissolved in fluids that bathe the two outer surfaces of the bilayer. Their hydrophobic tails are sandwiched between the heads.

Proteins associated with the bilayer carry out most membrane functions. Many are enzymes, transporters of substances across the bilayer, or receptors for extracellular substances. Other types function in cell-to-cell recognition or adhesion.

. . . and ending with one or more summary statements.

FIGURE A *A concept spread from this edition.*

VISUAL OVERVIEWS OF MAJOR CONCEPTS

While writing the text, we simultaneously develop the illustrations as inseparable parts of the same story. This integrative approach appeals to students who are visual learners. When they can first work their way through a visual overview of some process, then reading through the corresponding text becomes less intimidating. Over the years, students have repeatedly thanked us for our hundreds of overview illustrations, which contain step-by-step, written descriptions of biological parts and processes. We break down the information into a series of illustrated steps that are more inviting than a complex, "wordless" diagram. Figure *B* is a sample. Notice how simple descriptions, integrated with the art, take students through the stages by which mRNA transcripts become translated into polypeptide chains, one step at a time.

Similarly, we continue to create visual overviews for anatomical drawings. The illustrations integrate structure and function. Students need not jump back and forth from the text, to tables, to illustrations, and back again in order to comprehend how an organ system is put together and what its parts do. Even individual descriptions of parts are hierarchically arranged to reflect the structural and functional organization of that system.

COLOR CODING

In line illustrations, we consistently use the same colors for the same types of molecules and cell structures. Visual consistency makes it easier for students to track complex parts and processes. Figure C is the color coding chart.

ZOOM SEQUENCES

Many illustrations in the book progress from macroscopic to microscopic views of the same subject. Figure 7.2 is an example; this zoom sequence shows where the reactions of photosynthesis proceed, starting with a plant growing by a roadside.

ICONS

Within the text, small diagrams next to an illustration help relate the topic to the big picture. For instance, in Figure *A*, a simple representation of a cell subtly reminds students of the location of the plasma membrane relative to the cytoplasm. Other icons serve as reminders of the location of reactions and processes in cells and how they

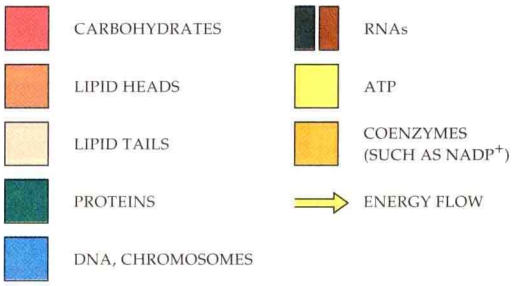


FIGURE C *Color coding chart for the diagrams of biological molecules and cell structures.*

Step-by-step art with simple descriptions helps students visualize a process before reading text about it.

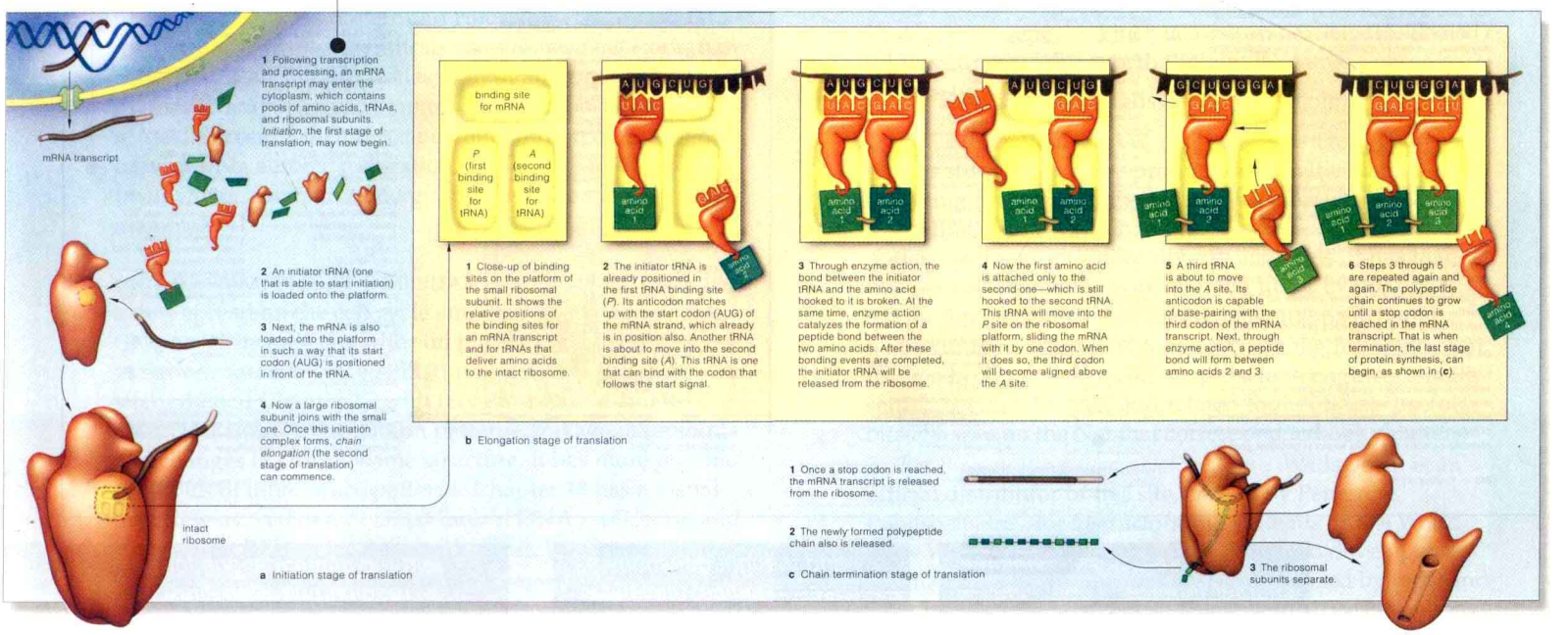


FIGURE B *A visual overview from this edition.*

interrelate to one another. Still other icons remind students of the evolutionary relationships among groups of organisms.

New to this edition are icons that invite students to use multimedia. One icon directs them to art in the CD-ROM enclosed with each student copy, another to supplemental material on the Web, and a third to InfoTrac:

CD-ROM ICON: WEB ICON: INFOTRAC ICON:

END-OF-CHAPTER STUDY AIDS

Figure *D* shows a sampling of our end-of-chapter study aids, which reinforce the key concepts. Each chapter ends with a summary in list form, review questions, a self-quiz, critical thinking questions, selected key terms, and a list of readings. Italicized page numbers tie the review questions and key terms to relevant text pages.

END-OF-BOOK STUDY AIDS

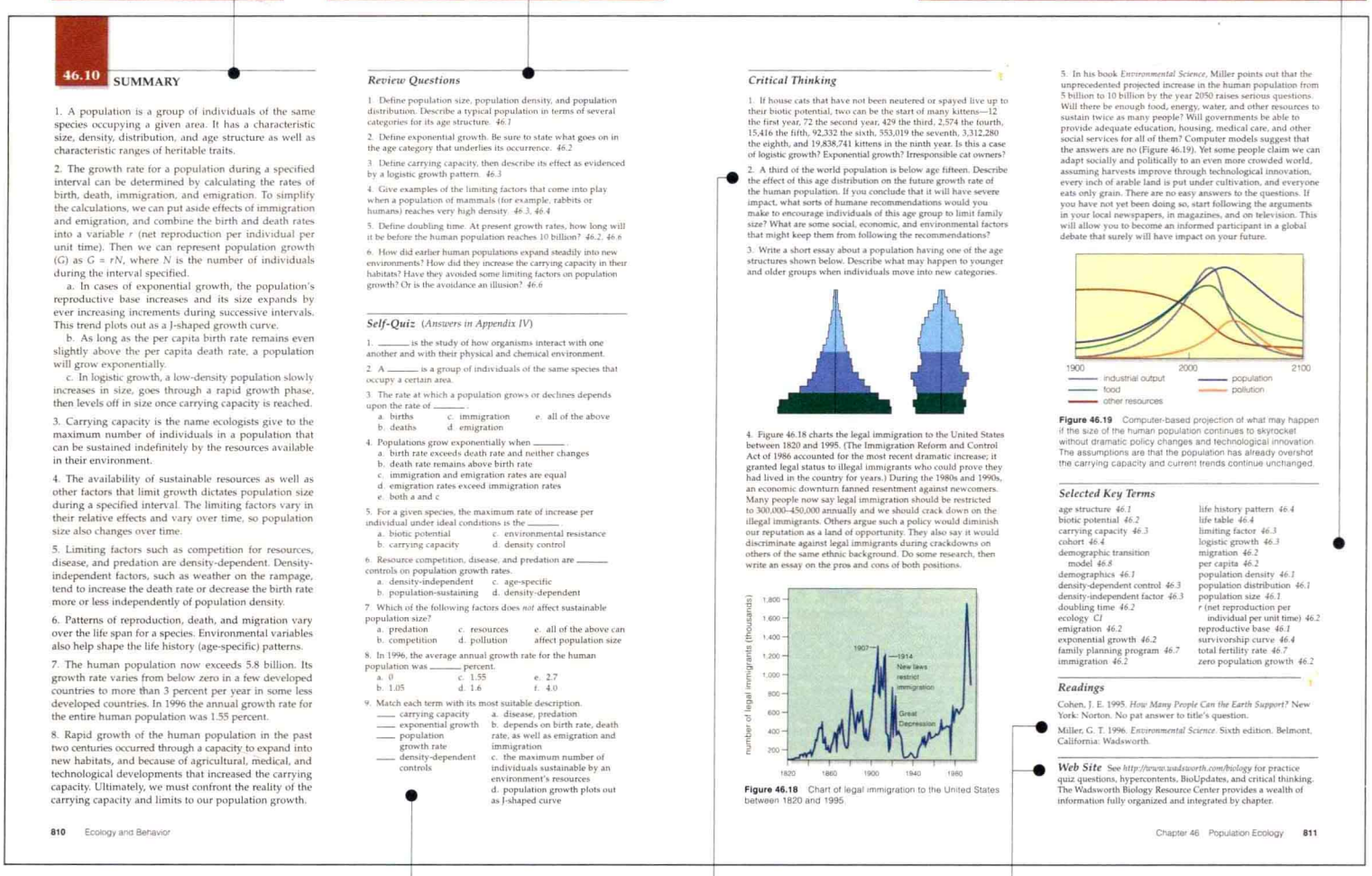
At the book's end, the detailed classification scheme in Appendix I is helpful for reference purposes. Appendix II includes metric-English conversion charts. Appendix III has detailed answers to the genetics problems in Chapters 11 and 12, and the fourth has answers to the self-quizzes at the end of each chapter. For those interested students and professors who prefer the added detail, Appendix V illustrates the structural formulas for the major metabolic pathways. Appendix VI shows the periodic table of the elements.

A Glossary includes boldfaced terms from the text, with pronunciation guides and word origins to make the formidable words less so. The Appendixes as well as the Glossary are printed on paper that is tinted different colors to preclude frustrating searches for where one ends and the next begins. The Index is detailed enough to help readers find doors to the text more quickly.

Each chapter ends with a summary . . .

. . . and review questions keyed to chapter sections . . .

. . . and a list of the chapter's boldfaced terms, linked to chapter sections . . .



46.10 SUMMARY

1. A population is a group of individuals of the same species occupying a given area. It has a characteristic size, density, distribution, and age structure as well as characteristic ranges of heritable traits.

2. The growth rate for a population during a specified interval can be determined by calculating the rates of birth, death, immigration, and emigration. To simplify the calculations, we can put aside effects of immigration and emigration, and combine the birth and death rates into a variable r (net reproduction per individual per unit time). Then we can represent population growth (G) as $G \approx rN$, where N is the number of individuals during the interval specified.

a. In cases of exponential growth, the population's reproductive base increases and its size expands by ever increasing increments during successive intervals. This trend plots out as a J-shaped growth curve.

b. As long as the per capita birth rate remains even slightly above the per capita death rate, a population will grow exponentially.

c. In logistic growth, a low-density population slowly increases in size, goes through a rapid growth phase, then levels off in size once carrying capacity is reached.

3. Carrying capacity is the name ecologists give to the maximum number of individuals in a population that can be sustained indefinitely by the resources available in their environment.

4. The availability of sustainable resources as well as other factors that limit growth dictates population size during a specified interval. The limiting factors vary in their relative effects and vary over time, so population size also changes over time.

5. Limiting factors such as competition for resources, disease, and predation are density-dependent. Density-independent factors, such as weather on the rampage, tend to increase the death rate or decrease the birth rate more or less independently of population density.

6. Patterns of reproduction, death, and migration vary over the life span for a species. Environmental variables also help shape the life history (age-specific) patterns.

7. The human population now exceeds 5.8 billion. Its growth rate varies from below zero in a few developed countries to more than 3 percent per year in some less developed countries. In 1996 the annual growth rate for the entire human population was 1.55 percent.

8. Rapid growth of the human population in the past two centuries occurred through a capacity to expand into new habitats, and because of agricultural, medical, and technological developments that increased the carrying capacity. Ultimately, we must confront the reality of the carrying capacity and limits to our population growth.

Review Questions

1. Define population size, population density, and population distribution. Describe a typical population in terms of several categories for its age structure. *46.1*

2. Define exponential growth. Be sure to state what goes on in the age category that underlies its occurrence. *46.2*

3. Define carrying capacity, then describe its effect as evidenced by a logistic growth pattern. *46.3*

4. Give examples of the limiting factors that come into play when a population of mammals (for example, rabbits or humans) reaches very high density. *46.3, 46.4*

5. Define doubling time. At present growth rates, how long will it be before the human population reaches 10 billion? *46.2, 46.6*

6. How did earlier human populations expand steadily into new environments? How did they increase the carrying capacity in their habitats? Have they avoided some limiting factors on population growth? Or is the avoidance an illusion? *46.6*

Self-Quiz (*Answers in Appendix IV*)

1. _____ is the study of how organisms interact with one another and with their physical and chemical environment.

2. A _____ is a group of individuals of the same species that occupy a certain area.

3. The rate at which a population grows or declines depends upon the rate of _____.
a. births c. immigration e. all of the above
b. deaths d. emigration

4. Populations grow exponentially when _____.
a. birth rate exceeds death rate and neither changes
b. death rate remains above birth rate
c. immigration and emigration rates are equal
d. emigration rates exceed immigration rates
e. both a and c

5. For a given species, the maximum rate of increase per individual under ideal conditions is the _____.
a. biotic potential c. environmental resistance
b. carrying capacity d. density control

6. Resource competition, disease, and predation are _____ controls on population growth rates.
a. density-independent c. age-specific
b. population-sustaining d. density-dependent

7. Which of the following factors does *not* affect sustainable population size?
a. predation c. resources e. all of the above can affect population size
b. competition d. pollution

8. In 1996, the average annual growth rate for the human population was _____ percent.
a. 0 c. 1.55 e. 2.7
b. 1.05 d. 1.6 f. 4.0

9. Match each term with its most suitable description.
___ carrying capacity a. disease, predation
___ exponential growth b. depends on birth rate, death rate, as well as emigration and immigration
___ population growth rate c. the maximum number of individuals sustainable by an environment's resources
___ density-dependent controls d. population growth plots out as J-shaped curve

Critical Thinking

1. If house cats that have not been neutered or spayed live up to their biotic potential, two can be the start of many kittens—12 the first year, 72 the second year, 429 the third, 2,574 the fourth, 15,416 the fifth, 92,332 the sixth, 553,019 the seventh, 3,312,280 the eighth, and 19,838,741 kittens in the ninth year. Is this a case of logistic growth? Exponential growth? Irresponsible cat owners?

2. A third of the world population is below age fifteen. Describe the effect of this age distribution on the future growth rate of the human population. If you conclude that it will have severe impact, what sorts of humane recommendations would you make to encourage individuals of this age group to limit family size? What are some social, economic, and environmental factors that might keep them from following the recommendations?

3. Write a short essay about a population having one of the age structures shown below. Describe what may happen to younger and older groups when individuals move into new categories.

4. Figure 46.18 charts the legal immigration to the United States between 1820 and 1995. (The Immigration Reform and Control Act of 1986 accounted for the most recent dramatic increase; it granted legal status to illegal immigrants who could prove they had lived in the country for years.) During the 1980s and 1990s, an economic downturn fanned resentment against newcomers. Many people now say legal immigration should be restricted to 300,000–450,000 annually and we should crack down on the illegal immigrants. Others argue such a policy would diminish our reputation as a land of opportunity. They also say it would discriminate against legal immigrants during crackdowns on others of the same ethnic background. Do some research, then write an essay on the pros and cons of both positions.

number of legal immigrants (thousands)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
1820 1860 1900 1940 1980
1907
1914 New laws restrict immigration
Great Depression

Figure 46.18 Chart of legal immigration to the United States between 1820 and 1995.

5. In his book *Environmental Science*, Miller points out that the unprecedented projected increase in the human population from 5 billion to 10 billion by the year 2050 raises serious questions. Will there be enough food, energy, water, and other resources to sustain twice as many people? Will governments be able to provide adequate education, housing, medical care, and other social services for all of them? Computer models suggest that the answers are no (Figure 46.19). Yet some people claim we can adapt socially and politically to an even more crowded world, assuming harvests improve through technological innovation, every inch of arable land is put under cultivation, and everyone eats only grain. There are no easy answers to the questions. If you have not yet been doing so, start following the arguments in your local newspapers, in magazines, and on television. This will allow you to become an informed participant in a global debate that surely will have impact on your future.

1900 2000 2100
industrial output
food
other resources
population
pollution

Figure 46.19 Computer-based projection of what may happen if the size of the human population continues to skyrocket without dramatic policy changes and technological innovation. The assumptions are that the population has already overshot the carrying capacity and current trends continue unchanged.

Selected Key Terms

age structure *46.1*
biotic potential *46.2*
carrying capacity *46.3*
cohort *46.4*
demographic transition model *46.8*
demographics *46.1*
density-dependent control *46.3*
density-independent factor *46.3*
doubling time *46.2*
ecology *CI*
emigration *46.2*
exponential growth *46.2*
family planning program *46.7*
immigration *46.2*
life history pattern *46.4*
life table *46.4*
limiting factor *46.3*
logistic growth *46.3*
migration *46.2*
per capita *46.2*
population density *46.1*
population distribution *46.1*
population size *46.1*
r (net reproduction per individual per unit time) *46.2*
reproductive base *46.1*
survivorship curve *46.4*
total fertility rate *46.7*
zero population growth *46.2*

Readings

Cohen, J. E. 1995. *How Many People Can the Earth Support?* New York: Norton. No pat answer to title's question.

Miller, G. T. 1996. *Environmental Science*. Sixth edition. Belmont, California: Wadsworth.

Web Site *See http://www.wadsworth.com/biology for practice quiz questions, hypercontents, BioUpdates, and critical thinking. The Wadsworth Biology Resource Center provides a wealth of information fully organized and integrated by chapter.*

. . . and a self-quiz to reinforce chapter terms and concepts . . .

. . . and thought questions as exercises in critical thinking . . .

. . . and recommendations for further reading and Web sites.

FIGURE D *Study aids at the end of a chapter from this edition.*

CONTENT REVISIONS

Instructors who use *Biology: The Unity and Diversity of Life* may wish to evaluate this overview of key modifications. Overall, conceptual development is more integrated. The writing is still crisp but not too brief, because some topics can confuse students when presented in insufficient detail. New research called for some adjustments in the overall framework. For example, we subscribe to the six-kingdom classification scheme, which now has exceptional support from comparative biochemical studies. Even the end-of-chapter Critical Thinking questions incorporate current material.

INTRODUCTION This conceptual overview for the book is more focused, starting with introductions to the molecular trinity (DNA to RNA to protein), energy, and the levels of biological organization. An early glimpse of life's diversity reflects the six-kingdom model. We follow it with a simple explanation of evolution by natural selection, a dominant theme throughout the book. We treat scientific methods in more detail. To highlight the power of scientific inquiry, we have a new spread on experimental tests of an alternative to antibiotics. This detailed, timely example builds on an earlier description of selection for antibiotic resistance.

UNIT I. PRINCIPLES OF CELLULAR LIFE Chapter 1 opens with a new vignette on a chemical element and a current application (phytoremediation, as at Chernobyl). Sections on radioactive decay and on acids, bases, and buffers are rewritten. Chapter 3 opens with a "carbon story" about swings in atmospheric CO_2. It has an essay on pesticides. Chapter 4 has better treatment of cytoskeletal elements and accessory proteins, including myosin. Chapter 5 has improved explanations of membrane proteins, diffusion, osmosis, and membrane transport mechanisms. A rewrite of Chapter 6 makes the ground rules of metabolism more intelligible. The photosynthesis chapter has new icons, new concept spreads on properties of light and photosynthetic pigments, and a visual comparison of carbon-fixing routes. Chapter 8 includes a new illustration of the energy harvest from aerobic respiration, and a more lively, updated treatment of alternative energy sources in humans and other mammals.

UNIT II. PRINCIPLES OF INHERITANCE Chapter 9 includes a new spread on the cell cycle and chromosome structure. Chapter 11 includes rewrites on pleiotropy, phenotypic variation, and some new, illustrated genetics problems. We strengthened Chapter 12 with reorganized text and new art on linkage, recombination patterns, linkage mapping, and changes in chromosome structure. It has more graphic examples of inheritance patterns. Chapter 13 has a visual overview as well as a detailed look at DNA replication and an essay on DNA mutations and cancer. We improved the Chapter 14 treatment of mutation. Chapter 15 opens with a new vignette on apoptosis, a prelude to an updated section on cancer at the chapter's end. Definitions are clarified. Chapter 16 has a new vignette and a new essay on RFLPs.

MULTIMEDIA SUPPLEMENTS

1. *Interactive Concepts in Biology.* Packaged free with all student copies, this is the first CD-ROM to address the full sweep of biology. The cross-platform CD-ROM covers all concept spreads in the book. Because students can learn by doing, it encourages them to manipulate the book's art. A combination of text, graphics, photographs, animations, video, and audio enhances each book chapter. The revised CD-ROM has three times as many animations, many more interactive quizzes, and many more interactive exercises.
2. *InfoTrac College Edition.* This on-line library is available FREE with each copy of *Biology: The Unity and Diversity of Life*. It gives students access to full articles—not abstracts—from more than 600 scholarly and popular periodicals dating back as far as four years. The articles are available through InfoTrac's impressive database that has such periodicals as *Discover*, *Audubon*, and *Health*.
3. *Student Guide to InfoTrac College Edition.* This guide is on the Wadsworth Biology Resource Center site on the World Wide Web. It has an introduction to InfoTrac and a set of electronic readings for each chapter, updated frequently. It links some of each chapter's critical thinking questions to InfoTrac articles to invite deeper examination of issues.
4. *Biology Resource Center.* All information is arranged by the eighth edition's chapters. Every month it has new BioUpdates on relevant applications, and hyperlinks and an average of 40 practice quiz questions per chapter. It includes descriptions of degrees and careers in biology, a student feedback site, cool clip art, ideas for teaching on the Web, and a forum where instructors can share ideas on teaching courses. It also includes flashcards for all glossary terms, critical thinking exercises, news groups, surfing lessons including biology surfing, and a variety of search engines, biological games, a BioTutor, and a final Blitz set of practice questions. Perhaps most importantly, it also has Internet exercises for each chapter to guide students to doing more than randomly browse sites. A cool event of the quarter will have an ongoing experiment in which students and instructors can participate. The address for the Wadsworth Biology Resource Center is:

   http://www.wadsworth.com/biology

5. *Internet Activities for General Biology.* This book guides students to more productive activities than browsing the Web. Students learn by interactive dissections, surveys, genetic crosses, lab experiments, notice postings, and other diverse activities. It has tear-out worksheets that may be handed in for evaluation.
6. *An Introduction to the Internet.* This 100-page booklet helps students learn how to get around the Internet when using a browser such as Netscape, search engines, e-mail, setting up home pages, and related topics. It lists useful biology sites on the Net that correspond to book chapters.
7. *The Biology Place (www.biology.com).* Wadsworth is an official distributor of this site, created by Peregrine Publishers, Inc., for instructors and students on the World Wide Web. A community of educators who developed and maintain it offer learning activities categorized by topic and type, including interactive study guides, lab investigations, study projects, and collaborative research. One can access Research News, Best of the Web, and *Scientific American*

Connection for cutting-edge research. Each learning activity has interactive self-assessment worksheets and notebooks. Results can be printed or e-mailed directly to instructors.

8. *American Botanical Society.* This site will be maintained on the Wadsworth Web page at http://www.thomson.com.

9. *BioLink 2.* With this presentation tool, instructors can easily assemble art and database files with lecture notes to create a fluid lecture that may help stimulate even the least-engaged students. It includes all illustrations in the book, animations and films from the student CD, and art from other Wadsworth biology textbooks. BioLink 2 also has a Kudo Browser with an easy drag-and-drop feature that allows file export into such presentation tools as Power Point. Upon its creation, a file or lecture with BioLink 2 can be posted to the Web, where students can access it for reference or for studying needs.

10. *Overheads and 35mm Slides.* All the micrographs and diagrams in the book are available as overheads and slides that are reproduced in vivid color with large, bold-lettered labels. All of the diagrams are on *CD-ROM*, Biolink 2.

11. *Cycles of Life: Exploring Biology.* Twenty-six programs of this telecourse feature compelling footage from around the world, original microvideography, and spectacular 3D animation. A student study guide, faculty manual, and laboratory manual are included. For information on course licensing and pricing, send queries to Coast Telecourses by fax 714-241-6286 or telephone 1-800-547-4748.

12. *Animations and Films from Cycles of Life Telecourse.* Tape One has animations for cell structure and function, and for principles of inheritance and evolution. Tape Two has more on diversity, plant structure and function, animal structure and function, and ecology and behavior.

13. *CNN Videos.* Produced by Turner Learning, nine videos can stimulate and engage students. They cover general biology, anatomy-physiology, and environmental science. New tapes are offered every year for these topics.

14. *Protecting Endangered Species* and *Science in the Rain Forest Videos.* Current treatment of these major issues.

15. *Life Science Video Library.* Films for the Humanities and CNN created this library.

16. *Wadsworth Biology Videodisc.* Carolina Biological Supply and Bill Surver (Clemson University) collaborated on this videodisc with new animations and films. Line art has large, boldface labels and often step-by-step or full-motion animation. It is available with fill-in-the-blank labels for tests. There are 3,500 still photographs, a correlation directory, bar code guide, and hypercard and toolbook software. All items are organized by book chapter.

17. *West's Biology Videodisc.* This videodisc provides thousands of additional images.

18. *Liquid Assets—The Ecology of Water.* Two double-sided level-3 videodiscs compare the ecologies of the Everglades and San Francisco Bay. A study guide is included.

19. *STELLA II.* Adopters can get a version of this software tool to develop critical thinking skills, and a workbook. This modeling software has 23 simulations. The textbook's critical thinking questions and 150 additional ones are arranged by chapter in *Critical Thinking Exercises.*

20. *Electronic Study Guide.* This has an average of 40 multiple-choice questions per book chapter that differ from those in the test-item booklet. Students respond to each question, and then an on-screen prompt allows them to review their answers and learn why they are correct or incorrect.

21. *West Nutrition CD.* This interactive learning tool has animations, video, hands-on exercises, and a glossary with pronunciation guides. In-depth sections allow students to learn more about the biochemistry of particular topics.

ADDITIONAL SUPPLEMENTS

Seven respected test writers created the *Test Items* booklet. The booklet has more than 4,500 questions in electronic form for IBM and Macintosh in a test-generating data manager. Questions also are available in Microsoft Word for Windows, DOS, and Mac.

For each book chapter, an *Instructor's Resource Manual* has an outline, objectives, list of boldface or italic terms, and detailed lecture outline, ideas for lectures, classroom and lab demonstrations, discussion questions, research paper topics, and annotations for filmstrips and videos. For those who wish to modify material, this resource manual is available electronically on the Wadsworth Web page.

An interactive *Study Guide and Workbook* lets students write answers to questions, which are arranged by chapter section with references to specific text pages. For those who wish to modify or select parts, *chapter objectives* are available on disk in the testing file.

A 100-page *Answer Booklet* answers the textbook's review questions. (The answers to the self-quizzes and genetics problems are given in appendixes to the book itself.)

Flashcards show 1,000 glossary items. A booklet, *Building Your Life Science Vocabulary,* helps students learn biological terms by explaining root words and their applications.

Study Skills for Science Students. Daniel Chiras's guide explains how to develop good study habits, sharpen memory and learning, prepare for tests, and produce term papers.

Strategies for Success: Learning Skills Booklets. Individual learning skills chapters from Gardner/Jewler's best-selling college success text can be customized together or singly and bundled with the text. Some chapters cover managing time, test taking, writing and speaking, note taking, reading and memory, computers and the Internet, critical thinking, and campus resources including the library.

Jim Perry and David Morton's *Laboratory Manual* has 38 experiments and exercises, with 600+ full-color, labeled photographs and diagrams. Many experiments are divided in parts for individual assignment, depending on available time. Each consists of objectives, discussion (introduction, background, and relevance), list of materials for each part, procedural steps, prelab questions, and post-lab questions. An *Instructor's Manual* for the lab manual lists quantities, procedure for preparing reagents, time requirements for each part of an exercise, hints to make the lab a success, and vendors of materials with item numbers. It has more investigative exercises that can be copied for lab use.

Customized Laboratory Manuals by Phillip Shelp and its accompanying instructor's manual can be tailored for individual courses. A new *Photo Atlas* has 700 full-color, labeled photographs and micrographs of the cells and organisms that students typically deal with in the lab.

Eight additional readings supplements are available: • *Contemporary Readings in Biology* is a collection of articles on applications of interest. • *Current Perspectives in Biology* is another collection of articles. • *A Beginner's Guide to Scientific Method* is a supplement for those who wish to treat this topic in detail. • *The Game of Science* gives students a realistic view of what science is and what scientists do. • *Environment: Problems and Solutions* provides a brief 120-page introduction to environmental concerns. • *Green Lives, Green Campuses* is a hands-on workbook to help students evaluate the environmental impact of their own life-styles. • *Watersheds: Classic Cases in Environmental Ethics* is a collection of important case studies. • *Environmental Ethics: An Introduction to Environment Philosophy* surveys environmental ethics and recent philosophical positions.

A COMMUNITY EFFORT

One, two, or a smattering of authors can write accurately and often very well about their field of interest, but it takes more than this to deal with the full breadth of the biological sciences. For us, it takes an educational network that includes more than 2,000 teachers, researchers, and photographers in the United States, Canada, England, Germany, France, Australia, Sweden, and elsewhere. On the next two pages, we acknowledge reviewers whose contributions continue to shape our thinking. There simply is no way to describe the thoughtful effort these individuals and others before them gave to our books. We can only salute their commitment to quality in education.

In large part, *Biology: The Unity and Diversity of Life* is widely respected because it reflects the understandings of our general advisors and contributors and their abiding concern for students. Steve Wolfe, author of acclaimed books on cell biology, works out alternative phrasings with us, sometimes line by line over the phone. Daniel Fairbanks, scholar and gentleman, still finds the time to ferret out errors that creep into the genetics manuscripts. Katherine Denniston, another long-time advisor, wrote original critical thinking questions, itself no small feat. Aaron Bauer, Paul Hertz, Samuel Sweet, and Jerry Coyne helped chisel major parts of the evolution unit. Jerry also created our new computer simulation of genetic drift. The unit on plant structure and function is strong, thanks to the initial resource manuscripts from Cleon Ross.

And what would we do without Robert Lapen, who wrote the definitive manuscript on immunology and lived to tell about it? What would we do if our abiding friends Gene Kozloff, John Jackson, and Ron Hoham did not work diligently to stop us from inventing biology? Also for this edition, in collaboration with Linda Beidleman, Gene assembled the book's detailed Index.

We thank Rob Colwell, George Cox, and Tyler Miller for their contributions to the ecology unit. John Alcock, author of a respected book on behavior, provided resource manuscripts for our animal behavior chapter. Bruce Levin and Jim Bull provided prepublication data when we wrote a new essay on experimental testing. Lauralee Sherwood, author of a fine animal physiology text, helped refine the respiration chapter. As always, Jane Taylor and Larry Sellers were meticulous in their attention to detail.

Also over the years, Nancy Dengler, Bruce Holmes, David Morton, and Frank Salisbury have been guardians of accuracy and teachability. So has Tom Garrison, himself a seasoned author, who dispenses sympathy with wit better than just about anybody. This time, Tom and Don Collins generously opened their lecture hall and laboratory, and the revelations will shape our thinking for years to come.

Mary Douglas has now become the finest production manager in the business. We cannot imagine our complex revisions traveling through computerized production without guidance from talented, even-tempered, flexible Mary. She also falls in the category of author's shrink. Myrna Engler-Forkner, in charge of oversight and art coordination, has become as patient and superb as Mary. Gary Head, Quarkmeister, has the patience to teach even computer-challenged authors how to do page layouts. He designed the book and its cover. He went out on many photographic assignments and came back with such treats as Fred-and-Ginger, the streetwise snail in Figure 17.1.

Sandra Craig is a good sport and a fine shepherdess who keeps editorial production on its convoluted route. Kristin Milotich is in charge of a vast enterprise known as the book's supplements program. She is remarkable for her endurance, a big heart, and no attitude problem. Our developmental editor and good friend, Mary Arbogast, is in a class by herself. Pat Waldo, force of nature, outruns clocks and moves mountains to keep us at the forefront of multimedia for biology education. Thanks to Chris Evers, outstanding author, consultant, and Pat's secret weapon in digital publishing. Thanks also to the rest of the 0's and 1's Club, Stephen Rapley, Steve Bolinger, Jennie Redwitz, and Cooperative Media Group.

If authors could invent the most supportive president of a publishing house, they would come up with Susan Badger. If we could bottle Halee Dinsey's energy, we would be able to power all cities west of the Rockies. Gary Carlson, Michael Burgreen, Andrea Geanacopoulos, and John Walker add formidable talent to the biology team. Stephen Forsling signed on as photo researcher, and Roberta Broyer as permissions editor. Carol Lawson and Rebecca Linquist cheerfully kept us Quarking. Kathie Head, Pat Brewer, Peggy Meehan, and Stephen Rapley have made valuable contributions for many years.

Of the artists with whom we have worked, Raychel Ciemma remains the best. She works directly with us to turn rough sketches into works of art. We also are grateful for the dedication of Mary Roybal, Karen Stough, and the others listed on the copyright page.

Jim Gallagher, J.C. Morgan, and Jan Troutt at Precision Graphics are superb professionals. Tom Anderson, John Deady, Nancy Dean, and Rich Stanislawski at H&S Graphics cheerfully put up with our interminable pursuit of excellence.

Twenty-two years ago, Jack Carey convinced us to write this book. Ever since, he has remained close counseler and abiding friend. And nothing, in all that time, has shaken our shared belief in the intrinsic capacity of biology to enrich the lives of each new generation of students.

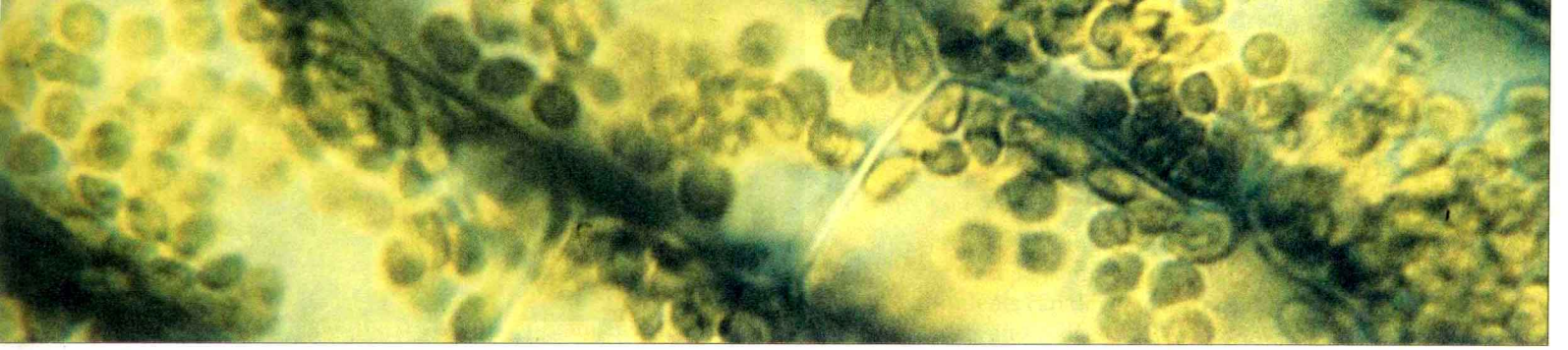
Current configurations of Earth's oceans and land masses —the geologic stage upon which life's drama continues to unfold. Thousands of separate images were pieced together to create this remarkable cloud-free view of our planet.

CONTENTS IN BRIEF

Highlighted chapters are included in CELL BIOLOGY AND GENETICS.

DETAILED CONTENTS

MEERKATS AT SUNRISE



CHLOROPLASTS IN LIVING PLANT CELLS

INTRODUCTION