

Preface

A revolution in the way information is shared has fundamentally changed the nature of biological inquiry. Interdisciplinary collaborations facilitated by instant, global access to data and ideas have fostered entirely new areas of research, both theoretical and practical. New discoveries and new technologies emerging from these collaborations are altering the way biologists think about their work—and the field in general.

Realizing that a traditional life science education would not adequately prepare students for the changing field, the American Association for the Advancement of Science and the National Science Foundation initiated a series of national conversations among leading life scientists, policymakers, educators, and students. The result was a document, "Vision and Change in Undergraduate Biology Education," that calls for a fundamental change in the way life sciences are taught to undergraduate students. A broad consensus recommends that science education become much more active, because personal experience with the process and limits of science better prepares students to evaluate scientific content and differentiate it from other information. A more concept-oriented approach that uses fundamental biological principles as a context for information (rather than the reverse) better prepares students to understand the rapidly changing field. Our future citizens and leaders will need this understanding to confront urgent societal problems such as climate change, threats to biodiversity, and the global spread of disease.

This book has been revised in alignment with "Vision and Change" recommendations. As always, recent discoveries are integrated in an accessible and appealing introduction to the study of life. This edition also includes tools to explore core biological concepts from a variety of perspectives (molecular, cellular, organismal, ecological, and so on).

Features of This Edition

Setting the Stage

Each chapter opens with a dramatic photo. A brief Links to Earlier Concepts paragraph reminds students of relevant information in previous chapters. A summary of chapter content is organized and presented in terms of Core Concepts: evolution; information flow; systems; pathways of transformation; structure/function; or the process of science.

Section-Based Learning Objectives

The content of every chapter is organized as a series of sections. Learning Objectives associated with each section are phrased as activities that the student should be able to carry out after reading the text.

On-Page Glossary

An On-Page Glossary includes boldface key terms introduced in each section. This section-by-section glossary offers pronunciations, definitions in alternate wording, and it can be used as a quick study aid. All glossary terms also appear in boldface in the Chapter Summary.

Emphasis on Relevance

We continue to focus on real-world applications, including social issues arising from new research and developments—particularly the many ways in which human activities continue to alter the environment and threaten both human health and Earth's biodiversity. Each chapter begins and ends with a section that explains a current topic in light of the chapter content.

Self-Assessment Tools

Many figure captions include a Figure-It-Out question designed to engage students in an active learning process; an upside-down answer allows a quick check of understanding. At the end of each chapter, Self-Quiz and Critical Thinking Questions provide additional self-assessment material. Another active-learning feature, the in-text Data Analysis Activity, sharpens analytical skills by asking the student to interpret data presented in graphic or tabular form. The data is presented with relevant chapter content, and is from a published scientific study in most cases.

Some Updates in This Revision

1 Invitation to Biology Expanded section "The Nature of Science" includes new, detailed coverage of pseudoscience and how it differs from science.

2 Life's Chemical Basis New table compares elemental composition of the human body with Earth's crust, seawater, and the universe. Updated art more clearly demonstrates vacancies. New art illustrates and compares bond polarity.

3 Molecules of Life Revised text further emphasizes levels of protein structure as related to protein function. New art illustrates patterns of secondary structure; new content reflects current research elucidating misfolded prion structure and pathogenesis of amyloid diseases.

4 Cell Structure New, major art depicts interactions among components of the endomembrane system. New art reveals ultrastructural details of cell junctions per recent discoveries. New photos illustrate a beneficial biofilm, cuticle, and basement membrane. Expanded section on the nature of life now includes theory of living systems.

5 Ground Rules of Metabolism New photos and art use firefly luciferase to illustrate energy flow in metabolism. Updated art clarifies selective permeability of cell membranes and tonicity, and directional orientation of membrane proteins during exocytosis. Expanded coverage of ATP as a coenzyme.

6 Where It Starts—Photosynthesis Chapter has been reorganized for a better introductory sequence. New art illustrates a special pair, light-harvesting complex, and cyclic photophosphorylation. Expanded discussion of the cyclic pathway emphasizes the interplay between both versions of light reactions, and the evolutionary significance of dual pathways. Expanded discussion of photorespiration incorporates new research on its adaptive value.

7 Releasing Chemical Energy Art updated throughout. New introductory table and art in each section detail inputs and outputs linking steps in aerobic respiration. Revised diagram better illustrates dual PGAL breakdown in glycolysis. New Data Analysis Activity concerns reprogramming of mitochondria in brown fat by dietary fat overload.

8 DNA Structure and Function Nucleotide structure art revised to better illustrate composition and two-dimensional accuracy. Updated art including model of a pyrimidine dimer clarifies how replication errors become mutations.

9 From DNA to Protein New art illustrates the overall structure of a gene and its relationship to RNA translated from it. New table compares DNA and RNA. Revised art better illustrates post-transcriptional modification; major translation figure updated to clarify elongation and polysomes. Expanded section on mutations includes material on a beneficial hemoglobin mutation (E6K, HbC) that offers resistance to malaria without the health consequences of HbS; and how a mutation in a regulatory site (an intron) can affect gene expression (resulting in hairlessness in cats).

10 Control of Gene Expression Updated art better illustrates points of control in eukaryotic gene expression. New flow chart shows gene expression cascade in *Drosophila* development; new art illustrates random nature of X chromosome inactivation. Added coverage of circadian cycles of gene expression; expanded discussion reflects current understanding of epigenetic mechanisms.

11 How Cells Reproduce New ultra-high resolution confocal live-cell images better illustrate mitosis and the spindle. Cell cycle illustration now correlated with illustration of ploidy changes in mitosis. Revised text and art showing cytokinesis include ultrastructural details/processes per current research and paradigms. Expanded material on telomeres now includes telomere-associated triggering and consequences of senescence.

12 Meiosis and Sexual Reproduction New figure illustrates how fertilization restores the chromosome number. Newly discovered mechanism of gene acquisition by individual rotifers added to revisited section.

13 Observing Patterns in Inherited Traits Marfan syndrome discussion updated to reflect change in life expectancy due to increased awareness, accompanied by new photo of former Baylor University basketball star Isaiah Austin.

14 Chromosomes and Human Inheritance Molecular pathogenesis of Huntington's and DMD updated to reflect current research. Table of genetic abnormalities now broken by section. Updated art better depicts chromosome structural changes.

15 Studying and Manipulating Genomes Art depicting recombinant DNA production and reverse transcription revised for clarity. Art and text revised to include structure and utility of eukaryotic expression vectors. New figure illustrates exponential amplification of DNA by PCR. New table lists human genome statistics. Gene therapy section revised to include mechanism, application, and social implications of CRISPR-Cas9 gene editing.

16 Evidence of Evolution Cetacean evolutionary sequence updated to reflect currently accepted narrative. Current research informed revisions of plate tectonics art. Paleogeography art revised to show Mercator projections.

17 Processes of Evolution Updated material on antibiotic resistance and overuse of antibiotics in livestock. Illustration of HbS allele frequency vs. incidence of malaria updated to reflect recent data in Gabon. New photo of bumblebee on white sage flower added to mechanical isolation figure. Discussion of sympatric speciation in wheat revised to reflect current research.

18 Organizing Information About Species Phylogeny section and parsimony analysis figure revised for clarity. Convergent and divergent evolution terminology introduced. New photo of stem reptile fossil added to divergent evolution figure. New close-up of saguaro cactus spines juxtaposed with Euphorbia spines for better illustration of convergent evolution.

19 Life's Origin and Early Evolution Expanded coverage of the Precambrian, including timeline. Updated information about the possibility of an RNA world, the earliest proposed fossil life, and the archaeal and bacterial ancestors of eukaryotes. New Data Analysis Activity about the effect of some antibiotics on mitochondria.

20 Viruses, Bacteria, and Archaea New opening essay about the human microbiota. Improved art comparing viral structures. Updated information about Ebola, AIDS, and Zika virus. Updated figure showing binary fission. New figure illustrating mechanisms of horizontal gene transfer in prokaryotes. New section about bacteria as pathogens. New Data Analysis Activity about antibiotics inspired by the study of bacteriophages.

21 The Protists Chapter reorganized to reflect our current understanding of the major eukaryotic supergroups. New overview of protist cell structure.

22 Plant Evolution Revised life cycle graphics throughout the chapter; improved figure illustrating generalized process of seed production.

23 Fungi Added photos of athlete's foot and ringworm. Updated information about white nose syndrome. Increased coverage of the use of fungi in food production, research, biotechnology, and as sources of medicine.

24 Animals I: Major Invertebrate Groups Added information about sponge regeneration. New figure showing schistosomes. Coverage of placozoans, rotifers, and tardigrades deleted.

25 Animals II: The Chordates New information about bone loss in the evolution of cartilaginous fishes.

26 Human Evolution Updated information about fossil hominids, including discussion of Denisovans and *Homo naledi*.

27 Plant Tissues New art includes illustration of stem structure and location of the vascular cylinder in a root.

Preface (continued)

28 Plant Nutrition and Transport Added information about use of phytoremediation at Fukushima. New micrographs and associated art detail the flow of water through xylem cells. Updated translocation art coordinates with new art illustrating sieve tube structure.

29 Life Cycles of Flowering Plants Detail added to plant life cycle art for accuracy. New photo illustrates root suckers.

30 Communication Strategies in Plants Current research informed updates to mechanisms of hormonal action. Table summarizing plant hormones has been broken by section. Added material includes the role of ABA in stress-related stomata closure; nastic movements and accompanying new photos; and explanation of *Phylloxera* resistance in American grapevines based on enhanced hypersensitive response involving resveratrol.

31 Animal Tissues and Organ Systems New summary table describing tissue types. Improved graphic illustrating relative volumes of the fluid components of a human body. New information about brown fat versus white fat and white matter and gray matter. Updated information about research on and clinical use of induced pluripotent stem cells (iPSCs) and about transdifferentiation as an alternative source of replacement cells.

32 Neural Control Updated information about brain damage among professional football players. New opening overview of intracellular signaling mechanisms. Revised/reorganized coverage of the peripheral nervous system. New subsection covers tissues and fluid of the CNS; information about neuroglia moved here.

33 Sensory Perception Updated illustration/discussion of retina anatomy to include light-channeling neuroglia.

34 Endocrine Control Added information about sites of human steroid hormone production (gonads/adrenals). Consolidated information about hormones in a single table. Moved discussion of pineal gland to follow discussion of pituitary/hypothalamus. Deleted coverage of the thymus. New Data Analysis Activity covers the disruptive effect of BPA on insulin secretion.

35 Structural Support and Movement Improved figures depicting locomotion of fly and earthworm. Revised figure showing the structure of skeletal muscle.

36 Circulation Updated photo depicting measurement of blood pressure. Expanded coverage of venule function. New art depicting atherosclerosis. Added discussion of heart attack symptoms and of causes and symptoms of stroke. New Data Analysis Activity on how hypertension affects the risk of stroke and heart attack.

37 Immunity New application section that details vaccination and benefits of herd immunity features a narrative about an unvaccinated child with permanent health consequences of contracting measles. New photos illustrate microbial sectors of a dental plaque biofilm, agglutination, and anaphylaxis. Revised art better illustrates specificity of antigen binding sites in antibodies. New content includes role of keratinocytes as immune cells in contact allergies.

38 Respiration Improved photo of insect tracheal system. Increased emphasis on evolutionary trends in vertebrate lung structure. Added information about the risks of vaping. New Data Analysis Activity addresses effects of tobacco and marijuana smoke on the lungs.

39 Digestion and Human Nutrition New opening essay about the role of human digestive enzymes and genetic variations in these enzymes. Added coverage of sponge digestion with new graphic. New figure compares length of digestive tract regions in a mammalian carnivore and herbivore. New graphics depict peristalsis and segmentation. Coverage of beneficial gut microflora moved to the section about the large intestine.

40 Maintaining the Internal Environment Material reorganized with separate sections describing formation and types of wastes and types of excretory organs. Variations on kidney structure in fish and desert rat kidneys now covered in a separate section after discussion of human kidney structure. Added information about human body hair as a temperature-related adaptation. Deleted coverage of human variation in sodium reabsorption.

41 Animal Reproduction Updated information about STDs, including new discussion of *Mycoplasma genitalium* infection.

42 Animal Development Morphogens now discussed in the context of embryonic induction. Added information about the teratogenic effects of the Zika virus.

43 Animal Behavior New information about epigenetic effects in a variety of contexts. Improved honeybee dance language figure. New information about tent caterpillars, a pre-social species. Added information about reciprocal altruism.

44 Population Ecology New information about research indicating that human hunting altered the life-history traits of woolly mammoths. Updated human population statistics.

45 Community Ecology Added coverage and photos of sundews and spiders that complete for insect prey. Updated photo of Surtsey.

46 Ecosystems Updated information about the increasing level of atmospheric carbon dioxide and the evidence that human activities are responsible for this increase.

47 The Biosphere Updated information about the movement of radioactive compounds released at Fukushima. Figure depicting seasonal overturn in a lake revised. Increased coverage of the importance of dissolved oxygen in aquatic habitats. New coverage of ocean acidification as a threat to reefs.

48 Human Effects on the Biosphere New opening section about the proposal to recognize human effects by naming a new geological epoch—the Anthropocene. New Data Analysis Activity about bioaccumulation of radioactive materials in tuna. Revised, updated coverage of biodiversity hotspots. New closing section about how citizen science can help document the distribution and decline of biodiversity.