basic concepts in
BIOLOGY

STARR / FIFTH EDITION

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BIOLOGY

FIFTH EDITION

FROM

BIOLOGY
CONCEPTS AND APPLICATIONS

FIFTH EDITION

CECIE STARR

LISA STARR
Biology Illustrator

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Preface

Teachers of introductory biology know all about the Red Queen effect, whereby one runs as fast as one can to stay in the same place. New and refined information from hundreds of fields of inquiry piles up daily, and somehow teachers are expected to distill it into Biology Lite, a zip through the high points, and help students deepen their understanding of a world of unbelievable richness.

Restricting textbook content runs the risk of splintering understanding of that world, as when an emphasis on human biology inadvertently reinforces archaic notions that everything on Earth is here in the service of Us; or when a molecular focus excludes knowledge of whole organisms. Here I am reminded of the well intentioned but lethal blanketing of habitats with DDT.

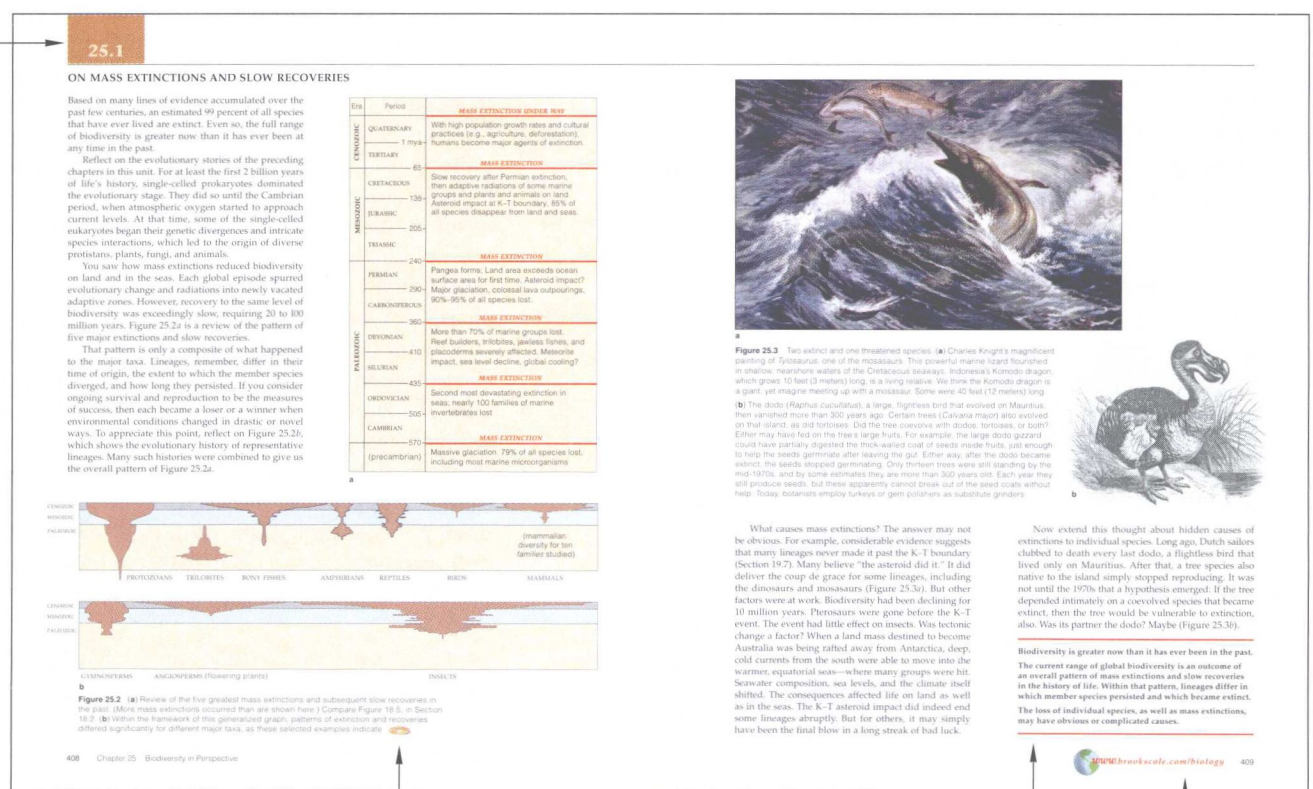
This book is a condensed version of *Biology: Concepts and Applications*, which is a coherent account of the sweep of life's diversity and its underlying unity. Through its examples of problem solving and experiments, it shows the power of thinking critically about the natural world. It highlights key concepts, current understandings, and research trends for major fields of biological inquiry. It explains the structure and function of a broad sampling of organisms in enough detail so that students can develop a working vocabulary about life's parts and processes.

We start with an overview of the basic concepts and scientific methods. Next are three units on the principles of biochemistry, inheritance, and evolution—a conceptual framework for exploring life's unity and diversity. Recognizing that details of anatomy and physiology are beyond the scope of some courses, this shorter book omits units on plant and animal structure/function but is still a self-contained introduction to the major principles of cytology, genetics, evolution and biodiversity, and ecology. The last unit focuses on the patterns and consequences of organisms interacting with one another and with the environment. This conceptual organization parallels the levels of biological organization.

CONCEPT SPREADS Over the years, ongoing feedback from teachers of more than 3 million students helped us refine our approach. We keep the story line in focus for students by subscribing to the question "How do you eat an elephant?" and its answer, "One bite at a time." We organize descriptions, art, and supporting evidence for each concept on two facing pages at most. Each *concept spread* starts with a numbered tab and concludes with boldfaced summaries of key points (*see below*). On-page summaries allow students to check their understanding of one concept before turning to another.

The clear conceptual organization within chapters also offers teachers flexibility in assigning text material to fit course requirements. For example, those who spend little

Numbered tabs indicate the start of a new concept as the chapter's story unfolds. The gold tabs identify basic chapter concepts. Blue tabs identify Focus essays that enrich the basics with examples of experiments (to demonstrate the power of critical thinking), of the nature of life, and of applying the basics to issues of human interest.


25.1

ON MASS EXTINCTIONS AND SLOW RECOVERIES

Based on many lines of evidence accumulated over the past few centuries, an estimated 99 percent of all species that have ever lived are extinct. Even so, the full range of biodiversity is greater now than it has ever been at any time in the past.

Reflect on the evolutionary stories of the preceding chapters in this unit. For at least the first 2 billion years of life's history, single-celled prokaryotes dominated the evolutionary stage. They did so until the Cambrian period, when atmospheric oxygen started to approach current levels. At that time, some of the single-celled eukaryotes began their genetic divergences and intricate species interactions, which led to the origin of diverse protistans, plants, fungi, and animals.

You saw how mass extinctions reduced biodiversity on land and in the seas. Each global episode spurred evolutionary change and radiations into newly vacated adaptive zones. However, recovery to the same level of biodiversity was exceedingly slow, requiring 20 to 100 million years. Figure 25.2*a* is a review of the pattern of five major extinctions and slow recoveries.

That pattern is only a composite of what happened to the major taxa. Lineages, remember, differ in their time of origin, the extent to which the member species diverged, and how long they persisted. If you consider ongoing survival and reproduction to be the measures of success, then each became a loser or a winner when environmental conditions changed in drastic or novel ways. To appreciate this point, reflect on Figure 25.2*b*, which shows the evolutionary history of representative lineages. Many such histories were combined to give us the overall pattern of Figure 25.2*a*.

Figure 25.2 (**a**) Review of the five greatest mass extinctions and subsequent slow recoveries in the past. (More mass extinctions occurred than are shown here.) Compare Figure 18.5, in Section 18.2. (**b**) Within the framework of this generalized graph, patterns of extinction and recoveries differed significantly for different major taxa, as these selected examples indicate.

a

b

Figure 25.3 Two extinct and one threatened species. (**a**) Charles Knight's magnificent painting of Tylosaurus, one of the mosasaurs. This powerful marine lizard flourished in shallow, nearshore waters of the Cretaceous seaways. Indonesia's Komodo dragon, which grows 10 feet (3 meters) long, is a living relative. We think the Komodo dragon is a giant, yet imagine meeting up with a mosasaur. Some were 40 feet (12 meters) long. (**b**) The dodo (*Raphus cucullatus*), a large, flightless bird that evolved on Mauritius, then vanished more than 300 years ago. Certain trees (*Calvaria major*) also evolved on that island, as did tortoises. Did the tree coevolve with dodos, tortoises, or both? Either may have fed on the tree's large fruits. For example, the large dodo gizzard could have partially digested the thick-walled coat of seeds inside fruits, just enough to help the seeds germinate after leaving the gut. Either way, after the dodo became extinct, the seeds stopped germinating. Only thirteen trees were still standing by the mid-1970s, and by some estimates they are more than 300 years old. Each year they still produce seeds, but these apparently cannot break out of the seed coats without help. Today, botanists employ turkeys or gem polishers as substitute grinders.

What causes mass extinctions? The answer may not be obvious. For example, considerable evidence suggests that many lineages never made it past the K-T boundary (Section 19.7). Many believe "the asteroid did it." It did deliver the coup de grace for some lineages, including the dinosaurs and mosasaurs (Figure 25.3*a*). But other factors were at work. Biodiversity had been declining for 10 million years. Pterosaurs were gone before the K-T event. The event had little effect on insects. Was tectonic change a factor? When a land mass destined to become Australia was being rafted away from Antarctica, deep, cold currents from the south were able to move into the warmer, equatorial seas—where many groups were hit. Seawater composition, sea levels, and the climate itself shifted. The consequences affected life on land as well as in the seas. The K-T asteroid impact did indeed end some lineages abruptly. But for others, it may simply have been the final blow in a long streak of bad luck.

Now extend this thought about hidden causes of extinctions to individual species. Long ago, Dutch sailors clubbed to death every last dodo, a flightless bird that lived only on Mauritius. After that, a tree species also native to the island simply stopped reproducing. It was not until the 1970s that a hypothesis emerged. If the tree depended intimately on a coevolved species that became extinct, then the tree would be vulnerable to extinction, also. Was its partner the dodo? Maybe (Figure 25.3*b*).

Biodiversity is greater now than it has ever been in the past.

The current range of global biodiversity is an outcome of an overall pattern of mass extinctions and slow recoveries in the history of life. Within that pattern, lineages differ in which member species persisted and which became extinct.

The loss of individual species, as well as mass extinctions, may have obvious or complicated causes.

This icon signifies that our interactive CD-ROM further explores the concept being illustrated.

Topic section ends with a summary of key concepts.

Website expands on the section's topic.

time on photosynthesis may choose to bypass the spreads on properties of light and the chemiosmotic theory of ATP formation. They may or may not assign Focus essays (one on the global impact of photosynthesis, another on how photosynthesis may have started in the first place). All of the concept spreads flow as parts of the same story, but some clearly offer depth that can be treated as optional.

Concept spreads are not gimmicks. Ongoing feedback guided decisions about when to add depth and when to loosen core material with applications. Within spreads, headings and subheadings help students keep track of the hierarchy of information. Transitions between spreads help them keep the greater story in focus and discourage memorization for its own sake. To avoid disrupting the basic story line while still attending to interested students, we include some details in optional, enriching illustrations.

Our organization helps students find assigned topics easily and translates into a tangible outcome—improved test scores. Its underlying logic also helps them develop enough confidence to dig deeper into biological science.

BALANCING CONCEPTS WITH APPLICATIONS Chapters start with a lively or sobering application and an advance organizer—a list of key concepts. Essays parallel the core material to help maintain student interest in the basics. The essays afford more depth on medical, environmental, and social issues without interrupting conceptual flows. Briefer applications are integrated in the text. The final pages index all applications separately for fast reference.

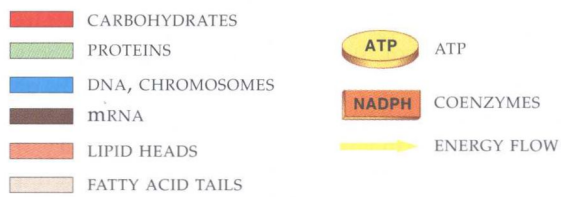
FOUNDATIONS FOR CRITICAL THINKING To help students sharpen their capacity for critical thinking, we walk them through experiments that yielded evidence in favor of or against hypotheses. The main index lists all of the experiments we selected for the book (see the entries *Experiment, examples*, and *Test, observational*).

We use certain chapter introductions as well as whole chapters to show students some productive results of critical thinking. The introductions to Mendelian genetics (Chapter 10), DNA structure and function (12), speciation (17), and behavior (28) are examples. Also, each chapter has a set of *Critical Thinking* questions, most of which were created by Katherine Denniston. Daniel Fairbanks created many of our original *Genetics Problems*, which help students grasp the usefulness of the principles of inheritance (Chapters 10 and 11).

VISUAL OVERVIEWS OF CONCEPTS We simultaneously develop text and art as inseparable parts of the same story. We give visual learners a means to work their way through a visual overview of major processes before reading the corresponding text. Students repeatedly let us know how much they appreciate this art. The overview illustrations include step-by-step descriptions of biological parts and processes. Instead of "wordless" diagrams, we break down information into a series of illustrated callouts. In Figure 13.10, for example, callouts integrated with the art walk students through the stages by which a mature mRNA transcript becomes translated. The diagram uses simple models of up-to-date molecular structures, explained in preceding figures (Figures 13.8 and 13.9).

ZOOM SEQUENCES Certain key illustrations progress from macroscopic to microscopic views of a system or process. Figure 6.3, for example, starts with a plant leaf and ends with reaction sites in the chloroplast. Figure 7.4 starts with sketches of animal, plant, and bacterial cells to show where glycolysis occurs, then shows all the carbons covalently bonded in a glucose molecule, then shows how the molecule is dismantled step by step to three-carbon pyruvates. Figure 7.5 starts with a micrograph and sketch of a mitochondrion and zooms in on the reaction sites.

COLOR CODES Consistent use of colors for molecules, cell structures, and processes helps students track what is going on. We use these colors throughout the book:



ICONS Small icons next to an illustration help students relate a topic to the big picture. For instance, a cell icon reminds them of the location of the plasma membrane relative to the cytoplasm. Some icons relate reactions and processes to cell locations and to one another. Others are reminders of evolutionary relationships among groups, as in Chapters 23 and 24. A multimedia icon directs students to art in the CD-ROM packaged in its own envelope at the back of their book. Others direct them to supplemental material on the Web and to InfoTrac® College Edition, an online database of full-length articles from hundreds of top academic journals and popular sources.

MAJOR CONTENT REVISIONS New to this edition is a chapter on biodiversity and mass extinctions (25). The chapters on principles of metabolism (5) photosynthesis (6), gene control (14), macroevolution (18), principles of animal reproduction/development (26), and ecosystems (30) are significantly reorganized. Like the other chapters, they are now more succinct and accessible owing to line-by-line snipping, as indirectly evidenced by the more open page layouts. Users will find major new art, crisper definitions, new end-of chapter material, and new or updated material throughout, as highlighted here:

Unit I. Principles of Cellular Life Chapter 2 has new atomic and molecular models. Chapter 3 shows the non-ionized and ionized forms of carboxyl and amino groups (a point of confusion for students, who see both in the literature); its hemoglobin model is new. Chapter 4 has new text and art on the cytoskeleton and, as elsewhere, distinguishes between prokaryotic cell and bacterial cell. Chapter 5 has

a new introduction on enzymes and aging, and weaves in fascinating experiments with *Caenorhabditis elegans*. The chapter has a new Critical Thinking question on cyanide poisoning. Revised and reorganized chapter 6 has livelier writing, as in Section 6.1, and a condensed Summary. It has new text and art on photosystems; the function of electron transport systems is stated more clearly. Art comparing carbon-fixing strategies has accurate cross-sections of C3 and C4 leaves. There are new Critical Thinking questions on the evolution of photosynthesis and on bioluminescence. Chapter 7, a tough topic, has more user-friendly art.

Unit II. Principles of Inheritance In Chapter 8, we moved the overview of chromosome structure forward, added a bit on the cell cycle, refined the mitosis art, and added photographs of Henrietta Lacks and HeLa cells. Micrographs accompany the meiosis diagram in Chapter 9; we finally found some uncomplicated ones that won't confuse students. Chapter 10 has refined definitions of monohybrid and dihybrid crosses, and new text and art on experiments that revealed environmental effects on *Achillea millefolium* phenotype. Chapter 11 has a CML update, the crossing over sketch is moved to the overview section, its karyotyping essay is simplified, and it has a new human example of an outcome of crossing over and genetic recombination. More human genetic disorders are covered (see Table 11.1). We expanded the Summary and added a Critical Thinking question on perceptions of genetic disorders. Chapter 12 includes a new model for DNA and mentions new evidence of the function of DNA's structure (page 195). The updated DNA cloning essay includes concerns about random mistakes in cloning processes. We added a Critical Thinking question on cloning extinct mammals. Updated Chapter 13 includes a recently deduced molecular model for the eukaryotic ribosome; text and art on translation are modified accordingly and show the rRNA catalytic site. The transposon material is updated here and elsewhere; the distinction between ionizing and non-ionizing radiation is clarified. The summary is tighter.

Chapter 14 has a shorter introductory essay on cancer and the nature of gene control; details are in an updated essay on the cell cycle and cancer. A new section gives an overview of control mechanisms. The lactose operon section also describes lactose intolerance. The point of X chromosome inactivation (dosage compensation) is clearly stated. A new invertebrate example (ecdysone control) is included. Chapter 15 includes a recent genetic engineering experiment on aspens plus updates on the mammalian cloning issue, the Human Genome Initiative, and gene therapy for bubble boys. We have an extended Critical Thinking question on genetically engineered food, and another on minimal organisms. We moved description and illustration of bacterial conjugation to Section 20.3.

Unit III. Principles of Evolution We refined the text on stabilizing and disruptive selection and balanced polymorphism and added Self-Quiz questions plus a Critical Thinking question on the rise of TB cases. Chapter 17 has new photographs for mechanicalisolation and sympatric speciation.

Chapter 18 has a new introduction based on insights into the biblical flood story as a way to put catastrophism and evolutionary theories in a cultural context. Next is a new section on the fossil record, a new focus essay on radiometric dating and the geologic time scale combined with major events in life history, and revised sections on biogeography and comparative morphology with new art. A revised comparative embryology section connects ideas about transposons to primate evolution; the comparative biochemistry section has been updated and has a better explanation of how molecular clocks are calibrated. A new section on taxonomy and classification follows; it has a simple description of how to construct a cladogram, and considers the pros and cons of the three-domain scheme. A new essay uses *Archaeopteryx* to show how evidence of evolution can be interpreted and misinterpreted. The Summary is revised.

Unit IV. Evolution and Biodiversity Chapter 19 has updates on the RNA world, the selective advantage of DNA structure, the Cambrian "explosion," Paleozoic and Mesozoic mass extinctions, and new reconstructions of early life (Figures 19.14 and 19.16). We moved the visual summary of Earth and life history to Chapter 18, but a concise version also is at the chapter's end. Chapter 20 has stunning new micrographs and art, more on archaebacteria and Lyme disease, a bit on bacterial conjugation, an update on prions and BSE, a bit on toxoplasmosis, a new table on the eight deadliest infectious diseases, and a look at food poisoning. The section on single-celled algae is revised, with a nod to The Cell From Hell. Two new Critical Thinking questions consider unsterilized needles and foot-and-mouth disease. Chapter 21 has new ascomycetes micrographs, a bit on household molds (page 336), an update on some imperfect fungi, and a better section on symbionts. Chapter 22 has new opening photos and more concise sections on evolutionary trends and the rise of seed-bearing plants. Chapter 23 has revised bits on cnidarians, roundworms, spiders and scorpions, and insects, and new Critical Thinking questions. Lobe-finned fishes are back with the fishes in Chapter 25, which also has an example of frog deformities, a cutaway turtle shell and skeleton, and more on birds and mammals, as in new Critical Thinking questions with art. Its sections on primates and human evolution have updated text and art, including new skull reconstructions. The summary is extensively revised.

New Chapter 25 puts biodiversity and extinction crises in evolutionary perspective. It starts with the Easter Island story and the nature of mass extinctions, slow recoveries, and individual species losses. It looks at threatened and endangered species, including their global distribution. It has a case study of coral reefs, an essay on Rachel Carson, and a section on conservation biology, including the role of systematics and bioeconomic analysis. It has two positive examples of recent attempts to reconcile biodiversity with human population growth and economic pressures (strip logging in the tropics and preservation of riparian zones).

Unit V. Animal Structure and Function Chapter 26 has major updates as well as text rewrites, especially on pattern formation and aging.

Unit VI. Ecology and Behavior Chapter 27 has updates on human population demographics, TFRs, age structure art, and California's rolling blackouts. The behavior chapter (28) is earlier in the unit to better correspond with levels of biological organization. The text is tighter; some overlaps between sections are eliminated. The example on altruism among termites is now a Critical Thinking question.

Chapter 29 on community interactions has tie-ins to Chapter 25 on biodiversity. It has updated material on the Canadian lynx/snowshoe hare puzzle, a new table on some species introductions, and a Criticial Thinking question on causes of frog deformities.

Chapter 30 (ecosystems) has major new sections with stunning art on the nature of food chains and food webs, using tallgrass prairie as the key example, followed by an essay on biological magnification based on the original DDT study. It has new art on seasonal shifts in an omnivore's diet, rewritten text for the carbon cycle, and updated text and art for the essay on global warming. It describes the effect of fertilizers on soil ion exchange.

Chapter 31 (biosphere) has new art on environmental gradients and on climate zones, new icon maps for biomes, new text and new photographs of tundra, and a revised section on wetlands that includes mangrove swamps. The coral reef section is now in Chapter 25. Chapter 32 has updates on ozone thinning and nuclear energy, and some changes to the essay on tropical rain forests.

SUPPLEMENTS The Instructors' Examination copy lists the comprehensive package of print and multimedia supplements to this book, including online resources.

A COMMUNITY EFFORT This book is the current version of an educational effort that started twenty-six years ago. About 2,000 teachers and researchers have contributed to its ongoing refinement, and along the way we have helped more than 3 million students gain insights into the nature of biology. Much of our art and text, which is accurate and pedagogically sound as an outcome of years of research, brainstorming, and classroom testing, is now standard fare in many textbooks. The individuals listed at right deserve recognition for their commitment to quality in education.

We entrusted this edition to Gary Head, Lisa Starr, Teri Hyde, Grace Davidson, Myrna Engler, and Angela Harris —an exceptionally dedicated publishing team. Each is a superior talent in publishing. Heidi Marschner, Diane Kimmel, and Karen Hunt helped out. Pat Waldo, Chris Evers, and Steve Bolinger created a terrific multimedia package. Susan Badger and Jack Carey especially, and Kathie Head and Sean Wakely, thank you so much for your creative, enlightened management.

Cecie Starr, June 2001

General Advisors/Contributors

JOHN ALCOCK *Arizona State University*
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LITTLE, ROBERT *Medical College of Georgia*
LOHMEIER, LYNNE *Mississippi Gulf Coast Community College*
LOPO, ALINA C. *University of California-Los Angeles Medical Center*
LUMSDEN, ANN *Florida State University*
MACKLIN, MONICA *Northeastern State University*
MANN, ALAN *University of Pennsylvania*
MARTIN, JAMES *Reynolds Community College*
MARTIN, TERRY *Kishwaukee College*
MATSON, RONALD *Kennesaw State College*
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MCCLURE, JERRY *Miami University*
MCEDWARD, LARRY *University of Florida*
MCKEAN, HEATHER *Eastern Washington State University*
MCKEE, DOROTHY *Auburn University, Montgomery*
MCNABB, ANN *Virginia Polytechnic Institute and State University*
MICKLE, JAMES *North Carolina State University*
MILLER, G. TYLER *Wilmington, North Carolina*
MINORKSY, PETER V. *Western Connecticut State University*
MOISES, HYLAN C. *University of Michigan Medical School*
MOORE–LANDECKER, ELIZABETH *Glassboro State University*
MORRISON–SHETLER, ALLISON *Georgia State University*
MORTON, DAVID *Frostburg State University*
MURPHY, RICHARD *University of Virginia Medical School*
MYRES, BRIAN *Cypress College*
NAGARKATTI, PRAKASH *Virginia Polytechnic Institute & State University*
NELSON, RILEY *University of Texas at Austin*
NORRIS, DAVID *University of Colorado*
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PECK, JAMES H. *University of Arkansas, Little Rock*
PERRY, JAMES *University of Wisconsin, Center-Fox Valley*
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PLETT, HAROLD *Fullerton College*
REESE, R. NEIL *South Dakota State University*
REEVE, MARIAN *Emeritus, Merritt Community College*
REID, BRUCE *Kean College of New Jersey*
RENFROE, MICHAEL *James Madison University*
REZNICK, DAVID *University of California, Riverside*
RICKETT, JOHN *University of Arkansas, Little Rock*
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SCHNEIDEWENT, JUDY *Milwaukee Area Technical College*
SCHNERMANN, JURGEN *University of Michigan School of Medicine*
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TROUT, RICHARD E. *Oklahoma City Community College*
TYSER, ROBIN *University of Wisconsin, LaCrosse*
WAALAND, ROBERT *University of Washington*
WAHLERT, JOHN *City University of New York, Baruch College*
WALSH, BRUCE *University of Arizona*
WARING, RICHARD *Oregon State University*
WARNER, MARGARET R. *Purdue University*
WEBB, JACQUELINE F. *Villanova University*
WEIGL, ANN *Winston-Salem State University*
WEISS, MARK *Wayne State University*
WELKIE, GEORGE W. *Utah State University*
WENDEROTH, MARY PAT *University of Washington*
WHITE, EVELYN *Alabama State University*
WHITENBERG, DAVID *Southwest Texas State University*
WINICUR, SANDRA *Indiana University, South Bend*
YONENAKA, SHANNA *San Francisco State University*

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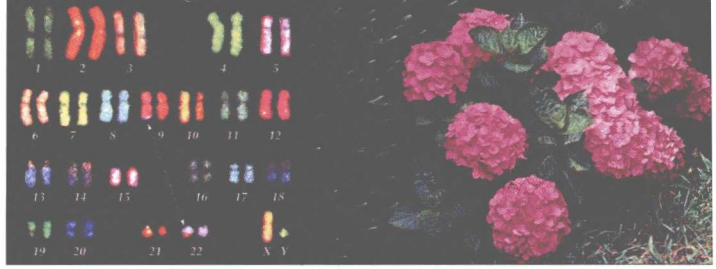

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