Explore Modern Astronomy and Its Connections to Our Lives

*The Cosmic Perspective* provides a thoroughly engaging and up-to-date introduction to astronomy for anyone who is curious about the universe. As respected teachers and active researchers, the authors present astronomy using a coherent narrative and a thematic approach that engages students immediately and guides them through connecting ideas. The *Ninth Edition* features major scientific updates, new content that focuses on the possibility of life in the universe and recent discoveries, and an enhanced focus on cultural diversity among scientists and ethics across science and astronomy. *Mastering Astronomy* includes a wealth of author-created resources for students to use before, during, and after class.
Chapter 11 has been updated with the latest discoveries from the Juno and Cassini missions, as well as new understanding of Jupiter’s weather, Saturn’s rings, and more.

Other updates include new material on the detection of gravitational waves (Chapters 53 and 18), new insights into extrasolar planets (Chapter 13), new discoveries about early life on Earth (Chapter 24), and much more.
Revised End-of-Chapter Exercises
Deepen Student Understanding

Inclusive Astronomy
Use these questions to reflect on participation in science.
33. Group Discussion: Ancestral Astronomy. No matter what your background, you had ancestors who watched the sky and observed how celestial objects move through it.
   a. Working independently, choose a particular branch of your ancestry to explore, then gather historical information dating back as far as possible (ideally at least several centuries) about how and why your ancestors made use of their observations of the sky.
   b. Gather in small groups (two to four students) and take turns sharing what you learned through your research. Be clear about the ancestral group you have chosen and the time period your research covers.
   c. Make a list of the major uses of astronomical knowledge that your group members found, categorizing the uses as practical, ceremonial/religious, or other. Which uses were most common? Do you see any noticeable differences among the cultures?
   d. Discuss how cultural or geographical factors may have influenced the astronomical knowledge of these different ancestral groups.

NEW! Each chapter now has Inclusive Astronomy exercises designed to spur student discussion about topics such as why astronomy belongs to everyone and the ways in which the astronomical community is working to address historical inequities.

The Process of Science, a major theme integrated throughout the main text, is reinforced with a set of short-answer questions at the end of each chapter, as well as a suite of tutorials available for assignment in Mastering Astronomy.

See the newly reorganized end-of-chapter exercise sets for additional problem types designed to help your students review key concepts, check their understanding, and learn to think critically. All exercises are also assignable through Mastering Astronomy.

The Process of Science
These questions may be answered individually in short-essay form or discussed in groups, except where identified as group-only.
34. What Makes It Science? Choose a single idea in the modern view of the cosmos as discussed in Chapter 1, such as “The universe is expanding,” “The universe began with a Big Bang,” “We are made from elements manufactured by stars,” or “The Sun orbits the center of the Milky Way Galaxy once every 230 million years.”
   a. Describe how this idea reflects each of the three hallmarks of science, discussing how it is based on observations, how our understanding of it depends on a model, and how that model is testable.
   b. Describe a hypothetical observation that, if it were actually made, might cause us to call the idea into question. Then briefly discuss whether you think that, overall, the idea is likely or unlikely to hold up to future observations.
35. The Importance of Ancient Astronomy. Why was astronomy important to people in ancient times? Discuss both the practical importance of astronomy and the importance it may have had for religious, ceremonial, or philosophical traditions. Which of those roles (practical or religious/ceremonial/philosophical) do you think was more important in leading to the development of modern astronomy? Defend your opinions.
36. The Impact of Science. The modern world is filled with ideas, knowledge, and technology that developed through science and application of the scientific method. Discuss some of these things and how they affect our lives. Which of these impacts do you think are positive? Which are negative? Overall, do you think science has benefited the human race? Defend your opinion.
Mastering Astronomy’s Study Area Helps Students Come Prepared to Class . . .

The Study Area features self-study Reading, Concept, and Visual quizzes for each chapter, many videos and interactive figures, a set of self-guided tutorials covering key concepts, a media workbook, World Wide Telescope tours, and much more — PLUS access to a full etext of The Cosmic Perspective.

NEW! Nearly 100 new videos about key concepts and figures in the text, all written and most narrated by the authors to ensure consistency of terminology and pedagogy. Most videos include embedded pause-and-predict questions that allow students to check their understanding as they watch. Students can use these videos to help prepare for lectures, while instructors will find the same videos with assignable tutorials in the instructor-accessible Item Library.
Many of the **assignable tutorials** use ranking or sorting tasks, which research shows to be particularly effective in building conceptual understanding.

**The Item Library** also includes all end-of-chapter exercises from the book, individual questions from the three self-study quizzes (Reading, Concept, and Visual) for each chapter, and a large test bank.
Reach Every Student with Pearson eText

**Pearson eText, optimized for mobile**, seamlessly integrates videos and other rich media with the text and gives students access to their textbook anytime, anywhere.
Engage Students Before and During Class with Dynamic Study Modules and Learning Catalytics

NEW! Dynamic Study Modules in Mastering Astronomy help students study effectively—and at their own pace—by keeping them motivated and engaged. The assignable modules rely on the latest research in cognitive science, using methods—such as adaptivity, gamification, and intermittent rewards—to stimulate learning and improve retention.

With Learning Catalytics, you’ll hear from every student when it matters most. You pose a variety of questions that help students recall ideas, apply concepts, and develop critical-thinking skills. Your students respond using their own smartphones, tablets, or laptops. You can monitor responses with real-time analytics and find out what your students do—and don’t—understand. Then you can adjust your teaching accordingly, and even facilitate peer-to-peer learning, helping students stay motivated and engaged.
**The Cosmic Perspective** includes a full suite of instructor support materials in the Instructor Resources area in Mastering Astronomy. Resources include lecture presentations, images, reading quizzes, and clicker questions in PowerPoint; labeled and unlabeled JPEGs of all images from the text; an instructor’s guide for each chapter; and a test bank.

Download instructor resources from the links below.

### PowerPoint Presentation Tools

<table>
<thead>
<tr>
<th>Resource</th>
<th>Format</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 7 Image PowerPoint</td>
<td>pptx, 25.9 MB</td>
<td></td>
</tr>
<tr>
<td>Chapter 7 Lecture Outline PowerPoint</td>
<td>zip, 16.4 MB</td>
<td></td>
</tr>
<tr>
<td>Chapter 7 Reading Quiz Clicker PowerPoint</td>
<td>pptx, 3.4 MB</td>
<td></td>
</tr>
<tr>
<td>Chapter 7 Review Clicker PowerPoint</td>
<td>pptx, 3.3 MB</td>
<td></td>
</tr>
</tbody>
</table>

### JPEG Images

<table>
<thead>
<tr>
<th>Resource</th>
<th>Format</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendices Labeled JPEG Images</td>
<td>zip, 11.5 MB</td>
<td></td>
</tr>
<tr>
<td>Labeled images from appendices in the text.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 7 Labeled JPEG Images</td>
<td>zip, 24.7 MB</td>
<td></td>
</tr>
<tr>
<td>Labeled images from the text.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapter 7 Unlabeled JPEG Images</td>
<td>zip, 6.2 MB</td>
<td></td>
</tr>
<tr>
<td>Unlabeled images from the text.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Preface

We humans have gazed into the sky for countless generations. We have wondered how our lives are connected to the Sun, Moon, planets, and stars that adorn the heavens. Today, through the science of astronomy, we know that these connections go far deeper than our ancestors ever imagined. This book tells the story of modern astronomy and the new perspective, The Cosmic Perspective, that astronomy gives us on ourselves and our planet.

Who Is This Book For?
The Cosmic Perspective provides a comprehensive survey of modern astronomy suitable for anyone who is curious about the universe, regardless of prior background in astronomy or physics. However, it is designed primarily as a textbook for college courses in introductory astronomy. The Cosmic Perspective contains enough material for a full-year introductory astronomy sequence but can be flexibly used for shorter courses as well.

Instructors of shorter courses may also wish to consider several available variations of this textbook. We offer two volumes containing selected chapters from this book: The Solar System, which consists of Chapters 1–14 (including S1), and Stars, Galaxies, and Cosmology, which consists of Chapters 1–6 (including S1), S2–S4, and 14–24. Those teaching one-term general survey courses may wish to consider The Essential Cosmic Perspective, which covers a smaller set of topics and is tailored to meet the needs of comprehensive one-term survey courses in astronomy, and The Cosmic Perspective Fundamentals, which is even shorter and covers only the most fundamental topics in astronomy. All of these options are also available with Mastering Astronomy.

New to This Edition
The underlying philosophy, goals, and structure of The Cosmic Perspective remain the same as in past editions, but we have thoroughly updated the text and made a number of other improvements. Here, briefly, is a list of the significant changes you’ll find in the ninth edition:

- Major Chapter-Level Changes: We have made numerous significant changes to both update the science and improve the pedagogical flow in this edition. The full list is too long to put here, but major changes include the following:
  - In Chapter 2, we have reworked the section on eclipses with a new set of art pieces and revised pedagogy to reflect the fact that many students heard about or witnessed the 2017 eclipse.
  - Chapter 5 has a new Common Misconception box on “Light Paths, Lasers, and Shadows.”
  - In Chapter 6, we have made three significant updates: a focus on major new and planned observatories, including the James Webb Space Telescope; a new subsection on the role of “big data” in astronomy, using LSST as an example; and an expanded discussion of multi-messenger astronomy, such as the gravitational-wave observatory LIGO.
  - Chapter 9 has numerous scientific updates based on recent planetary missions, especially in Section 9.4 on Mars, where we discuss how recent evidence from the Curiosity rover is providing a new view of past periods of liquid water on Mars. We also discuss recent reanalysis of the cause of dark streaks and gullies on crater walls.
  - Chapter 10 has similar updates for new data, including the addition of a new Learning Goal in Section 10.4 on Mars, to reflect a deeper discussion of the history of the Martian climate. Section 10.6 on global warming has also been significantly updated, with greater emphasis on expected consequences of the warming.
  - In Chapter 11, we have revamped the discussion of Jupiter’s weather to include new results from the Juno mission. We have also made important scientific updates to the information on Saturn’s moons and rings based on results from the final stages of the Cassini mission.
  - Chapter 12 includes updated data and images from the Dawn, Rosetta, and New Horizons missions, along with discussion of the possibility of an undiscovered “Planet 9” and a new Special Topic box on 'Oumuamua, the first confirmed object with origin beyond our solar system to pass through our solar system.
  - In Chapter 13, we have rewritten the section on gravitational waves to include their recent direct detection.
  - Chapter 14 includes new discussion and a new figure about the Sun’s influence on Earth’s climate, and how we can rule out a changing Sun as a cause of recent global warming.
  - In Chapter 18, we have almost completely rewritten Section 18.4—changing from the two learning goals in the prior edition to three learning goals—to include the detection of gravitational waves from neutron star and black hole mergers.
Chapters 20 and 21 have been updated in light of new research on galactic evolution, some of which is based on the work of two of the authors of this book (Donahue and Voit). Chapter 20 also incorporates updates in describing the cosmic distance scale, including honoring Henrietta Levitt by referring to her period-luminosity relation as Leavitt’s law.

In Chapter 24, the first section has significant changes to incorporate newly discovered evidence for early life on Earth. The second section has been reworked to update the discussion of searching for life on Mars, and its second learning goal has been reworked to cover more than just the moons of Jupiter and Saturn.

Fully Updated Science: Astronomy is a fast-moving field, and numerous new developments have occurred since the prior edition was published. In addition to the major chapter-level changes described above, we have made many other scientific updates to reflect the latest results from both ground-based and space-based observatories and from spacecraft missions within the solar system.

Revamped Exercise Sets: We have reorganized the end-of-chapter exercise sets in order to place greater emphasis on questions designed to promote discussion and group work.

New Feature—Inclusive Astronomy: The astronomical community is engaged in broad and wide-ranging conversations about inclusion and the persistent lack of diversity in the fields of astronomy and other sciences. To provide sample openings for discussions of inclusion in the classroom, we have (1) added a new set of exercises in every chapter under the heading “Inclusive Astronomy,” written to initiate student discussions about topics centered on inclusiveness in astronomy; (2) added a similar set of additional exercises that you can find in the set of Group Activities available in the Study Area of Mastering Astronomy; and (3) replaced many of the chapter-opening epigraphs in order to include a more diverse group of individuals.

New Content in Mastering Astronomy: The Cosmic Perspective is much more than a textbook; it is a complete “learning package” that combines the textbook with deeply integrated, interactive media developed to support every chapter of our book. We continually update the material on the Mastering Astronomy website, and for this edition we call your attention to nearly 100 new “prelecture videos,” all written by (and most narrated by) the authors, designed to help students understand key concepts. Students can watch the videos at any time in the Study Area, while instructors can find assignable tutorials based on the videos in the instructor-accessible Item Library. In addition to the new videos and their corresponding tutorials, you will find many other new tutorials in the Item Library, as well as a fully updated set of reading, concept, and visual quizzes for each chapter, available in both the Study Area and the assignable Item Library. These resources should be especially valuable to instructors who wish to offer assignments designed to ensure that students are prepared before class and to those using “flipped classroom” strategies.

The Pedagogical Approach of The Cosmic Perspective

The Cosmic Perspective offers a broad survey of modern understanding of the cosmos and of how we have built that understanding. Such a survey can be presented in a number of different ways. We have chosen to build The Cosmic Perspective around a set of key themes designed to engage student interest and a set of pedagogical principles designed to ensure that all material comes across as clearly as possible to students.

Themes

Most students enrolled in introductory astronomy courses have little connection to astronomy when their course begins, and many have little understanding of how science actually works. The success of these students therefore depends on getting them engaged in the subject matter. To help achieve this, we have chosen to focus on the following five themes, which are interwoven throughout the book.

Theme 1: We are a part of the universe and can therefore learn about our origins by studying the universe. This is the overarching theme of The Cosmic Perspective, as we continually emphasize that learning about the universe helps us understand ourselves. Studying the intimate connections between human life and the cosmos gives students a reason to care about astronomy and also deepens their appreciation of the unique and fragile nature of our planet and its life.

Theme 2: The universe is comprehensible through scientific principles that anyone can understand. The universe is comprehensible because the same physical laws appear to be at work in every aspect, on every scale, and in every age of the universe. Moreover, while professional scientists generally have discovered the laws, anyone can understand their fundamental features. Students can learn enough in one or two terms of astronomy to comprehend the basic reasons for many phenomena that they see around them—phenomena ranging from seasonal changes and phases of the Moon to the most esoteric astronomical images that appear in the news.

Theme 3: Science is not a body of facts but rather a process through which we seek to understand the world around us. Many students assume that science is just a laundry list of facts. The long history of astronomy can show them that science is a process through which we learn about our universe—a process that is not always a straight line to the truth. That is why our ideas about the cosmos sometimes change as we learn more, as they did dramatically when we first recognized that Earth is a planet going around the Sun rather than the center of the universe. In this book, we continually emphasize the nature of science so that students can understand how
and why modern theories have gained acceptance and why these theories may change in the future.

Theme 4: Astronomy belongs to everyone. Astronomy has played a significant role throughout history in virtually every culture, and the modern science of astronomy owes a debt to these early and largely unsung astronomers. We therefore strive throughout the book to make sure that students understand that astronomical knowledge belongs to everyone, that people of all backgrounds have made and continue to make contributions to astronomical understanding, and that everyone should have the opportunity to study astronomy. Moreover, we seek to motivate students enough to ensure that they will remain engaged in the ongoing human adventure of astronomical discovery throughout their lives, no matter whether they choose to do that only by following the news media or by entering careers relating to astronomy.

Theme 5: Astronomy affects each of us personally with the new perspectives it offers. We all conduct the daily business of our lives with reference to some “world view”—a set of personal beliefs about our place and purpose in the universe, which we have developed through a combination of schooling, religious training, and personal thought. This world view shapes our beliefs and many of our actions. Although astronomy does not mandate a particular set of beliefs, it does provide perspectives on the architecture of the universe that can influence how we view ourselves and our world, and these perspectives can potentially affect our behavior. For example, someone who believes Earth to be at the center of the universe might treat our planet quite differently from someone who views it as a tiny and fragile world in the vast cosmos. In many respects, the role of astronomy in shaping world views may represent the deepest connection between the universe and the everyday lives of humans.

Pedagogical Principles

No matter how an astronomy course is taught, it is very important to present material according to well-established pedagogical principles. The following list briefly summarizes the major pedagogical principles that we apply throughout this book.

- Stay focused on the big picture. Astronomy is filled with interesting facts and details, but they are meaningless unless they fit into a big-picture view of the universe. We therefore take care to stay focused on the big picture (essentially the themes discussed above) at all times. A major benefit of this approach is that although students may forget individual facts and details after the course is over, the big-picture framework should stay with them for life.

- Always provide context first. We all learn new material more easily when we understand why we are learning it. In essence, this is simply the idea that it is easier to get somewhere when you know where you are going. We therefore begin the book (Chapter 1) with a broad overview of modern understanding of the cosmos, so that students know what they will be studying in the rest of the book. We maintain this “context first” approach throughout the book by always telling students what they will be learning, and why, before diving into the details.

- Make the material relevant. It’s human nature to be more interested in subjects that seem relevant to our lives. Fortunately, astronomy is filled with ideas that touch each of us personally. For example, the study of our solar system helps us better understand and appreciate our planet Earth, and the study of stars and galaxies helps us learn how we have come to exist. By emphasizing our personal connections to the cosmos, we make the material more meaningful, inspiring students to put in the effort necessary to learn it.

- Emphasize conceptual understanding over “stamp collecting” of facts. If we are not careful, astronomy can appear to be an overwhelming collection of facts that are easily forgotten when the course ends. We therefore emphasize a few key conceptual ideas, which we use over and over again. For example, the laws of conservation of energy and conservation of angular momentum (introduced in Section 4.3) reappear throughout the book, and the wide variety of features found on the terrestrial planets are described in terms of just a few basic geological processes. Research shows that, long after the course is over, students are far more likely to retain such conceptual learning than individual facts or details.

- Proceed from the more familiar and concrete to the less familiar and abstract. It’s well known that children learn best by starting with concrete ideas and then generalizing to abstractions later. The same is true for many adults. We therefore always try to “build bridges to the familiar”—that is, to begin with concrete or familiar ideas and then gradually draw more general principles from them.

- Use plain language. Surveys have found that the number of new terms in many introductory astronomy books is larger than the number of words taught in many first-year courses on a foreign language. In essence, this means the books are teaching astronomy in what looks to students like a foreign language! Clearly, it is much easier for students to understand key astronomical concepts if they are explained in plain English without resorting to unnecessary jargon. We have gone to great lengths to eliminate jargon or, at minimum, to replace standard jargon with terms that are easier to remember in the context of the subject matter.

- Recognize and address student misconceptions. Students do not arrive as blank slates. Most students enter our courses not only lacking the knowledge we hope to teach but also holding misconceptions about astronomical ideas. Therefore, to teach correct ideas, we must help students recognize the paradoxes in their prior misconceptions. We address this issue in a number of ways, the most obvious being the presence of many Common Misconceptions boxes. These

*More detail on these pedagogical principles can be found in the Instructor Guide and in the book *On Teaching Science* by Jeffrey Bennett (Big Kid Science, 2014).
summarize commonly held misconceptions and explain why they cannot be correct.

The Organizational Structure of The Cosmic Perspective

The Cosmic Perspective is organized into seven broad topical areas (the seven parts in the table of contents), each corresponding to a set of chapters along with related content in Mastering Astronomy. Note that the above themes and pedagogical principles are woven into this structure at every level.

Part Structure

The seven parts of The Cosmic Perspective each approach their set of chapters in a distinctive way designed to help maintain the focus on the five themes discussed earlier. Here, we summarize the philosophy and content of each part. Note that each part concludes with a two-page Cosmic Context spread designed to tie the part content together into a coherent whole.

Part I: Developing Perspective (Chapters 1–3, S1)

Guiding Philosophy: Introduce the big picture, the process of science, and the historical context of astronomy.


The basic goal of these chapters is to give students a big-picture overview and context for the rest of the book, as well as to help them develop an appreciation for the process of science and how science has developed through history. Chapter 1 outlines our modern understanding of the cosmos, including the scale of space and time, so that students gain perspective on the entire universe before diving into its details. Chapter 2 introduces basic sky phenomena, including seasons and phases of the Moon, and provides perspective on how phenomena we experience every day are tied to the broader cosmos. Chapter 3 discusses the nature of science, offering a historical perspective on the development of science and giving students perspective on how science works and how it differs from nonscience. The supplementary (optional) Chapter S1 goes into more detail about the sky, including celestial timekeeping and navigation.

Part II: Key Concepts for Astronomy (Chapters 4–6)

Guiding Philosophy: Connect the physics of the cosmos to everyday experiences.

The Cosmic Context figure for Part II appears on pp. 188–189.

These chapters lay the groundwork for understanding astronomy through what is sometimes called the “universality of physics”—the idea that a few key principles governing matter, energy, light, and motion explain both the phenomena of our daily lives and the mysteries of the cosmos. Each chapter begins with a section on science in everyday life in which we remind students how much they already know about scientific phenomena from their everyday experiences. We then build on this everyday knowledge to help students learn the formal principles of physics needed for the rest of their study of astronomy. Chapter 4 covers the laws of motion, the crucial conservation laws of angular momentum and energy, and the universal law of gravitation. Chapter 5 deals with the nature of light and matter, the formation of spectra, and the Doppler effect. Chapter 6 covers telescopes and astronomical observing techniques.

Part III: Learning from Other Worlds (Chapters 7–13)

Guiding Philosophy: We learn about our own world and existence by studying about other planets in our solar system and beyond.

Note: Part III is essentially independent of Parts IV through VII and can be covered either before or after them.

The Cosmic Context figure for Part III appears on pp. 400–401.
This set of chapters begins in Chapter 7 with a broad overview of the solar system, including an 11-page tour that highlights some of the most important and interesting features of the Sun and each of the planets in our solar system. In the remaining chapters of this part, we seek to explain these features through a true comparative planetology approach, in which the discussion emphasizes the processes that shape the planets rather than the “stamp collecting” of facts about them. Chapter 8 uses the concrete features of the solar system presented in Chapter 7 to build student understanding of the current theory of solar system formation. Chapters 9 and 10 focus on the terrestrial planets, covering key ideas of geology and atmospheres, respectively. In both chapters, we start with examples from our own planet Earth to help students understand the types of features that are found throughout the terrestrial worlds and the fundamental processes that explain how these features came to be. We then complete each of these chapters by summarizing how the various processes have played out on each individual world. Chapter 11 covers the jovian planets and their moons and rings. Chapter 12 discusses small bodies in the solar system, including asteroids, comets, and dwarf planets. It also covers cosmic collisions, including the impact linked to the extinction of the dinosaurs and views on how seriously we should take the ongoing impact threat. Finally, Chapter 13 turns to the exciting topic of other planetary systems.

Part IV: A Deeper Look at Nature (Chapters S2–S4)
Guiding Philosophy: Ideas of relativity and quantum mechanics are accessible to anyone.

Note: These chapters are labeled “supplementary” because coverage of them is optional. Covering them will give your students a deeper understanding of the topics that follow on stars, galaxies, and cosmology, but the later chapters are self-contained so that they may be studied without having read Part IV at all.

Part V: Stars (Chapters 14–18)
Guiding Philosophy: We are intimately connected to the stars.

The Cosmic Context figure for Part V appears on pp. 578–579.

These are our chapters on stars and stellar life cycles. Chapter 14 covers the Sun in depth so that it can serve as a concrete model for building an understanding of other stars. Chapter 15 describes the general properties of other stars, how we measure these properties, and how we classify stars with the H-R diagram. Chapter 16 covers star birth, and the rest of stellar evolution is discussed in Chapter 17. Chapter 18 focuses on the end points of stellar evolution: white dwarfs, neutron stars, and black holes.

Part VI: Galaxies and Beyond (Chapters 19–23)
Guiding Philosophy: Present galaxy evolution and cosmology together as intimately related topics.

The Cosmic Context figure for Part VI appears on pp. 696–697.

Nearly all students have at least heard of things like the prohibition on faster-than-light travel, curvature of space-time, and the uncertainty principle. But few (if any) students enter an introductory astronomy course with any idea of what these things mean, and they are naturally curious about them. Moreover, a basic understanding of the ideas of relativity and quantum mechanics makes it possible to gain a much deeper appreciation of many of the most important and interesting topics in modern astronomy, including black holes, gravitational lensing, and the overall geometry of the universe. The three chapters of Part IV cover special relativity (Chapter S2), general relativity (Chapter S3), and key astronomical ideas of quantum mechanics (Chapter S4). The main thrust throughout is to demystify relativity and quantum mechanics by convincing students that they are capable of understanding the key ideas despite the reputation of these subjects for being hard or counterintuitive.
These chapters cover galaxies and cosmology. Chapter 19 presents the Milky Way as a paradigm for galaxies in much the same way that Chapter 14 uses the Sun as a paradigm for stars. Chapter 20 describes the properties of galaxies and shows how the quest to measure galactic distances led to Hubble’s law and laid the foundation for modern cosmology. Chapter 21 discusses how the current state of knowledge regarding galaxy evolution has emerged from our ability to look back through time. Chapter 22 then presents the Big Bang theory and the evidence supporting it, setting the stage for Chapter 23, which explores dark matter and its role in galaxy formation, as well as dark energy and its implications for the fate of the universe.

**Part VII: Life on Earth and Beyond (Chapter 24)**

*Guiding Philosophy: The study of life on Earth helps us understand the search for life in the universe.*

The Cosmic Context figure for Part VII appears on pp. 728–729.

This part consists of a single chapter. It may be considered optional, to be used as time allows. Those who wish to teach a more detailed course on astrobiology may wish to consider the text *Life in the Universe*, by Bennett and Shostak.

**Chapter Structure**

Each chapter is carefully structured to ensure that students understand the goals up front, learn the details, and pull all the ideas together at the end. Note the following key structural elements of each chapter:

- **Chapter Learning Goals:** Each chapter opens with a page offering an enticing image and a brief overview of the chapter, including a list of the section titles and associated learning goals. The learning goals are presented as key questions designed to help students both to understand what they will be learning about and to stay focused on these key goals as they work through the chapter.

- **Introduction and Epigraph:** The main chapter text begins with a one- to three-paragraph introduction to the chapter material and an inspirational quotation relevant to the chapter.

- **Section Structure:** Chapters are divided into numbered sections, each addressing one key aspect of the chapter material. Each section begins with a short introduction that leads into a set of learning goals relevant to the section—the same learning goals listed at the beginning of the chapter.

- **The Big Picture:** Every chapter narrative ends with this feature, designed to help students put what they have learned in the chapter into the context of the overall goal of gaining a broader perspective on ourselves, our planet, and prospects for life beyond Earth. The final entry in this section is always entitled “My Cosmic Perspective”; it aims to help students see a personal connection between themselves and the chapter content, with the goal of encouraging them to think more critically about the meaning of all that they learn in their astronomy course.

- **Chapter Summary:** The end-of-chapter summary offers a concise review of the learning goal questions, helping to reinforce student understanding of key concepts from the chapter. Thumbnail figures are included to remind students of key illustrations and photos in the chapter.

- **End-of-Chapter Exercises:** Each chapter includes an extensive set of exercises that can be used for study, discussion, or assignment. All of the end-of-chapter exercises are organized into the following subsets:
  
  - **Visual Skills Check:** This set of questions is designed to help students build their skills at interpreting the many types of visual information used in astronomy.
  
  - **Chapter Review Questions:** These questions are ones that students should be able to answer from the reading alone.
  
  - **Does It Make Sense? (or similar title):** Each of these short statements is to be critically evaluated by students, to explain why it does or does not make sense. These exercises are generally easy once students understand a particular concept, but difficult otherwise; this makes these questions an excellent probe of comprehension.
  
  - **Quick Quiz:** The short multiple-choice quiz allows students to check their basic understanding. Note that, for further self-testing, every chapter also has a Reading, Concept, and Visual quiz available on the Mastering Astronomy website.

- **Inclusive Astronomy:** These questions are designed to stimulate discussion about participation in science, and in particular about the ideas that (1) astronomy belongs to everyone; (2) all cultures have made contributions to astronomical understanding; (3) opportunities for women and minorities have historically been limited; and (4) the scientific community can take active steps to provide more equitable opportunities for the future.

- **Process of Science Questions:** These questions, which can be used for discussion or essays, are intended to help students think about how science progresses over time. This set always concludes with an activity designed for group work, in order to promote collaborative learning in class.

- **Investigate Further:** The remaining questions are designed for home assignment and are intended
to go beyond the earlier review questions. These questions are separated into two groups: Short-Answer/Essay questions, which focus on conceptual interpretation and sometimes on outside research or experiment, and Quantitative Problems, which require some mathematics and are usually based on topics covered in the Mathematical Insight boxes.

**Additional Pedagogical Features**

You’ll find a number of other features designed to increase student understanding, both within individual chapters and at the end of the book, including the following:

- **Think About It:** This feature, which appears throughout the book in the form of short questions integrated into the narrative, gives students the opportunity to reflect on important new concepts. It also serves as an excellent starting point for classroom discussions.

- **See It for Yourself:** This feature also occurs throughout the book, integrated into the narrative; it gives students the opportunity to conduct simple observations or experiments that will help them understand key concepts.

- **Common Misconceptions:** These boxes address popularly held but incorrect ideas related to the chapter material.

- **Special Topic Boxes:** These boxes address supplementary discussion topics related to the chapter material but not prerequisite to the continuing discussion.

- **Extraordinary Claims Boxes:** Carl Sagan made famous the statement “extraordinary claims require extraordinary evidence.” These boxes provide students with examples of extraordinary claims about the universe and how they were either supported or debunked as scientists collected more evidence.

- **Mathematical Insight Boxes:** These boxes contain most of the mathematics used in the book and can be covered or skipped depending on the level of mathematics that you wish to include in your course. The Mathematical Insights use a three-step problem-solving strategy—Understand, Solve, and Explain—that gives students a consistent and explicit structure for solving quantitative homework problems.

- **Annotated Figures:** Key figures in each chapter use the research-proven technique of annotation—the placement on the figure of carefully crafted text (in blue) to guide students in interpreting graphs, following process figures, and translating between different representations.

- **Cosmic Context Two-Page Figures:** These two-page spreads provide visual summaries of key processes and concepts.

- **Wavelength/Observatory Icons:** For astronomical images, simple icons indicate whether the image is a photo, artist’s impression, or computer simulation; whether a photo came from ground-based or space-based observations; and the wavelength band used to take the photo.

- **Video Icons:** These icons point to videos available in the Study Area of Mastering Astronomy that are relevant to the topic at hand. Tutorial assessments based on these videos are available for assignment in the instructor Item Library.

- **Cross-References:** When a concept is covered in greater detail elsewhere in the book, a cross-reference to the relevant section is included in brackets (e.g., [Section 5.2]).

- **Glossary:** A detailed glossary makes it easy for students to look up important terms.

- **Appendices:** The appendices contain a number of useful references and tables, including key constants (Appendix A), key formulas (Appendix B), key mathematical skills (Appendix C), and numerous data tables and star charts (Appendixes D–I).

**Mastering Astronomy**

What is the single most important factor in student success in astronomy? Both research and common sense reveal the same answer: study time. No matter how good the teacher or how good the textbook, students learn only when they spend adequate time learning and studying on their own. Unfortunately, limitations on resources for grading have prevented most instructors from assigning much homework despite its obvious benefits to student learning. And limitations on help and office hours have made it difficult for students to make sure they use self-study time effectively. That, in a nutshell, is why we created Mastering Astronomy. For students, it provides adaptive learning designed to coach them individually—responding to their errors with specific, targeted feedback and giving optional hints for those who need additional guidance. For professors, Mastering Astronomy provides unprecedented ability to automatically monitor and record students’ step-by-step work and evaluate the effectiveness of assignments and exams.

Note that nearly all the content available at the Mastering Astronomy site for *The Cosmic Perspective* has been written by the textbook authors. This means that students can count on consistency between the textbook and web resources, with both emphasizing the same concepts and using the same terminology and the same pedagogical approaches. This type of consistency ensures that students can study in the most efficient possible way.

All students registered for Mastering Astronomy receive full access to the Study Area, which includes three self-study multiple-choice quizzes for each chapter; a large set of prelecture videos, narrated figures, interactive figures, and math review videos; a set of interactive self-guided tutorials that go into depth on topics that some students find particularly challenging; a downloadable set of group activities; and much more.

Instructors have access to many additional resources, including a large Item Library of assignable material that features more than 250 author-written tutorials, all of the end-of-chapter exercises, all the questions from the self-study quizzes in the Study Area, and a test bank. Instructors also have access to the author-written Instructor Guide and teaching resources including PowerPoint® Lecture Outlines, a complete set of high-resolution JPEGs of all images from the book, and PRS-enabled clicker quizzes based on the book and book-specific interactive media.
Supplements for *The Cosmic Perspective*

*The Cosmic Perspective* is much more than just a textbook. It is a complete package of teaching, learning, and assessment resources designed to help both teachers and students. In addition to Mastering Astronomy (described above), the following supplements are available with this book:

<table>
<thead>
<tr>
<th>Name of Supplement</th>
<th>Instructor or Student Supplement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SkyGazer 5.0</strong> (Access code card ISBN 0-321-76518-5, CD ISBN 0-321-89843-2)</td>
<td>Student Supplement</td>
<td>Based on Voyager IV, one of the world’s most popular planetarium programs, SkyGazer 5.0 makes it easy for students to learn constellations and explore the wonders of the sky through interactive exercises and demonstrations. Accompanying activities are available in LoPresto’s Astronomy Media Workbook, Seventh Edition. Both SkyGazer and LoPresto’s workbook are available for download.</td>
</tr>
<tr>
<td><strong>Starry Night™ College</strong> (ISBN 0-321-71295-1)</td>
<td>Student Supplement</td>
<td>Now available as an additional option with <em>The Cosmic Perspective</em>, Starry Night™ College has been acclaimed as the world’s most realistic desktop planetarium software. This special version has an easy-to-use point-and-click interface and is available as an additional bundle. The Starry Night Activity Workbook, consisting of thirty-five worksheets for homework or lab, based on Starry Night Planetarium software, is available for download in the Mastering Astronomy Study Area or with a Starry Night College access code.</td>
</tr>
<tr>
<td><strong>Astronomy Active Learning In-Class Tutorials</strong> (ISBN 0-805-38296-8) by Marvin L. De Jong</td>
<td>Student Supplement</td>
<td>This workbook provides fifty 20-minute in-class tutorial activities to choose from. Designed for use in large lecture classes, these activities are also suitable for labs. The short, structured activities are designed for students to complete on their own or in peer-learning groups. Each activity targets specific learning objectives such as understanding Newton’s laws, understanding Mars’s retrograde motion, tracking stars on the H-R diagram, or comparing the properties of planets.</td>
</tr>
<tr>
<td><strong>Lecture Tutorials for Introductory Astronomy</strong> (ISBN 0-321-82046-0) by Ed Prather, Tim Slater, Jeff Adams, and Gina Brissenden</td>
<td>Student Supplement</td>
<td>These forty-four lecture tutorials are designed to engage students in critical reasoning and spark classroom discussion.</td>
</tr>
<tr>
<td><strong>Sky and Telescope</strong> (ISBN 0-321-70620-X)</td>
<td>Student Supplement</td>
<td>This supplement, which includes nine articles with an assessment insert covering general review, Process of Science, Scale of the Universe, and Our Place in the Universe, is available for bundling.</td>
</tr>
<tr>
<td><strong>Observation Exercises in Astronomy</strong> (ISBN 0-321-63812-3) by Lauren Jones</td>
<td>Student Supplement</td>
<td>This workbook includes fifteen observation activities that can be used with a number of different planetarium software packages.</td>
</tr>
<tr>
<td><strong>Instructor Resources</strong> (ISBN 0-135-17325-1)</td>
<td>Instructor Supplement</td>
<td>This comprehensive collection of instructor resources includes high-resolution JPEGs of all images from the book; Interactive Figures and Photos™ based on figures in the text; additional applets and animations to illustrate key concepts; PowerPoint® Lecture Outlines that incorporate figures, photos, checkpoint questions, and multimedia; and PRS-enabled clicker quizzes based on the book and book-specific interactive media, to make preparing for lectures quick and easy. These resources are located in the Mastering Astronomy Instructor Resource Area.</td>
</tr>
<tr>
<td><strong>Instructor Guide</strong> (ISBN 0-135-17324-4)</td>
<td>Instructor Supplement</td>
<td>The Instructor Guide contains a detailed overview of the text, sample syllabi for courses of different emphasis and duration, suggested teaching strategies, answers or discussion points for all Think About It and See It for Yourself questions in the text, solutions to all end-of-chapter problems, and a detailed reference guide summarizing media resources available for every chapter and section of the book.</td>
</tr>
<tr>
<td><strong>Test Bank</strong> (ISBN 0-135-17326-4)</td>
<td>Instructor Supplement</td>
<td>Available in both Word and TestGen formats in the Instructor Resource Center and Mastering Astronomy, the Test Bank contains a broad set of multiple-choice, true/false, and free-response questions for each chapter. The Test Bank is also assignable through Mastering Astronomy.</td>
</tr>
</tbody>
</table>
Acknowledgments

Our textbook carries only four author names, but in fact it is the result of hard work by a long list of committed individuals. We could not possibly list everyone who has helped, but we would like to call attention to a few people who have played particularly important roles. First, we thank our past and present editors at Addison-Wesley and Pearson, including Bill Poole, Robin Heyden, Sami Iwata, Ben Roberts, Adam Black, Nancy Whitlon, and Jeanne Zalesky, along with many others at Pearson who have contributed to making our books possible. Special thanks to our production teams, especially Sally Liland, and our art and design team.

We’ve also been fortunate to have an outstanding group of reviewers, whose extensive comments and suggestions helped us shape the book. We thank all those who have reviewed drafts of the book in various stages, including the following individuals (listed with their affiliations at the time they contributed their reviews): Eric Agol, University of Washington; Marilyn Akins, Broome Community College; Caspar Amman, NCA; Christopher M. Anderson, University of Wisconsin; John Anderson, University of North Florida; Peter S. Anderson, Oakland Community College; Nahum Arav, Virginia Technical University; Phil Armitage, University of Colorado; Keith Ashman; Thomas Ayres, University of Colorado; Simon P. Balm, Santa Monica College; Reba Bandyopadhyay, University of Florida; Radie Barlow, Northern Arizona University; Cecilia Barnbaum, Valdosta State University; John Beaver, Valdosta State University at Rock Valley; Peter A. Becker, George Mason University; Timothy C. Beers, National Optical Astronomy Observatory; Jim Bell, Arizona State University; Priscilla J. Benson, Wellesley College; Zach Berta-Thompson, University of Colorado; Rick Binzel, Massachusetts Institute of Technology; Philip Blanco, Grossmont College; Jeff R. Bodart, Chipola College; Howard Bond, Space Telescope Science Institute; Bernard W. Bopp, University of Toledo; Sukanta Bose, Washington State University; David Brain, University of Colorado; David Branch, University of Oklahoma; John C. Brandt, University of New Mexico; James E. Brau, University of Oregon; Jean P. Brodie, UCO/Lick Observatory, University of California, Santa Cruz; Erik Brogt, University of Canterbury; James Brooks, Florida State University; Daniel Bruton, Stephen F. Austin State University; Thomas Burbine, Moraine Valley Community College; Debra Burris, University of Central Arkansas; Scott Calvin, Sarah Lawrence College; Amy Campbell, Louisiana State University; Humberto Campins, University of Central Florida; Robin Canup, Southwest Research Institute; Eugene R. Capriotti, Michigan State University; Eric Carlson, Wake Forest University; David A. Cebula, Pacific University; Supriya Chakrabarti, University of Massachusetts, Lowell; Clark Chapman, Southwest Research Institute; Kwang-Ping Cheng, California State University, Fullerton; Dipak Chowdhury, Indiana University—Purdue University Fort Wayne; Chris Churchill, New Mexico State University; Kelly Cline, Carroll College; Josh Colwell, University of Central Florida; James Cooney, University of Central Florida; Anita B. Corn, Colorado School of Mines; Philip E. Corn, Red Rocks Community College; Kelli Corrado, Montgomery County Community College; Peter Cottrell, University of Canterbury; John Cowan, University of Oklahoma; Kevin Crosby, Carthage College; Christopher Crow, Indiana University—Purdue University Fort Wayne; Manfred Cuntz, University of Texas at Arlington; Charles Danforth, University of Colorado; Christopher De Vries, California State University, Stanislaus; John M. Dickey, University of Minnesota; Mark Dickinson, National Optical Astronomy Observatory; Matthias Dietrich, Worcester State University; Jim Dove, Metropolitan State College of Denver; Doug Duncan, University of Colorado; Bryan Dunne, University of Illinois, Urbana-Champaign; Suzan Edwards, Smith College; Robert Egler, North Carolina State University at Raleigh; Paul Eskridge, Minnesota State University; Dan Fabrycky, University of Chicago; David Falk, Los Angeles Valley College; Timothy Farriss, Vanderbilt University; Harry Ferguson, Space Telescope Science Institute; Robert A. Fesen, Dartmouth College; Tom Fleming, University of Arizona; Douglas Franklin, Western Illinois University; Sidney Freudenstein, Metropolitan State College of Denver; Martin Gaskell, University of Nebraska; Richard Gelderman, Western Kentucky University; Harold A. Geller, George Mason University; Donna Giford, Pima Community College; Mitch Gillam, Marion L. Steele High School; Bernard Gilroy, The Hun School of Princeton; Owen Gingerich, Harvard-Smithsonian (Historical Accuracy Reviewer); David Graff, U.S. Merchant Marine Academy; Richard Gray, Appalachian State University; Kevin Grazier, Jet Propulsion Laboratory; Robert Greeney, Holyoke Community College; Henry Greenside, Duke University; Alan Greer, Gonzaga University; John Griffith, Lin-Benton Community College; David Griffiths, Oregon State University; David Grinspoon, Planetary Science Institute; John Gris, University of Delaware; Bruce Gronich, University of Texas at El Paso; Thomasana Hall, Parkland University; Andrew Hamilton, University of Colorado; Jim Hamm, Big Bend Community College; Paul Harderson, Planetary Science Institute; Charles Hartley, Hartwick College; J. Hasbun, University of West Georgia; Joe Heafner, Catawba Valley Community College; Todd Henry, Georgia State University; David Herrick, Maysville Community College; Dennis Hibbert, Everett Community College; Scott Hildreth, Chabot College; Tracy Hodge, Berea College; Lynnette Hoerner, Red Rocks Community College; Mark Hollabaugh, Normandale Community College; Richard Holland, Southern Illinois University, Carbondale; Seth Hornstein, University of Colorado; Joseph Howard, Salisbury University; James Christopher Hurt, Prince George’s Community College; Richard Ignace, University of Wisconsin; James Imamura, University of Oregon; Douglas R. Ingram, Texas Christian University; Assad Istephan, Madonna University; Bruce Jakosky, University of Colorado; Adam G. Jensen, University of Colorado; Dave Jewitt, University of California, Los Angeles; Adam Johnston, Weber State University; Lauren Jones, Gettysburg College; Kishor T. Kapale, Western Illinois University; William Keel, University of Alabama; Julia Kennefick, University of Arkansas; Steve Kipp, University of Minnesota, Mankato; Kurtis Koll, Cameron University; Ichishiro Konno, University of Texas at San Antonio; John Kormendy, University of Texas at Austin; Eric Korpela, University of California, Berkeley; Arthur Kosowsky, University of Pittsburgh; Julia Kregenow, Penn State University; Kevin Krisciunas, Texas A&M; Emily Lakdawalla, The Planetary Society; David Lamp, Texas Technical University; Ted La Rosa, Kennesaw State
University; Kenneth Lanzetta, Stony Brook University; Kristine Larsen, Central Connecticut State University; Ana Marie Larson, University of Washington; Stephen Lattanzio, Orange Coast College; Chris Laws, University of Washington; Larry Lebofsky, University of Arizona; Patrick Leetrade, Mississippi State University; Nancy Leonson, University of Kentucky; Hal Levison, Southwest Research Institute; David M. Lind, Florida State University; Mario Livio, Space Telescope Science Institute; Abraham Loeb, Harvard University; Michael LoPresto, Henry Ford Community College; William R. Luebke, Modesto Junior College; Ihor Luhach, Valencia Community College; Darrell Jack MacConnell, Community College of Baltimore City; Marie Machacek, Massachusetts Institute of Technology; Loris Magnani, University of Georgia; Steven Majewski, University of Virginia; J. McKim Malville, University of Colorado; Geoff Marcy, University of California, Berkeley; Mark Marley, Ames Research Center; Linda Martel, University of Hawaii; Phil Matheson, Salt Lake Community College; John Mattox, Fayetteville State University; Marles McCurdy, Tarrant County College; Stacy McGaugh, Case Western University; Kevin McKin, University of Colorado; Michael Mendillo, Boston University; Steven Merriman, Moraine Valley Community College; Barry Metz, Delaware Community College; William Millar, Grand Rapids Community College; Dina Moch, Queensborough Community College of City University, New York; Steve Mojzsis, University of Colorado; Irina Mullins, Houston Community College—Central; Stephen Murray, University of California, Santa Cruz; Zdzislaw E. Musielak, University of Texas at Arlington; Charles Nelson, Drake University; Gerald H. Newsom, Ohio State University; Francis Nimmo, University of California, Santa Cruz; Tyler Nordgren, University of Redlands; Lauren Novatne, Reedley College; Brian Oetiker, Sam Houston State University; Richard Olenick, University of Dallas; John P. Oliver, University of Florida; Rachel Osten, Space Telescope Science Institute; Stacy Palen, Weber State University; Russell L. Palma, Sam Houston State University; Bob Pappalardo, Jet Propulsion Laboratory; Mark Pecaut, Rockhurst University; Jon Pedicino, College of the Redwoods; Bryan Penprase, Pomona College; Eric S. Perlman, Florida Institute of Technology; Peggy Perozzo, Mary Baldwin College; Greg Perugini, Burlington County College; Charles Peterson, University of Missouri, Columbia; Cynthia W. Peterson, University of Connecticut; Jorge Piekarewicz, Florida State University; Lawrence Pinsky, University of Houston; Stephanie Plante, Crossmont College; Jascha Polet, California State Polytechnic University, Pomona; Matthew Price, Oregon State University; Harrison B. Prosper, Florida State University; Monica Ramirez, Aims College, Colorado; Christina Reeves-Shull, Richland College; Todd M. Rigg, City College of San Francisco; Elizabeth Roettger, DePaul University; Roy Rubins, University of Texas at Arlington; April Russell, Siena College; Carl Rutledge, East Central University; Bob Sackett, Saddleback College; Rex Saffer, Villanova University; John Safko, University of South Carolina; James A. Scarborough, Delta State University; Britt Scharringhamen, Ithaca College; Ann Schmiedekamp, Pennsylvania State University, Abington; Joslyn Schoemer, Denver Museum of Nature and Science; James Schombert, University of Oregon; Gregory Seab, University of New Orleans; Bennett Seidenstein, Arundel High School; Larry Sessions, Metropolitan State College of Denver; Michael Shara, American Museum of Natural History; Anwar Shiek, Colorado Mesa University; Seth Shostak, SETI Institute; Ralph Siegel, Montgomery College, Germantown Campus; Philip L. Siemens, Oregon State University; Caroline Simpson, Florida International University; Paul Sipiera, William Harper Rainey College; Earl F. Skelton, George Washington University; Evan Skillman, University of Minnesota; Michael Skrutskie, University of Virginia; Mark H. Slovak, Louisiana State University; Norma Small-Warren, Howard University; Jessica Smay, San Jose City College; Dale Smith, Bowling Green State University; Brad Snowden, Western Washington University; Brent Sorensen, Southern Utah University; James R. Sowell, Georgia Technical University; Kelli Spangler, Montgomery County Community College; John Spencer, Southwest Research Institute; Darryl Stanford, City College of San Francisco; George R. Stanley, San Antonio College; Bob Stein, Michigan State University; Peter Stein, Bloomsburg University of Pennsylvania; Adriane Steinacker, University of California, Santa Cruz; Glen Stewart, University of Colorado; John Stolar, West Chester University; Irina Struganova, Valencia Community College; Jack Sulewski, University of Alabama; C. Sean Sutton, Mount Holyoke College; Beverley A. P. Taylor, Miami University; Brett Taylor, Radford University; Jeff Taylor, University of Hawaii; Donald M. Tendruper, Ohio State University; Dave Tholen, University of Hawaii; Nick Thomas, University of Bern; Frank Timmes, Arizona State University; David Trott, Metro State College; David Vakil, El Camino College; Trina Van Ausdal, Salt Lake Community College; Dimitri Veras, Cambridge University; Licia Verde, Institute of Cosmological Studies, Barcelona; Nicole Vogt, New Mexico State University; Darryl Walke, Raritan Valley Community College; Fred Walter, State University of New York, Stony Brook; Marina Walther-Antonio, Mayo Clinic; James Webb, Florida International University; John Weiss, Carleton College; Mark Whittle, University of Virginia; Paul J. Wiita, The College of New Jersey; Francis Wilkin, Union College; Lisa M. Will, Mesa Community College; Jonathan Williams, University of Hawaii; Terry Willis, Chesapeake College; Grant Wilson, University of Massachusetts, Amherst; Jeremy Wood, Hazard Community College; J. Wayne Wooten, Pensacola Junior College; Guy Worthey, Washington State University, Pullman; Jason Wright, Penn State University; Scott Yager, Brevard College; Don Yeomans, Jet Propulsion Laboratory; Andrew Young, Casper College; Arthur Young, San Diego State University; Tim Young, University of North Dakota; Min S. Yun, University of Massachusetts, Amherst; Dennis Zaritsky, University of Arizona; Robert L. Zimmerman, University of Oregon.

Finally, we thank the many people who have greatly influenced our outlook on education and our perspective on this book. We are grateful to the hundreds of students we have taught over the years, including Jim Ayres, Fran Bagenal, Forrest Boley, Robert A. Brown, George Dulk, Derrick Ellingson, Katya Garmey, Jeff Goldstein, David Grinspoon, Don Hunten, Joan Marsh, Catherine McCord, Dick McCray, Dee Mook, Cheryllyn Morrow, Charlie Pellerin, Carl Sagan, J. Michael Shull, John Spencer, and John Stocke.

Jeff Bennett, Megan Donahue, Nick Schneider, Mark Voit