INSTRUCTOR'S MANUAL

Earth: Portrait of a Planet

SIXTH EDITION

Stephen Marshak

Instructor's Manual by
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Other Instructor Resources Available with *Earth: Portrait of a Planet, 6e*

Interactive Instructor's Guide

All of the materials found in this Instructor's Manual are available online, searchable by chapter, keyword, or learning objective. The Interactive Instructor's Guide instantly provides multiple ideas for teaching: video clips, powerpoints, animations, and other class activities and exercises. This repository of lecture and teaching materials functions both as a course prep tool and as a means of tracking the latest ideas in teaching the Earth course.

To access the Interactive Instructor's Guide, to go https://iig.wwnorton.com/earth6/full.

Smartwork5 Online Homework

Smartwork5 is Norton's tablet-friendly, online activity platform. Both the system and its physical geology content were designed with the feedback of hundreds of instructors, resulting in unparalleled ease of use for students and instructors alike.

Smartwork5 features easy-to-deploy, highly visual assignments that provide students with answer-specific feedback. Students get the coaching they need to work through the assignments, while instructors get real-time assessment of student progress via automatic grading and item analysis. Th e question bank features a wide range of higher-order questions such as ranking, labeling, and sorting. All of the Narrative Art videos, animations, and interactive simulations are integrated directly into Smartwork5 questions—making them assignable. Smartwork5 also contains What a Geologist Sees questions that take students to sites not mentioned in the book, so they can apply their knowledge just as a geologist would. In addition, Smartwork5 offers reading quizzes for each chapter and Geotours-guided inquiry activities using Google Earth.

Based on instructor feedback, Smartwork5 offers three
types of pre-made activity:

- Chapter Reading Quizzes, designed to help students prepare for lecture
- Chapter Activities, consisting of highly visual exercises covering all chapter Learning Objectives
- Geotours Worksheets—guided inquiry activities that use Google Earth

Smartwork5 is fully customizable, meaning that instructors can add or remove questions, create assignments, write their own questions, or modify ours. Easy and intuitive tools allow instructors to filter questions

Smartwork5 is available for free with most newly purchased print or electronic versions of the text.
Immediate online access can also be purchased at the text's Digital Landing Page. Smartwork5 is easy to implement, and your local Norton representative will be happy to help you get started.

Norton Coursepacks for Campus Learning Management Systems

Available at no cost to professors or students, Norton Coursepacks bring high-quality Norton digital media into a new or existing online course. Coursepacks contain ready-made content for your campus LMS. For Earth: Portrait of a Planet, Sixth Edition, content includes the full suite of animations, simulations, and videos keyed to core figures in each chapter; the Test Bank; reading quizzes; new European case studies; Geotour questions; vocabulary flashcards; and links to the ebook. To download the Norton Coursepack for your campus LMS, go to the Earth Instructor's page.

Test Bank

The Test Bank has been written to correlate to the learning objectives found in *Earth* and provides carefully vetted and well-rounded assessment. Every item in the test bank has been reviewed to ensure scientific reliability and to make sure it truly tests students' understanding of the most important topics in the text. Each chapter features 50 multiple-choice questions and 10 short-answer or essay questions that test student critical thinking and knowledge-application skills. Several of these questions are art-based and use modified images from the text. Each question is tied to sortable metadata fields including text section, learning objective, difficulty level, and Bloom's taxonomy.

To download the Test Bank in PDF, Word, or Examview formats, go to the Earth Instructor's page.

PowerPoints

Several types of powerpoints are available, downloadable via the Earth Instructor's page.

- *Lecture PowerPoints*—Designed for instant classroom use, these slides utilize photographs and line art from the book in a form that has been optimized for use in the PowerPoint environment. The art has been relabeled and resized for projection formats. Think-Pair-Share questions, animation, and video slides help incorporate active learning into lecture.
- *Clicker Question PowerPoints* for each chapter can be added as-needed to existing PowerPoint decks to check student comprehension in class.
- *Labeled and Unlabeled Art PowerPoints*—These include all art from the book formatted as JPEGs that have been prepasted into PowerPoints. We offer one set in which all labeling has been stripped and one set in which labeling remains. All art files for the text are also available in JPEG format for creating your own handouts and presentations
- *Update PowerPoints*—W. W. Norton & Company offers an update service that provides new PowerPoint slides, with instructor support, covering three recent geologic events for fall and spring semesters. These updates will help instructors keep their classes current, tying events in the news to core concepts from the text.

Animations, Simulations, and Videos

Marshak's online resources are designed to be easy to use and visually appealing. Animations, interactive simulations, narrative figure videos, and real-world videos cover the core topics and bring in-class presentations to life. The animations and videos may be accessed at no cost from the Digital Landing Page. They are also available in the Coursepack and integrated into Smartwork5 assessment.

- Animations and interactive simulations are perfect for in-class lectures or student self-study use. Covering the most important topics, these 2-4 minute clips are available to help students better visualize and master key concepts and processes. Selected animations are also simulations, which include interactive tools that allow students to experiment with geologic variables.
- Narrative Figure Videos were written and narrated by Marshak himself. These videos bring textbook figures and supplementary photographs to life, helping students to better understand key concepts from the course.
- Real-World Videos are a streaming source of real world video content that exists on Norton's servers without advertising or broken links.

Instructor USB

USB drives are available for instructors and contain the Test Bank, Animations and Simulations, Narrative Art Videos, Lecture Slides, labeled and unlabeled art from the book, the Instructor's Manual, and See For Yourself and GeoTours kmz files in one easy-to-access location. Request an Instructor USB via Earth Instructor's page.

CONTENTS

PRELUDE

And Just What Is Geology?

Learning Objectives

By the end of this prelude, you should be able to . . .

A. describe the scope and applications of geology.
B. explain the foundational themes of modern geologic study.
C. demonstrate how geologists employ the scientific method.
D. provide a basic definition of the theory of plate tectonics.
E. explain what geologists mean by the Earth System concept.
F. name the main layers of the Earth's interior.

Summary from the Text

- Geologists are scientists who study the Earth. They search for the answers to the mysteries of our home planet, from why volcanoes explode to where we can find minerals.
- Geologic study can involve field exploration, laboratory experiments, high-tech measurements, and calculations with computers.
- Geologic research not only provides answers to academic questions such as how the Earth formed, but also addresses practical problems such as how to find groundwater or how to avoid landslides. Many people pursue careers as geologists.
- A set of themes underlies geologic thinking. Key concepts are that the Earth's outer shell consists of moving plates whose interactions produce earthquakes, volcanoes, and mountains; that the Earth is very old; and that interacting realms of material on the planet constitute the Earth System.

Real-World Videos

SCIENCE FOR A CHANGING WORLD

Learning Objectives Covered:

- A. describe the scope and applications of geology.
- C. demonstrate how geologists employ the scientific method.

Length: 8:11

Summary: The U.S. Geological Survey (USGS) is the leading agency providing reliable scientific information for informed decision and policy making. This video outlines a brief history of the USGS, and the significance of USGS's work and mission in today's world. When it was founded in 1879, the primary focus of the survey was mineral resources and mining geology, as well as mapping, paleontology, and stratigraphy. Since its foundation, the USGS has evolved to provide fundamental scientific data relevant to water resources, changing Earth processes, and even the moon landings. Today, USGS scientists throughout the 50 states gather data in six science mission areas critical to the well-being of the nation and world:

- **Ecosystems**—monitors many functions vital to human populations, including soil formation, crop pollination, nutrient cycling, water purification, waste treatment, and atmosphere regulation.
- **Energy, minerals, and environmental health**—assesses the quantity and quality of resources (including environmental impacts of extraction and use).
- **Climate and land use**—uses research, monitoring, remote sensing, modeling, and forecasting to address human impact.
- **Natural hazards**—assesses the threat of natural hazards for public knowledge and policy making.
- **Water**—monitors resources.
- **Core science systems**—translates scientific data into formats that are accessible and understandable.

Classroom Use: This video helps students to understand some of the many ways in which geology solves significant and critical problems faced by human populations today. Before showing the video, ask students to reflect on what geologists do and what types of problems they solve. Additionally, ask them to create a list of what they believe to be some of the greatest risks facing human populations (regionally or globally). After viewing the video, facilitate a discussion about the relevance of geology to society. What types of problems (e.g., climate change, clean water, land use, agriculture, natural resources) does geology seek to solve?

Adaptations:

- This video could be used together with the "Geology in the News" activity (which would provide specific examples of USGS projects) to form a lesson on the relevance of geologic research to society.

Review and Discussion Questions:

1. What are some of the major areas of geology that the USGS supports?
2. What are some of the greatest challenges that the Earth System faces today?
3. How does the work of the USGS help to address some of the challenges that the Earth System faces today?

Credit: USGS

HYDRAULIC FRACTURING: USING SCIENTIFIC METHODS TO EVALUATE TRADE-OFFS

Learning Objectives Covered:

- A. describe the scope and applications of geology.
- C. demonstrate how geologists employ the scientific method.

Length: 3:07

Summary: This video uses the example of hydraulic fracturing ("fracking") in Colorado to discuss how scientists gather objective data that can be used to guide environmental regulations. Environmental engineers are investigating the potential impacts of fracking on water and air quality, human health, and energy sustainability, with an emphasis on neutrality. Stakeholders will be able to use the information—such as methane concentration in the atmosphere, and the persistence of fracking fluids in ecosystems—to create a decision framework to improve environmental policy. In the case of fracking, where two opposing points of view are often at odds, science can provide the best source of trusted information.

Classroom Use:

1. Remind students that the scientific method yields verifiable results, and therefore science can provide impartial evidence in cases where opposing "sides" may have a biased view about a topic (see **Box P.1** in the text for a review).
2. Show the video as one example of a controversial topic.
3. Working in small groups of two to three, ask students to come up with another example of a controversial issue that geologists could evaluate in an impartial way. Some examples might include: global climate change and sea level rise, earthquake and tsunami hazards, soil conservation and land use planning, or ecosystem impacts of coal mining.

Review and Discussion Questions:

1. The video references one "side" contradicting the other "side." Who or what are the "sides" that are being referenced? What factors influence their view of fracking?
2. What are some of the questions that scientists are asking about hydraulic fracturing?
3. If you lived in Colorado where this fracking is happening, what sources of information would you turn to?

Credit: Science 360 News (NSF)

Activity

GEOLOGY IN THE NEWS

Learning Objectives Covered:

- A. describe the scope and applications of geology.
- C. demonstrate how geologists employ the scientific method.

Activity Type: Online Investigation

Time in Class Estimate: Variable (dependent on class size and depth of discussion)

Recommended Group Size: Individual to four students

Materials: Students will need to access websites with geology-related science news, including: U.S. Geological Survey Science Snippets (www.usgs.gov/news/science-snippets)

Classroom Procedures:

1. Visit the USGS Science Snippets website (www.usgs.gov/news/science-snippets) and select an article of interest to read.

2. While reading, focus on how the scientific method (see **Box P.1** for a review) is being implemented by answering the following:
    a. What is the problem being solved or hypothesis being tested?
    b. What kinds of data are being collected? How?
3. Summarize what you learned from your article and discuss the ways in which geology provides impartial scientific evidence that is relevant to challenges that our society faces.

Adaptations:

- For online classes, students can be assigned to groups to read and discuss the same article or all students can post summaries to a discussion board.
- For a less open-ended assignment, several articles could be preselected for the entire class.
- American Association of Petroleum Geologists News in Review (www.aapg.org/home/news-in-review) also has resources, and your state geologic agency may also have interesting news.
- This activity could be paired with the "Science For a Changing World" Real-World Video.

Reflection Questions: Do you think there are ever any cases where scientists might impart a bias on the data they collect? What safeguards are there in place to protect the integrity of scientists from things that might bias their work, such as political and financial influences?

THINK-PAIR-SHARE QUESTIONS

Classroom Procedures: Ask students to silently reflect on the question (and, optionally, write down an answer). Questions could be integrated into PowerPoint slides, asked verbally, or posted in discussion boards for online classes. After about a minute of reflection, cue students to share their thoughts with one or two people near them (or in assigned groups in online classes). After a minute or two of small-group discussion, ask students to report answers to the class—ask for volunteers, call on whole groups, or have groups submit consensus posts on a discussion board.

Questions/Answers:

1. Geology in Everyday Life

   How is geology relevant to your everyday life?

ANS: Answers will vary depending on demographics, location, and current events, but students might discuss natural resources, hazards, climate change, or recreation.

Learning Objectives Covered:

- A. describe the scope and applications of geology.

2. Geology and Society

   In what ways is geology increasingly important in today's society?

   ANS: Answers will vary depending on demographics, location, and current events but students might discuss climate change, oil and gas, rare-earth elements, groundwater, soils, or earthquakes.

   Learning Objectives Covered:

   - A. describe the scope and applications of geology.

3. Geology and You

   Whether or not you pursue further studies in geology, how might learning about geology affect your life?

   ANS: Answers will vary depending on demographics and location, but students might discuss an increased appreciation for the natural world, a better understanding of environmental issues, awareness of geologic issues (such as climate change or land use) in government and policy, and factors (such as hazards or climate change) that might influence personal decision making.

   Learning Objectives Covered:

   - A. describe the scope and applications of geology.

Answers to Review Questions

1. What are some of the practical applications of geology?

ANS: Geology is applied to a number of important problems, including: availability of resources (such as oil, minerals, and groundwater), pollution, and hazards such as earthquakes and landslides.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- A. describe the scope and applications of geology.

2. Explain the difference between internal processes and external processes.

ANS: Internal processes include plate motion, mountain building, earthquakes, and volcanoes. These processes are all driven by heat from inside the Earth. External processes, which result from the movement of air and water, are driven by heat from the sun. Both internal and external forces, together with gravity, interact to shape the surface of our planet.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- B. explain the foundational themes of modern geologic study.

3. How would the Earth's atmosphere differ if life didn't exist?

ANS: Without life, the Earth's atmosphere would not contain any oxygen, which is a product of photosynthesis in plants. Oxygen is an essential element for complex animals, and is important to chemical reactions that occur during the weathering process of rocks.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- B. explain the foundational themes of modern geologic study.

4. Explain the difference between a hypothesis and a theory, in the context of science.

ANS: A hypothesis is a potential explanation for an observation. Hypotheses may be correct explanations or they may be incorrect; this is assessed by testing the predictions made by the hypothesis. If a hypothesis is tested in many ways by many individuals over an extended period of time, and passes all tests, it becomes a theory. There is more certainty about a theory than there is about a hypothesis. The scientific community will continue to test an idea even after it becomes a theory.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- C. demonstrate how geologists employ the scientific method.

5. What is the basic premise of the theory of plate tectonics?

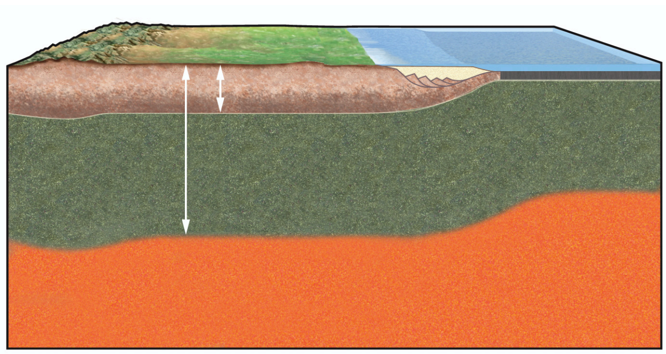
ANS: Plate tectonics is the theory that the outer layer of the Earth is broken up into rigid plates that move laterally relative to each other over the softer layer beneath them. This plate motion is responsible for earthquakes, volcanoes, and mountains. Plate tectonics is the foundational theory for understanding all geology.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- D. provide a basic definition of the theory of plate tectonics.

6. What are the main layers of the Earth's interior? Label them in the diagram.



ANS: From outside to inside: crust, mantle, outer core, and inner core.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- F. name the main layers of the Earth's interior.

7. What do geologists mean by the statement, "The Earth is a complex system"?

ANS: The Earth is a set of many interacting elements—including the surface, interior, oceans, atmosphere, and life—that cycle energy and matter, and change over time.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- E. Explain what geologists mean by the Earth System concept.

8. What are the sources of data that geologists can use to understand the Earth?

ANS: Geologists use data from a large number of wide-ranging sources, including (but certainly not limited to) direct observation of rocks in the field, laboratory methods and equipment, microscopes, satellites, computers, and models.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- C. demonstrate how geologists employ the scientific method.

9. What are the major subdivisions of geologic time? Which time unit is longer, the Precambrian or the Paleozoic?

ANS: The Precambrian (divided into the Hadean, Archean, and Proterozoic) spans from the birth of the Earth (4,565 million years ago) to 541 million years ago, and represents 88% of geologic time. The Paleozoic (divided into the Paleozoic, Mesozoic, and Cenozoic Eras) spans from 541 million years ago to the present day.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- B. explain the foundational themes of modern geologic study.

10. This mine truck carries 100 tons of coal. Where does this resource, and others like it, come from?

ANS: Coal is a natural resource that comes from geologic materials.

BLOOM'S LEVEL: Remembering

LEARNING OBJECTIVES COVERED:

- B. explain the foundational themes of modern geologic study.

CHAPTER 1

Cosmology and the Birth of Earth

Learning Objectives

By the end of this chapter, you should be able to . . .

A. assess how people's perceptions of the Earth's place in the Universe have changed over the centuries.
B. explain modern concepts concerning the basic architecture of our Universe and its components.
C. assess the evidence for the expanding Universe and the Big Bang theory.
D. describe where the elements that make up matter came from.
E. explain the nebular theory, a scientific model that explains how stars and planets form.

Summary from the Text

- The geocentric model of the Universe placed the Earth at the center of the Universe. The heliocentric model, which gained acceptance during the Renaissance, placed the Sun at the center. The geocentric model remained popular until the 17th century.
- Eratosthenes measured the size of the Earth in ancient times, but it was not until fairly recently that astronomers accurately determined the distances from the Earth to the Sun, planets, and stars. Distances in the Universe are so large that they must be described in light-years.
- The Earth is one of eight planets orbiting the Sun. Our Solar System lies on the outer edge of the Milky Way Galaxy, which contains about 300 billion stars. Perhaps a trillion galaxies populate the Universe.
- The red shift of light from distant galaxies, a manifestation of the Doppler effect, indicates that all distant galaxies are moving away from the Earth. This observation supports the expanding Universe theory. Most astronomers agree that this expansion began after the Big Bang, a cataclysmic explosion that occurred about 13.8 Ga.

- The first atoms of the Universe (hydrogen and helium) developed within minutes of the Big Bang. These atoms formed vast gas clouds called nebulae.
- Gravity caused clumps of gas and ice in the nebulae to coalesce into flattened disks with bulbous centers. The protostars at the centers of these disks eventually became dense and hot enough that fusion reactions began in them. When this happened, they became true stars.
- Heavier elements form during fusion reactions in stars; the heaviest are mostly made during supernova explosions. The Earth and the life forms on it contain elements that could only have been produced during the life cycle of stars, so we are all made of stardust.
- According to the nebular (condensation) theory of Solar System formation, planets developed from the rings of gas and dust surrounding the proto-Sun. The gas and dust condensed into planetesimals, which then clumped together to form protoplanets and finally true planets. Inner rings became the terrestrial planets. Outer rings grew into the giant planets.
- The Moon formed from debris ejected when a protoplanet collided with the Earth in the young Solar System.
- During differentiation, the interior of a planet separates into layers. A planet assumes a near-spherical shape when it becomes so soft that gravity can smooth out irregularities.

Narrative Figure Videos

FORMATION OF THE SOLAR SYSTEM

Learning Objectives Covered:

- 1D. describe where the elements that make up matter came from.
- 1E. explain the nebular theory, a scientific model that explains how stars and planets form.

Length: 3:18

Summary: This video gives an overview of the nebular theory of Solar System formation, broken down into several stages. First, the gravitational pull of a dense region of a nebula, which contains both volatile and refractory materials, attracts material from elsewhere in the nebula. The nebula eventually turns into a rotating accretionary disk. Next, matter in the center of the disk becomes a proto-Sun. Eventually, nuclear fusion reactions begin, and the Sun emits solar wind, which removes volatile materials from the inner part of the protoplanetary disk. Particles in the disk accrete to form planetesimals (like chondritic meteorites), and finally protoplanets.

Classroom Use:

1. This video is well-suited for an engaging start to a lecture, a break in lecture for students to switch gears for a short time, a summary of our Solar System formation processes, or as a wrap-up.
2. After showing the video, ask students to draw a sketch or write a description of our Solar System at three different stages of formation: nebula, protoplanetary disk, and present day. Have students focus on comparing and contrasting the distribution of volatile and refractory materials, the dominant processes occurring, and the types of bodies present (proto-Sun, planetesimals, etc.) in each stage.
3. Challenge students to pick just five words or phrases to summarize what happened during Solar System formation (e.g., "gravitational pull, nuclear fusion, solar wind, accretion, planetesimals"). This also works great as a Think-Pair-Share activity.

Review and Discussion Questions:

1. What are some characteristics of volatile and refractory materials?
2. Compare and contrast a nebula and a protoplanetary disk.

FORMATION OF THE EARTH

Learning Objectives Covered:

- 1E. explain the nebular theory, a scientific model that explains how stars and planets form.

Length: 2:30

Summary: This video includes a description of the changes that occurred as the proto-Earth transformed into the Earth. Volatile elements were excluded, gravity transformed the lumpy protoplanet into a sphere, and differentiation resulted in iron accumulating at the center and rocky material convecting in the mantle. Meteorites bombarded the surface until the region was swept clean of all other material, at which point the Earth became a true planet. Cooling created a solid crust. A catastrophic impact remelted the crust, and debris from that impact eventually formed the moon. Volcanic gases created the atmosphere; atmospheric oxygen condensed into oceans but the atmosphere remained oxygen-free until the evolution of photosynthesis.

Classroom Use:

1. This video is well-suited for an engaging start to a lecture, a break in lecture for students to switch gears for a short time, a summary of the transformations of the early Earth, or as a wrap-up.

Discussion Questions:

1. Why do smaller protoplanets have irregular, lumpy shapes while planets are spherical?
2. Describe the interior of the Earth before and after differentiation.

Real-World Videos

THE FAINT YOUNG STAR PARADOX: SOLAR STORMS MAY HAVE BEEN KEY TO LIFE ON EARTH

Learning Objectives Covered:

- 1E. explain the nebular theory, a scientific model that explains how stars and planets form.

Length: 1:29

Summary: The early Earth was warm enough to support life because of a balance between the weaker Sun and a strong greenhouse effect in our atmosphere. The young Sun produced less heat, but more frequent solar flares. The young Earth's less-developed magnetosphere allowed solar particles from these flares to interact with the atmosphere and create nitrous oxide, a powerful greenhouse gas.

Classroom Use:

1. Introduce the idea of a faint young Sun, and ask students to pose some hypotheses that might explain why Earth was warm enough to sustain life despite receiving significantly less solar radiation. How might they test their hypotheses? Next, show the video. Engage students in a discussion comparing their hypotheses to the commonly accepted idea of nitrous oxide acting as a greenhouse gas.

Adaptations:

- Students can think-pair-share their hypotheses.
- Include discussion of challenges associated with testing hypotheses about past conditions, and the utility of computer models.

Review and Discussion Questions:

1. When it first formed billions of years ago, how did the Sun differ from today's Sun?
2. Explain some of the ways in which the Earth's atmosphere has changed over time.
3. How did the early Sun contribute to changing the composition of Earth's early atmosphere?

Credit: NASA's Goddard Space Flight Center; music credit: Ocean Travel by Laurent Dury from the KillerTracks Catalog.

HOW PLANETS ARE BORN

Learning Objectives Covered:

- 1E. explain the nebular theory, a scientific model that explains how stars and planets form.

Length: 0:38

Summary: This animation condenses billions of years into a little over half a minute to illustrate the nebular theory of Solar System formation. Initially, diffuse material spins around a young star. The material gradually accretes into wide bands of material, then planetesimals, protoplanets and, eventually, discrete planets.

Classroom Use:

1. Use this animation as a visual aid to enhance a description of the nebular theory.
2. Ask students to create a narration to go along with the video. Either provide a link to the video through the Digital Landing Page or your campus Learning Management System (if devices are available in the classroom) or project the video on a loop. Give students 5–10 minutes to write a narration. You may want to offer some hints. For example, break the video down into three or four main ideas and describe what is happening in each; every time the image changes, describe what you are seeing; trim down your language so that you can say everything you need to in 30 seconds; for each statement, ask yourself "Is it important to understand this idea, or is it extra?" Once all groups have written a narration, you could collect the "scripts," have them share with one other group, or have a few groups present to the class.
3. Pause the video at a 10, 20, and 30 seconds and have students create a quick labeled sketch of what they observe.

Discussion Questions:

1. How does the nebular theory explain the structure and elements of our Solar System, such as the type and distribution of planets and the location of icy comets?
2. Why is the nebular theory difficult to test directly?

Credit: NASA

Activities

THE HUBBLE DEEP FIELD ACADEMY

Learning Objectives Covered:

- 1B. explain modern concepts concerning the basic architecture of our Universe and its components.

Activity Type: Quantitative Data Analysis

Time in Class Estimate: 30 minutes

Recommended Group Size: 1–2 students

Materials: Internet access

Classroom Procedures: Assign each student or group of students a role: stellar statistician, cosmic classifier, or distance wizard. Have students access the Hubble Deep Field Academy (http://deepfield.amazingspace.org), complete the "orientation" section, and then record their observations and answers while working on their "level." Meanwhile, provide space on the board (or in a discussion board on for online classes) for each group to report their calculations: stellar statisticians record the estimated number of objects in the universe, cosmic classifiers record the shapes of objects, distance wizards record objects in order of distance. Once all students or groups have reported their observations, discuss the variation in reported data and its relationship to the astronomer's results (reported on the website). Finally, ask all students to become deep-field observers and attempt to identify the mystery object. Ask students to find other groups of students from the same level and compare answers.

Adaptations:

- Have students complete all three "levels" (instead of just one) and compare conclusions.
- The activity could be completed individually as homework to prepare for in-class discussion about the types of galaxies and overall structure of the Universe.

- This is a good opportunity to introduce the idea of composite datasets.

Reflection Questions: What are some questions astronomers are trying to answer by studying the Hubble Deep Field? What questions would you like to answer? Why do astronomers conduct surveys? Do you think they are useful? How "deep" can these surveys eventually go? Is there a limit? Could this help our understanding of black holes? How?

IMAGINE NUCLEOSYNTHESIS

Learning Objectives Covered:

- 1D. describe where the elements that make up matter came from.

Activity Type: Imagine Yourself . . .

Time in Class Estimate: 15–45 minutes (depending on degree of detail)

Recommended Group Size: Individual plus whole-group sharing

Materials: None

Classroom Procedures: Ask students to imagine themselves as a hydrogen atom that was just created in the Big Bang. Have students write a detailed description of what happens to them as they are transformed in stars and eventually end up as part of the Earth in the present day. After some period of writing time (determined by the degree of detail you expect), students can exchange stories with other students and compare or post their stories to discussion boards for an online class.

Adaptations:

- Assign the writing portion as homework and ask students to share at the beginning of class.
- Ask students to include illustrations of what is happening.
- Go over the main stages of stellar nucleosynthesis as a class, then break students up into small groups and have each group describe one phase in detail.

Reflection Questions: How were nebulae in the early Universe different from those found today? Where did the atoms that make up your body originate?

THINK-PAIR-SHARE QUESTIONS

Classroom Procedures: Ask students to silently reflect on the question (and, optionally, write down an answer). Questions could be integrated into PowerPoint slides, asked verbally, or posted in discussion boards for online classes. After about a minute of reflection, cue students to share their thoughts with one or two people near them (or in assigned groups in online classes). After a minute or two of small-group discussion, ask students to report answers to the class—ask for volunteers, call on whole groups, or have groups submit consensus posts on a discussion board.

Questions/Answers:

1. Is There Life Out There?

   Do you think life exists elsewhere in the Universe? What conditions would be necessary for life as we know it to exist elsewhere?

   ANS: While we do not have a definitive answer to this question yet, we do know that certain features are necessary for life as we currently understand it. These features include the presence of liquid water, the existence of a hospitable atmosphere, and a planet that is the right distance from a right-sized star so that the intensity of stellar radiation is sufficient to sustain life but not so high that it destroys life. The Earth is in a unique "Goldilocks" position in our Solar System.

   Learning Objectives Covered:

   - 1A. assess how people's perceptions of the Earth's place in the Universe have changed over the centuries.

2. Picturing the Big Bang

   Imagine we have the ability to watch the first moments of the formation of the Universe. Describe your observations from an astronomer's perspective.

   ANS: Answers will vary. About 13.8 billion years ago, all the matter and energy in the Universe was located in a singularity, a single point in space with an indescribably high temperature and density. The Universe came into being when this singularity exploded and began to expand, an event called the Big Bang. Why the singularity exploded is still unknown and the topic of much speculation. Just after the Big Bang, the Universe was made up only of energy, but minutes later matter formed as the Universe cooled. In the beginning, the Universe was dark, since all of its matter was scattered throughout diffuse nebulae. However, the first stars had formed by the time the Universe was 400 million years old, shining the first rays of light into the Universe.

   Learning Objectives Covered:

- 1B. explain modern concepts concerning the basic architecture of our Universe and its components.
- 1C. assess the evidence for the expanding Universe and the Big Bang theory.
- 1D. describe where the elements that make up matter came from.

Answers to Review Questions

1. Contrast the geocentric and heliocentric Universe concepts.

ANS: The geocentric concept, popularized by Ptolemy and European church leaders, placed Earth at the center of the Universe with the Sun and the other planets revolving around it. The heliocentric concept, described by Copernicus, Galileo, Kepler, and Newton, placed the Sun at the center with Earth and the other planets revolving around it.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- 1A. assess how people's perceptions of the Earth's place in the Universe have changed over the centuries.

2. Describe how Foucault's pendulum demonstrates that Earth rotates on its axis.

ANS: Foucault used a heavy pendulum and the application of Newton's first law to observe the surface of the Earth rotating underneath the swinging pendulum. Foucault noticed that over time, the swing path of the pendulum appeared to rotate about a vertical axis. According to the property of inertia, a swinging pendulum will maintain its swinging plane unless a new force is added. Foucault concluded that Earth must be rotating in order for the plane to appear to change in this manner.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- 1A. assess how people's perceptions of the Earth's place in the Universe have changed over the centuries.

3. How did Eratosthenes calculate the Earth's circumference?

ANS: Eratosthenes knew that when the Sun's rays were directly overhead at the town of

Syene, they were seven degrees from vertical in Alexandria, a city due north of Syene. He assumed that the Earth is a sphere and measured the distance between the two cities to calculate (using the equation in **Figure 1.8**) a circumference of about 40,000 km—extremely close to correct.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- 1A. assess how people's perceptions of the Earth's place in the Universe have changed over the centuries.

4. Why do planets appear to move with respect to stars?

ANS: Stars are so relatively distant that they appear fixed with respect to one another as viewed from Earth. As Earth and the other planets traverse through their orbits around the Sun, the positions of the planets vary with respect to the "fixed" celestial sphere.

BLOOM'S LEVEL: Understanding

LEARNING OBJECTIVES COVERED:

- 1B. explain modern concepts concerning the basic architecture of our Universe and its components.

5. Imagine you hear the main characters in a low-budget science-fiction movie say that they will "return 10 light-years from now." What's wrong with their use of the term?

ANS: Light-years are a measure of distance (not time), specifically the distance light travels through a vacuum in one year. There are approximately 3.26 light-years in a parsec.

BLOOM'S LEVEL: Analyzing

LEARNING OBJECTIVES COVERED:

- 1B. explain modern concepts concerning the basic architecture of our Universe and its components.

6. Describe how the Doppler effect works. If the light you see from a distant galaxy has undergone a blue shift, is the galaxy traveling toward or away from you?