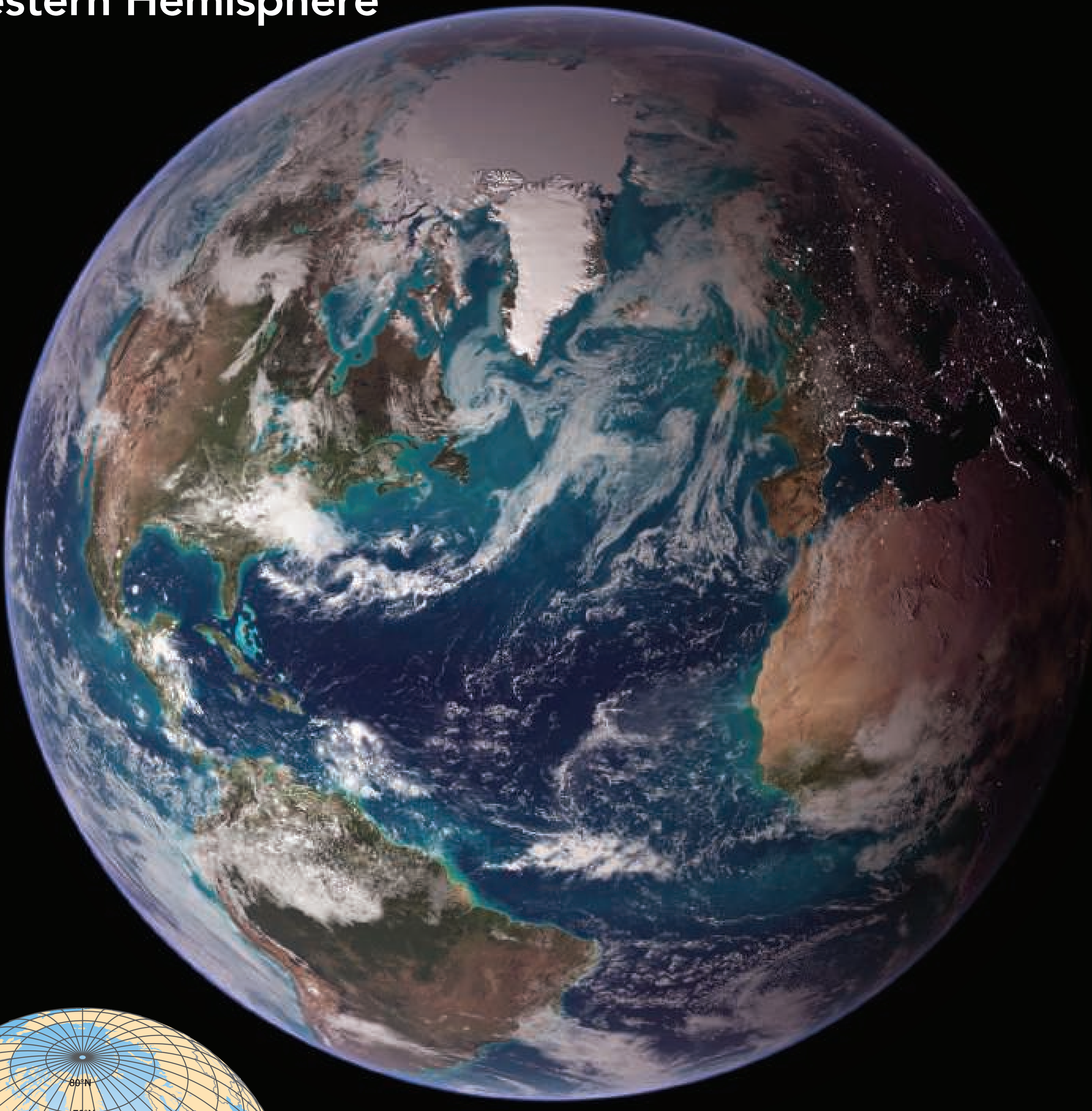
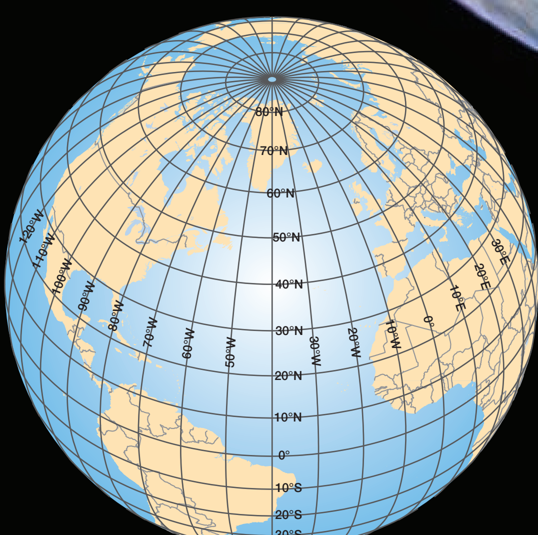
Geosystems 1e
Core

Christopherson / Cunha / Thomsen / Birkeland

Western Hemisphere

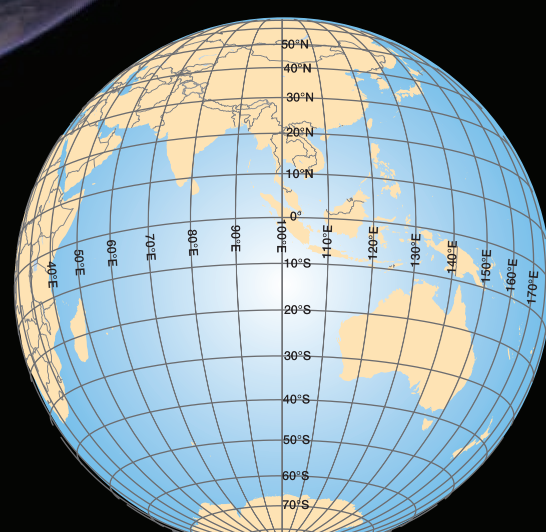




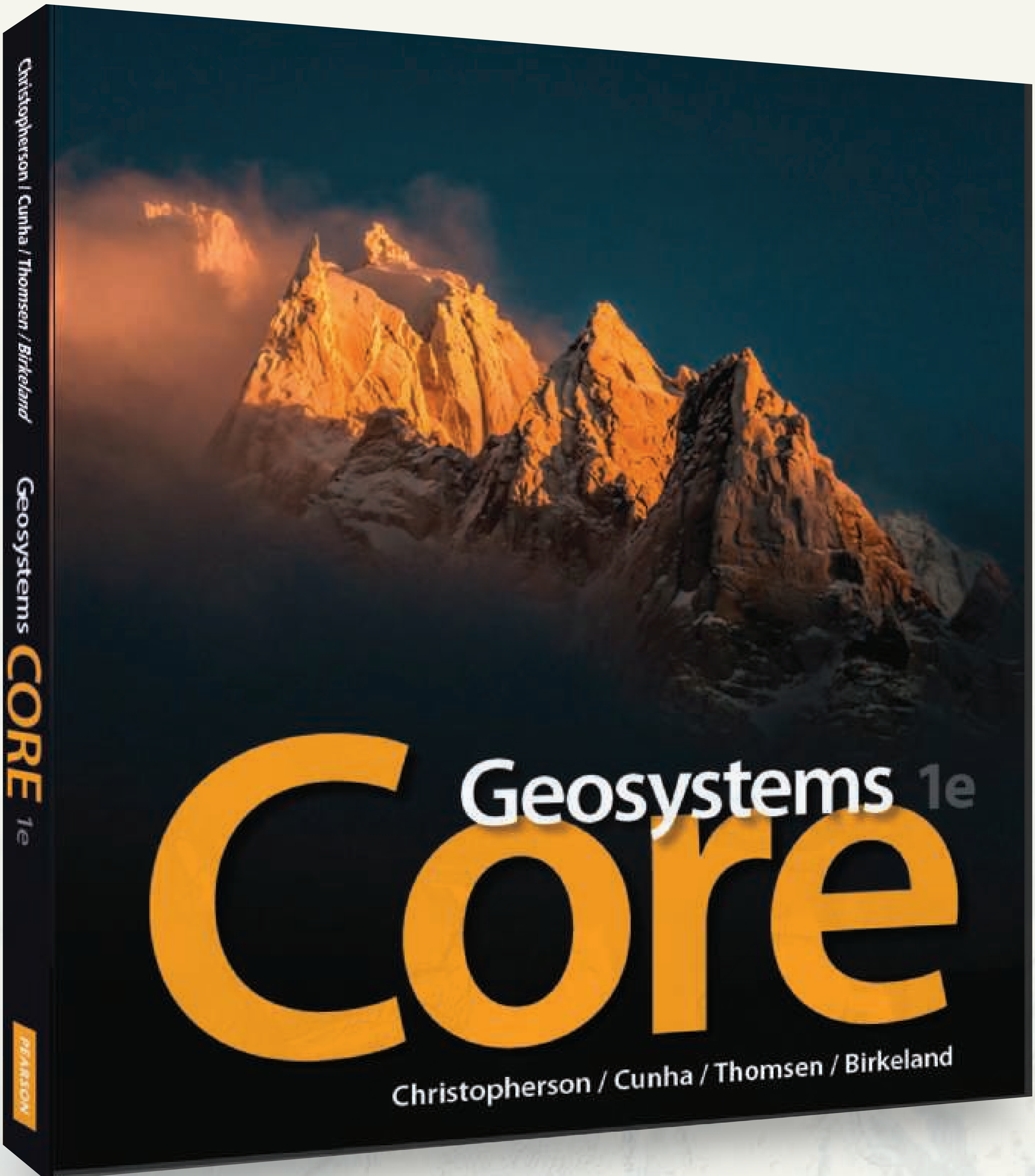
Multiple images from satellites *Terra*, *Aqua*, *Radarsat*, and *Defense Meteorological Satellite*, and from Space Shuttle *Endeavor's* radar data of topography, all merge in a dramatic composite to show the Western Hemisphere and Eastern Hemisphere of Earth. What indications do you see on these images that tell you the time of year? These are part of NASA's Blue Marble Next Generation image collection.

[NASA images by Reto Stöckli, based on data from NASA and NOAA.]

Eastern Hemisphere



A Brief, Visual Approach to Physical Geography



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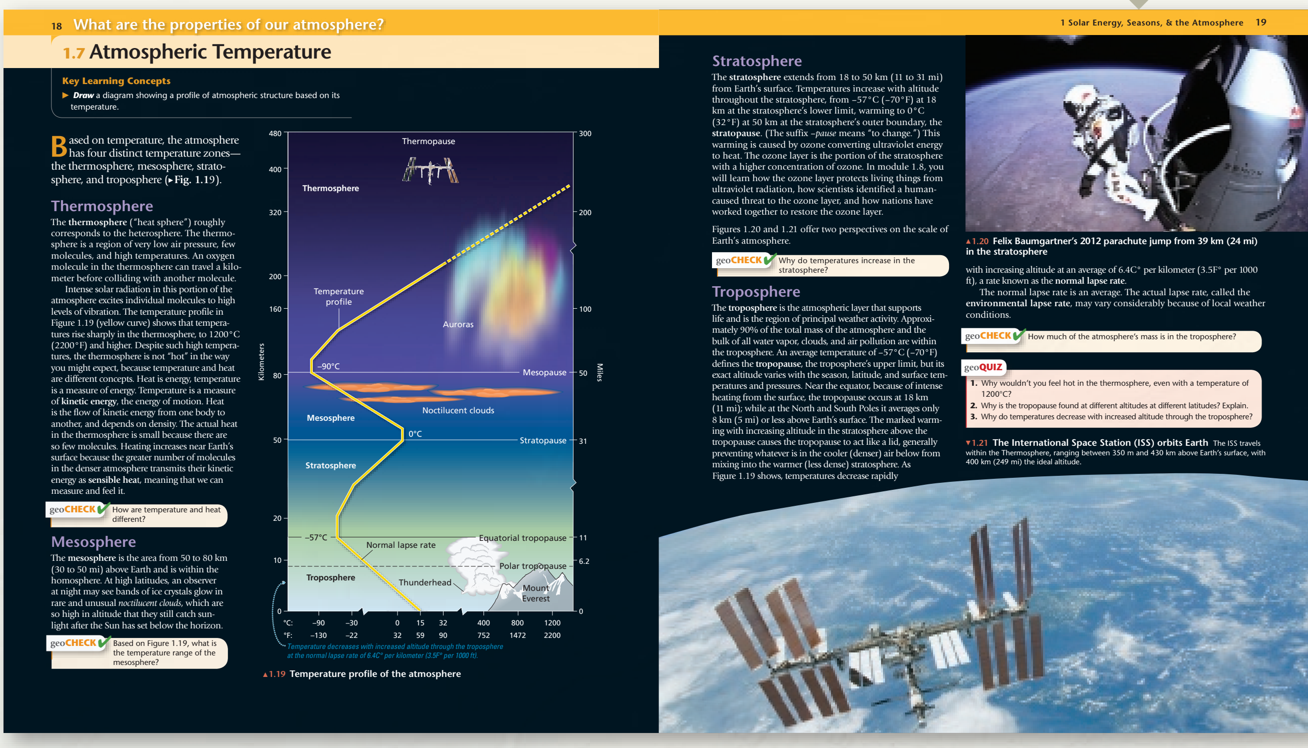
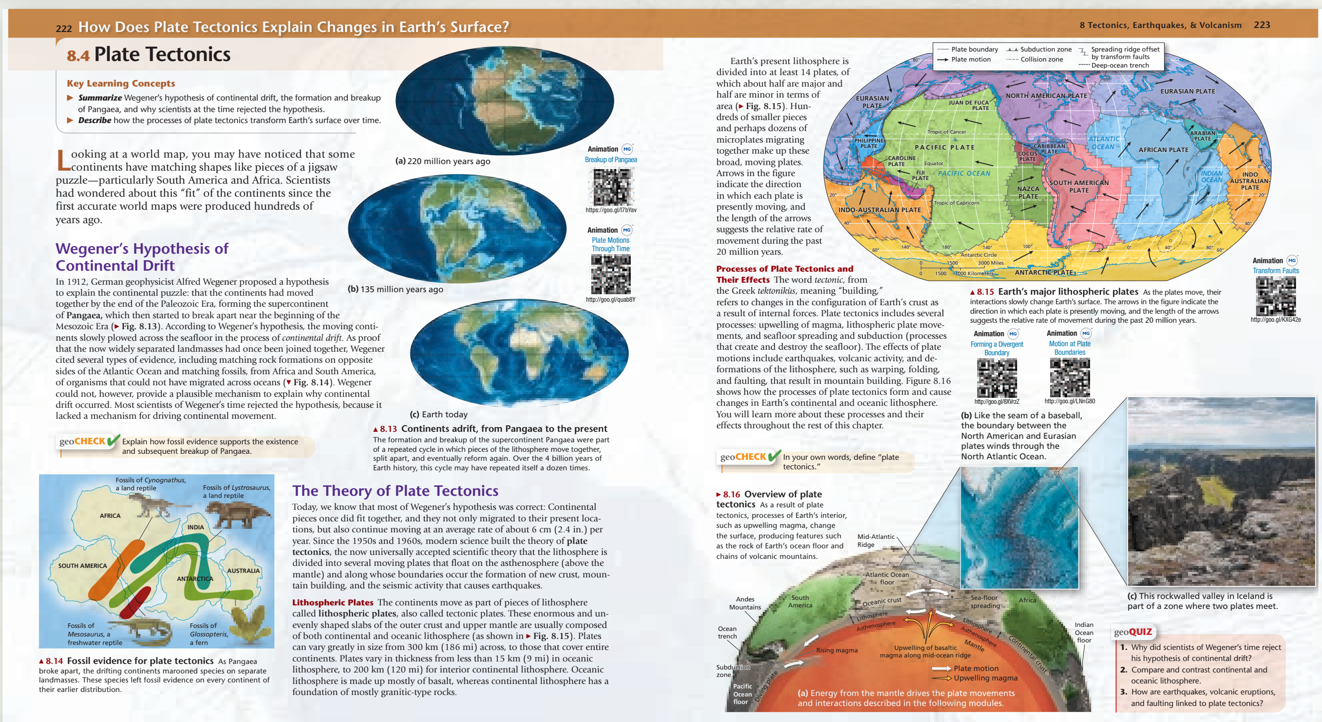
Brief, Modular, & Flexible

Two-page modules present the core concepts of physical geography. *Geosystems Core* focuses on a clear, concise, and highly-visual presentation of the essential science. Instructors can assign these flexible modules in whatever sequence best suits their course and teaching style. The consistent, focused, and engaging presentation prevents students from becoming lost in unnecessary detail.





Mobile-Ready Media Bring Geography to Life

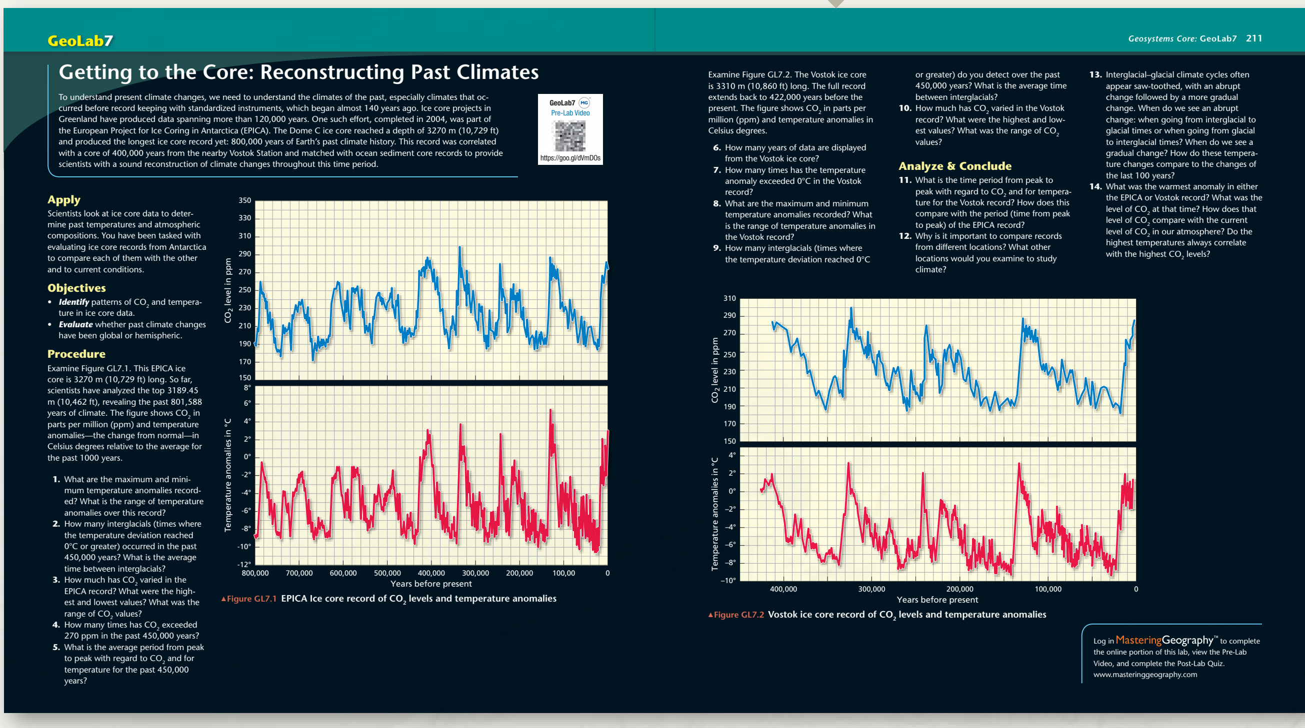
Over 130 videos & animations integrated within the chapters give readers instant access to visualizations of key physical processes, as well as applied case studies & virtual explorations of the real world. Readers use mobile devices to scan Quick Response (QR) links in the book to immediately access media as they read the chapters. These media are also available in the MasteringGeography Study Area, and can be assigned with automatically-graded assessments.

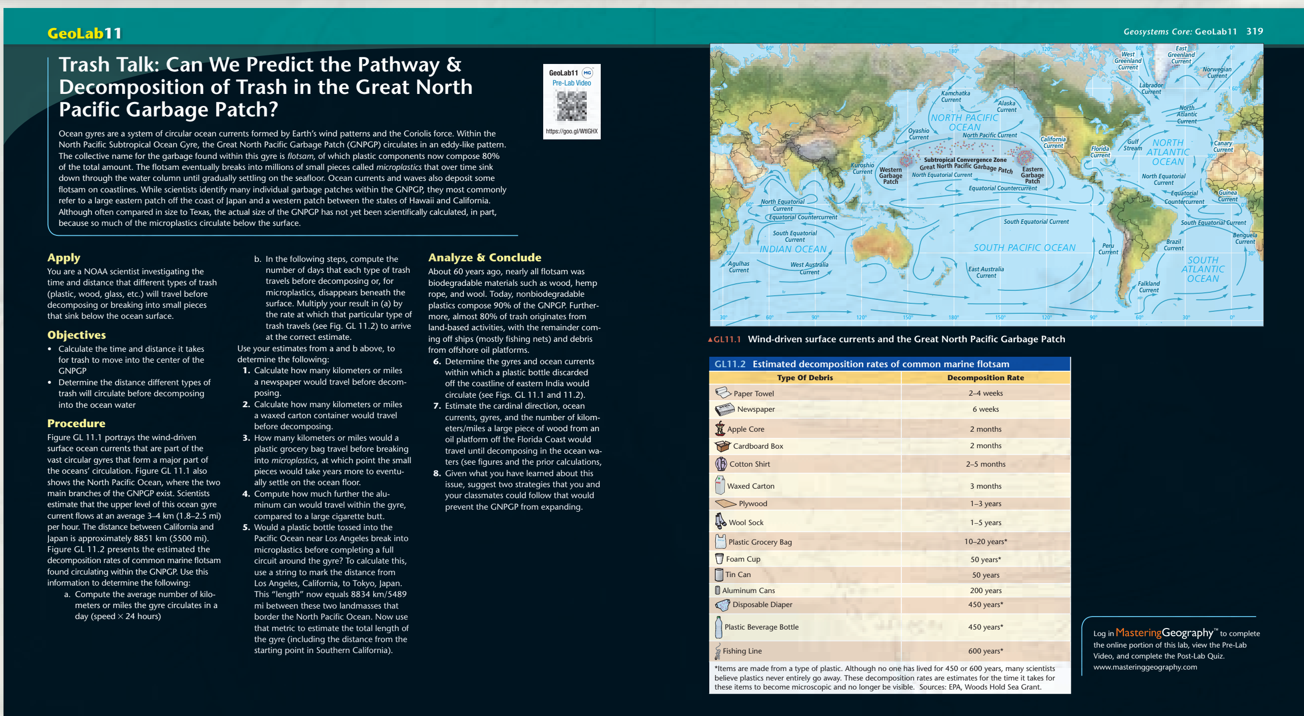
Mobile Field Trip
Videos transport students on adventures with acclaimed photographer and pilot Michael Collier, in the air and on the ground, exploring iconic landscapes of North America and the natural and human forces that have shaped them.

Project Condor
Quadcopter Videos take students out into the field through narrated & annotated quadcopter video footage, exploring the physical processes that have helped shape North American landscapes.

GeoLabs: An Integrated Lab Experience

***GeoLab* modules integrate the lab experience directly into the book,** enabling students to get hands-on with data & the applied tools of physical geography without the need for a separate lab manual. Perfect for lab work, homework, or group work, each *GeoLab* presents a context-rich & data-driven lab activity, and includes a QR-linked *Pre-Lab* Review Video that reviews the chapter concepts needed for the activity. Associated auto-gradable assessments in MasteringGeography can be assigned for credit.





The Human Denominator of Earth Systems

The Human Denominator concludes each chapter, explicitly focusing on human-Earth relationships in physical geography & Earth systems science. These highly-visual features include maps, aerial imagery, photos of real-world applications, and a brief overview of current & potential future issues.

THE**human**DENOMINATOR 11 Oceans, Coasts, & Dunes

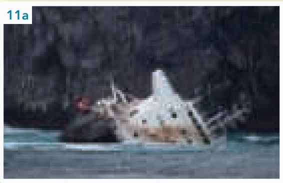
COASTAL SYSTEMS IMPACT HUMANS

- Rising sea level has the potential to inundate coastal communities.
- Tsunami cause damage and loss of life along vulnerable coastlines.
- Coastal erosion changes coastal landscapes, affecting developed areas; human development on depositional features such as barrier island chains is at risk from storms, especially hurricanes.

HUMANS IMPACT COASTAL SYSTEMS

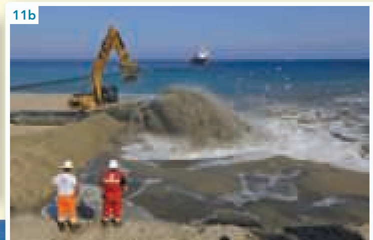
- Rising ocean temperatures, pollution, and ocean acidification impact corals and reef ecosystems.
- Human development drains and fills coastal wetlands and mangrove swamps, thereby removing their buffering effect during storms.

11a



A cargo vessel ran aground on Nightingale Island, Tristan da Cunha, in the South Atlantic in 2011, spilling an estimated 1500 tons of fuel, spilling tons of soybeans, and coating endangered Northern Rockhopper penguins with oil.

11b



Dredgers pump sand through a hose to replenish beaches on Spain's Mediterranean coast, a popular tourist destination. Near Barcelona, pictured here, sand is frequently eroded during storms; natural replenishment is limited by structures that block longshore currents.

11d

On Navajo Nation lands in the U.S Southwest, dune migration is threatening houses and transportation, and affecting human health. The Grand Falls dune field in northeast Arizona grew 70% in areal extent from 1997 to 2007. The increasingly dry climate of this region has accelerated dune migration and reactivated inactive dunes.

ISSUES FOR THE 21ST CENTURY

- Degradation and loss of coastal ecosystems—wetlands, corals, mangroves—will continue with coastal development and climate change.
- Continued building on vulnerable coastal landforms will necessitate expensive recovery efforts, especially as storm systems become more intense with climate change.

11c

Mangrove planting: In Aceh, Indonesia, near the site of the 2004 Indian Ocean tsunami, authorities encourage local people to plant mangroves for protection against future tsunami.

Looking Ahead

In the next chapter we examine glacial and periglacial landscapes. We will investigate how glacial formation and movement sculpts the land and leaves behind many distinctive landforms. Changes in the Earth's total mass of glacial ice is also important evidence used to monitor our changing climate.

Tools for Structured Learning

Key Concepts organize chapter modules around the big picture questions of physical geography.

I-20 What tools do geographers use?

1.6 Modern Geoscience Tools

Key Learning Concepts

▶ ***Explain*** how geographers use the Global Positioning System, remote sensing, geographic information systems, and geovisualizations.

Key Learning Concepts present the key information and skills that students need to master in each module, and also provide the organizing structure for the MasteringGeography item library of assessments.

GeoChecks in each module enable students to check their understanding as they read the module sections, for a "read a little, do a little" approach that fosters active critical thinking.

geoCHECK Why are at least three satellites needed to find a location using GPS?

geoCHECK Compare and contrast the two types of remote sensing.

geoCHECK Describe the two types of information that a GIS combines.

GeoQuizzes conclude each module, giving students a chance to check their understanding before moving on to the next module.

geoQUIZ

1. Explain at least two ways you have benefited from the GPS.
2. What types of remote-sensing data have you seen today? in the past week?
3. Describe the criteria for a GIS used to find a parcel of land to build a new subdivision using the following data layers: property parcels, zoning layer, floodplain layer, protected wetlands layer.

Critical Thinking, Review, & Spatial Analysis

Chapter Review includes a module-by-module summary with integrated *Review* questions, *Critical Thinking* exercises, *Visual Analysis* activities, *Interactive Mapping* activities using *MapMaster*, and *Explore* activities using *Google Earth*.

Visual Analysis

Glaciers in Alaska have been retreating dramatically due to warming temperatures. The Muir Glacier is a good example of this.

1. Examine the two photographs and describe the changes observed.
2. What are two examples visible in the photographs that show how much conditions have changed from 1941 to 2004?

(a)

(b)

▲R7.1 **Muir Glacier** (a) 1941 and (b) 2004.

Interactive Mapping | Login to the **MasteringGeography** Study Area to access **MapMaster.**

Climate Change

Earth's climate is changing, but not all locations will change equally. Some locations will change much more than others.

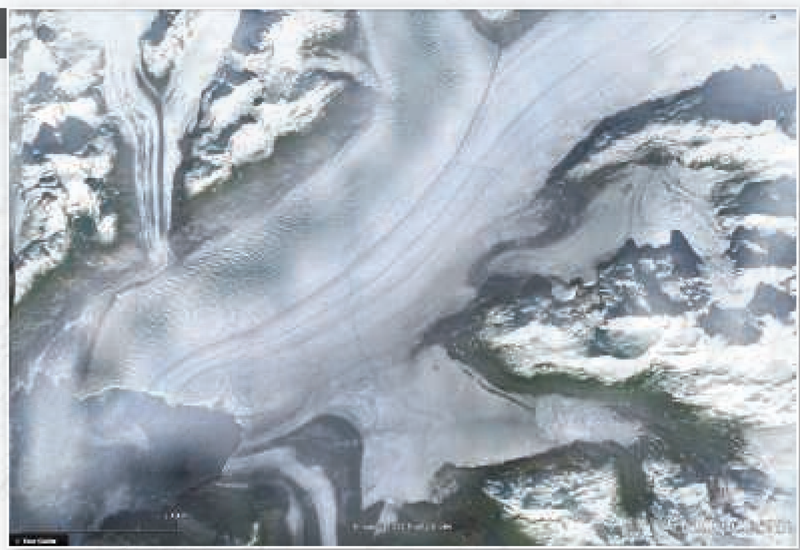
- Open MapMaster in MasteringGeography™.
- Select Global Surface Warming Worst Case Projections from the Physical Environment menu. Explore the sublayers of different temperature change projections.

1. What is the largest projected change for the land in the Northern Hemisphere? What is the largest projected change for the land in the Southern Hemisphere? What is the projected change for the Hawaiian Islands? For your home town?
2. Describe the pattern of projected change, as a function of latitude and continentality. What are the characteristics of the locations with the highest amount of projected change? Locations with the lowest amount of projected change?

Explore Earth | Use **Google Earth** to explore the **Glaciers of Alaska**.

Over 95% of glaciers are in retreat worldwide. Glaciers in Alaska are no exception. Search for the *Columbia Glacier, Alaska*. Zoom in until you can see where the end of the glacier meets the sea. Use the *Add Path* tool to trace the outline of the end of the glacier. Turn on *Historical Imagery* (the clock button), and go back to 11/27/2007. Use the *Add Path* tool again to draw the outline of the end of the glacier.

1. Use the *Show Ruler* tool to measure the retreat from 2007 to 2013 at several places. What is the maximum and minimum retreat?
2. How many miles or kilometers per year has the glacier been retreating?
3. If the glacier continues to retreat at this rate, how long until the retreat equals your daily commute to school?

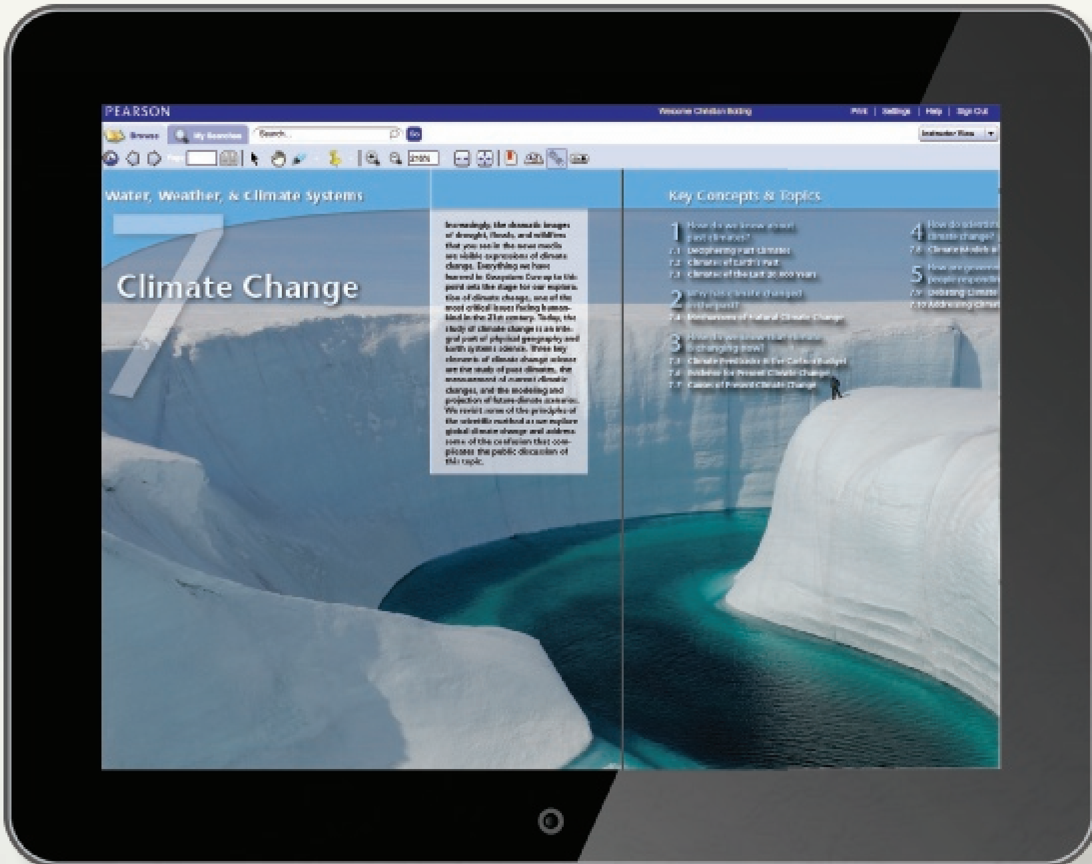


►R7.2

Continuous Learning
Before, During, and After Class

BEFORE CLASS

Mobile Media & Reading Assignments Ensure Students Come to Class Prepared.



Dynamic Study Modules personalize each student's learning experience. Created to allow students to acquire knowledge on their own and be better prepared for class discussions and assessments, this mobile app is available for iOS and Android devices.

Pearson eText in MasteringGeography gives students access to the text whenever and wherever they can access the internet. eText features include:

- Now available on smartphones and tablets.
- Seamlessly integrated videos and other rich media.
- Fully accessible (screen-reader ready).
- Configurable reading settings, including resizable type and night reading mode.
- Instructor and student note-taking, highlighting, bookmarking, and search.

Pre-Lecture Reading Quizzes are easy to customize & assign

Reading Questions ensure that students complete the assigned reading before class and stay on track with reading assignments. Reading Questions are 100% mobile ready and can be completed by students on mobile devices.

with MasteringGeography™

DURING CLASS

Learning Catalytics™ & Engaging Media

What has Teachers and Students excited? Learning Catalytics, a 'bring your own device' student engagement, assessment, and classroom intelligence system, allows students to use their smartphone, tablet, or laptop to respond to questions in class. With Learning Catalytics, you can:

- Assess students in real-time using open ended question formats to uncover student misconceptions and adjust lecture accordingly.
- Automatically create groups for peer instruction based on student response patterns, to optimize discussion productivity.

> ***"My students are so busy and engaged answering Learning Catalytics questions during lecture that they don't have time for Facebook."***
>
> **Declan De Paor, *Old Dominion University***

Enrich Lecture with Dynamic Media

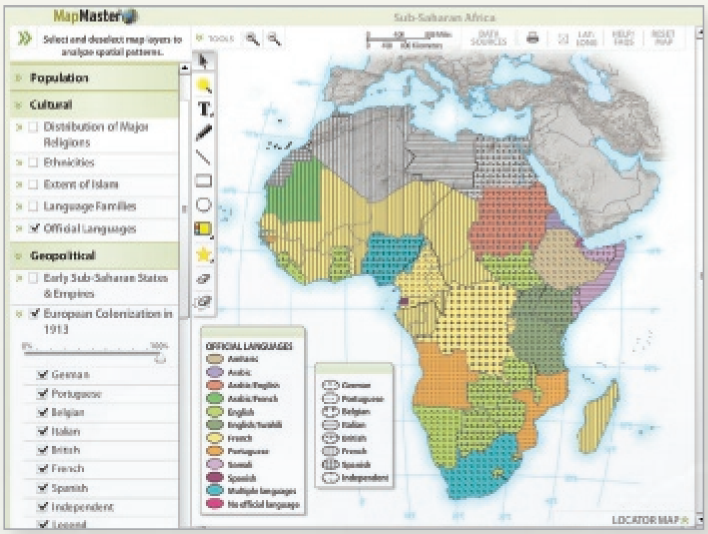
Teachers can incorporate dynamic media into lecture, such as Videos, Mobile Field Trips Videos, MapMaster Interactive Maps, Project Condor Quadcopter videos, and Geoscience Animations.

Mastering Geography™

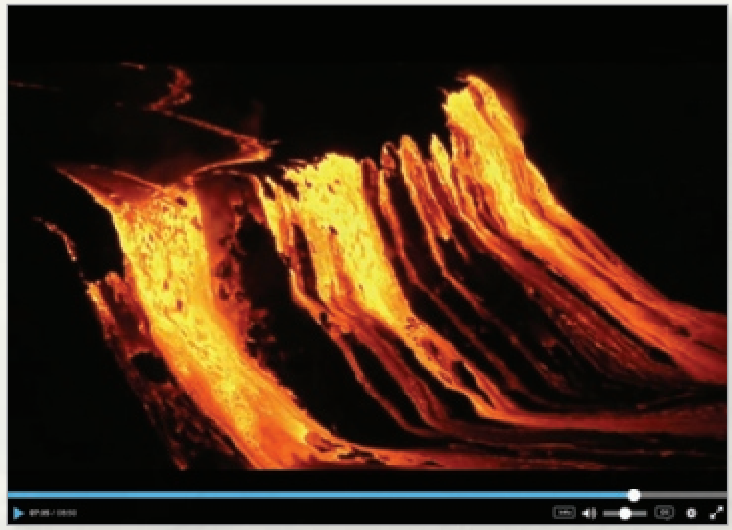
MasteringGeography delivers engaging, dynamic learning opportunities—focusing on course objectives and responsive to each student's progress—that are proven to help students absorb physical geography course material and understand challenging geography processes and concepts.

AFTER CLASS

Easy to Assign, Customizable, Media-Rich, and Automatically Graded Assignments



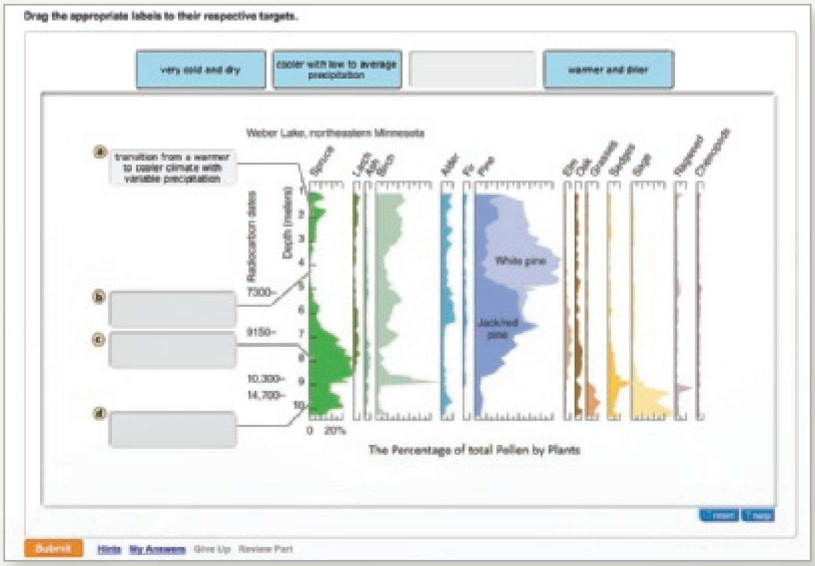
MapMaster Interactive Map Activities are inspired by GIS, allowing students to layer various thematic maps to analyze spatial patterns and data at regional and global scales. This tool includes zoom and annotation functionality, with hundreds of map layers leveraging recent data from sources such as NOAA, NASA, USGS, United Nations, and the CIA.



Geography Videos from such sources as the BBC and *The Financial Times* are now included in addition to the videos from Television for the Environment's Life and Earth Report series in **MasteringGeography**. Approximately 200 video clips for over 30 hours of footage are available to students and teachers and **MasteringGeography**.

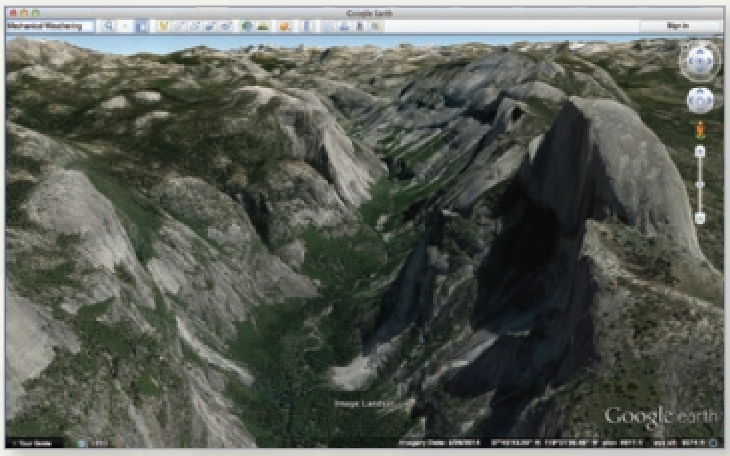
***Mobile Field Trip* Videos** have students accompany acclaimed photographer and pilot Michael Collier in the air and on the ground to explore iconic landscapes of North America and beyond. Readers scan Quick Response (QR) links in the book to access the 20 videos as they read. Also available within **MasteringGeography**.

www.masteringgeography.com

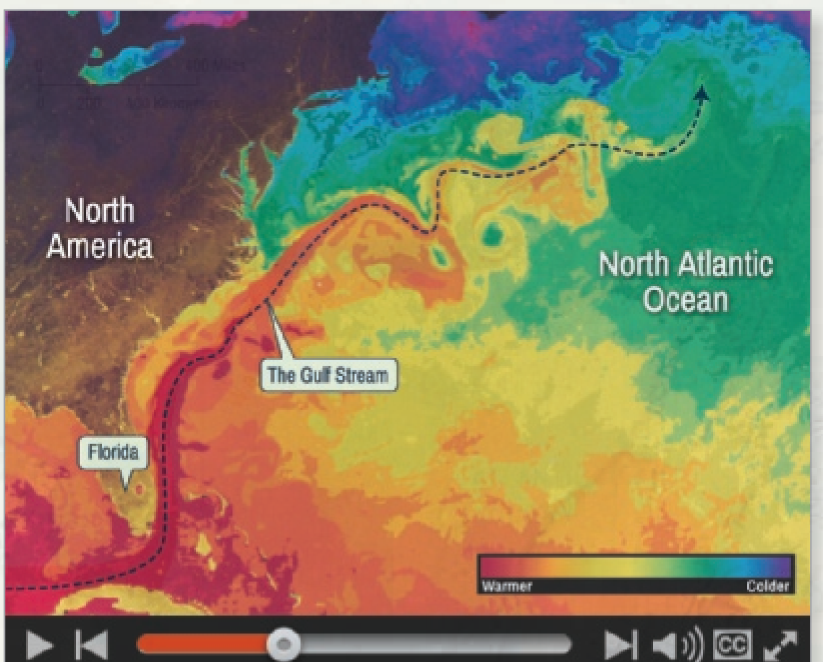


GeoTutors are highly visual and data-rich coaching items with hints and specific wrong answer feedback that help students master the toughest topics in geography.

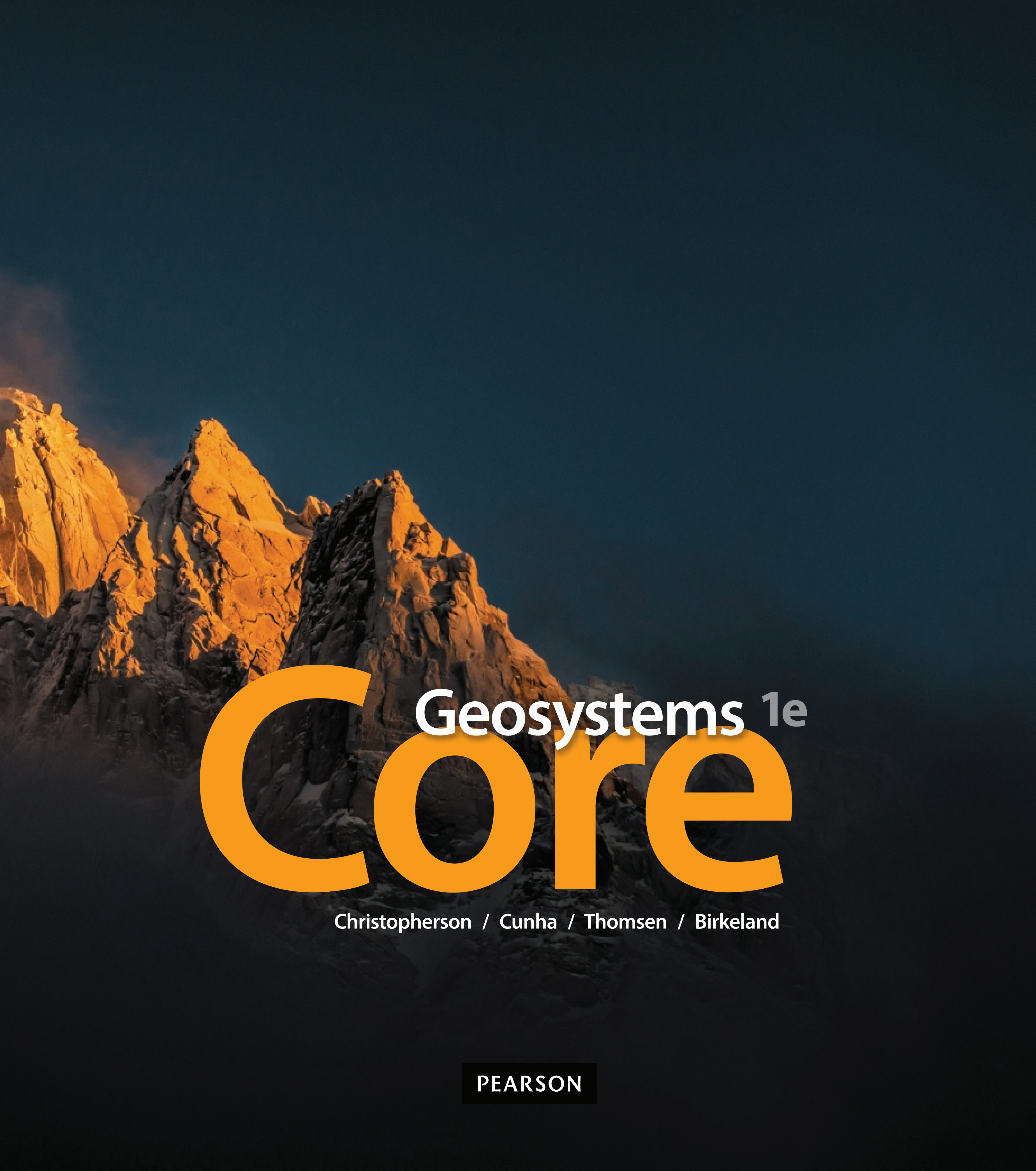
***Project Condor* Quadcopter Videos** take students out into the field through narrated & annotated quadcopter video footage, exploring the physical processes that have helped shape North American landscapes.



Encounter (Google Earth) activities provide rich, interactive explorations of physical geography concepts, allowing students to visualize spatial data and tour distant places on the virtual globe.



Geoscience Animations help students visualize the most challenging physical processes in the physical geosciences with schematic animations that include audio narration. Animations include assignable multiple-choice quizzes with specific wrong answer feedback to help guide students toward mastery of these core physical process concepts.



Geosystems Core 1e

Christopherson / Cunha / Thomsen / Birkeland

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Library of Congress Cataloging-in-Publication Data

Names: Christopherson, Robert W. | Cunha, Stephen F. | Thomsen, Charles E.
Title: Geosystems core / Robert Christopherson, Stephen Cunha, Charles Thomsen, Ginger Birkeland.
Description: Hoboken, New Jersey : Pearson Education, [2017]
Identifiers: LCCN 2015048457| ISBN 9780321834744 (alk. paper) | ISBN 0321834747 (alk. paper)
Subjects: LCSH: Physical geography. | Earth sciences.
Classification: LCC GB54.5 .C49 2017 | DDC 910/.02–dc23
LC record available at http://lccn.loc.gov/2015048457

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1 2 3 4 5 6 7 8 9 10—**V3P5**—20 19 18 17 16

ISBN 10: **0-321-83474-7;** ISBN 13: **978-0-321-83474-4** (Student edition)
ISBN 10: **0-134-14283-7;** ISBN 13: **978- 0-134-14283-8** (Instructor's Review Copy)

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Brief Contents

MasteringGeography™ Mobile-Ready Animations & Videos

Geosystems Core includes Quick Response links to over 130 mobile-ready animations and videos, which students can access using mobile devices. These media are also available in the Study Area of MasteringGeography, and can be assigned to students with quizzes.

Introduction to Physical Geography

Geoscience Animation
Map Projections

Mobile Field Trip
Introduction to Physical Geography

Video
GeoLab Pre-Lab Video

1 Solar Energy, Seasons, & the Atmosphere

Geoscience Animations
Earth Sun Relations
Formation of the Solar System
The Ozone Layer

Video
GeoLab Pre-Lab Video

2 Energy in the Atmosphere

Geoscience Animations
Global Warming, Climate Change
Earth-Atmosphere Energy Balance
The Gulf Stream

Videos
The Ozone Hole
The Ozone Layer
GeoLab Pre-Lab Video

3 Pressure, Winds, and Currents

Geoscience Animations
Coriolis Force
Global Atmospheric Circulation
Cyclones and Anticyclones
Jet Stream, Rossby Waves
Ocean Circulation
North Atlantic Deep Water Circulation
Thermohaline Circulation
El Niño and La Niña

Mobile Field Trip
El Niño

Video
GeoLab Pre-Lab Video

4 Atmospheric Water and Weather

Geoscience Animations
Water Phase Changes
Atmospheric Stability
Warm Fronts
Cold Fronts
Midlatitude Cyclones
Tornado Wind Patterns
Hurricane Wind Patterns

Mobile Field Trip
Clouds: Earth's Dynamic Atmosphere

Videos
NSSL in the Field
Radar Research at NSSL
Hurricane Hot Towers
Superstorm Sandy
Making of a Superstorm
GeoLab Pre-Lab Video

5 Water Resources

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Earth's Water and the Hydrologic Cycle
The Water Table

Mobile Field Trips
Oil Sands: An Unconventional Oil
Moving Water Across California

Videos
Hydrological Cycle
GeoLab Pre-Lab Video

6 Global Climate Systems

Geoscience Animation
Global Patterns of Precipitation

Videos
Supercomputing the Climate
GeoLab Pre-Lab Video

7 Climate Change

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Global Warming, Climate Change
End of the Last Ice Age
Earth-Sun Relations
Orbital Variations & Climate Change
The Carbonate Buffering System
Arctic Sea Ice Decline

Mobile Field Trip
Climate Change in the Arctic

Videos
20,000 Years of Pine Pollen
Taking Earth's Temperature
Keeping Up With Carbon
Temperature & Agriculture
Supercomputing the Climate
Superstorm Sandy
GeoLab Pre-Lab Video

8 Tectonics, Earthquakes, & Volcanism

Project Condor
Quadcopter Videos
Principles of Relative Dating
Intrusive Igneous Bodies

MasteringGeography™ Mobile-Ready Animations & Videos

Monoclines of the Colorado Plateau
Anticlines and Synclines
Faults versus Joints
Cinder Cones and Basaltic Lava Flows
Continental Rifting

Geoscience Animations
Applying Relative Dating Principles
Foliation of Metamorphic Rock
Breakup of Pangaea
Plate Motions through Time
Transform Faults
Forming a Divergent Boundary
Motion at Plate Boundaries
Subduction Zones
Seafloor Spreading and Plate Boundaries
Convection within the Mantle
Plate Boundaries
Hot Spot Volcano Tracks
Folds
Transform Faults
Seismic Wave Motion
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Volcano Types

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Desert Geomorphology
San Andreas Fault
Kilauea
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Video
GeoLab Pre-Lab Video

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Landslides

Video
GeoLab Pre-Lab Video

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Project Condor
Quadcopter Videos
River Terraces and Base Level
Meandering Rivers
Characteristics of Alluvial Fans

Geoscience Animations
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Oxbow Lake Formation
Stream Processes, Floodplains
Stream Terrace Formation

Mobile Field Trips
Streams of the Great Smoky Mountains
Mississippi River Delta

Video
GeoLab Pre-Lab Video

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Movement of a Barrier Island
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Video
GeoLab Pre-Lab Video

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The Critical Zone of Boulder Creek
Forest Fires in the West

Video
Flow of Ice Within a Glacier

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Videos
Plant Productivity in a Warming World
Amazon Deforestation
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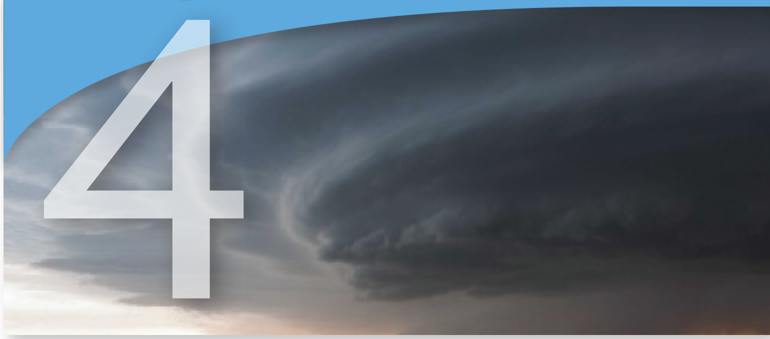

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Preface

Welcome to *Geosystems Core,* a new exploration of physical geography! Geography is a highly visual discipline. Images of landslides, waterfalls, shrinking glaciers, monsoon deluges, climate change impacts, weather events, and tropical rainforests fill our media. Photographs portray the human response to sudden earthquakes and floods, or to more gradual phenomena such as prolonged drought effects or soil creep. For this reason, Pearson—the world's foremost publisher of geography textbooks—invites you to explore physical geography in a new, highly visual, modular approach.

Physical Geography Surrounds Us

The main purpose of *Geosystems Core* is to introduce physical geography—a geospatial science that integrates a range of disciplines concerned with Earth's physical and living systems, including geology, meteorology, biology, and ecology, among others. It is intended for use in college-level introductory courses in physical geography, Earth science, and environmental science.

Geosystems Core teaches a holistic view of Earth's environment. Central to this approach is human-environment interaction. During the last two centuries, our expanding human population became a major force in shaping Earth's environment. Humans plant crops, plough soils, domesticate animals, clear forests, build settlements, extract precious metals, and burn fossil fuels. Human agency modifies the distribution of plant and animal species. We impound and divert most of the world's major rivers, and are altering the chemistry of the oceans. Moreover, in the last 20 years, mounting evidence from every scientific field supports the case for human-induced climate change.

As an academic discipline, the roots of geography stretch back to antiquity, yet physical geography is essential to understanding current environmental issues. For example, by 320 B.C.E., the Greek philosopher and scientist Aristotle recognized how vegetation and climate changed with elevation in the Pindos Mountains of Greece. Today, contemporary geography thrives on the cutting edge of knowledge, serving as the bridge between Earth and natural sciences. New geospatial technologies such as GPS, GIS, and Remote Sensing allow humans to view, record, and analyze the world anew.

Geographers analyze environmental problems from pole to pole, and from the ocean floor to Earth's highest summits. They use new technologies to analyze acid rain deposition in mountain lakes, trace dust storms across continents, and assess the changing distribution of plants and animals on a warming planet. Knowing where things are—the spatial arrangement of everything from deserts and rainforests, to active volcanoes and hurricanes—is key to understanding geography, and is emphasized throughout *Geosystems Core*.

Although dramatic global change is underway in physical, chemical, and biological systems that support and sustain us, the environmental future of our planet need not be bleak. Population growth rates are decreasing almost everywhere on Earth. Emerging technology is leading humanity away from dependence on fossil fuels and into an era where clean and renewable energy prevails. Important advances in soil science, water conservation, and crop management are making agriculture more productive and sustainable. Advancing scientific knowledge and possibly lowering poverty rates worldwide offer enormous potential to make this twenty-first century one of great environmental restoration. For that to occur, all of us must understand the complex and interrelated environmental systems that govern our unique planet. This study of physical geography takes us along this path.

Organization & Themes

The goal of physical geography is to explain the spatial dimension of Earth's dynamic systems—its energy, air, water, weather, climate, tectonics, landforms, rocks, soils, plants, ecosystems, and biomes. *Geosystems Core* focuses on the most essential, core concepts of physical geography. The following themes present the major organizational structure of the book.

- **Earth Systems Science:** *Geosystems Core* is organized around the natural flow of energy, materials, and information in our Earth system, presenting subjects in the same sequence in which they occur in nature (atmosphere, hydrosphere, geosphere, and biosphere)—an organic, holistic Earth systems approach that is unique in this discipline.
- **Climate Change Science:** Incorporating the latest climate change science and data throughout, *Geosystems Core* includes a dedicated chapter on climate change, covering paleoclimatology and mechanisms for past climatic change, climate feedbacks and the global carbon budget, the evidence and causes of present climate change, climate forecasts and models, and actions that we can take to moderate Earth's changing climate.
- **Human-Earth Relationships:** Each chapter concludes with *The Human Denominator*, explicitly focusing on the human-Earth dimension of physical geography within context of the chapter topic. These features include maps (spatial data), real-world examples (photos), and review of both current and potential future issues that help engage students by connecting physical geography concepts to their real-world environment.
- **Geospatial Technology:** Rapidly developing technologies pervade our everyday lives. Mapping and geospatial technologies such as GPS, GIS, and RS are high growth areas, critical tools in the twenty-first century that help us visualize, measure, and analyze Earth's natural and human-built features, and make every day decisions. *Geosystems Core* integrates geospatial technology throughout all chapters to help students visualize and critically analyze the spatial dimensions of Earth's physical geography.

Structured Learning

A structured learning path and tightly integrated pedagogy give students a reliable, consistent framework for mastering the major concepts of physical geography:

- **Two-page modules present key geographical concepts** that can stand on their own and be read in any order. Instructors can assign these flexible modules in whatever sequence best suits their course and teaching style. Each module in the text contains the essential content for each concept; this focused presentation prevents students from becoming lost in unnecessary detail.
- The chapter-opening **Key Concepts** list the learning objectives for each chapter.
- **GeoChecks** and **GeoQuizzes** are integrated into each module, enabling students to check their understanding as they read the module sections, for a "read a little, do a little" approach that is engaging, and that fosters active critical thinking.
- Chapters conclude with a **Chapter Review** that includes a module-by-module summary with various types of review activities including *Critical Thinking*, *Visual Analysis*, *Interactive Mapping*, and *Explore* activities using Google Earth.
- **GeoLabs** Unique, two-page *GeoLab* capstone modules integrate a lab experience directly into the book without the need for a separate lab manual or lab section, enabling students to get hands-on with the data and tools of physical geography. Each *GeoLab* includes an online component in MasteringGeography that can be assigned and automatically graded.

Mobile Media & MasteringGeography

- **Over 130 Animations & Videos** are **QR Linked** to provide just-in-time reinforcement to learners as they read, giving students instant mobile access to visualizations of key physical processes as well as applied case studies and virtual explorations of the real world. Sources include NASA/JPL, FEMA, and NOAA, *Mobile Field Trip* Videos by Michael Collier, and *Project Condor* Quadcopter videos.
- **MasteringGeography** is an online homework, tutorial, and assessment program designed to work with *Geosystems Core* to engage students and improve results. Interactive, self-paced coaching activities provide individualized coaching to keep students on track. With a wide range of visual and media-rich activities available, including GIS-inspired MapMaster interactive maps, Encounter *Google Earth* explorations, geoscience animations, GeoTutors on the more challenging topics in geography, and a range of videos, students can actively learn, understand, and retain even the most difficult concepts.

Acknowledgments

Geosystems Core took tremendous time, resources, and focus to develop as a first edition science textbook. This highly collaborative, multi-year effort involved authors, editors, graphic artists, media producers, and experts in page design, photo research, and logistics. Our thanks to the *Pearson* team for their expertise and enthusiasm for this project. These include Senior Geography Editor Christian Botting for his vision and expertise, Program Manager Anton Yakovlev and Project Manager Connie Long for keeping us on track and on schedule, Art Development Editor Jay McElroy for taking our visions and making them into art that teaches and is beautiful, and our wonderful Executive Development Editor Jonathan Cheney for clarifying and polishing our rough thoughts into words, and Market Development Manager Leslie Allen for arranging reviews and class tests.

Our thanks also to the production team at Cenveo, in particular Jeanine Furino and Cindy Miller, whose efforts proved essential to bringing our ideas to fruition. We also thank the art and cartography studios at International Mapping: Kevin Lear and Luchina, and Senior Permissions Project Manager, Lauren McFalls for helping us find the images we requested.

Thanks to all the teachers (and their students) who served as reviewers and class testers throughout the development of *Geosystems Core*:

- **Manuscript Development & Accuracy Reviewers**

Miriam Helen Hill, *Jacksonville State University*
James Kernan, *State University of New York at Geneseo*
Lisa DeChano, *University of Michigan*
Doug Goodin, *Kansas State University*
Janice Hayden, *Dixie State College of Utah*
David Holt, *The University of Southern Mississippi*
Kara Kuvakas, *Hartnell College*
James Vaughan, *The University of Texas at San Antonio*

- **Reviewers & Class Testers**

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Trent Biggs, *San Diego State University*
Michael Boester, *Monroe Community College*
Liana Boop, *San Jacinto College*
Carsten Braun, *Westfield State University*
Robert Bristow, *Westfield State University*
Joan Bunbury, *Univeristy of Wisconsin La Crosse*
Adam Burnett, *Colgate University*
John Conley, *Fullerton College*
Michael Davis, *Kutztown University*
Nicole DePue, *Salem State University*
James Dyer, *Ohio University - Athens*
Jonathan Fleming, *University of North Alabama*
Tyler Fricker, *Florida State University*
Anilkumar Gangadharan, *Kennesaw State University*

Julienne Gard, *El Camino College*
Katie Gerber, *Santa Rosa Junior College*
Lawrence Gilbert, *Virginia Western Community College*
Brett Goforth, *California State University - San Bernardino*
Dafna Golden, *Mount San Antonio College*
John Greene, *University of Oklahoma*
Roy Haggerty, *Oregon State University*
Amanda Hall, *Towson University*
Janice Hayden, *Dixie State College of Utah*
Donald (Don) Helfrich, *Central New Mexico Community College*
Joseph Hinton, *City College of Chicago*
Michael Keables, *University of Denver*
Ryan Kelly, *Kentucky Community and Technical College System*
James Kernan, *State University of New York at Geneseo*
John Keyantash, *California State University - Dominguez Hills*
Chris Krause, *Glendale Community College*
Paul Larson, *Southern Utah University*
Denyse Lemaire, *Rowan University-Glassboro*
Michael Lewis, *University of North Carolina at Greensboro*
Jonathon Little, *Monroe Community College*
Jing Liu, *Santa Monica College*
Kerry Lyste, *Everett Community College*
Joy Mast, *Carthage College*
Shannon McCarragher, *Northern Illinois University*
Benjamin McDaniel, *North Hennepin Community College*
Mystyn Mills, *California State University - Long Beach*
Monika Moore, *Delta College*
Nathan Moore, *Michigan State University*
Todd Moore, *Towson University*
Patrick Olsen, *University of Idaho*
Hal Olson, *Anne Arundel Community College*
Michael Paluzzi, *Rockland County Community College*
Jeremy Patrich, *Santa Monica College*
Mark Patterson, *Kennesaw State University*
Marius Paulikas, *Kent State University*
Nancy Perry, *Northern Virginia Community College*
Mike Pesses, *Antelope Valley College*
James Powers, *Pasadena City College*
Curtis Robinson, *Sacramento City College*
Steve Schultze, *University of South Alabama*
Anil Shrestha, *Northern Illinois University*
Jeremy Spencer, *University of Akron*
John Van Stan, *Georgia Southern University*
James Vaughan, *University of Texas at San Antonio*
Megan Walsh, *Central Washington University*
Richard Watson, *Central New Mexico Community College*
Susan White, *West Los Angeles College*
Cody Wiley, *University of New Mexico*
Erika Wise, *University of North Carolina at Chapel Hill*
Julie Wulff, *Oakton Community College*

Author Acknowledgments

- **From Robert:** I thank my family, especially my wife Bobbé, for believing in this work from the first edition of *Geosystems* in 1992. I give special gratitude to all the students during my 30 years of teaching, for it is in the classroom crucible that these books are forged. I offer special thanks to my talented coauthors: Stephen, Charlie, and Ginger, for their dedicated work in extending the *Geosystems* franchise in this dramatic, new, modular presentation. And, thanks to Pearson for supporting such a creative vision for physical geography.

- **From Stephen:** Sincere thanks to Douglas R. Powell of UC Berkeley, for introducing me to Physical Geography, and for inspiration to experience first hand, what I share with my students. I also thank my students over many years. I admire their enthusiasm to learn and their wonderful minds. Finally, deepest appreciation to my family, especially spouse Mary Beth Cunha—an accomplished geospatial scientist, university faculty, and traveler extraordinaire!

- **From Charlie:** Thanks to Robert, Stephen, and Ginger, I couldn't have asked for a better team of co-authors. Thanks to Ronald I. Dorn of Arizona State University, for formally introducing me to the wonderful world of geography. Thanks to my students and colleagues at American River College. I thank my supportive family for their patience and understanding, especially my wife Leslie, and my children Emma and Finn.

- **From Ginger:** Many thanks to Robert, for his dedication in pioneering the *Geosystems* approach, and to Stephen and Charlie, for their creative work extending *Geosystems* in this new and exciting direction. My sincere gratitude goes to my husband, Karl, for our many scientific discussions and his unwavering support, and to my daughters Erika and Kelsey. Through their eyes, I see a bright future for physical geography and the challenges ahead.

- **From all of us:** Physical geography teaches us a holistic view of the intricate supporting web that is Earth's environment and our place in it. Dramatic global change is underway in human-Earth relations as we alter physical, chemical, and biological systems. Our attention to climate change science and applied topics is in response to the impacts we are experiencing and the future we are shaping. All things considered, this is a perfect time for you to be enrolled in a physical geography course! The best to you in your studies—and ***carpe diem!***

Digital & Print Resources

For Students & Teachers

MasteringGeography™ with Pearson eText. The *Mastering* platform is the most widely used and effective online homework, tutorial, and assessment system for the sciences. It delivers self-paced tutorials that provide individualized coaching, focus on course objectives, and are responsive to each student's progress. The *Mastering* system helps teachers maximize class time with customizable, easy-to-assign, and automatically graded assessments that motivate students to learn outside of class and arrive prepared for lecture. MasteringGeography™ offers:

- **Assignable activities** that include GIS-inspired MapMaster™ interactive map activities, *Encounter* Google Earth™ Explorations, video activities, *Mobile Field Trips, Project Condor* Quadcopter videos, Geoscience Animation activities, map projections activities, GeoTutor coaching activities on the toughest topics in geography, Dynamic Study Modules that provide each student with a customized learning experience, end-of-chapter questions and exercises, reading quizzes, *Test Bank* questions, and more.
- **A student Study Area** with MapMaster™ interactive maps, videos, *Mobile Field Trips, Project Condor* Quadcopter videos, Geoscience Animations, web links, glossary flashcards, "In the News" readings, chapter quizzes, PDF downloads of outline maps, an optional Pearson eText and more.

Pearson eText gives students access to the text whenever and wherever they can access the Internet. Features of Pearson eText include:

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Television for the Environment Earth Report Geography Videos, DVD (0321662989). This three-DVD set helps students visualize how human decisions and behavior have affected the environment and how individuals are taking steps toward recovery. With topics ranging from the poor land management promoting the devastation of river systems in Central America to the struggles for electricity in China and Africa, these 13 videos from Television for the Environment's global *Earth Report* series recognize the efforts of individuals around the world to unite and protect the planet.

Geoscience Animation Library, 5th edition, DVD (0321716841). Created through a unique collaboration among Pearson's leading geoscience authors, this resource offers over 100 animations covering the most difficult-to-visualize topics in physical geography, meteorology, earth science, physical geology, and oceanography.

Practicing Geography: Careers for Enhancing Society and the Environment by Association of American Geographers (0321811151). This book examines career opportunities for geographers and geospatial professionals in the business, government, nonprofit, and education sectors. A diverse group of academic and industry professionals shares insights on career planning, networking, transitioning between employment sectors, and balancing work and home life. The book illustrates the value of geographic expertise and technologies through engaging profiles and case studies of geographers at work.

Teaching College Geography: A Practical Guide for Graduate Students and Early Career Faculty by Association of American Geographers (0136054471). This two-part resource provides a starting point for becoming an effective geography teacher from the very first day of class. Part One addresses "nuts-and-bolts" teaching issues. Part Two explores being an effective teacher in the field, supporting critical thinking with GIS and mapping technologies, engaging learners in large geography classes, and promoting awareness of international perspectives and geographic issues.

Aspiring Academics: A Resource Book for Graduate Students and Early Career Faculty by Association of American Geographers (0136048919). Drawing on several years of research, this set of essays is designed to help graduate students and early career faculty start their careers in geography and related social and environmental sciences. *Aspiring Academics* stresses the interdependence of teaching, research, and service—and the importance of achieving a healthy balance of professional and personal life—while doing faculty work. Each chapter provides accessible, forward-looking advice on topics that often cause the most stress in the first years of a college or university appointment.

For Students

***Applied Physical Geography—Geosystems in the Laboratory*, Ninth Edition** by Charlie Thomsen and Robert Christopherson (0321987284). A variety of exercises provides flexibility in lab assignments. Each exercise includes key terms and learning concepts linked to *Geosystems*. The Ninth Edition includes new exercises on climate change, soils, and rock identification, a fully updated exercise on basic GIS using ArcGIS online, and more integrated media, including Google Earth™ and Quick Response (QR) codes linking to Pre-Lab videos. Supported by a website with online worksheets as well as KMZ files for all of the Google Earth™ exercises found in the lab manual. www.mygeoscienceplace.com

Goode's World Atlas, 23rd Edition (0133864642). *Goode's World Atlas* has been the world's premiere educational atlas since 1923—and for good reason. It features over 250 pages of maps, from definitive physical and political maps to important thematic maps that illustrate the spatial aspects of many important topics. The 23rd Edition includes over 160 pages of digitally produced reference maps, as well as thematic maps on global climate change, sea-level rise, CO_2 emissions, polar ice fluctuations, deforestation, extreme weather events, infectious diseases, water resources, and energy production.

Pearson's Encounter Series provides rich, interactive explorations of geoscience concepts through Google Earth™ activities, covering a range of topics in regional, human, and physical geography. For those who do not use *MasteringGeography*™, all chapter explorations are available in print workbooks, as well as in online quizzes at www.mygeoscienceplace.com, accommodating different classroom needs. Each exploration consists of a worksheet, online quizzes whose results can be emailed to teachers, and a corresponding Google Earth™ KMZ file.

- *Encounter Physical Geography* by Jess C. Porter and Stephen O'Connell (0321672526)
- *Encounter World Regional Geography* by Jess C. Porter (0321681754)
  Encounter Human Geography by Jess C. Porter (0321682203)

Dire Predictions: Understanding Global Climate Change 2nd Edition by Michael Mann, Lee R. Kump (0133909778). Periodic reports from the Intergovernmental Panel on Climate Change (IPCC) evaluate the risk of climate change brought on by humans. But the sheer volume of scientific data remains inscrutable to the general public, particularly to those who may still question the validity of climate change. In just over 200 pages, this practical text presents and expands upon the essential findings of the IPCC in a visually stunning and undeniably powerful way to the lay reader. Scientific findings that provide validity to the implications of climate change are presented in clear-cut graphic elements, striking images, and understandable analogies.

The Second Edition covers the latest climate change data and scientific consensus from the IPCC *Fifth Assessment Report* and integrates mobile media links to online media. The text is also available in various eText formats, including an eText upgrade option from MasteringGeography courses.

For Teachers

Learning Catalytics is a "bring your own device" student engagement, assessment, and classroom intelligence system. With Learning Catalytics, you can:

- Assess students in real time, using open-ended tasks to probe student understanding.
- Understand immediately where students are and adjust your lecture accordingly.
- Improve your students' critical-thinking skills.
- Access rich analytics to understand student performance.
- Add your own questions to make Learning Catalytics fit your course exactly.
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Learning Catalytics is a technology that has grown out of twenty years of cutting-edge research, innovation, and implementation of interactive teaching and peer instruction. Available integrated with *MasteringGeography*™.

Instructor Resource Manual (Download) (0134142802). The manual includes lecture outlines and key terms, additional source materials, teaching tips, and a complete annotation of chapter review questions. Available from www.pearsonhighered.com/irc and in the Instructor Resources area of *MasteringGeography*™.

TestGen® Test Bank (Download) by Todd Fagin (0134142829). TestGen® is a computerized test generator that lets you view and edit *Test Bank* questions, transfer questions to tests, and print tests in a variety of customized formats. This *Test Bank* includes around 3,000 multiple-choice and short answer/essay questions. All questions are correlated against the National Geography Standards, textbook key learning concepts, and Bloom's Taxonomy. The *Test Bank* is also available in Microsoft Word® and importable into Blackboard. Available from www.pearsonhighered.com/irc and in the Instructor Resources area of *MasteringGeography*™.

Instructor Resource DVD (0134142810). The *Instructor Resource DVD* provides a collection of resources to help teachers make efficient and effective use of their time. All digital resources can be found in one well-organized, easy-to-access place. The IRDVD includes:

- All textbook images as JPEGs, PDFs, and PowerPoint™ Presentations
- Pre-authored Lecture Outline PowerPoint® Presentations which outline the concepts of each chapter with embedded art and can be customized to fit teachers' lecture requirements
- CRS "Clicker" Questions in PowerPoint™
- The TestGen software, *Test Bank* questions, and answers
  Electronic files of the *Instructor Resource Manual* and *Test Bank*

This *Instructor Resource* content is also available online via the Instructor Resources section of *MasteringGeography*™ and www.pearsonhighered.com/irc.

About the Authors

Robert W. Christopherson attended California State University, Chico for his undergraduate work and received his M.A. in Geography from Miami University-Oxford, Ohio. *Geosystems* evolved out of his physical geography research in grad school and thirty years of classroom teaching notes. His wife Bobbé is his principal photographer and provided more than 300 exclusive photos for each of his books. Together they completed eleven polar expeditions (most recently in summer 2013 and 2015). Robert is the recipient of numerous awards, including the 1998 and 2005 *Textbook and Academic Authors Association (TAA)* "Textbook Award" for *Geosystems* and *Elemental Geosystems, 4/e*, respectively. He was selected by American River College students as "Teacher of the Year" and received the American River College "Patrons Award." Robert received the 1999 "Distinguished Teaching Achievement Award" from the *National Council for Geographic Education* and the "Outstanding Educator Award" from the *California Geographical Society* in 1997. In 2012, California State University, Chico, presented him their "Distinguished Alumni Award." In 2013, TAA presented him with its "Lifetime Achievement Award." Robert has been deeply involved in the development of Pearson's *Geoscience Animation Library*, and he led the editorial board of Rand McNally's *Goode's World Atlas 22nd edition*. Robert currently serves on the Advisory Board of *Biosphere 2*, Earth's largest ecosystem research facility, operated by the University of Arizona.

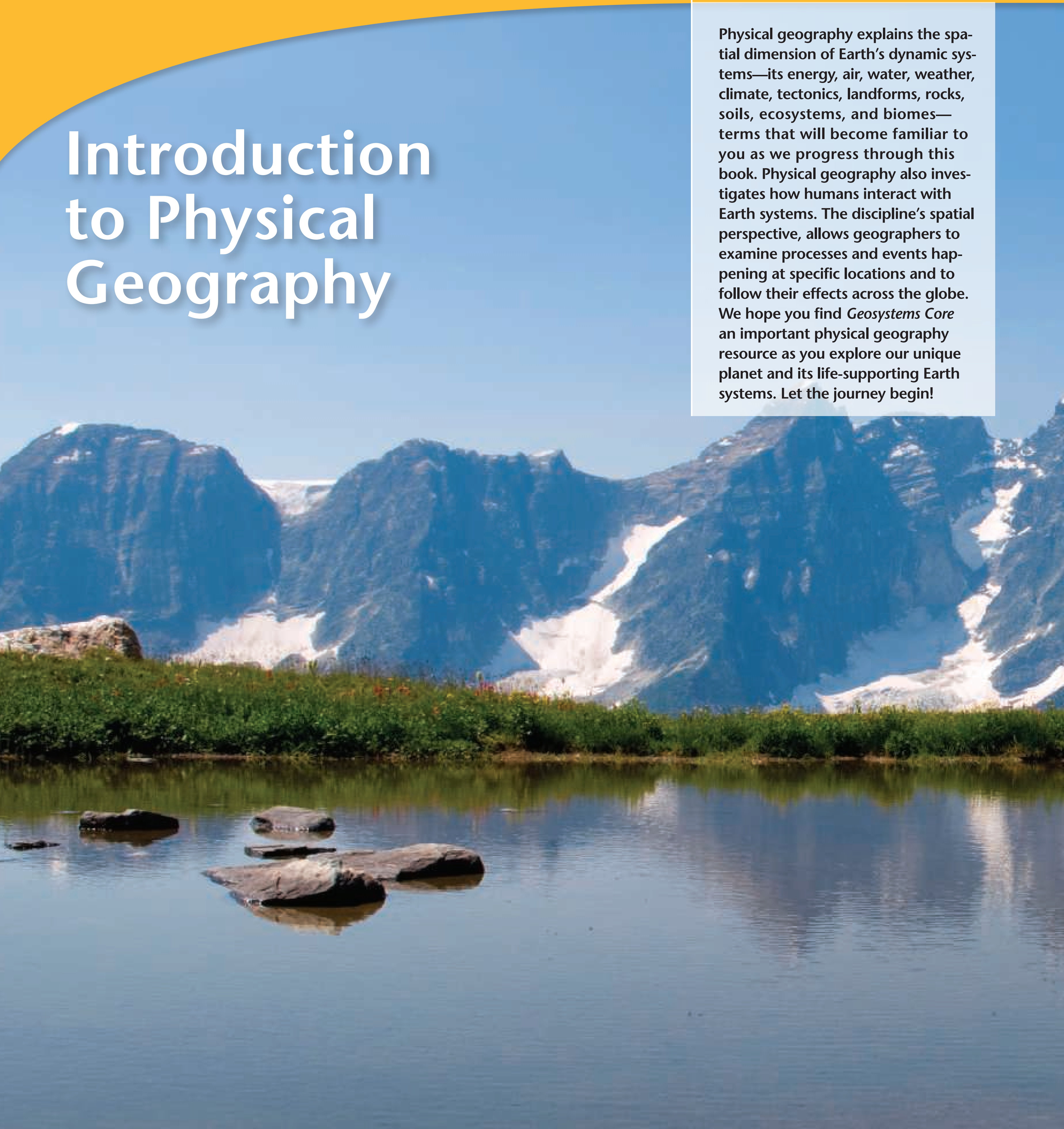
Stephen Cunha is professor of geography at Humboldt State University. He received his B.S. and B.A. degrees from University of California, Berkeley, and his M.A. and PhD in Geography from University of California, Davis. Stephen worked ten seasons as a park ranger in Yosemite and Alaska, and three years investigating the potential for a national park and biosphere reserve in the Pamir Mountains of Tajikistan. He is an active teacher, researcher, and mountain geographer, having co-authored geography textbooks and *The Atlas of California*. His travel experience in the Americas, Asia, Oceania, Europe, and Africa, brings new international perspective and content to *Geosystems Core*. Cunha has numerous teaching and research awards, and at press time serves as President of the *Association of Pacific Coast Geographers*.

Charlie Thomsen is professor of geography at American River College, where he teaches physical geography, human geography, field classes, and GIS. He has taught field courses in Yosemite National Park, backpacking down the Lost Coast Trail, snowshoeing in the Sierra Nevada, as well as in state and national parks throughout California. His career as an educator began in high school as a Boy Scout merit badge counselor at Camp Emerald Bay on Catalina Island, and he has been teaching ever since. Professor Thomsen received his B.A. from University of California, Los Angeles and his M.A. from California State University, Chico. He is the author of Pearson's *Encounter Geosystems* and *Applied Physical Geography: Geosystems in the Laboratory,* as well as many other assessment and media projects.

Ginger Birkeland received her B.A. from the University of Colorado, Boulder, and her M.A. and PhD in Geography from Arizona State University, with a focus in fluvial geomorphology. She taught physical geography at Montana State University and field courses at the Indiana University Geologic Field Station in Montana. Ginger worked as a professional river guide for 17 years on the Colorado River in Grand Canyon, as well as on rivers in Australia and throughout the U.S. West. She also worked as a geomorphology consultant on several government-funded projects, including the Truckee River Recovery Plan in California and Nevada. She is currently a coauthor with Robert Christopherson on *Geosystems* and *Elemental Geosystems.*

Introduction to Physical Geography

Physical geography explains the spatial dimension of Earth's dynamic systems—its energy, air, water, weather, climate, tectonics, landforms, rocks, soils, ecosystems, and biomes—terms that will become familiar to you as we progress through this book. Physical geography also investigates how humans interact with Earth systems. The discipline's spatial perspective, allows geographers to examine processes and events happening at specific locations and to follow their effects across the globe. We hope you find *Geosystems Core* an important physical geography resource as you explore our unique planet and its life-supporting Earth systems. Let the journey begin!



Key Concepts & Topics

A small glacial tarn reflects the peaks and glaciers of Canada's Purcell Mountains.

I.1 The World Around Us

Key Learning Concepts

▶ ***Give examples*** of the kinds of events, processes, and questions that physical geography investigates.

▲I.1 **Locations of events shown in Figure I.2**

Welcome to *Geosystems Core* and the study of physical geography. In this text, we examine the natural processes on Earth that influence our lives—ranging from weather and climate to earthquakes and volcanoes. We also examine the many ways humans interact with these Earth systems. A **system** is any set of ordered, interrelated components and their attributes, linked by flows of energy and matter—a concept we will expand upon later in this chapter. Physical geography involves the study of Earth's environments, including the landscapes, seascapes, atmosphere, and ecosystems on which humans depend. In the second decade of the 21st century, our natural world is changing, and the scientific study of Earth and its environments is more crucial than ever.

(a) Flowers blooming in the Atacama Desert, Chile

(b) Destruction in Nepal from a 2015 earthquake.

▲I.2 **Events that shape our changing planet** Every day, natural disasters and the effects of ordinary human activities, such as building a dam or using fossil fuels as an energy source, can raise questions to which geographers seek the answers.

Asking Geographic Questions

Consider as examples the following events, each of which raises questions for the study of Earth's physical geography (▲ **Figs. I.1** and **I.2**). This text provides tools for answering these questions and addressing the underlying issues.

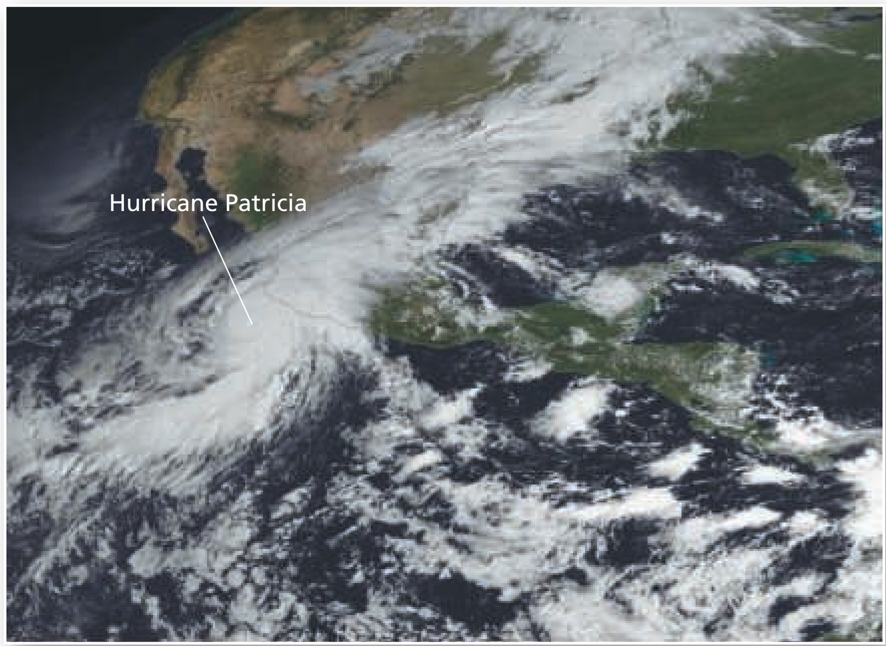
- In 2015, El Niño rains drenched northern Chile's Atacama Desert, one of the driest places on Earth. The unexpected deluge brought catastrophic flooding. However, all that water brought something else too. Within months, an explosion of wildflowers carpeted the normally barren ground (▲ **Fig. I.2a**). In some places, the seeds had been dormant in the soil for decades, until this perfect combination of rainfall and spring warmth brought them to life. Will climate change bring more frequent blooms in the future?
- In April 2015, a magnitude 7.8 earthquake stuck the Himalayan nation of Nepal. The earthquake killed more than 9000 people and injured another 23,000 (▲ **Fig. I.2b**). Why do earthquakes occur in particular locations across the globe? Why do earthquakes of similar magnitude and duration result in thousands of human casualties in one place, but almost none in another place?
- In 2014, the U.S. National Park Service finished dismantling two dams on the Elwha River in Washington—the largest dam removals in the world to date (▶ **Fig. I.2c**). The project will restore a free-flowing river for fisheries and associated ecosystems. How do dams change river environments? Can rivers be restored after dam removal?

- In 2015, Hurricane Patricia off the west coast of Mexico became the most powerful tropical storm ever measured in the Western Hemisphere (▼ **Fig. I.2d**). Although maximum winds over the ocean reached an unprecedented 220 kph (200 mph), the storm weakened quickly as it moved over the rugged terrain of central Mexico. Why are monster storms becoming more common, and how do they threaten human life and property?
- Rapidly evolving technologies such as Global Positioning Systems (GPS), remote sensing (RS), and geographic information systems (GIS)—terms discussed later in this chapter—increase our ability to collect and analyze the data needed to answer geographic questions (▼ **Fig. I.2e**). The rise of citizen science, volunteered geographic information (VGI), and participatory GIS (PGIS) provide opportunities for people to help monitor Earth's natural and human properties. Which areas interest you? This book will show you many possibilities.

Asking "Where?" & "Why?" Physical geography asks *where* and *why* questions about processes and events that occur at specific locations and then follow their effects across the globe. Why does the environment vary from equator to midlatitudes and between tropical and polar regions? What produces the patterns of wind, weather, and ocean currents? How does solar energy influence the distribution of trees, soils, climates, and human populations? In this book, we explore those questions and more through geography's unique emphasis on studying factors that affect the distribution of phenomena on Earth.

Climate Change Science & Physical Geography Climate change is now an overriding focus of the study of Earth systems. The past decade experienced the highest air temperatures over land and water in the instrumental record. In response, the extent of sea ice in the Arctic Ocean continues to decline to record lows. At the same time, melting of the Greenland and Antarctica Ice Sheets is accelerating and sea level is rising. Elsewhere, intense weather events, drought, and flooding continue to increase. In presenting the state of the planet, *Geosystems Core* surveys climate change evidence and considers its implications. Welcome to an exploration of physical geography and its impact on our daily lives!

(c) Dam removal on the Elwha River, Washington



(d) Hurricane Patricia approaching the coast of Mexico

(e) A student in Cambodia uses GPS to mark a location as part of a government-sponsored, land-reform effort.

geoCHECK ✔ What does the study of physical geography involve?

geoQUIZ

1. Pick one of the events described above and, using your own words, list three geographic questions you would like to answer about that event.
2. Based on the examples above, would you say that humans should be considered part of the natural world? Explain your answer.
3. What is some of the evidence for climate change that scientists have observed?

I.2 The Science of Geography

Key Learning Concepts

- ***Describe*** the main perspectives of geography and distinguish physical geography from human geography.
- ***Discuss*** the use of scientific methods in geography.
- ***Summarize*** how human activities and population growth impact the environment.

The world around us is constantly changing as the events and processes described in Module I.1 transform Earth's physical environment, affecting humans and other living things. One science seeks to provide answers to our questions about these changes: **Geography** (from geo, "Earth," and graphein, "to write") studies the relationships among natural environments, geographic areas, human society, and the interdependence of all of these across Earth. For geographers, "space" is a term with a special meaning: geographic space comprises Earth's surface, but as described below, also includes much more than that.

Geographic Perspectives

As a science, geography approaches the study of Earth from a number of distinctive perspectives:

- emphasis on spatial and locational analysis
- concern with human environment–interactions (discussed below)
- adoption of an *Earth systems* perspective to analyze how the physical, biological, and human components of those systems are interconnected (discussed in Module I.3)

Given the complexity of Earth systems, it's not surprising that geography has many subfields. The field's two main divisions—human geography and physical geography—are discussed below.

Spatial & Locational Analysis The term **spatial** refers to the nature and character of physical space, its measurement, and the distribution of things within it. Geographers use **spatial analysis** as a tool to explain distributions and movement across Earth and how these processes interact with human activities.

Maps showing locations and distributions are important tools for conveying geographic data and interpreting spatial relationships. Evolving technologies such as geographic information systems and the Global Positioning System are widely used for scientific applications as millions of people access maps and locational information every day on computers and mobile devices.

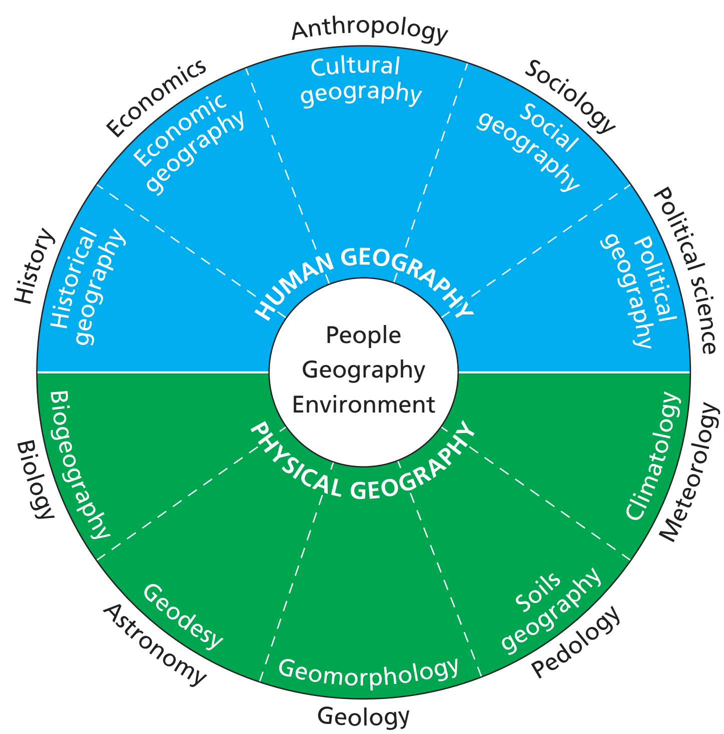
Human Geography & Physical Geography Although geography integrates content from many disciplines, it splits broadly into two primary subfields: *physical geography*, which draws on the physical and life sciences, and *human geography*, which draws on the social and cultural sciences (▸**Fig. I.3**). The growing complexity of the human–Earth relationship in the 21st century is shifting the study of geographic processes even farther toward the synthesis of physical and human geography. This more balanced and holistic perspective is the thrust of *Geosystems Core*. Within physical geography, research now emphasizes human influences on natural systems. For example, physical geographers monitor air pollution, examine the vulnerability of human populations to climate change, study impacts of human activities on forest health and the movement of invasive species, analyze changes in river systems caused by dam removal, and examine the response of glacial ice to changing climate.

Geography's spatial analysis method unifies the discipline more than does a specific body of knowledge. Geographers employ spatial analysis to examine how Earth's processes interact through space or over areas, and to analyze the differences and similarities between places. **Process**, a set of actions that operate in some special order, is also a central concept of geographic analysis. Therefore, **physical geography** is the spatial analysis of all the physical elements, processes, and systems that make up the environment: energy, air, water, weather, climate, landforms, soils, humans, animals, plants, microorganisms, and Earth itself.

geoCHECK ✔ Explain the two main subfields in geographical science.

The Scientific Process

The **scientific method** is the simple, organized steps leading toward concrete, objective conclusions about the natural world (▸**Fig. I.4**). Scientific inquiry has no single method as scientists in different fields approach their problems in different ways. However, the end result must be a conclusion that other



▲**I.3 The scope of geography** While physical geography focuses on processes affecting Earth systems, it shares with human geography tools, methods, and important concerns regarding the interactions among Earth's physical and human systems.

▲I.4 **Scientific method continuum** Scientists continually adjust the scientific method and formulate new hypotheses based on new observations, questions and results.

scientists can test repeatedly, either reproducing the results reached by other scientists or possibly showing that the results were false.

Using the Scientific Method Scientists who study the environment begin with clues they see in nature, followed by an exploration of the published scientific literature on their topic. Scientists then use questions and observations to form a *hypothesis*—a tentative explanation for the phenomena observed. Scientists test hypotheses using experimental studies in laboratories or natural settings (▶**Fig. I.5**). If the results support the hypothesis, repeated testing and verification may lead to a new *theory.* A **scientific theory** is a widely accepted explanation for a phenomenon that is based on evidence and experimentation and has withstood the scrutiny of the scientific community. Reporting research results in journals and books is also part of the scientific method. Science is objective by nature and does not make value judgments. Instead, science provides people and their institutions with objective information on which to base their own value judgments. The applications of science are increasingly important as Earth's natural systems respond to the impacts of modern civilization.

geo**CHECK** ✔ Compare and contrast a hypothesis and a scientific theory.

(a) Scientific Method Flow Chart

Real-World Observations
- Observe nature, ask questions, collect data
- Search for patterns, build conceptual or numerical models

Hypothesis and Predictions
- Formulate hypothesis (a logical explanation)
- Identify variables; determine data needed and data collection methods

Experimentation and Measurement
- Conduct experiments to test hypothesis

Result Support Hypothesis

Results Do Not Support Hypothesis
- Reject hypothesis
- Return to an earlier step of the process

Peer Review
- Communicate findings for evaluation by other scientists
- Publish scientific paper

Scientific Theory Development
- Hypothesis survives repeated testing
- Comprehensive explanation for an observation is widely accepted and supported by research

Dust darkens the surface of snowpack in the San Juan Mountains, CO, March 2009.

Snow pit for collecting dust from snowpack, San Juan Mountains, Colorado, 13 March 2009.

(b) Using the Scientific Method Process to Study the Effects of Dust on Mountain Snowpack

1. Observations
Farmers and ranchers in southern Colorado rely on melting snow from the San Juan Mountains. Water managers have determined that the mountain snowpack now melts earlier in the spring, so water is lost before it can be used.

2. Questions and Variables
- Are air temperature increases earlier in the spring responsible for more rapid snowmelt?
- Do non-temperature factors contribute to the earlier snowmelt?

3. Hypothesis
Although the most likely explanation for earlier snowmelt is increasing temperatures, dust churned up by livestock grazing in the lowlands may also promote rapid melting, as dark dust deposited on the white snow surface absorbs heat.

4. Testing
- Review monthly temperature data on changes in air temperatures.
- Monitor and measure the deposition of dust on the surface of the mountain snowpack.

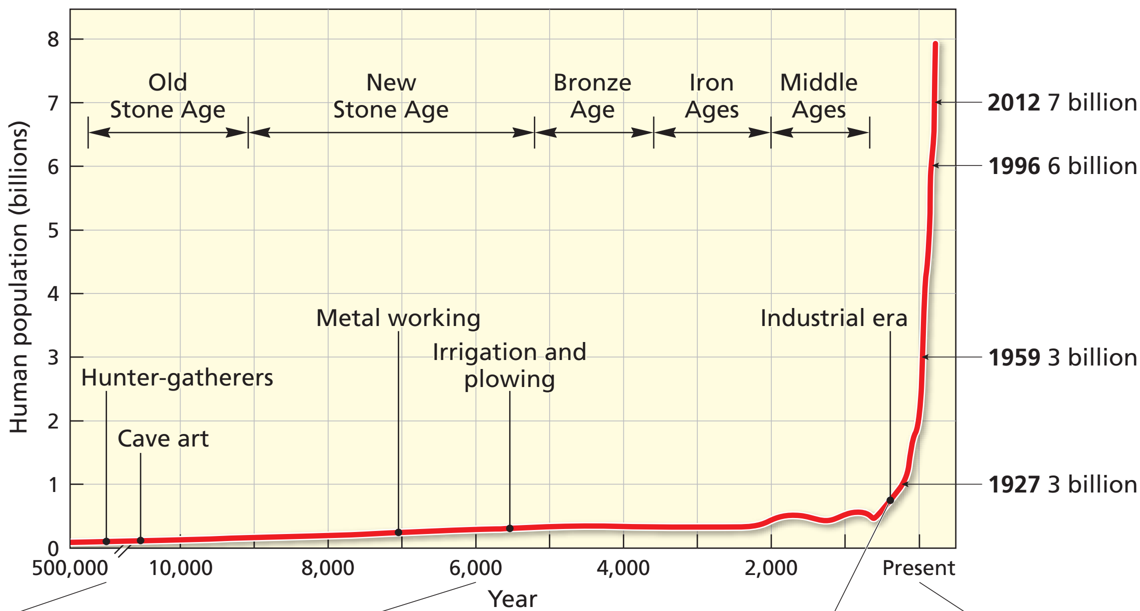
5. Results
The change in daily and seasonal air temperatures was minor. However, scientists did measure significant dust fall that darkened the snowpack, increasing the absorption of solar radiation and causing more snow to evaporate or to melt more quickly.

▲I.5 **Scientific method example application**

I.2 (cont'd) The Science of Geography

Human–Earth Interactions in the 21st Century

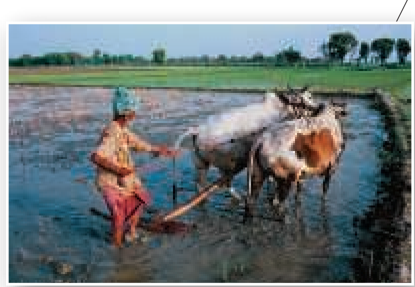
Throughout, *Geosystems Core* discusses issues surrounding the pervasive influence of humans on Earth systems. The global human population passed 7 billion in 2012 and is unevenly distributed among 195 countries. Virtually all population growth is in the less-developed countries that now possess 81% of the total population (▼**Fig. I.6**). We consider the totality of human impact on Earth to be the **human denominator**. (Each chapter in your textbook includes a Human Denominator feature that explores human impacts relevant to that chapter.) Just as the denominator in a fraction tells how many parts a whole is divided into, the growing human population and its increasing demand for resources and rising planetary impact suggest the stresses on the whole Earth system that supports us. Yet Earth's resource base—the numerator in this fraction—remains relatively fixed.



Mobile Field Trip MG
Introduction to Physical Geography
https://goo.gl/B2xTBh

(a) Hunter-gatherers depend on wild plants and animals.

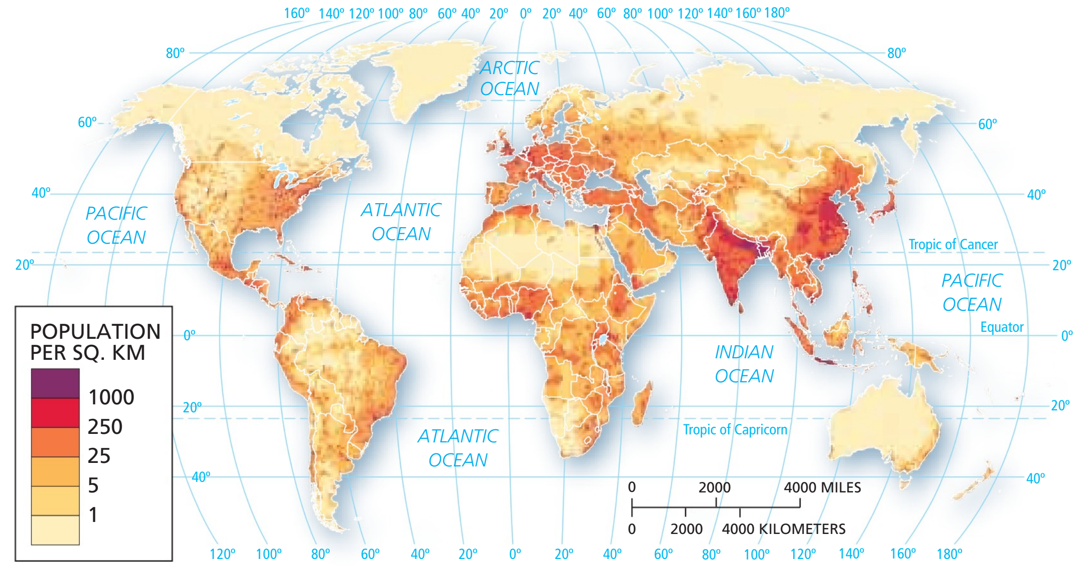
(b) Subsistence farmers use fire to clear the forest before planting crops.



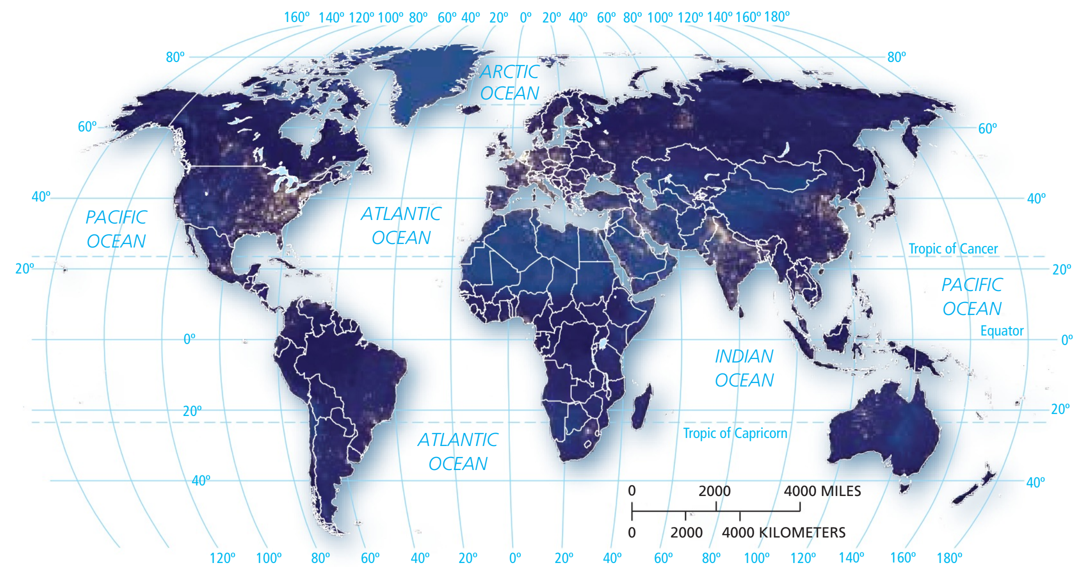
(c) The plow, irrigation, and application of fertilizers enable people to produce more food on the same land year after year.

(d) Today, farmers can use new technologies to produce foods in artificial environments, as in hydroponic farming.

▲**I.6 Human population growth** Human population remained relatively low for tens of thousands of years. The shift from hunting and gathering to farming, often called the Agricultural Revolution, occurred in several different regions beginning about 10,000 years ago. A larger, more stable food supply enabled more people to live together in permanent settlements, pursue specialized occupations, and develop new technologies. Cities grew, empires emerged, and population increased at higher rates—especially after the Industrial Revolution of the late 1700s. Humans interact with and impact the environment as we obtain food. Today, people still obtain food in ways that have sustained humanity for thousands of years.



(a) World population density map



(b) Night lights around the world

▲I.7 Population density and electric lights

Approximately 38% of Earth's population lives in China and India alone (◄**Fig. I.7**). The overall planetary population is young, with 26% still under the age of 25 years. However, people in more developed countries have a greater impact on the planet per person. The United States and Canada, with about 5% of the world's population, produce about 25% of the world's gross domestic product. These two countries use more than 2 times the energy per capita of Europeans, more than 7 times that of Latin Americans, 10 times that of Asians, and 20 times that of Africans. Therefore, the impact of this 5% on the Earth systems and natural resources is enormous.

Many key issues for this century fall beneath the umbrella of geographic science, such as global food supply, energy demands, climate change, biodiversity loss, and air and water pollution. Addressing these issues in new ways is necessary to achieve **sustainability** for both human and Earth systems (◄**Fig. I.8**). The term *sustainability* refers to the ability to continue a defined activity over the long term in a way that prevents or minimizes adverse impacts on the environment. Thus physical geography is concerned with environmental sustainability measures such as the rates of natural resource harvest, the creation and release of pollutants, and the consumption of nonrenewable resources such as coal and copper (which are only sustainable if comparable and renewable substances are developed in their place). In each of these three categories, activities are not sustainable unless people can prevent or mitigate their environmental impacts. Understanding Earth's physical geography and geographic science can help to inform your thinking on these issues.

▼I.8 Organic farming in Thailand Organic farming is a type of sustainable agriculture that maintains soil fertility.

geoCHECK ✔ What percent of the world population is under 25 years of age?

geoQUIZ

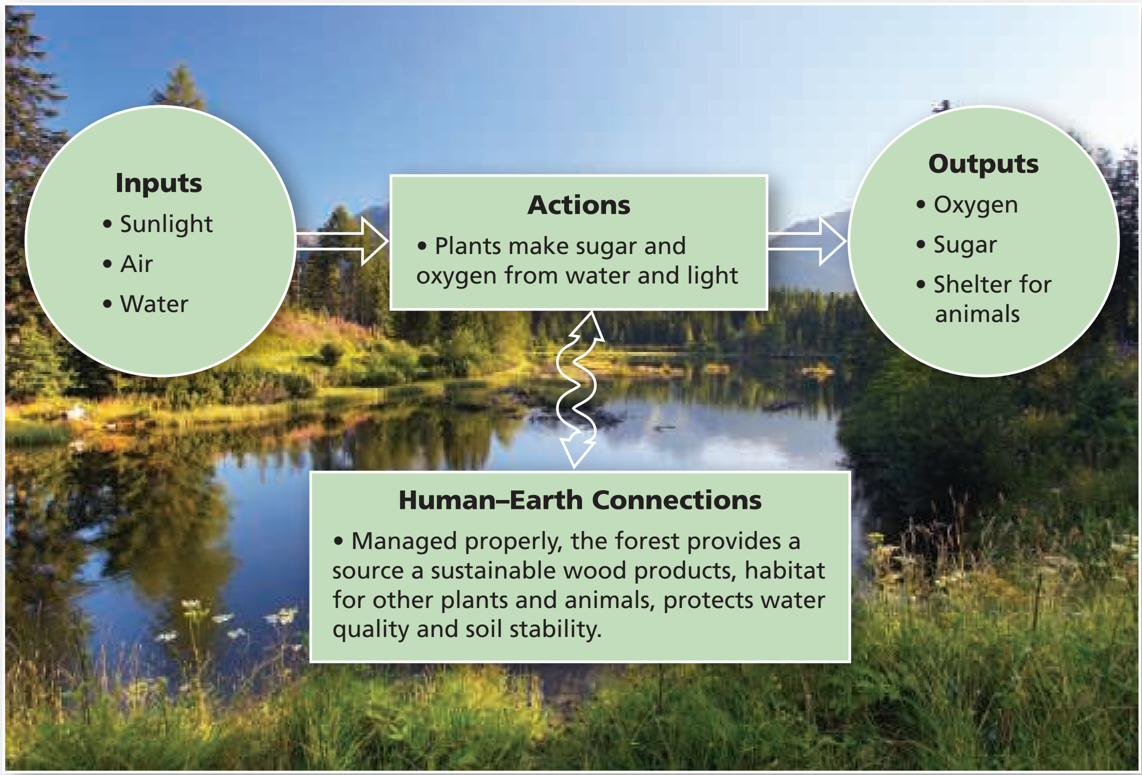
1. Explain the origin of the term *geography*.
2. Describe at least two perspectives that geography uses to study Earth.
3. Identify how much more—or less—energy you might use living in Latin America, Asia, or Africa.

I.3 Earth Systems

Key Learning Concepts

- ▶ ***Describe*** systems analysis, open and closed systems.
- ▶ ***Explain*** the difference between positive and negative feedback information.
- ▶ ***List*** Earth's four spheres and classify them as biotic or abiotic.

The word *system* is used in our lives daily: "Check the car's cooling system" or "A weather system is approaching." *Systems analysis* techniques in science began with studies of energy and temperature (thermodynamics) in the 19th century. Today, systems methodology is an important analytical tool.



▲I.9 **Example of a natural open system: a forest**

Systems Theory

A **system** is any set of ordered, interrelated components and their attributes, linked by flows of energy and matter, as distinct from the surrounding environment outside the system. The elements within a system may be arranged in a series or intermingled. A system comprises many interconnected subsystems. Within Earth's systems, both matter and energy are stored and retrieved, and energy is transformed from one type to another. *Matter* is mass that assumes a physical shape and occupies space. *Energy* is a capacity to change the motion and nature of matter.

Earth systems may be open or closed. **Open systems** are not self-contained in that inputs of energy and matter flow into the system and outputs of energy and matter flow from the system (▲**Fig. I.9**). Earth is an open system in terms of energy, because solar energy enters freely and heat energy returns back into space. Within the Earth system, many subsystems interconnect. Free-flowing rivers are open systems where inputs of solar energy, precipitation, and soil particles lead to outputs of water and sediments to the ocean. A forest is another example of an open system. The input of solar energy allows trees to absorb and then store sunlight as plant materials. Forests then output oxygen that plants and animals require to survive.

In contrast, a **closed system** is self-contained and shut off from the surrounding environment. Although rare in nature, Earth itself is a closed system in terms of physical matter and resources—air, water, and natural resources. The only exceptions are the slow escape of lightweight gases from the atmosphere into space and the input of tiny meteors and cosmic dust.

System Feedback As a system operates, it often generates outputs that influence its own operations. These outputs function as "information" that returns to various points in the system via pathways called **feedback loops**. Feedback information often forms a chain of cause and effect that can further influence system operations. If the feedback information discourages change in the system, it is **negative feedback**. Negative feedback loops are common in nature. For example, when a thriving forest sinks roots deep into the soil, the amount of erosion will decrease as the vegetation absorbs increasing amounts of water, leaving less water to transport soil particles downslope.

If feedback information encourages change in the system, it is **positive feedback**. Global climate change creates an example of positive feedback as summer sea ice melts in the Arctic. As arctic temperatures rise, summer sea ice and glacial melting accelerate. This causes light-colored snow and sea-ice surfaces, which reflect sunlight and so remain cooler, to be replaced by darker-colored open ocean surfaces, which absorb sunlight and become warmer. As a result, the ocean absorbs more solar energy, which raises the temperature, which in turn melts more ice, and so forth (▸**Fig. I.10**). This is a positive feedback loop, further enhancing the effects of higher temperatures and warming trends.

System Equilibrium Most systems maintain structure and character over time. A system that remains balanced over time, in which conditions are constant or recur, is in a *steady-state* **equilibrium**. For example, river channels commonly adjust their form in response to inputs of water and sediment (particles of rock or soil). These inputs may change in amount from year to year, but the channel form represents a stable average—a steady-state condition.

However, a steady-state system may demonstrate a changing trend over time, a condition described as **dynamic equilibrium**. The same river may become wider as it adjusts to greater inputs of sediment over some time scale, but the overall system will adjust to this new condition and thus maintain a dynamic equilibrium.

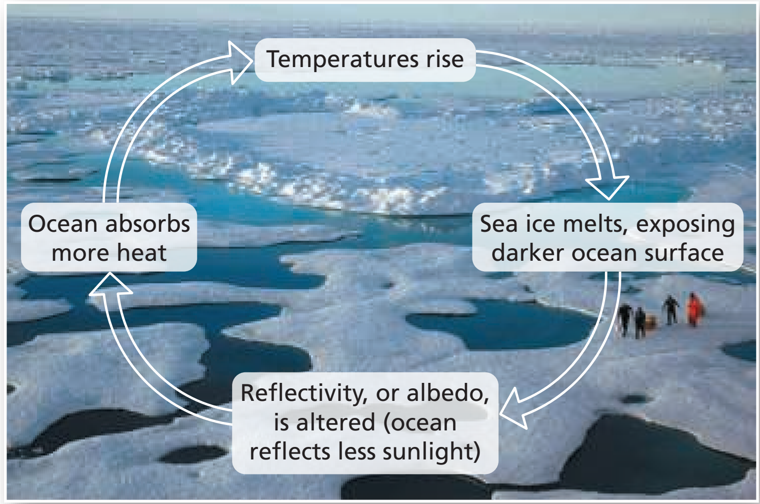
Systems in equilibrium tend to remain in equilibrium and resist abrupt change. However, a system may reach a **threshold**, or *tipping point*, where it can no longer maintain its character, so it lurches to a new operational level. A large flood in a river system may push the river channel to a threshold where it abruptly shifts, carving a new channel. Plant and animal communities also reach thresholds. For example, scientists identify climate change as one factor triggering a sudden decline in aspen trees in the southern Rocky Mountains.

geo**CHECK** Explain the difference between an open and closed system in nature.

Earth Spheres & Systems Organization in *Geosystems Core*

Earth's surface is a vast area where four immense open systems interact. The three **abiotic**, or nonliving, systems overlap as the framework for the realm of the **biotic**, or living, system. The abiotic spheres are the *atmosphere* (Chapters 1–3), *hydrosphere* (Chapters 4–7), and *lithosphere* (Chapters 8–12). The biosphere is the lone biotic sphere, where all living matter on Earth is found. The living matter of Earth and everything with which it interacts is the *biosphere* (Chapters 13–14). Together, these spheres form a simplified model of Earth systems (▸**Fig. I.11**).

From general layout to presentation of specific topics, *Geosystems Core* follows a systems flow. The book's structure is designed around Earth's four "spheres." Within each part, chapters and topics are arranged according to systems thinking, focusing on inputs, actions, and outputs, with an emphasis on human–Earth interactions and on interrelations among the other parts and chapters.



▲**I.10 The Arctic sea ice-albedo positive feedback loop**

▲**I.11 The four major Earth spheres** Of these, three are abiotic and one is biotic.

geo**CHECK** Describe the relationship between Earth spheres and the content organization in *Geosystems Core.*

geo**QUIZ**

1. Identify the role a "threshold" plays in an environmental system.
2. Describe an example of a "feedback" loop in nature.
3. Explain the difference between abiotic and biotic systems.

I.4 Earth Locations & Times

Key Learning Concepts

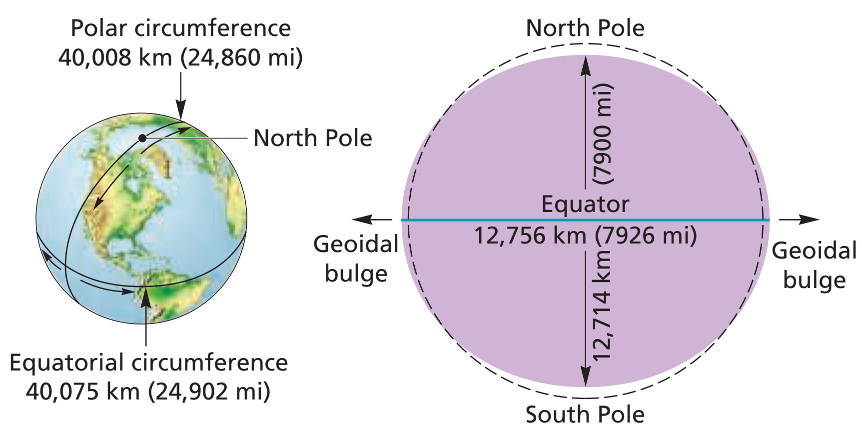
- ***Summarize*** progress in geographical knowledge about Earth's size and shape.
- ***Explain*** Earth's reference grid, including latitude and longitude and latitudinal geographic zones.
- ***Interpret*** a map of Earth's time zones.

As geographers study the physical features and processes on Earth's surface, they need to accurately locate these phenomena in space and time. You have probably noticed the network of lines that crisscrosses most globes and world maps. This "geographic grid" allows us to locate places and regions on Earth. The size and rotational velocity of Earth combine to make a 24-hour day, and Earth's annual revolution around the Sun determines the length of a year.

Earth's Dimensions & Shape

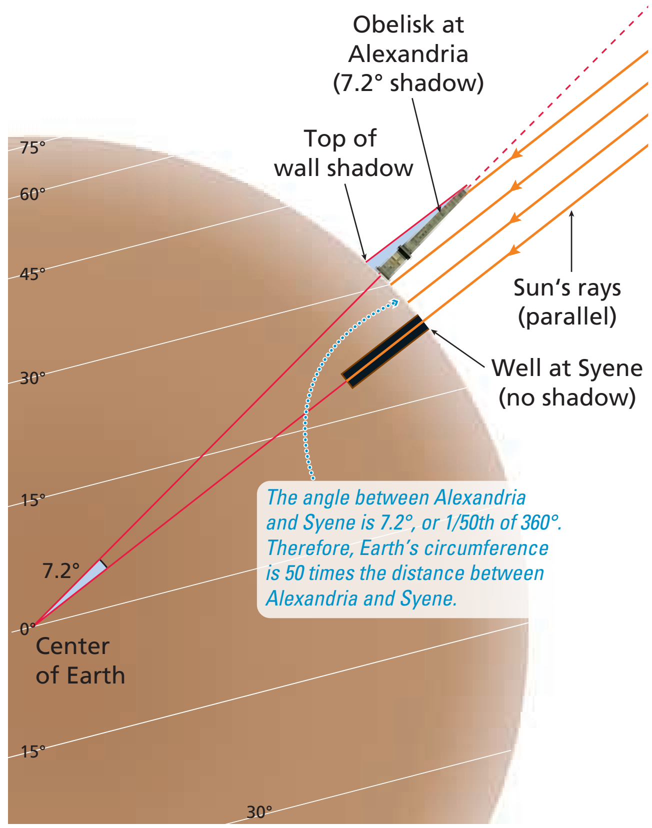
Humans have known that Earth is round since the first ship sailed over the horizon and viewers on shore saw the top sails disappear last. Our scientific understanding of Earth's size and shape began slowly, but has grown rapidly over the past 300 years. Over 2000 years ago, the Greek mathematician Pythagoras (ca. 580–500 BCE) determined that Earth is round, or *spherical.* Eratosthenes (ca. 276 BC –194 BCE) calculated the circumference of Earth in 247 BCE by comparing the angle of the Sun at noon at two different locations (▶**Fig. I.12**). By the first century CE, educated people generally accepted the idea of a spherical Earth. In 1687, Sir Isaac Newton reasoned that Earth's rapid rotation produced an equatorial bulge as centrifugal force pulled Earth's surface outward. As a result, Earth's equatorial circumference is 67 km (42 mi) greater than its polar circumference. Earth is indeed slightly misshapen into an *oblate spheroid* (oblate means "flattened"), with the flatness occurring at the poles.

Today, satellite observations have confirmed with tremendous precision Earth's equatorial bulge and polar "flatness." The irregular shape of Earth's surface, coinciding with mean sea level and perpendicular to the direction of gravity, is called the **geoid**. **Figure** I.13 shows Earth's polar and equatorial circumferences and diameters.



(a) Equatorial and polar circumferences **(b)** Equatorial and polar diameters

▲**I.13 Earth's dimensions** The dashed line is a perfect circle for comparison to Earth's geoid.

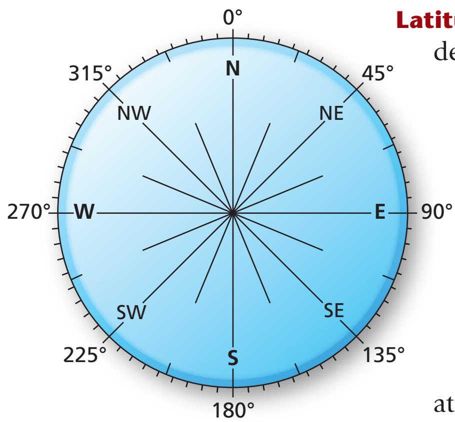


▲**I.12 Eratosthenes method for calculating Earth's circumference** Although Eratosthenes calculated the circumference of Earth over 2000 years ago, his answer, based on scientific and mathematical reasoning, was surprisingly accurate.

geoCHECK Why is Earth's equatorial circumference larger than its polar circumference?

Earth's Reference Grid

Fundamental to geography is an internationally accepted grid coordinate system to determine location. Geographers use pairs of numbers, or "coordinates," to locate specific points on the grid. Eratosthenes created the first world map with a rectangular grid to locate places around 200 BCE. The use of a geographic grid made it possible to accurately measure distances between locations. The terms **latitude** and **longitude** were used on maps in the first century CE to refer to distances measured in relation to standard lines on the grid. These distances are measured in degrees—units based on the division of a perfect circle into 360 equal parts (▶**Fig. I.14**).

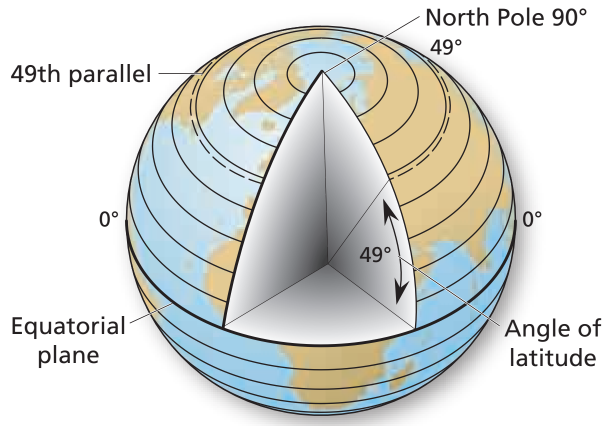


▲I.14 **360° in a circle, with the cardinal directions**

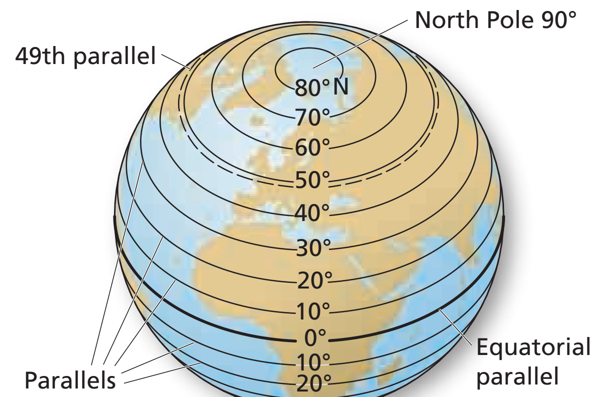
Latitude The angular distance in degrees north or south of the equator, measured from the center of Earth is latitude (▶ **Fig. I.15a**). (The equator is the line that divides the spherical Earth into northern and southern hemispheres). Lines of latitude run east-west, parallel to the equator (▶ **Fig. I.15b**). Latitude increases from the equator at 0° latitude, to the poles, at 90° north and south.

A line of latitude is called a **parallel**. In **Figure** I.15b, an angle of 49° is shown, and by connecting all points at 49° N, we can draw the 49th parallel. When writing the latitude of location, it is not necessary to include the word latitude, since the suffix of N or S indicates that you are giving the latitude, giving 40° N is sufficient. *Latitude* is the name of the angle (49° N), *parallel* names the line (49th parallel), and both indicate distance north of the equator.

Throughout this book, you will read references to latitudinal zones as a way of generalizing the location of different phenomena, from weather patterns to plant and animal communities. Lower latitudes are toward the equator, higher latitudes are toward the poles. The terms "the tropics" and "the Arctic" refer to environments created by different amounts of solar energy received at different latitudes. **Figure** I.**16** displays the names and locations of the *latitudinal geographic zones* used by geographers: *equatorial* and *tropical*, *subtropical*, *midlatitude*, *subarctic* or *subantarctic*, and *arctic* or *antarctic*. These latitudinal zones are useful for reference, but they do not have rigid boundaries. We discuss specific lines of latitude, such as the Tropic of Cancer and the Arctic Circle, in Chapter 1 as we learn about the seasons.

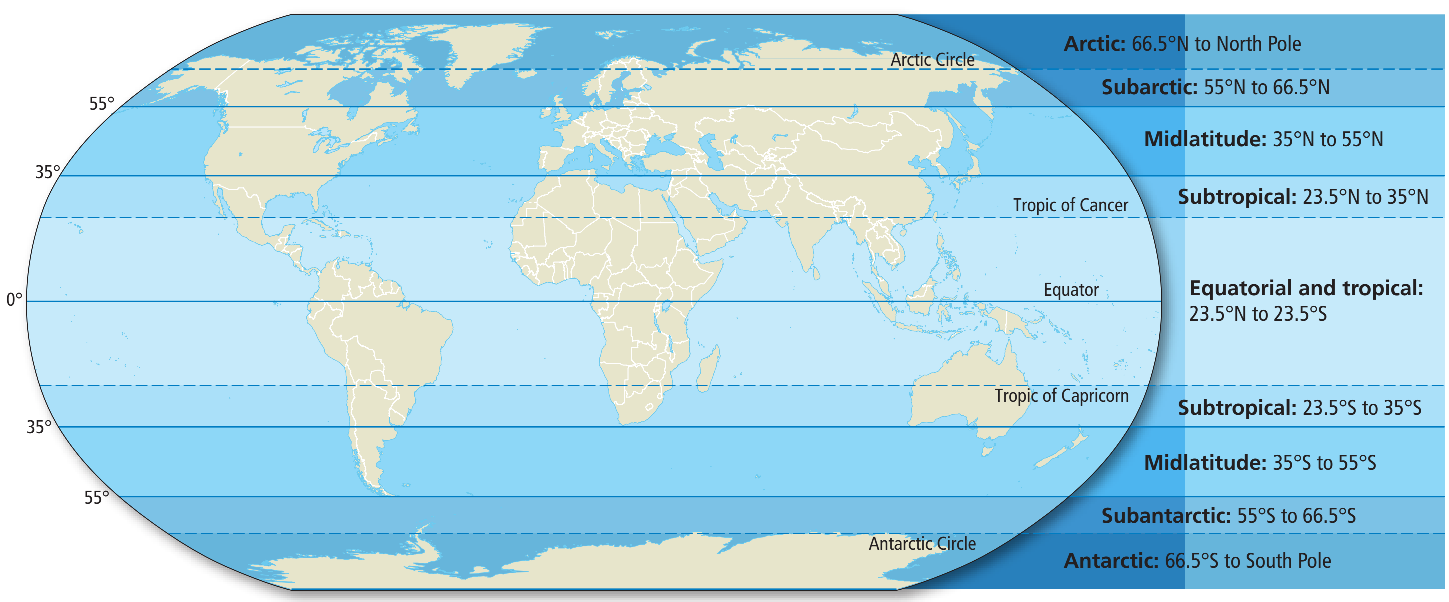


(a) Latitude is measured in degrees north or south of the Equator (0°). Earth's poles are at 90°. Note the measurement of 49° latitude.



(b) These angles of latitude determine parallels along Earth's surface.

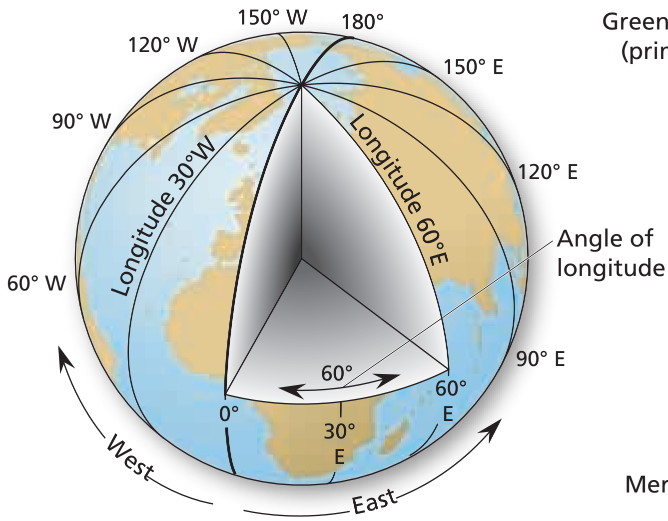
▲I.15 **Parallels of latitude** Do you know your present latitude?



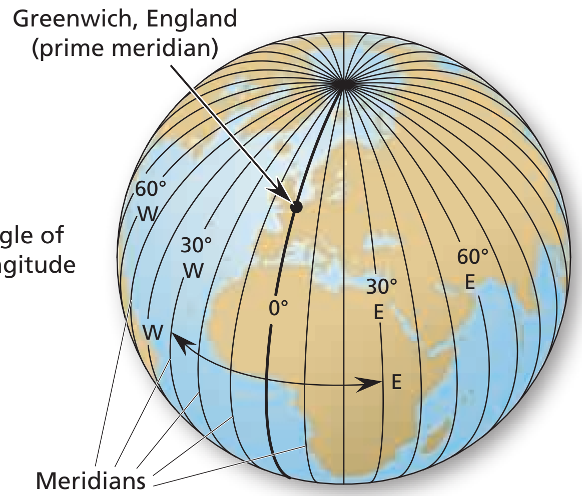
▲I.16 **Latitudinal geographic zones** Geographic zones are generalizations that characterize various regions by latitude.

I.4 (cont'd) Earth Locations & Times

Longitude The angular distance east or west of a point on Earth's surface, measured from the center of Earth is longitude (▶ **Fig. I.17a**). On a map or globe, the lines designating these angles of longitude run north and south (**Fig.** I.17a). A line connecting all points along the same longitude is a **meridian**. In the figure, a longitudinal angle of 60° is shown. These meridians run at right angles (90°) to all parallels. *Longitude* is the name of the angle, *meridian* names the line, and both indicate distance in degrees east or west of the **prime meridian**, designated as 0° (▶ **Fig. I.17b**). Earth's prime meridian—also called the *Greenwich meridian*—passes through the old Royal Observatory at Greenwich, England, as set by an 1884 treaty. Because meridians of longitude converge at the poles, the length on the ground of 1° of longitude is greatest at the equator and shrinks to zero at the poles. Longitude increases east and west from 0° at the prime meridian to 180°. Just as with latitude, it is not necessary to include the word *longitude* when writing a location's longitude. The suffix E or W indicates longitude.



(a) Longitude is measured in degrees east or west of a 0° starting line, the prime meridian. Note the measurement of 60° E longitude.



(b) Angles of longitude measured from the prime meridian determine other meridians. North America is west of Greenwich; therefore, it is in the Western Hemisphere.

▲I.17 **Meridians of longitude** Do you know your present longitude?

Figure I.18 combines latitude and parallels with longitude and meridians to illustrate Earth's complete coordinate grid system. Note the red dot that marks 49° N and 60° E, a location in western Kazakhstan. Next time you look at a world globe, follow the parallel and meridian that converge on your location.

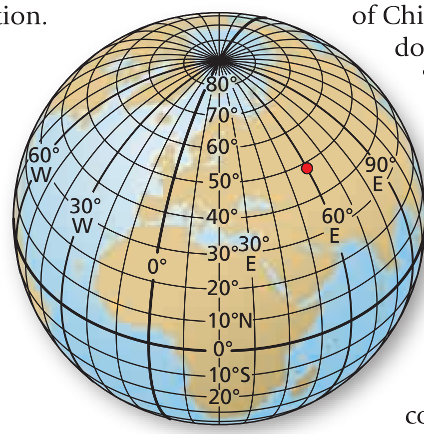
geoCHECK ✔ Which latitudinal zone do you live in? Why aren't lines of longitude parallel?

Meridians & Global Time

A worldwide time system is necessary to coordinate international trade, airline schedules, and daily life. Our time system is based on the fact that Earth rotates on its axis, rotating 360° every 24 hours, or 15° per hour (360° ÷ 24 = 15°).

In 1884 at the International Meridian Conference in Washington, DC, the prime meridian was set as the official standard for the world time zone system—Greenwich Mean Time (GMT). This standard time system established 24 equally spaced standard meridians around the globe, with a time zone of 1 hour spanning 7.5° on either side of these central meridians (▶ **Fig. I.19**). Before this universal system, time zones were not consistently defined, especially in large countries. In 1870, if you were traveling from Maine to San Francisco by railroad, you would have made 22 adjustments to keep on local time!

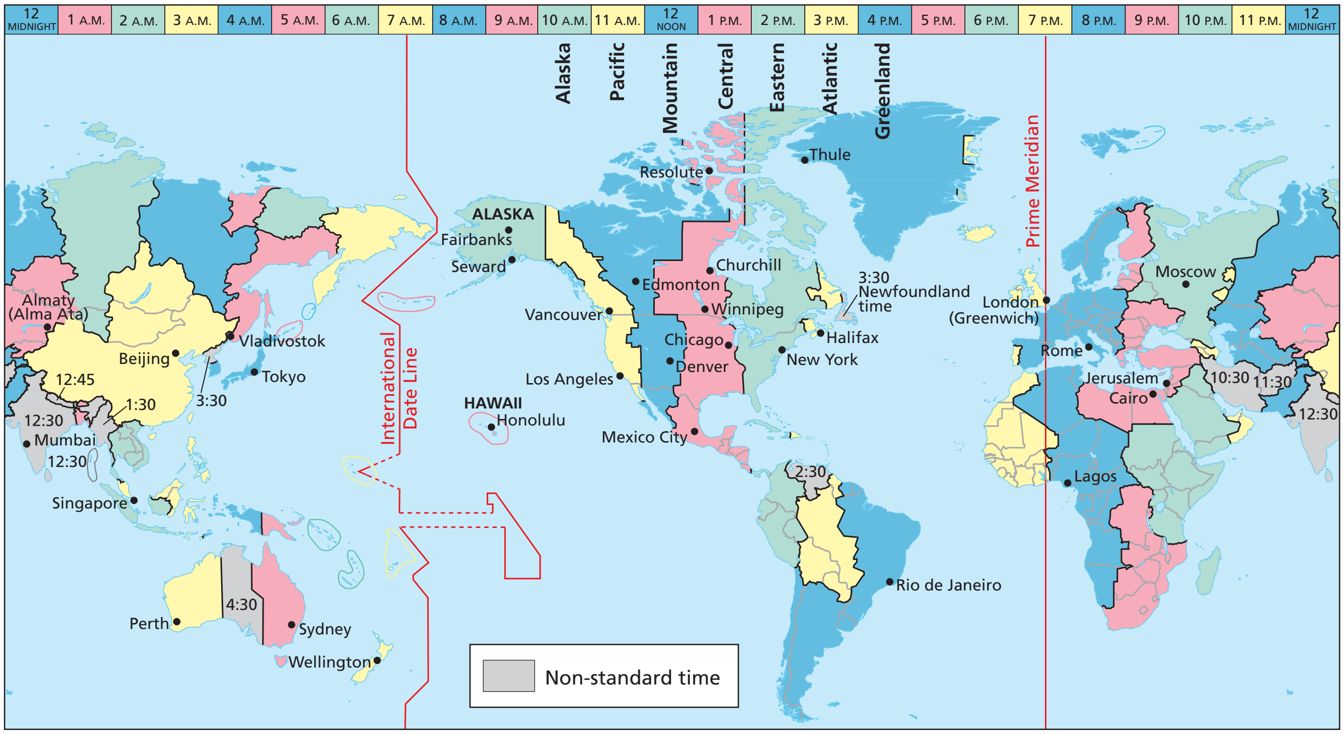
As you can see in **Figure** I.19, national or state boundaries and political considerations can distort time boundaries. For example, China spans four time zones, but its government decided to keep the entire country operating at the same time. Thus, in some parts of China clocks are several hours off from what the Sun is doing. In the United States, parts of Florida and west Texas are in the same time zone.



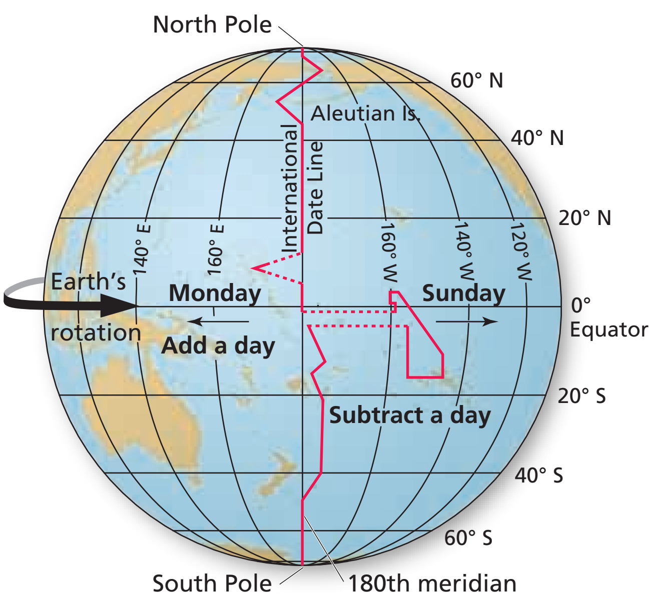
▲I.18 **Earth's coordinate grid system** Parallels of latitude and meridians of longitude allow us to locate all places on Earth precisely. The red dot is at 49° N and 60° E.

In 1972, **Coordinated Universal Time (UTC)** replaced GMT as the legal reference for official time in all countries. You might still see official UTC referred to as GMT or Zulu time.

International Date Line On the opposite side of the planet from the prime meridian is the **International Date Line** (▶ **Fig. I.20**), which marks the line where one day officially changes to another. The International Date Line does not completely coincide with the 180th meridian, but jogs east or west to avoid dividing countries. If you travel west across the International Date Line, you would immediately gain a day, and if you travel east you immediately lose a day. From this line, the new day moves westward as Earth



▲I.19 **Modern international standard time zones** If it is 7 p.m. in Greenwich, determine the present time in Moscow, London, Halifax, Chicago, Winnipeg, Denver, Los Angeles, Fairbanks, Honolulu, Tokyo, and Singapore.



▲I.20 **International Date Line** The International Date Line (IDL) location is approximately along the 180th meridian (see the IDL location on Figure I.19). The dotted lines on the map show where island countries have set their own time zones, but their political control extends only 3.5 nautical miles (4 mi) offshore. Officially, you gain 1 day crossing the IDL from east to west.

turns eastward on its axis. At the International Date Line, the west side of the line is always 1 day ahead of the east side of the line. No matter what the time of day when the line is crossed, the calendar changes a day.

Daylight Saving Time In 70 countries, mainly in the midlatitudes, time is set ahead 1 hour in the spring and set behind 1 hour in the fall—a practice known as daylight saving time. The idea to extend daylight for early evening activities at the expense of daylight in the morning, first proposed by Benjamin Franklin, was not adopted until World War I and again in World War II to save energy by reducing the use of electric light. In 1986 and again in 2007, the United States and Canada extended the number of weeks of daylight saving time. Currently, time "springs forward" 1 hour on the second Sunday in March and "falls back" 1 hour on the first Sunday in November, except in a few places that do not use daylight saving time (Hawaii, Arizona, and Saskatchewan).

geoCHECK How many degrees apart are time zones?

geoQUIZ

1. Compare the geoid with a hypothetical Earth-like planet of the same size that is a perfect sphere. How are they similar? How are they different?
2. Why is it important to have a standard prime meridian?
3. Determine your longitude using an online map or an atlas. How many degrees are you away from a time zone central meridian (75°, 90°, 105°, 120°, 135°)? Given that Earth rotates through 1° in 4 minutes, how many minutes apart are the Sun and your watch?

I.5 Maps & Cartography

Key Learning Concepts

- ***List*** the basic elements of a map.
- ***Explain*** the three different ways of expressing map scale.
- ***Summarize*** how and why map projections were developed and how they are used in cartography.
- ***Give examples*** of the different kinds of maps and how each is used.

For centuries, geographers have used maps as tools to display information and analyze spatial relationships. A **map** is a generalized view of an area, as seen from above and reduced in size. A map usually represents a specific characteristic of a place or area, such as rainfall, airline routes, physical features such as mountains and rivers, or political features such as state boundaries and place names. **Cartography** is the science and art of mapmaking, often blending geography, mathematics, computer science, and art.

We all use maps to visualize our location in relation to other places, to plan trips, or to understand a news story or current event. Understanding how to "read" or interpret different kinds of maps is essential to our study of physical geography.

Representative fraction: 1:500,000 or 1/500,000
Written scale: 1 inch = 8 miles; 1 cm = 5.0 km
Graphic scale: 0 4 8 MILES; 0 5 10 KILOMETERS

Legend:
- Point of interest
- Airport
- Interstate highway
- State highway
- Street

Representative fraction: 1:24,000 or 1/24,000
Written scale: 1 inch = 2000 feet; 1 cm = 0.25 km
Graphic scale: 0 1000 2000 FEET; 0 0.25 0.5 KILOMETERS

(a) Relatively small scale map of Los Angeles area shows less detail.

(b) Relatively large scale map of the same area shows a higher level of detail.

I.21 Map scale Examples of maps at different scales, with three common expressions of map scale—representative fraction, written scale, and graphic scale. Both maps are enlarged, so only the graphic scale is accurate.

Basic Map Elements

Most maps share the same elements:

- **title**—gives the subject of the map and may also include information about who made the map, the source of map data, and the date when the map was produced
- **north arrow**—tells the reader which direction is north on the map
- **symbols**—represent features on the map using lines, patterns, areas of color, icons, and other graphic elements
- **legend**—tells the map reader what each symbol means
- **map scale**—states the mathematical relationship between the size of the map and the size of the portion of Earth the map represents (discussed below)
- **map projection**—enables showing the round Earth as a flat map (discussed below)

geoCHECK What are the basic map elements?

The Scale of Maps

Architects, toy designers, and mapmakers all represent real things and places with models that are smaller than the thing they represent. Examples include the floorplan of a building; a diagram of a toy car, train, or plane; or a map. Each of these models has a particular *scale*, or relationship between the size of the model and the size of the actual thing it depicts. For example, an architect draws a blueprint for builders so that 0.25 inch on the drawing represents 1 foot on the building.

Cartographers do the same thing in making maps. The ratio of the size of a map to that area in the real world is the map's **scale**. Scale can be represented as a ratio (also called representative fraction), a graphic scale, or a written scale (◂**Fig. I.21**). For example, a useful scale for a local map is 1:24,000, a ratio in which 1 unit on the map represents 24,000 units on the ground. Geographers refer to as *small-*, *medium-*, or *large-scale* maps, depending upon the map's scale. A map with a scale of 1:24,000 is a large-scale map, while a scale of 1:50,000,000 is a small-scale map. The larger the number on the right, the smaller the scale. Small-scale maps have less detail for a larger area, while large-scale maps show more detail for a smaller area (**Fig.** I.**21**). Scale is represented as a representative fraction, a graphic scale, or a written scale (**Fig.** I.**21**).

Ratio Scale & Representative Fraction A ratio scale, or *representative fraction*, can be expressed with either a colon (for a ratio) or a slash (for a fraction), as in 1:24,000 or 1/24,000. No actual units of measurement are mentioned because both parts of the fraction are in the same unit: 1 cm to 24,000 cm or 1 in. to 24,000 in.

Graphic Scale A *graphic scale*, or *bar scale*, is a graphic with units to allow measurement of distances on the map. An advantage of a graphic scale is that if the map is enlarged or reduced, the scale is enlarged or reduced by the same amount, unlike written and fractional scales that become incorrect when map size changes.

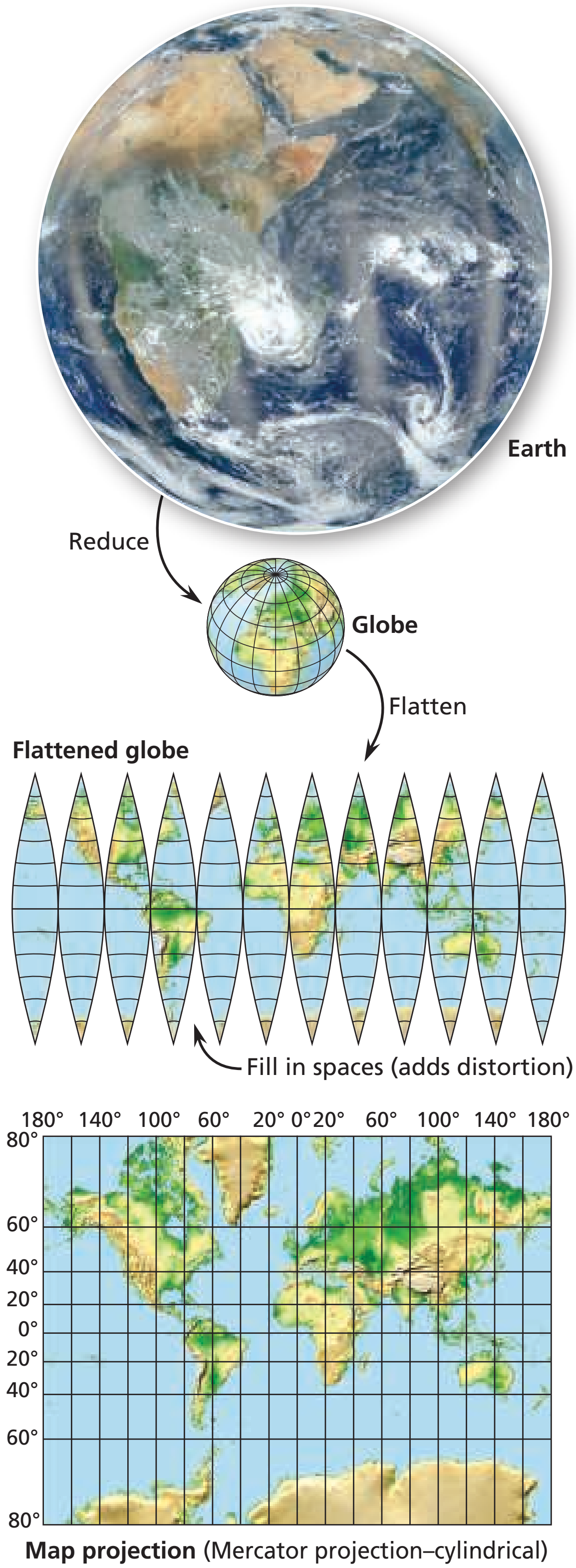
Written Scale A *written scale* usually has differing, but common, units such as 1 inch equals 1 mile. For example, the ratio scale 1:24,000 conveniently converts to "1 inch equals 2000 feet" when expressed as a written scale (by dividing 24,000 by 12 in./ft).

geo**CHECK**✔ Which map has more detail, a large-scale or small-scale map?

Map Projections

A globe is a small-scale, three-dimensional representation of Earth. Globes can provide an accurate representation of *area* and *shape* on Earth. However, if you wanted to go hiking or explore a new city, you need more information than a globe can provide. To provide more detail, cartographers make large-scale maps, which are two-dimensional representations of Earth. However, converting a three-dimensional sphere to a two-dimensional map causes some degree of distortion of areas and shapes. To control distortion on a flat map, cartographers use a **map projection**. By manipulating the grid coordinate system that is common to both globes and flat maps, a map projection enables cartographers to transfer data about points and lines on a globe accurately to a flat surface. Centuries ago, cartographers actually projected the shadow of a wire frame globe onto a geometric surface, such as a cylinder, plane, or cone. The wires represented parallels, meridians, and the outlines of continents. Modern cartography uses mathematical formulas to generate the many different kinds of map projections. Some are better at showing shape accurately, while others are better for showing area accurately. Cartographers must decide which characteristic to preserve, which to distort, and how much distortion is acceptable.

If you imagine taking a globe apart and trying to lay it flat on a table, that illustrates some of the problems with map projections (▸**Fig. I.22**). Although large-scale maps have less distortion than small-scale maps, all maps, regardless of the projection used, have some degree of distortion.



▴**I.22 From globe to flat map** Conversion of the globe to a flat map projection requires a decision about which properties to preserve and the amount of distortion that is acceptable.

I.5 (cont'd) Maps & Cartography

Equal Area or True Shape? One major decision a cartographer must make when beginning a map involves choosing between projections with the properties of *equal area* and *true shape*. Cartographers designed different kinds of **equal-area** projections so that areas are correct on the map regardless of their latitude and longitude (▼**Fig. I.23a**). For example, areas measuring 10° of latitude by 10° of longitude are equal whether they are near the equator or near the poles—although the two areas differ greatly in shape. In contrast, a **true-shape** projection (also called a *conformal* projection) can correctly represent the shapes of geographic features such as coastlines and islands, but the sizes of those features can be greatly distorted (**Fig.** I.22b). The commonly used **Mercator projection** seen in **Figure** I.22a is a true-shape projection. Gerardus Mercator developed the projection in 1569 to simplify navigation. Unfortunately, as we saw in **Figure** I.23b, Mercator maps present a false view of the size of midlatitude and high-latitude regions.

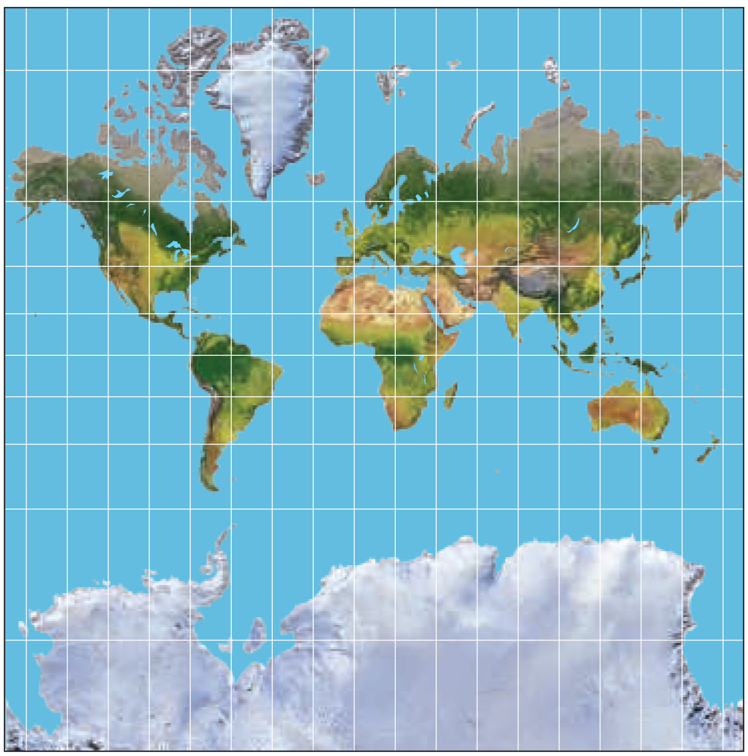
If a cartographer selects an equal-area projection for a map—for example, to show the distribution of world climates—then the map will sacrifice true shape, especially where areas are stretched along the edges of the map. If a cartographer selects a true-shape projection, such as for a map used for navigation, then the map will sacrifice the property of equal area, and different regions of the map will actually have different scales.

Geosystems Core uses equal-area and compromise map projections. *Goode's homolosine projection* is an interrupted equal-area projection and is excellent for mapping features when breaks in the map over oceans or continents is not a problem. Goode's homolosine projection is used in Geosystems Core for the world climate map in Chapter 6 (Fig. 6.), the world soil orders map (Fig. 14.8), and the terrestrial biomes map in Chapters 14 (Fig. 14.24).

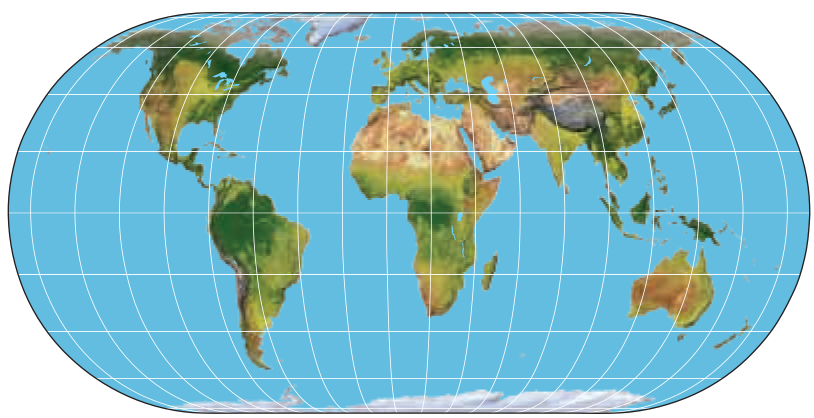
The text also uses the *Robinson projection*, designed by Arthur Robinson in 1963. This is a compromise projection that is neither equal area nor true shape, but a compromise between the two. Examples of the Robinson projection in *Geosystems Core* include the latitudinal geographic zones map (**Fig.** I.**16**), the distribution of insolation map and the temperature ranges map in Chapter 2 (Figs. 2.5 and 2.31), the maps of lithospheric plates and volcanoes and earthquakes in Chapter 8 (Figs. 8.15 and 8.21).

The *Miller cylindrical projection* is another compromise projection used in this text. This projection was first developed by Osborn Miller and presented by The American Geographical Society in 1942. This projection is neither true shape nor true area, but is a compromise that avoids the severe scale distortion of the Mercator. Examples of the Miller cylindrical projection in *Geosystems Core* include the world time zone map in **Figure** I.**19**, global temperature maps in Chapter 2 (Figs. 2.29 and 2.30), and the two global pressure maps in Chapter 3 (Figs. 3.9 and 3.10).

geoCHECK ✔ Which projection described above would be best for comparing the amounts of rain forest in Latin America, Africa, and Southeast Asia? Explain.



(a) Mercator projection



(b) Equal-area projection (Eckert IV)

Animation Map Projections
http://goo.gl/3wii0g

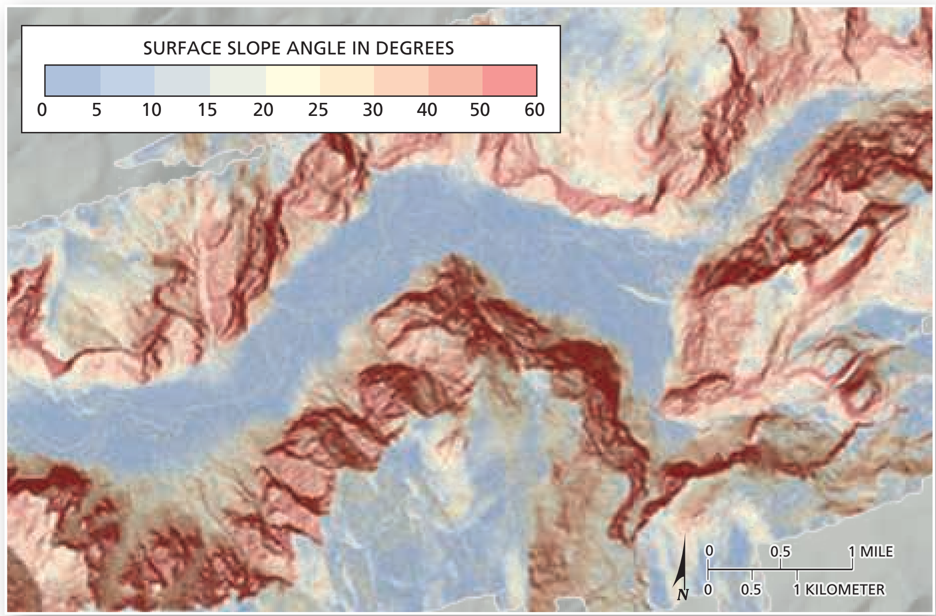
▲I.23 **True-shape projections vs. equal-area**

Types of Maps

There are many kinds of maps for a vast number of purposes. Maps portray everything from Earth's physical features to political boundaries to the demographic and economic data that are important to human geographers. Physical geographers often create physical maps that show information about a physical theme such as elevation or temperature. Physical maps often use *isolines*, which are lines that represent a given value: Contour lines show elevation, isotherms show temperature, isobars show air pressure. **Topographic maps** are physical maps that can give us a sense of the terrain, or the lay of the land (▶**Fig. I.24**). They use different colors to represent different features, blue for water, black for human-made objects, green for vegetation, brown for contour lines. A contour line connects all points at the same elevation. Contour lines show the slope of the land as well as elevation: widely spaced contour lines indicate gentle slopes, and closely spaced contour lines indicate steep slopes. You can also use contour lines to calculate **relief**, which is the difference in elevation between two locations. Figure i.24 uses shaded relief, an artistic technique of simulated shadows that conveys a sense of what the landscape looks like. Figure i.25 shows slopes derived from digital elevation models. Other important types of physical maps are geologic maps, which show rock formations and faults (▼**Fig. I.26**); weather maps, which show present or future forecasts of weather; and climate maps, which show long term averages of different weather elements such as temperature or rainfall.

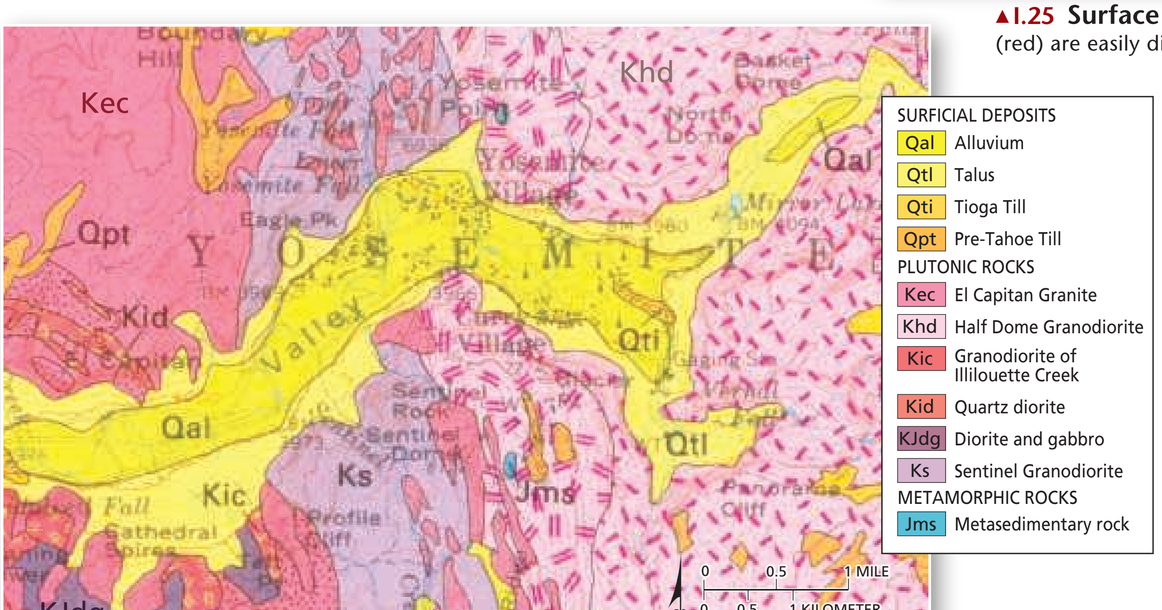
geo**CHECK** ✔ What are the two main types of maps?

▲**I.24 Topographic map of Yosemite Valley with shaded relief**



▲**I.25 Surface slope map for Yosemite Valley** Very steep valley walls (red) are easily distinguished from the nearly flat valley floor (blue).

▼**I.26 Geologic map of Yosemite Valley and surrounding areas**



geo**QUIZ**

1. For viewing maps on a smartphone, which type of map scale would be most helpful? Explain.
2. What are the advantages of a globe over a map? Of a map over a globe?
3. Describe the two main types of distortion in map projections.
4. As a cartographer, you are asked to produce a highly accurate topographic map of the county where you live. Would you choose a large-scale or small-scale for the map? An equal area or true shape projection? Explain your answer.

I.6 Modern Geoscience Tools

Key Learning Concepts

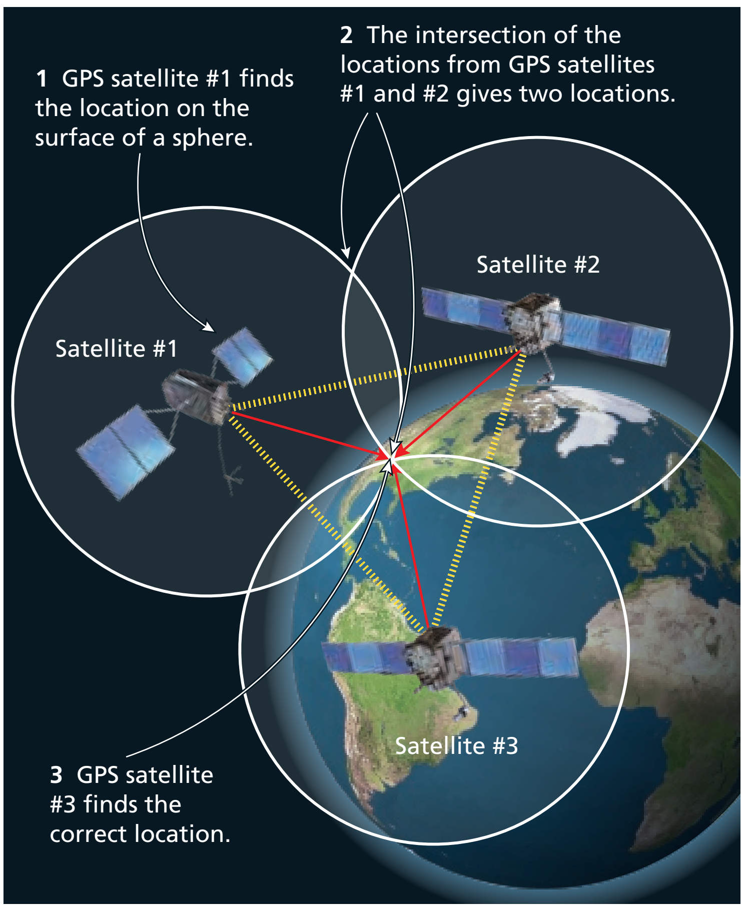
▶ ***Explain*** how geographers use the Global Positioning System, remote sensing, geographic information systems, and geovisualizations.

Geographers use a number of new and evolving technologies to analyze and map Earth—the Global Positioning System (GPS), remote sensing, and geographic information systems (GIS). GPS uses satellites to provide precise locations. Remote sensing uses satellites, aircraft, and other sensors to provide visual data that enhances our understanding of Earth. GIS is a means for storing and analyzing large amounts of spatial data as separate layers of geographic information.

Global Positioning System

Using radio signals from a global network of satellites, the **Global Positioning System (GPS)** accurately determines location anywhere on or near the surface of Earth. A GPS receiver receives radio signals from the satellites and calculates the distance between the receiver and each satellite. By using signals from at least four satellites, precise locations are possible (▼**Fig. I.27**). GPS units also report the time, accurate to 100 billionths of a second, which is used to synchronize communications systems, electrical power grids, and financial networks.

▼I.27 Using satellites to determine location through GPS



GPS receivers are built into many smartphones and motor vehicles. The GPS is useful for many commercial and scientific applications. GPS receivers have been attached to sharks and whales to track them in real time to study their migration patterns. Airlines and shipping companies use GPS to track their vehicles, improving fuel efficiency and on-time performance.

geoCHECK ✔ Why are at least three satellites needed to find a location using GPS?

Remote Sensing

Technological systems of **remote sensing** obtain information about objects without physically touching them. We do remote sensing with our eyes as we scan the environment, sensing the shape, size, and color of objects from a distance. Taking a picture with your phone is another example of remote sensing. Geographers use images captured by satellites and airborne sensors. During the last 50 years, satellite imagery has transformed Earth observation. Today, you have free access to high-quality remote-sensing imagery, through services such as Google Maps, that in the past would have been unavailable, extremely expensive, or restricted to government intelligence services. Remote sensing can be divided into passive and active remote-sensing systems.

Passive Remote Sensing Systems of passive remote-sensing record energy radiated from a surface, especially visible light and heat (▼**Fig. I.28**). Our eyes are passive remote sensors. Weather satellites are passive remote sensing systems with which you are probably familiar. Beginning in the 1970s, the Landsat series of satellites began recording images of Earth with sensors that captured visible light, as well as other wavelengths useful in studying agriculture, forestry, geology, regional planning, mapping, and global change research. Scientists can observe different phenomena with sensors that detect different wavelengths of energy. This allows them to compare healthy vegetation and distressed vegetation or a find outcroppings of a particular rock formation.

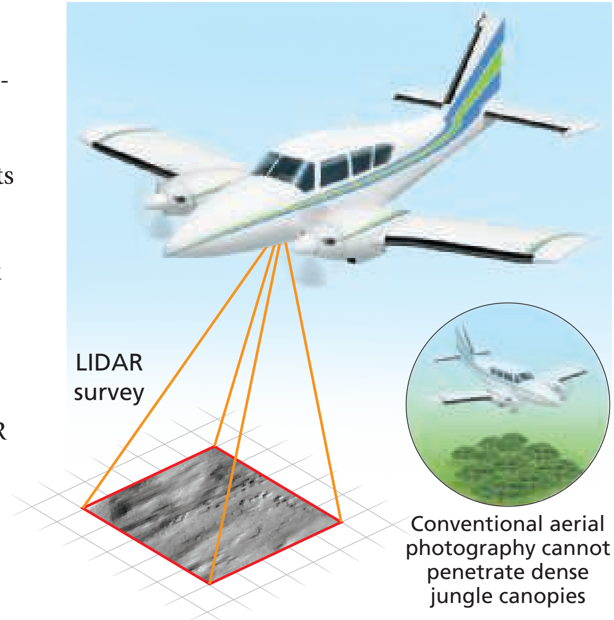
▼I.28 Passive remote sensing Image from October 15, 2015, showing muddy stream runoff from heavy rains in South Carolina interacting with ocean currents.

Today, sites such as Google Maps and Bing Maps show us detailed imagery, often in simulated three-dimensions, of any location in the world. Urthecast (www.urthecast.com) is now broadcasting near real-time views of Earth from cameras on the International Space Station.

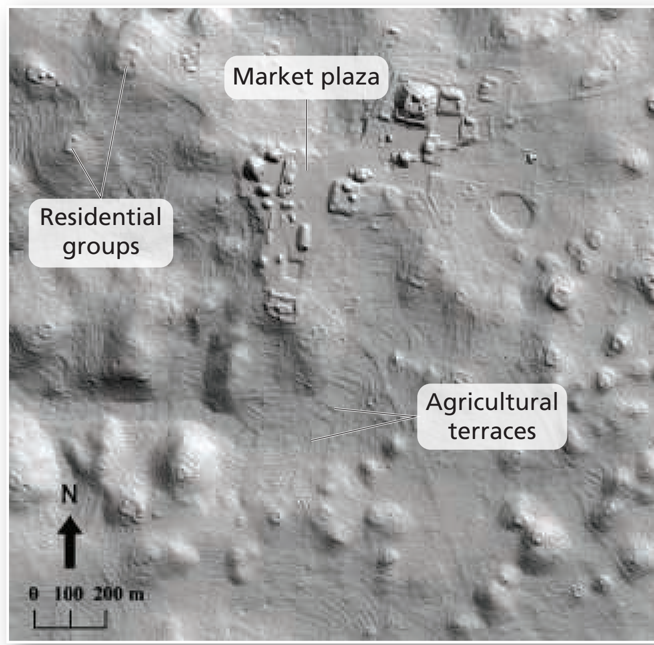
Active Remote Sensing A system that directs energy at a surface and analyzes the energy returned from the surface is referred to as active remote sensing. Taking pictures with a flash in a darkened room is an example of active remote sensing. Another example is sonar, which has been used to map the ocean floor. A sonar unit emits bursts of sound and measures their return. Another technology is **LIDAR** (*li*ght and ra*dar*), which uses pulses of visible light. LIDAR units can be mounted in aircraft and on cars. LIDAR can differentiate between the first pulses returned, usually off the highest vegetation, and later returns, which are usually from the actual ground surface. This capability allows scientists to measure tree canopy heights or to virtually strip away vegetation to create a three-dimensional model of the surface (▶**Fig. I.29**). Archaeologists have used LIDAR to discover several "lost" ancient cities in Central America. Detailed three-dimensional, LIDAR models of modern cities already exist, and LIDAR models of roads will be critical in the development of self-driving cars (▼**Fig. I.30**).

geoCHECK ✔ Compare and contrast the two types of remote sensing.

▼**I.29 Active remote sensing** LIDAR is used to produce canopy or bare ground maps.

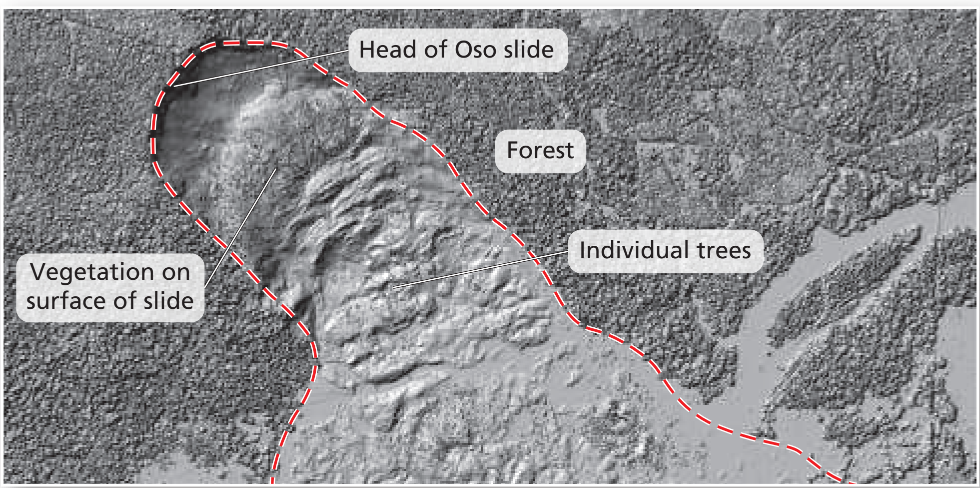


(a) LIDAR uses pulses of light to form a 3D image of elevated and ground level objects.

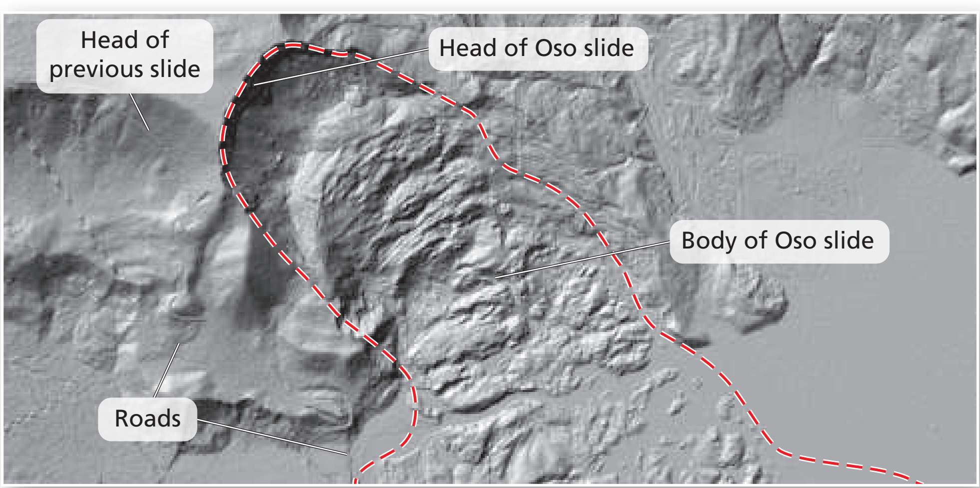


(b) LIDAR mapping of the lost city of Caracol hidden below the rain forest canopy in Central America.

▼**I.30 Comparison of first-return and bare ground images of the Oso landslide, WA**



(a) First return shows top of vegetation

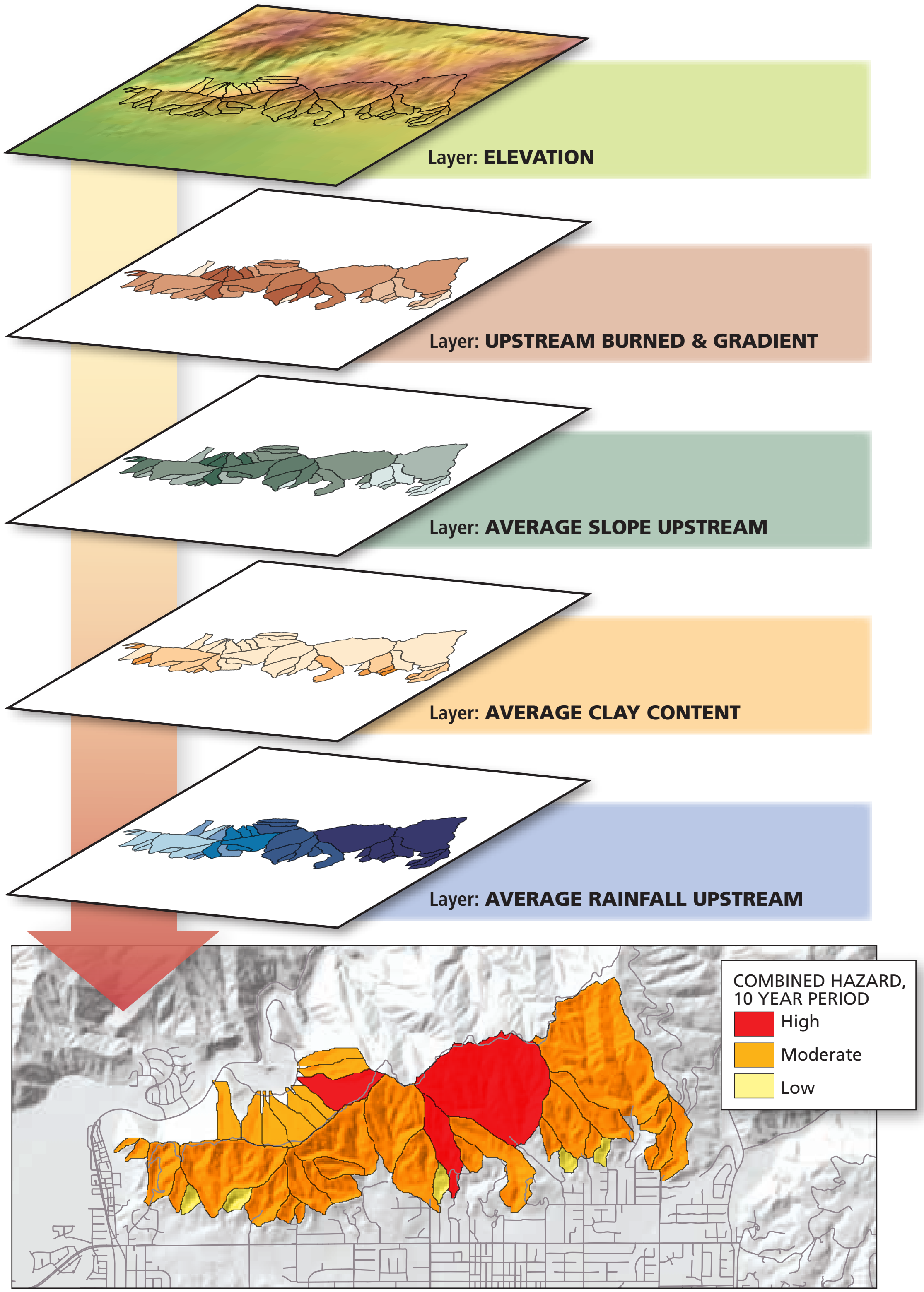


(b) Bare ground return shows ground under vegetation

I.6 (cont'd) Modern Geoscience Tools

Geographic Information Systems & Geovisualization

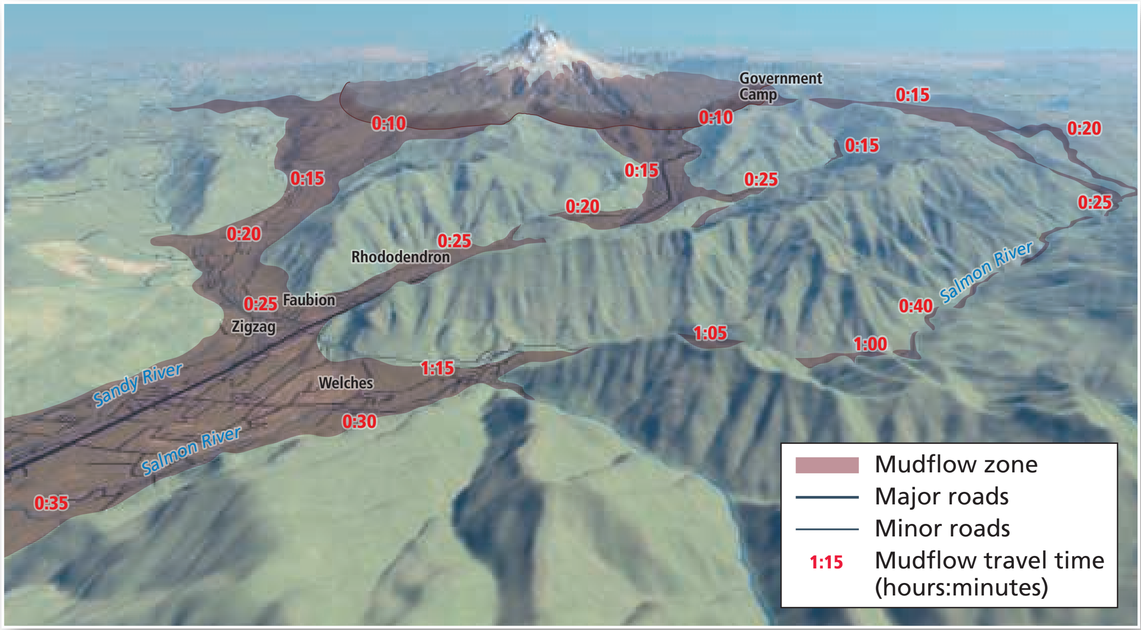
Techniques such as remote sensing generate large volumes of spatial data to be stored, processed, and analyzed in useful ways. A powerful tool for manipulating and analyzing this spatial data is a **geographic information system (GIS)**. A GIS is a computer-based data-processing tool that combines spatial data (where is it? what is its latitude/longitude? is it a point? a line? a polygon?) with attribute data (what is it?). In a GIS, spatial data can be organized in layers containing different kinds of data (▸**Fig. I.31**). When you ask your phone to find the nearest coffee shop, you are using a GIS, probably without realizing it. A GIS program and a database work together to ask spatial analysis questions such as Where are you? Where are the coffee shops? Which shops are closest to you? How do you get to the nearest coffee shop? GIS systems perform these queries across multiple data layers. In the coffee shop example, three layers are required: one with your location, one with the locations of the coffee shops, and one with the layout of the streets. **Figures** I.32 and I.33 show examples of GIS analysis used to predict natural hazards and map epidemics.



▸**I.31 Geographic information system (GIS)** Wildfires can change the response of hillsides to rainfall so that even modest rainstorms can result in dangerous flash floods and debris flows. The USGS uses a hazard assessment model that incorporates the shape of hillsides, the amount of land that is heavily burned, the steepness of hill slopes, the clay content of the soil, and the projected amount of rainfall on specific slopes to assess the probability and volume of debris flows in burned areas.

Geovisualization *Geovisualization* refers to the display of geographic information, often remote-sensing data combined with other data. Google Maps and Google Earth are two examples of geovisualization programs with which you might be familiar. Geovisualization programs often have limited GIS abilities, such as the ability to search for locations and add data layers. Many geovisualization programs allow users to upload their own data sets to combine with other user-generated data and the built-in data from the program.

geo**CHECK** Describe the two types of information that a GIS combines.

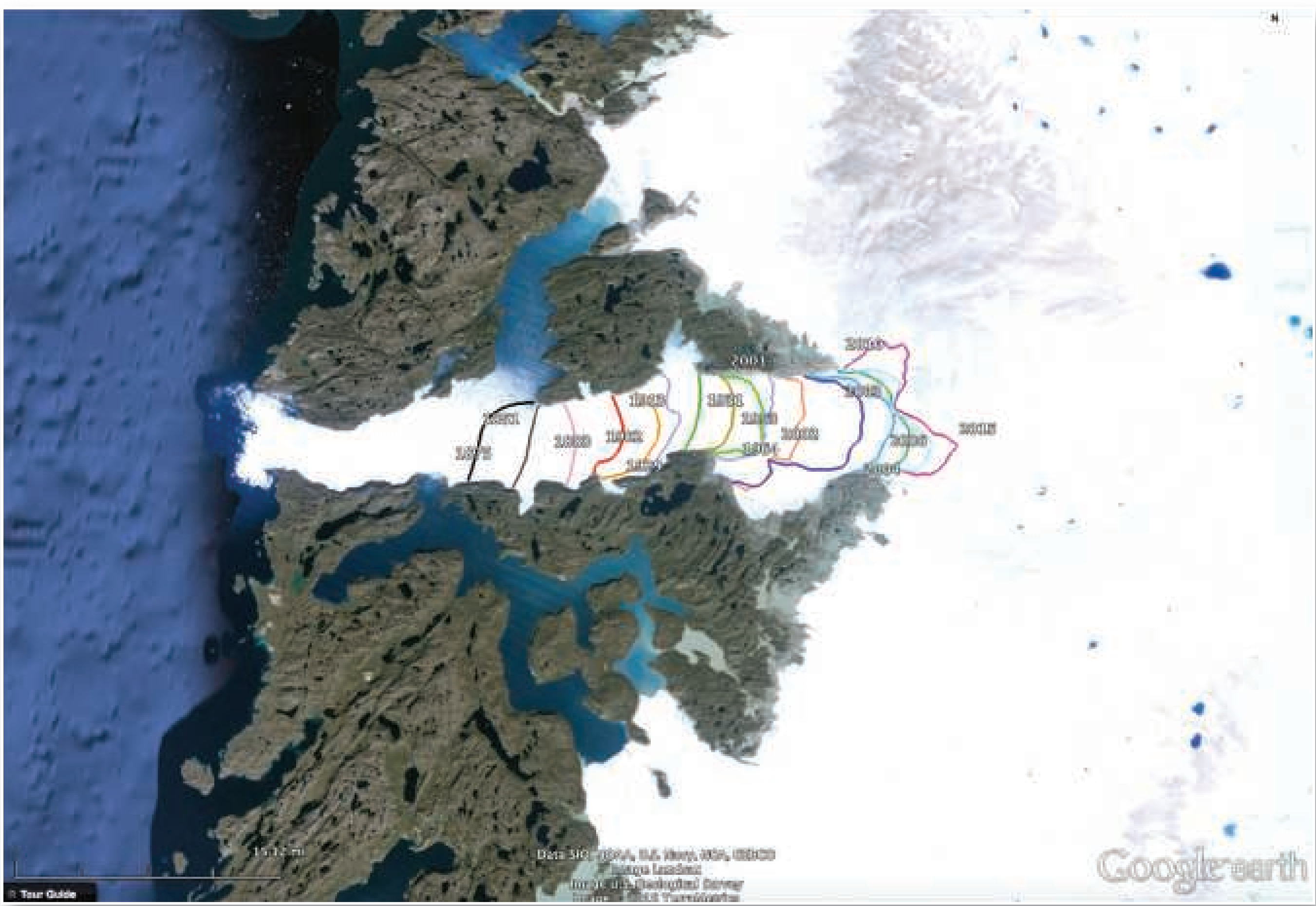


▲I.32 **Lahar hazard zones and arrival times for Mt. Hood**

geo**QUIZ**

1. Explain at least two ways you have benefited from the GPS.
2. What types of remote-sensing data have you seen today? in the past week?
3. Describe the criteria for a GIS used to find a parcel of land to build a new subdivision using the following data layers: property parcels, zoning layer, floodplain layer, protected wetlands layer.

▼I.33 **Google Earth used to track the retreat of the Jacobshavn glacier, Greenland**

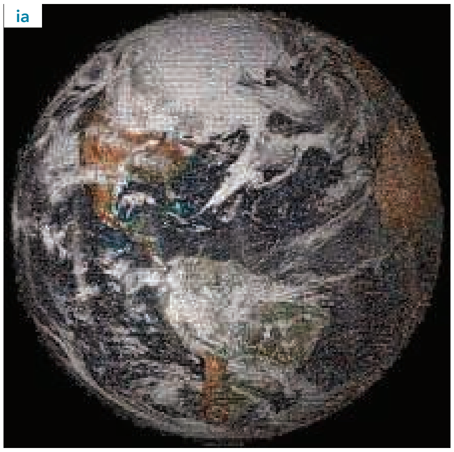


THEhumanDENOMINATOR Maps & Global Change

MAPS IMPACT HUMAN UNDERSTANDING

- Maps are much older than photographs.
- While maps appear in media and books everywhere, few appreciate the dynamic and vital applications they now offer.

ia



On Earth Day 2014, NASA broadcast a question on social media: "Where are you on Earth Right Now?" People from 113 different countries, representing every continent, submitted over 50,000 georeferenced images. This participatory mapping created our first global selfie.

HUMANS USE MAPS TO CHANGE THE WORLD

- Today as in the past, maps delineate empires, guide explorers, and inspire travelers to go beyond the next horizon.

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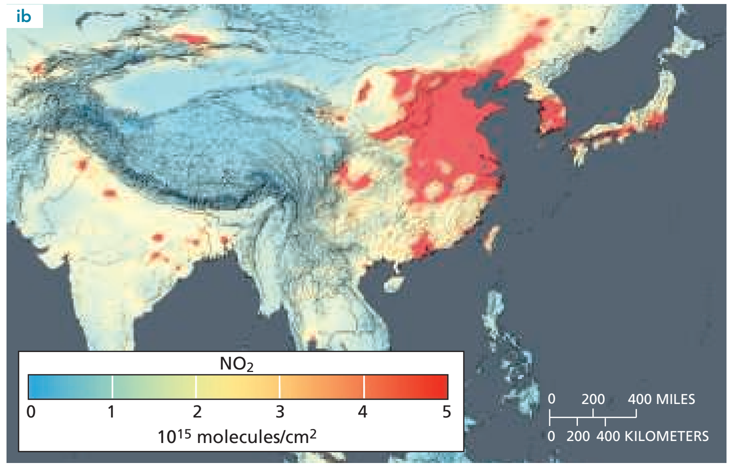

Maps like this one showing air pollution produced by industrial regions in East Asia help scientists monitor changes in air quality worldwide. This is part of a world map NASA compiled based on satellite-based data on nitrogen dioxide gas, a pollutant that can form ground-level ozone, a component of smog.

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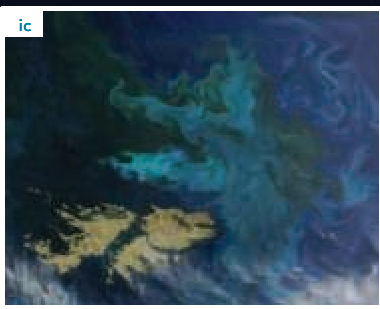
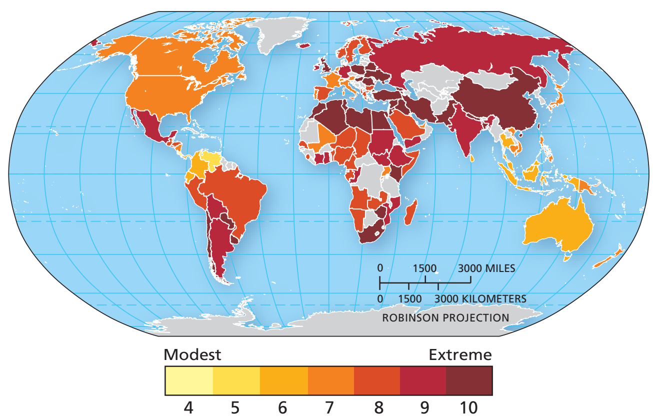


Scientists around the world use remotely sensed images to measure and analyze changing vegetation cover, water resources, wildlife migration, advancing urban development, and scores of other purposes. In this example, remotely sensed images from on NASA's Terra satellite portray the waters near the Falkland Islands off the coast of southern Argentina awash in greens and blues from concentrated phytoplankton. These microscopic, plant-like organisms grow on the ocean surface, and are the foundation of a thriving ocean food chain.

ISSUES FOR THE 21ST CENTURY

- Mapping of natural and human phenomena such as earthquakes, flooding, food insecurity, and terrorist movements, will play an important role in how governments respond to the challenges each event presents.
- Rapidly evolving technological advances in geovizualization, GPS, GIS, and cartography will make geospatial science an essential tool for monitoring and analyzing human-environmental change in the 21st century.

id New maps portray the current and projected impacts of climate change on plants, water resources, human settlement and economic activity.



VULNERABILITY TO CLIMATE CHANGE, 2100
(CLIMATE SENSITIVITY EQUAL TO 5.5°C)

Looking Ahead

We now embark on a journey through Earth's four spheres from the atmosphere in *Part I, Energy and Earth Systems,* to the atmosphere and hydrosphere in part *Part II, Water, Weather & Climate Systems. Part III,* The *Geosphere: Earth's Interior and Surface,* explores the processes that shape Earth's varied topography. *Part IV, The Biosphere,* analyzes the structure and function of the ecosystems and soils that sustain Earth's ecosystems, soils, and biomes.

Chapter 1 begins with the Sun, including seasonal changes in the distribution of its energy flow to Earth.

Each *Core* chapter ends with a Looking Ahead to act as a bridge from one chapter to the next.

Chapter Review

What is physical geography?

I.1 The World Around Us

Give examples **of the kinds of events, processes, and questions that physical geography investigates.**

- Geography combines disciplines from the physical and life sciences with disciplines from the human and cultural sciences to attain a holistic view of Earth. Physical geography explains the spatial dimension of Earth's dynamic systems—its energy, air, water, weather, climate, tectonics, landforms, rocks, soils, plants, ecosystems, and biomes. It also asks *where* and *why* questions about processes and events that occur at specific locations and then follow their effects across the globe. The analysis of process—a set of actions or mechanisms that operate in some special order—is also central to geographic understanding. The science of physical geography is uniquely qualified to synthesize the spatial, environmental, and human aspects of our increasingly complex relationship with our home planet—Earth.

1. On the basis of information in this chapter, define physical geography and review the approach that characterizes the geographic sciences.

I.2 The Science of Geography

Describe **the main perspectives of geography and distinguish physical geography from human geography.**

Discuss **the use of scientific methods in geography.**

Summarize **how human activities and population growth impact the environment.**

- This spatial viewpoint examines the nature and character of Earth and the distribution of phenomena within it. Physical geography applies spatial analysis to all the physical components and process systems that make up the environment: energy, air, water, weather, climate, landforms, soils, animals, plants, microorganisms, and Earth itself. Understanding the complex relations between Earth's physical systems and human society is important to human survival. Hypotheses and theories about the Universe, Earth, and life are developed through the scientific process, which relies on a general series of steps that make up the scientific method. Results and conclusions from scientific experiments can lead to basic theories as well as applied uses for the general public. Awareness of the human denominator, the role of humans on Earth, has led to physical geography's increasing emphasis on human–environment interactions. The concept of sustainability—the ability to continue activities indefinitely while minimizing their environmental impacts—and functioning Earth systems, is important to physical geography.

2. Sketch a flow diagram of the scientific process and method, beginning with observations and ending the development of a theory.

3. Which of the following economic activities—gold mining, salmon fishing, burning fossil fuels, and wheat farming—is sustainable? Explain your answer.

I.3 Earth Systems

Describe **systems analysis, open and closed systems.**

Explain **the difference between positive and negative feedback information.**

List **Earth's four spheres and classify them as biotic or abiotic.**

- A system is any ordered set of interacting components and their attributes, as distinct from their surrounding environment. Earth is an open system in terms of energy, receiving energy from the Sun, but it is essentially a closed system in terms of matter and physical resources. As a system operates, information is returned to various points in the operational process via pathways of feedback loops. If the feedback discourages change in the system, it is negative feedback that opposes system changes. If feedback information encourages change in the system, it is positive feedback that encourages system changes. When the rates of inputs and outputs in the system are equal and the amounts of energy and matter in storage within the system are constant (or when they fluctuate around a stable average), the system is in dynamic equilibrium. A threshold, or tipping point, is the moment at which a system can no longer maintain its character and lurches to a new operational level. Four immense open systems powerfully interact at Earth's surface. Three of these are abiotic (nonliving)—the atmosphere, hydrosphere, and lithosphere. The fourth is the biotic (living) biosphere.

4. Identify the main difference between an open system and a closed system.

5. Identify a major difference between the four large systems, or spheres, that comprise Earth. Would life on Earth be possible if one of these four spheres did not exist? Explain your answer.

How are locations on Earth located, mapped, & divided into time zones?

I.4 Determining Earth Locations & Times

Explain **Earth's reference grid: latitude and longitude and latitudinal geographic zones and time.**

- Earth's equatorial circumference is 40,075 km (24,902 mi), while its polar circumference is 40,008 km (24,860 mi). Latitude is the angular distance north or south of the equator. Lines of latitude are called parallels and run east-west. Longitude is the angular distance east or west of the prime meridian. Lines of longitude are called meridians, and they converge at the poles. The prime meridian is the basis for our system of global time. There are 24 time zones, each 15° wide, but they are distorted by political boundaries. On the opposite side of the planet from the prime meridian is the International Date

Line, which marks the place where each day officially begins. No matter what the time of day when the line is crossed, the calendar changes a day. Seventy countries use daylight saving time, setting clocks 1 hour ahead in the spring and 1 hour behind in the fall.

6. Draw a simple sketch describing Earth's shape and size.
7. Define latitude and parallel and define longitude and meridian using a simple sketch with labels.
8. What and where is the prime meridian? How was the location originally selected? Describe the meridian that is opposite the prime meridian on Earth's surface.

I.5 Maps & Cartography

Define **cartography and mapping basics: map scale and map projections.**

- A map is a generalized view of an area, as seen from above and reduced in size. Cartography is the science and art of mapmaking, often blending geography, mathematics, computer science, and art. The ratio of the size of a map to that area in the real world is the map's scale. Scale is represented as a representative fraction, a graphic scale, or a written scale. Graphic scales are used when the map may be enlarged or reduced in size. The basic map elements are a title, the scale, a guide to the map symbols, and a north arrow. Maps can be divided into physical and political maps. Topographic maps are physical maps that can give us a sense of the terrain. Relief is the difference in elevation between two locations. The conversion of a representation of the spherical Earth to a flat map is a map projection. All projections create distortion in size or shape or both.

9. What is map scale? What are three ways it can be shown on a map?
10. Describe the differences between the characteristics of a globe and those of a flat map.

What tools do geographers use?

I.6 Modern Geoscience Tools

Describe **modern geographic tools—the Global Positioning System (GPS), remote sensing, and geographic information systems (GIS).**

Explain **how these tools are used in geographic analysis.**

- Geographers use a number of new and evolving technologies to analyze and map Earth—the Global Positioning System (GPS), remote sensing, and geographic information systems. GPS uses radio signals from satellites to accurately determine location anywhere on or near the surface of Earth. Remote sensing refers to obtaining information about objects without physically touching them. Passive remote-sensing systems record energy radiated from a surface, especially visible light and infrared energy. Active remote sensing directs energy at a surface and analyzes the energy returned from the surface. LIDAR (*li*ght and ra*dar*), is an active remote-sensing technology that uses pulses of visible light, rather than radio waves to create a three-dimensional model. A GIS is a computer-based data-processing tool that combines spatial data with attribute data. A GIS program and a database work together to ask spatial analysis questions, often across several layers of data.

11. What is a GPS and how does it assist you in finding location and elevation on Earth?
12. What is remote sensing? What are you viewing when you observe a weather satellite image on TV or in the newspaper? Explain.
13. If you were planning the development of a large tract of land, how would a GIS help you? How might planning and zoning be affected if a portion of the tract in the GIS was a floodplain or prime agricultural land?

Key Terms

abiotic, p. I-11
biotic, p. I-11
cartography, p. I-16
closed system, p. I-10
Coordinated Universal Time (UTC) , p. I-14
equilibrium, p. I-11
dynamic equilibrium, p. I-11
equal area, p. I-18
feedback loop, p. I-10
geographic information system (GIS), p. I-22
geography, p. I-6
geoid, p. I-12
Global Positioning System (GPS), p. I-20
human denominator, p. I-8
International Date Line, p. I-14
latitude, p. I-12
LIDAR, p. I-21
longitude, p. I-12
map, p. I-16
map projection, p. I-17
Mercator projection, p. I-18
meridian, p. I-14
negative feedback, p. I-10
open system, p. I-10
parallel, p. I-13
physical geography, p. I-6
positive feedback, p. I-10
prime meridian, p. I-14
process, p. I-6
relief, p. I-19
remote sensing, p. I-20
scale, p. I-17
scientific method, p. I-6
scientific theory, p. I-7
spatial, p. I-6
spatial analysis, p. I-6
sustainability, p. I-9
system, p. I-4
threshold, p. I-11
topographic maps, p. I-19
true shape, p. I-18

Critical Thinking

1. Identify the various latitudinal geography zones that roughly subdivide Earth's surface. In which zones are a) Los Angeles, b) Moscow, and c) Quito?
2. In general terms, using the scientific method as a guide, how might a physical geographer analyze water pollution in the Great Lakes?
3. What and where is the prime meridian? How was the location originally selected? Describe the meridian that is opposite the prime meridian on Earth's surface.
4. Summarize how world population growth and environmental sustainability are related.
5. Is cartography an art or a science? Explain your answer.

Visual Analysis

▲RI.1

Figure RI.1 looks across a valley toward the Karakoram Range in Pakistan. The Indus River flows across the center portion of the image.

1. Identify evidence of each of Earth's four *spheres* in the image, and classify each of your examples as biotic or abiotic.

2. Does this picture portray and "open" or "closed" Earth system? Explain your answer.

3. Identify and describe any examples of human influences on this landscape.

Explore | Use **Google Earth** to explore the **geographic grid**.

▲RI.2

Viewing Earth from space is to see the world anew! Open Google Earth, and uncheck (or turn off) all *Borders and Labels*. On the upper right, there are three tools to navigate around Earth. Place your cursor on each tool to learn how they enable one to *Look Around*, *Move Around*, and *Zoom*. Once you are comfortable with zooming about Earth, take the following journey.

Identify and zoom in on each of the continents: Africa, Europe, Asia, North America, South America, Australia, and Antarctica. Which continent is larger: Africa or South America? Next, select the *View* menu and scroll down to and check *Grid*. The geographic grid of latitude and longitude lines will appear. Then trace the following imaginary lines around Earth: Equator, Prime Meridian, Tropic of Cancer, and the Tropic of Capricorn. Then zoom in to North America, and slowly trace a route from San Francisco to New York. Finally, enter your present location in the *Search* window, click "search," and then answer the following questions.

1. What are the latitude and longitude of your location? (It's O.K. to give the answer in whole degrees).

2. Notice the geographic data displayed across the bottom of the Google Earth screen and how the data change as you move the cursor. What is the elevation of the ground surface? What is your "eye altitude"? What is the scale of your current view of the area?

3. Describe the physical features visible in your view. What effects of human activity can you see in the landscape?

Interactive Mapping | Login to the **MasteringGeography** Study Area to access **MapMaster**.

Comparing the Spatial Distribution of World Population

- Open: MapMaster in MasteringGeography
- Select: *World*. Next, turn on the *Population* categories, and select *Population Growth Rates.*

1. Which regions of Earth currently have the highest natural rate of population increase, and which areas have the lowest rate of increase?

- Next, select *Literacy Rate* from the *Population* category.

2. Identify the relationship between literacy and population growth rates Europe and Africa.

MasteringGeography™

Looking for additional review and test prep materials? Visit the Study Area in MasteringGeography™ to enhance your geographic literacy, spatial reasoning skills, and understanding of this chapter's content by accessing a variety of resources, including MapMaster™ interactive maps, videos, *Mobile Field Trips*, *Project Condor* Quadcopter videos, *In the News* RSS feeds, flashcards, web links, self-study quizzes, and an eText version of *Geosystems Core*.

Mapping for Sustainability: How Eco-Friendly is Your Campus?

GeoLab Intro MG
Pre-Lab Video
https://goo.gl/zH6kly

Human-environment relationships are one of the key themes of geography. One aspect of this relationship is sustainability, the idea that our impact on Earth's key systems should be minimized. College campuses across the country are taking action to become more sustainable (Figs. GLI.2 and GLI.3). Table GLI.1 lists aspects of sustainability that are relevant to your college campus. In general, buildings are more sustainable if they use less energy and water and if they produce less pollution and solid waste than buildings not designed or modified for sustainability (Fig. GLI.2).

The process of becoming more sustainable often begins with an inventory of existing conditions. In this exercise you will evaluate how sustainable your campus is by mapping sustainable features of your student center.

Apply

You are the newly elected president of the Environment Club. You ran on a platform of increasing campus sustainability and your first step is to evaluate your campus's student center in terms of sustainability. You will map the student center building and all of its sustainability features, or lack thereof, and create a plan to enhance the center's sustainability.

Objectives

- Analyze your campus's student center in terms of sustainability.
- Evaluate changes that could be made to the student center to improve its sustainability.
- Create a map, using basic map elements, to portray your campus's student center and its sustainability features.

Procedure, Part I

1. Using Table GLI.1 as a checklist, make in inventory of your student center's sustainable features, and also note the sustainability features it lacks.
2. What other sustainability features could you add to Table GLI.1? Add them to the checklist and note whether your student center has (or lacks) them.
3. What Earth systems do these sustainability efforts and features impact the most? Explain your answer.

Procedure, Part II

4. Before you can map your student center, there are some mapping decisions to be made. First, what will the scale of your map be? How large is your student center? How much of the area around the student center will you show on your map? Map scale is the ratio of the size of objects on your map to objects on the ground. The size of your map will be dictated by the size of your paper. Your campus may have a detailed downloadable map with building footprints.
5. You'll also have to decide how to use symbols to represent the sustainability features you're mapping (Fig. GLI.1). Make a list of the features and their symbols that you can use for your map's legend.
6. Draw your map of your student center and the sustainability features you've selected.
7. What features did you map? Were there new features that you weren't aware of until you started mapping?
8. What scale is your map? Write the scale as both a representative fraction (such as 1:600) and as a written scale (such as one inch equals fifty feet).

Analyze & Conclude

9. Some campuses have offices of sustainability. If you were going to make a GIS map to give to the office of sustainability, how would you organize the data? Would you group the features by geometry, with one layer for the polygons, another layer for the lines, and a third layer for the point features, or would you group them into thematic layers? Discuss your choice.
10. Were there sustainability features did you expect to find in the student center, but didn't? Were there features that you were surprised to find?
11. Overall, how sustainable is your student center? What were the most sustainable aspects? The least sustainable? Make a list of changes needed to make the center more sustainable.
12. You want to submit your map as part of a sustainability plan for your campus that will appear in the student newspaper. Write a short summary of the plan's recommendations to improve the sustainability of your campus. Work with other students in your class to assemble a plan combining everyone's recommendations and send the class plan to your campus administrator, dean, or student paper.

Table GLI.1 Sustainability Inventory

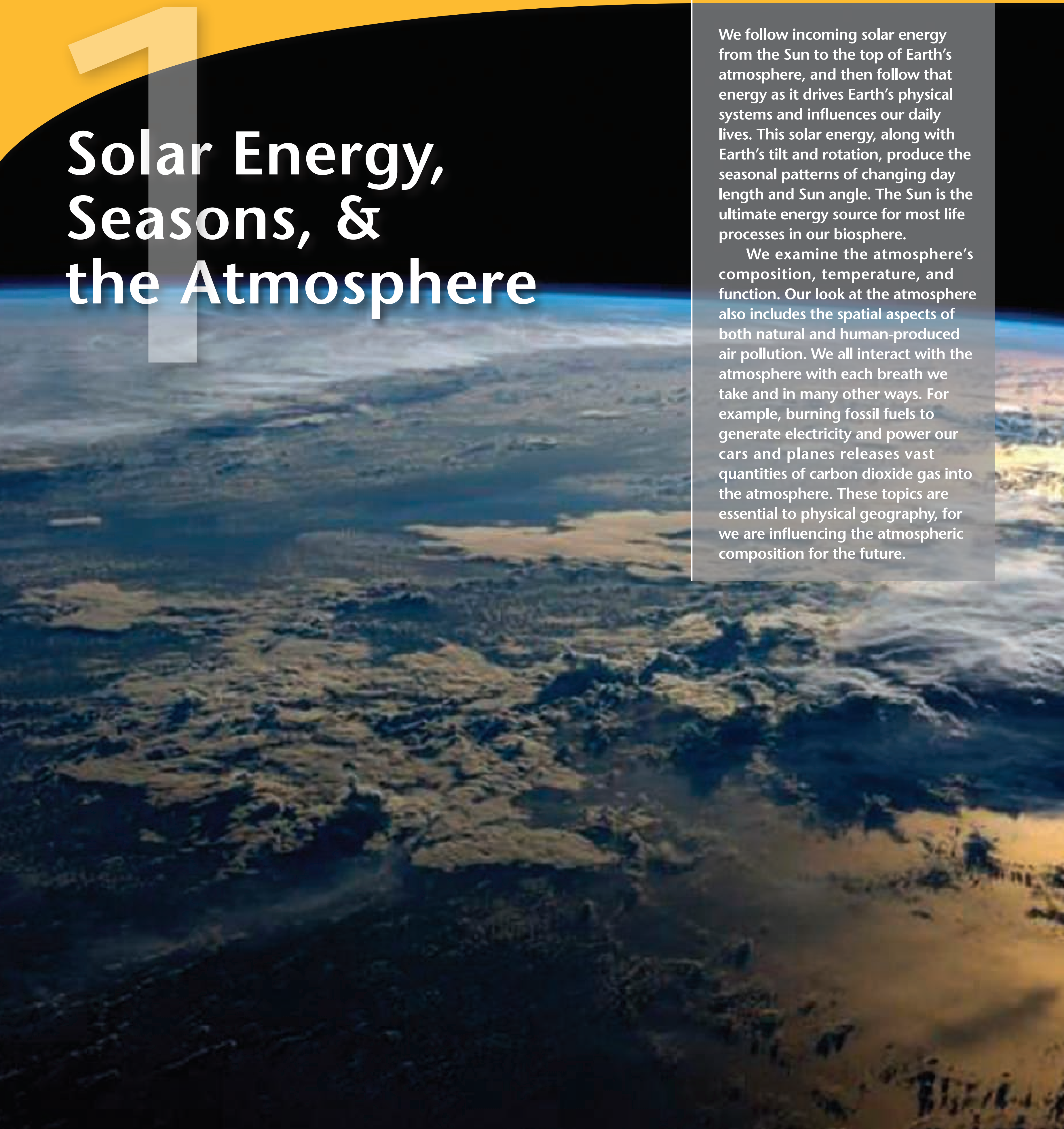
Energy • Solar photovoltaic panels? • Other renewables? wind turbines? solar hot water?
Buildings & Facilities • Is the building Leadership in Energy and Environmental Design (LEED) certified? • Sustainable materials such as hemp or sustainably harvest forest products? • Waterless urinals? • Innovative architecture such as straw bale, or windows and overhangs that block summer sun but let in winter sun? • How energy efficient is the building's heating and cooling system?
Food (I f the center serves food) • Organic food? • Is the food sourced from local farms?
Transportation • Public transportation: Where are the closest bus stops, light rail stops, or other public transportation facilities? • Where are the bike racks? How many bicycles can they hold? • Where is the Electronic Vehicle (EV) parking? • Is there special parking for carpools? • Other transportation features such as horse or ski parking?
Waste Reduction • Where are the recycling containers? • Are there compost containers in dining facility? • Is there composting by food services? • Are the paper towels recycled paper? • Are the paper napkins recycled paper?
Water • Where are the water bottle stations? • Does the landscaping outside use drought resistant, native vegetation? • If your campus is in an arid region, is the landscaping water saving?

▲GLI.1 **Symbols of sustainability** (Clockwise from top left): transportation (bicycle and electric vehicle); recycling; public transportation; and energy-efficient lighting.

▲GLI.2 **Energy efficiency** Solar panels on the roof Yale's School of Forestry and Environmental Studies at Kroon Hall make this building a model of sustainable practices.

▲GLI.3 **Sustainable transportation** Over 50 percent of students at the University of California, Davis travel to campus using a bike or skateboard.

Geosystems Core 1e



1 Solar Energy, Seasons, & the Atmosphere

We follow incoming solar energy from the Sun to the top of Earth's atmosphere, and then follow that energy as it drives Earth's physical systems and influences our daily lives. This solar energy, along with Earth's tilt and rotation, produce the seasonal patterns of changing day length and Sun angle. The Sun is the ultimate energy source for most life processes in our biosphere.

We examine the atmosphere's composition, temperature, and function. Our look at the atmosphere also includes the spatial aspects of both natural and human-produced air pollution. We all interact with the atmosphere with each breath we take and in many other ways. For example, burning fossil fuels to generate electricity and power our cars and planes releases vast quantities of carbon dioxide gas into the atmosphere. These topics are essential to physical geography, for we are influencing the atmospheric composition for the future.

Key Concepts & Topics

1 What is the origin & structure of our solar system?

1.1 Our Galaxy and Solar System
1.2 Energy from the Sun
1.3 Electromagnetic Spectrum
1.4 Incoming Energy and Net Radiation

2 Why do we have seasons?

1.5 The Seasons

3 What are the properties of our atmosphere?

1.6 Atmospheric Composition
1.7 Atmospheric Temperature
1.8 The Atmosphere's Functional Layers
1.9 Variable Atmospheric Components
1.10 Anthropogenic Pollution

Sunrise over the Pacific Ocean, as photographed from an altitude of 419 km (260 mi.) by Astronaut Reid Wiseman aboard the International Space Station on September 1, 2014 . We are seeing Earth's atmosphere from the side, as well as Earth's curvature. The different colors correspond to different layers in the atmosphere. This image highlights how thin our atmosphere is.

1.1 Our Galaxy & Solar System

Key Learning Concepts

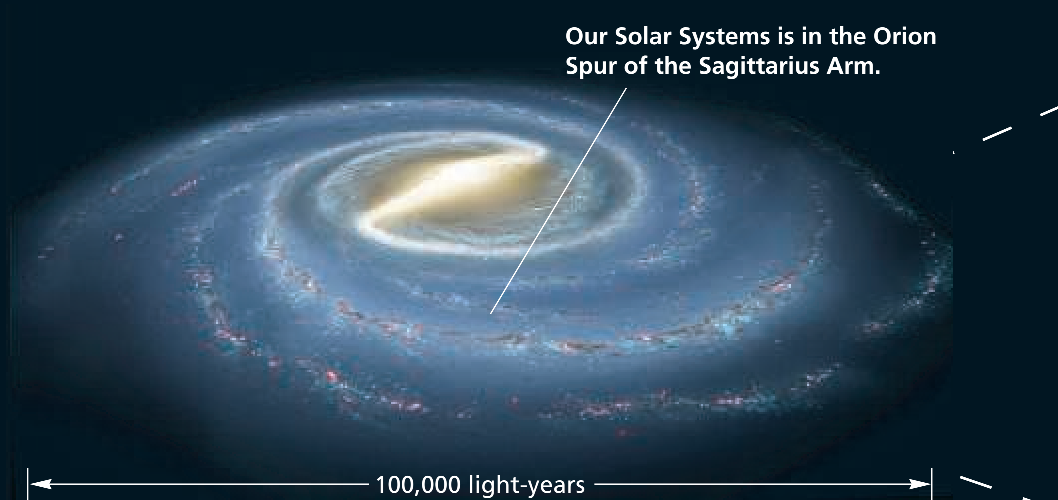
- ***Distinguish*** among galaxies, stars, and planets.
- ***Differentiate*** between the key distances of our solar system, and locate Earth.

Physical geography focuses on planet Earth. But Earth is not alone in space, and its setting within the vastness of the universe affects conditions and processes in Earth systems.

Earth's Place in Space

Our solar system is located on one of the outer "arms" of the **Milky Way Galaxy**, a disk-shaped spiral of stars (►**Fig. 1.1**). From our Earth-bound perspective in the Milky Way, the galaxy appears to stretch across the night sky like a narrow band of hazy light, although our eyes can see only a few thousand of these billions of stars. Our Sun is just one of 300 billion stars in the Milky Way Galaxy. The universe has at least 125 billion galaxies, each of which contains hundreds of billions of stars.

Our solar system condensed from a huge, slowly rotating and collapsing cloud of dust and gas, a *nebula*. **Gravity**, the mutual attraction exerted by every object upon all other objects in proportion to their mass, was the key force in this condensing solar nebula. The beginnings of the formation of the Sun and its solar system are estimated to have occurred more than 4.6 billion years ago. Within a nebula, stars condense from clouds of gas and dust, with planets gradually forming in orbits about the central mass. Astronomers study this process in other parts of the galaxy, where more than 1800 planets have been observed orbiting distant stars. An initial estimate of the number of planets in the Milky Way is 100 billion. Astronomers think there could be 500 million of these planets in the habitable zones with moderate temperatures where water can exist as a liquid.



▲1.1 **The Milky Way Galaxy** (a) The overal structure of our galaxy. (b) The Milky Way as seen from Earth.

geoCHECK What is the key difference between a galaxy and a solar system?

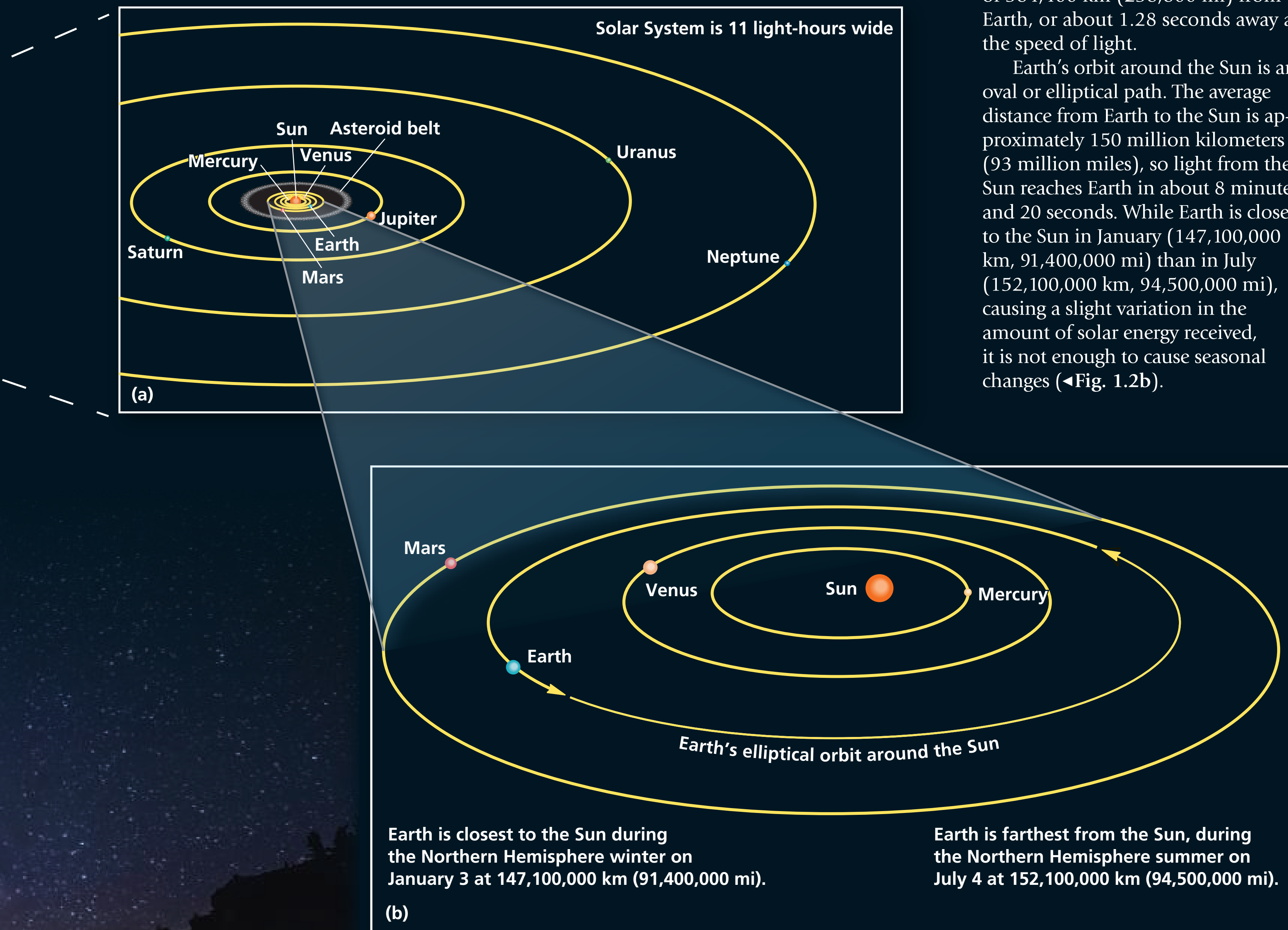
Animation MG Earth Sun Relations http://goo.gl/XVJd3y

Dimensions, Distances, & Earth's Orbit

One way to think about Earth's place in relation to the solar system and galaxy is to use the speed of light as a yardstick to measure the distances involved. The **speed of light** is 300,000 kmps (kilometers per second), or 186,000 mps (miles per second). The tremendous distance that light travels in a year, 9.5 trillion kilometers (6 trillion miles), is known as a *light-year*, and it is used as a unit of measurement for the vast universe.

The Milky Way is about 100,000 light-years from side to side, and the known universe stretches approximately 12 billion light-years in all directions. In contrast, our entire solar system is approximately 11 hours in diameter, if measured by the speed of light (◂**Fig. 1.2a**). The Moon is an average of 384,400 km (238,866 mi) from Earth, or about 1.28 seconds away at the speed of light.

Earth's orbit around the Sun is an oval or elliptical path. The average distance from Earth to the Sun is approximately 150 million kilometers (93 million miles), so light from the Sun reaches Earth in about 8 minutes and 20 seconds. While Earth is closer to the Sun in January (147,100,000 km, 91,400,000 mi) than in July (152,100,000 km, 94,500,000 mi), causing a slight variation in the amount of solar energy received, it is not enough to cause seasonal changes (◂**Fig. 1.2b**).



▲1.2 **Our solar system and Earth's orbit**

geoQUIZ

1. How did the solar system form from a nebula?
2. What is the diameter of our solar system? The distance across the known universe?
3. How much does the distance from Earth to the Sun vary over a year? How does this distance compare to the average distance from Earth to the Sun?

geoCHECK What is the speed of light?

1.2 Energy from the Sun

Key Learning Concepts

▶ ***Describe*** the Sun's operation, including solar wind.

The massive, glowing ball of gases we call the Sun continuously gives off radiant energy in all directions. The portion of that energy that reaches Earth provides energy for processes involving the planet's atmosphere, oceans, and land surface.

Solar Activity & Solar Wind

How does the Sun generate all of this energy? To generate enormous energy, you need matter—lots of it. The Sun captured about 99.9% of the matter from the original solar nebula. All the planets, their satellites, asteroids, comets, and debris are made up of the remaining 0.1%. In our entire solar system, the Sun is the only object having the enormous mass needed to sustain a nuclear reaction in its core and produce radiant energy.

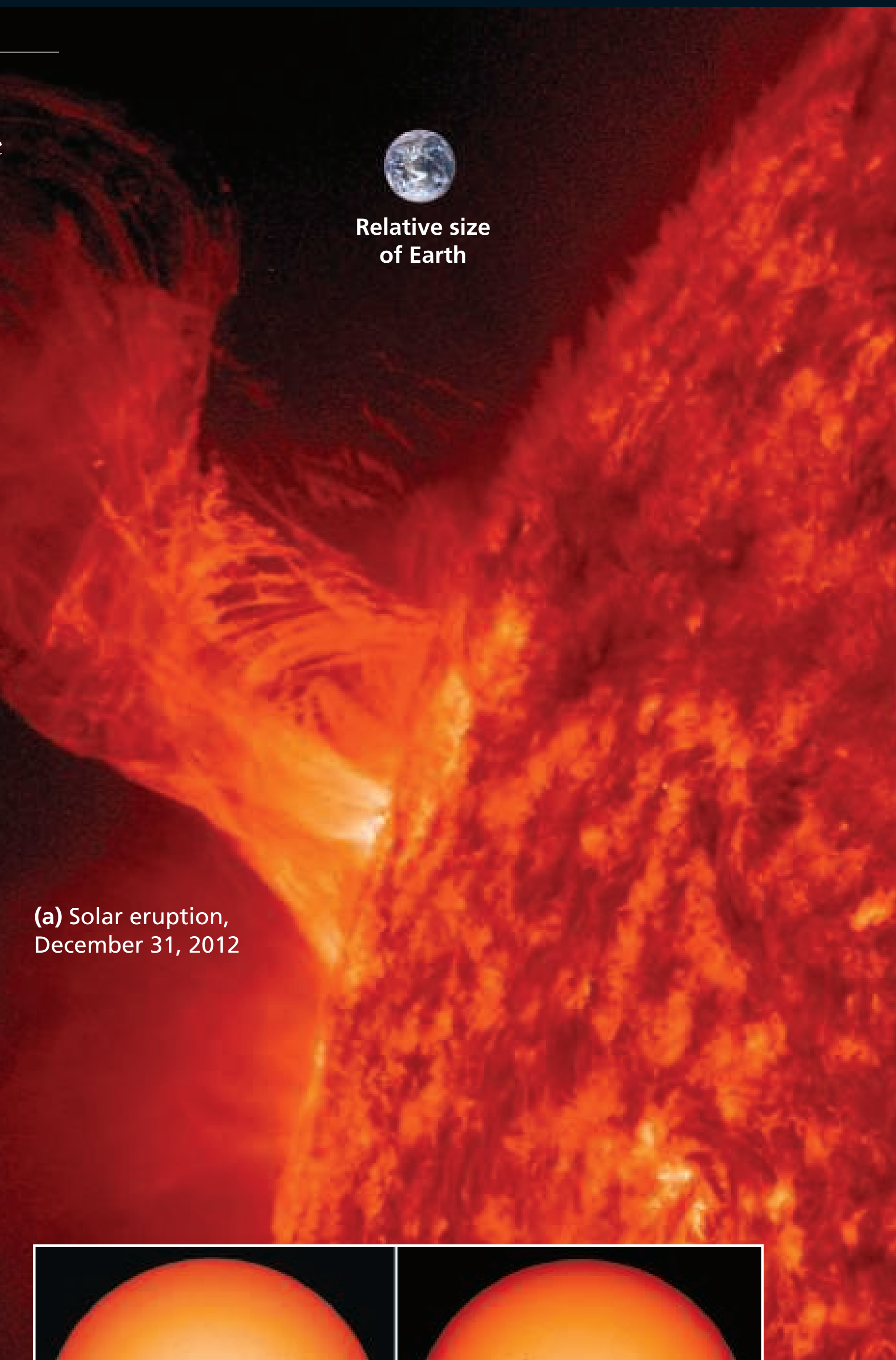
The huge mass of the Sun produces tremendous pressure and high temperatures deep in its dense interior. Here, the Sun's abundant hydrogen atoms are forced together and enormous quantities of energy are liberated in the process of **fusion**. The Sun converts 4.26 million metric tons of mass to heat and light energy every second!

In addition to light and heat, the Sun constantly emits clouds of electrically charged particles. This stream of **solar wind** travels at about 50 million kilometers (31 million miles) a day, taking approximately 3 days to reach Earth.

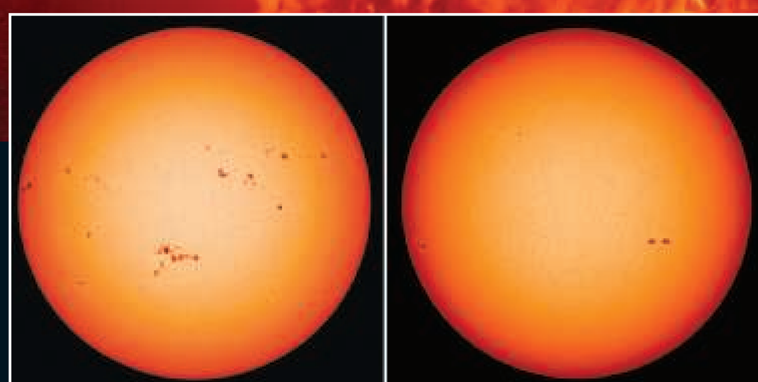
The Sun's most conspicuous features are large **sunspots**, caused by magnetic storms on the Sun (▶**Fig. 1.3**). The number of sunspots is related to the level of activity of the Sun—slightly more energy is radiated when there are more sunspots than when there are fewer sunspots. Individual sunspots may range in diameter from 10,000 to 160,000 km (6200 to 100,000 mi), more than 12 times Earth's diameter. The eruption in Figure 1.3a was 20 times the diameter of Earth. These produce flares and outbursts of charged material, referred to as coronal mass ejections, that affect radio and satellite communications.

A regular cycle exists for sunspot occurrences, as the number of sunspots increases and decreases, averaging 11 years from maximum to maximum. However, the cycle may vary from 7 to 17 years, with a minimum in 2009 and a maximum in 2014. (For more on the sunspot cycle, see http://solarscience.msfc.nasa.gov/SunspotCycle.shtml; for the latest space weather, see http://www.spaceweather.com/.)

geoCHECK ✔ Why is the Sun hot?



(a) Solar eruption, December 31, 2012



(b) Sunspot maximum in 2000 and minimum in 2009

▲**1.3 Solar coronal mass eruption and sunspots**

Auroras

The charged particles of the solar wind first interact with the **magnetosphere**, Earth's magnetic field, as they approach Earth. The magnetosphere is generated by the motions of Earth's molten iron outer core. The magnetosphere deflects the solar wind toward both of Earth's poles so that only a small portion of it enters the upper atmosphere.

This interaction of the solar wind and the upper layers of Earth's atmosphere produces the remarkable **auroras** that occur toward both poles (▼**Fig. 1.4**). These lighting effects are the *aurora borealis* (northern lights) and *aurora australis* (southern lights) in the upper atmosphere, 80–500 km (50–300 mi) above Earth's surface. They appear as folded sheets of green, yellow, blue, and red light that ripple across the skies of higher latitudes, especially poleward of 50°. The different colors of the aurora are due to different molecules in the atmosphere being excited—oxygen produces green or brownish-red light and nitrogen produces blue or red light. During a period in 2001 when the solar wind was stronger than usual auroras were visible as far south as Jamaica, Texas, and California.

(a) *Aurora australis* as seen from orbit.

(b) *Aurora borealis* over Whitehorse, Yukon Canada. On August 31, 2012, a coronal mass ejection erupted from the Sun into space, traveling at over 900 miles per second, causing this aurora four days later.

▲1.4 **Auroras from orbit and from the ground**

Animation (MG) Formation of the Solar System
http://goo.gl/alti7U

geo**CHECK** ✔ What causes the auroras?

geo**QUIZ**

1. How much of the mass of our solar system is the Sun?
2. Why is the Sun the only object in our solar system producing heat and light?
3. Why are auroras different colors?

1.3 Electromagnetic Spectrum

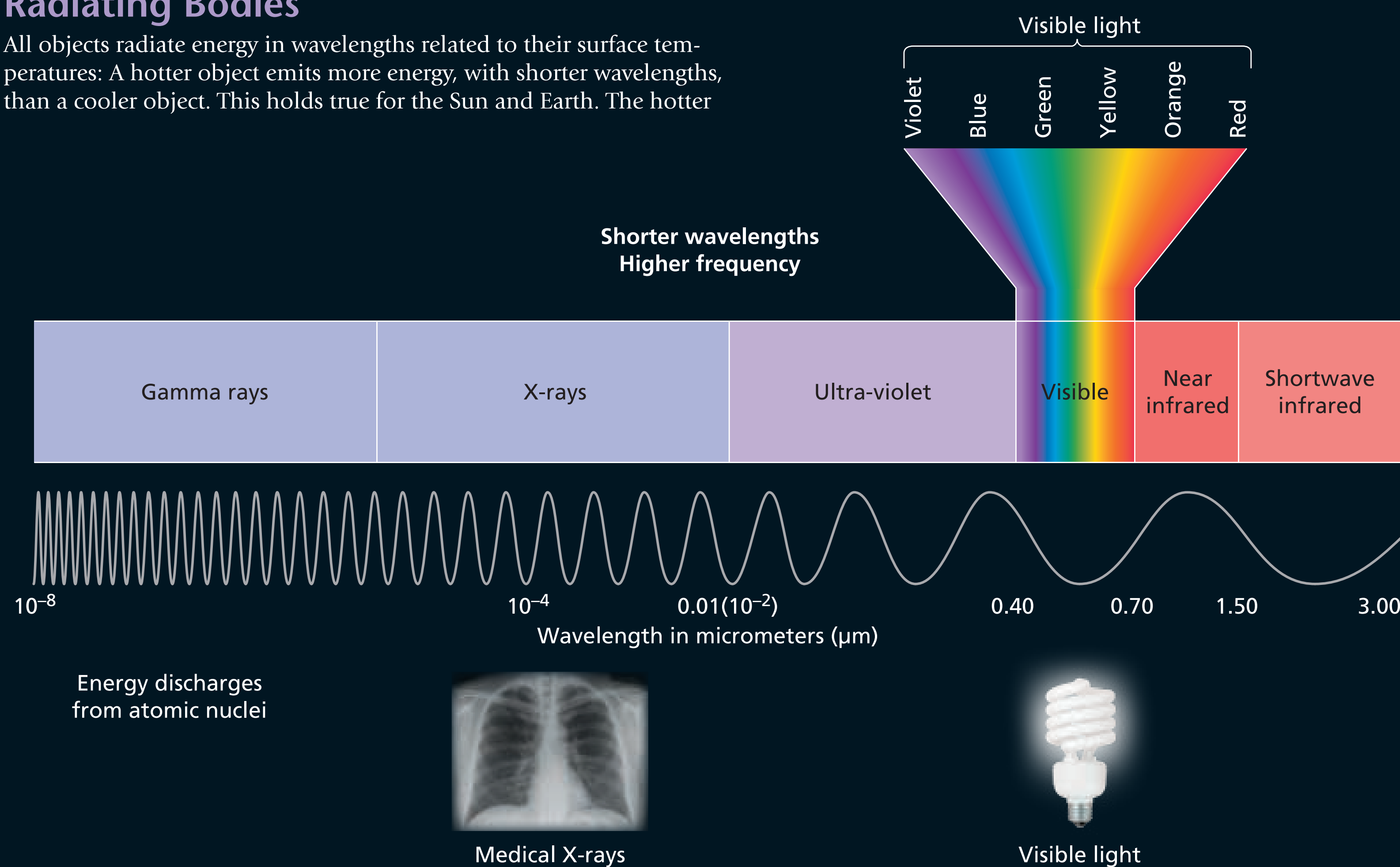
Key Learning Concepts

▶ ***Explain*** the characteristics of the electromagnetic spectrum of radiant energy.

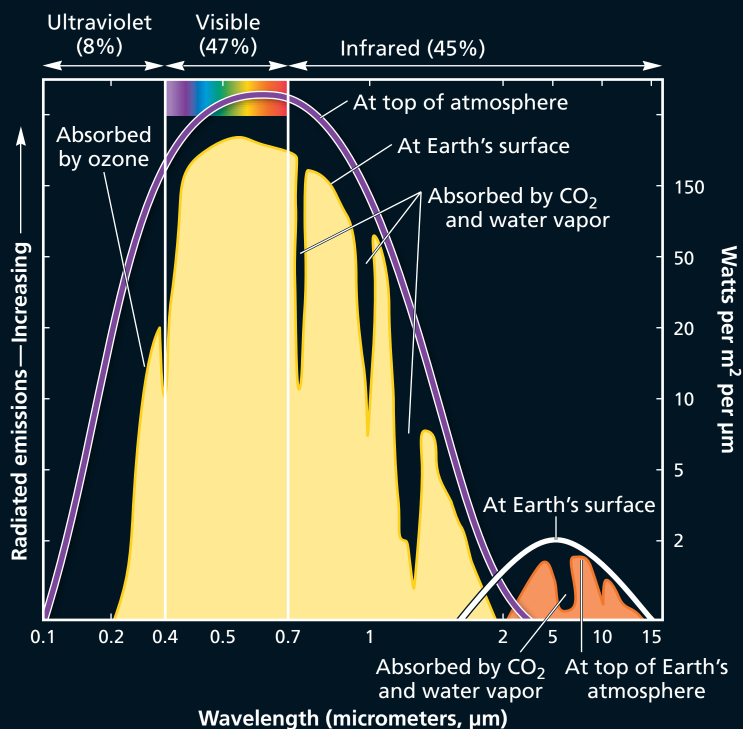
The essential input of energy to Earth is radiant energy from the Sun. This radiant energy travels to Earth at the speed of light. Solar radiation occupies a portion of the **electromagnetic spectrum**, which is the spectrum of all possible wavelengths of electromagnetic energy (**▾Fig. 1.5**). Light can be measured by both its wavelength and frequency. A **wavelength** is the distance between corresponding points on any two successive waves. The number of waves passing a fixed point in 1 second is the frequency, thus the shorter the wavelength, the higher the frequency.

Comparing Earth & Sun as Radiating Bodies

All objects radiate energy in wavelengths related to their surface temperatures: A hotter object emits more energy, with shorter wavelengths, than a cooler object. This holds true for the Sun and Earth. The hotter Sun radiates shorter-wavelength energy than does Earth, with the Sun's emissions concentrated around 0.5 μm (micrometer) (**▸Fig. 1.6**). The Sun emits radiant energy composed of 8% ultraviolet, X-ray, and gamma-ray wavelengths; 47% visible light wavelengths; and 45% infrared wavelengths. Ultraviolet energy, because of its shorter wavelength, is higher energy than longer wavelength infrared energy. This is why ultraviolet energy that reaches the surface causes sunburn, skin cancer, and damages the eyesight of human beings, while we perceive infrared energy as heat.



▲1.5 **Electromagnetic spectrum**



▲1.6 **Solar and terrestrial energy distribution by wavelength** The left hand side of the figure shows the distribution of energy from the Sun that reaches the top of our atmosphere (purple line) and Earth's surface (yellow curve). The right hand side of the figure shows the distribution of energy from Earth out to space as measured at the surface (white line) and at the top of the atmosphere (orange curve).

The Sun's surface temperature is about 6000 K (6273°C or 11,459°F). Shorter wavelength emissions are dominant at these higher temperatures.

Earth radiates nearly all of the energy that it absorbs. Because Earth is cooler, it emits less energy and at longer wavelengths, mostly in the infrared portion of the spectrum, centered around 10.0 μm. The smooth curves on the graph in Figure 1.6 represent the radiation emitted by the Sun and Earth. While the curves are smooth, notice that there are gaps at certain wavelengths for actual outgoing radiation. These are due to water vapor, water, carbon dioxide, oxygen, ozone (O_3), and other gases in Earth's atmosphere absorbing these wavelengths.

geoCHECK Why does the Sun emit shorter wavelengths than Earth?

geoQUIZ

1. What is the relationship between wavelength and frequency?
2. How does the range of visible wavelengths compare to the range of energy emitted by the Sun?
3. Which range of wavelengths accounts for most of the energy we receive from the Sun?