SIXTEENTH EDITION

Introduction to Geography

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MEET THE AUTHORS

Mark D. Bjelland earned his B.S. degree from the University of Minnesota and an M.S. degree from the University of Washington. He worked for six years as an environmental consultant on projects dealing with environmental justice, pollution cleanup, urban redevelopment, and water resources. He then earned a Ph.D. in geography from the University of Minnesota, writing his dissertation on abandoned, contaminated industrial lands in the U.S. and Canadian cities. He taught geography for 15 years at Gustavus Adolphus College before taking his current position as professor of geography in the Department of Geology, Geography, and Environmental Studies at Calvin University. He has led geography field courses to the Midwest, western Canada, Pacific Northwest, Hawaii, and Great Britain. He has been granted two Fulbright awards to study urban environmental planning in Germany and Great Britain. His research has been published in the *Research Journal of the Water Pollution Control Federation, the Journal of Environmental Engineering, The Geographical Review, The Professional Geographer, Urban Geography,* and a number of book chapters.

David H. Kaplan earned a B.A from Johns Hopkins and an M.S. and Ph.D. from the University of Wisconsin, Madison. He is a professor of geography at Kent State University. He has written some 65 peer-reviewed articles and chapters, and has also published *Segregation in Cities, Nested Identities, Boundaries and Place, Human Geography, Urban Geography, Landscapes of the Ethnic Economy, Perthes World Atlas,* the four-volume *Nations and Nationalism: A Global Historical Overview, Navigating Ethnicity,* and *Scaling Identities.* Dr. Kaplan's research interests include nationalism, borderlands, ethnic and racial segregation, urban and regional development, housing finance, and sustainable transportation. He has directly supervised 50 graduate students and teaches courses on many different aspects of human geography. He is the past-president for the American Association of Geographers, the largest academic geography association in the Americas, and is a councilor for the American Geographical Society, the United States' oldest geographical organization. He edits the *Geographical Review,* the flagship journal of the American Geographical Society, as well as *National Identities.*

Jon C. Malinowski earned a B.S.F.S. degree from the Edmund A. Walsh School of Foreign Service at Georgetown University and an M.A. and Ph.D. in geography from the University of North Carolina at Chapel Hill. His dissertation focused on the environmental preferences of boys. He has taught geography at the United States Military Academy since 1995, where he holds the title of Professor of Geography. He has taught physical geography and a host of human geography courses, including the Geography of Global Cultures, Foundations in Geography, and the Geography of Asia. His research has been published in several book chapters as well as in *Environment & Behavior, Journal of Environmental Psychology, Perceptual and Motor Skills,* and the *Journal of College Science Teaching.* He has co-authored four textbooks and two trade books on West Point. He is also the co-author of *The Summer Camp Handbook* and served on the Research Committee of the American Camp Association. Jon's contributions were completed in his personal capacity. The opinions expressed are his own and do not reflect the view of the United States Military Academy, the Department of Defense, or the United States government.

Arthur Getis received his B.S. and M.S. degrees from The Pennsylvania State University and his Ph.D. from the University of Washington. He is co-author of several geography textbooks as well as several books dealing with the analysis of spatial data. Together with Judith Getis, he was among the original unit authors of the High School Geography Project sponsored by the National Science Foundation and the Association of American Geographers (AAG). He has published widely in the areas of infectious diseases, spatial analysis, and geographic information systems. He is honorary editor of the *Journal of Geographical Systems,* and he serves on the executive committee of the *Geographical Analysis* journal and on the editorial board of the *Annals of Regional Science.* He has had administrative appointments at Rutgers University, the University of Illinois, and San Diego State University (SDSU), where he held the Birch Endowed Chair of Geographical Studies. In 2002, he received the AAG Distinguished Scholarship Award. Professor Getis is a member and an elected fellow of the University Consortium of Geographical Information Sciences, the Western Regional Science Association, and the Regional Science Association International. Currently he is Distinguished Professor of Geography Emeritus at SDSU.

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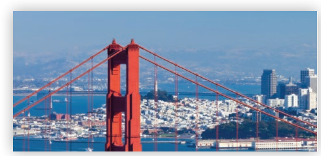

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PREFACE

Imagine designing a single university course to help students understand the world in which they live and prepare them to engage its most pressing issues. We are convinced that the introductory geography course for which this book was written would make an excellent approach. While many institutions offer separate introductory courses for human geography and physical geography, this text attempts to convey both the breadth and unity of academic geography. Students will learn where things are located in relationship to each other and develop a basic understanding of the physical systems that create landforms, weather, and climate. This will enable them to contribute to wise policy decisions regarding challenges of natural hazards and climate change. Students will gain an understanding of human systems, patterns of settlement, the distribution of different languages and religions, the spatial organization of the global economy, the location of natural resources, and the significance of boundaries in the political organization of territory. This knowledge provides a foundation for engaging contemporary issues as diverse as international migration, city planning, terrorism, globalization, international institutions, and electoral district gerrymandering. Finally, the text also provides a framework for understanding and responding to the negative consequences human activities have had on the integrity of physical systems of soils, water, air, and vegetation.

Approach

Our purpose is to convey concisely and clearly the nature of the field of geography, its intellectual challenges, and the logical interconnections of its parts. Even if students take no further work in geography, we are satisfied that they will have come into contact with the richness and breadth of our discipline and have at their command new insights and understandings for their present and future roles as informed adults. Other students may pursue further work in geography. For them, this text introduces the content and scope of the subfields of geography and provides the foundation for further work in their areas of interest.

A useful textbook must be flexible enough in its organization to permit an instructor to adapt it to the time and subject matter constraints of a particular course. Although designed with a one-quarter or one-semester course in mind, this text may be used in a full-year introduction to geography when employed as a point of departure for special topics and amplifications introduced by the instructor or when supplemented by additional readings and class projects.

Moreover, the chapters are reasonably self-contained and need not be assigned in the sequence presented here. The chapters may be rearranged to suit the emphases and sequences preferred by the instructor or found to be of greatest interest to the students. The format of the course should properly reflect the joint contribution of instructor and book, rather than be dictated by the book alone.

New to this Edition

Although we have retained the organizational structure introduced in previous editions of this book, we have revised, added, and deleted material for a variety of reasons.

- Current events and new technologies mandate an updating of facts and analyses and may suggest discussion of additional topics. Examples include new chapter opening vignettes on the COVID-19 global pandemic and on an accidental military invasion due to a digital map error.
- In every new edition, changes in both demographic parameters and the populations of countries and major urban areas require updating. Maps and tables depicting demographic variables and the populations of the world's largest countries and metropolitan regions were updated based on the most recent data available from the United Nations and Population Reference Bureau in 2019.
- Every table and figure in the book has been reviewed for accuracy and currency and has been replaced, updated, or otherwise revised where necessary.
- The addition of a political geographer to the author team led to increased depth of coverage and reorganization of existing material in the chapter on political geography.
- As always, we rely on reviewers of the previous edition to offer suggestions and to call our attention to new emphases or research findings in the different topical areas of geography. Our effort to incorporate their ideas is reflected not only in the brief text modifications or additions that occur in nearly every chapter but also in more significant alterations.

New Figures and Tables

To reflect the most recent data, many figures have been revised or newly drawn for the 16th edition of *Introduction to Geography*. Throughout the book, every effort has been made to update all maps, tables, and charts using the latest available data. They include:

- New maps representing travel times using multiple modes and global air traffic connectivity (Chapter 1)
- New images showing changes to the cultural landscape of New York City (Chapter 1)
- A new map of COVID-19 cases (Chapter 2)
- Additional photos of rock types and new photos of a shield volcano eruption, talus slope, landslide, and glacial landforms (Chapter 3)
- New table of earthquake magnitudes and effects (Chapter 3)
- New full-page display of photographs of severe storm types (Chapter 4)
- New photographs of vegetation types associated with six climate regions (Chapter 4)

- New graphs of trends in carbon dioxide emissions, greenhouse gas concentrations, land and ocean temperatures, and sea level rise (Chapter 4)
- Updated maps, graphs, charts, and tables related to population based on 2019 data (Chapter 5)
- Updated religion and language data (Chapter 6)
- Updated and more detailed world religions map (Chapter 6)
- Updated diffusion of Walmart map (Chapter 7)
- Updated graphs, tables, and maps based on the *2019 BP Statistical Review of World Energy* and the United States Geological Survey's *Mineral Commodities Summaries 2020* (Chapter 12)
- New graduated circle map of all hydropower facilities in the United States (Chapter 12)
- New choropleth map depicting the percentage of electricity generated by hydropower around the world (Chapter 12)
- New satellite images of rainforest destruction in the Amazon Basin (Chapter 12)
- New side-by-side photos of spray and drip irrigation techniques (Chapter 13)
- New maps from 2000 and 2018 depicting the reduction in acid rain in the United States (Chapter 13)
- Updated table of 2019 population, demographics, and socioeconomic data for all countries and world regions (Appendix 3)

New/Revised Boxes

The boxed elements in the book have been updated if necessary or replaced with new discussion texts.

- New Geography & Public Policy box "Citizenship and Mapping" introduces volunteered geographic information such as the OpenStreetMap project and shows students ways to use their geographic skills in humanitarian service (Chapter 2)
- Updated the "Risks of Motherhood" box to reflect the implementation of the United Nations' Sustainable Development Goals (Chapter 5)
- Updated data in the "Millions of Women Are Missing" box with a new accompanying graph of total fertility rate and sex ratios at birth in China from 1950 to 2017 (Chapter 5)
- Revised "Our Delicate State of Health" box to include COVID-19 (Chapter 5)
- New box about culture and the U.S. National Anthem (Chapter 6)
- New short box about sushi and cultural diffusion (Chapter 6)
- New box on the geography of breakfast (Chapter 6)
- New box about Medical Geography and COVID-19 (Chapter 7)
- "Broken Borders" box updated to reflect recent debates (Chapter 7)
- Updated "Public Land, Private Profit" box (Chapter 9)
- New box on coronavirus and the city (Chapter 11)
- New Geography & Public Policy box "Fuel-Efficient and Electric Vehicles" with international comparisons (Chapter 12)

New/Revised Topical Discussions

Expanded discussion of geospatial technologies including global navigation satellite systems, drones, and driverless vehicles.

- New opening vignette about the COVID-19 global pandemic with a focus on the ways that geographic analyses and geospatial techniques can help us both understand the pandemic and plan effective responses (Chapter 1)
- New opening vignette with firsthand account of visiting the scene of the 2018 eruption of Kilauea in Hawaii (Chapter 3)
- New opening vignette about Hurricane Harvey's effects on Houston in 2017 and how the destruction was worsened by climate change and patterns of urban growth (Chapter 4)
- Updated discussion of climate change using the 5th Assessment Report and subsequent updates from the Intergovernmental Panel on Climate Change (Chapter 4)
- New opening vignette about concerns of overpopulation in developing regions and fears of a population implosion in low-fertility countries (Chapter 5)
- New opening vignette about cultural diversity (Chapter 6)
- Revised discussion of culture complexes (Chapter 6)
- Introduction to medical geography with COVID-19 as an example (Chapter 7)
- New chapter opening vignette on the globalization of the textile and garment industry (Chapter 8)
- New material on evolution of the modern state in Chapter 8
- New material on electoral systems in chapter 8
- New opening vignette on the creation of South Sudan (Chapter 10)
- Significant reorganization of Chapters 8, 10, and 11 to better reflect the content
- Expanded and updated discussion of persistent organic pollutants, including emerging concerns with PFOS/PFAS compounds (Chapter 13)
- New discussion of the accumulation of wastes in the Great Pacific Garbage Patch, airborne toxins in Arctic regions, and the cap-and-trade system of controlling air pollution (Chapter 13)

Acknowledgments

A number of reviewers have greatly improved the content of this and earlier editions of *Introduction to Geography* by their critical comments and suggestions. Although we could not act upon every helpful suggestion, or adopt every useful observation, all were carefully and gratefully considered. In addition to those acknowledgments of assistance detailed in previous editions, we note the thoughtful advice provided by the following individuals.

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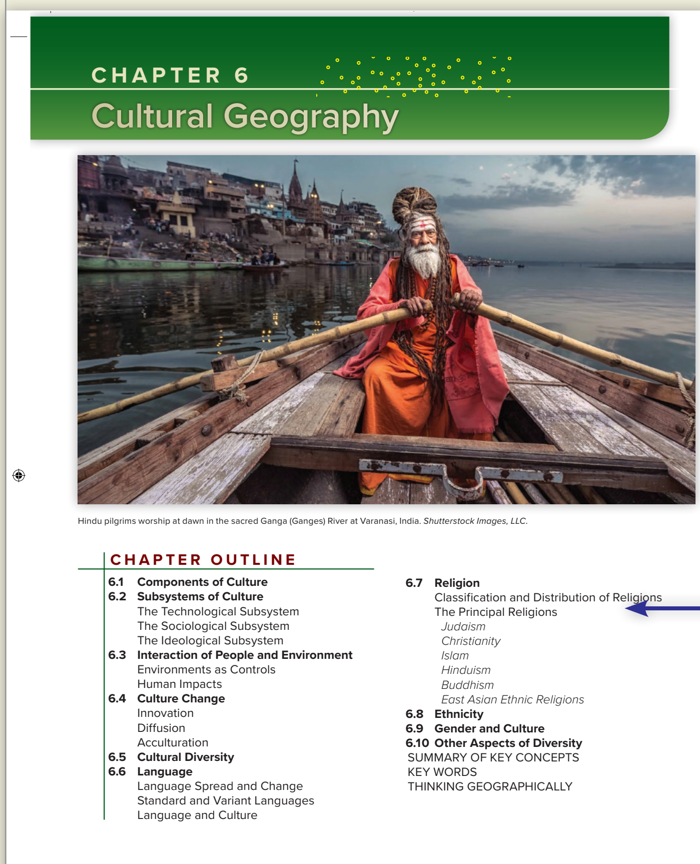
We gratefully express appreciation to these and unnamed others for their help and contributions and specifically absolve them of responsibility for decisions on content and for any errors of fact or interpretation that users may detect. Finally, we note with deep appreciation and admiration the efforts of the publisher's "book team," separately named on the copyright page, who collectively shepherded this revision to completion. We are grateful for their highly professional interest, guidance, and support.

Mark D. Bjelland
David H. Kaplan
Jon C. Malinowski
Arthur Getis

FEATURES

Pedigogical content in *Introduction to Geography* has been created to gain and retain student attention, the essential first step in the learning process.



CHAPTER 6

Cultural Geography

Hindu pilgrims worship at dawn in the sacred Ganga (Ganges) River at Varanasi, India. *Shutterstock Images, LLC.*

CHAPTER OUTLINE

6.1 Components of Culture
6.2 Subsystems of Culture
The Technological Subsystem
The Sociological Subsystem
The Ideological Subsystem
6.3 Interaction of People and Environment
Environments as Controls
Human Impacts
6.4 Culture Change
Innovation
Diffusion
Acculturation
6.5 Cultural Diversity
6.6 Language
Language Spread and Change
Standard and Variant Languages
Language and Culture
6.7 Religion
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The Principal Religions
Judaism
Christianity
Islam
Hinduism
Buddhism
East Asian Ethnic Religions
6.8 Ethnicity
6.9 Gender and Culture
6.10 Other Aspects of Diversity
SUMMARY OF KEY CONCEPTS
KEY WORDS
THINKING GEOGRAPHICALLY

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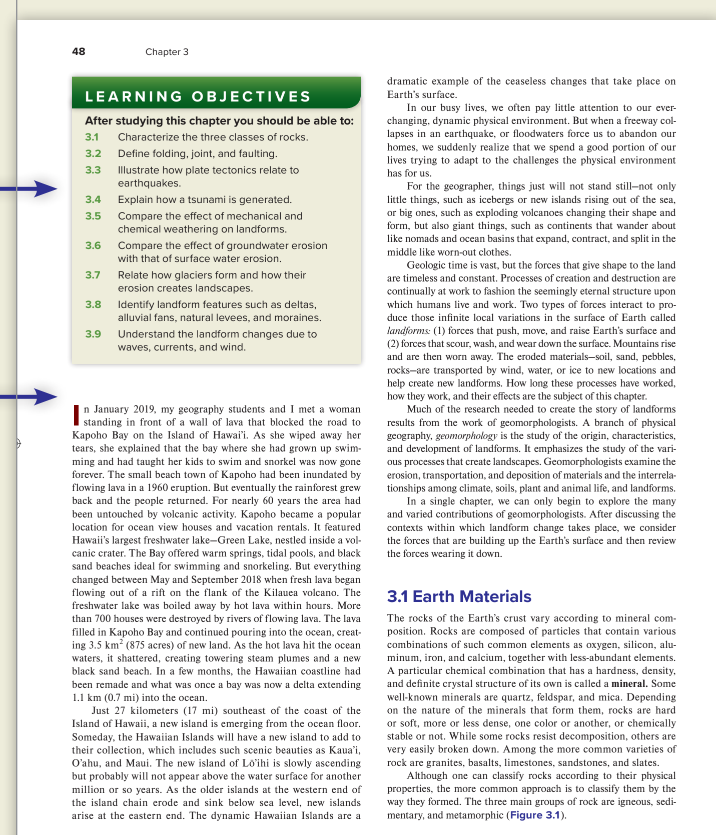
Numbered **Chapter Outlines** are included on the opening page of each chapter to clarify the organization of the chapter and to make it easy to locate specific topics of discussion.

Each chapter opens with **Learning Objectives** students can use to guide their study and help them focus on critical concepts. These objectives specify what students are expected to know, understand, and be able to do after studying the chapter.

Vignettes are used to begin each chapter with a brief real-life story intended to capture student interest and prepare them for the subject matter to follow.



48 Chapter 3

LEARNING OBJECTIVES

After studying this chapter you should be able to:

3.1 Characterize the three classes of rocks.
3.2 Define folding, joint, and faulting.
3.3 Illustrate how plate tectonics relate to earthquakes.
3.4 Explain how a tsunami is generated.
3.5 Compare the effect of mechanical and chemical weathering on landforms.
3.6 Compare the effect of groundwater erosion with that of surface water erosion.
3.7 Relate how glaciers form and how their erosion creates landscapes.
3.8 Identify landform features such as deltas, alluvial fans, natural levees, and moraines.
3.9 Understand the landform changes due to waves, currents, and wind.

In January 2019, my geography students and I met a woman standing in front of a wall of lava that blocked the road to Kapoho Bay on the Island of Hawai'i. As she wiped away her tears, she explained that the bay where she had grown up swimming and had taught her kids to swim and snorkel was now gone forever. The small beach town of Kapoho had been inundated by flowing lava in a 1960 eruption. But eventually the rainforest grew back and the people returned. For nearly 60 years the area had been untouched by volcanic activity. Kapoho became a popular location for ocean view houses and vacation rentals. It featured Hawaii's largest freshwater lake—Green Lake, nestled inside a volcanic crater. The Bay offered warm springs, tidal pools, and black sand beaches ideal for swimming and snorkeling. But everything changed between May and September 2018 when fresh lava began flowing out of a rift on the flank of the Kilauea volcano. The freshwater lake was boiled away by hot lava within hours. More than 700 houses were destroyed by rivers of flowing lava. The lava filled in Kapoho Bay and continued pouring into the ocean, creating 3.5 km^2 (875 acres) of new land. As the hot lava hit the ocean waters, it shattered, creating towering steam plumes and a new black sand beach. In a few months, the Hawaiian coastline had been remade and what was once a bay was now a delta extending 1.1 km (0.7 mi) into the ocean.

Just 27 kilometers (17 mi) southeast of the coast of the Island of Hawaii, a new island is emerging from the ocean floor. Someday, the Hawaiian Islands will have a new island to add to their collection, which includes such scenic beauties as Kaua'i, O'ahu, and Maui. The new island of Lō'ihi is slowly ascending but probably will not appear above the water surface for another million or so years. As the older islands at the western end of the island chain erode and sink below sea level, new islands arise at the eastern end. The dynamic Hawaiian Islands are a dramatic example of the ceaseless changes that take place on Earth's surface.

In our busy lives, we often pay little attention to our ever-changing, dynamic physical environment. But when a freeway collapses in an earthquake, or floodwaters force us to abandon our homes, we suddenly realize that we spend a good portion of our lives trying to adapt to the challenges the physical environment has for us.

For the geographer, things just will not stand still—not only little things, such as icebergs or new islands rising out of the sea, or big ones, such as exploding volcanoes changing their shape and form, but also giant things, such as continents that wander about like nomads and ocean basins that expand, contract, and split in the middle like worn-out clothes.

Geologic time is vast, but the forces that give shape to the land are timeless and constant. Processes of creation and destruction are continually at work to fashion the seemingly eternal structure upon which humans live and work. Two types of forces interact to produce those infinite local variations in the surface of Earth called *landforms:* (1) forces that push, move, and raise Earth's surface and (2) forces that scour, wash, and wear down the surface. Mountains rise and are then worn away. The eroded materials—soil, sand, pebbles, rocks—are transported by wind, water, or ice to new locations and help create new landforms. How long these processes have worked, how they work, and their effects are the subject of this chapter.

Much of the research needed to create the story of landforms results from the work of geomorphologists. A branch of physical geography, *geomorphology* is the study of the origin, characteristics, and development of landforms. It emphasizes the study of the various processes that create landscapes. Geomorphologists examine the erosion, transportation, and deposition of materials and the interrelationships among climate, soils, plant and animal life, and landforms.

In a single chapter, we can only begin to explore the many and varied contributions of geomorphologists. After discussing the contexts within which landform change takes place, we consider the forces that are building up the Earth's surface and then review the forces wearing it down.

3.1 Earth Materials

The rocks of the Earth's crust vary according to mineral composition. Rocks are composed of particles that contain various combinations of such common elements as oxygen, silicon, aluminum, iron, and calcium, together with less-abundant elements. A particular chemical combination that has a hardness, density, and definite crystal structure of its own is called a **mineral.** Some well-known minerals are quartz, feldspar, and mica. Depending on the nature of the minerals that form them, rocks are hard or soft, more or less dense, one color or another, or chemically stable or not. While some rocks resist decomposition, others are very easily broken down. Among the more common varieties of rock are granites, basalts, limestones, sandstones, and slates.

Although one can classify rocks according to their physical properties, the more common approach is to classify them by the way they formed. The three main groups of rock are igneous, sedimentary, and metamorphic (Figure 3.1).

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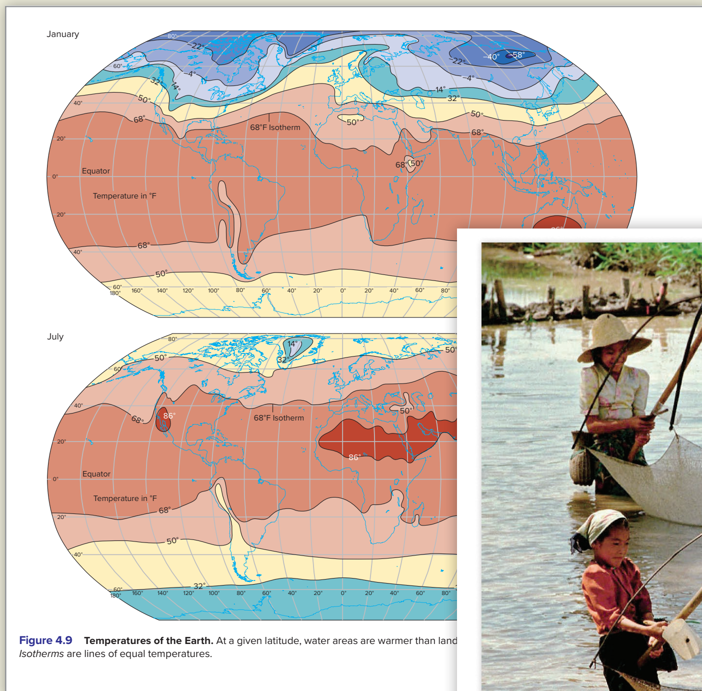
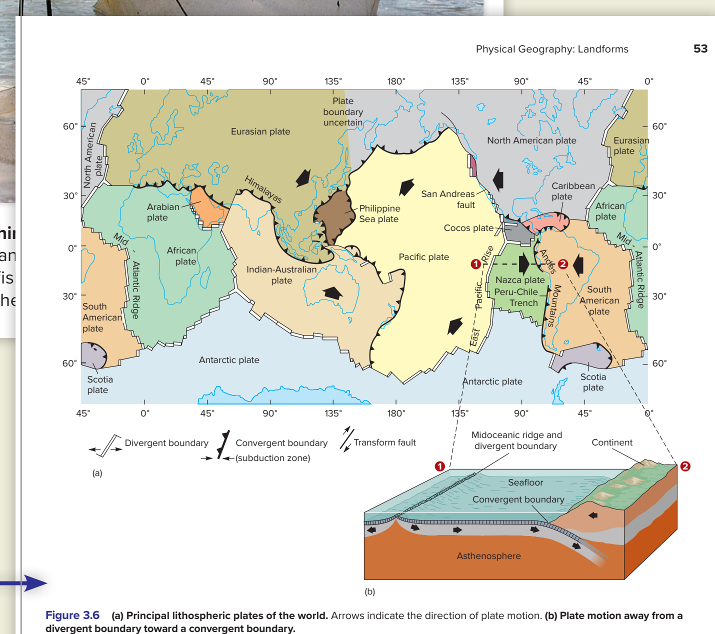
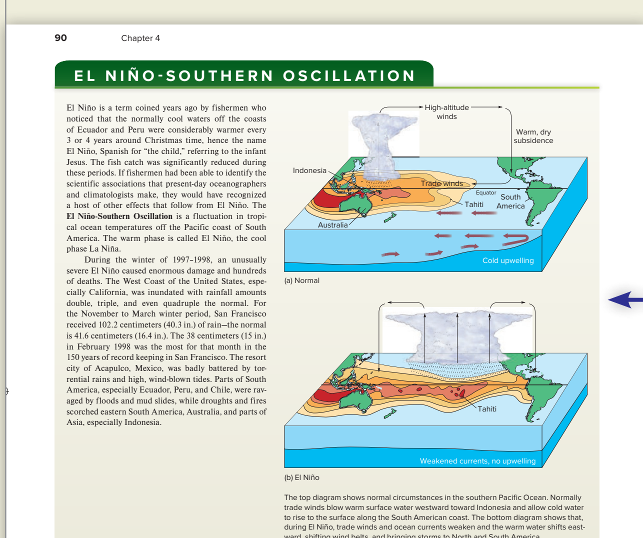


More than **450 full-color maps, charts, and photographs,** along with information and explanations, serve as an extension of the text. World maps have been created using the Robinson projection and colors have been chosen to accommodate most color-blind students. The Fold-out world map at the back of the text can be easily referenced for any chapter in the text.





Boxed inserts are written to further develop ideas and enhance student interest in the course material. Chapters generally include three to five boxes, and most chapters include a box on gender-related issues.

Geography & Public Policy boxes highlight important or controversial issues, encouraging students to think about the relevance of geography to real-world concerns. Critical thinking questions at the end of each box prompt students to reflect upon and form an opinion about specific issues and serve as a catalyst for class discussion.

GEOGRAPHY & PUBLIC POLICY

International Population Policies

Starting in Rome in 1954, the United Nations has hosted regular international population conferences. But the most important was the 1994 conference in Cairo, Egypt, which charted new directions for international population policy. The sometimes rancorous 9-day meeting of 20,000 delegates established a new program of action that gained support from 179 signatory countries and has continued to guide international efforts to address population and development. In 2019, the United Nations commemorated the 25th anniversary of the 1994 International Conference on Population and Development in Cairo and reaffirmed its commitment to the principles adopted at that conference.

The Cairo plan of action abandoned several decades of top-down government programs that promoted *population control* (a phrase avoided by the conference) based on targets and quotas. At previous conferences, delegates from wealthy, developed countries had pushed numerical targets for reductions in fertility and population growth rates in poor countries. Delegates from developing countries pushed back, arguing that development was the best contraceptive and that once they achieved development, population issues would take care of themselves. At Cairo for the first time, delegates embraced policies giving women greater control over their lives, greater economic equality and opportunity, and a greater voice in repro-duction decisions. It recognized that limiting population growth depends on programs that lead women to want fewer children and make them partners in economic development. In that recognition, the conference accepted the documented link between increased educational access and economic opportunity for women and falling birth rates. Earlier population conferences—1974 in Bucharest and 1984 in Mexico City—did not fully address these issues of equality, opportunity, education, and political rights; their adopted goals had failed to achieve hoped-for changes in birth rates, in large part because women in many traditional societies had no power to enforce contraception and feared their other alternative, sterilization.

The earlier population conferences had carefully avoided or specifically excluded abortion as an acceptable family planning method. It was the more open discussion of abortion in Cairo that sparked much of the spirited debate that registered religious objections by the Vatican and many Muslim and Latin American states to the inclusion of legal abortion as part of health care. Although the final text of the conference declaration did not promote the universal right to abortion and excluded it as a means of family planning, some delegations still registered reservations to its wording on both sex and abortion. At the conference's close, however, the Vatican endorsed the declaration's underlying principles, including the family as "the basic unit of society" and the need to "stimulate economic growth and to promote gender equality, equity, and the empowerment of women."

The director of the UN Population Division remarked in 2004: "A woman in a village making a decision to have one or two or at most three children is a small decision in itself. But . . . compounded by millions and millions . . . of women in India and Brazil and Egypt, it has global consequences." That women are making those decisions, demographers have observed, reflects important cultural factors emerging since Cairo. Satellite television and the Internet take contraceptive information to remote villages and show glamourous depictions of urban life with few or no children. Increasing urbanization reduces some traditional controls on women and makes contraceptives easier to find, and declining infant mortality makes mothers more confident their babies will survive. Perhaps most important is the dramatic increase in female school attendance, with corresponding reductions in the illiteracy rates of girls and young women, who will themselves soon be making fertility decisions.

The United Nation's Sustainable Development Goals for 2030 continue many of the Cairo conference's emphases on gender equality and empowerment of women. More recent publications of the United Nations Population Fund have urged measures ensuring safe and accessible abortion in countries where it is legal, instruction in sexual and reproductive health issues in schools, and family planning and health services for sexually active adolescents.

Another important contribution of the Cairo meeting was that it made direct links between population issues and the environmental issues discussed at the UN Conference on Environment and Development held in Rio de Janeiro in 1992. The Cairo conference endorsed a strategy for stabilizing the world's population at 7.27 billion by no later than 2015 in order to avoid the environmental consequences of rapid population growth. Obviously, the world's population did not stabilize at 7.27 billion in 2015. Still, fertility rates have declined almost universally since the 1990s. While population policy is not addressed directly in the United Nations' Sustainable Development Goals for 2030, many of the goals such as reducing the urban slum population and the number of people without safe drinking water could be achieved more easily with slower population growth in the least-developed countries.

Considering the Issues

1. Do you think it is appropriate for international bodies to promote policies affecting such purely personal or national concerns as reproduction, abortion, and family planning? Why or why not?
2. Do you think that current international concerns over population growth, development, and the environment are sufficiently pressing to justify imposing change from outside and risking the loss of long-enduring cultural norms and religious practices in regions such as sub-Saharan Africa? Why or why not?
3. The Cairo plan abandoned specific targets and quotas for reductions in population growth rates in developing countries and shifted the focus to empowering women. Given that the world's population continues to grow, was that a good or bad decision?
4. Should international migration be discussed as a potential solution to problems of a demographically divided world? What migration patterns would best address international population challenges?

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Summary of Key Concepts

- Maps are as indispensable to the geographer as are words, photographs, and statistics. Maps are also essential to the analysis and solution of many of the critical issues of our time, such as climate change, pollution, national security, and public health—all issues that call for the accurate representation of elements on the earth's surface.
- The geographic grid of longitude and latitude is used to locate points on the earth's surface. Latitude is the measure of distance north and south of the equator, while longitude is the angular distance east or west of the prime meridian.
- All systems of representing the curved Earth on a flat map distort one or more Earth features. Any given projection will distort area, shape, distance, and/or direction.
- Among the most accurate and most useful large-scale maps are the topographic quadrangles produced by a country's national mapping agency. They contain a wealth of information about both the physical and the cultural landscape and are used for a variety of purposes.
- Remote sensing from aircraft, satellites, and drones is an important source of spatial data. The need to store, process, and retrieve the vast amounts of data generated by remote sensing has spurred the development of geographic information systems, which provide a way to search for spatial patterns and processes.

As you read the remainder of this book, note the many different uses of maps. For example, notice in Chapter 3 how important maps are to your understanding of the theory of continental drift; in Chapter 6, how maps aid geographers in identifying cultural regions; and in Chapter 7, how behavioral geographers use maps to record people's perceptions of space.

Key Words

area cartogram (value-by-area map) 32
azimuthal projection 27
cartography 21
choropleth map 31
conformal projection 25
contour interval 29
contour line 29
dot density map 31
drone 36
equal-area (equivalent) projection 24
equidistant projection 27
flow-line map 33
geographic database 43
geographic grid 22
geographic information system (GIS) 43
Global Navigation Satellite Systems (GNSS) 38
Global Positioning System (GPS) 38
globe properties 24
graduated symbol map 31
International Date Line 23
isoline 32
Landsat satellite 37
latitude 22
longitude 23
map projection 24
prime meridian 23
remote sensing 35
scale 27
topographic map 28

Thinking Geographically

1. What important map purpose does the *prime meridian* serve? Is the prime, or any other, meridian determined in nature or devised by humans? How is the prime meridian designated or recognized?

A **Summary of Key Concepts** appears at the end of each chapter as a way to reinforce the major ideas of the chapter and guide student understanding of key concepts.

Thinking Geographically questions are easily assignable and provide students an opportunity to check their grasp of chapter material.

A **Key Words** list with page references makes it easy for students to verify their understanding of the most important terms in the chapter.

Appendix 1: Map Projections includes a discussion of methods of projection, globe properties and map distortion, and classes of projection.

Appendix 2: Climates, Soils, and Vegetation supplements Chapter 4 *Physical Geography: Weather and Climate* by providing information about soil formation, soil profiles and horizons, soil taxonomy, and natural vegetation regions.

Appendix 3: 2019 World Population Data Sheet ~~for the Population Reference Bureau~~ ~~(a modified version)~~ includes basic demographic data and projections for countries, regions, and continents, as well as selected economic and social statistics helpful in national and regional comparisons. The comparative information in the appendix ~~data~~ is useful for student projects, regional and topical analyses, and the study of world patterns.

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CHAPTER 1

Introduction

Two Sherpas carry heavy packs in the Himalayas near Mount Everest. Sherpas are an ethnic group who live in the high mountains of Nepal. Their livelihoods are linked to their physical environment and many of them work as guides and porters for the tourist mountain climbing industry. *Sean White/Design Pics.*

CHAPTER OUTLINE

1.1 What Is Geography?
1.2 Evolution of the Discipline
Subfields of Geography
Why Geography Matters
1.3 Some Core Geographic Concepts
Location, Direction, and Distance
Location
Direction
Distance
Size and Scale
Physical and Cultural Attributes
Attributes of Place Are Always Changing
Interrelations between Places
Place Similarity and Regions
Spatial Distributions
Types of Regions
1.4 Geography's Themes and Standards
1.5 Organization of This Book

LEARNING OBJECTIVES

After studying this chapter you should be able to:

1.1 Understand what geographers mean when they say that “location matters.”

1.2 Describe what is meant by physical and cultural landscapes.

1.3 Discuss how geography aids in understanding national and international problems.

1.4 Explain how the word *spatial* is used in the discipline of geography.

1.5 Appreciate which concepts are used to understand the processes of human interaction.

1.6 Summarize the kinds of understanding encompassed in the National Standards.

Nepal is home to some of the mos FPO he world. Rising from tropical lowl ia to the world’s highest peaks in the H ry has been nicknamed “the mountain kingdom.” The Himalayas were built and continue to grow due to the collision of two of the Earth’s crustal plates. The Indian subcontinent is moving northeast at a rate of about 4 centimeters per year, about the same rate at which human fingernails grow. The collision of the Indian crustal plate with Eurasia pushes up mountains and builds stresses that are periodically relieved by earthquakes. On April 28, 2015, a magnitude 7.9 earthquake struck Nepal, just 77 kilometers from Kathmandu, the country’s capital and largest city. Thousands of buildings crumpled and landslides buried villages and roadways, killing over 9,000 people (see **Figure 1.1**). Adding to the tragedy, many cultural treasures such as monumental towers, Buddhist stupas, and Hindu temples were damaged or destroyed. The Kathmandu Valley has seven cultural landscape sites designated by the United Nations as being of global significance. These cultural sites include historic royal palace squares, sacred sites, and celebrated Hindu and Buddhist monuments. The quake also triggered an avalanche on Mount Everest, the world’s highest mountain, killing 19 climbers in the base camp and stranding hundreds of climbers and their Sherpa guides on the mountainside. Thus, the earthquake also devastated both the cultural tourism and ecotourism sectors that are vital to Nepal’s economy. Long after the world’s media attention has moved on, Nepal’s residents work to rebuild their country’s homes, businesses, roads, utilities, historic landmarks, and religious structures. As they rebuild their lives, institutions, and economy, they hope that the tourists will soon return.

The study of geography, by combining knowledge of earth systems and human societies, sheds important light on events such as these. Studying geography can also help societies become more resilient and sustainable. In Chapter 3, for example, we discuss the processes that cause earthquakes and build mountains and other landforms. While news reports often refer to catastrophes such as these as “natural disasters,” there was more than nature involved in the 2015 Nepal earthquake. For example, natural disasters, such as hurricanes, floods, landslides, and earthquakes that hit poor low-income countries have death tolls many times higher than those that hit high-income countries. Partly to blame for the many deaths in the 2015 Nepal earthquake were construction materials that could not withstand the forces unleashed by this earthquake. Brick, stone, or concrete buildings without steel reinforcing bars cannot handle the ground shaking of an earthquake and often collapse. As discussed in Chapter 7, Nepal is classified by the United Nations as among the least developed countries in the world. Per capita incomes in Nepal average 1/25th of those in the United States of America. Nepali scientists actively monitor the earthquake hazards in their country and in 1994 building regulations were passed to increase earthquake safety. But in many cases, the building code was ignored because the builders simply could not afford the steel reinforcing materials to make homes, schools, and commercial buildings safe.

Relief and recovery efforts were complicated by poor road and utility systems and the lack of emergency services. Extreme poverty meant there was no insurance policy or bank account

Figure 1.1 The *USNS Comfort* arrives in New York harbor on March 30, 2020 in response to the COVID-19 pandemic. The *USNS Comfort* hospital ship was sent to New York to provide an additional 1,000 hospital beds. By late March 2020, the epicenter of the COVID-19 global pandemic had shifted from Wuhan, China, to New York City. Hospitals were overwhelmed with patients and in addition to the *USNS Comfort*, makeshift hospitals were opened in a convention center and in tents in Central Park. *Kenneth Wilsey, FEMA/U.S. Department of Defense.*

to fall back upon for many Nepali residents who lost homes, jobs, and family members. One bright spot was the use of new geographic techniques to assess damage and map the changing locations of people displaced by the earthquake. Satellite imagery provided insights into the condition of buildings and the location of landslides. Anonymous cell phone data from millions of Nepali users were collected by a nonprofit organization and used to track the location of people displaced by the quake so that relief could be directed to where it was needed. The tragic Nepal earthquake of 2015 is a reminder that human actions take place in the context of a particular geographic environment. It is also a reminder that, just as maps were essential tools in the rescue, relief, and recovery processes, many of the world's pressing problems require a geographic understanding that brings together earth systems, human cultures, the locations of human activities, and the relationships between human societies and their environment—all important themes in the study of geography.

1.1 What Is Geography?

Many people associate the word *geography* simply with knowing *where* things are: whether they be countries, such as Myanmar and Uruguay; cities, such as Timbuktu or Almaty; or deposits of natural resources, such as petroleum or iron ore. Some people pride themselves on knowing which rivers are the longest, which mountains are the tallest, and which deserts are the largest. Such factual knowledge about the world has value, permitting us to place current events in their proper spatial setting. When we hear of an earthquake in Turkey or an assault in Chechnya, we at least can visualize where they occurred. Knowing *why* they occurred in those places, however, is considerably more important.

Comp/CLS: we may need permission to use this quote from Barack Obama.

Geography is much more than place names and locations. As U.S. president Barack Obama put it in his speech at the 2012 National Geographic Bee, "It's about understanding the complexity of our world, appreciating the diversity of cultures that exists across continents. And in the end, it's about using all that knowledge to help bridge divides and bring people together." Put differently, geography is the study of spatial variation, of how and why things differ from place to place on the surface of the Earth. Just as knowing the names and locations of organs in the human body does not equip one to perform open-heart surgery, knowing where things are located is only the first step toward understanding why things are where they are, and what events and processes determine or change their distribution. Why are earthquakes common in Turkey but not in Russia? Why did the United Kingdom leave the European Union in 2020 while at the same time Serbia, Montenegro, and Turkey were in negotiations to join the European Union. Why are the mountains in the eastern United States rounded and those in the western states taller and more rugged? Why do you find French speakers concentrated in Quebec but not in other parts of Canada?

In answering questions such as these, geographers focus on the interaction of people and social groups with their environment—planet Earth—and with one another; they seek to understand how and why physical and cultural spatial patterns evolved through time and continue to change. Because geographers study both the physical environment and human use of that environment, they are sensitive to the variety of forces affecting a place and the interactions among them. To explain why Brazilians burn a significant portion of the tropical rain forest each year, for example, they draw on their knowledge of the climate and soils of the Amazon Basin; population pressures, landlessness, and the need for greater agricultural area in rural Brazil; the country's foreign debt status; midlatitude markets for lumber, beef, and soybeans; and Brazil's economic development objectives. Understanding the environmental consequences of the burning requires knowledge of, among other things, the oxygen and carbon balance of the Earth; the contribution of the fires to the greenhouse effect, acid rain, and depletion of the ozone layer; and the relationships among deforestation, soil erosion, and floods.

Geography, therefore, is about Earth space and the content of that space. We all rely on our geographical knowledge for our daily lives. Such knowledge helps us navigate our daily travels, make sense of news events, make decisions, and even plan our vacations. We think of and respond to places from the standpoint of not only where places are but, what is more important, what they contain or what we think they contain. Reference to a place or an area usually calls up images about its physical nature or what people do there, and this often suggests to us, without our consciously thinking about it, how those physical features and activities are related. Examples include "Bangladesh," "farming," and "flooding" as well as "Colorado," "mountains," and "skiing." That is, the content of an area has both physical and cultural aspects, and geography is always concerned with understanding both (**Figure 1.2**).

Figure 1.2 **Telluride, Colorado, demonstrates changing interactions between physical environment and human activity.** Telluride's Main Street buildings are a legacy of its origin as a mining town. The mountains towering above Telluride once furnished zinc, lead, copper, and silver. When the mines closed in the 1970s, "hippies" moved in and ski runs opened. Today, the town makes its living off the beautiful mountains that draw mountain bikers, hikers, golfers, and skiers from afar. Photography by Deb Snelson/Moment/Getty Images.

1.2 Evolution of the Discipline

Geography's combination of interests was apparent even in the work of the early Greek geographers who first gave structure to the discipline. Geography's name was reputedly coined by the Greek scientist Eratosthenes over 2200 years ago from the words *geo,* "the Earth," and *graphein,* "to write." From the beginning, that writing focused both on the physical structure of the Earth and on the nature and activities of the people who inhabited the known world. To Strabo (c. 64 B.C.–A.D. 20), the task of geography was to "describe the several parts of the inhabited world, . . . to write the assessment of the countries of the world [and] to treat the differences between countries." Even earlier, Herodotus (c. 484–425 B.C.) had found it necessary to devote much of his writing to the lands, peoples, economies, and customs of the various parts of the Persian Empire in order to understand the causes and course of the Persian wars.

Greek (and, later, Roman) geographers measured the Earth, devised the global grid of parallels and meridians (marking latitudes and longitudes; see p. xxx), and drew upon that grid surprisingly sophisticated maps of their known world (**Figure 1.3**). They explored the apparent latitudinal variations in climate and described in numerous works the familiar Mediterranean Basin and the more remote lands of northern Europe, Asia, and equatorial Africa. Employing nearly modern concepts, they described river systems, explored cycles of erosion and patterns of deposition, cited the dangers of deforestation, described variations in the natural landscape, and warned of the consequences of environmental abuse. Against that physical backdrop, they focused their attention on what humans did in home and distant areas—how they lived; what their distinctive similarities and differences were in language, religion, and custom; and how they used, altered, and perhaps destroyed the lands they inhabited. Strabo, indeed, cautioned against the assumption that the nature and actions of humans were determined by the physical environment they inhabited. He observed that humans were the active elements in a human-environmental partnership.

The questions explored by the early Greek and Roman geographers are enduring and universal. The ancient Chinese, for example, were as involved in the study of geography as were westerners, though there was no exchange between them. Further, as Christian Europe entered its Middle Ages between A.D. 800 and 1400 and lost its knowledge of Greek and Roman geographic work, Muslim scholars—who retained that knowledge—undertook to describe and analyze their known world in its physical, cultural, and regional variation.

In the 15th and 16th centuries, European voyages of exploration and discovery put geography at the forefront of the scientific revival. Modern geography had its origins in the surge of scholarly inquiry that, beginning in the 17th century, gave rise to many of the traditional academic disciplines we know today. In its European rebirth, geography from the outset was recognized—as it always had been—as a broadly based integrative study. Patterns and processes of the physical landscape were early interests, as was concern with humans as part of the Earth's variation from place to place. The rapid development of geology, botany, zoology, climatology, and other natural sciences by the end of the 18th century strengthened regional geographic investigation and increased scholarly and popular awareness of the intricate interconnections of things in space. By that time, accurate determination of latitude and longitude and scientific mapping of the Earth made location information more reliable and comprehensive. A key figure during this period of geographic research was Alexander von Humboldt. Humboldt, one of the two namesakes of Humboldt University in Berlin, Germany, led ambitious scientific expeditions to distant places and synthesized vast amounts of geographic data in his famous writings. His 5-year expedition through Latin America led to advances in the study of climate, volcanoes, and the location of plants and animals.

Subfields of Geography

During the 19th century, national censuses, trade statistics, and ethnographic studies gave firmer foundation to human geographic investigation. By the end of the 19th century, geography had become a distinctive and respected discipline in universities throughout Europe and in other regions of the world where European academic models were followed. The proliferation of professional geographers and geography programs resulted in the development of a whole series of increasingly specialized disciplinary subdivisions, many represented by separate chapters of this book. Political geography, urban geography, and economic geography are examples of some of these subdivisions.

Geography's specialized subfields are not isolated from one another; rather, they are closely interrelated. Geography in all its subdivisions is characterized by three dominating interests. The first is in the spatial variation of physical and human phenomena on the surface of the Earth; geography examines relationships between human societies and the natural environments that they occupy and modify. The second is a focus on the systems that link physical phenomena and human activities in one area of the Earth with other areas. Together, these interests lead to a third enduring theme, that of regional analysis: Geography studies human-environmental (or "ecological") relationships and spatial systems in specific locational settings. This areal orientation pursued by some geographers is called *regional geography.*

As knowledge has grown more complex, most geographers now select particular classes of things, rather than segments of the Earth's surface, for specialized study. These *systematic geographers* may focus their attention on one or a few related aspects of the physical environment or of human populations and societies. In each case, the topic selected for study is examined in its interrelationships with other spatial systems and areal patterns. *Physical geography* directs its attention to the natural environmental side of the human-environmental structure. Its concerns are with landforms and their distribution, with atmospheric conditions and climatic patterns, with soils or vegetation associations, and the like. The other systematic branch of geography is *human geography.* Its emphasis is on people: where they are, what they are like, how they interact over space, and what kinds of landscapes of human use they erect on the natural landscapes they occupy.

Why Geography Matters

There are three good reasons why people study geography. First, it is the only discipline concerned with understanding why and how both physical and cultural phenomena differ from place to place on the

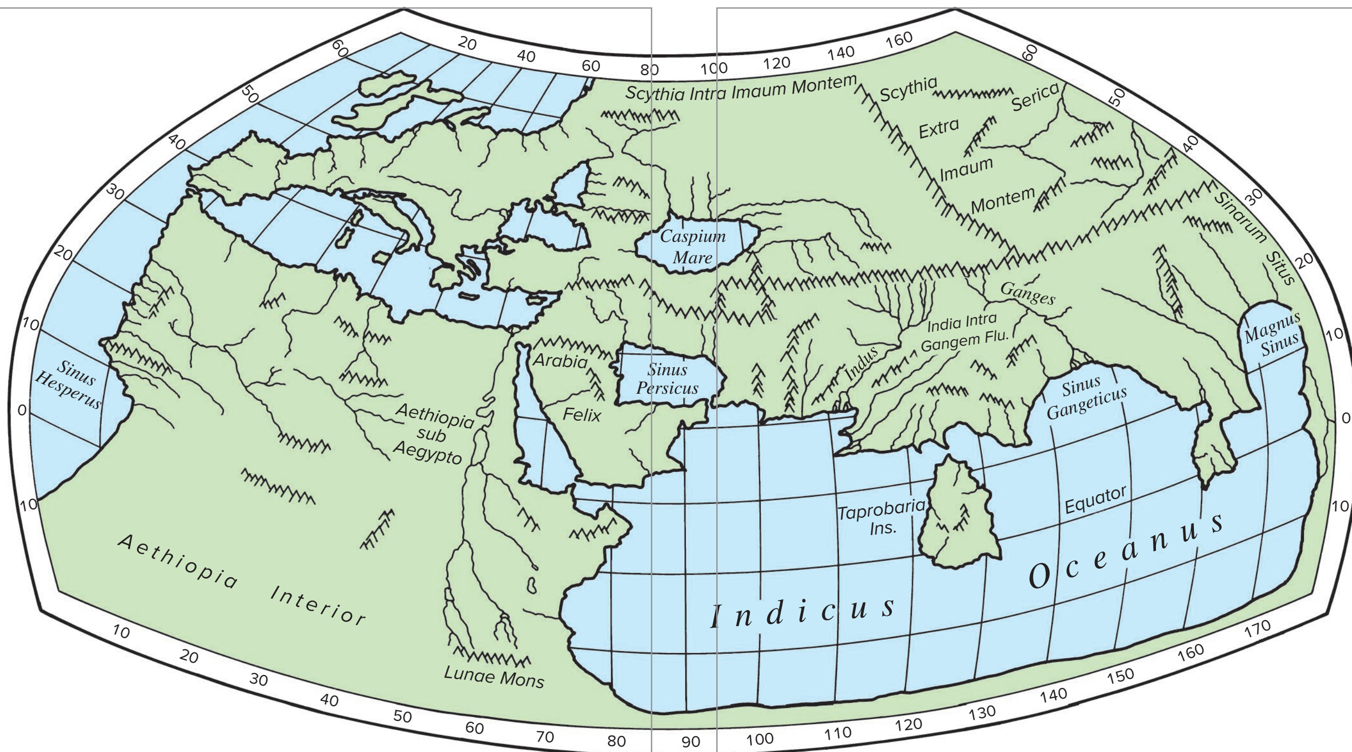


Figure 1.3 **World map of the 2nd century A.D. Greco-Egyptian geographer-astronomer Ptolemy.** Ptolemy (Claudius Ptolemaeus) adopted a previously developed map grid of latitude and longitude based on the division of the circle into 360°, permitting a precise mathematical location for every recorded place. Unfortunately, errors of assumption and measurement rendered both the map and its accompanying six-volume gazetteer inaccurate. Ptolemy's map, accepted in Europe as authoritative for nearly 1500 years, was published in many variants in the 15th and 16th centuries. The version shown here summarizes the extent and content of the original. Its underestimation of Earth's size and depiction of Asia extending farther east than it does convinced Columbus a short westward voyage from Europe would carry him to Asia.

surface of the Earth. Each chapter in this book is designed to give you a basic knowledge of the many processes that shape our world. Chapter 3, for example, introduces you to the tectonic forces that warp, fold, and fault landforms; create volcanoes; and cause earthquakes and tsunami. The discussion of cultural geography in Chapter 6 will give you a framework for understanding the technological, sociological, and ideological components of culture and an awareness of the forces that bring about changes in a culture over time.

Second, a grasp of the broad concerns and topics of geography is vital to an understanding of the national and international problems that dominate daily news reports. Global climate change; the diffusion of HIV-AIDS, Ebola, Zika, and other viruses; international trade imbalances; inadequate food supply and population growth in developing countries; turmoil in Africa and the Middle East—all of these problems have geographic dimensions, and geography helps explain them. Geographical literacy is essential to being able to comprehend local and world problems and contribute meaningfully to the development of solutions.

Third, because geography is such a broad field of study and yields such powerful insights, a great diversity of job opportunities await those who pursue university training in the discipline. Geographic training opens the way to careers in a wide array of fields (see "Careers in Geography"). Geographical techniques of analysis are used for determining the optimum location for new businesses, monitoring the spread of infectious diseases, delineating voting districts, interpreting satellite images, and a host of other tasks. A good introduction is *Why Geography Matters* (Oxford University Press, 2005) by Harm J. de Blij.

1.3 Some Core Geographic Concepts

The topics included within the broad field of geography are diverse. That very diversity, however, emphasizes the reality that all geographers—whatever their particular topical or regional interests—are united by the similar questions they ask and the common set of basic concepts they employ to consider their answers. Of either a physical or cultural phenomenon, they will inquire: What is it? Where is it? How did it come to be what and where it is? How is it related to other physical or cultural realities that affect it or are affected by it? How is it part of a functioning

CAREERS IN GEOGRAPHY

Geography admirably serves the goals of a liberal arts education. It makes us better-informed citizens, more able to understand the important issues facing our communities, our country, and our world and better prepared to contribute solutions.

Can it, as well, be a pathway to employment for those who specialize in the discipline? The answer is yes, in many different types of jobs.

Because of the breadth and diversity of the field, geography students learn techniques and approaches applicable to a wide variety of jobs outside the academic world. Modern geography is both a physical and social science and fosters a wealth of technical skills that are in high demand. The employment possibilities for geographers are as many and varied as are the public and private agencies and enterprises dealing with the natural environment, with human economic and social activities, and with the acquisition and analysis of spatial data. Training in geography offers a strong complement to many other fields such as biology, business, data science, economics, international development, political science, and sociology.

Many professional geographers work in government at the federal, state, and local levels and in a variety of international organizations. Indeed, geographers have made careers in essentially all of the many bureaus and offices of the executive departments of the U.S. national government—Agriculture, Commerce, Education, Environmental Protection, Health and Human Services, Homeland Security, Housing and Urban Development, Interior, Transportation, and others—and in their counterparts at the state level. Such major independent federal agencies as the Central Intelligence Agency (CIA), National Aeronautics and Space Administration (NASA), Federal Trade Commission, National Geospatial-Intelligence Agency (NGA), Federal Aviation Agency, and many others have steady need for geographically trained workers.

Although many positions do not carry a geography title, physical geographers serve as water and other natural resource analysts, weather and climate experts, soil scientists, and the like. Areas of recent high demand include environmental managers and technicians and geographic information specialists. Geographers who have specialized in environmental studies find jobs in both public and private agencies. Their work may include assessing the environmental impact of proposed development projects on air and water quality and endangered species, as well as preparing the environmental impact statements required before construction can begin.

Human geographers work in many different roles in the public sector. Jobs include data acquisition and analysis in health care, transportation, population studies, economic development, and international economics. Many geography graduates find positions as planners in local and state government agencies concerned with housing and community development, park and recreation planning, and urban and regional planning. They map and analyze land use plans and transportation systems, monitor urban land development, make informed recommendations about the location of public facilities, and engage in basic social science research.

Most of the same specializations are found in the private sector. Geographic training is ideal for such tasks as business planning and market analysis; factory, store, and shopping center site selection; and community and economic development programs for banks, public utilities, and railroads. Publishers of maps, atlases, news and travel magazines, and the like employ geographers as writers, editors, and mapmakers.

The combination of a traditional, broad-based liberal arts perspective with the technical skills required in geographic research and analysis gives geography graduates a competitive edge in the labor market. These field-based skills include familiarity with geographic information systems (GIS, explained in Chapter 2), cartography and computer mapping, remote sensing and photogrammetry, and competence in data analysis and problem solving. In particular, students with expertise in GIS, who are knowledgeable about data sources, hardware, and software, have strong employment opportunities.

Finally, another broad cluster of jobs involves supporting the field itself through teaching and research. Teaching opportunities exist at all levels, from elementary to university postgraduate.

whole? How does its location affect people's lives and the content of the area in which it is found?

These and similar questions are rooted in geography's concern with Earth and are derived from enduring central themes in geography. In answering them, geographers draw upon a common store of concepts, terms, and methods of study that together form the basic structure and vocabulary of geography. Geographers believe that recognizing spatial patterns is the essential starting point for understanding how people live on and shape the Earth's surface.

Geographers use the word *spatial* as an essential modifier in framing their questions and forming their concepts. Geography, they say, is a *spatial science.* It is concerned with the *spatial distribution* of phenomena, the *spatial extent* of regions, the *spatial behavior* of people, the *spatial relationships* between places on the Earth's surface, and the *spatial processes* that underlie those behaviors and relationships. Geographers use *spatial data* to identify *spatial patterns* and to analyze *spatial systems, spatial interaction, spatial diffusion,* and *spatial variation* from place to place.

The word *spatial* comes, of course, from *space,* and to geographers it always carries the idea of the way things are distributed, the way movements occur, and the way processes operate over the whole or a part of the surface of the Earth. The geographer's space, then, is Earth space, the surface area occupied or available to be occupied by humans. Spatial phenomena have locations on that surface, and spatial interactions occur among places, things, and people at different locations on Earth. The need to understand those relationships, interactions, and processes helps frame the questions that geographers ask.

Teachers with training in geography are in increasing demand in elementary and high schools in the United States, reflecting geography's inclusion as a core subject in federal education bills and the national determination to create a geographically literate society (see "The National Standards," p. xxx). The rapid growth of Advanced Placement Human Geography has also increased demand for geography teachers. At the university level, specialized teaching and research in all branches of geography have long been established. In addition to formal geography departments, geographically trained scholars teach and conduct research in urban, community, and environmental studies; regional science; locational economics; and other interdisciplinary programs.

The following table, based on the booklet "Careers in Geography,"[a] summarizes some of the professional opportunities open to students who have specialized in one (or more) of the various subfields of geography. Also, be sure to read the discussion of geography careers accessed on the homepage of the American Association of Geographers at www.aag.org. Additional links on the topic of geography careers can be found in the Online Learning Center for this text. The link can be found in the Preface.

Geographic Field of Concentration	Employment Opportunities
Cartography and geographic information systems	GIS specialist, cartographer, or remote sensing analyst for federal government (Defense Mapping Agency, U.S. Geological Survey, or Environmental Protection Agency), state or local government (city planning, natural resources, parks, or transportation), or private sector (land developers, real estate agencies, utility companies, or surveyors). GIS developer for Bentley, DigitalGlobe, Environmental Systems Research Institute, Google, Here, Hegagon, Mapbox, Microsoft-Bing Maps, Trimble, Uber, or other companies that provide geospatial technology.
Physical geography	Weather forecaster; outdoor guide; coastal zone manager; hydrologist; soil conservation/agricultural extension agent
Environmental studies	Environmental technician or manager; forestry technician; park ranger; naturalist
Cultural geography	Community developer; Peace Corps volunteer; health care analyst
Economic geography	Site selection analyst for business and industry; market researcher; traffic/route delivery manager; real estate agent/broker/appraiser; economic development researcher
Urban and regional planning	Urban and community planner; transportation planner; housing, park, and recreation planner; health services planner
Regional geography	Area specialist for federal government; international business representative; travel agent; travel writer
Geographic education	Elementary/secondary school teacher; university geography professor; overseas teacher

[a] "Careers in Geography," by Richard G. Boehm. Washington, D.C.: National Geographic Society, 1996. Previously published by Peterson's Guides, Inc.

Those questions have their starting point in basic observations about the location and nature of places and about how places are similar to or different from one another. Such observations, though simply stated, are profoundly important to our comprehension of the world we occupy.

- Places have location, direction, and distance with respect to other places.
- A place has size; it is large, medium, or small. Scale is important.
- A place has both physical structure and cultural content.
- The attributes, or characteristics, of places develop and change over time.
- The content of places is structured and explainable.
- Places are connected to other places.
- Places may be generalized into regions sharing similar features.

These basic notions are the means by which geographers express fundamental observations about the Earth space they examine and put those observations into a common framework of reference. Each of the concepts is worth further discussion, for they are not quite as simple as they seem.

Location, Direction, and Distance

Location, direction, and *distance* are everyday ways of assessing the space around us and identifying our position in relation to other things and places of interest. They are also essential in understanding the processes of spatial interaction that figure so importantly in the study of both physical and human geography.

Location

The **location** of places and things is the starting point of all geographic study as well as of our personal movements and spatial actions in everyday life. We think of and refer to location in at least two different senses, *absolute* and *relative.*

Absolute location is the identification of place by a precise and accepted system of coordinates; therefore, sometimes it is called *mathematical location.* We have several such accepted systems of pinpointing positions. One of them is the global grid of parallels and meridians—that is, latitude and longitude (discussed in Chapter 2, pp. xxx). With it, the absolute location of any point on the Earth can be accurately described by reference to its degrees, minutes, and seconds of *latitude* and *longitude.*

Other coordinate systems are also in use. Survey systems such as the township, range, and section description of property in much of the United States give mathematical locations on a regional level. A street address precisely defines a building according to the reference system of an individual town. Absolute location is unique to each described place, is independent of any other characteristic or observation about that place, and is used in the legal description of places, in measuring the distance separating places, or in finding directions between places on the Earth's surface.

When geographers—or real estate agents—remark that "location matters," however, their reference is usually not to absolute but to **relative location**—the position of a place or thing in relation to that of other places or things (**Figure 1.4**). Relative location expresses spatial interconnection and interdependence and may carry social and economic implications. For a real estate developer, a good location might mean proximity to a highway, a growing neighborhood, and high rents. On an immediate and personal level, we think of the location of the school library not in terms of its street address but where it is relative to our classrooms, the cafeteria, or another reference point. On the larger scene, relative location tells us that people, things, and places exist not in a spatial vacuum but in a world of physical and cultural characteristics that differ from place to place.

New York City, for example, may be described in absolute terms as located at (approximately) latitude 40°43′N (read as 40 degrees, 43 minutes north) and longitude 73°58′W. We have a better understanding of the meaning of its location, however, when reference is made to its spatial relationships: to the continental interior through the Hudson-Mohawk lowland corridor or to its position on the eastern seaboard of the United States. Within the city, we gain understanding of the locational significance of Central Park or the Lower East Side not solely by reference to the street addresses but also by their spatial and functional relationships to the land use, activity, and population patterns of New York City.

In view of these different ways of looking at location, geographers make a distinction between the *site* and the *situation* of a place (**Figure 1.5**). **Site,** an absolute location concept, refers to the physical and cultural characteristics and attributes of the place itself. It is more than mathematical location, for it tells us something about the specific features of that place. **Situation,** on the other hand, refers to the relations between a place and other places. It is an expression of relative location with particular reference to items of significance to the place in question. Site and situation in the city context are further examined in Chapter 11.

Figure 1.4 **The reality of *relative location*** on the globe may be strikingly different from the impressions we form from flat maps. The position of Russia with respect to North America when observed from a polar perspective emphasizes that relative location properly viewed is important to our understanding of spatial relationships and interactions between the two world areas.

Direction

Direction is the second universal spatial concept. Like location, it has more than one meaning and can be expressed in absolute or relative terms. **Absolute direction** is based on the cardinal points of north, south, east, and west. These appear in all cultures, derived from the obvious "givens" of nature: the rising and setting of the sun for east and west, the sky location of the noontime sun and of certain fixed stars for north and south.

We also commonly use **relative,** or *relational,* **directions.** In the United States, we go "out West," "back East," or "down South"; we worry about conflict in the "Near East" or economic competition from the "Far Eastern countries." Despite their reference to cardinal compass points, these directional references are culturally based and locationally variable. Orientalism—labels and descriptions of North Africa and Asia that reflect a European colonizer's perspective—shaped commonly used regional names. The Near East and the Far East locate parts of Asia from the European perspective; they are retained in the Americas by custom, even though one would normally travel westward across the Pacific, for example, to reach the "Far East" from California, British Columbia, or Chile. For many Americans, "back East" and "out West" are reflections of the migration paths of earlier generations for whom home was in the eastern part of the country, to which they might look back. "Up North" and "down South" reflect our accepted custom of putting north at the top and south at the bottom of our maps.

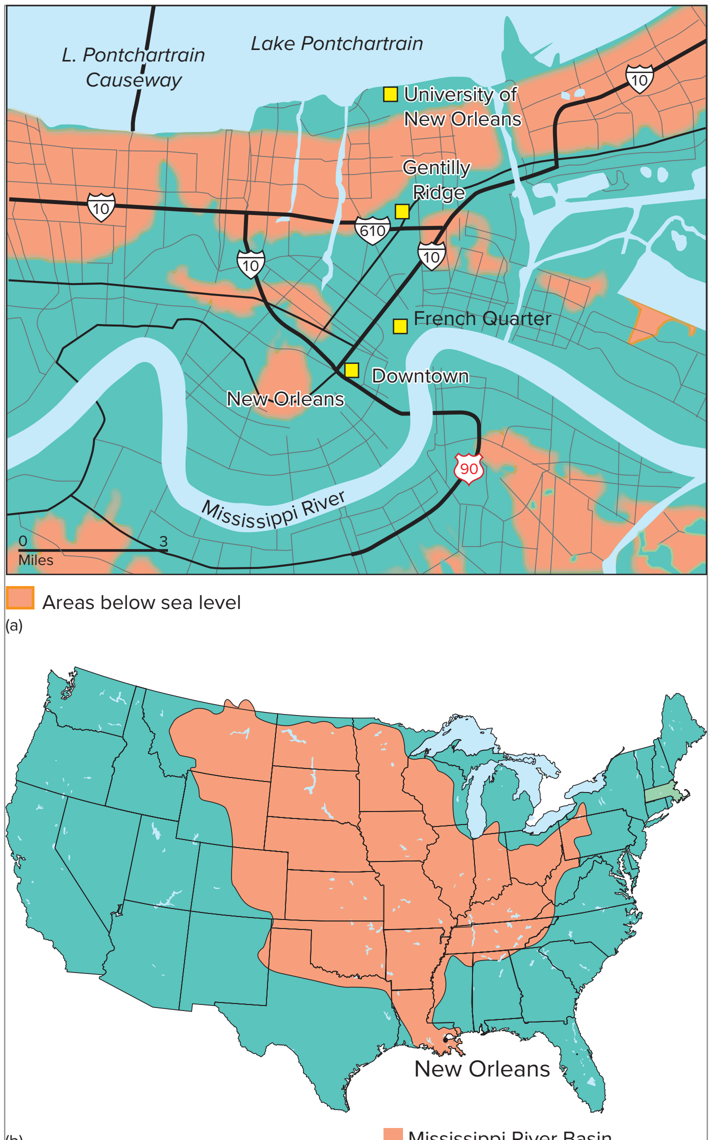


Figure 1.5 **Site and Situation (a)** The *site* of New Orleans is hardly ideal for building a city. The French occupied the most suitable high ground they could find near the mouth of the Mississippi River. The site extends from the "high ground" on the natural levee next to the Mississippi River to former wetlands near Lake Pontchartrain. Much of the city and its suburbs are below sea level on sinking soils composed of soft sediments deposited by past river floods. **(b)** The *situation* of New Orleans is ideal for building a city. New Orleans is connected to 9000 miles of navigable waterways through the Mississippi River, which drains a basin that stretches from the Rocky Mountains to the Appalachian Mountains.

Distance

Distance joins *location* and *direction* as a commonly understood term that has dual meanings for geographers. Like its two companion spatial concepts, distance may be viewed in both an absolute and a relative sense.

Absolute distance refers to the spatial separation between two points on the Earth's surface, measured by an accepted standard unit—such as miles or kilometers for widely separated locales, feet or meters for more closely spaced points. **Relative distance** transforms those linear measurements into other units more meaningful to human experience or decision making.

To know that two competing malls are about equidistant in miles from your residence is perhaps less important in planning your shopping trip than is knowing that, because of street conditions or traffic congestion, one is 5 minutes and the other 15 minutes away (**Figure 1.6**). Most people, in fact, think of time distance rather than linear distance in their daily activities: Downtown is 20 minutes by bus; the library is a 5-minute walk. In some instances, money rather than time is the measure of relative distance. An urban destination might be estimated to be a $20 Uber ride away, information that may affect either the decision to make the trip at all or the choice of travel mode to get there. As a university student, you already know that rooms and apartments are less expensive at a greater distance from campus.

A *psychological* transformation of linear distance is also common. A solitary late-night walk back to the car through an unfamiliar or dangerous neighborhood seems far longer than a daytime stroll of the same distance through familiar and friendly territory. A first-time trip to a new destination frequently seems much longer than the return trip over the same path. Nonlinear distance and spatial interaction are further considered in Chapter 7.

Size and Scale

When we say that a place may be large, medium, or small, we speak both of the nature of the place itself and of the generalizations that can be made about it. Geographers are concerned with **scale,** though we may use that term in different ways. We can, for example, study a problem such as population or landforms at the local scale or on a global scale. Here, the reference is purely to the size of unit studied. More technically, scale tells us the relationship between the size of an area on a map and the actual size of the mapped area on the surface of the Earth. In this sense, as Chapter 2 makes clear, scale is a feature of every map and is essential to recognizing what is shown on that map.

In both senses of the word, *scale* implies the degree of generalization represented (**Figure 1.7**). Geographic inquiry may be broad or narrow; it occurs at many different size scales. While the study of climate relies on universal scientific principles, climates can be studied at the global scale, the continental scale, or even that of the microclimates of a city. Awareness of scale is very important. In geographic work, concepts, relationships, and understandings that have meaning at one scale may not be applicable at another.

For example, the study of world agricultural patterns may refer to global climate patterns, cultural food preferences, levels of economic development, and patterns of world trade. These large-scale relationships are of little concern in the study of crop patterns within single counties of the United States, where topography, soil and drainage conditions, farm size, ownership, and capitalization, or even personal management preferences, may be of greater explanatory significance.

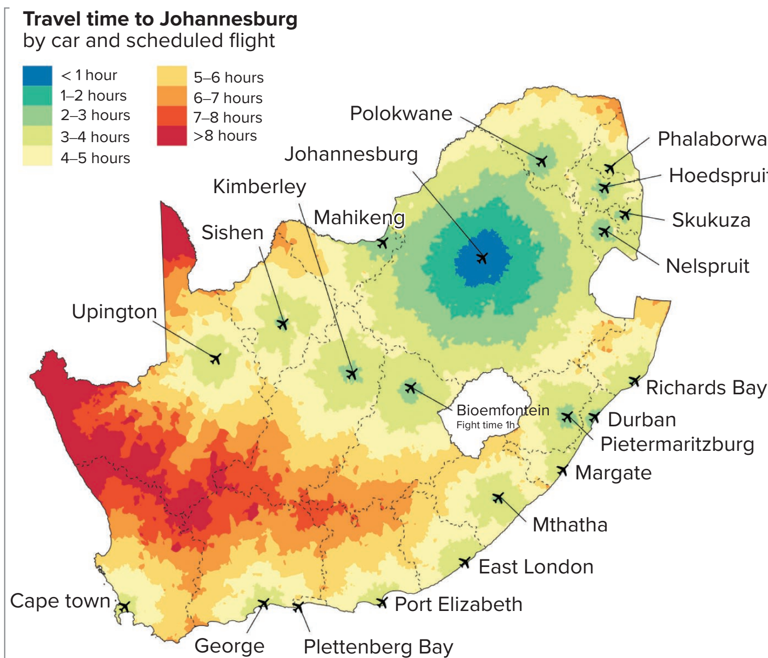


Figure 1.6 Travel times to Johannesburg, South Africa, 2017. This map includes travel by both car and airplane using the existing road and airport network and assumed airport check-in delays. Lines of equal travel time (*isochrones:* from Greek *isos,* equal, and *chronos,* time) indicate areas that are the same relative distance from the destination, regardless of their absolute distance. The fingerlike outlines of isochrone boundaries reflect variations in road accessibility and speeds. Note the effect of proximity to airports on travel time. *Courtesy of Adrian Frith.*

Physical and Cultural Attributes

All places have individual physical and cultural attributes distinguishing them from other places and giving them character, and meaning. Geographers are concerned with identifying and analyzing the details of those attributes and, particularly, with recognizing the interrelationship between the physical and cultural components of area: the human-environmental interface.

The physical characteristics of a place are such natural aspects as its climate, soil, water supplies, mineral resources, terrain features, and the like. These **natural landscape** attributes provide the setting within which human action occurs. They help shape—but do not dictate—how people live. The resource base, for example, is physically determined, though how resources are perceived and utilized is culturally conditioned.

Environmental circumstances directly affect agricultural potential and reliability; indirectly, they may affect such matters as employment patterns, trade flows, population distributions, national diets, and so on. The physical environment simultaneously presents advantages and disadvantages with which humans must deal. Thus, all places offer trade-offs in terms of climate favorability, natural hazards, farming and fishing productivity, natural resources, and natural scenery. For example, a scenic volcano may someday erupt, or a mild, coastal location may be vulnerable to hurricanes, and so forth. Physical environmental patterns and processes are explored in Chapters 3 and 4 of this book.

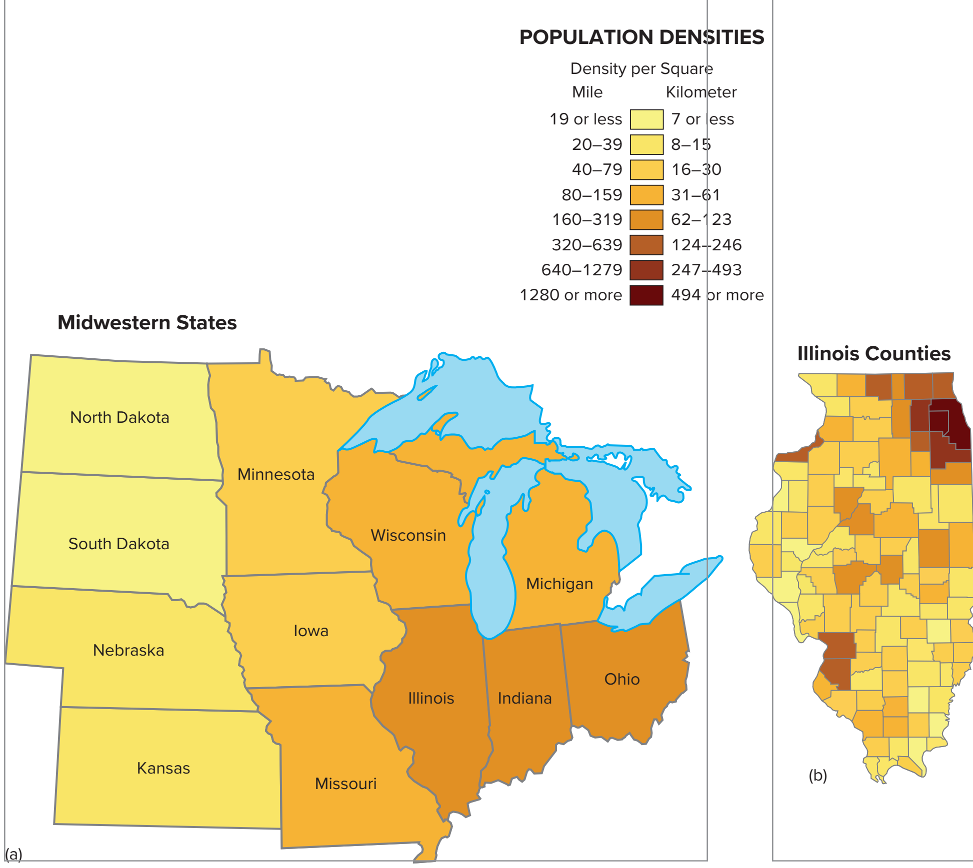


Figure 1.7 Population density and map scale. "Truth" depends on one's scale of inquiry. Map **(a)** reveals that the maximum year 2010 population density of midwestern states was no more than 123 people per square kilometer (319 per sq mi). From map **(b)**, however, we see that population densities in three Illinois counties exceeded 494 people per square kilometer (1280 per sq mi) in 2010. If we were to reduce our scale of inquiry even further, examining individual city blocks in Chicago, we would find densities reaching 2500 or more people per square kilometer (10,000 per sq mi). Scale matters!

At the same time, by occupying a given place, people modify its physical attributes. The visible imprint of that human activity is called the **cultural landscape.** It, too, exists at different scales and at different levels of visibility. Contrasts in agricultural practices and land use between Mexico and southern California are evident from space, as shown in **Figure 1.8**, whereas the signs, structures, and people of Los Angeles's Chinatown leave a smaller, more confined imprint within the larger cultural landscape of the metropolitan area itself.

The physical and human characteristics of places are the keys to understanding both the simple and the complex interactions and interconnections between people and the environments they occupy and modify. Those interconnections and modifications are not static or permanent but are subject to continual change.

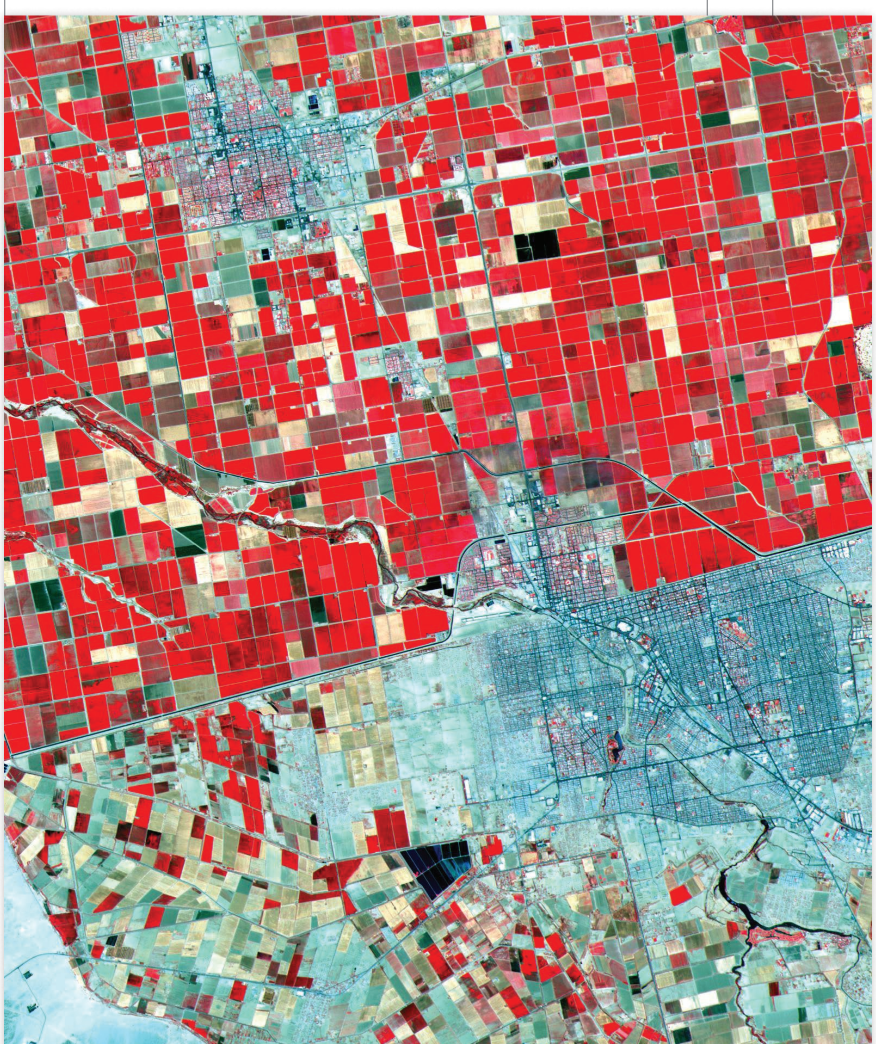


Figure 1.8 This Landsat satellite image reveals contrasting cultural landscapes along the Mexico-California border. Move your eyes from the Salton Sea (the dark patch at the top of the image) southward to the agricultural land extending to the edge of the picture. Notice how the regularity of the fields and the bright colors (representing growing vegetation) give way to a marked break, where irregularly shaped fields and less prosperous agriculture are evident. Above the break is the Imperial Valley of California; below the border is Mexico. *NASA/GSFC/MITI/ERSDAC/JAROS, and the U.S./Japan ASTER Science Team.*

The existence of the U.S. Environmental Protection Agency (and its counterparts elsewhere) is a reminder that humans are the active and frequently harmful agents in the continuing interplay between the cultural and physical worlds (**Figure 1.9**). Virtually every human activity leaves its imprint on the Earth's soil, water, vegetation, animal life, and other resources, as well as on the atmosphere common to all Earth space, as Chapters 12 and 13 make clear.

Attributes of Place Are Always Changing

The physical environment surrounding us seems eternal and unchanging but, of course, it is not. In the framework of geologic time, change is both continuous and pronounced. Islands form and disappear; mountains rise and are worn low to swampy plains; vast continental glaciers form, move, and melt away, and sea levels fall and rise in response. Geologic time is long, but the forces that give shape to the land are timeless and relentless.

Even within the short period of time since the most recent retreat of continental glaciers—12,000 or 13,000 years ago—the environments occupied by humans have been subject to change. Glacial retreat itself marked a period of climatic alteration, extending the area habitable by humans to include vast reaches of northern Eurasia and North America formerly covered by thousands of feet of ice. With moderating climatic conditions came changes in vegetation and fauna. On the global scale, these were natural environmental changes; humans were as yet too few in number and too limited in technology to alter materially the course of physical events. On the regional scale, however, even early human societies exerted an impact on the environments they occupied. Fire was used to clear forest undergrowth, to maintain or extend grassland for grazing animals and to drive them in the hunt, and later to clear openings for rudimentary agriculture.

With the dawn of civilizations and the invention and spread of agricultural technologies, humans accelerated their management and alteration of the now no longer "natural" environment. Even the classical Greeks noted how the landscape they occupied differed—for the worse—from its former condition. With growing numbers of people, and particularly with industrialization and the spread of European exploitative technologies throughout the world, the pace of landscape change accelerated. The built landscape—the product of human effort—increasingly replaced the natural landscape. Each new settlement or city; each agricultural assault on forests; and each new mine, dam, or factory changed the content of regions and altered the previous spatial interconnections between humans and the environment.

Characteristics of places today are the result of constantly changing past conditions. They are the forerunners of future human-environmental relationships. Geographers are concerned with places

Figure 1.9 All human activities have some impact on the environment. Sites such as this Anacortes, Washington, oil refinery are major emitters of potentially toxic chemicals to the atmosphere, land, and water. Pollution control technologies have significantly reduced, but not eliminated, their negative impacts on the environment. However unsightly or smelly they may be, oil refineries provide the gasoline, diesel, heating oil, jet fuel, and asphalt products that are necessary to economic activity and everyday life in industrialized countries. *Walter Siegmund.*

at given moments of time. But to understand fully the nature and development of places, to appreciate the significance of their relative locations, and to understand the interplay of their physical and cultural characteristics, geographers must view places as the present result of past physical and cultural processes (**Figure 1.10**).

You will recall that one of the questions geographers ask about a place or thing is "How did it come to be what and where it is?" This is an inquiry about processes of change. The forces and events shaping the physical and explaining the cultural environment of places today are an important focus of geography and are the topics of most of the chapters of this book. To understand them is to appreciate the changing nature of the spatial order of our contemporary world.

Interrelations between Places

The concepts of relative location and distance that were introduced earlier lead to another fundamental spatial reality: Places are interrelated with other places in ways that geographers attempt to describe, measure, and map. In describing the processes and patterns of that **human interaction,** geographers add *accessibility* and *connectivity* to the ideas of location and distance.

Tobler's First Law of Geography tells us that, in a spatial sense, everything is related to everything else, but relationships are stronger when things are near one another.

(a)

(b)

Figure 1.10 The process of change in a cultural landscape. (a) New York's natural harbor made it a great location for a city to grow. It was already the largest city in the United States when this bird's-eye-view map was created in 1874. **(b)** The continued growth of New York and the development of high-rise construction techniques allowed the city's buildings and population density to soar. *(a) Library of Congress Geography and Map Division [LC-DIG-pga-02708]. (b) Sokolova23/Shutterstock.com.*

Our observation, therefore, is that interaction between places diminishes in intensity and frequency as distance between them increases—a statement of the idea of "distance decay," which we explore in Chapter 7. Are you more likely to go to a fast-food outlet next door or to a nearly identical restaurant across town? Our decision making sometimes is unpredictable, but in this case you can see that most people would probably choose the nearer place more often.

Consideration of distance implies concern with **accessibility.** How easy or difficult is it to overcome the "friction of distance"? That is, how easy or difficult is it to overcome the barrier of the time and spatial separation of places? Distance isolated North America from Europe until the development of ships (and aircraft) that reduced the effective distance between the continents. All parts of ancient and medieval cities were accessible by walking; they were "walking cities," whereas today's cities are based on public transit or automobiles and highways. Accessibility between city districts increased with the development of public transit systems whose fixed lines of travel increased the ease of movement between connected points but reduced it between areas not on the transit lines themselves.

Accessibility, therefore, suggests the idea of **connectivity,** a broader concept implying all the tangible and intangible ways in which places are connected: by physical telephone lines, street and road systems, and pipelines and sewers; by unrestrained walking across open countryside; by radio and TV broadcasts; by cell phone service areas; and in nature even by movements of wind systems and ocean currents. Where routes are fixed and flow is channelized, *networks*—the patterns of routes connecting sets of places—determine the efficiency of movement and the connectedness of points. Demand for universal instantaneous connectivity is often an unquestioned assumption in today's advanced societies. Technologies and devices to achieve it proliferate, as our own lifestyles show. Cell phones, e-mail, broadband wireless Internet, instant messaging, video chat, and more have erased time and distance barriers formerly separating and isolating individuals and groups. These communication technologies have reduced our dependence on physical movement and on networks fixed in the landscape.

There is, inevitably, interchange between connected places. **Spatial diffusion** is the process of spread or dispersion of an idea or a thing (a new consumer product or a new song, for example) from a center of origin to more distant points. The rate and extent of that diffusion are affected, again, by the distance separating the origin of the new idea or technology and other places where it is eventually adopted. Diffusion rates are also affected by such factors as population densities, means of communication, advantages of the innovation, and importance or prestige of the originating node. Further discussion of spatial diffusion is found in Chapter 7.

Geographers study the dynamics of spatial relationships. Movement, connection, and interaction are part of the social and economic processes that give character to places and regions (**Figure 1.11**). The increasingly global reach of those spatial interactions is expressed in the term *globalization.* **Globalization** implies the increasing interconnection of more and more peoples and parts of the world as the full range of social, cultural, political, economic, and environmental processes becomes international in scale and effect. Promoted by continuing advances in worldwide accessibility and connectivity, globalization encompasses other

Figure 1.11 An indication of one form of spatial interaction and connectivity is suggested by this network map depicting airports and the air traffic routes that connect them. *Martin Grandjean.*

core geographic concepts of spatial interaction, accessibility, connectivity, and diffusion. More detailed implications of globalization will be touched on in Chapters 7 through 10.

Place Similarity and Regions

The distinctive characteristics of places—physical, cultural, locational—suggest two geographically important ideas. The first is that no two places on the surface of the Earth can be *exactly* the same. Not only do they have different absolute locations, but—as in the features of the human face—the precise mix of physical and cultural characteristics of place is never exactly duplicated. The inevitable uniqueness of place would seem to impose impossible problems of generalizing spatial information.

That this is not the case results from the second important idea, that the natural and cultural characteristics of places show patterns of similarity in some areas. For example, a geographer doing fieldwork in Brazil may find that all farmers in one area are growing the same crops in their fields. Often, such similarities are striking enough for us to conclude that spatial regularities exist. They permit us to recognize and define **regions,** Earth areas that display significant elements of internal uniformity and external differences from surrounding territories. Places are, therefore, both unlike and like other places, creating patterns of areal differences and spatial similarity.

The problems of the historian and the geographer are similar. Each must generalize about objects of study that are essentially unique. The historian creates arbitrary but meaningful and useful historical periods for reference and study. The "Roaring Twenties" and the "Victorian Era" are shorthand summary names for specific time spans, internally quite varied but significantly distinct from what went before or followed after. The region is the geographer's equivalent of the historian's era: a device to classify the complex reality of the Earth's surface into manageable pieces. Just as historians focus on key events to characterize certain historical periods, geographers focus on key unifying elements or similarities to determine the boundaries of regions. By identifying and naming regions, a complex set of interrelated environmental or cultural attributes can easily be conveyed through a simpler construct.

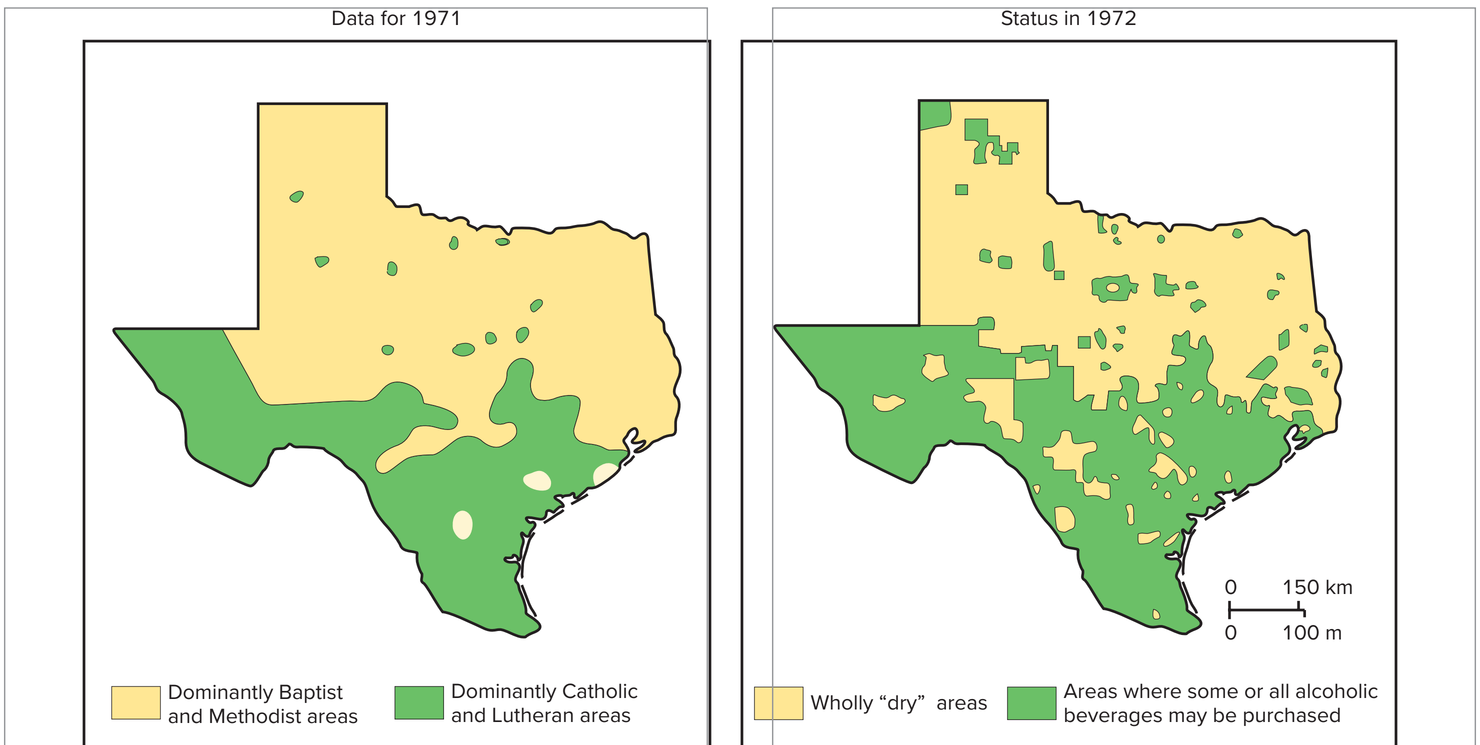


Figure 1.12 **Spatial distributions of religion and alcohol sales in Texas.** Catholic and Lutheran areas tend to be "wet," and Baptist and Methodist areas tend to retain prohibition. Both Baptist and Methodist churches have traditionally taken a stand against the consumption of alcohol. The two maps suggest a spatial association between religion and alcohol prohibition laws. *Sources: 38th Annual Report of the Texas Alcoholic Beverage Commission, Austin, 1972, p. 49; and Churches and Church Membership in the United States: 1971, National Council of Churches of Christ in the U.S.A., 1974.*

Spatial Distributions

Regions are not "given" in nature any more than "eras" are given in the course of human events. Regions are devised; they are spatial summaries designed to bring order to the infinite diversity of Earth's surface. At their root, they are based on the recognition and mapping of *spatial distributions*—the spatial arrangement of environmental, human, or organizational features selected for study. For example, the location of Welsh speakers in Great Britain is a distribution that can be identified and mapped. As many spatial distributions exist as there are physical, cultural, or connectivity elements to examine. Those that are selected for study, however, are those that contribute to the understanding of a specific topic or problem.

Let us assume that we are interested in studying burglary rates in the United States. Statistics indicate that some states have significantly higher rates than others. A resident of California is roughly three times as likely to be a victim of a burglary as a resident of New Hampshire. We would ask whether the distribution of rates appears random. Mapping the spatial distribution is a first step and shows that the states with the highest rates appear to be clustered along the southern border and the West Coast. Next, we must try to explain the spatial distribution. We would ask what factors account for the observed pattern. We would ask whether the pattern is similar to that for other types of crimes. Because it is commonly assumed that big cities, poverty, and youthful populations are associated with crime, we would want to see whether any of those distributions were correlated with burglary rates.

When two spatial distributions are closely related, they are said to have a *spatial association*. In **Figure 1.12**, we observe that communities in Texas where consuming alcoholic beverages is legal tend to have a majority of Catholic or Lutheran residents, while so-called dry communities are more likely to be predominantly Baptist or Methodist. Geographers attempt to identify spatial associations that are stronger than expected by chance alone.

Types of Regions

Regions may be *administrative, formal, functional,* or *perceptual.* **Administrative regions** are created by laws, treaties, or regulations. Examples include countries, states, counties, cities, and school districts. The political map of the world shows the boundaries of one set of administrative regions. Even the end zone on a football field—where the scoring takes place—is an administrative region. Boundaries of administrative regions are as precisely defined as measurement allows, and generally laws and rules are applied uniformly to all places within those boundaries.

A **formal** (or **uniform**) **region** is an area of essential uniformity for a single physical or cultural feature or a limited combination of physical or cultural features. The name *Corn Belt* suggests a region based on its farm economy and predominant crop. **Figure 1.13** depicts formal regional patterns. The formal region is based on objective, often statistically derived identifiers. Whatever the basis of its definition, the formal region is a sizable area over which a

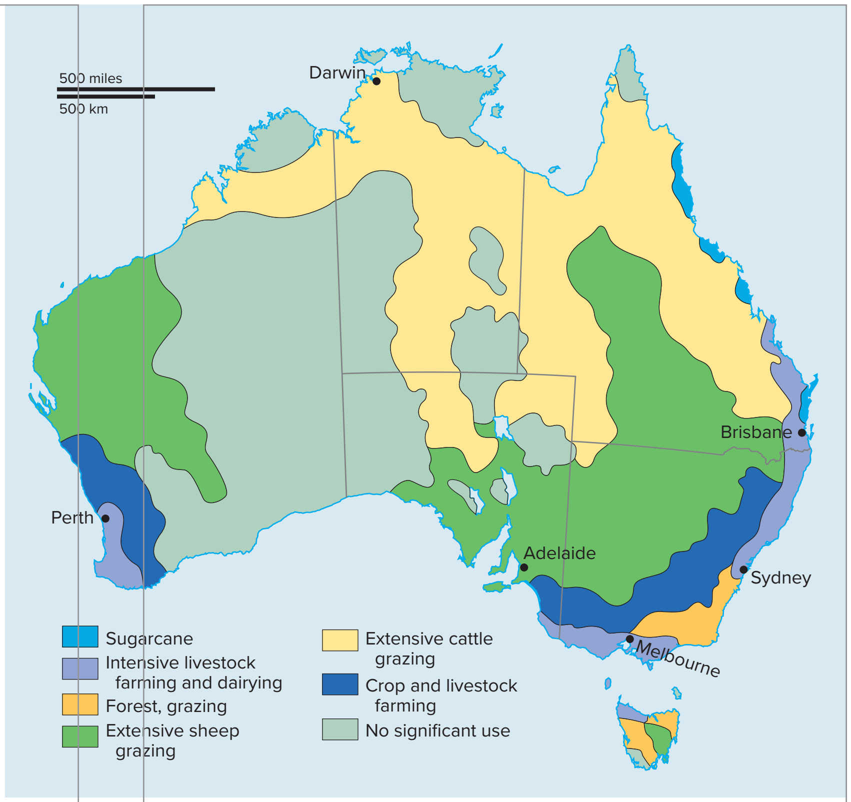


Figure 1.13 **This generalized land use map of Australia** is composed of *formal regions* whose internal economic characteristics show essential uniformities, setting them off from adjacent territories of different condition or use.

valid generalization of uniformity with respect to some attribute or attributes holds true.

A **functional** (or **nodal**) **region,** in contrast, may be visualized as a spatial system. Its parts are interdependent, and throughout its extent the functional region operates as a dynamic, organizational unit. Like the formal region, a functional region is objectively defined, but a functional region has unity in its active connectivity, not its static content. The defining interaction and connection of a functional region are most clearly recognized at its node or core. As the extent of control and interaction in an area changes, the boundaries of the functional region change in response; that is, a nodal region's boundaries remain constant only as long as the interchanges that establish it remain unaltered. Examples are the trade areas of towns, the circulation area of a newspaper, the area that receives a television station's signal, and the territories served by the financial, administrative, health care, and retail functions of regional centers, such as Chicago, Atlanta, or Denver (**Figure 1.14**).

Perceptual (or **vernacular** or **popular**) **regions** are less rigorously structured than the formal and functional regions geographers devise. They are regions that exist in the perceptions of their inhabitants and the general society. As composites of the mental maps of ordinary folk, they reflect feelings and images rather than objective data. Because of that, perceptual regions may be more meaningful in individuals' daily lives than the more objective regions of geographers.

Ordinary people have a clear idea of spatial variation and employ the regional concept to distinguish between areas. People individually and collectively agree on where they live. The vernacular regions they recognize have reality in their minds and are reflected in regional names employed in businesses, by sports teams, or in advertising slogans. The frequency of references to "New England" in the northeastern United States represents that kind of regional consensus and awareness, as does "Midwest" in popular understanding and literary references (**Figure 1.15**). The boundaries of vernacular regions, of course, vary on the mental maps of different groups both within and outside the area. Still, the regions are important for they reflect the way people view space, assign their loyalties, and interpret their world. At a different scale, urban ethnic enclaves such as "Little Italy" and "Chinatown" have clear regional identities in the minds of their inhabitants. Less clearly perceived by outsiders but unmistakable to their inhabitants are the "turfs" of urban clubs or gangs. Their boundaries are sharp, and the perceived distinctions between them are paramount in the daily lives of their occupants.

As you read the chapters of this book, notice how many examples of regions are presented in map form and discussed in the text. Note, too, how those depictions and discussions vary between the four different regional types as the subjects and purposes of the examples change.

1.4 Geography's Themes and Standards

The core geographic concepts discussed so far in this chapter reflect both the "fundamental themes in geography" and the "National Geography Standards." Together, the "themes" and

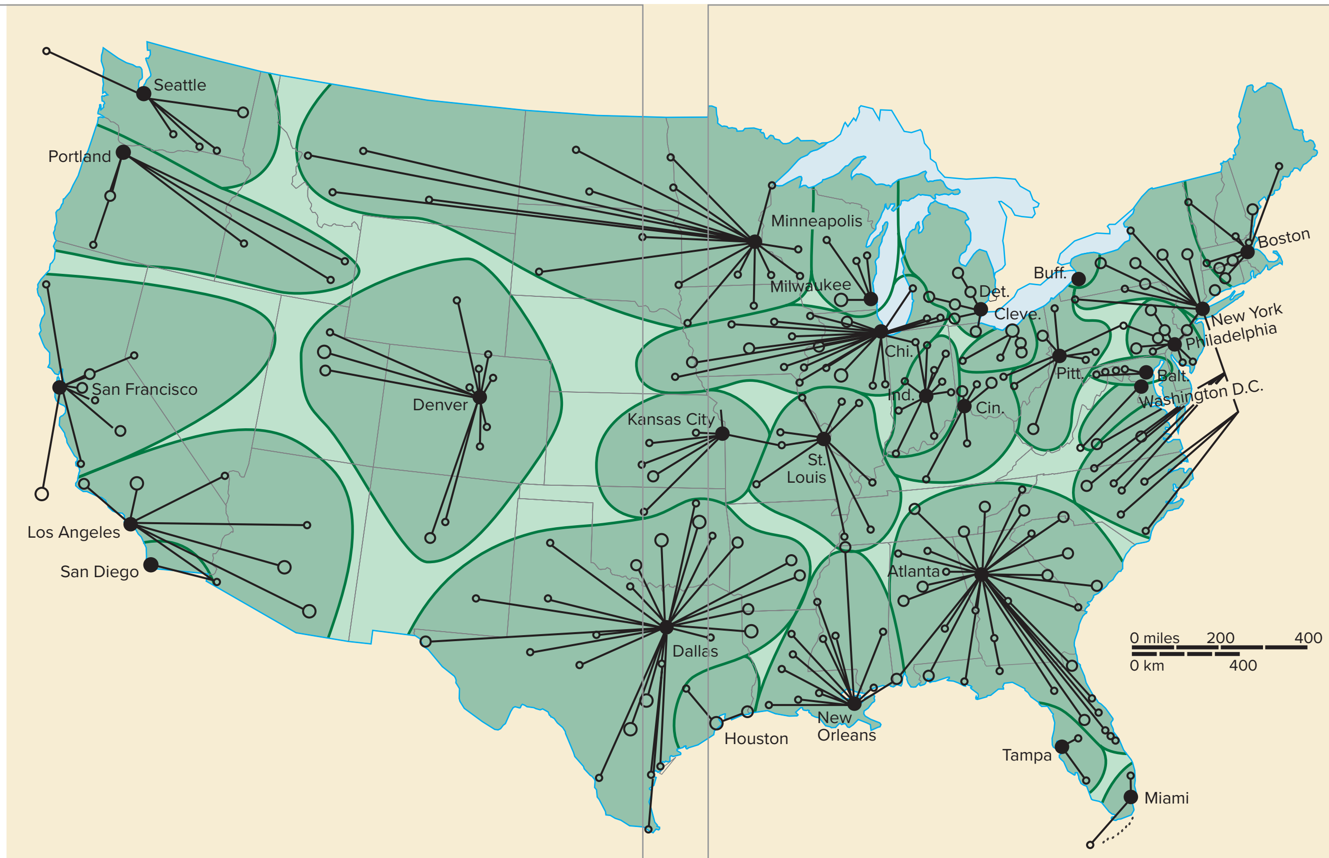


Figure 1.14 **The functional regions shown on this map were based on linkages between large banks of major central cities and the "correspondent" banks they formerly served in smaller towns.** Although the rise of nationwide banks has reduced their role, the regions once defined an important form of *connectivity* between principal cities and locales beyond their own immediate metropolitan area. *Source: Redrawn by permission from* Annals of the Association of American Geographers, *John R. Borchert, Vol. 62, p. 358, Association of American Geographers, 1972.*

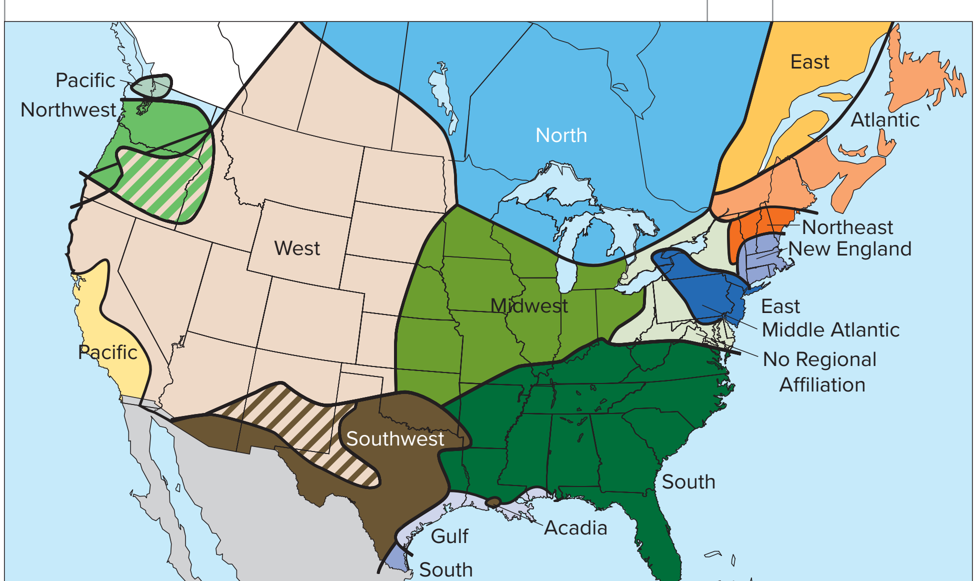


Figure 1.15 **Perceptual (vernacular or popular) regions of North America.** *Source: Wilbur Zelinsky, "North America's Vernacular Regions" in* Annals of the Association of American Geographers, *Vol. 70, Figure l, p. 14, 1980. Redrawn with permission.*

"standards" have helped organize and structure the study of geography over the past several years at all grade and college levels. Both focus on the development of geographic literacy. The former represent an instructional approach keyed to instruction in the knowledge, skills, and perspectives students should gain in geographic education. The latter—"standards"—codify the essential subject matter, skills, and perspectives of geography essential to the mental equipment of all educated adults.

THE NATIONAL STANDARDS

There is a widespread consensus that a grasp of the skills and content of geography is essential to productive and responsible citizenship. Geographic literacy is key to making wise decisions about economic development, urban growth, environmental protection, and national security. Thus, geography is listed as a core subject in the Every Student Succeeds Act, which U.S. president Barack Obama signed into law in 2015. The National Geography Standards 1994 help frame the purpose and benefit of studying geography. This book was written to provide the kind of geographic understanding called for by the National Geography Standards.

The National Geography Standards consist of six essential elements and 18 specific standards. The geography standards tell us that: *The geographically informed person knows and understands:*

Essential Element 1: The World in Spatial Terms

1. How to use maps and other geographic tools and technologies to acquire, process, and report information from a spatial perspective.
2. How to use mental maps to organize information about people, places, and environments in a spatial context.
3. How to analyze the spatial organization of people, places, and environments on Earth's surface.

Essential Element 2: Places and Regions

4. The physical and human characteristics of places.
5. That people create regions to interpret Earth's complexity.
6. How culture and experience influence people's perceptions of places and regions.

Essential Element 3: Physical Systems

7. The physical processes that shape the patterns of Earth's surface.
8. The characteristics and spatial distribution of ecosystems on Earth's surface.

Essential Element 4: Human Systems

9. The characteristics, distribution, and migration of human populations on Earth's surface.
10. The characteristics, distribution, and complexity of Earth's cultural mosaics.
11. The patterns and networks of economic interdependence on Earth's surface.
12. The processes, patterns, and functions of human settlement.
13. How the forces of cooperation and conflict among people influence the division and control of Earth's surface.
14. How human actions modify the physical environment.

Essential Element 5: Environment and Society

15. How physical systems affect human systems.
16. The changes that occur in the meaning, use, distribution, and importance of resources.

Essential Element 6: The Uses of Geography

17. How to apply geography to interpret the past.
18. How to apply geography to interpret the present and plan for the future.

Source: *Geography for Life: National Geography Standards 1994.* Washington, D.C.: National Geographic Society Committee on Research and Exploration, 1994.

The *five fundamental themes,* as summarized in 1984 by a joint committee of the National Council for Geographic Education and the Association of American Geographers, are those basic concepts and topics that should appear in all levels of geographic instruction:

1. location: the meaning of relative and absolute position on the Earth's surface;
2. place: the distinctive and distinguishing physical and human characteristics of locales;
3. relationships within places: the development and consequences of human-environmental interactions;
4. movement: patterns and change in human spatial interaction on the Earth;
5. regions: how they form and change.

The National Geography Standards were established in 1994 to summarize the knowledge and skills of a geographically literate person (see "The National Standards"). Designed specifically as a guide to the essential geographic literacy to be acquired by students who have gone through the U.S. public school system, the standards address the same conviction underlying this edition of *Introduction to Geography*—that being literate in geography is a necessity for all informed persons.

1.5 Organization of This Book

Despite its diversity, geography has a broad consistency of purpose achieved by having a limited number of distinct but closely related areas of study. The unifying categories within which geographers work and the plan of this book can be seen in **Figure 1.16**. Not included in this book, however, is an emphasis on specific regions, such as Europe, the Mississippi Valley, the developing world, etc. These are discussed in separate regional geography courses where students can gain a deep understanding and knowledge of a particular area.

In this book, we begin by introducing ways to see the world in spatial terms through using core geographic concepts and **techniques of geographic analysis** (Chapters 1 and 2). The emphasis is on the nature of maps and the skills necessary to create them. Basic cartography (mapmaking) is discussed as well as some of the exciting new technologies, such as geographic information systems (GIS) and global positioning systems (GPS), which allow for great detail, flexibility in map use, and creativity in "seeing" the Earth as it has never been seen before. In our introduction to seeing the world in spatial terms, we consider ways in which maps can be used to understand patterns of change, such as population

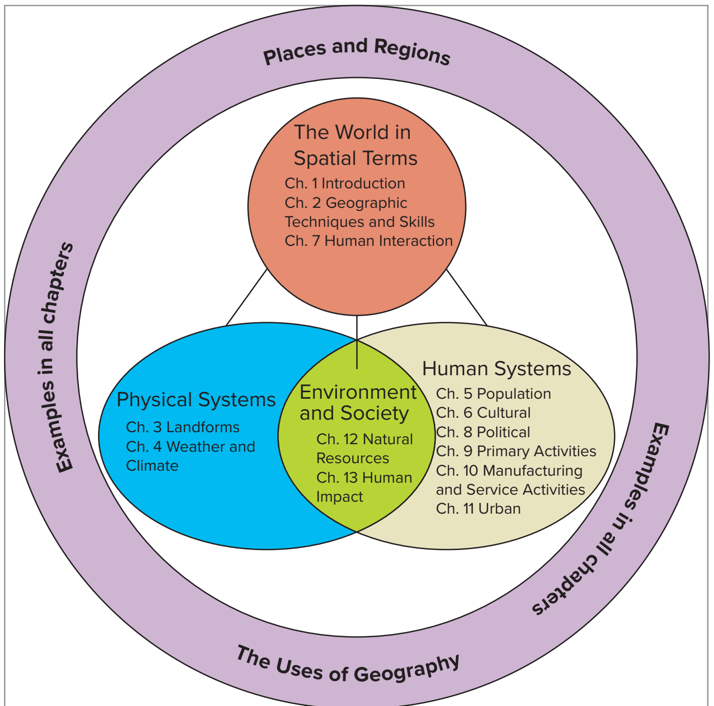


Figure 1.16 **The areas of study of geography do not stand alone.** Rather, each is interconnected with the others, and all together depend on the unifying view of the world in spatial terms. As the diagram indicates, it is possible to group chapters according to the essential elements in the National Geography Standards: Physical Systems, Human Systems, and Environment and Society, all held together by viewing the world in spatial terms. Examples of Places and Regions and Uses of Geography are found throughout the book.

growth, the spread of a disease, or the diffusion of a commercial enterprise, and so on.

To understand the physical systems of the Earth, we begin, in Chapter 3, Physical Geography: Landforms, to explore **physical systems.** The approach of geography is to attempt to recognize the processes responsible for surface physical features such as mountains and streams. In Chapter 4, weather and climate are investigated. This requires that we identify the principles of the science of the lower atmosphere where Earth-sun relations are the backbone of any understanding of changes in weather and climate. Also included is a geographic climate classification system that simplifies understanding the great variation Earth's weather and climate.

Human systems on Earth are many and complex. In its development, the discipline of geography has found efficient ways to compartmentalize these complexities. Chapters 5, 6, 8, 9, 10, and 11 each singles out a particular human system. Chapter 5 is a study of population geography. Although there is much in common with the field of demography, the emphasis in population geography is on the location, distribution, and spatial trends in the numbers of people over time. In Chapter 6, we discuss the fundamentals of cultural geography, including the technological, sociological, and ideological systems of human behavior. Differences in language, religion, and ethnicity play major roles in the human use of the Earth. A section on gender and culture helps to foster a deep appreciation for geographic variations in roles humans play. Chapter 7, on human interaction, offers a focused treatment of how geographers view human systems in spatial terms. It provides a conceptual view of geographic controls on human communication, commerce, and migration. Chapter 8 contains a comprehensive look at the geographic characteristics of political systems. Nations, states, cooperative behavior, and local and regional political organizations are understood in terms of culture and past history. In geography, emphasis is on the size of political entities, their locations, and the cohesiveness of their boundaries.

A key set of human systems involves the ways that different individuals and communities make their economic livelihood. Primary economic activities relate to the use of the physical environment, such as mining and agriculture. These are discussed in Chapter 9. A major point made is that none of these activities occurred by chance and that the nature of the land in places and the demand for the output of that land have much to do with the kinds of activities in which humans engage.

The output of primary activities gives rise to manufacturing (secondary) and commercial (tertiary) activities. These are explored in Chapter 10. The point of view of geography is to attempt to understand the changing of these activities. Principles of location are investigated, and the resulting interaction and commercial trade are discussed. The outputs and demand for primary, secondary, and tertiary activity give rise to settlements of varying size and complexity. These complexities represent the field of urban geography, which is studied in Chapter 11. The city and its hinterland are examined; the internal spatial arrangement of cities in different cultures and societies in which they appear is dissected. Principles of city systems and the increasingly intertwined world city system are discussed in the chapter.

The final two chapters explore the interaction of human societies and the **environment** of Earth. Our focus is on how the environment and its resources are used and abused by humans. Chapter 12 on the geography of natural resources explains the meaning of renewable and nonrenewable resources. Emphasis is on the critical resources of energy and land. Our hope is that if humans can understand the issues related to the exploitation of resources, they can better cope with their dwindling supplies. Thus, relatively new energy resources such as solar, wind, and natural gas power are discussed as alternatives to coal and oil resources. In Chapter 13, the point is made that humans play a crucial role in altering the environment. Many of the important issues of the day are discussed with regard to negative human impacts. In turn, the human impacts on water, air, climate, landforms, plants, and animals are discussed, and possible solutions are introduced.

Throughout the book, current issues are introduced and public policy alternatives explored. An informed citizenry can come to thoughtful decisions about the future use of the Earth only if it is well-informed and understands available options.

Key Words

absolute direction 8
absolute distance 9
absolute location 8
accessibility 13
administrative region 14
connectivity 13
cultural landscape 11
environment 18
formal (uniform) region 14
functional (nodal) region 15
globalization 13
human interaction 12
human systems 18
location 8
natural landscape 10
perceptual (vernacular, popular) region 15
physical systems 18
region 15
relative direction 8
relative distance 9
relative location 8
scale 9
site 8
situation 8
spatial diffusion 13
techniques of geographic analysis 17

Thinking Geographically

1. In what two ways and for what different purposes do geographers refer to *location?* When geographers say "location matters," what aspect of location commands their interest?
2. What does the term *cultural landscape* imply? How is the cultural landscape related to the physical environment?
3. What kinds of distance transformations are suggested by the term *relative distance?* How is the concept of *psychological distance* related to relative distance?
4. How are the ideas of *distance, accessibility,* and *connectivity* related to processes of *human interaction?*
5. Why do geographers concern themselves with *regions?* How are *formal* and *functional* regions different in concept and definition?
6. What are the National Standards for geography? How does the geographic knowledge and skills contained in the National Standards help to understand a specific local, national, or international problem?

CHAPTER 2

Techniques of Geographic Analysis

A map of the Americas by Louis-Charles Desnos, published in Paris in 1770. *Library of Congress Geography and Map Division [G3290 1781 .D4 Vault Oversize]*

CHAPTER OUTLINE

2.1 Maps as the Tools of Geography
2.2 Locating Points on a Sphere
The Geographic Grid
Land Survey Systems
2.3 Map Projections
Area
Shape
Distance
Direction
2.4 Scale
2.5 Types of Maps
Topographic Maps and Terrain Representation
Thematic Maps and Data Representation
Point Symbols
Area Symbols
Line Symbols
Map Misuse
2.6 Contemporary Spatial Technologies
Remote Sensing
The Global Positioning System
Virtual and Interactive Maps
2.7 Integrating Technology: Geographic Information Systems
The Geographic Database
Applications of GIS
Systems, Maps, and Models
SUMMARY OF KEY CONCEPTS
KEY WORDS
THINKING GEOGRAPHICALLY

LEARNING OBJECTIVES

After studying this chapter you should be able to:

2.1 Locate places on the Earth's surface, using latitude and longitude.

2.2 Understand how map projections are constructed.

2.3 Identify the properties of a map.

2.4 Recognize distortions or possible misuse of maps.

2.5 Discuss how remote sensing can be useful for exploring the earth's surface.

2.6 Explain the characteristics and many uses of a geographic information system.

In 2010, an error on a digital map from Google led to Nicaragua's accidental invasion of Costa Rica. Noticing that Google Maps showed the border between the two countries several kilometers to the south of its established location, Nicaraguan military commander Eden Pastora led his troops into what the map showed was Nicaraguan territory. The troops took down a Costa Rican flag and replaced it with the Nicaraguan flag. However, it turns out that Google Maps had drawn the border incorrectly in a complicated area where the border follows the bank of the San Juan River and then crosses the river where the river meets the Caribbean Sea. When the mistake was revealed, Google quickly fixed its maps, the Nicaraguan troops returned home, and a military conflict was avoided. Digital maps are powerful but are only as good as the underlying data. Unfortunately, the map mistake reopened an old wound from a protracted 1800s border dispute between the two countries. A representative for Google Latin America wrote on Google's public blog that "Google maps are of very high quality and Google works constantly to improve and update existing information, by no means should they be used as a reference to decide military actions between two countries."

Just five years earlier, the nuclear attack submarine *USS San Francisco* sped along at top speed some 150 meters (500 ft) beneath the surface of the South Pacific on its way from Guam to Brisbane, Australia. Many of the 136 crew members were eating lunch when they heard a horrible screeching followed by a thunderous blast. Within seconds, sailors were tossed about like dolls. The *USS San Francisco* had crashed head-on into an undersea mountain that is part of a range of undersea volcanoes and reefs. One crewman was killed and 98 were injured, many of them severely. Although the mountain rises to within 30 meters (100 ft) of the ocean surface, it was not on the submarine's navigational charts, which did not show any potential obstacles within 4.7 kilometers (3 mi) of the crash.

Accurate maps can literally mean the difference between life and death. Governmental agencies rely on maps of flood-prone areas, of volcanic eruptions, of earthquake hazard zones, and of areas subject to landslides to develop their long-range plans. Epidemiologists map the occurrence of a disease over time and space, which helps them identify the source of the outbreak and create a plan to halt the spread of the disease. Law enforcement agencies use maps to identify patterns of specific types of crime and to help them predict where those crimes are likely to occur in the future. The power of maps, the importance of acccuracy, and the need for careful usage cannot be overstated.

Digital maps are also an essential part of daily life for anyone with a smartphone or a high-speed Internet connection. Digital maps allow us to retrieve road conditions and travel speeds in real time and can give us step-by-step directions to our destination. Digital maps can tell us when our bus, train, or ride-share is due to arrive. As we travel, digital mapping applications allow us to check out the locations and reviews of nearby hotels and restaurants. At home, location-based applications help us to meet people based on shared interests and their proximity to us and allow us to track our runs, bike rides, and favorite fishing spots. When the weather turns bad, digital maps can zoom into our neighborhood so we can know exactly when the storm will affect us. If we lose power in a storm, an interactive digital map from the utility company will show the location of outages and tell us when the electricity will be restored to our street. All of these examples demonstrate the importance of maps and also the need for accuracy and knowledgeable users.

2.1 Maps as the Tools of Geography

"The role of geography is a platform for understanding the world. Geographic Information Systems (GIS) is making geography come alive. It condenses our data, information, and science in a language that we can easily understand: maps." So said Jack Dangermond, president of ESRI, the largest company in the world to provide GIS software (*ArcNews,* Fall 2012). Maps have a special significance for geographers. They are geographers' primary tools of spatial analysis. For a variety of reasons, the spatial distributions, patterns, and relations of interest to geographers usually cannot easily be observed in the landscape itself.

- Many phenomena, such as landform or agricultural regions or major cities, are so large that they cannot be seen or studied in their totality from one or a few vantage points.
- Many distributions, such as those of language usage or religious belief, are spatial phenomena but are not tangible or visible.
- Many interactions, flows, and exchanges such as the movement of money or ideas may not be directly observable at all.

Even if everything of geographic interest could be seen and measured through field examination, we would need to isolate particular features for special investigation.

Therefore, the map—an abstraction of reality—has become the essential and distinctive tool of geographers. Only through the map can spatial distributions and interactions be reduced to an observable scale, isolated for study, and combined to reveal relationships not directly measurable in the landscape itself.

The art, science, and technology of making maps are called **cartography.** Modern scientific mapping has its roots in the 17th century, although the Earth scientists of ancient Greece are justly famous for their contributions. They recognized the spherical form of the Earth and developed map projections and the grid system. Unfortunately, much of the cartographic tradition of Greece was lost to Europe during the Middle Ages and essentially had to be rediscovered. Several developments during the Renaissance gave an impetus to accurate cartography. Among these were the development of printing, the rediscovery of the work of Ptolemy and other Greeks, and the great voyages of discovery.

In addition, the rise of nationalism in many European countries made it imperative to determine and accurately portray boundaries and coastlines, as well as to depict the kinds of landforms contained within the borders of a country. During the 17th century, important national surveys were undertaken in France and England. Many conventions in the way data are presented on maps had their origin in these surveys.

Knowledge of the way information is recorded on maps enables us to read and interpret them correctly. To be on guard against drawing inaccurate conclusions or to avoid being swayed by distorted or biased presentations, we must be able to understand and assess the ways in which facts are represented. Of course, all maps are necessarily distorted because of the need to portray the round Earth on a flat surface, to use symbols to represent objects, to generalize, and to record features at a different size than they actually are. This distortion of reality is necessary because the map is smaller than the things it depicts and the mapmaker must selectively focus on only a portion of reality. As long as map readers know the limitations of the commonly used types of maps and understand what relationships are distorted, they can interpret maps correctly.

2.2 Locating Points on a Sphere

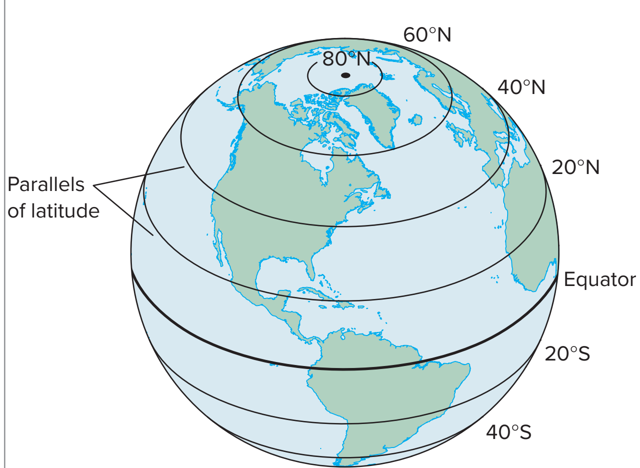
As we noted in Chapter 1, the starting point of all geographic study is the absolute location of places and features using a precise and accepted system of coordinates.

The Geographic Grid

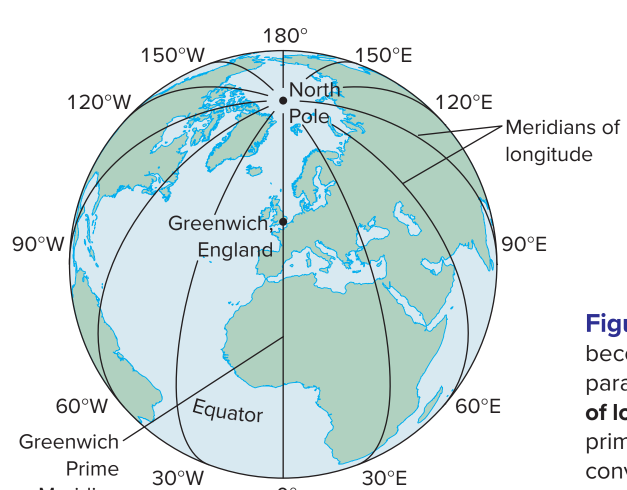
In order to visualize the basic system for locating points on Earth, think of the world as a sphere with no markings whatsoever on it. There would, of course, be no way of describing the exact location of a particular point on the sphere without establishing a system of reference. We use the **geographic grid,** a set of imaginary lines that intersect at right angles to form a system of reference for locating points on the surface of Earth. The key reference points in that system are the North and South Poles, the equator, and the prime meridian.

The North and South Poles are the end points of the axis about which the Earth spins. The line that encircles the globe halfway between the poles, perpendicular to the axis, is the *equator.* We can describe the location of a point in terms of its distance north or south of the equator, measured as an angle at the earth's center. Because a circle contains 360 degrees, the distance between the two poles is 180 degrees and between the equator and each pole, 90 degrees. **Latitude** is the angular distance north or south of the equator, measured in degrees ranging from 0° (the equator) to 90° (the North and South Poles). As is evident in **Figure 2.1a**, the parallels of latitude are parallel to one another and to the equator and run east-west.

The polar circumference of the Earth is 40,071 kilometers (24,899 miles); thus, the distance between degrees of latitude equals 40,071 divided by 360, or about 111 kilometers (69 mi). If the Earth



(a)



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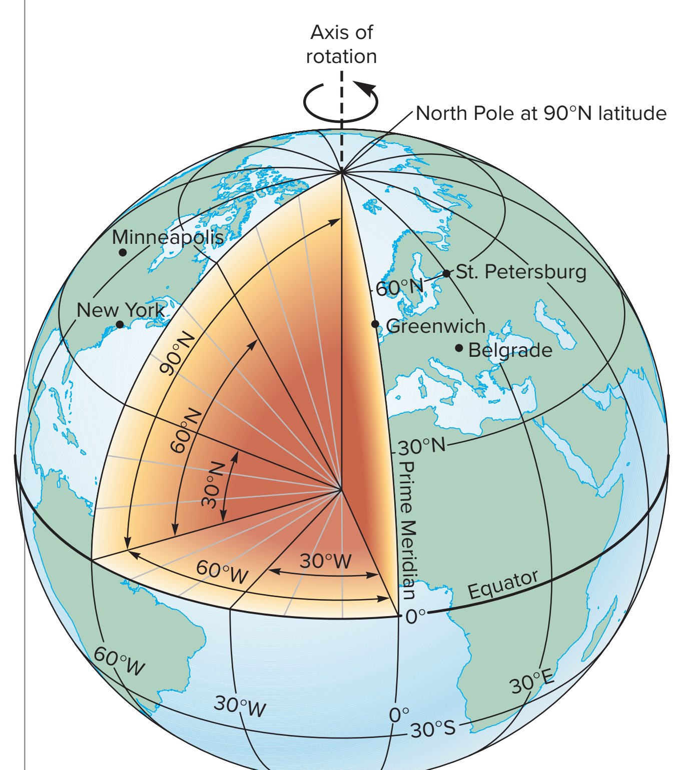


(c)

Figure 2.1 **(a) The grid system: parallels of latitude.** Note that the parallels become increasingly shorter closer to the poles. On the globe, the 60th parallel is only one-half as long as the equator. **(b) The grid system: meridians of longitude.** East-west measurements range from 0° to 180°—that is, from the prime meridian to the 180th meridian in each direction. Because the meridians converge at the poles, the distance between degrees of longitude becomes shorter as one moves away from the equator. **(c) The Earth grid, or graticule, consisting of parallels of latitude and meridians of longitude.**

were a perfect sphere, all degrees of latitude would be equally long. Due to the slight flattening of the Earth in polar regions, however, degrees of latitude are slightly longer near the poles (111.70 km; 69.41 mi) than near the equator (110.56 km; 68.70 mi).

To record the latitude of a place in a more precise way, degrees are divided into 60 *minutes* (′), and each minute into 60 *seconds* (″), exactly as in an hour of time. One minute of latitude is about 1.85 kilometers (1.15 mi), and one second of latitude is about 31 meters (101 ft). The latitude of the center of Chicago is written 41°52′50″N.

Because the distance north or south of the equator is not by itself enough to locate a point in space, we need to specify a second coordinate to indicate distance east or west from an agreed-upon reference line. As a starting point for east-west measurement, cartographers in most countries use the **prime meridian,** which is an imaginary line passing through the Royal Observatory at Greenwich, England. This prime meridian was selected as the zero-degree longitude by an international conference in 1884. Just as the equator divides the northern and southern hemispheres, the prime meridian divides Earth's western and eastern hemispheres. Like all *meridians,* it is a true north-south line connecting the poles of the Earth (**Figure 2.1b**). ("True" north and south vary from magnetic north and south, the direction of the earth's magnetic poles, to which a compass needle points.) Meridians are farthest apart at the equator, come closer and closer together as latitude increases, and converge at the North and South Poles. Unlike *parallels* of latitude, all meridians are the same length.

Longitude is the angular distance east or west of the prime (zero) meridian measured in degrees ranging from 0° to 180°. Directly opposite the prime meridian is the 180th meridian, located in the Pacific Ocean. Like parallels of latitude, degrees of longitude can be subdivided into minutes and seconds. However, the distance between the adjacent degrees of longitude decreases away from the equator because the meridians converge at the poles. With the exception of a few Alaskan islands, all places in North and South America are in the area of west longitude and, thus, the western hemisphere; with the exception of a portion of the Chukchi Peninsula of Siberia, all places in Asia and Australia have east longitude.

Time zones and longitude are related. The Earth, which makes a complete 360-degree rotation once every 24 hours, is divided into 24 time zones roughly centered on meridians at 15-degree intervals. *Greenwich mean time (GMT)* is the time at the prime meridian. The **International Date Line,** where each new day begins, generally follows the 180th meridian. As **Figure 2.2** indicates, however, the date line deviates from the meridian in some places in order to avoid having two different dates within a country or an island group. Thus, the International Date Line zigzags so that Siberia has the same date as the rest of Russia and the Aleutian Island and Fiji Island groups are

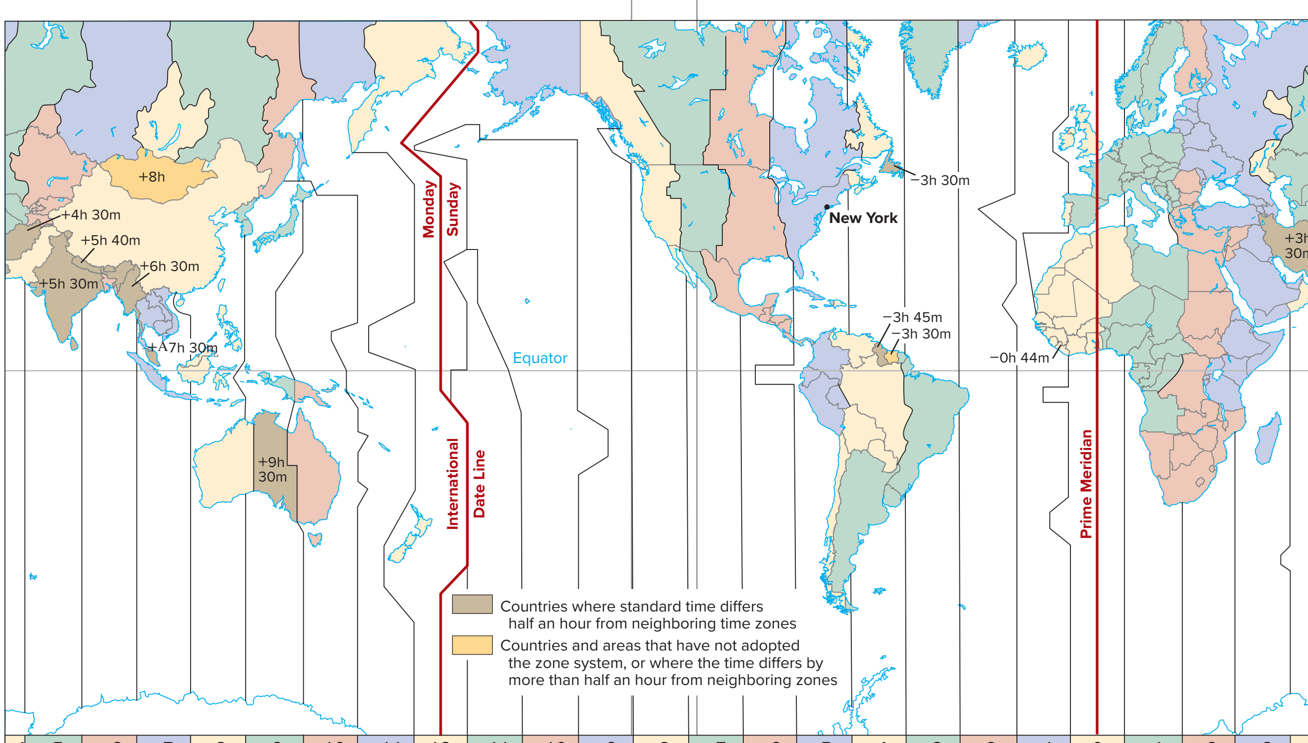


Figure 2.2 **World time zones.** Each time zone is about 15 degrees wide, but variations occur to accommodate political boundaries. The figures at the bottom of the map represent the time difference in hours when it is 12 noon in the time zone centered on Greenwich, England. New York is in column −5, so the time there is 7 A.M. when it is noon at Greenwich. Modifications to the universal system of time zones are numerous. Thus, Iceland operates on the same time as Britain, although it is a time zone away. Spain, entirely within the boundaries of the GMT zone, sets its clocks at +1 hour, whereas Portugal conforms to GMT. China straddles five time zones, but the whole country operates on Beijing time (+8 hours). In South America, Chile (in the −5 hour zone) uses the 24-hour designation, whereas Argentina uses the −3 hour zone instead of the −4 hour zone to which it is better suited.

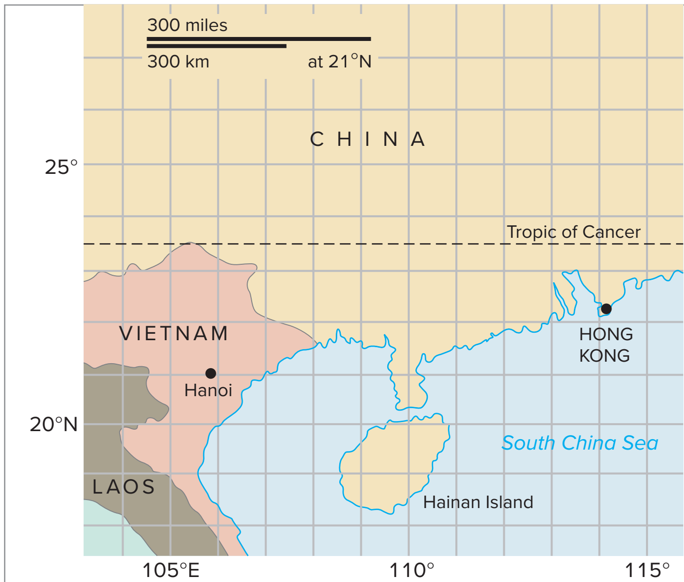


Figure 2.3 The latitude and longitude of Hong Kong are 22°17′N, 114°10′E. What are the coordinates of Hanoi?

not split. New days begin at the date line and proceed westward, so that west of the line is always 1 day later than east of the line.

By citing the degrees, minutes, and, if necessary, seconds of longitude and latitude, we can describe the location of any place on the earth's surface. To conclude our earlier example, the center of Chicago is located at 41°52′50″N, 87°38′28″W. Hong Kong is at 22°17′40″N, 114°10′26″E (**Figure 2.3**).

Land Survey Systems

When independence from Great Britain was achieved, the U.S. government decided that the public domain should be surveyed and subdivided before being opened for settlement. The Land Ordinance of 1785 established a systematic survey known as the *township and range* system. It was based on survey lines oriented in the cardinal directions: *base lines* that run east-west and *meridians* that run north-south (**Figure 2.4**). A grid of lines spaced at 6-mile (9.7-km) intervals divided the land into a series of squares. A *township* consisted of a square 6 miles (9.7 km) on a side; this was further divided into 36 *sections* 1 mile (1.6 km) on a side. Every section of 640 acres (259 hectares) was subdivided into quarter-sections of 160 acres (64.8 hectares), and these quarter-sections—considered the standard size for a farm—were originally designated the minimum area that could be purchased for settlement. That minimum was later reduced to 80 acres (32.4 hectares) and then to 40 acres (16.2 hectares). Each parcel of land had a unique identification.

The township and range rectangular survey system was first used in eastern Ohio and later extended across most of the United States, as far west as the Pacific Ocean and as far north as Alaska. The Canada Land Survey System is similar to that developed in the United States, employing base lines and meridians and dividing land into townships, ranges, sections, and subdivisions of sections. The rectangular survey system transformed the landscape of the central and western United States and Canada, creating the basic checkerboard pattern of townships, the regular pattern of section-line and quarter-line country roads, the block patterns of fields and farms, and the gridiron street systems of towns and cities.

2.3 Map Projections

Earth can be represented with reasonable accuracy only on a globe, but globes are not as convenient as flat maps to store or use and are too small to depict much detail. For example, if we had a large globe with a diameter of 1 meter, we would have to fit the details of over 100,000 square kilometers of Earth's surface in an area a few centimeters on a side. Obviously, a globe cannot show the transportation system of a city or the location of very small towns and villages.

In transforming a globe into a map, we cannot flatten the curved surface and keep intact all the properties of the original. The **globe properties** are as follows:

1. All meridians are of equal length; each is one-half the length of the equator.
2. All meridians meet at the North and South Poles and are true north-south lines.
3. All parallels of latitude are parallel to the equator and to one another.
4. Parallels decrease in length with distance from the equator.
5. Meridians and parallels intersect at right angles.
6. The scale on the surface of the globe is everywhere the same in all directions.

Only the globe itself retains all of these characteristics. To project it onto a flat surface is to distort some or all of these properties and consequently to distort the reality the map attempts to portray.

The term **map projection** designates the way the curved surface of the globe is represented on a flat map. All flat maps distort, in different ways and to different degrees, some or all of the four main properties of the actual Earth's surface relationships: area, shape, distance, and direction. **Figure 2.5** shows how distortion occurs.

Area

Some projections, such as the Mollweide and cylindrical equal-area projection (Figures 2.5a, b), enable the cartographer to represent the *areas* of regions in correct or constant proportion to Earth's reality. That means that any square inch on the map represents an identical number of square miles (or of similar units) anywhere else on the map. As a result, the shape of the portrayed area is inevitably distorted. A square on the Earth, for example, may become a rectangle on the map, but that rectangle has the correct area. Such projections are called **equal-area** or **equivalent projections.** *A map that shows correct areal relationships always distorts the shapes of regions.* Equal-area projections are used when a map is intended to show the actual areal extent of a phenomenon on the earth's surface.

Shape

Although no projection can provide correct shapes for large areas, some accurately portray the shapes of small areas by preserving

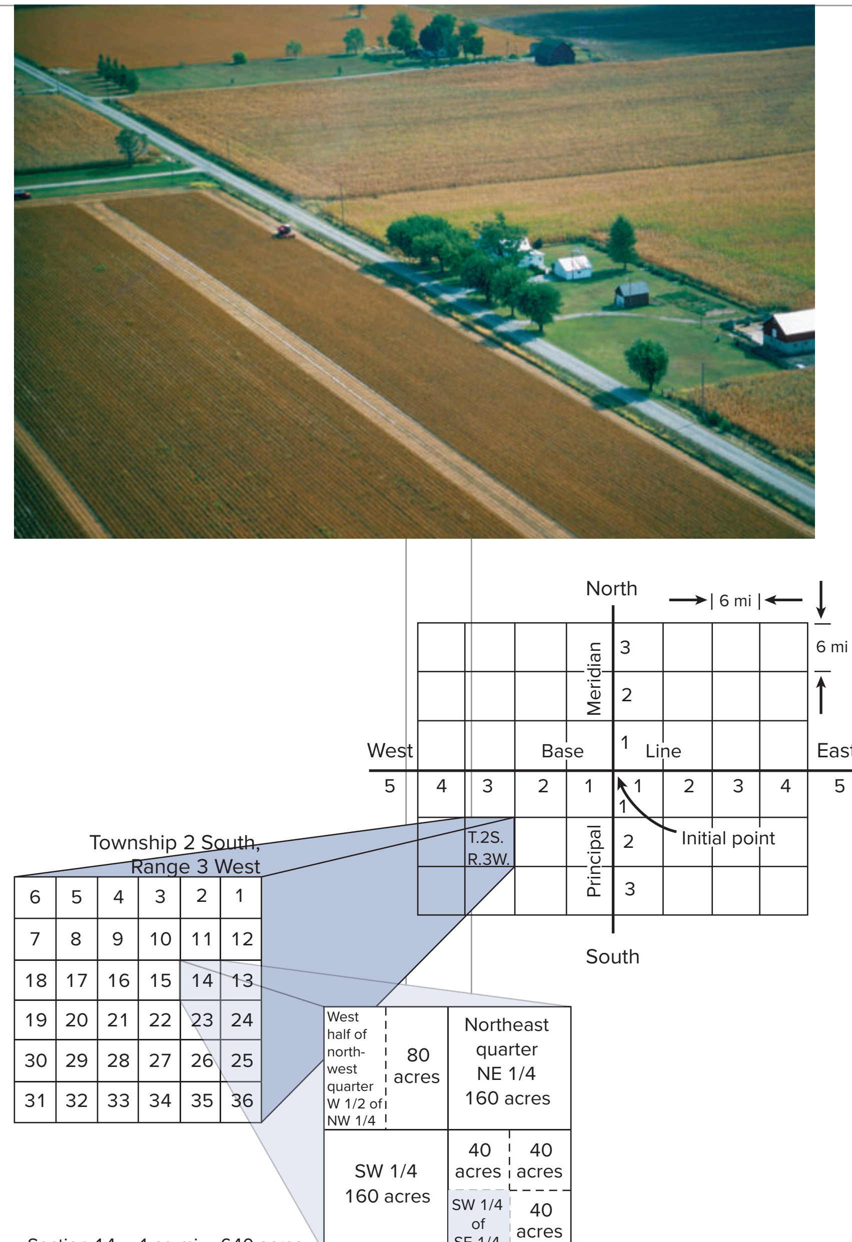
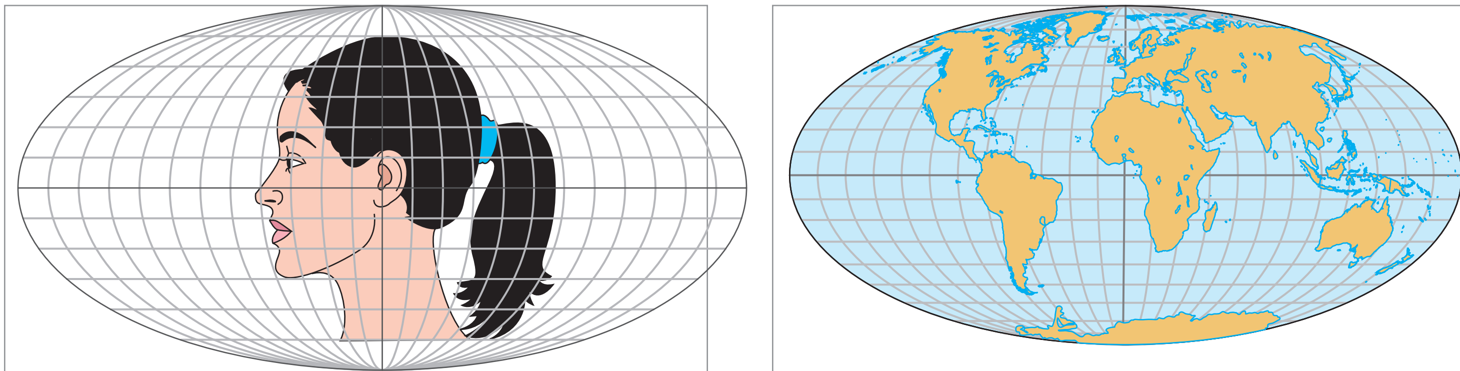


Figure 2.4 **(a) The geometric landscape created by the U.S. Public Land Survey (USPLS).** As shown in this Ohio scene, roads were typically built along section and half-section lines and thus run north to south and east to west. **(b) Township, section, and further divisions of the USPLS.** The township and range survey system gives each parcel of land a unique identification. *Townships* are numbered by rows (called tiers) and columns (called ranges). In the example shown here, the township in the second tier south of the base line and in the third range west of the principal meridian is labeled T.2S, R.3W. Every township is divided into sections 1 mile (1.6 km) on a side and numbered from 1 to 36, beginning at the northeast corner of the township. *Sections* can be divided into quarters, eighths ("half-quarters"), and sixteenths ("quarter-quarters"). The Land Office code for the shaded area in the lower right diagram would be SW 1/4 of the SE 1/4 of Sec. 14, T.2S, R.3W. *(a) Glow Images*

correct angular relationships (Figure 2.5c). These true-shape projections are called **conformal projections,** and the importance of *conformality* is that regions and features "look right" and have the correct directional relationships. They achieve these properties for small areas by ensuring that parallels of latitude and meridians of longitude cross one another at right angles and that the scale is the same in all directions at any given location. Both these conditions exist on the globe but can be retained for only relatively small areas on maps. Because that is so, the shapes of large regions—continents, for example—are always different from their true Earth shapes, even on conformal maps. *A map cannot be both equal-area and conformal.*

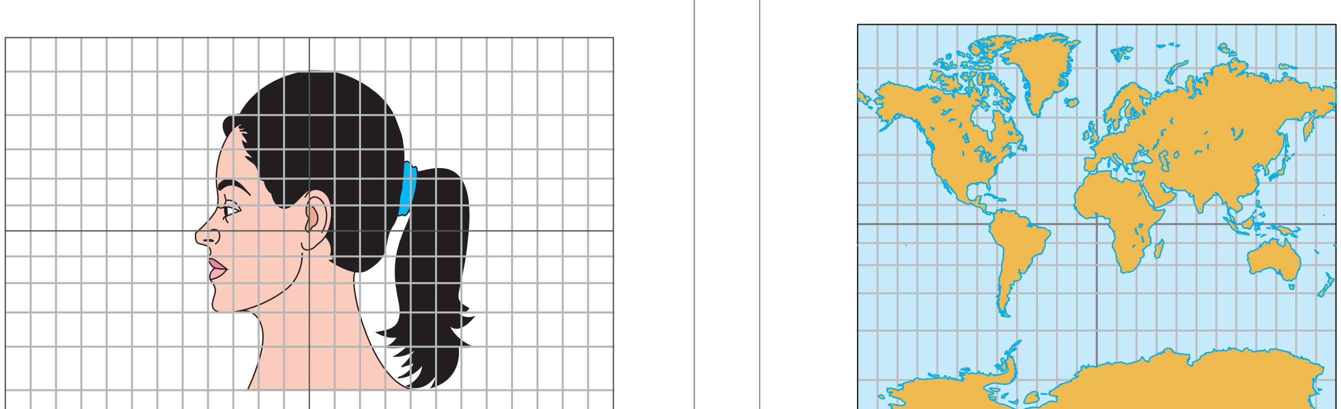
Distance

Distance relationships are nearly always distorted on a map, but some projections maintain true distances in one direction or along



(a) Mollweide projection

(b) A cylindrical equal-area projection with standard parallels at 30°N and S

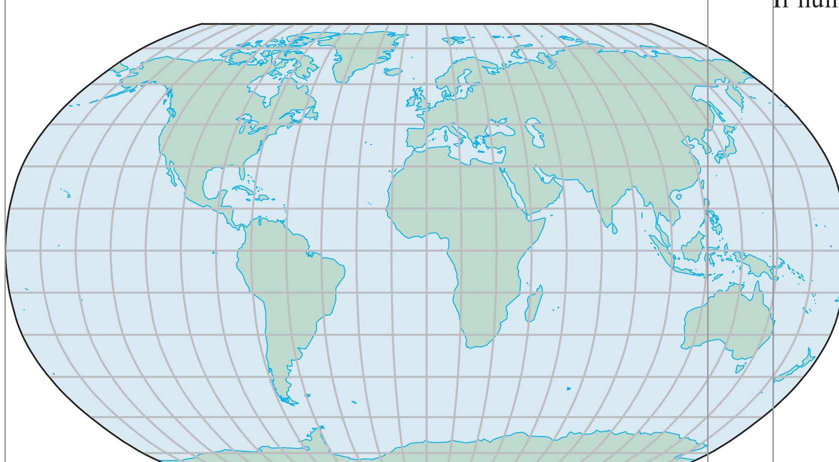


(c) Mercator projection

Figure 2.5 **This figure illustrates the distortion inherent in three different map projections.** A head drawn on one projection (Mollweide) has been transferred to two other projections, keeping the latitude and longitude the same as they are found on the first. This does *not* mean the first projection is the best of the three. The head could have been drawn on any one of them and then plotted on the others. *Source: Arthur Robinson et al.,* Elements of Cartography, *5th ed., Fig. 5.6, p. 85. New York, Wiley, © 1984.*

certain selected lines. Others, called **equidistant projections,** show true distance in all directions, but only from one or two central points (**Figure 2.6a**). Distances between all other locations are incorrect and, quite likely, greatly distorted. An equidistant map centered on Detroit, for example, shows the correct distance between Detroit and the cities of Boston, Los Angeles, and any other point on the map. But it does *not* show the correct distance between Los Angeles and Boston. *A map cannot be both equal-area and conformal.*

(a) Azimuthal equidistant projection, polar case



(b) Robinson projection

Figure 2.6 **(a) On this equidistant projection,** distances and directions to all places are true only from the center (North Pole). No flat map can be both equidistant and equal-area. **(b) The Robinson projection,** a compromise between an equal-area and a conformal projection, gives a fairly realistic view of the world. The most pronounced shape distortions are in the less-populated areas of the higher latitudes, such as northern Canada, Greenland, and Russia. On the map, Canada is 21% larger than in reality, while the 48 contiguous states of the United States are 3% smaller than they really are.

Direction

As is true of distances, directions between all points cannot be shown without distortion. On **azimuthal projections,** however, true directions are shown from one central point to all other points. (An *azimuth* is the angle formed at the beginning point of a straight line, in relation to a meridian.) Directions or azimuths from points other than the central point to other points are not accurate. The azimuthal property of a projection is not exclusive—that is, an azimuthal projection may also be equivalent, conformal, or equidistant. The equidistant map shown in **Figure 2.6a** is a true-direction map from the same North Pole origin.

Not all maps are equal-area, conformal, or equidistant; most are compromises. One example of such a compromise is the *Robinson projection,* which was designed to show the whole world in a visually satisfactory manner and which is used for most of the world maps in this textbook (**Figure 2.6b**). It does not show true distances or directions and is neither equal-area nor conformal. Instead, it permits some exaggeration of size in the high latitudes in order to improve the shapes of land-masses. Size and shape are most accurate in the temperate and tropical zones, where most people live.

Mapmakers must be conscious of the properties of the projections they use, selecting the one that best suits their purposes. If a map shows only a small area, the choice of a projection is not critical—virtually any can be used. The choice is more important when the area to be shown extends over a considerable longitude and latitude; then the selection of a projection depends on the purpose of the map. Some projections are useful for navigation. If numerical data are being mapped, the relative sizes of the areas involved should be correct, so that one of the many equal-area projections is likely to be used. Display maps usually employ conformal projections. Most atlases indicate which projection has been used for each map, thus informing the map reader of the properties of the maps and their distortions. More information about map projections can be found in Appendix 1.

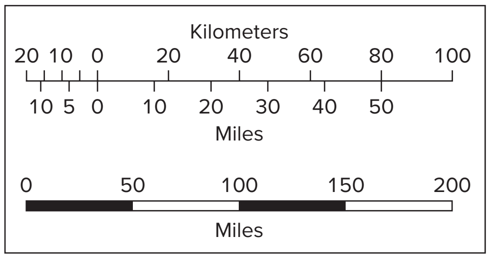
Selection of the map grid, determined by the projection, is the first task of the mapmaker. A second decision involves the scale at which the map is to be drawn.

2.4 Scale

The **scale** of a map is the ratio between the measurement of something on the map and the corresponding measurement on the Earth. Scale is typically represented in one of the three ways: verbally, graphically, or numerically as a representative fraction (**Figure 2.7**). As the name implies, a *verbal* scale is given in words, such as "1 inch to 1 mile" or "10 centimeters to 1 kilometer." A *graphic* scale, sometimes called a *bar* scale, is a line or bar placed on the map that has been subdivided to show the map lengths of units of the Earth's distance.

"1 inch to 1 mile"
"1 centimeter to 5 kilometers"

(a) **Verbal scale**



(b) **Graphic scale**

$\frac{1}{62{,}500}$ 1:62,500

(c) **Representative fraction scale**

Figure 2.7 **Map scales** relate a map distance to a distance on the earth's surface. **(a) A verbal scale** is given in words. **(b) A graphic scale** divides a line into units, each unit representing the distance between two points on the earth's surface. The graphic scale is the only kind of scale to remain correct if the map is reproduced as a different size, *provided that* the scale is enlarged or reduced by the same percentage. **(c) A representative fraction** *(RF) scale* is a simple fraction or ratio. The units of distance on both sides of the scale must be the same; they need not be stated.

A *representative fraction (RF)* scale gives two numbers, the first representing the map distance and the second indicating the ground distance. The fraction may be written in a number of ways. There are 5280 feet in 1 mile and 12 inches in 1 foot; 5280 times 12 equals 63,360, the number of inches in 1 mile. The fractional scale of a map at 1 inch to 1 mile can be written as 1:63,360 or 1/63,360. On the simpler metric scale, 1 centimeter to 1 kilometer is 1:100,000. The units used in each part of the fractional scale are the same; thus, 1:63,360 could also mean that 1 foot on the map represents 63,360 feet on the ground, or 12 miles—which is, of course, the same as 1 inch represents 1 mile. Numerical scales are the most accurate of all scale statements and can be understood in any language.

The map scale, or ratio between the map dimensions and those of reality, can range from very large to very small. A *large-scale map,* such as a plan of a city, shows an area in considerable detail. That is, the ratio of map to ground distance is relatively large—for example, 1:600 (1 in. on the map represents 600 in., or 50 ft, on the ground) or 1:24,000. At this scale, features such as buildings and highways can be drawn to scale and appear large. Figure 2.9 on page 30 is an example of a large-scale map. *Small-scale maps,* such as those of countries or continents, have a much smaller ratio. Buildings, roads, and other small features would be too small to be drawn to scale and must be magnified and represented by symbols to be seen. Figures 2.2 and 2.3 are small-scale maps. Although no rigid numerical limits differentiate large-scale from small-scale maps, most cartographers would consider large-scale maps to have a ratio of 1:50,000 or less, and maps with ratios of 1:500,000 or more to be small-scale.

Each of the four maps in **Figure 2.8** is drawn at a different scale. Although each is centered on Boston, notice how the scale affects both the area that can be shown in a square that is 2 inches on a side and the amount of detail that can be depicted. On map (a), at a scale of 1:25,000, about 2.6 inches represent 1 mile, so that the 2-inch square shows less than 1 square mile. At this scale, one can identify individual buildings, highways, rivers, and other landscape features. Map (d), drawn to a scale of 1 to 1 million (1:1,000,000, or 1 in. represents almost 16 mi), shows an area of almost 1000 square miles. In this map, only major features, such as main highways and the location of cities, can be shown, and even the symbols used for that purpose are generalized and occupy more space on the map than would the features depicted if they were drawn true to scale.

Small-scale maps such as (c) and (d) in Figure 2.8 are said to be very *generalized.* They give a general idea of the relative locations of major features but do not permit accurate measurement. They show significantly less detail than do large-scale maps and typically smooth out such features as coastlines, rivers, and highways.

2.5 Types of Maps

Out of the many features that can be shown on a map, geographers must first select those that are relevant to the problem at hand and then decide how to display them in order to communicate their message. In that effort, they can choose from different types of maps.

General-purpose, reference, or *location* maps make up one major class of maps familiar to everyone. Their purpose is simply to display one or more natural and/or cultural features of an area or of the world as a whole. Common examples of the natural features shown on reference maps are water features (coastlines, rivers, lakes, and so on) and the shape and elevation of terrain. Cultural features include transportation routes, populated areas, property-ownership lines, political boundaries, and names.

The other major type of map is called the *thematic,* or *special-purpose,* map, one that shows a specific spatial distribution or category of data. Again, the phenomena being mapped may be physical (climate, vegetation, soils, and so on) and/or cultural (e.g., the distribution of population, religions, diseases, or crime). Unlike in reference maps, the features on thematic maps are limited to just those that communicate the specific spatial distribution.

Topographic Maps and Terrain Representation

As we noted, some general-purpose maps depict the shape and elevation of the terrain. These are called **topographic maps.** They usually portray the surface features of relatively small areas, often with great accuracy (**Figure 2.9**). They not only show landforms, streams, and other natural features but also may display things that people have added to the natural landscape. These include transportation routes, buildings, and such land uses as orchards, vineyards, and cemeteries. Many types of boundaries, from state borders to field or airport limits, are also depicted on topographic maps.

The U.S. Geological Survey (USGS), the chief federal agency for topographic mapping in this country, produces several topographic

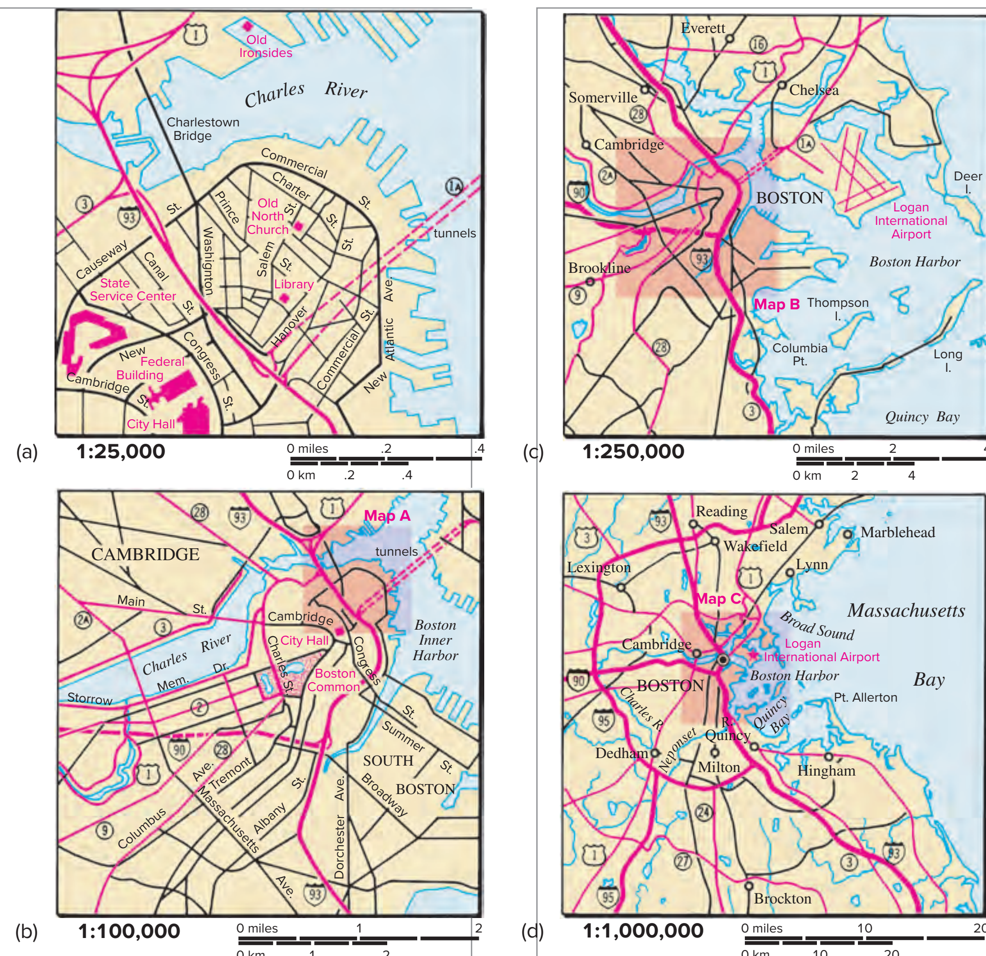


Figure 2.8 **The effect of scale on area and detail.** The four maps all show Boston, but at different scales. The larger the scale, the greater the number and kinds of features that can be included. Among other things, at a scale of 1:25,000, map **(a)** shows streets, street names, and some buildings. Map **(d),** at the smallest scale, shows only major cities, highways, and water bodies. The area shown in map **(a)** is indicated by the pink square on map **(b),** the area covered in **(b)** by the pink square on map **(c),** and the area of map **(c)** by the square on map **(d)**.

map series, each on a standard scale. Complete topographic coverage of the United States is available at scales of 1:250,000 and 1:100,000. Maps are also available at various other scales. Scales used for state maps depend on the size of the state and range from 1:125,000 (Connecticut) to 1:500,000 (Alaska).

A single map in one of these series is called a *quadrangle.* Topographic quadrangles at the scale of 1:24,000 exist for the entire area of the 48 contiguous states, Hawaii, and territories, a feat that requires about 57,000 maps. Each map covers a rectangular area that is 7.5 minutes of latitude by 7.5 minutes of longitude. As is evident from Figure 2.9, these 7.5-minute quadrangle maps provide detailed information about the natural and cultural features of an area. Because of Alaska's large size and sparse population, the primary scale for mapping that state is 1:63,360 (1 in. represents 1 mi). The Alaska quadrangle series consists of more than 2900 maps.

As noted earlier, topographic maps depict the surface of the Earth. Cartographers use a variety of techniques to represent the three-dimensional surface of the Earth on a two-dimensional map. The easiest way to show relief, or variation in elevation, is to use numbers called *spot heights* to indicate the elevation of selected points. A *bench mark* is a particular type of spot height that is used as a reference in calculating elevations of nearby locations (see "Geodetic Control Data," p. xx).

The principal symbol used to show elevation on topographic maps, however, is the **contour line,** along which all points are of equal elevation above a datum plane, usually the mean sea level. Contours are imaginary lines, perhaps best thought of as the outlines that would occur if a series of parallel, equally spaced horizontal slices were made through a vertical feature. Figure 2.10 shows the relationship of contour lines to elevation for an imaginary island.

The **contour interval** is the vertical spacing between contour lines, and it is normally stated on the map. The more irregular the surface is, usually, the greater will be the number of contour lines that needs to be drawn; the steeper the slope is, the closer will be the contour lines rendering that slope. Contour intervals of 10 and 20 feet are often used, though in relatively flat areas the interval may be only 5 feet. In mountainous areas, the spacing between contours is greater: 40 feet, 100 feet, or more.

Although contour lines represent terrain, giving the map reader information about the elevation of any place on the map and the size, shape, and slope of all relief features, most map readers find it difficult to visualize the landscape from contour lines. To heighten

Figure 2.9 **A portion of the Tacoma North, Washington, 7.5-minute series of U.S. Geological Survey topographic maps.** The fractional scale is 1:24,000 (1 in. equals about 1/3 mi), allowing considerable detail to be shown. Water bodies are shown in blue, vegetation in green. The footprints of larger structures are shown in black. A gray or pink tint denotes densely built-up areas, in which only schools, churches, cemeteries, parks, and other public facilities are shown. *Source: U.S. Geological Survey (USGS).*

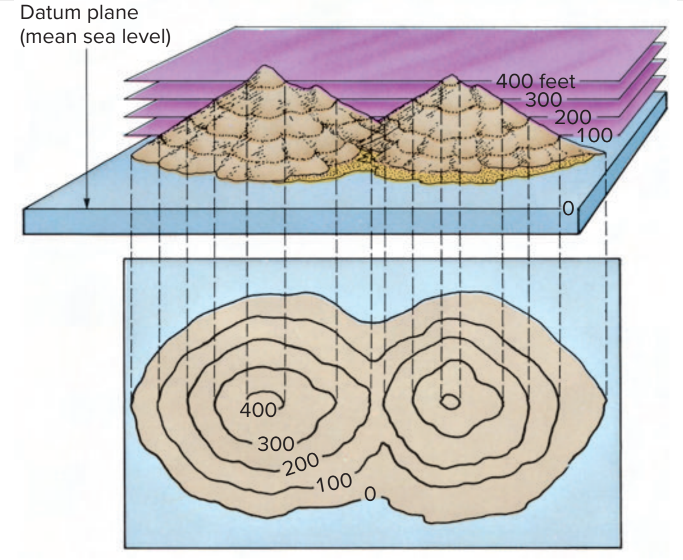


Figure 2.10 Contours drawn for an imaginary island. The intersection of the landform by a plane held parallel to sea level is a contour representing the height of the plane above sea level.

the graphic effect of a topographic map, contours are sometimes supplemented by the use of *shaded relief.* An imaginary light source, usually in the northwest, can be thought of as illuminating a model of the area, simulating the appearance of sunlight and shadows and creating the illusion of three-dimensional topography. Additionally, bands of color for elevation ranges can be used to "color between" the contour lines. These are called elevation, or *hypsometric,* tints.

The tremendous amount of information on topographic maps makes them useful to engineers, regional planners, land use analysts, and developers, as well as to recreational users. Given such a wealth of information, the experienced map reader can make deductions about both the physical character of the area and the cultural use of the land.

Thematic Maps and Data Representation

The study of the spatial patterns and interrelationships of things, whether people, crops, or traffic flows, is the essence of geography. Various kinds of symbols are used to record the location or numbers of these phenomena on thematic maps. The symbols and maps may be either *qualitative* or *quantitative.*

The principal purpose of the qualitative map is to show the distribution of a particular class of information. The world location of producing oil fields, the distribution of national parks, and the pattern of areas of agricultural specialization within a country are examples. The interest is in where these things are, without reporting about, for example, the barrels of oil extracted, number of park visitors, or value of crops produced.

In contrast, quantitative thematic maps show the spatial characteristics of numerical data. Usually, a single variable, such as population, income, or land value, is chosen, and the map displays the variation of that feature from place to place. Multivariate maps show two or more variables at once.

Point Symbols

Features that occur at a particular point in space are represented on maps by *point symbols.* Thousands of types of such features exist on the Earth: houses of worship, schools, cemeteries, and historical sites, to name a few. Symbols used to represent them include dots, crosses, triangles, and other shapes. On a qualitative thematic map, each such symbol records merely the location of that feature at a particular point on Earth.

Sometimes, however, our interest is in showing the variation in the number of things that exist at several points—for example, the population of selected cities, the tonnage handled at certain terminals, or the number of passengers at given airports.

There are two chief means of symbolizing such distributions, as **Figures 2.11a** and **2.11b** indicate. One method is to choose a symbol, usually a dot, to represent a given quantity of the mapped item (such as 50 people) and to repeat that symbol as many times as necessary.

Such a **dot density map** is easily understood because the dots give the map reader a visual impression of the pattern. Sometimes pictorial symbols—for example, human figures or oil barrels—are used instead, to mimic the phenomenon being mapped.

If the range of the data is great, the geographer may find it inconvenient to use a repeated symbol. For example, if one country has 500 times the population of another, or one port handles 50 or 100 times as much tonnage as another, that many more dots would have to be placed on the map and could begin to coalesce. To circumvent this problem, the cartographer can choose a second method and use a **graduated symbol map**. The size of the symbol is varied according to the quantities represented. Thus, if squares or circles are used, the *area* of the symbol ordinarily is proportional to the quantity shown (Figure 2.11b).

There are occasions, however, when the range of the data is so great that even circles or squares would take up too much room on the map. In such cases, symbols such as spheres or cubes are used, and their *volume* is proportional to the data. Unfortunately, it is difficult for map readers to accurately perceive differences in volume, and most cartographers do not recommend the use of such symbols.

Area Symbols

One way to show how the *amount* of a phenomenon varies from area to area is by using **choropleth maps.** The term is derived from the Greek words *choros* ("place") and *pleth* ("magnitude" or "value"). The quantities shown may be absolute numbers (e.g., the population of counties) or derived values, such as percentages, ratios, rates, and densities (e.g., population density by county). Using absolute numbers can, however, be misleading if the size of the mapping regions varies considerably. Thus, most mapmakers prefer to use derived values for choropleth maps. The data are grouped into a limited number of classes, each represented by a distinctive color, shade, or pattern. **Figure 2.11c** is an example of a choropleth map. In this case, the areal units are states. Other commonly used subdivisions are counties, townships, cities, and census divisions.

Features found within defined areas of the earth's surface are represented on maps by *area symbols.* As with point symbols, such

GEODETIC CONTROL DATA

The horizontal position of a place, specified in terms of latitude and longitude, constitutes only two-thirds of the information needed to locate it in three-dimensional space. Also needed is a vertical control point defining elevation, usually specified in terms of altitude above sea level. Together, the horizontal and vertical positions constitute *geodetic control data.* A network of more than 1 million points whose latitude, longitude, and elevation have been precisely determined, recorded, and marked covers the entire United States.

Each point is indicated by a bronze marker fixed in the ground. You may have seen some of the vertical markers, called *bench marks,* on mountaintops, hilltops, or even city sidewalks. The marker indicates which agency put it in place, its elevation, and sometimes the date it was put in place. Every U.S. Geological Survey (USGS) map shows the markers in the area covered by the map, and the USGS maintains Geodetic Control Lists containing the description, location, and elevation of each marker. A bench mark is indicated on the map by the letters *BM,* a small *x,* and the elevation.

These lists were revised in 1987 when, after 12 years' effort, federal scientists completed the recalculation of the precise location of some 250,000 bench marks across the country. In using a satellite locating system for the first national resurvey of control points since 1927, the National Oceanic and Atmospheric Administration (NOAA) found, for example, that New York's Empire State Building is 36.7 meters (120.4 ft) northeast of where it formerly officially stood. The Washington Monument has been moved northeast by 28.8 meters (94.5 ft), the dome of California's state capitol in Sacramento has been relocated 91.7 meters (300.9 ft) southwest, and Seattle's Space Needle now has a position 93 meters (305.1 ft) west and 20 meters (65.6 ft) south of where maps formerly showed it. The satellite survey provides much more accurate locations than did the old system of land measurement of distances and angles. The result is more accurate maps and more precise navigation.

Roger Scott

maps fall into two general categories: those showing differences in kind and those showing differences in quantity. Atlases contain numerous examples of the first category, such as patterns of religions, languages, political entities, vegetation, or types of rock. Normally, different colors or patterns are used for different areas, as shown in **Figure 2.12**.

As Figures 2.11c and 2.12 reveal, three main problems characterize maps that show the distribution of a phenomenon in an area:

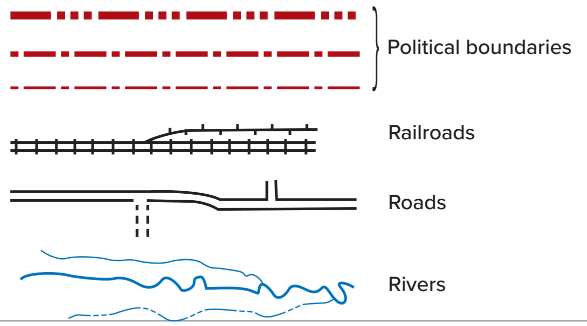
1. They give the impression of uniformity to areas that may actually contain significant variations.
2. Boundaries attain unrealistic significance, implying abrupt changes between areas, when, in reality, the changes may be gradual.
3. Unless colors are chosen wisely, some areas may look more important than others.

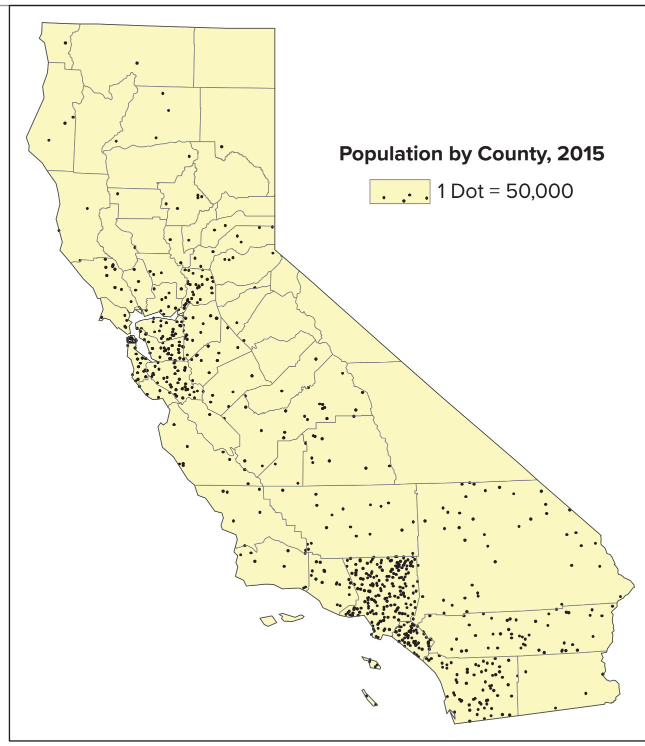
A special type of area map is the **area cartogram,** or **value-by-area map,** in which the areas of units are drawn proportional to the data they represent (**Figure 2.13**). Population, income, cost, or another variable becomes the standard of measurement. Depending on the idea that the mapmaker wishes to convey, the sizes and shapes of areas may be altered, distances and directions may be distorted, and contiguity may or may not be preserved (see "Red States, Blue States," p. xx).

Line Symbols

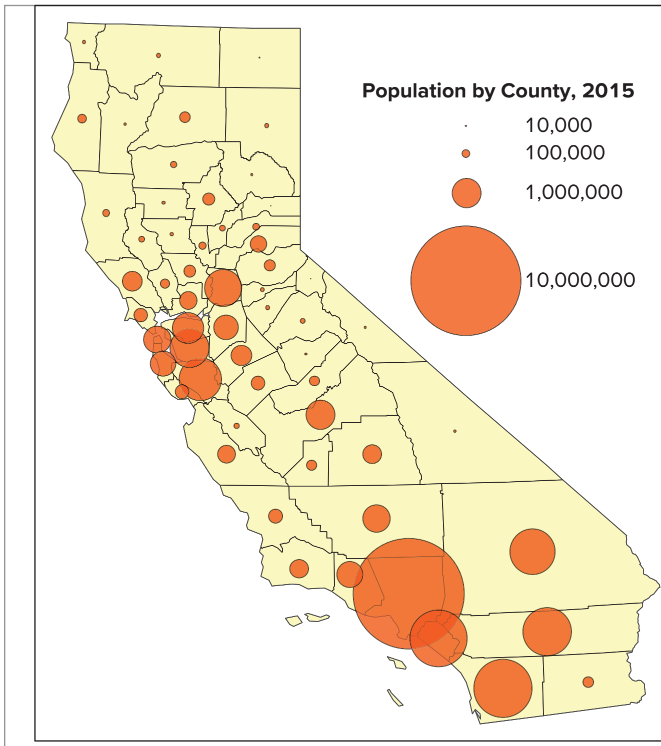
As the term suggests, *line symbols* represent features that have length but insignificant width. Some lines on maps do not have numerical significance. The lines representing rivers, political boundaries, roads, and railroads, for example, are not quantitative. They are indicated on maps by such standardized symbols as those that follow.

Often, however, lines on maps do denote specific numerical values. Contour lines that connect points of equal elevation above mean sea level are a kind of **isoline,** or line of constant value. Other examples of isolines are *isohyets* (equal rainfall), *isotherms* (equal temperature), and *isobars* (equal barometric pressure).

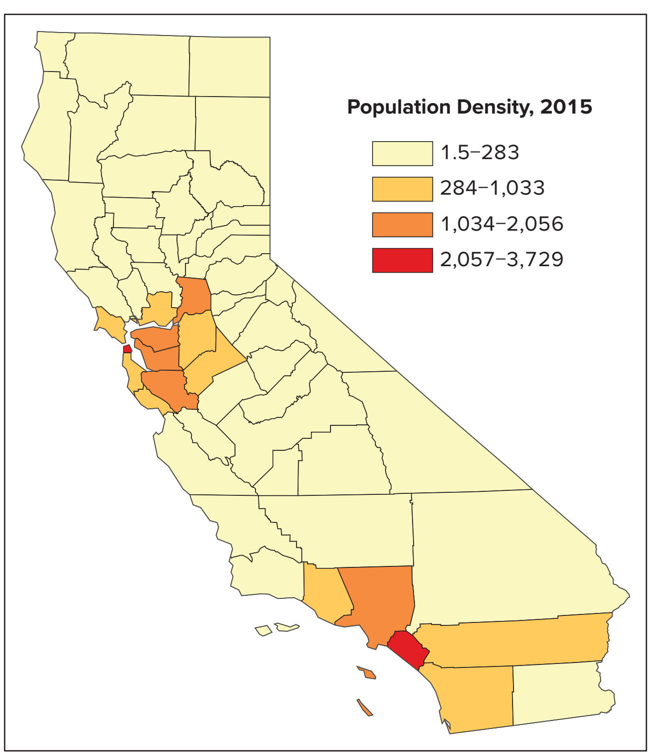




(a)



(b)



(c)

Figure 2.11 Although population is the theme of each, these different California maps present their information in strikingly different ways. **(a)** In a **dot density map** where large numbers of items are involved, the value of each dot is identical and stated in the map legend. The placement of dots on the map does not indicate precise locations of people within the county, but simply their total number. **(b)** In the **graduated circle map,** the area of the circle is approximately proportional to the absolute number of people within each county. **(c)** This is a **choropleth map** that shows population density by county. Quantitative variation by area is more easily visualized in a map than in a table.

Flow-line maps are used to portray linear movement between places. They may be qualitative or quantitative. Examples of *qualitative* flow maps are those showing ocean currents or airline routes. The lines are of uniform thickness and generally have arrowheads to denote direction of movement. On *quantitative* flow maps, on the other hand, the flow lines are scaled so that their widths are proportional to the amounts they represent. Migration, traffic, and commodity flows are usually portrayed in this way. The location of the route taken, the direction of movement, and the volume of flow can all be depicted. The amount shown may be either an absolute or a derived value—for example, the actual traffic flows or a per-mile figure. In **Figure 2.14**, the width of the flow lines is proportional to the number of interstate migrants in the United States.

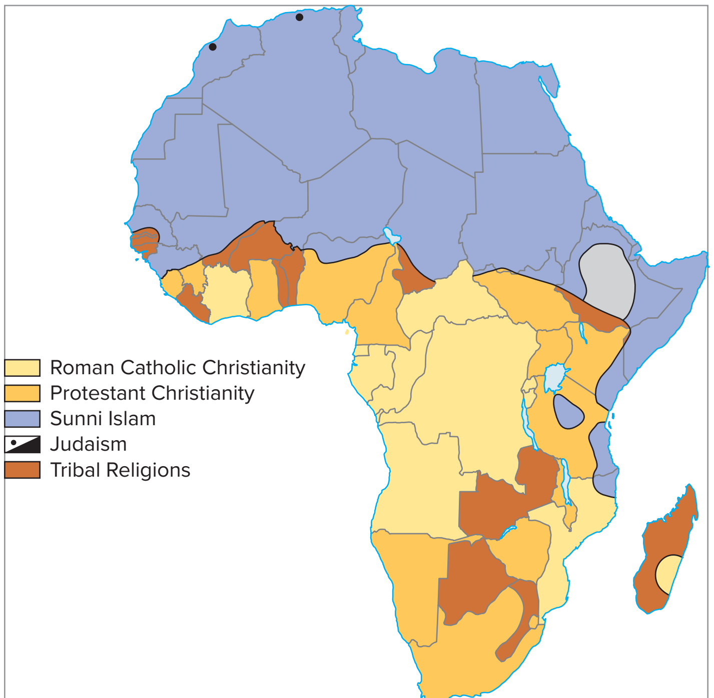


Figure 2.12 **Religious regions of Africa.** Maps such as this one may give the false impression of uniformity within a given area—for example, that only Protestant Christianity is practiced in southern Africa. In reality, regions contain mixtures of different religious faiths as well as nonbelievers. A particular individual might even practice more than one faith. Such maps are intended to represent only the predominant religious faith in an area.

Map Misuse

Most people have a tendency to believe what they see in print. Maps are particularly persuasive because of the implied scientific precision and official content. It is useful to remember that all maps are abstractions and inevitably distort reality. As in all forms of communication, the message conveyed by a map reflects the intent and, perhaps, the biases of its author. Maps can subtly or blatantly manipulate the message they impart or intentionally contain false information.

Sometimes the cause of cartographic distortion has been ignorance, such as when the cartographers of the Middle Ages filled the unknown interiors of continents with mythical beasts. Other times the distortion was deliberate to promote a cause or to thwart foreign military and intelligence operations. Cartographers use various techniques to make deliberately distorted maps.

- Lack of a scale. A scale may be absent and the sizes of some areas diminished while others are enlarged.
- A simple design that omits data or features that would make the map more accurate.
- Colors that have a strong psychological impact.
- Bold, oversized, and/or misleading symbols.
- Action symbols, such as arrows to indicate military invasions or repulsions and pincers to show areas threatened by encirclement (**Figure 2.15**).
- Selective omission of data: many governments, for example, do not indicate the location of military installations on their maps; the hub maps in airline magazines typically show lines radiating from the hub to the cities the airline serves, giving the impression that the flights are nonstop.
- Inaccuracies or "disinformation" for military opponents. The chief cartographer of the USSR acknowledged in 1988 that for 50 years the policy of the Soviet Union had been to deliberately falsify almost all publicly available maps of the country. The types of cartographic distortions on Soviet maps included the displacement and omission of features and the use of incorrect grid coordinates. The routes of highways, rivers, and railroads were sometimes altered by as much as 10 kilometers (6 mi). A city or town might be shown on the east bank of a river, when, in fact, it was on the west bank. Even when features were shown correctly, the latitude and longitude grid might be misplaced.
- An inappropriate projection. For more than a decade, the John Birch Society and other political groups concerned about the "Red Menace" used the Mercator projection, which grossly exaggerates the sizes of areas in the higher latitudes, to magnify the Communist threat, and China and Russia were colored red. On the other hand, the equal-area Peters projection was developed to promote social justice (see "The Peters Projection" p. xx).

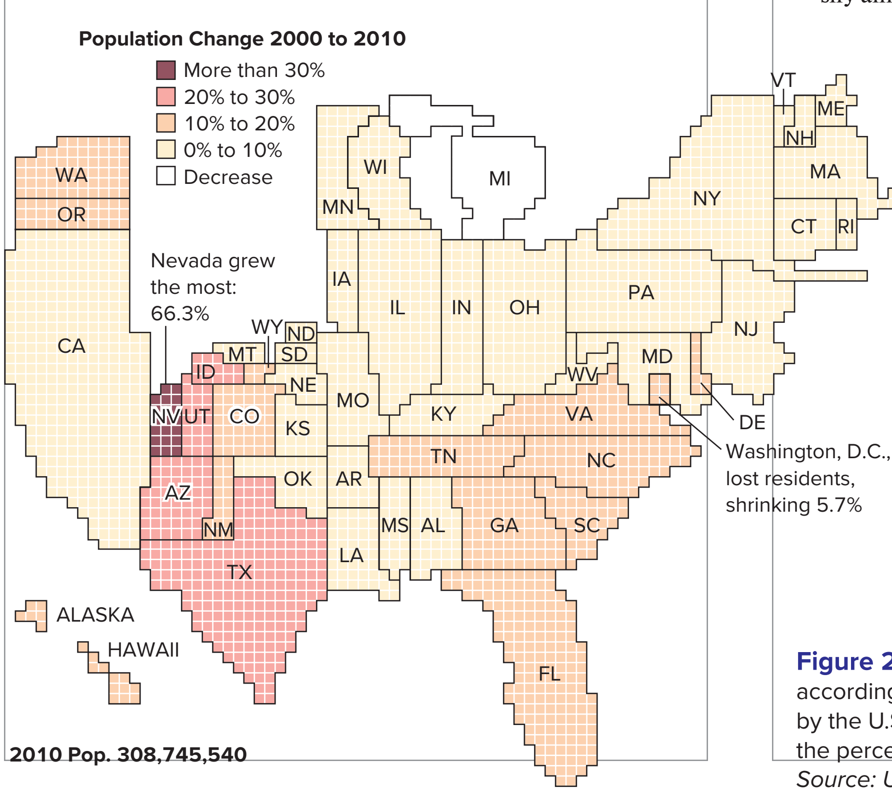


Figure 2.13 **A cartogram** in which each state is sized according to its number of residents in the year 2010 as reported by the U.S. Bureau of the Census. The cartogram also shows the percentage change in population between 2000 and 2010. *Source: U.S. Bureau of the Census.*

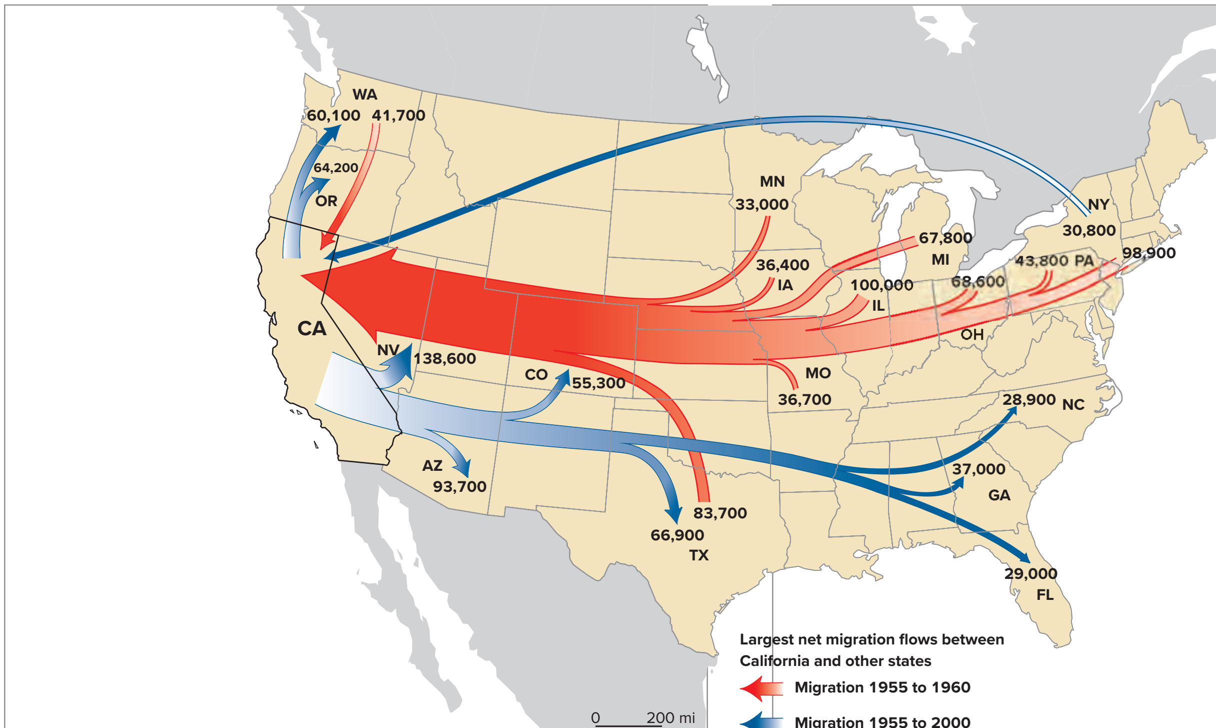


Figure 2.14 **A quantitative flow-line map** comparing migration patterns in the United States from 1955–1960 versus 1995–2000. The widths of the flow lines are proportional to the number of net migrants.

In summary, maps can distort and lie as readily as they can convey accurate spatial data. The more that map users are aware of those possibilities and the greater understanding they possess of map projections, symbolization, and common styles of thematic and reference mapping, the greater their ability to be intelligent and critical map users.

2.6 Contemporary Spatial Technologies

The latter half of the 20th century saw a revolution in mapping that has continued into the 21st century. New means of collecting, storing, analyzing, and presenting geographic data increased the power of mapping. New applications of mapping emerged for government, business, science, and everyday life. Two of the important new technologies involve remote sensing and global positioning satellites.

Remote Sensing

When topographic maps were first developed, it was necessary to obtain the data for them through fieldwork, a slow and tedious process that involved measuring a point's distance, direction, and altitude difference from a known point by a direct line of sight. Mapmakers trudged through jungles, deserts, and tundra. Much fieldwork has now been replaced by **remote sensing,** obtaining geographic data without direct contact with the ground. In the early 20th century, fixed-wing aircraft provided a platform for the

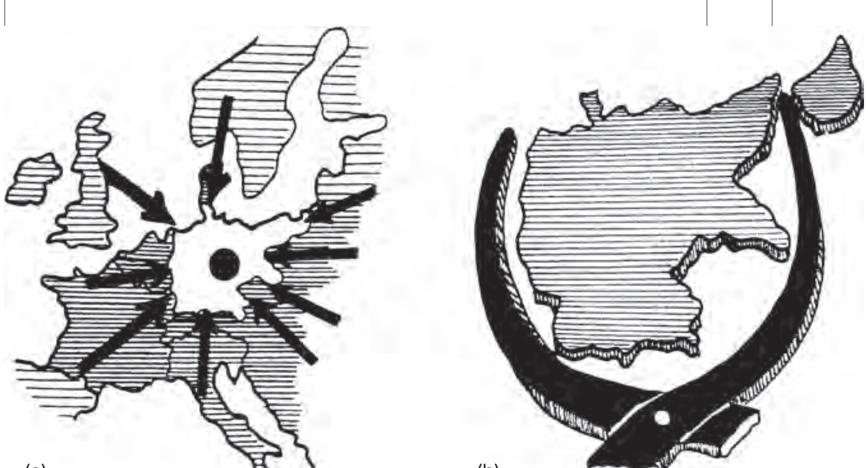


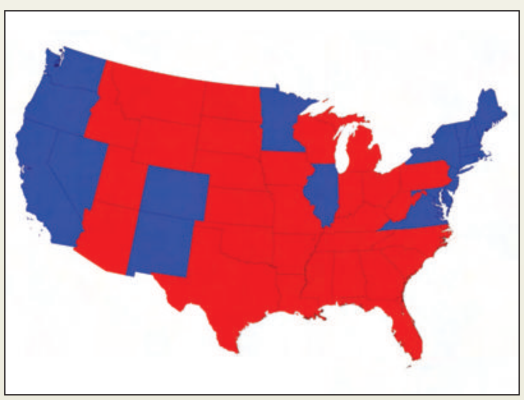
Figure 2.15 **The Nazis, who ruled Germany from 1933 to 1945, used maps as tools of propaganda.** The maps shown here were designed to increase sympathy for Germany by showing it threatened by encirclement. **(a)** Arrows represent pressure on Germany from all sides. **(b)** Pincers signify pressure against Germany from France and Poland. *Source: Karl Springenschmid,* Die Staaten als Lebewesen: Geopolitisches Skizzenbuch *(Leipzig: Verlag Emst Wunderlich, 1934).*

RED STATES, BLUE STATES

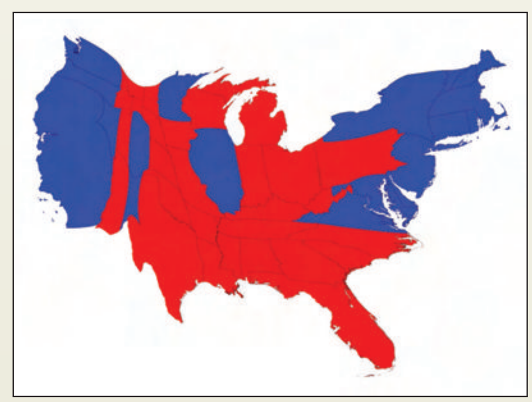
Every map has a purpose. The mapmaker's decision of what data to represent and how to represent them can affect our view of reality. The media discussed the results of the U.S. presidential election of 2016 in terms of "red" states and "blue" states. Red were those where a majority of voters voted for the Republican candidate, Donald Trump, while blue states favored the Democratic candidate, Hillary Clinton. On both maps shown here, the 48 contiguous states are colored accordingly: red and blue to indicate Republican and Democratic majorities, respectively.

Nationwide, the Democrats won the popular vote:—48% for Clinton, 46% for Trump. Trump was elected president, however, because the winner of each state receives all of that state's votes in the electoral college. Nonetheless, map (a) gives the impression that the Republican candidate got more popular votes, because there is more red than blue on the map. While the map is accurate, it is misleading in that most red states have small populations, whereas most blue states have large ones. Three researchers at the University of Michigan's Center for the Study of Complex Systems devised an area cartogram, map (b), that reconfigures the states based on the size of their population rather than their land area. On this map, there is clearly more blue than red. States with more people appear larger than states with fewer people. Rhode Island, for example, with its 1.1 million inhabitants, appears about twice the size of Wyoming, which has half a million—even though Wyoming has 60 times the acreage of Rhode Island.

The researchers created a number of other maps depicting the results of the election. Some show election results by county, others the sizes of states proportional to their number of electoral votes; on still others, red and blue are joined by a third color, purple, to indicate a nearly balanced percentage of Democratic and Republican votes. They can be viewed at www-personal.umich.edu/~mejn/election/2016/.



(a) Conventional view. This map of the November 2016 presidential election shows state-by-state results, colored red and blue to indicate Republican and Democratic majorities, respectively.



(b) Population cartogram. Election results are shown on a cartogram where state sizes are based on population rather than land area.

camera and the photographer, and by the 1930s aerial photographs from planned positions and routes permitted reliable data gathering for mapping purposes.

Although there are now a variety of sensing devices, specially designed aircraft employing digital cameras remain a widely used remote-sensing technique. A **drone** or unmanned aerial vehicle is a powerful tool for mapping smaller areas and can collect the same types of imagery and elevation data as aircraft. Mapping from the air has certain obvious advantages over surveying from the ground, the most evident being the bird's-eye view that the cartographer obtains. Using stereoscopic devices, the cartographer can determine the exact slope and size of features such as mountains, rivers, and coastlines. Areas that are otherwise hard to survey, such as mountains and deserts, can be mapped easily from the air. Furthermore, millions of square miles can be surveyed in a very short time.

Standard photography detects reflected energy within the visible portion of the electromagnetic spectrum (**Figure 2.16a**). It can be supplemented by special sensitized infrared film or digital camera sensors that are particularly useful for measuring vegetation and water features. Color-infrared photography yields what are called *false-color images*—"false" because the image does not appear natural (**Figure 2.16b**). For example, leaves of healthy vegetation have a high infrared reflectance and are recorded as red on color-infrared images, while unhealthy or dormant vegetation appears as blue, green, or gray. Clear water appears as black, but sediment-laden water may appear light blue.

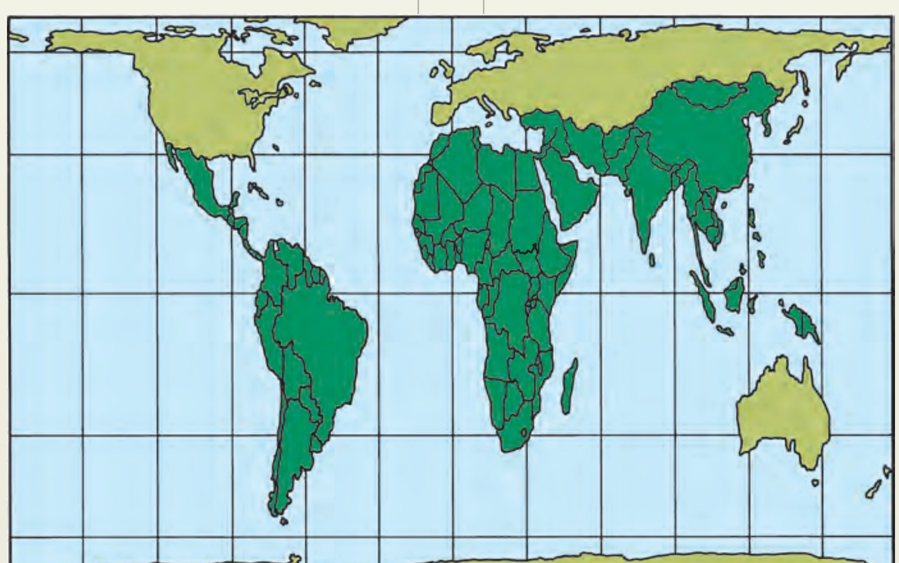
For wavelengths longer than 1.2 micrometers (1 micrometer is 1 one-millionth of a meter), mapmakers use thermal scanners, radar, and lidar.

- *Thermal scanners* record the longwave radiation emitted by water bodies, clouds, and vegetation, as well as by buildings and other structures and are used to produce images of thermal radiation (**Figure 2.17**). Unlike conventional photography, thermal sensing works during nighttime as well as daytime, giving it military applications. It is widely used for studying various aspects of water resources, such as ocean currents, water pollution, surface energy budgets, and irrigation scheduling.

THE PETERS PROJECTION

Developed and promoted by Arno Peters, a German journalist-historian, the Peters projection purports to reflect concern for the problems of the developing countries by providing a less European-centered representation of the world. Because it is an equal-area map, Peters claimed that it shows the densely populated parts of the Earth and the countries of the developing world in proper proportion. A number of socially concerned agencies, including the World Council of Churches, the Evangelical Lutheran Church of America, Boston Public Schools, and UNESCO and several other United Nations organizations, have officially adopted the map.

Presented in 1973 as a "new invention," the projection aroused a storm of controversy. Critics pointed out that, by saying his projection was fairer and more accurate than the Mercator, Peters used the latter as a meaningless foil, a "straw man" to knock down. If Peters wanted to demonstrate that the less-developed countries deserve a larger share of our attention and resources, he might better have used an area cartogram (see Figure 2.13) in which each country is scaled according to its number of inhabitants, which would do more to call attention to enormous populations of developing countries, such as India and Indonesia. Detractors also noted that the Peters projection badly distorts shapes in the tropics and at high latitudes and that many equal-area projections yield a world map with less distortion of shapes. In addition, distances and directions cannot be measured except under very limited conditions. Finally, the projection was not new but, in fact, a very slight modification of an equal-area projection developed by James Gall in 1855.



- Operating in a different band of the electromagnetic spectrum, *radar* (short for *ra[dio] d[etection] a[nd] r[anging]*) systems also can be used day or night. Because radar can penetrate clouds and vegetation as well as darkness, it is particularly useful for monitoring the locations of airplanes, ships, and storm systems and for mapping parts of the world that are perpetually hazy or cloud-covered (**Figure 2.18**).
- *Lidar* (short for *li[ght] d[etection] a[nd] r[anging]*) is a remote-sensing technology that utilizes an airborne laser that sends hundreds of thousands of pulses of light every minute. Some of the light is reflected back to the instrument, where it is analyzed to yield elevation information for the target. Lidar is ideal for any kind of mapping that requires precise three-dimensional models of buildings, trees, and the ground surface (see Figure 2.21).

Since the 1970s, both staffed and unstaffed spacecraft have supplemented the airplane as the vehicle for imaging Earth features. Many images are now taken either from continuously orbiting satellites or from staffed spacecraft flights, such as those of the International Space Station. Among the advantages of satellites are the speed of coverage and the fact that views of large regions can be obtained.

In addition, satellites are equipped to record and report back to the Earth digitized information from multiple parts of the electromagnetic spectrum that are outside the range of human eyesight. Satellites enable us to map the invisible, including atmospheric and weather conditions, soil moisture for agriculture, vegetation health for forestry, identification of geologic structures and mineral deposits, and monitoring of a variety of environmental phenomena, including water pollution and the effects of acid rain. Military applications of remotely sensed images include better aircraft navigation, improved weapons targeting, and enhanced battlefield management and tactical planning, which raises the question of who should have access to the information (see "Civilian Spy Satellites" p. xx).

Perhaps the best known remote-sensing spacecraft are the **Landsat satellites,** the first of which was launched in 1972. The different sensors of the Landsat satellites are capable of resolving