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CHAPTER 2

GEOGRAPHIC INQUIRY: DATA, TOOLS, AND TECHNOLOGY

CRITICAL VIEWING As part of a mapping project initiated by UNICEF, Fatima Wariou, a university student from Niamey, Niger, captures GPS coordinates in the Sahara desert. Other participants of the MAP4DEV group study the movement of the sand toward an inhabited area nearby. ▮ Explain how collecting data helps these geographers to analyze the progression of the sand.

GEOGRAPHIC THINKING What tools do geographers use to depict spatial relationships?

2.1 THINKING LIKE A GEOGRAPHER: THE GEO-INQUIRY PROCESS

Geographers use spatial analysis to explain patterns of human behavior and understand how places and societies are organized. They seek to understand where things are, why they are there, and how they develop and change over time.

THINKING LIKE A GEOGRAPHER

Geographers think spatially in terms of space, place, arrangement, and interconnections between humans and the environment. Understanding the complexities of the world, or even of a small community, involves observing the environment, aspects of culture, politics, economics, and more. Therefore, thinking like a geographer requires the integration of many topics and disciplines. Geographic thinking calls for asking questions, collecting and organizing data from a myriad of sources, making connections, and presenting data in a usable way. Only then can people make informed decisions and take appropriate action.

Using the National Geographic Geo-Inquiry Process supports geographic thinking. Tools such as maps, globes, graphs, photographs, and satellite imagery provide geographers with vast amounts of data about the world that is analyzed to understand the processes driving human geography. Following the Geo-Inquiry Process provides geographers a systematic way to examine complex issues at various scales—local, regional, or global. It also helps users make connections among various components of an issue, identify patterns, and draw conclusions to make informed predictions and decisions that can impact communities.

THE GEO-INQUIRY PROCESS

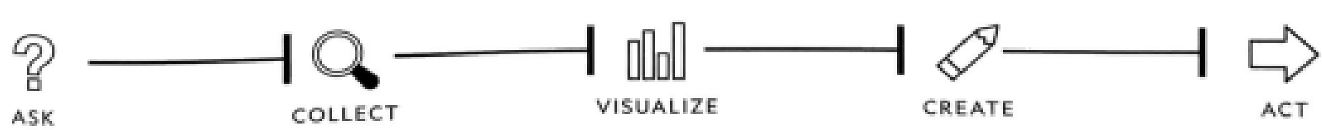
The Geo-Inquiry question is at the heart of the process. Geographers ask questions about spatial distributions, such as *Why do the majority of people migrate to urban areas?* or *Why did many settlements on rivers grow to become cities?*

Suppose local leaders have proposed building a new school in your community, but they have not determined where it should be built. To address this issue, you might first ask: *Where should the school be located?* Note that even this basic geographic question can generate multiple responses and lead to further questions depending on the purpose

THE GEO-INQUIRY PROCESS

The Geo-Inquiry Process is a five-step method, summarized here. As you read this chapter, you will find tips on carrying out each step.

- **ASK** In the first step of the process, you explore an issue or problem through a geographic lens that addresses the three basic questions you're already familiar with: *Where? Why there? Why care?* As you explore the problem or issue further, you reach a more complex understanding of the issue that will help narrow your focus into an overarching Geo-Inquiry question. This question will drive your project.
- **COLLECT** In the second step, you collect the data you need to answer the question. You might collect this data through interviews and field work, by contacting experts or organizations, or other forms of research.
- **VISUALIZE** Once you've collected your data, you will have a large amount of information that you need to organize. Visual representation is critical. Data can be displayed in maps or through other visuals. Visuals can make complex information easier to understand and better reveal connections and patterns.
- **CREATE** In this step, you create a Geo-Inquiry story that answers your Geo-Inquiry question. This step walks people through the issue. The way you choose to create and communicate your story should be well matched to your audience.
- **ACT** This final step includes sharing your Geo-Inquiry story with decision-makers to inspire them to take action. Ask yourself: *What action should be taken based on the findings?*



of the question. One answer might focus on the school's potential site, which refers to its physical characteristics, such as its location in a flood zone. The description might also include its situation, which refers to the place's location in relation to other places. In addition to asking where something is, geographers seek to understand *why*. As you consider locations, you should ask yourself: *Why is this a good location and not somewhere else? Why do people care about the school's location?* These questions ultimately lead to further investigation.

Identifying and gathering the data you need to answer the Geo-Inquiry question is the second step in the Geo-Inquiry Process: *Collect*. As in any scientific process, the evidence derived from the data you collect will be chosen based on relevancy to the topic or issue. To determine the best location for the school, identify data that tells where other schools in the community are located, which schools are overcrowded, where student populations are located, and how trends in the community's population or demographics might impact this data in the future. Information about site characteristics like major roads, available land, and building costs is also necessary. You might examine satellite or aerial photos to identify areas with sufficient room to build a school. In addition, you could consider interviewing local school principals and superintendents to have them identify key characteristics of good school locations that might include efficient bus routes or proximity to other schools.

Now you're ready for the next step: *Visualize*. Visualizing your data is key to sharing your data and telling your story. For example, you might use a map to show the location of schools in your community and land that is available. You could share data that shows population and other demographic information. As your Geo-Inquiry story takes shape, think about the visuals that would help others better understand the issue and resulting actions that can be taken.

Create is the next step of the process. In this step, you organize your supporting evidence in a format that puts your data into context. A multimedia presentation is a good choice for displaying your data. You can use storyboarding to organize the visual, audio, and text elements of your story. In the storyboard, you can sketch what each component of your story will look or sound like and indicate the visual elements that will appear on the screen. This is also the time to anticipate what elements of your presentation—either spoken or visual—the stakeholders will want to know more about. Think about responses to possible questions.

In the final step of the process, *Act*, you present your information to decision-makers. Since your Geo-Inquiry project focuses on the location of the new school, you may want to share your data with local leaders and try to convince them to consider the location you have identified.

GEOGRAPHIC THINKING

1. Describe the Geo-Inquiry Process.
2. Explain how thinking like a geographer benefits all decision-making.
3. Identify three geographic questions about any environmental, social, or economic issues that interest you, and then explain how your questions might change when considering different scales of analysis.

THE GEO-INQUIRY PROCESS | TIPS FOR SUCCESS

ASK

- Choose a topic that you want to investigate. Developing Geo-Inquiry questions can help you examine a community issue.
- Brainstorm for three minutes. Write as many questions during this time as possible without editing them. This will help you think of numerous questions beyond the first basic questions that come to mind.
- Write additional need-to-know questions after researching your topic or issue. Your initial research may spark additional interesting questions.
- Choose a Geo-Inquiry question of appropriate scope. If you can answer the question by looking at a map or doing a 10-minute search on the internet, it is not sufficient to drive the Geo-Inquiry Process.
- Choose a Geo-Inquiry question that you can research. You will need to be able to collect data or information pertinent to the question. A good question will require multiple sources of information and encompass the need to understand various related questions.
- Think of questions that will help you make connections. *Why is that there? How does that being there affect the people living nearby or the surrounding natural environment? What are the various perspectives about the issue? Does spatial analysis inform actions that could be taken?*

CRITICAL VIEWING An aerial photograph is a tool that gives geographers information about the site and situation of a place. The photo shows a school nestled in the Santa Susana Mountains north of Los Angeles, California. ▮ Identify some questions geographers may have asked about the location when considering whether or not to build a school there.

2.2 GEOGRAPHIC DATA AND TOOLS

Geographic data is information about the characteristics of locations on Earth. Geographers use data to explore and better understand places and the processes that influence these locations.

COLLECTING DATA

LEARNING OBJECTIVE
IMP-1.B Identify different methods of geographic data collection.

Geographers use a variety of methods for collecting data. Geographic information is any data with a location tied to it, such as a street address or its elevation. It is information at a given spot whether it is about the human world, natural world, or anything else. Approximately 80 percent of the world's data is spatial.

The methods by which data are collected include observing and systematically recording information, reading and interpreting maps and other graphic representations of spaces and places, reading reports and policy documents, and interviewing people who can provide both information and perspectives about places and issues. The data collected through these methods are **quantitative** or **qualitative**. Information measured by numbers is called quantitative data. The population of a city is quantitative data. Qualitative data are interpretations of data sources such as field observations, media reports, travel narratives, policy documents, personal interviews, landscape analysis, and visuals such as art or photographs. Skills involved in analyzing quantitative and qualitative data involve seeking patterns, relationships, and connections.

The data geographers collect has to be at the appropriate scale and align to the nature of the research questions. So, for example, answering a question about the migration patterns out of a country would require population data at the country level but not at the neighborhood level.

Suppose you want to determine the effects of the use of pesticides and herbicides in your community. A number of data sources should be considered. You could first collect information about the pesticides and herbicides used locally—the benefits and risks of their use, and data about where and how often they are used. Initial data might be gathered from media reports and other online sources to determine the effects of the chemicals on the land and humans. Field observations and personal interviews with local farmers and gardeners can provide invaluable insights about the location and frequency of use of the chemicals.

Land-use maps and aerial photography could also be analyzed to see if areas of high use are adjacent to waterways or neighborhoods. In addition, you might seek policy documents from government agencies such as the Environmental Protection Agency, Food and Drug Administration, or the county agricultural agent about the regulations and guidance regarding the use of pesticides and herbicides. All of these sources provide evidence about the impact of humans and their use of chemicals on the land that could be used to frame an argument and take action.

WHO COLLECTS DATA? Countless organizations, both public and private, collect and analyze data. The U.S. Census Bureau, for example, conducts a **census** of the U.S. population every 10 years. A census is an official count of the number of people in a defined area. The U.S. Census Bureau also conducts dozens of other surveys, including the American Community Survey, which gathers information about educational attainment, employment, income, language proficiency, migration, and housing. The Census Bureau also gathers information from American businesses as part of its Economic Census. All information collected by the U.S. Census Bureau is available to the public through written reports as well as online, where a search feature enables users to gather information at a range of scales, about a particular city, county, or zip code.

The federal government also collects census information on agriculture every five years. The U.S. Department of Agriculture analyzes data on meat, dairy products, and crops to ensure the quality and availability of food and to help American farmers and businesspeople make informed decisions. In addition, the Economic Research Service provides a wealth of data related to food security.

U.S. government agencies also collect information about elections at a range of spatial scales to observe patterns of voting behavior. Results of past elections are kept by the Federal Election Commission and the National Archives, and state and local governments also keep election records.

In addition to making use of the data gathered by organizations, individuals conduct their own data-gathering efforts based on the specific question they want to answer. Data gathering takes multiple forms, such as written surveys or in-person or phone interviews that gather information about people and their experiences. Individuals also conduct field observations using photography, sensors, and scientific probeware, a tool connected to probes and sensors to collect real-time data and to record information about specific locations and spatial elements. Travel narratives that describe the physical and cultural characteristics of a place are useful as well.

THE GEO-INQUIRY PROCESS | TIPS FOR SUCCESS

COLLECT

- Identify types of data that will help you answer your Geo-Inquiry question. Use multiple sources to obtain a full picture.
- Consider primary sources (surveys, interviews) and secondary sources (census data, topographic data, satellite imagery).
- Use reliable data sets. Make sure they are credible, reliable, and timely. Don't be afraid to collect the data you need in the field.
- Keep your data organized and have a backup copy. Create a spreadsheet, image folder, or other method to stay organized.
- When collecting data through interviews or surveys, design your questions so they elicit the data you want. Write them in a way so participants can take the survey quickly.
- With parent or teacher approval and the participant's permission, use a smartphone or other device to record interviews. Notify the participant before starting the recording.
- Take precautions when gathering data in the field. Wear protective gloves or a life jacket. Do not go to remote areas or approach strangers alone when conducting interviews.

GEOGRAPHIC INFORMATION SYSTEMS

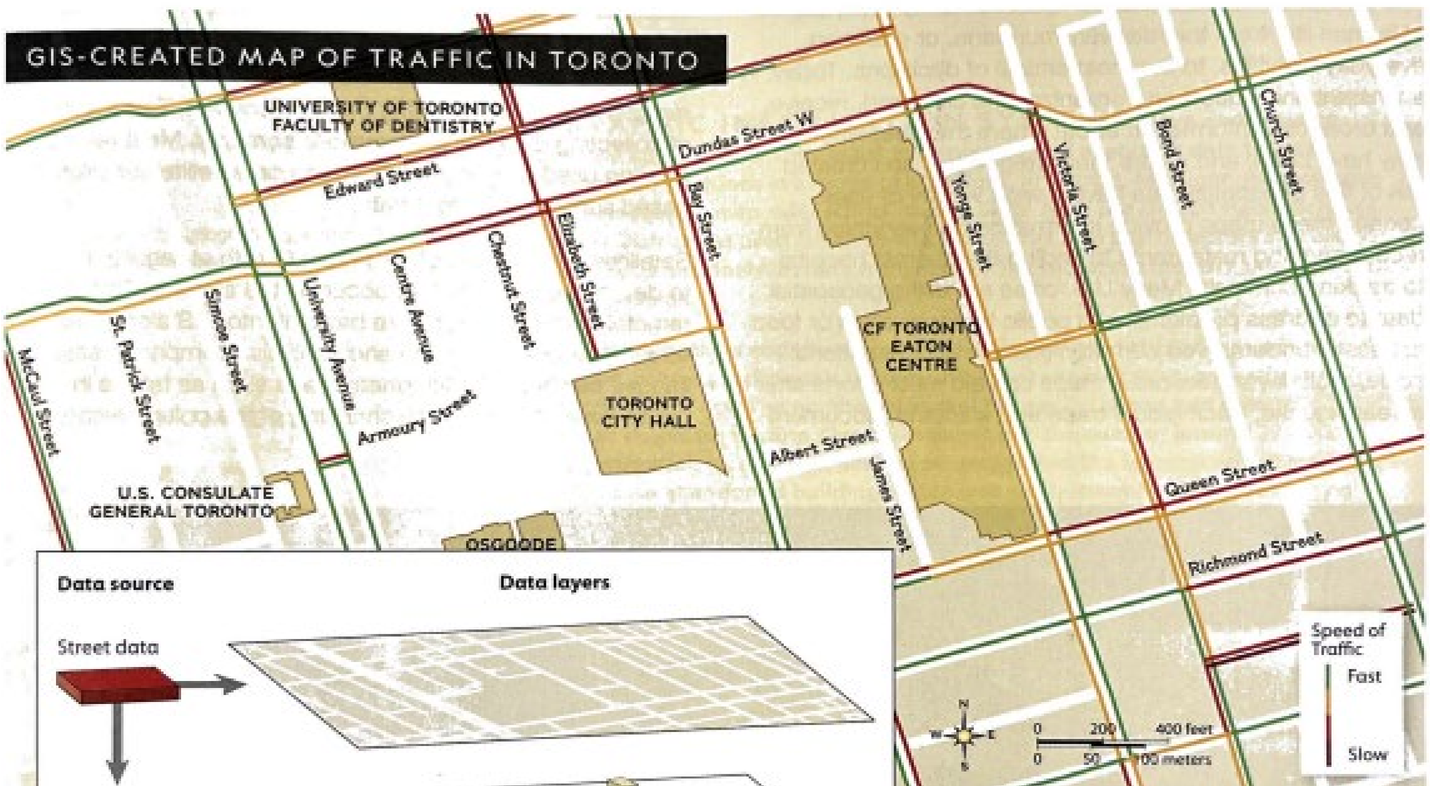
LEARNING OBJECTIVES

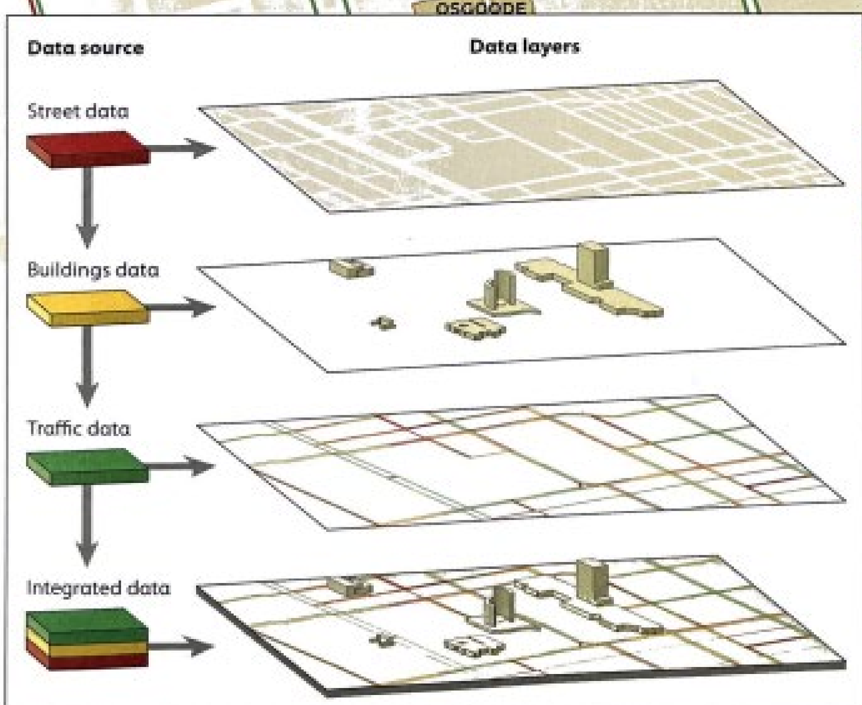
IMP-1.A Identify types of maps, the types of information presented in maps, and different kinds of spatial patterns and relationships portrayed in maps.

IMP-1.B Identify different methods of geographic data collection.

Geospatial technologies encompass the modern tools used to analyze data about specific locations across the globe. Organizations and individuals use the technologies to find precise locations, collect and share data, create maps, and track changes in characteristics of places on Earth's surface. The development of sophisticated mapping software systems called **geographic information systems (GIS)** has immensely helped geographers and others with their work. GIS captures, stores, organizes, and displays geographic data that can then be used to configure both simple and complex maps. Such maps are created by organizing layers of information to form a combined image. Each type of information is stored in a separate layer that represents a specific theme and dataset, such as roads, population, voting district boundaries, and much more. The layers that are selected to display will vary depending on the goals of the project and the question that geographers seek to answer.

A wide range of spatial data is easily compared and analyzed using GIS. A GIS map can display information about the physical geography of the land, such as elevation or **topography**, which is the shape and features of land surfaces. It can also display demographic information about the people who live in a certain place, such as age, ethnicity, income, or family size. Combining the data from these layers





GENERATING A GIS MAP GIS organizes different kinds of data into visuals. A map of traffic in downtown Toronto would include layers of data showing streets and buildings. Then real-time traffic information—in this case, collected by satellites and other sources—would be added. The integrated map could then be accessed by drivers using a smartphone, for example.

makes it easy for geographers to make connections, for instance, understanding how natural resources impact the economic activities that take place in a region.

GIS maps support geovisualization, which is the process of creating visuals for geographic analysis using maps, graphs, and multimedia. This process allows users to analyze geospatial data interactively, aiding visual thinking and providing insights into the issues geographers are studying. One common use of GIS involves comparing natural features with human activity. GIS could be used to evaluate environmental risks to a community such as flood potential or human-made risks such as industrial pollution levels. Such information can help communities plan for future sustainable development.

Geospatial technologies collect and analyze immense amounts of data—data accessible to anyone with internet access—leading to a revolution in spatial decision-making. The geospatial revolution encompasses nearly every aspect of human life, from the relatively mundane, or common, everyday activities, to the most critical of decisions. Today, in an instant, individuals and organizations can send, receive, and broadcast information about where they are, where they have been, and where they are going. Maps created out of this geospatial data have a wide variety of uses. Locally, these maps provide information on everything from recommending restaurants to finding the nearest hospital to tracking criminals. Many U.S. cities are using geospatial data to address problems with public transportation or food access in underserved communities. On an international scale, multi-layer geospatial maps can aid relief efforts after an earthquake, track global trade and shipping, document the potential impacts of climate change, support the deployment of troops during conflict, or assist in the drawing of territorial boundaries as a part of peacemaking.

GEOGRAPHIC THINKING

1. Describe the difference between quantitative and qualitative data and provide an example of each.
2. Explain what GIS is and how it is used to understand spatial patterns and relationships.

OTHER REMOTE SENSING TOOLS

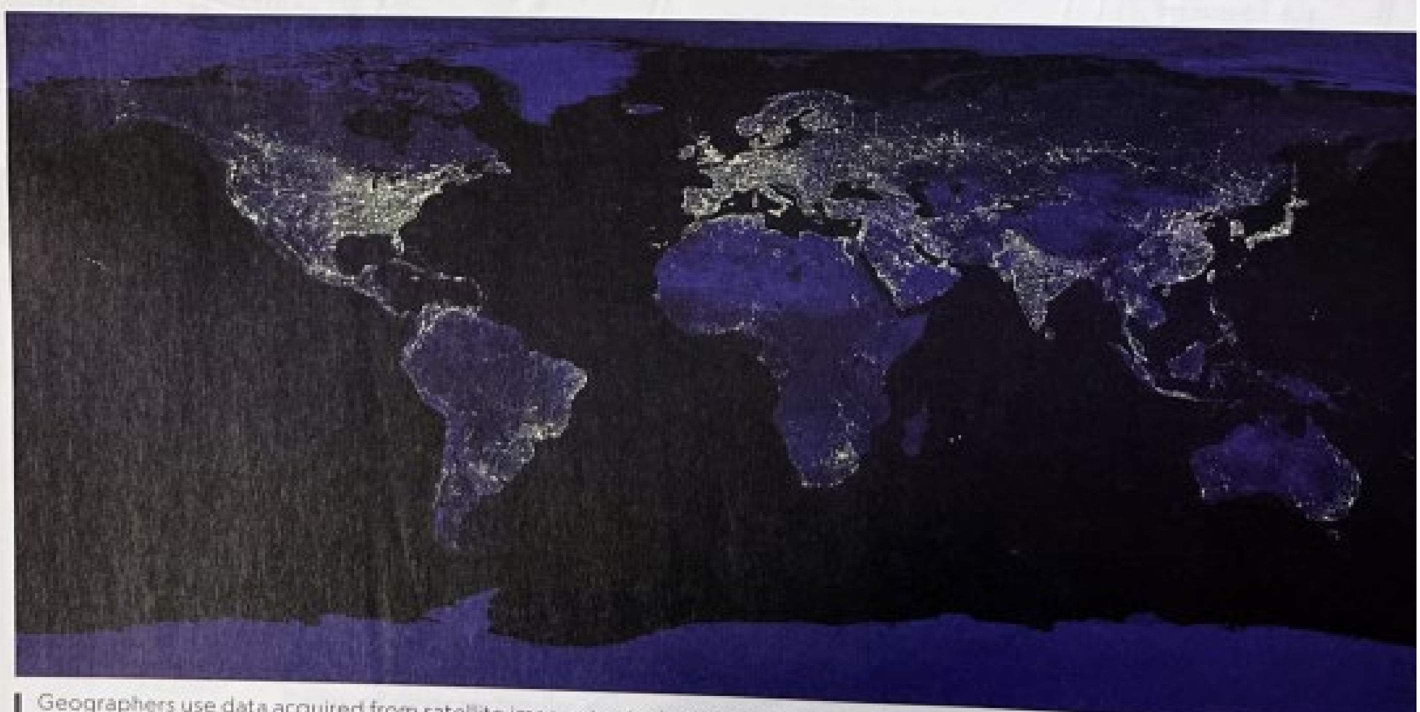
LEARNING OBJECTIVES

IMP-1.B Identify different methods of geographic data collection.

IMP-1.C Explain the geographical effects of decisions made using geographical information.

A variety of geospatial technologies gather data; some do so remotely, or without making physical contact. This method of collecting data is called **remote sensing**. Most remote sensing used by geographers relies on satellites or aircraft-based sensors to collect data.

Satellites take images of sections of Earth at regular intervals to determine changes that occur on the surface. Then the remotely-sensed images are brought into GIS along with other data for comparison and analysis. Comparing satellite images can help identify phenomena such as trends in urban development or the shrinking of the polar ice caps.



Geographers use data acquired from satellite images to study environmental and developmental changes. This image of Earth at night, compiled from more than 400 satellite images, provides insights into the location of urban populations and economic development using the nighttime light cities emit.

CASE STUDY

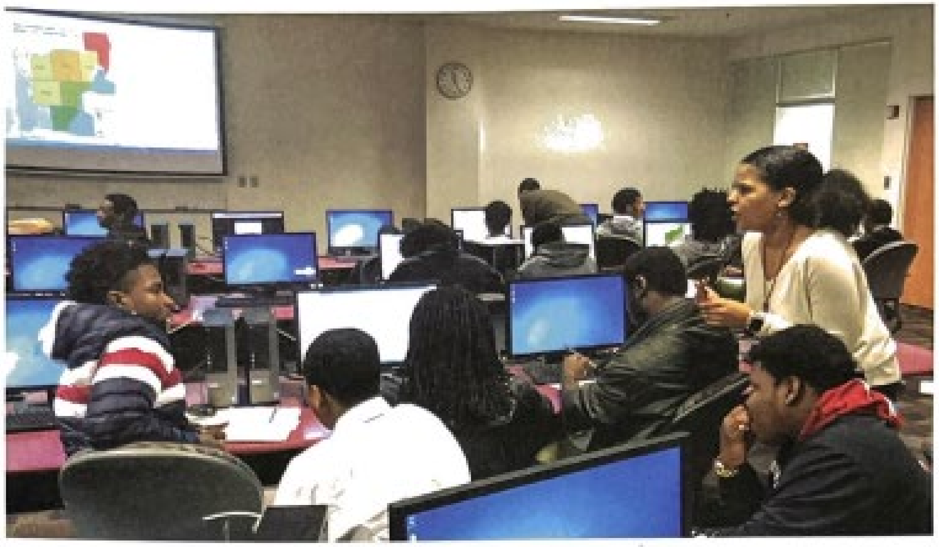
DETROIT—GIS HELPS FIND SAFER ROUTES

THE ISSUE Getting to and from school safely was a problem for some students in Detroit, as an economic decline contributed to abandoned houses and urban blight.

LEARNING OBJECTIVES

IMP-1.B Identify different methods of geographic data collection.

IMP-1.C Explain the geographical effects of decisions made using geographical information.



At Wayne State University's Center for Urban Studies in Detroit, middle and high school students learned how to use GIS to map their neighborhoods and discover safer routes to and from school.

GEOGRAPHIC INFORMATION SYSTEMS have a wide range of real-world applications. They assist in displaying and analyzing data to make evidence-based decisions in a range of situations. In Detroit, Michigan, for example, GIS has been used to map safer school routes. Since 1999, the Detroit Public Schools Community District has used GIS to divide the district into patrol sectors and blocks. The city collects and analyzes data from each of the sectors to identify safe routes to school for students.

Nonprofit organizations and the school district also enlisted students to address urban blight, or areas in disrepair. Studies show that vacant structures are a strong predictor of assault risk. The number of vacant houses in Detroit had grown following an economic decline. One assessment put the number around 22,000, but an investigation by a Detroit newspaper suggested the number was at least 30,000. Because abandoned buildings often lack easily identifiable addresses, no one had been able to pinpoint the locations of the vacant structures. Even as the city struggled to board up or sell the vacant homes, new abandoned buildings appeared. In an innovative program called Mapping Out A Safer Community, middle and high school students used GIS software and handheld GPS to map the vacancies. The technology allowed them to identify the exact locations of abandoned buildings and vacant properties. The students then compiled their data, presented it to local government officials, and suggested areas to target for code enforcement. Using the students' information, the city boarded up abandoned buildings. The students taking action is an example of the last step in the Geo-Inquiry Process.

The student initiative was just one part of a broader data-gathering initiative, however. Members of the AmeriCorps Urban Safety Project walked the school routes and conducted surveys of parents, students, and school personnel to identify hazards. In addition to abandoned buildings, they mapped issues related to lighting, sidewalks, and dangerous intersections. This information has been used as part of a broader, federally funded program called Safe Routes to School (SRTS) that continues to work to ensure safe travel for Michigan students to and from school. ▮

BY THE NUMBERS

672,662
population of Detroit in 2019

51,000
students enrolled in Detroit Public Schools Community District in 2019

30,000+
estimated number of abandoned houses in Detroit in 2018

Sources: *World Population Review; Chalkbeat; Detroit Metro Times*

GEOGRAPHIC THINKING

Think about the mental mapping you did in Chapter 1. What would you expect to find if you followed Detroit's example in mapping routes to your school?

A forestry conservation analyst from the World Wildlife Fund (WWF) uses an unmanned drone to map an area of the Western Amazon rain forest in Brazil. Unmanned drones can be used in more locations than traditional aircraft and they provide the same data-collection capacity at a fraction of the cost. This makes them an increasingly valuable data-collection tool.

Satellites are also used for real-time decision-making. For example, satellites can track the path of a hurricane and the speed it is traveling. This data can be used to help predict where a hurricane will land. After an event, it also can be used to show the extent of damage, enabling aid to be directed appropriately. Days after Hurricane Maria devastated much of Puerto Rico in 2017, satellite images showed dramatic changes to the landscape and helped identify the hardest-hit areas.

Remote sensors mounted on aircraft or drones are another source of data. In addition to satellite images, aerial photographs were taken of the land months after Maria's damage. The photographs, along with GIS, helped the U.S. Army Corps of Engineers analyze existing and new data about the island's electrical power grid so they could make repairs and provide generators to those without power even in remote areas. Airplane-mounted sensors are also used to measure the gradual sinking of land along the Gulf Coast to assess risk to local communities. As the technology advances and becomes less expensive, drones are making remotely-sensed data more accessible than ever. They enable scientists, including cartographers and other geographers, to take detailed measurements between features or places on Earth's surface. Drones collect data that is then brought into GIS to determine changes in land use or environmental conditions. For example, farmers can use the data to get a bird's-eye view of the condition of their crops. The use of drones to identify a cluster of diseased plants in a large field or areas in need of water helps farmers treat targeted areas of their land and save resources.

Another source of geographic data is the **global positioning system (GPS)**, an integrated network of at least 31 satellites in the U.S. system that orbit Earth and transmit location data to handheld receivers. Essentially, a GPS receiver uses the time it takes to receive a transmitted signal to measure the distance to each satellite. The receiver uses this data to pinpoint the exact location of the receiver. The accuracy of the information allows people to determine the precise distance between two points, making GPS especially useful for navigation purposes. Pilots of airplanes and ships use GPS to stay on course. Smartphones and automobiles also are equipped with GPS receivers, enabling motorists to receive instructions for the fastest or most direct route to a desired destination. GPS-based mapping systems provide users with both maps and verbal directions to follow while traveling. GPS also uses information collected from other receivers to determine the speed of travelers and where traffic is stopped. GPS is used for several geospatial applications beyond GIS.

One of the challenges that geographers face today is the enormous amount of available data. In addition to the GPS satellites that provide positioning data and satellites that collect images of Earth, there are hundreds of satellites collecting information about population, migration, soils, ocean currents, and more. Online mapping services collect and share even more data through aerial photographs and street-level cameras. The amount of real-time data, or information that is available for analysis immediately after being collected, has grown tremendously. Now internet-based supercomputer systems are being developed to help geographers manage, analyze, and share this data.

GEOGRAPHIC THINKING

3. **Identify three ways geographers collect data.**
4. **Describe how drones have impacted the acquisition of geospatial data.**
5. **Explain why it is important to collect data at the appropriate scale.**
6. **Describe one way geographers could use GPS in their work.**

Sarah Parcak analyzed satellite images and maps to identify priorities for protecting archaeological sites in Egypt.

NATIONAL GEOGRAPHIC EXPLORER **SARAH PARCAK**

PROTECTING ARCHAEOLOGICAL SITES

LEARNING OBJECTIVES

IMP-1.B Identify different methods of geographic data collection.

IMP-1.C Explain the geographical effects of decisions made using geographic information.

Throughout the world, expanding development and natural environmental changes can put archaeological sites at risk. Looting, the stealing of artifacts from a site, presents another challenge. The demand for ancient artifacts fuels a black market that pays looters handsomely. Archaeologist Sarah Parcak has used geospatial technologies to preserve and protect archaeological sites in Egypt.

Parcak is a professor of archaeology at the University of Alabama at Birmingham. She specializes in Egypt, which is where she had her first dig almost two decades ago. In her early work, she recognized that archaeological sites were in danger of being lost forever as a result of encroaching urban development and the rampant looting of artifacts. She posed an important geographic question: *How could her team preserve and protect these irreplaceable records of human history?* This guiding question led to others: *Where are Egypt's archaeological sites? What is the most efficient way to find them? Which sites are in greatest need of protection? How can we encourage people to recognize the importance of protecting these sites?*

Parcak set about gathering data to help answer these questions. She conducted extensive background research and examined satellite images showing discolored soil, changes in vegetation, or other differences in the landscape that might suggest that ancient ruins lay under the surface.

Following Egypt's political upheaval in 2011, Parcak learned from social media that people were digging illegally at various sites and stealing artifacts. Comparing satellite images of the region taken in 2010 to images taken after 2011 (such as the one above) revealed a landscape increasingly scarred by looting pits, and confirmed that the theft of artifacts was on the rise. Parcak used the satellite images and maps to show government officials where looting was taking place. The government used her data to improve its protection of the endangered sites. As a result, Parcak not only helped Egypt solve a problem that it didn't know it had, but she facilitated the preservation of ancient artifacts for future generations.

GEOGRAPHIC THINKING

Explain how geospatial technologies used for data collection have impacted geographers' work.

2.3 UNDERSTANDING MAPS

Maps are the way geographers depict relationships of time, space, and scale. Maps are indeed among the geographer's most important tools because they display data in a spatial way. Geographers use many different types of maps to help them answer the three questions you've already learned about: *Where? Why there? Why care?*

MAPMAKING

LEARNING OBJECTIVE

IMP-1.A Identify types of maps, the types of information presented in maps, and different kinds of spatial patterns and relationships portrayed in maps.

Maps are the fundamental tool most uniquely identified with geography. People have used maps to depict information for thousands of years, and they continue to use increasingly sophisticated maps today. As you know, maps come in all shapes, sizes, and formats, and have a wide variety of uses and purposes. One of the most common uses of maps is to locate something, such as a country or a river. The purpose of many maps, such as road maps or subway maps, is to communicate how to get from one place to another. Centuries ago, **cartographers** created maps to help explorers follow the routes of those who came before them and to estimate how long it might take to travel to uncharted lands. These explorers then collected critical data for the creation of new maps.

Patterns in our world are seldom random; spatial features tend to be clustered, dispersed, or linear. For example, geographers use maps to illustrate the clustering or

CRITICAL VIEWING This map from Ortelius's atlas shows the world in two dimensions. ■ Explain what this map reveals about geographers' knowledge of the world in 1570. Then compare it to today's maps.

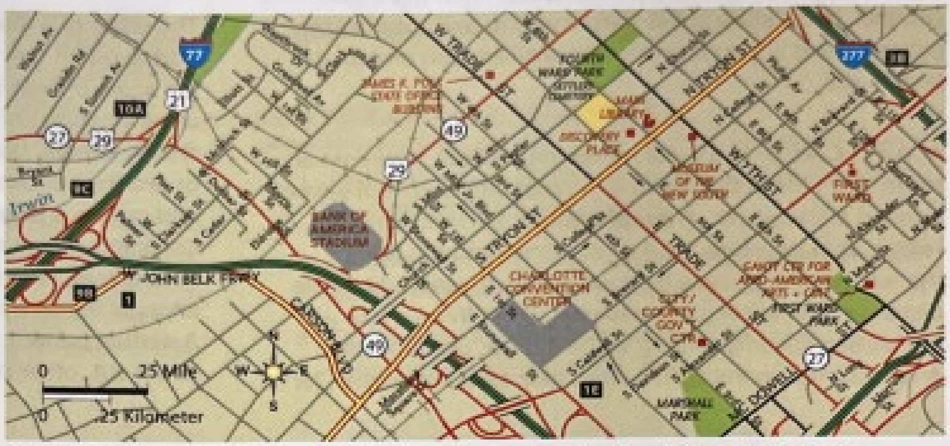
dispersal of patterns of the distribution of populations. To describe the spacing of places or people, the terms **absolute distance** and **relative distance** are used. Absolute distance is distance that can be measured using a standard unit of length. Relative distance is measured in terms of other criteria such as time or money. For instance, it takes approximately 7 hours to fly from New York City to Paris, France, or a ride share in New York City from Manhattan to LaGuardia airport costs $40. The terms **absolute direction** (the cardinal directions north, south, east, and west) and **relative direction** (left, right, up, down, front, or behind based on people's perceptions) are used to describe direction and location when interpreting maps.

Maps are important problem-solving tools. For example, depicting the spread of a disease epidemic on a map can often be the first step in finding its cause and stopping further outbreaks. Mapping cholera cases in the mid-1800s helped doctors recognize that outbreaks of the disease tended to happen near water supplies. That helped them identify the use of contaminated water as the cause. About 150 years later, geographer Korine N. Kolivras used GIS to analyze dengue fever outbreaks in Hawaii. Dengue fever is a disease carried by a particular type of mosquito, so Kolivras's work included analyzing the breeding conditions needed for this mosquito to thrive. By mapping the precipitation, vegetation, and other related variables, Kolivras was able to predict the places at greatest risk of dengue fever and other mosquito-borne illness.

As representations of the entire world or part of the world, maps are selective in the information they represent. It is impossible to fit every feature or piece of data onto a single map. So mapmakers must decide how much of Earth to show and how to show it. These decisions are driven by the purpose of the map. Maps have many different purposes—to show location, distance, or some other spatial relationship. Maps can also be used

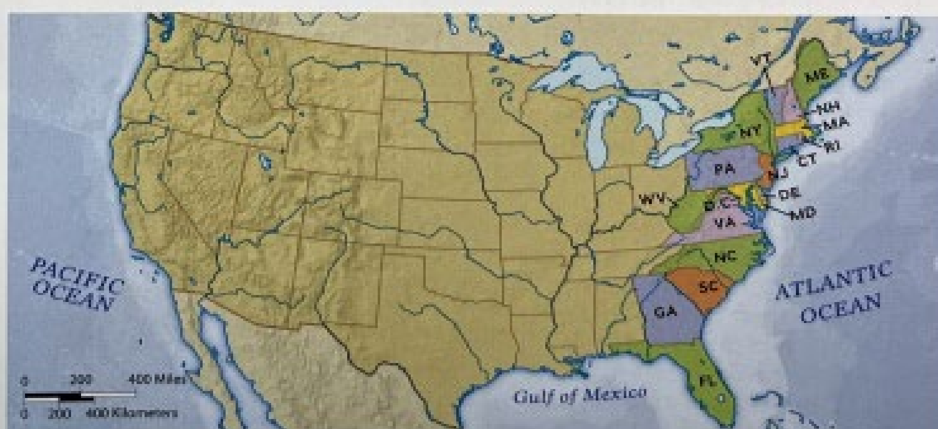
MAP SCALES

On a walk through a city, such as Charlotte, North Carolina, you might use a highly detailed map that shows only the downtown area. To drive up the Atlantic coast, however, you would use a map that covers a large area, including several states. These maps have different scales.



LARGE-SCALE MAP This detailed map shows only the city of Charlotte, North Carolina. The map scale shows that a half inch on the map represents a quarter mile on Earth's surface.

MEDIUM-SCALE MAP This map shows the entire state of North Carolina. It includes fewer details than the large-scale map and shows a larger area. The map scale shows that three-quarters of an inch on the map represents 100 miles on Earth's surface.



SMALL-SCALE MAP This map identifies the Atlantic coast states from Florida to Maine. It covers a large area and shows even fewer details than the medium-scale map. The map scale shows that a half inch on the map represents 200 miles on Earth's surface.

to measure change over time. Comparing a map of Boston from 1775 with one of the city today reveals how humans have altered the landscape over time.

As with any secondary source material, it is important to evaluate maps critically by considering the source of the data and the intent of the cartographer. You might ask yourself, *What story is this map trying to tell?* Learning to critically read and interpret maps will help you create your own maps.

MAP SCALE Maps can show information at almost any scale, from the entire world to a neighborhood, to a school, or even a classroom. A **map scale** is the mathematical relationship between the size of a map and the part of the real world it shows. It allows you to measure absolute distance. The scale can be expressed in three ways: as a representative fraction, a written scale, or graphically. A representative fraction is often expressed as a ratio, for example a scale of 1:1,000,000 means 1 unit on the map represents 1 million of the same units on Earth's surface. An example of a written scale is 1 inch representing 200 miles. A graphic scale is expressed with a scale bar showing the relationship between the distance on the map and the distance on Earth's surface.

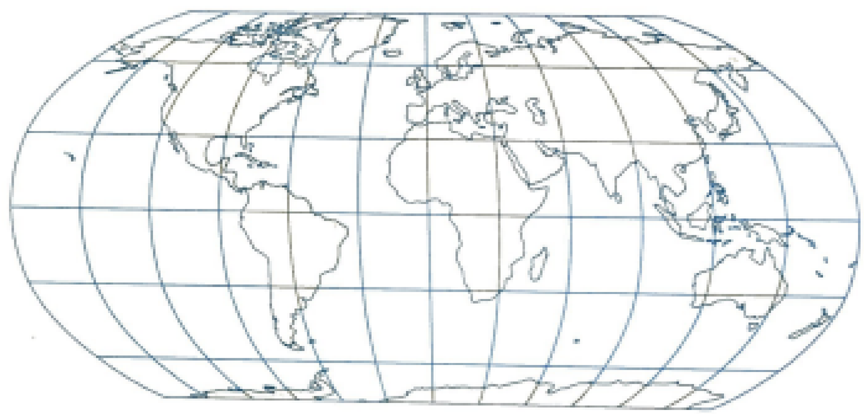
The scale of a map is an important clue to the level of detail portrayed on the map as well as the purpose of the map. As the scale of analysis varies, so does the kind and amount of information shown on the map. For example, a city map shows streets, buildings, and landmarks. A map of a state or province shows less detail—cities, rivers, and highways—and covers a larger area. A map of an entire country or continent shows even less detail; perhaps just the major natural features and national borders. The scale of a map impacts the analysis of the map and therefore its purpose. A certain pattern may be obvious at one scale, but as you zoom out, other patterns may become clear. When making

MAP PROJECTION TYPES

Within the broad categories of projections, including conformal, cylindrical, and equal-area, are four common projection types: Robinson, Mercator, Gall-Peters, and azimuthal. Each projection has advantages and limitations and distorts the sizes and shapes of Earth's landmasses in different ways. The different projections also handle direction differently.

The Robinson projection has curved lines of longitude and straight lines of latitude, which means directions are true only along the parallels (including the equator) and the central meridian. Its unique, globe-like appearance makes the Robinson projection useful for many different types of maps.

The Mercator and Gall-Peters projections show true direction, which is direction measured with reference to the north geographic pole. These two projections are often used for navigation. The azimuthal projection is well-suited for maps of the Arctic and Antarctic.



ROBINSON PROJECTION The shapes of the continents become more distorted farther away from the equator or the map's central meridian.

MERCATOR PROJECTION The continents' shapes are maintained and direction is displayed accurately, but the sizes of the continents are very distorted.

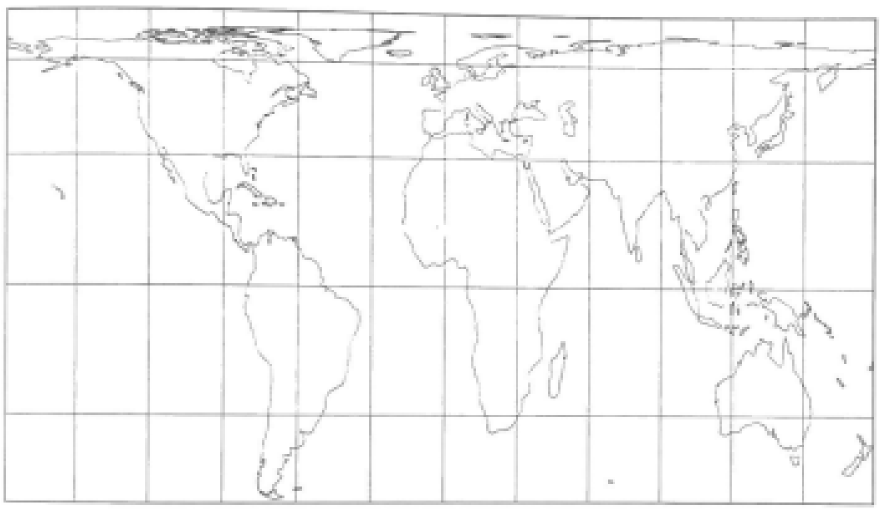
decisions or conducting spatial analyses, it is important to use a map at the appropriate scale that shows pertinent details. The scale of a map must fit the purpose.

MAP PROJECTIONS Cartographers are tasked with using just two dimensions to represent a three-dimensional object—Earth. A sphere cannot be flattened onto a piece of paper or screen without altering its original shape. Over time, cartographers have developed various mathematical equations to handle the distortion, or misleading impressions, of Earth's surface that occur during the mapmaking process.

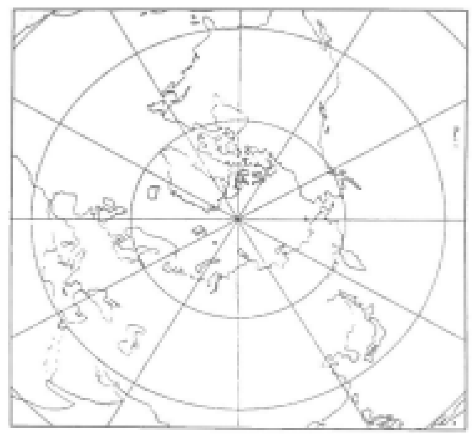
A map projection is any method used to represent the world or part of the world in two dimensions. Different projections distort spatial relations in shape, area, direction, or distance. All map projections create distortion, but the types and degrees of distortion vary considerably. The purpose of the map should guide the type of projection used. A conformal projection distorts area but keeps the shapes intact, giving the impression that some continents are larger than they actually are. Cylindrical projections also distort shapes, but they preserve direction. Equal-area projections, on the other hand, attempt to distribute the distortion of area equally throughout the map; however, in so doing, they distort the shapes of landmasses.

GEOGRAPHIC THINKING

1. Describe one example of absolute distance and one example of relative distance.
2. Compare the three ways scale is expressed on maps by explaining how they are alike and different.
3. Explain why the Robinson projection is one of the most commonly used map projections.



GALL-PETERS PROJECTION The relative size of the continents is more easily displayed than with other projections, but the shape of the continents is distorted.



AZIMUTHAL PROJECTION A flattened disk-shaped portion of Earth is shown from a specific point.

MAP PROJECTION	ADVANTAGES	LIMITATIONS
MERCATOR	• Shows true direction • Good for navigation purposes	• Distorts area • Size is distorted increasingly near the poles
GALL-PETERS	• Shows true direction • Area is relatively precise	• Distorts shape • Continents appear elongated
ROBINSON	• A globe-like appearance that "looks real" • Distorts size and shape, but not too much	• Imprecise measurements • Extreme distortion at the poles; flat on the poles and compressed near the equator
AZIMUTHAL	• Preserves direction • When used from the point of the North Pole, no country is seen as center	• Distorts shape and area • Only shows one half of Earth

TYPES OF MAPS

LEARNING OBJECTIVE

IMP-1.A Identify types of maps, the types of information presented in maps, and different kinds of spatial patterns and relationships portrayed in maps.

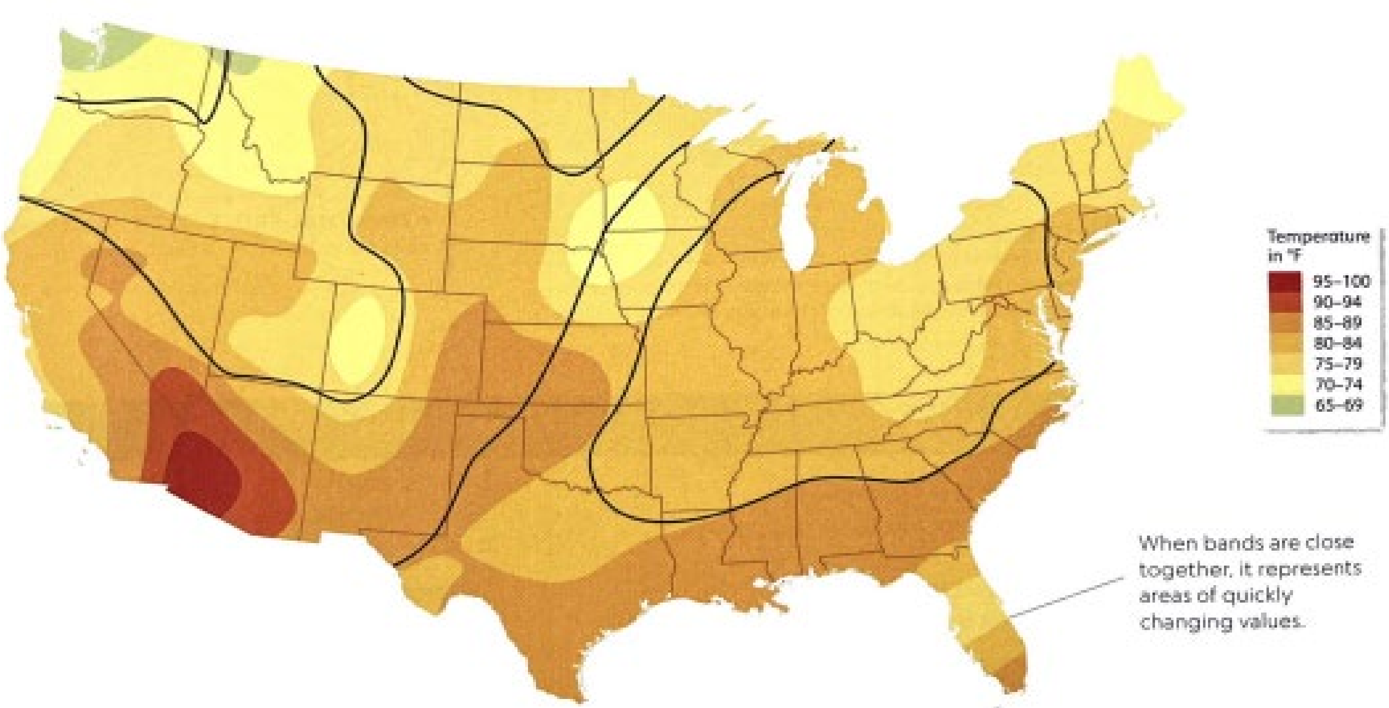
There are two major categories of maps: reference and thematic. **Reference maps** are generalized sources of geographic data and focus on location. **Thematic maps** have a theme or specific purpose and focus on the relationship among geographic data. A reference map might show streets and other general city features, while a thematic map might show the spread of disease across a city, or trade patterns around the world.

REFERENCE MAPS Reference maps illustrate the boundaries, names, and other unique identifiers of places and regions. They focus on the location of geospatial elements such as countries, cities, lakes, and other features of a landscape. Physical maps, which primarily show landforms and other natural features, and political maps, which primarily show boundaries between governmental units like countries or states, are examples of reference maps. Reference maps often show absolute location in terms of latitude and longitude. For example, the absolute location of Portland, Oregon, is 45.52° N latitude and 122.68° W longitude. You can locate Portland on any map marked with latitude and longitude using these coordinates.

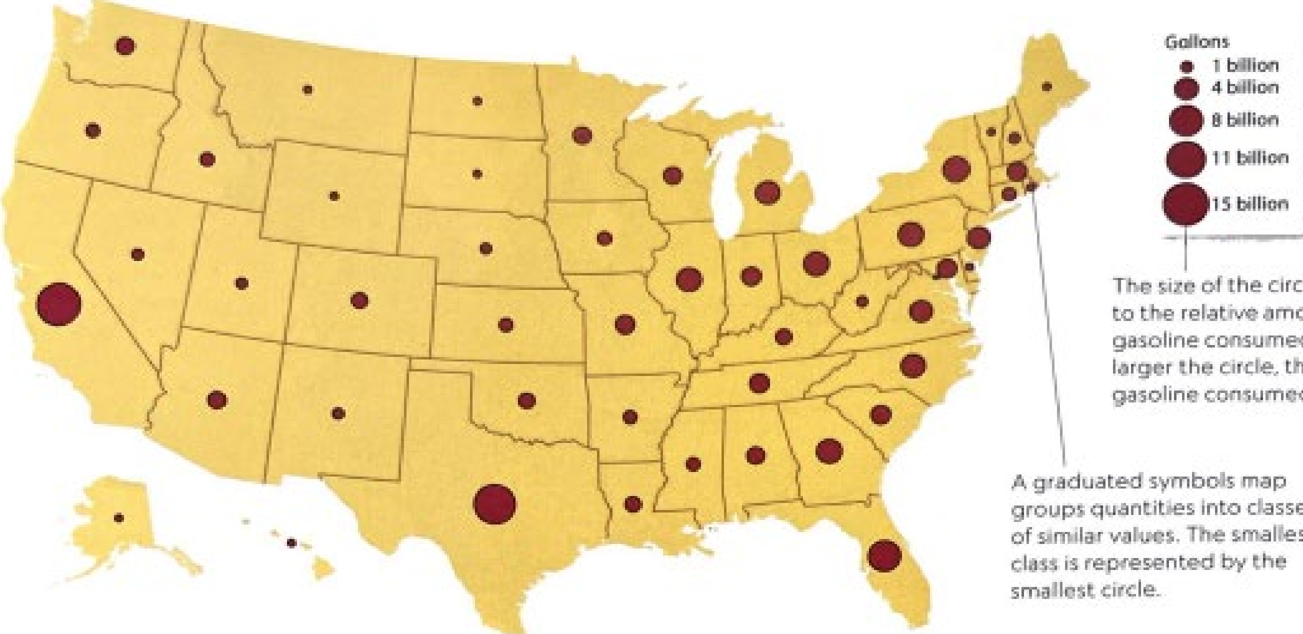
Beginning in 2005, online mapping services began to use satellite imagery, aerial photography, street maps, and panoramic views of streets to enable users to see reference maps of almost any place on Earth at almost any scale. Mapping services take advantage of GPS-enabled software systems to provide real-time traffic conditions and route planning that includes estimated travel time. In addition to travel by car, mapping services offer reference maps for travel on foot, by bicycle, and by public transportation.

THEMATIC MAPS Thematic maps are maps focused on a particular topic or theme. For example, a map showing early human migrations out of Africa and their rate of dispersion to other parts of the world can be shown on a thematic map. Thematic maps can show the distribution, flow, connection of, or relationship among one or more attributes. They might focus only on population density, or multiple attributes, such as ethnicity, election results, and population density. Showing too many attributes on the same map can confuse its message.

SURFACE TEMPERATURES OF THE CONTIGUOUS UNITED STATES, JULY 25, 2019

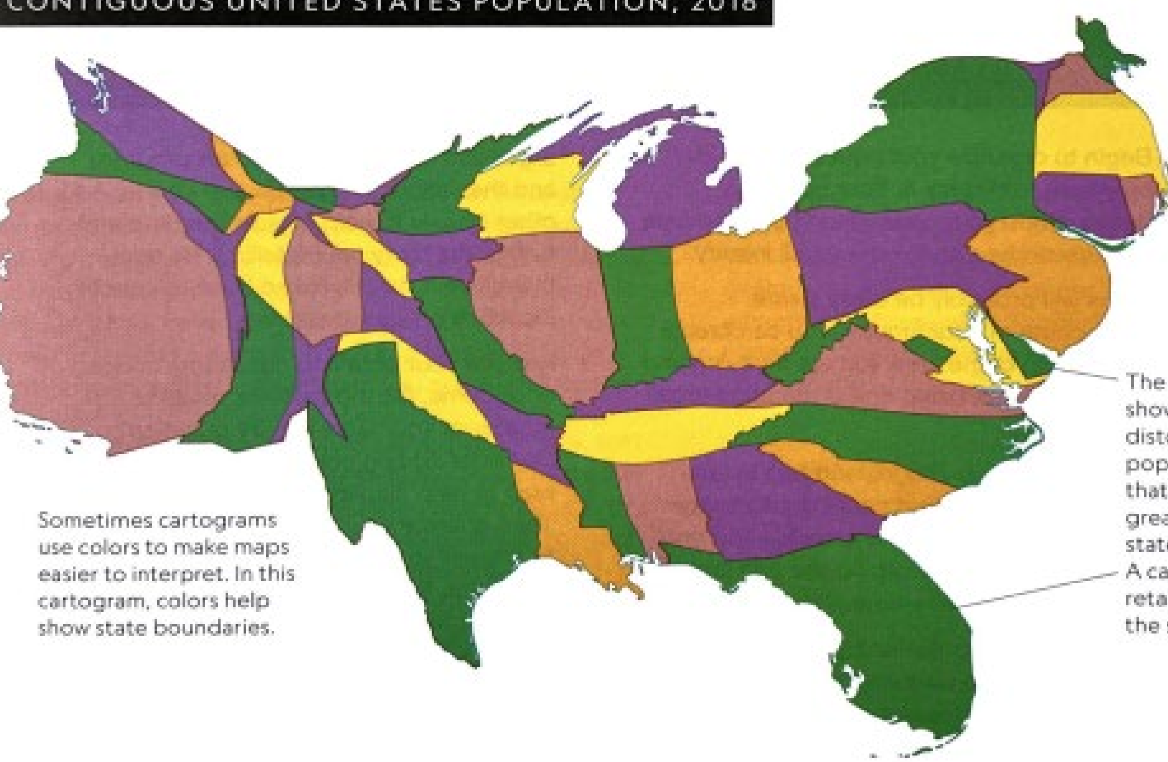


ISOLINE MAP Lines connect data points of the same value. Isoline maps are used to show particular characteristics of an area. On this temperature map, isolines represent bands of similar surface temperatures and the black lines show areas of high and low air pressure across the United States.

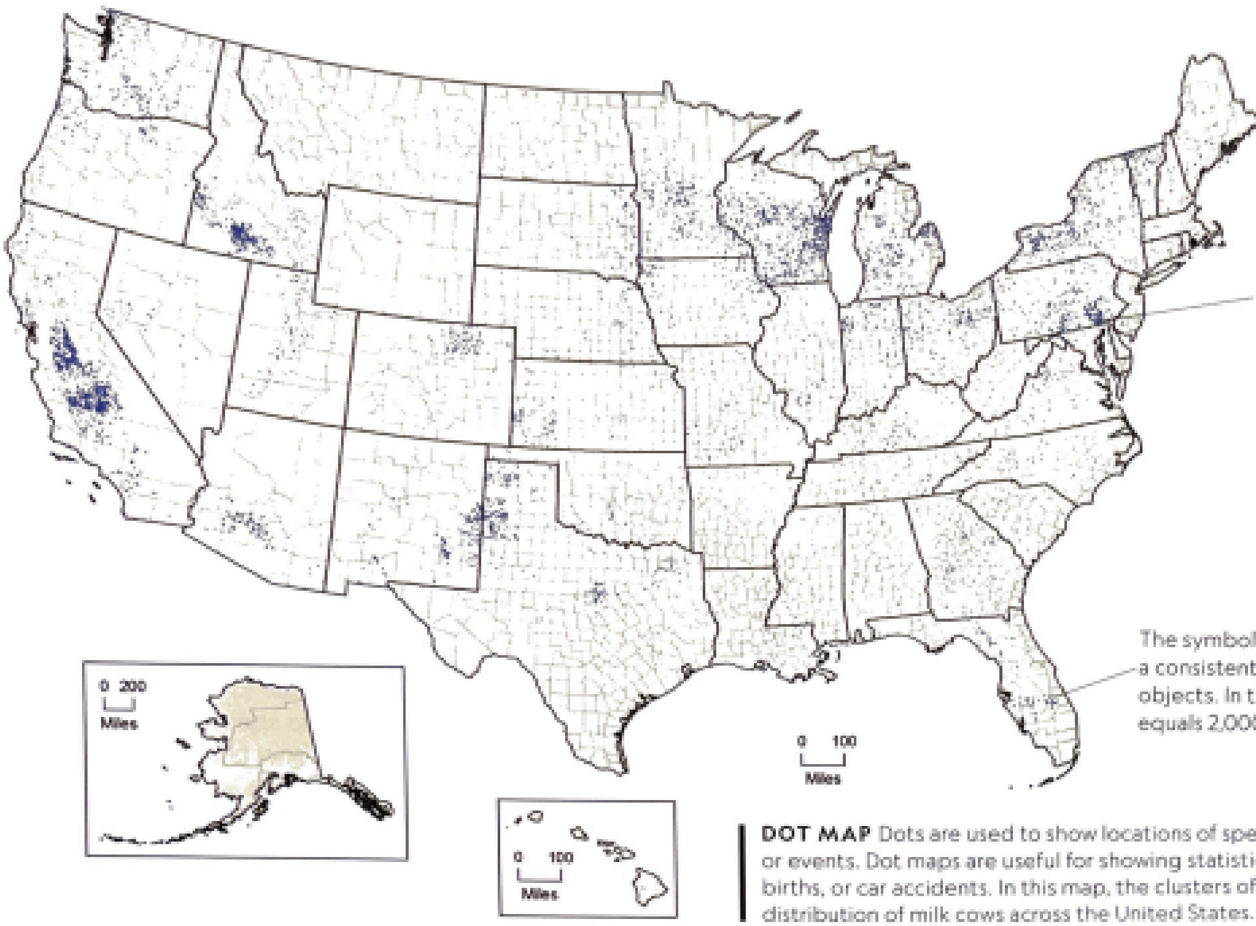


GRADUATED SYMBOLS MAP Differently sized symbols are used to indicate quantitative data. Bigger circles or icons represent a larger numerical value of a particular attribute. A graduated symbols map is useful for showing population, earthquake magnitude, or, as in this map, gasoline consumption.

CONTIGUOUS UNITED STATES POPULATION, 2018



CARTOGRAM Statistical data and geographic location are combined to communicate information at a glance. Cartograms show the relative size of an area based on a particular attribute, like population or energy consumption. Sometimes geographic regions are distorted to convey quantity or extent.



Dot maps reveal distribution or density. The more dots in an area, the larger the quantity.

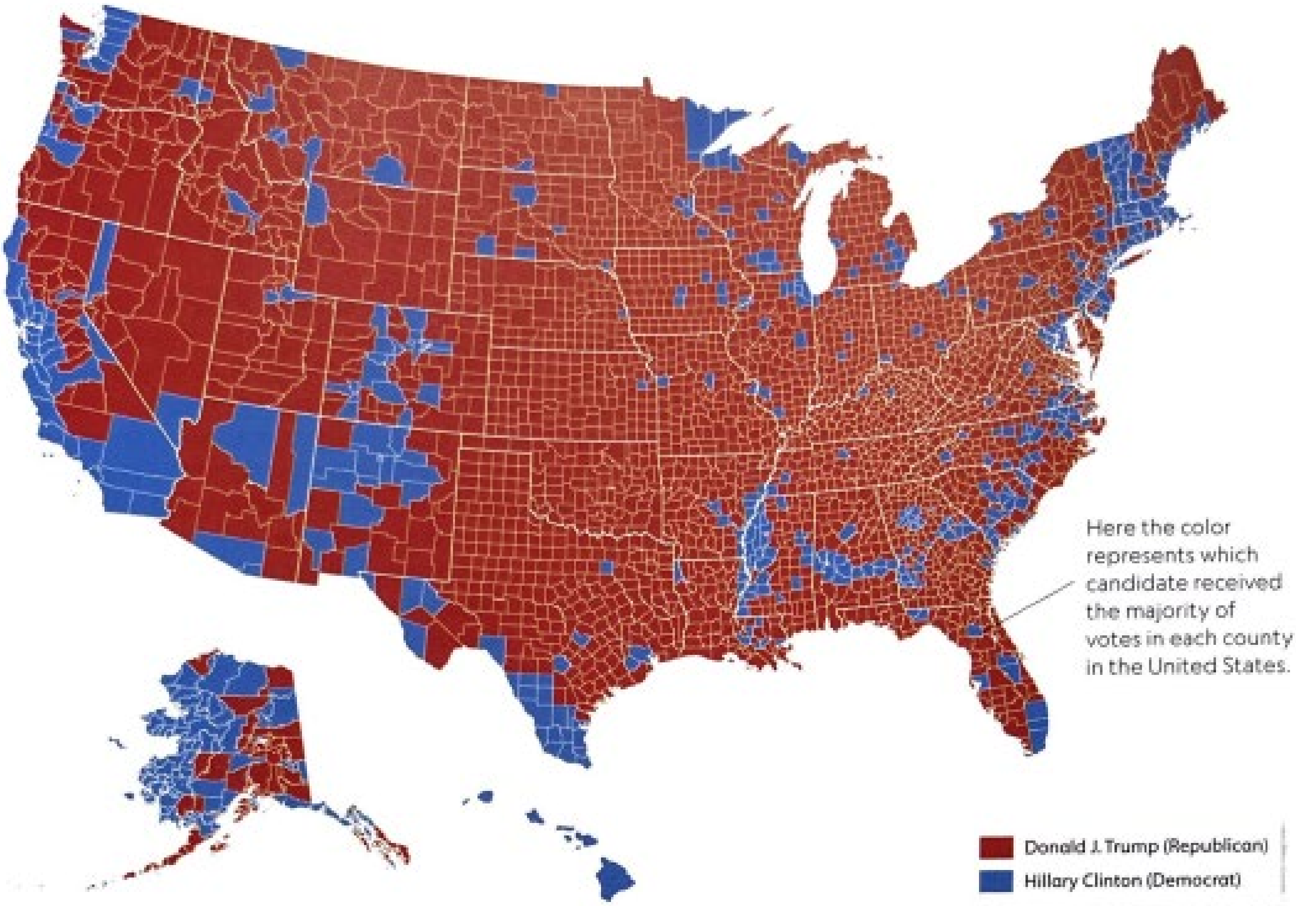
The symbol or dot represents a consistent number of objects. In this case 1 dot equals 2,000 milk cows.

DOT MAP Dots are used to show locations of specific observations or events. Dot maps are useful for showing statistics like crimes, births, or car accidents. In this map, the clusters of dots reveal the distribution of milk cows across the United States.

THE GEO-INQUIRY PROCESS | TIPS FOR SUCCESS

VISUALIZE

- Begin to organize your data and consider how best to display it. Your goal is to demonstrate your understanding of the data you researched and your overall inquiry.
- Maps will probably be a key visual component of your inquiry. You can create a basemap of the area you are studying and add data layers using online mapping tools and sources.
- Consider adding images and text to your map. You can cut and paste or use online programs. Online mapping tools allow you to turn items on and off, so you can look at one type of data at a time.
- Add any first impressions you have about the area you are visualizing to your map. Attach sticky notes to printed visuals, or add markers if you are using an online mapping program.
- How you organize your data depends on the data type. Quantitative data can be organized using a spreadsheet program and then shown in graphs and charts. Add other visuals to help explain the data and further the story you're telling. Be sure that all your data is linked back to specific locations on your basemap.
- Analyze your data and notice any trends or patterns. Do the patterns relate to or answer your Geo-Inquiry question? Consider adding colors or symbols to your map to help display patterns or trends. Then analyze your map. You should be able to answer your Geo-Inquiry question at this point. If you can't, revisit your data and conduct further research.
- Finalize your map once you know it can answer your Geo-Inquiry question. Make adjustments to your map and your other visuals so they are clear and clean. Include a title and make sure all labels are clear and relevant.



CHOROPLETH MAP This thematic map uses colors or shading to represent categories of data for predetermined geographic areas such as census tracts, counties, states, provinces, or countries. Choropleth maps are useful for communicating quantitative data, such as demographics or election results.

Basemaps form the foundations of both reference and thematic maps. Many thematic maps use a basemap showing coastlines, city locations, and political boundaries. The map's theme is then layered onto this basemap. Political divisions, cities, or natural features provide reference points to help users understand the data that is presented on a thematic map, which can focus on any number of topics.

Most geographic data relates to specific points, lines, and areas. The way maps display these types of data affects analysis. Clusters are best illustrated in maps that use dots or graduated symbols, for instance. Isoline maps connect data points of equal value, like elevation, temperature, or precipitation. Choropleth maps use color or shading to display quantitative data in preset regions. Graduated symbols represent differences in size or extent of something in an area, like populations of a state or traffic volume by county. Greater numbers are represented by larger symbols.

A cartogram is a unique type of map that conveys information by making the areas on a map proportional to the variable being mapped. As one example, a cartogram might redraw the spatial features of the U.S. states according to population distribution, so that New York state or Massachusetts appears much larger than Alaska or Montana.

GEOGRAPHIC THINKING

4. Choose one of the thematic maps from this lesson. Based on specific details, describe one conclusion you can draw from the map.
5. Explain similarities and differences between dot maps and graduated symbols maps. Why might one or the other be preferable for different types of data?

2.4 THE POWER OF DATA

Geographic data help people make informed decisions at all scales—from individuals making personal decisions to businesses determining their marketing strategy, and from communities engaged in development planning to countries and international organizations looking to solve the world's most pressing problems.

HOW DATA ARE USED

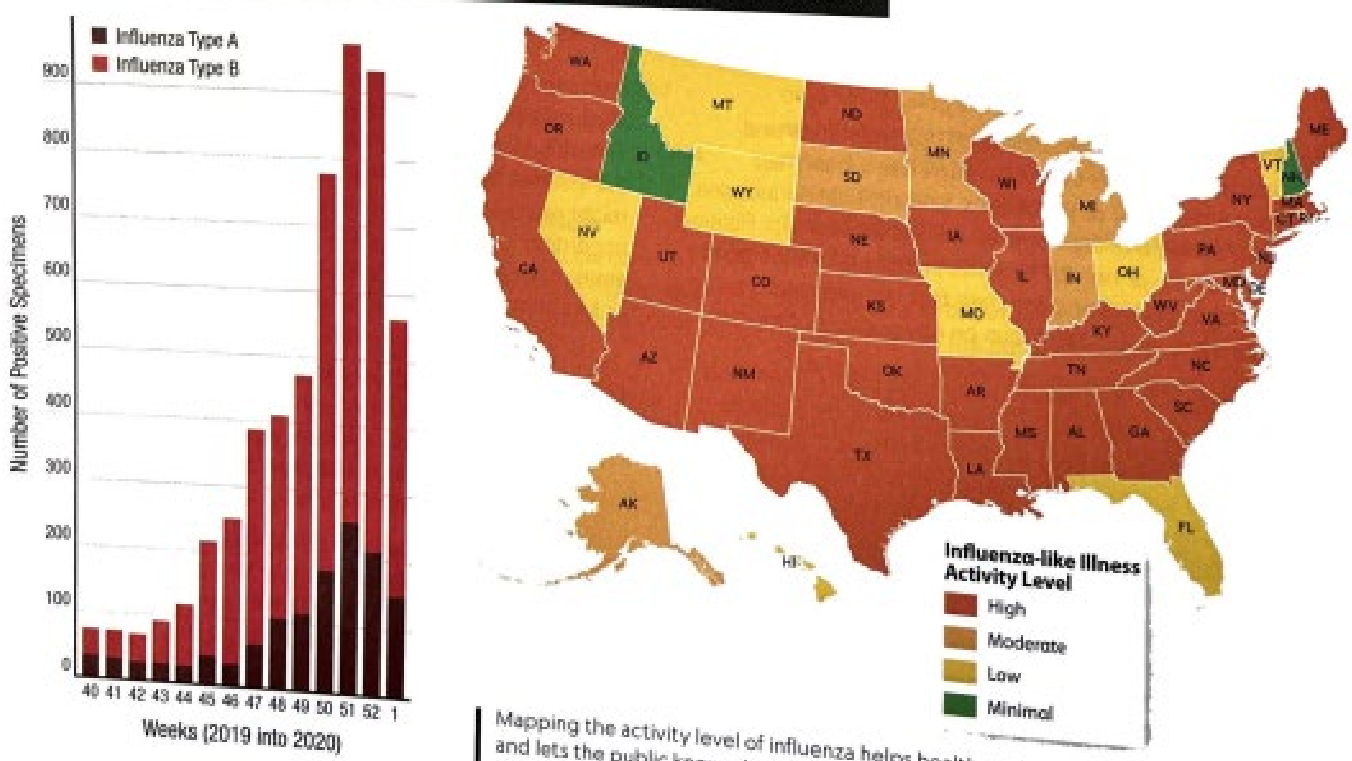
LEARNING OBJECTIVE

IMP-1.C Explain the geographical effects of decisions made using geographical information.

Geographic data are used to help people understand problems, consider options that lead to making decisions, and measure the effects of those decisions. For example, understanding common behaviors—where people work and shop, and their commuting habits—helps city planners determine the future location of roads or make decisions about land use. Data can convince people to take action. Examining data about people's shopping habits can help determine how many parking places are needed for a new shopping center.

U.S. health officials use data to help public health departments make decisions when planning for the annual flu season. Data from the Centers for Disease Control and Prevention (CDC), the leading national public health institute in the United States, are used to provide feedback, inform policy, and make recommendations for new and better flu vaccines. The CDC receives and characterizes the genetic makeup of thousands of influenza viruses each year from across the United States and around the world. Compiling and analyzing these data allows the CDC to track when and where flu activity is occuring, determine what flu viruses are circulating, detect changes in the viruses, and measure the impact of the virus on hospitalizations and deaths. In addition, using data from past seasons helps to determine the severity of the virus each season. The CDC shares this information with health officials and agencies to help them make better decisions about what goes in each year's flu vaccine. It also helps evaluate viruses for their pandemic potential, allowing health agencies to better prepare for and prevent the spread of illness.

INFLUENZA ACTIVITY IN THE UNITED STATES, WEEK 48, 2019



Mapping the activity level of influenza helps health workers prepare for sick patients and lets the public know where there are a high number of reported cases. The number of people infected with Influenza Types A and B continued to rise throughout December 2019 and into 2020, as indicated by the chart.

MAKING DECISIONS WITH GEOGRAPHIC DATA

LEARNING OBJECTIVE

IMP-1.C Explain the geographical effects of decisions made using geographical information.

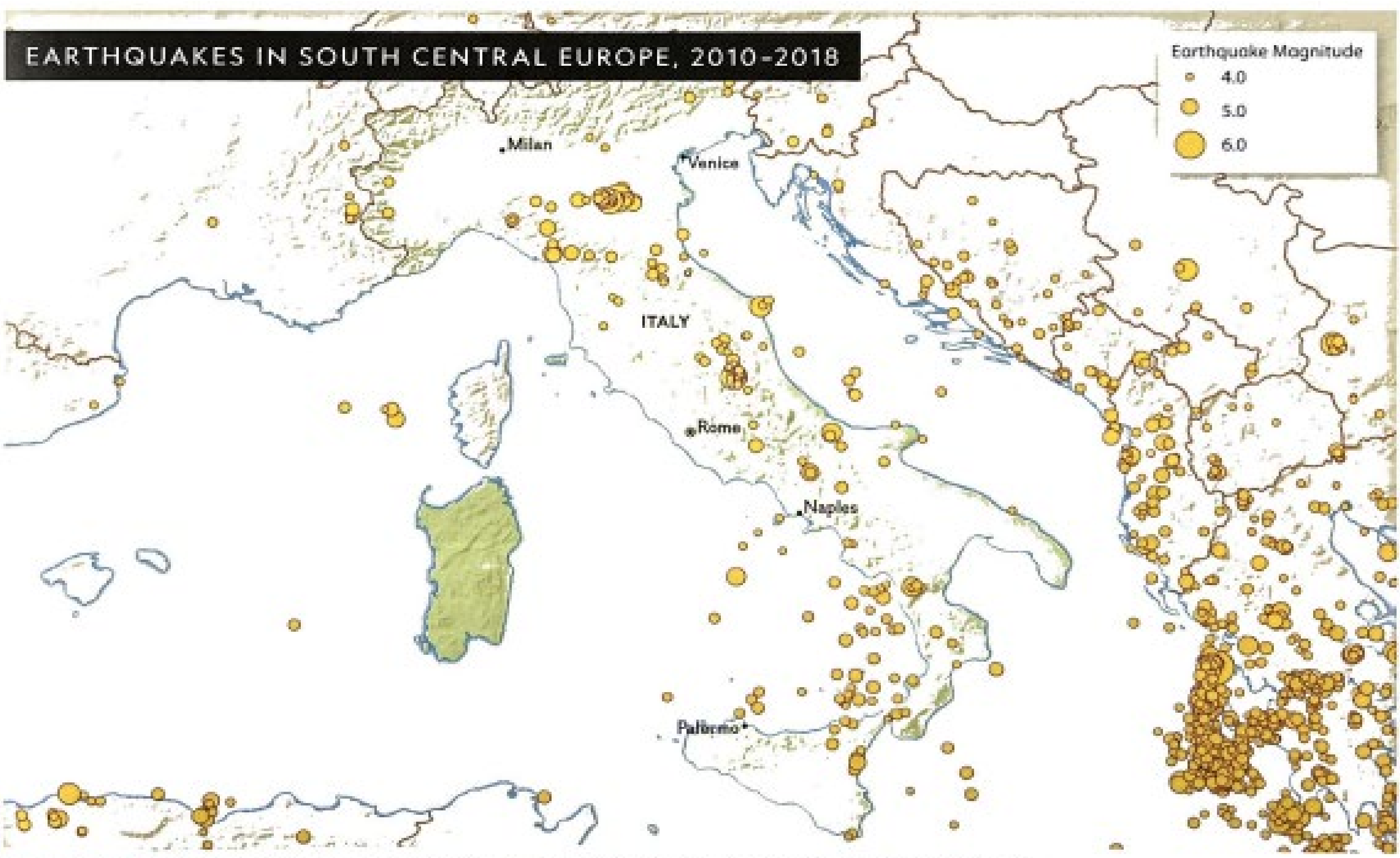
Improving health and wellness is only one use of data. Individuals and businesses also make use of a variety of geographic data, formally and informally.

PERSONAL AND ORGANIZATIONAL DECISION-MAKING Geographic data influence where people decide to live. People in the market for a home consider its walkability and proximity to work. They also may look at property taxes, crime statistics, school zones, floodplain or earthquake data, and other risks. People may study sources that provide information on the neighborhood and commute time. Individuals looking to sell their home will also employ geographic data to determine their property's value. For example, how much other homes in the area have been sold for can help predict a home's value.

Businesses make location decisions in ways similar to individuals'. When deciding where to locate, businesses typically review demographic data on potential customers, the workforce, tax rates, and more. Some organizations need data and maps that are specialized. For instance, a home insurance company may look at floodplain maps.

Other groups seek to expand data related to quality of life, mapping public health, education, and public safety services, for instance. OpenStreetMap has become a catalyst for such purposes. OpenStreetMap was founded in 2004 by software developers who wanted to create an open-source network for mapmaking. Today, it maintains data about locations—roads, parks, railway stations, and more—all over the world. OpenStreetMap has become important in mapping lands of Native Americans and other indigenous peoples. It also has played an important role in saving lives. Following a devastating earthquake that struck Haiti in 2010, volunteers used satellite imagery to create detailed digital maps of roads, buildings, and other features, facilitating recovery and relief services.

Similar efforts have resulted following other disasters. After Hurricane Harvey hit Houston, Texas, in 2017, people stranded in their homes or neighborhoods used online mapping services as a tool for assistance. An app enabled them to mark their location; some apps enabled people to add notes indicating the type of help required, such as "WOMAN IN LABOR!!"

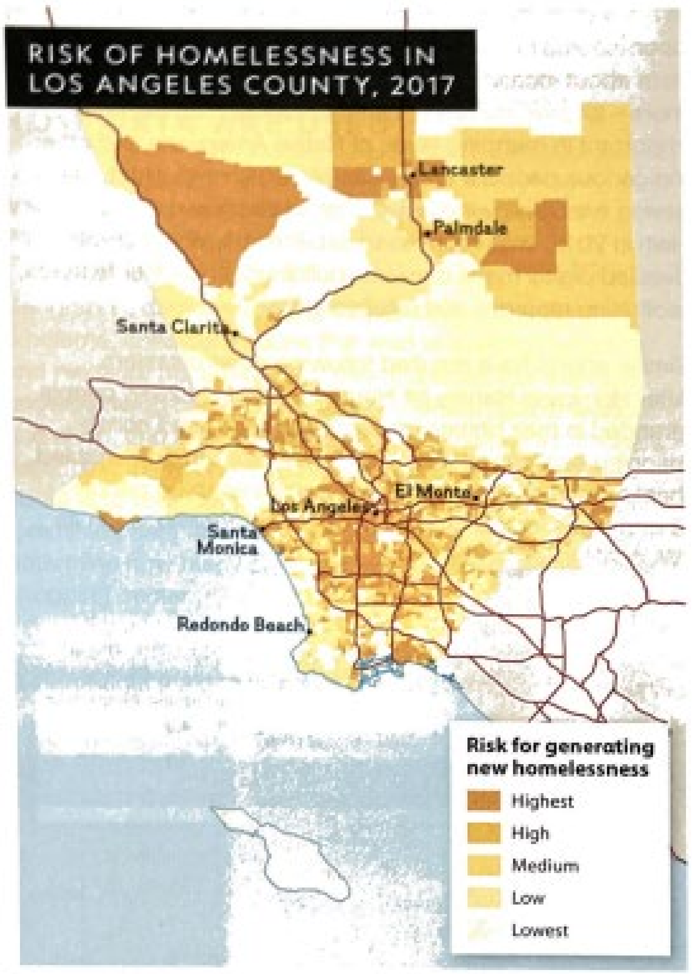


READING MAPS GIS software can be used to display the location and intensity of earthquakes. This map shows earthquakes that occurred in Italy and surrounding countries between 2010 and 2018. Each circle corresponds to an earthquake of varying intensity. ■ Describe how the information in this map might be used by individuals, businesses, and governments.

GOVERNMENTAL DECISION-MAKING

Governments at all levels use GIS data for myriad purposes. Researchers indicate that as much as 80 percent of data stored by the government has a spatial component.

Local governments use GIS data for addressing local problems. For instance, a police department may use spatial data with one layer showing where various types of crimes have occurred and another showing the presence of streetlights or surveillance cameras. In addition to helping communities identify places to target for police presence and enforcement, this can help the government analyze the effectiveness of lighting and other deterrence strategies.



The risk for homelessness varies in different parts of Los Angeles. The darker colors represent higher levels of risk.

National governments often focus their GIS efforts on disaster prevention and mitigation. Data published by the U.S. Geological Survey helps officials assess the risk of earthquakes in specific regions and develop strategies for mitigating such risks. The Environmental Protection Agency uses GIS to monitor air quality by overlaying spatial information with environmental data like ground-level ozone. The data are used to identify areas with poor air quality.

In Los Angeles County, GIS produces maps used to address homelessness. Agencies have mapped the distribution and characteristics of the homeless population, as well as various risk factors. The maps enable decision-makers to recognize and analyze spatial patterns, using the data to weigh options for locating shelters and other resources for homeless populations. In addition to considering where the homeless populations are today, decision-makers have mapped where people were when they became homeless. Analysis of spatial data is used to predict where people are likely to become homeless and is factored into homelessness prevention efforts.

GEOGRAPHIC THINKING

1. Explain how showing spatial patterns can help decision-making. Use an example from the text.
2. If you wanted to create a map that demonstrated to the public the seriousness of a certain city's homelessness problem, what type of thematic map would you use? Explain your thinking.

THE GEO-INQUIRY PROCESS | TIPS FOR SUCCESS

CREATE

ACT

- Consider how to tell your story in a compelling way. Use infographics, maps, photographs, and personal stories to create an interest in the topic and an emotional tie. Storyboarding can help organize your story.
- Make sure to explain your findings, answer your question, and outline viable solutions.
- Identify the audience of decision-makers for presentation of your story, and answer questions you think they will have about the topic. If the issue requires changing a law, the audience might be local or state government officials.
- Choose the most relevant data to present to your audience.
- Consider whether your proposed action has spatial connections beyond the immediate locale or could be transferable to other communities.

NATIONAL GEOGRAPHIC EXPLORER **SHAH SELBE**

DEPLOYING TECHNOLOGY FOR CONSERVATION PURPOSES

Shah Selbe began his career as a rocket scientist but left to pursue his true passion: saving the planet.

LEARNING OBJECTIVE

IMP-1.C Explain the geographical effects of decisions made using geographical information.

Scientists can be limited by the high cost of data-collection technology. Shah Selbe thought he could help, so he left his aerospace engineer job to become a conservation technologist.

Shah Selbe founded a group called Conservify, which builds data-collection technology using the same kinds of affordable parts found in your average smartphone. At Conservify, Selbe is essentially helping scientists complete the Geo-Inquiry Process.

One recent research question was asked about humans' impact on the Amazon (shown above): *What effects might some 400 proposed dams have on the river and its communities?* After determining what data were needed, Selbe customized different sensor modules to measure such things as rainfall, windspeed, air and water temperatures, and water levels. He also used geographic information about indigenous people's interactions with the river to assess changes in water quality, the presence of fish species, and flooding over time.

To help visualize what it all meant, Selbe built software called FieldKit, which receives transmitted data from sensors and organizes it for analysis. The data showed that damming the Amazon would disrupt migratory paths, flooding patterns, indigenous people's transportation and fishing systems, and the overall connectivity of the river. Action based on the findings has yet to unfold.

Take note that Selbe's work may impact yours. FieldKit is being refined so that everyone will be able to use it. Whether you are a geographer or a student in need of data for a project, reliable, data-driven research will be available to everyone.

GEOGRAPHIC THINKING

How were scale and information from indigenous people incorporated into Selbe's approach to gathering data?

CHAPTER 2 # SUMMARY & REVIEW

CHAPTER SUMMARY

Geographers use a spatial perspective to interpret the world.

The Geo-Inquiry Process provides a systematic way to investigate and understand the world through the patterns, processes, and interactions between human and natural systems. There are five phases of the Geo-Inquiry Process:

- Ask: Developing a Geo-Inquiry question
- Collect: Acquiring geographic information
- Visualize: Organizing and analyzing geographic information
- Create: Developing Geo-Inquiry stories
- Act: Sharing Geo-Inquiry stories

Maps are among a geographer's most important tools. Maps depict data spatially, representing relationships among time, space, and scale.

- There are two main categories of maps:
  - Reference maps focus on location and phenomena.
  - Thematic maps focus on the spatial variation of one or more characteristics.
- Map scale shows the relationship of the size of the map to the size of the area it represents on Earth's surface. It determines the level of detail of a map.
- All maps are distorted because of the problems of representing a three-dimensional spherical object (Earth) in two dimensions. Maps distort shape, area, direction, or distance.
- Each type of map projection has both advantages and disadvantages. The projection used depends on the purpose of the map.
- Types of maps include dot maps, choropleth maps, isoline maps, graduated symbols maps, and cartograms.

Today's technologies enable complex data to be gathered in real time by individuals and organizations. Geographers collect a range of data that can help individuals, businesses, organizations, and governments make informed decisions.

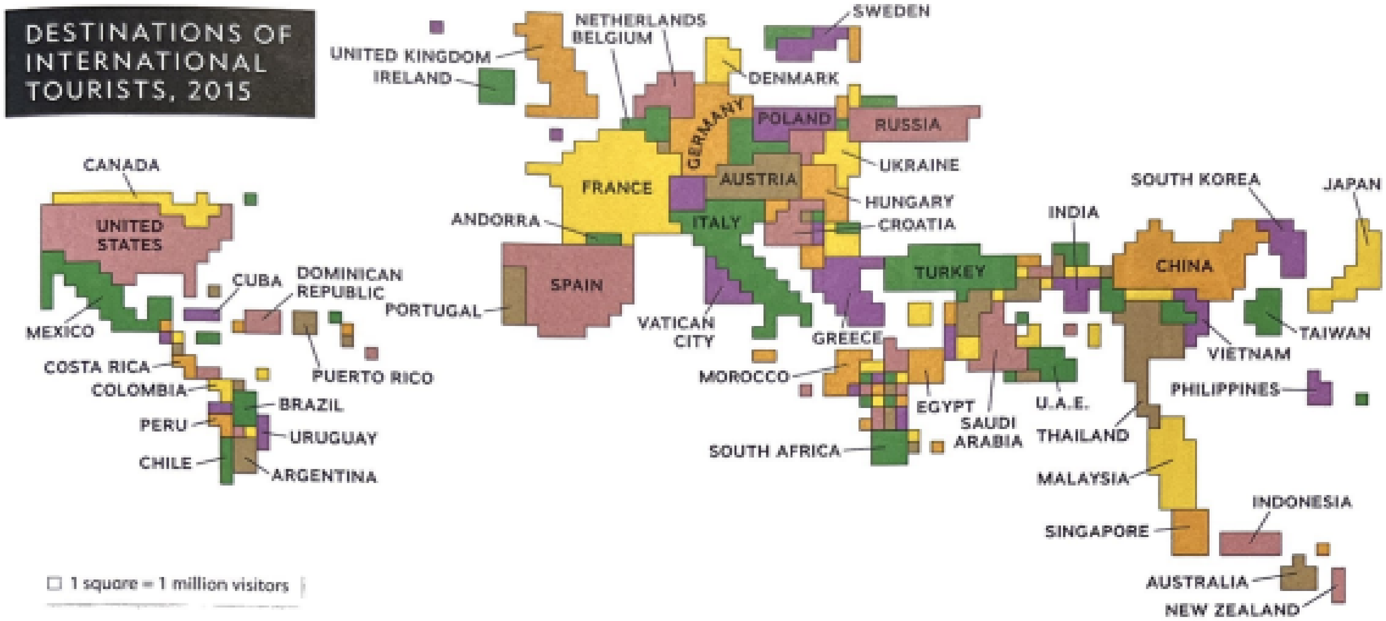
- Geographers gather data through a variety of remote sensing methods, including satellite images and aerial photographs, as well as through field observation and interviews, and written accounts including media reports and policy documents.
- Geographic information systems (GIS) capture, store, analyze, and display geographic data. The data can be used to create map layers that are combined on a single map. Location is the key aspect that links these data layers.
- The global positioning system (GPS) enables geographers (and others) to determine the precise distance between two points on Earth's surface.

KEY TERMS AND CONCEPTS

Use complete sentences to answer the questions.

1. **APPLY CONCEPTUAL VOCABULARY** Consider the term *distortion*. Write a standard dictionary definition of the term. Then provide a conceptual definition—an explanation of how the term is used in the context of the chapter.
2. How might a cartographer show the topography of a region or country?
3. Describe how remote sensing tools have improved the work geographers do. Provide an example.
4. What is the primary difference between GPS and GIS?
5. Differentiate between reference maps and thematic maps. Give an example of each.
6. How does map scale affect cartography?
7. How are the terms *map projection* and *distortion* related?
8. What is the Mercator projection and how does it distort?
9. Explain similarities and differences between choropleth maps and isoline maps. Give a common use for each.
10. Do you think the U.S. census contains mostly quantitative or qualitative data? Explain.
11. Describe the absolute distance and the relative distance between your school and where you live.

INTERPRET MAPS



Study the cartogram and then answer the questions.

12. **DESCRIBE GEOGRAPHIC CONCEPTS** What aspects of the map tell you it is a cartogram?

13. **EXPLAIN SPATIAL RELATIONSHIPS** Why is the United States represented as so much larger than Canada?

14. **EVALUATE MODELS & THEORIES** What is the advantage of using a cartogram to show this data?

15. **SYNTHESIZE** How might different countries use this map when considering how to promote tourism in the future?

GEO-INQUIRY | A NEW COMMUNITY RESOURCE

A good Geo-Inquiry project begins with an overarching topic and question that guides inquiry. For example, *How might a new grocery store location support the reduction of obesity in our community?* Use the Geo-Inquiry Process below to explore an issue in your community.

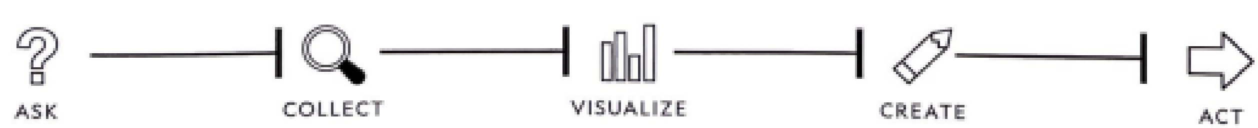
ASK Start with an authentic investigation into issues in the community. Many need-to-know questions will arise as you think about the issue, but the Geo-Inquiry question is an open-ended question that prompts further investigation. Using the example, need-to-know questions would include *Where are the nearest grocery stores? What is the obesity rate in adults and children? Where do most people shop for food? What types of food are available?*

COLLECT Decide the geographic information you need in order to answer your original question. Explore local sources of information, such as maps of the community or demographic data about particular neighborhoods. You might survey community members or experts.

VISUALIZE Organize and analyze the information you collected. Use a chart to analyze the results of surveys you conducted, or a map of current businesses to help you think about your community spatially. Look for patterns to help you draw conclusions.

CREATE Focus on how to tell a Geo-Inquiry story that will support your recommendation. Keep your audience in mind. Will you be pitching your story to a developer interested in building a grocery store? Consider using images, videos, compelling story lines, and charts and graphs to help tell your story.

ACT Consider how your project can inform decisions regarding the location of community resources, thereby improving the health, educational, or economic options for residents. Take informed action by reaching out to community leaders who determine the location of community resources and share your ideas with them.



THEY ARE WATCHING YOU

BY ROBERT DRAPER

The Dove satellite being held by a senior spacecraft technician at the San Francisco-based tech company Planet, is camera equipped and able to snap two images per second. Satellites are important geographic tools that are used to investigate even small changes on Earth.

Expanding networks of satellites are providing unprecedented views of humans' influence on the land, the climate, and ourselves—documented in real time. The technology in question can monitor Earth's entire landmass every single day. It's the brainchild of a San Francisco–based company called Planet, founded by two idealistic former NASA scientists named Will Marshall and Robbie Schingler. At NASA they had been captivated by the idea of taking pictures from space, especially of Earth—and for reasons that were humanitarian rather than science-based.

They experimented by launching ordinary smartphones into orbit, confirming that a relatively inexpensive camera could function in outer space. "We thought, What could we do with those images?" Schingler said. "List the world's problems: poverty, housing, malnutrition, deforestation. All of these problems are more easily addressed if you have more up-to-date information about our planet."

A CHANGING VIEW OF EARTH In storybook fashion, Marshall and Schingler developed their first model in a garage in Silicon Valley. The idea was to design a relatively low-cost, shoebox-sized satellite to minimize military-scale budgets often required for designing such technology—and then, as Marshall told me, "to launch the largest constellation of satellites in human history." By deploying many such devices, the company would be able to see daily changes on Earth's surface in totality.

In 2013, they launched their first satellites and received their first photographs, which provided a far more dynamic look at life around the world than previous global mapping imagery. "The thing that surprised us most," said Marshall, "is that almost every picture that came down showed how Earth was changing. Fields were reshaped. Rivers moved. Trees were taken down. Buildings went up. Seeing all of this completely changes our concept of the planet as being static."

WHAT SATELLITES CAN DO Today, Planet has more than 200 satellites in orbit, with about 150 so-called Doves that can image every bit of land every day when conditions are right. The company works with the Amazon Conservation Association to track deforestation in Peru. It has provided images to Amnesty International that document attacks on Rohingya villages by security forces in Myanmar. At the Middlebury Institute's Center for Nonproliferation Studies, recurring global imaging helps the think tank watch for the sudden appearance of a missile test site in Iran or North Korea.

Those are pro bono clients. Its paying customers include Orbital Insight, a Silicon Valley-based geospatial analytics firm that interprets data from satellite imagery. With such visuals, Orbital Insight can track the development of road or building construction in South America, the expansion of illegal palm oil plantations in Africa, and crop yields in Asia. In the company's conference room, James Crawford, the chief executive, opened his laptop and showed me aerial views of Chinese oil tanks, with their floating lids indicating they were about three-quarters full. "Hedge funds, banks, and oil companies themselves know what's in their tanks," he said with a sly grin, "but not in others', so temporal resolution [the amount of time needed to collect data] is extremely important."

Meanwhile, Planet's marketing team spends its days gazing at photographs, imagining an interested party somewhere out there who might benefit from the images. An insurance company wanting to track flood damage to homes in the Midwest. A researcher in Norway seeking evidence of glaciers eroding. But what about . . . a dictator wishing to hunt down a dissident army?

Here is where Planet's own ethical guidelines would come into play. Not only could it refuse to work with a client having malevolent motives, but it also doesn't allow customers to stake a sole proprietary claim over the images they buy. The other significant constraint is technological. Planet's surveillance of the world at a resolution of 10 feet is sufficient to discern the grainy outline of a single truck but not the contours of a human.

THE FUTURE OF PLANET On a bracing autumn evening in San Francisco, I returned to Planet to see the world through its all-encompassing lens. More than a dozen clients would be there to show off how they're using satellite imagery—what it meant, in essence, to see the world as it's changing.

I zigzagged among semicircles of techies gathered raptly around monitors. Everywhere I looked, the world came into view. I saw, in the Brazilian state of Pará, the dark green stretches of the Amazon jungle flash red, prompting automatic emails to the landowners: *Warning, someone is deforesting your land!* I saw the Port of Singapore teem with shipping activity. I saw the croplands of southern Alberta, Canada, in a state of flagging health. I saw oil well pads in Siberia—17 percent more than in the previous year, a surprising sign of stepped-up production that seemed likely to prompt frantic reassessments in the world's oil and gas markets.

Planet's hosts halted the show-and-tell to say a few words. Andy Wild, the chief revenue officer, spoke of the new frontier. It was one thing to achieve, as Wild put it, "a daily cadence of the entire landmass of the Earth." Now the custodians of this technology had to "turn it into outcomes." Tom Barton, the chief operating officer, said, "I hope one year from now, we're here saying, 'We really did change the world.'" ■

Adapted from "They Are Watching You" by Robert Draper, *National Geographic*, February 2018

WRITE ACROSS UNITS

Unit 1 explored the tools geographers use in their work. This article focuses on one of those tools—satellite imagery—and the astonishing array of spatial and temporal data it can yield for geographical study. Use information from the article and this unit to write a response to the following questions.

LOOKING BACK

1. What sets Planet's satellite network apart from other data collection tools you learned about? UNIT 1

LOOKING FORWARD

2. What types of data could Planet's satellites provide to a government agency seeking to understand the effects of migration within a region? UNIT 2
3. How might the existence of mass data gathering and communication technology such as satellite networks influence cultural changes? UNIT 3
4. What political advantages could a government gain by possessing satellite-gathered data about its own territories? UNIT 4
5. How might satellites help researchers trace the effects of technology on agriculture globally? UNIT 5
6. How could planners use satellite data to design a public transportation system for a city? UNIT 6
7. What types of satellite data could help a government create and implement policies for sustainable development? UNIT 7

WRITE ACROSS REGIONS & SCALES

Identify two locations in the world experiencing issues related to a topic mentioned in Unit 1, such as income inequality or crime. Review the Geo-Inquiry Process outlined in Chapter 2 and use the information to plan a Geo-Inquiry project to examine these issues.

Determine your question. Then write a paragraph for each of the steps in the process, explaining how you would collect information, visualize the data, create a presentation, and act on what you learned. Draw on evidence from the unit and article to plan your project.

THINK ABOUT

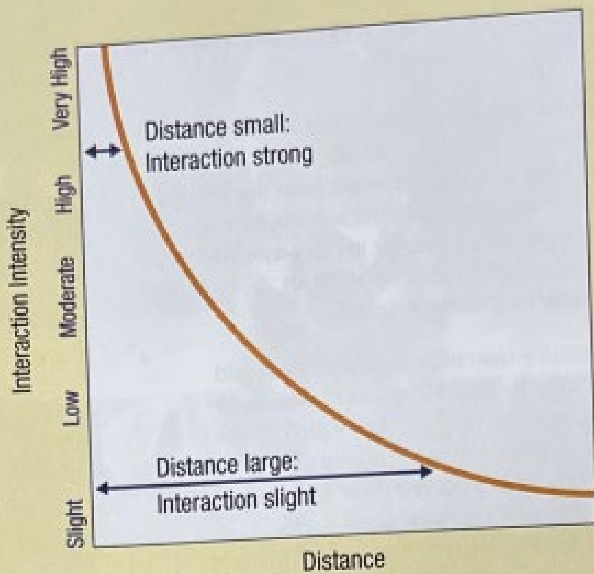
- how comparing data from more than one location might inform the way you present your findings and choose to act on them
- the advantages and disadvantages of satellite imagery and other forms of data collection

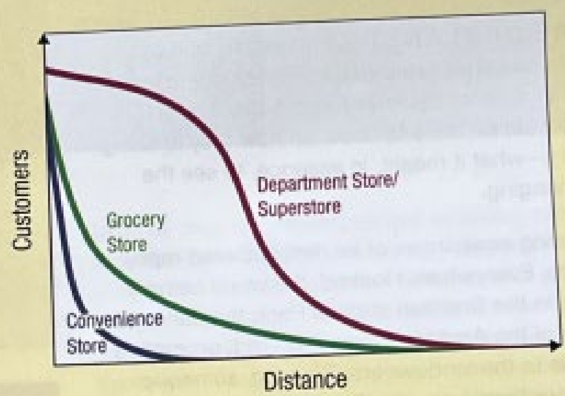
CHAPTER 1

DISTANCE DECAY MODEL

A model is a represention of one aspect of reality, such as a geographic relationship, in a generalized form. It is important to examine models and compare them to real-world data to determine the degree to which they explain geographic effects in different contexts or at different scales.

The distance decay model describes a fundamental relationship in human geography: the impact of distance on interactions between locations. Specifically, the model states that the farther away two things or places are from each other, the less interaction they will have. Friction of distance—the idea that distance requires time, effort, and cost to overcome—explains some key factors that contribute to distance decay. Here, the first graph illustrates the distance decay model in its generalized form. The second graph illustrates the effects of distance decay on consumers deciding how far they will travel to shop. ▌Explain the degree to which the distance decay model explains the geographic effects of distance on individuals' shopping behavior.





CHAPTER 1

TIME-SPACE COMPRESSION

Some concepts are visually depicted in different ways. Here, time-space compression is represented by a shrinking globe, while the visual you studied in Chapter 1 highlights travel times across the Atlantic. The concept of time-space compression reflects the forces, such as improvements in transportation and communication, that can overcome the friction of distance. By compressing the amount of time it takes to travel or transmit information, these forces give the impression of lessening the space between distant locations. ▌Compare this visual with the one in Chapter 1 and identify which you think most clearly illustrates the effects of time-space compression. Explain.

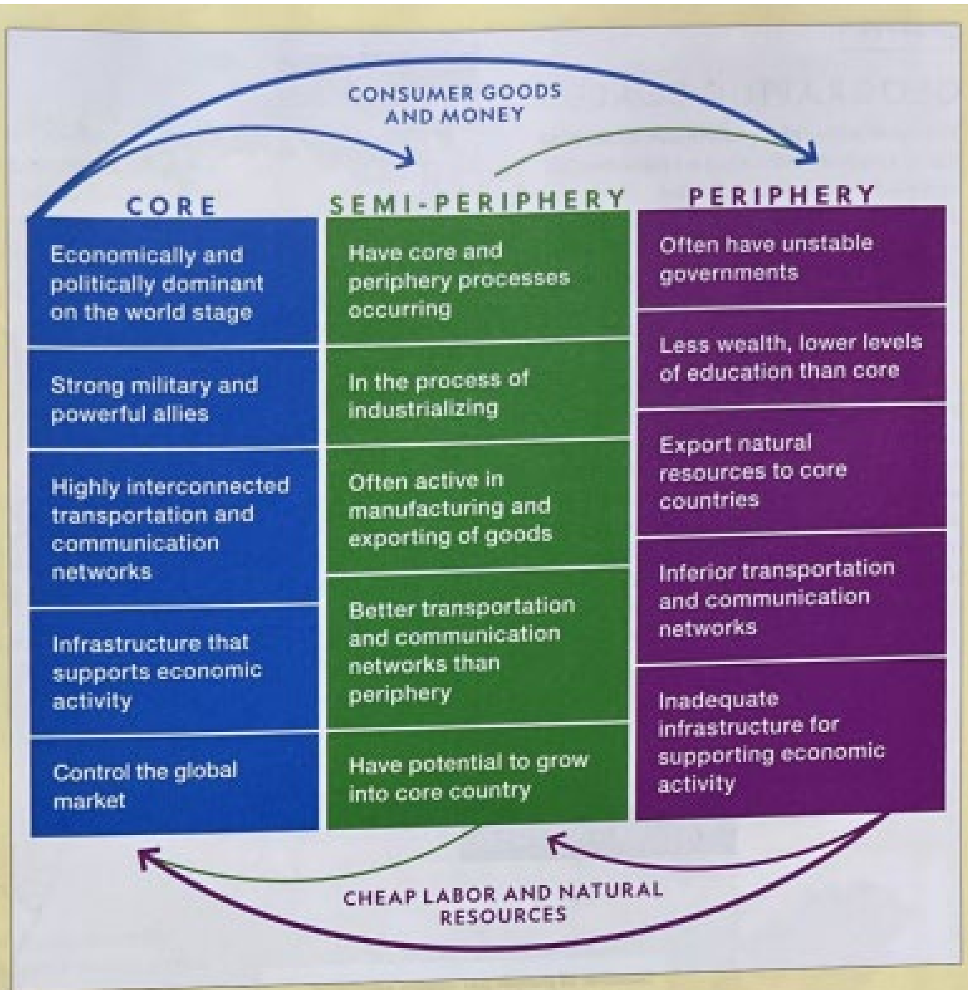
ADVANCES IN TRANSPORTATION AND COMMUNICATION

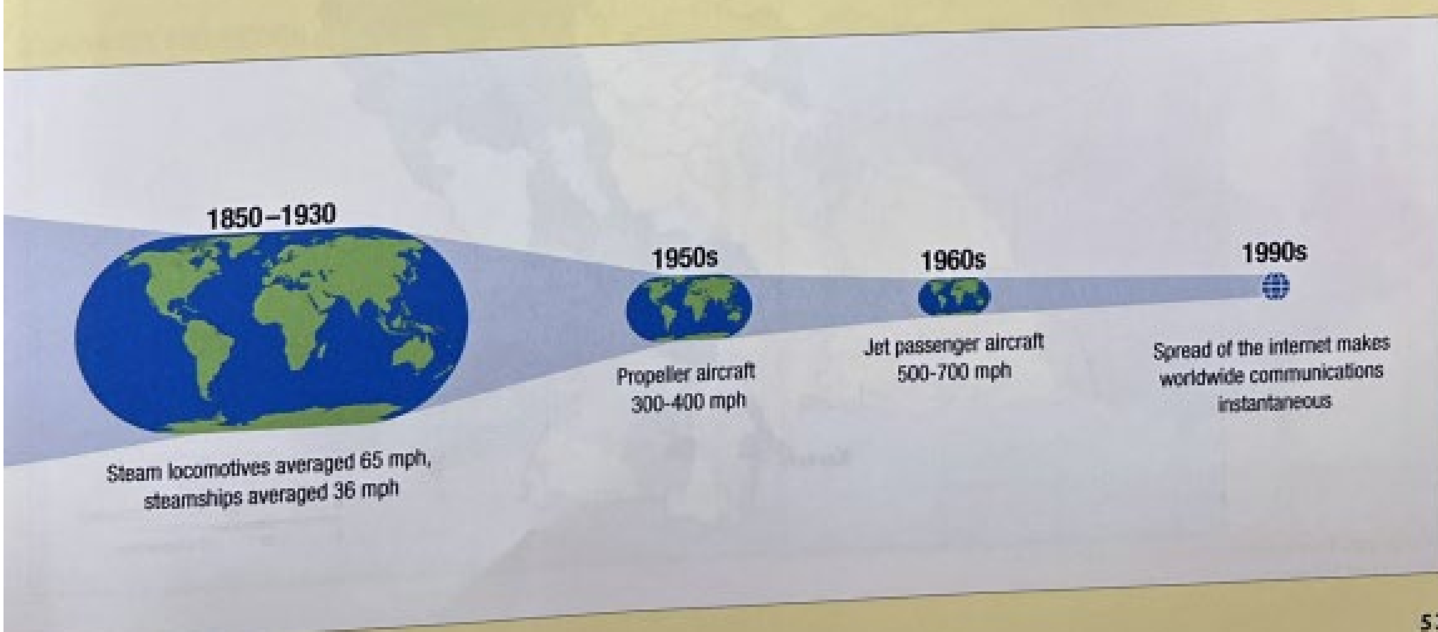
WALLERSTEIN'S WORLD SYSTEM THEORY

A theory is a system of ideas that attempt to explain observed phenomena. Like models, theories explain geographic effects to varying degrees, depending on where and how they are applied.

Immanuel Wallerstein developed the world system theory to explain the global economic phenomena that he observed. Wallerstein's theory views the entire globe as a single economic system bound together through a complex network of trade and communications. It describes not only the economic ties between countries but also patterns of power across the globe.

Core countries derive the greatest benefits from the world economy and tend to dominate politically as well. Countries in the semi-periphery and periphery have less wealth and often less-stable governments, and thus find themselves in positions of lesser power. ▮ Explain the degree to which the world system theory explains the economic influence of a smaller core country such as France.

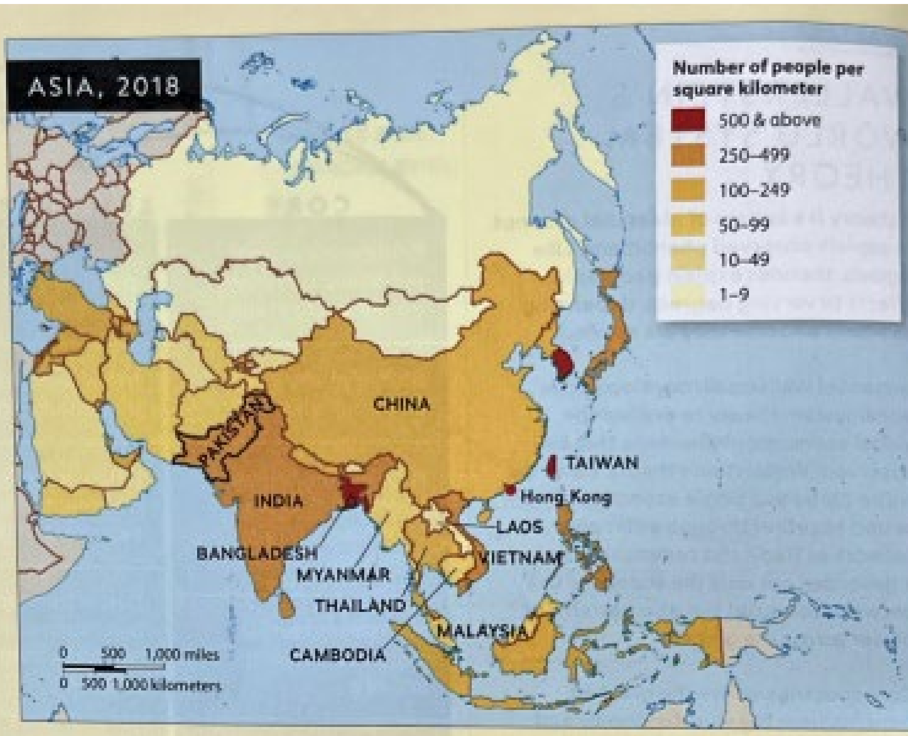


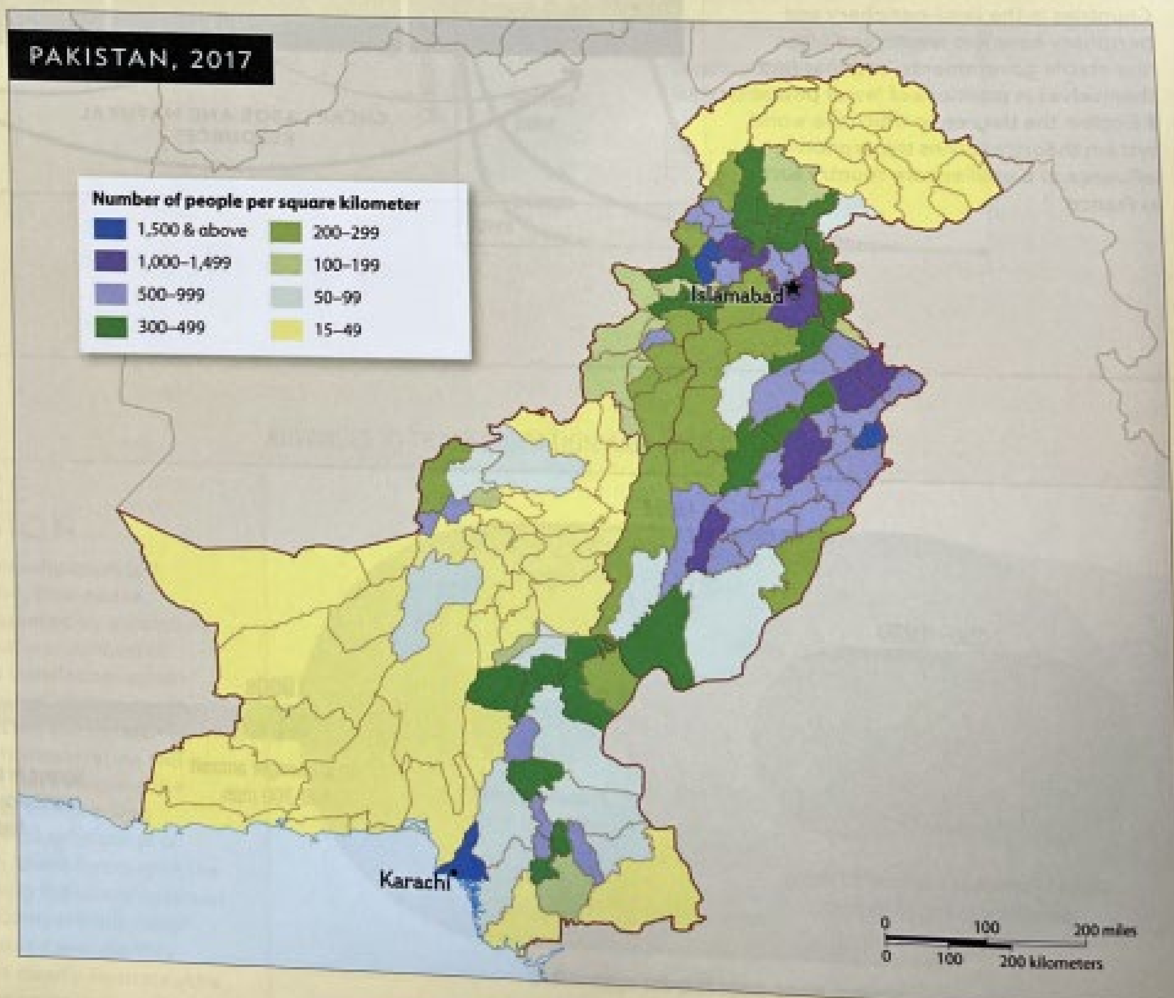


GEOGRAPHIC SCALE

The term scale refers to the size of an area being studied. Examining a phenomenon at different scales reveals new perspectives that can lead to a deeper understanding. For example, geographers studying population density—the number of people relative to the amount of land—look at maps on a variety of scales.

These maps show the population densities in Asia on a national scale and the population of Pakistan on a district-wide scale. ▮ Compare the maps and describe what each reveals about the population density of Pakistan. What additional information could you expect to learn from a density map of Islamabad?

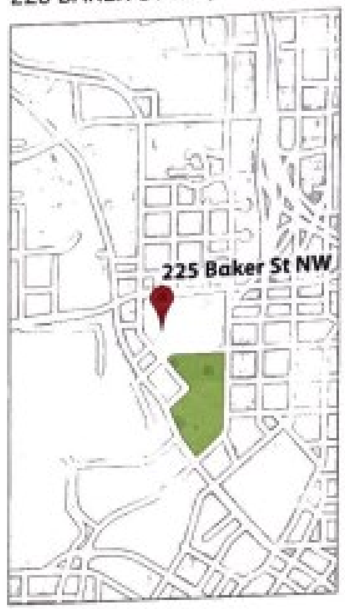


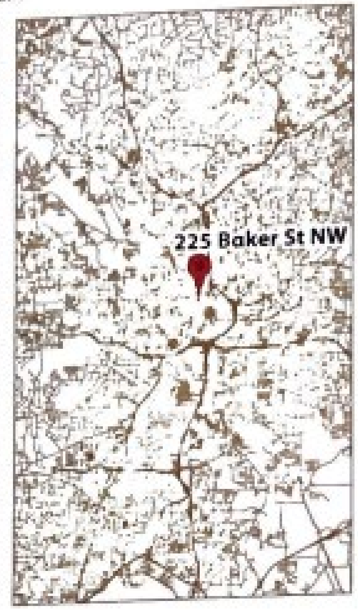


SMARTPHONE MAPS

The maps many people interact with most often are found in their smartphone's GPS navigation app. One advantage of smartphone maps is their ability to display an area at a seemingly infinite variety of scales. The two smartphone maps provided show the same location at different scales. ▮ Compare the maps and describe what each scale reveals to the map user.

225 BAKER ST NW, ATLANTA, GA

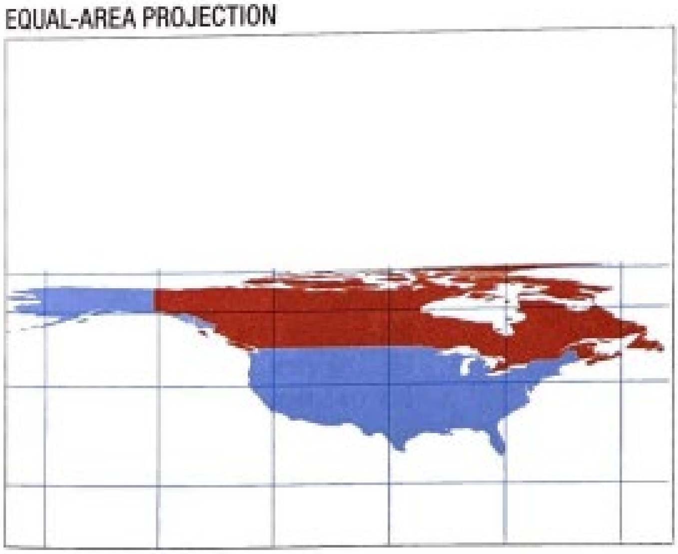




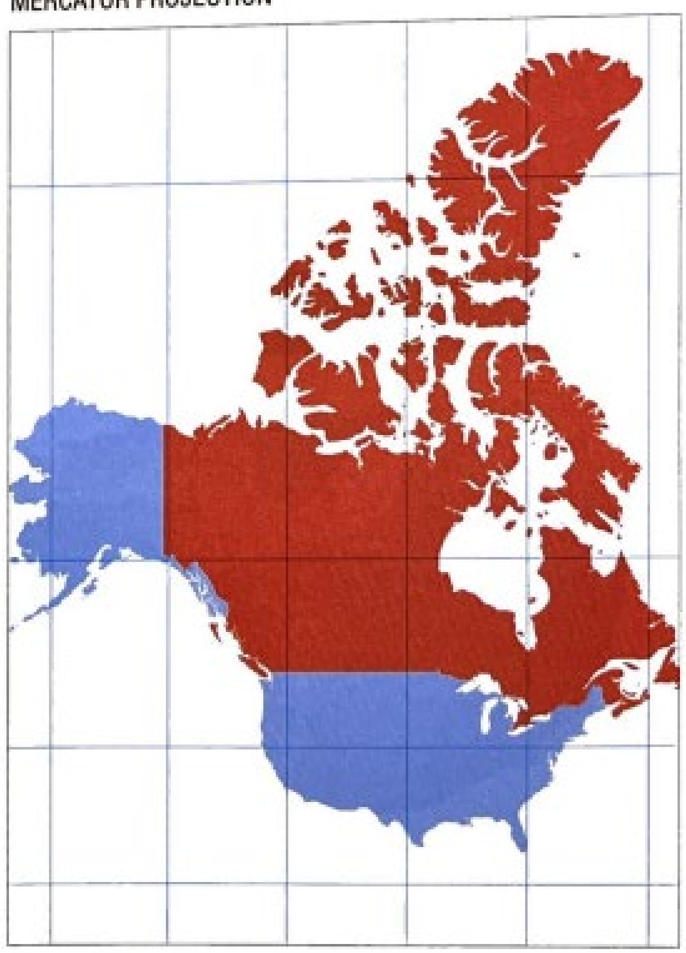
MAP PROJECTIONS

Our perceptions about countries and continents are strongly influenced by map projections. Equal-area projections accurately portray the area of a landmass, but they distort the shapes of various continents. Mercator projections preserve the continents' shapes and show accurate direction, making this projection ideal for plotting straight-line courses on navigation charts. However, the Mercator projection distorts the true area of landmasses, an effect that increases with distance from the equator. ▮ Compare the way the equal-area projection and the Mercator projection each depict the United States and Canada.

EQUAL-AREA PROJECTION



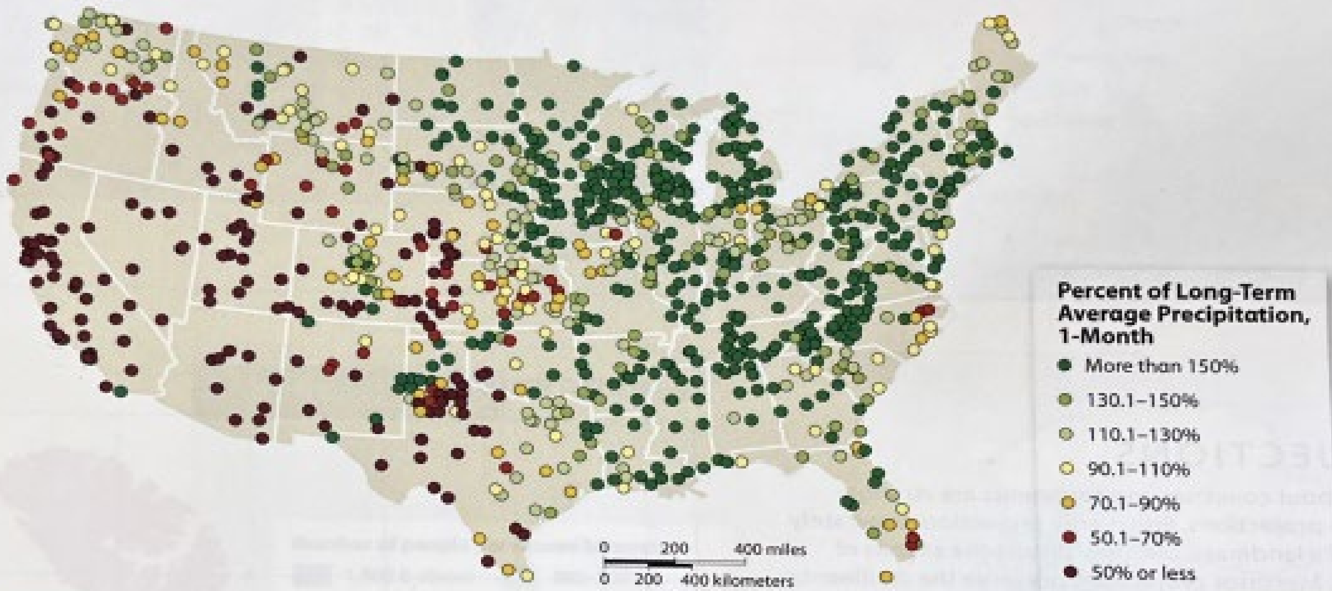
MERCATOR PROJECTION



COMPARING TYPES OF MAPS

At times, it is useful to portray the same set of data on more than one type of map. Both maps show the percentage of the long-term average precipitation that has fallen over the period of one month in November. The long-term average precipitation is calculated over a 50-year base period. The dark red color indicates areas that received 50 percent or less of the long-term average precipitation. Dark green indicates areas that received 150 percent or more than the average. ▮ Compare the dot and isoline maps. Describe what each map helps viewers understand about precipitation during November 2019.

DOT MAP OF PRECIPITATION IN THE CONTIGUOUS UNITED STATES, NOVEMBER 2019



ISOLINE MAP OF PRECIPITATION IN THE CONTIGUOUS UNITED STATES, NOVEMBER 2019

MAP LAYERS OF A THEMATIC MAP

This thematic map depicts where wildfires burned in the Amazon Basin in 2019. Its basemap is the shape of the South American continent. One GIS map layer shows the political borders of each country. ▮ Identify other map layers used to create this map. Explain how the map layers could be used by decision-makers in South America.