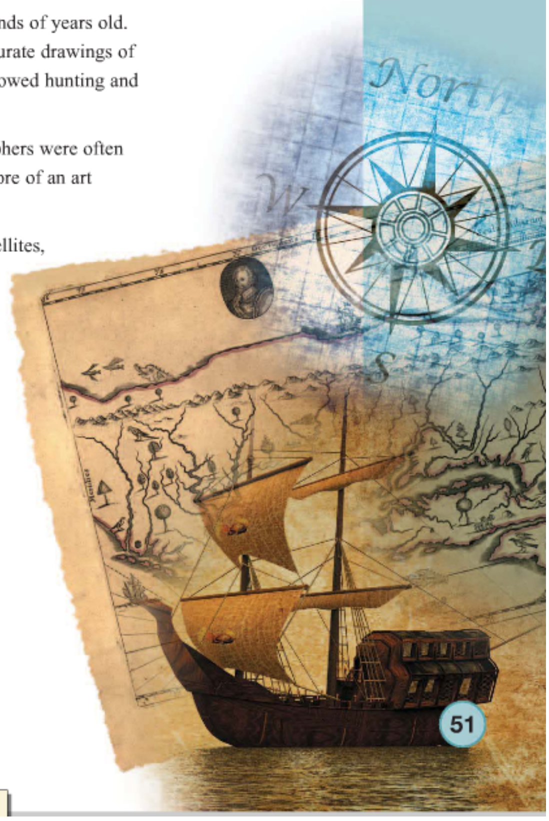
Chapter 3
Mapping Earth

According to archaeologists, mapmaking is thousands of years old. The early maps are rough but show amazingly accurate drawings of surroundings. Some of the earliest known maps showed hunting and fishing areas with detailed drawings.

Mapmaking is also known as *cartography*. Early European cartographers were often painters and other artists. In the past, cartography was considered more of an art than a science.

Now, thanks to sophisticated measuring devices, computers, and satellites, cartography is truly a science. One thing that hasn't changed is the importance of and the need for maps. A picture really is worth a thousand words when it comes to finding your way.



Key Questions

- ✔ *What is the prime meridian?*
- ✔ *What does the topographic map of a mountain look like?*
- ✔ *How are bathymetric maps made?*

Next

3.1 Position, Coordinates, and Maps

Where are you right now? You could answer that question by saying, “In my classroom” or “At my desk.” Someone might then ask where your classroom or desk is located. To answer the question precisely, you can use the concepts of position, coordinates, and mapping. These ideas can be used to describe the location of ordinary objects, such as cars, bicycles, and people. They can also describe the location of tiny objects, such as atoms, and the location of enormous objects, such as planets and stars. Let’s begin by studying the position variable.

VOCABULARY

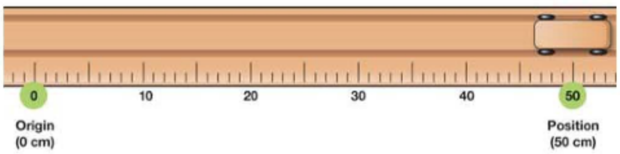
position - a variable that tells location relative to an origin.

origin - a place where the position has been given a value of zero.

The position variable

Position as a variable

You might do an experiment that uses a car on a track. How do you tell someone exactly where the car is at any given moment? You can do this by measuring the car’s position. **Position** is a variable. The position of the car describes where the car is relative to the track. In the diagram below, the position of the car is 50 centimeters (cm). This means the center of the car is at the 50 cm mark on the track.



Position and distance

Position and distance are similar but not the same. Both use units of length. However, position is given relative to an origin. The **origin** is the place where position equals 0 (near the left end of the track above). Here’s an example of the difference between position and distance. Assume the track is 1 meter long. Suppose the car moves a *distance* of 20 cm away from the 50 cm mark. Where is it now? You know a distance (20 cm) but you still don’t know where the car is. It could have moved 20 cm to the right (Figure 3.1) or 20 cm to the left (Figure 3.2). Saying the car is at a *position* of 70 cm tells you where the car *is*. A position is a unique location relative to an origin.

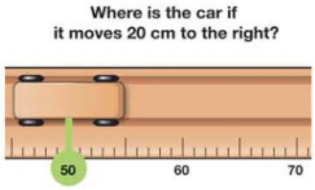


Figure 3.1: *If the car moves 20 cm to the right, its position will be 70 cm.*

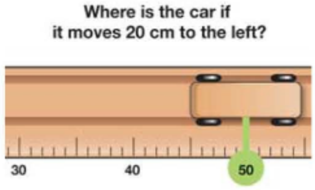


Figure 3.2: *If the car moves 20 cm to the left, its position will be 30 cm.*

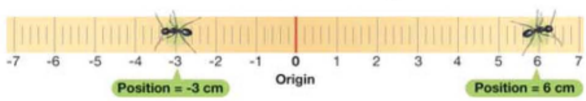
Next

Vectors and position

Telling the difference between "in front" and "behind" How can you tell the difference between one meter in front of you and one meter behind you? The variable of *distance* is not the answer. The distance between two points can only be positive (or zero). You can't have a negative distance. For example, the distances between the ants in Figure 3.3 are either positive or zero. Likewise, 1 meter in front of you and 1 meter behind you both have the same distance: 1 meter.

Using positive and negative numbers The solution is to use *position*, which allows positive and negative numbers. In the diagram below, positive numbers describe positions to the right (in front) of the origin. Negative numbers are to the left (or behind) the origin.

Position can be positive or negative.



Vectors Position is an example of a kind of variable called a *vector*. A **vector** is a variable that tells you a direction as well as an amount. Positive and negative numbers provide enough information for a variable when the only directions are forward and backward. When up-down and right-left are also possible directions, vectors get more complicated.

***Mars Pathfinder* mission** The Mars *Pathfinder* is an unmanned spacecraft launched in 1996. *Pathfinder* and its robot, called *Sojourner*, landed on one of the ancient floodplains of Mars (Figure 3.4). *Sojourner* collected data about the climate, atmosphere, and geology of Mars. Information collected by scientific instruments on both the lander and *Sojourner* suggest that Mars was once warm and wet, with liquid water and a thicker atmosphere than it has now.

***Sojourner* used vectors** As it moved, *Sojourner* needed to keep track of its position. The robot used speed and time data to calculate the position vector, and then added up position vectors to come up with a final position. If it moved forward +2 meters and then backward -0.8 meters, its final position would be +1.2 meters. In this way, *Sojourner* kept track of each move (Figure 3.5).

VOCABULARY

vector - a variable that gives direction information included in its value.

Distance is always positive or zero.

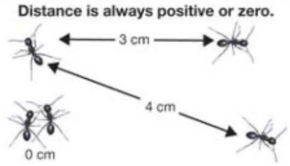


Figure 3.3: *Distance is always a positive value or zero*

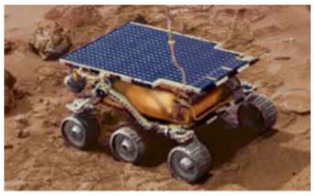


Figure 3.4: Sojourner, *the robotic rover for* Pathfinder.

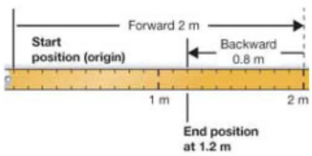


Figure 3.5: *Each change in position is added up using positive and negative numbers.*

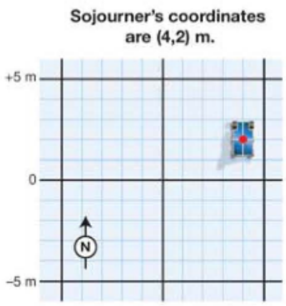
Next

Maps and coordinates

Two dimensions If *Sojourner* had been crawling on a narrow, straight board, it would have had only two choices for direction: positive, or forward, and negative, or backward. Out on the surface of Mars, *Sojourner* could also turn and go sideways. The possible directions included north, east, south, west, and anything in between. A flat surface has *two dimensions*. We say two because it takes two lines of direction to describe every point (Figure 3.6).

North, south, east, and west One way to describe two dimensions is to use number lines, or **axes**. One axis goes north–south. Positive positions are north of the origin and negative positions are south. The other axis goes east–west. Positive positions on this axis are east of the origin and negative positions are west.

Coordinates describe position



Sojourner's exact position at any given time can be described with two numbers. These numbers are called **coordinates**. The graph at the left shows *Sojourner* at the coordinates of (4, 2) m. The first number (or coordinate) gives the position on the east–west axis. *Sojourner* is 4 m east of the origin. The second number gives the position on the north–south axis. *Sojourner* is 2 m north of the origin.

Maps A graph using north–south and east–west axes can accurately show where *Sojourner* was. The graph can also show any path *Sojourner* took, curved or straight. This kind of graph is called a **map**. Many street maps use letters on the north–south axis and numbers for the east–west axis. For example, the coordinates F-4 identify the square that is in row F, column 4 of the map shown in Figure 3.7. A popular way to present a map of the world is to use a globe, as you will see on the next page.

VOCABULARY

axis - one of two (or more) number lines that form a graph.

coordinates - values that give a position relative to an origin.

map - a representational drawing of a location.

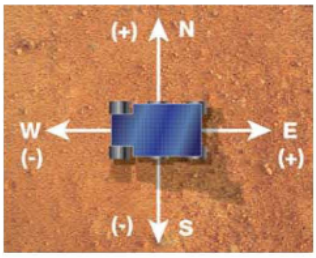
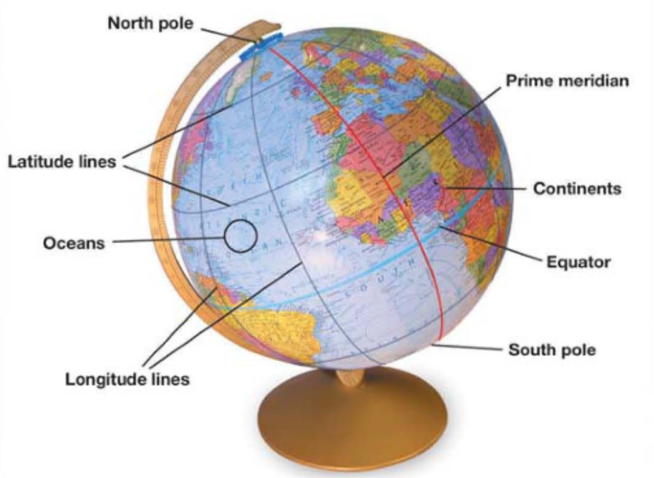


Figure 3.6: *A flat surface has two perpendicular dimensions: north–south and east–west. Each dimension has positive and negative directions.*

Figure 3.7: *Street maps often use letters and numbers for coordinates.*

Position on a globe

A model of Earth A **globe** is a model of Earth. Looking at a globe, you can see the oceans and continents on Earth's surface. Because a globe is a sphere, Earth's land masses are represented accurately. Key features of a globe are shown below.



How is a globe made? A simple classroom globe is relatively easy to manufacture. First, flat, round maps of the northern and southern hemispheres are glued to cardboard backings. The cardboard hemisphere circles are cut into pinwheel-like shapes then glued onto dome-shaped molds (Figure 3.8). Once the two hemispheres are shaped, they are glued together and the seam is covered with tape. The tape hides the seam and also shows exactly where the equator is located on the model.

VOCABULARY

globe - a map of Earth that models its shape and the locations and relative sizes of oceans and continents.

SOLVE IT!

Eartha™—the World's Largest Revolving and Rotating Globe

Eartha™, the world's largest revolving and rotating globe, is located in Yarmouth, Maine at the DeLorme headquarters (a company that makes maps). If you go to DeLorme's headquarters, you can see Eartha™ in its three-story glass room. The globe's diameter is 41 feet 1.5 inches (0.01 km). The diameter of our planet is 12,756 km. How much bigger is Earth compared to Eartha™; ten times, a thousand times, or a million times bigger?

Figure 3.8: *You can cut a flat paper map to form it into a hemisphere for a globe.*

Latitude

What are those lines? Horizontal and vertical lines on a globe or map form a grid that is useful for identifying the location of any place on our planet. Let's first look at the most well-known horizontal line—the equator.

The equator The **equator** is an imaginary line around Earth's middle that lies between the North and South Poles. Earth's equator is 40,075.0 kilometers (24,901.5 miles) long. Places located at or near the equator experience about 12 hours of daylight and 12 hours of night every day of the year.

Latitude lines The equator is a line of latitude. **Latitude** lines appear horizontal on a map. They are east–west lines that are north or south of the equator (Figure 3.9). Lines of latitude are also called *parallels.* The equator is at 0° latitude.

Degrees, minutes, and seconds Each line of latitude represents one *degree* on Earth's surface. The average distance between each degree is 111 kilometers (69 miles). Each degree is divided into 60 *minutes* and each minute is divided into 60 *seconds*. Minutes and seconds in this context represent distances, not time! The latitude of the equator is written as **0° 0' 0"**. Minutes are indicated by an apostrophe (') and seconds are indicated by a double apostrophe (").

Latitude lines with names The equator is one line of latitude you know about. Other latitude lines that you may have heard of are listed below. Can you find these on a globe?

Name of Latitude Line	Approximate Location
Arctic Circle	66.5° N
Tropic of Cancer	23.5° N
Tropic of Capricorn	23.5° S
Antarctic Circle	66.5° S

How latitude lines are drawn Following is the process used to draw latitude lines on a globe. First, draw a line from the North Pole straight down to the equator so you have a line that forms a 90-degree angle with the equator (Figure 3.10). Next, draw 30- and 60-degree angles between the equator and the North Pole. Finally, draw lines parallel to the equator along these measured angles. These are the 30-degree north and 60-degree north latitude lines. The same process is used to draw latitude lines south of the equator.

VOCABULARY

equator - an imaginary line around Earth's middle; lies between the North and South poles.

latitude - east–west lines that are north or south of the equator.

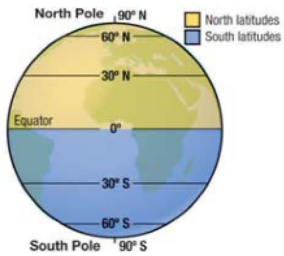


Figure 3.9: *Latitude lines.*

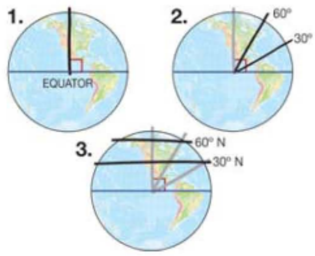


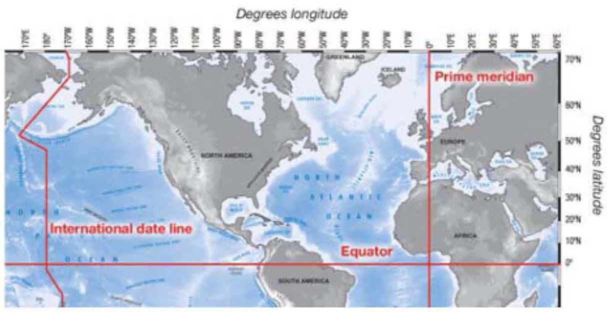
Figure 3.10: *How latitude lines are drawn.*

Longitude

Prime meridian **Longitude** lines (or *meridians*) run north–south and are east or west of the **prime meridian**, which is an imaginary line that passes through Greenwich, England and is perpendicular to the equator. The prime meridian is the 0° line of longitude (Figure 3.11).

The international date line The **international date line** is an imaginary longitude line located mainly at 180°. Each new day begins at 12:00 a.m. at this line. As a result, you lose a day when you travel east across the line. For example, just before you cross the line it might be 3:00 p.m. on Sunday, but when you cross it, the time is 3:00 p.m. on Monday! If you travel westward across the line, you gain a day. Since this situation can be confusing, the international date line zigzags to avoid crossing through countries or territories.

Time zones For every 15° of longitude past the international date line, time changes by one hour. For example, when it is 2:00 p.m. at the international date line, it is noon in Sydney, Australia (about 30° west of the line).



Longitude labels Longitude lines *east* of the prime meridian are numbered from 1 to 179 degrees east, while lines *west* of the prime meridian are numbered from 1 to 179 degrees west. The 0- and 180-degree lines are not labeled east or west.

VOCABULARY

longitude - north–south lines that are east or west of the prime meridian.

prime meridian - an imaginary line through Greenwich, England and perpendicular to the equator; 0° longitude.

international date line - an imaginary longitude line located at 180° from the prime meridian.

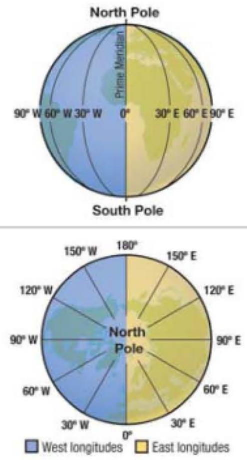


Figure 3.11: *Longitude lines.*

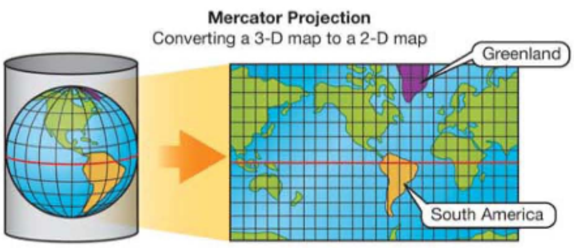
Projections

Globes On a globe, you can see how the size of Greenland compares to the size of South America (Figure 3.12). Greenland is much smaller. But, look at the map below. On this flat map, Greenland looks larger than South America. Why does it appear that way?

From a globe to a flat map People often prefer flat maps to globes, but it is difficult to accurately take a three dimensional (3-D) object like Earth and display it on a two dimensional (2-D) map. When you project Earth's surface onto a flat map, you end up with some degree of distortion in distance, direction, scale, or area. To show grid lines accurately on a two-dimensional map, map makers have to distort the sizes of the landforms and oceans. Different methods of representing Earth's surface on a two-dimensional map are called *projections*. There are dozens of different projections, and each group of map-users has a favorite.

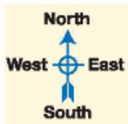
Mercator projection A Mercator projection is a popular map-making method that converts a section of a globe to a rectangular, flat map. A Mercator projection map shows a section of the world as though it were projected on a cylinder. Mercator projections are most accurate where the cylinder touches the globe, which would be at the equator. This is why landforms and oceans are more accurate in size and shape near the equator, while landforms and oceans near the poles are distorted and appear much larger than they actually are.

Figure 3.12: *The image above shows how the size of Greenland compares to the size of South America in reality and on a globe.*



Features of maps

Direction symbols On maps, there is usually a symbol that indicates direction—north, south, east, and west. An example of this direction symbol is shown at the right. Sometimes only the arrow pointing north is shown.



VOCABULARY

legend - a special area on a map that lists and explains the symbols that are used.

Map legends Maps usually have a **legend** that lists and explains the symbols that are used on the map. For example, the legend on a globe might include special lines to indicate the boundaries between countries, and circles of different sizes to represent the population sizes of cities. A legend on a road map might include special lines to indicate different kinds of roads (Figure 3.13) and the locations of places of interest, such as parks, airports, and hospitals.

Scale of maps The *scale* of a map helps you relate the distances on the map to the larger, real-life distances. There are three kinds of map scales. A *fractional scale* shows the ratio of the map distance to the real-life distance as a fraction. The scale 1/100,000 means that one unit on the map is equal to 100,000 units in real life. A *verbal scale* expresses the relationship in words, for example, "1 centimeter is equal to 1 kilometer." A *bar scale* is simply a bar drawn on the map with the size of the bar proportional to a distance in real life.

Types of Map Scales

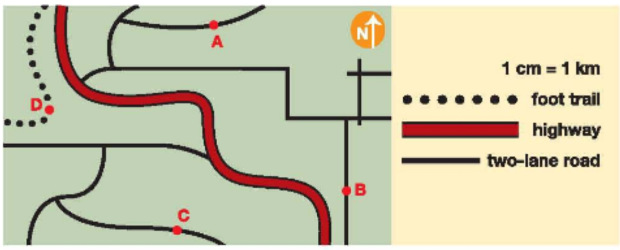
Fractional	Verbal	Bar
1/100,000	1 cm = 1 km	0 1 2 3 4 5 kilometers

What type of scale does the map in Figure 3.13 have? You are correct if you answered "bar scale". This scale is shaded in increments of 10 miles. If a road map contains an inset portion to show details of a certain area, be aware that the scale for that portion of the map will probably be different from the scale for the part of the map that covers a wider area.

Figure 3.13: *A road map with a legend and a scale.*

Section 3.1 Review

1. What is the difference between *distance* and *position*?
2. From an origin, you walk 3 meters east, 7 meters west, and then 6 meters east. What is your position now?
3. A globe is a more accurate map of the sizes and shapes of landforms on Earth's surface than a flat, paper map. Why?
4. What is the difference between latitude and longitude lines?
5. How is the prime meridian like the equator?
6. How is the prime meridian different from the equator?
7. Give the degree location for the international date line.
8. You can find Omaha, Nebraska at 41° 18' north and 95° 54' west. You can find Poughkeepsie, New York at 41° 38' north and 73° 55' west. Are Poughkeepsie and Omaha near the same line of longitude or near the same line of latitude?
9. What is a Mercator projection?
10. Answer the following questions using the map below.
    a. Using only two-lane roads, how many kilometers is it from point A to point B?
    b. Which point is the furthest east on the map—A, B, C, or D?
    c. Which of the map locations would be most likely to have few or no cars—A, B, C, or D?



SOLVE IT!

The location of the Tropic of Cancer is 23.5° N.

How far is the Tropic of Cancer from the equator?

Use this conversion factor: one degree latitude = 111 km

STUDY SKILLS

Remembering the definitions of terms is an important task in science. One way to make this task easier is to come up with a unique way to remember them.

For example, can you think of a way to remember the difference between *latitude* and *longitude*? Give it a try!

Suggestions: Latitude lines are like the rungs on a ladder (ladder and latitude both start with *la*-). Longitude lines run the long way from one pole to the other.