Name: ______________________ Laboratory Section: ______________________

Date: ______________________ Score/Grade: ______________________

Video
Exercise 4
Pre-Lab Video

http://goo.gl/BppTYe

4

LAB EXERCISE

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Map Projections, Map Reading, and Interpretation

A **map** is a generalized view of an area, usually some portion of Earth's surface, as seen from above and greatly reduced in size. The part of geography that embodies mapmaking is called **cartography**. Maps are critical tools with which geographers depict spatial information and analyze spatial relationships. We all use maps at some time to visualize our location and our relationship to other places, or maybe to plan a trip, or to coordinate commercial and economic activities.

In this lab exercise, we begin with an overview of various map projections that are used for a variety of purposes. An important decision in making maps is the proper scale to use. Maps, like architectural blueprints, are produced at a greatly reduced size compared to reality. Then, we specifically work with a U.S. mapping program—the township and range system. Lab Exercise 4 has four sections.

Key Terms and Concepts

cartography
conic
cylindrical
equal area (equivalent)
gnomonic projection
great circle
map
map projection
Mercator projection
planar
rhumb lines
scale
standard line
township and range
true shape (conformal)

KEY LEARNING concepts

After completion of this lab, you should be able to:

1. *Define* the map projection concept and *identify* the four classes of map projections.
2. *Recognize* distortions that are characteristic of selected map projections and *compare* distortions in order to *select* the appropriate map for a given use.
3. *Plot* a great circle route from a gnomonic projection to a Mercator projection.
4. *Compare* methods of expressing map scale and *calculate* map scales.
5. *Explain* the township and range system employed in the U.S.

Materials/Sources Needed

tracing (or wax) paper or notebook paper
world globe
scissors
color pencils
calculator
ruler

Lab Exercise and Activities

SECTION 1

Map Projections

We worked with Earth's coordinate grid system in Lab Exercise 2. Cartographers prepare large-scale flat maps—two-dimensional representations (scale models) of our three-dimensional Earth. This transformation of spherical Earth and its latitude–longitude coordinate grid system to a flat surface in some orderly and systematic realignment is called a **map projection**.

A globe is the only true representation of distance, direction, area, shape, and proximity, and preparation of a flat version requires decisions as to the type and amount of distortion that will be acceptable. To understand this problem, consider these important physical properties of a globe:

- Parallels always are parallel to each other, always are evenly spaced along meridians, and always decrease in length toward the poles.
- Meridians converge at both poles and are evenly spaced along any individual parallel.
- The distance between meridians decreases toward poles, with the spacing between meridians at the 60th parallel equal to one-half the equatorial spacing.
- Parallels and meridians always cross each other at right angles.

The problem with preserving these properties is that all globe qualities cannot be reproduced on a flat surface. The larger the area of Earth depicted on a map, the greater the distortion will be. Simply taking a globe apart and laying it flat on a table illustrates the problem cartographers face in constructing a flat map (Figure 4.1).

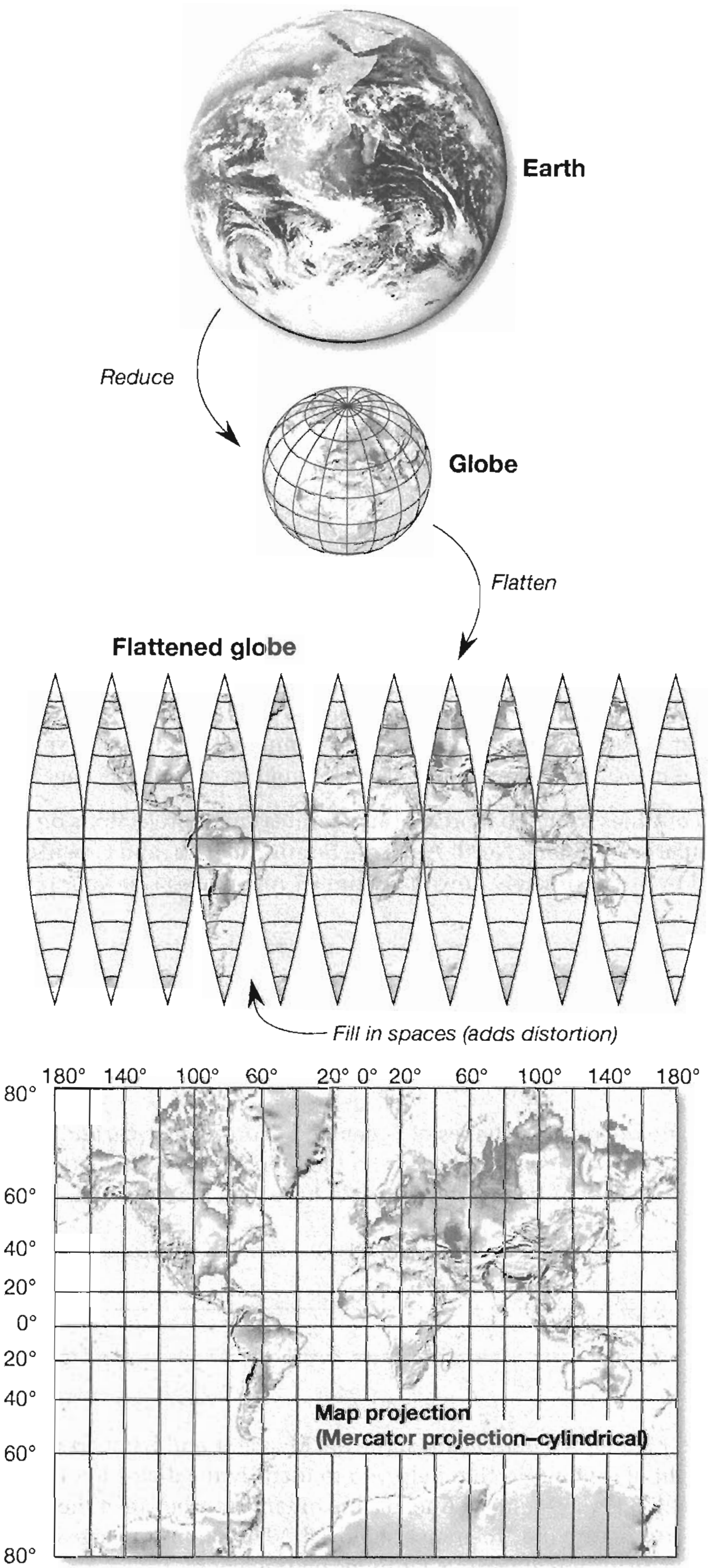
In Figure 4.1, you can see the empty spaces that open up between the sections, or gores, of the globe when it is flattened. Flat maps always possess some degree of distortion—much less for large-scale maps representing a few kilometers, and much more for small-scale maps covering individual countries, continents, or the entire world.

The best projection is always determined by its intended use. The major decisions in selecting a map projection involve the properties of **equal area** (equivalence) and **true shape** (conformality). If a cartographer selects equal area as the desired trait, as for a map showing the distribution of world climates, then shape must be sacrificed by *stretching* and *shearing* (having parallels and meridians cross at other than right angles).

If, on the other hand, true shape is desired, as for a map used for navigational purposes, then equal area must be sacrificed, and the scale will actually change from one region of the map to another. Two additional properties related to map projections are true direction and true distance.

The fold-out flap of the back cover shows four classes of map projections and geometric-surface perspectives from which three classes of maps—**cylindrical**, **planar** (or *azimuthal*), and **conic**—are generated. Another class of projections that cannot be derived from this physical-perspective approach is the non-perspective *oval*-shaped. Still others are derived from purely mathematical calculations.

With all projections, the contact line (or point) between the globe and the projection surface—called a **standard line**—is *the only place where all globe properties are preserved.* A *standard parallel* or *standard meridian* is true to scale along its entire length, without any distortion. Areas away from this critical tangent line or tangent point become increasingly distorted. Consequently, this area of optimum spatial properties should be centered on the region of immediate interest so that greatest accuracy is preserved there.



▲ **Figure 4.1 Conversion of a globe to a flat map requires decisions about the desired properties to preserve, how much distortion is acceptable, and which projection best serves the purpose of the map.**

SECTION 2

Cylindrical, Planar, and Conic Projections

This step may be done by working in groups. Your instructor will direct you.

1. Using a globe and tracing (or wax) paper—notebook paper works with an illuminated globe—trace outlines of North America, South America, and Greenland. You can do this quickly; a rough outline showing size and shape is sufficient.

   Using a globe and your tracings, compare the relative sizes of North America, South America, and Greenland. Which is larger and by approximately how many times? Describe your observations.

2. Examples of two cylindrical projections are presented in Figure 4.2, the **Mercator projection** (conformal, true-shape), and Figure 4.3, the *Lambert projection* (equivalent, equal-area). These two map projections—the Mercator and the Lambert—are simply being used to examine *relative* size and shape in each portrayal of Earth.

   Trace around the outlines of the same continents and island as indicated above—North America, South America, and Greenland. You might want to mark and color code the tracings according to their source (Mercator or Lambert) for future reference. Use your tracings to answer the following questions. Keep in mind that these two sets of map outlines compared to the globe you used are not at the same scale: the distance measured along their respective equators will not be equal.

   a) Using the outlines from the Mercator and Lambert map projections on the next pages, make the same comparisons among North America, South America, and Greenland. Which is relatively larger and by approximately how many times? Again, describe your observations.

   Mercator ____

   ____

   Lambert ____

   ____

   b) Now compare the relative shapes of Greenland, North America, and South America from the globe (shows true shape) with those from the Mercator and Lambert projections. Is there distortion in terms of shape? If so, briefly explain how they are distorted.

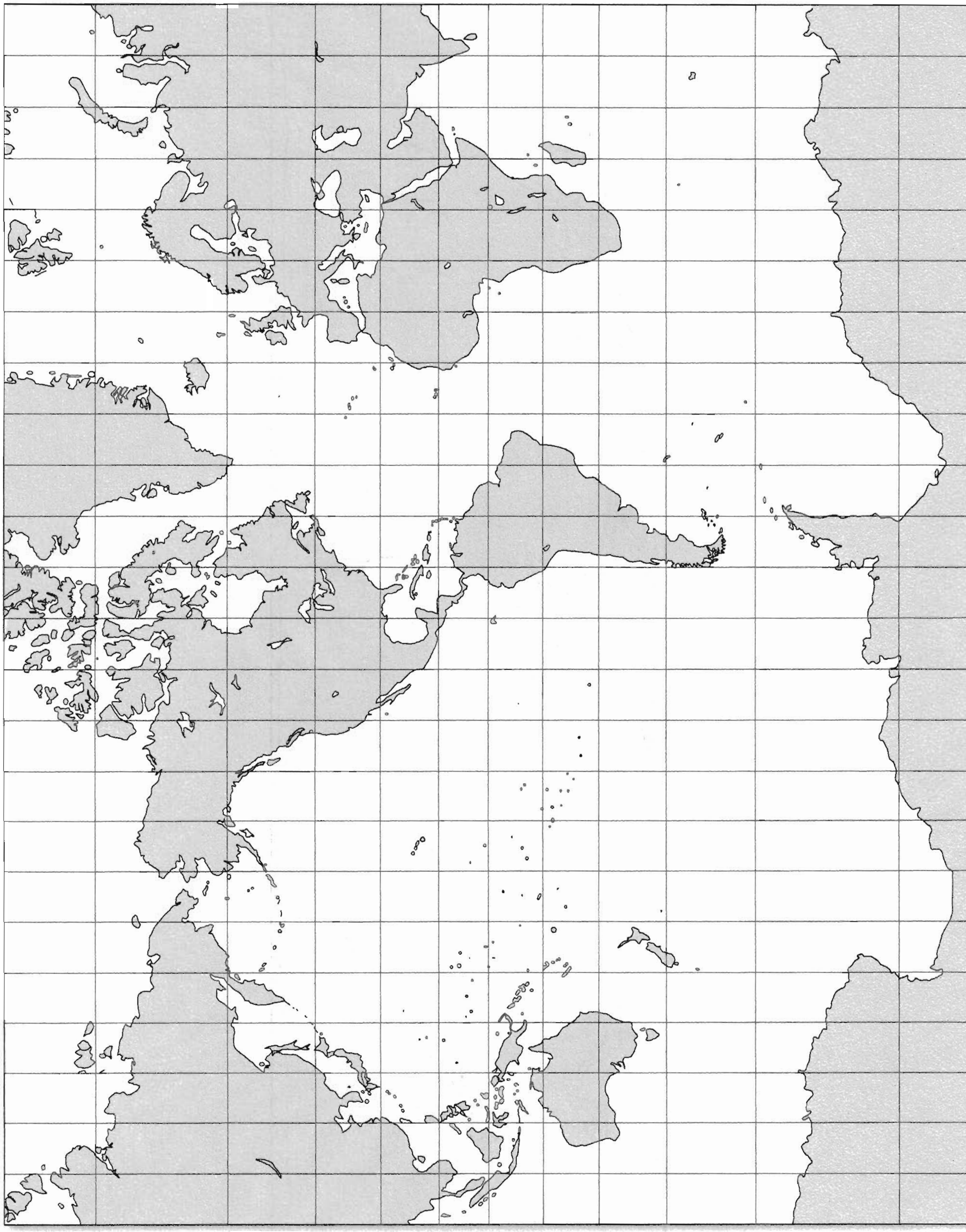
   Mercator ____

   ____

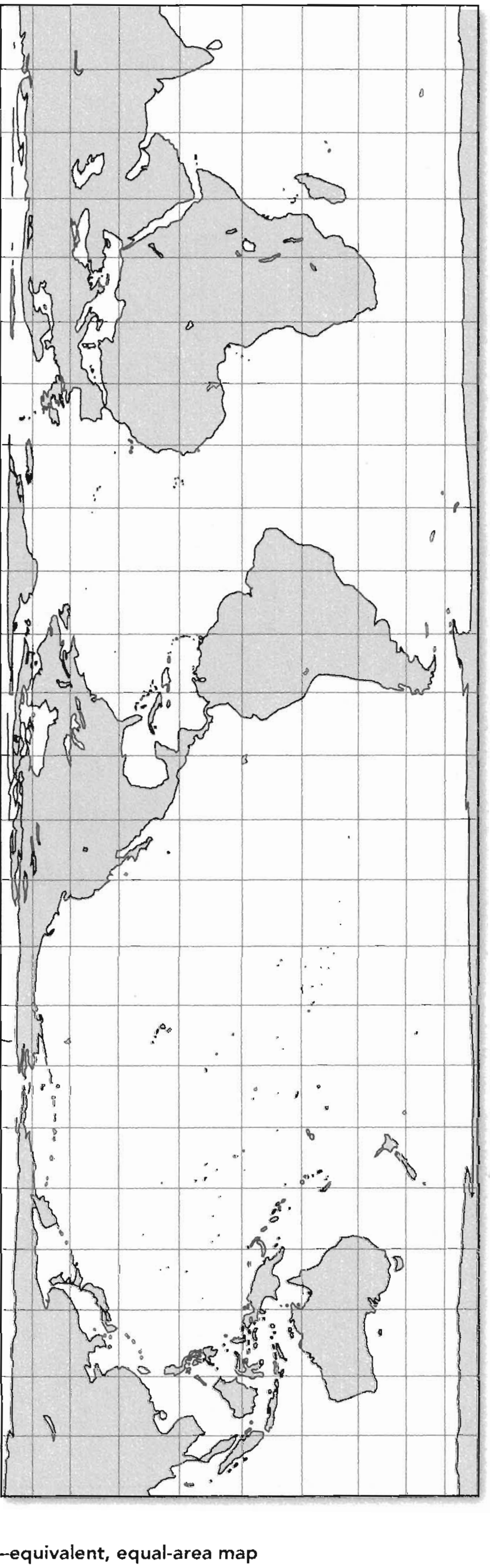
   Lambert ____

   ____

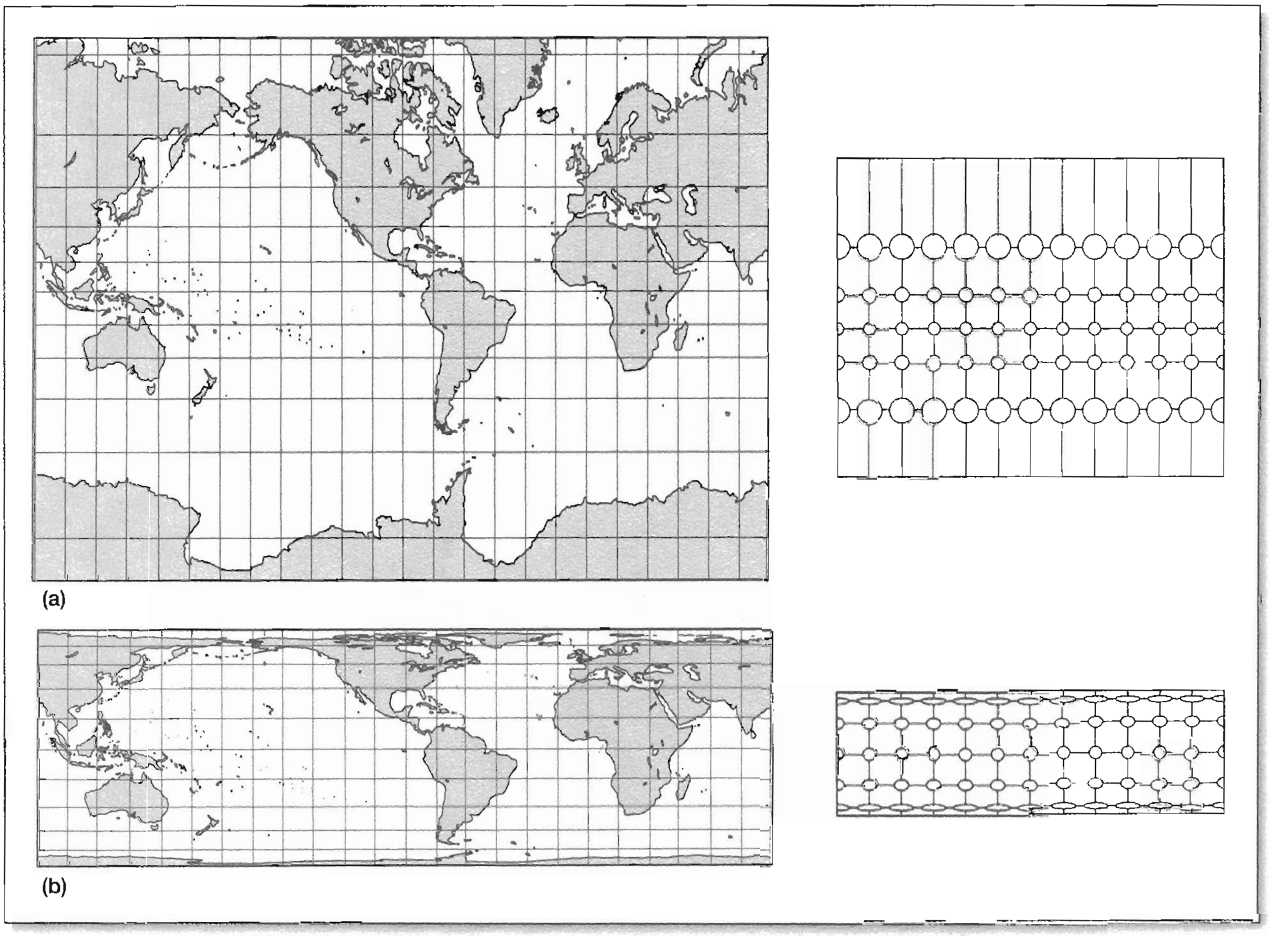
   Figure 4.4a and Figure 4.4b once again show the Mercator and Lambert cylindrical projections. Diagrams to the right of each projection help you to identify the distortion in each. The circles along the equator—which is the standard line, or line of tangency between the globe and the cylinder and is without distortion—are the "reference standard." The shape and size of the other "circles" is proportionate to the distortion at various latitudes on the maps.



▲ Figure 4.2 Mercator projection—conformal, true-shape map



▲ Figure 4.3 **Lambert projection—equivalent, equal-area map**

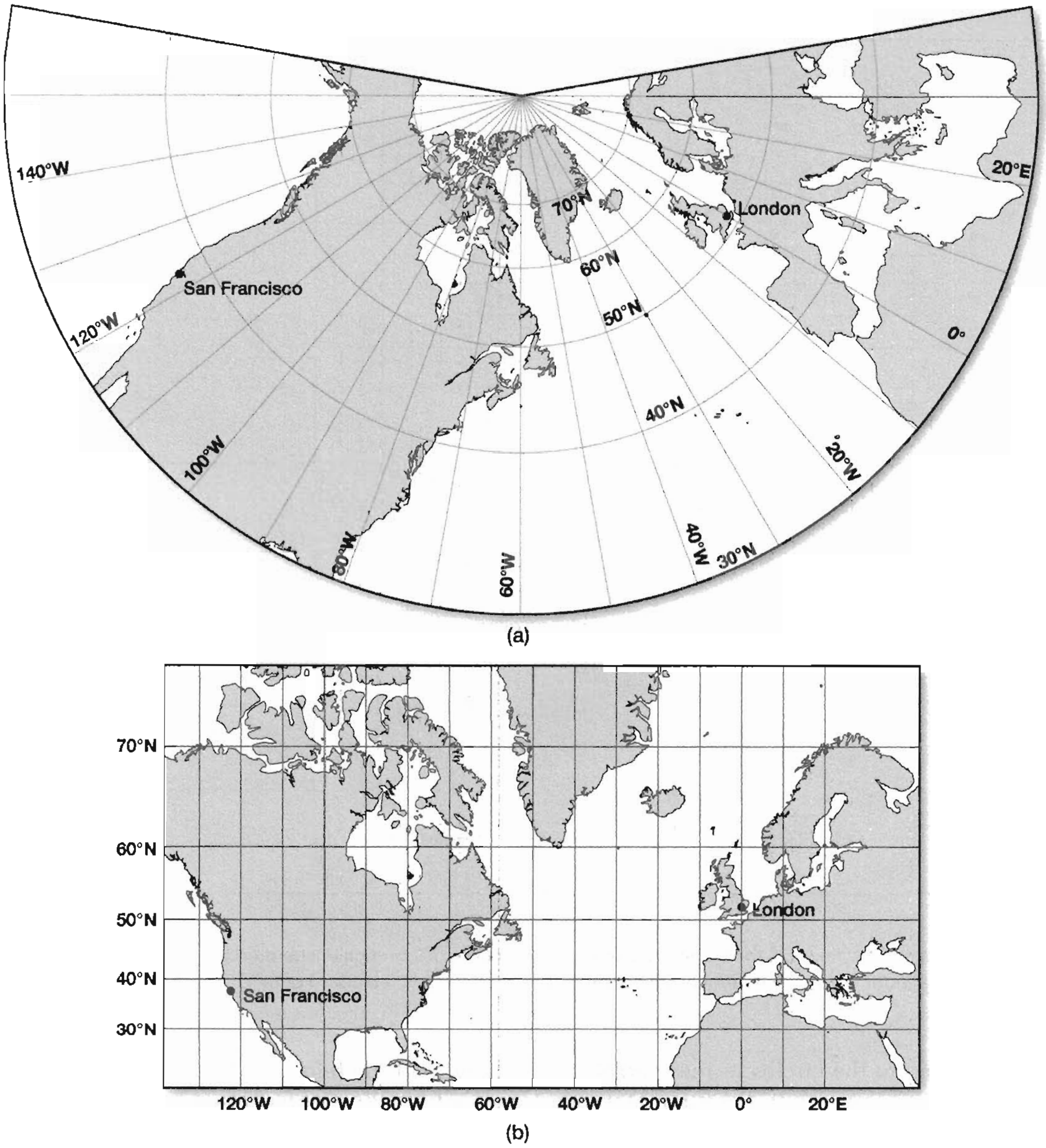


▲ Figure 4.4 (a) Mercator cylindrical true shape (conformal) projection, 30° graticule; standard parallel 0° central meridian 90°W. (b) Lambert cylindrical equal area (equivalent) projection, 30° graticule; standard parallel 0° central meridian 90°W.

3. What happens to the circles in the Mercator projection (and, therefore, to the landmasses) as latitude increases? What causes this distortion of the circles away from the equator? (*Hint:* Compare parallels and meridians with those on the globe.)

4. What happens to the circles in the Lambert projection (and, therefore, to the landmasses) as latitude increases? What causes this distortion of the circles away from the equator? (Once again, compare parallels and meridians.)

5. Cylindrical projections such as Mercator and Lambert would best be used in mapping what areas of the globe? Why?



▲ **Figure 4.5** **(a) Gnomonic/planar projection; (b) Mercator/cylindrical projection.**

6. Figure 4.5a shows Earth on a *planar* projection, in which the globe is projected onto a plane. This is a **gnomonic projection** and is generated by projecting a light source at the center of a globe onto a plane that is tangent to (touching) the globe's surface. The resulting increasingly severe distortion as distance increases from the standard point prevents showing a full hemisphere on one projection.

   a) Where is the projection surface tangent to (touching) the globe? (See end flap of this lab manual.)

   ____

   ____

   b) What kind of distortion, if any, occurs on a planar projection, and where?

   ____

   ____

c) Can you show the entire Earth on a single gnomonic projection? If not, why not?

d) Which areas of the globe would likely be mapped on a planar projection, and why?

The Mercator projection is useful in navigation and has become the standard for nautical charts since Gerardus Mercator, a Flemish cartographer, devised it for navigational purposes in 1569. The advantage of the Mercator projection is that lines of constant compass direction, called **rhumb lines**, are straight and thus facilitate the task of plotting compass directions between two points. However, these lines of constant direction, or bearing, are not the shortest distance between two points.

From the *planar* class of projections, a gnomonic projection possesses a valuable feature: All straight lines are ***great circles***—the shortest distances between two points on Earth's surface. A gnomonic projection is used to determine the coordinates of a great-circle (shortest) route; these coordinates are then transferred to a Mercator (true-direction) projection for determination of precise compass headings—the route along which the pilot or captain steers the airplane or ship.

Complete:

7. Use the two maps in Figure 4.5 to plot a great circle route between San Francisco (west coast of the United States, where you can see small details of San Francisco Bay) and London (southern England at the 0° prime meridian). The straight line on the gnomonic projection will show the shortest route between the two cities. Transfer the coordinates of this route over to the Mercator map and connect with a line plot to show the route's track. Note the route arching over southern Greenland on the Mercator.

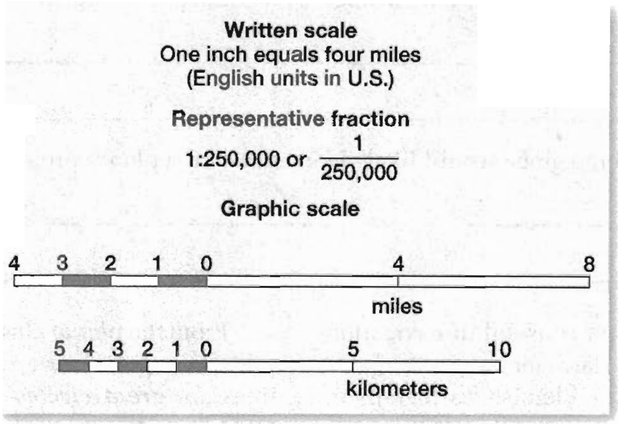
8. Assume you board a plane in San Francisco for a flight to London. Briefly describe your great-circle flight route between the two cities (plotted on the map in Figure 4.5b). What are some of the features over which you fly? Describe the landscape and water below.

SECTION 3

Map Scale

The ratio of the measured distance on a map to the actual distance on the ground is called **scale**; it relates a unit on the map to a similar unit on the ground. A 1:1 scale would mean that a centimeter on the map represents a centimeter on the ground, or an inch on the map represents an inch on the ground. A more appropriate scale for a local map is 1:24,000, in which 1 unit on the map represents 24,000 identical units on the ground.

Map scales may be presented in several ways. A *written* (or verbal) *scale* simply states the ratio using words—for example, "one centimeter to one kilometer" or "one inch to one mile." A *representative fraction* (RF, or fractional scale) can be expressed with either a : or a /, as in 1:125,000 or 1/125,000. No actual units of measurement are mentioned because any unit is applicable as long as both parts of the fraction are in the same unit: 1 cm to 125,000 cm, 1 in. to 125,000 in., or even 1 arm length to 125,000 arm lengths, and so on. A *graphic* (bar) *scale* is a line or a bar divided into segments illustrating the correct map-to-ground ratio (Figure 4.6).



▲ Figure 4.6 **Three expressions of map scale: written scale, representative fraction, and graphic (bar) scale**

Scales are called "small," "medium," and "large," depending on the ratio described. Thus, a scale of 1:24,000 is a large scale, whereas a scale of 1:50,000,000 is a small scale. The greater the size of the denominator in a fractional scale (or number on the right in a ratio scale), the smaller the scale and the more abstract the map must be in relation to what is being mapped.

Examples of selected representative fractions and written scales are listed in Table 4.1 for small-, medium-, and large-scale maps.

System	Scale Size	Representative Fraction	Written Scale
English	Small	1:3,168,000	1 in. = 50 mi
		1:2,500,000	1 in. = 40 mi
		1:1,000,000	1 in. = 16 mi
		1:500,000	1 in. = 8 mi
		1:250,000	1 in. = 4 mi
	Medium	1:125,000	1 in. = 2 mi
		1:63,360 (or 1:62,500)	1 in. = 1 mi
		1:31,680	1 in. = 0.5 mi
		1:30,000	1 in. = 2500 ft
	Large	1:24,000	1 in. = 2000 ft
System		**Representative Fraction**	**Written Scale**
Metric		1:1,000,000	1 cm = 10.0 km
		1:50,000	1 cm = 0.50 km
		1:25,000	1 cm = 0.25 km
		1:20,000	1 cm = 0.20 km

▲Table 4.1 **Sample representative fractions and written scales for small-, medium-, and large-scale maps**

Assume:

If a world globe is 61 cm (24 in.) in diameter and we know Earth has an equatorial diameter of 12,756 km (7926 mi), then the scale of the globe is the ratio of 61 cm to 12,756 km. Therefore, in order to determine the globe's representative fraction:

$$\textbf{RF} = \frac{\text{diameter of globe}}{\text{diameter of Earth}} = \frac{61\ \text{cm}}{12{,}756\ \text{km}} = \frac{61\ \text{cm}}{1{,}275{,}600{,}000\ \text{cm}} = \frac{1\ \text{cm}}{20{,}911{,}000\ \text{cm}}$$

Thus, the representative fraction for the 61 cm globe is expressed in centimeters as 1:20,900,000 (rounded off). This representative fraction can now be expressed in *any* unit of measure, metric or English, as long as both numbers are in the same units.

Complete:

1. Several companies manufacture large world globes for display in museums, corporate lobbies, and science exhibit halls. If such a globe featured a *diameter* of 4 m (13 ft), what is the scale of this globe expressed as a representative fraction? (Show your work.) (*Hint:* Earth's equatorial diameter = 12,756 km [7926 miles].)

2. Given the large globe in question #1 and your calculation of its representative fraction, convert the RF to a *written scale* for this globe (1 cm on the globe =? km on Earth). (Show your work and remember that there are 100,000 cm in 1 km.)

3. Use the topographic maps in the section at the back of the lab manual and a ruler (inches or cm) to measure the map distance between the points indicated. Noting the RF scales posted on each map, calculate the approximate ground distance (miles or km). Keep in mind that there are 63,360 inches in a mile: 12 in/ft × 5280 ft/mile. Compare results with the graphic scale. (Show your work.)

   a) **Kilauea Crater, HI Topographic Map #1:** from the Park Headquarters to Sand Hill, BM 3700.

   ____

   b) **Mt. Rainier National Park Topographic Map #6:** from Columbia Crest to McClure Rock

   ____

   c) **Point Reyes, CA Topographic Map #8:** from McClures Ranch to Chimney Rock

   ____

4. Find three different maps or globes as follows. Briefly describe the content of each and record the scale as a representative fraction or other scale noted on each map or globe.

   a) Classroom globe ______________________________

   b) Map from your atlas ______________________________

   c) Topo map at back of this manual ______________________________

5. Give an example of a specific scale for each of the following:

   a) Small scale: ______________________________

   b) Medium scale: ______________________________

   c) Large scale: ______________________________

6. What is an appropriate scale to use in preparing a world map for a classroom (pull-down "wall" map)? Why?

7. If you wanted a map to help you plan a local trip within your state or province, what scale would be best?

8. **Challenge question:** If you were helping to plan the painting of a world map on a local school playground that is approximately 10 meters along the equator, what scale would be best?

   RF: ______________________________

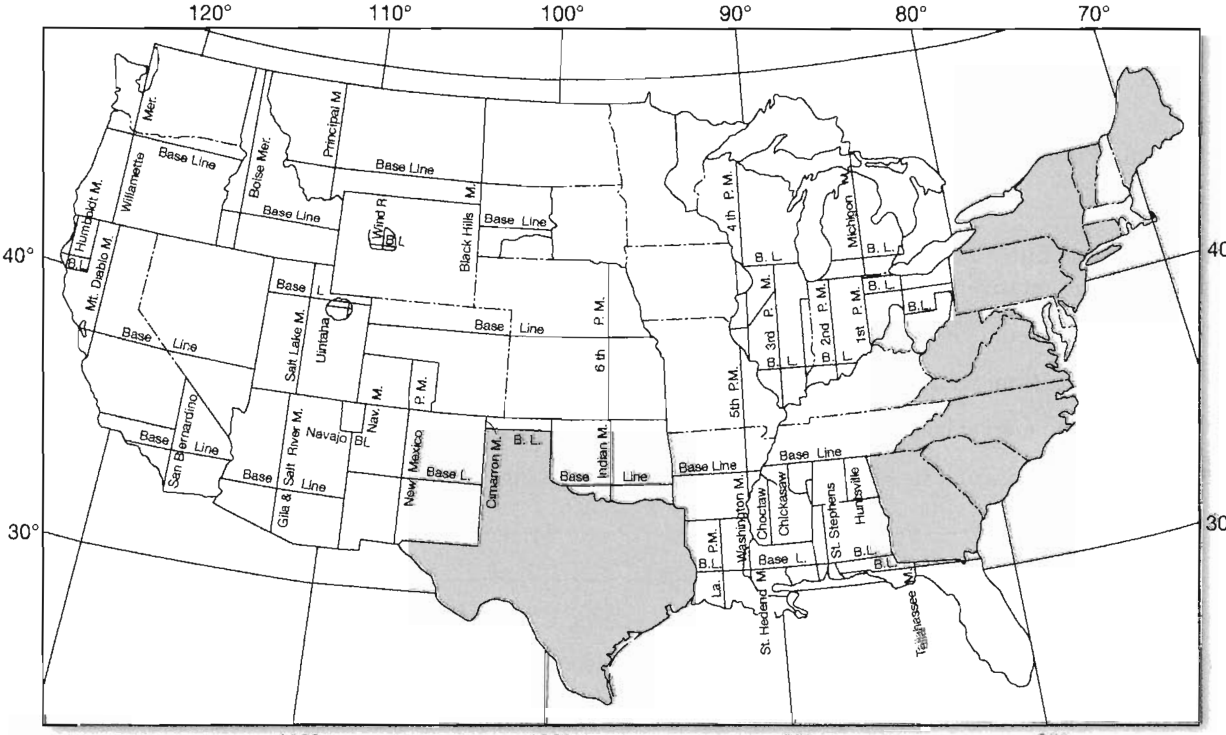
   Written scale: ______________________________

9. Using the metric-to-English conversion chart on the inside of the fold-out back flap of this manual, what would be the approximate length of the equator, in feet?

SECTION 4

Township and Range Survey System

The Public Lands Survey System (1785) delineated locations in the United States. After modifications and adjustments, the final plan called for the establishment of the **township and range** grid system, based on an initial survey point. For those portions of the United States surveyed under this system, the *initial points* are presented in Figure 4.7. Places are designated as north or south of the base line and east or west of the principal meridian. For example, Township 3 N means 3 "tiers" north of the base line and Range 4 W means 4 "columns" west of the principal meridian. Note that due to the latitudinal extent of California (southern border: 32°40′N; northern border: 42°N), three initial points are used.

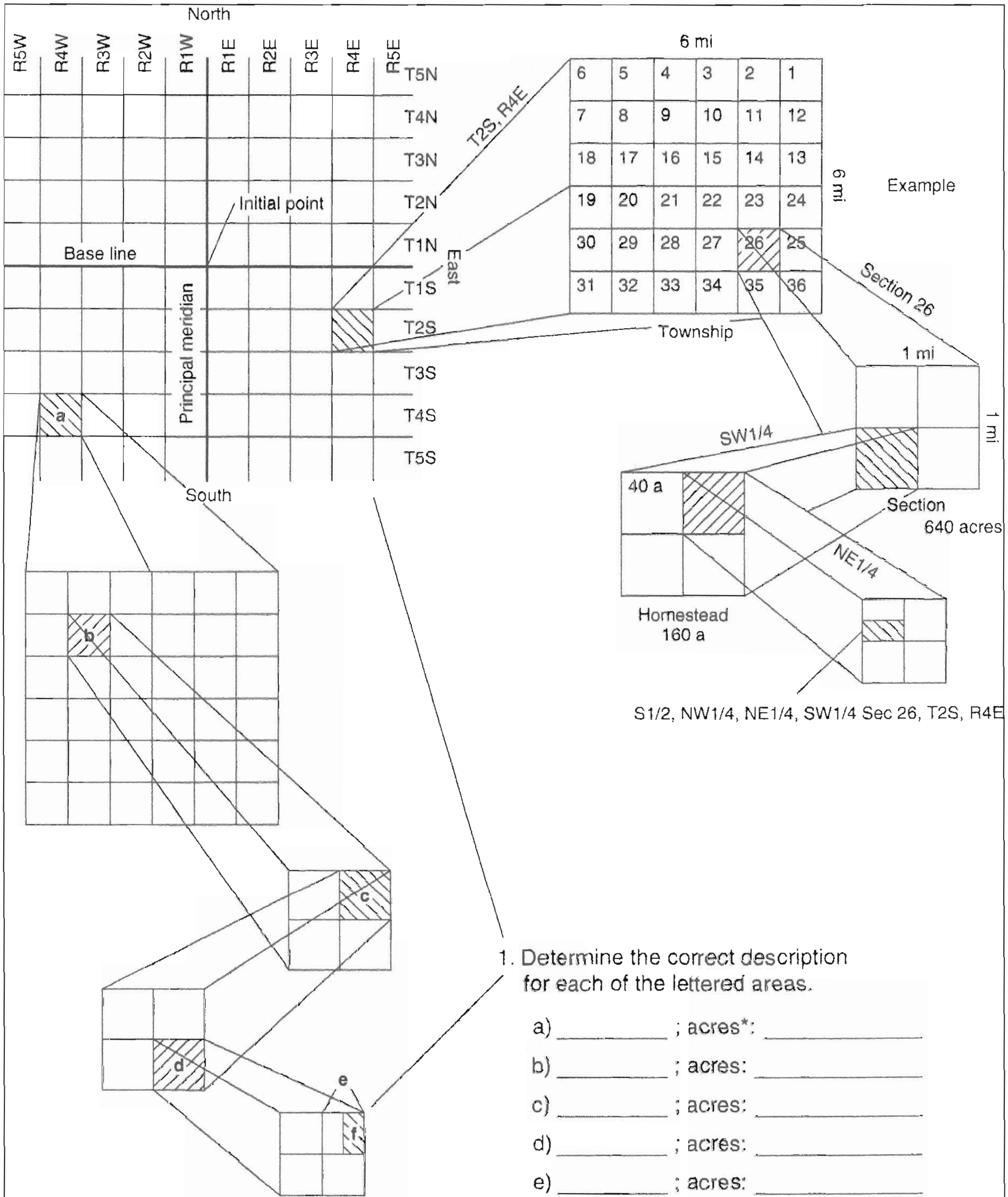


▲ Figure 4.7 Principal meridians and base lines used for the township and range public-land surveys. Shaded states were not surveyed with the PLSS. (Adapted from the Bureau of Land Management, Manual of Surveying Instructions, Washington, DC, 1947, p. 168.)

The township and range grid system is based on 6-mile square *townships*, subdivided into 1-mile square *sections*, and quarter-section *homesteads*. Figure 4.8 portrays this system and shows the derivation of a parcel of land described as "S1/2, NW1/4, NE1/4, SW1/4, Sec. 26, T2S, R4E." Note that you start from the smallest parcel of land ("the south half, of the northwest quarter, of the north-east quarter ..."). Some land deeds still reflect this system.

Questions and analysis about the township and range system.

1. Complete the fill-ins presented in Figure 4.8 on the next page.
2. Using Figure 4.7 as your guide, which meridian and base line pair would be used to survey the area you are in?
3. If your campus was surveyed using the public-lands system, give a full description of the campus in standard township and range format (consult a topographic map for your campus area).
4. If the state or region where your campus is located was surveyed under a different system (for example, parts of Texas, the original 13 colonies), describe it relative to this system.



1. Determine the correct description for each of the lettered areas.

a) __________ ; acres*: ______________

b) __________ ; acres: ______________

c) __________ ; acres: ______________

d) __________ ; acres: ______________

e) __________ ; acres: ______________

f) __________ ; acres: ______________

* 1 acre (a) = 2.59 hectares (ha)

▲ **Figure 4.8 Township and range rectangular survey grid system illustrating a parcel of land at S1/2, NW1/4, NE1/4, SW1/4, Sec 26, T2S, R4E.**

