Geographic Information Systems work with maps.

Since most maps in the world are older maps, they have been drawn on paper and must be converted to a digital format for use in a GIS.
The most commonly used coordinate system for these maps is latitude and longitude. Longitude and Latitude are spherical coordinates.
Equator and Prime Meridian

The Equator and the Prime Meridian are the reference lines used to measure latitude and longitude. The equator which lies halfway between the poles is a natural reference for latitude. A line through Greenwich, England, just outside London, is the Prime Meridian.

Latitude
Runs from 0° at the equator to 90°N or 90°S at the poles. These lines of latitude, called parallels, run in an east-west direction.

Longitude
Lines of longitude, called meridians, run in a north-south direction intersecting at both poles. Runs from 0° at the prime meridian to 180° east or west, halfway around the globe.
More on Degrees, Minutes, and Seconds

On the globe, one degree of latitude equals approximately 70 miles. One minute is just over a mile, and one second is around 100 feet. Length of a degree of longitude varies, from 69 miles at the equator to 0 at the poles. Because meridians converge at the poles, degrees of longitude tend to 0.

Longitude and Time
Since the earth rotates 360 degrees every 24 hours, or 15 degrees every hour, it's divided into 24 time zones- 15 degrees of longitude each. When it is noon at Greenwich, it is 10:00 A.M. 30 degrees W., 6:00 A.M. 90 degrees W., and midnight at 180 degrees on the opposite side of the earth.

Historical Note

Nature gave no clear direction on selecting the Prime Meridian, as it did with the equator as the 0 degree of latitude. (Half-way between the poles) As late as 1881, there were 14 different prime meridians still being used on topographic survey maps alone. The International Meridian Conference of 1884 adopted the Prime Meridian line passing through the Greenwich Observatory near London, England.
The Earth is Flat - I Know, I’ve seen it drawn on paper maps!

How can that be?

The simplest way is to ignore the fact that latitude and longitude are angles at the center of the earth, and just pretend that they are x and y values.

X ranges from -180 to + 180

Y ranges from +90 to - 90
This map is not a map projection because the earth’s geographical coordinates have been mapped onto a flat surface.
“How can a round earth be portrayed on a flat map?” Actually, the earth is not truly a round, or spherically shaped feature.

The earth resembles a figure called an *oblate ellipsoid* or *spheroid*, the three-dimensional shape you get by rotating an ellipse about its shorter axis.
There have been many attempts to measure the size and shape of the earth’s spheroid.

In 1866 the mapping of the U.S. was based on the ellipsoid measured by Sir Alexander Ross Clarke.

This is called the Clarke 1866 ellipsoid. Illinois maps are based on this ellipsoid.

In 1924 a simpler measure was adopted as an international standard. However, as mapping had already begun in the U.S., a version specific to North America was adopted as the North American Datum of 1927 (NAD27).
The satellite era has brought with it more accurate means of measurement, including the global positioning system (GPS).
The world geodetic system WGS84 has been derived from GPS measurements.

It is vital that when maps are used in GIS that the datum and ellipsoid reference systems are known and consistent for each theme in the GIS.
Position Shifts from Datum Differences
Texas Capitol Dome Horizontal Benchmark
Combinations You Will Generally See

State of Illinois (older maps, not new clearinghouse)
- NAD27 datum and Clarke1866 spheroid

National Atlas of the United States
- NAD83 datum and GRS1980 spheroid

U.S. Census Bureau
- NAD83 datum for 1995 TIGER files
- NAD27 datum for earlier TIGER files
Use ArcTool Box to define a projection for the states map you downloaded from the National Atlas website

Click on ArcTool Box on ArcMap Menu bar

Click on Data Management Tools, then Projections and Transformations and then Double Click Define Projections.

Click File Open Folder icon, select the file you need to define

Click Next

Click Select Coordinate System

Click Select button

Double-click Geographic Coordinate Systems

Double-click North America

Click North American Datum 1983.prj

Click Add, Click Apply, Click OK

Click OK
Latitude and Longitude can be projected though, in a number of ways.

The sphere can be projected onto any of three flat surfaces and then unfolded to make the map.

Note: the cylinder slices through the sphere and thus intersects the sphere at two latitudes, or parallels - these are called the 1st and 2nd Standard Parallels - they are arbitrary and must be included in meta-data.
Azimuthal Projections

Planar Projection Surface
Conic projections

Again, the cone slices through the sphere and has two Standard Parallels
Projections can also vary by the direction of the cylinder, cone or plane.
Map projections are attempts to portray the surface of the earth or a portion of the earth on a flat surface.

Some distortions of \textit{conformality, distance, direction, scale,} and \textit{area} always result from this process.

Some projections minimize distortions in some of these properties at the expense of maximizing errors in others.

Some projections are attempts to only moderately distort all of these properties.
Conformality
When the scale of a map at any point on the map is the same in any direction, the projection is conformal. Meridians and parallels intersect at right angles. *Shape is preserved locally on conformal maps.*

Scale
Scale is the relationship between a distance portrayed on a map and the same distance on the Earth.

Distance
A map is equidistant when it portrays distances from the center of the projection to any other place on the map.
Direction

A map preserves direction when azimuths (angles from a point on a line to another point) are portrayed correctly in all directions.

Area

When a map portrays areas over the entire map so that all mapped areas have the same proportional relationship to the areas on the Earth that they represent, the map is an equal-area map.
Geometric differences among projections

Why is the U.S. the same, but other areas are not?

Albers Equal Area
and
Lambert Conformal Conic
Projections
Origin 39 N, 96 W
Standard Parallels 33 N and 45 N
Besides geometry and distortion, the main difference among map projections is that some have **absolute** coordinate systems while others have **relative** coordinate systems.
Absolute Coordinate Systems

Latitude and Longitude is an absolute coordinate system. Origin is 0° latitude and 0° longitude.

Note how you can tell it is Lat/Long by the flattening.

Longitude in the eastern hemisphere is denoted either by:

+ 100 degrees 50 minutes 32 seconds
or
E 100 degrees 50 minutes 32 seconds

Longitude in the western hemisphere is denoted either by:

- 100 degrees 50 minutes 32 seconds
or
W 100 degrees 50 minutes 32 seconds

Latitude is simply denoted as N for northern hemisphere and S for southern hemisphere.

N 44 degrees 32 minutes 15 seconds
S 15 degrees 18 minutes 17 seconds
In relative coordinate systems, the map maker chooses:

- Latitude of origin
- Longitude of origin
- False X value for this origin
- False Y value for this origin

- Longitude of Origin: -90
  - False Y: 1,000,000

- Centered on the United States
- Latitude of Origin: 45N
  - False X: 1,000,000

Mercator projection
Or I could choose this origin centered on Africa

Longitude of origin

Latitude of origin

Longitude of Origin 0
False Y = 1,000,000.

False X value for this origin
False Y value for this origin

Latitude of Origin 0
False X = 1,000,000

Note: I keep the same relative False easting and False Northing values.
Note how all three projections fit pretty good in the central part of the map, around Kansas.

That is because the *origin of the projection* was centered on Kansas.
Display the Illinois county boundary map
Use the project program to change the map to Albers Equal Area conic projection.
Hmmm, try that all over again using the Lambert Conformal Conic projection (remember to start with a new map file to reset data frame coordinate system)
Display the Illinois county boundary map
I don’t like that map either, so let’s make a Lambert Conformal Conic using our own parameters.

Latitude of origin
Longitude of origin
False X value for this origin 0.
False Y value for this origin 0.

Latitude of Origin 40N
False Y = 1,000,000

Longitude of Origin -89
False X = 1,000,000.

Centered on Illinois

1st standard parallel
2nd standard parallel
Run project program again and select New, Projected
Make a layout for this map.

Include in this layout the parameters for our Lambert projection.
When working in a relatively small study area the *Universal Transverse Mercator (UTM) Projection* is the best choice because the USGS quad sheets and digital line graphs (DLG) derived from them are in a UTM coordinate system.
The World is Divided into 60 UTM Zones
Each zone is 6 degrees of Longitude wide
Coordinates in each zone are measured in meters. The origin is the equator and the central meridian of the zone.

A **Northing** for distance north and south of the Equator.

An **Easting** for distance east and west of the Central Meridian (always 500,000 meters).
Not very useful if your area extends beyond a single UTM Zone

This Easting is from the central meridian of zone 15

What happens to values as you approach 96W in Zone 14 and Zone 15?
Some Guidelines for Selecting a Projection

- **At Global Resolution** - geographic coordinate systems is used (latitude and longitude)

- **At continental resolution** (USA) Albers Equal Area projection is used (features that are about 2/3 high as they are wide)

- **At state resolution** (Illinois) Lambert Conic Conformal projection is used

- **At local resolution** UTM coordinate system
Add the Illinois county boundary file to a new workspace, then double-click the theme name, click on source tab to see the geographic extent of these files.
Locate these coordinates on the UTM Zone map to determine which zone your files are in. Then you can project these files to a UTM projection.
Since Illinois is covered by two zones, you can’t map the entire state using a UTM projection. For your next assignment, create a map of potential agricultural chemical contamination (pesticides) of aquifers that underly 100 year flood zones in McClean County, Illinois. All layers must be projected to UTM.

Layers to show on map

• county boundary
• 100 year flood zones
• potential pesticide contamination within the 100 year flood zones
• water wells
• populated places (point feature type)
• hospitals