Earth Science Notes—
Topics 1: Observation and Measurement **Topic 2:** The Changing Environment

Review book pages 1-38

Scientists **observe** the environment around them using their five senses.

When scientists interpret or make conclusions based on observations, they are making **inferences**. For example: There are puddles on the sidewalk (**observation**) , so it might have rained last night (**inference**).

A **scientific hypothesis** is an inference scientists seek to prove through experimentation.

SCIENTIFIC MEASUREMENT-- Scientists measure quantities using metric units:

Quantity	Definition	Unit	Of Note
length	the distance between 2 points	meter (m)	1 meter is longer than 1 yard (slightly more than 39 inches).
volume	the amount of space an object takes up or occupies	liter (L) or cubic meters (m^3)	1 liter of liquid is greater than 1 quart.
mass	the amount of matter In an object	gram (g)	1 kilogram (kg) = 2.2 pounds (lb)
temperature	the average kinetic energy of the molecules of a substance	Celsius (^{o}C) Fahrenheit (^{o}F) Kelvin (K)	**Melting/Freezing point**: 0 ^{o}C, 32 ^{o}F, 273 K **Boiling point:** 100 ^{o}C, 212 ^{o}F, 373 K

Absolute zero: the temperature at which all molecular motion stops = 0 K

Fundamental quantities: basic, not obtained by combining units (Ex.: mass, time, length).

Derived quantities: obtained by combining units (density, temperature, weight)
Ex.: density = mass/volume
temperature = the average of molecular kinetic energy

SCIENTIFIC NOTATION

uses the powers of ten to express very large or very small numbers

Step 1: change the original number to a number equal to or greater than one but less than 10 by moving the decimal to the right or to the left.

Step 2: assign a power of 10 using an exponent equal to the number of spaces the decimal point was moved.

Examples: .000356 = 3.56×10^{-4}
4,600,000,000 = 4.6×10^{9}

Prefix	Symbol	Multiplication factor		
exa	**E**	10^{18}	=	1 000 000 000 000 000 000
peta	**P**	10^{15}	=	1 000 000 000 000 000
tera	**T**	10^{12}	=	1 000 000 000 000
giga	**G**	10^{9}	=	1 000 000 000
mega	**M**	10^{6}	=	1 000 000
kilo	**k**	10^{3}	=	1 000
hecto	h	10^{2}	=	100
deca	da	10^{1}	=	10
deci	d	10^{-1}	=	0.1
centi	c	10^{-2}	=	0.01
milli	**m**	10^{-3}	=	0.001
micro	**µ**	10^{-6}	=	0.000 001
nano	**n**	10^{-9}	=	0.000 000 001
pico	**p**	10^{-12}	=	0.000 000 000 001
femto	**f**	10^{-15}	=	0.000 000 000 000 001
atto	**a**	10^{-18}	=	0.000 000 000 000 000 001

PERCENT ERROR OR PERCENT DEVIATION

Measurements are not always perfect; they contain some error.

The percent error or percent deviation is determined by comparing the calculated measurement to an accepted scientific value.

$$PE = \frac{\text{difference from accepted value}}{\text{accepted value}} \times 100\%$$

Ex.: The accepted value for the density of aluminum is 2.7 g/cm^3. A student finds its density to be 2.9 g/cm^3.

$$PE = \frac{2.9-2.7}{2.7} \times 100 \; ; \quad PE = \frac{.2}{2.7} \times 100 = 7.4\%$$

DENSITY

Pure substances have characteristic densities **as long as temperature and pressure remain constant.**

Ex: density of solid aluminum = 2.7 g/cm^3

As temperature increases, density decreases (inverse relationship).
As pressure increases, density increases (direct relationship).

STATES OF MATTER—solid, liquid, gas

Matter is most dense in the solid phase, least dense in the gas phase.
(H_2O is an exception).

Adding heat energy to a substance increases molecular movement, causing molecules to move farther apart and take up more space.
This increase in volume decreases density.

Ex: add heat to water → vaporizes to become water vapor

WATER (H_2O)

Water is the only substance found naturally on Earth in all 3 phases:
ice   liquid water   water vapor.

Water (H_2O) is unique because it is less dense in the solid phase (ice floats).
Water is most dense around 4° C (see front of ESRT).

CHANGE

A change or series of changes = an **event**

Time and space are common **frames of reference** by which we measure change.

Ex: The shoreline at Rocky Point has changed drastically since last year. (time)
Land forms change from New York City to the Catskills. (space).

Rate of Change expresses the amount of change per unit of time. It is calculated using the following formula:

$$\textbf{rate of change} = \frac{\textbf{difference in field value}}{\textbf{time}}$$

Graphs are useful tools to help interpret changes.

The **independent variable** is manipulated or controlled by the investigator, and is plotted on the **horizontal (x) axis.**

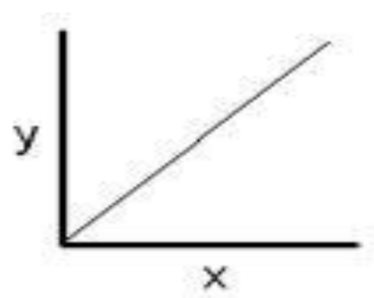
The **dependent variable** is that variable that responds to or results from the independent variable , and is plotted on the **vertical (y) axis.**

Ex.: "The effects of calcium on the regeneration of starfish."

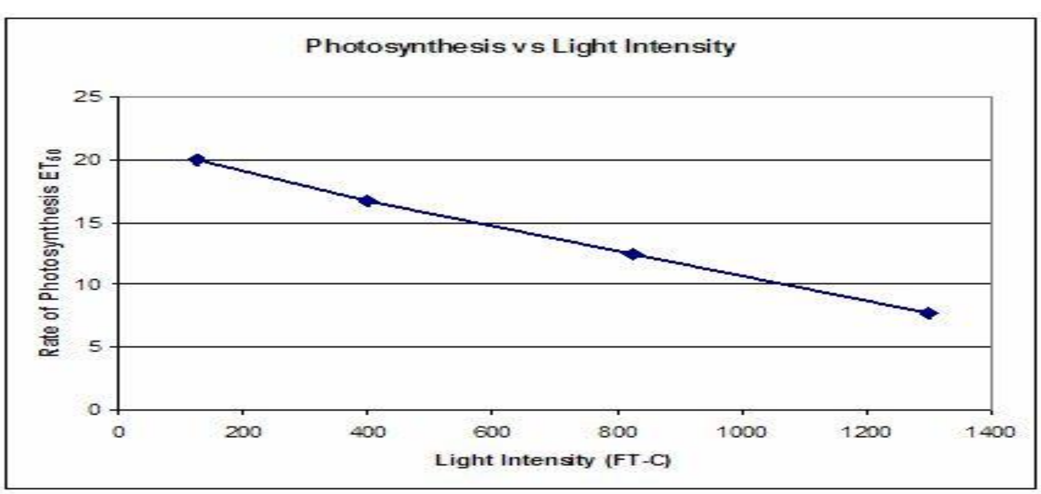
Calcium is the **independent variable**, because it's the chemical the investigator chooses to test.
Regeneration is the **dependent variable** that may or may not respond to the calcium.

GRAPH INTERPRETATION:

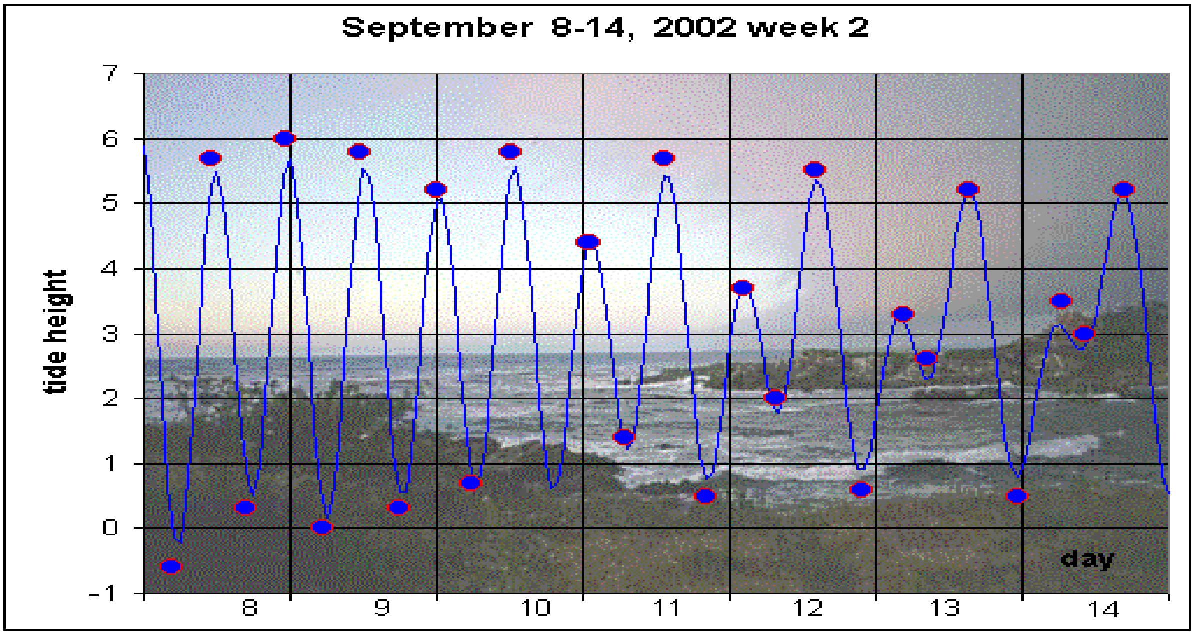
Direct relationship between the variables**: as value of the independent variable increases, the value of the dependent variable increases as well.**



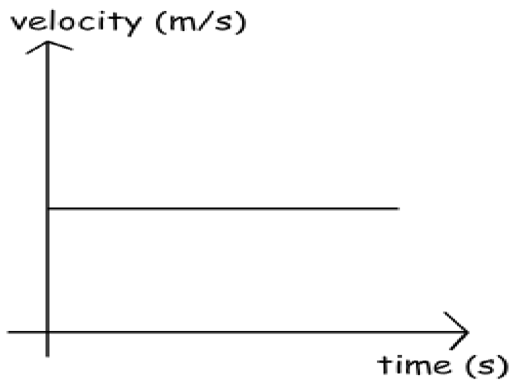
Inverse or indirect relationship between the variables**: as value of the independent variable increases, the value of the dependent variable decreases.**



A graph showing a **cyclic relationship between the variables** (such as the height of ocean tides) is shown on the next page:

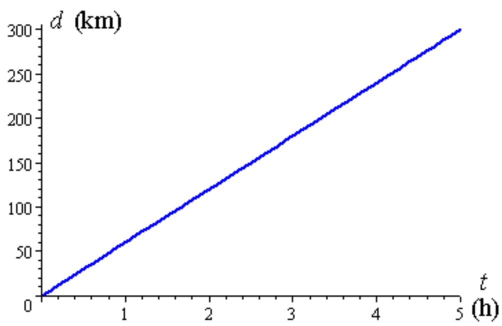


A graph showing **a straight horizontal line** indicates **no change in the dependent variable as independent variable increases:**



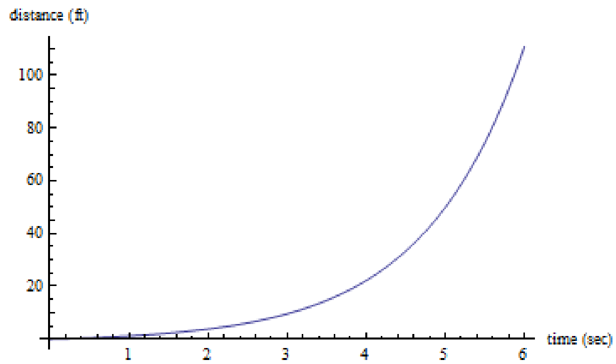
How would you describe the motion of the object shown by this graph?

The **slope and shape** of the graphed line **describes the <u>rate of change</u>:**



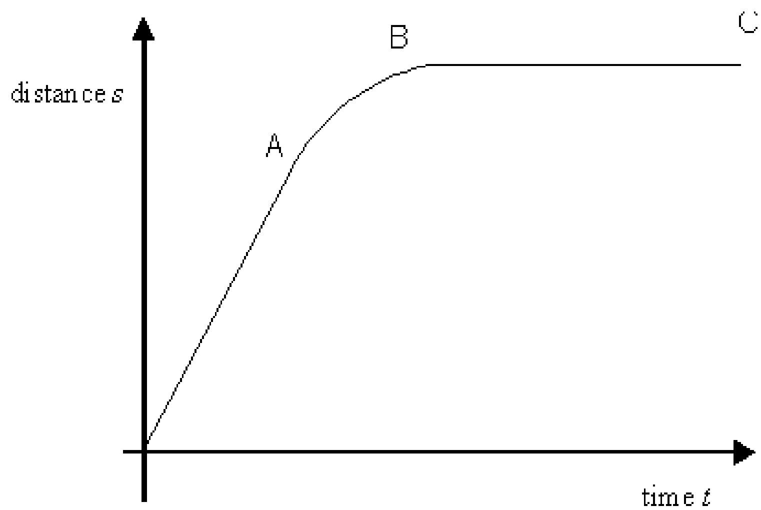
Constant rate of change:

(straight diagonal line)



Accelerated rate of change: (curved line)

As the slope of the line becomes steeper, the rate of change increases



Decelerated rate of change: (curved line)

As the slope of the line becomes less steep, the rate of change decreases

How would you interpret the motion shown on this graph?

Change and Energy

Changes usually involve a flow of energy across an interface (boundary) between where energy is lost to where it is gained.

For example: at the shoreline of an ocean—
the kinetic energy carried by ocean waves is transferred to the sand on the shore.

Interfaces that are not well defined--for example the interface between Earth's atmosphere and outer space-- are known as **diffused interfaces**.

A **dynamic or natural equilibrium** occurs when small changes in a system are naturally restored back to balance over time. (Flushing a toilet, for example).

Measuring the Earth

Scientists use **models** to represent the properties of an object or a system.

Ex: globe = physical model of the Earth
electric train = mechanical (moving), scaled model
graphs model mathematical relationships

Careful observations have helped us learn about Earth's true shape. These observations were made more accurate through technological advances.

EVIDENCE OF EARTH'S SHAPE

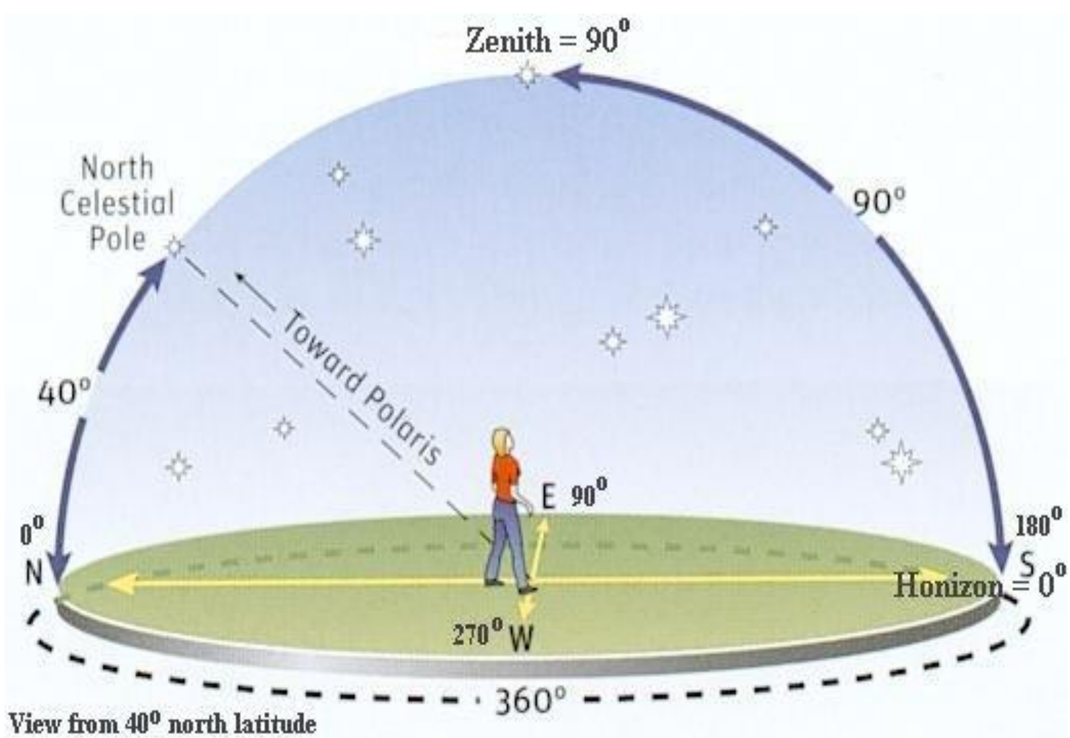
	FLAT AND ROUND	CURVED	SPHERICAL
EVIDENCE	**Shape of Earth's shadow during a lunar eclipse** **A single photo of Earth taken from space**	**Ships on the horizon: the top of the sail is seen before the bottom** **Sunlight fades last from the tops of trees**	**Polaris Rule*** **Several satellite photos from space** **Changes in gravitational pull (oblateness)**

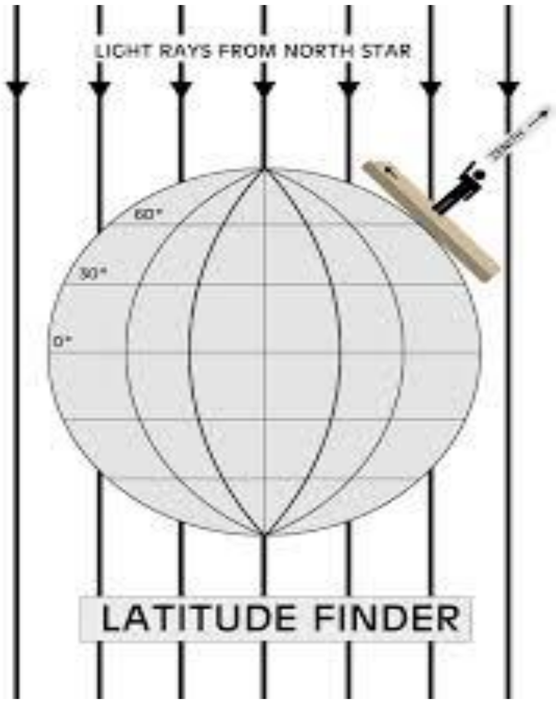
***The Polaris Rule** mathematically proves Earth's spherical shape.

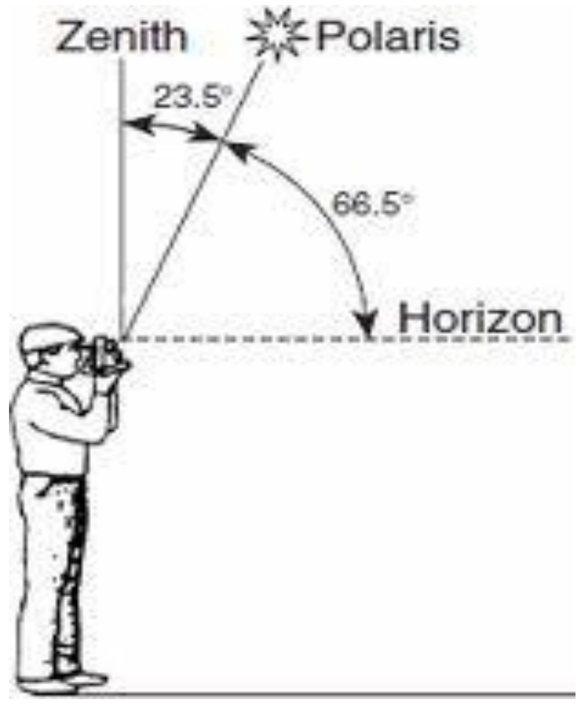
Polaris, the "North Star" is located above Earth's northern spin axis, the North Pole.

The Polaris rule states that in the northern hemisphere,
<u>the angular altitude of Polaris above the northern horizon is equal to the latitude of the observer.</u>

For every kilometer north of the Equator, the angular altitude of Polaris increases a specific number of degrees above the horizon.







What is the latitude of this observer?

Earth is not a perfect sphere.

Earth's shape is **a slightly oblate spheroid**, because its polar diameter measures slightly less than its equatorial diameter:

Polar diameter: 12, 714 km
Equatorial diameter: 12, 757 km

From space, however, Earth appears spherical.

Gravitational force is slightly stronger at the poles than at the Equator:

Polar circumference: 40,008 km
Equatorial circumference: 40,076 km

Eratosthenes, a scholar from ancient Greece, was the first to calculate the Earth's circumference.

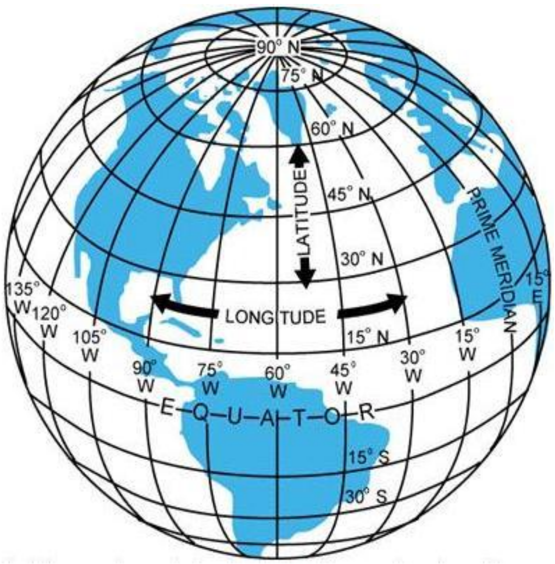
Earth's surface is classified into three parts:

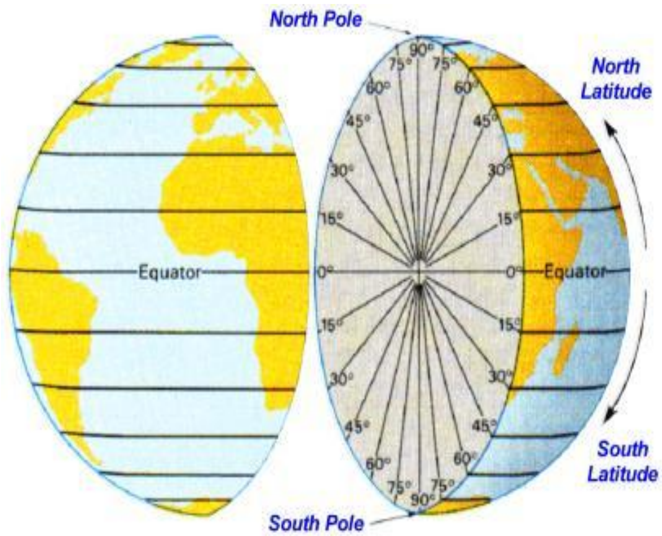
Lithosphere	Hydrosphere	Atmosphere
Earth's solid surface; extends under oceans, lakes, rivers, etc. Upper layer = crust (less dense than rest of lithosphere) 10km thick under oceans and more dense; 30 km thick under continents and less dense	**Liquid part;** lays on top of the lithosphere Includes streams, rivers, lakes, oceans and ice caps Makes up 70% of the Earth's surface, but shallow; 4 km on average	**Gaseous layer** that surrounds Earth 78% nitrogen, 21% oxygen— the rest is CO_2 , inert gases etc. Temperature changes create atmospheric zones: troposphere, stratosphere, mesosphere, thermosphere

<u>Earth's Coordinate System: latitude and longitude</u>

A coordinate system assigns 2 numbers to every point on a surface.
Latitude and longitude form a grid of circular lines that enable us to describe each point on Earth's surface.

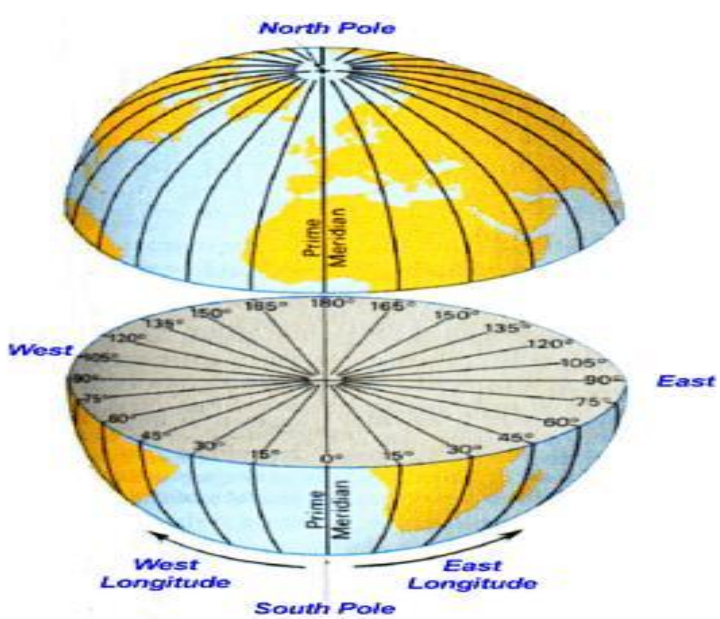
East-West lines are latitude lines. Latitude is measured as the angular distance north or south of the Equator (0**°**). **Latitudes range from 0° to 90° N, and 0° to 90°S.**





Longitude lines run north-south, and converge or meet at the poles. They are **not parallel to each other**, as latitude lines are.

Longitude is measured in degrees east or west of the Prime Meridian (0°). The Prime Meridian is a semicircle that connects the north and south poles, running through Greenwich, England**. Longitudes range from 0° to 180° east or west.**
0° = Prime Meridian; 180° = International Dateline
For example, a longitude reading might be 156° E, or it could be 70° W.



A degree of latitude or longitude can be divided into smaller units:

1° of latitude or longitude = 60′ (minutes)
1′ of latitude or longitude = 60″ (seconds)

Dividing degrees into minutes and seconds allows us to describe points on Earth's surface more precisely. **Remember: minutes and seconds of latitude and longitude describe space not time.**

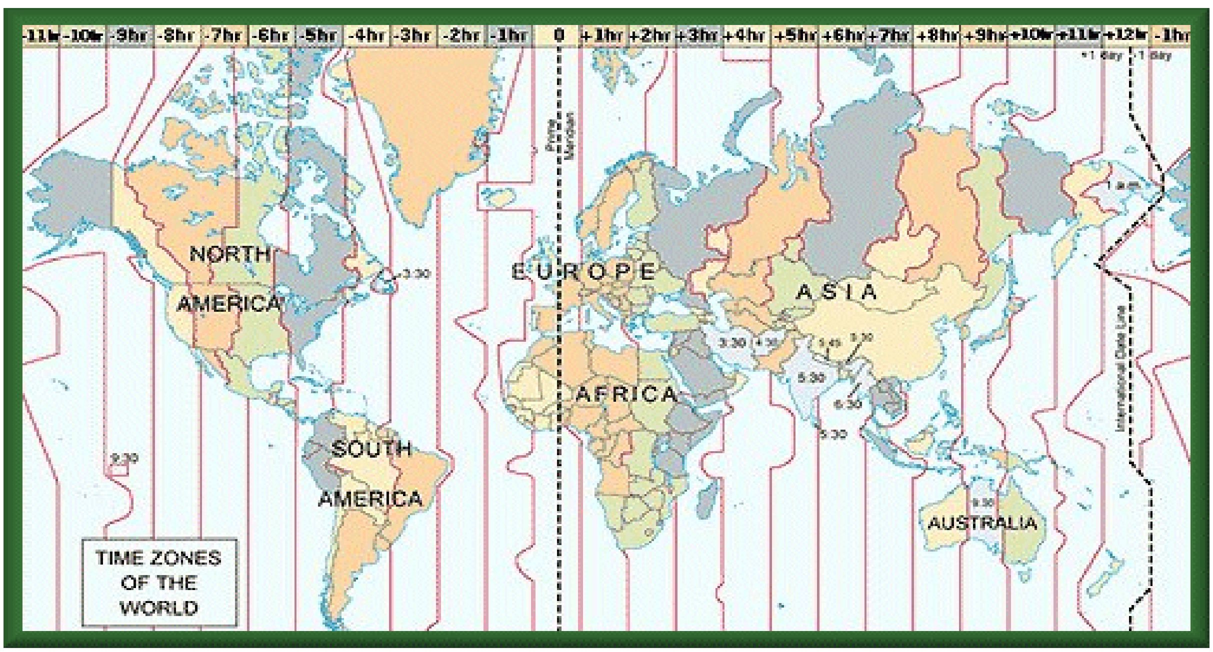
<u>TIME ZONES</u>

Time is based on Earth's rotational speed from west to east (counterclockwise viewed from the north pole).

Rotational speed = 360° in 24 hours, or 15° per hour.

Time is the same for all points lying on the Prime Meridian (PM). **Cities on the same <u>longitude</u> generally have the same time.**

For every 15° west of the PM, time is one hour earlier.
For every 15° east of the PM, time is one hour later.



Solar Noon is based on when the sun reaches its highest position in the sky.
Mean Solar Noon = 12 PM clock time.
Time zones were set so that Solar noon and Mean Solar noon are very close.

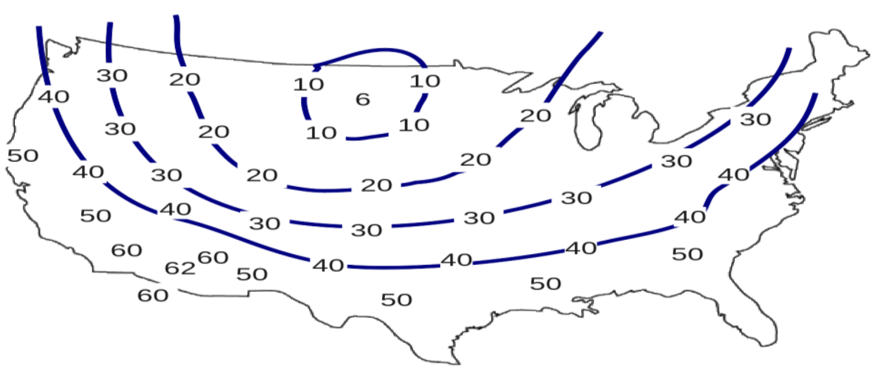
<u>FIELD</u>: a space in which some definite property can be measured at any given point.

Ex: the extent of the magnetic field around a magnet

> **scalar field**: described in terms of magnitude
> (temperature, atmospheric pressure, speed)
> **vector field**: described in terms of magnitude and direction
> (wind velocity—35 mph NE)

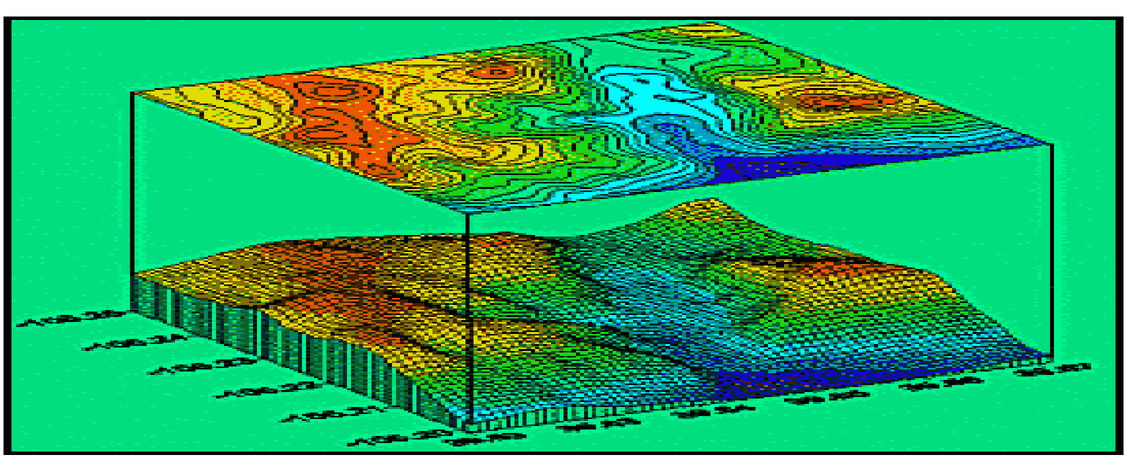
<u>Isolines</u> connect points of equal value on a field map, and thus are helpful when interpreting field data.

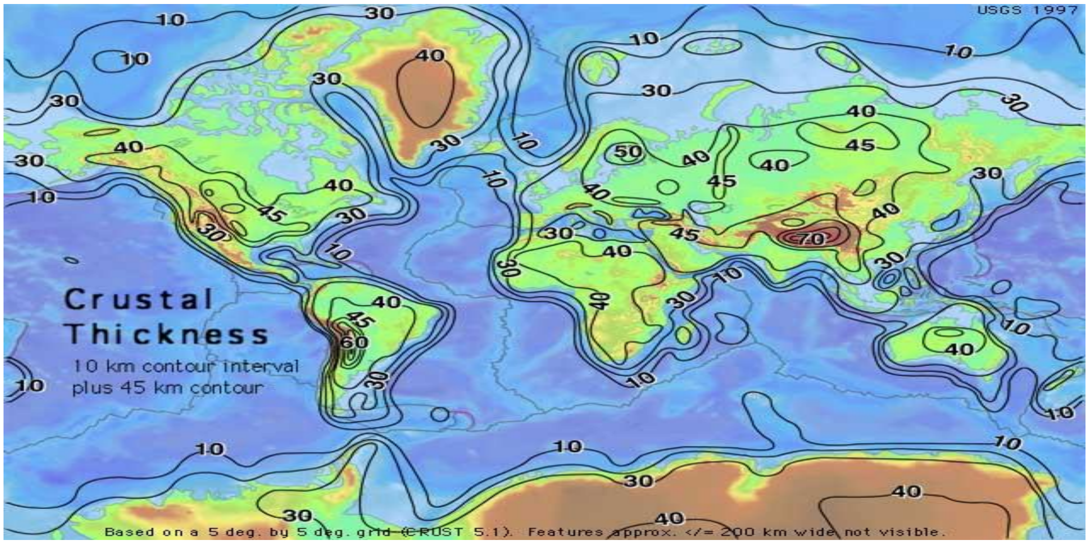
For example, the **isotherms** below connect points of equal temperatures:



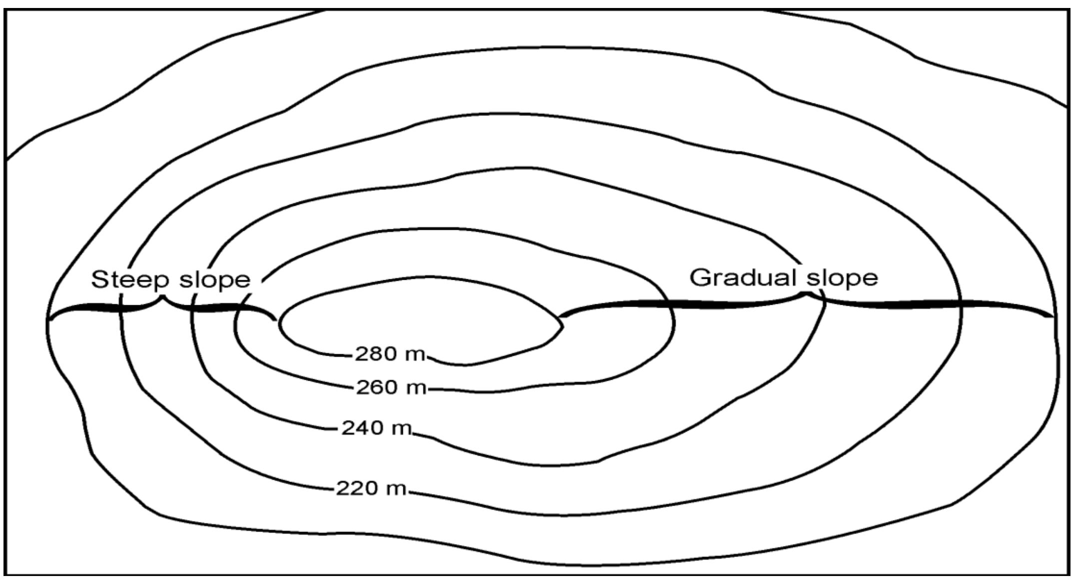
Isotherms connect points of equal temperatures.
Isobars connect points of equal atmospheric pressure.
Contour lines connect points of equal elevation.

Topographic maps or **contour maps** show the shape of Earth's surface.
Measured heights above sea level are indicated as numbers.
Contour lines are then drawn to connect points of equal height or elevation.

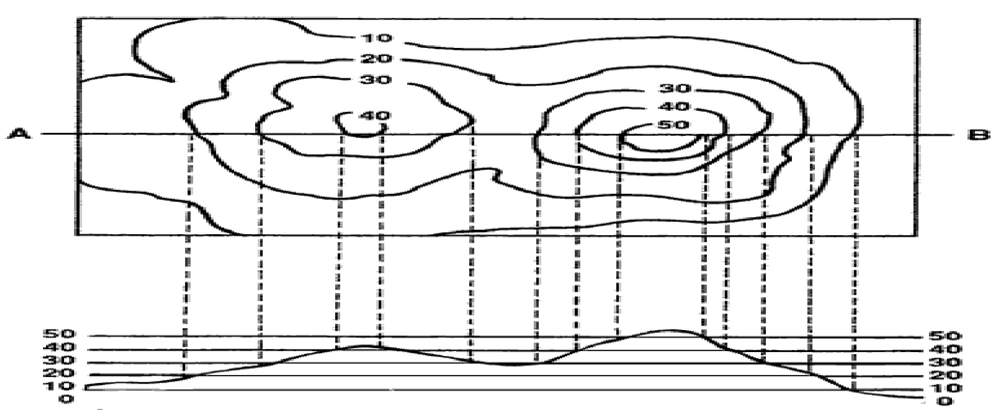




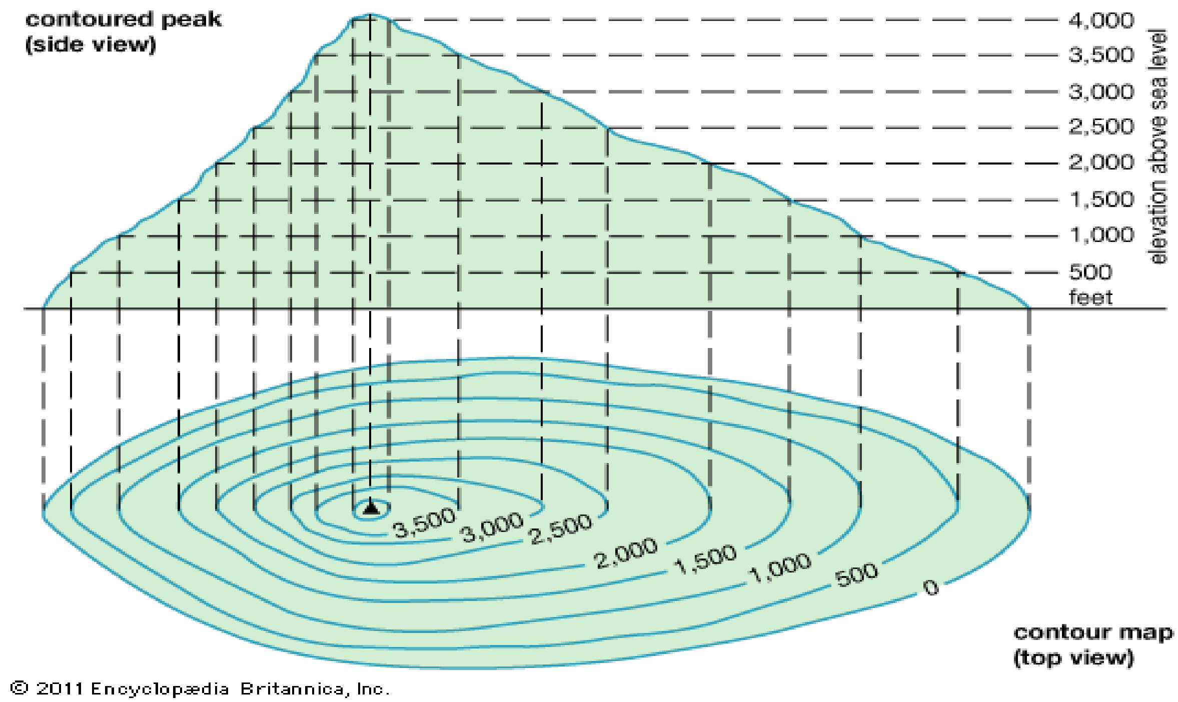
The **contour interval is** the term given to the uniform elevation that separates one contour line from the next. It is the difference in height between two adjacent contours.
What is the contour interval in the contour map below?



Hills, valleys, depressions and cliffs can all be indicated by contour lines on topographic maps. **Contour lines that are close together indicate a steep slope; those that are farther apart indicate a gentler slope.**



Profiles drawn from contour maps show differences in slope or gradient:



Gradient = the rate of change within a field or on contour maps:
High gradient = steep slope; **low gradient** = gentle slope

Formula:

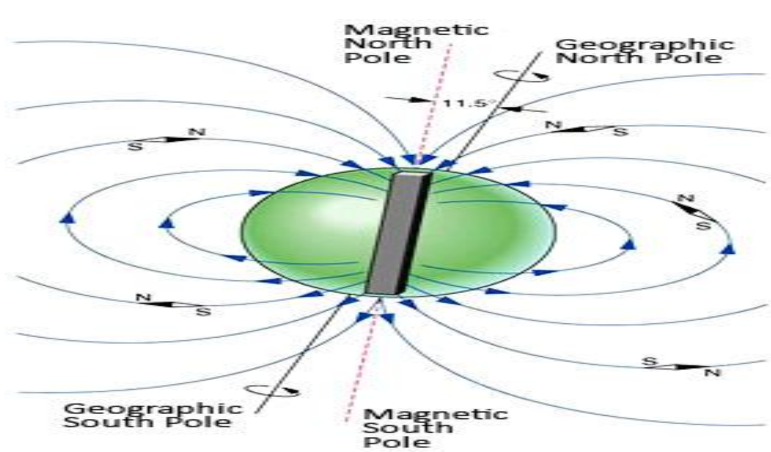
$$\textbf{Gradient} = \frac{\textbf{change in field value}}{\textbf{Distance}}$$

Ex: A mountain trail climbs from an elevation of 480 meters to 980 meters over 4 kilometers. What is the gradient of this slope?

$$\text{Gradient} = \frac{980\text{m} - 480\text{m}}{4\text{ km}} = \frac{500\text{m}}{4\text{ km}} = \mathbf{125\ m/km}$$

EARTH'S MAGNETIC FIELD

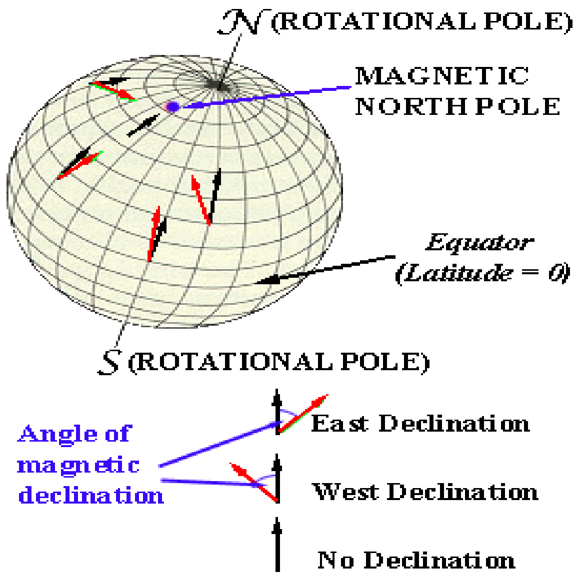
There is a magnetic field around Earth that acts like a giant bar magnet.

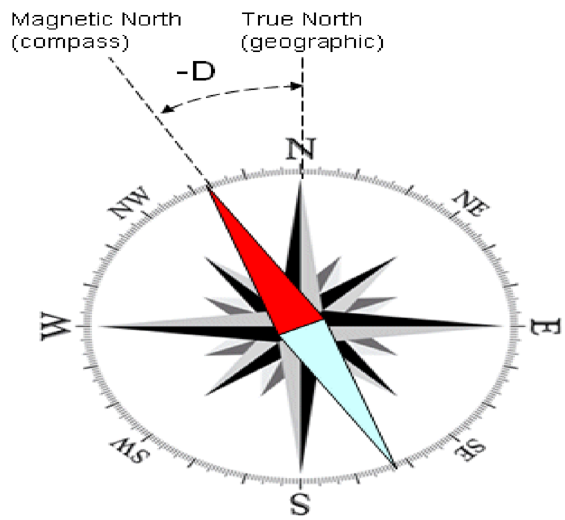


Earth's magnetic north pole is about 12° away from Earth's axis of rotation (spin axis), on which true north or geographic north is located.

Thus, Earth's magnetic north pole, where compasses point to, is not in the same place as Earth's true geographic north pole.

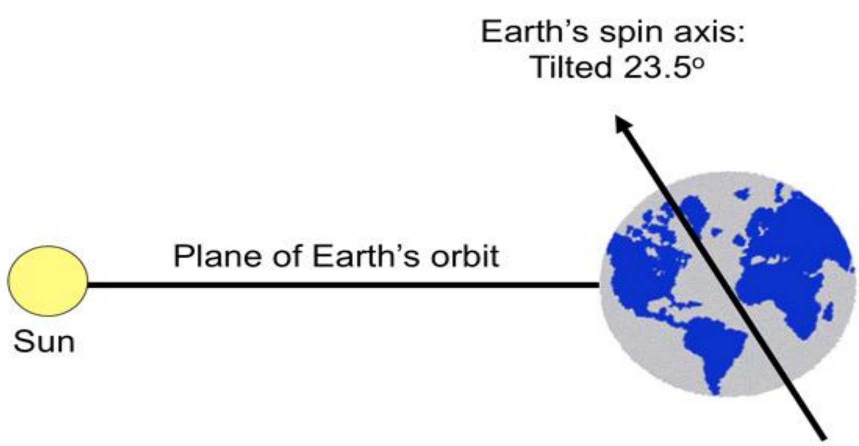
The difference between magnetic north and geographic north is called **magnetic declination**. It is measured in degrees, and varies from year to year.



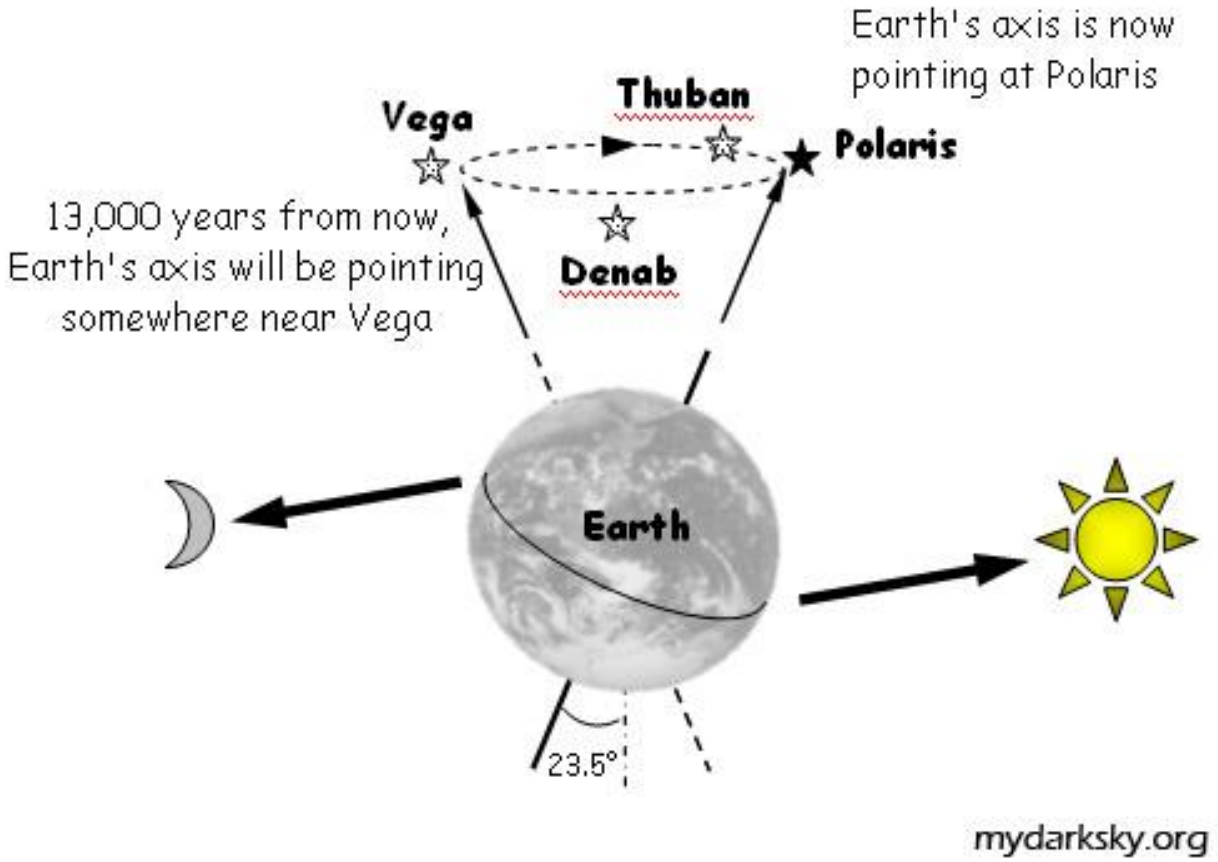


EARTH'S PRECESSION

Earth's spin axis (geographic north-south axis) maintains the same angle of tilt (23.5°) with respect to Earth's orbital plane:



However, the direction toward which the spin axis points changes. The Earth's spin is similar to a spinning top that wobbles from side to side. This wobbling is called **precession.**



In 13,000 years, Earth's north pole will no longer point to Polaris.

It will point to Vega, which will remain the north pole star for a few thousand years.

Earth's period of precession = 26,000 years.
Around AD 28,000, Earth's north pole will again point to Polaris.