Historical knowledge regarding the Earth: 5/4/03

The Hellenic Period.

1. Aristotle (384-322 B.C.) reasoned that Earth blocks Sun's light so that the Moon appears crescent in shape, and deduced that the Earth is spherical in shape. He postulated that the Sun and other heavenly bodies revolved around the Earth with uniform speed.

The Greeks determined that no matter the size of a circle, the ratio of its circumference to its diameter is constant, 3.1414, which they called pi (π). They also knew the mathematical relationships between diameter (D) and radius (R), circumference ($C= 2 \pi R$), area ($A= \pi R^2$), and volume [$V = (4/3)\pi R^3$] of a circle. They understood the 3,4, 5 method of finding the right angle of a triangle, or what is commonly called the Pythagorean theorem of $3^2 +4^2 = 5^2$, i.e., the sum of the squares of the smaller sides of a triangle is equal to the sum of the larger side (the hypotenuse). They also knew that alternate angles between parallel lines are equal.

2. Phytheas (325 BC) reasoned that a line extending from the center of the Earth to the North Star (Polaris) is parallel to another that is extended from the surface of the Earth to the same far away star. By measuring the angle between a line of sight from a place to the North Star and the horizon at that place, Pytheas reasoned that alternate-angle relationships show that the measured angle is equal to the latitude, or the angular distance from the Equator to the place. The Greeks knew that angular measure of a circular Earth is 360°, and the angular distance from the Equator to the North Pole is 90°. Pytheas determined **latitude** by using the angle of the North Star above the horizon. After developing this method, he knew how far north or south he was from a given position and also how to navigate along the same latitude. He was **able to navigate from Greece to England and Norway and back to Greece.** He also knew that the moon caused tides.

3. Eratosthenes (276-192 BC) calculated the **circumference of the Earth** from measurements of the shadow of a stick he placed at Alexandria and the fact that there will be no such shadow at Aswan (Syene), Egypt, during the summer solstice. The angle between the vertical stick and the Sun's ray at Alexandria is 7.2°. He reasoned that the extension of the Sun's rays through Aswan, and the vertical stick at Alexandria will intersect at the center of the Earth, and by alternate- angle relationships, the angle of intersection is 7.2°. Since he knew the distance between Aswan and Alexandra, and 7.2° is the angle it subtended, he calculated what 360° would subtend and arrived at an estimate of the **circumference** of the Earth. His value is very close to the modern value of the circumference of the Earth being about **40,000 kilometers**. This value allows calculating radius of the **Earth, which is about 6400 km**. As described below, kilometer as a measure of distance was determined in the 18th century, during the French Revolution. Since the angular distance between the Equator and the North Pole is 90°, and the distance on the surface 10,000 km. It follows that **1° latitude is equivalent to111.1 km**. Thus, latitude and horizontal surface distances north or south of the Equator are well known.

The 4 seasons: Ancients knew how to explain the four seasons of the planet. They considered the Earth as the center of the universe, with the sky revolving around the Earth. The sky is spherical, which has a North Pole and equator, the **celestial equator**. On this sky, the apparent revolution of the Sun around the Earth would trace another circle, called the **ecliptic**. The two circles, the celestial equator and the ecliptic intersect at two places during March 21 and September 21, where night and day have equal hours, **equinoxes**. The acute angle of intersection between the two circles is 23.5°, indicating that the pole to the ecliptic is inclined by 23.5° with respect to the celestial north pole. From March 22 through June 21 to September 20, the days have longer hours than the nights in the Northern Hemisphere. From September 22 through December 21 to March 20 the nights have longer hours than the days in the Northern Hemisphere. When the position of the sun lies in the ecliptic above the celestial equator, it is summer in the Northern Hemisphere. The sun will be directly above 23.5° North latitude on June 21 (**the summer solstice**). When the Sun lies on the ecliptic below the celestial equator, it is winter in the Northern Hemisphere. On December 21, the Sun will be directly on top of 23.5° South latitude (**the winter solstice**). **The fall season begins on September 21, when the Sun crosses the equinox and ends on December 20, winter is from December 21 through March 20, Spring is from March 21 through June 20, and Summer is from June 21**.

The rainy season, "kirmet" in Ethiopia is in June, July, and August, the summer season. The rain comes from seasonal sea breeze, called the Monsoon. Drought occurs when the summer Monsoon fails to yield rain. Why the monsoons fail to give rain and that they fail to do so every so often is well known, and is a subject of climate study. Why there is famine is however in the realm of poor administration and is a political problem.

The Middle Eastern religions and the "Dark ages".

The three religions of Judaism, Christianity, and Islam provided explanations for everything, so that man did not see the need for discoveries for quite a number of centuries. Many intelligent people got immersed in religious affairs. Christians fought against Moslems and vice versa, and all fought against Jews. People of similar faith also quarreled among each other. For example, Christians disagreed among each other over interpretations of the same Bible, and the politically powerful among them excommunicated, condemned, banished, or otherwise burnt alive or stoned to death the politically weaker ones. At the end of it all, they provided a distillation of human thought, and guided human spiritual needs.

The dawn of the age of reason.

4. Nicholas Copernicus (1473-1543) in the 16th century challenged the Aristotelian view of the universe. Instead of the Earth revolving around the Sun, he proposed that the **Earth revolved around the Sun**.

5. Galilee Galileo (1564-1642) showed that Copernicus was right, and saw that four moons revolved around Jupiter, further indicating that the Earth is not the center of the universe.

6. Johannes Kepler (1571-1630) proposed that:

1st. Planets travel in **elliptical orbits** about the Sun. This is different from the circular orbits proposed by Aristotle, Copernicus and Galeleo. However, unlike Aristotle, Copernicus and Galileo placed the Sun as the center of the Solar System.

2nd. In equal intervals of time, a line from the planet to the Sun sweeps out equal areas. This implies that the speed of the planet is not constant, contradicting Aristotle's uniform speed idea.

3rd. For any planet, the square of its time of revolution (its period) around the sun, divided by the cube of its mean distance (radius) from the sun, is the same as for any other planet.

The Enlightenment Period

7. Isaac Newton (1642-1727) was born the year Galileo died. Newton's contributions are many and include the following three famous laws of mechanics.

1) A body at rest would stay in that state unless a force acts upon it.
2) A moving body will maintain a constant motion unless some force acts upon it.
3) To every action there is an equal and opposite reaction.

Newton also showed that all materials attract each other toward themselves, by a force called the gravitational attraction. He developed the **inverse square law** to determine the force of attraction. If the distance between the bodies is halved, the attraction between them is quadrupled. If the distance between the bodies is doubled, then the attractive force is reduced by a quarter. In short, the law indicates that the attractive force between two bodies is inversely proportional to the square of the distance, which separates them.

$$\mathbf{F = G ((M*m)/R^2)}$$

Newton showed that there is a proportionality constant for the relationship between the period of revolution of planets and the mean radius of their elliptical orbits, which Kepler determined. From Newton's form of Kepler's equation we are able to determine the masses of heavenly bodies including that of the Earth. Actually, Newton's gravitational law ($g = GM/R^2$ may be used to determine **the mass of the Earth, which is $5.98 * 10^{24}$ Kg**. Dividing the mass by the volume gives the **density of the Earth to be 5.5 gm/cm^3**. Surface rocks have densities of 2.67 gm/cm^3, whilst astronomical calculation of density of the Earth gives 5.5 gm/cm^3. Obviously, the greater mass of the Earth is found at its center, and by comparison to different materials, it is estimated to be iron.

8. James Hutton (1726-1797), born a year before the death of Newton, is known for his observations and powerful deductions that changed our view of the Earth and Earth

processes. He proposed the **Uniformitarianism** principle, which states that present day processes also operated in the past, so that natural phenomena may be explained by observing existent present day processes. He debunked the basis of catastrophism that relied on extraterrestrial explanations for natural Earth phenomena. He enabled humans to dare and examine evidence though globally viewed the data may be incomplete or may contain missing records. He expanded human thought to look beyond interpretations of biblical scholars regarding the age of the Earth, and to think of vast time. As he put it, "In the economy of the Earth, I see no vestiges of a beginning, no prospect of an end." Yet, he was a religious Christian. He is known as the father of modern Geology.

10. After the French Revolution, a committee, which included **Lavoisier, Laplace, and Lagrange** was assigned to revise weights and measures, and they returned with the metric system, which was officially adopted on November 25, 1792. The **meter** was defined as 1 per ten millionth of the distance from the Equator to the North Pole. Lavoisier, who taught us that the atmosphere has oxygen, was also a very rich tax collector, and for the latter the revolutionary people executed him. The French provided the metric system, which contains measures of weight, and length that are divisible by ten or raised to a power of ten.

11. Charles Darwin (1809-1882), a profound observer of natural processes is credited for underscoring the **principle of evolution** more than any other person before or since his time. Put simply, he showed that **all species originated from one initial organism by means of natural selection**. Obviously, the laws of natural selection also governed the evolution man, at least the physical aspect. The spiritual aspect of man is a property dictated by religious edicts. Organisms are not mere tenants of the Earth. They are of the Earth, and they contribute to the management of the surface environment, by changing the climate for example.

12. Albert Einstein (1879-1955) showed that time is relative and it depends on the reference frame at which it is measured. He showed time to be one dimension of a four dimensional spacetime thereby revolutionizing an understanding of cosmology. His famous equation, $\mathbf{E = mc^2}$**,** showed how mass and energy are interchangeable. Fusion of hydrogen within stars generate heat and light by converting mass to energy, similar to but more powerfully than does the fusion process to make hydrogen bombs. For example, inside the Sun, when hydrogen fuses to form helium, the mass of helium is smaller than the sum of the hydrogen ions. The difference in mass during fusion is converted to energy as per Einstein's famous equation. The Sun's light and heat greatly affect the climate of the Earth. Fusion and fission both of which involve converting mass into energy are important in cosmology. Einstein had proposed his "cosmological constant", which he used in his equations in order to explain his view of a non-expanding universe. Since Hubble gazed at the galaxies and found them to be going away from us, it has believed that the universe is expanding, and the universe probably resulted from an explosion (Big Bang) from a tiny spot, about 13 billion years ago. This span of time can be contemplated because of crucial work of preceding scientists, such as James Hutton.

If Hutton shattered the time barrier imposed by Usher's 4004 BC origin of the Earth, Einstein shattered the notion of uniform time, that Newton assumed it to be so.

13. **Milankovitch** (1930), a Yugoslavian mathematical physicist pointed out that **the ice ages** on Earth would likely occur when the maxima of the obliquity, the precession and eccentricity of the Earth's orbital parameters coincide.

a) The **Earth's shape is a spheroid of revolution** (oblate spheroid) with a larger girdle (radius being 21 km longer) at its Equator than at the poles.

b) As a consequence of having been whacked by a large meteorite early in its history, the Earth has a spin axis that is currently tilted at 23.5° to the vertical.

c) The Earth rotates faster than the moon revolves around the Earth. **The Moon's (and the Sun's) gravitational pull on the Earth's equatorial bulge** reduces the speed of the rotation of the Earth, and causes the Earth's spin-axis (and the equinox) to precess westward in relation to the celestial north pole.

*** The precession period is 26,000 years**.

900 million years ago the year was 481 days long of 18-hour days.

d) As the Moon (and the Sun) move above and below the equatorial plane of the Earth, the Earth's spin-axis wobbles, and the declination (obliquity) changes from 22° to 25° over a period of 41,000 years.

*** The obliquity period is 41,000 years.**

e) The Earth revolves around the Sun in an **elliptical orbit**. As explained from Kepler's laws, the speed with which the Earth orbits the Sun is not constant. Earth revolves faster when it is close to the Sun (perihelion) and slower farther away. Yet, the shape of the orbital path (eccentricity) changes from being circular to slightly being flattened due to a tag between the gravitational pull by Sun on one side and by Jupiter on the other. Eccentricity is a measure of the flatness of the Earth's orbit.

***The period for the eccentricity is 100.000 and 400,000 years.**

According to Milankovitch, ice ages develop at about N 65° latitude and expand when (1) the eccentricity is the maximum so that the Earth spends more time in the aphelion, the obliquity (wobble) is the maximum so that incident light is the minimum, and when the precession changes the months and places July in the perihelion, which brings severe change in seasons. Milankovitch calculated that these coincidences occur every 100,000 year.

We know believe a Mars-size meteorite whacked the Earth, about 4.5 billion years ago, the impact of which resulted in tearing up the Earth out of which the Moon accreted.

Concluding remarks. The laws of physics and chemistry, and the principles of uniformitarianism and evolution guide hard core scientists in the attempt to understand the physical world and how to use it for human advantage. Spiritual knowledge is of a different kind, and quite necessary for humans since we are not robots. Both the physical and spiritual knowledge continue to be refined.

Return to home page.