

TU 130

Integrated Sciences and Technology

by

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TU 130: Integrated Science and Technology

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- Try to imagine a world without science and technology.
- Would you want to live in the world without science and technology?
- For most of us the answer would certainly be **no**, for science and technology affect every aspect of our lives.

- Animals rely on adaptations for their survival, humans rely on science and technology for our survival.
- The link between human beings and technology is inseparable, because technology is an important extension of the human minds that allows us to do things and live like no other organism on the Earth.

- Equally important to humans is our search for knowledge and understanding of the world in which we live. This forms the base of what we call "science".
- Science: systemized knowledge derived from observation, study and experimentation carried on in order to determine the nature or principles of what is being studied.

- Technology: the science or study of the practical or industrial arts, applied science etc.
- Human possesses the ability to extend their own capabilities by using tools.

- The appearance of a new type of primate occurred on the African continent approximately 4 million years ago.
- Primate: any of an order (Primates) of mammals characterized especially by flexible hands and feet, each with five digits, including humans, great apes, monkeys and lemurs.

- This new species belonged to a family of what anthropologists called the hominid.
- Hominid: any of a family (Hominidae) of two-legged primates including all forms of humans, extinct and living.

- Although this creature would hardly have looked like a modern-day human being, it possessed two very unique adaptations. The first was the ability to walk upright on two legs. The second was the ability to make stone tools.

- These ancestors of modern humans are called Homo Habilis (“clever human”) by anthropologists and are the first known hominid to create customized tools.
- Modern humans are called Homo Sapiens (“Intelligent human”).

- The oldest tools discovered so far are approximately 2 million years old. These consist of crude stone implements called choppers.

“Stone Age Technology”

- The stone age is divided into 2 periods; the first is called the Paleolithic (“old stone”) period, the second is called Neolithic (“new stone”).

- During the Paleolithic period, hominids used crude stones mainly for chopping and for breaking open animal bones to expose the nutritious marrow.
- During the Neolithic period, our ancestors began to manipulate stones to form customized sharp cutting tools for use in farming the land.

“Agricultural Revolution”

- The appearance of modern humans approximately 100,000 years ago led to major advancements in technology.
- Modern humans began to craft very specialized tools in the form of spears and knives.

- About 35,000 years ago, people began creating pieces of art and primitive musical instruments.
- After fire and the wheel, one of the greatest advancements in human technology was human domestication of plants and animals. This is called the Agricultural Revolution, which began ~10,000 years ago in southwest Asia.

- During the Agricultural Revolution, humans created many customized tools made from stone, wood and animal bones for the purpose of growing and harvesting food crops.

“Bronze Age and Iron Age”

- The use of naturally occurring metal ore deposits such as copper and tin to create new, stronger tools.
- This began more than 5,000 years ago and marked the beginning of the Bronze age.

- Bronze is an alloy, or mixture, of copper and tin.
- Eventually humans found that iron was better than bronze for making tools.
- Iron was much stronger than bronze and quickly improved human tool-making abilities.

- This led to what is called the Iron Age.

“Industrial Revolution”

- Human being began to build cities, conquer the oceans and construct complicated machinery.
- The culmination of human ingenuity began a new era called the Industrial Revolution, which started in the late 1800's.

“Technology Timeline”

- Paleolithic Period:
 - First use of stone tools by *Homo Habilis* (~2.5 million years ago)
 - Emergence of modern humans (*Homo Sapiens* ~100,000 years ago).

- Neolithic Period:
 - Use of stone, wood and animal bone tools.
 - Emergence of art and musical instruments (~ 35,000 years ago).
 - Beginning of Agricultural Revolution (~10,000 years ago).

- First known use of wooden plow in south-west Asia (~7,000 years ago).
- First known use of the wheel (~5,500 years ago).

- Bronze Age:
 - Emergence of copper and bronze in tool making (~5,000 years ago).
 - Beginning of textile production in Mesopotamia (~5,000 years ago).

- Iron Age:
 - Smelting of iron in Africa (~3,000 years ago).
 - Use of iron in Europe and China (~2,000 years ago).
 - Construction of the Roman aqueducts (~300 B.C.)

- Industrial Age:

- Invention of steam engine (1720 A.D.)

- Invention of the steamboat (1807 A.D.)

- First airplane flight (1903 A.D.)

- First moon landing (1969 A.D.)

- Information Age:

“The Birth of Science”

- It is difficult to determine when humans actually began to practice science, it can be assumed from our ancient beginnings that we have always wondered at how our world works.

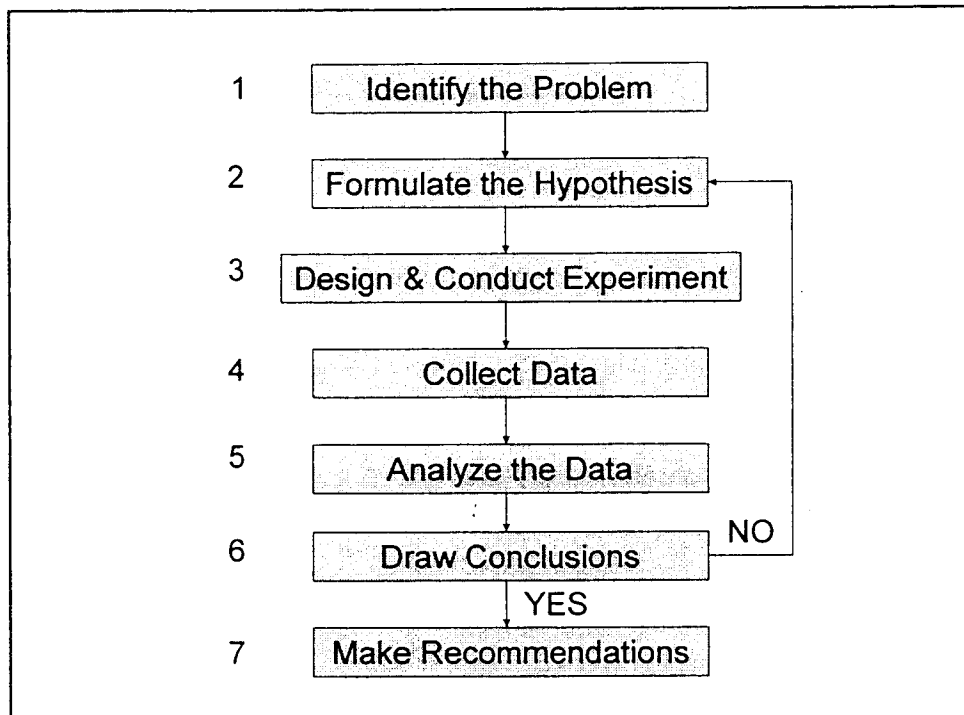
- The birth of formal science most likely had its roots in the study of celestial objects.
- Careful observation and measurement of astronomical phenomena lead to the birth of astronomy and to the birth of modern science.

- Many of the world's most well known scientists were and are astronomers.
- Aristotle, Newton, Kepler, Galileo, Copernicus, Einstein, Hubble, Hawking and Sagan are all famous astronomers who helped to revolutionize science.

- Today science continues to improve our world and increase our understanding of how it works. To do this, scientists use a formal method of inquiry to attempt to unlock the secrets of nature; this is called the scientific method.

“The Scientific Method”

- The scientific method of inquiry is based on three main concepts:
 - Observation
 - Experimentation
 - The development of theories or natural laws.



- Hypothesis: an unproved theory tentatively accepted to explain certain facts.
- Theory: a formulation of apparent relationships or underlying principles of certain observed phenomena which has been verified to some degree.

- Law: a sequence of events in nature or in human activities that has been observed to occur with unvarying uniformity under the conditions(Law of nature).
- One of the most important aspects of the scientific method is experimentation.

- An experiment allows scientists to prove or disprove a hypothesis.
- Conducting experiments follows an organized patterns, which include stating the purpose of the experiment, creating a hypothesis, writing out step-by-step procedures, collecting and analyzing data, and formulating a conclusion.

- Carefully conducting an experiment in an organized way ensures that scientific discovery can be well documented and recreated.
- The general goal of science has been to try to understand how the natural world works.

- The goal of technology is to take the knowledge gained by scientific inquiry and apply it in a practical way.

- Today many of the technologies that our society uses are the direct result of scientific inquiry and research. These include technologies like the airplane, the telephone, radio, computers, satellites, the light bulb, lasers and countless more inventions.

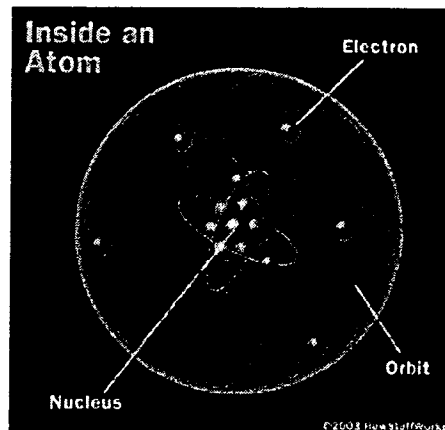
- The role of science and technology will play an important role in the future of the human race.

“Matter and Energy”

- All substances that exist on the Earth consist of matter.
- Matter is made up of fundamental particles called atom (ατομωσ)

- Atoms are extremely small particles that possess unique physical and chemical properties.
- All atoms are composed of three subatomic particles: protons, electrons, and neutrons.

- Protons and neutrons form an atom's nucleus, around which revolves electrons.
- The Bohr model has become the most popular model of the atom; however, today it is believed the atomic nucleus is surrounded by an electron "cloud", which is composed of electrons possessing different energy levels.



- A model of an atom which shows the nucleus surrounded by an electron cloud.

- Protons are a subatomic particle that have a positive electric charge, whereas the electron possesses a negative charge, the neutron has no charge.

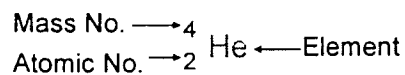
- Recent research has demonstrated that these subatomic particles are made up of even smaller basic particles called quarks, which form protons and neutrons when combined.

- Together the mass of the particular number of protons and neutrons in an atom's nucleus creates its atomic mass.
- The atomic number of an atom helps to classify the different atoms that exist, which are also known as elements.

- There are 109 different atoms or elements that have been identified based on their atomic numbers.
- The 109 elements are arranged in an organized chart called the periodic table of elements.

- Among these 109 elements: 90 elements exist by nature, the rests are synthetic elements.
- The number of protons in a nucleus called the atomic number.
- The total number of protons and neutrons in a nucleus is called the mass number.

- Scientific symbol



He = Helium

H = Hydrogen

O = Oxygen

Pb = Lead

- Atoms of the same element may differ in the number of neutrons in the nucleus called isotopes.
- ${}^4\text{He}_2$ and ${}^3\text{He}_2$ are isotopes also called helium-4 and helium-3.

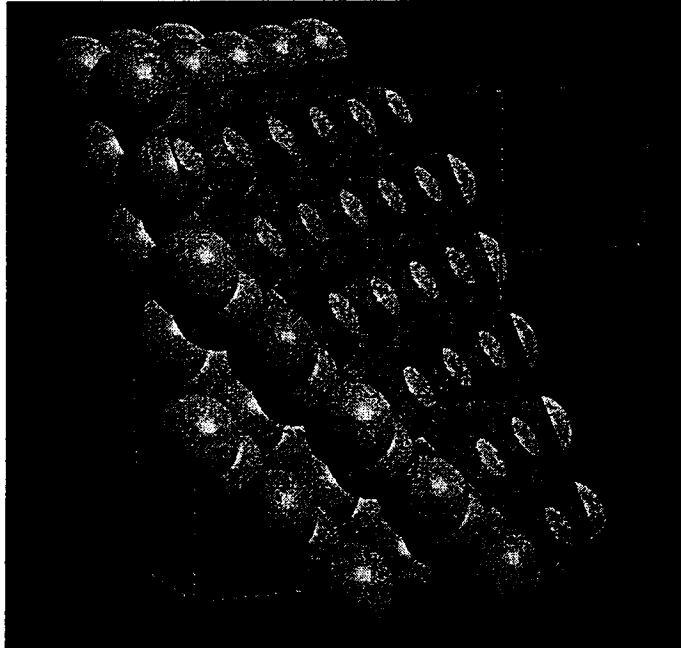
- | Element | Mass no. | Relative Abundance(%) |
|------------|----------|-----------------------|
| U(Uranium) | 234 | 0.0057 |
| | 235 | 0.72 |
| | 238 | 99.27 |
| Pb(Lead) | 204 | 1.48 |
| | 206 | 23.6 |
| | 207 | 22.6 |
| | 208 | 52.3 |

- Isotopes usually have the same chemical properties.

“States of Matter”

- All matter in the universe exists in 4 distinct states that possess unique physical properties.
- The 4 states of matter: solids, liquids, gasses and plasma.

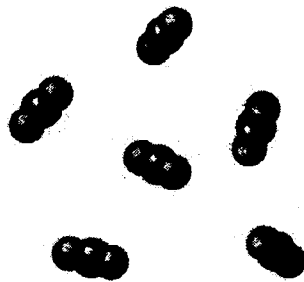
- The solid form of matter is the state in which atoms most tightly packed together and are most restricted in their movement.
- Many solids are composed of atoms organized into a crystal pattern, which is an orderly, recurring arrangement of atoms.



- Atoms in a solid state possess the least amount of atomic movement and tend to have a definite shape.
- The next state of matter is liquid.
- Liquids are composed of atoms that are more loosely arranged.

- The atoms in a liquid have more freedom of movement, which gives liquid a more fluid property that has no definite shape.
- The third state of matter is gaseous state.

- The gaseous state of matter provides atoms with the highest degree of movement.



- The fourth state of matter is called plasma, which is not as common as the other three.
- Plasma forms when the atoms that compose a gas become exposed to such high energy that they begin to ionize, or lose their electrons.

- Plasma got its name from a Greek word $\square\pi\lambda\alpha\sigma\mu\alpha\square$ which means “moldable substance”, or “jelly”.
- Stars are composed of plasma.

- The relationship between matter and energy in the universe is the fundamental cause for the existence of the living and non-living world.
- Albert Einstein revealed that energy and mass have a mutual relationship.

$$E = mc^2$$

E = energy

m = mass

c = speed of light in vacuum = 2.998×10^8 m/s

- Energy is defined as the ability to do work or cause change.
- Matter that is exposed to energy is said to be in motion.
- Energy is classified in two basic forms: kinetic energy and potential energy.

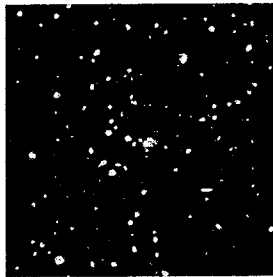
- Kinetic energy is the energy of motion.
- The movement of the Earth around the Sun is kinetic energy.
- Potential energy is stored energy.

- The gasoline in the tank of your car is a type of potential energy.
- The Law of the Conservation of Energy.

“Human and the Universe”

- What is universe?
- Let imagine that we are now the space travelers.
- The first thing to see is galaxy.

- The universe is composed of enormous number of galaxies.



- On the average, a galaxy is composed of 100,000 million stars (or 10^{11} stars).

- The distance between galaxies is about 150,000 light years (ly).



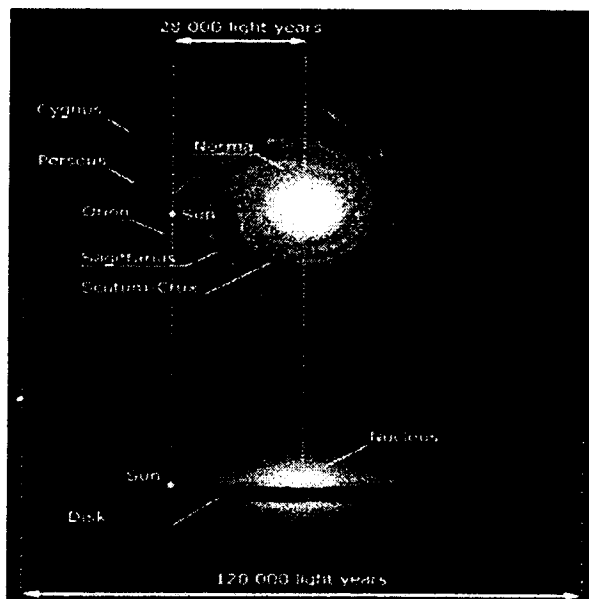
- Light year is an astronomical unit for measuring distance between celestial objects.
- 1 light year is the distance that light can travel in one year.
- The speed of light in vacuum is 3×10^8 km/s.

- In one second, light can make a round-trip between BKK-Chiang Mai about 200 trips.
- $1 \text{ ly} = 9.5 \times 10^{15} \text{ m}$
- Astronomical Distance Units:
 $1 \text{ AU} = 150 \times 10^6 \text{ km}$
(AU = Astronomical Unit)
 $1 \text{ ly} = 9.5 \times 10^{12} \text{ km}$
 $1 \text{ parsec} = 3.26 \text{ ly} = 3.09 \times 10^{13} \text{ km}$

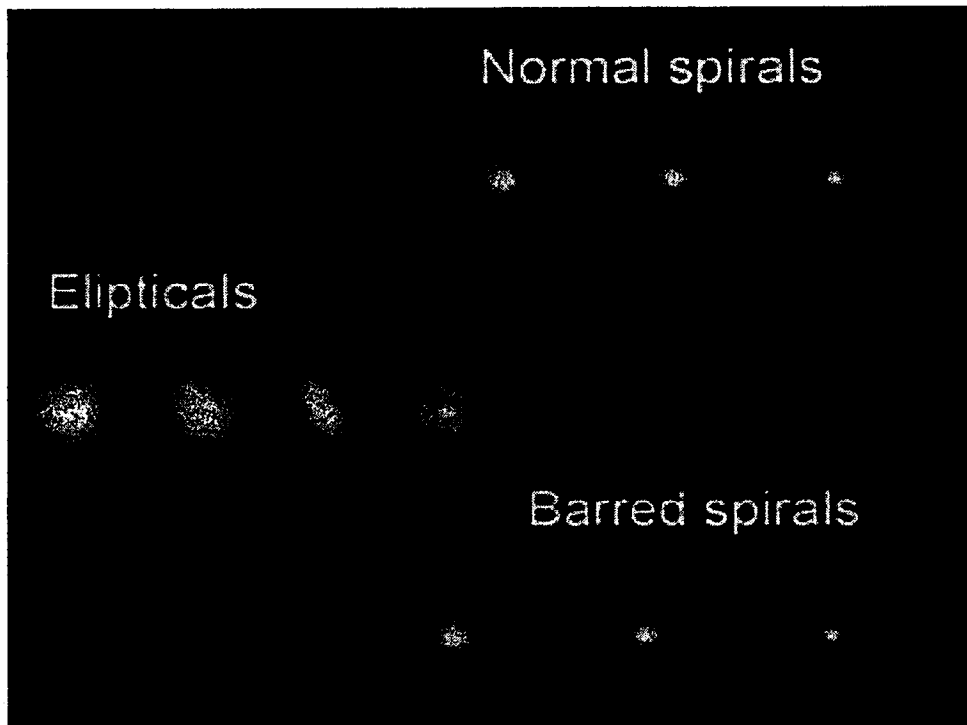
- The galaxy that our sun belongs to is called "the Milky Way".
- How does the Milky Way look like?
- From the radio signal (wavelength 21 cm), astronomer concluded that the Milky Way looks like a galaxy called the Andromeda galaxy.

- The Andromeda galaxy is about 2×10^6 ly away.
- We are looking at the past of the Andromeda two million years ago.

•Structure of the Milky Way



- Galaxy Classification
(by physical appearance)
 1. Elliptical galaxy
 2. Spiral galaxy can be divided into two subclasses:
 - 2.1 Normal Spiral
 - 2.2 Barred Spiral



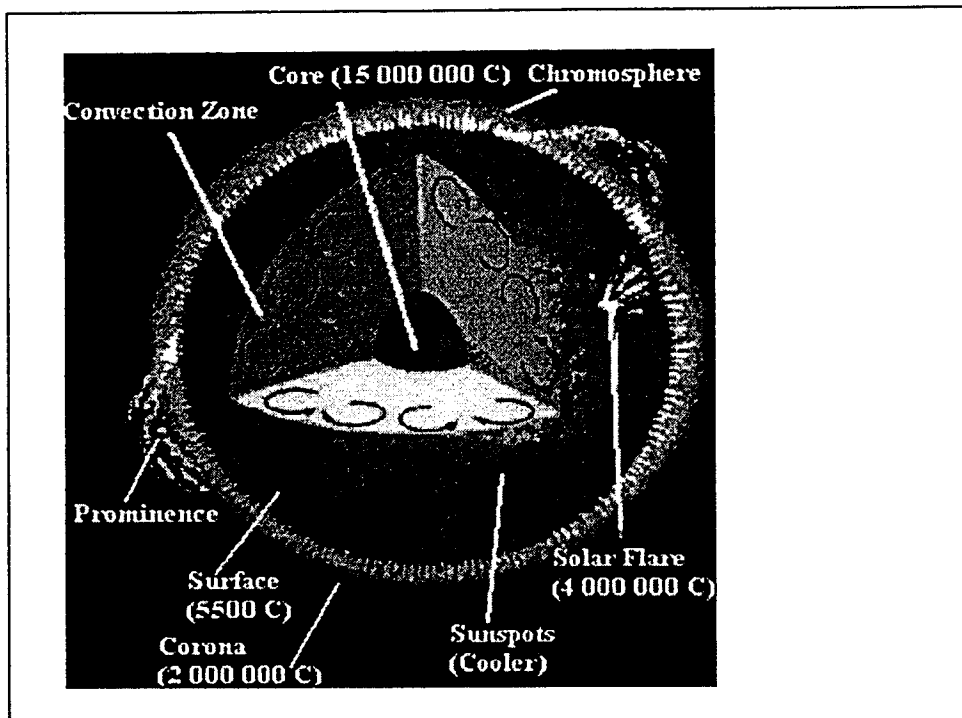
3. Irregular galaxy

e.g. Large Magellanic Cloud
(LMC)

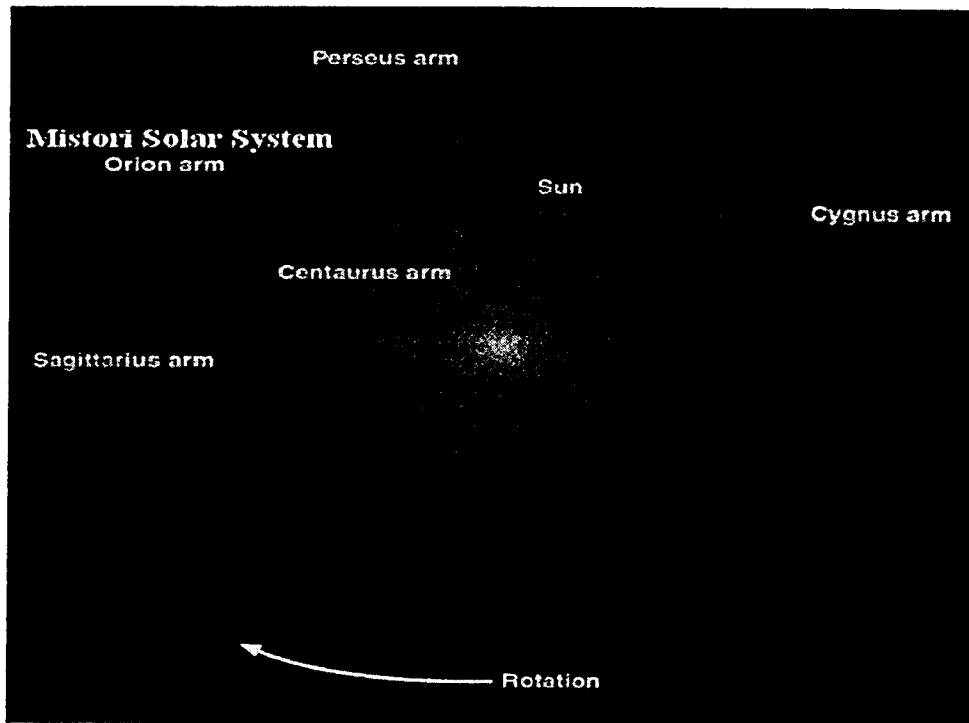


- Nucleus consists of millions of stars (old stars).
- Spiral arms consist of young stars, interstellar gases, molecular clouds, and space dust.
- Stars are huge hydrogen gas in plasma state hold together by gravitational force.

Formic acid



- The Milky Way consists of about 10^{11} stars.
- The Sun is one of the stars in the Milky Way.
- The Sun is the average star (Mass, luminosity, temperature)



- The nearest star to the Sun is Proxima Centauri (about 4 ly away).
- So we are looking at the past of Proxima Centauri (about 4 years ago).
- The average distance between the Earth and the Sun is about 1.5×10^8 km.

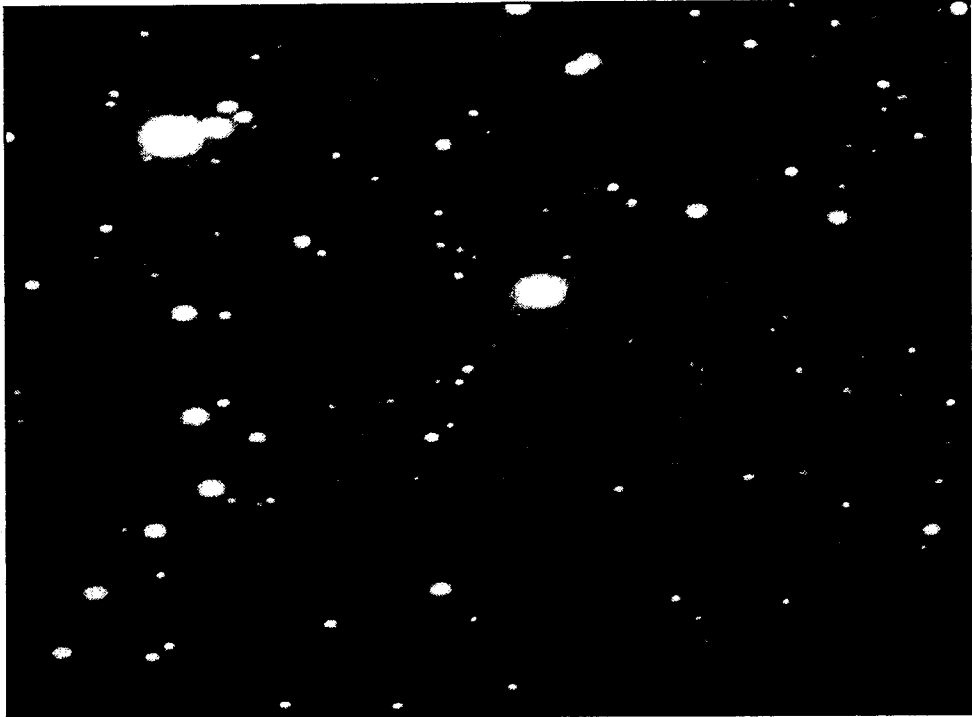
- Light needs 8 minutes and 20 seconds to reach the Earth (from the Sun).

- Star clusters
 1. Globular Clusters
 2. Open Clusters

- Globular Clusters: A gravitationally bound group of stars, symmetrical shaped.
- Consists of 10^5 - 10^7 stars
- 100 parsec (or ~ 300 ly) in diameter
- Old stars
- Found in the halo of the galaxy and orbiting the galactic center.



- Open cluster: A small group of gravitationally bound stars.
- Consists of about ten to a few hundred stars.
- Young stars.
- Found in or near the plane of the galaxy.
- E.g. Pleiades, in the constellation Taurus, lie about 400 ly away (contains ~ 100 stars within a diameter of 10 ly.)



- Interstellar Matter (ISM): All the gas and dust found between stars.
 - Composition of ISM
 - Hydrogen ~ 90%
 - Helium
 - Nitrogen
 - Oxygen†
 - Carbon
 - Sulphur
- } ~10%

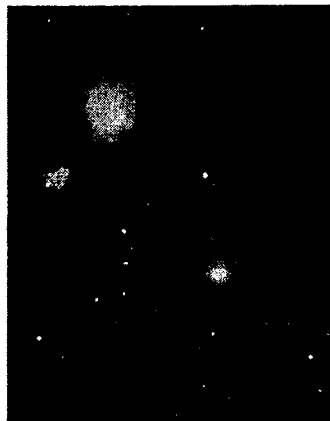
- ISM that can be seen by the naked eyes or by small telescope is called “nebula” which means “cloud”.

- Nebula can be classified into 3 groups:
 1. Emission nebula
 2. Reflection nebula
 3. Dark nebula
- Emission nebula: A cloud of hot ionized gas, mostly hydrogen, with an emission-line spectrum.

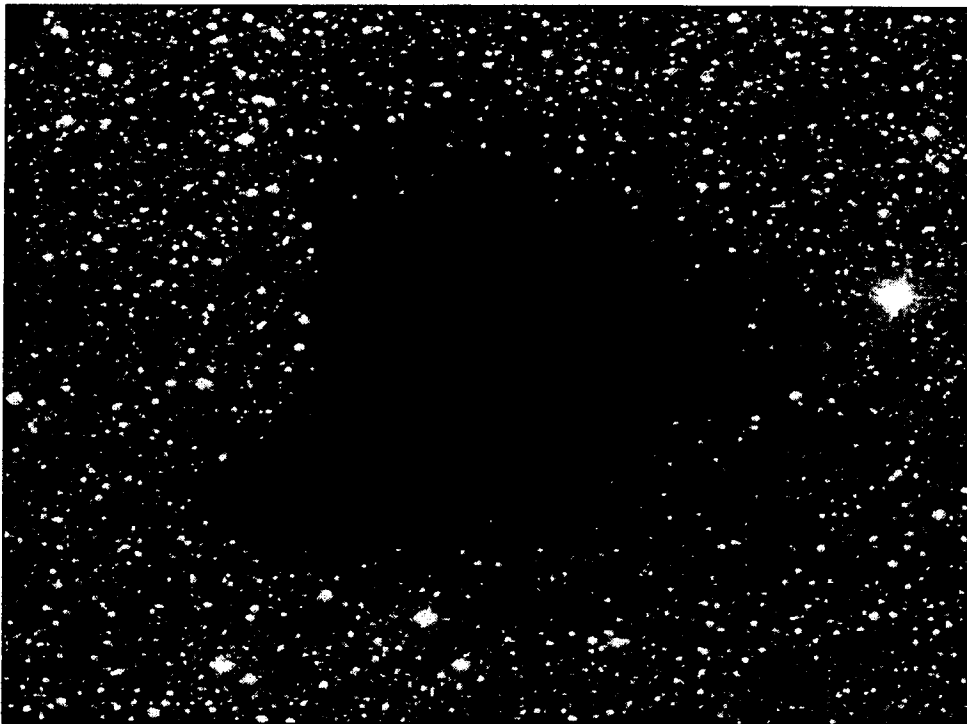
- Emission-line spectrum is produced by the radiation from a hot star (Temp $\geq 20,000$ K) embedded in the nebula.

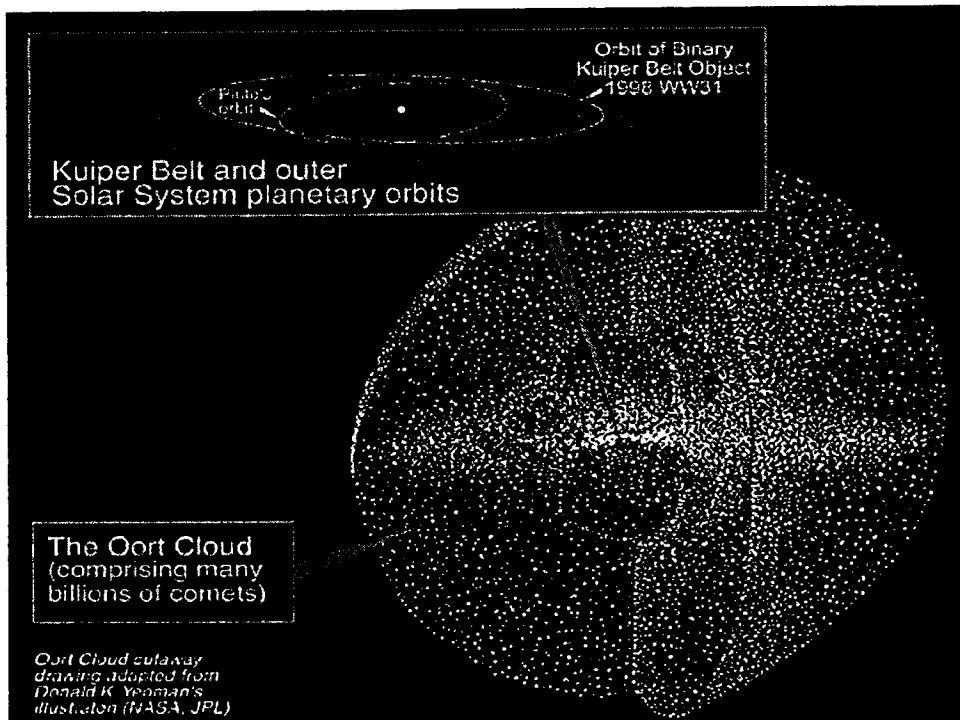


- Reflection nebula: A bright cloud of gas and dust that is visible because of the reflection of starlight by the dust.



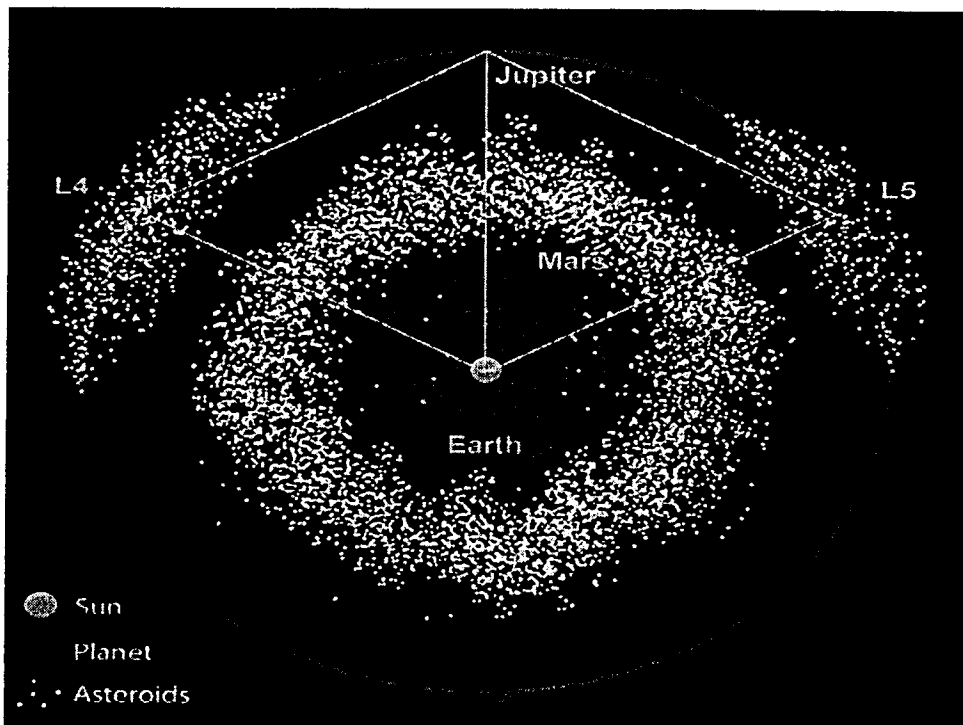
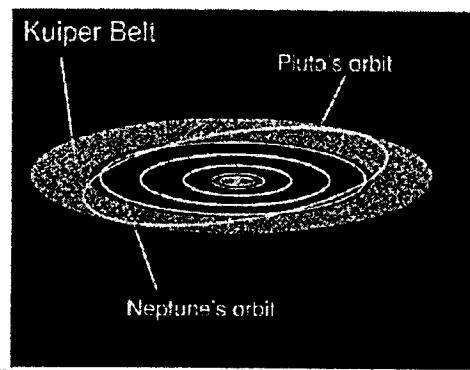
- The temperature of the star is too low to produce fluorescence process.
- Dark nebula: An interstellar cloud of gas and dust that contains enough dust to blot out the light of stars behind it (as seen from the earth).



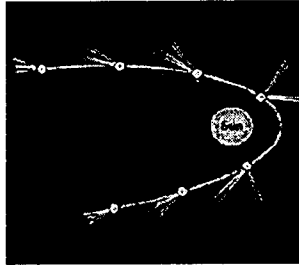


- Oort's cloud: A cloud of comet nuclei in orbit around the solar system, formed at the time the solar system formed; the reservoir for new comets.
- Solar system
- The sun is at the center of the system.
- Eight planets orbiting around the Sun.
- Moons or satellites orbiting around planets.

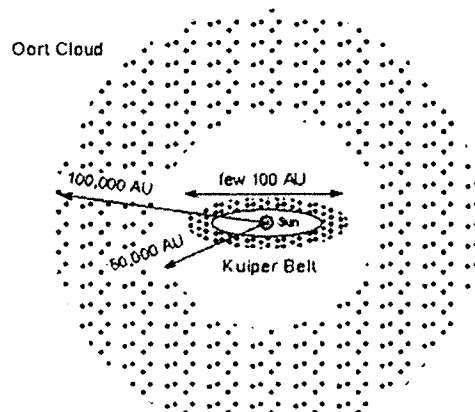
- Asteroids: Minor planet; one of several thousand very small members of the solar system that revolve around the Sun, generally between the orbits of Mars and Jupiter. †



- Comets: Bodies of small mass that revolve around the sun, usually in highly elliptical orbits; in the dirty snowball model, comets consist of small, solid particles (probably of rocky material) embedded in frozen gases.



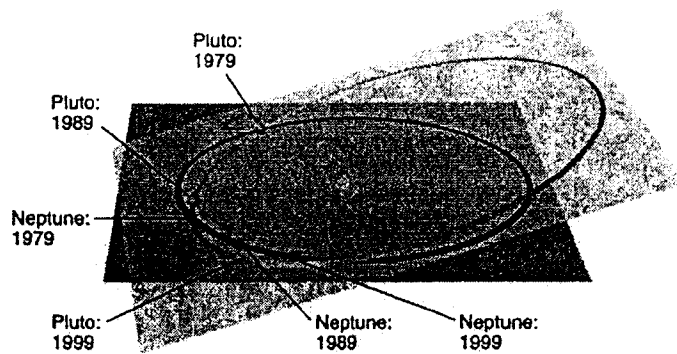
- Oort's cloud (named after a Dutch astronomer Jan Oort) has a diameter of about 100,000 AU.



- The Oort cloud does not explain all comets, however, and in 1951, Gerard Kuiper proposed that a second, smaller band of comets must exist inside the Oort cloud. The first object in this Kuiper belt was discovered in 1992.

- Kuiper belt: A disk-shaped region beyond Neptune's orbit, 30-500 AU from the Sun, closer to the Sun than the Oort cloud and presumed to be the source of short-period comets.
- The comets with periods of less than 200 years are called the short-period comets

- The origin of these short-period comets is believed to be in the Kuiper belt.
- Pluto and charon are now classified to be the dwarf planets.



Orbital of Pluto

“Creation of the Universe”

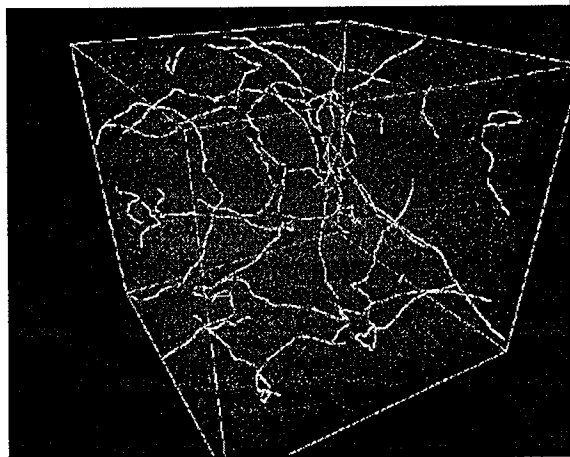
- At about 15×10^9 years ago the Universe was a dot about the size of one-baht coin called the “singularity”.
- Singularity had infinite density and infinite temperature.

- There was a big explosion called “big bang”.

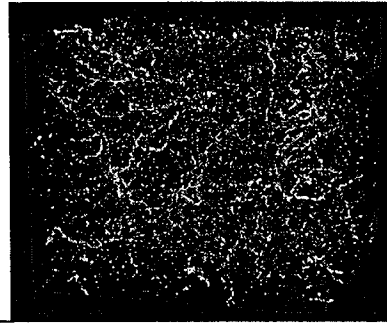
- Radiation Era

Temperature $\sim 10^{10}$ K

$$E = mc^2$$

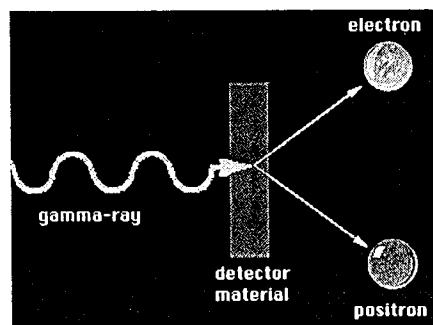


- Energy can be converted into matter.
- When the temperature of the Universe reduced to be $\sim 1 \times 10^9$ K, no matter can be converted from energy.



- From the big bang to about 10^3 years after the big bang explosion, the period of time is called "radiation era".
- In the radiation era, the Universe composed of elementary particles and radiation.

- Pair Production: The conversion of a high-energy gamma-ray into an electron and positron, which are formed simultaneously.



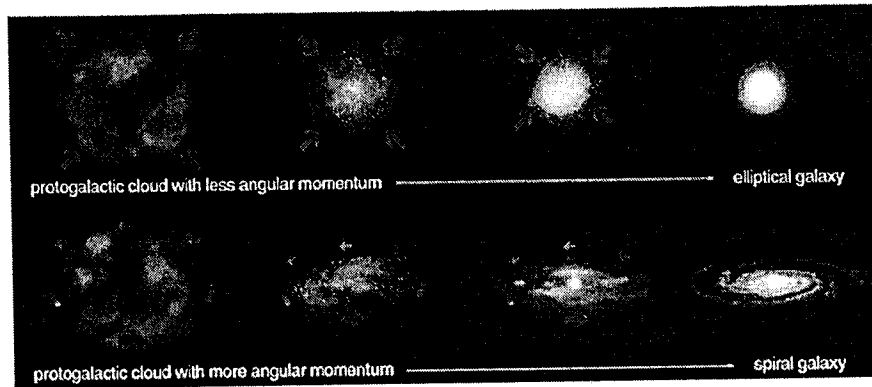
- The combined energy of gamma-rays must be greater than the mass energy of the particle-antiparticle pair.
- About 1,000 years after the big bang, the matter era started.
- Early matter era, the density $\sim 10^{-13}$ kg/m³ and temperature $\sim 6 \times 10^4$ K (K = Kelvin).

“Creation of Atoms”

- Hydrogen atom was created about 100 seconds after the big bang.
- Helium atom was created about 2 minutes after the big bang and the temperature of the Universe at that moment was about 900×10^6 K.

- Galactic Epoch: the period of galaxy formation that is about 10^6 to 10^9 years after the big bang.
- Stellar Epoch: the period of star formation in the galaxy, this period is about 10^9 to more than 10^{10} years after the big bang.

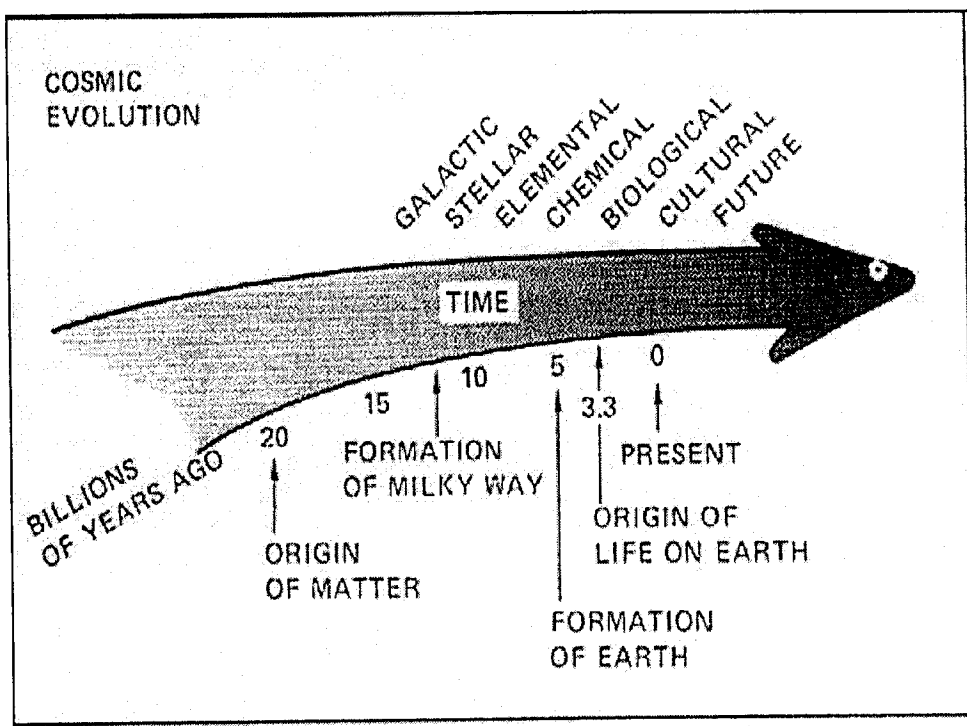
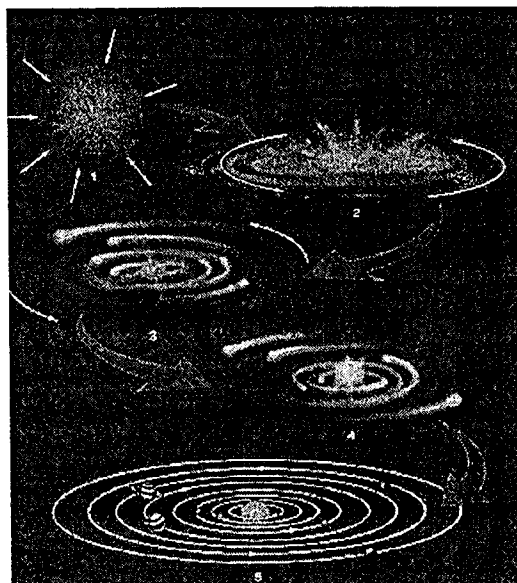
- Galaxy Formation



- Stellar Formation
(Case I)



- Stellar Formation (Case II)



“Life in the Universe”

- Are we alone?
- What are the characteristics of life?
 - Growth (metabolism)
 - Reproduction (heredity)
 - Movement
 - Response to stimuli
 - Death

- Do we have any direct evidence that life could have developed from non-living molecules?
- The answer is “yes”.
- The smallest and simplest entity that sometimes appears to be alive is a virus (virus is the Latin word for “poison”).

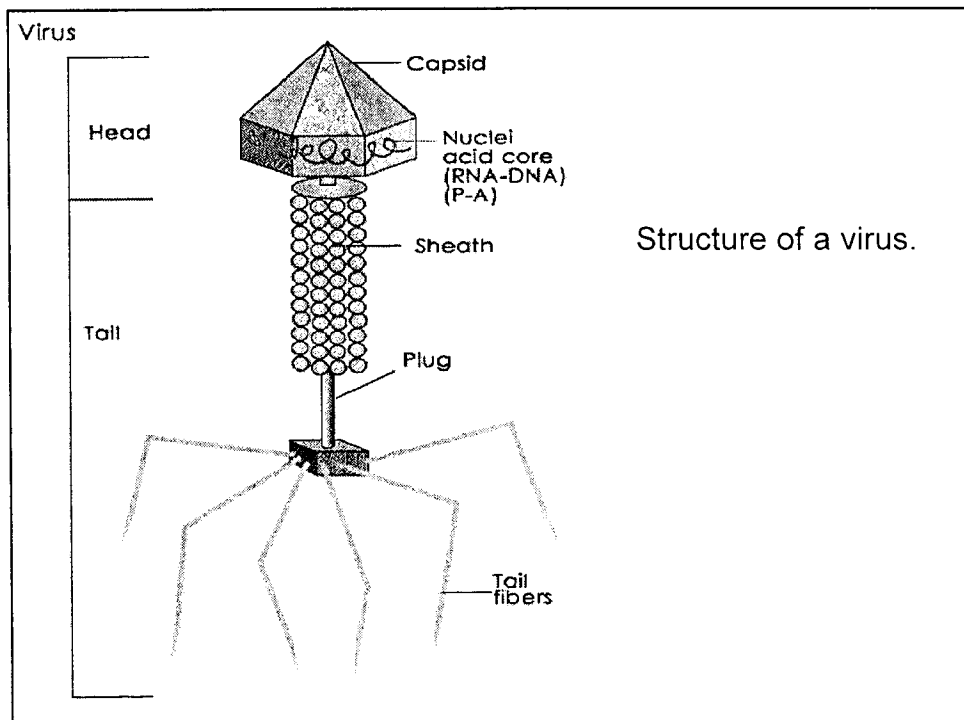
- All viruses are smaller than the size of a typical modern cell.
- Some viruses are made of only a few thousand atoms.
- Viruses seem to bridge the gap between cells that are living and molecules that are not.

- Viruses contain some proteins and genetic information (in the form of DNA) - none of the material by which living organisms normally grow and reproduce.
[DNA (deoxyribonucleic acid)]: A nucleic acid that contains the genetic information found in most organisms]

- How can a virus be considered alive?
- When alone, it cannot
 - A virus is absolutely lifeless when isolated from living organisms.
 - But when the virus gets inside a living system, it has all the properties of life.

- Viruses come alive by transferring their genetic material into living cells.
- The genes of a virus seize control of a cell and establish themselves as the new master of chemical activity.
(gene: a unit of heredity)
(genome: the total genetic makeup of an organism. The human genome is all the DNA normally contained in a human cell.)

- Viruses grow and reproduce copies of themselves by using the genetic machinery of the invaded cell, often robbing the cell of its usual function.
- Some viruses multiply rapidly and widely, spreading the disease and eventually killing the invaded organism.



“Intelligent Life in the Galaxy”

- We look for life beyond our solar system, in the Milky Way and in other galaxies.
- SETI: search for extra-terrestrial intelligence.

- The pioneering program was Frank Drake's Ozma Project of 1960.
- In 1983 a long-term SETI program began, financed by NASA.

The Drake's Equation

Number of Technological, Intelligent civilizations now present in the Milky Way. = $\textcircled{1}$ Rate of star formation, averaged over the lifetime of the Galaxy. \times $\textcircled{2}$ Fraction of those stars having planetary systems.

\times $\textcircled{3}$ Average number of planets within those planetary systems that are suitable for life. \times $\textcircled{4}$ Fraction of those habitable planets on which life actually arises. \times $\textcircled{5}$ Fraction of those life-bearing planets on which intelligence evolves.

⑥

Fraction of those
x intelligent-life planets that develop technological society.

⑦

Average lifetime of a technological civilization.

- Rate of star formation
- Now there are at least 100×10^9 stars shine in the Milky Way.
- Lifetime of the Milky Way $\sim 10 \times 10^9$ years

$$\text{Rate of star formation} = \frac{100 \times 10^9 \text{ stars}}{10 \times 10^9 \text{ years}} = 10 \text{ stars/year}$$

- Fraction of stars having planetary systems.
- Many astronomers believe planet formation result of the star-formation process.
- Is there any direct evidence for planets in orbit around other stars?
- Yes.

- The theory of star-formation is called the condensation theory.
- Accepting the condensation theory and its consequences the astronomers believe that essentially all stars have planetary systems.

- Fraction of stars having planetary systems ~1
- Number of habitable planets per planetary system
- It is found that temperature, more than any other single quantity, determines the feasibility of life on a given planet.

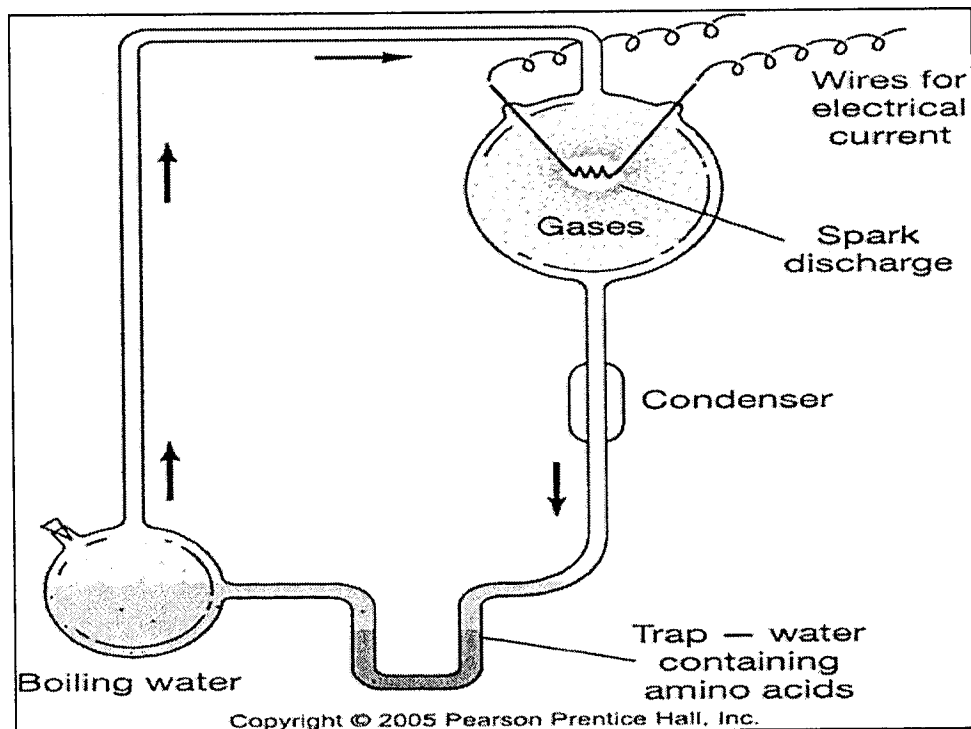
- The surface temperature of a planet depends on two things:
 1. The planet's distance from its parent star.
 2. The thickness of its atmosphere

- Taking all these factors, we assign a value of 1/10 to this term in Drake's equation.
- Fraction of habitable planets on which life arises.
 - Laboratory experiments seem to suggest that certain chemical combinations are strongly favored over others: synthesization of amino acids.

(amino acids: The basic building blocks of all polypeptides and proteins. 20 common amino acids are found in proteins.)

(Polypeptide: A single chain of amino acids. It is differentiated from a protein only by its smaller size and relative lack of complexity).

- In 1953, Urey and Miller designed an chemical experiment which allowed them to synthesize the amino acid from some gases in nature.



- To assign a value close to 1 is to believe that life is inevitable, given the proper ingredients, a suitable environment and a long enough period of time.
- So we will take the optimistic view and adopt a value of 1.

- Fraction of life-bearing planets on which intelligence arises.
 - Biological evolution through natural selection is a mechanism that generates intelligence.
 - We will be optimistic and adopt a value of 1.

- Fraction of planets on which intelligent life develops and uses technology.
- We need to estimate the probability that intelligent life eventually develops technological competence.
- Technology is inevitable.
- Why haven't other life-forms on Earth also found technology useful?

- Possibly the competitive edge given by intellectual and technological skills to humans, the first species to develop them.
- Some species will probably always fill the niche of technological intelligence that we will take this term to be close to 1.

- Average lifetime of a technological civilization.
- The longevity of technological civilization is unknown (from other planets).
- Only human civilization is known.
- If civilizations typically survive for 1000 years.
- The last term of Drake's equation should be 1000.

Number of	①	②	③	④	⑤	⑥	⑦							
technological	=	10	x	1	x	0.1	x	1	x	1	x	1	x	1000
intelligent	=	1000												
civilizations														
now present in														
the Milky Way														

Number of
technological
intelligent
civilizations
now present in
the Milky Way

=

The average lifetime
of a technologically
competent civilization
(in years)

“Determination of the Age of the Earth”

- How old is the Earth?
- In 1664 Bishop James Ussher of the Church of Ireland based solely upon his personal interpretation of Biblical texts, placed the Creation on 26 October, 4004 BC, at 9:00 AM.

- As the evidence for vast periods of geological time became more and more persuasive during the 18th century, opinions on this issue became institutionalized under two principal schools of thought.

- First, those who accepted the Ussher interpretation of biblical chronology attributed the abrupt endings of geological ages to the domination of a handful of catastrophic events (in extreme cases, only the single event of Noah's flood) that did virtually all the work of laying down the kilometers of sediment in the geological record.

These Catastrophists began with the conclusion that Earth is really only a few thousand years old. Fossils were often dismissed by Catastrophists as the remains of “that accursed race which perished with the Flood” or as artifacts made by Satan to mislead us or by God to “test our faith”.

- At the other extreme were those geologists who accepted that these vast thicknesses of sediments took many millions of years to be deposited.
- This view gave rise to the Uniformitarian school, which attributed all the work of geology to very slow, unspectacular processes working over vast periods of time.

- The Uniformitarians denied the reality of global catastrophes, which smacked of magic and seemed intended not to explain the observational data, but to provide an excuse for disregarding the data.

- The debate was both sharpened and heated in the mid-1860s by Charles Darwin's work on the origin of biological species.
(species: A group of organisms that resemble each other and are generally able to interbreed and produce fertile offspring.)

- Darwin proposed that the proliferation of species occurred as the combined effect of two main factors, chance isolation of populations and natural selection.

- The Darwinian explanation for the fossil record emphasized migration or division of preexisting species by slow geological change to establish independent gene pools that initially differed only slightly. In these smaller, isolated populations, combinatorial variation of existing genes played out different roles in different environments, where the criteria for survival were different.

A trait that is useful to a jungle gene pool might be irrelevant to a grassland gene pool and harmful in a desert setting; therefore, differing environments will favor different traits and lead to genetic divergence even if the original gene pools were identical. Further, mutations occurring randomly and independently within these separate gene pools lead inevitably to genetic drift.

(Mutation: Any change in the DNA of an organism. Most mutations are deleterious but are often recessive. Beneficial mutations may increase in the population due to natural selection. The spontaneous mutation rate is quite low (on the order of one in a million to one in a trillion). (10^{-12}) Three major sources of mutational damage to DNA are high-energy radiation such as X-rays that cause physical breakage, low-energy radiation such as UV light that creates DNA cross-links, and chemical modification of DNA bases. The latter two ultimately lead to replication errors.)

- Most mutations are harmful or nonfunctional, many are lethal, and only a few will confer some functional advantage on their carriers. Individuals with helpful mutations will tend to be more successful and leave more offspring, and hence these new traits will tend to spread throughout the local breeding population.

- After a series of such mutations, the different populations will cease to be able to interbreed and will become separate species.
- The natural time scale for such divergence of a cluster of species from a common ancestor by this process of natural selection is on the order of 10^5 to 10^6 years.

(Natural selection: The process by which organisms well adapted to their environment survive to produce offspring while those more poorly adapted may not. In this way, particular combinations of genes are propagated differentially. According to Darwinism, natural selection acting on a varied population results in evolution.)

- By observing the succession of plants and animals, geologists developed “sequence-geochronology”.
- Geologists and paleontologists at that period estimated the time required for such sedimentation to be around 100 to 400 million years.

- Lord Kelvin calculated how long it would have taken a body the size of the Earth to cool from an initially molten state to its present temperature.
- Kelvin found the age of the Earth to be 20 to 40 million years.

- The age of the Earth found by Kelvin was wrong because the rate of cooling of the Earth is much more slower than expected by Kelvin.
- Kelvin knew nothing about the heat released from the radioactive substances inside the Earth.

- This due to radioactivity
- Becquerel discovered radioactivity
(Radioactivity: The spontaneous transformation of one atomic nucleus into another with the emission of energy. The energy is released in the form of an energetic particle, usually an alpha particle, beta particle, sometimes accompanied by a gamma-ray photon. The unstable isotopes of an

element that can undergo such transformations are called radioactive isotopes, or radioisotopes. The emission of a particle from the nucleus of a radioisotope of a different element, as in the beta decay of carbon-14 to nitrogen-14. The isotope produced is itself often radioactive. The average time taken for half a given number of nuclei of a particular radioisotope to decay is the half-life of that radioisotope; values range from a fraction of a second to thousands of millions of years.)

- The modern quantitative study of the history of the Earth and its life dates back only a few decades. The German physicist C.F. von Weizsacker proposed the principle underlying potassium-argon dating in 1937.

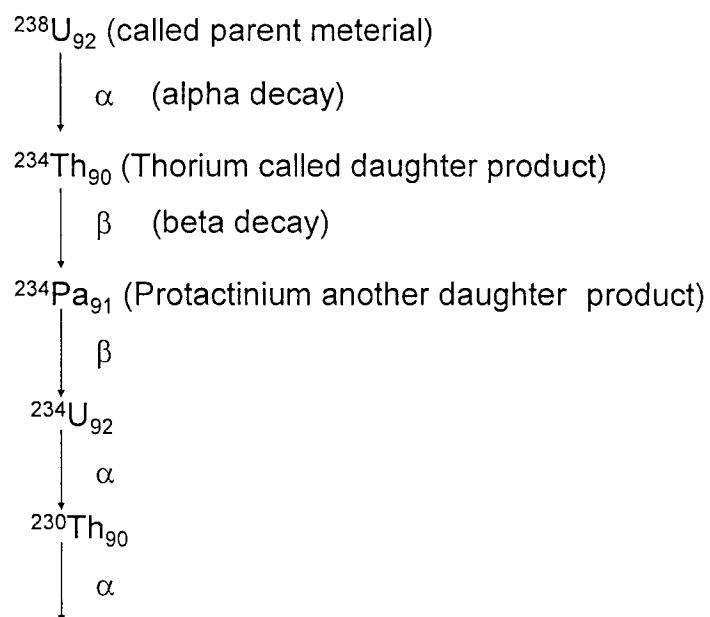
- The radionuclide ^{40}K decays to ^{40}Ar , a stable isotope of the noble gas argon. The half-life for this decay is 1.25×10^9 years. A measurement of the ratio of ^{40}K to ^{40}Ar , as found in the rock in question, can be used to calculate the age of that rock.

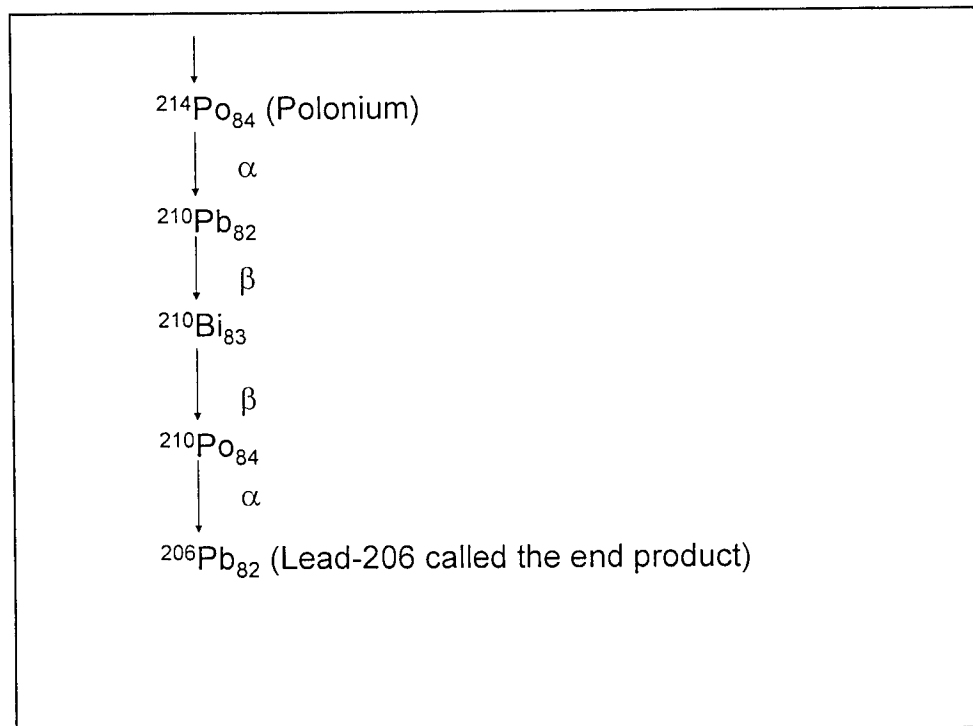
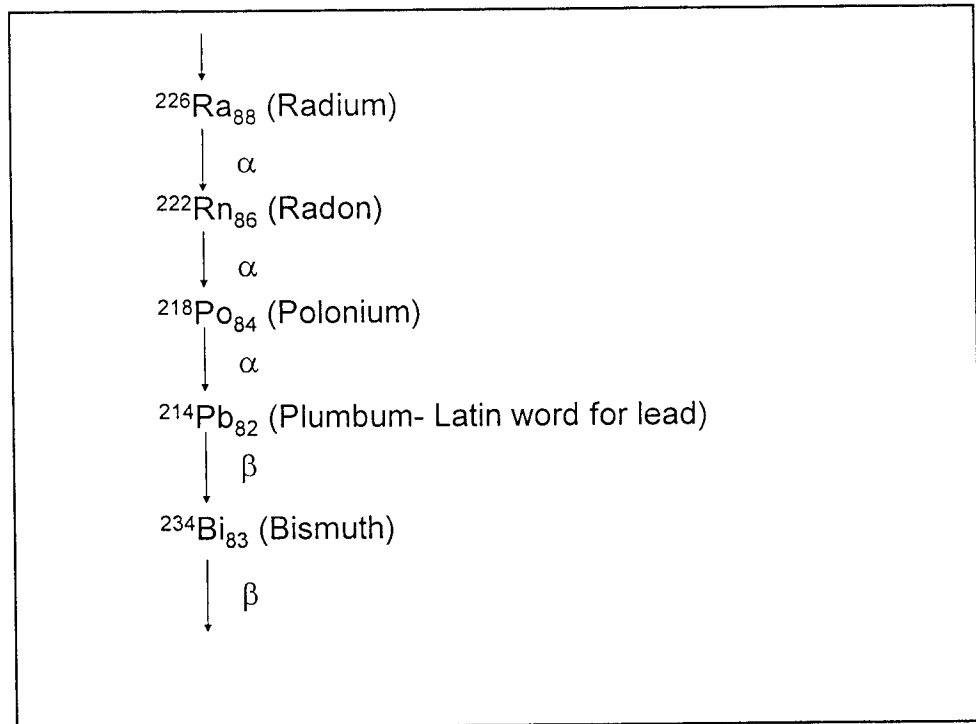
$$t = \ln(1 + (N_{\text{Ar}}/N_{\text{K}})) / \lambda$$

λ = the half-life

$(N_{\text{Ar}}/N_{\text{K}})$ = the ratio of ^{40}Ar to ^{40}K

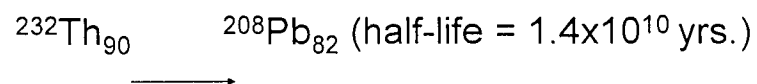
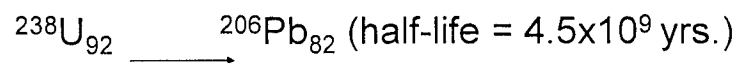
- In the 1940s the U/Th-He technique was introduced to be another method to determine the age of the Earth.
- U-238 series (Uranium-238)





- The half-life of U-238 is 4.5×10^9 years.
- Lead consists of several different isotopes, not all of them produced by radioactivity (radiogenic material).

- $^{204}\text{Pb}_{82}$ is a non-radiogenic.



- If common non-radiogenic lead-204 and the radiogenic lead-206 and lead-207 are added together, excessive ages are obtained.

- In 1917 J. Barrell of Yale University tried to solve the problem by using only samples in which no non-radiogenic lead-204 is present.
- Barrell got the age of the Earth to be about 1.8×10^9 years which was wrong because of the impurity of his samples.

- There are no differences in chemical characteristics between the isotopes of a given chemical element, the only differences are very small variations in mass.

- In order to solve this problem the scientists need a special equipment called “mass spectrometer” which in the 1930s, a physicist named A.O.C. Nier at the University of Minnesota was the one who was able to make a perfected mass spectrometer.

- Then in the year 1956, C. Patterson of the California Institute of Technology got an approximate age for the Earth and the solar system to be $(4.55 \pm 0.07) \times 10^9$ years.
- G. Tilton with his colleague R.H. Steiger and others made some refinements in the techniques and got the currently accepted age of the Earth to be about 4.57×10^9 yrs.

- Other methods to determine the age of the Earth Rubidium-87
Strontium-87 (The half-life is 48.8×10^9 years) Potassium-40
Argon-40 (The half-life is 1.25×10^9 years)

- If you know the half-life of a given radionuclide, you can in principle use the decay of that radionuclide as a clock to measure time intervals. The decay of very long-lived nuclides, for example, can be used to measure the age of rocks - that is, the time that has elapsed since they were formed. Such measurements for rocks from Earth and the moon, and for meteorites, yield a consistent maximum age of about 4.5×10^9 years for these bodies.

- $^{87}\text{Rb}_{37}$ - $^{87}\text{Sr}_{38}$ method gave the age of the Earth to be $(4.6 \pm 0.1) \times 10^9$ years.
- For measuring shorter time intervals, in the range of historical interest, radiocarbon dating has proved invaluable. The radionuclide ^{14}C (with half-life = 5730 years) is produced at a constant rate in the upper atmosphere as atmospheric nitrogen is bombarded by cosmic rays. This radiocarbon mixes with

the carbon that is normally present in the atmosphere (as CO_2) so that there is about one atom of ^{14}C for every 10^{13} atoms of ordinary stable ^{12}C . Through biological activity such as photosynthesis and breathing, the atoms of atmospheric carbon take places randomly, one atom at a time, with the atoms of carbon in every living thing, including mushrooms, penguins and humans.

Eventually an exchange equilibrium is reached at which the carbon atoms of every living thing contain a fixed small fraction of the radioactive nuclide ^{14}C . This equilibrium persists as long as the organism is alive. When the organism dies, the exchange with the atmosphere stops and the amount of radiocarbon trapped in the organism, since it is no longer being replenished, dwindles away with a half-life of 5,730 years.

By measuring the amount of radiocarbon per gram of organic matter, it is possible to measure the time that has elapsed since the organism died. Charcoal from ancient campfires, the Dead Sea scrolls and many prehistoric artifacts have been dated in this way. The age of the scrolls was determined by radiocarbon dating a sample of the cloth used to plug the jars in which the scrolls were sealed.

- This carbon-14 method of dating was developed by W.F.Libby in 1952.
- Carbon-14 dating applies only to deposits younger than about 40,000 years. (special techniques will take it back to 70,000 or perhaps 100,000 years)