# THE ORIGIN OF THE UNIVERSE

# #OriginoftheUniverse

# Specific Learning outcomes

- Describe the different hypotheses explaining the origin of the solar system.
- Compare the different hypotheses explaining the origin of the solar system.
- Describe the characteristics of Earth that are necessary to support life.

- Explain that Earth consists of four subsystems across whose boundaries matter and energy flow.

- Create a model of the solar system showing the uniqueness of Earth being the only planet in the solar system with properties necessary to support life

# Formation of the universe

- http://www.space.com/52-the- expanding-universe-from-the-big-bang-to-today.html

# A. Big bang theory

According to the big bang theory, ***the universe was once very small and very hot, and then it expanded over time until it reached its peak*** (which may be perceived as a massive explosion for some) around ***13.7 billion ye***ars ago—considered the age of the universe.

http://map.gsfc.nasa.gov/media/121238/index.html

The big bang theory remains to be the top prevailing cosmological model for the early development of the universe.

Why?

It provides the best explanation and is implicitly accepted.

In the recent past, astronomers have based their new findings on the beginnings of the universe through ***cosmic microwave background*** **(CMB)** .

**CMB**- is a thermal radiation used in observational cosmology because it is considered the oldest light in the universe.

CMB can be detected as a glow which is believed to be a remnant from an early stage of the development of the universe.

Because of this belief, the big bang theory gained the most support from the scientific community among the various theories on the origin of the universe.

The big bang model also asserts that seconds after the explosion, the surroundings were at a high temperature of about 10 billion degrees Fahrenheit (5.5 billion Celsius) with aggregates of fundamental particles such as neutrons, electrons, and protons.

As the universe cooled in later phases, these particles either combined with each other or decayed.

Over time, those particles created neutral atoms which allowed light to shine through.

This light is the CMB, also referred to as *"**afterglow**"* of the big bang.

This is now the reference point for studying previous and later events in the formation of the universe.

The CMB was believed to have been released ***380 000 years*** after the big bang.

The clumping of particles, later on, formed the stars and the galaxies that we have at present.

The CMB is also used to study the composition and age of the universe.

The universe was also said to continue to expand over the next 13 billion years until present.

**http://burro.astr.cwru.edu/stu/advanced/cosmos_bigbang.html

# B. Cosmic inflation theory

The most recent cosmic inflation theory was proposed by physicists ***Alan Guth (1947-present)*** and ***Andrei Linde (1948-present)*** in the 1980s.

The term ***inflation*** refers to the rapid expansion of space-time.

http://hetdex.org/dark_energy/

According to this theory, ***the early universe was a rapidly expanding bubble of pure vacuum energy***. It did not have any matter or energy.

After the expansion and cooling arising from this inflation, the potential energy converted into kinetic energy of matter and radiation. Then, a big bang occurred because of the extremely hot, dense condition of matter.

QUESTION:

1. Explain what could have come before the formation of the universe, according to the cosmic inflation theory?

ANSWER:

According to this theory, the early universe was rapidly expanding bubble of pure vacuum energy. It did not have any matter or radiation. After the expansion and cooling that took place due to the inflation, the potential energy was converted into kinetic energy of matter and radiation. Then a big bang occurred because of the extremely hot dense condition of the matter.

The cosmic inflation theory answered many “puzzling” observations that arose in the big bang theory.

- One puzzling observation is the homogeneity of objects in space. During the expansion period, objects that used to be in contact got farther away from one another. Their composition, however, remained almost intact.

- The second puzzling observation about the universe is its appearance of flatness or smoothness. The continuous expansion “dilutes” or gradually loses the curvature of objects.  E.g. Inflation of a balloon with small bumps.

- The third puzzling observation has something to do with the formation of stars and star systems in the later years. It asserts that during expansion, small density fluctuations happen.

This causes gravity to attract gas into masses, giving birth to stars and eventually galaxies. This also explains why the universe would always look full of planetary objects instead of appearing completely empty.

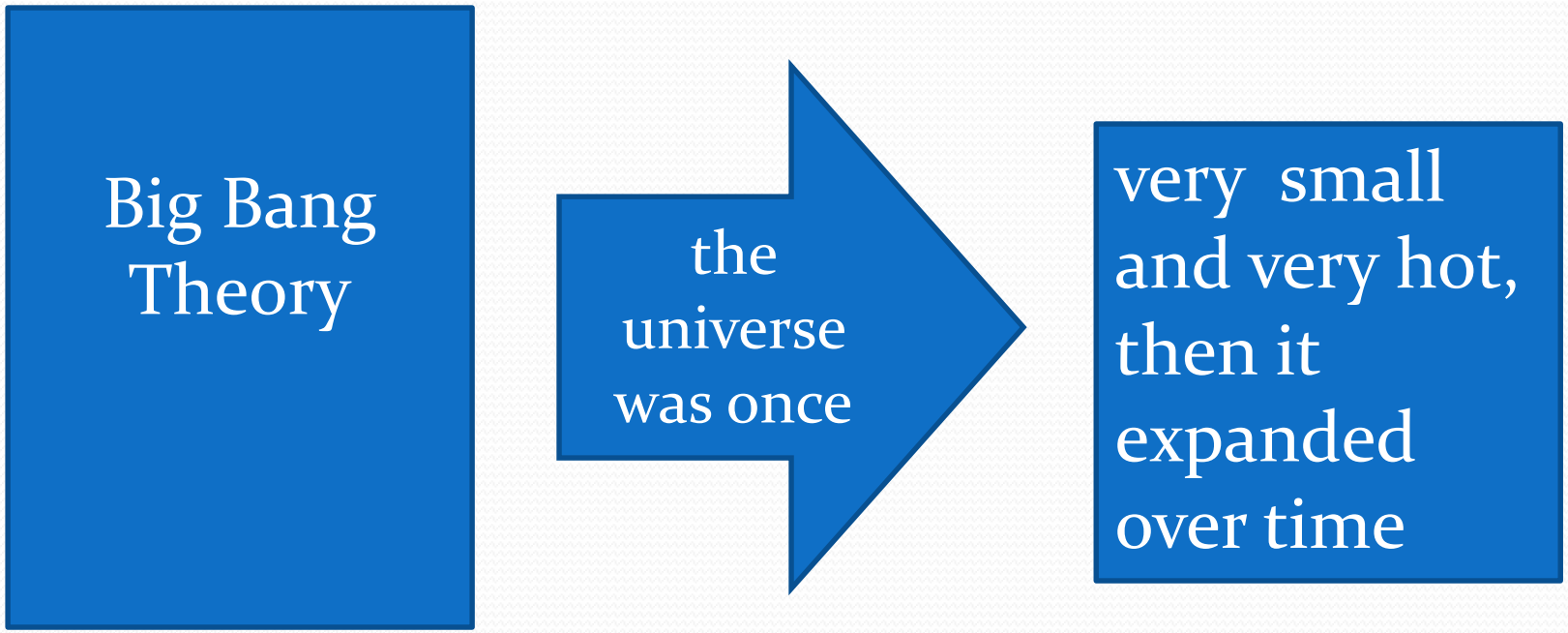
**Reflect Upon : Write your answer in a 1 whole sheet of paper.**

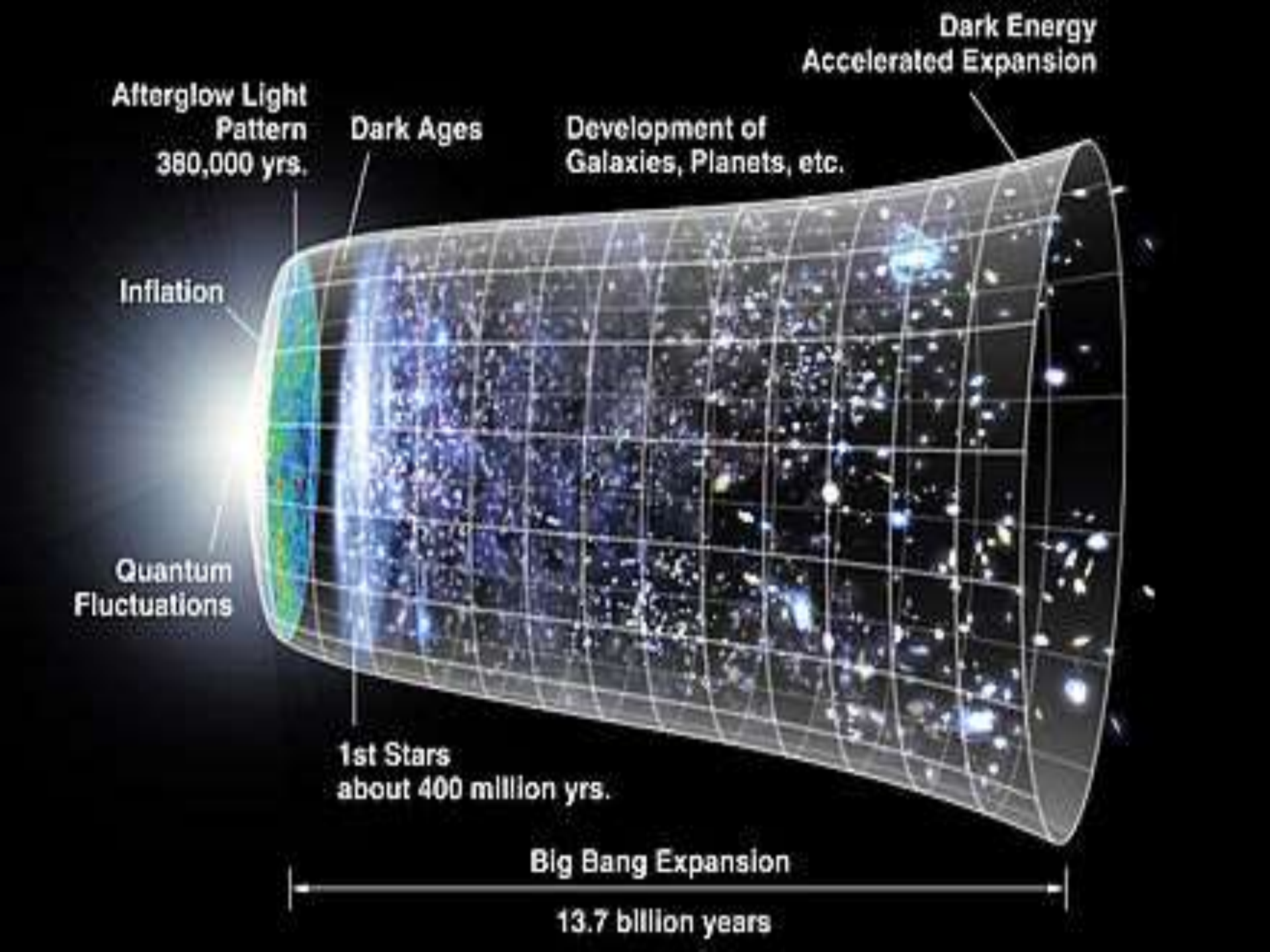
How will the continuous expansion of the universe affect Earth? If you were an astrophysicist, what else can you investigate about the universe?

# Quiz

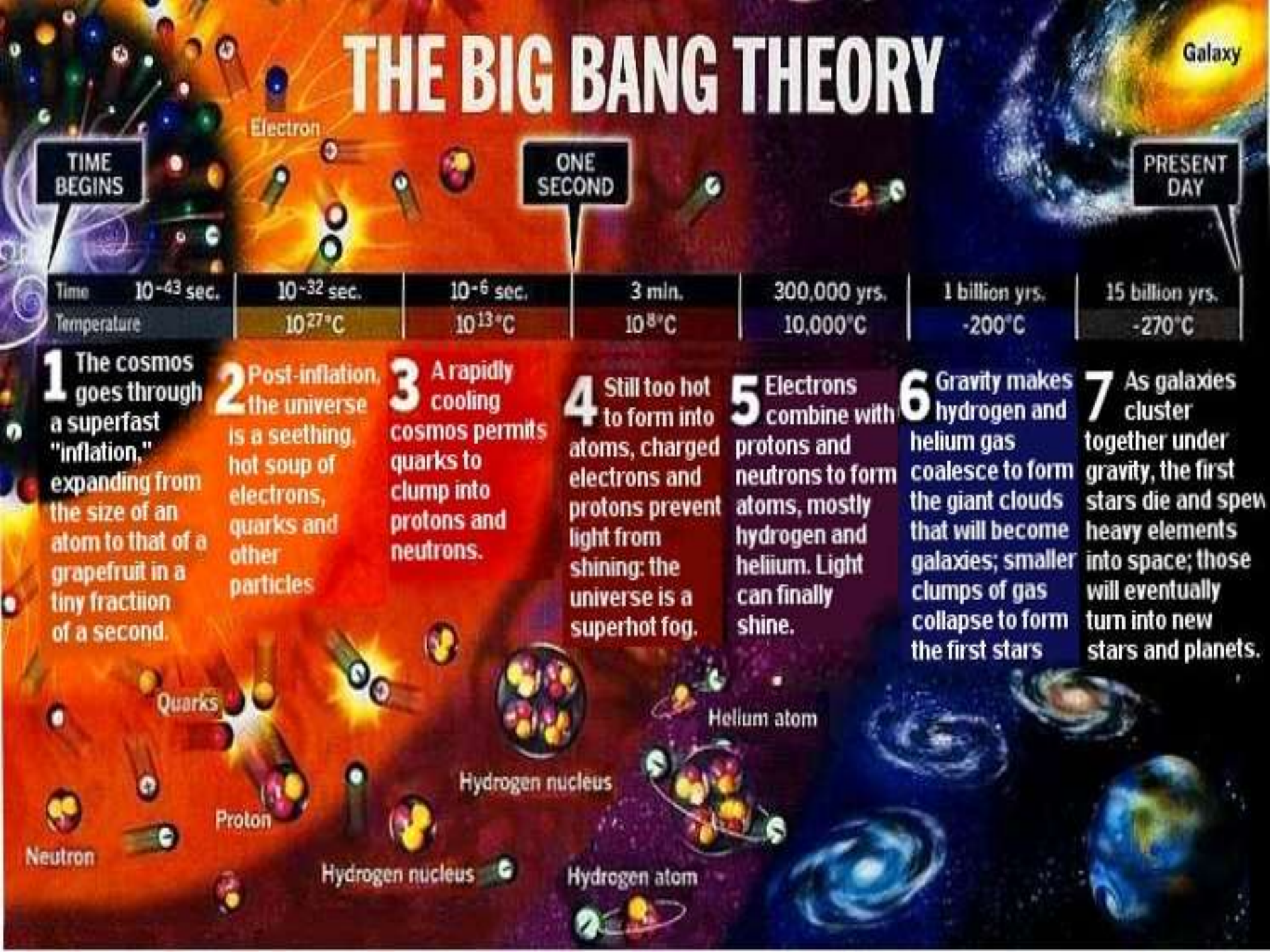
1. Describe the Big Bang theory.
2. Describe the Cosmic Inflation Theory.
3. Differentiate the Big Bang Theory from the Cosmic Inflation Theory.
4. How did the CMB help strengthen the Big Bang Theory?
5. Why does the big bang theory remain to be the top prevailing cosmological model for the early development of the universe?

# #throwbackFriday




Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

# THE BIG BANG THEORY




| | | | | | | |
|---|---|---|---|---|---|---|
| Time | $10^{-43}$ sec. | $10^{-32}$ sec. | $10^{-6}$ sec. | 3 min. | 300,000 yrs. | 1 billion yrs. | 15 billion yrs. |
| Temperature | | $10^{27}$°C | $10^{13}$°C | $10^{8}$°C | 10,000°C | -200°C | -270°C |

**1** The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fractiion of a second.

**2** Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles

**3** A rapidly cooling cosmos permits quarks to clump into protons and neutrons.

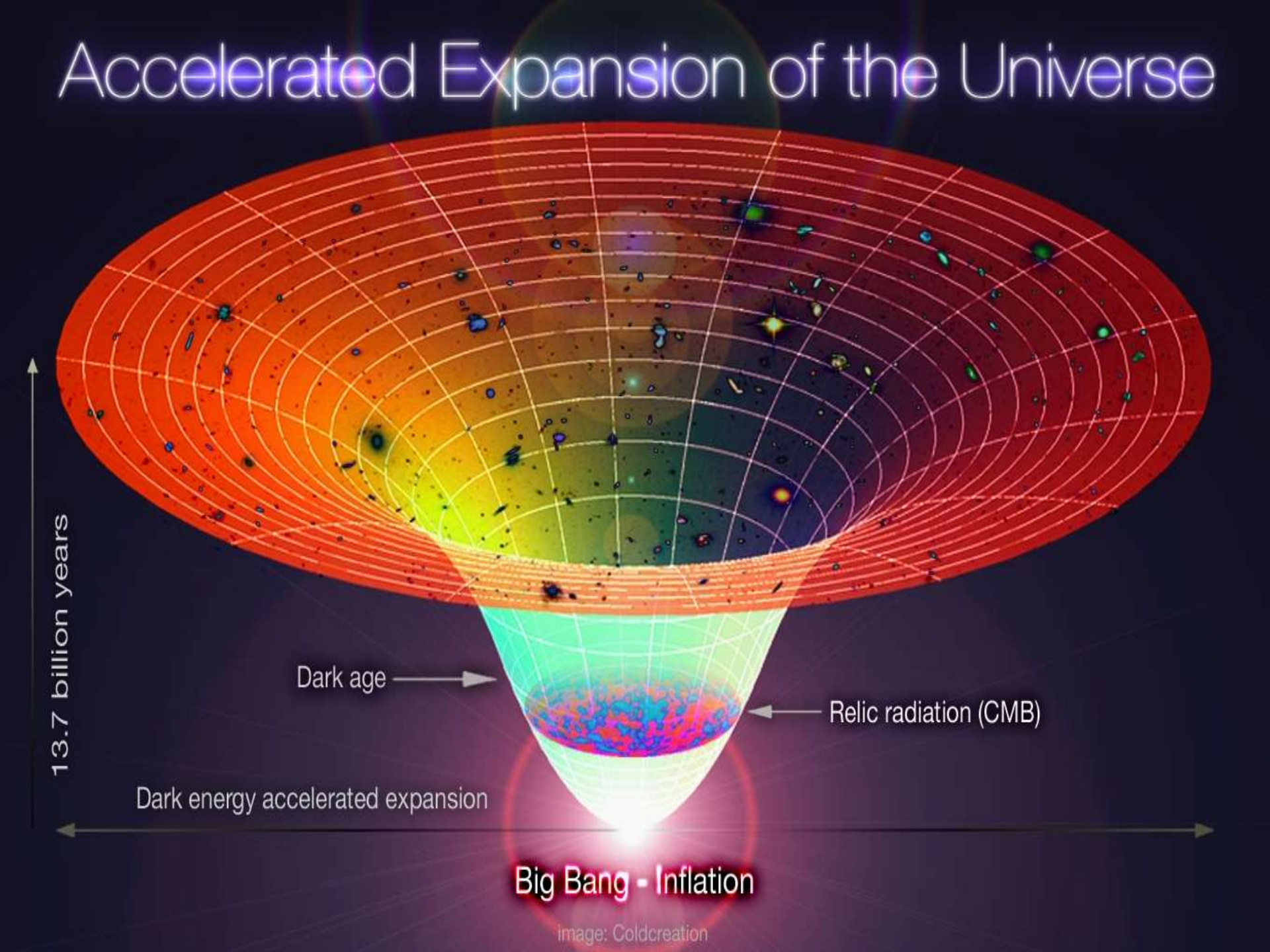
**4** Still too hot to form into atoms, charged electrons and protons prevent light from shining: the universe is a superhot fog.

**5** Electrons combine with protons and neutrons to form atoms, mostly hydrogen and heliium. Light can finally shine.

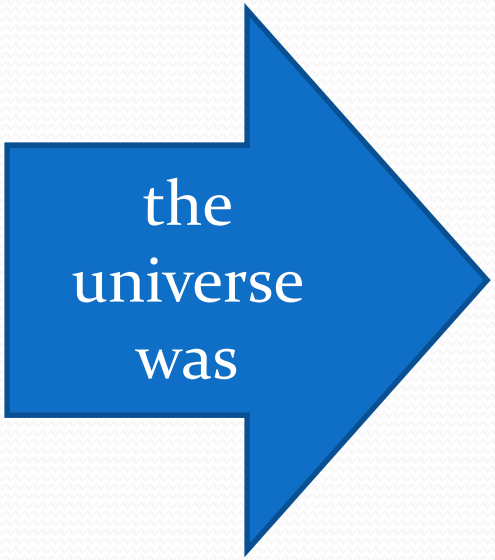
**6** Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars

**7** As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; those will eventually turn into new stars and planets.

# Accelerated Expansion of the Universe

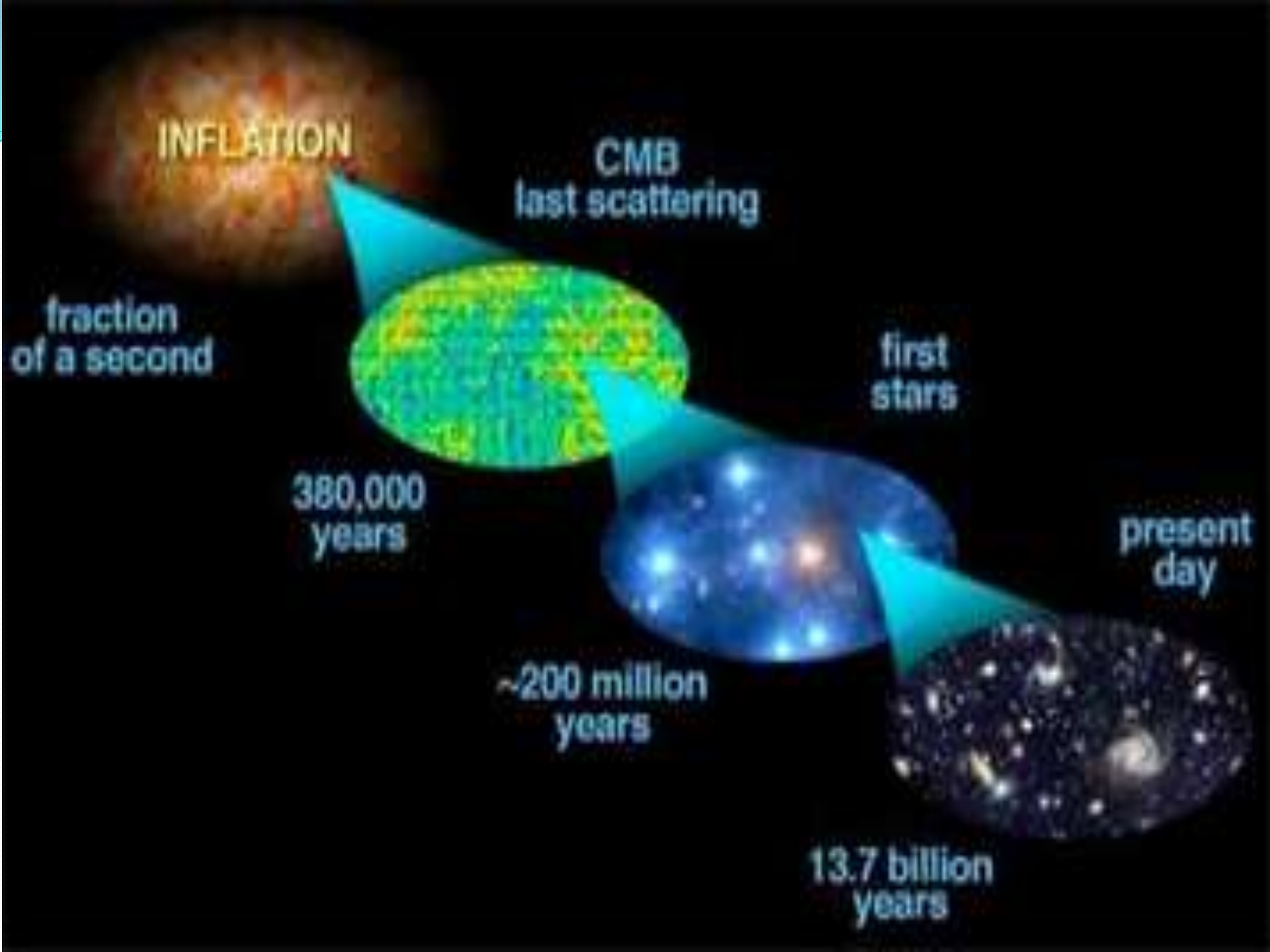


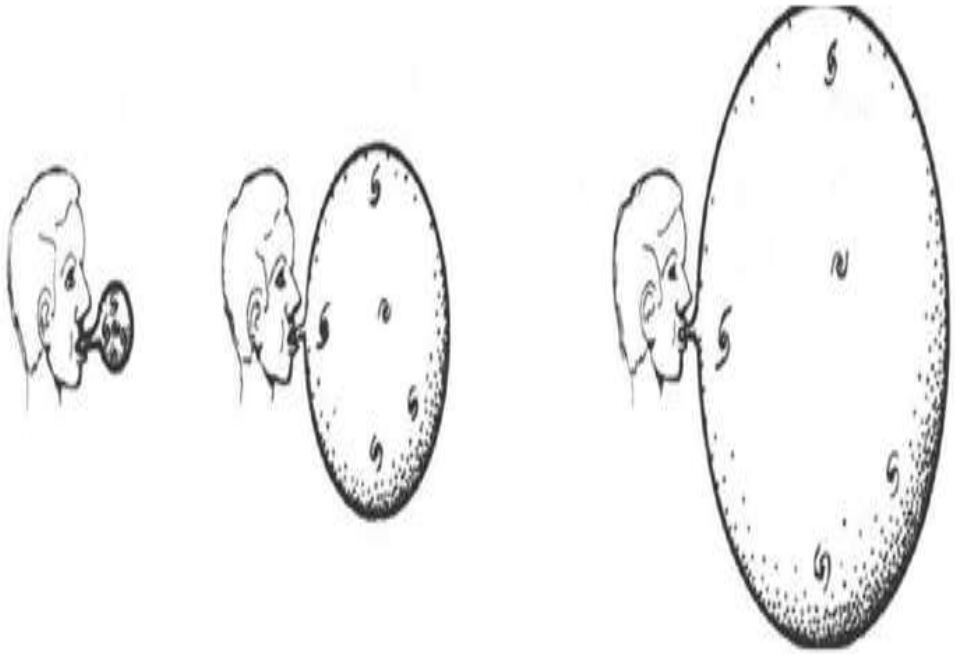
Cosmic Inflation Theory



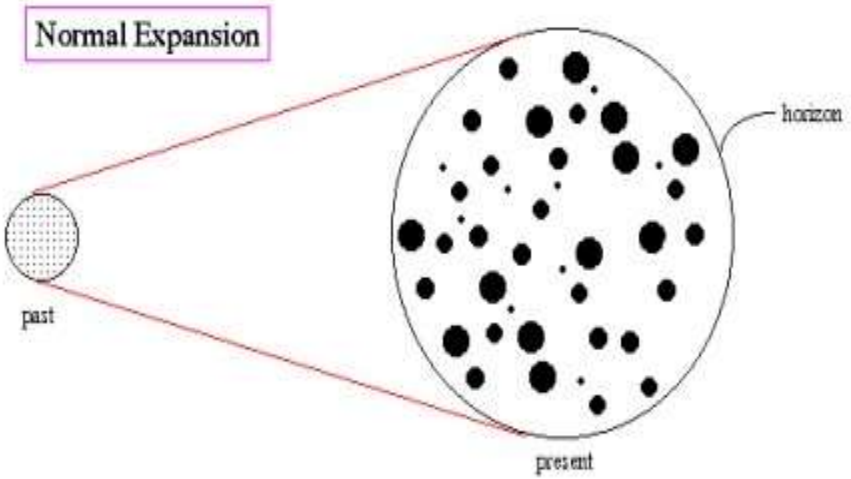

a rapidly expanding bubble of pure vacuum energy

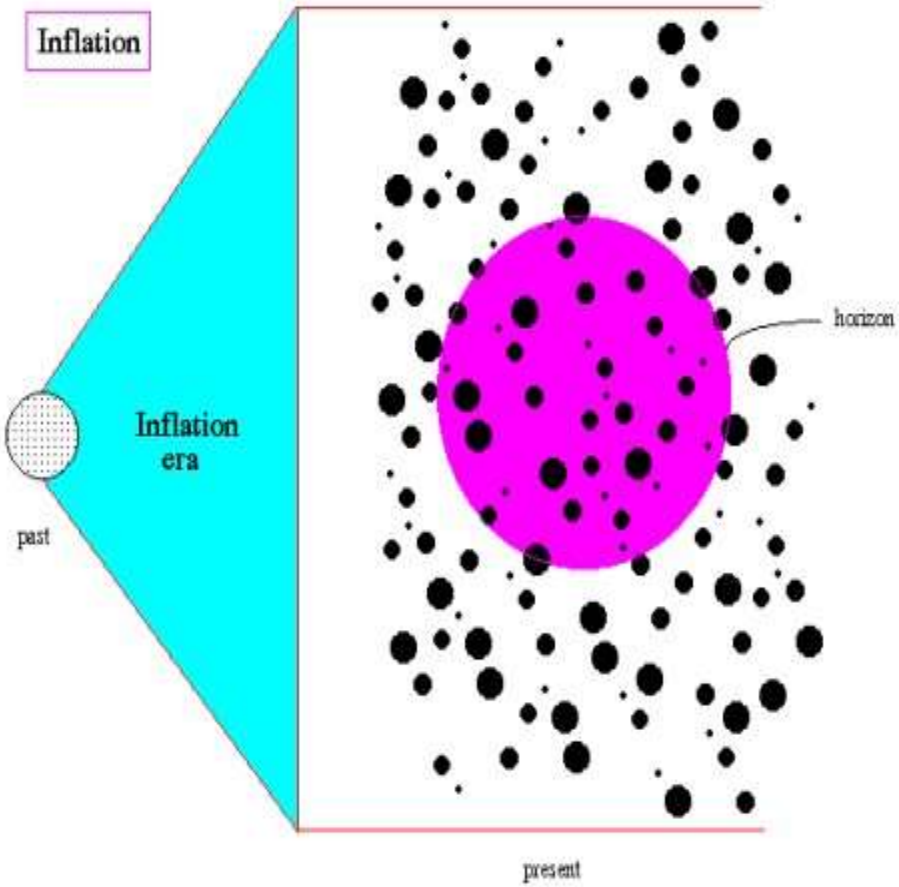
***It did not have any matter or energy.


INFLATION
CMB
last scattering
fraction
of a second
first
stars
380,000
years
present
day
~200 million
years
13.7 billion
years



The Expanding Universe



Steady State Theory

the universe is

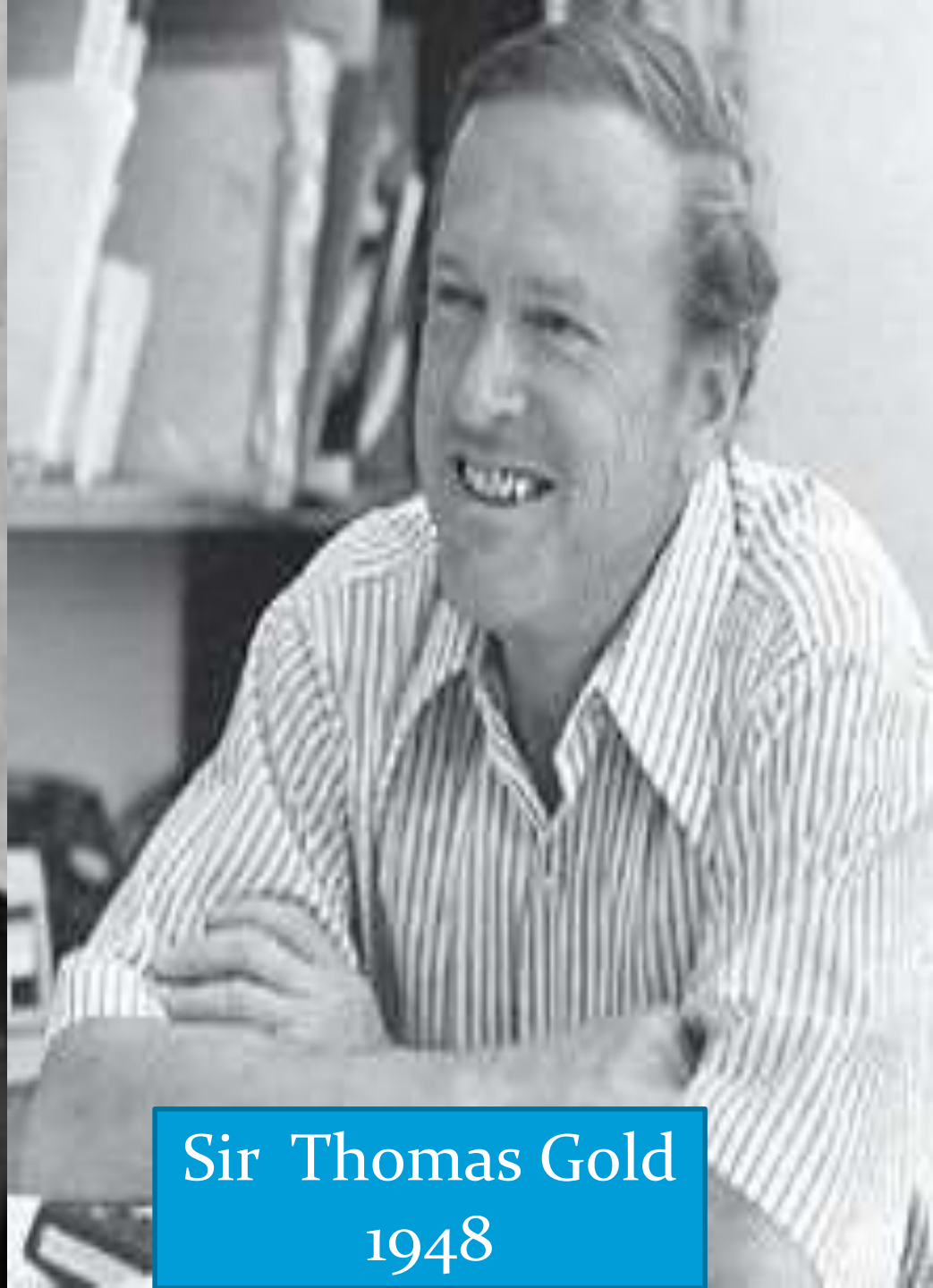
always expanding

***Matter is constantly formed as the universe is expanding

Sir James Jeans
1920

Sir Fred Hoyle
1948

Sir Hermann Bondi
1948



Sir Thomas Gold
1948

# Assigned tasks for class discussion

Topics: Solar system and the subsystem :

- Formation of the Solar System
- Earth's internal structure
- Geosphere
- Hydrosphere
- Atmosphere
- Biosphere

# C. Steady state theory

The steady state theory states that ***the universe is always expanding. It also states that new matter is constantly formed as the universe continues to expand***.

This theory further claims that the universe has no beginning or no end in time, and even though it is expanding, its appearance remains the same over time.

This theory was first proposed by **Sir James Jeans** in 1920.

It gained popularity after it was revised by **Sir Fred Hoyle**, **Sir Hermann Bondi**, and **Thomas Gold** in 1948 as an alternative to the big bang theory.

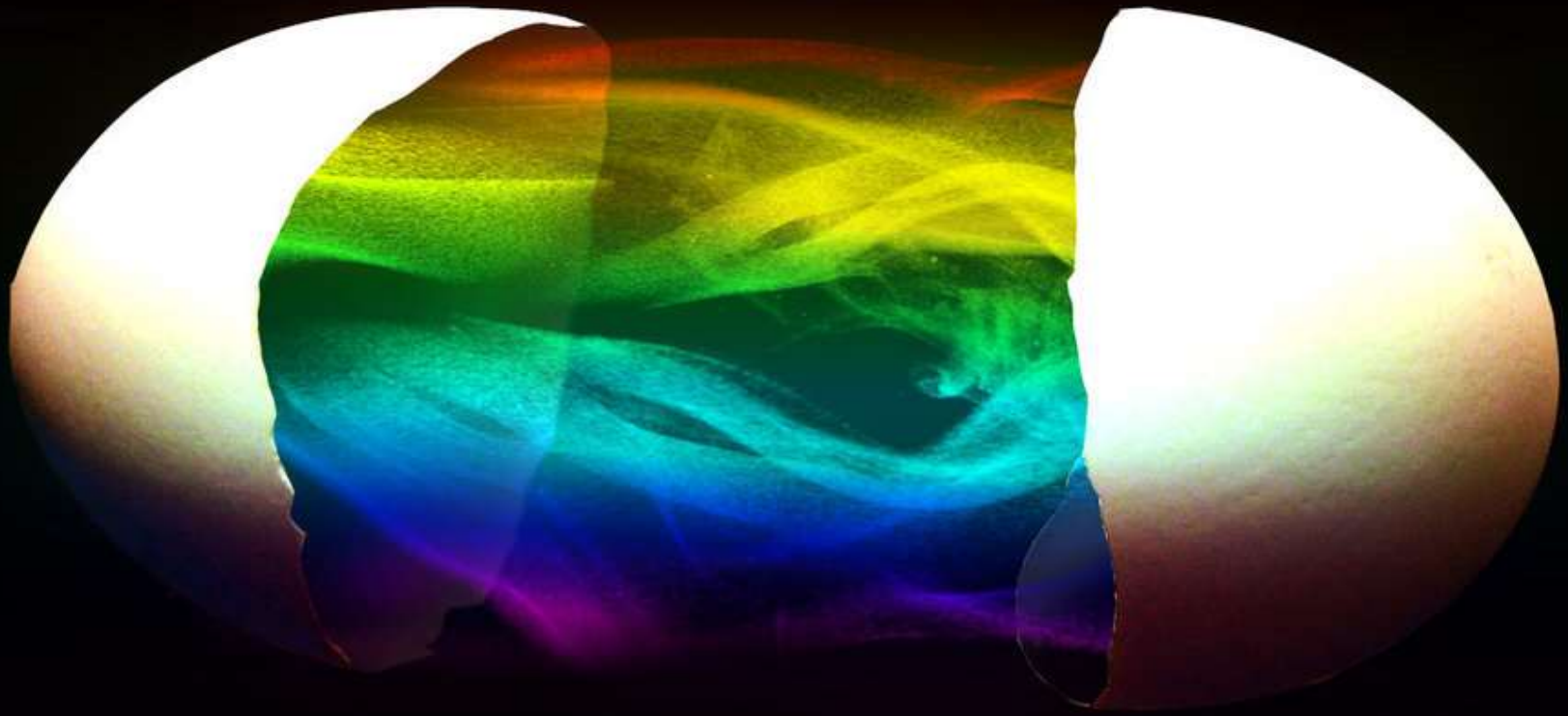
However, toward the middle of 1960s, evidences that would contradict the steadiness or the unchanging state of the universe were brought out.

One of these evidences was when galactic bodies such as quasars and radio galaxies were found a long way from the sun at far distances in space (and found none nearby); it disproved the idea that similar bodies are created and found everywhere.

This implies that the universe is actually dynamic (and not steady). In cosmology, the steady state is now considered obsolete.

# Other Theories

**Cyclical or Oscillating Universe (15th -12th BCE)** – Hindu Rigveda described the universe as a cyclical or oscillating universe in which a "cosmic egg" or ***Brahmanda*** containing the whole universe including the sun, moon, and planets and all of the space expands out a single concentrated point called a ***Bindu*** before subsequently collapsing again.



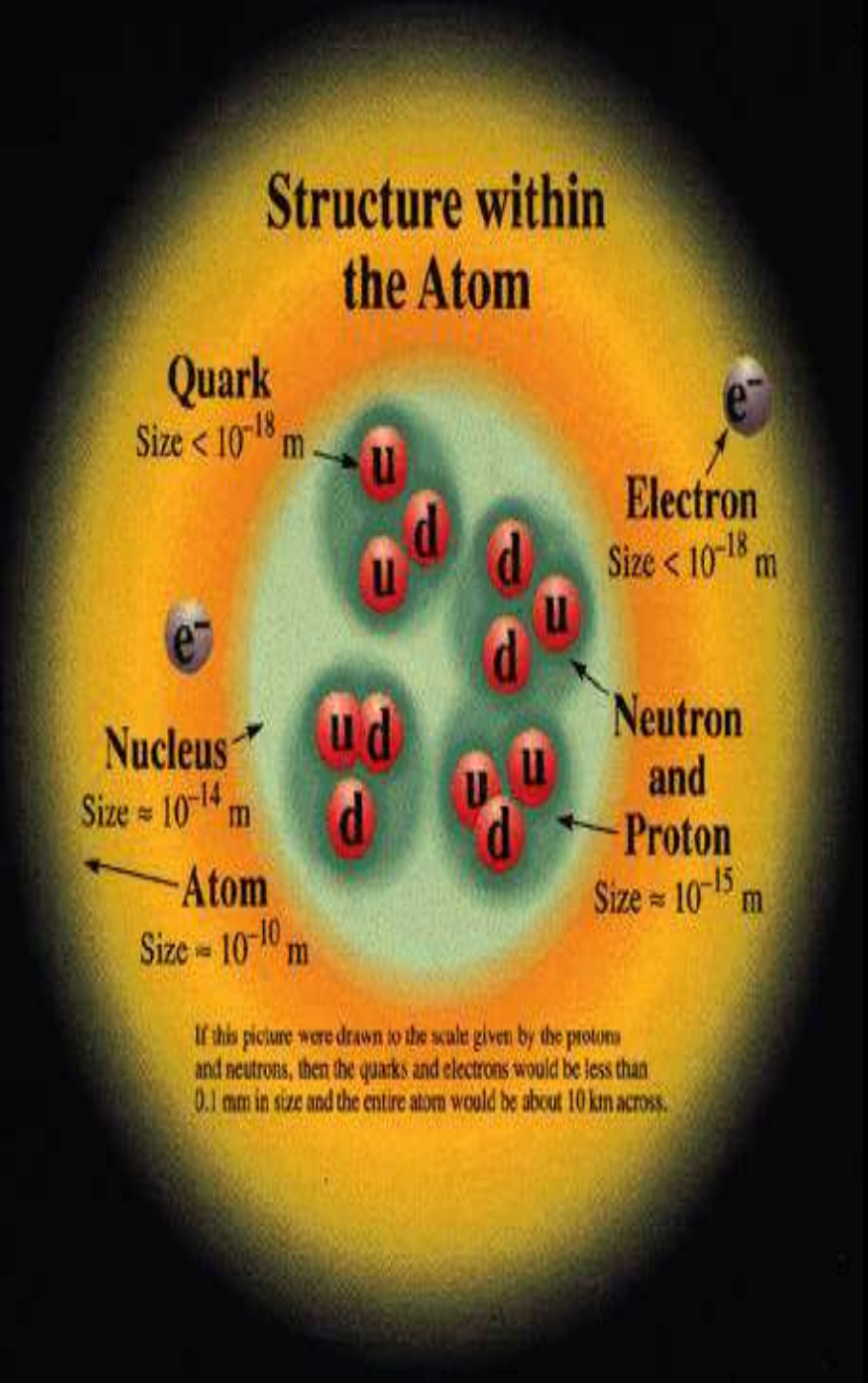
**Primordial universe (5th century BCE)**—the Greek philosopher **Anaxagoras** believed that the original state of the cosmos was a primordial mixture of all its ingredients, which existed, in the infinitesimally small fragments of themselves.

This mixture was not entirely uniform, and some ingredients were present in high concentrations than others, as well as varying from place to place.

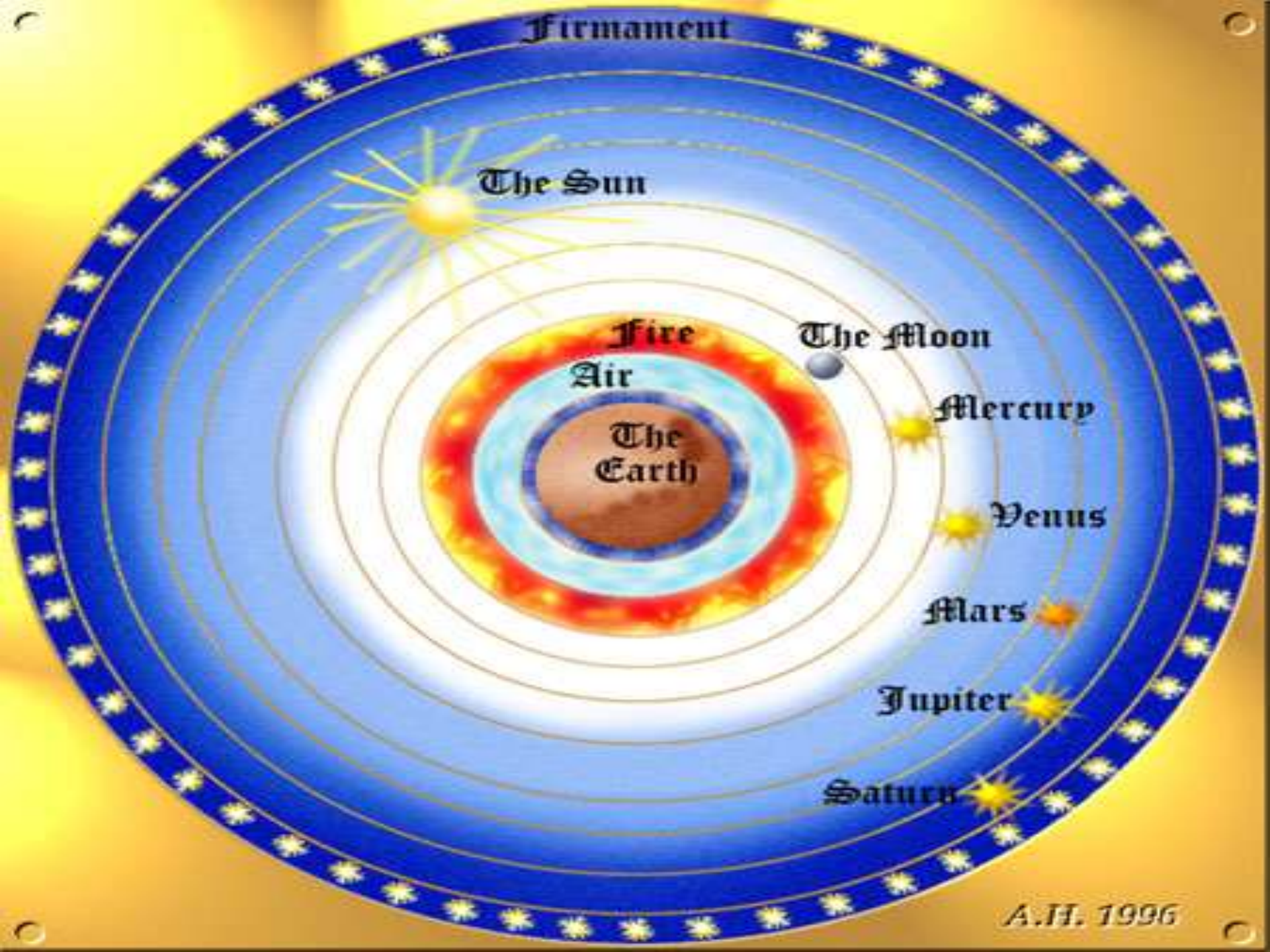
At some point in time, this mixture was set in motion by the action of "**nous**" **or mind**, and the whirling motion shifted and separated out the ingredients, ultimately producing the cosmos of separate material objects, all with different properties, that we see today.

**Atomic universe (5th century BCE)**—the Greek philosophers **Leucippus** and **Democritus** founded the school of Atomism where they held that the universe was composed of very small, indivisible and indestructible building blocks known as atoms.

All of reality and all the objects in the universe are composed of different arrangements of these eternal atoms and an infinite void in which they form different combinations and shapes.


Structure within the Atom
Quark
Size < $10^{-18}$ m
Electron
Size < $10^{-18}$ m
Nucleus
Size ≈ $10^{-14}$ m
Neutron and Proton
Size ≈ $10^{-15}$ m
Atom
Size ≈ $10^{-10}$ m
If this picture were drawn to the scale given by the protons and neutrons, then the quarks and electrons would be less than 0.1 mm in size and the entire atom would be about 10 km across.

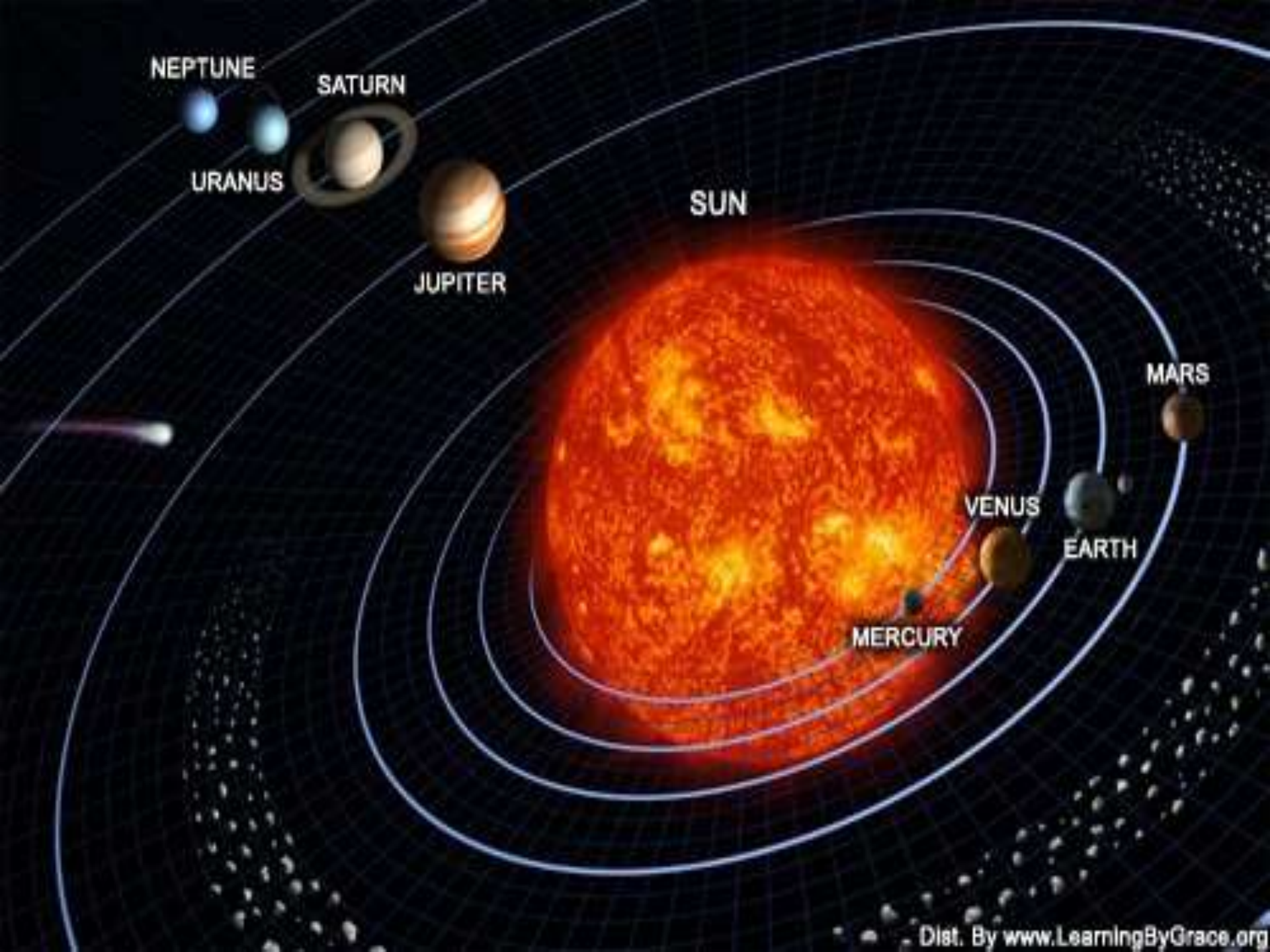
**Aristotelian universe (4th century BCE)**—**Aristotle** established a geocentric universe in which fixed, spherical Earth is at the center surrounded by concentric celestial spheres of planets and stars and four classical elements of fire, air, earth, and water., which were acted on by two forces—gravity, which is the tendency of Earth and water to sink, and, levity, which is the tendency of air and fire to rise.


Firmament
The Sun
Fire
Air
The Earth
The Moon
Mercury
Venus
Mars
Jupiter
Saturn
A.H. 1996

**Stoic universe (3rd century BCE)**—the Stoic philosophers of ancient Greece believed that the universe is like a giant living body, with its leading part being the stars and the sun in which all parts are interconnected. What happens in one place affects what happen elsewhere.

**Heliocentric universe (3rd century BCE)** –the Greek astronomer and mathematician **Aristarchus** of Samos was the first person to present an explicit argument for a heliocentric model of the solar system, placing the sun, not the Earth, at the center of the known universe.

He described the Earth as rotating daily on its axis and revolving annually about the sun in a circular orbit along with sphere of fixed stars.


NEPTUNE
SATURN
URANUS
JUPITER
SUN
MARS
VENUS
EARTH
MERCURY
Dist. By www.LearningByGrace.org

**Seleucus of Selucia** who lived about a century after Aristarchus supported this theory and used tides to explain heliocentricity and the influence of the Moon.

# Quiz

_____1. It is a top prevailing theory that best explains the origin of the universe.

_____2. It is a thermal radiation used in observational cosmology because it is considered the oldest light in the universe.

_____3. It refers to the rapid expansion of space-time.

_____4. It is considered the age of the universe.

_____5 . It is referred to as the afterglow of the big bang.

_____6. _____7. They are the proponents of the Cosmic Inflation Theory.

_____8. According to this theory, the early universe was a rapidly expanding bubble of pure vacuum energy.

_____9. According to this theory, the universe is always expanding.

_____10. It is formed when the universe is always expanding.

_____11-13. The proponents who revised the Steady State Theory.

_____14. The first scientist to propose the Steady State Theory.

_____15. It is the theory that describes universe as a cosmic egg.

_____16. According to this theory, universe is a mixture of all its ingredients, which existed, in the infinitesimally small fragments of themselves.

_____17. _____18. The Greek philosophers who founded the school of Atomism

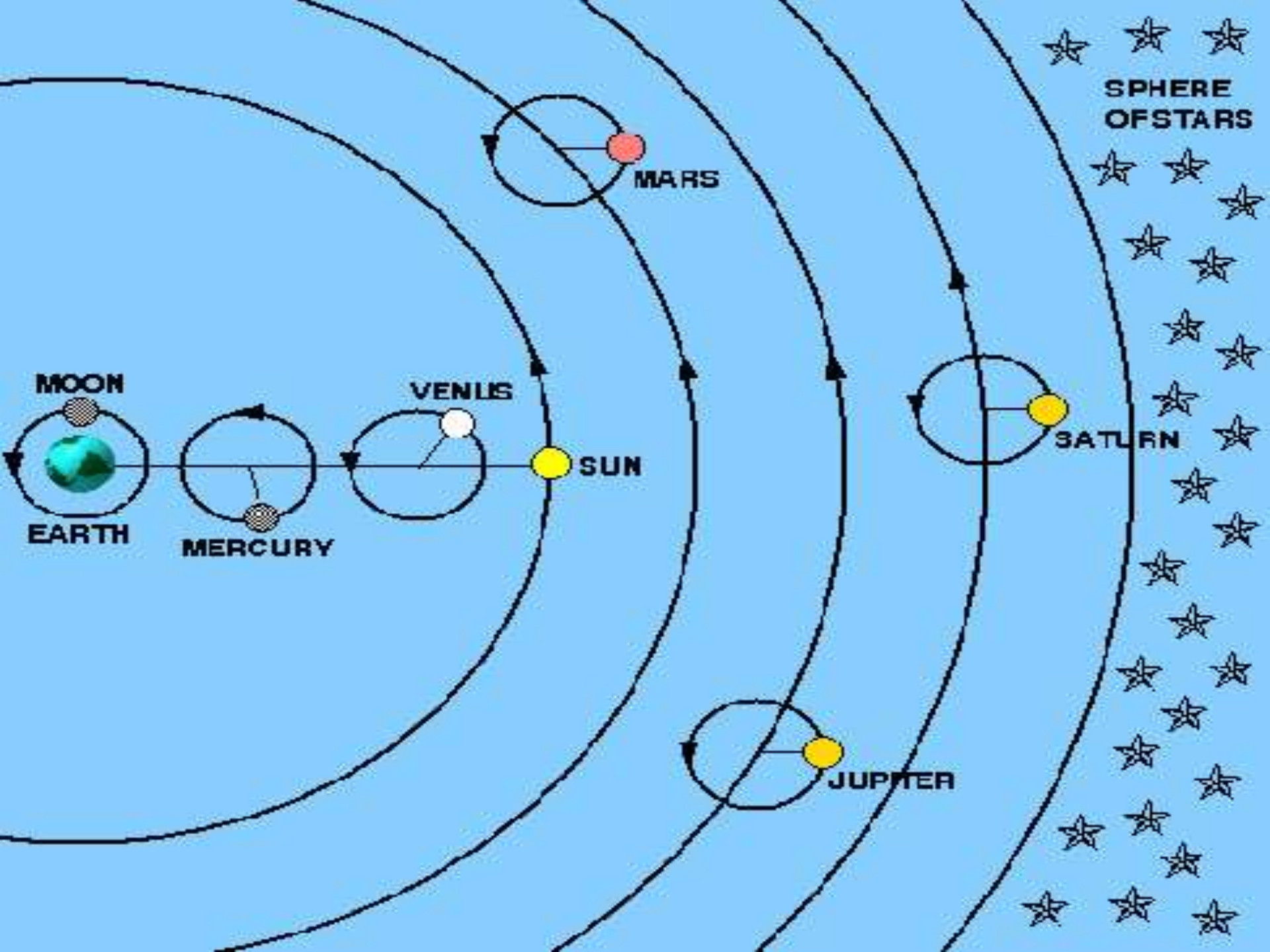
_____19. It is a very small, indivisible and indestructible building blocks of the composition of the universe.

_____20. State the things you learned about the Theories of the origin of the universe. (6pts.)

1. Big Bang Theory
2. Cosmic Microwave background
3. Inflation
4. 13. 7 billion years
5. CMB
6. Alan Guth
7. Andrei Linde
8. Cosmic Inflation Theory
9. Steady State Theory
10. Matter
11. Sir Fred Hoyle
12. Hermann Bondi
13. Thomas Gold
14. Sir James Jeans
15. Cyclical Universe
16. Primordial universe
17. Leucippus
18. Democritus
19. atom

**Ptolemaic universe (2nd century CE)** –the Roman-Egyptian mathematician and astronomer

**Claudius Ptolemaeus** described a geocentric model of the universe based on the theory of Aristotle in which planets and the rest of the universe orbit a stationary Earth in circular epicycles.


SPHERE
OFSTARS
MARS
MOON
VENUS
SUN
SATURN
EARTH
MERCURY
JUPITER

**Abrahamic universe (6th century CE)** –Several medieval Christian, Muslim, and Jewish scholars put forward the idea of a universe, which was finite in time.

Christian philosopher **John Philoponus of Alexandria** was the first to argue that the universe is finite in time and therefore had a beginning.

Muslim theologians such as **Al-Kindi in the 9th century CE** and **Al-Ghaali in the 11th century CE**, Jewish philosopher **Saadia Gaon in the 10th century CE** supported a finite universe.

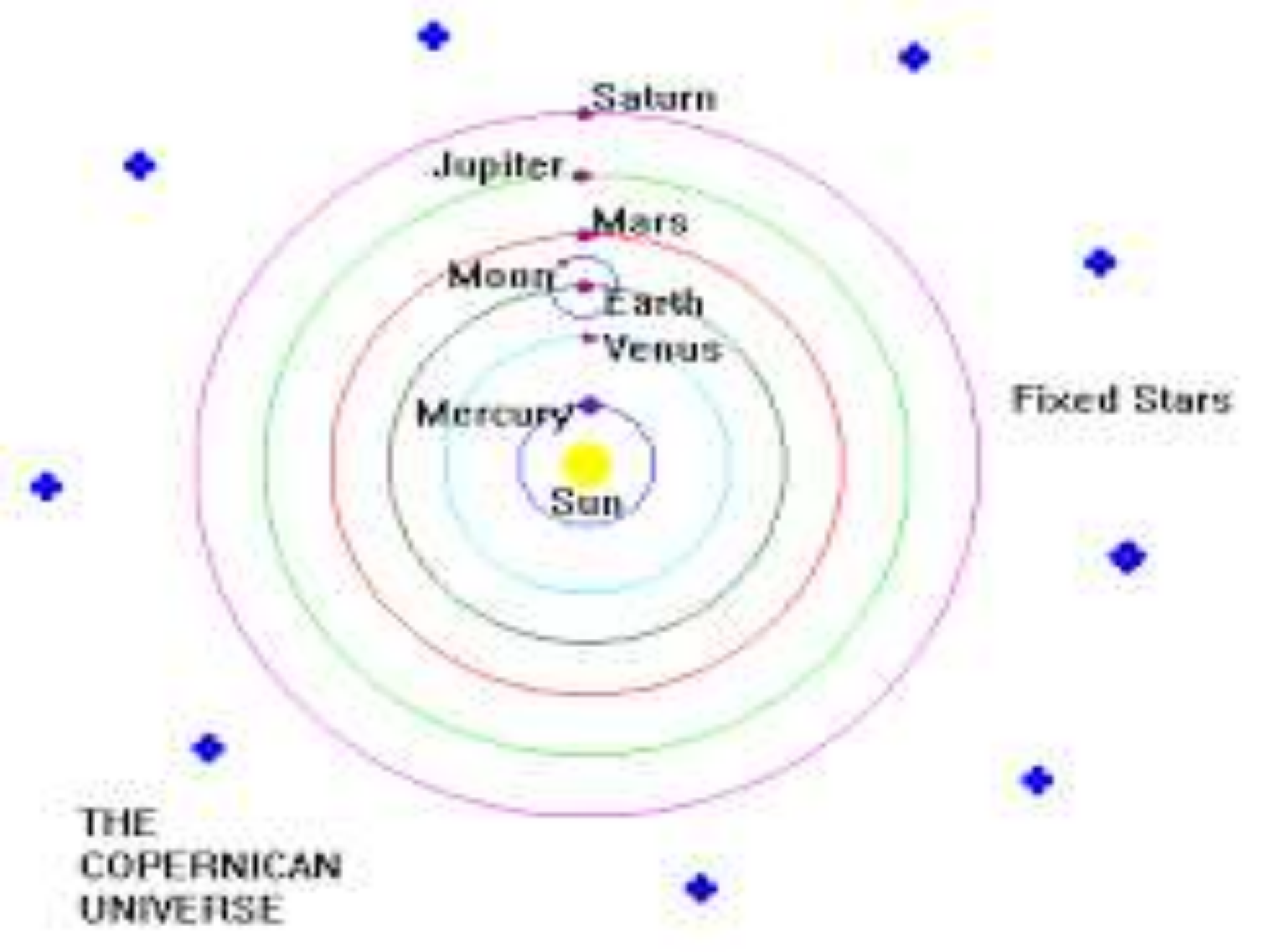

And God said,
Let there be...

## Partially heliocentric universe (15th to 16th century CE)

—**Somayaji Nilakantha** of the Kerala School of Astronomy and Mathematics in southern India developed a computational system for a partially heliocentric planetary model in which the planets Mercury, Venus, Mars, Jupiter, and Saturn orbited the sun, which in turn orbited Earth.


Jupiter
Mars
Venus
Saturn
Mercury
Sun
Earth
Moon

**Copernican universe (1543)** –The Polish astronomer **Nicolaus Copernicus** adapted the geocentric Maragha of Ibn al-Shatir to meet the requirements of the heliocentric universe of Aristarchus.




THE
COPERNICAN
UNIVERSE

# Reflect upon:

Make a reaction paper  based on the documentary research on the extreme orbits and formation of the stars, galaxies and planets.

½ cross-wise sheet of white paper.

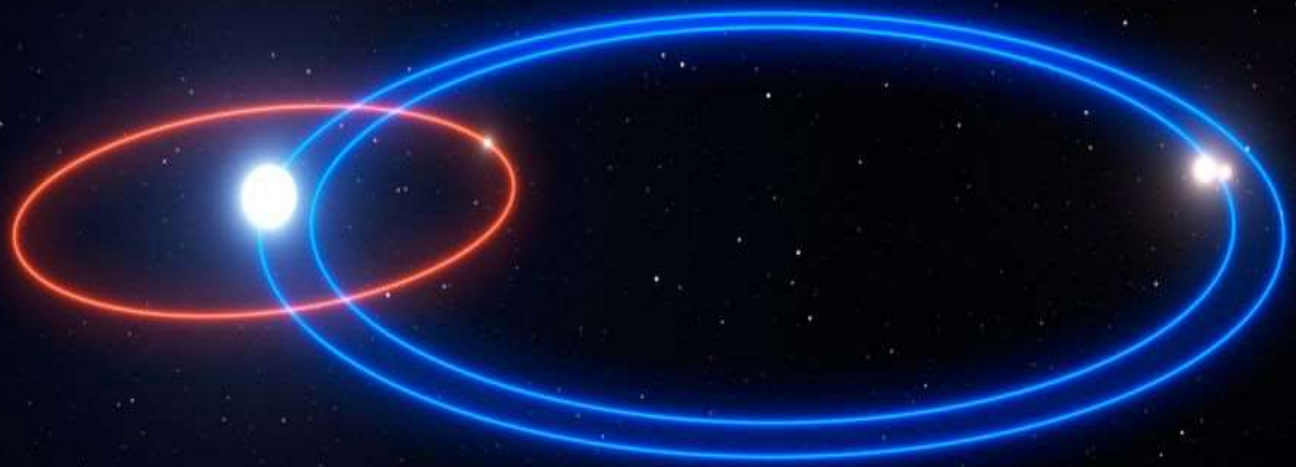
# Triple sunrises, sunsets at this strange new world

Astronomers revealed such a place Thursday: a strange new world in the Constellation Centaurus that has not one, not two, but three suns. What's more, a year there lasts half a millennium from Earth's perspective.

Triple-star systems with detected planets are rare enough; this is believed to be just the fifth such discovery. But the giant gassy world in this one — formally known as **Planet HD 131399Ab** — has the biggest known orbit in a multi-star system.

"Informally, we called in "The Planet," Apai said in an email. "But with more possible planet candidates in sight, we will have to change this soon."

# What else can they discover?



# Solar System: Properties and Current Information

The solar systems show remarkable regularities in some properties? These regularities are observed in the motion and location of the planets and their satellites.

**Among these observed regularities are the following:**

1. The orbits of all the planets are almost in the same plane.
2. The planetary orbits are nearly circular.
3. The orbits of the planets are nearly in the same plane as the rotation of the sun.
4. All planets revolve around the sun in a counter clockwise direction.
5. The distances of the planets from the sun can be expressed in a similar relationship called Bode's law.

**Bode's Law** was named after the German astronomer **Johann Bode** (1747-1826).

According to this law, the calculated distances and the observed distances of the planets from the sun are almost the same with the exception of Neptune and pluto.

6. The satellite systems of Jupiter and Saturn are nearly identical in their arrangements with the solar system.
7. The satellites and planets contain almost all the rotational motion of the solar system.
8. The solar system also contains asteroids and comets.

# Asteroids

-- are made up of rocks and are sometimes referred as minor planets in many ways.

-- are atmosphere-free and orbit around the sun.

-- tend to congregate in what is known as main **asteroid belt.**

Main belt asteroids are located between the orbits of Mars and Jupiter.

# Still on Asteroids…

-- are thought of as remnants from the early stages of the solar system formation.

-- never formed into planets because of Jupiter's high gravitational force.

The first known asteroids is named **Ceres**.

There are asteroids that can be perturbed out of their main belt and may especially come close to Earth.

They are called ***near-earth asteroids (NEAs).***

NASA is monitoring these asteroids because of the possibility of them hitting Earth which could cause catastrophic consequences.

# Performance Tasks: Project output

**Group 1** : Solar system model—sun, 8 planets, asteroid belt, kuiper belt

**Group 2**: Earth's Structure—layers and sub-layers and the 2 boundaries

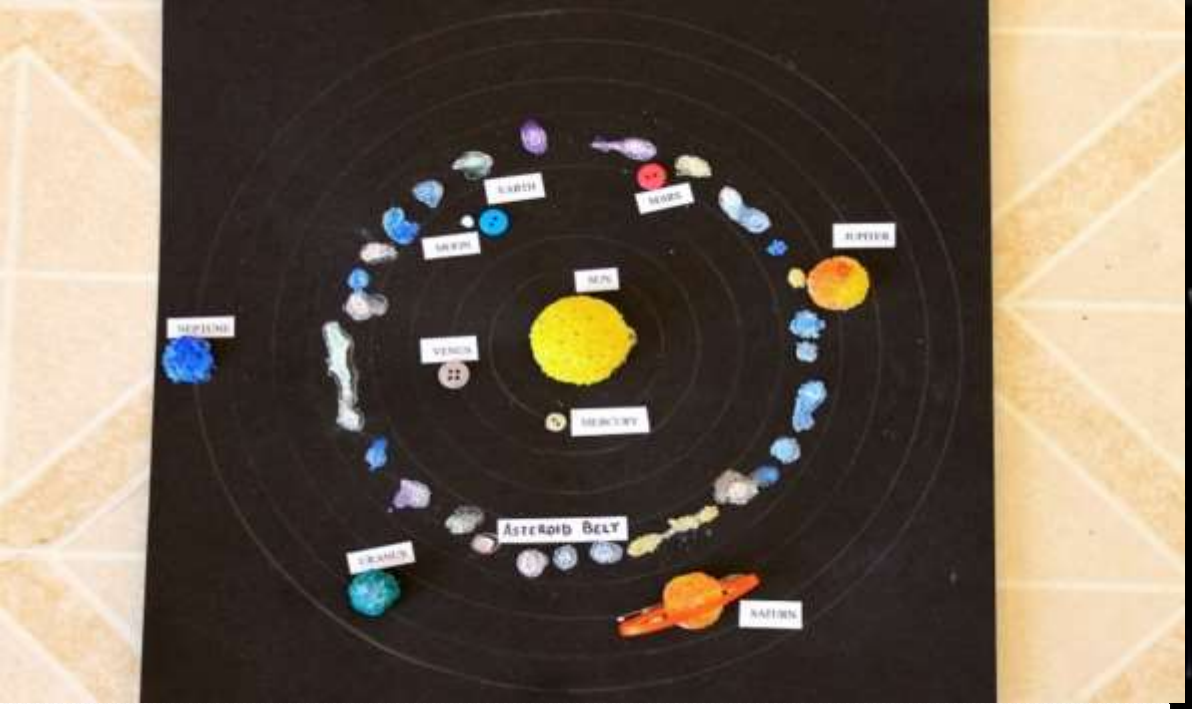
**Group 3**: Pangea-Continental map with 3 types of tectonic plate boundaries

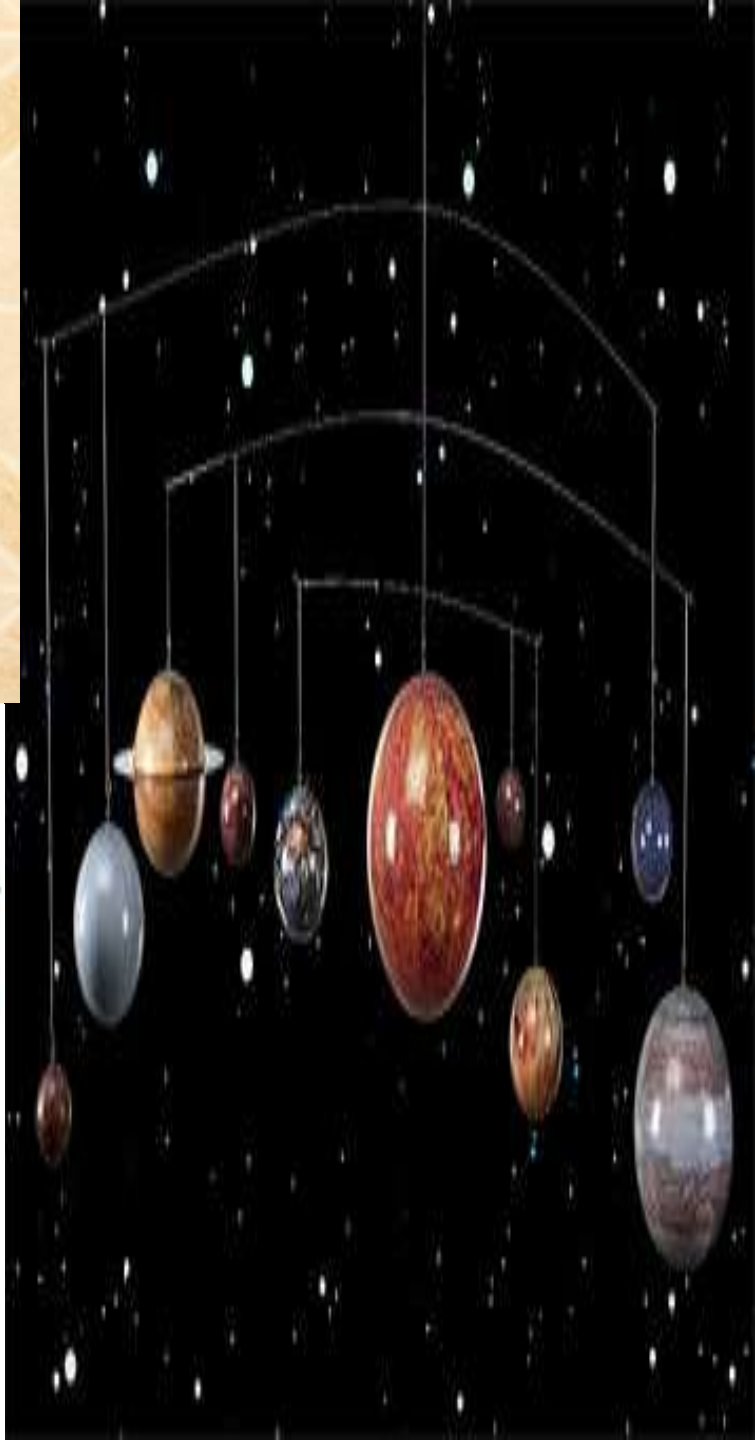
**Group 4**: Earth model showing the layers of the atmosphere

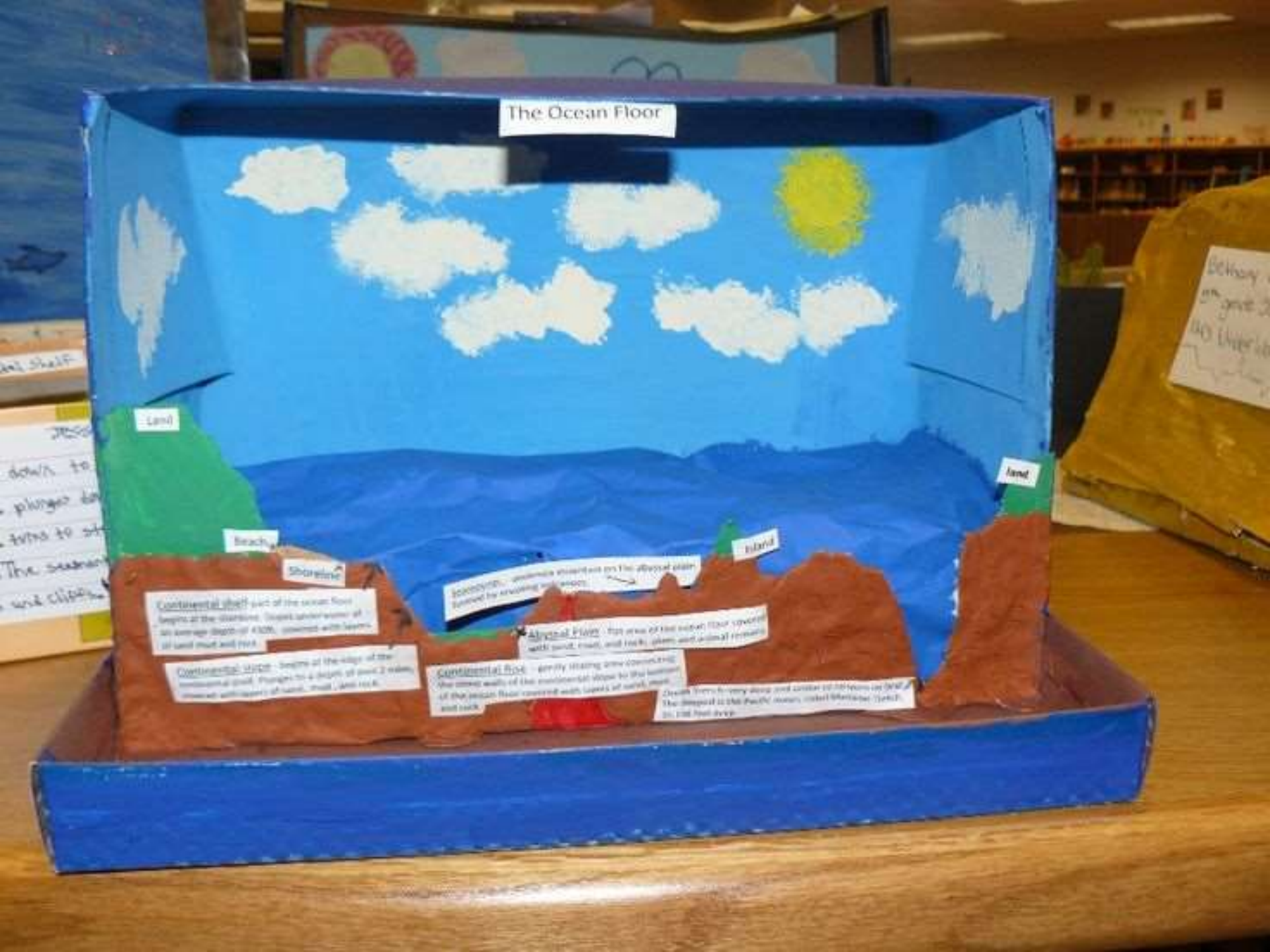
**Group 5**: Model of a hydrosphere—horizontal ocean zones from coastal zone to ocean zone

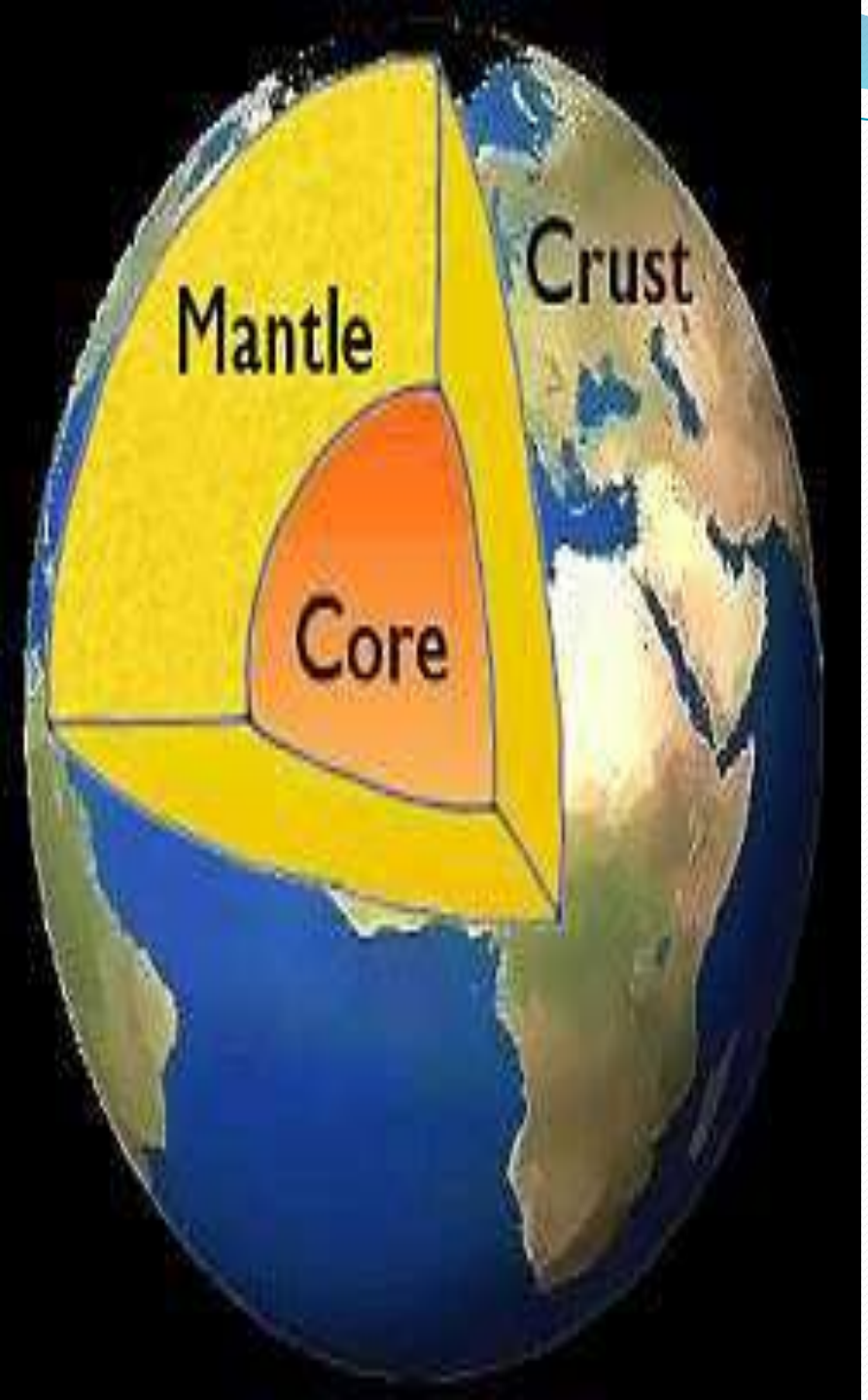
**Group 6**: Design and make a terrarium to represent a model of a biosphere.


Plants
Potting Soil
Charcoal
Rocks

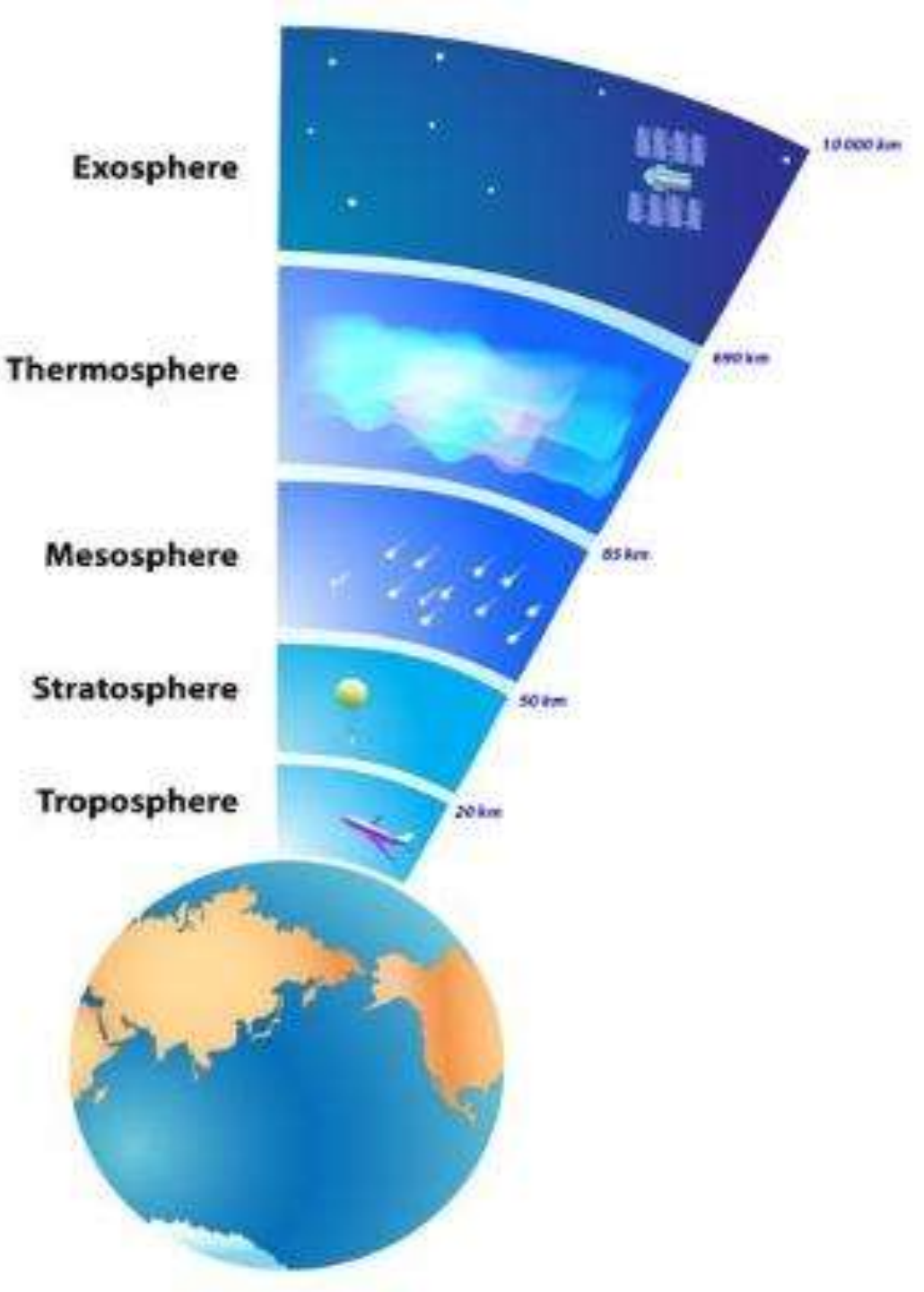

EARTH
MARS
JUPITER
SUN
VENUS
MERCURY
ASTEROID BELT
SATURN




The Ocean Floor
Land
Beach
Shoreline
Continental shelf
Continental slope
Abyssal Plain
Continental Rise
Island
land


Mantle
Crust
Core

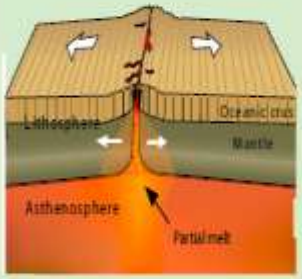

Description Key for Layers of Earth
Crust
Mantle
Outer Core
Inner Core
(c)BongCookBook
Crust


Exosphere
Thermosphere
Mesosphere
Stratosphere
Troposphere
10 000 km
690 km
85 km
50 km
20 km



## Divergent Boundaries & Spreading Zones

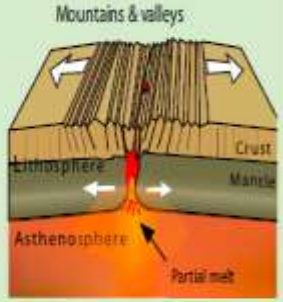
**Spreading center—Fast**




Divergent boundaries occur mostly along spreading centers where the magma rises forming new crust. (Ex. East Pacific Rise, Mid Atlantic Ridge.)

Spreading zones (no graphic) on continents create parallel mountains and valleys as the crust pulls apart (ex: Basin & Range, U.S. and the Great Rift Valley, Africa.)

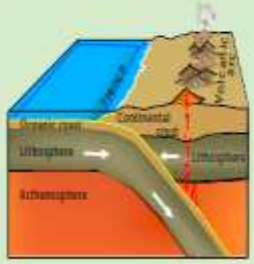
**Spreading center—Slow**



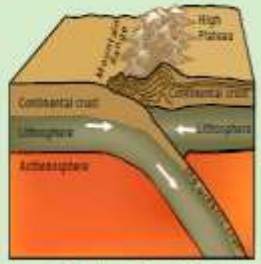

## Convergent Boundaries

When two plates move toward each other, crust is destroyed as one plate dives (is subducted) beneath the other. The location where sinking of a plate occurs is called a subduction zone.


**Ocean-Ocean**—Ocean plate dives beneath another ocean plate; volcanic island chain forms above the zone (ex. The Marianas)




**Ocean-Continent:** Ocean plate dives beneath a continental plate. Volcanic mountain chain forms inland. (ex. Cascade Range, Sumatra, Japan)




**Continent-Continent:** Two thick continental plates collide and buckle into high mountains. (ex: Himalaya Mountain Range.)

# The Evolution of Earth

- **How did the planet Earth evolve?**
- **Earth Materials**

Earth has naturally occurring materials of which many are necessary for existence. Earth materials include minerals and rocks. These materials, along with other materials such as soil, water, air, and organic matter are essential for the growth and survival of organisms, the structure of the land, and the development of human civilization. All these Earth materials give information about the history of Earth and of life.

**Group activity:**

Each member of the group brings 3 – 5 different rocks taken from different places like mountain, beaches, river banks, road cuts, vacant lots ect.

Ask permission from owner's especially private lands. Observe care in collecting sample.

Classify the rocks based on thin characteristic features. You may use magnifying glass to help you describe their features.

Can you infer the origin of the rocks based on their properties? Cite evidences.

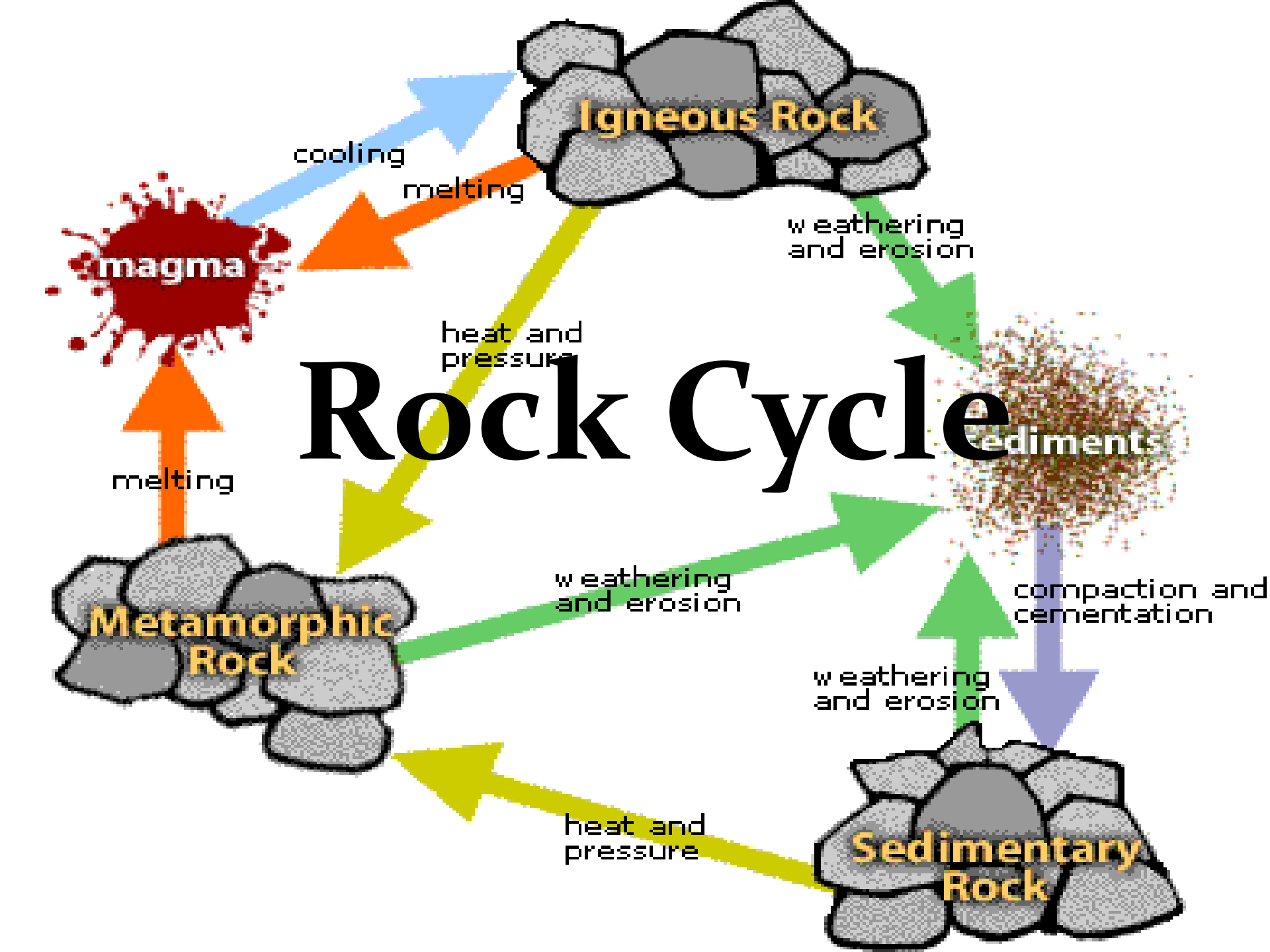
Share your finding to the class.

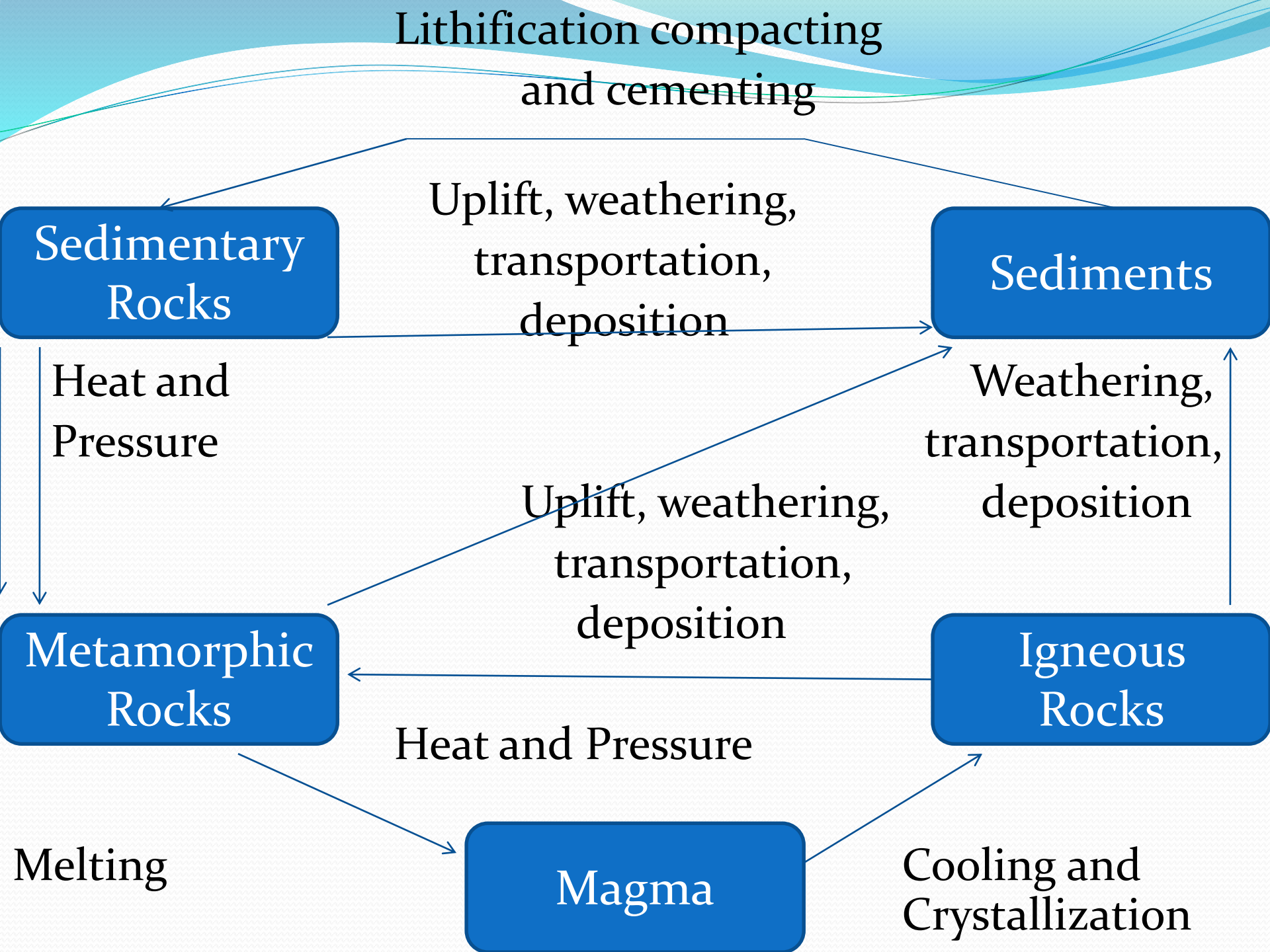
**Follow up questions:**

1. Based on your activity, how did you classify rocks?

2. Are there features common to one group of rocks?

3. Do the feature tell the origin of the rocks?


Igneous Rock
cooling
melting
magma
weathering
and erosion
heat and
pressure
Rock Cycle
melting
Sediments
Metamorphic
Rock
weathering
and erosion
compaction and
cementation
weathering
and erosion
heat and
pressure
Sedimentary
Rock


Lithification compacting and cementing
Sedimentary Rocks
Uplift, weathering, transportation, deposition
Sediments
Heat and Pressure
Weathering, transportation, deposition
Uplift, weathering, transportation, deposition
Metamorphic Rocks
Igneous Rocks
Heat and Pressure
Melting
Magma
Cooling and Crystallization

# Igneous Rocks

Igneous rocks came from Latin "**Ignis**" which means "**fire**". The rocks are formed by volcanic activity.

**Magma** is molten rock generated by partial melting of rocks in the Earth's mantle. It consists mainly of **Si** and **O2**, and lesser amounts of **Al, Ca**, **Na**, **K**, **Mg**, and **Fe**.

## 2 Types of Igneous Rocks:

1. **Extrusive Igneous Rock** or **Volcanic** – when molten rocks solidifies at the surface called **Lava**.

2. **Intrusive Igneous Rocks** or **Plutonic** – when most magma loses its mobility before reaching the surface and crystallizes at depth.

- Extrusive igneous rocks
- Formed from lava “exiting” the volcano and cooling quickly
- Forms fine-grain crystals

Andesite

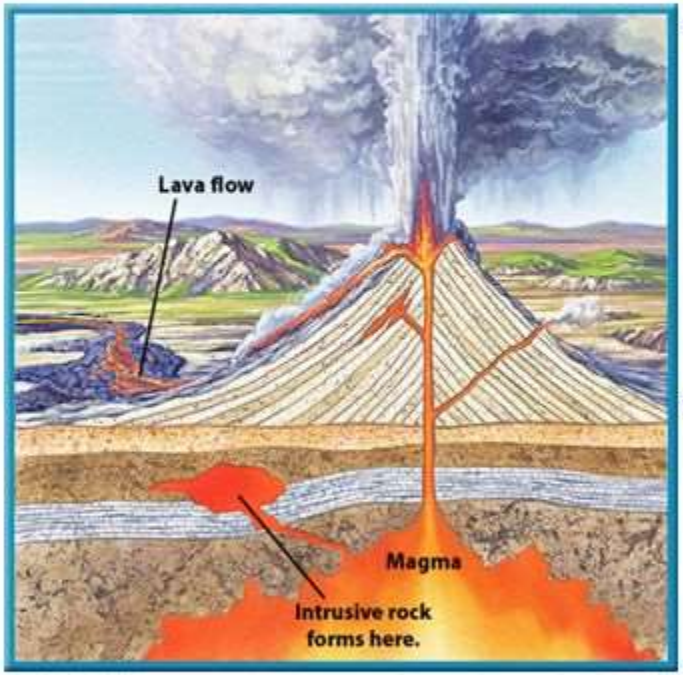

Basalt


Obsidian

Pumice


Rhyolite

# Intrusive Igneous Rocks




- Igneous rocks that form below the Earth's surface are called intrusive igneous rocks.
- They form when magma enters a pocket or chamber underground that is relatively cool and solidifies into crystals as it cools very slowly.

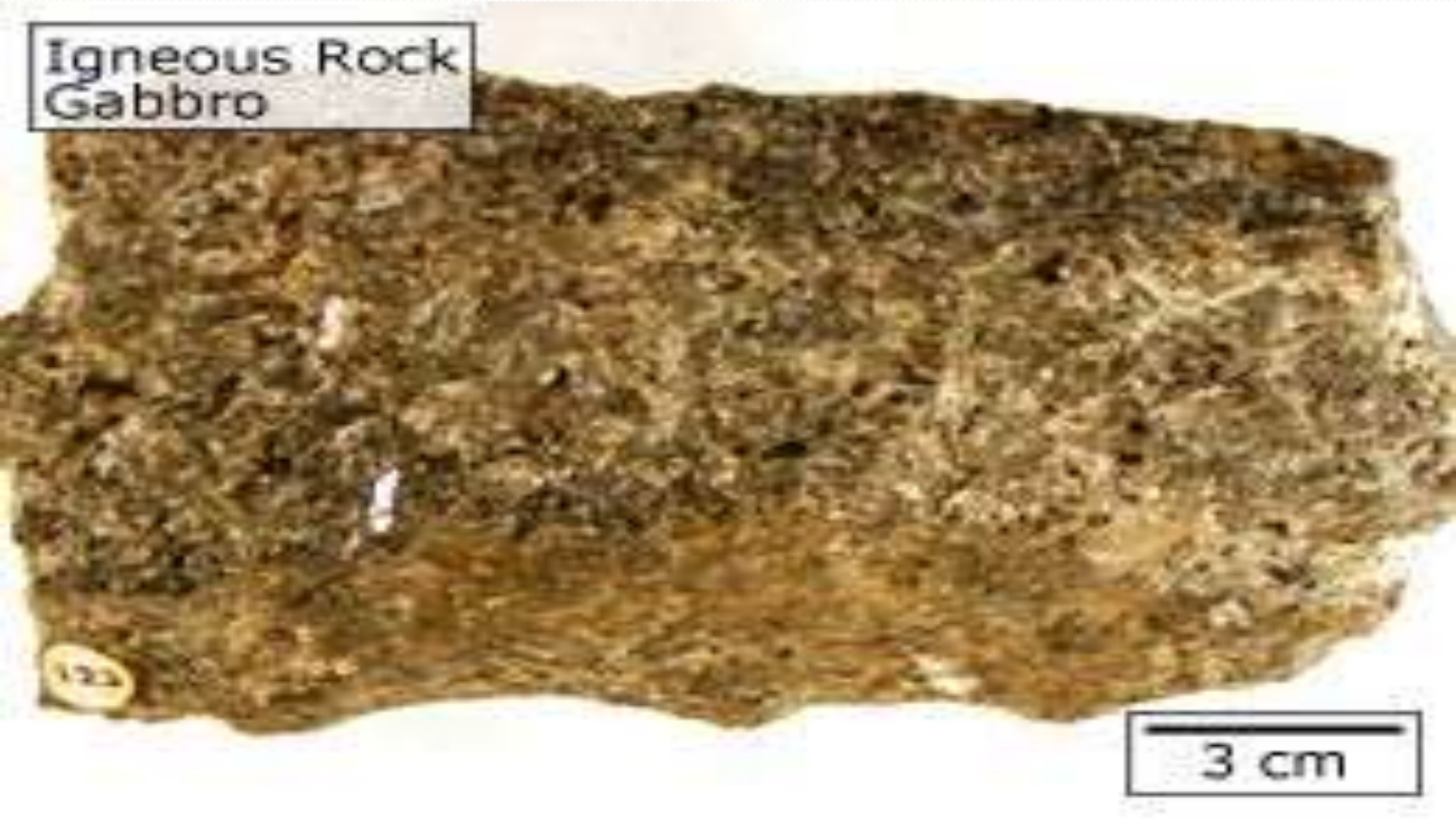
Igneous rocks may be characterized by their **texture** and **composition.**

**Texture**

-- describes the overall appearance of the igneous rocks based on the size, shape, and arrangement of the interlocking crystals.

- **<u>Coarse-grained</u>** – grains (crystals) can be seen with bare eyes

- **<u>Medium-grained</u>** – grains can only be seen through hand lens



- **<u>Fine-grained</u>** – grains can only be seen trough the microscope

## Fine-grained




## Mineral Composition

The mineral compositions are based on the chemical makeup of the parent magma. They may be divided according to light and dark colored materials such as:

- **<u>Light-colored</u>** like granite and ryolite composed of feldspar and quartz

- **<u>Medium-colored</u>** including diorite and andesite

- **<u>Dark-colored</u>** including gabbro rock and basalt composed mainly of pyroxene, calcium-rich plagioclase feldspar.


Table 4.1

IGNEOUS ROCKS CLASSIFIED BY COMPOSITION

| Texture/Color | Light | Medium | Dark |
|---|---|---|---|
| Coarse-Grained (Intrusive) | Granite | Diorite | Gabbro |
| Fine-Grained (Extrusive) | Rhyolite | Andesite | Basalt |

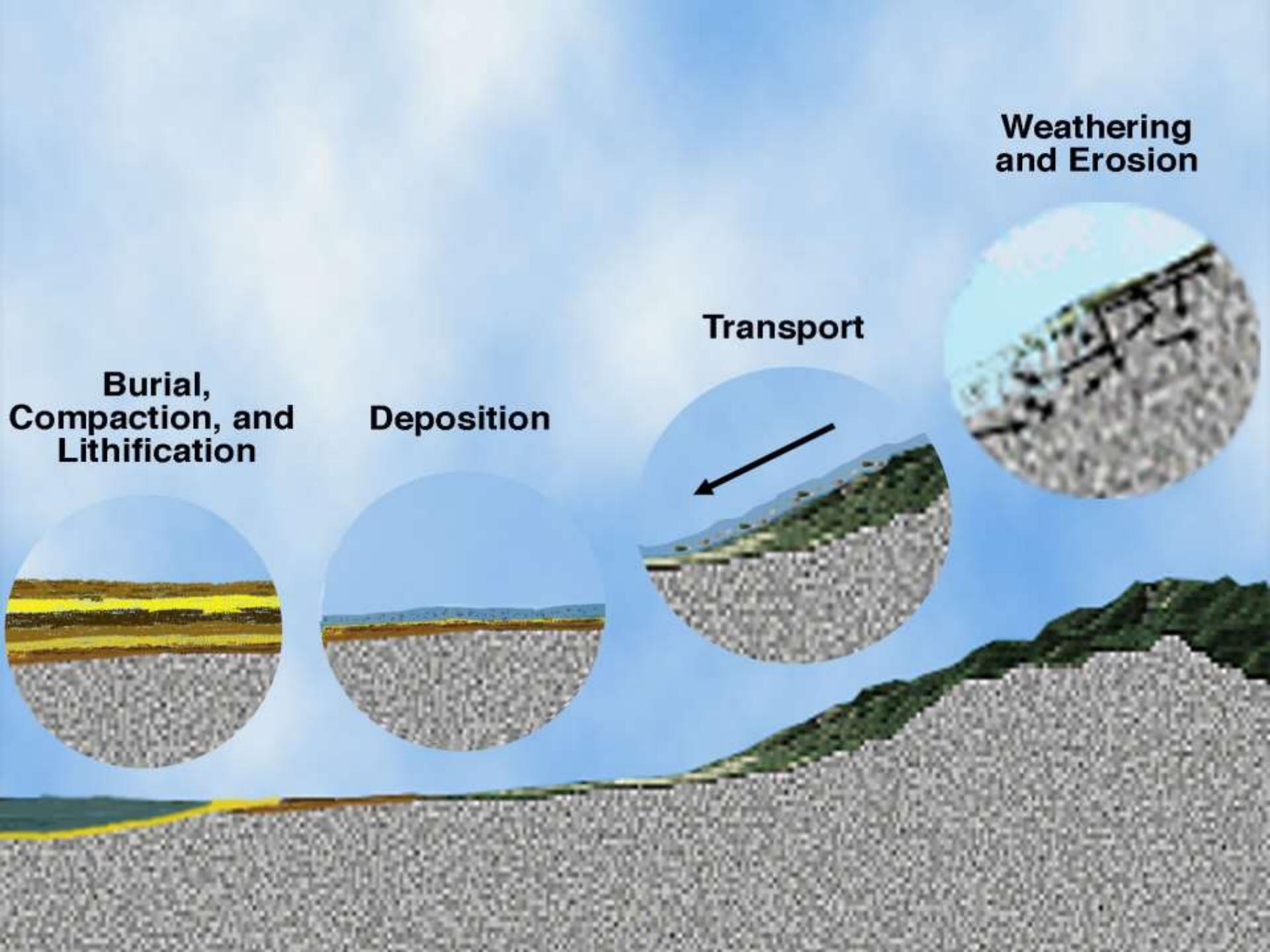
## Sedimentary Rocks

As shown in the rock cycle, sediments result from the uplift and weathering which are then transported and deposited in different areas.

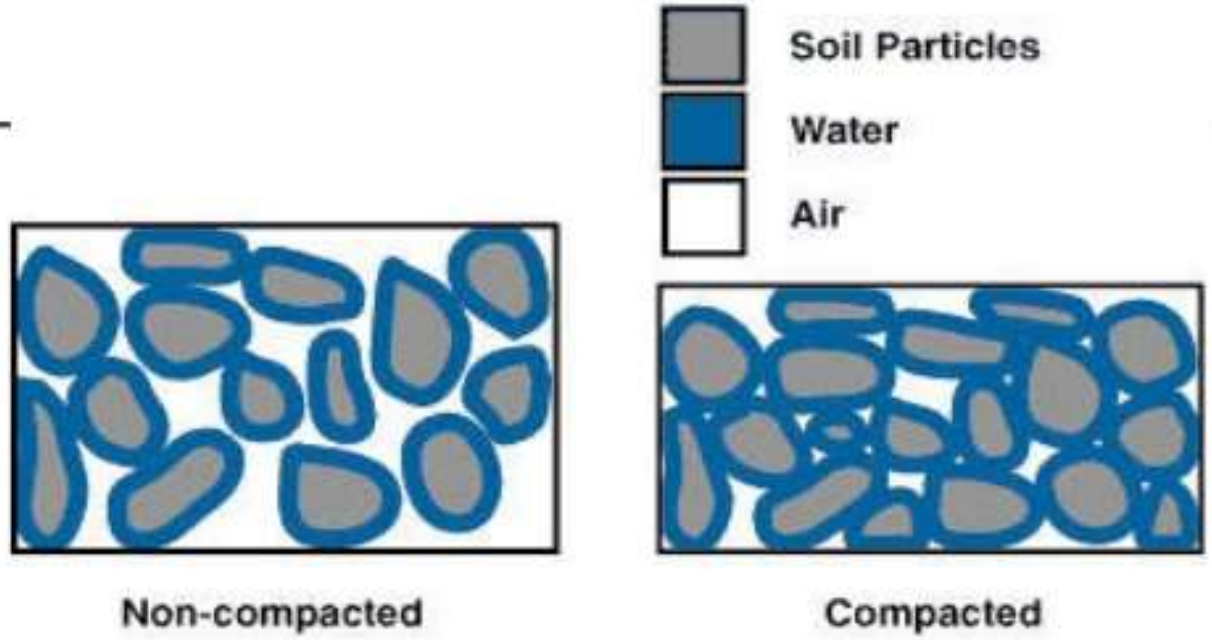
# Sedimentary Rocks

- Made up of smaller rocks cemented together
- Sometimes have fossils
- Usually have layers.





Weathering
and Erosion
Transport
Deposition
Burial,
Compaction, and
Lithification

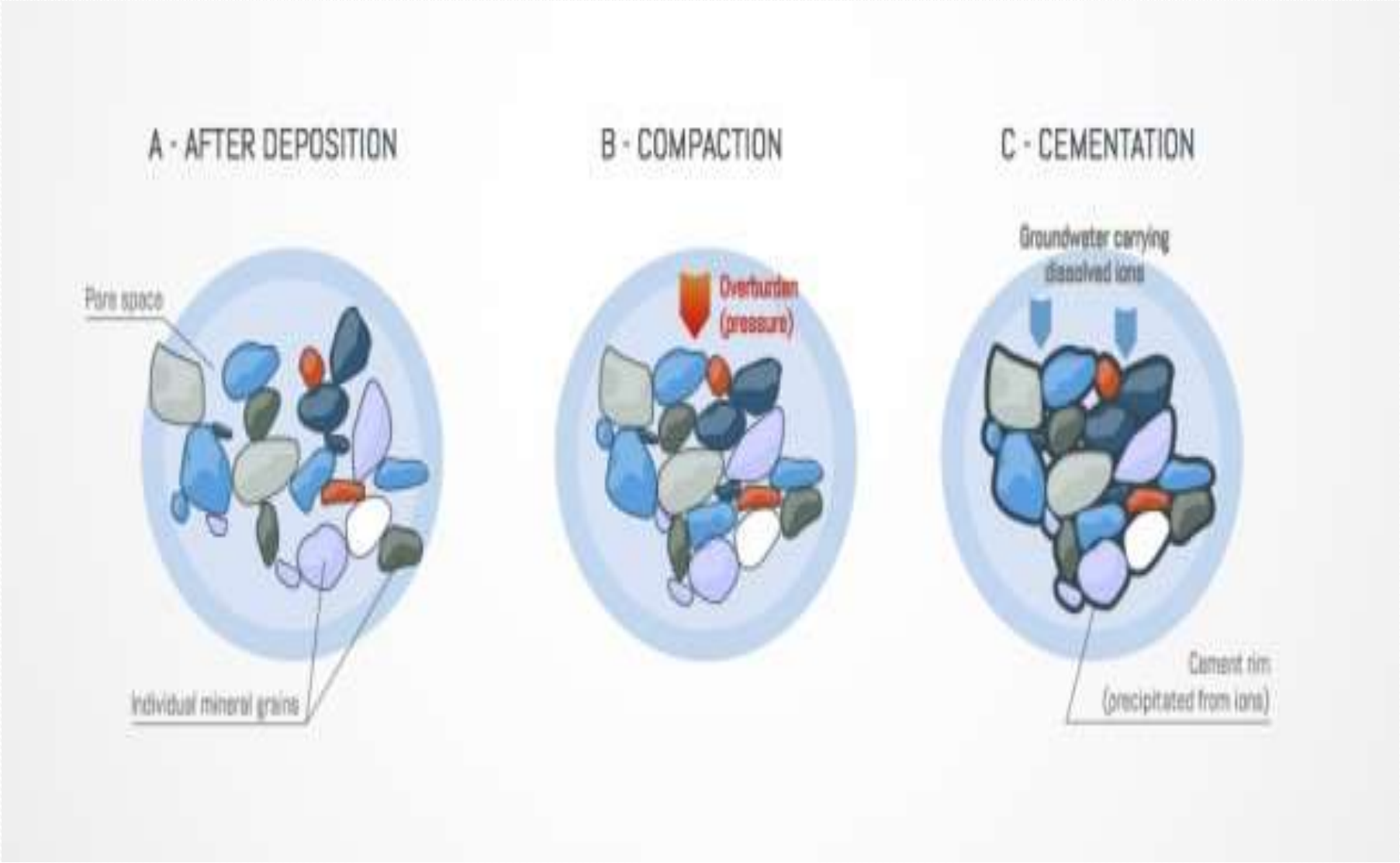
# COMPACTION-DEFINITION




Thus, SOIL COMPACTION is the process to increase the soil (ground) density in order to make use the ground surface for development, ie, building, road, etc.

The volume of void space is reduced by applying high loads over a small area to force the air out of an unsaturated soil mass.

3. **<u>Cementation</u>** – is another process by which sediments are converted to sedimentary rock.



→Sedimentary rocks are of particular importance to Earth's history.

As layer upon layer of sediments are accumulated, they carry with them the records of the nature of environment at the time the sediments are deposited.

These layers are called **strata.** Fossils are only found in the sedimentary rocks.

## Types of Sedimentary Rocks based on sources:

**1.Detrimental sedimentary rocks** – from weathered rocks such as igneous rocks.

**2. Chemical sedimentary rocks** – from soluble material produced largely by chemical weathering.

Table 4.2

Classification of Detrital Sedimentary Rocks Based on Particle Size

| Partial Size | Sediment Name | Rock Name |
|---|---|---|
| Coarse | Gravel (rounded particles)<br>Gravel (angular particles) | Conglomerate<br><br>Breccia |
| Medium | Sand | Sandstone |
| Fine | Mud | Siltstone |
| Very fine | Mud | Shale |

Table 4.3

Classification of Sedimentary Rocks Based on Chemical Composition

| Composition | Rock Name |
|---|---|
| Calcite, $CaCO_3$ | Limestone<br>Coquina<br>Fossil Ferrous<br>Biochemical Limestone<br>Limestone<br>Chalk |
| Quartz, $SiO_2$ | Chert (Light Colored)<br>Flint (Dark Colored) |
| Gypsum, $CaSO_4$, $2H_2O$ | Rock Gypsum |
| Halite, Nacl | Rock Salt |
| Altered Plant fragments | Bituminous rock |

- Gravel and sand are used in building and road construction. The main composition of chalk is calcium carbonate. Glass is made up of silica, $SiO_2$.

- Gypsum is the main ingredient of plaster of paris.

- Halite is rock salt, used in cracking and seasoning foods.

## Metamorphic Rocks

*Metamorphic rocks* came from pre-existing rocks are called parent rock.

- The pre-existing rocks may undergo changes in the mineralogy, texture (like grain size) and chemical composition by the action of heat, pressure (stress) and chemical agents.

- The process of transformation of parent rock is called ***metamorphism.***

- The most important agent of metamorphism is **heat**.
- The parent rock is “baked” by magma.
- Another source of heat