

Components of the Solar System, Planets and Their Major Moons



The Formation of the Solar System: Nuclear Disc Model (Neo-Laplacian model)

Early Theories (With Limitations)

- **Nebular Hypothesis (Kant & Laplace):** Assumed solar system formed from a giant cloud (nebula). Got the nebula idea right, but had flawed assumptions.
- **Close Encounter Hypothesis (Chamberlain & Moulton):** Wandering star pulled material from the Sun, which later formed planets.
- **Revised Nebular Hypothesis (Schmidt & Weizascar):** Sun was surrounded by a nebula of gas and dust. Planets formed through collisions and clumping (accretion).

Modern Theories

- **Big Bang Theory:** Universe began with a massive expansion.
- **Nuclear Disc Model (Neo-Laplacian):** Focuses specifically on the solar system:
 - Nebula collapses about 5.6 billion years ago.
 - Sun and planets form roughly 4.6 billion years ago.

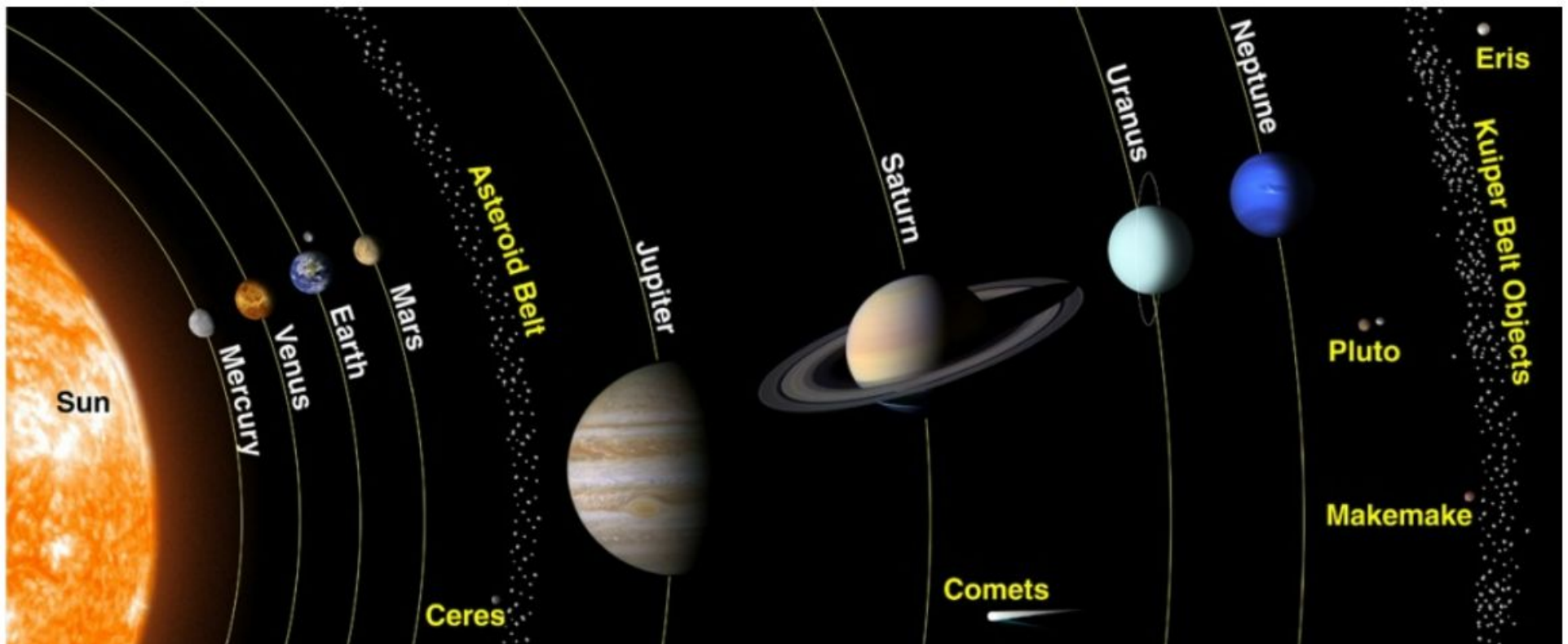
How the Planets Formed

1. **Accretion:** Dust particles collide and clump together within the nebula.
2. **Planetesimals:** Larger bodies form, up to a few kilometers across.
3. **Protoplanets:** Planetesimals continue to grow, attracting more material.
4. **Planets:** Protoplanets become large enough to sweep up remaining debris and form the planets we know.
5. **Planet Types:**
 - Inner Planets (Terrestrial): Closer to the Sun, made of rock and metals.
 - Outer Planets (Gas/Ice Giants): Farther from the Sun, formed where water ice was abundant.
6. **Leftovers:** Rocks that didn't become planets form asteroids and the asteroid belt.

Iron Catastrophe & Planetary Differentiation

- **Early Earth:** A hot, uniform ball of rock.
- **Iron Catastrophe:** Radioactive decay and leftover heat melt Earth's iron (around 500 million years after formation).
- **Planetary Differentiation:**
 - Heavy elements (iron, nickel) sink to the core.
 - Lighter materials (silicates, water) rise towards the surface.

Our solar system consists of the sun, eight planets, dwarf planets (Pluto, Ceres, Eris), satellites & countless minor planets, asteroids, meteors, comets, etc.



Key Ideas About the Solar System:

- **Heliocentric Model:** Nicolaus Copernicus pioneered the idea that the Earth and planets revolve around the Sun (not the other way around).
- **Ecliptic Plane:** Most objects orbiting the Sun, including planets, lie close to a flat plane called the ecliptic. Planets are close to the ecliptic, while comets and Kuiper belt objects often have greater angles to it.
- **Orbits:**
 - Planets: Nearly circular orbits around the Sun.
 - Comets, Asteroids, Kuiper Belt Objects: Often highly elliptical (oval-shaped) orbits.

Ancient Understanding of the Earth:

- **Spherical Earth:**
 - Pythagoras (around 500 BC) suggested the idea of a round Earth.
 - Aristotle (340 BC) provided evidence to support it.

Kepler's Laws of Planetary Motion:

- The orbit of a planet is an ellipse with the Sun at one of the two foci.
- A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
- The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Some values of the planet



Planet	Surface Temp in °C	Period of Rotation	Period of Revolution	Distance in AU	Diameter (km)		Size Rank	Moons	Density (gm/cm ³)	Specific gravity (m/s ²)	
1. Mercury	+427	58 days	87 days	0.4	4,878	0.38	8	0	5.4	3.7	0.38
2. Venus	+480	243 days	224 days	0.7	12,104	0.95	6	0	5.2	8.9	0.9
3. Earth	+22	23:56 hrs	365 days	1	12,756	1.00	5	1	5.5	9.8	1
4. Mars	-23	1.025 days	687 days	1.5	6,787	0.53	7	2	3.9	3.7	0.38
5. Jupiter	-150	9.9 hrs	11.9 years	5.2	1,40,000	11.19	1	79	1.3	24.9	2.53
6. Saturn	-180	10.7 hrs	29 years	9.6	1,16,000	9.46	2	82	0.7	10.4	1.06
7. Uranus	-214	17 hrs	84 years	19.2	51,000	4.11	3	27	1.3	8.8	0.9
8. Neptune	-220	16 hrs	164 years	30.0	48,000	3.88	4	14	1.6	11.1	1.13

Our Solar System

Original Graphic Courtesy of NASA

The Planets
Today.com

Radius (km):	2,440	6,052	6,371	3,389	69,911	58,232	25,362	24,622
Earth mass:	5.5%	81.5%	100%	10.7%	x317.8	x95.2	x14.5	x17.1
Orbit (earth time):	88days	224.7days	365.25days	1.9yrs	11.9 yrs	29.5yrs	84yrs	164.8yrs

Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune

Luna
Radius (km): 1,737
Earth mass %: 1.2
Orbit (earth days): 27.3

Asteroid Belt

Ceres

Radius (km): 476
Luna mass %: 0.015
Orbit (earth yrs): 4.6

Pluto

1,187
17.8
247.7

Haumea

~620
5.4
284.1

Makemake

~715
?
309.1

Eris

1,163
23
558

← Planets

← Dwarf Planets

Orbit distances from the Sun in billions of km



Distances and Light Years:

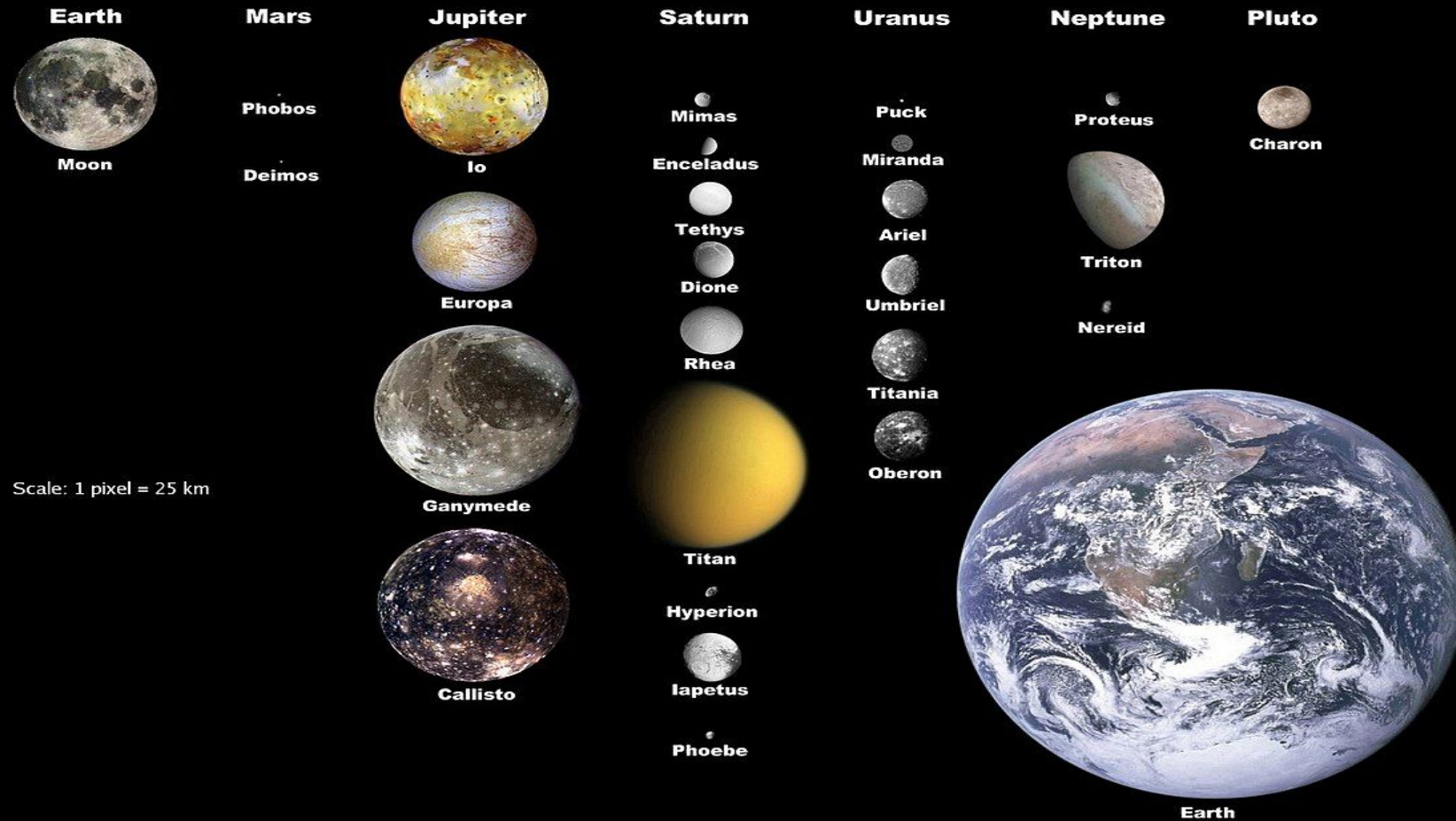
- Measure of distance, not time.
- Light travels at 3,00,000 km/second.
- One light year equals 9.461×10^{12} km.
- Mean distance from the Sun to Earth: 149,598,000 km.
- Earth-Sun distance in light years: 8.311 minutes of a year.

Time and Formation:

- Planets formed around 4.6 billion years ago.
- Solar nebula collapse and core formation about 5-5.6 billion years ago



Selected Moons of the Solar System, with Earth for Scale



How the Moon Formed

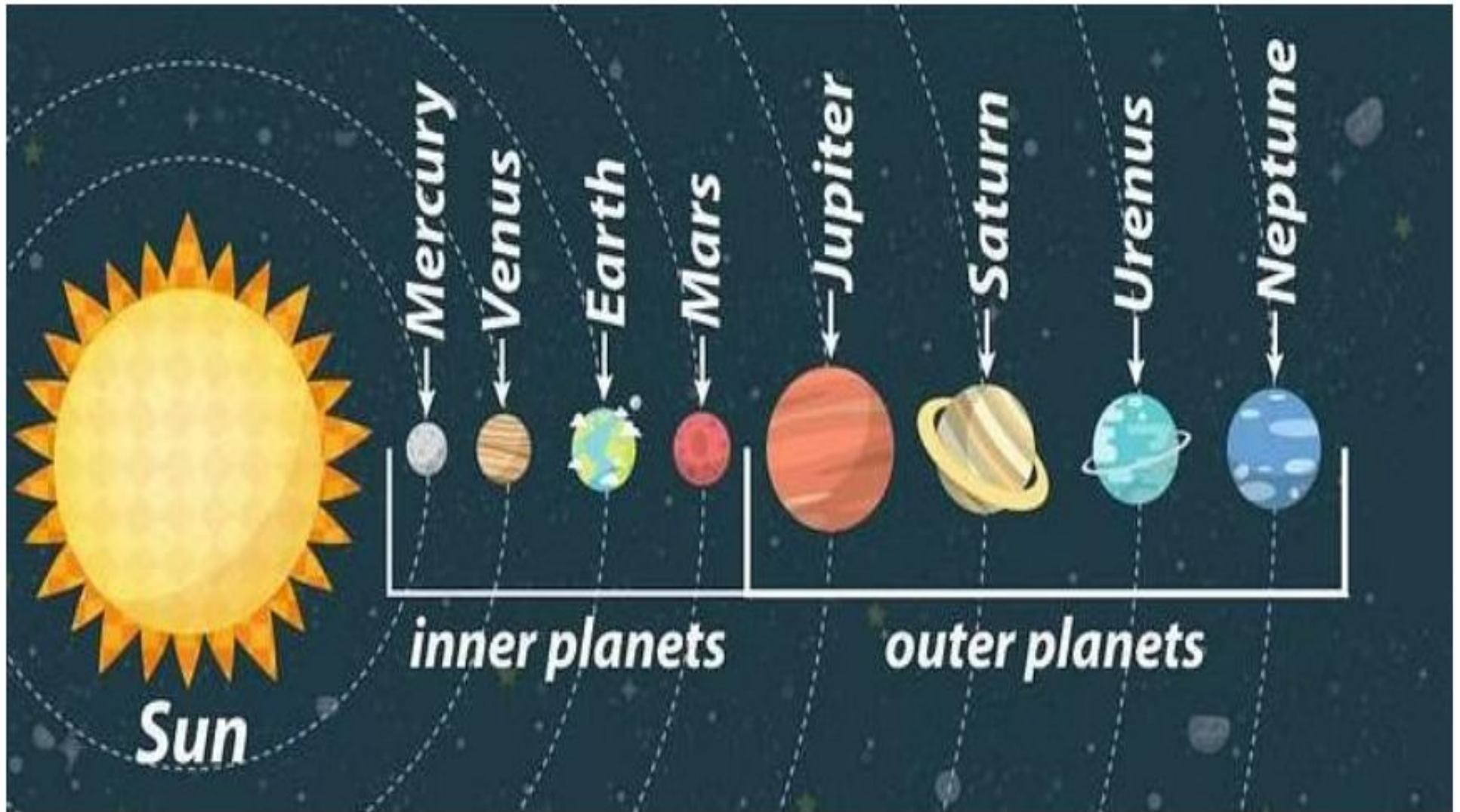
- **Giant Impact Theory:** A Mars-sized object collided with early Earth, blasting debris into space. This material eventually clumped together to form the Moon (about 4.44 billion years ago).

How the Moon Affects the Earth

- **Tides:** The Moon's gravity causes the oceans to rise and fall (tides).
- **Earth's Rotation:** Friction between the tides and Earth gradually slows down our planet's rotation.
- **Moon's Distance:** As the Earth slows, the Moon moves slightly farther away each year (about four cm).

Lunar Exploration Milestones

- **Luna 2 (Soviet Union):** First artificial object to reach the Moon (hard impact landing).
- **Apollo 8 (USA):** First crewed mission to orbit the Moon (1968).
- **Apollo 11 (USA):** Neil Armstrong and Buzz Aldrin became the first humans to walk on the Moon (July 29, 1969).



Planets in Our Solar System

Types of Planets:

- **Inner Planets (Terrestrial):**
 - Location: Closer to the Sun, before the asteroid belt.
 - Composition: Rocky and metallic, with high densities.
 - Examples: Mercury, Venus, Earth, and Mars.
- **Outer Planets (Gas Giants):**
 - Location: Beyond the asteroid belt.
 - Composition: Mostly gas, hence the name "gas giants".
 - Examples: Jupiter, Saturn, Uranus, Neptune, and dwarf planet Pluto.

Rotation:

- **Most Planets:** Rotate counter-clockwise, like the Sun.
- **Exceptions:**
 - Venus: Clockwise rotation (retrograde)
 - Uranus: Clockwise rotation (retrograde)

Comparison between Inner and Outer Planets

Inner Planets

- Also known as Terrestrial planets or Rocky planets.
- Mercury, Venus, Earth, Mars
- Nearer to sun, move faster and have shorter period of revolution
- Thin and rocky crust and mantle is rich in iron and magnesium
- Have solid surfaces
- No ring systems around them
- Thin atmosphere
- Very less number or no natural satellite

Outer Planets

- Also known as Jovian planets or gaseous planets or gas giants.
- Jupiter, Saturn, Uranus and Neptune
- Far away from the sun, move slowly and have longer period of revolution
- These are gaseous bodies and mantle is also made of gases.
- Do not have solid surfaces
- Rings are present around these planets.
- Large number of natural satellites

Why are the Inner Planets rocky while the Outer Planets are mostly in gaseous form?

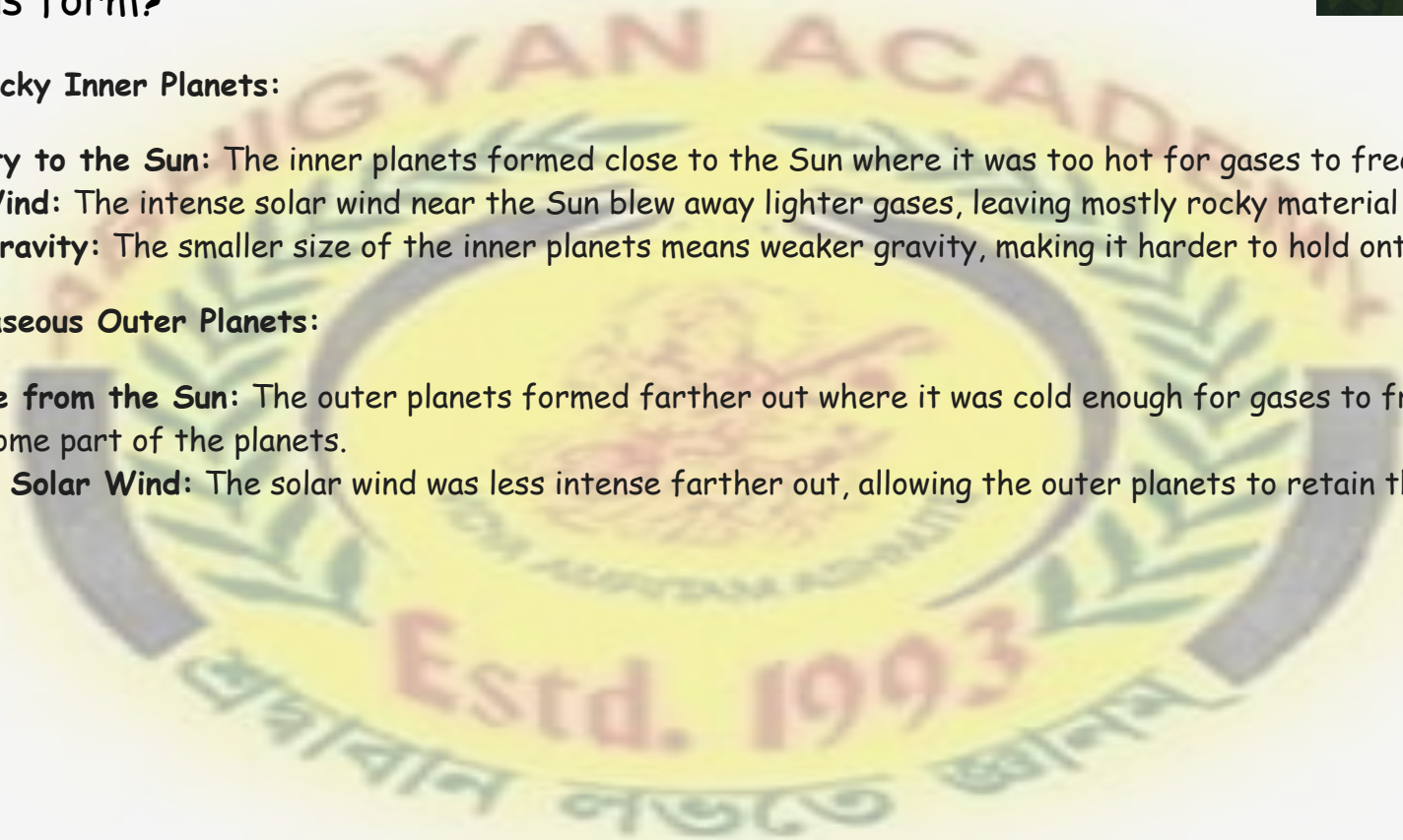


Reason for Rocky Inner Planets:

- **Proximity to the Sun:** The inner planets formed close to the Sun where it was too hot for gases to freeze into solids.
- **Solar Wind:** The intense solar wind near the Sun blew away lighter gases, leaving mostly rocky material behind.
- **Weak Gravity:** The smaller size of the inner planets means weaker gravity, making it harder to hold onto lighter gases.

Reason for Gaseous Outer Planets:

- **Distance from the Sun:** The outer planets formed farther out where it was cold enough for gases to freeze into solids and become part of the planets.
- **Weaker Solar Wind:** The solar wind was less intense farther out, allowing the outer planets to retain their gases.



Lets Practise

1. [UPSC Prelims 1997] Which one of the following conditions is most relevant for the presence of life on Mars?
- a. Atmospheric composition
 - b. Thermal conditions
 - c. Occurrence of ice caps and frozen water
 - d. Occurrence of ozone

Hint: on earth, prokaryotes (their cells lack a nucleus) were the earliest life forms. They fed on carbon compounds that were accumulating in Earth's early oceans.

2. [UPSC Prelims 1998] Match List-I with List-II and select the correct answer by using the codes given below the lists:



List-I (Special characteristic)	List-II (Planet)
A. Smallest planet	1. Earth
B. Largest planet in the solar system	2. Venus
C. Planet second from the sun in the solar system	3. Jupiter
D. Planet nearest to the Sun in the solar system	4. Mercury

Codes:

- a. A-2; B-3; C-5; D-1
- b. A-3; B-5; C-1; D-2
- c. A-4; B-1; C-2; D-3
- d. A-4; B-3; C-2; D-1

3. [UPSC Prelims 2003] Among the following which planet takes maximum time for one revolution around the Sun?

- a. Earth
- b. Jupiter
- c. Mars
- d. Venus

4. [UPSC Prelims 2008] In order of their distances from the Sun, which of the following planets lie between Mars and Uranus?

- a. Earth and Jupiter
- b. Saturn and Earth
- c. Jupiter and Saturn
- d. Saturn and Neptune

5. [UPSC Prelims 2009] Which one of the following planets has largest number of natural satellites or moons?

- a. Jupiter
- b. Mars
- c. Saturn
- d. Venus