IAS BABA

Integrated Learning Program (ILP) - 2026

The Most Comprehensive Self-Study Program

VALUE ADD NOTES (VAN)

GEOGRAPHY

BOOK - 1

Dear Aspirants,

As a subject that bridges the natural and human worlds, **Geography** plays a pivotal role in the UPSC syllabus. Its interdisciplinary nature makes it highly relevant across all three stages of the exam. Whether it is the Prelims, Mains, or the Interview, Geography builds the **spatial, environmental, and socio-economic awareness** that a future administrator must possess.

In the **Prelims**, Geography consistently features as a high-weightage subject, testing both **conceptual clarity** and **map-based** awareness. It covers **physical, Indian, and world geography**, along with emerging areas like **climate change, resources, and environment**—all critical to clearing the first stage.

In the **Mains**, particularly **GS Paper I** and to an extent in **GS Paper III**, Geography finds its relevance in understanding **population dynamics, urbanization, resource distribution, disaster management, and environmental sustainability**. The ability to integrate geographical perspectives with current affairs can significantly enrich your answers. During the **Interview**, a strong grounding in geography enhances your ability to respond to questions related to development, regional planning, environmental challenges, and policy implementation with practical insight.

To streamline your preparation, **IASbaba's Value Added Notes (VAN)** offer a powerful advantage. These well-structured notes distill vast content into crisp, exam-oriented material—bridging static fundamentals with contemporary issues such as climate events, geopolitical shifts, and sustainable development. **VAN enables quicker revision, better retention, and clearer articulation**—essential for every stage of the exam.

Our program, with integrated **VAN** and expert mentorship, ensures that your Geography preparation is not just wide but deep. We emphasize core themes like Geomorphology, Climatology, Indian Agriculture, Resources, Disaster Management, and Human Geography, while continuously linking them with current trends and developments. Geography is a subject that **rewards** both **curiosity and consistency**. With a conceptual approach, map practice, and timely revision, it can become one of your most dependable allies in the UPSC journey. At **IASbaba**, we are dedicated to supporting you every step of the way—helping you turn preparation into performance, and knowledge into success. Let's decode Geography together and pave the way for your success in the civil services.

With warm regards and best wishes,

Mohan Kumar S

Founder, IASbaba

Chapter 01:

Understanding the Universe

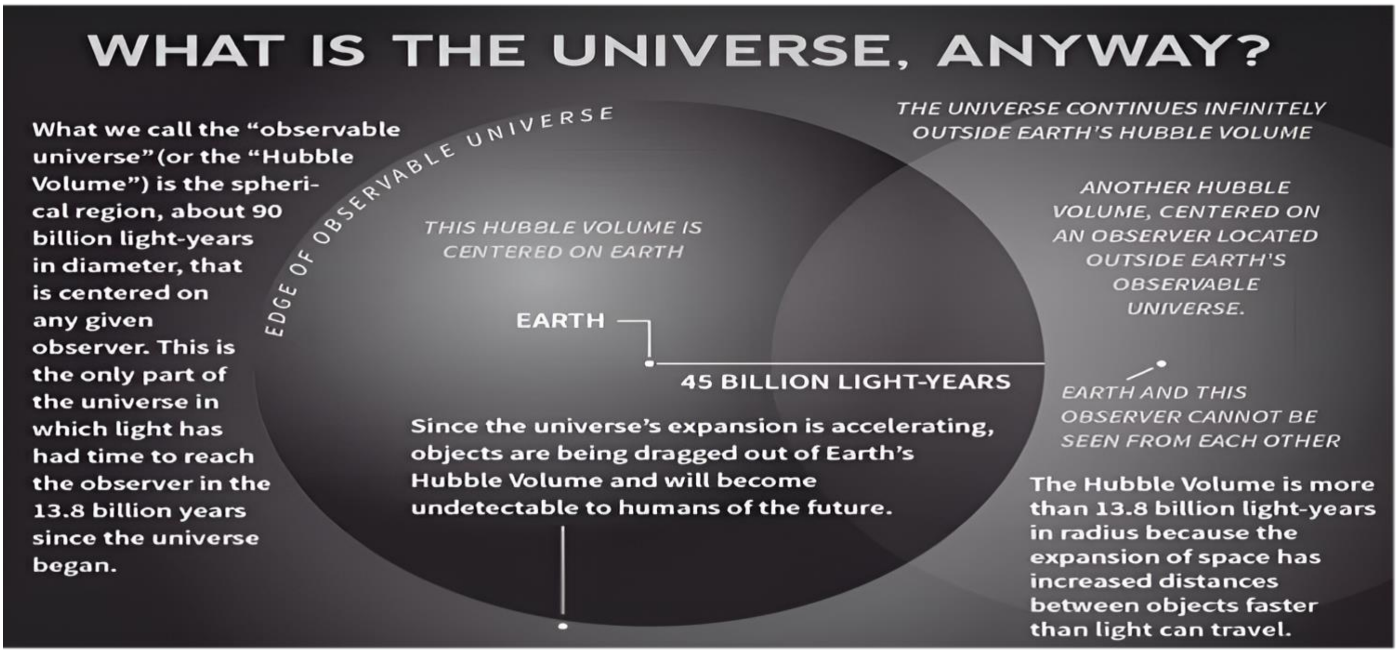
Since ancient times, humans have looked up at the night sky, wondering about the stars, planets, and the nature of the Universe. From the early astronomers of Mesopotamia and Egypt who tracked celestial movements to the sophisticated mathematical models of Indian and Greek astronomers, our curiosity about the cosmos has been unending. With time, our understanding has evolved—thanks to the development of modern astronomy, physics, and cosmology.

Today, we know that the **Universe is not only immense but also dynamic and ever-changing**. It is filled with galaxies, stars, black holes, dark matter, and dark energy. We have learned that the Universe had a beginning, is expanding, and has complex structures at every scale.

From the smallest subatomic particles to the largest galaxy clusters, this journey will reveal the incredible complexity and beauty of our Universe.

Understanding the Universe helps us grasp our own existence and prepares us for future explorations into the mysteries that lie beyond our solar system. As we unravel these cosmic secrets, we find ourselves humbled by the grandeur and inspired by the possibility that we are part of something far greater than ourselves.

This chapter begins with the origin and observable limits of the Universe, examines fundamental theories, explores cosmic structures and celestial objects, and finally focuses on our own Solar System and Earth's unique evolution."



The revolution in our understanding began with **Copernicus and Galileo, who challenged Earth-centered models, and continued through Newton's laws of motion and Einstein's theories of relativity**, which fundamentally changed how we perceive space and time.

In this chapter, we will explore the origin of the Universe, its structure, components, celestial objects, and our place in the vast cosmos. You will learn about key theories, including the Big Bang, and understand the fundamental differences between types of planets and celestial structures.

The Universe and Its Observable Limits

Definition

The **Universe** refers to all of space and everything it contains—matter, energy, planets, stars, galaxies—and the physical laws that govern them. It can be finite or infinite in extent; we do not fully know.

However, **the Observable Universe** is the portion of the entire cosmos we can see or detect from Earth, limited by the finite speed of light (about 300,000 km/s). Currently, that limit is about **46.5**

billion light-years in radius, even though the Universe is approximately **13.8 billion years** old. This apparent paradox arises because **space itself has been expanding** while light travels.

Why the Observable Universe is Limited

- **Finite Speed of Light**: We can only observe objects whose light (or other signals) has had time to reach us since the Big Bang.
- **Expansion of Space**: Distant regions recede from us faster over time due to cosmic expansion, especially with the accelerating effect of dark energy. Some regions will never become visible, no matter how long we wait.
- **Possibility of an Infinite Universe**: Beyond our observable limit might lie vast (or infinite) regions we cannot detect.

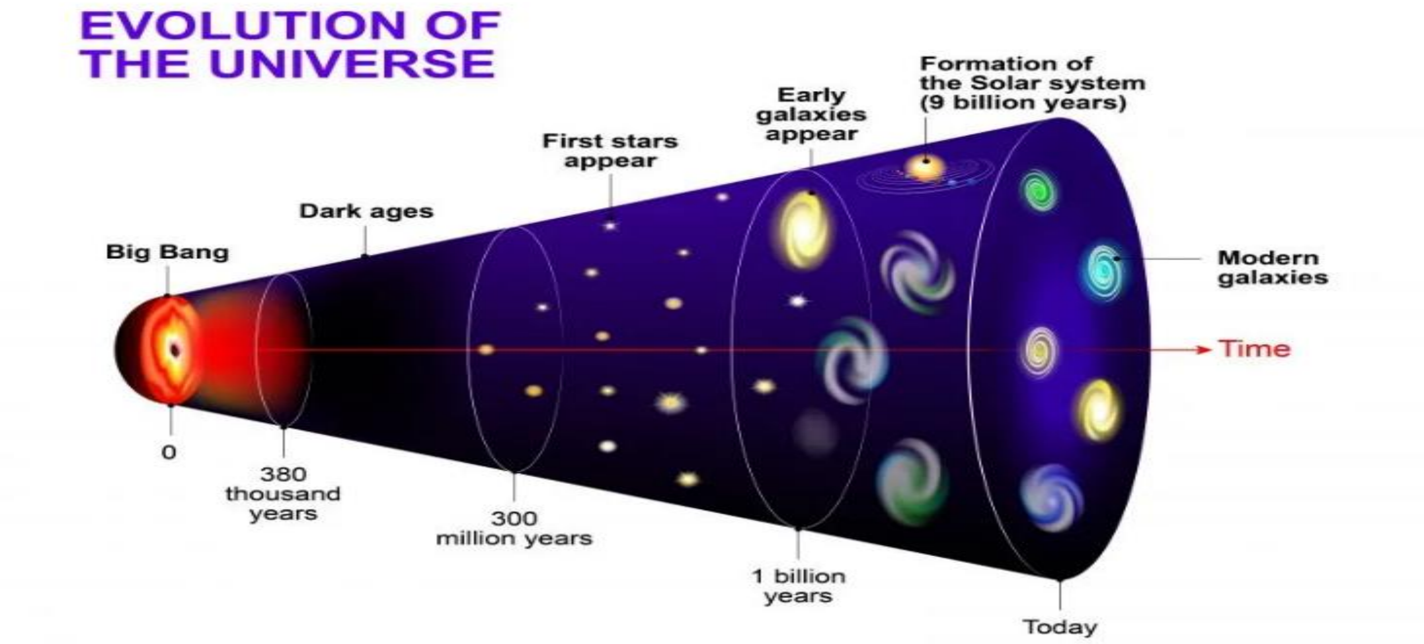


Fig. The Big Bang

Note on Cosmic Inflation: Right after the Big Bang, the Universe is believed to have undergone a brief but incredibly rapid expansion called *cosmic inflation*. This helps explain why distant regions of space are so far away today, contributing to the large observable radius.

Theories of the Origin of the Universe

1. Big Bang Theory

The Big Bang Theory is the most widely accepted explanation of how the Universe began. According to this theory, the Universe originated from an extremely hot and dense singularity about 13.8 billion years ago. It then expanded rapidly, giving rise to all space, time, matter, and energy.

In the first moments after the Big Bang:

- The Universe was incredibly hot (over 10^{32} degrees Celsius)
- The fundamental forces (gravitational, electromagnetic, strong nuclear, and weak nuclear) were unified
- As the Universe cooled, these forces separated, and subatomic particles formed
- After about 380,000 years, the Universe cooled enough for atoms to form (primarily hydrogen and helium)
- Over billions of years, gravity pulled matter together to form stars, galaxies, and the structures we see today

Key Evidence:

1. **Cosmic Microwave Background (CMB):** Faint radiation left over from the early Universe, detected in all directions. This "afterglow" of the Big Bang was predicted by theory and discovered accidentally by Arno Penzias and Robert Wilson in 1965, earning them the Nobel Prize. The CMB represents the moment when the Universe became transparent, about 380,000 years after the Big Bang.

2. **Redshift of Galaxies:** Observations show galaxies moving away from each other, suggesting expansion. This universal recession was first observed by Edwin Hubble in the 1920s and is consistent with an expanding Universe that originated from a single point.

3. **Abundance of Light Elements:** Proportions of hydrogen and helium in the Universe match predictions made by the Big Bang theory. About 75% of the mass of the Universe is hydrogen, and 25% is helium, with trace amounts of other elements—exactly what we would expect from Big Bang nucleosynthesis.

4. **The Big Bang was not an explosion in space—it was the expansion of space itself.** This subtle but crucial distinction helps explain how the Universe can expand uniformly in all directions without having a center.

Important Distinction: The Big Bang was not an "explosion" in space; it was an **expansion** of space itself in all directions.

2. Steady State Theory

This theory, proposed by Fred Hoyle, Thomas Gold, and Hermann Bondi in 1948, suggests the Universe has no beginning or end. As the Universe expands, new matter is continuously created to keep the density constant. According to this model, the Universe looks the same at all times and all places on a large scale—a principle called the "perfect cosmological principle."

Why It Failed:

- **Cannot explain the CMB:** The Steady State theory has no mechanism to explain the uniform background radiation observed throughout the Universe.

- **Lacks observational support:** The theory predicts that distant galaxies should look similar to nearby ones, but observations show that distant (and therefore older) galaxies are noticeably different.

- **The discovery of evolving galaxies contradicted the theory:** We now observe that galaxies evolve over time, with different populations of stars and different structures at different cosmic epochs.

- Fred Hoyle, ironically, coined the term **"Big Bang"** as a derisive nickname for the competing theory, but the name stuck and entered popular usage.

3. Oscillating Universe Theory

Also known as the **Cyclic Model,** it proposes the Universe undergoes cycles of expansion (Big Bang) and contraction (Big Crunch). After collapsing, it rebounds with another Big Bang, continuing eternally. This theory attempts to answer the question of what came before the Big Bang by suggesting that our Universe is just one in an infinite series.

Modern versions of cyclic models, such as the ekpyrotic scenario proposed by Paul Steinhardt and Neil Turok, suggest that our Universe might be one of many "branes" (membrane-like structures in higher dimensions) that periodically collide, creating Big Bang-like events.

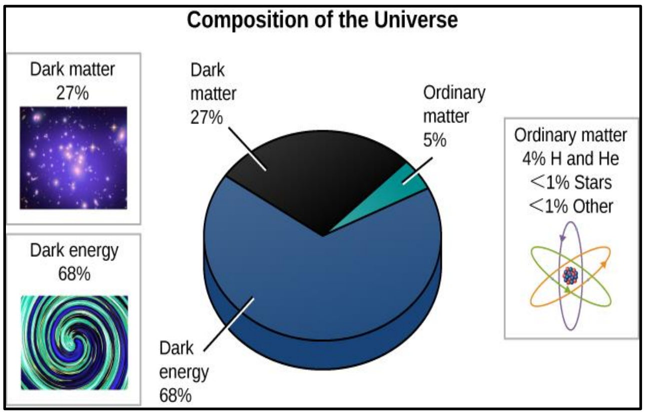
Summary Table: Theories of the Universe's Origin

Theory	**Description**	**Current Status**
Big Bang	Universe began from a singularity and expanded	Widely accepted
Steady State	Universe is eternal and unchanging	Largely rejected
Oscillating Universe	Universe goes through cycles	Theoretical, less favored

Components of the Universe

The Universe consists of:

Component	**Percentage of Universe**	**Description**
Dark Energy	~68%	Accelerates Universe's expansion
Dark Matter	~27%	Invisible mass; affects galaxy rotation
Normal Matter	~5%	Stars, planets, gas, dust—what we can see



Normal Matter (Atoms)

Atoms form the basic building blocks of stars, planets, and living beings. They consist of protons, neutrons, and electrons. Despite being what we can directly observe and interact with, normal (or baryonic) matter makes up only about 5% of the Universe's total energy content.

Normal matter exists in various states:

- Stars (mostly hydrogen and helium)
- Interstellar gas and dust
- Planets and moons
- Asteroids and comets
- Living organisms (on Earth)
- Intergalactic medium (thin gas between galaxies)

Even though it represents a small fraction of the Universe, normal matter is responsible for all the beautiful structures we see through telescopes—the colourful nebulae, the spiral arms of galaxies, and the planets of our solar system.

Dark Matter

Dark Matter does not emit, absorb, or reflect light, making it invisible. Its presence is inferred from its gravitational effects on visible matter. Scientists believe dark matter consists of exotic particles that interact very weakly with normal matter.

Its presence is inferred from:

- **Galaxy rotation speeds:** Stars at the edges of galaxies orbit faster than can be explained by the visible mass alone, suggesting additional unseen mass.

- **Gravitational lensing:** Dark matter bends light from distant objects, creating magnified or distorted images.

- **Cosmic structure formation:** Computer simulations show that without dark matter, galaxies and galaxy clusters could not have formed as they did.

The search for dark matter particles is ongoing, with various experiments deep underground trying to detect rare interactions between dark matter and normal matter. Leading candidates include Weakly Interacting Massive Particles (WIMPs) and axions, though neither has been definitively detected yet.

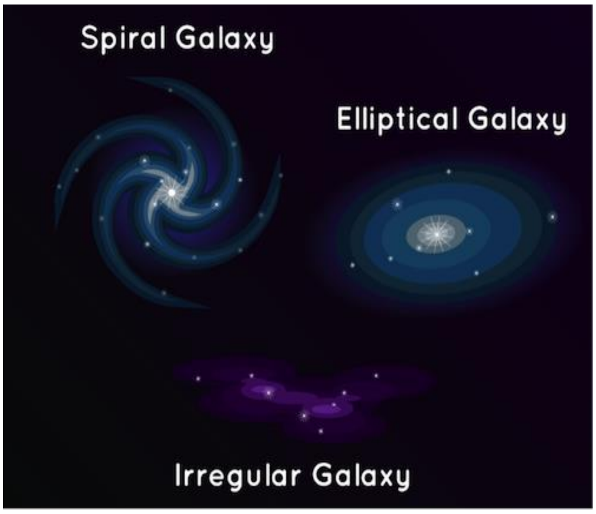
Dark Energy

Dark Energy is even more mysterious than dark matter. It acts against gravity, causing galaxies to move apart faster. First detected through observations of distant supernovae, dark energy appears to be a property of space itself.

Possible explanations for dark energy include:

- Einstein's cosmological constant (a form of energy inherent to empty space)
- A dynamical quantum field called quintessence
- A modification of Einstein's theory of gravity on cosmic scales

Dark energy's nature remains one of the biggest mysteries in modern physics, but its effects are critical in cosmic expansion and the ultimate fate of the Universe. If dark energy continues to dominate, the Universe may expand forever, eventually becoming cold and empty as galaxies move beyond each other's visible horizons.



Celestial Bodies in the Universe

Galaxies: Galaxies are large systems of stars, gas, dust, and dark matter bound together by gravity. A typical galaxy contains billions to trillions of stars and spans tens of thousands of light-years.

Fig. Types of Galaxies

Types:

1. **Spiral (e.g., Milky Way):** Characterized by a flat disk with spiral arms, a central bulge, and often a bar structure. Rich in gas and young stars, spiral galaxies are sites of active star formation.
2. **Elliptical:** Oval-shaped galaxies with little gas and dust, containing mostly older stars. They range from nearly spherical to highly elongated shapes and are common in galaxy clusters.
3. **Irregular:** Galaxies with no definite structure. Often the result of gravitational interactions or collisions between galaxies.

Galaxies are not evenly distributed throughout the Universe but form a cosmic web, with filaments and walls of galaxies surrounding vast voids.

The Milky Way

Our home galaxy is a barred spiral galaxy with a diameter of about 100,000 light-years. From Earth, it appears as a milky band across the night sky, hence its name.

- **Spiral galaxy** with four major arms and several minor arms
- **Contains 100–400 billion stars,** with new estimates leaning toward the higher end
- **Solar System is located in the Orion Arm,** about 26,000 light-years from the galactic center
- At the center of the Milky Way lies a supermassive black hole called Sagittarius A*, with a mass of about 4 million times that of our Sun.

- The galaxy is surrounded by a halo of dark matter, which makes up most of its mass.

Fig. Milky Way Galaxy

Other Important Galaxies

- **Andromeda (M31):** The closest spiral galaxy to the Milky Way, located about 2.5 million light-years away. It is on a collision course with our galaxy and will merge with the Milky Way in about 4.5 billion years.
- **Triangulum Galaxy (M33):** The third-largest member of the Local Group (after Andromeda and the Milky Way), another spiral galaxy about 3 million light-years away.

Stars

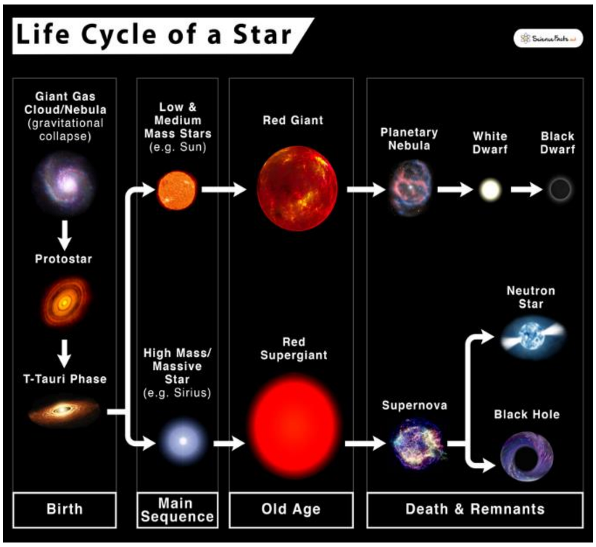


Fig. Life Cycle of a Star

Stars are nuclear furnaces where hydrogen fuses into helium, releasing enormous amounts of energy. This process, called nuclear fusion, is what makes stars shine. Stars come in various colors, sizes, and masses:

- Red stars are cooler (about 3,000°C)
- Yellow stars like our Sun are medium temperature (about 5,500°C)
- Blue stars are the hottest (over 30,000°C)

Stars have life cycles that depend on their mass:

- Low-mass stars (like red dwarfs) burn fuel slowly and can live for trillions of years
- Mid-mass stars like our Sun live for about 10 billion years

- Massive stars burn through their fuel quickly and may live only a few million years before exploding as supernovae

Star Formation

Process of Star Formation

1. **Nebula Stage:** Stars begin as large clouds of gas and dust called nebulae floating in space.
2. **Gravitational Collapse:** Gravity pulls the gas particles together, causing regions of the nebula to become denser.
3. **Dense Core Formation:** The denser regions collapse further, forming concentrated cores of gas and dust.
4. **Protostar Development:** As the core continues to collapse, it heats up and becomes a protostar - not yet a true star.
5. **Temperature Increase:** Gravitational energy converts to heat, causing the temperature and pressure at the core to rise dramatically.
6. **Nuclear Fusion Ignition:** When the core temperature reaches approximately 10 million degrees Celsius, hydrogen atoms begin to fuse into helium, releasing enormous energy.
7. **Star Birth:** With stable nuclear fusion occurring, a new star is born, generating light and heat.
8. **Protoplanetary Disk:** The leftover gas and dust around the new star may form a rotating disk, which can eventually develop into planets, moons, and other celestial bodies.

Planets

Planets are large celestial bodies orbiting stars. They are massive enough for their gravity to pull them into a roughly spherical shape but not massive enough to trigger nuclear fusion.

Planetesimal Hypothesis

Here's a step-by-step explanation of how planets form according to the Planetesimal Hypothesis:

1. **Nebular Disk Formation**: After a star forms, leftover gas and dust flatten into a rotating protoplanetary disk around the new star.
2. **Dust Aggregation**: Tiny dust particles within this disk begin to collide and stick together due to electrostatic forces, forming small clumps.
3. **Planetesimal Formation**: These clumps grow larger (from millimeters to kilometers in size) through continued collisions, becoming planetesimals - the building blocks of planets.
4. **Gravitational Growth**: Once planetesimals reach sufficient size (about 1 km across), their gravity becomes strong enough to attract other planetesimals.
5. **Runaway Accretion**: Larger planetesimals grow faster than smaller ones as they can gravitationally capture more material, creating a runaway growth process.
6. **Protoplanet Formation**: The largest planetesimals become protoplanets, bodies that have cleared their orbital path of smaller objects.
7. **Inner vs. Outer System Differentiation**:
    a. Inside the "frost line" (where water exists as vapor): Rocky materials condense, forming terrestrial planets like Earth.
    b. Beyond the frost line (where water freezes): Ice can form, creating larger cores that attract gases, leading to gas giants like Jupiter.
8. **Final Planet Formation**: Through continued accretion and occasional giant impacts, protoplanets eventually form the mature planets of a solar system.

Moons

Moons are natural satellites orbiting planets. Earth has one large moon, while Jupiter has at least 95 moons of various sizes. Some moons, like Jupiter's Europa and Saturn's Enceladus, have subsurface oceans that might harbor life.

Earth's Moon formed about 4.5 billion years ago, likely from debris ejected when a Mars-sized object collided with the early Earth. The Moon stabilizes Earth's axial tilt, creating relatively consistent seasons and moderating our climate.

Earths's Moon formation theory:

1. Fission Theory

The Fission Theory, proposed by George Darwin, suggests that the Moon was once a part of the Earth. In the early days, the Earth spun so rapidly that a portion of it broke away due to centrifugal force. This fragment eventually became the Moon. Some early versions of the theory even proposed that the Pacific Ocean basin was the leftover scar. However, this theory is not widely accepted today because it does not fully explain the Moon's composition and orbit.

2. Capture Theory

According to the Capture Theory, the Moon was formed elsewhere in the solar system and later got caught by Earth's gravitational pull. This explains why the Moon's orbit is different from Earth's equatorial plane. However, this theory faces major difficulties in explaining how such a large body could be captured without breaking apart or escaping, making it an unlikely explanation.

3. Co-formation (Twin) Theory

The Co-formation or Twin Theory suggests that the Earth and the Moon formed together from the same cloud of gas and dust in the early solar system. This explains why some elements in the Moon and Earth are similar. However, the theory falls short in explaining the differences in density and internal composition between the two bodies, and hence is not the most favored.

4. Giant Impact Hypothesis

The most widely accepted theory today is the Giant Impact Hypothesis. It proposes that a Mars-sized object, named Theia, collided with the early Earth. The impact threw a large amount of debris into orbit, which eventually came together to form the Moon. This theory explains many features of the Moon, such as its similar composition to Earth's crust and its stable orbit. It is supported by both simulations and evidence from lunar rock

Asteroids

Asteroids are rocky bodies, mostly found between Mars and Jupiter in the Asteroid Belt. They range in size from Ceres (about 940 km in diameter) to small boulders. Asteroids are remnants from the early solar system that never accreted into planets.

Near-Earth Asteroids (NEAs) occasionally pass close to Earth, and some pose potential impact hazards. Scientists track these objects and develop strategies for potentially deflecting any that might threaten Earth.

Comets

Comets are icy bodies that develop tails when near the Sun. They consist of a nucleus (made of ice, dust, and rocky material), a coma (a cloud of gas and dust that forms around the nucleus when heated by the Sun), and potentially two tails (a dust tail and an ion tail).

Most comets originate from either:

- The Kuiper Belt, beyond Neptune
- The Oort Cloud, a spherical shell of icy objects at the outer boundary of our solar system

Halley's Comet is perhaps the most famous, visible from Earth every 76 years, with its next appearance expected in 2061.

Difference Between Comets and Asteroids

Feature	Comets	Asteroids
Composition	Made of **ice, dust, and rocky material**	Made mostly of **rock and metal**
Location	Found in the **Kuiper Belt** and **Oort Cloud**	Mostly found in the **Asteroid Belt** between Mars and Jupiter
Appearance	Have a **bright coma** and **long tail** when near the Sun	Appear as **rocky or metallic** bodies; no tail
Orbit	Have **elongated orbits** around the Sun	Have **more circular or elliptical orbits**
Behaviour near Sun	Develop **glowing tails** due to evaporation of ice	**Do not develop tails**
Examples	Halley's Comet, Hale-Bopp	Ceres, Vesta, Eros

Meteoroids, Meteors, and Meteorites

- **Meteoroids** are small rocky or metallic bodies that travel through space. They are usually fragments of asteroids or comets and range in size from tiny grains to objects several meters wide. As long as they remain in space and have not entered Earth's atmosphere, they are called meteoroids.
- **Meteors** are the bright streaks of light we see in the sky when meteoroids enter Earth's atmosphere and burn up due to intense friction with the air. These are often called "shooting stars," although they are not stars at all. The light is

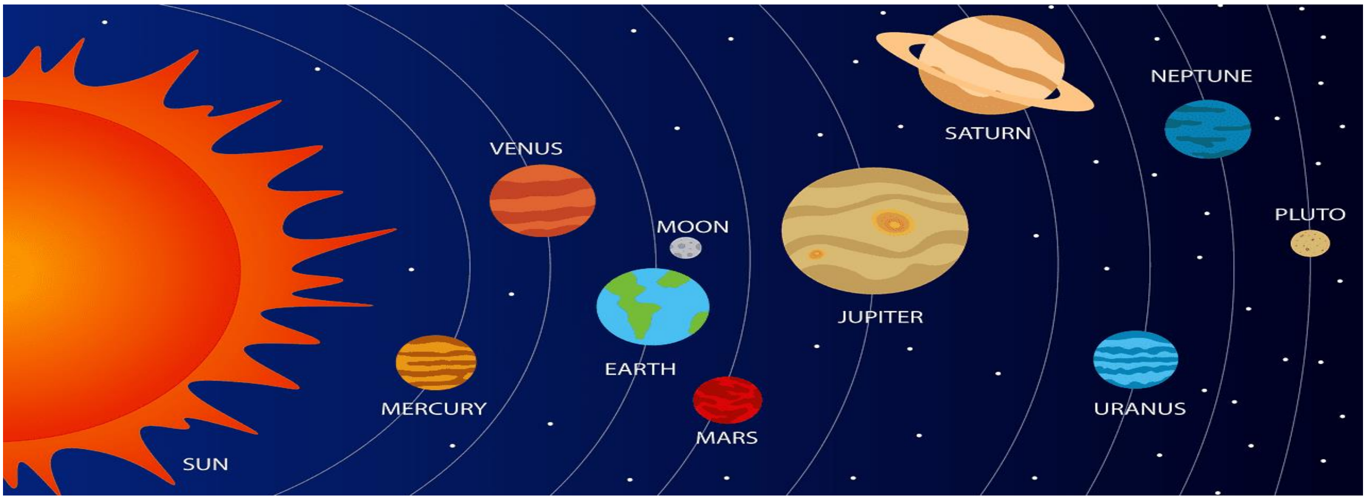
produced by the heat generated as the object travels at high speed through the atmosphere.

- **Meteorites** are the remnants of meteoroids that survive the journey through Earth's atmosphere and actually land on the ground. These can range in size from tiny pebbles to large rocks and are valuable to scientists because they provide clues about the early solar system.

supermassive black hole at the center of galaxy M87.

Pulsars and Quasars

- **Pulsars** are rapidly rotating neutron stars that emit beams of electromagnetic radiation from their magnetic poles. As they rotate, these beams sweep across Earth like a lighthouse, creating regular pulses of radio waves and other radiation. The first pulsar was discovered by Jocelyn Bell Burnell in 1967.



Special Objects

Black Holes

Black holes are regions of spacetime where gravity is so strong that nothing—not even light—can escape once it passes the event horizon. Contrary to popular belief, black holes don't "suck" matter in; rather, their extreme gravity warps spacetime around them.

Formation:

- Stellar black holes form when massive stars collapse after running out of fuel
- Supermassive black holes (millions to billions of times the mass of our Sun) are found at the centers of most galaxies, including our Milky Way

In 2019, the Event Horizon Telescope collaboration captured the first-ever image of a black hole's shadow—specifically, the

- **Quasars** (quasi-stellar radio sources) are extremely bright, distant objects powered by supermassive black holes actively consuming matter. As material falls toward the black hole, it forms an accretion disk that heats up to millions of degrees, releasing enormous amounts of energy. Quasars can outshine entire galaxies and are among the most distant objects we can observe, providing glimpses of the early Universe.

The Solar System

Fig. The Solar System

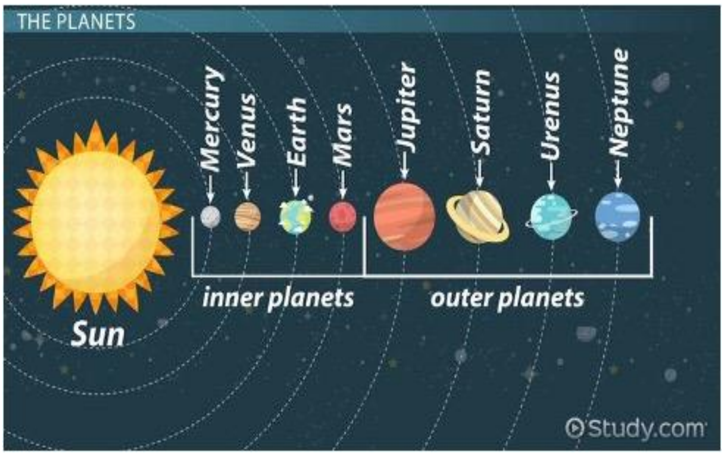
Formation Theories

Nebular Hypothesis

The most widely accepted theory for the formation of our solar system:

- About 4.6 billion years ago, a rotating cloud (nebula) collapsed under gravity

- As it collapsed, it flattened into a disk and began rotating faster



- The central mass became denser and hotter, eventually forming the Sun
- Remaining material in the disk formed the planets through a process called accretion

This theory explains why all planets orbit the Sun in the same direction and roughly the same plane.

The Sun

Our Sun is a G-type main-sequence star, often called a yellow dwarf:

- Medium-sized star, about halfway through its 10-billion-year lifespan
- Core temperature: ~15 million °C, where nuclear fusion converts hydrogen to helium
- Produces energy equivalent to billions of hydrogen bombs every second

Layers:

- **Core:** Where nuclear fusion occurs
- **Radiative zone:** Energy moves outward via radiation
- **Convective zone:** Energy moves via convection currents
- **Photosphere:** The visible "surface" of the Sun
- **Chromosphere:** A thin layer above the photosphere
- **Corona:** The extended outer atmosphere, visible during solar eclipses

Solar Activity:

- **Sunspots:** Cooler areas (about 3,500°C) that appear dark against the hotter surrounding photosphere
- **Solar flares:** Explosive eruptions that release radiation across the electromagnetic spectrum
- **Coronal mass ejections (CMEs**): Huge bubbles of plasma ejected from the Sun
- **Solar wind:** Stream of charged particles flowing outward from the Sun, creating the heliosphere

In our solar system, planets are divided into two categories:

- **Terrestrial (rocky) planets:** Mercury, Venus, Earth, Mars
- **Jovian (gas/ice giant) planets:** Jupiter, Saturn, Uranus, Neptune

Reasons for Differences Between Terrestrial and Jovian Planets

The key differences between terrestrial and Jovian planets can be explained by these factors:

1. **Distance from the Sun**:
   a. Inner regions were hotter, allowing only metals and silicates to condense
   b. Outer regions were cooler, permitting ices of water, ammonia, and methane to form
2. **Composition of planetesimals**:
   a. Inner planetesimals were made primarily of rocks and metals
   b. Outer planetesimals contained ices along with rocks and metals
3. **Size of the cores**:
   a. Terrestrial planets had smaller rocky cores
   b. Jovian planets developed larger cores from ice and rock that could attract gases
4. **Gravitational capture**:
   a. Inner planets lacked sufficient gravity to hold light gases like hydrogen and helium
   b. Outer planets' larger cores had enough gravity to capture and retain vast amounts of light gases
5. **Temperature differences**:
   a. Higher temperatures in the inner solar system caused lighter elements to evaporate
   b. Lower temperatures in the outer solar system allowed these gases to be captured and retained

Comparison of Planets in the Solar System (Without Atmosphere Column)

The planets in the Solar System can be compared based on several physical and orbital characteristics such as their **distance from the Sun**, **diameter**, **number of moons**, **rotation and revolution periods**, and **surface temperatures**. These parameters help distinguish between **terrestrial (inner) planets** and **gas/ice giants (outer planets)**.

Pluto was considered the ninth planet in our solar system from its discovery in 1930 until 2006. However, as astronomers discovered more Pluto-like objects in the outer solar system, questions arose about whether Pluto should still be classified as a planet.

In 2006, the International Astronomical Union (IAU)—the official authority responsible for naming and defining celestial objects—introduced a new definition of a planet. Under this definition, Pluto does not meet all the criteria and was reclassified as a "dwarf planet."Who makes the rules?

The International Astronomical Union (IAU) is the global organization of professional astronomers. It is responsible for standardizing definitions and naming of celestial bodies. In August 2006, during a meeting in Prague, the IAU voted on and approved the official definition of a planet.

IAU's 3 Rules to Be a Planet

According to the IAU, for an object to be called a planet, it must meet all three of the following criteria:

1. It must orbit the Sun.
2. It must be spherical in shape (due to its own gravity).
3. It must have "cleared its orbit" of other debris.This means it must be gravitationally dominant and not share its orbit with other objects of similar size.

Note: Pluto does not meet this criterion because it shares its orbit with other icy objects in the Kuiper Belt.

Because Pluto meets the first two criteria but fails the third, the IAU reclassified it as a dwarf planet. Other dwarf planets include Eris, Haumea, Makemake, and Cere

Other Solar System Bodies

Dwarf Planets: Objects that orbit the Sun and are massive enough to be rounded by their own gravity but have not cleared their orbital neighbourhood. Examples include Pluto, Ceres, Eris, Haumea, and Makemake.

Asteroids: Found primarily in the asteroid belt between Mars and Jupiter, though some groups (like the Trojans) share orbits with planets. The largest asteroid, Ceres, is also classified as a dwarf planet.

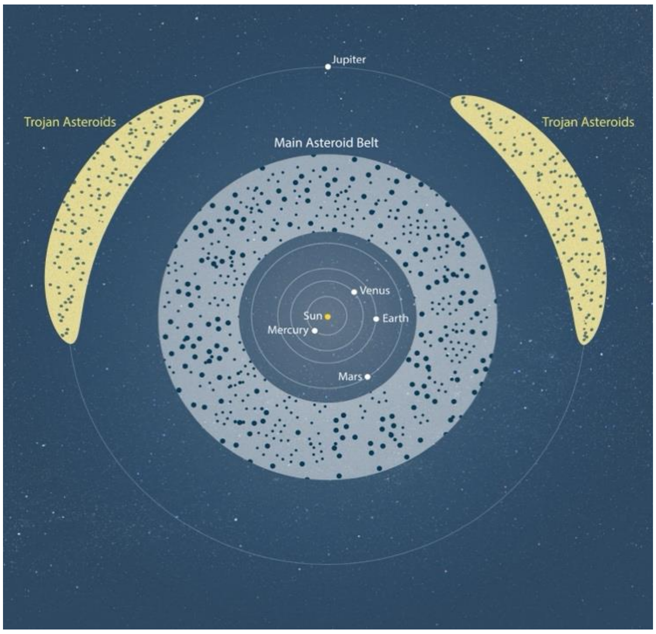


Fig. Asteroid Belt

Comets: Originate primarily from two regions:

- **Oort Cloud**: A spherical shell of icy objects extending from 2,000 to 100,000 AU from the Sun
- **Kuiper Belt**: A disk-shaped region beyond Neptune's orbit

Halley's Comet, visible every 76 years, was last seen in 1986 and **will return in 2061.**

Trans-Neptunian Objects (TNOs): Objects that orbit the Sun at a greater average distance than Neptune, including Kuiper Belt objects and scattered disk objects.

Earth's Position and the Goldilocks Zone

Fig. Goldilocks Zone

Earth lies in the Goldilocks Zone—the habitable zone around a star where temperatures allow for liquid water. This zone is not too hot (where water would evaporate) and not too cold (where water would freeze permanently), but "just right" for liquid water to exist on a planet's surface.

The exact boundaries of the habitable zone depend on many factors, including:

- The star's brightness and temperature
- The planet's atmosphere and greenhouse effect
- The planet's reflectivity (albedo)

For our Sun, the habitable zone extends roughly from Venus's orbit to Mars's orbit, with Earth situated comfortably within it.

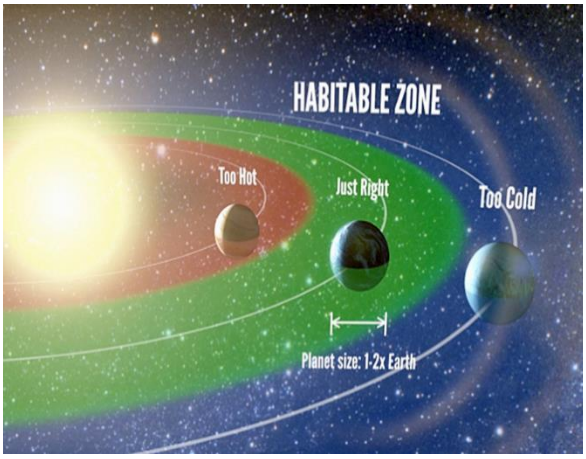
Earth's unique features:

1. **Presence of water** in all three states (solid, liquid, gas), covering about 71% of the surface
2. **Atmosphere with oxygen,** which allows for complex life forms and protects against harmful radiation
3. **Protective magnetic field** generated by Earth's liquid outer core, which shields us from solar wind
4. **Stable climate,** partly due to the moderating influence of our large Moon
5. **Plate tectonics,** which recycles carbon and helps regulate temperature over geological timescales

Evolution of the Earth

1.Early Earth: A Rocky, Hot Planet

When Earth first formed about **4.6 billion years ago**, it looked nothing like it does today. It was a **barren, rocky, and extremely hot object** surrounded by a thin atmosphere primarily made up of **hydrogen and helium**. There were no oceans, no air to breathe, and certainly no life.



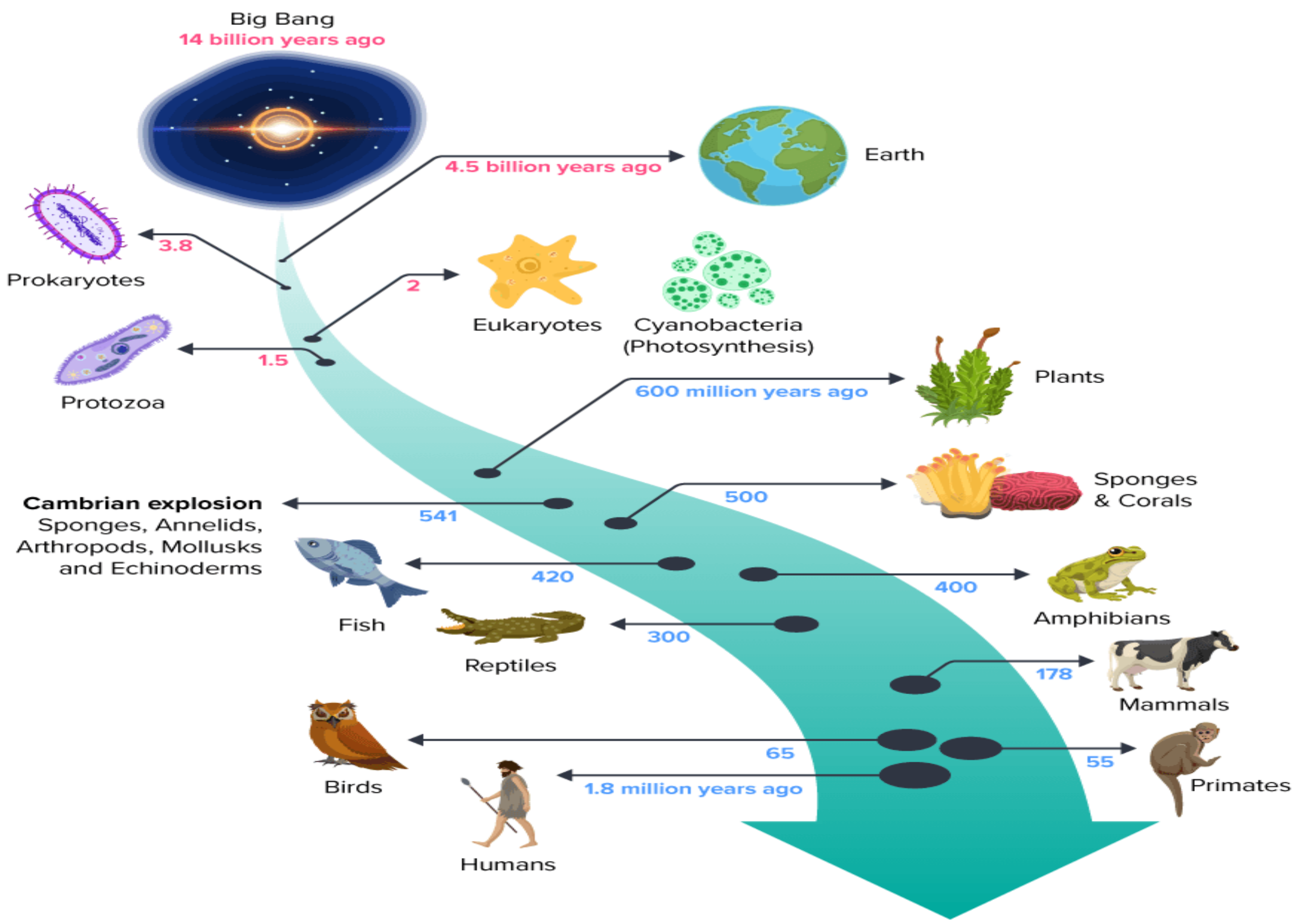
Over time, however, Earth began to change. Heat from its interior and energy from the Sun helped transform the planet. Volcanoes released gases and water vapor, leading to the gradual formation of the atmosphere and hydrosphere.

2.Formation of Earth's Layers (Lithosphere Evolution)

In its early stage, Earth was in a **molten state**. As it cooled, **heavier elements like iron and nickel** sank towards the center while **lighter materials** moved upward. This process is called **differentiation**. As a result, the Earth developed a **layered structure**: **crust, mantle, outer core, and inner core**. Each layer has different density and composition, and the formation of the outer crust marked the beginning of the solid Earth or **lithosphere**.

3. Evolution of the Atmosphere

Earth's atmosphere evolved in **three stages**. The **first atmosphere**, rich in hydrogen and helium, was lost due to **solar winds** from the young Sun. In the **second stage**, gases like water vapor, carbon dioxide, methane, and nitrogen were **released from Earth's interior** through volcanic eruptions—a process known as **degassing**. The **third stage** began with the evolution of **photosynthetic life**, which released **oxygen** into the oceans and



eventually into the atmosphere, forming the basis of the modern air we breathe.

4.Formation of Hydrosphere (Water Bodies)

As Earth cooled, water vapor in the atmosphere began to condense and fall as **rain**. This rainfall continued for thousands of years, collecting in surface depressions and forming the **first oceans**. This process occurred within the **first 500 million years** of Earth's formation. Thus, the oceans are roughly **4 billion years old**. The presence of water played a crucial role in the evolution of life and the regulation of Earth's temperature.

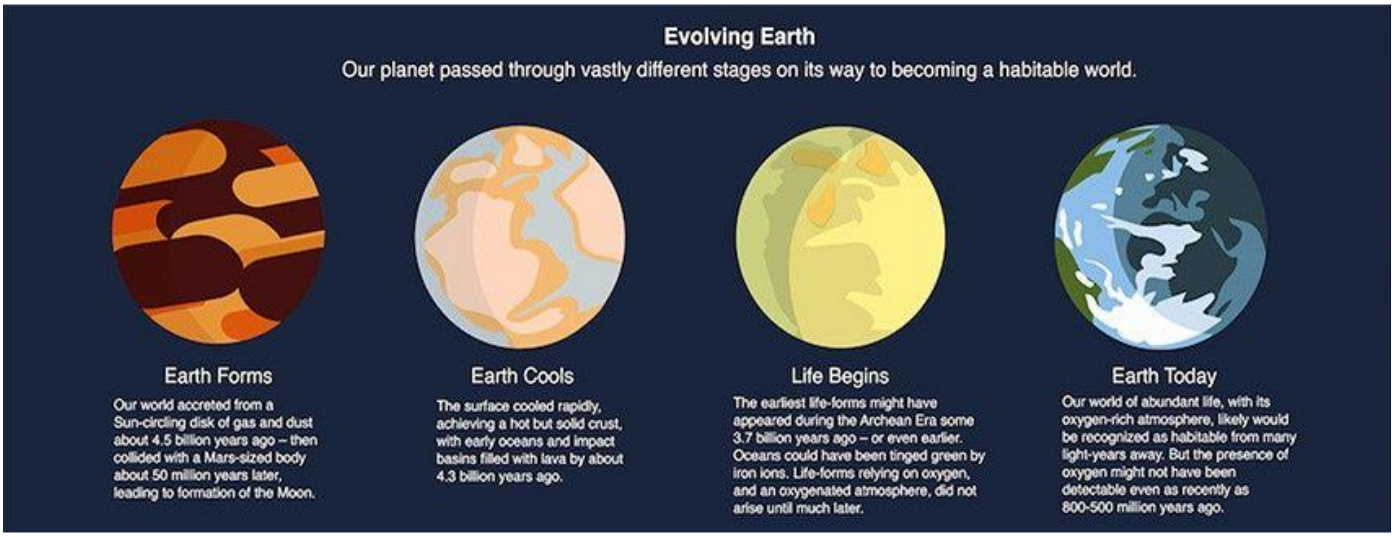


Fig. Evolution of Life on Earth

5. Origin and Evolution of Life

Life is believed to have originated around **3.8 billion years ago**, beginning in Earth's oceans. Scientists suggest life started through **chemical evolution**—complex organic molecules formed in water and began to **self-replicate**, turning non-living matter into **living cells**. The earliest life forms were **unicellular**. Around **2.5 to 3 billion years ago**, **photosynthesis evolved**, leading to the release of oxygen into the oceans. Once oceans became saturated with oxygen, it began accumulating in the atmosphere around **2 billion years ago**, creating conditions for more complex life to evolve.

These features combined make Earth uniquely suitable for life as we know it. While other planets and moons in our solar system (like Mars or Europa) might harbor simple life forms, Earth remains the only known planet with a rich biodiversity.

The study of habitable zones has gained new importance with the discovery of thousands of exoplanets. Several potentially habitable exoplanets have been identified, including those in the **TRAPPIST-1 system and Proxima Centauri b**, the closest known exoplanet to our solar system.

As we continue to explore our solar system and beyond, we gain a deeper appreciation for Earth's special place in the Universe and the delicate balance of conditions that allow life to flourish on our blue planet.

Geologic Time Scale Reference:

- **Hadean Eon** (4.6–4.0 Ga): Formation and initial cooling, earliest crust.
- **Archean Eon** (4.0–2.5 Ga): First life, limited oxygen.
- **Proterozoic Eon** (2.5–0.54 Ga): Rising oxygen, more complex cells.
- **Phanerozoic Eon** (last ~540 million years): Diverse life, from Cambrian explosion to present.

The study of the **universe and the evolution of the Earth** offers a profound understanding of our cosmic origins and the dynamic processes that shaped our planet. From the **Big Bang**—the starting point of space and time—to the **formation of galaxies, stars, and planetary systems**, this journey traces how matter coalesced under gravity to create the solar system and, eventually, Earth.

Understanding the **observable universe**, including its vast scales, expanding boundaries, and the cosmic microwave background, allows us to appreciate our place within a much larger and ever-evolving cosmos. The formation of Earth about **4.6 billion years ago**, followed by processes like **planetary differentiation, volcanism, and atmosphere formation**, laid the foundation for the development of life and continents.

For **CSE Aspirants**, this chapter provides not just factual knowledge but also a conceptual lens to examine themes of **scientific temper**, **evolutionary processes**, and **Earth's uniqueness** in sustaining life. It lays the groundwork for later topics in **physical geography**, **environment**, and **climate science**, and strengthens one's ability to interlink **space science with geography and sustainability**—an increasingly important trend in UPSC Mains and interview discussions.

In essence, this chapter reminds us that the Earth is both **a cosmic rarity and a product of universal laws**, and understanding its origin deepens our responsibility to protect its future.

A Planet in Motion

Have you ever wondered why the Sun rises and sets each day, or why different parts of the world experience changing seasons? Even though the ground under our feet seems still, Earth is always on the move. It has two main types of motion—**rotation** and **revolution**—and each affects our daily lives in ways we often take for granted.

1. **Rotation** is Earth spinning on its own axis (imagine a line passing through the North and South Poles).

2. **Revolution** is Earth's yearly orbit around the Sun.

Let's explore these fascinating movements to understand how they create day and night, shape our seasons, and guide how we measure time and location.

Planet	Type	Surface	Moons	Special Features	Rotation Period	Revolution Period
Mercury	Terrestrial	Rocky, cratered	0	Closest to Sun; extreme temperature variations	~59 Earth days	~88 Earth days
Venus	Terrestrial	Rocky, volcanic	0	Hottest planet; retrograde rotation	~243 Earth days (retrograde)	~225 Earth days
Earth	Terrestrial	Rocky, 71% water-covered	1	Supports life; active water cycle	24 hours	365.25 days
Mars	Terrestrial	Rocky, dusty, polar ice caps	2	Known as Red Planet; evidence of past water	~24.6 hours	~687 Earth days
Jupiter	Jovian	Gaseous, liquid hydrogen interior	95+	Largest planet; strongest magnetic field	~10 hours	~12 Earth years
Saturn	Jovian	Gaseous	80+	Beautiful ring system; lowest density	~10.7 hours	~29.5 Earth years
Uranus	Jovian	Icy/gaseous	27	Rotates on its side; blue-green color	~17.2 hours (retrograde)	~84 Earth years
Neptune	Jovian	Icy/gaseous	14	Strongest winds; Great Dark Spot	~16.1 hours	~165 Earth years

Practice Questions

Conceptual Questions

1. What do you understand by Observable Universe? What is its composition?

2. Trace the process of evolution of life on earth.

3. Differentiate between Terrestrial and Jovian Planets.

4. What are the various celestial bodies observed in the universe? Explain any 4.

5. Elaborate the process of Star formation.

One Liner revision questions

1. How old is the Universe according to current Big Bang estimates?

2. What is the approximate radius of the observable Universe in light-years?

3. Which method involving light bending provides evidence for dark matter?

4. Between which two planets is the main asteroid belt located?

5. What do we call the dark, cooler regions on the Sun's surface.

PYQ Prelims

1. **Which of the following phenomena might have influenced the evolution of organisms? [2014]**

   1. Continental drift
   2. Glacial cycles

Select the correct answer using the code given below.

a) 1 only
b) 2 only
c) Both 1 and 2
d) Neither 1 nor 2

2. Which one of the following sets of elements was primarily responsible for the origin of life on the Earth? [2012]

a) Hydrogen, Oxygen, Sodium
b) Carbon, Hydrogen, Nitrogen
c) Oxygen, Calcium, Phosphorus
d) Carbon, Hydrogen, Potassium

Mains Exam PYQ

1. How does the Juno Mission of NASA help to understand the origin and evolution of earth? [150 Words, 10 Marks] (2017)