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CUET · GEOGRAPHY · CLASS XI · CODE 313

The Origin and Evolution of the Earth

CUET unit: The Earth (Structure and Physiography)

By **UniDrill** · NCERT-grounded study material

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📌 Snapshot

- The universe, stars, and the solar system formed in sequence, culminating in the origin of Earth ~4,600 million years ago.
- The key sequence is **Big Bang** → **galaxies** → **stars** → **planetesimals** → **planets** → **Earth's internal differentiation** → **atmosphere** → **oceans** → **life**.
- CUET tests specific dates/figures (age of Earth, Big Bang time, first life, first oxygen), named theories (Nebular Hypothesis, Big Bang Theory, Steady State) and their proponents (Kant, Laplace, Schmidt, Weizascar, Hubble, Hoyle).
- The distinction between **primordial theories** (Kant-Laplace Nebular Hypothesis, about the planets) and **modern theories** (Big Bang, about the universe) is a frequent source of MCQ distractors.
- Understanding the processes of **differentiation, degassing, and photosynthesis** is essential — these are the mechanisms that explain Earth's layered structure and its life-supporting conditions.

📖 Detailed Notes

2.1 Core concepts

Early Theories — Origin of the Earth

- **Immanuel Kant** (German philosopher) put forward one of the earlier and most popular arguments on the origin of the earth. **Mathematician Laplace revised it in 1796**, and the resulting theory is the **Nebular Hypothesis**. It held that the planets were formed out of a **cloud of material associated with a youthful sun, which was slowly rotating**. (NCERT Ch. 2, §Early Theories, p. 13)
- **In 1950, Otto Schmidt (Russia) and Carl Weizascar (Germany)** somewhat revised the nebular hypothesis. They considered that **the sun was surrounded by a solar nebula containing mostly hydrogen and helium along with dust**. The friction and collision of particles led to the formation of a **disk-shaped cloud**, and the planets were formed through the process of **accretion**. (NCERT p. 13)
- A central limitation of these early theories is that they sought only the origin of the earth or the planets, not of the universe itself; modern science addressed the larger question later.

Modern Theories — Origin of the Universe

- The most popular argument is the **Big Bang Theory**, also called the **expanding universe hypothesis**. **Edwin Hubble, in 1920, provided evidence that the universe is expanding** — as time passes, galaxies move further and further apart. The balloon analogy (points marked on an inflating balloon move apart) is "only partially correct" because it suggests galaxies themselves expand, which observations do not support. (NCERT §Modern Theories, p. 13)
- **Stages of the Big Bang:**
- (i) In the beginning, all matter forming the universe existed in one place in the form of a **"tiny ball" (singular atom) with an unimaginably small volume, infinite temperature and infinite density**.
- (ii) At the Big Bang the "tiny ball" exploded violently, leading to huge expansion. **It is now generally accepted that the event of Big Bang took place 13.7 billion years before the present.** Within fractions of a second after the bang, expansion was particularly rapid; thereafter it slowed. **Within first three minutes from the Big Bang, the first atom began to form.**
- (iii) **Within 300,000 years from the Big Bang, temperature dropped to 4,500 K (Kelvin) and gave rise to atomic matter. The universe became transparent.** (NCERT p. 14)
- Expansion means an **increase in space between galaxies**, not expansion of galaxies themselves.
- An alternative was **Hoyle's Steady State concept**, which considered the universe to be roughly the same at any point of time. With growing evidence for an expanding universe, the scientific community at present favours the expanding-universe argument. (NCERT p. 14)

Star Formation

- The distribution of matter and energy was not even in the early universe. **Initial density differences gave rise to differences in gravitational forces**, causing matter to be drawn together — these were the bases for the development of **galaxies**. A galaxy contains a large number of stars and is measured in thousands of light years; **diameters of individual galaxies range from 80,000–150,000 light years**. (NCERT §Star Formation, p. 14)
- A galaxy starts to form by accumulation of hydrogen gas in the form of a very large cloud called a **nebula**. Growing nebulae develop localised clumps of gas, which continue to grow into even denser gaseous bodies, giving rise to stars. **The formation of stars is believed to have taken place some 5-6 billion years ago.** (NCERT p. 14)
- A **light year is a measure of distance, not time** — light travels at 300,000 km/second, and a light year equals **9.461×10^{12} km**. The mean distance between the

sun and earth is **149,598,000 km**, or about **8.311 minutes** in light-time terms. (NCERT p. 14)

Formation of Planets

- Three stages: (i) Stars are localised lumps of gas within a nebula; gravitational force within the lumps leads to the formation of a **core** and a **huge rotating disc of gas and dust** around it. (ii) The gas cloud condenses; matter around the core develops into small-rounded objects which, through **cohesion**, develop into **planetesimals** — a large number of smaller bodies — and larger bodies form by collision under gravitational attraction. (iii) These large numbers of small planetesimals **accrete** to form a fewer large bodies — the **planets**. (NCERT pp. 14-15)

Evolution of Lithosphere

- The planet earth initially was **barren, rocky and hot** with a thin atmosphere of hydrogen and helium — very different from today's earth. The period between 4,600 million years ago and the present transformed it. (NCERT §Evolution of the Earth, p. 15)
- During the primordial stage, the earth was mostly in a **volatile state**. Due to gradual increase in density, the temperature inside increased, causing **material to separate by density** — heavier materials (like iron) sank to the centre and lighter ones moved to the surface. This is **differentiation**. With time, the earth cooled, solidified and condensed into a smaller size; the outer surface developed into a **crust**. (NCERT §Evolution of Lithosphere, p. 15)
- During the formation of the moon, a **giant impact** further heated up the earth. Through differentiation, the earth-forming material got separated into layers — from surface to centre: **crust, mantle, outer core, inner core**. **Density increases from crust to core.** (NCERT p. 15)

Evolution of Atmosphere and Hydrosphere

- The present composition of earth's atmosphere is chiefly contributed by **nitrogen and oxygen** (detailed in Ch. 7).
- **Three stages of atmospheric evolution:**
- **Stage 1 — Loss of primordial atmosphere.** The early atmosphere with hydrogen and helium was stripped off as a result of **solar winds**. This happened not only to Earth but to all terrestrial planets.
- **Stage 2 — Degassing.** During the cooling of the earth, gases and water vapour were released from the interior solid earth. The early atmosphere thus largely contained **water vapour, nitrogen, carbon dioxide, methane, ammonia and very little free oxygen**. The process through which the gases were outpoured from the interior is called **degassing**; continuous volcanic eruptions contributed water vapour and gases.

- **Stage 3 — Photosynthesis.** Composition was modified by the living world through photosynthesis — adding free oxygen. (NCERT §Evolution of Atmosphere, pp. 15-16)
- As the earth cooled, water vapour condensed; **CO_2 dissolved in rainwater**, lowering temperature further; rainwater collected in depressions to give rise to **oceans**. **The earth's oceans were formed within 500 million years from the formation of the earth — oceans are as old as 4,000 million years.** (NCERT p. 16)
- Around **3,800 million years ago, life began to evolve**. Around **2,500–3,000 million years before the present, photosynthesis evolved**. Life was confined to oceans for a long time; oceans began to receive oxygen through photosynthesis. Eventually oceans were saturated, and **about 2,000 million years ago, oxygen began to flood the atmosphere**. (NCERT p. 16)

Origin of Life

- Modern scientists refer to the origin of life as a kind of **chemical reaction**, which first generated complex organic molecules and assembled them so they could duplicate themselves — converting inanimate matter into living substance. (NCERT §Origin of Life, p. 16)
- The record of life that existed in different periods is found in rocks as **fossils**. **Microscopic structures closely related to the present form of blue algae have been found in geological formations older than 3,000 million years.** (NCERT p. 16)

2.2 Definitions to memorise

Term	Definition	Page
Nebular Hypothesis	Kant-Laplace hypothesis: planets formed from a cloud of material around a slowly rotating youthful sun	13
Solar nebula	Cloud of hydrogen, helium and dust surrounding the sun (Schmidt-Weizascar revision)	13
Big Bang Theory	Also called expanding universe hypothesis; all matter existed as a tiny ball that exploded 13.7 billion years ago	13-14
Expanding universe	Theory that space between galaxies is increasing over time	13
Steady State concept	Hoyle's alternative that the universe is roughly the same at any point of time — now disfavoured	14
Galaxy	Large gravitationally-bound collection of stars; diameter 80,000–150,000 light years	14
Nebula	Large cloud of hydrogen gas that accumulates to form a galaxy	14
Light year	Unit of distance (not time); 9.461×10^{12} km — distance light travels in one year	14

Term	Definition	Page
Star	Dense gaseous body formed by localised clumps within a growing nebula; formed ~5-6 billion years ago	14
Planetesimals	Small rounded objects formed by cohesion in the rotating disc around a star; building blocks of planets	15
Accretion	Process by which planetesimals collide and stick together by gravity to form planets	13, 15
Cohesion	Process by which small condensed objects join to form planetesimals	15
Differentiation	Density-based separation of earth's interior — heavier materials sink, lighter rise	15
Crust	Outermost solidified layer formed when the earth cooled	15
Giant impact	Moon-forming collision that further heated the early earth	15
Layers of the earth	Crust → mantle → outer core → inner core; density increases inward	15
Primordial atmosphere	Earliest H_2/He envelope stripped by solar winds	15
Solar winds	Charged-particle streams from the sun that removed primordial atmosphere	15
Degassing	Outpouring of gases (H_2O, N_2, CO_2, CH_4, NH_3) from the earth's hot interior via volcanic eruptions	15-16
Photosynthesis	Biological process that added free O_2 to the atmosphere starting ~2,500-3,000 mya	16
Oceans (age)	Formed within 500 million years of the earth → ~4,000 million years old	16
Blue algae fossils	Microscopic structures > 3,000 million years old — evidence of early life	16
Fossils	Records of past life preserved in rocks	16
Hubble (Edwin)	Provided evidence in 1920 that the universe is expanding	13
Hoyle (Fred)	Proposed the Steady State concept	14

2.3 Diagrams / processes to remember

- **Figure 2.1 — The Big Bang (p. 14):** A schematic showing the singularity exploding outward into the expanding universe with galaxies forming as space expands. The diagram conveys the difference between expansion of space (real) and expansion of galaxies themselves (not real) — the limitation of the balloon analogy.
- **Three-stage atmospheric evolution (pp. 15-16):** A linear process diagram you should be able to draw —

- Stage 1: H_2/He primordial atmosphere → stripped by solar winds
- Stage 2: Degassing via volcanoes → H_2O, N_2, CO_2, CH_4, NH_3 (very little O_2)
- Stage 3: Photosynthesis (algae, plants) → free O_2 added → modern composition.
- **Planet-formation sequence (pp. 14-15):** Nebula → gravitational core in localised lumps → huge rotating disc of gas and dust → condensation → cohesion of small rounded objects → planetesimals → accretion → planets. Place each stage in order.
- **Earth's interior layers (p. 15):** Crust → mantle → outer core → inner core. Density increases inward — direct outcome of differentiation. Compare with Ch. 3 (Interior of the Earth) for detail.
- **Big Bang chronology timeline:** 0 sec — singularity → 0-3 min — first atom forms → 300,000 yrs — atomic matter, transparency, 4,500 K → 5-6 bn yrs ago — stars form → 4.6 bn yrs ago — Earth forms → 4.0 bn yrs ago — oceans → 3.8 bn yrs ago — life → 3.0 bn yrs ago — blue algae fossils → 2.5-3.0 bn yrs ago — photosynthesis → 2.0 bn yrs ago — O_2 floods atmosphere → present.
- **Differentiation process:** Volatile early earth → density rises → temperature rises → heavy elements (Fe) sink to centre → light elements rise → cooling → crust solidifies → layered earth.
- **Hubble's balloon experiment (p. 13):** Inflate a balloon with marked points → points move apart → demonstrates expansion of space; caveat — points themselves don't grow, unlike on the balloon.

2.4 Common confusions / NTA trap points

- **Age confusion:** The **earth is 4.6 billion years old**; the **Big Bang occurred 13.7 billion years ago**. NTA frequently swaps these or substitutes "million" for "billion."
- **Nebular Hypothesis vs Big Bang Theory:** Nebular Hypothesis deals with the **origin of the earth/planets** (Kant-Laplace); Big Bang Theory deals with the **origin of the universe** (post-1920 modern theory). Conflating the two is a classic trap.
- **Differentiation vs Degassing:** Differentiation explains the **layered interior** (density-based separation); degassing explains the **second stage of atmospheric evolution** (gases released from interior via volcanism). They are distinct processes — Exercise 1(ii) explicitly tests this by asking which is not related to atmospheric evolution (answer: differentiation).
- **Light year is distance, not time** — a perennial distractor. It equals 9.461×10^{12} km, the distance light travels in one year.
- **Sequence of atmospheric evolution:** Loss of primordial → degassing → photosynthesis. Reversing degassing and primordial-loss is a frequent trap.
- **Timing of life and oxygen:** Life ~3,800 mya; photosynthesis ~2,500-3,000 mya; oxygen floods atmosphere ~2,000 mya. The order matters — distractors swap photosynthesis and free-oxygen timings.

- **Edwin Hubble vs Fred Hoyle:** Hubble — expanding universe evidence (1920); Hoyle — Steady State concept. Easy to invert.
- **Otto Schmidt + Carl Weizascar (1950)** revised the Nebular Hypothesis — both names are testable; NCERT spells "Weizascar" exactly so.
- **Star formation ~5-6 billion years ago** — not 13.7 billion (that's the Big Bang) and not 4.6 billion (that's Earth).
- **Galaxies' diameters: 80,000–150,000 light years** — a specific range; distractors may state "thousands of km."
- **Oceans formed within 500 million years of earth formation** → oceans ≈ 4,000 million years old, not 4,600.
- **Blue algae fossils > 3,000 million years old** — direct evidence of life having begun ~3,800 mya.

2.5 Key data table (NCERT figures only)

Parameter	Figure / fact	Source (NCERT p.)
Age of the Universe (Big Bang)	13.7 billion years	14
First atom formed	Within 3 minutes of Big Bang	14
Atomic matter / transparent universe	Within 300,000 years; temperature 4,500 K	14
Star formation epoch	5-6 billion years ago	14
Galaxy diameter range	80,000–150,000 light years	14
Light year	9.461×10^{12} km	14
Speed of light	300,000 km/s	14
Sun-Earth mean distance	149,598,000 km (≈ 8.311 light-minutes)	14
Age of the Earth	4.6 billion years (4,600 million)	15
Age of oceans	~4,000 million years	16
Oceans formed within	500 million years of earth formation	16
Origin of life	~3,800 million years ago	16
Photosynthesis evolved	2,500–3,000 million years ago	16
Oxygen flooded atmosphere	~2,000 million years ago	16
Blue algae fossils (age)	> 3,000 million years	16

🎯 Practice MCQs

📊 PYQ Alignment

This chapter appears regularly in CUET Geography as part of the physical environment unit; questions typically focus on specific numerical data (age of Earth = 4.6 billion years, Big Bang = 13.7 billion years, life began ~3,800 million years ago, photosynthesis 2,500-3,000 mya, oceans 4,000 mya), named theories and their proponents (Kant, Laplace, Schmidt, Weizascar, Hubble, Hoyle), and the three-stage evolution of the atmosphere — making **factual recall and sequencing** the dominant question formats. Statement-based items routinely combine the Nebular Hypothesis with the Big Bang to test conceptual separation, and assertion-reason items often anchor on differentiation, degassing or the Hubble expansion finding.