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COMPREHENSIVE STUDY GUIDE

Physical Geography

Earth · Atmosphere · Landforms · Climate

Ten Illustrated Lectures · 300 Practice MCQs

CONTENTS

Ten Lectures in Physical Geography

LECTURE I

01

Origin and Evolution of the Earth

Physical Geography · Study Companion

- **The Nebular Hypothesis (1796):** Initially proposed by German philosopher Immanuel Kant and later revised by mathematician Laplace. It posited that planets formed out of a slowly rotating cloud of material (a nebula) associated with a youthful sun.
- **The Wandering Star Theory (1900):** Chamberlain and Moulton hypothesized that a wandering star approached the sun, pulling away a cigar- shaped extension of solar material. As the star departed, this separated material continued to revolve around the sun, slowly condensing into planets. Sir James Jeans and Sir Harold Jeffrey supported this theory.
- **Binary Theories:** These later arguments suggested that the sun originally had a coexisting companion star.
- **The Revised Nebular Hypothesis (1950):** Otto Schmidt (Russia) and Carl Weizascar (Germany) revised Kant's theory, suggesting the sun was surrounded by a "solar nebula" consisting mostly of hydrogen, helium, and dust. The friction and collision of these particles formed a disk-shaped cloud, from which planets formed via accretion.

Modern Theories: The Origin of the Universe

Scientists eventually shifted focus from just planetary formation to the origin of the universe itself.

- **The Big Bang Theory (Expanding Universe Hypothesis):** Supported by Edwin Hubble's 1920 discovery that the universe is expanding.
- **The Balloon Analogy & Its Flaw:** To understand expansion, imagine galaxies as dots on a balloon. As the balloon inflates, the dots move further apart. However, while the space between real galaxies expands,

scientific observations do not support that the galaxies themselves are expanding (unlike the dots on the balloon, which stretch).

- Stages of the Big Bang:

1. **The Singular Atom:** All matter existed in a "tiny ball" featuring unimaginably small volume, infinite temperature, and infinite density.
2. **The Explosion:** Around 13.7 billion years ago, this tiny ball violently exploded, resulting in massive expansion. Within fractions of a second, rapid expansion converted some energy into matter.
3. **Atomic Formation:** Within the first three minutes of the event, the first atom began to form.
4. **A Transparent Universe:** Within 300,000 years, the universe's temperature dropped to 4,500 Kelvin, giving rise to atomic matter and making the universe transparent.

- **Steady State Concept:** An alternative proposed by Hoyle, suggesting the universe remains roughly the same at any point in time. However, the expanding universe model is currently favored by the scientific community due to overwhelming evidence.

Formation of Stars and Planets

- **Star Formation (5–6 billion years ago):** Early on, matter and energy were unevenly distributed, causing differences in gravitational forces that drew matter together to form galaxies.
  - Galaxies spread over vast distances, with individual diameters ranging from 80,000 to 150,000 light-years.
  - Galaxies start as massive hydrogen clouds called a nebula. Localized gas clumps develop within the nebula, growing denser until they form stars.
- **Understanding the Light Year:** A light year measures distance, not time. It is the distance light travels in one year at 300,000 km/second (equal to 9.461×10^{12} km). The mean distance between the Earth and the Sun (149,598,000 km) is 8.311 light-minutes.
- Stages of Planetary Formation:

1. Stars form localized gas lumps within a nebula. Gravity creates a core to the gas cloud, surrounded by a huge rotating disc of gas and dust.
2. The gas cloud condenses. Through the process of cohesion, small- rounded objects develop into planetesimals.
3. These planetesimals collide and, driven by gravitational attraction, stick together (accrete) to form fewer, larger bodies known as planets.

Deep Dive into Our Solar System

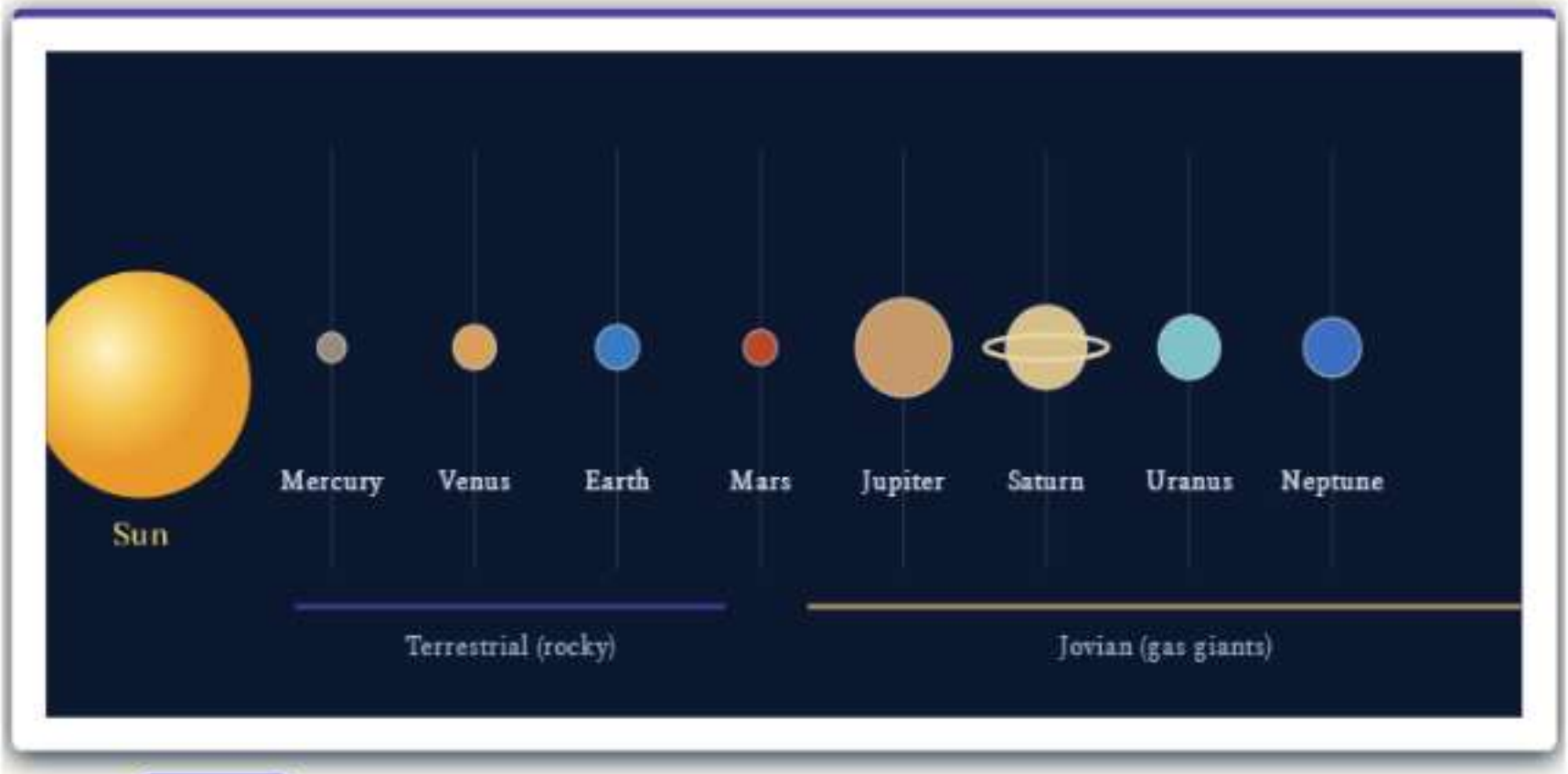

FIGURE 1 *The eight planets of the Solar System, from the rocky terrestrial worlds to the outer gas giants (not to scale).*

- **Timeline:** The solar nebula collapsed between 5 to 5.6 billion years ago, and planets formed roughly 4.6 billion years ago. The system contains the sun, 8 planets, 63 moons, asteroids, comets, and dust/gas.
- **Terrestrial Planets (Inner Planets):** Mercury, Venus, Earth, and Mars. They are Earth-like, rocky, metal-rich, and have high densities.
- **Jovian Planets (Outer / Gas Giants):** Jupiter, Saturn, Uranus, and Neptune. They are Jupiter-like, much larger, and feature thick atmospheres composed mostly of hydrogen and helium.
- Why Terrestrial Planets are Rocky vs. Jovian Gas Giants:

1. **Temperature:** Terrestrial planets formed too close to the sun for gases to condense into solid particles, whereas Jovian planets formed at a distant, cooler location.
2. **Solar Winds:** Intense solar winds near the sun blew off lots of gas and dust from terrestrial planets. The winds were too weak to do this to the distant Jovian planets.
3. **Gravity:** The smaller terrestrial planets lacked the lower gravity needed to hold onto escaping gases.

- **Note:** In August 2006, the International Astronomical Union downgraded Pluto to a 'dwarf planet'.

Evolution of the Moon

- **The Dumb-bell Theory (1838):** Sir George Darwin suggested Earth and the Moon were once a rapidly rotating dumb-bell-shaped mass that broke apart, leaving behind the depression now occupied by the Pacific Ocean. Scientists reject this today.

- **The Giant Impact** (**"The Big Splat"**): Shortly after Earth's formation, a body roughly one to three times the size of Mars collided with Earth. A large part of Earth was blasted into space, orbited the planet, and coalesced into the moon about 4.44 billion years ago.

Geological Evolution of the Earth

Early Earth was a barren, hot, rocky object with a thin hydrogen and helium atmosphere.

- **Evolution of the Lithosphere** (**Differentiation**): In its volatile primordial stage, Earth's density and internal temperature gradually increased. This heat caused materials to separate based on density—a process known as differentiation. Heavier elements (like iron) sank to the core, while lighter materials rose to the surface. Cooling caused the outer surface to solidify into the crust. Earth's layers are now distinctly defined as the crust, mantle, outer core, and inner core.
- Evolution of the Atmosphere:

1. **Stage 1 - Loss of Primordial Atmosphere:** Solar winds stripped away the original hydrogen and helium.
2. **Stage 2 - Degassing:** As Earth cooled, volcanic eruptions outpoured gases from the hot interior. The early atmosphere was rich in water vapor, nitrogen, carbon dioxide, methane, and ammonia, with very little free oxygen.
3. **Stage 3 - Biological Modification:** Living organisms modified the atmosphere via photosynthesis.

- **Evolution of the Hydrosphere** (**Oceans**): As Earth cooled, atmospheric water vapor condensed. Carbon dioxide dissolved in the rainwater, accelerating the cooling and causing heavy, continuous rain. This water filled massive surface depressions, forming oceans within 500 million years of Earth's formation (meaning oceans are roughly 4,000 million years old).

Origin of Life & The Geological Time Scale

- **The Dawn of Life:** Modern science views the origin of life as a chemical reaction that created self-duplicating complex organic molecules around 3,800 million years ago. Microscopic fossils resembling modern blue-green algae date back to over 3,000 million years ago.
- **The Oxygenation of Earth:** For a long time, life was strictly confined to the oceans. Photosynthesis evolved between 2,500 and 3,000 million years ago, saturating the oceans with oxygen. Around 2,000 million years ago, this oxygen finally began to flood the atmosphere.
- Key Evolutionary Milestones (From the Geological Time Scale):
  - **Pre-Cambrian Era** (**570 – 4,800 Million Years Ago**): Dominated by oceans, blue-green algae, and soft-bodied arthropods.
  - **Palaeozoic Era** (**245 – 570 Million Years Ago**): Saw the first fish (Ordovician), the first trace of terrestrial plant life (Silurian), amphibians (Devonian), and the first reptiles and coal beds (Carboniferous).
  - **Mesozoic Era** (**65 – 245 Million Years Ago**): The "Age of Dinosaurs" (Jurassic period) and their subsequent

extinction (Cretaceous period).

- **Cainozoic Era (Present – 65 Million Years Ago):** The era of mammals. Notable epochs include the Miocene (apes and flowering plants), the Pliocene (early human ancestors), the Pleistocene (Homo Sapiens), and the Holocene (Modern Man).

Practice Questions

30 MCQs

Q1 Consider the following pairs regarding the early theories of the Earth's origin: 1. Nebular Hypothesis: Immanuel Kant and Laplace 2. Wandering Star Theory: Chamberlain and Moulton 3. Revised Nebular Hypothesis: Otto Schmidt and Carl Weizascar Which of the pairs given above is/are correctly matched?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · D

EXPLANATION Immanuel Kant and Laplace proposed the Nebular Hypothesis. Chamberlain and Moulton proposed the wandering star theory. Otto Schmidt and Carl Weizascar proposed the revised Nebular Hypothesis.

Q2 Regarding the "Big Bang Theory", consider the following statements: 1. It is also known as the expanding universe hypothesis. 2. The event of the Big Bang took place approximately 4.6 billion years ago. 3. Within the first three minutes from the Big Bang event, the first atom began to form. Which of the statements given above is/are correct?

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2, and 3

Answer · B

EXPLANATION The Big Bang Theory is also called the expanding universe hypothesis. The event took place 13.7 billion years ago, not 4.6 billion years ago. Within the first three minutes, the first atom began to form.

Q3 Who among the following provided evidence in 1920 that the universe is expanding?

A Edwin Hubble

B Immanuel Kant

C Harold Jeffrey

D Hoyle

Answer · A

EXPLANATION Edwin Hubble provided evidence in 1920 that the universe is expanding.

Q4 The "Steady State Concept" regarding the universe was proposed as an alternative to the expanding universe hypothesis by:

A Sir James Jeans

B Sir George Darwin

C Hoyle

D Carl Weizascar

Answer · C

EXPLANATION Hoyle's concept of steady state was proposed as an alternative to the expanding universe hypothesis.

Q5 Consider the following statements regarding "Light Year": 1. It is a measure of time. 2. It is the distance light travels in one year at a speed of 300,000 km/second. 3. The mean distance between the sun and the earth is about 8.311 minutes in terms of light years. Which of the statements given above is/are correct?

A 2 only

B 1 and 3 only

C 2 and 3 only

D 1, 2, and 3

Answer · C

EXPLANATION A light year is a measure of distance and not of time. It is the distance light travels in one year at 300,000 km/second, and the sun-earth distance is 8.311 light minutes.

Q6 Arrange the following stages in the development of planets in the correct chronological order: 1. Formation of planetesimals by cohesion. 2. Formation of a core to the gas cloud and a rotating disc of gas and dust. 3. Accretion of planetesimals to form planets. Select the correct answer using the code given below:

A 1-2-3

B 2-1-3

C 3-1-2

D 2-3-1

Answer · B

EXPLANATION First, a core forms with a rotating disc of gas. Then, the matter condenses into planetesimals. Finally, planetesimals accrete to form planets.

Q7 Which of the following is/are the reasons for the inner planets (terrestrial planets) being rocky compared to the Jovian planets? 1. They were formed in the close vicinity of the parent star where it was too warm for gases to condense into solid particles. 2. Intense solar wind nearer the sun blew off lots of gas and dust from them. 3. Their lower gravity could not hold the escaping gases. Select the correct answer using the code given below:

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · D

EXPLANATION Terrestrial planets are rocky because they formed near the sun (too warm for gases to condense), solar winds blew off their gas/dust, and their lower gravity couldn't hold escaping gases.

Q8 The Jovian planets are characterised by:

A Relatively high densities and a rock-metal composition.

B Thick atmospheres composed mostly of helium and hydrogen.

C Formation in the close vicinity of the parent star.

D Absence of any satellites or moons.

Answer · B

EXPLANATION Jovian (Gas Giant) planets are large with thick atmospheres mostly of helium and hydrogen.

Q9 Consider the following statements regarding the origin of the Moon: 1. Sir George Darwin suggested that the Earth and the Moon initially formed a single rapidly rotating body that broke apart. 2. The modern accepted theory of the Moon's formation is known as "the big splat". 3. The Moon was formed approximately 4.44 billion years ago. Which of the statements given above is/are correct?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · D

EXPLANATION Sir George Darwin suggested the dumb-bell theory in 1838. The current accepted theory is "the big splat" or giant impact, leading to the moon's formation 4.44 billion years ago.

Q10 The process by which the earth-forming materials separated into different layers (crust, mantle, core) based on their densities is known as:

A Accretion

B Degassing

C Differentiation

D Condensation

Answer · C

EXPLANATION The separation of materials into different layers from the surface to the central parts based on density is called differentiation.

Q11 Consider the following statements regarding the evolution of Earth's atmosphere: 1. The first stage of atmosphere evolution was marked by the loss of the primordial atmosphere due to solar winds. 2. Volcanic eruptions contributed water vapour and gases during the cooling of the earth. 3. The early atmosphere was rich in free oxygen. Which of the statements given above is/are correct?

A 1 and 2 only

B 2 only

C 1 and 3 only

D 1, 2, and 3

Answer · A

EXPLANATION The first stage was the loss of the primordial atmosphere due to solar winds. Volcanic eruptions contributed gases. The early atmosphere contained very little free oxygen.

Q12 What was the composition of Earth's primordial atmosphere before it was stripped off?

A Nitrogen and Oxygen

B Carbon dioxide and Methane

C Hydrogen and Helium

D Ammonia and Water Vapour

Answer · C

EXPLANATION The early primordial atmosphere consisted of hydrogen and helium, which was stripped off by solar winds.

Q13 In the context of the Earth's evolution, what does the term 'degassing' refer to?

A The stripping away of the primordial atmosphere by solar winds.

B The process through which gases were outpoured from the earth's hot interior.

C The modification of the atmosphere by living organisms through photosynthesis.

D The separation of heavy and light materials within the earth.

Answer · B

EXPLANATION Degassing is the process through which gases and water vapour were outpoured from the interior of the earth.

Q14 With reference to the geological timescale, match List I (Events) with List II (Time period) and select the correct answer: List I

A Formation of oceans

B Beginning of life evolution

C Evolution of photosynthesis

D Flooding of atmosphere with oxygen List II 1. ~3,800 million years ago 2. ~4,000 million years ago 3. ~2,000 million years ago 4. ~2,500-3,000 million years ago Code:

A a-2, b-1, c-4, d-3

B a-1, b-2, c-3, d-4

C a-2, b-1, c-3, d-4

D a-1, b-2, c- 4, d-3

Answer · A

EXPLANATION Oceans formed ~4,000 million years ago. Life evolved ~3,800 million years ago. Photosynthesis evolved 2,500-3,000 million years ago. Oxygen flooded the atmosphere 2,000 million years ago.

Q15 According to the Big Bang theory, what happened roughly 300,000 years after the Big Bang?

A The first atom began to form.

B The temperature dropped to 4,500 Kelvin and the universe became transparent.

C A giant star exploded.

D The solar system was formed.

Answer · B

EXPLANATION Within 300,000 years from the Big Bang, the temperature dropped to 4,500 Kelvin, giving rise to atomic matter, and the universe became transparent.

Q16 The "Giant Impact" or "The Big Splat" theory involves a collision between the early Earth and a body approximately the size of:

A Jupiter

B One to three times that of Mars

C The Sun

D Venus

Answer · B

EXPLANATION The "big splat" theory posits that a body the size of one to three times that of Mars collided with the earth.

Q17 Which of the following celestial bodies was reclassified as a 'dwarf planet' in August 2006 by the International Astronomical Union?

A Neptune

B Uranus

C Pluto

D Mercury

Answer · C

EXPLANATION In August 2006, the International Astronomical Union decided that Pluto may be called a 'dwarf planet'.

Q18 According to the Revised Nebular Hypothesis by Otto Schmidt and Carl Weizascar, the solar nebula that surrounded the sun primarily contained:

A Carbon dioxide and water vapor

B Hydrogen, helium, and dust

C Iron, nickel, and silica

D Oxygen and nitrogen

Answer · B

EXPLANATION The revised nebular hypothesis considered that the solar nebula contained mostly hydrogen and helium along with dust.

Q19 Consider the following statements about the Earth's interior structure: 1. During Earth's primordial stage, the temperature inside increased due to a gradual decrease in density. 2. Heavier materials like iron sank towards the centre of the earth. 3. From the crust to the core, the density of the material increases. Which of the statements given above is/are correct?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · B

EXPLANATION The temperature inside increased due to a gradual increase in density, not decrease. Heavier materials sank to the center, and density increases from the crust to the core.

Q20 In the Geological Time Scale, which of the following has the longest duration?

A Era

B Period

C Epoch

D Eons

Answer · D

EXPLANATION Eons have the longest duration (e.g., Hadean, Archean, Proterozoic) as shown in the Geological Time Scale chart and the textbook exercises.

Q21 The extinction of dinosaurs occurred during which of the following periods?

A Jurassic

B Cretaceous

C Triassic

D Permian

Answer · B

EXPLANATION According to the Geological Time Scale, the extinction of dinosaurs occurred in the Cretaceous period (65 - 144 Million years ago).

Q22 Consider the following statements regarding the balloon experiment used to explain the expanding universe: 1. The distance between the points on the balloon increases as it is inflated, simulating galaxies moving apart. 2. The points themselves expand, which perfectly matches scientific observations of galaxies. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · A

EXPLANATION The balloon example simulates galaxies moving apart, but scientists believe observations do not support the expansion of the galaxies themselves. The balloon example is only partially correct.

Q23 Which period in the geological time scale is known as the "Age of Dinosaurs"?

A Cretaceous

B Jurassic

C Triassic

D Permian

Answer · B

EXPLANATION The Geological Time Scale table explicitly labels the Jurassic period (144 - 208 Million years ago) as the "Age of Dinosaurs".

Q24 The first trace of life on land (Plants) is associated with which period?

A Devonian

B Silurian

C Ordovician

D Cambrian

Answer · B

EXPLANATION The Silurian period (408 - 438 Million years ago) marks the "First trace of life on land: Plants".

Q25 Which era is associated with the dominance of mammals from 65 million years ago to the present times?

A Mesozoic

B Palaeozoic

C Cainozoic

D Pre- Cambrian

Answer · C

EXPLANATION The Cainozoic era stretches from 65 million years to the present times and includes the evolution of mammals up to modern man.

Q26 Consider the following about the early origins of life: 1. Modern scientists refer to the origin of life as a kind of chemical reaction. 2. Life initially began and remained confined to the land for a long time. 3. Microscopic structures related to present-day blue algae have been found in formations older than 3,000 million years. Which of the statements given above is/are correct?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · C

EXPLANATION Life is referred to as a chemical reaction. It was confined to the oceans (not land) for a long time. Fossils of blue algae exist in formations older than 3,000 million years.

Q27 The modern human (Homo Sapiens) appeared during which Epoch?

A Holocene

B Pleistocene

C Pliocene

D Miocene

Answer · B

EXPLANATION The Geological Time Scale notes "Homo Sapiens" under the Pleistocene epoch (10,000 - 2 million years before present). (Modern Man is listed under Holocene, but Homo Sapiens is Pleistocene).

Q28 What led to the initial density differences in the early universe, which eventually formed the bases for the development of galaxies?

A The giant impact of a wandering star.

B **The uneven distribution of matter and energy.**

C The continuous volcanic eruptions.

D The chemical reaction of complex organic molecules.

Answer · B

EXPLANATION The distribution of matter and energy was not even in the early universe. These initial density differences gave rise to differences in gravitational forces, leading to the formation of galaxies.

Q29 According to the text, what is the approximate age of the Earth?

A 13.7 billion years

B 5.6 billion years

C **4.6 billion years**

D 3.8 billion years

Answer · C

EXPLANATION The planets, including Earth, were formed about 4.6 billion years ago.

Q30 Coal beds are historically associated with which of the following geological periods?

A Devonian

B **Carboniferous**

C Permian

D Triassic

Answer · B

EXPLANATION The Carboniferous period (286 - 360 Million years ago) is associated with the first reptiles, vertebrates, and "Coal beds".

CHAPTER 1 · AT A GLANCE

Origin and Evolution of the Earth

Cosmos & Deep Time

13.7	4.6	8	63
Billion yrs — Big Bang	Bya — Earth & planets	Planets in Solar System	Known moons

1796 Nebular Hypothesis › **1900** Wandering Star › **1950** Revised Nebular › **Now** Big Bang Model

TERRESTRIAL (INNER)

Mercury · Venus · Earth · Mars

JOVIAN (OUTER)

Jupiter · Saturn · Uranus · Neptune

GEOLOGICAL ERAS

Pre-Cambrian · Palaeozoic · Mesozoic · Cainozoic

★ *The Moon formed ~4.44 Bya via the "Big Splat" — a Mars-sized body colliding with the early Earth.*

LECTURE II

02

Interior of the Earth

Physical Geography · Study Companion

Introduction to the Earth's Interior

- **Forces at Play:** The configuration of the earth's surface is the product of both exogenic (external) and endogenic (internal) processes. Understanding these forces is essential for grasping how landscapes develop and why phenomena like earthquakes and tsunamis occur.
- **Evidential Limits:** The interior of the earth can only be understood through indirect evidences, as it is impossible to physically reach the earth's core.

Sources of Information About the Interior

Direct Sources:

- **Mining Activity:** Provides direct evidence that temperature, pressure, and density increase as you move deeper into the earth.
- **Volcanic Eruptions:** When molten magma is thrown onto the surface (becoming lava), it becomes available for direct laboratory analysis, though finding the exact depth of the magma source is difficult.

Indirect Sources:

- **Meteors:** Although not from earth, meteors are solid bodies with materials and structures similar to our planet, making them a valuable comparative source.
- **Gravitation:** Gravity is not uniform across the globe; it is greater near the poles and less at the equator because of the differing distances from the earth's centre. Differences between expected and observed gravity readings are known as gravity anomalies, which reveal the uneven distribution of mass in the earth's crust.

- **Magnetic Surveys:** Help map the distribution of magnetic materials within the crustal portion.
- **Seismic Activity (Earthquakes):** The study of earthquake waves is one of the most critical sources, providing a complete picture of the earth's layered interior.

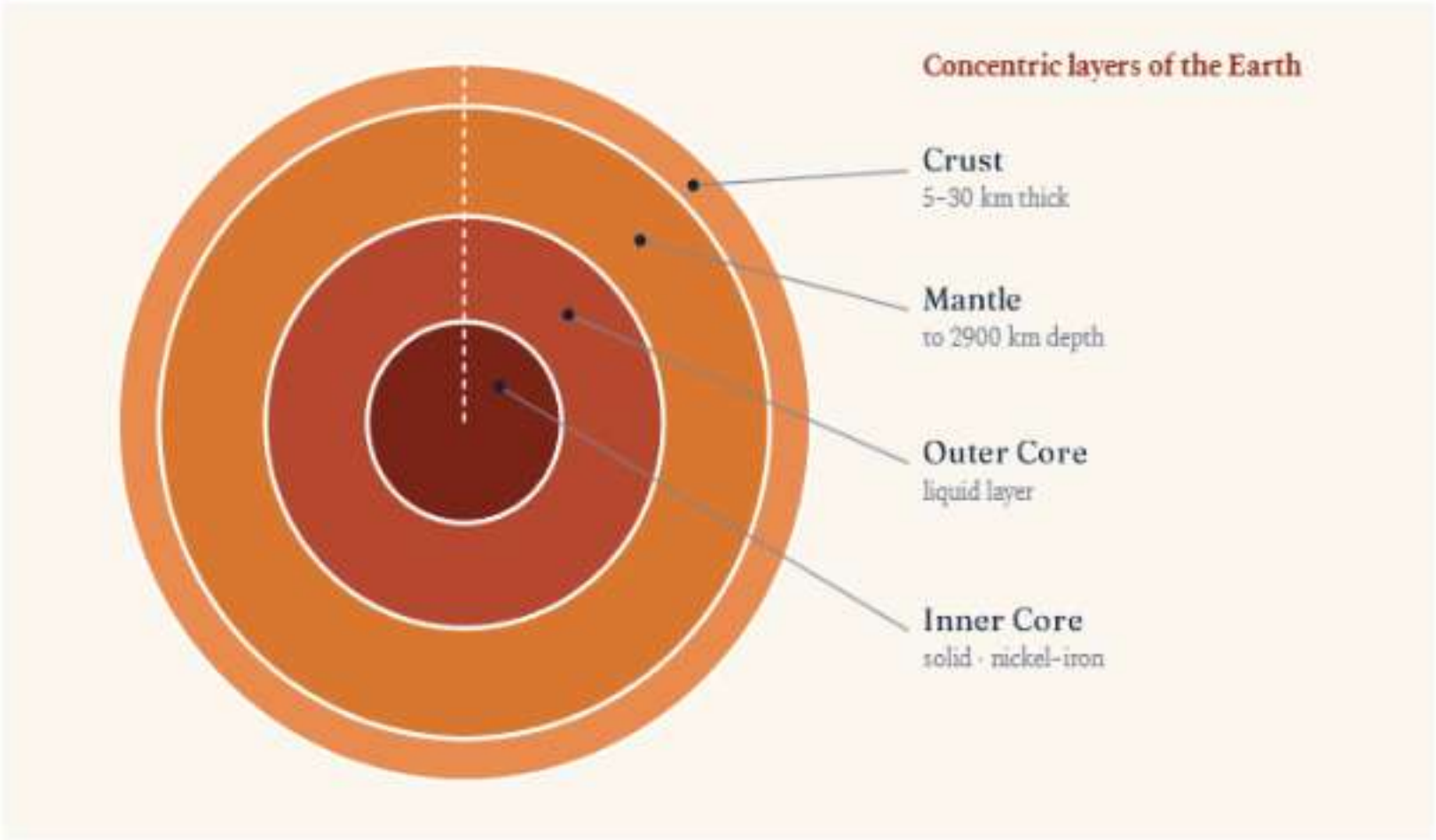

FIGURE 2 *A cross-section of the Earth showing its concentric layers — from the thin crust to the solid inner core.*

Earthquakes and Seismic Activity

- **The Mechanism:** An earthquake is the shaking of the earth caused by a release of energy along a fault (a sharp break in crustal rocks). Rocks along a fault press against each other, locking due to friction. When the pressure overcomes the friction, they slide past one another abruptly, releasing energy waves.
- **Focus (Hypocentre):** The exact point deep within the earth where the energy is initially released.
- **Epicentre:** The point on the surface directly above the focus; it is the nearest point to the focus and the first to experience the seismic waves.
- **Locating an Epicentre:** Scientists use data from three seismograph stations. They compute the time lag between the arrival of P-waves and S- waves. For every second of time lag, the earthquake is roughly 8 km away. They draw intersecting circles based on this distance to pinpoint the epicentre.

Types and Measurement

- Types:
  - **Tectonic:** Generated by sliding rocks (most common).

- **Volcanic:** Confined to active volcano areas.
- **Collapse:** Minor tremors from collapsing underground mine roofs.
- **Explosion:** Tremors from chemical or nuclear explosions.
- **Reservoir-induced:** Occur near large water reservoirs.

- Scales:
  - **Richter Scale:** Measures magnitude (actual energy released) on a scale of 0-10. Quakes above magnitude 5 are highly devastating, while those above 8+ are rare (occurring once every 1-2 years).
  - **Mercalli Scale:** Measures intensity (visible damage) on a scale of 1- 12. Earthquake Waves:
- **Body Waves:** Travel through the earth's body and are generated at the focus. Wave velocities increase in denser materials, and they refract/reflect when crossing varying densities.
  - **P-waves (Primary):** Arrive first, are similar to sound waves, and can travel through gaseous, liquid, and solid materials. They vibrate parallel to the direction of wave propagation, exerting pressure that stretches and squeezes the rock.
  - **S-waves (Secondary):** Arrive with a time lag and travel ONLY through solid materials (which helped scientists map the earth's liquid layers). They vibrate perpendicular to the wave direction in the vertical plane, creating troughs and crests.
- **Surface Waves:** Formed when body waves interact with surface rocks. They are the last to report on a seismograph and are the most damaging, causing rock displacement and structural collapse.

The Shadow Zone

- **Definition:** Specific areas where seismographs do not record earthquake waves.
- **P-wave Shadow Zone:** Exists as a band around the earth between 105° and 145° away from the epicentre.
- **S-wave Shadow Zone:** Encompasses the entire zone beyond 105°, covering over 40 per cent of the earth's surface.

Effects of Earthquakes

- **Landform impacts:** Ground shaking, differential ground settlement, land/mud slides, soil liquefaction, ground lurching, and avalanches.
- **Life/Property impacts:** Ground displacement, floods from dam/levee failures, fires, structural collapse, falling objects, and Tsunamis.
- **Tsunami note:** Tsunamis are waves generated by tremors, not the earthquake itself. They only occur if the tremor's epicentre is below oceanic waters and the magnitude is sufficiently high.

Structure of the Earth

- **The Crust:** The outermost, brittle, solid part of the earth.
  - **Oceanic crust:** Mean thickness of 5 km.
  - **Continental crust:** Mean thickness of 30 km (reaching up to 70 km in major mountain systems like the Himalayas).

- **The Mantle:** Extends from Moho's discontinuity to a depth of 2,900 km.
  - **Asthenosphere:** The upper portion extending up to 400 km. The word "astheno" means weak. It is the main source of magma for volcanic eruptions.
  - **Lithosphere:** Comprises the crust and uppermost part of the mantle, ranging from 10-200 km in thickness.
  - **Lower Mantle:** Extends beyond the asthenosphere and is entirely in a solid state.
- **The Core:** Begins at the core-mantle boundary at a depth of 2,900 km.
  - The outer core is liquid, while the inner core is solid.
  - It is composed of very heavy materials, predominantly nickel and iron, often referred to as the nife layer.

Volcanoes and Volcanic Landforms

- **Overview:** A volcano is a vent where gases, ashes, and molten rock escape to the surface. Material in the upper mantle is called magma; once it moves toward the crust or reaches the surface, it is known as lava.
- **Emissions:** Include lava flows, pyroclastic debris, volcanic bombs, ash, dust, and gases (nitrogen compounds, sulphur compounds, chlorine, hydrogen, and argon).

Major Types of Volcanoes

- **Shield Volcanoes:** Made mostly of highly fluid basalt, making them broad and not steep. They are the largest volcanoes on earth (barring flood basalts) and have low explosivity unless water gets into the vent. Lava fountains can develop into a cinder cone.
- **Composite Volcanoes:** Erupt cooler, more viscous lavas than basalt, often explosively. Large quantities of pyroclastic material and ash accumulate, forming layered mounts.
- **Caldera:** The most explosive volcanoes. Their huge magma chambers are so close to the surface that during an eruption, they collapse on themselves instead of building tall structures, forming collapsed depressions called calderas.
- **Flood Basalt Provinces:** Outpour highly fluid lava over thousands of square kilometres. Individual flows can extend hundreds of kilometres and exceed 50 m in thickness (e.g., the Deccan Traps in India).
- **Mid-Ocean Ridge Volcanoes:** Occur in oceanic areas along a ridge system stretching more than 70,000 km, featuring frequent eruptions in their central portions.

Intrusive Volcanic Landforms (Plutonic Rocks)

- **Note:** Lava cooling at the surface forms volcanic rocks; lava cooling within the crust forms plutonic rocks (intrusive forms).
- **Batholiths:** Large, deep granitic bodies forming large domes. They represent the cooled portions of magma chambers and only appear on the surface after extensive denudation.
- **Lacoliths:** Large dome-shaped intrusive bodies with a level base and connected by a pipe-like conduit from below (e.g., domal hills on the Karnataka plateau).
- **Lapolith:** Lava that settles in weak planes and develops into a saucer-shaped body, concave to the sky.

- **Phacoliths:** Wavy masses of intrusive rocks found at the base of synclines or the top of anticlines in folded igneous areas, fed by magma chambers beneath.
- **Sills and Sheets:** Near-horizontal bodies of intrusive igneous rock. Thinner deposits are called sheets, while thick horizontal deposits are called sills.
- **Dykes:** Formed when lava makes its way through land cracks/fissures and solidifies almost perpendicular to the ground, creating a wall-like structure. They are very common in western Maharashtra and are considered feeders for the Deccan Traps.

Practice Questions

30 MCQs

Q1 What is the approximate radius of the earth?

A 5,370 km

B 6,370 km

C 7,370 km

D 8,370 km

Answer · B

EXPLANATION 6,370 km

Q2 Which of the following is considered a direct source of information about the interior of the earth?

A Meteors

B Volcanic eruptions

C Gravitation

D Magnetic field

Answer · B

EXPLANATION Volcanic eruptions

Q3 What is the maximum depth reached by the deep drilling project at Kola in the Arctic Ocean?

A 3 km

B 4 km

C 12 km

D 70 km

Answer · C

EXPLANATION 12 km

Q4 As distance from the surface towards the interior increases, what happens to temperature, pressure, and density?

A They all decrease.

B Temperature increases, but pressure decreases.

C Density decreases while temperature and pressure increase.

D Temperature, pressure, and density all increase.

Answer · D

EXPLANATION Temperature, pressure, and density all increase

Q5 Why is the gravitational force (g) less at the equator than near the poles?

A Due to higher temperatures at the equator.

B Because the distance from the centre of the earth is greater at the equator.

C Because the crust is thinner at the poles.

D Due to magnetic anomalies.

Answer · B

EXPLANATION Because the distance from the centre of the earth is greater at the equator

Q6 What term refers to the difference between expected gravity readings and actual gravity readings at different places?

A Magnetic anomaly

B Gravity anomaly

C Gravitational shift

D Mass discrepancy

Answer · B

EXPLANATION Gravity anomaly

Q7 The exact point where earthquake energy is initially released is known as the:

A Epicentre

B Shadow zone

C Focus (or hypocentre)

D Fault line

Answer · C

EXPLANATION Focus or hypocentre

Q8 The lithosphere refers to the solid portion of the earth extending up to what depth from the surface?

A 100 km

B 200 km

C 400 km

D 2,900 km

Answer · B

EXPLANATION 200 km

Q9 Which type of earthquake body waves can travel through gaseous, liquid, and solid materials?

A P-waves

B S-waves

C Surface waves

D Tsunami waves

Answer · A

EXPLANATION P-waves

Q10 Which unique characteristic of S-waves helped scientists understand the structure of the earth's interior?

A They vibrate parallel to the direction of propagation.

B They can travel only through solid materials.

C They arrive first at the surface.

D They travel through the outer liquid core.

Answer · B

EXPLANATION They can travel only through solid materials

Q11 Which earthquake waves are considered the most damaging and cause the displacement of rocks and structural collapse?

A P-waves

B S-waves

C Surface waves

D Body waves

Answer · C

EXPLANATION Surface waves

Q12 How do P-waves vibrate in relation to their direction of wave propagation?

A Perpendicularly

B In a circular motion

C Parallel to the direction of the wave

D They do not vibrate

Answer · C

EXPLANATION Parallel to the direction of the wave

Q13 Between which degrees from the epicentre does the P-wave shadow zone appear as a band around the earth?

A 105° and 145°

B 0° and 105°

C 145° and 180°

D 90° and 105°

Answer · A

EXPLANATION 105° and 145°

Q14 The S-wave shadow zone is significantly larger and covers approximately what percentage of the earth's surface?

A 10 per cent

B 25 per cent

C A little over 40 per cent

D 60 per cent

Answer · C

EXPLANATION A little over 40 per cent

Q15 What does the Richter scale measure regarding an earthquake?

A Visible damage

B Magnitude (actual energy released)

C Structural collapse

D Size of the shadow zone

Answer · B

EXPLANATION Magnitude - actual energy released

Q16 The Mercalli scale ranges from 1-12 and takes into account which aspect of an earthquake?

A Time of arrival of S-waves

B Visible damage (intensity)

C Energy magnitude

D Depth of the hypocentre

Answer · B

EXPLANATION Visible damage - intensity

Q17 What is the mean thickness of the oceanic crust?

A 5 km

B 30 km

C 70 km

D 200 km

Answer · A

EXPLANATION 5 km

Q18 What is the weak, upper portion of the mantle that extends up to 400 km and acts as the main source of magma called?

A Lithosphere

B Asthenosphere

C Outer core

D Mesosphere

Answer · B

EXPLANATION Asthenosphere

Q19 The boundary separating the mantle and the core is located at what depth?

A 400 km

B 2,900 km

C 5,100 km

D 6,370 km

Answer · B

EXPLANATION 2,900 km

Q20 What is the physical state of the outer core and the inner core, respectively?

A Liquid outer core, solid inner core

B Solid outer core, liquid inner core

C Liquid outer core, liquid inner core

D Solid outer core, solid inner core

Answer · A

EXPLANATION Liquid outer core, solid inner core

Q21 Why is the earth's core sometimes referred to as the "nife" layer?

A It contains a high concentration of nitrogen and iron.

B It is mostly constituted by nickel and iron.

C It is composed of nickel and feldspar.

D It is heavily mineralized with neodymium and iron.

Answer · B

EXPLANATION It is mostly constituted by nickel and iron

Q22 Barring flood basalts, which broad, gently sloping volcanoes are the largest on earth?

A Composite Volcanoes

B Shield Volcanoes

C Calderas

D Mid- Ocean Ridge Volcanoes

Answer · B

EXPLANATION Shield Volcanoes

Q23 Which volcanoes are characterized by explosive eruptions of cooler, more viscous lavas and the layered accumulation of pyroclastic material?

A Shield Volcanoes

B Calderas

C Flood Basalt Provinces

D Composite Volcanoes

Answer · D

EXPLANATION Composite Volcanoes

Q24 Which volcanic structures are considered the most explosive and tend to collapse on themselves when they erupt?

A Calderas

B Shield Volcanoes

C Cinder Cones

D Stratovolcanoes

Answer · A

EXPLANATION Calderas

Q25 The Deccan Traps in India, which presently cover most of the Maharashtra plateau, are a prime example of which volcanic formation?

A Mid-Ocean Ridge Volcanoes

B Composite Volcanoes

C Flood Basalt Provinces

D Calderas

Answer · C

EXPLANATION Flood Basalt Provinces

Q26 What is the approximate length of the system of mid-ocean ridges that stretches through all the ocean basins?

A 5,000 km

B 30,000 km

C More than 70,000 km

D 100,000 km

Answer · C

EXPLANATION More than 70,000 km

Q27 Large, granitic magmatic bodies that cool deep within the crust and develop into large domes are known as:

A Lacoliths

B **Batholiths**

C Dykes

D Sills

Answer · B

EXPLANATION Batholiths

Q28 Large, dome-shaped intrusive bodies with a level base and connected by a pipe-like conduit from below are known as:

A Batholiths

B **Lacoliths**

C Phacoliths

D Sheets

Answer · B

EXPLANATION Lacoliths

Q29 When lava moves upwards and rests in a saucer shape that is concave to the sky, it is called a:

A Phacolith

B Sill

C **Lapolith**

D Dyke

Answer · C

EXPLANATION Lapolith

Q30 Wall-like intrusive structures that form when lava cools and solidifies almost perpendicular to the ground are known as:

A Sills

B Dykes

C Sheets

D Phacoliths

Answer · B

EXPLANATION Dykes

CHAPTER 2 · AT A GLANCE

Interior of the Earth

Inside the Planet

6370	2900	12	5/30
km — Earth's radius	km — depth to core	km — deepest drill (Kola)	km crust: ocean / continent

Crust — Si-Al / Si-Ma › **Mantle** — to 2900 km › **Outer Core** — Liquid › **Inner Core** — Solid "Nife"

SEISMIC WAVES

- P-waves: solid+liquid+gas
- S-waves: solids only

SHADOW ZONES

- P-shadow 105°–145°
- S-shadow beyond 105°

EVIDENCE SOURCES

- Direct: rocks, drilling, lava
- Indirect: seismic, gravity, meteorites

★ *S-waves cannot pass through the liquid outer core — the key proof that the outer core is molten.*

LECTURE III

03

Distribution of Continents and Oceans

Physical Geography · Study Companion

Historical Progression of Continental Theories

- **Early Mapmakers:** The symmetry of the Atlantic coastlines led Abraham Ortelius, a Dutch mapmaker, to first propose in 1596 that the Americas, Europe, and Africa were once joined. Antonio Pellegrini later visualized this by drawing a map showing the three continents together.
- **Alfred Wegener & Continental Drift (1912):** German meteorologist Alfred Wegener formalized the "continental drift theory," proposing a single supercontinent named PANGAEA ("all earth") surrounded by a mega-ocean named PANTHALASSA ("all water").
- **The Breakup:** Around 200 million years ago, Pangaea began splitting into a northern component (Laurasia) and a southern component (Gondwanaland), which subsequently broke into the smaller continents seen today.

Exhaustive Evidence for Continental Drift

- **Jig-Saw-Fit:** The shorelines of South America and Africa present an unmistakable match. In 1964, Bullard used a computer program to confirm this fit flawlessly at the 1,000-fathom line rather than the present-day shoreline.
- **Radiometric Dating:** Ancient rock belts dating back 2,000 million years on the Brazil coast exactly match those found in western Africa. Additionally, the earliest marine deposits along these coastlines date only to the Jurassic age, suggesting the Atlantic Ocean did not exist prior to this period.
- **Tillite (Glacial Evidence):** Tillite is sedimentary rock formed from glacier deposits. The Gondwana system in India features thick tillite at its base, indicating extensive and prolonged glaciation. Counterparts to

these specific sediments are found in six landmasses: Africa, Falkland Island, Madagascar, Antarctica, and Australia, providing unambiguous evidence of shared palaeoclimates.

- **Placer Deposits:** The Ghana coast contains rich placer deposits of gold, but lacks the necessary source rock. The actual source veins for this gold are located across the ocean in the Brazil plateau.
- Fossil Distribution:
  - **Mesosaurus:** Skeletons of this small reptile, adapted only to shallow brackish water, are found exclusively in the Southern Cape province of South Africa and the Iraver formations of Brazil—localities now separated by 4,800 km of ocean.
  - **Lemurs:** Their specific presence in India, Madagascar, and Africa led some scientists to theorize the past existence of a contiguous landmass linking them, which they named "Lemuria".
- **Wegener's Flawed Mechanics:** Wegener proposed two forces for this drift: a pole-fleeing force (related to Earth's rotation and equatorial bulge) and a tidal force (gravitational attraction of the moon and sun developing oceanic tides). However, contemporary scholars considered these forces totally inadequate to move solid continents over millions of years.

1. Post-Drift Discoveries & Detailed Ocean Floor Configuration In the 1930s, Arthur Holmes proposed the Convectional Current Theory, suggesting that radioactive elements cause thermal differences in the mantle, generating convection currents that could provide the missing force behind continental movement.

Following World War II, detailed ocean mapping revealed the ocean floor is full of dramatic relief, divided into three main segments:

1. **Continental Margins:** The transition zone between shores and deep-sea basins, encompassing the continental shelf, continental slope, continental rise, and deep-oceanic trenches. Deep-oceanic trenches are of particular interest to the study of shifting continents.
2. **Abyssal Plains:** Extensive plains where continental sediments that move beyond the margins are deposited.
3. **Mid-Oceanic Ridges:** The longest interconnected mountain chain on Earth's surface, submerged under water. It features a central rift system at its crest (a zone of intense volcanic activity), a fractionated plateau, and a flank zone.

- **Mapping Seismic Activity:** A distinct line of shallow-depth earthquakes and volcanoes runs through the central Atlantic, extends into the Indian Ocean, and bifurcates south of India—one branch heading to East Africa and the other toward Myanmar and New Guinea. This line perfectly coincides with the mid- oceanic ridges. Conversely, deep-seated earthquakes occur along the Alpine- Himalayan belt and the Pacific rim (Ring of Fire).

1. The 5 Facts Leading to Sea Floor Spreading (Harry Hess, 1961) Hess formulated the "sea floor spreading" hypothesis based on five critical pieces of data from post-drift mapping and paleomagnetic studies:
2. Mid-oceanic ridges experience constant volcanic eruptions, bringing huge amounts of fresh lava to the surface.

3. Rocks equidistant on either side of the mid-oceanic ridge crest show remarkable similarities in their period of formation, chemical composition, and magnetic properties. Rocks closest to the crest have normal polarity and are the youngest, with age increasing as one moves further away.
4. Oceanic crust is far younger (nowhere more than 200 million years old) than continental rocks (which can be up to 3,200 million years old).
5. Ocean floor sediments are unexpectedly thin; nowhere is the sediment column older than 200 million years.
6. Earthquake foci are extremely deep at oceanic trenches, but very shallow at mid-oceanic ridges.

- **Hess's Conclusion:** Constant eruptions at the ridge crest rupture the crust, wedging new lava into it and pushing the ocean floor apart. Because the Earth is not expanding, Hess maintained that this continuously spreading oceanic crust sinks down at the deep oceanic trenches and gets consumed back into the mantle.

1. **Plate Tectonics:** The Unified Theory (1967) Independently compiled by McKenzie, Parker, and Morgan, this theory defines a tectonic (or lithospheric) plate as a massive, irregularly shaped slab of solid rock composed of both continental and oceanic lithosphere.

- **Lithosphere Thickness:** Ranges from 5 to 100 km in oceanic areas and roughly 200 km in continental areas. Plates move horizontally over the softer asthenosphere as rigid units.
- **Wandering Landmasses:** Plate tectonics proved Wegener wrong on one key point: continents do not independently plow through oceans; rather, continents are resting on massive plates that do the moving. Pangaea was merely a temporary resulting landmass caused by the converging of these plates. Past positions of landmasses are verified using paleomagnetic data (e.g., India's past position is traced via rocks from the Nagpur area).

Plate Boundaries and Movements

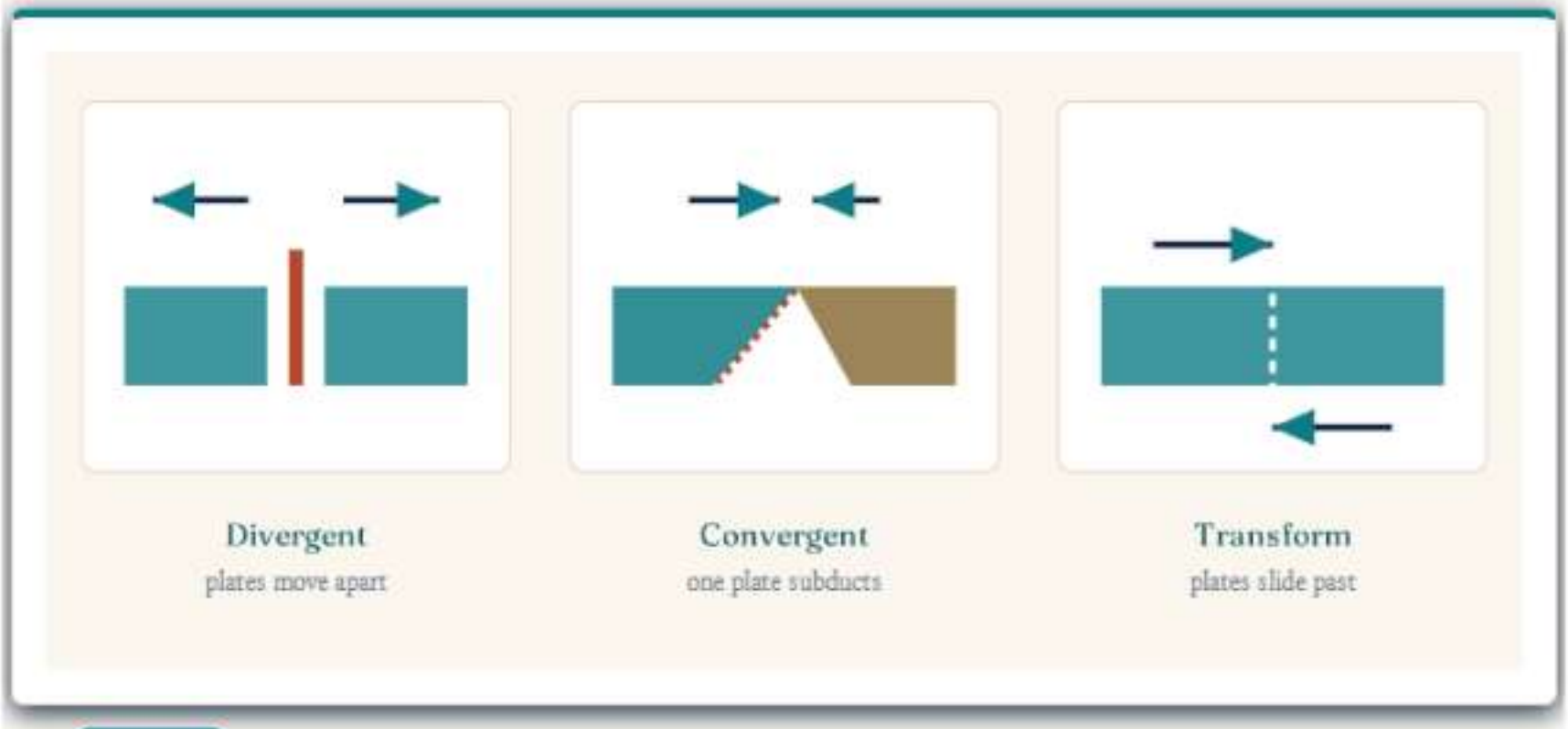

FIGURE 3 *The three types of plate boundary — divergent, convergent and transform — defined by how the plates move relative to one another.*

- **Divergent:** Plates pull away from each other at "spreading sites" to generate new crust (e.g., the Mid-Atlantic Ridge separating the American plates from the Eurasian and African plates).
- **Convergent:** Crust is destroyed at a "subduction zone" where one plate dives under another. This can occur between oceanic-continental, oceanic-oceanic, or continental-continental plates.
- **Transform:** Plates slide horizontally past one another, neither producing nor destroying crust. Transform faults are generally perpendicular to mid-oceanic ridges; they occur because eruptions do not happen along the entire ridge crest simultaneously, creating differential movements that are also influenced by the Earth's rotation.
- **Rates of Movement:** Measured using the parallel strips of normal and reverse magnetic fields on the sea floor. The Arctic Ridge is the slowest (less than 2.5 cm/yr), while the East Pacific Rise (near Easter Island) is the fastest (more than 15 cm/yr).
- **The Driving Mechanism:** Plates are moved by a "convection cell" or convective flow of hot, softened mantle rock. Heated material rises, spreads, cools, and sinks back down, fueled by the Earth's internal radioactive decay and residual heat.

1. The Exact Geologic Journey of the Indian Plate The Indian plate encompasses Peninsular India and the Australian continental portions.

- Complex Boundaries:
  - **North:** Continent-continent convergence subduction zone along the Himalayas.
  - **East:** Extends through Myanmar's Rakinyoma Mountains to the Java Trench island arc, functioning as a spreading site east of Australia in the SW Pacific.

- **West:** Follows Pakistan's Kirthar Mountain, extends along the Makrana coast, and joins the Red Sea rift spreading site southeastward along the Chagos Archipelago.
- **South:** An oceanic ridge divergent boundary running roughly West- East, merging south of New Zealand.

- **Timeline of the Journey:** o 225 Million Years Ago: India was a large island situated off the Australian coast, separated from the Asian continent by the vast Tethys Sea. o 200 Million Years Ago: Pangaea broke, and India began its northward journey. o 140 Million Years Ago: The Indian subcontinent was located as far south as 50°S latitude, while the Tibetan block was much closer to the Asiatic landmass. o 60 Million Years Ago: As India moved rapidly north while still close to the equator, massive volcanic eruptions occurred, forming the Deccan Traps. o 40-50 Million Years Ago: India finally collided with Asia, destroying the Tethys Sea and initiating the rapid, immense uplift of the Himalayan mountains—a tectonic event that is still actively raising the height of the mountains today.

Practice Questions

30 MCQs

Q1 Consider the following statements regarding the early theories of continental movement: 1. Abraham Ortelius, a Dutch mapmaker, first proposed the possibility of the Americas, Europe, and Africa being joined together in 1596. 2. Antonio Pellegrini put forth the comprehensive argument known as the "continental drift theory" in 1912. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · A

EXPLANATION Abraham Ortelius first proposed the possibility in 1596, but it was Alfred Wegener, a German meteorologist, who put forth the continental drift theory in 1912; Antonio Pellegrini merely drew a map showing the three continents together.

Q2 According to Alfred Wegener's Continental Drift Theory, what do the terms "Pangaea" and "Panthalassa" describe?

A. A mega-ocean and a super continent, respectively.

B. A super continent and a mega-ocean, respectively.

C. The northern and southern landmass components of the super continent.

D. The moving oceanic plates and stationary continental plates.

Answer · B

EXPLANATION Wegener named the super continent PANGAEA and the surrounding mega-ocean PANTHALASSA.

Q3 Which of the following statements about the matching of continents is incorrect?

A. The shorelines of Africa and South America facing each other have an unmistakable match.

B. A computer program to find the best fit of the Atlantic margin was presented by Bullard in 1964.

C. Bullard's match was tried perfectly at the present shoreline rather than the 1,000-fathom line.

D. The belt of ancient rocks of 2,000 million years from the Brazil coast matches those from western Africa.

Answer · C

EXPLANATION Bullard's perfect match was tried at the 1,000-fathom line instead of the present shoreline.

Q4 Consider the following statements about 'Tillite': 1. It is a sedimentary rock formed out of deposits of glaciers. 2. The Gondwana system of sediments from India has thick tillite at its base and shares its remarkably similar history with Madagascar, Antarctica, and Australia. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · C

EXPLANATION Tillite is formed out of deposits of glaciers, and the Gondwana system has counterparts in Africa, Falkland Island, Madagascar, Antarctica, and Australia.

Q5 Which anomaly correctly describes the placer deposits of gold on the Ghana coast?

A The gold deposits are heavily mined despite the source rocks being buried deep beneath the oceanic crust.

B There is an absolute absence of source rock in the Ghana region, and the corresponding gold-bearing veins are located in Brazil.

C The gold is derived from glacial tillite brought over from Antarctica during continental drift.

D The deposits contain fossils of Mesosaurus intertwined with the gold veins.

Answer · B

EXPLANATION The gold deposits on the Ghana coast have an absolute absence of source rock, with the corresponding gold-bearing veins located in Brazil.

Q6 Consider the following statements regarding fossil distribution: 1. Lemurs are found in India, Madagascar, and Africa, which led to the theory of a contiguous landmass called 'Lemuria'. 2. Mesosaurus was a small reptile adapted to deep oceanic waters, whose skeletons are found in South Africa and Brazil. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · A

EXPLANATION Lemurs occur in India, Madagascar, and Africa. Mesosaurus was a small reptile adapted to shallow brackish water, not deep oceanic waters.

Q7 What were the specific forces suggested by Wegener as being responsible for the drifting of continents?

A Convectional currents in the mantle and radioactive decay.

B Pole-fleeing force related to Earth's rotation and tidal force from the sun and moon.

C Sea floor spreading and subduction zone gravity pulls.

D Thermal differences in the mantle and polar ice cap melting.

Answer · B

EXPLANATION Wegener suggested the pole-fleeing force (related to Earth's rotation) and tidal force (due to the sun and moon).

Q8 **Arthur Holmes discussed the possibility of convection currents operating in the mantle in the 1930s. According to him, how are these currents generated?**

A Due to the tidal attraction of the moon and the sun over millions of years.

B Due to the Earth's rotation creating a bulge at the equator.

C **Due to radioactive elements causing thermal differences in the mantle portion.**

D Due to continuous volcanic eruptions pushing oceanic crust at mid-oceanic ridges.

Answer · C

EXPLANATION Arthur Holmes argued these currents are generated due to radioactive elements causing thermal differences in the mantle.

Q9 **Consider the following regions of the ocean floor: 1. Continental Margins 2. Abyssal Plains 3. Mid-Oceanic Ridges Which of the following describes 'Abyssal Plains'?**

A Transition zones between continental shores and deep-sea basins containing deep-oceanic trenches.

B **Extensive plains lying between continental margins and mid-oceanic ridges where continental sediments get deposited.**

C Interconnected mountain systems characterized by a central rift system at the crest.

D Submerged mountain ranges actively experiencing intense volcanic eruptions.

Answer · B

EXPLANATION Abyssal plains are extensive plains between continental margins and mid- oceanic ridges where continental sediments get deposited.

Q10 Consider the following statements about the distribution of earthquakes: 1. Earthquakes in the areas of mid-oceanic ridges have shallow depths. 2. Earthquakes along the Alpine-Himalayan belt and the rim of the Pacific are deep-seated. Which of the statements given above is/are correct?

A 1 only

B 2 only

C **Both 1 and 2**

D Neither 1 nor 2

Answer · C

EXPLANATION Earthquake foci at mid-oceanic ridges are at shallow depths, whereas along the Alpine-Himalayan belt and Pacific rim, they are deep-seated.

Q11 Which observation was NOT a contributing factor to Harry Hess's formulation of the "sea floor spreading" concept?

A Volcanic eruptions are common all along the mid-oceanic ridges, bringing huge amounts of lava to the surface.

B The oceanic crust rocks are much younger than the continental rocks.

C **The sediments on the ocean floor are unexpectedly thick and often older than 200 million years.**

D Rocks equidistant on either sides of the crest of mid-oceanic ridges show remarkable similarities in formation period and magnetic properties.

Answer · C

EXPLANATION The sediments on the ocean floor are unexpectedly very thin, and nowhere older than 200 million years.

Q12 According to Hess's concept of Sea Floor Spreading, what happens to the older ocean floor as new lava pushes it apart?

A It continues to expand globally, causing the Earth's overall circumference to increase.

B It sinks down at the oceanic trenches and gets consumed.

C It piles up at continental margins to form young fold mountains.

D It subducts directly under the mid-oceanic ridges to create shallow earthquakes.

Answer · B

EXPLANATION Hess maintained that the ocean floor pushed by volcanic eruptions sinks down at oceanic trenches and gets consumed.

Q13 Consider the following statements regarding tectonic plates: 1. A tectonic plate is composed of both continental and oceanic lithosphere. 2. The lithosphere includes the crust and top mantle, with its thickness reaching about 200 km in continental areas. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · C

EXPLANATION Plates are composed of both continental and oceanic lithosphere, and lithospheric thickness ranges up to about 200 km in continental areas.

Q14 Which of the following is considered a major tectonic plate rather than a minor plate?

A Nazca plate.

B Cocos plate.

C India-Australia-New Zealand plate.

D Philippine plate.

Answer · C

EXPLANATION India-Australia-New Zealand is one of the seven major plates, while Nazca, Cocos, and Philippine plates are minor.

Q15 Match the following minor plates with their correct locations: List I:

A Cocos plate

B Nazca plate

C Caroline plate List II: 1. Between South America and Pacific plate 2. Between Central America and Pacific plate 3. Between the Philippine and Indian plate Select the correct code:

A a-2, b-1, c-3

B a-1, b-2, c-3

C a-2, b-3, c-1

D a-3, b-1, c-2

Answer · A

EXPLANATION Cocos is between Central America and Pacific; Nazca is between South America and Pacific; Caroline is between Philippine and Indian plates.

Q16 Consider the following statements about Plate Tectonics versus Continental Drift: 1. Wegener believed that continents move as independent masses through the oceans. 2. Plate tectonics asserts that it is the plate that moves, and continents are resting parts of a plate. 3. Pangaea was a result of converging different continental masses that were parts of one or the other moving plates. Which of the statements given above are correct?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · D

EXPLANATION All three statements correctly outline the transition from Wegener's early drift theory to modern plate tectonics.

Q17 At which type of plate boundary is new crust generated as plates pull away from each other?

A Convergent boundaries.

B Divergent boundaries.

C Transform boundaries.

D Subduction zones.

Answer · B

EXPLANATION Divergent boundaries are where new crust is generated as plates pull away from each other.

Q18 Consider the following statements regarding transform plate boundaries: 1. The crust is neither produced nor destroyed. 2. The plates slide horizontally past each other. 3. Transform faults are generally parallel to the mid-oceanic ridges. Which of the statements given above is/are correct?

A 1 and 2 only

B 2 and 3 only

C 1 and 3 only

D 1, 2, and 3

Answer · A

EXPLANATION Transform faults are planes of separation generally perpendicular, not parallel, to the mid-oceanic ridges.

Q19 How do scientists primarily determine the rates of plate movement?

A By measuring the thickness of the tillite deposits across the Southern Hemisphere.

B By using the strips of normal and reverse magnetic field that parallel the mid-oceanic ridges.

C By calculating the pole-fleeing force acting upon the equator.

D By carbon-dating the oldest continental crust rocks.

Answer · B

EXPLANATION The strips of normal and reverse magnetic fields that parallel the mid- oceanic ridges help scientists determine plate movement rates.

Q20 Which of the following locations represents the fastest rate of tectonic plate movement?

A The Arctic Ridge, moving at less than 2.5 cm/yr.

B The Mid- Atlantic Ridge, moving at 5 cm/yr.

C The East Pacific Rise near Easter Island, moving at more than 15 cm/yr.

D The Java Trench, moving at 10 cm/yr.

Answer · C

EXPLANATION The East Pacific Rise has the fastest rate at more than 15 cm/yr.

Q21 Consider the following statements about the force driving plate movement: 1. The mobile rock beneath the rigid plates moves in a circular manner, generating a convection cell. 2. Heat within the Earth comes exclusively from residual heat trapped since its formation. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · A

EXPLANATION Heat within the earth comes from two main sources: radioactive decay AND residual heat, not exclusively residual.

Q22 Which type of plate boundary forms the northern boundary of the Indian plate along the Himalayas?

A Oceanic-oceanic convergence.

B Continent-continent convergence.

C Divergent boundary.

D Transform boundary.

Answer · B

EXPLANATION The boundary along the Himalayas is a continent-continent convergence.

Q23 Trace the geological position of the Indian subcontinent over time. Consider the following statements: 1. India was separated from the Asian continent by the Tethys Sea roughly 225 million years ago. 2. About 140 million years before the present, the subcontinent was located as far south as 50°S latitude. 3. India collided with Asia about 40-50 million years ago, causing rapid uplift of the Himalayas. Which is the correct chronological sequence of these events from oldest to most recent?

A 1-2-3

B 2-1-3

C 3-1-2

D 1-3-2

Answer · A

EXPLANATION The events naturally progress from 225 million years ago (Tethys Sea separation), to 140 million years ago (at 50°S), and finally 40-50 million years ago (collision).

Q24 During the movement of the Indian plate towards the Eurasian plate, when did the massive outpouring of lava and the formation of the Deccan Traps begin?

A About 200 million years ago, exactly when Pangaea broke.

B Around 140 million years ago, when India was positioned at 50°S latitude.

C Around 60 million years ago, while the subcontinent was still close to the equator.

D About 40 million years ago, immediately following the collision with Asia.

Answer · C

EXPLANATION Outpouring of lava and formation of the Deccan Traps started somewhere around 60 million years ago while the subcontinent was close to the equator.

Q25 The historical positions of the Indian sub-continent (mostly Peninsular India) in different geological periods were traced using palaeomagnetic data analyzed from rocks located in which specific area?

A The Himalayan mountain range.

B **The Nagpur area.**

C The Makrana coast.

D The Rakinyoma Mountains.

Answer · B

EXPLANATION The position of the Indian sub-continent is traced with the help of rocks analyzed from the Nagpur area.

Q26 Consider the following statements regarding the borders of the Indian Plate: 1. The eastern margin extends through the Rakinyoma Mountains towards the island arc along the Java Trench. 2. The western margin follows the Kirthar Mountain of Pakistan and extends along the Makrana coast. Which of the statements given above is/are correct?

A 1 only

B 2 only

C **Both 1 and 2**

D Neither 1 nor 2

Answer · C

EXPLANATION The eastern margin extends through Rakinyoma Mountains, and the western margin follows Kirthar Mountain along the Makrana coast.

Q27 Consider the following statements about the age of rocks based on sea floor spreading: 1. Rocks closer to the mid-oceanic ridges have normal polarity and are the youngest. 2. The age of rocks in the oceanic crust is generally older than those found in continental rock formations. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · A

EXPLANATION Oceanic crust rocks are nowhere more than 200 million years old, making them much younger than continental rocks, which can be up to 3,200 million years old.

Q28 Which specific observation led some scientists to consider the past existence of a contiguous landmass called 'Lemuria'?

A The presence of Mesosaurus skeletons isolated in South Africa and Brazil.

B The correlation of the Brazil coast's 2,000-million-year-old rocks with those in western Africa.

C The occurrence of Lemurs across India, Madagascar, and Africa.

D The sequence of thick tillite deposits located at the base of the Gondwana system.

Answer · C

EXPLANATION Observations that Lemurs occur in India, Madagascar, and Africa led some to consider a contiguous landmass named 'Lemuria' linking them.

Q29 Consider the following statements about the major Pacific Plate: 1. It is defined largely as a continental plate. 2. Its rim is famously referred to as the "ring of fire" due to the existence of active volcanoes. Which of the statements given above is/are correct?

A 1 only

B 2 only

C Both 1 and 2

D Neither 1 nor 2

Answer · B

EXPLANATION The Pacific plate is largely an oceanic plate, not a continental one, but its rim is indeed called the "ring of fire".

Q30 According to the text, the earliest marine deposits along the coastline of South America and Africa date back to which age, suggesting the ocean did not exist prior to that time?

A Precambrian age.

B Jurassic age.

C Cretaceous age.

D Holocene age. Answer Key and Explanations:

Answer · B

EXPLANATION The earliest marine deposits along these coastlines are of the Jurassic age.

CHAPTER 3 · AT A GLANCE

Distribution of Continents and Oceans

Drifting Earth

1912	200	7	1961
Wegener's drift theory	Mya — Pangaea breakup	Major lithospheric plates	Sea-floor spreading

1596 Ortelius notes fit › **1912** Wegener: Pangaea › **1961** Hess: spreading › **1967** Plate Tectonics

ANCIENT LANDMASSES

- Pangaea
- Panthalassa
- Laurasia
- Gondwanaland

EVIDENCE

- Jigsaw fit
- Tillite deposits
- Placer gold
- Mesosaurus fossils

BOUNDARY TYPES

- Divergent
- Convergent
- Transform

★ *Matching fossils of Mesosaurus across South America and Africa show the continents were once joined.*

LECTURE IV

04

Minerals and Rocks

Physical Geography · Study Companion

Earth's Composition

- The earth is composed of elements that exist in a solid form in the outer layer (crust) and in a hot, molten form in the interior.
- Composition of the Earth's Crust:
  - 98% of the total crust is made up of eight specific elements: oxygen, silicon, aluminium, iron, calcium, sodium, potassium, and magnesium.
  - The remaining 2% consists of titanium, hydrogen, phosphorous, manganese, sulphur, carbon, nickel, and other elements.

Introduction to Minerals

- Elements in the crust rarely occur exclusively; they combine to form substances known as minerals.
- **Definition:** A mineral is a naturally occurring organic and inorganic substance with an orderly atomic structure, a definite chemical composition, and specific physical properties.
- **Composition:** Minerals typically consist of two or more elements. However, some are single-element minerals, such as sulphur, copper, silver, gold, and graphite.
- There are at least 2,000 named and identified minerals in the earth's crust, but most commonly occurring ones belong to six major mineral groups (known as major rock-forming minerals).
- **Source:** The basic source of all minerals is the hot magma inside the earth. As magma cools, mineral crystals appear and solidify in a systematic sequence to form rocks.
- **Organic Minerals:** Minerals like coal, petroleum, and natural gas are organic substances found in solid, liquid, and gaseous forms, respectively.

Physical Characteristics of Minerals

Minerals are identified by ten primary physical characteristics:

1. **External crystal form:** Determined by the internal molecular arrangement (e.g., cubes, octahedrons, hexagonal prisms).
2. **Cleavage:** The tendency to break in specific directions, creating relatively flat surfaces, resulting from internal molecular arrangement. Cleavage can occur in one or multiple directions and at any angle.
3. **Fracture:** Occurs when internal molecular arrangements are too complex to have cleavage planes; the crystal breaks in an irregular manner.
4. **Lustre:** The appearance of the material regardless of its colour. Each mineral has a distinct lustre (e.g., metallic, silky, glossy).
5. **Colour:** Some minerals have characteristic colours based on their molecular structure (e.g., malachite, azurite, chalcopyrite). Others are coloured by impurities; for example, quartz can be white, green, red, or yellow due to impurities.
6. **Streak:** The colour of the mineral's ground powder. It may match the mineral's colour or differ entirely. For instance, malachite is green with a green streak, but fluorite is purple or green with a white streak.
7. Transparency:

Transparent: Light rays pass through, and objects can be seen plainly.

Translucent: Light passes through but diffuses, so objects cannot be seen clearly.

Opaque: No light passes through.

1. **Structure:** The specific arrangement of individual crystals, which can be fine, medium, or coarse-grained; or fibrous (separable, divergent, radiating).
2. **Hardness:** A mineral's relative resistance to being scratched. The Mohs scale measures hardness from 1 to 10 using ten selected minerals:

Talc

1. Gypsum
2. Calcite
3. Fluorite
4. Apatite
5. Feldspar
6. Quartz
7. Topaz

8. Corundum
9. Diamond

Comparisons: A human fingernail has a hardness of 2.5, and glass or a knife blade is 5.5.

1. **Specific Gravity:** The ratio of a given object's weight to the weight of an equal volume of water. It is calculated by weighing the object in air, weighing it in water, and dividing the air weight by the difference between the two weights.

Classification of Minerals

Minerals are divided into two primary categories based on metal content:

A. Metallic Minerals: Contain metal content and are subdivided into three types:

- **Precious metals:** Gold, silver, platinum, etc..
- **Ferrous metals:** Iron, and other metals mixed with iron to create various kinds of steel.
- **Non-ferrous metals:** Includes metals like copper, lead, zinc, tin, and aluminium.

B. Non-Metallic Minerals: Do not contain any metal content.

- Examples include sulphur, phosphates, and nitrates.
- Cement is a mixture of non-metallic minerals.

Rocks and Petrology

- The earth's crust is composed of rocks.
- **Definition:** A rock is an aggregate of one or more minerals.
- Rocks lack a definite composition of mineral constituents, though feldspar and quartz are the most common minerals found in them.
- They vary greatly; granite is hard, while soapstone is soft; gabbro is black, while quartzite can be milky white.
- **Petrology:** The science of rocks. A petrologist studies rocks across all aspects: mineral composition, texture, structure, origin, occurrence, alteration, and their relationships with other rocks.

The Three Families of Rocks

Rocks are grouped into three families based on their mode of formation: I. Igneous Rocks

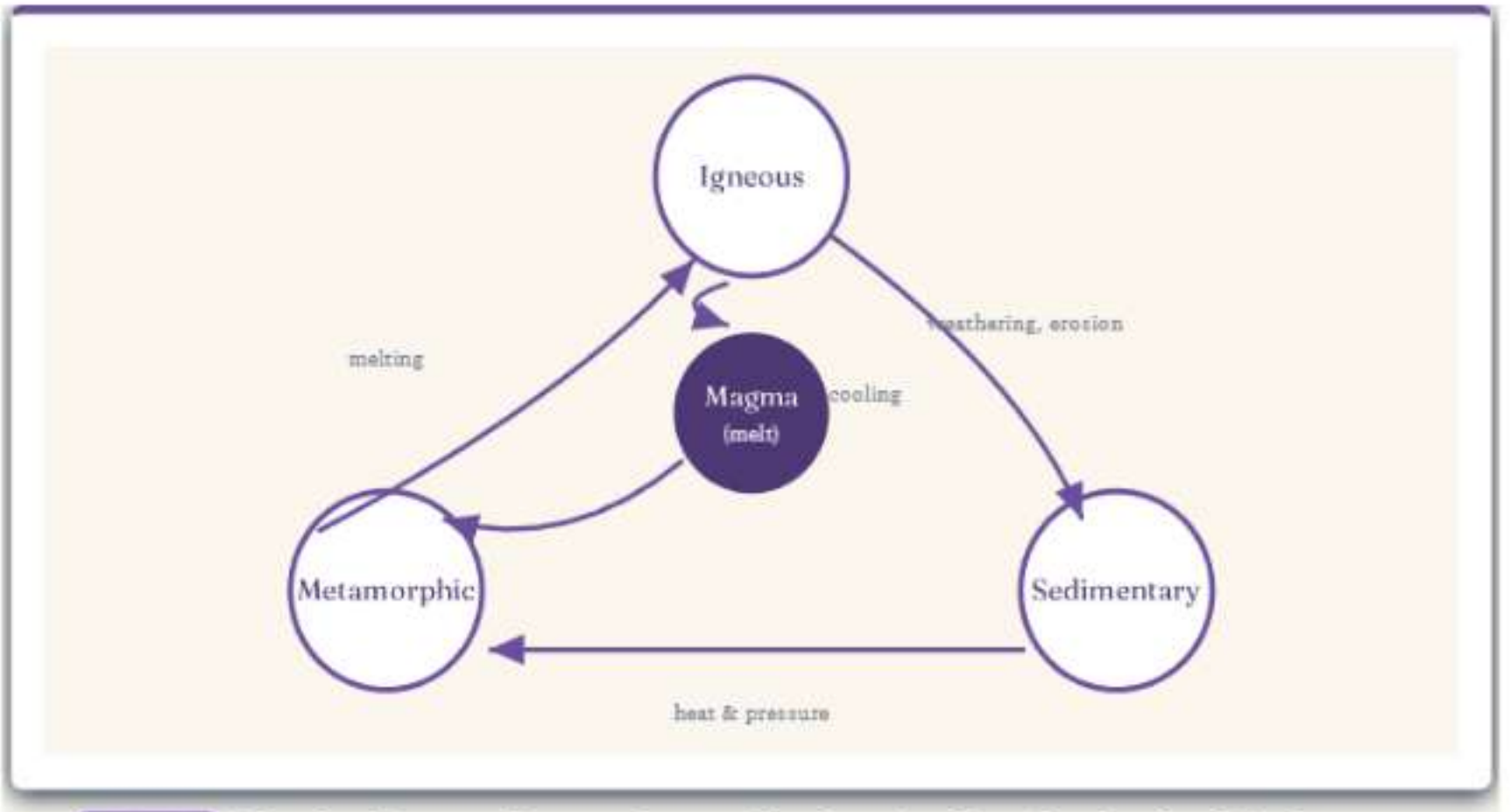

FIGURE 4 *The rock cycle: igneous, sedimentary and metamorphic rocks continuously transform through weathering, heat, pressure and melting.*

- **Formation:** Solidified from cooling magma and lava coming from the earth's interior. They are known as primary rocks.
- **Etymology:** The word 'igneous' comes from the Latin word Ignis, meaning 'Fire'.
- Cooling and solidification can happen deep within the earth's crust or on the surface.
- **Classification by Texture:** Depends on the size and arrangement of grains or other physical conditions:
  - **Slow cooling at great depths:** Results in very large mineral grains.
  - **Sudden cooling at the surface:** Results in small, smooth grains.
  - **Intermediate conditions:** Result in intermediate grain sizes.
- **Examples:** Granite, gabbro, pegmatite, basalt, volcanic breccia, and tuff.

II. Sedimentary Rocks

- **Formation:** Result from the deposition of rock fragments by exogenous processes. Earth's surface rocks are broken into fragments by denudational agents, transported by exogenous agencies, and deposited.
- **Lithification:** The process where these deposits turn into solid rocks through compaction. Even after lithification, the distinct layers of deposits often retain their characteristics, resulting in visible layers of varying thicknesses.
- **Etymology:** The word 'sedimentary' comes from the Latin word sedimentum, which means 'settling'.
- Classification by Formation Mode:

1. **Mechanically formed:** Sandstone, conglomerate, limestone, shale, loess.
2. **Organically formed:** Geyserite, chalk, limestone, coal.
3. **Chemically formed:** Chert, limestone, halite, potash.

III. Metamorphic Rocks

- **Formation:** Formed from existing rocks that undergo recrystallisation under changes in Pressure, Volume, and Temperature (PVT).
- **Etymology:** The word metamorphic means 'change of form'.
- Occurs when rocks are forced to lower levels by tectonic processes, when rising hot magma contacts crustal rocks, or under extreme pressure from overlying rocks.
- Types of Metamorphism:
  - **Dynamic Metamorphism:** Mechanical disruption and reorganization of original minerals due to breaking and crushing, without appreciable chemical changes.
  - **Thermal Metamorphism:** Chemical alteration and recrystallisation. Has two subtypes: • Contact metamorphism: Rocks come into direct contact with hot intruding magma/lava, recrystallising under high heat. New materials are often added. • Regional metamorphism: Recrystallisation due to deformation from tectonic shearing combined with high temperature, high pressure, or both.
- Structural Features:
  - **Foliation or Lineation:** The arrangement of grains or minerals in distinct layers or lines.
  - **Banding:** Minerals of different groups arranged into alternating thin to thick layers appearing in light and dark shades. Rocks displaying this are called banded rocks.
- **Classification:** Metamorphic rocks are grouped into foliated and non- foliated rocks.
- **Examples:** Gneissoid, granite, syenite, slate, schist, marble, and quartzite. (Note: Marble is exclusively listed as a metamorphic rock and not a sedimentary rock).

The Rock Cycle

- **Definition:** A continuous process through which old rocks are transformed into new ones; rocks do not remain in their original form indefinitely.
- The Process:
  - Igneous rocks are the primary rocks. Fragments derived from weathering and erosion of igneous (and metamorphic) rocks turn into sediments, which lithify to become sedimentary rocks.
  - Both igneous and sedimentary rocks can be subjected to heat and pressure to change into metamorphic rocks.
  - Sedimentary rocks can also break back down into fragments to form new sedimentary rocks.
  - Through tectonic subduction (where crustal plates go down under other plates), any crustal rocks (igneous, sedimentary, metamorphic) can be carried down into the earth's mantle, melt due to increased temperature, and turn back into magma—the original source for igneous rocks, restarting the cycle.

Practice Questions

30 MCQs

Q1 About 98 percent of the total crust of the earth is composed of eight elements. Which of the following groups contains elements that belong exclusively to this majority?

A Titanium, hydrogen, phosphorous

B Oxygen, silicon, aluminium, calcium

C Manganese, sulphur, carbon

D Nickel, potassium, magnesium

Answer · B

EXPLANATION The earth's crust is predominantly made up of eight elements: oxygen, silicon, aluminium, iron, calcium, sodium, potassium, and magnesium, which account for about 98% of the total crust.

Q2 Consider the following statements about minerals: I. A mineral is defined as an exclusively inorganic substance. II. While most minerals are composed of two or more elements, single element minerals like sulphur, copper, and gold are also found in nature. Which of the statements given above is/are correct?

A I only

B II only

C Both I and II

D Neither I nor II

Answer · B

EXPLANATION Statement I is incorrect because the sources explicitly define a mineral as a "naturally occurring organic and inorganic substance". Statement II is correct because, although minerals are usually composed of two or more elements, single element minerals such as sulphur, copper, silver, gold, and graphite do exist.

Q3 When the internal molecular arrangement of a mineral is so complex that there are no planes of molecules, it breaks in an irregular manner. What is this physical characteristic called?

A Cleavage

B Structure

C Fracture

D Streak

Answer · C

EXPLANATION Fracture occurs when the internal molecular arrangement is so complex that there are no planes of molecules, causing the crystal to break in an irregular manner rather than along planes of cleavage.

Q4 The streak of a mineral is the colour of its ground powder, which may differ from the mineral's actual physical colour. Which of the following accurately describes the colour and streak of fluorite?

A It is purple or green but gives a white streak.

B It is green and gives a green streak.

C It is white but gives a purple streak.

D It is yellow and gives a red streak.

Answer · A

EXPLANATION Streak is the colour of a mineral's ground powder, which can differ from its physical appearance. Fluorite is physically purple or green, but it gives a white streak.

Q5 The Mohs scale measures hardness from 1 to 10 by evaluating a mineral's relative resistance to being scratched. Which of the following sequences is correctly ordered from softest to hardest?

A Gypsum, Calcite, Fluorite, Apatite

B Talc, Quartz, Feldspar, Topaz

C Apatite, Fluorite, Calcite, Gypsum

D Topaz, Corundum, Quartz, Diamond

Answer · A

EXPLANATION The Mohs scale ranks ten selected minerals from softest to hardest (1-10) in this exact order: 1. talc; 2. gypsum; 3. calcite; 4. fluorite; 5. apatite; 6. feldspar; 7. quartz; 8. topaz; 9. corundum; 10. diamond.

Q6 **Specific gravity is the ratio between the weight of a given object and the weight of an equal volume of water. How is it correctly calculated?**

A Weight in air divided by weight in water.

B Weight in water divided by the difference between weight in air and water.

C **Weight in air divided by the difference between weight in air and weight in water.**

D Weight in water divided by weight in air.

Answer · C

EXPLANATION Specific gravity is calculated by first weighing the object in air, then weighing it in water, and finally dividing the weight in air by the difference between these two weights.

Q7 **Metallic minerals can be subdivided into precious, ferrous, and non-ferrous metals. Which of the following groups contains ONLY non-ferrous metals?**

A Iron, lead, zinc

B **Copper, lead, zinc, tin**

C Gold, silver, platinum

D Sulphur, phosphates, nitrates

Answer · B

EXPLANATION Non-ferrous metals are a sub-category of metallic minerals that include metals like copper, lead, zinc, tin, and aluminium.

Q8 **Rocks are aggregates of one or more minerals and do not have a definite composition of mineral constituents. Which of the following pairs represents the most common minerals found in rocks?**

A Quartz and Diamond

B **Feldspar and Quartz**

C Topaz and Apatite

D Talc and Gypsum

Answer · B

EXPLANATION While rocks do not have a definite composition of mineral constituents, feldspar and quartz are identified as the most common minerals found within them.

Q9 Petrology is the science of rocks. Which of the following is NOT typically studied by a petrologist?

A Mineral composition

B Atmospheric interaction

C Texture and structure

D Alteration and relationship with other rocks

Answer · B

EXPLANATION Petrologists study rocks across multiple aspects, including mineral composition, texture, structure, origin, occurrence, alteration, and relationships with other rocks. Atmospheric interaction is not listed as a primary aspect of petrology in the text.

Q10 Igneous rocks are classified based on their texture, which is determined by cooling conditions. What texture results when molten material cools slowly at great depths?

A Small and smooth grains

B Intermediate sizes of grains

C Very large mineral grains

D Fibrous radiating grains

Answer · C

EXPLANATION The texture of igneous rocks is determined by cooling conditions. When molten material cools slowly at great depths, it results in the formation of very large mineral grains.

Q11 Igneous rocks solidify from magma and lava. Which of the following sets consists exclusively of igneous rocks?

A Granite, gabbro, pegmatite, basalt

B Sandstone, shale, loess, chalk

C Syenite, slate, schist, marble

D Chert, limestone, halite, potash

Answer · A

EXPLANATION Granite, gabbro, pegmatite, basalt, volcanic breccia, and tuff are all explicitly listed as examples of igneous rocks.

Q12 Sedimentary rocks form when transported fragments of rock turn into solid rock through compaction. What is this specific process called?

A Metamorphism

B Subduction

C Lithification

D Recrystallization

Answer · C

EXPLANATION The process where deposits of rock fragments undergo compaction and turn into solid rocks is called lithification.

Q13 Because layers of deposits retain their characteristics even after lithification, what feature is commonly visible in sedimentary rocks like sandstone and shale?

A Distinct large mineral crystals

B Foliation lines

C A number of layers of varying thickness

D Interlocking metallic grains

Answer · C

EXPLANATION Because layers of deposits retain their characteristics even after lithification, sedimentary rocks like sandstone and shale frequently display a number of layers of varying thickness.

Q14 Sedimentary rocks are classified into mechanically, organically, and chemically formed groups. Which of the following is a chemically formed sedimentary rock?

A Sandstone

B Geyserite

C Chert

D Loess

Answer · C

EXPLANATION Sedimentary rocks are classified by their mode of formation. Chert, limestone, halite, and potash are examples of chemically formed sedimentary rocks.

Q15 **Metamorphic rocks form under the action of PVT changes. What does PVT stand for in this geological context?**

A Pressure, Velocity, and Temperature

B Pressure, Volume, and Temperature

C Porosity, Volume, and Texture

D Pressure, Viscosity, and Time

Answer · B

EXPLANATION Metamorphic rocks form under the action of changes in pressure, volume, and temperature, which is abbreviated as (PVT).

Q16 **Mechanical disruption and reorganization of original minerals within rocks due to breaking and crushing without appreciable chemical changes is known as:**

A Contact metamorphism

B Regional metamorphism

C Dynamic metamorphism

D Thermal metamorphism

Answer · C

EXPLANATION Dynamic metamorphism is defined as the mechanical disruption and reorganisation of original minerals within rocks due to breaking and crushing, occurring without any appreciable chemical changes.

Q17 During contact metamorphism, rocks come in direct contact with hot intruding magma and lava. What is a primary outcome of this process?

A Rocks break and crush without chemical changes.

B Materials are exposed to denudational agents.

C Rock materials recrystallize under high temperatures, and new materials from magma are quite often added.

D Rocks form mechanically driven alternating light and dark bands.

Answer · C

EXPLANATION During contact metamorphism, rocks come into direct contact with hot intruding magma or lava, causing the rock materials to recrystallise under high temperatures, and quite often, new materials from the magma or lava are added.

Q18 In the process of metamorphism, some rocks have grains or minerals that get arranged into distinct lines or layers. What is this arrangement called?

A Lithification

B Banding

C Cleavage

D Foliation or lineation

Answer · D

EXPLANATION The arrangement of grains or minerals into distinct layers or lines during the process of metamorphism is called foliation or lineation.

Q19 **Sometimes, minerals of different groups in a metamorphic rock are arranged into alternating thin to thick layers appearing in light and dark shades. What is this specific structural feature called?**

A Banding

B Foliation

C Strata

D Fracture

Answer · A

EXPLANATION When minerals of different groups arrange into alternating thin to thick layers appearing in light and dark shades, this specific structural feature is called banding.

Q20 **Metamorphic rocks are formed from existing rocks undergoing recrystallization. Which of the following rocks is an example of a metamorphic rock?**

A Gabbro

B Tuff

C Syenite

D Halite

Answer · C

EXPLANATION According to the text, gneissoid, granite, syenite, slate, schist, marble, and quartzite are provided as examples of metamorphic rocks. (Note: While granite is also listed as igneous, syenite is uniquely listed in the metamorphic examples here).

Q21 **According to the rock cycle, crustal rocks can be carried down into the mantle through the subduction process. What happens to these rocks once they reach the interior of the earth?**

A They undergo dynamic metamorphism and become foliated.

B They immediately lithify into sedimentary rocks.

C They melt down due to an increase in temperature and turn into molten magma.

D They mechanically break into fragments without chemical changes.

Answer · C

EXPLANATION Through the process of subduction, crustal rocks carried down into the earth's interior melt down due to the increase in temperature and turn into molten magma.

Q22 Based on the textbook exercises, which two elements are identified as the main constituents of granite?

A Iron and silver

B **Silica and aluminium**

C Iron oxide and potassium

D Iron and nickel

Answer · B

EXPLANATION Based on the textbook multiple-choice exercise 1(i), "Silica and aluminium" is the correct choice for the two main constituents of granite.

Q23 According to the textbook exercises, what is identified as the salient feature of metamorphic rocks?

A Changeable

B Crystalline

C **Foliation**

D Quite

Answer · C

EXPLANATION Based on the textbook multiple-choice exercise 1(ii), "Foliation" is listed as the salient feature of metamorphic rocks.

Q24 Single element minerals consist of only one type of element. According to the textbook exercises, which of the following is NOT a single element mineral?

A Gold

B Silver

C **Mica**

D Graphite

Answer · C

EXPLANATION The text identifies sulphur, copper, silver, gold, and graphite as single element minerals. In the textbook exercise 1(iii), Mica is the only option that is not a single element mineral.

Q25 **Identifying rock types correctly is a core skill in petrology. According to the textbook exercises, which of the following is NOT classified as a sedimentary rock?**

A Tillite

B Borax

C Breccia

D **Marble**

Answer · D

EXPLANATION The textbook exercise 1(v) asks to identify which option is not a sedimentary rock. Marble is the correct answer because it is classified earlier in the text as a metamorphic rock.

Q26 **Because they form directly out of magma and lava from the interior of the earth, igneous rocks are also known as:**

A **Primary rocks**

B Secondary rocks

C Foliated rocks

D Lithified rocks

Answer · A

EXPLANATION Because igneous rocks form directly out of magma and lava originating from the interior of the earth, they are known as primary rocks.

Q27 **The tendency of a mineral to break in given directions producing relatively plane surfaces is a result of the internal arrangement of its molecules. What is this physical characteristic called?**

A Fracture

B **Cleavage**

C Lustre

D Hardness

Answer · B

EXPLANATION Cleavage is defined as the tendency of a mineral to break in given directions, producing relatively plane surfaces due to its internal molecular arrangement.

Q28 Non-metallic minerals do not contain metal content. Which of the following is defined by the text as a mixture of non-metallic minerals?

A Chert

B Halite

C Cement

D Coal

Answer · C

EXPLANATION Non-metallic minerals do not contain metal content, and the text specifically notes that cement is a mixture of non-metallic minerals.

Q29 The rock cycle is a continuous process of transformation. How can sedimentary rocks themselves directly become a source for the formation of new sedimentary rocks?

A By melting into magma.

B By undergoing thermal metamorphism.

C By turning into fragments through weathering and erosion.

D By undergoing tectonic subduction.

Answer · C

EXPLANATION The rock cycle diagram and text explain that sedimentary rocks themselves can turn into fragments, and these fragments can then become the source material for the formation of new sedimentary rocks.

Q30 **Regional metamorphism causes rocks to undergo recrystallization. What specific conditions trigger this type of metamorphism?**

A Rocks mechanically breaking without chemical alteration.

B Rocks coming into direct contact with hot intruding magma.

C Deposition of rock fragments by exogenous processes.

D **Deformation caused by tectonic shearing together with high temperature or pressure or both.**

Answer · D

EXPLANATION Regional metamorphism happens when rocks undergo recrystallisation due to deformation caused by tectonic shearing, combined with high temperature, pressure, or both.

CHAPTER 4 · AT A GLANCE

Minerals and Rocks

Earth's Building Blocks

98	1–10	3	8
% crust = 8 elements	Mohs hardness scale	Major rock classes	Dominant crustal elements

Igneous — Cooled magma → **Weathering** → sediments → **Sedimentary** — Compacted → **Metamorphic** — Heat + pressure

TOP CRUSTAL ELEMENTS

- Oxygen
- Silicon
- Aluminium
- Iron
- Calcium
- Sodium
- Potassium
- Magnesium

MINERAL PROPERTIES

- Cleavage
- Fracture
- Streak
- Lustre
- Hardness
- Specific gravity

HARDNESS ENDPOINTS

- 1 — Talc
- 10 — Diamond

★ *The rock cycle continuously recycles igneous, sedimentary and metamorphic rock through Earth's systems.*

LECTURE V

05

Geomorphic Processes

Physical Geography · Study Companion

I. Introduction to the Dynamic Earth and Geomorphic Processes The surface of the earth is inherently uneven because the earth's crust is dynamic and constantly moving both vertically and horizontally. The variation in the earth's surface is the result of continuous interactions between two opposing forces: endogenic (internal) and exogenic (external) forces.

- **Exogenic Forces:** These are external forces originating from the earth's atmosphere and driven fundamentally by energy from sunlight. They are primarily "land wearing" forces that lead to the degradation (wearing down) of elevated reliefs and the aggradation (filling up) of basins and depressions. The overall process of wearing down relief variations through erosion is called gradation.
- **Endogenic Forces:** These are internal forces that originate from within the earth. They function as "land building" forces that continuously elevate and build up parts of the earth's surface, ensuring that surface variations remain present.
- **Geomorphic Processes:** The physical stresses and chemical actions caused by endogenic and exogenic forces that bring about changes in the configuration of the earth's surface are defined as geomorphic processes.
- **Geomorphic Agents:** Any exogenic element of nature capable of acquiring and transporting earth materials—such as running water, groundwater, glaciers, wind, waves, and currents—is termed a geomorphic agent. While a process is a force applied to earth materials, an agent is the mobile medium that removes, transports, and deposits these materials.
- **The Role of Gravity:** Gravity is the fundamental directional force that switches on the movement of all surface materials, keeping us in contact with the earth and activating all downslope movements. Without gravity and gradients, there would be no mobility, making erosion, transportation, and deposition impossible.

II. Endogenic Processes The main force behind endogenic geomorphic processes is energy emanating from within the earth, generated by radioactivity, rotational and tidal friction, and primordial heat. This internal

heat and geothermal gradients induce two major processes in the lithosphere:

- **Diastrophism:** This encompasses all processes that move, elevate, or build up portions of the earth's crust. Diastrophism includes:
  - **Orogeny:** A mountain-building process involving severe folding and affecting long, narrow belts of the crust.
  - **Epeirogeny:** A continental-building process involving the simple uplift or warping of large portions of the crust.
  - **Earthquakes:** Localized, relatively minor movements.
  - **Plate Tectonics:** The horizontal movement of crustal plates.
  - All diastrophic processes cause changes in pressure, volume, and temperature (PVT), which subsequently induce the metamorphism of rocks.
- **Volcanism:** This includes the movement of molten rock (magma) toward or onto the earth's surface. It is responsible for forming various intrusive and extrusive volcanic structures.

III. Exogenic Processes Exogenic processes derive their energy from the atmosphere (sunlight) and from gradients created by tectonic factors. They operate through the application of stresses, such as gravitational stress, shear stresses (which separate and break earth materials), and molecular stresses caused by temperature changes, crystallization, and melting.

- **Denudation:** All exogenic geomorphic processes fall under the general term "denudation," which means to strip off or uncover. This encompasses weathering, mass wasting/movements, erosion, and transportation.
- **Factors Influencing Exogenic Processes:** Temperature and precipitation are the most crucial climatic elements controlling these processes. The intensity of exogenic actions also depends heavily on rock type and structure, including folds, faults, joint presence, hardness, chemical susceptibility, and permeability. Differential resistance to these processes gives rise to vast differences in topography. IV. Weathering Weathering is the mechanical disintegration and chemical decomposition of rocks through the actions of various weather and climate elements. Because it involves little to no motion of materials, it is considered an in-situ or on- site process. The depth of the weathering mantle and the specific processes at play are heavily conditioned by geological, climatic, topographic, and vegetative factors.
- **Chemical Weathering:** This involves processes like solution, carbonation, hydration, oxidation, and reduction. These reactions depend on oxygen, surface/soil water, carbon dioxide, and heat to decompose, dissolve, or reduce rocks into a fine clastic state.
- **Physical (Mechanical) Weathering:** These processes rely on applied forces such as gravitational forces (overburden pressure, shear stress), expansion forces (from temperature changes or crystal growth), and water pressures from wetting and drying cycles. Repetitive expansion and contraction cause significant damage to rocks through continued fatigue.
- **Biological Weathering:** Organisms contribute to weathering through movement and growth. Burrowing animals (earthworms, termites, rodents) expose new rock surfaces to chemical attacks, while decaying plant and animal matter produces humic and carbonic acids that enhance decay. Plant roots also mechanically break rocks apart by exerting tremendous pressure.
- **Special Effects (Exfoliation):** Exfoliation is a result (not a process) where curved sheets of shells flake off rocks, creating smooth, rounded surfaces. This flaking can occur due to temperature changes or unloading

pressure, forming exfoliation domes and tors.

- **Significance of Weathering:** Weathering prepares rocks for mass movements, erosion, and soil formation. It is responsible for biodiversity because forests depend on the depth of the weathering mantle. Furthermore, weathering causes the chemical or physical leaching of base materials, enriching and concentrating valuable remaining ores like iron, manganese, aluminum, and copper to economically viable levels.

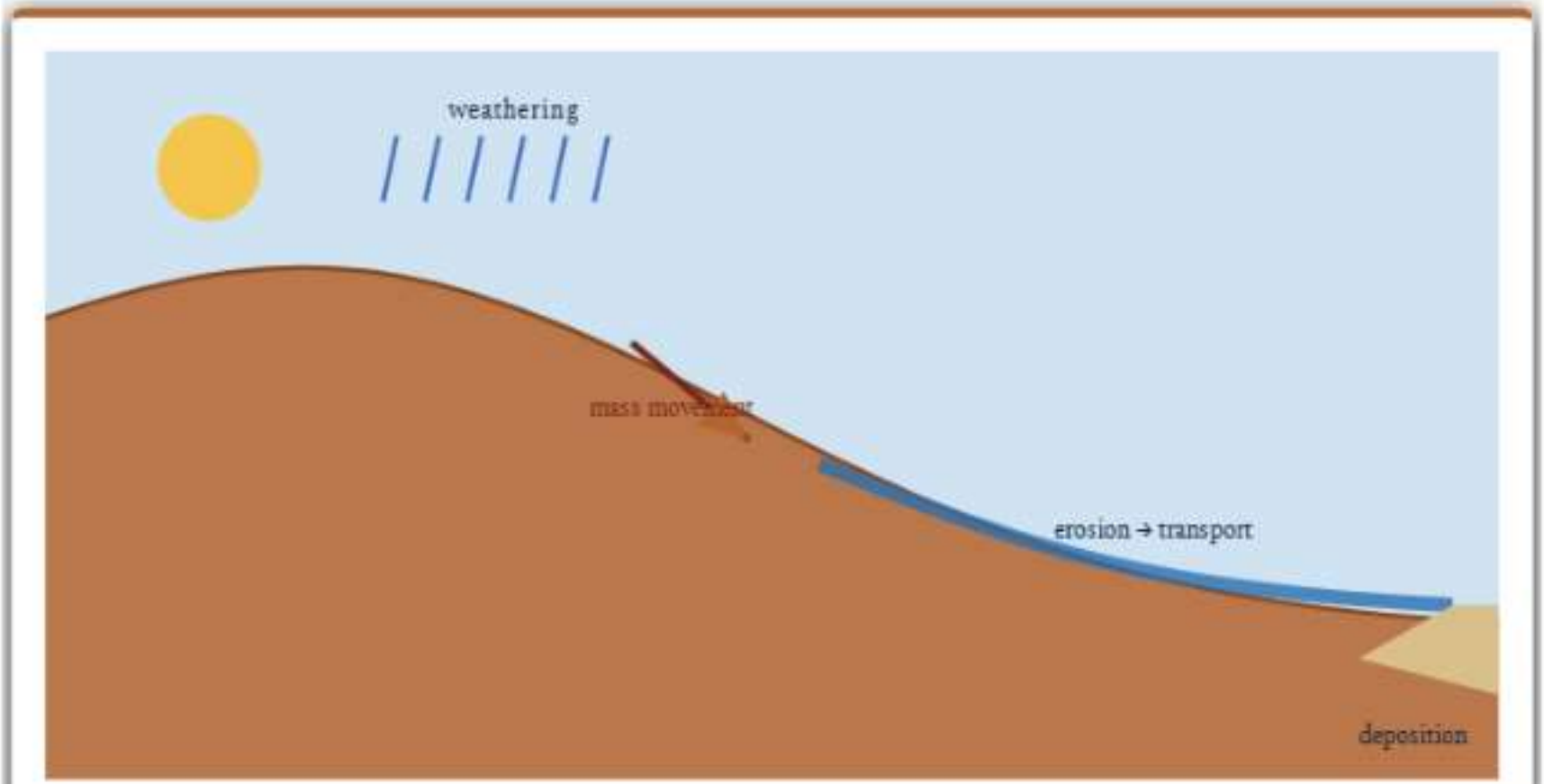

FIGURE 5 *Exogenic processes on a hillslope: weathering breaks down rock, mass movement and running water erode and transport it, and material is finally deposited.*

V. Mass Movements Mass movements involve the transfer of rock debris down slopes under the direct influence of gravity. Gravity exerts force on bedrock and weathering products alike. Notably, no geomorphic agent (like running water or wind) participates in the actual process of mass movement, and the debris itself carries air, water, or ice with it.

- **Activating Causes:** Mass movements yield when disturbing forces exceed the shearing resistance of materials. Causes include the removal of underlying support, increased slope gradients, overloading (from heavy rain, artificial filling, or natural saturation), excessive seepage, earthquakes, removal of natural vegetation, and rapid drawdown of water from lakes or rivers.
- **Forms of Movement:** The main forms include heave, flow, and slide.
- **Landslides:** A category of relatively rapid and perceptible mass movements involving dry materials. Types include:
  - **Slump:** Slipping of rock debris units with a backward rotation relative to the slope.
  - **Debris Slide:** Rapid rolling or sliding of earth debris without backward rotation.
  - **Debris Fall:** Nearly free fall of earth debris from an overhanging face.

- **Rockslide:** Sliding of individual rock masses down bedding or fault surfaces.
- **Rock Fall:** Free falling of rock blocks from the superficial layers of a steep rock face.

- **Regional Occurrences:** Landslides and debris avalanches are frequent in the Himalayas due to tectonic activity, steep slopes, and unconsolidated sedimentary deposits. They also occur in the relatively stable Western Ghats and Nilgiris due to near-vertical cliffs, heavy rainfall over short periods, and pronounced mechanical weathering.

VI. Erosion and Deposition

- **Erosion:** This degradational process involves the acquisition and transportation of rock debris by geomorphic agents, largely controlled by kinetic energy. Running water, glaciers, and wind are climatically controlled agents of erosion, whereas waves and groundwater are determined by coastal locations and lithological rock characteristics, respectively. Erosion wears down the landscape and is primarily responsible for continuous continuous changes to the earth's surface.
- **Deposition:** Deposition is the direct consequence of erosion. As erosional agents reach gentler slopes, they lose their velocity and energy, causing carried materials to settle. Coarser materials deposit first, followed by finer materials, ultimately filling up depressions.

VII. Soil Formation (Pedogenesis) Soil is a dynamic, changing, and developing medium where chemical, physical, and biological activities take place constantly. It serves as both a result of decay and a medium for growth.

- **The Process:** Pedogenesis begins with the weathering mantle. The weathered material is colonized by bacteria, mosses, and lichens. The accumulation of dead remains creates humus. As grasses and trees grow, and animals burrow, the material becomes porous and sponge-like, gaining the capacity to retain water and air, eventually maturing into a complex mixture of minerals and organic products.
- **Soil-Forming Factors:** Five basic factors control soil formation:

1. **Parent Material (Passive factor):** This includes in-situ weathered rock debris (residual soils) or transported deposits (transported soils). The texture, structure, and chemical composition of the parent rock strongly link to the resulting young soils.
2. **Topography (Passive factor):** Topography influences the amount of sunlight exposure and drainage. Soils tend to be thin on steep slopes and thick over flat upland areas where erosion is slow and water percolation is high.
3. **Climate (Active factor):** Climate controls soil development through moisture and temperature. High precipitation facilitates the downward transport of soil components (eluviation) and their deposition below (illuviation), and can lead to the removal of silica (desilication). In dry climates, high evaporation draws groundwater up via capillary action, leaving salt crusts called hardpans. High temperatures increase chemical activity, whereas freezing conditions halt it.
4. **Biological Activity:** Vegetation and organisms add organic matter, nitrogen, and aid in moisture retention. Dead plants produce humus, while organic acids aid in decomposing minerals. Bacterial growth rapidly oxidizes vegetation in warm climates (leaving low humus), but is slow in cold climates

(allowing peat accumulation). Bacteria like Rhizobium fix nitrogen, and animals like earthworms mechanically rework and alter the chemistry of the soil.

5. **Time:** The duration that soil-forming processes operate determines the maturation and profile development of the soil. Soils from recent deposits (like alluvium or glacial till) are considered young and exhibit poorly developed or no horizons.

Practice Questions

30 MCQs

Q1 **Which of the following forces are mainly known as land building forces?**

A Exogenic forces

B Endogenic forces

C Gravitational forces

D Denudational forces

Answer · B

EXPLANATION Endogenic forces continuously elevate or build up parts of the earth's surface and are mainly known as land building forces.

Q2 **The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as what?**

A Aggradation

B Diastrophism

C Gradation

D Volcanism

Answer · C

EXPLANATION The phenomenon of wearing down of relief variations of the surface of the earth through erosion is known as gradation.

Q3 Which of the following is considered a geomorphic agent rather than a geomorphic process?

A Weathering

B Running water

C Diastrophism

D Mass wasting

Answer · B

EXPLANATION An agent is a mobile medium like running water, whereas weathering and mass wasting are processes.

Q4 What directional force switches on the movement of all surface material on earth?

A Magnetism

B Gravity

C Solar radiation

D Centrifugal force

Answer · B

EXPLANATION Gravity is the force that switches on the movement of all surface material on earth.

Q5 The energy emanating from within the earth, which drives endogenic processes, is mostly generated by primordial heat, rotational and tidal friction, and what else?

A Solar radiation

B Radioactivity

C Kinetic energy

D Atmospheric pressure

Answer · B

EXPLANATION The energy emanating from within the earth is mostly generated by radioactivity, rotational and tidal friction, and primordial heat.

Q6 Which diastrophic process involves continental building through the uplift or warping of large parts of the earth's crust?

A Orogeny

B Epeirogeny

C Earthquakes

D Plate tectonics

Answer · B

EXPLANATION Epeirogenic processes involve the uplift or warping of large parts of the earth's crust, serving as a continental building process.

Q7 Orogeny is best described as which type of process?

A A soil-forming process

B A continental building process

C A mountain building process

D An exogenic weathering process

Answer · C

EXPLANATION Orogeny is specifically a mountain building process involving severe folding.

Q8 Which of the following processes is NOT included under the general term 'denudation'?

A Weathering

B Mass wasting

C Erosion

D Diastrophism

Answer · D

EXPLANATION Denudation includes weathering, mass wasting/movements, erosion, and transportation, but not internal diastrophic processes.

Q9 What are the two most important climatic elements that control various exogenic processes?

A Humidity and wind direction

B Temperature and precipitation

C Atmospheric pressure and altitude

D Solar radiation and cloud cover

Answer · B

EXPLANATION Temperature and precipitation are the two important climatic elements that control various exogenic processes.

Q10 Weathering is defined as the mechanical disintegration and chemical decomposition of rocks through the actions of what?

A Internal heat and pressure

B Various elements of weather and climate

C Tectonic plate movements

D Geomorphic agents like glaciers

Answer · B

EXPLANATION Weathering is defined as mechanical disintegration and chemical decomposition of rocks through the actions of various elements of weather and climate.

Q11 Why is weathering considered an in-situ or on-site process?

A Because it relies on fast-moving running water for transport.

B Because very little or no motion of materials takes place.

C Because it only happens deep underground.

D Because it strictly involves volcanic activity.

Answer · B

EXPLANATION As very little or no motion of materials takes place in weathering, it is considered an in-situ or on-site process.

Q12 Which of the following is a chemical weathering process?

A Hydration

B Thermal expansion

C Unloading

D Frost wedging

Answer · A

EXPLANATION Hydration is a chemical weathering process, whereas the others are physical weathering processes.

Q13 Most physical (mechanical) weathering processes are caused by:

A Solution and carbonation

B Thermal expansion and pressure release

C Oxidation and reduction

D Burrowing by animals

Answer · B

EXPLANATION Most of the physical weathering processes are caused by thermal expansion and pressure release.

Q14 Flaking off of more or less curved sheets of shells from over rocks, which results in smooth and rounded surfaces, is known as:

A Hydration

B Exfoliation

C Oxidation

D Carbonation

Answer · B

EXPLANATION Flaking off of more or less curved sheets of shells from over rocks or bedrock resulting in smooth and rounded surfaces is known as exfoliation.

Q15 How does weathering aid in the exploitation of valuable ores like iron, manganese, and copper?

A It melts the ores into a liquid state for easier extraction.

B It concentrates them through chemical or physical leaching of other materials.

C It mechanically transports the ores to the earth's surface.

D It converts the ores into harder metamorphic rocks.

Answer · B

EXPLANATION When rocks undergo weathering, materials are removed through leaching, which increases the concentration of the remaining valuable materials.

Q16 Which of the following best describes mass movements?

A The transfer of rock debris down slopes under the direct influence of gravity.

B The transportation of earth materials by running water.

C The elevation of portions of the earth's crust due to tectonic stress.

D The wearing down of the landscape by powerful winds.

Answer · A

EXPLANATION Mass movements transfer the mass of rock debris down the slopes under the direct influence of gravity.

Q17 Which geomorphic agent participates in the actual process of mass movements?

A Running water

B Wind

C Glaciers

D No geomorphic agent participates

Answer · D

EXPLANATION Mass movements are aided solely by gravity, and no geomorphic agent participates in the process.

Q18 The slipping of one or several units of rock debris with a backward rotation with respect to the slope is known as:

A Debris slide

B Rock fall

C Slump

D Debris fall

Answer · C

EXPLANATION Slump is slipping of rock debris units with a backward rotation with respect to the slope.

Q19 Rapid rolling or sliding of earth debris without backward rotation of mass is called a:

A Slump

B Debris slide

C Rockslide

D Rock fall

Answer · B

EXPLANATION Rapid rolling or sliding of earth debris without backward rotation of mass is known as a debris slide.

Q20 Free falling of rock blocks over any steep slope, keeping itself away from the slope, is known as:

A Rock fall

B Rockslide

C Debris avalanche

D Slump

Answer · A

EXPLANATION Rock fall is the free falling of rock blocks over any steep slope, keeping itself away from the slope.

Q21 Why do debris avalanches and landslides occur very frequently in the Himalayas?

A They are mostly made of very hard, highly resistant rocks.

B **They are tectonically active and made up of sedimentary and unconsolidated deposits.**

C They feature very gentle slopes that encourage sliding.

D They receive almost no rainfall throughout the year.

Answer · B

EXPLANATION The Himalayas are tectonically active, composed of sedimentary rocks, and feature unconsolidated and semi-consolidated deposits.

Q22 Which of the following is an example of a degradational process?

A Volcanism

B Diastrophism

C **Erosion**

D Epeirogeny

Answer · C

EXPLANATION Weathering, mass-wasting, and erosion are all degradational processes.

Q23 Denudational processes like erosion and transportation are fundamentally controlled by what type of energy?

A Geothermal energy

B Chemical energy

C **Kinetic energy**

D Magnetic energy

Answer · C

EXPLANATION Denudational processes like erosion and transportation are controlled by kinetic energy.

Q24 The work of groundwater as an agent of erosion is primarily determined by:

A Altitude and latitude

B **The lithological character of the region (i.e., permeable and soluble rocks)**

C High wind speeds and storm frequency

D Sunlight exposure

Answer · B

EXPLANATION The work of groundwater is determined more by the lithological character of the region, such as whether rocks are permeable and soluble.

Q25 Deposition occurs when erosional agents:

A Increase their velocity on steep slopes.

B **Lose their velocity and energy on gentler slopes.**

C Are heated by intense solar radiation.

D Encounter harder rock structures.

Answer · B

EXPLANATION Depositions occur when erosional agents lose their velocity and energy on gentler slopes and the carried materials start to settle.

Q26 Pedogenesis refers to the process of:

A Mountain building

B Volcanic eruption

C **Soil formation**

D Glacial erosion

Answer · C

EXPLANATION Pedogenesis is another term for soil formation.

Q27 Which of the following is considered a passive control factor in soil formation?

A Climate

B Biological activity

C Parent material

D Time of year

Answer · C

EXPLANATION Topography, time, and parent material are passive control factors in soil formation.

Q28 In climates like wet equatorial rainy areas, the removal of silica from the soil is known as:

A Illuviation

B Desilication

C Hydration

D Eluviation

Answer · B

EXPLANATION The removal of silica from the soil under high rainfall conditions is known as desilication.

Q29 What causes the formation of hardpans in dry climates?

A High precipitation causing downward transport of minerals.

B Rapid bacterial growth oxidizing all vegetation.

C High evaporation causing groundwater to be brought to the surface by capillary action, leaving behind salts.

D Deep frost penetration that mechanically hardens the soil.

Answer · C

EXPLANATION In dry climates, evaporation exceeds precipitation, causing capillary action to bring groundwater to the surface, leaving salts behind as crusts known as hardpans.

Q30 **In cold climates, bacterial growth is slow, which leads to the accumulation of undecomposed organic matter. This develops into layers of what in sub-arctic and tundra climates?**

A Calcium carbonate nodules

B Kanker

C Peat

D Hardpans Answer Key and Explanations

Answer · C

EXPLANATION With undecomposed organic matter because of low bacterial activity, layers of peat develop in sub-arctic and tundra climates.

CHAPTER 5 · AT A GLANCE

Geomorphic Processes

Forces That Shape Land

2	3	4	∞
Process families	Weathering types	Mass-movement modes	Continuous gradation

Endogenic — Build up › **Weathering** — Break down › **Erosion** — Carry away › **Deposition** — Lay down

ENDOGENIC

- Diastrophism
- Volcanism

EXOGENIC

- Weathering
- Mass movement
- Erosion
- Deposition

WEATHERING TYPES

- Physical
- Chemical
- Biological

MASS MOVEMENTS

- Creep
- Slump
- Slide
- Fall

★ *Pedogenesis — the formation of soil — begins where weathering breaks bedrock into a workable mantle.*

LECTURE VI

06

Landforms and Their Evolution

Physical Geography · Study Companion

Foundational Concepts

- Landforms vs. Landscapes: A landform is a small to medium tract or parcel of the earth's surface, while a landscape consists of several related landforms.
- **Evolution:** Just like life, landmasses pass through comparable developmental stages: youth, mature, and old age. This transformation is driven by geomorphic agents (water, groundwater, wind, glaciers, waves) performing erosion and subsequent deposition.

1 RUNNING WATER

In humid regions with heavy rainfall, running water is the most dominant geomorphic agent. It operates as both overland flow (sheetflow causing sheet erosion) and linear flow (streams/rivers).

Stages of River Landscape Development

- **Youth:** Features shallow V-shaped valleys with virtually no floodplains. Streams are few and poorly integrated. Waterfalls and rapids form over hard rock bodies. Broad divides contain marshes, swamps, and lakes.
- **Mature:** Streams are plentiful with excellent integration, carving deep V- shaped valleys. Swamps and rapids disappear as divides turn sharp. Wider floodplains emerge, confining streams to meanders.
- **Old Age:** Rivers meander freely over vast floodplains featuring natural levees and oxbow lakes. Most of the landscape is at or slightly above sea level. The divides are completely flattened, resulting in a peneplain (an almost-plain), sometimes dotted with low, resistant rocky remnants called monadnocks.

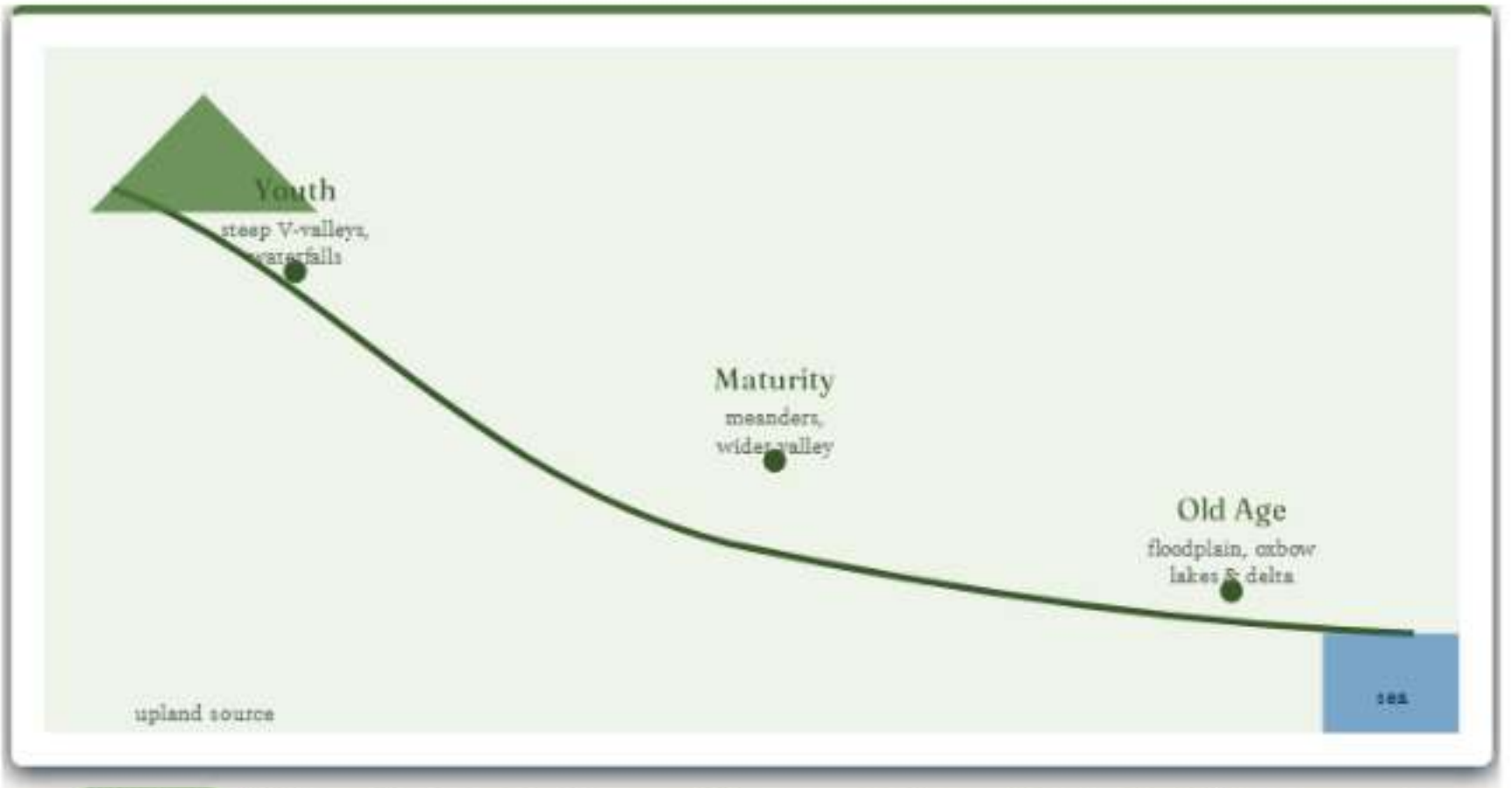

FIGURE 6 *The long profile of a river, from its steep youthful upper course to the meandering, depositional old-age course near the sea.*

Erosional Landforms

- **Valleys:** Start as narrow rills, grow into gullies, and evolve into valleys.
  - **Gorge:** Almost equal in width at the top and bottom with steep, straight sides. Commonly forms in hard rocks.
  - **Canyon:** Wider at the top with step-like side slopes. Commonly forms in horizontally bedded sedimentary rocks.
- **Potholes & Plunge Pools:** Pebbles collect in shallow rocky stream bed depressions and are rotated by flowing water, carving circular potholes. At the base of waterfalls, the sheer impact of water forms massive holes called plunge pools.
- **Incised/Entrenched Meanders:** Very deep, wide meandering loops cut firmly into hard rocks due to rapid streams focusing erosion on the channel bottom.
- **River Terraces:** Bedrock or alluvial surfaces marking former valley floors. They are called paired terraces if they exist at the exact same elevation on both sides of a river.

Depositional Landforms

- **Alluvial Fans:** Formed when heavily loaded mountain streams hit flat foot- slopes and dump coarse cones of debris. In humid areas, these fans are low cones with gentle slopes, while in arid regions, they form high cones with steep slopes.
- **Deltas:** Unlike fans, deltas form where rivers enter the sea. The deposits are very well sorted and clearly stratified, with the coarsest materials settling first.
- **Floodplains, Levees & Point Bars:** As waters spill over banks, they leave flood deposits. Natural levees are low, parallel linear ridges of coarse deposits lining the river banks. Point bars (meander bars) are uniform linear sediments deposited on the concave sides of meanders.

- **Meanders:** Not a landform, but a channel pattern. They form over gentle gradients due to the lateral working of water, the unconsolidated nature of alluvial banks, and the Coriolis force deflecting water. Active deposition happens on the slip-off (concave) bank, while erosion undercuts the steep convex bank. Cut-off loops become oxbow lakes.

1 GROUNDWATER (KARST TOPOGRAPHY)

Groundwater shapes regions rich in limestone or dolomites via the chemical processes of solution and precipitation. This topography is named "Karst" after a typical limestone region in the Balkans near the Adriatic Sea.

Erosional Landforms

- **Sinkholes & Swallow Holes:** Funnel-shaped openings at the surface. Solution sinks are formed via pure chemical dissolution. Collapse sinks (Dolines) form when the roof of an underground cave collapses.
- **Uvalas & Lapies:** When sinkholes or dolines merge into long trenches, they form valley sinks or uvalas. A highly irregular, maze-like limestone surface carved by differential solution is known as a lapies field, which may smooth out into limestone pavements over time.
- **Caves:** Form horizontally along bedding planes where water dissolves alternating rock/limestone layers. Caves open at both ends are called tunnels.

Depositional Landforms: Calcium carbonate in the water precipitates when carbon dioxide is lost.

- **Stalactites:** Icicle-shaped deposits hanging from cave ceilings, broad at the base and tapering at the ends.
- **Stalagmites:** Rise from the cave floor beneath dripping water, sometimes possessing a miniature crater-like depression at the top.
- **Pillars:** Form when stalactites and stalagmites eventually fuse together into distinct columns.

1 GLACIERS

Glaciers are masses of ice moving under the force of gravity. By dragging un- weathered angular blocks along the valley floor, glaciers cause severe damage through friction, abrasion, and plucking. (Note: In India, glaciers feed major rivers; e.g., Gangotri feeds the Bhagirathi, and Alkapuri feeds the Alakananda).

Erosional Landforms

- **Cirques (Tarn Lakes):** Deep, long troughs with vertically dropping walls at the heads of glacial valleys. Post-melting, they hold water known as tarn lakes.
- **Horns & Arêtes:** High, sharp peaks formed when multiple radiating cirques erode headward (e.g., Mount Everest, Matterhorn). The narrow, saw-toothed divides between them are called arêtes.
- **Glacial Valleys/Troughs:** Broad, smooth U-shaped valleys. They feature hanging valleys that drop into the main trough. In high latitudes, deep sea- filled glacial troughs are called fjords/fiords.

Depositional Landforms

- Glacial Till vs. Outwash: Till is unassorted, angular debris dropped directly by melting ice. Outwash consists of sorted, roughly stratified glacio-fluvial deposits washed down by melt-water streams.
- **Moraines:** Ridges of glacial till. Types include Terminal (at the toe), Lateral (along the sides), Medial (in the center), and Ground (irregular sheets over the valley floor).
- **Eskers:** Sinuous ridges of coarse materials (boulders/blocks) formed by stream channels flowing beneath the glacier ice.
- **Outwash Plains:** Broad, flat plains of gravel and sand located beyond the limits of continental ice sheets.
- **Drumlins:** Smooth, oval-shaped ridges of glacial till. The stoss end (facing the glacier) is blunt and steep, while the tail is gentle. They indicate the direction of glacier movement.

1 WAVES AND CURRENTS (COASTAL PROCESSES)

Coasts are dynamically sculpted by breaking waves, storm waves, and destructive tsunamis. Natural coastal barriers (off-shore bars, dunes, and mangroves) act as the first line of defense absorbing storm impact.

🪨 High Rocky Coasts (Submerged Coasts):

- **Characteristics:** Highly indented, irregular, and dominated by erosion initially (e.g., the West Coast of India).
- **Features:** Pounding waves carve steep sea cliffs. The rubble drops to form a wave-cut terrace. Lashing waves hollow out sea caves, and roof collapses leave isolated rock pillars called sea stacks. Eventually, materials are deposited offshore to form a wave-built terrace.

Low Sedimentary Coasts (Emerged Coasts)

- **Characteristics:** Smooth, gently sloping, featuring marshes and swamps, dominated by deposition (e.g., the East Coast of India).
- Features:
  - **Beaches & Dunes:** Patches of sand or small pebbles (shingle beaches). Wind lifts beach sand to create parallel sand dunes behind the coastline.
  - **Bars, Barriers & Spits:** Submerged ridges of sand parallel to the coast are off-shore bars. When exposed, they become barrier bars. If attached to a headland, they form a spit.
  - **Lagoons:** Form when bars and spits block a bay. Over time, lagoons fill with sediment and transform into broad coastal plains.

1 WINDS (DESERTS)

Wind creates landforms through deflation (lifting fine dust), abrasion (sand- blasting), and impact. However, torrential sheet floods / rain are actually responsible for general mass erosion in deserts.

Erosional Landforms

- **Pediments & Pediplains:** Pediments are gently inclined rocky floors at the foot of mountains. Erosion forces the steep wash slopes to retreat backwards (a process called parallel retreat of slopes through backwasting). This reduces mountains to flat featureless pediplains, leaving only resistant remnant hills known as inselbergs.
- **Playas:** Shallow, short-lived lakes in the center of desert basins. When evaporated, they leave salt-covered plains called alkali flats.
- **Deflation Hollows & Caves:** Persistent winds blow out the weathered mantle, creating shallow depressions called blow outs, which can deepen into caves.
- **Mushroom, Table & Pedestal Rocks:** Resistant rocks polished by wind abrasion into distinct shapes—some resembling mushrooms with a slender stalk and broad cap. Depositional Landforms (Sand Dunes): Wind is an excellent sorting agent, dropping specific grain sizes based on its velocity.
- **Barchans:** Crescent-shaped dunes with wings pointing downwind.
- **Parabolic Dunes:** Essentially reversed barchans that form when sandy surfaces are anchored by vegetation.
- **Seif Dunes:** Similar to barchans but possess only a single long wing due to shifting wind directions.
- **Longitudinal Dunes:** Long, low ridges aligned parallel to the wind, forming where the sand supply is poor.
- **Transverse Dunes:** Long ridges aligned perpendicular to the wind, forming where the sand source is elongated.

Practice Questions

30 MCQs

Q1 What are small to medium tracts or parcels of the earth's surface called?

A Landscapes

B Landforms

C Peneplains

D Monadnocks

Answer · B

EXPLANATION In simple words, small to medium tracts or parcels of the earth's surface are called landforms. Several related landforms together make up landscapes.

Q2 **Which of the following refers to a lowland of faint relief with some low resistant rock remnants, formed as a result of stream erosion?**

A Pediplain

B Floodplain

C Peneplain

D Delta plain

Answer · C

EXPLANATION In the old stage of running water regimes, the divides between drainage basins are lowered until they are almost completely flattened leaving a lowland of faint relief with some low resistant remnants called monadnocks. This type of plain forming as a result of stream erosion is called a peneplain.

Q3 **In which stage of river landscape development do waterfalls and rapids typically exist?**

A Youth

B Mature

C Late Mature

D Old Age

Answer · A

EXPLANATION During the youth stage of running water, streams flow over original slopes showing shallow V-shaped valleys. Waterfalls and rapids may exist where local hard rock bodies are exposed.

Q4 **A deep valley characterized by steep, step-like side slopes is known as a:**

A Gorge

B U-shaped valley

C Canyon

D Blind valley

Answer · C

EXPLANATION A canyon is characterised by steep step-like side slopes and is wider at its top than at its bottom. In contrast, a gorge has steep, straight sides and is almost equal in width at its top and bottom.

Q5 Very deep and wide meandering loops cut firmly into hard rocks are called:

A Point bars

B **Incised or entrenched meanders**

C Oxbow lakes

D Natural levees

Answer · B

EXPLANATION Very deep and wide meanders can be found cut into hard rocks. Such meanders are called incised or entrenched meanders.

Q6 Which depositional landform is created when coarse mountain streams break into foot slope plains of low gradient?

A Delta

B Floodplain

C Point bar

D **Alluvial fan**

Answer · D

EXPLANATION Alluvial fans are formed when streams flowing from higher levels break into foot slope plains of low gradient. The coarse load is dumped and spread as a broad low to high cone-shaped deposit called an alluvial fan.

Q7 Point bars, which are sediments deposited in a linear fashion by flowing waters, are also known as:

A Off-shore bars

B Barrier bars

C **Meander bars**

D Natural levees

Answer · C

EXPLANATION Point bars are also known as meander bars. They are found on the concave side of meanders of large rivers and are sediments deposited in a linear fashion by flowing waters along the bank.

Q8 **Any limestone or dolomitic region showing typical landforms produced by the action of groundwater is known as:**

A Pediplain topography

B **Karst topography**

C Glacial topography

D Arid topography

Answer · B

EXPLANATION Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called Karst topography.

Q9 **In karst topography, when the roof of an underground cave collapses, the resulting large hole is specifically called a:**

A Swallow hole

B Solution sink

C **Collapse sink or doline**

D Uvala

Answer · C

EXPLANATION If the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or void below, which is known as a collapse sink. The term doline is sometimes used to refer to collapse sinks.

Q10 **Highly irregular limestone surfaces with a maze of points, grooves, and ridges formed by differential solution activity are called:**

A **Lapies**

B Sinkholes

C Stalactites

D Stalagmites

Answer · A

EXPLANATION When much of the surface of the limestone is eaten away by pits and trenches, it leaves an extremely irregular surface with a maze of points, grooves, and ridges known as lapies.

Q11 Which depositional feature rises up from the floor of limestone caves?

A Stalactite

B Stalagmite

C Pillar

D Lapie

Answer · B

EXPLANATION Stalagmites rise up from the floor of the caves. They form due to dripping water from the surface or through the thin pipe of the stalactite immediately below it.

Q12 Deep, long, and wide troughs or basins with very steep concave to vertically dropping high walls at the heads of glacial valleys are called:

A Eskers

B Drumlins

C Cirques

D Fjords

Answer · C

EXPLANATION Cirques are deep, long, and wide troughs or basins with very steep concave to vertically dropping high walls at their heads and sides. They are the most common of landforms in glaciated mountains.

Q13 High, sharp-pointed, and steep-sided peaks formed when three or more radiating glaciers cut headward are called:

A Horns

B Arêtes

C Monadnocks

D Inselbergs

Answer · A

EXPLANATION If three or more radiating glaciers cut headward until their cirques meet, high, sharp-pointed, and steep-sided peaks called horns form.

Q14 What are very deep glacial troughs filled with sea water and making up shorelines called?

A Lagoons

B Hanging valleys

C Fjords/fiords

D Cirque lakes

Answer · C

EXPLANATION Very deep glacial troughs filled with sea water and making up shorelines in high latitudes are called fjords or fiords.

Q15 Sinuous ridges of coarse materials like boulders and blocks formed by water flowing in a channel beneath the glacier ice are called:

A Eskers

B Drumlins

C Moraines

D Outwash plains

Answer · A

EXPLANATION When ice melts, water flows beneath the glacier like streams. Very coarse materials settle in this ice valley beneath the glacier and after the ice melts, they are left as a sinuous ridge called an esker.

Q16 Smooth, oval-shaped ridge-like features composed mainly of glacial till that indicate the direction of glacier movement are called:

A Moraines

B Barchans

C Eskers

D Drumlins

Answer · D

EXPLANATION Drumlins are smooth oval-shaped ridge-like features composed mainly of glacial till. The stoss end gets blunted due to pushing by moving ice, giving an indication of the direction of glacier movement.

Q17 The west coast of India is primarily an example of a:

A Low sedimentary coast

B High rocky retreating coast

C Emerged coast

D Deltaic coast

Answer · B

EXPLANATION The west coast of our country is a high rocky retreating coast where erosional forms dominate.

Q18 Resistant masses of rock that stand isolated just off the shore, originally part of a receding sea cliff, are called:

A Sea caves

B Spits

C Sea stacks

D Off-shore bars

Answer · C

EXPLANATION Retreat of a sea cliff may leave some remnants of rock standing isolated as small islands just off the shore. Such resistant masses of rock, originally parts of a cliff or hill, are called sea stacks.

Q19 When a barrier bar gets keyed up to the headland of a bay, it is called a:

A Lagoon

B Spit

C Sea stack

D Terrace

Answer · B

EXPLANATION An off-shore bar exposed above water is a barrier bar. A barrier bar which gets keyed up to the headland of a bay is called a spit.

Q20 What feature is formed when barrier bars and spits form at the mouth of a bay and block it?

A Delta

B Lagoon

C Fjord

D Estuary

Answer · B

EXPLANATION When barrier bars and spits form at the mouth of a bay and block it, a lagoon forms.

Q21 In desert environments, what is the primary agent responsible for general mass erosion?

A Wind deflation

B Wind abrasion

C Sheet floods or sheet wash

D Groundwater solution

Answer · C

EXPLANATION While wind moves fine materials in deserts, general mass erosion is accomplished mainly through sheet floods or sheet wash during brief torrential rains.

Q22 In deserts, high relief is gradually reduced through the parallel retreat of slopes, leaving low featureless plains known as:

A Peneplains

B Floodplains

C Outwash plains

D Pediplains

Answer · D

EXPLANATION Through the parallel retreat of slopes, pediments extend backwards at the expense of the mountain front. That is how high relief in desert areas is reduced to low featureless plains called pediplains.

Q23 **The remnants of mountains left behind in a desert pediplain are called:**

A Inselbergs

B Monadnocks

C Horns

D Sea stacks

Answer · A

EXPLANATION Gradually, the mountain gets reduced leaving a remnant of the mountain known as an inselberg.

Q24 **Shallow, short-lived lakes at the center of desert basins that leave behind salt-covered plains when evaporated are called:**

A Tarn lakes

B Oxbow lakes

C Playas

D Lagoons

Answer · C

EXPLANATION In desert basins, shallow lakes that retain water only for a short duration due to evaporation are called playas. When covered by salts, the plain is called an alkali flat.

Q25 **Shallow depressions created by persistent wind currents blowing out weathered mantle or bare soil are called:**

A Uvalas

B Sinkholes

C Deflation hollows

D Potholes

Answer · C

EXPLANATION Weathered mantle from over the rocks or bare soil gets blown out by persistent movement of wind currents in one direction, creating shallow depressions called deflation hollows.

Q26 Crescent-shaped dunes with wings or points directed away from the wind direction are called:

A Parabolic dunes

B Seif dunes

C Barchans

D Transverse dunes

Answer · C

EXPLANATION Crescent-shaped dunes called barchans possess points or wings directed away from the wind direction (downwind).

Q27 Which type of sand dune forms when sandy surfaces are partially covered with vegetation?

A Longitudinal dunes

B Parabolic dunes

C Barchans

D Seif dunes

Answer · B

EXPLANATION Parabolic dunes form when sandy surfaces are partially covered with vegetation. They are essentially reversed barchans.

Q28 Which type of sand dune has only one wing or point due to a shift in wind conditions?

A Seif

B Barchan

C Transverse

D Parabolic

Answer · A

EXPLANATION A Seif is similar to a barchan but it has only one wing or point. This happens when there is a shift in wind conditions.

Q29 **Sand dunes that appear as long, low ridges and form when the supply of sand is poor and wind direction is constant are called:**

A Transverse dunes

B Barchans

C **Longitudinal dunes**

D Parabolic dunes

Answer · C

EXPLANATION Longitudinal dunes form when the supply of sand is poor and the wind direction is constant. They appear as long ridges of considerable length but low in height.

Q30 **Which term refers to the unassorted coarse and fine debris dropped directly by melting glaciers?**

A Outwash deposits

B **Glacial till**

C Alluvium

D Loess Answer Key & Explanations

Answer · B

EXPLANATION The unassorted coarse and fine debris dropped by melting glaciers is called glacial till. In contrast, outwash deposits washed down by melt-water streams are roughly stratified and assorted.

CHAPTER 6 · AT A GLANCE

Landforms and Their Evolution

Sculpted Landscapes

5	3	4	$CaCO_3$
Major geomorphic agents	Fluvial stages	Classic dune forms	Karst rock

Youth — Steep V-valleys › **Mature** — Wide floodplains › **Old** — Meanders & oxbows › – Peneplain

AGENTS

- Running water
- Groundwater
- Glaciers
- Waves
- Wind

DUNE TYPES

- Barchan
- Seif
- Parabolic
- Longitudinal

LANDFORM PAIRS

- Erosional
- Depositional

★ *In limestone country, groundwater dissolves rock to create karst caves, sinkholes and stalactites.*

LECTURE VII

07

Composition and Structure of the Atmosphere

Physical Geography · Study Companion

1 Introduction and Significance

- **The Necessity of Air:** While humans can survive for some time without food or water, we cannot survive even a few minutes without breathing.
- **Definition:** The atmosphere is a mixture of different gases that completely envelopes the earth.
- **Life-Sustaining Properties:** It contains essential, life-giving gases such as oxygen for humans and animals, and carbon dioxide for plants.
- **Mass Concentration:** The air is an integral part of the earth's mass, and remarkably, 99% of the atmosphere's total mass is confined within just 32 km from the earth's surface.
- **Physical Traits:** Air is naturally colourless and odourless; it can only be felt when it blows as wind.

1 Composition of the Atmosphere

The atmosphere is primarily composed of gases, water vapour, and dust particles. The proportion of these elements changes dramatically at higher altitudes. For example, oxygen becomes practically negligible at a height of 120 km, while carbon dioxide and water vapour are only found up to 90 km from the surface.

A. Important Gases

- **Carbon Dioxide (CO2):** Meteorologically vital, CO2 is transparent to incoming solar radiation but opaque to outgoing terrestrial radiation. It absorbs a portion of terrestrial radiation and reflects it back, making it largely responsible for the greenhouse effect. Due to the burning of fossil fuels, CO2 levels have been rising, leading to increased air temperatures.

- **Ozone:** Found between 10 and 50 km above the earth's surface, ozone acts as a crucial planetary filter. It absorbs highly harmful ultra-violet (UV) rays radiating from the sun, preventing them from reaching the surface.

B. Water Vapour

- **Distribution:** Water vapour is a variable gas that decreases with altitude and also decreases from the equator towards the poles. In warm, wet tropics, it can account for up to 4% of the air by volume, while in dry deserts and cold polar regions, it is less than 1%.
- **Function:** It absorbs incoming solar insolation and preserves the earth's radiated heat, functioning as a protective blanket that keeps the earth from becoming too cold or too hot. It also contributes to the stability and instability in the air.

C. Dust Particles

- **Sources:** The atmosphere holds various small solid particles, including sea salts, fine soil, smoke-soot, ash, pollen, dust, and disintegrated meteor particles.
- **Distribution:** While generally concentrated in the lower layers, strong convectional currents can transport dust to great heights. Subtropical and temperate regions possess a higher concentration of dust particles than equatorial or polar regions due to dry winds.
- **Function:** Dust and salt particles act as hygroscopic nuclei, which means water vapour condenses around them to produce clouds.

1 Structure of the Atmosphere

Atmospheric density is highest near the surface of the earth and decreases as altitude increases. Based on temperature conditions, the atmosphere is strictly divided into five distinct layers.

I. Troposphere

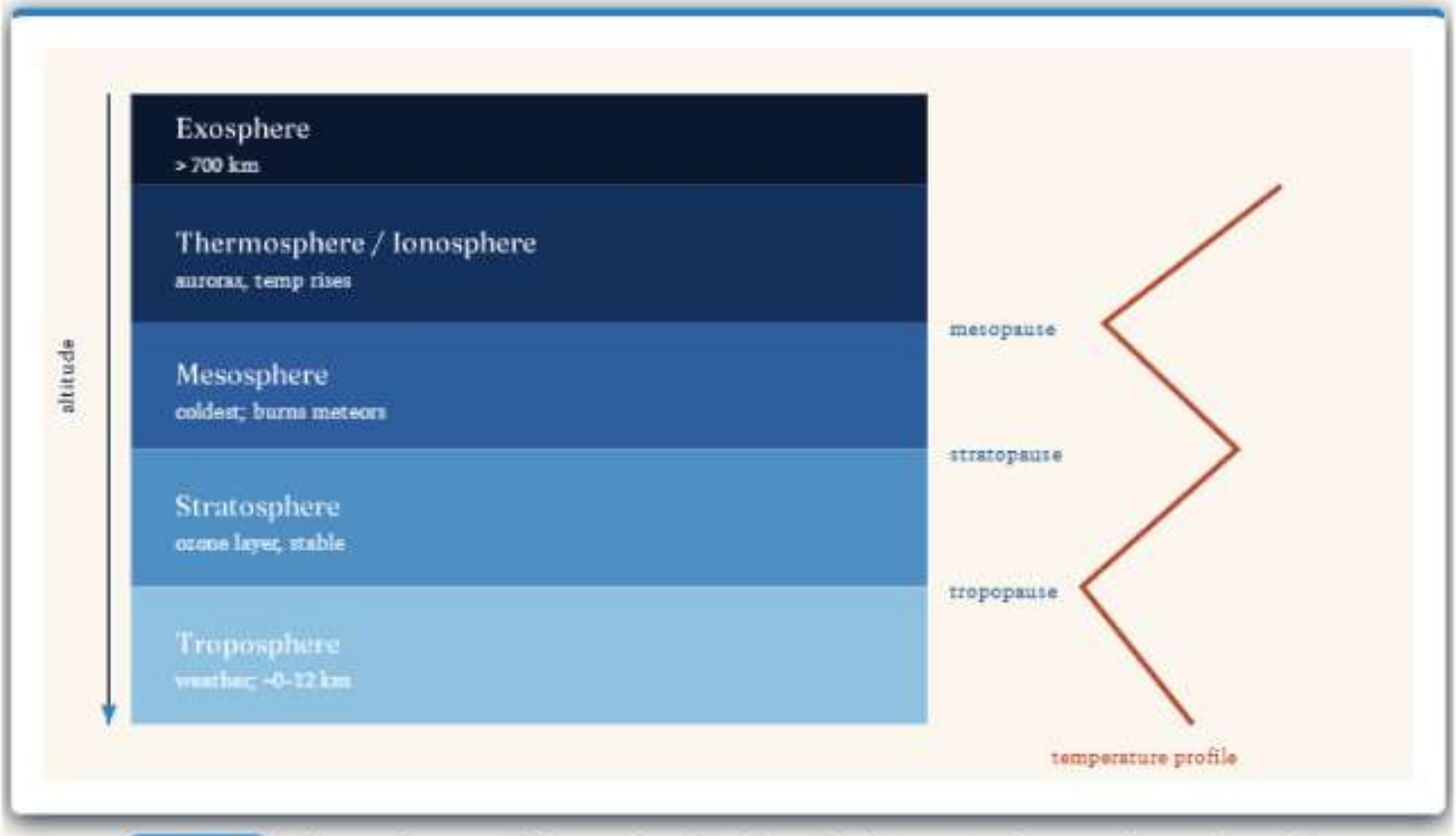

FIGURE 7 *The vertical structure of the atmosphere, from the weather-bearing troposphere up to the exosphere, with its characteristic temperature profile.*

- The lowermost layer and the most important layer for all biological activity.
- **Height:** Its average height is 13 km, extending roughly 8 km near the poles and about 18 km at the equator.
- **Equatorial Thickness:** The thickness is greatest at the equator because strong convectional currents transport heat to great heights.
- **Features:** It contains dust particles and water vapour; all climate and weather changes take place within this layer.
- **Lapse Rate:** The temperature decreases at a strict rate of 1°C for every 165m of height.

II. Tropopause (The Transition Zone)

- The boundary zone separating the troposphere from the stratosphere above it.
- **Temperature Profile:** The air temperature here is about -80°C over the equator and about -45°C over the poles. The temperature remains nearly constant in this zone, hence the name "tropopause".

III. Stratosphere

- Located directly above the tropopause, extending up to a height of 50 km.
- Its most significant feature is that it contains the ozone layer, which shields life on earth from intense,

harmful UV energy.

IV. Mesosphere

- Lies above the stratosphere and extends up to a height of 80 km.
- **Temperature Profile:** In this layer, the temperature starts decreasing once again with increased altitude, dropping to -100°C at the 80 km mark.
- The upper limit of this layer is known as the mesopause.

V. Ionosphere (Thermosphere)

- Located between 80 and 400 km above the mesopause.
- **Features:** It contains electrically charged particles known as ions. It is incredibly useful for human technology because radio waves transmitted from the earth are reflected back down by this layer.
- **Temperature Profile:** Unlike the mesosphere, the temperature here starts increasing with height. VI. Exosphere
- The uppermost and highest layer of the atmosphere, situated above the thermosphere.
- Very little is known about it; whatever gaseous contents exist here are extremely rarefied (thin), and the layer gradually merges into outer space. (Note: Geographers are primarily concerned with only the first two layers of the atmosphere.)

1 Elements of Weather and Climate

The primary elements of the atmosphere that are subject to constant change and which directly influence human life on earth are:

- Temperature
- Pressure
- Winds
- Humidity
- Clouds
- Precipitation

Practice Questions

30 MCQs

Q1 What percentage of the total mass of the atmosphere is confined within 32 km from the earth's surface?

A 50%

B 75%

C 90%

D 99%

Answer · D

EXPLANATION The air is an integral part of the earth's mass, and 99 per cent of the total mass of the atmosphere is confined to the height of 32 km from the earth's surface.

Q2 At what height does oxygen become almost negligible in quantity?

A 50 km

B 90 km

C 120 km

D 165 km

Answer · C

EXPLANATION The proportion of gases changes in higher layers such that oxygen will be almost in negligible quantity at the height of 120 km.

Q3 Up to what maximum height from the earth's surface are carbon dioxide and water vapour found?

A 50 km

B 90 km

C 120 km

D 400 km

Answer · B

EXPLANATION Carbon dioxide and water vapour are found only up to 90 km from the surface of the earth.

Q4 Which gas is transparent to incoming solar radiation but opaque to outgoing terrestrial radiation?

A Oxygen

B Nitrogen

C Carbon dioxide

D Ozone

Answer · C

EXPLANATION Carbon dioxide is meteorologically very important as it is transparent to the incoming solar radiation but opaque to the outgoing terrestrial radiation.

Q5 Which gas is largely responsible for the greenhouse effect by reflecting terrestrial radiation back to the earth's surface?

A Ozone

B Water Vapour

C Carbon dioxide

D Nitrogen

Answer · C

EXPLANATION Carbon dioxide absorbs a part of terrestrial radiation and reflects some of it back, making it largely responsible for the greenhouse effect.

Q6 Between what heights above the earth's surface is the ozone layer primarily found?

A 0 and 10 km

B 10 and 50 km

C 50 and 80 km

D 80 and 400 km

Answer · B

EXPLANATION Ozone is an important component of the atmosphere found between 10 and 50 km above the earth's surface.

Q7 What is the primary function of the ozone layer?

A It traps heat to create the greenhouse effect.

B It produces clouds through condensation.

C It reflects radio waves back to earth.

D It absorbs harmful ultra-violet rays from the sun.

Answer · D

EXPLANATION Ozone acts as a filter and absorbs the ultra-violet rays radiating from the sun, preventing them from reaching the surface.

Q8 In warm and wet tropics, water vapour may account for up to what percentage of the air by volume?

A 1%

B 4%

C 10%

D 21%

Answer · B

EXPLANATION In the warm and wet tropics, water vapour may account for four per cent of the air by volume.

Q9 How does the concentration of water vapour change geographically?

A It increases from the equator towards the poles.

B It decreases from the equator towards the poles.

C It remains constant across all latitudes.

D It is highest in dry deserts.

Answer · B

EXPLANATION Water vapour decreases from the equator towards the poles.

Q10 Which atmospheric component acts like a blanket, preventing the earth from becoming either too cold or too hot?

A Dust particles

B Nitrogen

C Water vapour

D Ozone

Answer · C

EXPLANATION Water vapour absorbs parts of the insolation from the sun and preserves radiated heat, acting like a blanket.

Q11 Where is the higher concentration of dust particles generally found?

A Equatorial regions

B Polar regions

C Subtropical and temperate regions

D The stratosphere

Answer · C

EXPLANATION The higher concentration of dust particles is found in subtropical and temperate regions due to dry winds, compared to equatorial and polar regions.

Q12 What role do dust and salt particles play in the atmosphere?

A They act as hygroscopic nuclei to produce clouds.

B They block outgoing terrestrial radiation.

C They reflect radio waves back to earth.

D They destroy the ozone layer.

Answer · A

EXPLANATION Dust and salt particles act as hygroscopic nuclei around which water vapour condenses to produce clouds.

Q13 Where is atmospheric density the highest?

A In the exosphere

B Near the surface of the earth

C At the tropopause

D In the mesosphere

Answer · B

EXPLANATION Density is highest near the surface of the earth and decreases with increasing altitude.

Q14 How many distinct layers is the atmosphere divided into based on temperature conditions?

A Three

B Four

C Five

D Six

Answer · C

EXPLANATION The column of atmosphere is divided into five different layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

Q15 What is the average height of the troposphere?

A 8 km

B 13 km

C 18 km

D 50 km

Answer · B

EXPLANATION The average height of the troposphere is 13 km.

Q16 While the troposphere is roughly 8 km high near the poles, what is its approximate height at the equator?

A 10 km

B 13 km

C 18 km

D 50 km

Answer · C

EXPLANATION It extends roughly to a height of 8 km near the poles and about 18 km at the equator.

Q17 Why is the thickness of the troposphere greatest at the equator?

A Because of the presence of the ozone layer.

B Because heat is transported to great heights by strong convectional currents.

C Because it contains higher amounts of water vapour.

D Because of a lack of dust particles.

Answer · B

EXPLANATION Thickness of the troposphere is greatest at the equator because heat is transported to great heights by strong convectional currents.

Q18 Which atmospheric layer is considered the most important for all biological activity?

A Troposphere

B Stratosphere

C Mesosphere

D Thermosphere

Answer · A

EXPLANATION The troposphere is where all changes in climate and weather take place, making it the most important layer for all biological activity.

Q19 At what rate does the temperature decrease in the troposphere as altitude increases?

A 1°C for every 100m

B 1°C for every 165m

C 2°C for every 165m

D 5°C for every 1000m

Answer · B

EXPLANATION The temperature in the troposphere decreases at the rate of 1°C for every 165m of height.

Q20 What is the zone separating the troposphere from the stratosphere called?

A Mesopause

B Thermopause

C Tropopause

D Stratopause

Answer · C

EXPLANATION The zone separating the tropsophere from stratosphere is known as the tropopause.

Q21 What is the approximate air temperature at the tropopause over the equator?

A -45°C

B -80°C

C 0°C

D -100°C

Answer · B

EXPLANATION The air temperature at the tropopause is about minus 80°C over the equator.

Q22 Up to what height does the stratosphere extend?

A 18 km

B 32 km

C 50 km

D 80 km

Answer · C

EXPLANATION The stratosphere is found above the tropopause and extends up to a height of 50 km.

Q23 Which layer lies directly above the stratosphere?

A Troposphere

B Mesosphere

C Ionosphere

D Exosphere

Answer · B

EXPLANATION The mesosphere lies above the stratosphere, which extends up to a height of 80 km.

Q24 What temperature is reached at the height of 80 km in the mesosphere?

A -45°C

B -80°C

C -100°C

D 0°C

Answer · C

EXPLANATION In the mesosphere, temperature starts decreasing with altitude and reaches up to minus 100°C at the height of 80 km.

Q25 What is the upper limit of the mesosphere called?

A Stratopause

B Tropopause

C Mesopause

D Ionosphere

Answer · C

EXPLANATION The upper limit of mesosphere is known as the mesopause.

Q26 Between which altitudes is the ionosphere located?

A 10 and 50 km

B 50 and 80 km

C 80 and 400 km

D 400 and 1000 km

Answer · C

EXPLANATION The ionosphere is located between 80 and 400 km above the mesopause.

Q27 What is a key practical function of the ionosphere?

A It acts as a blanket for preserving earth's heat.

B It reflects radio waves transmitted from the earth back to the surface.

C It filters out harmful ultraviolet radiation.

D It provides hygroscopic nuclei for cloud formation.

Answer · B

EXPLANATION Radio waves transmitted from the earth are reflected back to the earth by the ionosphere.

Q28 How does temperature change with height in the ionosphere?

A It decreases rapidly.

B It remains completely constant.

C It starts increasing with height.

D It drops to -100°C.

Answer · C

EXPLANATION Temperature in the ionosphere starts increasing with height.

Q29 What is the highest and uppermost layer of the atmosphere called?

A Stratosphere

B Mesosphere

C Thermosphere

D Exosphere

Answer · D

EXPLANATION The uppermost layer of the atmosphere above the thermosphere is known as the exosphere, which gradually merges with outer space.

Q30 Which of the following is considered an element of weather and climate?

A Longitude

B Altitude

C Precipitation

D Meteors

Answer · C

EXPLANATION The main elements of atmosphere which are subject to change and influence human life are temperature, pressure, winds, humidity, clouds and precipitation.

CHAPTER 7 · AT A GLANCE

Composition and Structure of the Atmosphere

The Air Above

78	21	0.93	0.03
% Nitrogen	% Oxygen	% Argon	% Carbon dioxide

Troposphere — Weather zone › **Stratosphere** — Ozone layer › **Mesosphere** — Coldest › **Thermosphere** — Ionosphere

LAYERS (LOW → HIGH)

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Exosphere

KEY NUMBERS

- Lapse rate ≈ 1°C / 165 m
- Tropopause −80°C equator
- Tropopause −45°C poles

★ *The stratospheric ozone layer absorbs harmful ultraviolet radiation, shielding life at the surface.*

LECTURE VIII

08

Solar Radiation, Heat Balance and Temperature

Physical Geography · Study Companion

I. The Earth's Atmosphere and Energy System

- **The Atmosphere:** Earth is wrapped in a massive envelope of numerous gases that support all life on the surface. We exist at the bottom of this huge pile of air, feeling it primarily when it is in motion, which we call wind.
- **Energy Balance:** The sun supplies almost all of Earth's energy, which the Earth eventually radiates back into space. This perfect balance ensures the Earth neither progressively warms up nor cools down over time.
- **Heat Transfer:** Different parts of the Earth receive varying amounts of heat, causing pressure differences in the atmosphere. These pressure differences drive winds that transfer heat from one region to another.

II. Solar Radiation (Insolation)

- **Insolation Defined:** Earth receives its solar energy in short wavelengths, formally known as incoming solar radiation, or insolation.
- **Earth's Geometry:** Because Earth is a geoid (resembling a sphere), the sun's rays strike the top of the atmosphere obliquely, meaning Earth intercepts only a tiny fraction of the sun's total energy. At the top of the atmosphere, Earth receives an average of 1.94 calories per square centimeter per minute.
- Orbital Variations (Aphelion & Perihelion):
  - **Aphelion (July 4th):** Earth is farthest from the sun (152 million km).
  - **Perihelion (January 3rd):** Earth is nearest to the sun (147 million km), receiving slightly more annual insolation than on July 4th.

- **Note:** The daily weather impact of this variation is masked by atmospheric circulation and the distribution of land and sea.

III. Factors Controlling the Variability of Insolation The amount and intensity of insolation vary by day, season, and year due to five main factors:

1. **Angle of Inclination of Sun's Rays:** The higher the latitude, the smaller the angle of the sun's rays, resulting in slant rays. Slant rays cover a larger area (decreasing energy density) and must travel through a thicker layer of the atmosphere, leading to greater absorption, scattering, and diffusion.
2. **Earth's Axis Tilt:** Earth's axis sits at an angle of 66½° with its orbital plane, heavily influencing insolation distribution across latitudes.
3. Rotation of the earth on its axis.
4. Length of the day.
5. **Atmospheric Transparency & Land Configuration:** While having less influence, suspended particles and water vapor scatter and absorb radiation. The scattering of the visible spectrum by particles creates the blue color of the sky and the red colors of sunrise and sunset.

- **Spatial Distribution:** Insolation ranges from 320 Watt/m^2 in the tropics to 70 Watt/m^2 at the poles. The highest insolation is found in subtropical deserts due to minimal cloud cover. The equator actually receives less insolation than the tropics.

IV. Heating and Cooling Processes of the Atmosphere

The atmosphere is mostly transparent to short-wave solar radiation but is heated from below by the Earth through several processes:

- **Conduction:** When the sun heats the Earth, the surface transfers heat to the lower atmospheric layers through direct contact. Energy flows from the warmer body to the cooler one until temperatures equalize.
- **Convection:** Air that touches the warm Earth rises vertically in currents, transmitting heat upward. This vertical heating is confined exclusively to the troposphere.
- **Advection:** The horizontal movement of air, which is actually more important than vertical movement for daily weather. In middle latitudes, advection causes most diurnal (day/night) weather variations. A local summer example is the "loo" wind in northern India.
- **Terrestrial Radiation:** After absorbing short-wave insolation, Earth becomes a radiating body, emitting energy in long-wave form. Atmospheric greenhouse gases (like carbon dioxide) absorb these long waves, effectively heating the atmosphere indirectly from the ground up. V. The Earth's Heat Budget (Albedo & Balance)

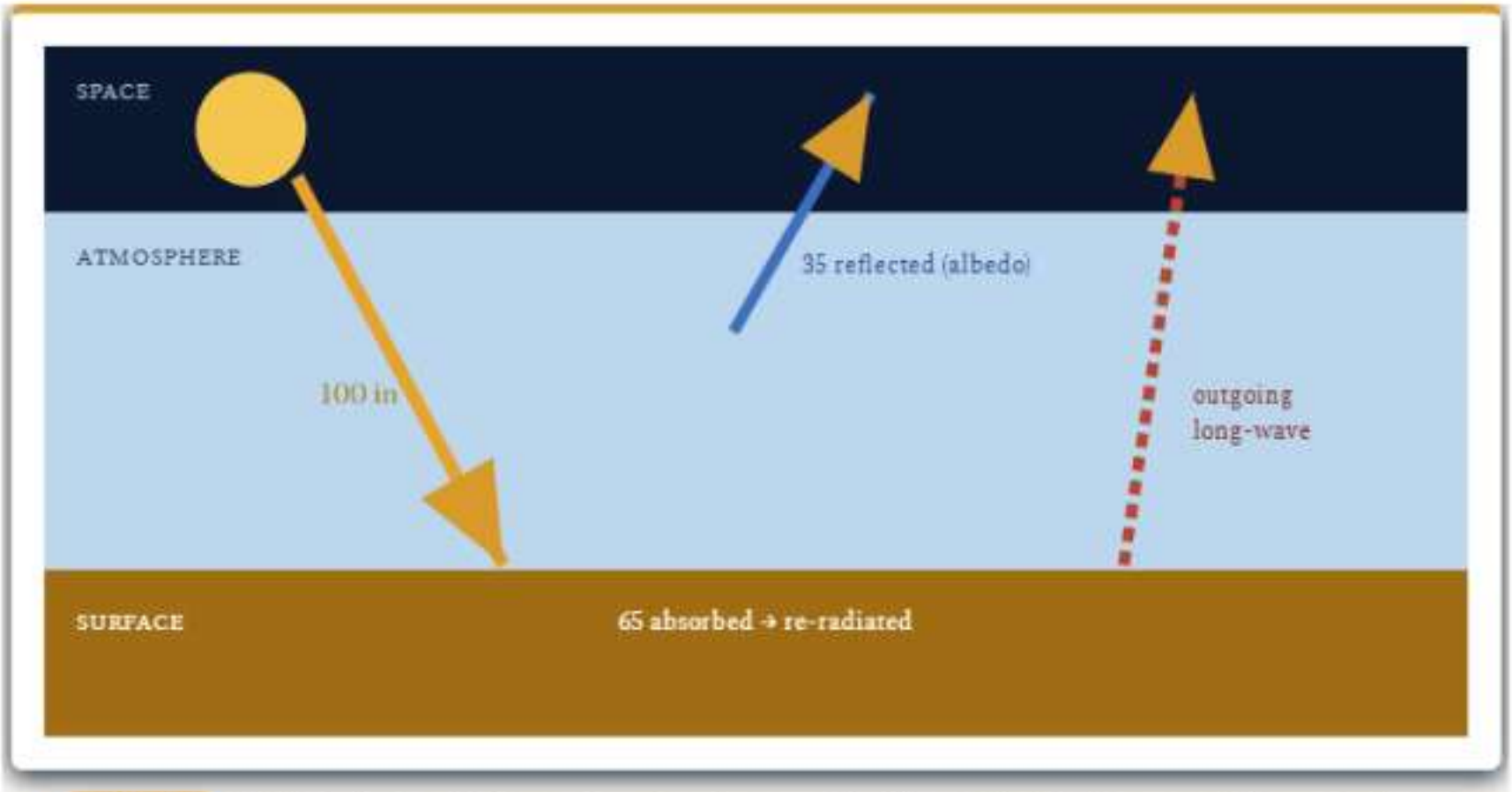

FIGURE 8 *Earth's heat budget: of 100 units of incoming solar energy, about 35 are reflected back to space and 65 are absorbed and re-radiated, keeping the planet in balance.*

Earth maintains its temperature because incoming heat equals outgoing heat. Out of 100% incoming solar insolation:

- **The Albedo Effect (35 Units Reflected):** Before reaching the surface, roughly 35 units are reflected straight back to space (27 from cloud tops, 2 from snow/ice-covered areas).
- **Absorption (65 Units Absorbed):** 14 units are absorbed by the atmosphere, and 51 units are absorbed by the Earth's surface.
- **Terrestrial Output (51 Units):** Earth radiates its 51 units back: 17 units go directly into space, and 34 units are absorbed by the atmosphere (6 directly, 9 via convection/turbulence, and 19 via the latent heat of condensation).
- **Atmospheric Output (48 Units):** The atmosphere radiates its total 48 absorbed units (14 from the sun + 34 from Earth) back to space.
- **Final Balance:** The total units returned to space (17 from Earth + 48 from atmosphere = 65 units) perfectly balance the 65 units initially absorbed.
- **Latitudinal Heat Imbalance:** Between 40° North and 40° South, there is a net radiation surplus, while the poles have a deficit. Winds and ocean currents redistribute this excess heat polewards to prevent the tropics from overheating and the poles from permanently freezing.

VI. Temperature and its Controlling Factors

- **Definition:** Heat represents the molecular movement within a substance, whereas temperature is the specific degree measurement of how hot or cold a place is.
- Key Controlling Factors:

- **Latitude:** Determines the amount of insolation received.
- **Altitude:** Because the atmosphere is heated from below, temperature drops as elevation rises. The Normal Lapse Rate is a decrease of 6.5°C per 1,000 meters.
- **Distance from the Sea:** Land heats and cools quickly, while water heats and cools slowly. Coastal areas experience a moderating influence from sea and land breezes, minimizing temperature variations.
- **Air-masses and Ocean Currents:** Warm ocean currents and warm air- masses elevate temperatures, whereas cold currents and air-masses lower them. VII. Global Distribution of Temperature (Isotherms)

Temperature distribution is mapped using isotherms (lines joining places of equal temperature), which generally run parallel to latitudes.

- **January Distribution:** The effect of large landmasses is highly pronounced in the Northern Hemisphere. Isotherms bend north over the warmer oceans (e.g., warmed by the Gulf Stream) and bend sharply south over the frigid continents like Europe and Siberia. The Siberian plain reaches plunging temperatures, with a mean of -20°C along the 60° E longitude. In the Southern Hemisphere, where there is more ocean, isotherms are more strictly parallel to latitudes (e.g., the 20°C, 10°C, and 0°C lines run parallel to 35°S, 45°S, and 60°S respectively).
- **July Distribution:** Isotherms run more consistently parallel to latitudes globally. Subtropical Asia experiences temperatures over 30°C.
- **Temperature Range:** The highest annual temperature range (>60°C) occurs in northeastern Eurasia due to extreme continentality (distance from oceans), while the smallest range (3°C) is near the equator between 20°S and 15°N.

VIII. Inversion of Temperature

- **The Phenomenon:** Normally, temperature drops with altitude, but when this reverses (air gets warmer with height), it is called temperature inversion.
- **Causes & Conditions:** It commonly occurs during long, still, clear winter nights when the Earth radiates heat away faster than the air above it, making the ground colder than the sky. In polar regions, this inversion is a year-round normal state.
- **Effects:** Inversion creates atmospheric stability, trapping smoke and dust in the lower strata and causing dense morning winter fogs.
- **Air Drainage:** In mountainous regions, heavy, dense cold air rolls down slopes at night due to gravity, pooling in valleys beneath warmer air. This natural phenomenon protects mountain plants from frost damage.

IX. Important Scientific Definitions

- **Planck's Law:** The hotter a body is, the more energy it radiates, and the shorter the wavelength of that radiation will be.
- **Specific Heat:** The exact amount of energy required to raise the temperature of one gram of a substance by one degree Celsius.

Practice Questions

30 MCQs

Q1 What is the envelope of air that surrounds the earth and supports life over its surface called?

A Hydrosphere

B **Atmosphere**

C Lithosphere

D Biosphere

Answer · B

EXPLANATION Atmosphere. The earth is surrounded by an envelope of air called the atmosphere, which is composed of numerous gases that support life over the earth's surface.

Q2 What is the term for the incoming solar energy that the earth receives in short wavelengths?

A Terrestrial radiation

B Albedo

C **Insolation**

D Advection

Answer · C

EXPLANATION Insolation. The energy received by the earth in short wavelengths is known as incoming solar radiation, which is commonly termed as insolation.

Q3 On average, how much solar energy does the earth intercept at the top of its atmosphere?

A **1.94 calories per sq. cm per minute**

B 2.94 calories per sq. cm per minute

C 1.50 calories per sq. cm per minute

D 3.14 calories per sq. cm per minute

Answer · A

EXPLANATION 1.94 calories per sq. cm per minute. On an average, the earth receives 1.94 calories per sq. cm per minute at the top of its atmosphere.

Q4 **Occurring around January 3rd, what is the term for the position when the earth is nearest to the sun (147 million km)?**

A Aphelion

B Solstice

C **Perihelion**

D Equinox

Answer · C

EXPLANATION Perihelion. On 3rd January, the earth is nearest to the sun at a distance of 147 million km, a position called perihelion.

Q5 **During aphelion on July 4th, what is the distance between the earth and the sun?**

A 140 million km

B 147 million km

C **152 million km**

D 160 million km

Answer · C

EXPLANATION 152 million km. During its revolution around the sun, the earth is farthest from the sun at a distance of 152 million km on 4th July, a position known as aphelion.

Q6 **Which of the following is NOT listed as a factor causing variations in the insolation received at the earth's surface?**

A The rotation of the earth on its axis

B The length of the day

C **The moon's gravitational pull**

D The transparency of the atmosphere

Answer · C

EXPLANATION The moon's gravitational pull. The factors causing variations in insolation are the rotation of the earth, the angle of inclination of the sun's rays, the length of the day, the transparency of the atmosphere, and the configuration of land. The moon's gravitational pull is not listed as a factor.

Q7 What angle does the earth's axis make with the plane of its orbit around the sun?

A 23.5°

B 66.5°

C 90°

D 45°

Answer · B

EXPLANATION 66.5°. The earth's axis makes an angle of 66.5° with the plane of its orbit round the sun, heavily influencing the amount of insolation received at different latitudes.

Q8 What atmospheric process is responsible for the red color of the rising and setting sun, as well as the blue color of the sky?

A Convection

B Conduction

C Absorption

D Scattering

Answer · D

EXPLANATION Scattering. Very small suspended particles in the troposphere scatter the visible spectrum, which adds color to the sky, including the red color of sunrise and sunset and the blue color of the sky. 9. C) Over the subtropical deserts. Maximum insolation is received over the subtropical deserts, where cloudiness is at its least, while the equator receives comparatively less.

Q9 In which global region is the maximum insolation received due to the least cloudiness?

A Over the equator

B In the middle latitudes

C Over the subtropical deserts

D Near the poles

Answer key not provided

Q10 What is the process of heating the lower layers of the atmosphere through direct contact with the heated land called?

A Conduction

B Convection

C Advection

D Radiation

Answer · A

EXPLANATION Conduction. Conduction takes place when two bodies of unequal temperature are in contact; the air in contact with the land gets heated slowly, effectively transferring heat to the lower atmospheric layers.

Q11 Which vertical heating process involves the rise of air in currents and is confined exclusively to the troposphere?

A Conduction

B Convection

C Advection

D Reflection

Answer · B

EXPLANATION Convection. The air in contact with the earth rises vertically on heating in the form of currents, a process of vertical heating known as convection that is confined exclusively to the troposphere.

Q12 The local wind known as 'loo' in northern India during the summer is an outcome of which horizontal heat transfer process?

A Advection

B Conduction

C Convection

D Terrestrial radiation

Answer · A

EXPLANATION Advection. The transfer of heat through the horizontal movement of air is advection, and local winds like 'loo' in northern India during the summer season are the outcome of this process.

Q13 **After being heated by insolation, in what form does the earth radiate energy back to the atmosphere?**

A Short wave form

B Visible light form

C Long wave form

D Ultraviolet form

Answer · C

EXPLANATION Long wave form. The earth, after being heated by short-wave insolation, becomes a radiating body itself and emits energy back to the atmosphere in long wave form.

Q14 **Out of 100 percent incoming solar insolation, what total percentage (or units) is reflected back into space before even reaching the earth's surface?**

A 14 units

B 27 units

C 35 units

D 51 units

Answer · C

EXPLANATION 35 units. Roughly 35 units out of 100 are reflected back to space even before reaching the earth's surface.

Q15 **What is the specific term for the amount of radiation that is reflected by the earth, such as from cloud tops and snow-covered areas?**

A Terrestrial radiation

B Albedo

C Insolation

D Heat budget

Answer · B

EXPLANATION Albedo. The reflected amount of radiation from cloud tops and snow/ice- covered areas is collectively called the albedo of the earth.

Q16 How many units of incoming solar energy are directly absorbed by the earth's surface?

A 14 units

B 34 units

C 51 units

D 65 units

Answer · C

EXPLANATION 51 units. Out of the remaining 65 units of solar energy that aren't immediately reflected, 14 units are absorbed within the atmosphere and 51 units are absorbed directly by the earth's surface.

Q17 Out of the 34 units of terrestrial radiation absorbed by the atmosphere, how many units are absorbed specifically through the latent heat of condensation?

A 6 units

B 9 units

C 14 units

D 19 units

Answer · D

EXPLANATION 19 units. Out of the 34 units of terrestrial radiation absorbed by the atmosphere, 6 units are absorbed directly, 9 via convection, and 19 units are absorbed through the latent heat of condensation.

Q18 According to the latitudinal variation in the net radiation balance, between which latitudes does the earth possess a surplus of net radiation?

A Between 10 degrees north and south

B Between 23.5 degrees north and south

C Between 40 degrees north and south

D Between 60 degrees north and south

Answer · C

EXPLANATION Between 40 degrees north and south. There is a surplus of net radiation balance between 40 degrees north and south, whereas the regions near the poles suffer a deficit.

Q19 What is the exact measurement in degrees of how hot or cold a place is?

A Heat

B Temperature

C Albedo

D Insolation

Answer · B

EXPLANATION Temperature. While heat represents the molecular movement of particles, temperature is the specific measurement in degrees of how hot or cold a thing or place is.

Q20 What is the normal lapse rate, which describes the rate of temperature decrease with increasing height?

A 4.5°C per 1,000 m

B 6.5°C per 1,000 m

C 8.5°C per 1,000 m

D 10.0°C per 1,000 m

Answer · B

EXPLANATION 6.5°C per 1,000 m. The rate of decrease of temperature with increasing height is termed the normal lapse rate, which equals 6.5°C per 1,000 m. 21. C) Isotherms. The global distribution of temperature is generally shown on maps using isotherms, which are lines joining places having equal temperatures.

Q21 What are the lines on a map that join places having equal temperatures called?

A Isobars

B Isohyets

C Isotherms

D Contours

Answer key not provided

Q22 **In January, why do the isotherms bend towards the north over the North Atlantic Ocean?**

A Due to the presence of cold air masses

B Due to intense continentality

C **Due to warm ocean currents like the Gulf Stream**

D Due to the high altitude of the region

Answer · C

EXPLANATION Due to warm ocean currents like the Gulf Stream. In January over the North Atlantic Ocean, the presence of warm ocean currents like the Gulf Stream and North Atlantic drift makes the ocean warmer, causing the isotherms to bend towards the north.

Q23 **In which region is the highest range of temperature between January and July (more than 60°C) found?**

A Subtropical deserts

B **The north-eastern part of the Eurasian continent**

C The equatorial oceans

D Subtropical Asia

Answer · B

EXPLANATION The north-eastern part of the Eurasian continent. The highest range of temperature, measuring more than 60°C, is found over the north-eastern part of the Eurasian continent primarily due to extreme continentality.

Q24 **What is the phenomenon called when the normal lapse rate is reversed, and the temperature actually increases with elevation?**

A Normal lapse rate

B Advection

C **Inversion of temperature**

D Air drainage

Answer · C

EXPLANATION Inversion of temperature. When the normal lapse rate is reversed and the normal decrease of temperature with elevation is inverted, it is termed an inversion of temperature.

Q25 Which set of conditions is the most ideal situation for a temperature inversion to occur?

A A long summer night with cloudy skies

B A windy day with heavy precipitation

C A long winter night with clear skies and still air

D A short winter day with strong ocean currents

Answer · C

EXPLANATION A long winter night with clear skies and still air. A long winter night with clear skies and still air is an ideal situation for an inversion, allowing the earth to radiate its heat away and become cooler than the air above.

Q26 What does surface temperature inversion promote in the lower layers of the atmosphere?

A Heavy rainfall

B Severe thunderstorms

C Stability, often trapping smoke and causing dense morning fogs

D High-speed winds

Answer · C

EXPLANATION Stability, often trapping smoke and causing dense morning fogs. Surface inversion promotes stability in the lower layers of the atmosphere, allowing smoke and dust particles to collect and spread horizontally, which causes dense fogs in mornings during the winter season.

Q27 In hills and mountains, what natural process involves dense, cold air moving down a slope to pool in valley bottoms, ultimately protecting plants from frost?

A Advection

B Convection

C Air drainage

D Thermal lifting

Answer · C

EXPLANATION Air drainage. In hills and mountains, dense, cold air flows under the influence of gravity down slopes to pile up deeply in valley bottoms, a phenomenon called air drainage which protects mountain plants from frost damages.

Q28 **Which scientific principle states that the hotter a body is, the more energy it will radiate and the shorter the wavelength of that radiation will be?**

A Newton's Law

B Specific Heat Law

C Planck's law

D Terrestrial Law

Answer · C

EXPLANATION Planck's law. Planck's law states that the hotter a body is, the more energy it will radiate and the shorter the wavelength of that radiation will be.

Q29 **What is the exact amount of energy required to raise the temperature of one gram of a substance by one degree Celsius called?**

A Latent heat

B Sensible heat

C Specific heat

D Heat budget

Answer · C

EXPLANATION Specific heat. Specific heat is defined as the energy needed to raise the temperature of one gram of a substance by one degree Celsius.

Q30 **Why does the atmosphere essentially act as a greenhouse, getting heated indirectly from below?**

A Because atmospheric gases absorb incoming short wave radiation

B Because atmospheric gases scatter visible light

C Because the atmosphere reflects solar insolation

D **Because atmospheric gases, like carbon dioxide, absorb the long wave radiation emitted by the earth Answer Key & Explanations**

Answer · D

EXPLANATION Because atmospheric gases, like carbon dioxide, absorb the long wave radiation emitted by the earth. The long wave terrestrial radiation emitted by the earth is absorbed by atmospheric gases, particularly carbon dioxide and other greenhouse gases, indirectly heating the atmosphere from below.

CHAPTER 8 · AT A GLANCE

Solar Radiation, Heat Balance and Temperature

Energy Balance

100	35	65	=0
Units incoming	Reflected (albedo)	Absorbed	Net heat balance

Insolation Sun → Earth › **Reflection** Albedo 35 › **Absorption** Surface + air › **Re-radiation** Back to space

CONTROLS ON TEMPERATURE

Latitude · Altitude · Land–sea contrast · Ocean currents · Cloud cover

CONCEPTS

Isotherms · Temperature inversion · Specific heat · Planck's law

★ *Incoming and outgoing energy balance over the year — otherwise Earth would steadily heat or cool.*

LECTURE IX

09

Atmospheric Circulation and Weather Systems

Physical Geography · Study Companion

Atmospheric Pressure

Air expands when heated and gets compressed when cooled, resulting in pressure variations that cause the movement of air (wind) from high to low pressure. Atmospheric pressure is defined as the weight of a column of air contained in a unit area from the mean sea level to the top of the atmosphere.

- **Measurement:** It is measured in units of millibars (mb) using a mercury or aneroid barometer. At sea level, the average atmospheric pressure is 1,013.2 mb.
- **Vertical Variation:** Pressure decreases rapidly with altitude—about 1 mb for every 10 meters of elevation in the lower atmosphere. For example, standard pressure drops from 1013.25 mb at sea level to 265 mb at 10 km. While there is a strong vertical pressure gradient, it is nearly perfectly balanced by the opposing downward gravitational force, preventing strong upward winds.
- **Horizontal Distribution:** Horizontal pressure is mapped using isobars (lines connecting places of equal pressure, reduced to sea level). Low- pressure systems have the lowest pressure in the center, while high-pressure systems have the highest in the center.
- **Global Pressure Belts:** The globe features distinct belts: the equatorial low near the equator, subtropical highs along 30° N and S, sub-polar lows along 60° N and S, and polar highs near the poles. These belts are not permanent; they oscillate north and south in response to the apparent movement of the sun.

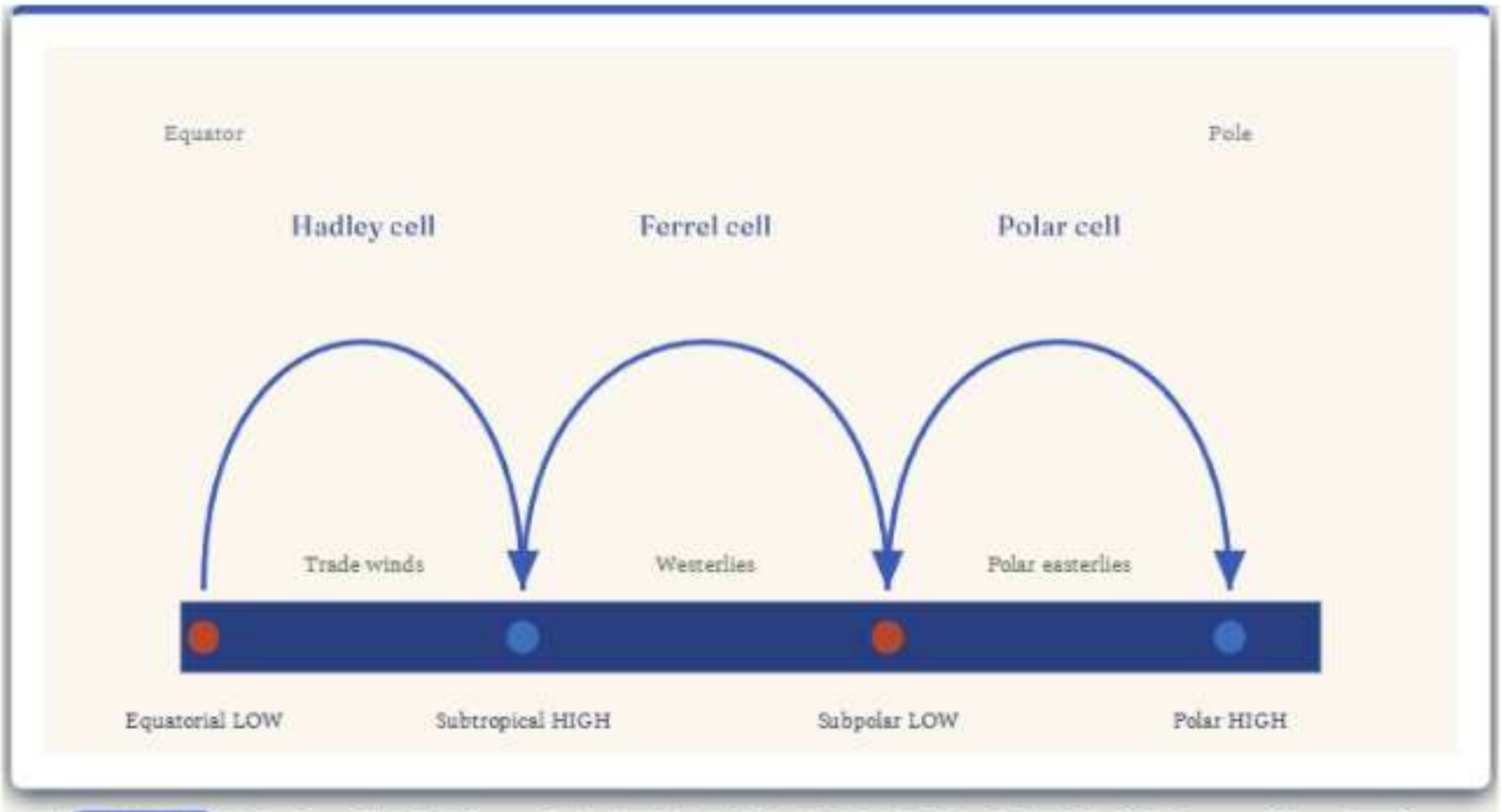

FIGURE 9 *The three-cell model of atmospheric circulation (Hadley, Ferrel and Polar cells) and the global pressure belts and surface winds it produces.*

1. Forces Affecting Wind Velocity and Direction Wind is the horizontal motion of air driven by pressure differences. Its velocity and direction are determined by the combined effect of three horizontal forces, plus downward gravity:

- **Pressure Gradient Force:** The rate of pressure change over distance. The force is strongest, resulting in higher wind speeds, where isobars are close together.
- **Frictional Force:** Friction limits wind speed. Its influence is greatest at the surface and generally extends up to an elevation of 1 to 3 km, but is minimal over the sea surface.
- **Coriolis Force:** Caused by the rotation of the earth, this force deflects wind to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Deflection increases with wind velocity. The Coriolis force is directly proportional to latitude, meaning it is maximum at the poles and zero at the equator. At the equator, because the Coriolis force is zero, low- pressure areas simply fill up rather than intensifying into spinning storms— this is why tropical cyclones are not formed near the equator.

Wind Circulation and General Patterns

- **Geostrophic Wind:** In the upper atmosphere (2–3 km above the surface) where surface friction is absent, the Coriolis force balances the pressure gradient force. This balance causes winds to blow strictly parallel to straight isobars.
- Cyclonic and Anticyclonic Circulation:
  - **Cyclonic (Low Pressure):** Air converges and rises. Wind circulation is anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.

    - **Anticyclonic (High Pressure):** Air subsides and diverges. Wind circulation is clockwise in the Northern Hemisphere and anti- clockwise in the Southern Hemisphere.
- **General Circulation Cells:** The transfer of heat energy from lower to higher latitudes establishes planetary wind patterns.
    - **Hadley Cell:** Tropical air rises at the Inter Tropical Convergence Zone (ITCZ), reaching up to 14 km altitude, and moves towards the poles. It cools and sinks near 30° N and S, forming subtropical highs, and returns to the equator as surface easterlies.
    - **Ferrel Cell:** In middle latitudes, sinking cold polar air meets rising warm air blowing from the subtropical highs, creating surface westerlies.
    - **Polar Cell:** Dense, cold air subsides near the poles and blows toward middle latitudes as polar easterlies.
- **ENSO (El Nino and Southern Oscillation):** The general atmospheric circulation is strongly linked to the oceans. When warm water drifts into the central Pacific and replaces the cool Peruvian current (El Nino), it is coupled with pressure variations known as the Southern Oscillation. A strong ENSO drastically alters global weather, bringing heavy rainfall to South America's normally arid coast, floods to China, and droughts to Australia and India.

Local Winds

Differences in heating and cooling create localized wind patterns:

- **Land and Sea Breezes:** During the day, land heats faster than water, causing air to rise (low pressure) and drawing in a cooler sea breeze. At night, land loses heat faster than the sea (high pressure), causing a land breeze to blow toward the relatively warmer ocean.
- **Mountain and Valley Winds:** Daytime solar heating on mountain slopes creates an upslope movement of air known as a valley breeze. At night, the slopes cool, causing dense air to descend into the valley, creating a mountain wind or katabatic wind. Additionally, winds descending the leeward side of mountains warm up adiabatically and can rapidly melt snow.

Air Masses and Fronts

- **Air Masses:** A large body of air with very little horizontal variation in temperature and moisture. It acquires these traits by remaining over homogenous "source regions" (like vast oceans or snow-covered plains) for an extended time. They are classified into five types: Maritime tropical (mT), Continental tropical (cT), Maritime polar (mP), Continental polar (cP), and Continental arctic (cA).
- **Fronts:** The boundary zone where two different air masses meet. The formation of fronts is known as frontogenesis. There are four main types: Cold (cold air moves toward warm), Warm (warm air moves toward cold), Stationary (stationary boundary), and Occluded (when an air mass is fully lifted off the ground). Fronts cause steep temperature gradients, massive cloud formation, and precipitation.

Cyclones

- **Extra Tropical Cyclones:** These originate in the mid and high latitudes along polar fronts. They differ from tropical cyclones because they feature a clear frontal system (a warm sector wedged between cold sectors). The rapidly moving cold front eventually overtakes the warm front, lifting the warm air completely (occlusion) and dissipating the storm. They cover a larger area than tropical cyclones, form over both land and sea, and move from west to east.
- **Tropical Cyclones:** Highly destructive storms known regionally as Hurricanes (Atlantic), Typhoons (Western Pacific), and Willy-willies (Western Australia).
    - **Conditions for Formation:** Require a large sea surface with temperatures higher than 27°C, the Coriolis force, weak low- pressure, small vertical wind variations, and upper divergence.
    - **Structure:** Features a calm center of subsiding air called the eye (150– 250 km in diameter). Surrounding this is the eye wall, where air ascends strongly to the tropopause, producing the most violent winds (up to 250 km/h) and torrential rain.
    - **Energy and Lifespan:** They are fueled entirely by continuous moisture condensation in massive cumulonimbus clouds. Moving from east to west, the storm dissipates instantly upon reaching land (a process called landfall) because the moisture supply is cut off.

Severe Local Storms

- **Thunderstorms:** Short-duration, highly localized, violent storms caused by intense convection on moist, hot days. They are characterized by massive cumulonimbus clouds driven by an intense updraft of warm air, producing thunder, lightning, and eventually a downdraft of cool air and rain. If sub- zero temperatures are reached aloft, hail forms; if there is insufficient moisture, they can generate severe dust-storms.
- **Tornadoes:** Descending from severe thunderstorms like an elephant's trunk, these spiraling winds feature extreme low pressure at their center. They cause massive destruction, typically in middle latitudes. When a tornado occurs over the sea, it is called a water

Practice Questions

30 MCQs

Q1 What is the standard unit used to express atmospheric pressure?

A Isobars

B **Millibars**

C Celsius

D Kilometers

Answer · B

EXPLANATION The atmospheric pressure is expressed in units of millibar.

Q2 What is the average atmospheric pressure at sea level?

A 898.7 mb

B 1,000.0 mb

C **1,013.2 mb**

D 1,025.5 mb

Answer · C

EXPLANATION At sea level the average atmospheric pressure is 1,013.2 millibar.

Q3 Which instrument is commonly used to measure atmospheric pressure?

A Thermometer

B Anemometer

C **Mercury barometer**

D Hygrometer

Answer · C

EXPLANATION Air pressure is measured with the help of a mercury barometer or the aneroid barometer.

Q4 At what approximate rate does atmospheric pressure decrease with height in the lower atmosphere?

A 1 mb for each 10 m increase

B 10 mb for each 1 m increase

C 1 mb for each 100 m increase

D 10 mb for each 10 m increase

Answer · A

EXPLANATION In the lower atmosphere, the decrease in pressure amounts to about 1 mb for each 10 m increase in elevation.

Q5 What is the term for lines connecting places of equal sea-level pressure on a weather map?

A Isotherms

B Isobars

C Isohyets

D Isotachs

Answer · B

EXPLANATION Figure 10.1 shows the patterns of isobars corresponding to pressure systems, where a low-pressure system is enclosed by one or more isobars.

Q6 Where are the high-pressure belts known as the subtropical highs located?

A Near the equator

B Along 30° N and 30° S

C Along 60° N and 60° S

D Near the poles

Answer · B

EXPLANATION Along 30° N and 30° S are found the high-pressure areas known as the subtropical highs.

Q7 Which of the following is NOT one of the forces affecting horizontal wind velocity and direction near the earth's surface?

A Pressure gradient force

B Coriolis force

C Frictional force

D Gravitational force

Answer · D

EXPLANATION The horizontal winds near the earth surface respond to the combined effect of three forces – the pressure gradient force, the frictional force and the Coriolis force, whereas the gravitational force acts downward.

Q8 Up to what approximate elevation does the frictional force primarily affect wind speed?

A 1 - 3 km

B 5 - 7 km

C 10 - 12 km

D 15 - 20 km

Answer · A

EXPLANATION Frictional force is greatest at the surface and its influence generally extends up to an elevation of 1 - 3 km.

Q9 In which direction does the Coriolis force deflect wind in the Northern Hemisphere?

A To the left

B To the right

C Upward

D Downward

Answer · B

EXPLANATION The Coriolis force deflects the wind to the right direction in the northern hemisphere and to the left in the southern hemisphere.

Q10 **Where is the Coriolis force at its maximum intensity?**

A At the equator

B At 30° N and S

C At 60° N and S

D At the poles

Answer · D

EXPLANATION The Coriolis force is directly proportional to the angle of latitude, meaning it is maximum at the poles and is absent at the equator.

Q11 **Why do tropical cyclones fail to form near the equator?**

A The sea surface temperature is too low.

B The Coriolis force is zero.

C Frictional force is too high.

D There is too much landmass.

Answer · B

EXPLANATION At the equator, the Coriolis force is zero, meaning the low pressure gets filled instead of getting intensified, which is the reason why tropical cyclones are not formed near the equator.

Q12 **What is geostrophic wind?**

A Wind that blows perpendicular to the isobars.

B Wind in the upper atmosphere blowing parallel to straight isobars.

C Wind spiraling into a low-pressure center.

D Surface wind affected heavily by friction.

Answer · B

EXPLANATION When isobars are straight and there is no friction, the pressure gradient force is balanced by the Coriolis force and the resultant wind blows parallel to the isobar, which is known as geostrophic wind.

Q13 What is the pattern of wind direction around a low-pressure center (cyclone) in the Northern Hemisphere?

A Clockwise

B Anticlockwise

C Parallel to isobars

D Diverging outward

Answer · B

EXPLANATION The wind circulation around a low is called cyclonic circulation, which moves in an anticlockwise direction in the Northern Hemisphere.

Q14 What type of wind circulation occurs around a high-pressure center (anticyclone) in the Southern Hemisphere?

A Cyclonic, anticlockwise

B Cyclonic, clockwise

C Anticyclonic, anticlockwise

D Anticyclonic, clockwise

Answer · C

EXPLANATION According to Table 10.2, the pattern of wind direction around a high- pressure anticyclone in the Southern Hemisphere is anticlockwise.

Q15 What is the circulation cell in the tropics between the equator and 30° N/S called?

A Ferrel Cell

B Polar Cell

C Hadley Cell

D Equatorial Cell

Answer · C

EXPLANATION The surface air that flows towards the equator converges and rises; such a cell in the tropics is called the Hadley Cell.

Q16 The El Nino phenomenon is characterized by the appearance of warm water off the coast of which region?

A Australia

B India

C China

D Peru

Answer · D

EXPLANATION The warm water of the central Pacific Ocean slowly drifts towards the South American coast and replaces the cool Peruvian current, an appearance of warm water known as El Nino.

Q17 What does the acronym ENSO stand for?

A Equatorial North Southern Oscillation

B El Nino and Southern Oscillation

C Eastern National Sea Oscillation

D Extra-tropical Northern System Oscillation

Answer · B

EXPLANATION The combined phenomenon of southern oscillation and El Nino is known as ENSO.

Q18 When does a sea breeze typically occur?

A During the day

B During the night

C Only in winter

D Only in summer

Answer · A

EXPLANATION During the day the land heats up faster and becomes warmer than the sea, creating a pressure gradient from the relatively cool sea to the land, resulting in a sea breeze.

Q19 What defines a katabatic wind?

A Warm air rising up a valley during the day.

B Cool dense air draining into a valley at night.

C A dry, warm wind melting snow on the leeward side of a mountain.

D A localized wind formed over the oceans.

Answer · B

EXPLANATION During the night, mountain slopes get cooled and the dense air descends into the valley as the mountain wind; the cool air of high plateaus and ice fields draining into the valley is called a katabatic wind.

Q20 What is an air mass?

A A small packet of air rising rapidly.

B A large body of air having little horizontal variation in temperature and moisture.

C A violent storm system.

D The boundary zone between two different air temperatures.

Answer · B

EXPLANATION An air mass is defined as a large body of air having little horizontal variation in temperature and moisture.

Q21 According to the text, which of the following is a possible source region for the formation of air masses?

A The Himalayas

B The Deccan Plateau

C The Equatorial forest

D The Siberian Plain

Answer · D

EXPLANATION The Siberian Plain is a recognized source region for the formation of air masses.

Q22 What is the boundary zone between two different air masses called?

A A cell

B An isobar

C A front

D A cyclone

Answer · C

EXPLANATION When two different air masses meet, the boundary zone between them is called a front.

Q23 What defines an occluded front?

A Warm air moves towards a cold air mass.

B The front remains stationary.

C An air mass is fully lifted above the land surface.

D Cold air moves towards a warm air mass.

Answer · C

EXPLANATION If an air mass is fully lifted above the land surface, it is called the occluded front.

Q24 Where do extra tropical cyclones primarily form?

A Over the equator

B Along the polar front in mid and high latitudes

C Only over warm tropical oceans

D Exclusively over desert regions

Answer · B

EXPLANATION The systems developing in the mid and high latitude, beyond the tropics, are called the middle latitude or extra tropical cyclones, which form along the polar front.

Q25 In what direction do extra tropical cyclones generally move?

A East to west

B North to south

C West to east

D South to north

Answer · C

EXPLANATION The extra tropical cyclones move from west to east but tropical cyclones move from east to west.

Q26 Which of the following is a necessary condition for the formation of a tropical cyclone?

A A stationary cold front

B Sea surface temperature higher than 27° C

C Absence of the Coriolis force

D Large variations in vertical wind speed

Answer · B

EXPLANATION A favourable condition for the formation and intensification of tropical storms is a large sea surface with temperatures higher than 27° C.

Q27 What characterizes the "eye" of a tropical cyclone?

A It is the area of highest wind speeds.

B It is a region of calm with subsiding air.

C It produces torrential rain and hail.

D It is a high-pressure zone generating thunderstorms.

Answer · B

EXPLANATION The center of a tropical cyclone is called the eye, which is a region of calm with subsiding air.

Q28 What happens to a tropical cyclone when it reaches land?

A It gains energy and intensifies.

B It remains stationary.

C It dissipates (peters out).

D It turns into an extra tropical cyclone.

Answer · C

EXPLANATION A tropical cyclone creates storm surges that inundate coastal low lands, and the storm peters out on the land.

Q29 What type of cloud is responsible for producing severe thunderstorms?

A Cirrus

B Stratus

C Cumulonimbus

D Altocumulus

Answer · C

EXPLANATION A thunderstorm is a well-grown cumulonimbus cloud producing thunder and lightening.

Q30 What is a tornado called when it occurs over the sea?

A A hurricane

B A typhoon

C A water spout

D A storm surge Explanations

Answer · C

EXPLANATION Tornadoes generally occur in middle latitudes, and a tornado over the sea is called a water spout.

CHAPTER 9 · AT A GLANCE

Atmospheric Circulation and Weather Systems

Winds & Weather

4	3	mb	2
Global pressure belts	Planetary wind belts	Pressure unit	Cyclone families

Equatorial Low › **Subtropical** High › **Subpolar** Low › **Polar** High

PLANETARY WINDS

- Trade winds
- Westerlies
- Polar easterlies

DISTURBANCES

- Tropical cyclones
- Temperate cyclones
- Jet streams
- Fronts

KEY FORCE

- Coriolis effect

★ *The Coriolis force deflects winds right in the Northern Hemisphere and left in the Southern.*

LECTURE X

10

Water in the Atmosphere

Physical Geography · Study Companion

The atmosphere contains water vapour that varies from zero to four per cent by volume and is essential for weather phenomena. Water exists in the atmosphere in gaseous, liquid, and solid forms. The continuous cycle of water moving between the earth's oceans, continents, and the atmosphere happens through four main processes: evaporation, transpiration, condensation, and precipitation.

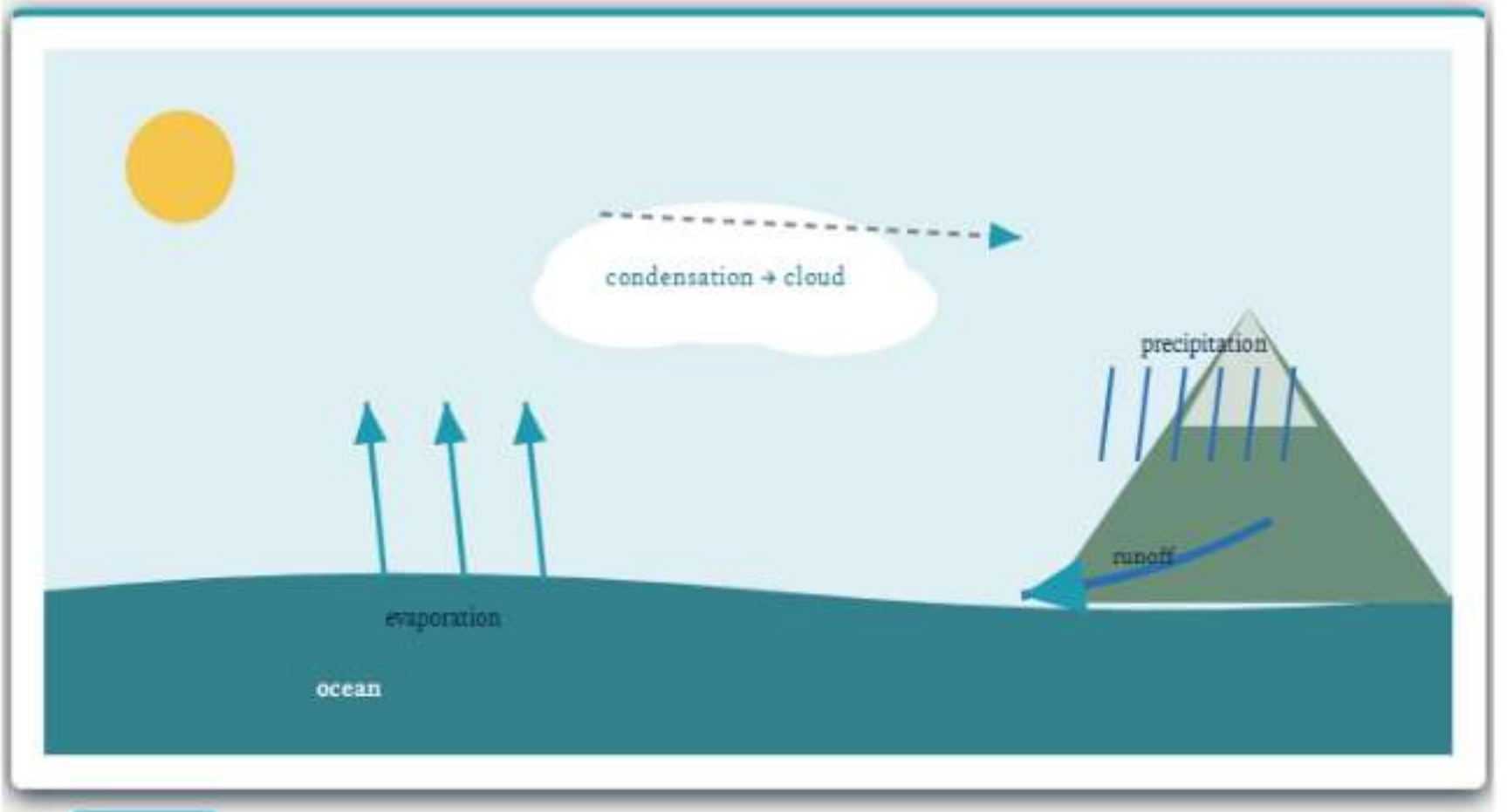

FIGURE 10 *The water cycle: solar energy drives evaporation from the ocean, vapour condenses into cloud, falls as precipitation, and runoff returns water to the sea.*

Humidity and Moisture

- Humidity is the term used for water vapour present in the air.
- Absolute Humidity refers to the actual weight of water vapour per unit volume of air, measured in grams per cubic metre. The total capacity of air to hold this moisture depends entirely on its temperature.
- Relative Humidity is the percentage of moisture currently in the air compared to the absolute maximum capacity the air could hold at that specific temperature. Because it is tied to temperature, as air temperature changes, its capacity to hold moisture changes, which in turn alters the relative humidity. Relative humidity is generally highest over oceans and lowest over landmasses.
- Saturated Air occurs when the air is holding its absolute maximum capacity of moisture at a given temperature and cannot absorb any more.
- The Dew Point is the specific temperature at which a given sample of air becomes completely saturated.

Evaporation and Condensation

- Evaporation is the heat-driven process that transforms liquid water into a gas. The latent heat of vapourisation is the temperature at which water begins to evaporate. Evaporation rates are higher when temperatures rise, when the air's current moisture content is low, and when there is greater wind movement, because wind replaces saturated layers of air with unsaturated ones.
- Condensation is the transformation of water vapour back into liquid, driven by a loss of heat. If vapour bypasses the liquid stage and turns directly into a solid, it is called sublimation. In the atmosphere, condensation forms around microscopic particles called hygroscopic condensation nuclei, which are typically dust, smoke, or ocean salt. The most favourable condition for condensation to occur is a decrease in air temperature, causing the air to reach its dew point.

Forms of Condensation Depending on temperature and location, condensation manifests in four primary ways:

- **Dew:** This forms when moisture condenses into water droplets on cooler solid objects like stones or grass. Dew requires clear skies, calm air, high relative humidity, cold and long nights, and crucially, a dew point that remains above the freezing point.
- **Frost:** Frost shares the same ideal atmospheric conditions as dew, but occurs when the dew point is at or below the freezing point (0°C). Because of the freezing temperatures, excess moisture deposits as minute ice crystals rather than liquid droplets.
- **Fog and Mist:** These are effectively low-lying clouds that form near the ground when a large mass of moist air suddenly cools, condensing onto fine dust particles and drastically reducing visibility. Mist features a thicker layer of moisture on each nucleus compared to fog, and is very common in mountainous regions when warm air rises and hits cold surfaces. Fogs are comparatively drier and typically occur where warm and cold air currents collide. In industrial areas, when fog mixes with thick smoke, it creates smog.

Clouds Clouds are masses of minute water droplets or ice crystals floating at higher elevations, categorized by height, expanse, density, and transparency:

- **Cirrus:** High-altitude clouds (8,000 - 12,000m) that are always white, thin, detached, and look like feathers.

- **Cumulus:** Mid-altitude clouds (4,000 - 7,000m) that exist in scattered patches with flat bases, resembling cotton wool.
- **Stratus:** Layered clouds covering massive portions of the sky, formed either by heat loss or the mixing of air masses with different temperatures.
- **Nimbus:** Thick, dark gray or black clouds forming at middle levels or very close to the surface. They are shapeless, extremely dense, and block out the sun's rays.

Precipitation Precipitation occurs when continuously condensing particles grow too heavy for air resistance to support, causing gravity to pull them down to earth.

- **Rainfall:** Precipitation that falls in a liquid state.
- **Snowfall:** When the temperature drops below 0°C, precipitation falls as fine, hexagonal ice crystals or flakes.
- **Sleet:** Forms when a layer of warm, above-freezing air sits above a freezing layer near the ground. Raindrops fall from the warm air into the cold air and freeze into small pellets of ice.
- **Hailstones:** Raindrops that solidify into small, rounded pieces of ice after passing through colder upper atmospheric layers. Hailstones feature several concentric layers of ice built up over one another.

Types of Rainfall Rainfall originates in three main ways

- **Convectional Rain:** When air heats up, it becomes light, rises in convection currents, expands, cools, and forms cumulus clouds. This causes heavy, short- lived rain with thunder and lightning, common in summer, equatorial regions, and the interior of northern hemisphere continents.
- **Orographic (Relief) Rain:** When a saturated air mass is forced to travel up and over a mountain, it expands and cools, dropping heavy rain on the mountain's windward slope. As the wind crests the mountain and descends the opposite side, it warms and absorbs moisture, leaving the leeward slope dry. This dry side is known as the rain-shadow area.
- **Cyclonic or Frontal Rain:** This type is associated with extra-tropical cyclones.

World Distribution of Rainfall

- **General Patterns:** Rainfall generally decreases from the equator toward the poles. Because oceans are massive sources of water, they receive more rain than landmasses, and coastal areas receive more rain than continental interiors.
- **Latitudinal Patterns:** Between 35° and 40° N and S, eastern coasts get heavier rain. Between 45° and 65° N and S, westerly winds cause western continental margins to receive the heaviest rain. Coastal mountains also cause heavy windward rain and create leeward rain shadows.
- **Precipitation Regimes:** Heavy rainfall (over 200 cm/year) hits the equatorial belt, monsoon coasts, and windward cool temperate coasts. Moderate rainfall (100 - 200 cm/year) occurs in continental interiors, while lighter rain (50 - 100 cm/year) falls in central tropical and eastern temperate lands. The lowest rainfall (less than 50 cm/year) happens in high latitudes and rain shadow zones. Regions like the equatorial belt see this rainfall evenly distributed throughout the entire year.

Practice Questions

30 MCQs

Q1 What is the volume percentage of water vapour present in the atmosphere?

A Zero to four per cent

B Ten to twenty per cent

C Five to fifteen per cent

D Zero to one per cent

Answer · A

EXPLANATION Water vapour varies from zero to four per cent by volume of the atmosphere.

Q2 The actual amount of water vapour present in the atmosphere is known as:

A Relative humidity

B Absolute humidity

C Specific humidity

D Maximum humidity

Answer · B

EXPLANATION The actual amount of the water vapour present in the atmosphere is known as the absolute humidity.

Q3 In what unit is absolute humidity expressed?

A Kilograms per square metre

B Grams per cubic metre

C Litres per square metre

D Milligrams per cubic centimetre

Answer · B

EXPLANATION Absolute humidity is the weight of water vapour per unit volume of air and is expressed in terms of grams per cubic metre.

Q4 **The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is called:**

A Saturated humidity

B Absolute humidity

C **Relative humidity**

D Variable humidity

Answer · C

EXPLANATION The percentage of moisture present in the atmosphere as compared to its full capacity at a given temperature is known as the relative humidity.

Q5 **What term is used to describe air that contains moisture to its full capacity at a given temperature?**

A Condensed air

B Unsaturated air

C **Saturated air**

D Evaporated air

Answer · C

EXPLANATION The air containing moisture to its full capacity at a given temperature is said to be saturated.

Q6 **The temperature at which saturation occurs in a given sample of air is known as the:**

A Freezing point

B Melting point

C Evaporation point

D **Dew point**

Answer · D

EXPLANATION The temperature at which saturation occurs in a given sample of air is known as dew point.

Q7 Which process transforms water from a liquid to a gaseous state?

A Condensation

B Precipitation

C Evaporation

D Sublimation

Answer · C

EXPLANATION Evaporation is a process by which water is transformed from liquid to gaseous state.

Q8 What is the primary cause for the evaporation of water?

A Atmospheric pressure

B Heat

C Wind velocity

D Condensation nuclei

Answer · B

EXPLANATION Heat is the main cause for evaporation.

Q9 The temperature at which water starts evaporating is referred to as the:

A Latent heat of vapourisation

B Absolute vapour point

C Sublimation threshold

D Condensation point

Answer · A

EXPLANATION The temperature at which the water starts evaporating is referred to as the latent heat of vapourisation.

Q10 If water vapour directly condenses into a solid form, the process is known as:

A Condensation

B Transpiration

C Sublimation

D Precipitation

Answer · C

EXPLANATION If excess water vapour directly condenses into solid form, it is known as sublimation.

Q11 In free air, condensation results from cooling around very small particles known as:

A Droplet cores

B Hygroscopic condensation nuclei

C Sublimation nuclei

D Water crystals

Answer · B

EXPLANATION In free air, condensation results from cooling around very small particles termed as hygroscopic condensation nuclei.

Q12 Which of the following is the most favourable condition for condensation to take place?

A A decrease in air temperature

B An increase in air volume

C A decrease in atmospheric pressure

D An increase in air temperature

Answer · A

EXPLANATION The most favourable condition for condensation is the decrease in air temperature.

Q13 When moisture is deposited in the form of water droplets on cooler surfaces of solid objects like stones or plant leaves, it is known as:

A Frost

B Fog

C Dew

D Mist

Answer · C

EXPLANATION When the moisture is deposited in the form of water droplets on cooler surfaces of solid objects such as stones, grass blades and plant leaves, it is known as dew.

Q14 What is a necessary condition regarding the dew point for the formation of dew?

A It must be below the freezing point

B It must be equal to the freezing point

C It must be above the freezing point

D It must be absolute zero

Answer · C

EXPLANATION For the formation of dew, it is necessary that the dew point is above the freezing point.

Q15 Frost forms on cold surfaces when the dew point is:

A Above the freezing point

B At or below the freezing point

C Exactly 10 degrees Celsius

D Above the boiling point

Answer · B

EXPLANATION Frost forms on cold surfaces when condensation takes place below freezing point, meaning the dew point is at or below the freezing point.

Q16 A cloud with its base at or very near to the ground is called:

A Cirrus

B Cumulus

C Fog

D Stratus

Answer · C

EXPLANATION When condensation takes place within a rapidly cooling air mass on fine dust particles, it forms a fog, which is a cloud with its base at or very near to the ground.

Q17 What is the condition called when fog is mixed with smoke in urban and industrial centres?

A Mist

B Smog

C Dust cloud

D Frost

Answer · B

EXPLANATION In urban and industrial centres, smoke provides nuclei for fog, and the condition when fog is mixed with smoke is described as smog.

Q18 What is the primary difference between mist and fog?

A Fog forms only over mountains, while mist forms over oceans

B Mist contains more moisture than fog

C Fog contains more moisture than mist

D Mist only occurs at high altitudes

Answer · B

EXPLANATION The only difference between the mist and fog is that mist contains more moisture than the fog, with each nucleus containing a thicker layer of moisture.

Q19 Which type of cloud is formed at high altitudes of 8,000 to 12,000 metres and has a feathery appearance?

A Nimbus

B Stratus

C Cumulus

D Cirrus

Answer · D

EXPLANATION Cirrus clouds are formed at high altitudes (8,000 - 12,000m) and are thin and detached clouds having a feathery appearance.

Q20 Clouds that look like cotton wool, exist in patches, and have a flat base are known as:

A Cumulus

B Stratus

C Cirrus

D Nimbus

Answer · A

EXPLANATION Cumulus clouds look like cotton wool, have a flat base, and are generally formed at a height of 4,000 to 7,000 metres.

Q21 Layered clouds covering large portions of the sky are called:

A Cirrus

B Cumulus

C Stratus

D Nimbus

Answer · C

EXPLANATION As their name implies, stratus clouds are layered clouds covering large portions of the sky.

Q22 Which clouds are black or dark gray and are extremely dense and opaque to the rays of the sun?

A Cirrus

B Cumulus

C Nimbus

D Stratus

Answer · C

EXPLANATION Nimbus clouds are black or dark gray, form at middle levels or very near to the surface, and are extremely dense and opaque to the rays of the sun.

Q23 The release of moisture onto the earth's surface after the condensation of water vapour is known as:

A Precipitation

B Sublimation

C Evaporation

D Hydration

Answer · A

EXPLANATION After the condensation of water vapour, the release of moisture when condensed particles fall to the earth's surface is known as precipitation.

Q24 When the temperature is lower than 0°C, precipitation takes place in the form of fine flakes of snow and is called:

A Rainfall

B Snowfall

C Hail

D Sleet

Answer · B

EXPLANATION When the temperature is lower than 0°C, precipitation takes place in the form of fine flakes of snow and is called snowfall.

Q25 Frozen raindrops and refrozen melted snow-water that fall as small pellets of ice are called:

A Frost

B Dew

C Sleet

D Hailstones

Answer · C

EXPLANATION Sleet is frozen raindrops and refrozen melted snow-water that solidify and reach the ground as small pellets of ice.

Q26 Solid rounded pieces of ice with several concentric layers formed by rainwater passing through colder layers are called:

A Hailstones

B Sleet

C Frost

D Snowflakes

Answer · A

EXPLANATION Raindrops that become solidified into small rounded solid pieces of ice with several concentric layers are called hailstones.

Q27 Which type of rainfall is characterized by cumulous clouds, thunder, and lightning, and is common in the summer or equatorial regions?

A Orographic rain

B Cyclonic rain

C Convectional rain

D Frontal rain

Answer · C

EXPLANATION Convectional rain features cumulous clouds, thunder, and lightning, and is very common in the summer, equatorial regions, and interior parts of continents.

Q28 In the context of orographic rain, the area situated on the leeward side which gets less rainfall is known as the:

A Rain-shadow area

B Windward area

C Convectional zone

D Precipitation basin

Answer · A

EXPLANATION After winds descend on the leeward slopes, their capacity to take in moisture increases, leaving the area dry; this area getting less rainfall is known as the rain-shadow area.

Q29 What is the general trend of rainfall distribution as one proceeds from the equator towards the poles?

A It goes on increasing steadily

B It goes on decreasing steadily

C It remains constant

D It fluctuates unpredictably

Answer · B

EXPLANATION In general, as we proceed from the equator towards the poles, rainfall goes on decreasing steadily.

Q30 The equatorial belt, windward slopes in cool temperate zones, and monsoon coastal areas typically receive how much annual rainfall?

A Less than 50 cm

B 50 - 100 cm

C 100 - 200 cm

D Over 200 cm

Answer · D

EXPLANATION The equatorial belt, the windward slopes of the mountains along the western coasts in the cool temperate zone, and the coastal areas of the monsoon land receive heavy rainfall of over 200 cm per annum.

CHAPTER 10 · AT A GLANCE

Water in the Atmosphere

Moisture & Rain

0–4	3	4	200
% water vapour by volume	Humidity measures	Main cloud families	cm — heavy-rain belt

Evaporation — Water → vapour › **Condensation** — At dew point › **Clouds** — Droplets form › **Precipitation** — Rain / snow

HUMIDITY

- Absolute (g/m³)
- Specific
- Relative (%)

CLOUD TYPES

- Cirrus
- Cumulus
- Stratus
- Nimbus

RAINFALL TYPES

- Convectional
- Orographic
- Cyclonic

★ *On a mountain's leeward side, descending dry air creates a rain-shadow region of low rainfall.*