**Science Reviewer**

**Earth and Its Processes**

**Nebula Theory:**

* The **Earth** is about **4.5 billion years old**. One of the theories that explains the history of the Earth is the nebula theory.
* **Nebula Theory** – Explains that **the Earth (and the whole solar system) formed from a giant rotating cloud of gas and dust**. **Gravity pulled the materials together**, the Sun formed at the center, and the remaining matter clumped into planets including Earth.
* **Stages of the Nebula Theory:**
* **Formation of Planetesimals** – In the outer parts of the disk, **dust and gas particles stuck together through collision and gravity**, **forming clumps**. These clumps **grew larger** and became **planetesimals.**
* **Growth Into Protoplanets** – The **planetesimals collided and merged**, **forming larger bodies called protoplanets**.
* Closer to the sun, **lighter gases were blown away by the solar wind**, so **only heavy rocky materials remained**.
* This is why the **inner planets are rocky** and the **outer planets are gas** giants.
* **Formation of the Earth** - One of these **protoplanets** in the inner solar system grew into the **Earth.**
* **Early Earth was very hot due to collisions**, radioactive decay and gravitational compression.
* Heavy elements like **iron** and **nickel** sank to the **center** to form the **core**, while lighter elements rose to form the crust and the atmosphere.

**Major Parts of the Earth:**

* **Lithosphere** – Refers to the **solid outer part of the earth (crust and uppermost mantle)**. Includes **rocks**, **mountains**, **volcanoes**, **soil** and **landforms**.
* Provides the **foundation** for **ecosystems** and is the source of **minerals** and **fossil** **fuels**. Solid, **rigid “land**” part of the Earth.
* **Hydrosphere** - Refers to **all water on Earth’s surface, underground and in the atmosphere** Includes **oceans**, **rivers**, **lakes**, **groundwater**, **glaciers** and **water vapor**.
* Covers about **71%** of the **Earth’s surface**, with **oceans making up the largest portion**. The water system: essential for climate, weather and life.
* **Atmosphere** - The gases surrounding Earth. Composed mostly of nitrogen (78%) and oxygen (21%) with small amounts of carbon dioxide, argon and water vapor.
* Divided into layers: **troposphere, stratosphere, mesosphere, thermosphere and exosphere**.
* **Protects life by blocking harmful radiation** and regulating temperature.
* **Air Envelope** – Allows breathing and weather.
* **Biosphere** – **Refers to all living things on Earth**. Extends into parts of the **lithosphere**, **hydrosphere** and **atmosphere**. **Interacts with all other spheres**. The **life-supporting sphere**; includes every living organism
* **Cryosphere** – **Sometimes considered separately as part of the hydrosphere**. Includes all **frozen** **water**: **glaciers, ice caps, sea ice and permafrost**. Plays a key role in climate and sea level regulation.

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| **Summary Table** | | | |
| **Sphere:** | **What it Includes:** | **State:** | **Importance:** |
| **Lithosphere** | Rocks, land, soil, mountains | Solid | Provides land & resources |
| **Hydrosphere** | Oceans, rivers, lakes, groundwater | Liquid (and some ice) | Essential for life & climate |
| **Atmosphere** | Gases surrounding Earth | Gas | Provides air, regulates temperature |
| **Biosphere** | All living things | Living organisms | Supports and sustains life |
| **Cryosphere** | Ice, glaciers, frozen water | Solid (ice) | Regulates climate & sea level |

**Tectonic Plates:**

* **Tectonic Plates** – Are **large, rigid pieces of the Earth’s lithosphere** (the outer solid shell of the Earth, made up of the crust and the uppermost mantle) that move and interact with one another on the planet’s surface.
* **Structure** – **Each plate consists of continental crust, oceanic crust or both**. They “float” on the softer, semi-fluid layer of the mantle called the asthenosphere which allows them to move slowly.
* **Major Plates**:

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| African Plate | North American Plate |
| Antarctic Plate | Pacific Plate |
| Eurasian Plate | South American Plate |
| Indo-Australian Plate |  |

* **Movement** – Plates move a few centimeters per year due to convection currents in the mantle. Movement can cause plates to collide, pull apart or slide past each other.
* **Plate Boundaries**:
* Divergent boundaries
* Convergent boundaries
* Transform boundaries
* **Geological Effects** – Formation of earthquakes, volcanoes, mountains, ocean trenches and rift valleys. **Continuous reshaping of Earth’s surface over millions of years.**
* Tectonic plates are **giant puzzle pieces of Earth’s surface that move slowly** but powerfully, **shaping the planet’s geography** and causing major geological events.

**Plate Tectonics**

* **Plate Tectonics** – The scientific theory that explains how and why Earth’s surface is constantly changing due to the movement of large, rigid pieces of the lithosphere called **tectonic plates**.
* **Mantle Convection Currents** – The driving force for the movement of the plates.
* **Slab Pull** – **Sinking** of dense oceanic crust.
* **Ridge Push** – Gravity acting on elevated mic-ocean ridges) also contribute.
* **Topographical and Geological Evidence for Plate Boundaries:**
* The evidence for plate boundaries comes from **both topography (the shape of the Earth’s surface) and geology** (the rocks, structures and processes found there).
* **Distribution** of **earthquakes and volcanoes**, they **outline the plate boundaries** like a map.
* **Fit of continents, coastlines** (south America and Africa) suggest plates once fit together.
* **Fossil and rock matches**, similar fossils and rock types found on different continents.
* **Types of Plate Boundaries:**
* **Divergent Boundaries** – Plates **move away** from each other.
* Shallow earthquakes, volcanic activity, seafloor spreading.
* **Convergent Boundaries** - Plates move **towards each other** (collision or subduction).
* Strong earthquakes, volcanoes, mountain building.
* **Transform Boundaries** – Plates **slide horizontally** past each other.
* Shallow but powerful earthquakes, displacement of surface features.

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| **Key Differences of Plate Boundaries** | | | |
| **Boundary Type:** | **Plate Motion:** | **Surface Features:** | **Main Effects:** |
| **Divergent** | Plates move apart | Mid-ocean ridges, rift valleys | New crust, volcanic eruptions, shallow quakes |
| **Convergent** | Plates collide | Mountains, trenches, volcanic arcs. | Strong quakes, volcanoes, mountain building |
| **Transform** | Plates slide past | Fault lines, linear valleys | Shallow but powerful earthquakes, no new crush |

**Models of the Earth:**

* **Flat Earth Model (Ancient Belief)** – Early civilization thought Earth was flat, like a **disk or plate, often supported by animals of floating** on water.
* **Basis** – Based on everyday observation-land looks flat and people did not notice earth’s curvature
* **Limitation** – Could not explain why ships disappear hull-first over the horizon or why stars change with latitude
* **Spherical Earth Model (Classical Greece-6th century)** –Proposed by philosophers like Pythagoras, Aristotle and later Eratosthenes. **Earth was seen as a perfect sphere.**
* **Evidence** – Ships disappeared bottom-first on the horizon. Earth’s shadow on the moon during eclipses was round. Stars seen in one place could not be seen elsewhere.
* **Importance** – Shifted human understanding from flatness to roundness.
* **Oblate Spheroid Model (17th century, Newton’s theory)** – Isaac Newton proposed **Earth is not a perfect sphere but slightly flattened at the poles and bulging at the equator** due to its rotation.
* **Evidence** – Measurements from expeditions confirmed earth’s equatorial diameter is larger than its polar diameter.
* **Shape** – This is earth’s true geometric shape, often called spheroid or ellipsoid.
* **Geoid Model (Modern Scientific Model)** – Earth is **modeled as a geoid** (from Greek geo = Earth, eidos = shape). The **geoid** represents the shape of Earth as **defined by mean sea level** and gravity.
* **Appearance** – Looks bumpy rather than smooth, because gravity varies depending on Earth’s interior mass distribution.
* **Use** – Best for geodesy (measuring earth precisely), navigation and satellite data.
* **Digital Model or Earth System Model (21st Century)** – **Modern technology** (satellites, GPS, GIS, 3D computer model) **represents earth** with high accuracy in real-time.
* **Features** – Shows physical geography, climate systems, tectonic movements and even simulations of earth’s past or future conditions.
* **Use** – Education, environmental science, disaster monitoring, global mapping.

**Earth’s Interior:**

* The Earth’s interior is **made up of several layers** **that differ** in composition, temperature, density and physical state. Scientists know about these layers **mainly from seismic waves, volcanic materials, gravity and magnetic field studies**.
* **Seismic Waves** – Are **vibrations** that travel through earth.
* **Compositional Layers** – Of earth are distinguished based on the different components that build the layer.
* **Crust** – **Outer skin of the earth** where life, landforms and ocean exist. Mostly silicate rocks rich in aluminum, potassium, calcium, sodium and silicon.
* **Continental Crust** – Granite-rich thicker (30-70km) less dense
* **Oceanic Crust** – Basalt-rich, thinner (5-10km) more dense
* **Mantle** – The mantle’s convection **currents drive plate tectonics, earthquakes and volcanism.**  Composed by **silicate rocks rich in magnesium and iron** (more metallic than crust).
* **Core** – Source of Earth’s magnetism and contains most of the planet’s heavy metals. Composed of mainly **iron and nickel**, with some lighter elements.
* **Outer core** – **Liquid iron-nickel**, responsible for Earth’s **magnetic field**.
* **Inner core** – **Solid** **iron-nickel** due to immense pressure, even though it’s hotter than the outer core.

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| **Key Differences Between Compositional Layers** | | | | |
| **Layer** | **Composition** | **Density** | **Thickness** | **Special Features** |
| **Crust** | Silicates rich in Al, Na, K, Ca (granite/basalt) | Least dense | 5–70 km | Outer shell, where we live |
| **Mantle** | Silicates rich in Mg, Fe (peridotite) | Denser than crust | ~2,900 km | Largest layer, convection causes tectonics |
| **Core** | Iron & Nickel (Fe–Ni) | Most dense | ~3,471 km (outer + inner) | Generates magnetic field, stores heavy metals |

* **Mechanical Layers** – Are characterized by their physical properties.
* **Lithosphere** **(100km)** – **Includes the crust and uppermost solid mantle**. Responsible for **earthquakes, volcanoes and plate tectonic**. **Rigid and brittle**, breaks into tectonic plates
* **Asthenosphere** **(100 – 350km)** – **Located beneath the lithosphere**, **upper mantle**. It is made of **plastic and ductile that flows slowly**. And acts as a **lubricating layer** allowing tectonic plates to move.
* **Mesosphere (350 – 3,900km)** – Located in the **lower mantle**. It is solid but capable of slow convectional flow due to high pressure. It transports head from the core upward.
* **Convectional Flow** – The movement of a flu**id driven by density differences caused by temperature variations** or other factors, such as pressure or chemical potential differences.
* **Outer Core (2,900 – 5,150km)** – Made of pure liquid iron and nickel that flows and circulates that generates earth’s magnetic field (geodynamo).
* **Geodynamo** – Is the **process within Earth's liquid outer core** that generates and sustains our planet's magnetic field.
* **Inner Core (5,150 - 6,371km)** – Made out of **solid iron and nickel**, which is solid due to extreme pressure. Rigid, but may **slowly rotate at a slightly different speed** than the mantle.
* **Summary**:
* **Lithosphere** – Rigid Plates
* **Asthenosphere** – Soft, Flowing Layer
* **Mesosphere** – Solid but Slowly Convecting
* **Outer Core** – Liquid, Magnetic Generator
* **Inner Core** – Solid, Metallic Center

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| **Key Differences Between Mechanical Layers** | | | |
| **Layer** | **Location** | **State/Behavior** | **Special Role** |
| **Lithosphere** | Crust + upper mantle | Rigid, brittle | Broken into tectonic plates |
| **Asthenosphere** | Upper mantle (below lithosphere) | Plastic, flows slowly | Allows plate movement |
| **Mesosphere** | Lower mantle | Solid but slowly flowing | Convection transfers heat |
| **Outer Core** | Core (liquid layer) | Liquid metal | Generates magnetic field |
| **Inner Core** | Core (center) | Solid metal | Stabilizes magnetic field |

**Discontinuities:**

* **Discontinuities** – The **boundary surfaces between different layers** inside the Earth. They were **discovered through seismic wave** **studies** – when seismic waves suddenly change speed or direction, it signals a boundary where material composition or physical state.

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| **Discontinuity** | **Boundary Between** | **Depth (approx.)** | **Key Feature** |
| **Conrad** | Upper & lower crust | 15–20 km | Divides granitic (upper) & basaltic (lower) crust |
| **Moho** | Crust & Mantle | 5–70 km | Seismic waves speed up (denser mantle rock) |
| **Repetti** | Upper & lower mantle | ~700–800 km | Phase change in mantle minerals |
| **Gutenberg** | Mantle & Outer Core | ~2,900 km | P-waves slow, S-waves vanish (liquid outer core) |
| **Lehmann** | Outer Core & Inner Core | ~5,100 km | P-wave reflection/refracting, shows solid inner core |

**Geological Time Scale**

**Definition of Terms:**

* **Geologic Time Scale (Geologic Calendar) –** The **system geologists use to divide the Earth’s 4.6-billion-year history.** It’s hierarchical, with different time units that describe the length and scale of Earth’s past.
* **Eon** – **Largest unit** of geological time, measured in **billions** of years.
* Paleozoic (ancient life)
* Mesozoic (middle life, age of reptiles)
* Cenozoic (recent life, age of mammals)
* **Era** – **Subdivisions of an eon**, marking major global changes in life and earth’s structure, measured in **hundreds of millions** of years.
* Paleozoic (ancient life)
* Mesozoic (middle life, age of reptiles)
* Cenozoic (recent life, age of mammals)
* **Period** – **Subdivision of era**, measured in **tens of millions** of years.
* Cambrian (explosion of marine life)
* Jurassic (dinosaurs thrive)
* Quaternary (ice ages, humans)
* **Epoch** – **Subdivision of a period**, used mainly in the Cenozoic where the fossil record is more detailed, measured in **millions** of years.
* Paleocene, Eocene, Oligocene (early mammals)
* Pleistocene (Ice Ages)
* Holocene (Current Epoch, last 11,700 years)
* **Age (Stage)** - **Smallest standard unit** of geologic time, finer divisions within an epoch, measured in **hundreds of thousands** to a **few million** years.
* Meghalayan Age
* **Summary:**
* **Eon** – A book
* **Era** – Chapters
* **Period** – Sections
* **Epoch** – Paragraphs
* **Age** – Sentences

**Precambrian Era:**

* **Precambrian Era** – Is the **earliest and longest span of geologic tim**e, covering about 88% of Earth’s history. It extends from the **formation of Earth about 4.6 billion years ago** to the start of the Paleozoic Era (around 541 million years ago).
* **Hadean (4.6 – 4.0 billion years ago)** – **Formation** of Earth and its earliest crust.
* **Archean (4.0 – 2.5 billion years ago)** – **Stabilization** of Earth’s crust, first continents and earliest known life (prokaryotes).
* **Proterozoic (2.5 billion – 541 million years ago)** – **Oxygen build-up** in the atmosphere and appearance of multicellular life.
* The **Precambrian** was a time of **Earth’s formation**, the **rise of continents** and oceans, **oxygenation of the atmosphere** and the **origin** and **early evolution** of life.
* Key Features of the Precambrian:
* Formation of Earth and Its Crust
* Early Atmosphere and Oceans
* Origin of Life
* Continental Development
* Great Oxidation Event
* Snowball Earth Episodes
* First Eukaryotes and Multicellular Life

**Paleozoic Era:**

* **Paleozoic Era (Age of Ancient Life)** – One of the **major eras of geologic** time. It lasted around **289 million years** and it is divided into six geologic periods, each with distinct environmental, climatic and biological features.
* **Cambrian Period (541 – 485 million years ago)** – Known as the beginning of complex animal life with abundant marine fossils.
* **Ordovician Period (485 – 444 million years ago)** - **First vertebrates** (jawless fish) appeared; earliest **land plants** colonized land.
* **Devonian Period** – Marked by the **rise of fish** and first vertebrate **transition to land**.
* **Carboniferous Period (359 – 299 million years ago)** – Known for massive **coal-forming forests** and **where amphibians thrived** where **oxygen levels were very high.**
* **Permian Period** - Culmination of Paleozoic life where **Pangaea formed**, **ended** in **Earth’s** greatest **mass** **extinction (Permina-Triassic Extinction Event)**.
* **Summary:**
* **Cambrian** – Explosion of marine life
* **Ordovician** – first fish and land plants
* **Silurian** – Plants and arthropods colonize land
* **Devonian** – Age of fishes, first amphibians and forests
* **Carboniferous** – Coal forests, giant insects, reptiles appear
* **Permian** – Pangaea, mammal-like reptiles

**Mesozoic Era:**

* **Mesozoic Era (Age of Reptiles)** – Re**ptiles-especially dinosaurs-dominated life** on land, sea and air. It lasted 186 million years and is divided into three main periods.
* **Triassic Period (252 – 201 million years ago)** – Known as the **transition period**, with the **first true dinosaurs and mammals** emerging.
* **Jurassic Period (201 – 145 million years ago)** – Known as the “**Golden Age of Dinosaurs**” **with massive diversity**, and also the **first birds**.
* **Cretaceous Period** – Marked by **flowing plants’** **rise**, peak **dinosaur diversity** and ended with the **extinction of most reptiles.**
* **Summary:**
* **Triassic** – First dinosaurs and mammals, hot or dry world, Pangaea intact.
* **Jurassic** – Age of giant dinosaurs, first birds, lush climate, break-up of Pangaea begins.
* **Cretaceous** – Peak dinosaur diversity, first flowering plants, continents drift apart, ends with mass extinction.

**Cenozoic Era:**

* **Cenozoic Era (Age of Mammals)** - About **66 million years ago to present**. Where **mammals became the dominant life forms** after the extinction of non-avian dinosaurs at the end of the Mesozoic.
* **Paleogene Period (66 – 23 million years ago)** – Known as the period of **mammal diversification** right after the dinosaurs’ extinction.
* **Neogene Period** – Marked by the **rise of modern mammals** and the **first human** ancestors.
* **Quaternary Period (2.6 million years ago – present)** – Defined by **human evolution** and dominance, along with dramatic climate changes.
* **Summary:**
* **Paleogene** – Explosion of mammal and bird diversity after dinosaurs.
* **Neogene** – Rise of modern mammals, grasslands and the first hominids.
* **Quaternary** – Ice ages, extinction of large mammals and rise of humans.

**Tertiary Period:**

* **Tertiary Period** – An **older classification in the geologic time scale**. In modern geology, the Tertiary has been **replaced by the Paleogene and Neogene** periods under the Cenozoic era.
* **Paleocene Epoch (66 – 56 million years ago)** – Start of **mammalian radiation** after dinosaurs went extinct.
* **Eocene Epoch (56 – 34 million years ago)** – Origin of many **modern mammal** orders.
* **Oligocene Epoch (34 – 23 million years ago)** – **Transition from warm**, **forest-dominated** **world to cooler**, open habitats.
* **Miocene Epoch (23 – 5.3 million years ago)** – Expansion of grasslands and **early stages of human** lineage.
* **Pliocene Epoch (5.3 – 2.6 million years ago)** – **Earliest humans appeared**; climate shifts toward Ice ages.
* **Summary**:
* **Paleocene** – Recovery from dinosaur extinction, first mammals diversify.
* **Eocene** – Warmest epoch, modern mammal orders appear.
* **Oligocene** – Cooling, grasslands expand, primates and apes arise.
* **Miocene** – Explosion of apes and grazing mammals. First hominids.
* **Pliocene** – Cooling continues, Australopithecus emerges, Ice age nears.

**Relative and Absolute Dating**

**Relative Dating:**

* **Relative Dating** – Method used by geologists and archeologists to **determine the chronological order of past events without knowing their exact age** in years. Instead of giving a numerical age, **relative dating tells whether something is older or younger** **compared to something else**.
* **Principle of Superposition** – In undisturbed rock layers, **the oldest rocks are at the bottom** and the **youngest are at the top**.
* **Principle of Original Horizontality** – **Layers of sediment** are originally **deposited horizontall**y; if they are tilted or folded, it happened later.
* **Principle of Cross-Cutting Relationships** – A geologic feature like a fault or intrusion, that **cuts across other rocks is younger than the rocks it cuts**.
* **Principle of Inclusions** – **Pieces of one rock unit included in another** are older than the surrounding rock.
* **Rate of Erosion** – Measures **how quickly rocks or land are worn away** by natural forces like wind, water, or ice.
* **Rate of Deposition of Sediments** – Estimates ho**w fast sediment layers accumulate** over time in a given area.
* **Varve Count** – Uses a**nnual layers of sediment (varves) in lakes to determine the number of years** that have passed.
* **Radiocarbon Dating** – Determines the **age of organic materials by measuring the decay of carbon-14** isotopes.
* **Fossil Succession** – **Fossils appear in a specific, recognizable order through layers**, so fossils can help identify the relative age of rocks.
* It places rocks, fossils and geologic fe**atures in a sequence but does not assign a specific numerical age**. It is **widely used in stratigraphy** (the study of rock layers) and is **essential for reconstructing Earth’s geologic history**.

**Absolute Dating:**

* **Absolute Dating** – Absolute dating is a **method used by scientists to determine the actual numerical age of rocks**, fossils or archaeological materials in years. Absolute dating provides a more precise measurement of age.
* **Radiometric dating** – **Measures the decay of radioactive isotopes** into stable products to calculate the actual age.
* **Dendrochronology** – Uses **tree ring patterns to determine the exact year** a tree lived.
* **Ice Core Sampling** – **Analyzes trapped gases** **and layers** in ice cores to estimate ages.
* **Thermoluminescence and Electron Spin Resonance** – Measures **trapped electrons in minerals** to calculate when they were last heated or exposed to sunlight.
* It is **more accurate than relative dating** and is often **used alongside it to build a reliable geologic timeline**.
* It **helps scientists understand the exact timing of geological events**, the age of fossils and the chronology of human history.

**Anthropocene:**

* **Anthropocene –** Is a proposed new geologic epoch that **highlights the significant and lasting impact of human activities** on the Earth’s geology, ecosystems and climate. The term comes from “**Anthropos**” (**human**) and “**cene**” (**new**), meaning the age of humans.
* The **Anthropocene** refers to the time period in **Earth’s history** when **humans** became the **dominant force** shaping the **planet**, leaving a clear and measurable **mark** on the **environment** that will persist in the **geologic record**.
* Scientists suggest the **Anthropocene** began in the **mid-20ᵗʰ century**, around the time of the **Industrial Revolution** or the **Great Acceleration** (after **World War II**), when **population**, **industrialization** and **consumption** sharply increased.
* The **Anthropocene** is **not yet formally recognized** as an **official epoch** by the **International Commission on Stratigraphy**, but it is **widely used** in **scientific** and **environmental discussions**.
* **Defining Features:**
* **Climate Change** – Caused by **greenhouse gas emissions** leading to global warming.
* **Mass Extinctions** – Due to **habitat destruction**, overexploitation and pollution.
* **Pollution and Plastics** – Widespread **deposition of plastics, heavy metals and radioactive particles** in sediments.
* **Land Use Changes** – **Deforestation**, **agriculture** and **urbanization** reshaping landscapes.
* **Biosphere Alteration** – Human-driven **genetic changes**, invasive species spread and ecosystem disruptions.