Earth and Space Science Reviewer

The Origin of the Universe

Big Bang Theory

- The universe expanded rapidly.
- It is the most accepted theory.
- Estimated age of the universe is 13.8 billion years.

4 Stages after the Big Bang

- Stage 1: Initial Expansion. Space itself began expanding; energy and matter formed.
- Stage 2: Formation of Atoms. Hydrogen and helium were produced, becoming the building blocks of stars.
- Stage 3: Formation of Stars and Galaxies. Gravity pulled matter together, forming stars and galaxies.
- Stage 4: Formation of Planetary Systems. Solar systems developed around stars; Earth formed about 4.6 billion years ago.

Steady State Theory

- States that the universe always existed, with no beginning or end.
- It is an eternal universe that always expands, where new matter is always created.

Difference between Big Bang Theory and Steady State Theory

- The Big Bang Theory states that the universe had a beginning, starting from a hot and dense point that expanded over time.
- In contrast, the Steady State Theory suggests that the universe has no beginning or end, has always existed, and remains the same overall because new matter is continuously created.

Evidence for the Big Bang Theory

- Expansion of the Universe: The continuous stretching of the fabric of space-time over time, carrying galaxies away from one another.
- Red Shift: The stretching of light waves toward longer, redder wavelengths as an object moves away from the observer, indicating it is receding.
- Cosmic Microwave Background (CMB) Radiation: The faint, uniform glow of microwave energy filling the universe, which is the cooled-down leftover heat from the Big Bang.
- Hubble's Observation: The discovery that distant galaxies are moving away from Earth, and a galaxy's speed is directly proportional to its distance from us.

Scientists and their Contributions

- Georges Lemaître: Proposed the Big Bang Theory.
- Edwin Hubble: Proposed the Expanding Universe Theory.
- Fred Hoyle: Proposed the Steady State Theory.
- Claudius Ptolemy: Proposed the Geocentric Theory (Earth-centered).
- Nicolaus Copernicus: Proposed the Heliocentric Theory (Sun-centered).
- Johannes Kepler: Proposed that planets orbit in elliptical motion.

- Galileo Galilei: Observed space using a telescope, discovered 4 moons on Jupiter, and discovered the phases of Venus.
- Immanuel Kant: Proposed the early form of the Nebular Theory, stating the Solar System formed from a large rotating cloud of gas and dust.
- Pierre-Simon Laplace: Improved Kant's idea and proposed the Nebular Hypothesis.

Formation of the Solar System

1. Solar Nebula: A massive, rotating interstellar cloud of gas and dust drifts in space.
2. Gravity's Role: Gravity pulls the nebula inward. As it collapses, it spins faster and flattens into a swirling protoplanetary disk.
3. Protosun: The majority of matter accumulates at the dense, hot center of the disk, forming the Protosun.
4. Dust Particles: As the outer regions cool, heavier elements condense into solid dust particles of rock, metal, and ice.
5. Accretion: Tiny dust particles collide and stick together due to static electricity and gentle impacts, growing larger.
6. Planetesimals: Clusters of dust grow into mile-sized rocky or icy bodies with their own small gravitational pull.
7. Protoplanets: Planetesimals continuously collide and merge over millions of years, turning into moon- to Mars-sized protoplanets.
8. Formation of Planets: Protoplanets sweep up remaining debris, collide with one another, and settle into stable orbital paths.
9. Ignition of the Sun: Nuclear fusion triggers at the center of the Protosun due to intense temperature and pressure. The newborn Sun releases a massive solar wind that blows away leftover gas and dust, locking the Solar System into place.

Celestial Objects

- Asteroid: Space rocks. Large, irregularly shaped, cratered bodies smaller than a planet but larger than a boulder. Composed of rock, metals, and carbon. Found mostly in the Asteroid Belt between Mars and Jupiter. They do not burn up easily in Earth's atmosphere and cause massive craters upon impact.
- Comet: Dirty snowballs. Icy bodies that develop a glowing atmosphere (coma) and long tails of gas and dust when heated by the Sun. Composed of frozen gases, ice, rock, and dust. Found in the outer Solar System (Kuiper Belt and Oort Cloud). They vaporize rapidly in Earth's atmosphere, breaking apart and often triggering meteor showers.
- Meteoroid: Space debris. Small fragments of rock or metal ranging from a grain of sand to a large boulder. Composed of asteroid fragments or comet debris. Found drifting anywhere in space. They heat up when entering Earth's atmosphere by compressing the air in front of them.
- Meteor: Shooting stars. The momentary streak of bright light visible in the night sky. Composed of glowing, superheated air surrounding a vaporizing meteoroid. Found in Earth's upper atmosphere (the mesosphere), where it completely burns up due to atmospheric friction.

- Meteorite: Space survivors. The solid, charred remnant of a space object that successfully passes through the atmosphere and hits the ground. Composed of dense stone, iron, and nickel, often covered in a dark fusion crust.
- Moon: Natural satellites. Large, solid spheres or irregular bodies locked in gravitational paths around larger worlds. Composed of rock, metal, and sometimes ice. They remain safely in their cosmic orbits and do not enter Earth's atmosphere.

Earth as a Habitable Planet

1. Distance from the Sun: Earth is positioned exactly 1 Astronomical Unit (~93 million miles or 150 million km) from the Sun. This acts as the primary thermostat, dictating the solar energy and light received.
2. Goldilocks (Habitable) Zone: The orbital band around a star where temperatures allow water to exist in liquid form on the surface rather than permanently freezing or boiling away.
3. Earth's Rotation: The planet's 24-hour spin acts as a climate equalizer. It ensures all sides regularly get light and darkness, preventing extreme temperature swings between day and night.
4. Earth's Size and Gravity: Earth has just enough gravity to hold onto a thick blanket of gases (atmosphere) without being so massive that it crushes surface features.
5. Magnetic Field: An invisible barrier generated by Earth's spinning liquid iron core. It acts as a shield that deflects the harsh solar wind and protects life from deadly cosmic radiation.
6. The Moon: A stability anchor that uses its gravity to stabilize Earth's axial tilt at around 23.5 degrees. This prevents chaotic climate shifts over millions of years and drives ocean tides that mix vital nutrients.

Important Earth Facts

- Earth is about 150 million km from the Sun.
- About 71% of Earth's surface is covered by water.
- The Solar System is about 4.6 billion years old.
- The Universe is about 13.8 billion years old.

Situational Questions

What happens if Earth moves closer to the Sun?

- The Result: Earth leaves the Goldilocks Zone and becomes a scorching desert.
- The Chain Reaction: Extreme solar heat evaporates the oceans. Because water vapor is a powerful greenhouse gas, it triggers a runaway greenhouse effect that traps massive amounts of heat, bakes the crust, and makes life impossible.

What happens if Earth moves farther from the Sun?

- The Result: Earth leaves the Goldilocks Zone and experiences a global ice age.
- The Chain Reaction: Solar energy drops, causing global temperatures to plummet. Oceans freeze into solid ice, and the water cycle stops, locking away the liquid water required for life.

Why is liquid water important?

- It is the universal solvent and the medium of life. It dissolves and transports nutrients within cells, regulates planetary and biological temperatures, and serves as the essential fluid required for organic chemical and metabolic reactions.

Why is the magnetic field important?

- It acts as a planetary deflector shield. It deflects high-energy solar wind and cosmic radiation, preventing the atmosphere from being stripped away into space and protecting surface organisms from radiation damage.

Why is the atmosphere important?

- It is a multi-tool shield. It acts as a protective thermal blanket that traps heat via the greenhouse effect, burns up incoming meteoroids, and filters out destructive UV rays while providing the oxygen and carbon dioxide needed for life.

What happens if a planet has no magnetic field?

- It experiences atmospheric stripping. The planet's atmosphere is exposed to the solar wind, which erodes the upper atmosphere over time. This dries up surface water and leaves the surface barren and radioactive, similar to Mars.

Can a planet inside the habitable zone automatically support life?

- No. Being in the habitable zone only means a planet is at the right distance to potentially host liquid water. It still requires other crucial ingredients to be habitable, such as a protective magnetic field, the right atmospheric composition, and a solid rocky surface.