CLASS 9 SCIENCE

Chapter 13 Notes

Earth as a System: Energy, Matter and Life

Chapter focus

This chapter explains the Earth as an interconnected system of spheres; solar radiation and uneven heating; atmosphere, winds and ocean currents; biogeochemical cycles of water, carbon, nitrogen and oxygen; and the effects of human activities on these natural processes.

1. Earth as an Interconnected System

- Life on Earth depends on a continuous flow of energy and matter. The Sun is the main source of energy, while the Earth's interior and chemical reactions also contribute.
- Processes such as winds, the water cycle, nutrient cycling and climate are connected rather than isolated.
- A change in one part of the Earth system can produce changes in several other parts.

Sphere	What it includes
Geosphere	Solid rocks, soil, landforms and the Earth's interior.
Hydrosphere	Liquid water such as oceans, rivers, lakes and groundwater.
Cryosphere	Solid water such as snow, glaciers and polar ice.
Atmosphere	The layer of air surrounding the Earth.
Biosphere	All living organisms and their habitats.

2. Interactions Among the Earth's Spheres

- Natural processes such as solar heating, movement of air and water and nutrient cycling continuously connect the five spheres.
- Less snowfall can reduce summer lake water, which may reduce grass growth and affect animals that depend on it.
- Warmer Arabian Sea water can increase evaporation and contribute to variability in the southwest monsoon.
- Rising atmospheric temperature can accelerate melting of glaciers and polar ice, raise sea level and threaten low-lying coastal regions and habitats.

3. Uneven Heating of the Earth

- Solar radiation is the main source of energy on the Earth.
- Solar radiation reaches the Earth as electromagnetic waves, which can travel through vacuum.
- About 99% of the Sun's energy reaching Earth lies mainly in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.
- Visible light supports photosynthesis. Infrared radiation warms the Earth's surface. Much harmful short-wavelength UV radiation is absorbed by the ozone layer.

Important value
Speed of light in vacuum = 3×10^8 m s^{-1}

Insolation and Solar Constant

Term	Meaning
Insolation	The amount of the Sun's radiation that reaches the Earth's surface.
Solar constant	Average solar energy received per unit time per unit area perpendicular to the Sun's rays at the top of the atmosphere; approximately 1.4 kW m^{-2}.

- Because gases, clouds and dust absorb or scatter some radiation, maximum insolation at the surface under clear-sky conditions is about 1 kW m^{-2}.
- India receives abundant sunlight because much of the country lies in tropical and subtropical regions.
- Solar insolation is important for India's climate, southwest monsoon, agriculture and renewable-energy potential.

Solar Energy Calculation

Relation	E = Intensity × Area × Time
Example	At 1 kW m^{-2}, a 1 m^2 area receives 3.6×10^6 J of solar energy in one hour.

4. Interaction of Solar Radiation with the Earth's Surface

- Different materials absorb and heat up differently under sunlight.
- Land generally heats faster than water and dark surfaces absorb more solar radiation than light-coloured surfaces.

Albedo
The fraction of incoming solar radiation reflected by a surface. High-albedo surfaces reflect more and remain cooler; low-albedo surfaces absorb more and heat up faster.

- Snow and ice have high albedo, whereas black soil and ocean water have lower albedo.
- All objects re-radiate heat. Concrete, brick and asphalt can store solar energy and release heat later.

Urban Heat Island Effect

- Cities are often warmer than surrounding rural areas because buildings and roads absorb and retain more solar radiation.
- Re-radiated heat from concrete, steel, brick and asphalt raises urban temperatures, especially at night.
- Vegetation cools rural areas through shade and transpiration, so loss of vegetation can intensify local warming.

5. Latitude, Earth's Shape and Uneven Heating

- Because the Earth is spherical, the Sun's rays strike different latitudes at different angles.
- Near the equator, solar energy is concentrated over a smaller area; toward the poles, the same radiation spreads over a larger area.
- Therefore, equatorial regions remain relatively warmer while polar regions are colder.
- The Earth's shape, latitude and axial tilt contribute to variations in insolation and seasons.
- Global differences in heating help drive winds and ocean currents.

6. Role of the Atmosphere

- The atmosphere is held around the Earth by gravity and consists mainly of nitrogen (78%) and oxygen (21%), with smaller amounts of argon, carbon dioxide, water vapour and other gases.

Layer	Approximate altitude	Important feature
Troposphere	0–12 km	Most weather occurs here; temperature decreases with height by about 6.5 °C per km.
Stratosphere	12–50 km	Contains the ozone layer; ozone absorbs UV radiation and temperature increases with height.
Mesosphere	Above stratosphere	Upper atmospheric layer; minor role in regulating surface climate.
Thermosphere	Above mesosphere	Upper atmospheric layer.
Exosphere	Outermost layer	Transition toward outer space.

- The atmosphere protects life by absorbing part of incoming solar radiation and by trapping part of the outgoing infrared radiation.
- Greenhouse gases such as CO_2, CH_4 and water vapour absorb re-radiated heat and keep the Earth warm enough for life.
- Excess CO_2 from human activities strengthens the greenhouse effect and contributes to global warming.

Ozone Layer

- The ozone layer acts as a protective shield by absorbing harmful ultraviolet radiation.
- Chlorofluorocarbons (CFCs) caused serious ozone depletion over Antarctica, known as the ozone hole.
- The Montreal Protocol reduced CFC use and has contributed to gradual recovery of the ozone layer.
- Stratospheric ozone is protective, whereas ground-level ozone formed in polluted air is harmful to health.

7. Uneven Heating Causes Winds

- Wind is the movement of air from a region of high pressure to a region of low pressure.
- Pressure differences are mainly produced by uneven heating of the Earth's surface.

Valley and Mountain Breezes

Wind	When	Formation
Valley breeze	Day	Sun-facing slopes heat rapidly; warm air rises along the slopes and cooler valley air moves upward to replace it.
Mountain breeze	Night	Slopes cool rapidly; cooler, denser air flows down the slopes into the relatively warmer valley.

- These local winds influence temperature, moisture, agriculture and daily life in hilly regions.

Planetary Winds

- Strong heating near the equator produces an equatorial low-pressure belt.
- Air rises near the equator, moves poleward aloft, cools and sinks around 30° North and South, forming subtropical high-pressure belts.
- Around 60° North and South, rising air contributes to sub-polar low-pressure belts.
- At the poles, cold dense air sinks and forms polar high-pressure belts.
- Earth's rotation deflects winds to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

8. Ocean Currents

- Ocean currents are continuous movements of large masses of ocean water.
- Surface currents are driven partly by planetary winds. Temperature, salinity, Earth's rotation and the distribution of continents also influence ocean circulation.
- Warm equatorial surface water moves toward the poles, while colder and denser water can move toward the equator at deeper levels.
- Higher-salinity water is denser and tends to sink; lower-salinity water is less dense and tends to remain nearer the surface.
- Earth's rotation helps form large circular current systems called gyres.
- Gyres rotate clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere.
- Ocean currents redistribute heat and nutrients. The North Atlantic Drift helps keep parts of northwestern Europe milder and ports ice-free in winter.

9. Biogeochemical Cycles

Biogeochemical cycle
The cyclic movement of matter and energy between the living (biotic) and non-living (abiotic) components of the Earth.

- These cycles recycle essential materials and help maintain environmental balance.
- It focuses on the water, carbon, nitrogen and oxygen cycles.

Water Cycle

- Major processes are evaporation, transpiration, condensation, precipitation, infiltration, groundwater movement and runoff.
- Water evaporates from water bodies, condenses into clouds, returns as rain, hail or snow and eventually flows or seeps back toward water bodies.
- Water dissolves and transports minerals and nutrients through terrestrial and aquatic systems.
- Climate change can intensify rainfall in some places, increase drought in others, accelerate glacier melt, raise sea level, increase runoff and reduce groundwater recharge.

Carbon Cycle

- Carbon is present in proteins, carbohydrates, fats and DNA and circulates among the atmosphere, biosphere, geosphere and hydrosphere.
- In the fast carbon cycle, photosynthesis removes atmospheric CO_2, while respiration and decomposition return CO_2 to the atmosphere.
- In the slow carbon cycle, buried organic matter can become fossil fuels over millions of years.
- Burning fossil fuels releases stored carbon rapidly as CO_2.
- Oceans exchange CO_2 with the atmosphere; phytoplankton use dissolved carbon in photosynthesis and some marine organisms use carbon compounds to build shells.
- The Keeling curve shows atmospheric CO_2 rising from about 315 ppm in 1960 to about 420 ppm by 2025.
- Excess atmospheric CO_2 strengthens greenhouse warming and is linked with glacier and sea-ice melt, sea-level rise and more extreme weather.

Nitrogen Cycle

- Nitrogen is essential for proteins and nucleic acids, but atmospheric N_2 cannot be used directly by most plants and animals.

Process	What happens
Nitrogen fixation	Rhizobium, Azotobacter and lightning convert atmospheric nitrogen into usable nitrogen compounds.
Nitrification	Nitrosomonas converts ammonia to nitrite; Nitrobacter converts nitrite to nitrate.
Assimilation	Plants absorb nitrogen compounds; animals obtain nitrogen through food.
Ammonification	Decomposers convert nitrogen in dead matter and wastes into compounds such as ammonia.
Denitrification	Bacteria such as Pseudomonas convert nitrates back into nitrogen gas.

- The Haber-Bosch process fixes atmospheric nitrogen industrially to make ammonia used in fertilisers.
- Although artificial nitrogen fixation greatly supports agriculture, excessive fertiliser use can damage soil and water systems.

Oxygen Cycle

- About 21% of the atmosphere consists of free oxygen gas.
- Respiration and combustion consume oxygen and release carbon dioxide.
- Photosynthesis uses sunlight, water and CO_2 to make glucose and release oxygen.
- The balance between oxygen consumption and oxygen production circulates oxygen among the atmosphere, land, oceans and living organisms.

10. Human Impact on Earth's Processes

- Burning fossil fuels and deforestation increase atmospheric CO_2 and disturb the carbon cycle.
- Extra atmospheric CO_2 increases ocean absorption and can make seawater more acidic, threatening plankton and coral reefs.
- Warmer oceans can also reduce the ocean's capacity to act as an effective carbon sink.
- Excess fertiliser runoff adds nitrates to water bodies, causing algal blooms. The resulting oxygen depletion can kill fish; this process is called eutrophication.
- Deforestation reduces photosynthesis and transpiration, can decrease local rainfall, alters albedo, increases soil erosion and destroys habitats.
- Vehicular emissions can react in sunlight to form smog and harmful ground-level ozone.

11. Restoring Environmental Balance

- Reducing fossil-fuel use and shifting toward renewable sources such as solar and wind can lower greenhouse-gas emissions.
- Planting trees, saving water, conserving energy, reducing waste, reusing and recycling materials and practising sustainable farming can help restore balance.
- The Montreal Protocol is presented as an example of successful international cooperation in reducing ozone-depleting substances.
- Mission LiFE encourages mindful, environment-friendly lifestyles and resource conservation.

12. Important Scientists and Indian Contributions

Scientist / Institution	Contribution
Anna Mani	Mapped solar insolation across India and published Solar Radiation Over India, contributing to India's solar-energy knowledge.
K. R. Ramanathan	Studied atmospheric ozone and helped lay foundations for understanding ozone variation and monsoon forecasting.
Indian Institute of Tropical Meteorology (IITM), Pune	Uses coupled computer models and observations to simulate the Indian monsoon and study possible effects of global warming.

13. Important Comparisons

Feature	High albedo	Low albedo
Reflection	Reflects a larger fraction of solar radiation	Reflects less and absorbs more
Heating	Stays comparatively cooler	Heats up more readily
Examples	Snow, ice	Black soil, ocean water

Feature	Troposphere	Stratosphere
Altitude	About 0–12 km	About 12–50 km
Temperature trend	Decreases with height	Increases with height
Main importance	Most weather phenomena	Ozone layer absorbs UV radiation

14. Key Terms

Term	Meaning
Earth system	The interacting geosphere, hydrosphere, cryosphere, atmosphere and biosphere.
Insolation	Solar radiation reaching the Earth's surface.
Solar constant	Solar energy received per unit time per unit area at the top of the atmosphere on a surface perpendicular to the rays.
Albedo	Fraction of incoming solar radiation reflected by a surface.
Greenhouse effect	Warming caused when greenhouse gases absorb part of the heat re-radiated by the Earth.
Valley breeze	Daytime flow of cooler valley air up heated mountain slopes.
Mountain breeze	Night-time flow of cool dense air down mountain slopes.
Planetary winds	Large-scale winds produced by global pressure differences and influenced by Earth's rotation.
Ocean current	Continuous movement of large masses of ocean water.
Gyre	Large circular pattern of ocean currents.
Biogeochemical cycle	Cyclic movement of matter and energy between biotic and abiotic components.
Nitrogen fixation	Conversion of atmospheric nitrogen into usable nitrogen compounds.
Nitrification	Bacterial conversion of ammonia to nitrite and then nitrate.
Ammonification	Conversion of organic nitrogen in wastes and dead matter into ammonia compounds.
Denitrification	Conversion of nitrates back to atmospheric nitrogen.
Eutrophication	Excess nutrient enrichment causing algal blooms and depletion of dissolved oxygen.

15. Exam-Oriented Self-Check Questions

1. Name the five major spheres of the Earth and give one example of each.
2. Explain how a disturbance in one Earth sphere can affect the other spheres.
3. What is electromagnetic radiation? Which regions of solar radiation are most important for Earth's climate and life?
4. Define insolation and solar constant. State the approximate value of the solar constant.
5. What is albedo? How does it affect surface temperature?
6. Explain the urban heat island effect.
7. Why are equatorial regions warmer than polar regions?
8. Describe the composition and important layers of the atmosphere.
9. How does the atmosphere maintain a suitable temperature for life?
10. Why is the ozone layer important? How did the Montreal Protocol help?
11. Explain the formation of valley breeze and mountain breeze.
12. How does uneven heating produce planetary winds?
13. Why are planetary winds deflected from straight paths?
14. What are ocean currents? List the factors that influence them.
15. What are gyres? State their direction of rotation in the two hemispheres.
16. Explain how ocean currents regulate climate and support life.
17. Define a biogeochemical cycle. Why are these cycles important?
18. Explain the water cycle and how climate change can disturb it.
19. Describe the fast and slow parts of the carbon cycle.
20. Why is excess atmospheric CO_2 undesirable even though plants require CO_2?
21. Explain nitrogen fixation, nitrification, assimilation, ammonification and denitrification.
22. What is the role of Rhizobium, Nitrosomonas, Nitrobacter and Pseudomonas in the nitrogen cycle?
23. Explain the oxygen cycle and the role of photosynthesis in maintaining atmospheric oxygen.
24. What is eutrophication? How can excessive fertiliser use cause it?
25. Explain the effects of deforestation on the carbon cycle, oxygen cycle, water cycle, soil and biodiversity.
26. Distinguish between protective stratospheric ozone and harmful ground-level ozone.
27. Suggest individual actions that can reduce greenhouse-gas emissions and conserve resources.
28. Describe the contribution of Anna Mani to the study of solar radiation in India.

One-Minute Chapter Summary

Quick revision

The Earth functions as an interconnected system made of the geosphere, hydrosphere, cryosphere, atmosphere and biosphere. Solar radiation is the main source of energy. Because the Earth is spherical and different surfaces heat differently, solar energy is distributed unevenly. This produces pressure differences, winds and ocean currents. The atmosphere protects life by absorbing harmful radiation and trapping enough heat to keep the planet warm. Matter is continuously recycled through the water, carbon, nitrogen and oxygen biogeochemical cycles. Human activities such as fossil-fuel burning, deforestation, excessive fertiliser use and pollution can disturb these cycles, intensify global warming and damage ecosystems. Renewable energy, conservation, sustainable farming, tree planting, reuse and recycling can help restore environmental balance.

Prepared for learning and revision | Tiwari Academy