PREFACE

In the journey toward achieving excellence in the UPSC Civil Services Examination, the importance of mastering the subject of Environment and Ecology cannot be overstated. With an evolving pattern of questions and increasing focus on environmental issues in both the Prelims and Mains, a thorough understanding of this domain is crucial for aspirants aiming to secure top ranks.

This comprehensive study material on **Environment and Ecology** has been meticulously crafted under the expert guidance of **Gokul Kumar** (CAPF 2017 – AIR 24) and **Arindum Soni** (Director, SAARTHI IAS). It is designed not only to cater to the specific demands of the UPSC syllabus but also to offer a holistic understanding of the environmental challenges faced by India and the world. The study material covers a wide spectrum of topics, making it an indispensable resource for UPSC aspirants.

Key Areas Covered:

1. **Environment Basics and Ecology:** Fundamental concepts such as types of ecosystems, the dynamics of ecological balance, and interdependencies that sustain life are detailed with clarity to provide a strong foundation.
2. **Biodiversity:** This section delves into the significance of biodiversity, focusing on India's biomes, hotspots, and key species. Special attention has been given to species conservation efforts such as those for Tigers, Snow Leopards, and Indian Vultures, which hold significant importance in India's conservation narrative.
3. **Pollution and Waste Management:** This section covers the multifaceted problem of pollution, including air, water, and soil pollution, along with various waste management strategies like e-waste, plastic pollution, and biomedical waste. The latest international initiatives and national programs have also been included to ensure updated and relevant content.
4. **Climate Change:** One of the most pressing issues of our time, climate change and its far-reaching consequences are analyzed, along with global and national mitigation strategies. The section also provides insights into international climate change agreements and climate funding mechanisms.
5. **Environmental Impact Assessment (EIA):** This topic holds special relevance for environmental governance and policymaking, and it is covered in depth to ensure that

aspirants are equipped with the knowledge to critically analyze developmental projects and their environmental impacts.

6. **Conservation Efforts and International Agreements:** Major global and national initiatives such as CITES, the Ramsar Convention, UNESCO's Man and the Biosphere Programme, and various national efforts toward conserving biodiversity are comprehensively covered, providing aspirants with a global perspective on environmental conservation.

This material is not just an academic resource; it is a carefully structured tool designed to enhance your preparation. The content is crisp, concise, and consolidated, reflecting the ethos of SAARTHI IAS's commitment to delivering quality education. Visual aids such as diagrams, flowcharts, and tables are used to simplify complex concepts, making learning both engaging and effective.

As you embark on your preparation with this material, we hope it not only equips you for the examination but also nurtures a deeper understanding of the environment—an understanding that transcends the UPSC syllabus and inspires you to contribute to the global discourse on sustainable development and environmental conservation.

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ENVIRONMENT AND ECOLOGY

ENVIRONMENT: Everything that surrounds or affects an organism or any other things during its lifetime is collectively known as its environment which comprises both living (biotic) and nonliving (abiotic) components. In a biological sense, the environment constitutes the physical (nutrients, water, air) and biological factors (biomolecules, organisms) along with their chemical interactions (chemical cycles – carbon cycle, nitrogen cycle etc.) that affect an organism or a group of organisms.

All organisms (from virus to man) are obligatorily dependent on the environment for food, energy, water, oxygen, shelter, and other needs. The **environment is defined as** 'the sum total of living, non-living components; influences and events surrounding an organism'. The relationship and interaction between organisms and the environment are highly complex. No organism can live alone without interacting with other organisms. So, each organism has other organisms as a part of its environment. Each and everything with which we interact or which we need for our sustenance forms our environment.

- **The environment includes two types of factors: ABIOTIC & BIOTIC**

ABIOTIC FACTORS: are the non-living aspects of the environment. They include factors such as sunlight, soil, temperature, and water.

MAJOR ABIOTIC FACTORS:

1. **LIMITING FACTOR:** A lot of factors determine the survival of an organism. One single factor can limit the range of an organism. This single factor is called as a limiting factor. **For example,** seeds don't germinate quickly in evergreen rain forests in spite of good rains and vegetation as the surface soil is heavily leached (nutrients washed away by running water). **Here, poor soil is the limiting factor**.

2. **TEMPERATURE:** Temperature is an important abiotic factor in an ecosystem. With the variations in the temperature, variations occur in the type of plants and animals. For eg: Yak lives in cold regions where there is low temperature. Nature has adjusted the body like the presence of long furs which make it possible to survive. Similarly, **in the case of microorganisms,** d-epending on the temperature they are classified as psychrophiles, mesophiles, thermophiles / thermotolerant, and extremophiles.

Psychrophiles: Psychrophiles are "Cold loving" organisms, they can grow at 0°C.	**Mesophiles**: Mesophiles "middle loving" are microorganisms with an optimum temperature near 37°C (the body temperature of warm-blooded animals). Mesophiles can grow in the temperature range of 25-40°C. Most of the pathogenic microorganisms and normal human microbiota are mesophiles.
Thermophiles / Thermotolerant: Thermophiles are "heat-loving" organisms having optimum growth between 50-60°C. Many thermophiles cannot grow below 45°C. Some thermophiles form extremely heat-resistant endospores.	**Extremophiles:** It is an organism that is tolerant to environmental extremes and that has evolved to grow optimally under one or more of these extreme conditions. (high or low temperature, high or low pH)

The presence of microbes in the Yellowstone hot spring to the Antarctic regions suggests that variations of temperature have evolved various mechanisms, making it suitable for survival. The temperature determines the rate of the metabolic reactions. It affects various enzyme-catalysed reactions.

At the higher temperature, enzymes denature but some enzymes are thermostable. Example: **Taq polymerase** isolated from the bacterium Thermus aquaticus can withstand the higher temperature. It is used in the Polymerase chain reaction (PCR). Most of the other enzymes will be denatured and cannot be functioned well at this temperature.

Adaptation to temperature is essential for the survival of the species/organisms. Organisms which can survive a wide range of temperatures are referred to as **Eurytherms**. (cat, dog, tiger, human). The ability to survive in a wide range of temperatures increases a species' ability to inhabit other areas, an advantage for natural selection. Eurythermal is an aspect of thermoregulation in organisms.

Those organisms which can tolerate only a narrow range of temperature are **Stenotherms**. (Fish, Frogs, Lizards and Snakes).

3. **WATER:** Water is an essential abiotic factor. Not only plants but animals, even tiny micro-organisms also need water for their survival. In the absence of water, plants will die, i.e producers will die. Even the plants in the desert require some amount of water.
   In the case of micro-organism, they need water for proper functioning which we call water activity. We can take a simple example by giving insight into our kitchen. Dry fruits can be stored for a long time as compared to juicy fruits. Among the various factors, the water activity of an organism also plays a vital role in the spoilage of the different foods.

4. **SUNLIGHT:** Sunlight is the major source of energy. Plants require sunlight for the **photosynthesis** process. It is the process by which plants make oxygen and food using carbon dioxide and water and make it available for the animals. The presence of sunlight also affects the breeding cycle in animals. Some **animals are nocturnal**, they are active only at nighttime. It is due to the sunlight. Light also determines the reproductive and migratory activities.

5. **SOIL:** It is made up of rocks along with the decomposed plants and animals. With the help of the roots, plants acquire the water and minerals from the soil. Soils are also of various types, whose nature and composition vary and have different functions. The water holding capacity is also determined by its composition.

   In the **aquatic environment**, depending upon the characteristics of the sediment, it determines the type of the benthic animals. **It has four major functions** -
   - medium for plant growth.
   - means for water storage and purification.
   - modifier of earth's atmosphere.
   - habitat for many organisms, which in turn modify the soil.

6. **PH:** The increase or decrease in pH also affects the living creatures. In some parts of the world, there is an increase in acidity due to the increase in carbon dioxide. It has created an acidic condition.

Urbanisation along with industrial revolutionization is the major factor. Due to the increase in acidity, it is also found that the shell of the snail has also dissolved. Similarly, coral are also unable to survive in an acidic environment. In the **human body,** gastric acid helps in killing the harmful microorganism in the stomach. But, the bacteria Helicobacter pylori has a urease enzyme. It increases the pH so that it can survive in it. It is the causative agent of peptic ulcer.
The vagina is slightly acidic in nature. It is maintained by the lactobacilli so that pathogens may not colonise it.

7. **AIR HUMIDITY:** Humidity means the presence of water vapour in the air. Too much of the humid environment can be dangerous to the organisms.Excessive water may disrupt the internal balance in the organisms in various ways. Changes in pH may also occur. In order to counteract this, plants, animals, and microorganisms have got their own strategies. For eg: In animals, lungs and kidney help in excess of the water.

8. **WIND:** At the place where wind occurs regularly, plants are a bit different. They grow closer to the ground to escape from the harsh wind. Similarly, some plants may use it for their own benefits like pollination. Dispersal of seed can be done.

9. **ALTITUDE / ELEVATION:** There is a decrease in the temperature as we go up to the higher altitude. It is also due to the low partial pressure with the increase in the elevation. At 2 km there is a decrease in the ambient partial pressure by 20 % and over 50 % at the 6km. Vertical zonation of vegetation is caused due to altitude.

10. **BUFFERING CAPACITY OF THE EARTH:** A **neutral pH (pH of 7)** is maintained in the soil and water bodies due to the buffering capacity of earth. The neutral pH is conducive for the survival and sustenance of living organisms.

11. **SALINITY:** Some organisms are tolerant of a wide range of salinities **(euryhaline)**. Others are restricted to a narrow range of salinities **(stenohaline)**.

Effect of Abiotic Components on Terrestrial Primary Producers (Plants):

LIGHT: Extremely high intensity of light favours root growth than shoot growth which results in increased transpiration, short stem, and smaller thicker leaves. On the other hand, low intensity of light retards growth, flowering and fruiting. Plants cease to grow due to the accumulation of CO_2 and finally die.Of the visible part of the spectrum, **only red and blue are effective in photosynthesis**. Plants grown in blue light are small, red-light results in elongation of cells (etiolated plants). Plants grown in ultraviolet and violet light are dwarf.

- **Phototaxis:** The movement of organisms in response to light, either towards the source of light as in Moths (positive phototaxis) or away from light (Euglena, Volvox, earthworm (negative phototaxis).
- **Phototropism:** The growth or orientation of an organism in response to light, either towards the source of light (positive phototropism) as seen in Sunflower, or away from light (negative phototropism) as in case of the root of plants.
- **Photokinesis:** A change in the speed of locomotion (or frequency of turning) in a motile organism or cell which is made in response to a change in light intensity is called Photokinesis. It involves undirected random movement in response to light.

FROST: Frost results in freezing the soil moisture. The plants are killed due to increased transpiration when their roots are unable to supply moisture. Water in the intercellular spaces of the plant gets frozen into ice. This results in increasing concentration of salts and dehydration of cells.Also, frost leads to the formation of canker (various plant diseases with similar symptoms caused by a wide range of fungi, bacteria, and viruses).

SNOW: Snow acts as a blanket, prevents a further drop in temperature and protects seedlings from excessive cold and frost. Accumulation of snow on tree parts can break the branches or even uproot the tree. Snow shortens the period of vegetative growth.

TEMPERATURE: High-temperature results in the death of plants due to coagulation of protoplasmic proteins (some bacteria can survive high temperatures because of their protoplasmic proteins that don't coagulate at normally high temperatures). **High temperature disturbs the balance between respiration and photosynthesis**. It also results in desiccation of plant tissues and depletion of moisture.

DIEBACK: Refers to the progressive dying usually backwards from the tip of any portion of the plant. This is one of the adaptive mechanisms to avoid adverse conditions like drought. **In this mechanism, the root remains alive for years together, but the shoots die.** E.g. sal, red sanders, silk cotton tree etc.

BIOTIC FACTORS are the living aspects of the environment. They consist of other organisms, including members of the same and different species.

1. **Primary producers** or **AUTOTROPHS** (self-nourishing): Primary producers are green plants, certain bacteria and algae that carry out photosynthesis. In the aquatic ecosystem, microscopic algae (plankton) are the primary producers.

2. **Consumers** or **HETEROTROPHS** or **PHAGOTROPHS** (other nourishing): Consumers are incapable of producing their own food. They depend on organic food derived from plants, animals or both. Consumers can be divided into two broad groups namely **micro and macro consumers**.
    - **MICRO CONSUMERS** or **SAPROTROPHS**: They are bacteria and fungi which obtain energy and nutrients from dead organic substances (detritus). Earthworms and certain soil organisms (such as nematodes, and arthropods) are detritus feeders and help in the decomposition of organic matter and are called detritivores.
    - **MACRO CONSUMERS: Herbivores** are primary consumers which feed mainly on plants. E.g. sheep, rabbit, etc. Secondary consumers feed on primary consumers. E.g. wolves, dogs, snakes, etc. **Carnivores** which feed on both primary and secondary consumers are called tertiary consumers. E.g. lions (can eat wolves), snakes etc. **Omnivores** are organisms which consume both plants and animals. E.g. man, bear, pig, etc.

3. **Oligotroph:** Organism that can survive in a low-nutrient environment. Deep oceanic sediments, caves, glacial and polar ice, deep subsurface soil, aquifers, ocean waters, and leached soils are all examples of oligotrophic environments. Nutrient accumulation in vegetation is high in nutrient-deficient soils. **Mycorrhizae**, which have a mutualistic relationship with roots, are found on many plants that grow in Oligotrophic conditions. They aid in the efficient absorption of nutrients from the soil (for example, phosphorus).

4. **Decomposers:** Death and decomposition are an essential part of all life cycles on earth. This process provides essential nutrients for plants and also for the growth and development of new organisms.

What is Decomposition?
The term decomposition means "to break down". It typically corresponds to the disintegration or rupture of complex organic matter into a simpler inorganic matter. It is one of the significant and essential processes of the ecosystem.
Hence, decomposition is a metabolic process, taking up raw materials in the form of complex compounds, processing it and then converting it into simpler compounds.

Bacteria, fungi and a few other microorganisms initiate the process of decomposition and are known as decomposers. They feed on dead organisms to survive.

The decaying and dead animals and plants serve as the raw materials which, on the breakdown, produce nutrients, carbon dioxide, and water, etc. Detritus are the raw materials such as dead animals, plants and their remains. Microbes then process this detritus which are collectively known as **saprophytes**.

Process of Decomposition: Death and decomposition are an essential part of all life cycles on earth. In order to permit a successful continuation of life and growth of new plants and animals, older specimens must die and decompose. This process provides essential nutrients for plants and also for the growth and development of new organisms.

A complete process of decomposition takes place in **five different phases**:

1. **Fragmentation -** It is the initial stage of decomposition. Fragmentation means the breakdown of detritus into smaller pieces by the detritivores.

2. **Leaching -** The fragmented particles may contain a lot of water-soluble nutrients which are inorganic in nature. These nutrients get dissolved in the water and seep into the soil and get precipitated in the process of leaching.

3. **Catabolism -** Once the complex material is broken down into smaller particles and the inorganic nutrients are removed, it is time to convert the detritus into simpler inorganic compounds. This process is carried out by various fungal and bacterial enzymes by the process of catabolism.

4. **Humification -** It is the process of formation of a dark-coloured layer of amorphous substance on the soil called humus. It cannot be decomposed easily as it is highly resistant to the action of microbes. The layer of humus is very rich in nutrients as it provides high fertility to the soil.

5. **Mineralization -** It is the final step in the process. Mineralization is the process of the degradation of the hummus to release inorganic nutrients.

Responses of Biotic Factor to Abiotic Factor:

1. **HOMEOSTASIS:** refers to the capacity of the body to maintain the stability of internal variables, such as temperature, acidity and water level against constant environmental disturbance.

2. **REGULATE:** Regulators are organisms that use energy to maintain the internal environment at a steady state regardless of the external environment. The two most affected internal factors that require regulation are – Temperature and Osmolarity.

An organism's ability to maintain body temperature within a narrow range is called **thermoregulation.** It is also called heat regulation. Thermoregulators includes endotherms like birds and mammals. Normal human body temperature is 37 C. In summer or desert environments where temperatures are higher than 37C, our body temperature also rises. This is sensed by our nervous system (hypothalamus), and it signals following changes:

- Dilation of capillaries near skin – this will allow heat to radiate from the body.
- Sweating and evaporation – evaporative cooling of the body.

And thus, **normal body temperature is maintained** irrespective of the condition outside.
Note: **Plants cannot thermoregulate**.

It is important to note that not all regulators are capable of regulating both temperature and osmolarity. For example, fishes cannot regulate their temperature, but they can very well maintain their osmolarity. Active regulation of body fluid is called **osmoregulation**. Mechanism of Osmoregulation is different for freshwater fishes and marine fines as they live in different habitats.

In freshwater fishes, the body fluids are hypertonic compared to the surrounding water. This is because the gills of these fishes actively absorb ions from the surrounding water for bodily functions. As a result, water enters the body of the fish by **endosmosis** through gills and skin. To get rid of excess incoming water, the fish excretes dilute urine.In marine fishes, the body fluids are hypotonic compared to the surrounding sea or ocean water which leads to **exosmosis** of water from the fishes' body into the surrounding. To prevent excess loss of water the marine fishes drink seawater. The salts ingested along with water are actively pumped out through gills. To balance the excess loss of water and surplus salts, the marine fishes excrete concentrated urine.

3. **CONFORM:** Most bony fishes are osmoregulators, but other marine organisms like crabs and molluscs come under **osmoconformers** (maintain their internal salinity similar to their ambient conditions). They do not use energy from metabolism to maintain their internal environment at a steady state. Maintaining a constant internal environment requires a lot of energy input, which is not feasible. Therefore, most animals and plants do not regulate their internal environment and conform to the changes in the external environment.This specifically holds true for smaller organisms such as the hummingbird. As heat loss or gain is a function of surface area of the body, small organisms like the hummingbird with a small volume but large surface area, tend to lose body heat rapidly under cold conditions.

4. **PARTIAL REGULATION:** Some species of animals have evolved to regulate their internal environment within a limited range of environmental conditions, beyond which they conform to the changes in their environment.

Example: Ground squirrels – below a set point their body temperature varies with atmosphere, but above the point it becomes stable irrespective of external condition.

5. **MIGRATION:** Organisms travel to far-off places during a particular weather condition and return when the weather condition is restored. For example, birds from Siberia migrate to the southern countries during winter to avoid the cold weather.

6. **HIBERNATION:** Physiological adaptation practised by some animals. It is a state of inactivity and dormancy that enables some animals to survive in cold environments with reduced food availability during the winter months. Hibernation is mostly done by the endotherms or warm-blooded animals. A variety of animals can hibernate, including bats, bears, rodents, and some species of birds and reptiles. It is also known as winter response.

7. **BRUMATION:** Hibernation for cold-blooded animals. In a nutshell, brumation is to reptiles what hibernation is to mammals.

Hibernating animals need to eat to have enough food storage to last them through their hibernation period as their metabolism while decreased is still active.	Brumating animals stop eating before entering inactivity as their metabolic rate drops so low that they are unable to fully digest their meal until outside temperatures increase.

8. **AESTIVATION:** It is a physiological adaptation whereby the animal enters a long period of dormancy or inactivity in response to high temperatures or maybe even drought-like conditions. It is also known as summer response.

9. **CAMOUFLAGE:** Also called cryptic coloration, is a defence mechanism or tactic that organisms use to disguise their appearance, usually to blend in with their surroundings. Organisms use camouflage to mask their location, identity, and movement. This is an important aspect in almost all biomes, including the animals that live in the tropical rainforests. Primarily, animals need camouflage for either predation or to avoid becoming the prey.

10. **MIMICRY:** Sometimes, having a good camouflage is not enough. So, some animals resort to mimicry, where they change their physical appearance to mimic other animals, which are usually poisonous or venomous.

11. **APOSEMATISM:** It is also known as warning colouration, this refers to how animals change colour or adapt physically to counter threats from various predators. The word aposematic is derived from the Greek ('apo' standing for 'away', and 'semantic' standing for 'sign').
Instead of merging into the background, they actually aggressively advertise themselves through colouration or shape that they are not worth eating. The brightly coloured animal could be toxic, taste bad, smell foul or have spines or just be too aggressive. The most common colours are red, yellow, black and white.

12. **ADAPTATION:** Permanent and long-time adjustment done by living organisms with respect to changes in the environment. Different animals have developed different adaptations to survive in their habitat.

Prominent Polar Region Animal Adaptations:

- **Dense Fur:** This is an important adaptation as it protects the organisms from the extreme cold. Animals such as polar bears have fur even covering the soles of their feet. This prevents them from slipping on the ice. Sometimes, the white colour of the fur helps to camouflage the animal against the background of the snow. This helps in predation or not becoming prey.
- **Blubber:** In some sea mammals such as whales and seals, a thick layer of fat covers the entire body, except for the fins and flippers. This layer provides insulation from the bitter cold and also

aids in buoyancy. They can also fall back on this fat as a food resource when there is no food available in the environment or during periods of inactivity (such as hibernation).

- **Diapause:** It is the natural interruption or the cause of delay in the development of certain animals characterised by alterations in their metabolic activity.

13. **ACCLIMATISATION:** Temporary and short time adjustment with respect to change in the environment.

Acclimatisation in Humans:

- **High altitudes:** One of the best known examples of acclimatisation in humans can be observed when travelling to high altitude locations – such as tall mountains or hill stations.
  Some of the changes that take place during acclimatisation to high altitudes involves:
  1. Increased production of red blood cells.
  2. Increased pressure in pulmonary arteries – thereby forcing blood into sections of the lungs that are usually not used during normal breathing at lower altitudes.
  3. Increased depth of respiration.
  4. Increased depth (volume) of breath.

- **Deep Diving:** Deep sea divers have to acclimatise when ascending from a certain depth. This form of acclimatisation during deep-sea diving involves a process called decompression, where the dissolved inert gases are eliminated from the diver's body by pausing at several stops during the ascent to the water's surface.
  The issue arises when the diver starts descending – which leads to an increase in hydrostatic pressure as well as ambient pressure. Moreover, the breathing gas which is used with the dive is supplied at ambient pressure. This means the gases begin to dissolve in the diver's body. On depressurization (during ascent), the dissolved gases form bubbles inside the body, often causing debilitating pain. In severe cases, it can also cause coma or even death.

How is Acclimatisation Different from Adaptation?

The presence of special features or habits in a species that help to survive in a particular habitat is called adaptation. For example, desert plants have leaves reduced into spines to reduce water loss by transpiration.

But acclimatisation helps to overcome the small problems caused by changes in the surroundings. For example, tomatoes are plants that grow best in temperate climates. However, they can survive freezing temperatures if the temperature drop happens over a few days rather than occurring suddenly.

This short-term "adjustment" is how the tomato acclimatises to the harsh temperature. It happens in short period within the lifetime of an entity. On the other hand, the adaptation of a species to a particular environment takes place over generations.

Adaptation.	Acclimatisation.
It is a gradual and long-term process.	It is a short-term and fast process.
It contributes to evolution and genetic change.	It does not contribute to evolution and genetic change.
It occurs over many generations.	It occurs in individual organisms.

Strategy Of Adaptation In Plants:
Plants can be classified ecologically **based on their light requirements.** Those that require full sunlight for good growth are called **heliophytes**, while those that thrive in the shade are called **sciophytes**.

- **The Heliophytes Plants:** These are more adaptable than others, which can survive in partial shade, these are the pioneer species of tropical forests. Under natural conditions, heliophytes can never reach photosynthetic saturation, no matter how bright the light is. Heliophytes' growth and reproduction, as well as yields, are severely hampered when they are shaded. Examples: Sugar cane, sunflower, and maize.

- **The Sciophytes plants:** These are unaffected by brief bursts of bright light. They are the secondary species that colonised the area after the establishment of heliophytic trees. Less efficient at using high light intensities than heliophytes. Can often achieve saturation at light intensities as low as 20% full sunlight. Also known as **photophobic plants**, reach saturation in only 20% of the light they receive.

- **Ephemerals:** Plants with short life cycles are known as ephemerals. The term ephemeral refers to something that is fleeting or quickly disappearing. When it comes to plants, it refers to a variety of different growth strategies. **Spring ephemeral** plants emerge quickly in the spring and die back to their underground parts after a brief growth and reproduction phase. **Desert ephemerals** are plants that have evolved to take advantage of arid climates' brief wet periods. **Weedy ephemerals** are very short-lived plants that live for less than a growing season in areas subjected to recurring human disturbance, such as ploughing.

- **Xerophytes:** A xerophyte is a plant species that has evolved to survive in a dry environment, such as a desert or an ice- or snow-covered region in the Alps or the Arctic. Cacti, pineapple, and some Gymnosperm plants are examples of xerophytes. They have deep-spreading roots and the ability to store water, xerophytes like cacti can withstand prolonged periods of drought. The leaves are waxy and thorny, which prevents water and moisture from escaping. Even their fleshy stems have the ability to store water. Xerophytic adaptations include small leaves, sunken stomata, leathery leaf surfaces, thorns in place of leaves, leaves reduced to spines, no leaves, and so on.Many xerophytes may accumulate **proline** (an amino acid) in response to stress or **chaperonins** (heat shock proteins), which help other proteins maintain their structure and avoid denaturation in high temperature conditions.

- **Succulent plants:** Also known as succulents, are plants with thickened and fleshy parts that are thickened and fleshy in places where water is scarce, such as arid climates or soil conditions. The term "succulent" is derived from the Latin word sucus, **which means "juice" or "sap."** Water can be stored by succulent plants in a variety of structures, including leaves and stems.The term

"succulent" is sometimes used in horticultural contexts to exclude plants that botanists would consider succulents, such as cacti. Because of their striking and unusual appearance, succulents are frequently grown as **ornamental plants**.

Strategy of Plants to Adapt to Aquatic Environment:

- **Hydrophytes**: Plants that are naturally adapted to growing in water or waterlogged soil are known as aquatic plants, **hydrophytes**, or hydrophytic or water-loving plants. They can grow completely submerged, partially submerged, floating on the water's surface, or with roots anchored to the ground in swamps or near bodies of water. Because of morphological and anatomical changes, they can thrive in watery environments as their natural habitat.

  Aerenchyma (large air spaces in the leaves and petioles) may be present, which aids in the transportation of oxygen produced during photosynthesis. **Free floating plants** and hydrophytes have poorly developed or absent roots. As a result, they usually have emergent leaves (i.e. leaves that protrude above the water surface), which aid in gas exchange and provide buoyancy.

Strategy of Plants to Adapt to Saline Environment:

- Under hot and dry conditions, halophytes can become succulents and dilute salt concentrations by storing water in their stems and leaves. The **presence of salt glands** aids in the excretion of excess salt into the soil. Osmoregulation also aids in the prevention of salt accumulation. Glycerol, proline, and sorbitol are organic compounds that aid in osmoregulation.

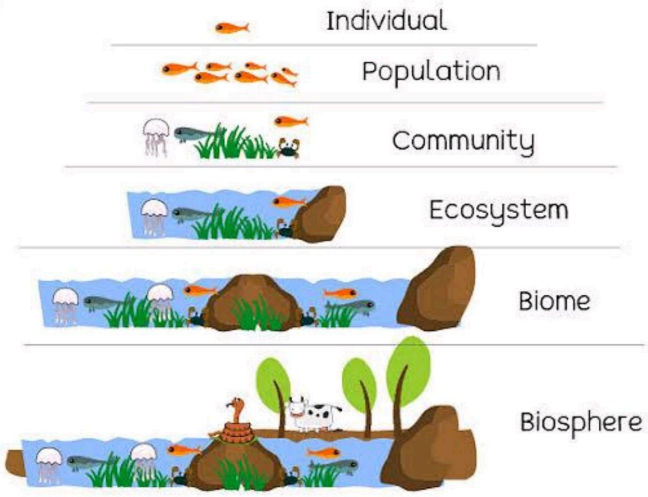
DOMAINS OF ENVIRONMENT

Lithosphere (land): The lithosphere refers to rocks and minerals which is basically the land on which we stand, it comprises the crust and the upper mantle.	**Hydrosphere (sea):** The hydrosphere refers to the liquid water component of the earth; it includes the oceans, seas, lakes, ponds, rivers and streams. The hydrosphere covers about 70% of the surface of the earth and it is the home for many plants and animals.
Atmosphere (air): It is a thin layer of gases that exist above our planet's surface. It acts like a shield which doesn't allow some life essential gases like oxygen to go out in space likewise it also prevents the incoming harmful rays of the sun to reach the earth surface. The atmosphere is an important part of what makes earth liveable.	**Biosphere:** It consists of living organisms from human beings to animals to plants to bacteria to multicellular organisms. Basically, it includes all the living components of the earth. The unique thing about the biosphere is that it interacts with other components of other components of natural landscapes such as land, water and soil. They are also influenced by the atmospheric elements such as temperature, rainfall, moisture and sunlight. This interaction makes life on the earth possible and the survival of any living being on the earth depends on the interactions of these four domains. The biosphere also includes dead organic matter produced by all living organisms. The biosphere is absent at extremes of the North and South poles, the highest mountains and the deepest oceans since existing hostile conditions there do not support life (**life is the characteristic feature of the biosphere**).

ECOLOGY: The **word "ecology"** ("Ökologie") was coined in 1866 by the German scientist Ernst IHaeckel. It has been derived from two Greek words, 'Oikos', meaning home or estate, and 'logos' meaning study. **Ecology is the study of how living things interact with each other and with their environment.** It is a major branch of biology but has areas of overlap with geography, geology, climatology, and other sciences.

There are certain fundamental ecological principles which describe various aspects of living organisms e.g. evolution and distribution of plants and animals, extinction of species consumption and transfer of energy in different components of biological communities, cycling, and recycling of organic and inorganic substances, interactions and inter-relationships among the organisms and between organisms and physical environment, etc.

ORGANISM: Organisms are individual living things. Despite their tremendous diversity, all organisms have the same basic needs: energy and matter. These must be obtained from the environment. Therefore, **organisms are not closed systems**.



Levels of organisation in an ecosystem

LEVEL OF ORGANISATION IN ECOLOGY

1. **Population:** Population is defined as any group of organisms of the same species which can interbreed among themselves and occupy a particular space and function as part of a biotic community.

A **population has various properties** like population density, natality (birth rate), mortality (death rate), age distribution, biotic potential, dispersion and 'r', 'K' selected growth forms.
A population possesses genetic characteristics that are directly related to their adaptiveness, reproductive success, and persistence in their habitats over time. The population has a definite structure and function that can be described with reference to time.

Population Attributes:

- **Population density:** The density of a population refers to its size in relation to unit of space and time. **Population density** is the total number of that species within a natural habitat. The size of the population can be measured in several ways, including abundance (absolute number

in population), numerical density (number of individuals per unit area (or) volume) and biomass density (biomass per unit area (or) volume).

- **Natality:** Populations increase because of natality. Natality is equivalent to birth rate and is an expression of the production of new individuals in the population by birth, hatching, germination (or) fission.

The two main aspects of reproduction, namely fertility and fecundity play a significant role in a population. Natality rate may be expressed in crude birth rate number of organisms born per female per unit time. **Birth rate (b) = number of births per unit time.**

- **Mortality:** Mortality is the population decline factor and is opposite to natality. Mortality can be expressed as a loss of individuals in unit time or death rate. The crude death rate of a population can be calculated by the equation - **Death rate (d)= number of deaths per unit time average population.**

The rate of mortality (death) is determined by density. Mortality is high at high density because of the hazards of overcrowding, increased predation and spread of disease. Mortality rates vary among species and are correlated and influenced by a number of factors such as destruction of nests, eggs or young by storms, wind, floods, predators, accidents and desertion by parents.

- **Migration:** Migration is a peculiar and unique kind of mass population movement from one place to another and back. Some fishes are known to migrate from sea to fresh water (**anadromous** migration, Salmon) and some from fresh water to sea (**catadromous** migration, Eel).

- **Emigration:** Emigration usually occurs when there is overcrowding. This is regarded as an adaptive behaviour that regulates the population in a particular site and prevents over exploitation of the habitat.

- **Immigration:** It leads to a rise in population levels. If the population increases beyond the carrying capacity, it can result in increased mortality among the immigrants or decreased reproductive capacity of the individuals.

Growth Models / Curves Populations show characteristic growth patterns or forms:
These patterns can be plotted and termed as **J-shaped growth** form and S-shaped growth form. (Sigmoid form) J-Shaped growth form - when a population increases rapidly in an exponential fashion and then stops abruptly due to environmental resistance or due to sudden appearance of a limiting factor, they are said to exhibit J-shaped growth form. Many insects show explosive increase in number during the rainy season followed by their disappearance at the end of the season.

S-Shaped growth form (Sigmoid form). Some populations, as in a population of small mammals, increase slowly at first then more rapidly and gradually slow down as environmental resistance increases whereby equilibrium is reached and maintained. Their growth is represented by S - shaped growth curve.

2. **Community:** Communities in most instances are named after the dominant plant form. For example, a grassland community is dominated by grasses, though it may contain herbs, trees, etc.

3. **Ecosystem:** An ecosystem is a community of organisms interacting with each other and with their environment such that energy is exchanged and system-level processes, such as the cycling of elements, emerge.

4. **Biome:** A biome is a large naturally occurring community of flora and fauna occupying a major habitat. E.g. Rainforest biome or tundra biome. Plants and animals in a biome have common characteristics due to similar climates and can be found over a range of continents. Biomes are distinct from habitats so any biome can comprise a variety of habitats.

5. **Biosphere:** The biosphere includes all living organisms on earth, together with the dead organic matter produced by them.

Basic Definitions

NICHE: One of the most important concepts associated with the ecosystem is the niche. A niche refers to the role of a species in its ecosystem. Grinnel (1917) first used the term 'Niche' to explain microhabitats. Ecological niche of an organism includes the physical space occupied by it and its functional role in the habitat i.e. trophic position. **Gauss Law: No two species have identical niches due to competition.**
HABITAT: Habitat is the physical environment in which a species lives and to which it is adapted. A habitat's features are determined mainly by abiotic factors such as temperature and rainfall. These factors also influence the traits of the organisms that live there. A **habitat** always has life in it, whereas the **environment** does not necessarily have life in it. All habitats are environments, but all environments are not habitats. A habitat is always a preference of one species.
PHENOTYPE: A phenotype is defined as the observable traits or characteristics of an organism which is the result of the interaction of genes and environmental factors. These traits include physical appearances and any other traits that we can observe. For example, flamingos are originally white in colour but turn pink due to pigments they acquire from their diet. Thus, flamingos portray how they are influenced by environmental factors.
GENOTYPE: A genotype is the total sum of genes transferred from parents to offspring. Alternatively, a genotype can also be defined as the complete set of heritable genes that can be transferred to the offspring from its parents. These genes help to encode specific features and characteristics that can be physically expressed in an organism.
ECOTYPE: Ecotype refers to a genetically distinct population or group of individuals that are adapted to a specific set of environmental conditions.It is important to note that not all populations with different physical characteristics are necessarily ecotypes. For example: 1. The ecotype of birds has developed a unique beak shape to feed on a specific type of fruit.
ECOPHENE / ECAD: Ecophene refers to any observable trait or characteristic of an organism that is influenced by environmental factors. For example:

1. The coloration of butterflies is an ecophene that varies depending on the temperature during development.

ECOTONE: Ecotone is an area that works as the transitional boundary between the two ecosystems. For example:
1. Marshlands between the drylands and wet ecosystem.
2. Mangrove Forests between the terrestrial and marine ecosystem.
3. Estuaries between the saltwater and Freshwater.

ECOCLINE: There is no sharp boundary between the two ecosystems, there are gradual but continuous environmental gradients composed of abiotic factors such as temperature, slope, precipitation, water, soil, etc and subsequently biotic communities also change.

BIOTIC POTENTIAL / REPRODUCTIVE CAPACITY (r): It is the maximum reproductive capacity of an organism under optimum environmental conditions.

CARRYING CAPACITY (K): The maximum number of organisms that a region can support without environmental degradation is called carrying capacity.

Differences between r- selected and K selected species

Smaller sized organisms.	Larger sized organisms.
Produce many offspring.	Produce few offspring.
Mature early.	Late maturity with extended parental care.
Short life expectancy.	Long life expectancy.
Each individual reproduces only once or few times in their lifetime.	Can reproduce more than once in lifetime.
Only a few reaches adulthood.	Most individuals reach maximum life span.
Unstable environment, density independent.	Stable environment, density dependent.

INTERSPECIFIC INTERACTIONS

AMENSALISM (--, 0): This is the ecological interaction in which an individual species harms another without obtaining benefit, large powerful animals harm weak animals. e.g., animals destroyed at the feet of elephants.

MUTUALISM (+, +): It is the type of interaction where both species benefit from the interaction. Mutualism may be facultative when the species involved are capable of existence independent of one another, or obligate, when the relationship is imperative of the existence of one or both species.

Example: The cross pollination of flowers by insects and birds seeking nectar and pollen which is of great importance in agriculture. Small birds cleaning the teeth of crocodiles. Here, the birds get food and the crocodile's teeth are cleaned.

COMMENSALISM (+, o): This defines the interaction in which two or more species are mutually associated in activities centering on food and one species at least derives benefit from the association while the other associates are neither benefited nor harmed. The concept of commensalism has been broadened in recent years, to apply to coactions other than those centering on food such as cover, support, production, and locomotion.

Example: Barnacles attached to Whales travel thousands of miles collecting and filtering food from the moving water. The whales are not affected by the barnacles.

COMPETITION (--, --): It refers to the type of interaction in which individuals of a species or members of different species vie for limited availability of food, water, nesting space, cover, mates or other resources. When resources are more than adequate to meet the demands of the organisms seeking them, competition does not occur, but when inadequate to satisfy the need of the organisms seeking them, the weakest, least adapted, or least aggressive individuals are often forced to face challenges. This phenomenon is known as the **competitive exclusion principle of Hardin**.

PARASITISM (+, --): It is a kind of harmful interaction between two species, wherein one species is the 'parasite' and the other its 'host'. The parasite benefits at the expense of the host. A parasite derives shelter, food and protection from the host. Parasites exhibit adaptations to exploit their hosts.

The parasites may be viral parasites (plant / animal viruses), microbial parasites (e.g., bacteria / protozoa / fungi), phyto parasites (plant parasites) and zooparasites (animal parasites such as Platyhelminthes, nematodes, arthropods).

Parasites may inhabit or attach to the surface of the host (Ectoparasites - Head lice, Leech) or live within the body of the host (endoparasites – ascaris, tapeworm). The endoparasites usually live in the alimentary tract, body cavities, various organs or blood or other tissues of the host.

Parasites may be permanent or temporary. Temporary parasites spend only a part of their life cycle as parasites. For example, Glochidium larva of Anadonia (freshwater mussel) attaches itself to the body of fish. Permanent parasites spend their life completely dependent on their host organism. The common examples of permanent parasites are Plasmodium, Entamoeba, Roundworms, Pinworms, Tape worms, etc.

PREDATION (+, --): It is a form of interaction, where one animal kills another animal for food. Like parasitism, predation is important in community dynamics, but both differ in the point that a predator tends to be larger than its prey, and it catches its prey from without, while a parasite is smaller than its host and consumes it from within.

This type of interaction helps in the transfer of energy up the trophic levels and is an essential strategy in population regulation.

ECOSYSTEM

An ecosystem can be visualised as a functional unit of nature, where living organisms (producers, consumers, and decomposers) interact among themselves and also with the surrounding physical environment. An ecosystem can be of any size but usually encompasses specific and limited species. E.g. Aquatic Ecosystem. (This is how ecosystem is different from Environment)

In the ecosystem, biotic and abiotic components are linked together through nutrient cycles and energy flows. Everything that lives in an ecosystem is dependent on the other species and elements that are also part of that ecological community. If one part of an ecosystem is damaged or disappears, it has an impact on everything else.

Ecosystem – Structure:
Interaction of biotic and abiotic components results in a physical structure that is characteristic of each type of ecosystem. Identification and enumeration of plant and animal species of an ecosystem give its species composition. The important structural features are species composition (types of plants and animals) and stratification (vertical and horizontal distribution of various species occupying different levels). Another way of looking at the structural components is through the food relationships of producers and consumers. Several trophic levels exist in the ecosystem. For example, trees occupy the top vertical strata or layer of a forest, shrubs the second, and herbs and grasses occupy the bottom layers. These structural components function as a unit and produce certain functional aspects of an ecosystem.Some of these aspects are: Productivity, energy flow, and nutrient cycle.

Ecosystems - Types: Ecosystems are classified as follows:
(i) **Natural ecosystems -** Totally dependent on solar radiation e.g. forests, grasslands, oceans, lakes, rivers, and deserts. They provide food, fuel, fodder, and medicines. Example: Tropical rain forests, tidal estuaries, and coral reefs.

(ii) **Man Made ecosystems** - Environments intentionally created and managed by humans to serve specific purposes. These ecosystems, both terrestrial and aquatic, are designed to meet human needs and preferences. Example: agricultural fields and aquaculture ponds, Urban and industrial ecosystems.

Ecosystem - Function:
Ecosystems are complex dynamic systems. They perform certain functions. These are: -
1. Energy flow through the food chain.
2. Nutrient cycling. (biogeochemical cycles)
3. Ecological succession or ecosystem development.
4. Homeostasis (or cybernetic) or feedback control mechanisms.

Energy Flow through Ecosystem:
Food chains and energy flow are the functional properties of ecosystems that make them dynamic. The biotic and abiotic components of an ecosystem are linked through them. Charles Elton gave the concept of Food Chain, Food Web, and Ecological pyramid.

- **Food Chain:** The transfer of food energy from green plants (producers) through a series of organisms with repeated eating and being eaten is called a food chain. Each step in the food chain is called a trophic level. During this process of transfer of energy some energy is lost into the system as heat energy and is not available to the next trophic level. Therefore, the number of steps is limited in a chain to 4 or 5.

E.g. Grasses → Grasshopper → Frog → Snake → Hawk/Eagle

There are two types of food chains:

1. **Grazing food chains:** This starts from the green plants that make food for herbivores and herbivores in turn for the carnivores.
2. **Detritus food chains:** start from the dead organic matter to the detrivores organisms which in turn make food for protozoan to carnivores, etc.

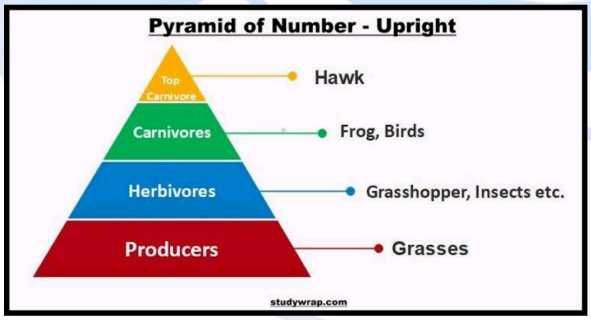
The total rate at which the radiant energy is stored by the process of photosynthesis in the green plants is called **Gross Primary Production (GPP).** This is also known as total photosynthesis or total assimilation.

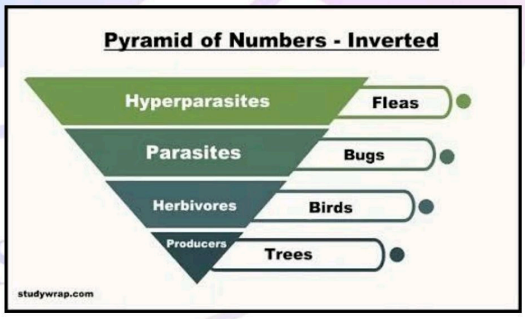
From the gross primary productivity, a part is utilised by the plants for its own metabolism. The remaining amount is stored by the plant as **Net Primary Production** (NPP) which is available to consumers.

- **Food web:** Trophic levels in an ecosystem are not linear rather they are interconnected and make a food web. Thus, the food web is a network of interconnected food chains existing in an ecosystem. One animal may be a member of several different food chains. Food webs are more realistic models of energy flow through an ecosystem. **The flow of energy in an ecosystem is always linear or one-way.** The quantity of energy flowing through the successive trophic levels decreases. At every step in a food chain or web, the energy received by the organism is used to sustain itself and the leftover is passed on to the next trophic level.

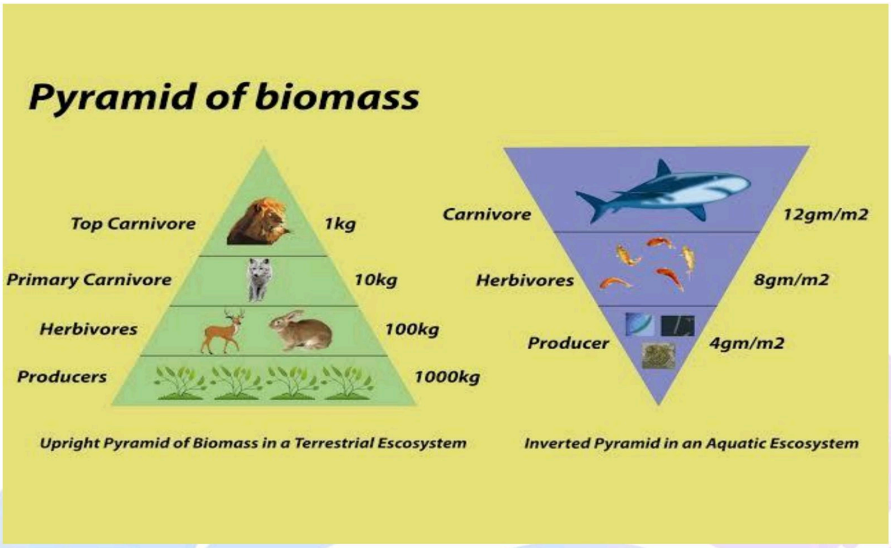
- **Ecological pyramid:** Ecological pyramids are graphic representations of trophic levels in an ecosystem. The producers make the base of the pyramid, and the subsequent tiers of the pyramid represent herbivore, carnivore, and top carnivore levels. They are pyramidal in shape, and they are of three types:

Pyramid of number: This represents the number of organisms at each trophic level. For example, in grassland, the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores. In some instances, the pyramid of number **may be inverted**, i.e. herbivores are more than primary producers as you may observe that many caterpillars and insects feed on a single tree.

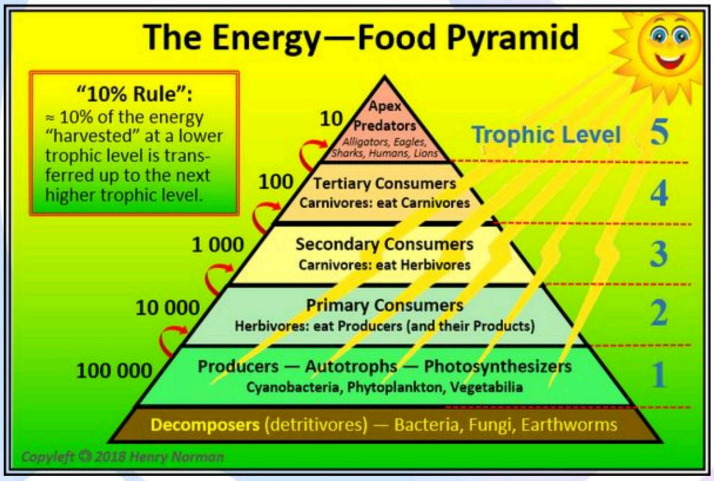




Pyramid of biomass: This represents the total standing crop biomass at each trophic level. Standing crop biomass is the amount of living matter at any given time. It is expressed as gm/unit area or kilo Cal/unit area. In most of the terrestrial ecosystems, the pyramid of biomass is upright. However, in the case of aquatic ecosystems, the pyramid of biomass may be inverted.



Pyramid of Energy: This pyramid represents the total amount of energy at each trophic level. Energy pyramids are never inverted.



Note: Energy pyramids, however, must always be upright because of the laws of thermodynamics. The first law of thermodynamics states that energy can neither be created nor destroyed; thus, each trophic level must acquire energy from the trophic level below.

The second law of thermodynamics states that, during the transfer of energy, some energy is always lost as heat; thus, less energy is available at each higher trophic level.

Limitations of Ecological Pyramids:

1. It does not consider the same species belonging to two or more trophic levels.
2. It assumes a simple food chain, something that seldom exists in nature; it does not accommodate a food web.
3. Moreover, saprophytes (plant, fungus, or microorganism that lives on decaying matter) are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

Productivity of Ecosystem:
The productivity of an ecosystem refers to the rate of production, i.e., the amount of organic matter accumulated in any unit of time.

Productivity is of the following types:
1. **Primary Productivity:** It is defined as the rate at which radiant energy is stored by the producers, most of which are photosynthetic, and to a much lesser extent the chemosynthetic microorganisms. Primary productivity is of the following types:

- **Gross Primary Productivity:** It refers to the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. It depends on the chlorophyll content. The rate of primary productivity is estimated in terms of either chlorophyll content as chl/g dry weight/unit area, or photosynthetic number, i.e., amount of CO_2 fixed/g chl/hour.

- **Net Primary Productivity:** Also known as apparent photosynthesis or net assimilation, it refers to the rate of storage of organic matter in plant tissues in excess of the respiratory utilisation by plants during the measurement period.

2. **Secondary Productivity:** It is the rate of energy storage at consumer's levels-herbivores, carnivores, and decomposers. Consumers tend to utilise already produced food materials in their respiration and also converts the food matter to different tissues by an overall process. Some ecologists such as Odum (1971) prefer to use the term assimilation rather than 'production' at this level-the consumer's level. It actually remains mobile (i.e., keeps on moving from one organism to another) and does not live in situ like the primary productivity.

3. **Net Productivity:** It refers to the rate of storage of organic matter not used by the heterotrophs or consumers, i.e., equivalent to net primary production minus consumption by the heterotrophs during the unit period, as a season or year, etc. It is thus the rate of increase of biomass of the primary producers which has been left over by the consumers.

Highest Productivity:
- In terrestrial ecosystems Tropical rainforests show the highest productivity.
- In aquatic ecosystems, coral reefs have the highest productivity.

Important Definitions:

Ecological Debt: It is referred to as the level of resource consumption and waste discharge by a population in excess of locally sustainable natural production and assimilative capacity.
Green GDP is a monetization of the loss of biodiversity caused by climate change. It is calculated by subtracting resource depletion, environmental degradation from the traditional GDP figure.

Pollutants and Trophic Levels:
Non-degradable pollutants move between different trophic levels. Non-degradable (persistent) is one which cannot be metabolised by living organisms. E.g. Chlorinated Hydrocarbons.

CHCs are hydrocarbons in which one or more hydrogen atoms have been replaced by chlorine E.g. DDT, Endosulfan, chloroform, carbon tetrachloride, etc.

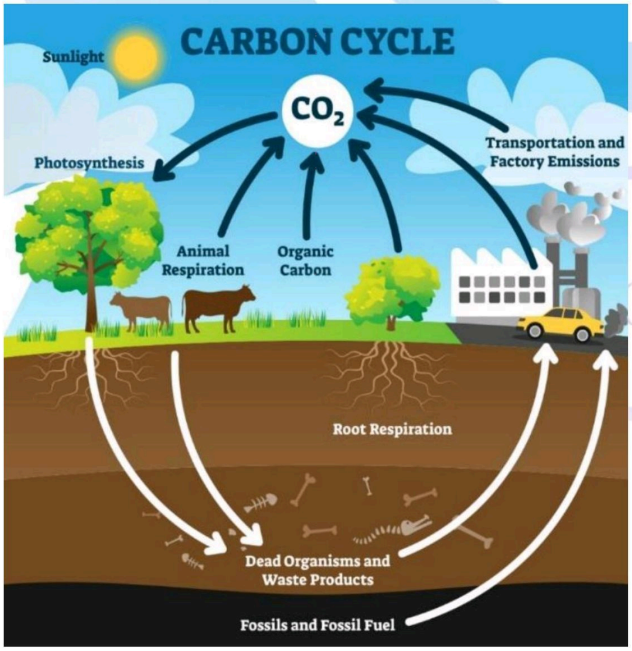
- **Bioaccumulation:** Bioaccumulation is the gradual accumulation of pollutants, chemicals (chronic poisoning) or other substances in an organism. Bioaccumulation occurs when the rate of loss of the substance from the body of the organism through catabolism (breakdown of complex molecules in living organisms), or excretion is lower than the rate of accumulation of the substance. As persistent organic pollutants like DDT are long-lasting, the risk of bioaccumulation is high even if the environmental levels of the pollutant are not high.

- **Biomagnification:** Biomagnification refers to progressive bioaccumulation (increase in concentration) at each trophic level with the passage of time. In order for biomagnification to occur, the pollutant must have a long biological half-life (long-lived), must not be soluble in water but must be soluble in fats. E.g. DDT.

Biogeochemical Cycles:
The movement of nutrient elements through the various components of an ecosystem is called **nutrient cycles.** Another name of nutrient cycling is **biogeochemical cycles** (bio: living organism, geo: rocks, air, and water). In ecosystems flow of energy is linear but that of nutrients is cyclical. The entire earth or biosphere is a closed system i.e. nutrients are neither imported nor exported from the biosphere.

Nutrient cycles are of two types:
(a) **Gaseous -** The reservoir for the gaseous type of nutrient cycle (e.g., nitrogen, carbon cycle) exists in the atmosphere.
(b) **Sedimentary -** sedimentary cycle (e.g., Sulphur and phosphorus cycle); the reservoir is located in Earth's crust.

- **The Carbon Cycle:** Of all the biogeochemical cycles, the carbon cycle is the most important. All life is composed of carbon compounds of one form or another. The carbon cycle is a biogeochemical cycle in which carbon flows among storage pools in the atmosphere, ocean, and on the land. Human activity has affected the carbon cycle, causing carbon dioxide concentrations in the atmospheric storage pool to increase. The source of all carbon is carbon dioxide present in the atmosphere. It is highly soluble in water; therefore, oceans also contain large quantities of dissolved carbon dioxide.



The global carbon cycle consists of following steps -

1. **Photosynthesis:** Green plants in the presence of sunlight utilise CO_2 in the process of photosynthesis and convert the inorganic carbon into organic matter (food) and release oxygen. Forests act as reservoirs of CO_2 as carbon fixed by the trees remain stored in them for a long time due to their long-life cycles.

2. **Respiration:** Respiration is carried out by all living organisms. It is a metabolic process where food is oxidised to liberate energy, CO_2, and water. The energy released from respiration is used for carrying out life processes by living organisms (plants,

animals, decomposers, etc.). Thus, CO_2 is released into the atmosphere through this process.

3. **Decomposition:** All the food assimilated by animals or synthesised by plants is not metabolised by them completely. A major part is retained by them as their own biomass which becomes available to decomposers on their death. The dead organic matter is decomposed by microorganisms and CO_2 is released into the atmosphere by decomposers.

4. **Combustion:** The burning of biomass releases carbon dioxide into the atmosphere.

Impact of human activities:

The global carbon cycle has been increasingly disturbed by human activities particularly since the beginning of the industrial era. Large-scale deforestation and ever-growing consumption of fossil fuels by growing numbers of industries, power plants, and automobiles are primarily responsible for increasing the emission of carbon dioxide. Carbon dioxide has been continuously increasing in the atmosphere due to human activities such as industrialization, urbanisation, and increasing use and number of automobiles. This is leading to an increasing concentration of CO_2 in the atmosphere, which is a major cause of global warming.

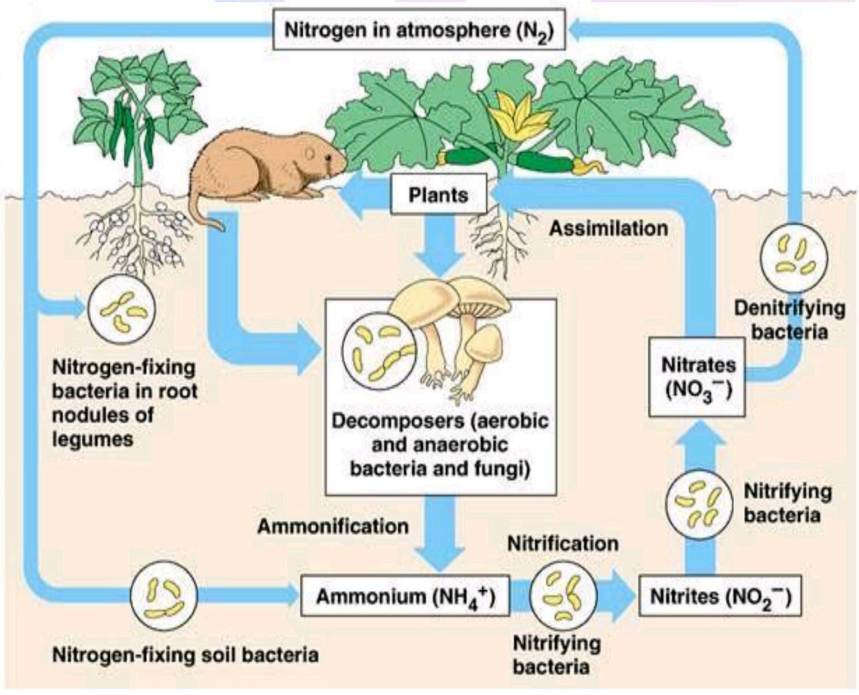
- **Nitrogen cycle:** Nitrogen is an essential component of protein and required by all living organisms including human beings. Our atmosphere contains nearly 79% of nitrogen but it cannot be used directly by the majority of living organisms. Broadly like carbon dioxide, nitrogen also cycles from the gaseous phase to the solid phase then back to the gaseous phase through the activity of a wide variety of organisms. The cycling of nitrogen is vitally important for all living organisms.

There are five main processes which is essential for nitrogen cycle are elaborated below:

1. **Nitrogen fixation:** This process involves the conversion of gaseous nitrogen into Ammonia, a form in which it can be used by plants. Atmospheric nitrogen can be fixed by the following three methods: -

   1.1. **Atmospheric Fixation:** Lightening, combustion, and volcanic activity help in the fixation of nitrogen.

   1.2. **Industrial Fixation:** At high temperature (400C) and high pressure (200 atm.), molecular nitrogen is broken into atomic nitrogen which then combines with hydrogen to form ammonia.



1.3. **Bacterial Fixation:** E.g. Rhizobium in the root nodules of leguminous plants. Free living or symbiotic e.g. Nostoc, Azotobacter, Cyanobacteria can combine atmospheric or dissolved nitrogen with hydrogen to form ammonia.

2. **Nitrification**: It is a process by which ammonia is converted into nitrates or nitrites by Nitrosomonas and Nitrococcus bacteria respectively. Another soil bacterium Nitrobacter can convert nitrate into nitrite.

3. **Assimilation:** In this process nitrogen fixed by plants is converted into organic molecules such as proteins, DNA, RNA, etc. These molecules make the plant and animal tissue.

4. **Ammonification:** Living organisms produce nitrogenous waste products such as urea and uric acid. These waste products as well as dead remains of organisms are converted back into inorganic ammonia by the bacteria. This process is called ammonification. Ammonifying bacteria help in this process.

5. **Denitrification:** Conversion of nitrates back into gaseous nitrogen is called denitrification. Denitrifying bacteria live deep in the soil near the water table as they like to live in the oxygen-free medium. Denitrification is the reverse of nitrogen fixation.

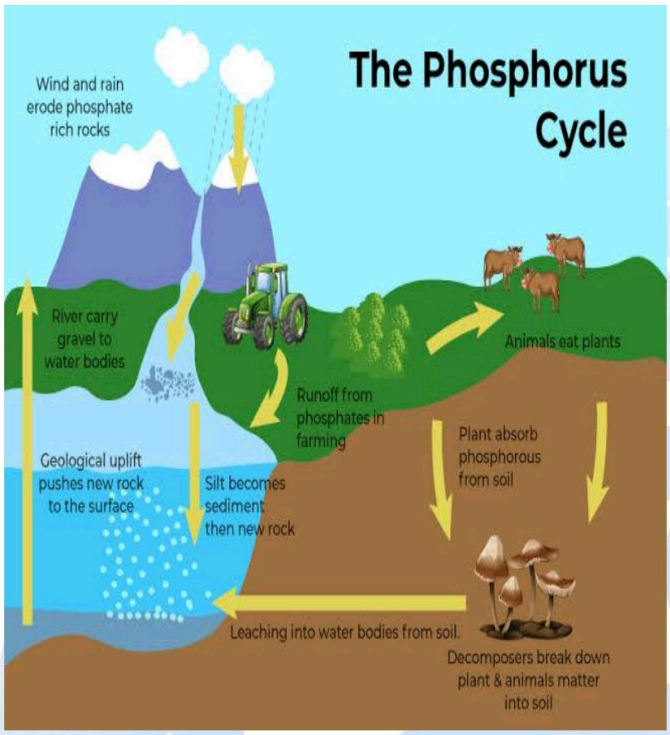
- **Water Cycle:** Water is essential for life. No organism can survive without water. Precipitation (rain, snow, slush dew etc.) is the only source of water on the earth. Water received from the atmosphere on the earth returns back to the atmosphere as water vapour resulting from direct evaporation and through evapotranspiration the continuous movement of water in the biosphere is called water cycle (hydrological cycle).

Water is not evenly distributed throughout the surface of the earth. Almost 95 % of the total water on the earth is chemically bound to rocks and does not cycle. Out of the remaining 5%, nearly 97.3% is in the oceans and 2.1% exists as polar ice caps. Thus, only 0.6% is present as fresh water in the form of atmospheric water vapours, ground, and soil water.

Evaporation and Precipitation are the two main processes involved in the water cycle. These two processes alternate with each other. Water from oceans, lakes, ponds, rivers, and streams evaporates by the sun's heat energy. Plants also transpire huge amounts of water. Water remains in the vapour state in the air and forms clouds that drift with the wind. Clouds meet with the cold air in the mountainous regions above the forests and condense to form rain precipitate which comes down due to gravity.

On average 84% of the water is lost from the surface of the oceans by evaporation. While 77% is gained by it from precipitation. Water runoff from lands through rivers to oceans makes up 7% which balances the evaporation deficit of the ocean. On land, evaporation is 16% and precipitation is 23%.

- **Phosphorus Cycle:** Phosphorus is a major constituent of biological membranes, nucleic acids, and cellular energy transfer systems. Many animals also need large quantities of this element to make shells, bones, and teeth.



The natural reservoir of phosphorus is rock, which contains phosphorus in the form of phosphates. When rocks are weathered, minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of the plants. Herbivores and other animals obtain this element from plants. The waste products and the dead organisms are decomposed by phosphate solubilizing bacteria releasing phosphorus. Unlike the carbon cycle, there is no respiratory release of phosphorus into the atmosphere. Atmospheric inputs of phosphorus through rainfall are much smaller than carbon inputs, and gaseous exchanges of phosphorus between organism and environment are negligible.

- **Sulphur Cycle:** The sulphur cycle is a biogeochemical cycle in which sulphur moves between rocks, waterways, and living systems. It is a sedimentary cycle, but hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) are the gaseous components of the sulphur cycle. The soil and sediments act as the sulphur reservoir where they are captured in organic (coal, oil, Peat) and inorganic (pyrite, sulphur rock).

It is released by weathering of rocks, erosional runoff, and decomposition of organic matter. It is carried to terrestrial and aquatic ecosystems in the form of salt solutions. The sulphides are converted to elemental sulphur by bacterial action. This is again converted to sulphates by chemolithotrophic bacteria. Plants take up sulphur in the form of sulphates and convert it into sulphur-containing amino acids through a series of metabolic processes.

These amino acids are incorporated in the proteins of the autotroph tissues which eventually pass along through the grazing food chain. The sulphur is carried back into soil, lakes, and seas from living organisms through the excretion and decomposition of dead organic matter. Sulphur enters the atmosphere from sources like volcanic eruptions, burning of fossil fuels, the surface of oceans, and gases released by decomposition. Atmospheric H_2S gets oxidised to SO_2 which is carried back to earth after being dissolved in rainwater as weak sulphuric acid (acid rain).

Ecological Succession:

Hult used the term first-time "Ecological Succession" for the 'Orderly changes in communities. **Odum** called it Ecosystem development. **Ragnar Hult** was the first (1881) to publish a comprehensive study of ecological succession as it is taking place in a given region.

He was the first to recognize that a relatively large number of pioneer plant communities give way to a comparatively small number of relatively stable communities. **F.E. Clements** (1916) defined succession as a natural process by which same locality becomes successively colonised by different groups of plants or communities thus communities are never stable.

Biotic communities are dynamic in nature and change over a period of time. The process by which communities of plant and animal species in an area are replaced or changed into another over a period of time is known as **ecological succession.** Both the biotic and abiotic components are involved in this change. This change is brought about both by the activities of the communities as well as by the physical environment in that particular area. The physical environment often influences the nature, direction, rate, and optimal limit of changes.

During succession both the plant and animal communities undergo change. Some species colonise an area and their populations become more numerous, whereas populations of other species decline and even disappear. **The entire sequence of communities that successively change in a given area is called sere(s).** The individual transitional communities are termed seral stages or **seral communities.**

In the successive seral stages, there is a change in the diversity of species of organisms, an increase in the number of species and organisms as well as an increase in the total biomass.

There are two types of successions:

- **Primary succession:** Primary succession takes place over bare or unoccupied areas such as rock outcrop, newly formed deltas, and sand dunes, emerging Volcano Islands and lava flows as well as glacial moraines (muddy area exposed by a retreating glacier) where no community has existed previously.

The plants that invade first bare land, where the soil is initially absent are called **pioneer species.** A pioneer species generally shows high growth rate but a short life span. The assemblage of pioneer plants is collectively called the **pioneer community.** The pioneer community after some time gets replaced by another community with different species combinations. This second community gets replaced by a third community. This process continues sequence-wise in which a community is replaced previously by another community.
The terminal (final) stage of succession forms the community which is called a **climax community.** It is stable, mature, more complex, and long-lasting. Climax community, as long as it is undisturbed, remains relatively stable in dynamic equilibrium with the prevailing climate and habitat factors.

> Succession that occurs on land where moisture content is low for e.g. on bare rock is known as **xerarch**. Succession that takes place in a water body, like ponds or lakes is called **hydrarch**.

- **Secondary Succession:** Secondary succession is the development of a community which forms after the existing natural vegetation that constitutes a community is removed, disturbed, or destroyed by a natural event like a hurricane or forest fire or by human-related events like tilling or harvesting the land.Secondary succession is reltively fast as the soil has the necessary nutrients as well as a large pool of seeds and other dormant stages of organisms.

Causes of Ecological Succession:

1. **Initial Causes:** Those are responsible for the destruction of existing habitat. Such occurrences happen due to the following factors:
    - Climatic Factor: Such as wind, deposits, erosion, fire, etc.
    - Biotic Factor: Such as various activities of organisms.

2. **Continuing Causes:** Those are responsible for changes in population shifting features of an area. Such factors are:
    - Migration for safety against outside aggregation.
    - Migration due to industrialization and urbanisation.
    - As a reactionary step against local problems.
    - Feeling of Competition.

3. **Stabilising Cause:** Causes which bring stability to the communities. Such factors are: (a) Fertility of land, (b) Climatic condition of the area, (c) Abundance of availability of minerals etc.

Homeostasis of Ecosystem: Ecosystems are capable of maintaining their state of equilibrium. They can regulate their own species structure and functional processes. This capacity of the ecosystem of self-regulation is known as **homeostasis**. In ecology, the term applies to the tendency for a biological system to resist changes.
For example, in a pond ecosystem, if the population of zooplankton increased, they would consume a large number of phytoplankton and as a result, soon zooplankton would be a short supply of food for them. As the number of zooplankton is reduced because of starvation, the phytoplankton population starts increasing. After some time, the population size of zooplankton also increases and this process continues at all the trophic levels of the food chain.

Note: In a homeostatic system, the negative feedback mechanism is responsible for maintaining stability in an ecosystem. However, the homeostatic capacity of ecosystems is not unlimited as well as not everything in an ecosystem is always well regulated.

TYPES OF ECOSYSTEM

Terrestrial Ecosystem

A terrestrial ecosystem is a land-based community of organisms and the interactions of biotic and abiotic components in a given area. The terrestrial ecosystems can be found anywhere apart from heavily saturated places.As the anime suggests, the terrestrial type of ecosystem is all about those environments that don't involve water bodies. One of the best examples of terrestrial ecosystems would be the forest. The terrestrial part of the biosphere is divisible into enormous regions called **biomes**. The climate determines the boundaries of a biome and abundance of plants and animals found in each one of them.

- **Tundra Ecosystem:**

Winters are long with little daylight, summers are short, with long daylight hours. Precipitation is less than 250 mm per year. It is a zone of permafrost. The tundra ecosystem is found both bordering boreal forests in the Northern Hemisphere and in far southern regions like Antarctica.

The abiotic factors found in tundras make it very difficult for plants to grow, and the plants that do survive are small and adapted to short growing seasons.In fact, tundra comes from the Finnish word tunturia, which means **treeless hill.**

Tundra wildlife includes small mammals that are adapted to cold weather like lemmings, arctic hares, and arctic ground squirrels. Top predators in the tundra ecosystem include arctic foxes, arctic wolves, polar bears, and snowy owls. Because of the severe winters, many of the animals are migratory. For example, the many shorebirds and waterfowl such as ducks and geese, nest in the Tundra during the summer and migrate south for the winter. All fauna or animal species found in the tundra use a combination of thick coats of fur and fat stores to survive the winter. Some tundra animals hibernate in the winter as well to survive a season with minimal food. Most of the animals have long life, e.g. arctic willow has a life span of 150 to 300 years.

FORESTS:

Forests represent the largest and most ecologically complex systems. They contain a wide assortment of trees, plants, mammals, reptiles, amphibians, invertebrates, insects and microorganisms which vary depending on the zone's climate.

- **Taiga or Boreal Ecosystem:**

The Taiga is a 1300-1450 km wide zone south of the Tundra. This area has long and cold winters. Summer temperature ranges from 10^0 C to 21^0 C. Precipitation ranges about 380-1000 mm annually. The Taiga ecosystem includes forests in the subarctic region of the Northern Hemisphere. Found just south of the Arctic Circle, the taiga experiences low temperatures all year long with long winters and very short summers. The boreal forest is therefore made mostly of coniferous or evergreen trees that have adapted to these cold temperatures. It is absent in the southern hemisphere because of the narrowness of the southern continents in the high latitudes.Moose, caribou, and other large mammals are most abundant in the taiga. Bears, lynx, and Siberian tigers can be found in boreal forests as well, but most birds and smaller mammals are unable to live in this ecosystem year-round due to the extreme temperatures.

- **Temperate Forest Ecosystem:**

These forests occur in eastern North America, northeastern Asia and western and central Europe. Have well-defined seasons with a distinct winter. Moderate climate and a growing season of 140-200 days during 4-6 frost free months distinguish temperate forests. Annual temperature varies from -30° C to 30° C. Precipitation (750-1500 mm) is distributed evenly throughout the year. Soil is fertile, enriched with

decaying litter. Canopy is moderately dense and allows light to penetrate, resulting in well-developed and richly diversified understorey vegetation and stratification of animals.

Trees have broad leaves that are lost annually such as oak, hickory, beech, hemlock, maple, basswood, cottonwood, elm, willow, and spring-flowering herbs. Fauna consists of squirrels, rabbits, skunks, birds, deer, mountain lion, bobcat, timber wolf, fox, and black bear. The temperate forest ecosystem is characterised by high levels of precipitation as both rain and snow and temperatures change with the seasons. Depending on where they're found in the world, temperate forests can be composed mostly of deciduous trees that lose their leaves in the fall or coniferous forests that are evergreens. There are even temperate rainforests, which are more commonly found closer to a coast where the humidity is higher. Temperate forests have a high diversity of flora and fauna supported by rich soils and abundant precipitation. In addition to trees, lichen and mosses are commonly found in temperate forest ecosystems.

- **Tropical Rainforest Ecosystem:**

They occur near the equator (between latitudes 23.5^0 at north and 23.5^0 at south). The major characteristic of tropical forests is their distinct seasons. Only two seasons are present (rainy and dry). Winter is absent. The length of daylight is about 12 hours and varies little. The average annual temperature ranges between 20° C and 25° C. Precipitation are evenly distributed throughout the year with annual rainfall exceeding 2000 mm. Soil is nutrient-poor and acidic. Decomposition is rapid and soils are subject to heavy leaching. Tree canopy is multilayered and continuous, allowing little light penetration.

Flora is highly diverse: one square kilometre may contain as many as 100 different tree species. Trees are 25-35 m tall, with buttressed trunks and shallow roots, mostly evergreen, with large dark green leaves. Common vegetation are orchids, bromeliads, vines (lianas), ferns, mosses, and palms. They are characterised by the greatest diversity of fauna which includes birds, bats, small mammals, and insects.

The tropical rainforest ecosystem is characterised by high temperatures and humidity throughout the year, with up to 400 inches (10.16 m) of rainfall annually. The high temperatures and humidity are caused by their location in the tropics, where the sun's rays are most intense. In fact, tropical rainforests are one of the most diverse ecosystems in the world, with roughly half of the world's species found in tropical rainforests.

The tropical rainforest ecosystem can be found in Central and South America, western and central Africa, western India, Southeast Asia, New Guinea, and Australia. The Amazon rainforest in South America is the largest tropical rainforest in the world, with estimates of 2.5 million different insects, 40,000 plant species, 1,300 bird species, 3,000 fish species, and 427 mammal species.

TYPES OF INDIAN FORESTS:

- **Tropical Evergreen and Semi Evergreen Forests**

Location: Found in the western slope of the Western Ghats, hills of the northeastern region and the Andaman and Nicobar Islands in.
Climatic condition: Warm and humid conditions with an annual precipitation of over 200 cm and mean annual temperature above 220C.

Characteristics: Stratified with layers closer to the ground and are covered with shrubs and creepers, with short-structured trees followed by a tall variety of trees. Trees reach great heights up to 60 m or above. There is no definite time for trees to shed their leaves, flowering and fruition and these forests appear green all the year round.

Floral composition: Rosewood, mahogany, ebony, etc. The under growing climbers provide an evergreen character to these forests. Main species are white cedar, and kail. The semi evergreen forests are found in the less rainy parts of these regions. Such forests have a mixture of evergreen and moist deciduous trees.

Faunal composition: Elephants, monkey, lemur and deer, one-horned rhinoceros are found in jungles of Assam and West Bengal along with plenty of birds, bats, sloth, scorpions and snails etc.

- **Tropical Deciduous Forests:** Most widespread forests in India, also called the monsoon forests.

Climatic condition: They spread over regions which receive rainfall between 70-200 cm. Based on the availability of water and rainfall, they are divided into:

1. **Tropical Moist Deciduous Forests:**

Location: Northeastern states along the foothills of Himalayas, eastern slopes of the Western Ghats and Odisha.

Climatic condition: Rainfall between 100-200 cm.

Floral Composition: Teak, sal, shisham, hurra, mahua, amla, semul, kusum, and sandalwood etc. **Faunal** Composition: Mammals include the predators Indian tiger, wolf, dhole, and sloth bear, and the herbivores gaur, chousingha, blackbuck, and chinkara.

2. **Dry Deciduous Forest:**

Location: Rainier areas of the Peninsula and the plains of Uttar Pradesh and Bihar. In the higher rainfall regions of the peninsular plateau and the Northern Indian plain. **Climatic Condition:** Rainfall ranges between 70 -100 cm.
Characteristics: On the wetter margins, it has a transition to the moist deciduous, while on the drier margins to thorn forests. Forests have a parkland landscape with open stretches in which teak and other trees interspersed with patches of grass are common. As the dry season begins, the trees shed their leaves completely and the forest appears like a vast grassland with naked trees all around.

Floral Composition: Tendu, palas, amaltas, bel, khair, axlewood, etc.

- **Tropical Thorn Forests:**

Location: It includes semi-arid areas of south-west Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh.

Climatic condition: Tropical thorn forests occur in the areas which receive rainfall less than 50 cm.

Characteristics: Variety of grasses and shrub, plants remain leafless for most part of the year and give an expression of scrub vegetation.

Floral composition: Babool, ber, and wild date palm, khair, neem, khejri, palas, etc.

- **Montane Forests:**