14. ECOSYSTEM

An ecosystem is a functional unit of nature, where living organisms interact each other and with the physical environment.

ECOSYSTEM – STRUCTURE & FUNCTION

Types of ecosystems

- **Terrestrial ecosystem:** Forest, grassland, desert etc.
- **Aquatic ecosystem:** Pond, lake, wetland, river & estuary.
- **Man-made ecosystem:** Crop fields and aquarium.

- Entire biosphere is regarded as **global ecosystem.**
- In an ecosystem, biotic and abiotic components interact and function as a unit.
- Vertical distribution of different species occupying different levels is called **stratification**. E.g. in a forest, trees occupy top strata (layer), shrubs the second and herbs & grasses the bottom layers.

Pond (Aquatic ecosystem)

A pond is a shallow, simple, self-sustainable water body that exhibits all basic components of an ecosystem.

- **Abiotic components:** Water and soil deposit.
- **Climatic conditions:** Solar input, cycle of temperature, day-length etc.
- **Autotrophic components:** Phytoplankton, some algae and the floating, submerged and marginal plants.
- **Consumers (heterotrophs):** Zooplankton, free swimming and bottom dwelling forms.
- **Decomposers:** Fungi, bacteria and flagellates.

Pond performs all the functions of an ecosystem such as

- Conversion of inorganic into organic material using solar radiant energy by the autotrophs.
- Consumption of the autotrophs by heterotrophs.
- Decomposition and mineralization of the dead matter to release them back for reuse by the autotrophs.

4 basic components of functioning of an ecosystem:

1) Productivity 2) Decomposition
3) Energy flow 4) Nutrient cycling

PRODUCTIVITY

- Solar energy is the basic requirement for an ecosystem to function and sustain.
- Amount of biomass (organic matter) produced per unit area over a time period by plants during photosynthesis is called **primary production.** It is expressed in weight (g^{-2}) or energy (kcal m^{-2}).
- The rate of biomass production is called **productivity**. It is expressed in $g^{-2}\ yr^{-1}$ or (kcal m^{-2}) yr^{-1}.
- It is divided into gross primary productivity (GPP) and net primary productivity (NPP).
- **Gross primary productivity:** It is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants in respiration.
- **Net primary productivity (NPP):** It is the available biomass for the consumption to heterotrophs (herbivores & decomposers). i.e., NPP is the Gross primary productivity minus respiration losses (R).

$$\mathbf{NPP = GPP - R}$$

- **Secondary productivity:** It is the rate of formation of new organic matter by consumers.
- Primary productivity varies in different ecosystems because it depends on
  - The plant species inhabiting a particular area
  - Environmental factors
  - Availability of nutrients
  - Photosynthetic capacity of plants
- **Annual net primary productivity** of whole biosphere is about **170 billion tons** (dry weight) of organic matter. Of this, despite occupying about 70 % of the surface, the productivity of the oceans is only 55 billion tons.

DECOMPOSITION

- It is the breakdown of complex organic matter by decomposers into inorganic substances like CO_2, water and nutrients. It is largely an oxygen-requiring process.
- Raw material for decomposition is called **Detritus.** E.g. dead plant remains (leaves, bark, flowers etc.), dead remains of animals, fecal matter etc.

Steps of decomposition

a. **Fragmentation:** It is the breakdown of detritus into smaller particles by **detritivores** (e.g. earthworm).
b. **Leaching:** Water soluble inorganic nutrients go down into soil horizon and precipitate as unavailable salts.
c. **Catabolism:** Degradation of detritus into simpler inorganic substances by bacterial and fungal enzymes.

The above three processes occur simultaneously.

d. **Humification:** Accumulation of **humus** (dark amorphous substance) in soil. Humus is resistant to microbial action and so decomposes very slowly. Being colloidal in nature it serves as a reservoir of nutrients.
e. **Mineralization:** It is the release of inorganic nutrients due to the degradation of humus by some microbes.

Factors influencing decomposition

- **Chemical composition of detritus:** Decomposition rate is slower in detritus rich in lignin & chitin. It is quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.
- **Climatic factors (temperature & soil moisture):** Warm and moist environment favour decomposition. Low temperature and anaerobiosis inhibit decomposition resulting in buildup of organic materials.

ENERGY FLOW

- Sun is the only source of energy for all ecosystems (except deep sea hydro-thermal ecosystem).
- Of the incident solar radiation, less than 50% is **photosynthetically active radiation (PAR).**
- Plants and photosynthetic & chemosynthetic bacteria (autotrophs), fix solar radiant energy to make food.
- Plants capture only **2-10%** of the PAR. This energy sustains the entire living world.
- Ecosystems obey 2nd Law of thermodynamics. They need a constant supply of energy to synthesize the molecules. It helps to counteract the entropy.

Producers (Autotrophs):

- These are organisms that synthesize food.
- In a terrestrial ecosystem, major producers are herbaceous and woody plants. Primary producers in an aquatic ecosystem are phytoplankton, algae and higher plants.
- The energy trapped by the producer is either passed on to a consumer or the organism dies.

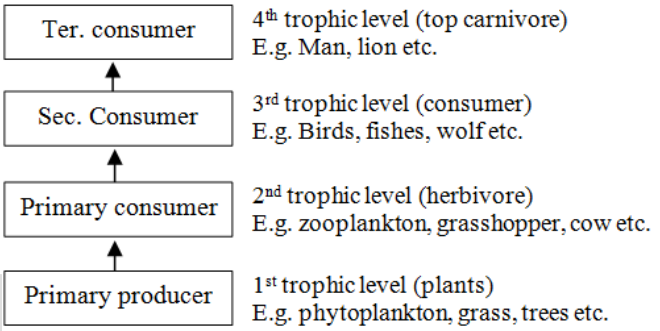
Consumers (heterotrophs):

- These are animals that directly or indirectly depend on plants for food. They include:
  - **Primary consumers (herbivores):** Feed on plants. E.g. insects, birds, mammals, molluscs etc.
  - **Secondary consumers (primary carnivores):** Feed on herbivores. E.g. frog, fox, man etc.
  - **Tertiary consumers (secondary carnivores):** Feed on primary carnivores. E.g. tiger, lion etc.
- The chain of feeding relationship between different organisms is called a **food chain.** It is 2 types:
  - **Grazing Food Chain (GFC):** Here, primary consumer feeds on living plants (producer). E.g.

Grass ⇢ Goat ⇢ Man

(Producer) (Primary Consumer) (Secondary consumer)

  - **Detritus Food Chain (DFC):** Here, primary consumer feeds on dead organic matter (detritus). Death of organism is the beginning of the DFC.
- Detritus is made up of **decomposers (saprotrophs)** such as fungi & bacteria. They secrete digestive enzymes that breakdown detritus into simple, inorganic materials, which are absorbed by them. Thus, they get energy & nutrients.
- In an aquatic ecosystem, GFC is the major conduit for energy flow.
- In a terrestrial ecosystem, a much amount of energy flows through the DFC than through the GFC.
- DFC may be connected with GFC at some levels. Some organisms of DFC are prey to the GFC animals. Some animals (cockroaches, crows etc.) are omnivores. Such interconnections of food chains make a **food web**.
- A specific place of organisms in the food chain is known as their **trophic level**.

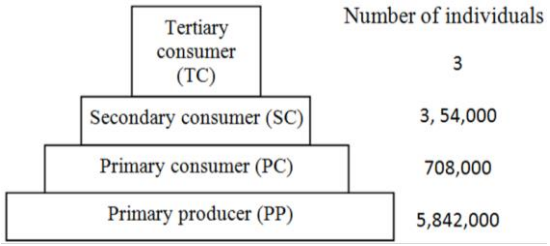


- The amount of energy decreases at successive trophic levels. When an organism dies it becomes **dead biomass (detritus).** It is an energy source for decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy.
- Each trophic level has a certain mass of living material at a particular time called as the **standing crop**. It is measured as the **biomass** (mass of living organisms) or the number in a unit area.
- Biomass of a species is expressed in terms of **fresh or dry weight.** It is more accurate measurement.
- Number of trophic levels in GFC is restricted as it follows **10% law** (only 10% of energy is transferred to each trophic level from the lower trophic level).

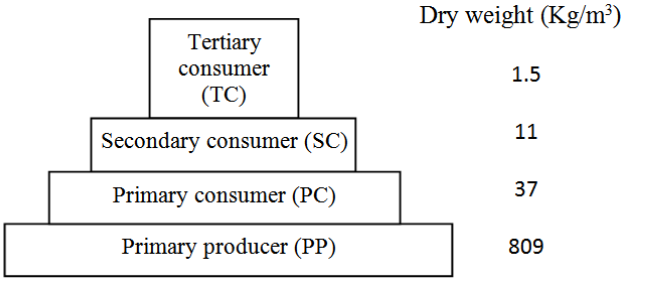
ECOLOGICAL PYRAMIDS

- The representation of a food chain in the form of a pyramid is called **ecological pyramid.**
- The base of a pyramid represents producers (first trophic level). The apex represents tertiary or top level consumer.
- Ecological pyramids are 3 types: Pyramid of number, Pyramid of biomass and Pyramid of energy.

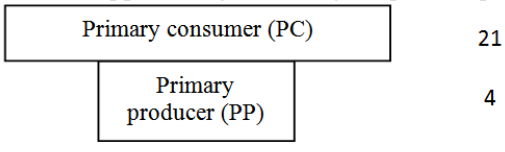
a) Pyramid of number: E.g. grassland ecosystem.



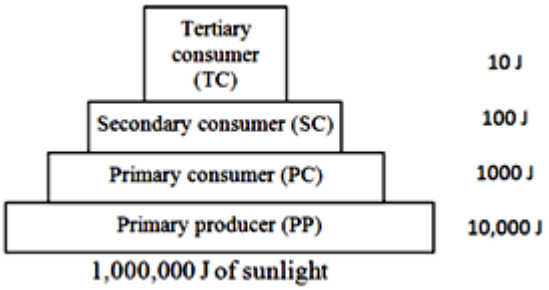
b) Pyramid of biomass: It shows a sharp decrease in biomass at higher trophic levels.



Inverted pyramid of biomass: Small standing crop of phytoplankton supports large standing crop of zooplankton.



c) Pyramid of energy: Primary producers convert only 1% of the energy in the sunlight available to them into NPP.



- Any calculations of energy content, biomass, or numbers has to include all organisms at that trophic level.
- The trophic level represents a functional level, not a species as such. A given species may occupy more than one trophic level in the same ecosystem at the same time. E.g. A sparrow is a primary consumer when it eats seeds, fruits, peas. It is a secondary consumer when it eats insects & worms.
- In most ecosystems, all the pyramids are upright, i.e., producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores. Also, energy at a lower trophic level is always more than at a higher level.
- **Examples for inverted pyramids:**
  - Insects feeding on a big tree
  - Pyramid of biomass in sea is inverted because the biomass of fishes far exceeds that of phytoplankton.
- Pyramid of energy is always upright, because when energy flows from a trophic level to the next trophic level, some energy is always lost as heat at each step.
- **Limitations of ecological pyramids:**
  - It does not consider the same species belonging to two or more trophic levels.
  - It assumes a simple food chain that almost never exists in nature; it does not accommodate a food web.
  - Saprophytes are not included in ecological pyramids even though they play a vital role in the ecosystem.

ECOLOGICAL SUCCESSION

- It is a gradual, slow and predictable change in the species composition of an area leading to a **climax community** (community that is in equilibrium with the environment).
- In this, some species colonize an area and increase in number, whereas other species decline and disappear.
- The entire sequences of communities that successively change in an area are called **sere**. Individual transitional communities are termed **seral stages (seral communities).**
- In the successive seral stages there is a change in species diversity, increase in number of species and organisms and an increase in the total biomass.
- The present-day communities are due to succession of millions of years. Succession and evolution would have been parallel processes at that time.
- Succession is 2 types:
  - **Primary:** The succession taking place in areas where no living organisms ever existed. E.g. newly cooled lava, bare rock, newly created pond or reservoir.
    Before a biotic community is established, there must be formation of fertile soil through natural processes. So the primary succession is a very slow process.
  - **Secondary:** The succession taking place in an area after the existed organisms are lost. E.g. abandoned farm lands, burned or cut forests, lands that are flooded.
    Since some soil or sediment is present, succession is faster than primary succession.
    The species that invade depend on the condition of the soil, availability of water etc.
- In succession, changes in vegetation affect food & shelter of animals. Thus, as succession proceeds, the number and types of animals & decomposers also change.
- Natural or human induced disturbances (deforestation, fire etc.) convert a particular seral stage to an earlier stage. They create new conditions that encourage some species and discourage or eliminate other species.

Succession of Plants

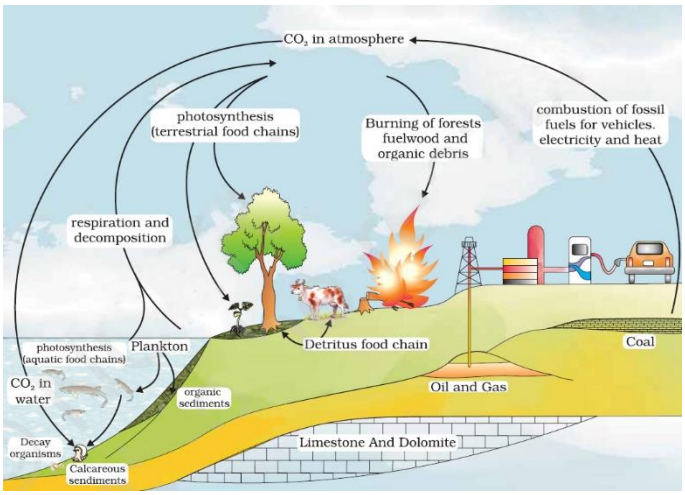
- Based on the nature of the habitat, succession of plants is 2 types: hydrarch and xerarch.
  - **Hydrarch succession:** It takes place in wetter areas. The successional series progress from hydric to the mesic conditions.
  - **Xerarch succession:** It takes place in dry areas. The series progress from xeric to mesic conditions.
- Hence, both hydrarch & xerarch successions lead to medium water conditions **(mesic,** the climax community).
- The species invading a bare area are called **pioneer species**.
- **Primary succession on rocks (xerophytic habitat):**
  Lichens (pioneer species. They secrete acids to dissolve rock, helping in weathering & soil formation) → small plants like bryophytes (they need only small amount of soil) → bigger plants → stable climax forest community (mesophytic).
  The **climax community** remains stable as long as the environment remains unchanged.
- **Primary succession in water:**
  Phytoplankton (pioneers) → free-floating angiosperms → rooted hydrophytes → sedges, grasses → trees (climax community is a forest).
  With time, the water body is converted into land.

NUTRIENT CYCLING

- The amount of nutrients like carbon, nitrogen, phosphorus, calcium etc. present in the soil at any given time, is referred to as the **standing state**. It varies in different kinds of ecosystems and also on a seasonal basis.
- Nutrients are never lost from the ecosystems. They are recycled again and again. The movement of nutrient elements through various components of an ecosystem is called **nutrient cycling (biogeochemical cycles).**

- Nutrient cycles are 2 types:
  a. **Gaseous cycle:** For this, the reservoir exists in the atmosphere. E.g. Nitrogen & Carbon cycles.
  b. **Sedimentary cycle:** For this, the reservoir is located in Earth's crust. E.g. Sulphur & Phosphorus cycles.
- Environmental factors (soil, moisture, pH, temperature, etc.) regulate the rate of release of nutrients into the atmosphere. The reservoir meets with the deficit of nutrients due to imbalance in the rate of influx and efflux.

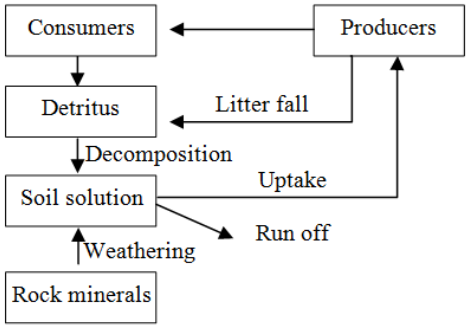
Carbon Cycle



- **Reservoir of carbon:** Atmosphere (about 1%), organisms (49% of dry weight), oceans (71% dissolved carbon. It regulates the amount of atmospheric CO_2), fossil fuel etc.
- Carbon cycling occurs through atmosphere, ocean and through living and dead organisms.
- 4×10^{13} kg of carbon is fixed in the biosphere through photosynthesis annually.
- A major amount of carbon returns to the atmosphere as CO_2 through respiration.
- Processing of wastes & dead organic matter by decomposers also release CO_2.
- Some amount of the fixed carbon is lost to sediments and removed from circulation.
- Burning of wood, forest fire and combustion of organic matter, fossil fuel and volcanic activity are other sources for releasing CO_2 in the atmosphere.
- **Role of human activities in carbon cycle:** Deforestation, burning of fossil fuel etc. has increased the rate of release of CO_2 into the atmosphere.

Phosphorus Cycle

- Phosphorus is a constituent of biological membranes, nucleic acids & cellular energy transfer systems. Many animals use phosphorus to make shells, bones and teeth.
- The natural reservoir of phosphorus is rock (in the form of phosphates).
- When rocks are weathered, minute amounts of phosphates dissolve in soil solution and are absorbed by the plants. Herbivores and other animals obtain this from plants. The waste products and the dead organisms are decomposed by phosphate-solubilising bacteria releasing phosphorus.



Differences between carbon and phosphorous cycles

Carbon cycle	Phosphorous cycle
Atmospheric input is higher	Much smaller
There is gaseous exchange b/w organism & environment	Gaseous exchange is negligible

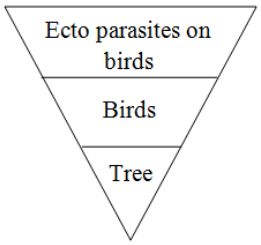
ECOSYSTEM SERVICES

- The products of ecosystem processes are called **ecosystem services.**
- E.g. healthy forest ecosystems purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage site for carbon and provide aesthetic, cultural & spiritual values.
- **Robert Constanza** and his colleagues have tried to put price tags on nature's life-support services.
- Researchers have put an average price tag of US $ 33 trillion a year on fundamental ecosystems services. This is nearly twice the value of the global gross national product GNP (US $ 18 trillion).
- Out of this total cost, soil formation accounts for about 50%.
- Contributions of other services like recreation & nutrient cycling are less than 10% each.
- The cost of climate regulation and habitat for wildlife are about 6 % each.

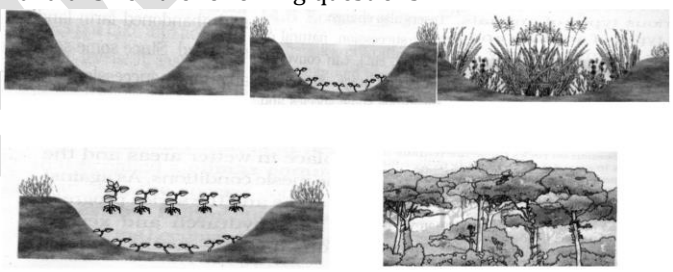
MODEL QUESTIONS

1. Fill in the blanks by noticing the relationship of the given pair
   a. Producer: plant Consumer: ……..
   b. Carbon cycle: gaseous cycle Phosphorus cycle: ……..
2. Analyze the following food chain.
   Partially decomposed organic matter ⟶ Earthworm ⟶ Hen ⟶ Fox
   a. Name the above mentioned food chain.
   b. How do the members in this food chain meet their energy and nutrient requirements?
3. "Pyramid of number is always upright." Comment on this statement.
4. In nature one species can occupy more than one trophic level. Is this possible? Comment.
5. Even though biological pyramids are helpful in studying food chain, they have certain limitations. Account them.
6. While visiting the forest during a study tour, a teacher told the students that once this area was a barren rocky area.
   a. Name the ecological succession on a bare rock.
   b. Which was the pioneer species in that succession?
   c. Write the changes that lead to the formation of forest from barren rocky place.
7. Different stages of an ecological succession are given below.
   - Marsh - meadow stage
   - Reed swamp stage
   - Scrub stage
   - Phytoplankton stage
   - Submerged free floating stage
   - Forest stage

   a. Arrange them in the correct sequence.
   b. Name the type of ecological succession and mention the pioneer and climax communities in this succession
8. Given below is the pyramid of number of an ecosystem.



   a. Identify the nature of pyramid.
   b. Give reason for this nature of pyramid.
9. Observe the figure given below and answer the following questions



   a. Identify the ecological concept converged through the given figures.
   b. Name the group of organisms as pioneer community and climax community in this ecological process.