## Introduction

- An ecosystem can be visualised as a functional unit of nature, where living organisms interact among themselves and also with the surrounding physical environment.
- Ecosystem is the interaction of living things among themselves and with their surrounding environment.
- There are two basic ecosystems
  - Terrestrial
    - Forest, grassland and desert ecosystem
  - Aquatic
    - Pond, lake, wetland, river and estuary ecosystem

## Ecosystem- Structure and Function

- The interactions between the various biotic and abiotic factors of an ecosystem lead to the maintenance of the ecosystem.
- **Stratification**: Vertical distribution of different species occupying different levels.
  - trees occupy top vertical strata or layer of a forest,
  - shrubs the second and
  - herbs and grasses occupy the bottom layers.
- The components of the ecosystem
  - Productivity;
  - Decomposition;
  - Energy flow; and
  - Nutrient cycling
- Example of pond ecosystem:
  - Abiotic component: the water with all the dissolved inorganic and organic substances and the rich soil deposit at the bottom of the pond.
  - Producers: autotrophic components that include the phytoplankton, some algae and the floating, submerged and marginal plants found at the edges.
  - Decomposers: the fungi, bacteria and flagellates especially abundant in the bottom of the pond.
  - The pond performs all the functions of any ecosystem and of the biosphere as a whole, i.e.,
    - Conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs;
    - Consumption of the autotrophs by heterotrophs;
    - decomposition and mineralisation of the dead matter to release them back for reuse by the autotrophs.
  - There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment.

## Productivity

- A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.
- **Primary production**: The amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis. [Unit: weight (g – 2) or energy (kcal m – 2)].
- **Productivity**: The rate of biomass production. [Unit: g – 2 yr –1 or (kcal m – 2 ) yr –1]
- **Gross primary productivity (GPP)**: The rate of production of organic matter during photosynthesis.
- **Net primary productivity (NPP)**: Gross primary productivity minus respiration losses (R), GPP – R = NPP
- **Secondary productivity**: The rate of formation of new organic matter by consumers.
✓ Primary productivity depends upon:
  o type of plant species inhabiting a particular area
  o photosynthetic capacity of plants
  o nutrient availability

**Decomposition**
✓ **Decomposition**: Break down complex organic matter into inorganic substances like carbon dioxide, water and nutrients by the decomposers.
✓ Detritus: Dead plant remains such as leaves, bark, flowers and dead remains of animals, including fecal matter.
✓ Detritus acts as the raw materials for the decomposition.
✓ The important steps in the process of decomposition are fragmentation, leaching, catabolism, humification and mineralisation.
  o Fragmentation: Break down of detritus into smaller particles by detrivores (earthworm)
  o Leaching: Water-soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
  o Catabolism: Bacterial and fungal enzymes degrade detritus into simpler inorganic substances.
  o Humification: Accumulation of humus (a dark coloured amorphous substance).
    ▪ Humus is highly resistant to microbial action.
    ▪ It undergoes decomposition at an extremely slow rate.
    ▪ It serves as a reservoir of nutrients.
  o Mineralisation: Degradation of humus to release inorganic nutrients.
✓ Decomposition is largely an oxygen-requiring process.
✓ Rate of decomposition is controlled by:
  o chemical composition of detritus
    ▪ decomposition rate is slower if detritus is rich in lignin and chitin.
    ▪ quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.
  o climatic factors
    ▪ Warm and moist environment favour decomposition.
    ▪ Low temperature and anaerobiosis inhibit decomposition.

**Energy Flow**
✓ **Photosynthetically active radiation (PAR)**: Of the incident solar radiation less than 50% of solar radiation; that can be used by autotrophs to make food from simple inorganic materials.
✓ Plants capture only 2-10 per cent of the PAR.
✓ **Producers**: The green plant in the ecosystem that produces the food.
  o In terrestrial ecosystem: herbaceous and woody plants
  o In aquatic ecosystem: various species like phytoplankton, algae and higher plants.
✓ **Consumers**: All animals depend on plants (directly or indirectly) for their food needs.
✓ **Food Chain**:
✓ **Grazing food chain (GFC)**: A food chain that begins with producers.
✓ **Detritus food chain (DFC)**: A food chain that starts with dead organic matter.
  o It is made up of decomposers which are heterotrophic organisms, mainly fungi and bacteria.
  o They meet their energy and nutrient requirements by degrading dead organic matter or detritus.
  o Secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them. (saprophytes)
✓ **Food Web**:
✓ **Trophic level**: Every organism occupies a specific level in their food chain known as the trophic level.
  o Producers - first trophic level
  o Herbivores (primary consumer) - second trophic level
Carnivores (secondary consumer) - third trophic level

- **Standing crop**: The mass of living material (biomass) that is present in a trophic level at a particular time.
- **10% law**: Only 10 per cent of the energy is transferred to each trophic level from the lower trophic level; as a result of which the number of trophic levels in the grazing food chain is restricted.

**Ecological pyramids:**

- An ecological pyramid is a graphical representation of the food or energy relationship between organisms at different trophic levels.
- The relationship is expressed in terms of number, biomass or energy.
- The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer.

**Pyramid of numbers in a grassland ecosystem:**

- Only three top-carnivores are supported in an ecosystem based on production of nearly 6 millions plants.

**Pyramid of biomass:**

- Sharp decrease in biomass at higher trophic levels.

**Inverted pyramid of biomass:**

- Small standing crop of phytoplankton supports large standing crop of zooplankton.
- E.g.: Number of insects feeding on a big tree.
  - Pyramid of biomass in sea - biomass of fishes far exceeds that of phytoplankton.

**An ideal pyramid of energy:**

- Only 1% of the energy in the sunlight available to them into NPP
Pyramid of energy is always upright, can never be inverted -
  - Because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step.

A trophic level represents a functional level and not a single species as such. Also, a single species may become a part of more than one trophic level in the same ecosystem at the same time depending upon the role it plays in the ecosystem.

Limitations of ecological pyramids:
  - The ecological pyramids do not take into account the same species belonging to more than one trophic level.
  - It assumes a simple food chain that almost never exists in nature. It does not explain food webs.
  - Saprophytes are not given a place in ecological pyramids even though they play a vital role in ecosystem.

Ecological Succession

- The gradual and fairly predictable change in the species composition of a given area.
- The composition and structure of a community constantly change in response to the changing environmental conditions.
- These changes lead finally to a climax community.
- **Climax community:** The community that is in near equilibrium with the environment.
- **Sere:** The entire sequence of communities that successively change in a given area.
- **Seral stages / seral communities:** The individual transitional communities.
- **Primary succession:** The succession that happens in areas where no life forms ever existed as in bare rocks, cool lava, etc.
  - It takes hundreds to thousands of years as developing soil on bare rocks is a slow process.
- **Secondary succession:** The succession that happens in areas which have lost all life forms due to destructions and floods, etc.
  - Since some soil or sediment is present, succession is faster than primary succession.

Successions of plants

- **Hydrarch succession:** It takes place in wetter areas and the successional series progress from hydric to the mesic conditions.
- **Xerarch succession:** It takes place in dry areas and the series progress from xeric to mesic conditions.
- Both hydrarch and xerarch successions lead to medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).
- **Pioneer species:** The first species that invade a bare area.

**Primary succession on rocks:**
  - Lichens are the pioneer species.
  - They secrete acids to dissolve rock, helping in weathering and soil formation.
  - This later helps the plants like bryophytes to grow there.
  - The bryophytes with time gets succeeded by bigger plants.
  - After several more stages, ultimately a stable climax forest community is formed.
  - The xerophytic habitat gets converted into a mesophytic one.

- The climax community remains stable as long as the environment remains unchanged.

**Primary succession in water:**
  - Pioneer species are the small phytoplanktons.
  - They are replaced with time by rooted-submerged plants.
  - Rooted-floating angiosperms are replaced by free-floating plants.
The free-floating plants are replaced by reed-swamp, marsh-meadow, scrub, and finally the trees. The climax community here is forest. With time, the water body is converted into land.

**Secondary Succession:**

✓ The pioneer species depend on the following factors:
  o Condition of the soil
  o Availability of water
  o The environment
  o The seeds or other propagules present

✓ As the soil is present at the beginning, the climax community is reached much quickly.

**Nutrient Cycling**

✓ The amount of nutrients present in the soil at a given time is known as the standing state.

✓ Nutrients are never lost from the ecosystem. They are only recycled from one state to another.

✓ The movement of nutrients through the various components of the ecosystem is called nutrient cycling or biogeochemical cycles. They are of two types:
  o Gaseous – Reservoir for these types of cycles exist in the atmosphere.
  o Sedimentary – Reservoir for these types of cycles exist in the earth’s crust.

**Ecosystem-Carbon Cycle**

✓ About 49% of the dry weight of living organisms is made up of carbon.

✓ The ocean reserves and fossil fuels regulate the amount of CO$_2$ in the atmosphere.

✓ Plants absorb CO$_2$ from the atmosphere for photosynthesis, of which a certain amount is released back through respiratory activities.

✓ A major amount of CO$_2$ is contributed by the decomposers who contribute to the CO$_2$ pool by processing dead and decaying matter.

✓ The amount of CO$_2$ in the atmosphere has been increased considerably by human activities such as burning of fossil fuels, deforestation.

**Ecosystem-Phosphorous 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, some of the phosphate gets dissolved in the soil solution and is absorbed by plants.

✓ The consumers get their phosphorus from the plants.

✓ Phosphorus returns back to the soil by the action of phosphate-solubilising bacteria on dead organisms.

**Ecosystem Services**

✓ The products of ecosystem processes are named as ecosystem services:
  o healthy forest ecosystems purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, etc.

✓ Robert Constanza and his colleagues tried to put price tags on nature’s life-support services.

✓ The Average price tag was calculated to be of US $33 trillion a year on these fundamental ecosystems services.

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