ECOSYSTEM – FUNCTION

- Ecosystems naturally work to keep going, thanks to their many activities.
- For instance, leaves make food through photosynthesis, roots take in nutrients from the soil, herbivores eat plants and become food for carnivores, and decomposers break down dead matter to make things that producers can use.
- These activities happen in a balanced and controlled way in the ecosystem, known as processes.
- Thus, the main aspects of ecosystem function include:

(A) Productivity
(B) Decomposition
(C) Energy flow
(D) Nutrient cycling

(A) Productivity

(i) Primary productivity

- Primary production means how much plant material or organic matter is made in a certain area over time through photosynthesis.
- We measure it in weight (grams per square meter) or energy (kilocalories per square meter).
- The speed at which biomass is made is called productivity, measured in grams per square meter per year or kilocalories per square meter per year, to see how productive different ecosystems are.
- This can be split into gross primary productivity (GPP) and net primary productivity (NPP).

Primary productivity involves two types:

a) Gross Primary Productivity (GPP):

- The production of organic matter by producers through photosynthesis in a given area over a specific time is known as GPP (AIPMT-2015).
- This process includes energy loss through respiration and other metabolic activities.

b) Net Primary Productivity (NPP):

- The quantity of organic matter stored in producers through photosynthesis in a specific area over a specific time is termed NPP. NPP = GPP - R, where R represents respiration.
- NPP represents the available biomass for consumers such as herbivores or decomposers.

(ii) Secondary productivity:

- This is the process of secondary consumers making organic matter again.
- Energy loss through respiration is 20% in producers, 30% in herbivores, and 60% in carnivores.

(iii) Net community productivity or Net productivity –

- Net community productivity, or simply net productivity, refers to the speed at which organic matter is stored without being utilized by organisms that cannot produce their own food. This includes energy not consumed by heterotrophs, which are organisms relying on external sources for nutrition.
- Primary productivity relies on the types of plants present in an area and various environmental factors like nutrient availability and plant photosynthetic capabilities. As a result, it fluctuates across different ecosystems. Globally, the biosphere accumulates around 170 billion tons of organic matter annually, with oceans contributing only 55 billion tons.

- Tropical rainforests exhibit the highest productivity per unit area on land, while deep lakes are the least productive aquatic ecosystems, and coral reefs are highly productive.
- Nitrogen limits productivity in oceans, while phosphorus is the limiting factor in lake ecosystems. Tropical rainforests boast the highest land productivity at approximately 5 kg per square meter per year, while deserts and tundra exhibit the lowest productivity.
- Among agro-ecosystems, those cultivating sugarcane and rice are the most productive, yielding around 3-4 kg per square meter per year.

(B) Decomposition

- Decomposition, also known as the formation of humus, occurs when decomposers break down complex organic matter into simpler substances like carbon dioxide, water, and nutrients. This process involves the breakdown of dead plant material such as leaves, bark, flowers, and animal remains, including feces, collectively known as detritus, which serves as the starting material for decomposition.

Detritus involves two types:

(A) Above ground detritus: (Plant litter, dead plant parts & animal parts excretory substances).

(B) Below ground detritus: Dead roots of plant, Dead animals in soil.

- The key stages in the decomposition process include fragmentation, leaching, catabolism, humification, and mineralization.

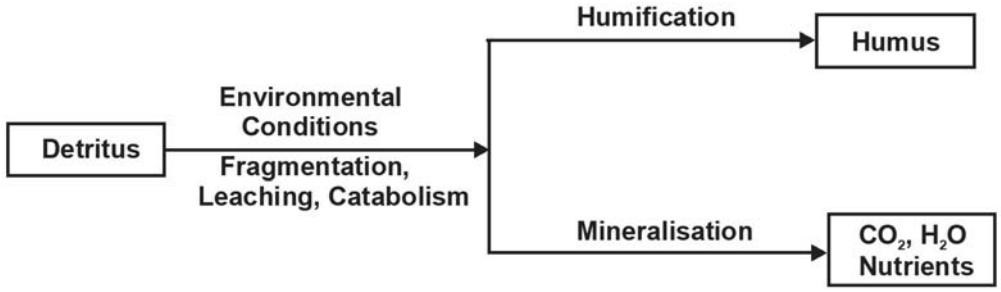


Fig: Processes involved in decomposition of detritus

- Detritivores like earthworms break down detritus into smaller pieces, a process called fragmentation. Through leaching, water-soluble nutrients move down into the soil and form salts that are not readily available. Bacterial and fungal enzymes break detritus down into simple substances in a process called catabolism.
- It's important to note that all these decomposition steps happen simultaneously. Humification and mineralization occur in the soil during decomposition. Humification leads to the formation of dark-colored humus, which is resistant to microbial breakdown and acts as a nutrient reservoir. Some microbes further degrade humus, releasing inorganic nutrients in a process known as mineralization.
- Decomposition primarily requires oxygen. The rate of decomposition depends on the chemical composition of detritus and climatic factors. Warmer temperatures and adequate soil moisture enhance decomposition, while low temperatures and anaerobic conditions slow it down.
- Decomposition takes years in high-altitude or latitude regions and is slow in dry environments like tropical deserts. The rate of decomposition varies depending on environmental conditions and detritus quality.
- During decomposition, some nutrients become temporarily bound to microbial biomass, a process called nutrient immobilization. These nutrients are released back into the ecosystem after microbial death, preventing them from being washed away.

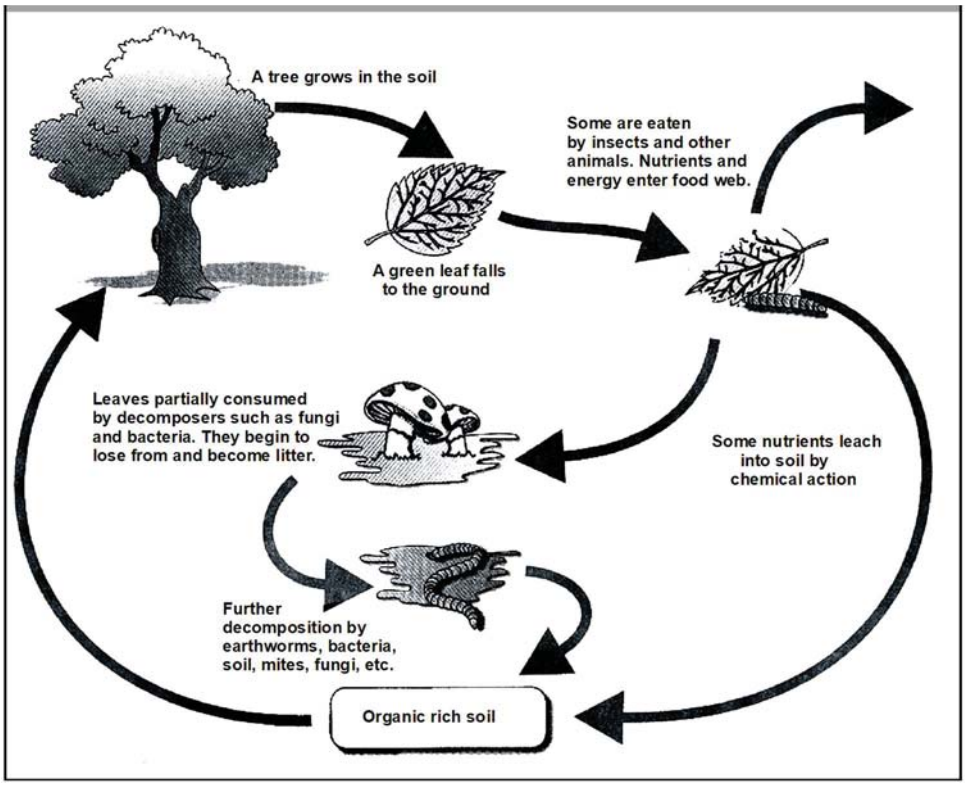
Two types of Humus –

(i) Mor (Coarse textured humus)-

- This raw humus forms in acidic soil with a pH between 3.8 and 4.0. In such soil, litter decomposition is sluggish due to fewer decomposer organisms present.

(ii) Mull –

- This refers to thoroughly decomposed litter, essentially humus, resulting from rapid decomposition due to the high pH of the soil. (The ideal pH range for soil is 5.5 to 6.5.)



(C) Energy Flow

- Typically, energy flow in an ecosystem moves in one direction: from sunlight to producers, then to consumers, and finally to decomposers.
- The process of energy flow in ecosystems can be understood through two fundamental laws of thermodynamics.

(i) First law of thermodynamics:

- The first law of thermodynamics states that energy cannot be created or destroyed, but it can be transformed from one form to another.

(ii) Second law of thermodynamics:

- The second law of thermodynamics explains that as energy moves from one level to the next in an ecosystem, some energy is inevitably lost as heat or entropy.
- Producers, like plants, capture only a small fraction of solar energy, typically around 1-5 percent of total solar radiation. Most of the unused energy dissipates as heat. A portion of the captured energy is used by producers for their own metabolic processes, such as respiration, and to provide food to

herbivores. The remaining unused energy is eventually converted into detritus, which becomes a source of energy for decomposers.

- As energy moves up the trophic levels, from herbivores to carnivores, there is a further loss of energy. Only a small fraction of the energy assimilated by herbivores is transferred to the next trophic level. This pattern continues, with each successive trophic level receiving less energy than the one before it.
- The cost of respiration also increases as you move up the trophic levels. Producers typically use about 20 percent of their gross productivity on respiration, while herbivores use around 30 percent, and carnivores use approximately 60 percent. This significant loss of energy at each trophic level means that there is not enough energy left to support additional trophic levels beyond a certain point.
- Due to these energy losses, the length of food chains in an ecosystem is usually limited to 3-4 trophic levels.

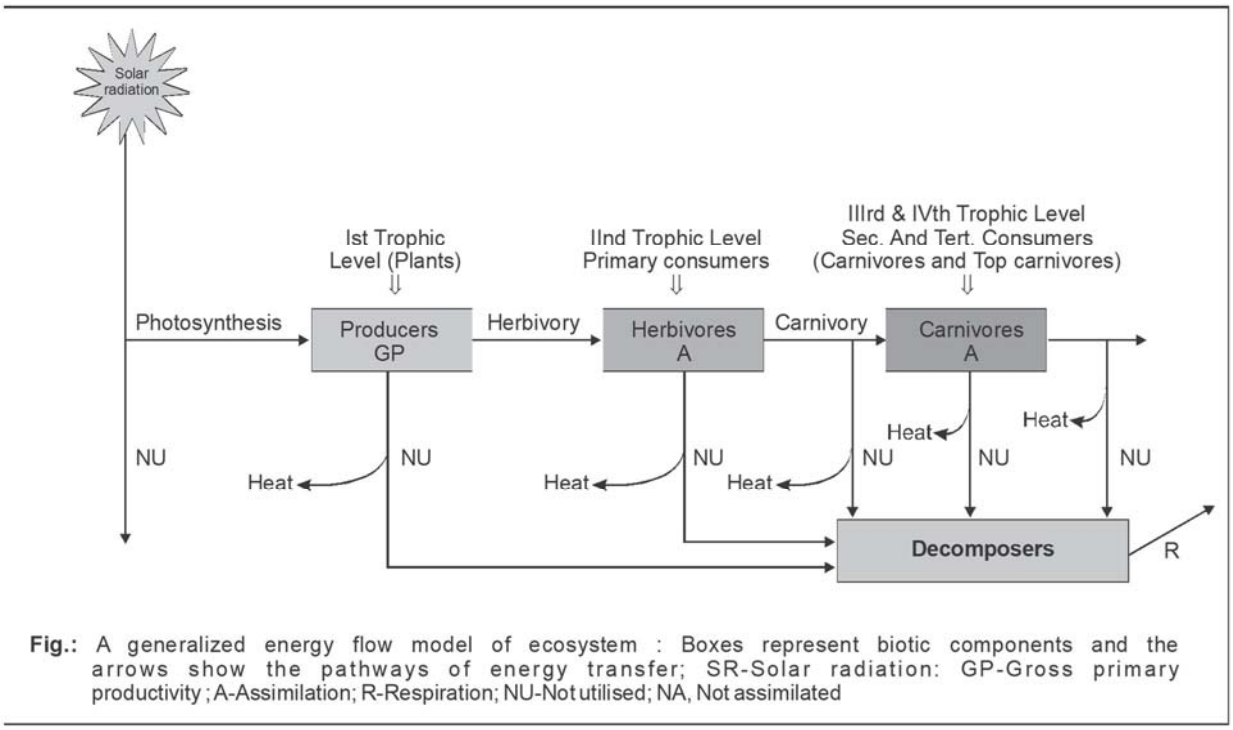


Fig.: A generalized energy flow model of ecosystem : Boxes represent biotic components and the arrows show the pathways of energy transfer; SR-Solar radiation: GP-Gross primary productivity ; A-Assimilation; R-Respiration; NU-Not utilised; NA, Not assimilated

Trophic level:

- Any food level of an ecosystem or food chain is called trophic level.
  (a) Producers –T1
  (b) Primary consumers –T2
  (c) Secondary consumers –T3
  (d) Tertiary consumers – T4
  (e) Quartinary or Top consumers –T 5
  (f) Decomposers –T6

Parasites can present any trophic level

Food Chain

- In an ecosystem, every organism relies on others for food, forming a sequence from herbivores to carnivores, known as a food chain. This chain involves repeated eating and being eaten, with energy flowing in the form of food.
- Food material and energy move from one trophic level to the next in a food chain.

- Ecosystems typically have four trophic levels due to the decrease in energy as it moves from one level to the next.
- In more complex ecosystems, like those with five trophic levels, tertiary consumers are present between secondary consumers and top consumers. The top consumer forms the fifth trophic level (T5).
- Energy flows in a food chain from producers to herbivores in one direction.
- Shorter food chains tend to provide more energy.
- Decomposers like bacteria and fungi are usually not considered part of the food chain, but if included, they are placed as the last trophic level.

Type of Food Chains:

Food chains are of three types:

(A) Parasitic food chain:

- It starts from large organisms and ended on parasite/small organism.

Tree → Birds → Parasite

(B) Detritus food Chain:

- It starts from dead organic matter that is eaten by detrivores
- (E.g. earthworm) the latter is prayed by pr. carnivores that is captured by secondary carnivores.

Detritus → Earthworm → frog → snake

↓ ↓

Sparrow Falcon / Hawk / Peacock

↓

Falcon

(C) Grazing food chain or predatory food Chain: It starts from producers

(1) Terrestrial ecosystem:

(a) Grass ⟶ Grasshopper ⟶ frog ⟶ Snake ⟶ Peacock / hawk

(b) Grass ⟶ Dear ⟶ Wolf ⟶ Lion / Tiger

(c) Grass ⟶ Rabbit ⟶ Fox ⟶ Wolf ⟶ lion / Tiger

(d) Grass ⟶ Rat ⟶ Fox ⟶ lion / Tiger,

(e) Grass ⟶ Deer ⟶ Tiger / lion,

(f) Grass ⟶ Elephant.

(2) Aquatic ecosystem:

(A) Phytoplanktons → zooplanktons→ small fishes

↓

Large fishes.

(B) Phytoplanktons → Zooplanktons → Crustaceans

↓

Predatory insects

↓

Small fishes

↓

Large fishes
↓
Crocodile

(C) Phytoplanktons → Zooplanktons → Crustaceans
↓
Small fishes
↓
Birds – kingfisher

Note:

- Within mangrove vegetation, this food chain extends to larger organisms.
- The food chain in dead mangrove leaves progresses from bacteria and fungi to amphipods, mollusks, crabs, nematodes, small fishes, and finally fish-eating birds.
- It is not reliant on light.
- In aquatic ecosystems, the Grazing Food Chain (GFC) serves as the primary pathway for energy flow. Conversely, in terrestrial ecosystems, a significantly greater amount of energy flows through the detritus food chain due to its smaller size compared to the grazing food chain.

(D) Food Chain

- In large ecosystems, multiple food chains are interconnected across different trophic levels to create a food web. In a food web, the transfer of food energy is one-way but occurs through various alternative pathways.
- In a food web, members of a specific trophic level choose their food based on preference and taste, unlike in a food chain where there's only one option. This means they have multiple alternatives for obtaining food.
- The more complex a food web, the more stable and enduring the ecosystem becomes. Such ecosystems are less likely to be naturally destroyed and can persist for a long time. They are resilient to the loss of any organism from a particular trophic level. Conversely, ecosystems with simple food webs are less stable and can be easily disrupted if there are changes at any trophic level.