

Ecosystem, its Structure & Functioning

"Eventually we will realise that if we destroy the ecosystem, we destroy ourselves"

-- Jonas Salk (American virologist who developed one of the first successful polio vaccines)

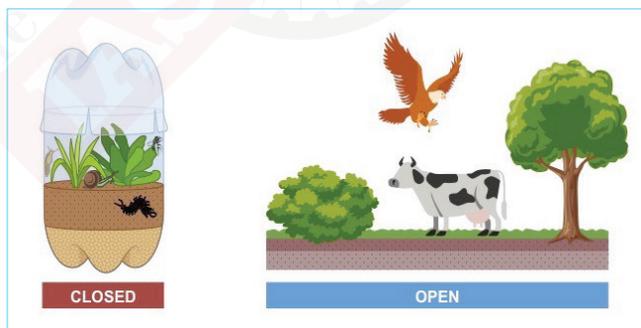
2.1 Types of Ecosystems

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 varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire biosphere as a global ecosystem, as a composite of all local ecosystems on Earth.

Since this system is too much big and complex to be studied at one time, it is convenient to divide it into different categories.

Based on material exchange into and out of ecosystems, they can be classified into:



A. **Open Ecosystem:** An open ecosystem exchanges both

energy and matter with surrounding environments (e.g. natural ecosystems like forest).

B. **Closed Ecosystem:** A closed ecosystem exchanges energy but not matter with its surroundings – it is self-contained (e.g. Mesocosm which can be any experimental system that examines the natural environment under controlled conditions.)

Based on existence, they can be classified into:



Poly-house: A man-made ecosystem

A. **Natural Ecosystem:** A natural ecosystem is made of all the plants, animals, and environmental features in an area. E.g. Lake, Desert etc.

B. **Man-made/Artificial Ecosystem:** Artificial ecosystems have been created or altered by humans, and are not

necessarily found in nature. E.g. An Aquarium, Crop fields etc.

Based on area they are found, they can be classified into:

- A. **Terrestrial Ecosystem:** Ecosystem which is found on land is known as terrestrial ecosystem. Forest, grassland and desert are some examples of terrestrial Ecosystems.
- B. **Aquatic Ecosystem:** Ecosystem which is found in water is known as Aquatic ecosystem. Pond, lake, wetland, river and estuary are some examples of aquatic ecosystems.



Coral Reef- An Aquatic Ecosystem

It is important to look at the **structure of the ecosystem**, in order to appreciate the input (productivity), transfer of and the output (decomposition) and other services offered by ecosystems.

Interaction of **biotic and abiotic components** result in a physical structure that is characteristic for each type of ecosystem.

The components of the ecosystem are seen to function as a unit when we consider the following aspects:

1. **Energy flow**
2. **Decomposition**
3. **Productivity**
4. **Nutrient cycling** (discussed in the first chapter)

2.2 Energy Flow in an Ecosystem

Sun is the **ultimate source** of energy for all ecosystems on Earth.

Plants and **photosynthetic** and **chemosynthetic bacteria**, fix sun's radiant energy to make food from simple inorganic materials. Plants capture **only 2-10 per cent of the**

Photosynthetically Active Radiation and this small amount of energy sustains the entire living world.

So, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem. All organisms are dependent for their food on producers, either directly or indirectly.

So it is clear that there is only a **unidirectional flow** of energy from the sun to producers and then to consumers.

We will understand the concept of energy flow through an ecosystem through different concepts like **food chain, food web, trophic level etc.**

2.2.1 Food Chain in an Ecosystem

Transfer of food energy from green plants (**producers**) through a series of organisms with **repeated eating and being eaten** link is called a food chain.

Organisms in food chains are grouped into categories called **trophic levels**.

A trophic level is also a **representation of energy flow** in an ecosystem.

Each trophic level has a certain mass of living material at a particular time called as the **standing crop**. The standing crop is measured as the mass of living organisms (**biomass**) or the number in a unit area.

These levels are divided into **producers** (first trophic level), **consumers** (second, third, and fourth trophic levels), and decomposers.

Producers, also known as **autotrophs**, make their own food. They make up the first level of every food chain. Autotrophs are usually plants or one-celled organisms.

All animals depend on **autotrophs** (directly or indirectly) for their food needs. They are hence called **consumers** and also **heterotrophs**.

The second trophic level consists of organisms that eat the producers. These are called **primary consumers**, or herbivores. Deer, turtles, and many types of birds are herbivores. **Secondary consumers** eat the herbivores. **Tertiary consumers** eat the secondary consumers. There may be more levels of consumers before a chain finally reaches its **top predator**. Top predators, also called **apex predators**, eat other consumers.

Detritivores and decomposers are the final part of food chains. Detritivores are organisms that eat non-living plant and animal remains. For example, **scavengers** such as vultures eat dead animals.

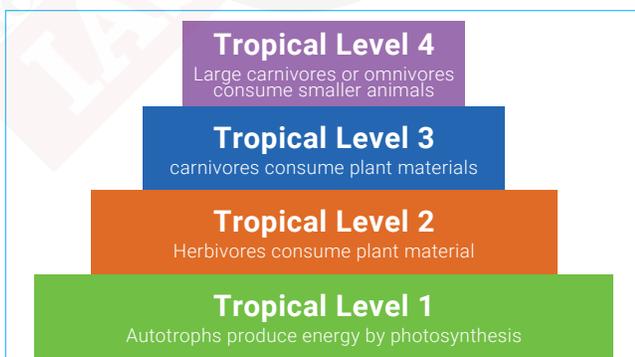
Decomposers like **fungi and bacteria** complete the food chain. They turn organic wastes, such as decaying plants, into inorganic materials, such as nutrient-rich soil. Decomposers complete the cycle of life, returning nutrients to the soil or oceans for use by autotrophs. This starts a whole new food chain.

Based on the **nature of first level of consumption**, food chains are classified into:

1. **Grazing food chain:** The consumers which start the food chain, **utilising the plant or plant part** as their food, constitute the grazing food chain. For example, in a terrestrial ecosystem, the grass is eaten by a caterpillar, which is eaten by lizard and lizard is eaten by a snake. In Aquatic ecosystem **phytoplankton** (primary producers) are eaten by zooplanktons which are eaten by fishes and fishes are eaten by pelicans.
2. **Detritus food chain:** The **detritus food chain** (DFC) begins with **dead organic matter**. It is made up of **decomposers** which are heterotrophic organisms, mainly **fungi and bacteria**. They meet their energy and nutrient requirements by degrading dead organic matter or detritus. These are also known as **saprotrophs**. Decomposers secrete **digestive enzymes** that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them. In an aquatic ecosystem, the grazing food chain is the major conduit for energy flow. As against this, in a terrestrial ecosystem, a much larger fraction of energy flows through the detritus food chain than through the grazing food chain.

Trophic level: In ecology, the trophic level is defined as the position that an organism occupies in a food chain - what it eats, and what eats it.

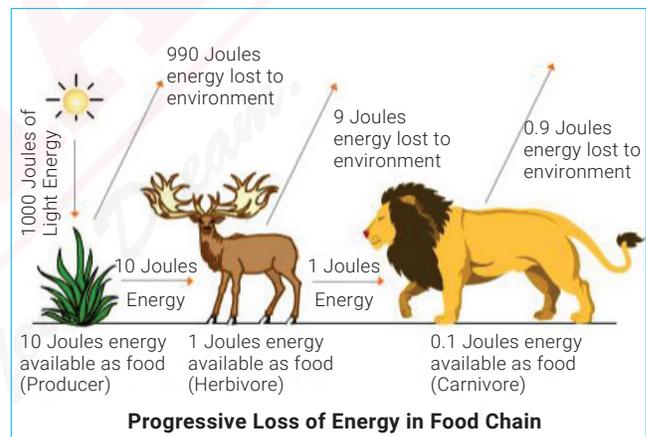
- The first trophic level known as the base of the ecosystem has the highest energy concentration which is transferred to the organisms at different trophic levels.



| Trophic Level | Where It Gets Food | Example |
|---------------------------------------|------------------------------|----------------------|
| 1st Trophic Level: Producer | Makes its own food | Plants make food |
| 2nd Trophic Level: Primary Consumer | Consumes producers | Mice eat plant seeds |
| 3rd Trophic Level: Secondary Consumer | Consumes primary consumers | Snakes eat mice |
| 4th Trophic Level: Tertiary Consumer | Consumes secondary consumers | Hawks eat snakes |

2.2.2 Ecological Efficiency & The 10% Law

Ecological efficiency describes the efficiency with which energy is **transferred from one trophic level to the next**, i.e. in unidirectional way from producers to consumers.



Energy transfer between trophic levels is **generally inefficient**, such that net production at one trophic level is **generally only 10% of the net production at the preceding trophic level**- this is known as the Ten percent law.

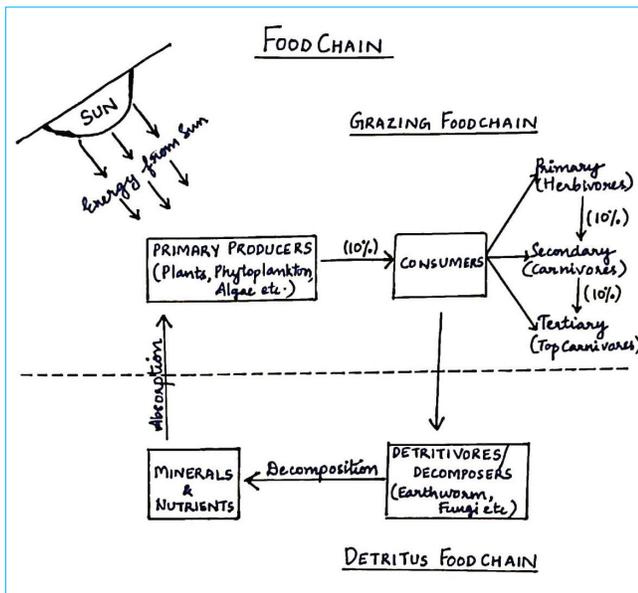
According to this law, during the transfer of organic food energy from one trophic level to the next higher level, **only about ten percent of the transferred energy is stored as flesh**. The remaining is lost during transfer, broken down in respiration, or lost to incomplete digestion by higher trophic level.

The **number of trophic levels** in the grazing food chain is restricted as the transfer of energy follows **10 per cent law**.

Generally the maximum number of trophic levels in a grazing food chain is **limited to 4 or 5**.

10% law is **not applicable to detritus food chain** as there

is very limited physical activities such as respiration in decomposers.

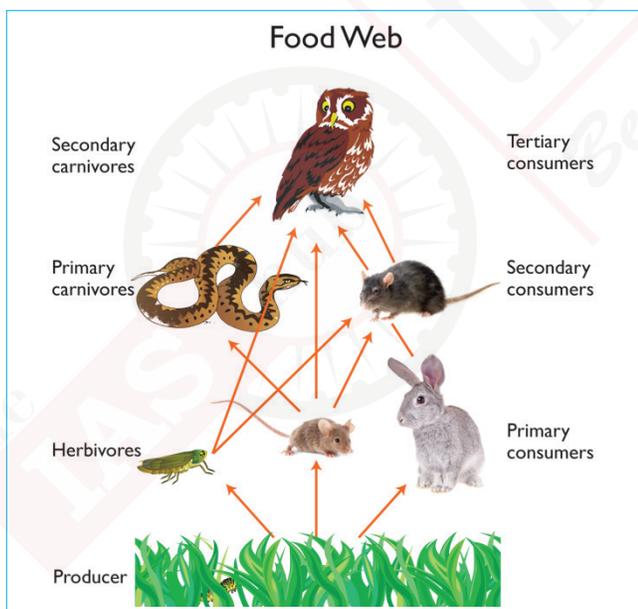


2.2.3 Food Web in an Ecosystem

Multiple interlinked food chains make a food web.

A food web consists of **all the food chains in a single ecosystem**.

Each living thing in an ecosystem is part of multiple food chains.



Each food chain is one possible path that energy and nutrients may take as they move through the ecosystem.

All of the interconnected and overlapping food chains in an

ecosystem make up a food web.

Food web **represents all the possible paths of energy flow** in an ecosystem.

If any of the intermediate food chains is removed, the succeeding links of the chain will be affected largely.

The food web **provides more than one alternative for food** to most of the organisms in an ecosystem and therefore increases their chance of survival.

2.2.4 Biomass & The Food Web

Food webs are **defined by their biomass**. Biomass represents the **accumulation of living matter / energy** in living organisms.

Autotrophs, the producers in a food web, convert the sun's energy into biomass. **Biomass decreases with each trophic level**. There is always more biomass in lower trophic levels than in higher ones.

Because biomass decreases with each trophic level, there are always more autotrophs than herbivores in a healthy food web. There are more herbivores than carnivores.

An ecosystem **cannot support a large number of omnivores** without supporting an even larger number of herbivores, and an even larger number of autotrophs.

A healthy food web has an abundance of autotrophs, many herbivores, and relatively few carnivores and omnivores. This balance helps the ecosystem maintain and recycle biomass.

Every link in a food web is connected to at least two others.

The biomass of an ecosystem depends on how balanced and connected its food web is. When one link in the food web is threatened, some or all of the links are weakened or stressed. The ecosystem's biomass declines.

2.2.5 Toxins Accumulation in a Food Chain

Biomass declines as it moves up through the trophic levels. However, some types of materials, especially **toxic chemicals, increase with each trophic level** in the food web. These chemicals usually collect in the fat of animals.

In order to accumulate within the bodies of consumers, a toxin should have the following **characteristics**:

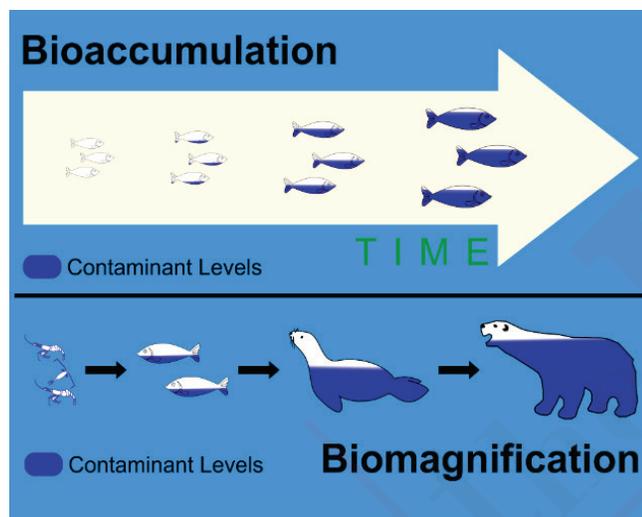
- Not soluble in water/ Fat soluble
- Chemically stable/ non-degradable
- Biologically active

These **non-degradable/persistent pollutants**, which cannot

be broken down by detritivores, not only move through the various trophic levels but also **remain in that trophic level for a very long duration.**

Movement of these pollutants involves two main processes:

1. **Bioaccumulation/Bioconcentration:** Bioaccumulation is the **gradual accumulation** of pollutants, chemicals 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.



| S. NO. | Bioaccumulation | Biomagnification |
|--------|--|--|
| 1 | Bioaccumulation refers to the accumulation of a toxic chemical in the tissue of a particular organism. | Biomagnification refers to the increased concentration of a toxic chemical the higher an animal is on the food chain. |
| 2 | Occurs in organisms | Occurs between trophic levels |
| 3 | Organisms take toxic chemicals into the body either through the skin or through ingestion, causing bioaccumulation | In biomagnification, toxic chemicals start in small amounts at the lower levels of the food chain and gradually increase in amount when it moves to higher levels. |

Mercury poisoning of Minamata Bay

In Japan, mass mercury poisoning (Minamata disease) was

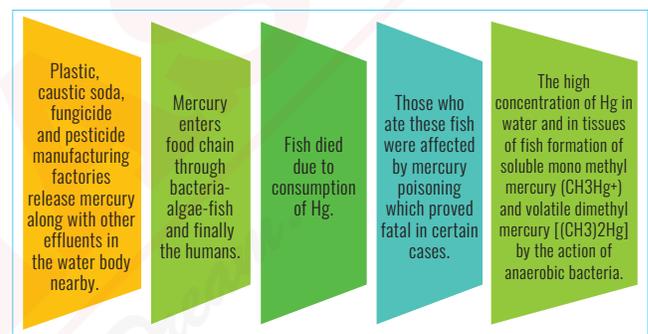
observed in 1960s, caused by eating fish from Minamata Bay which were contaminated with methyl mercury.

Largest source of mercury pollution is through aquatic animals such as fish which accumulate mercury as methyl mercury.

Mercury kills cells in the body and damages organs which come in contact with mercury and thus impairs their functioning. Inhalation of mercury vapours is more dangerous than its ingestion.

Chronic exposure causes lesions in the mouth and skin and neurological problems. Typical symptoms of mercury poisoning are irritability, excitability, loss of memory, insomnia, tremor and gingivitis.

The Minamata Disease



2. **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 life (long-lived), must not be soluble in water but must be soluble in fats. E.g. DDT. If the pollutant is soluble in water, it will be excreted by the organism. Pollutants that dissolve in fats are retained for a long time. Hence it is traditional to measure the amount of pollutants in fatty tissues of organisms such as fish.

For Example:

Diclofenac poisoning in Vultures:

DICLOFENAC DEBACLE

- > In 1991 diclofenac was introduced in the country
- > Animals were given injected doses of the drug
- > Vultures, which scavenged on carcasses of animals treated with diclofenac, suffered renal failure and died
- > From 4 crore, the number of vultures in the wild dwindled to 1 lakh in 2007
- > The Centre banned veterinary use in 2006, but cattle owners procured the drug illegally

- The major reason behind the vulture population getting nearly wiped out was the drug Diclofenac.
- It was found in the carcass of cattle on which the vultures feed.
- The drug was commonly administered to cattle to treat inflammation.
- Its veterinary use was banned in 2008 by the Government of India.
- Bioaccumulation (the gradual accumulation of substances, such as pesticides, or other chemicals in an organism) of Diclofenac caused kidney failure in Vultures, leading to death.
- Diclofenac is dangerously fatal for Vultures. Even 1% of it in carcass would kill the Vulture in a short time after it feeds such carcass.
- The poisoned carcasses were dumped to kill some local stray animals. But when vultures fed on them, it became one of the vital reasons leading to their death.

Minamata Convention on Mercury

It is a global treaty to protect human health and the environment from the adverse effects of mercury.

It was agreed at the fifth session of the Intergovernmental Negotiating Committee on mercury in Geneva, Switzerland. The Minamata Convention entered into force on 16 August 2017.

Objectives:

- Draws attention to a global and ubiquitous metal that, while naturally occurring, has broad uses in everyday objects and is released to the atmosphere, soil and water from a variety of sources.
- Controlling the anthropogenic releases of mercury throughout its lifecycle has been a key factor in shaping the obligations under the Convention.

Major highlights of the Minamata Convention:

- Ban on new mercury mines, the phase-out of existing ones, the phase out and phase down of mercury use in a number of products and processes.
- Control measures on emissions of mercury to air and on releases to land and water, and the regulation of the informal sector of artisanal and small-scale gold mining.
- The Convention also addresses interim storage of

mercury and its disposal once it becomes waste, sites contaminated by mercury as well as health issues.

Nitrogen Contamination of Ground Water

Nitrogen contaminates ground water in form of Dissolved nitrates.

Modern agriculture uses a lot of nitrogenous fertilizers and manures. This leads to increased levels of nitrates in the ground water as nitrates being soluble in water easily leach into the soil. Once the level exceeds 10 ppm it may become harmful.

Sources of nitrates include sewage, fertilizers, air pollution, landfills and industries

High level of nitrates causes:

- Blue baby disease (Methemoglobinemia) in children
- May form carcinogens
- Acceleration of eutrophication in surface waters

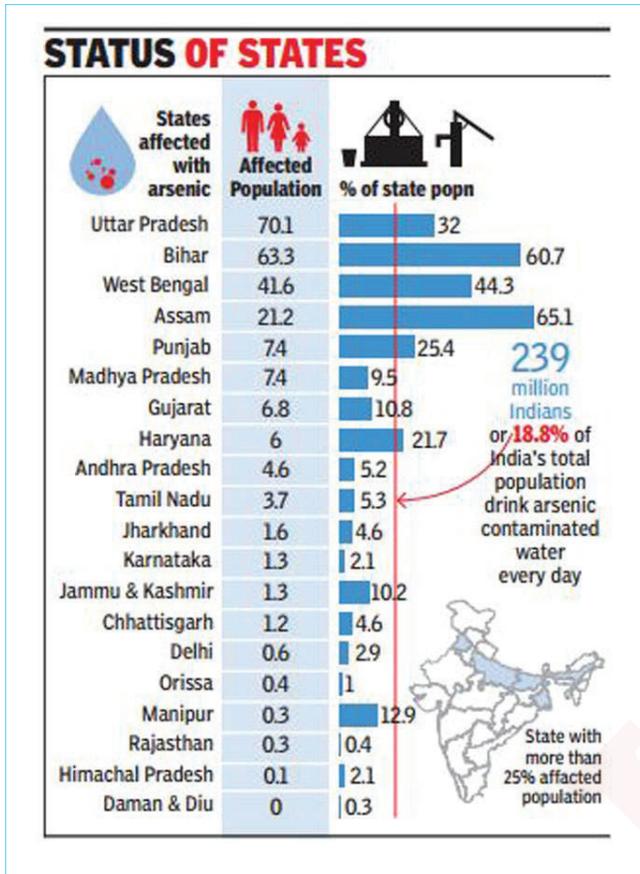
Nitrates can be removed from the water by processes like electrodialysis and reverse osmosis. Nitrites in the water can be oxidized to nitrates by introducing a strong oxidant like ozone in the water.

Blue Baby Syndrome Disease

- In areas where ground water is the only source of drinking water, this causes methemoglobinemia particularly in bottle fed infants who are very sensitive to this pollutant.
- Babies drink large quantities of water; water is used to mix powdered or concentrated recipes or juices.
- When water containing nitrates is consumed and it reaches intestines, the intestinal bacteria convert nitrates into nitrites.
- The nitrite ions combine with haemoglobin to form methaemoglobin which inhibits the oxygen carrying capacity of the blood causing a kind of anaemia known as methemoglobinemia.
- Due to reduced carrying capacity for oxygen the babies gradually acquire a blue tinge and hence the name "Blue Baby disease".

Arsenic Contamination of Ground Water

Arsenic contamination in groundwater is one of the most crippling issues in the drinking water scenario of India.



Causes of arsenic pollution in groundwater

- Use of insecticides and pesticides
- Waste disposal
- Use of arsenic-treated wooden poles for power grids
- The excessive lifting of groundwater for irrigation purposes

According to the latest report of the Central Ground Water Board (CGWB), 21 states across India have pockets with arsenic levels higher than the BIS stipulated permissible limit of 0.01 milligram per litre (mg/l).

The states along the Ganga-Brahmaputra-Meghna (GBM) river basin – Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam – are the worst affected by this human-amplified geogenic occurrence.

2.3 Ecological Pyramids

The pyramidal representation of **relationships between trophic levels** of different organisms based on their **ecological position** (producer to final consumer) is called as an ecological pyramid.

The pyramid consists of a number of horizontal bars depicting specific trophic levels. The length of each bar

represents the total number of individuals or biomass or energy at each trophic level in an ecosystem.

Producers form the base of the pyramid and the top carnivore forms the tip. Other consumer trophic levels are in between.

The ecological pyramids are of three categories:

- 1) Pyramid of numbers
- 2) Pyramid of biomass
- 3) Pyramid of energy or productivity

Any calculations of energy content, biomass, or numbers **has to include all organisms at that trophic level**. No generalisations we make will be true if we take only a few individuals at any trophic level into account.

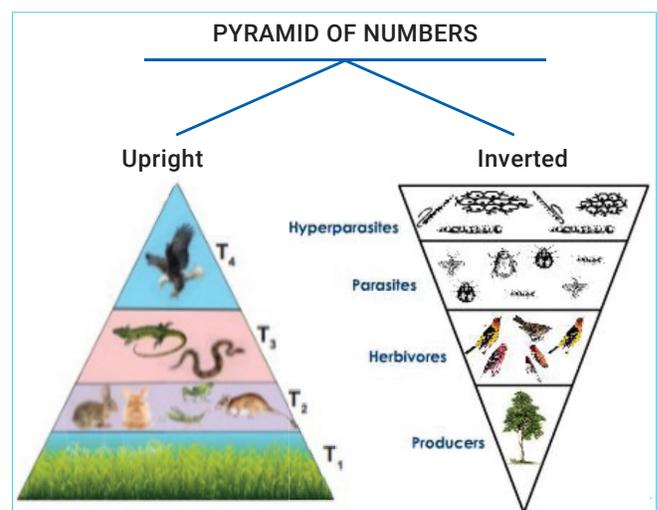
Also a given **organism may occupy more than one trophic level simultaneously**. It should be remembered that the trophic level represents a functional level, not a species as such.

A **given species may occupy more than one trophic level** in the same ecosystem at the same time; for example, a sparrow is a primary consumer when it eats seeds, fruits, peas, and a secondary consumer when it eats insects and worms.

There are certain **limitations** of ecological pyramids such as:

- It does not take into account the **same species belonging to two or more trophic levels**.
- It **assumes a simple food chain**, something that almost never exists in nature.
- It does **not accommodate a food web**.
- **Saprophytes are not given any place** in ecological pyramids even though they play a vital role in the ecosystem.

2.3.1 Pyramid of Numbers

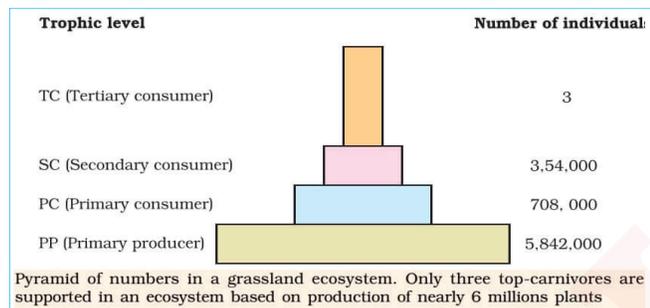


A graphical representation in the form of a pyramid showing the feeding relationship and the number of organisms at each trophic level.

Depending upon the size and nature of the ecosystem, **the pyramid of numbers can be up-righted as well as inverted.**

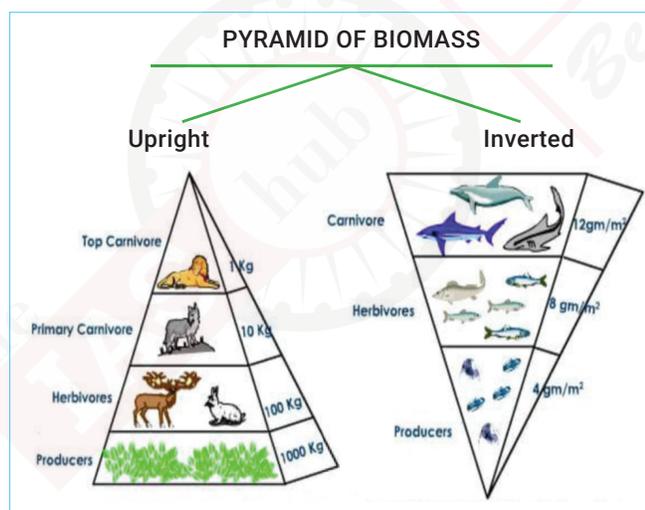
Sometimes the pyramid of numbers does not look like a pyramid at all. This could happen if the producer is a large plant such as a tree, or if one of the animals is very small. i.e. tree dominated ecosystems.

It is very difficult to count all the organisms, in a pyramid of numbers and so the pyramid of number does not completely define the trophic structure for an ecosystem.



2.3.2 Pyramid of Biomass

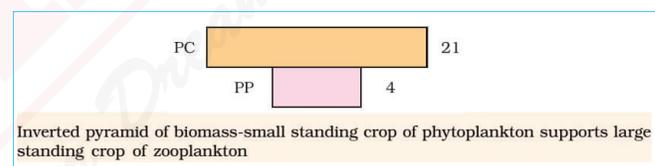
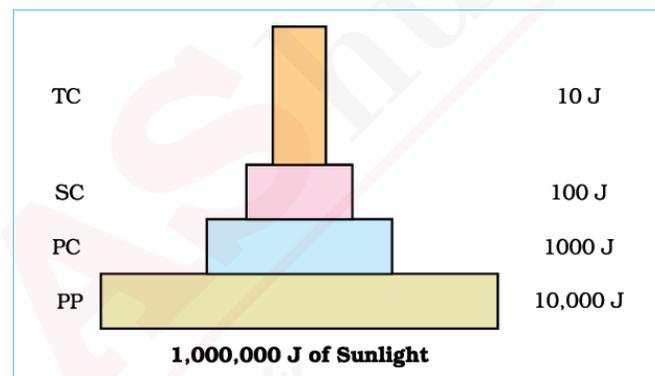
Pyramid of biomass is usually determined by collecting **all organisms occupying each trophic level separately and measuring their dry weight.** Each trophic level has a certain mass of living material at a particular time called the standing crop.



For **most ecosystems on land**, the pyramid of biomass has a large base of primary producers with a smaller trophic level perched on top. The biomass of producers (autotrophs) is at the maximum. The biomass of next trophic level i.e. primary consumers is less than the producers. The biomass

of next higher trophic level i.e. secondary consumers is less than the primary consumers. The top, high trophic level has very less amount of biomass.

In contrast, in many aquatic ecosystems, the pyramid of biomass may assume an inverted form. (In contrast, a pyramid of numbers for the aquatic ecosystem is upright). This is because the producers are tiny phytoplankton that grows and reproduces rapidly. Here, the pyramid of biomass has a small base, with the consumer biomass at any instant exceeding the producer biomass and the pyramid assumes an inverted shape.

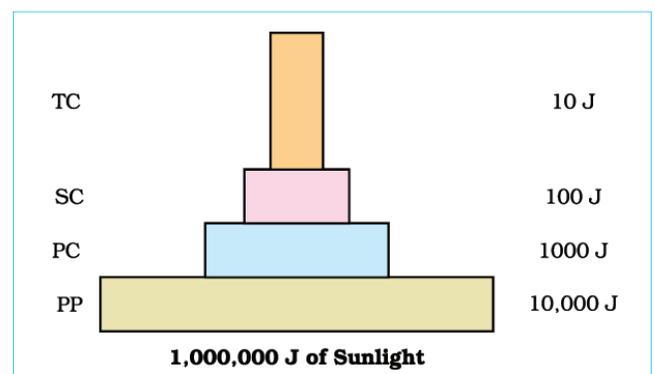


2.3.3 Pyramid of Energy/Productivity

A pyramid of energy is a graphical representation of the **amount of energy at each trophic level of a food chain.**

Each level should be roughly one tenth of the size of the preceding level (10% law).

An energy pyramid represents the amount of energy at each trophic level and loss of energy at each transfer to another trophic level. **Hence the pyramid is always upward, with a large energy base at the bottom.**



2.4 Process of Decomposition

Decomposers break down **complex organic matter into inorganic substances like carbon dioxide, water and nutrients** and the process is called decomposition.

Dead plant remains such as leaves, bark, flowers and dead remain of animals, including faecal matter, constitute **detritus**, which is the raw material for decomposition.

Detritus: Detritus is defined as matter composed of leaves and other plant parts, animal remains, waste products, and other organic debris that falls onto the soil or into bodies of water from surrounding terrestrial communities.

Microorganisms (such as bacteria or fungi) break down detritus, and this microorganism-rich material is eaten by invertebrates, which are in turn eaten by vertebrates.

Many freshwater streams have detritus rather than living plants as their energy base. Above ground and Below ground Detritus.

Detritus is of two types:

- Above ground Detritus: consists of leaf litter, Plant parts, dead animals, and excreta.
- Below ground Detritus: consists of mainly dead roots and underground dead animals.

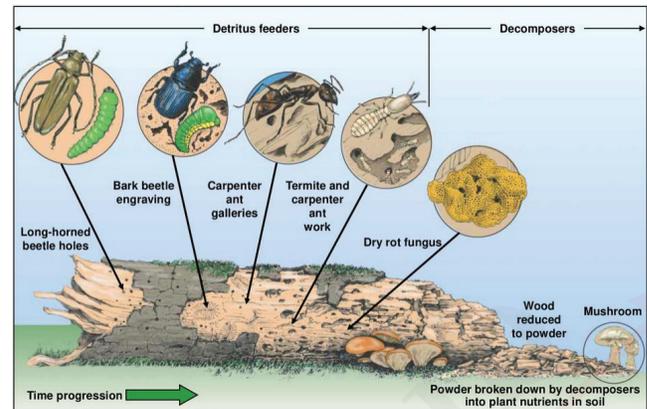
In terrestrial ecosystems it is present as leaf litter and other organic matter that is intermixed with soil, which is denominated **"soil organic matter"**.

The detritus of aquatic ecosystems is organic material that is suspended in the water and accumulates in depositions on the floor of the body of water; when this floor is a seabed, such a deposition is denominated **"marine snow"**.

Detritivores (also known as detritivores) are heterotrophs that obtain nutrients by consuming detritus. By doing so, all these detritivores contribute to decomposition and the nutrient cycles. In simple words, these are detritus feeding invertebrates.

Typical detritivores includes millipedes, springtails, woodlice, dung flies, slugs, many terrestrial worms, sea stars, sea cucumbers, fiddler crabs etc.

They should be distinguished from other **decomposers**, such as many species of bacteria, fungi and protists, which **are unable to ingest discrete lumps of matter**, but instead live by absorbing and metabolizing on a molecular scale (saprotrophic nutrition).



Detritivores are an important aspect of many ecosystems. They can live on any type of soil with an organic component, including marine ecosystems, where they are termed interchangeably with **bottom feeders**.

In food webs, detritivores generally play the roles of **decomposers**. Detritivores are often eaten by consumers and therefore commonly play important roles as recyclers in ecosystem energy flow and biogeochemical cycles.

The important steps in the process of decomposition are

1. **Fragmentation:** detritivores (e.g., earthworm) break down detritus into smaller particles. This process is called fragmentation.
2. **Leaching:** by the process of leaching, water-soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
3. **Catabolism:** bacterial and fungal enzymes degrade detritus into simpler inorganic substances. This process is called as catabolism.
4. **Humification:** humification leads to accumulation of a dark coloured amorphous substance called humus that is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Being colloidal in nature it serves as a reservoir of nutrients. Humus is highly resistant to microbial action and undergoes extremely slow decomposition.
5. **Mineralisation:** the humus is further degraded by some microbes and release of inorganic nutrients occur by the process known as mineralisation.

It is important to note that all the above steps in decomposition **operate simultaneously** on the detritus.

Decomposition is largely an **oxygen-requiring** process.

The rate of decomposition is controlled by **chemical composition** of detritus and climatic factors. In a particular

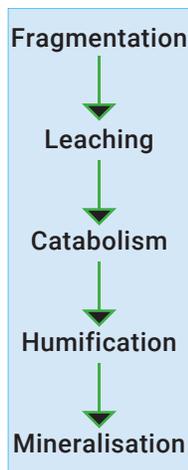
climatic condition, decomposition rate is slower if detritus is rich in lignin and chitin, and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.

Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes.

Warm and moist environment favour decomposition whereas **low temperature and anaerobiosis (lack of oxygen)** inhibit decomposition resulting in build-up of organic materials.

Detritus which is rich in Nitrogen decomposes faster, whereas lignin, pectin and chitin rich detritus undergoes slow decomposition.

Process of decomposition leads to release of Carbon dioxide and Water vapours, so regulating process of decomposition in agricultural fields can limit the release of GHGs in environment.



The **rate of biomass production is called productivity**.

It can be divided into **gross primary productivity (GPP)** and **net primary productivity (NPP)**.

Gross primary productivity of an ecosystem is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilised by plants in respiration. **Gross primary productivity minus respiration losses (R), is the net primary productivity (NPP)**.

Net primary productivity is the available biomass for the consumption to heterotrophs (herbivores and decomposers). The largeness of primary productivity depends on the photosynthetic capacity of producers and the existing environmental conditions, such as solar radiation, temperature and soil moisture.

High levels of NPP can be witnessed in nature tropical rain forests.

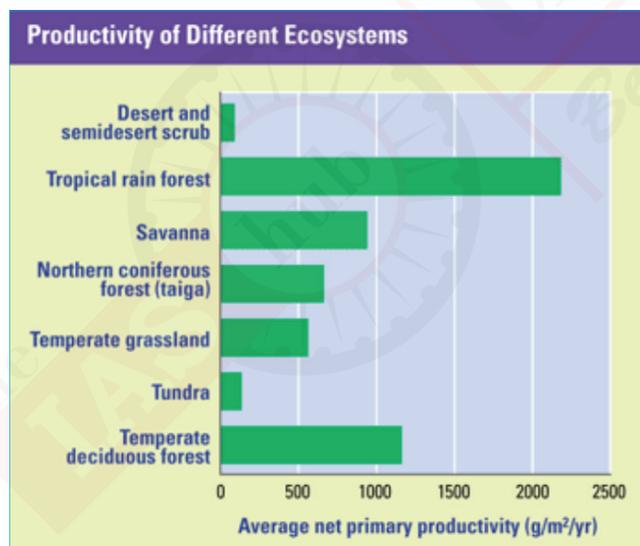
Sequence of Net Primary Productivity of various Ecosystems

The highest primary productivity is found in Tropical Forests, Estuaries and Swamps/ Marshes.

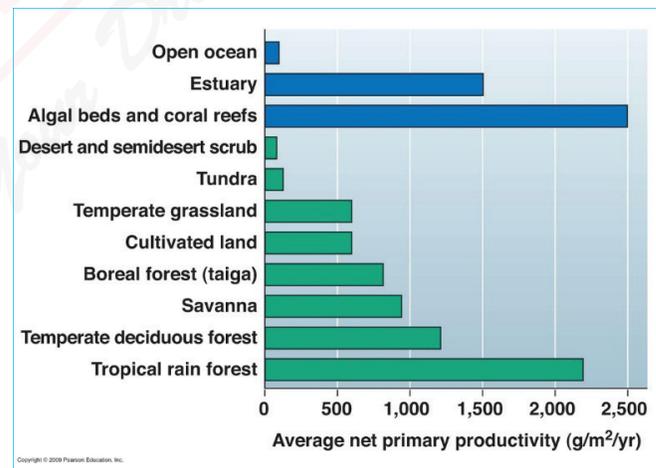
Each of them produces around 9000 Kcal per meter² per year.

2.5 Productivity in Ecosystems

A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.



Primary production in an ecosystem is defined as the amount of biomass or organic matter produced per unit area over a time period by plants during photosynthesis. It is expressed in terms of weight (g-m⁻²) or energy (kcal m⁻²).



- Tropical Rainforests have high primary productivity because of availability of plenty of solar light and water.
- A typical estuary has high primary productivity because it is shallow (gets plenty of sunlight) and has turbulent water (which brings the nutrient rich material from sea bed).
- Swamps and Marshes have high primary productivity because they have lots of nutrients and sunlight.
- After Tropical Rainforests, Estuaries and Swamps /

Marshes, the highest primary productivity is found in coral reefs, algal beds and temperate forests. Least primary productivity is found in cold and hot deserts including tundra.

In **tropical conditions**, primary productivity may remain continuous throughout the year, provided adequate soil moisture remain available.

While **in temperate regions**, primary productivity is limited by cold climate and a short snow-free growing period during the year.

Secondary productivity is defined as the rate of formation of new organic matter by consumers.

It reflects the utilization part only. i.e. utilization of energy produced by primary producers at the level of consumers for generation of consumer biomass.

Primary productivity depends on the plant species inhabiting a particular area. It also depends on a variety of environmental factors, availability of nutrients and photosynthetic capacity of plants. **Therefore, it varies in different types of ecosystems.**

Factors Affecting the Productivity in Ecosystem

1. Solar radiation and temperature
2. Moisture (soil moisture, precipitation rate, transpiration etc.)
3. Mineral nutrition
4. Biotic activities like grazing, consumption and diseases of primary producers etc.
5. Impact of human populations
6. In aquatic systems, productivity is generally limited by light, which decreases with increasing water depth.
7. In deep oceans nutrients often become limiting for productivity.
8. Nitrogen is most important nutrient limiting productivity in marine ecosystems.

2.6 Ecological Succession

2.6.1 Definition

The **characteristics of different species** in ecosystems and their response to environment vary from an individual

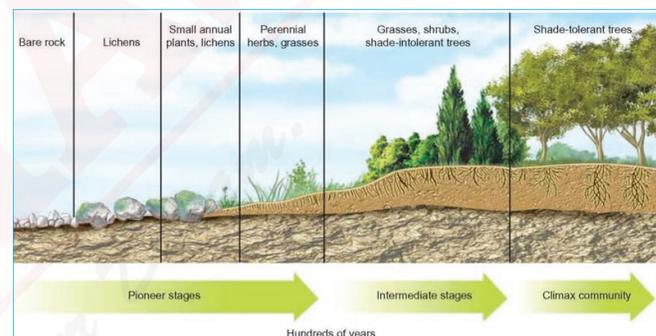
response. An important characteristic of all communities is that **composition and structure constantly change** in response to the changing environmental conditions. This change is orderly and sequential, parallel with the changes in the physical environment. This process by which communities of plant and animal species in an area are **replaced or changed into another over a period of time** is known as ecological **succession**.

Succession is a **universal process of directional change in vegetation**, on an ecological time scale.

Succession occurs due to large scale changes or destruction (natural or manmade).

The process involves a progressive series of changes with one community replacing another until a stable, mature, **climax community** develops.

2.6.2 Stages of Succession



The first plant to colonize an area is called the **pioneer community**. E.g. Lichens, Fungi etc.

The final stage of succession is called the **climax community**. E.g. Tropical Rainforests

A climax community is stable, mature, more complex and long-lasting. A pioneer community must be with shorter lifespan and low stability.

The entire sequence of communities that successively change in a given area are 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, increase in the number of species and organisms as well as an increase in the total biomass.

Description of ecological succession usually focuses on changes in vegetation. However, these vegetational changes in turn affect food and shelter for various types of animals. Thus, as succession proceeds, the numbers and types of animals and decomposers also change.

The present day communities in the world have come to be because of succession that has occurred over millions of years since life started on earth. Actually **succession and evolution would have been parallel** processes at that time.

2.6.3 Types of Succession based on Order of Occurrence

Succession is a process that starts where no living organisms are there – these could be areas where no living organisms ever existed, say bare rock; or in areas that somehow, lost all the living organisms that existed there. The former is called **primary succession**, while the latter is termed **secondary succession**.

Examples of areas where primary succession occurs are newly cooled lava, bare rock, newly created pond or reservoir.

The **establishment of a new biotic community is generally slow**. Before a biotic community of diverse organisms can become established, there must be soil. Depending mostly on the climate, it takes natural processes several hundred to several thousand years to produce fertile soil on bare rock.

Secondary succession begins in areas where natural biotic communities have been destroyed such as in abandoned farm lands, burned or cut forests, lands that have been flooded. Since some soil or sediment is present, succession is faster than primary succession. Shifting cultivation/slash burn agriculture is also an example of secondary succession.

At any time during primary or secondary succession, natural or human induced disturbances (fire, deforestation, etc.), can convert a particular seral stage of succession to an earlier stage. Also such disturbances create new conditions that encourage some species and discourage or eliminate other species.

2.6.4 Types of Succession in Plants

Based on the nature of the habitat – whether it is water (or very wet areas) or it is on very dry areas – succession of plants is called **hydrarch or xerarch**, respectively.

Hydrarch succession takes place in wetter areas and the successional series progress from hydric to the mesic conditions. As against this, **xerarch succession** takes place in dry areas and the series progress from xeric to mesic conditions.

Hence, **both hydrarch and xerarch successions lead to**

medium water conditions (mesic) – neither too dry (xeric) nor too wet (hydric).

2.6.5 Types of Succession based on Agents of Change

When succession is brought about by **living inhabitants** of that community itself, the process is called **autogenic succession**, while change brought about by **outside forces** is known as **allogenic succession**.

Autogenic succession is driven by the biotic components of an ecosystem.

Allogenic succession is driven by the abiotic components (fire, flood) of the ecosystem.

2.7 Ecosystem Services

Healthy ecosystems are the base for a wide range of economic, environmental and aesthetic goods and services. The **products of ecosystem processes are named as ecosystem services**.

While scientists and environmentalists have discussed ecosystem services implicitly for decades, **the Millennium Ecosystem Assessment (MA)** in the early 2000s popularized this concept.

As per the 2006 Millennium Ecosystem Assessment (MA), ecosystem services are **“the benefits people obtain from ecosystems”**. There, ecosystem services are grouped into four broad categories:

1. **Provisioning Services**
2. **Regulating Services**
3. **Supporting Services**
4. **Cultural Services**

By 2010, there had evolved various working definitions and descriptions of ecosystem services in the literature. To prevent double counting in ecosystem services audits, for instance, **The Economics of Ecosystems and Biodiversity (TEEB)** replaced “Supporting Services” in the MA with “Habitat Services” and “ecosystem functions”, defined as “a subset of the interactions between ecosystem structure and processes that underpin the capacity of an ecosystem to provide goods and services”.

Ecosystem services are referred to as **“GDP of the poor”** as poor people/forest dwellers are dependent upon natural resources/forests for their survival.

| Provisioning Services | Regulating Services | Supporting Services | Cultural Services |
|-----------------------|--|---------------------|---|
| Food | Carbon Sequestration | Nutrient Cycles | Spiritual Services |
| Raw Materials | Climate Regulation | Oxygen Production | Historical Services |
| Genetic Resources | Predation Regulates Prey Populations | | Recreational Experiences Including Ecotourism |
| Water Purity | Waste Decomposition And Detoxification | | Science And Education |
| Biogenic Minerals | Pest And Disease Control | | Therapeutic Services |
| Energy | Flood Protection | | |
| Ornamental Services | | | |

The Millennium Ecosystem Assessment (MA)

The Millennium Ecosystem Assessment (MA) was called for by the **United Nations Secretary-General Kofi Annan in 2000**. Initiated in 2001, the objective of the MA was **to assess the consequences of ecosystem change for human well-being** and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being. The MA has involved the work of more than **1,360 experts worldwide**. Their findings, contained in five technical volumes and six synthesis reports, provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such as **clean water, food, forest products, flood control, and natural resources**) and the options to restore, conserve or enhance the sustainable use of ecosystems.

The Economics of Ecosystems and Biodiversity (TEEB)

Launched at the **G8 meeting** of environment ministers in Potsdam, Germany, in 2007, TEEB is funded by the European Commission, Germany, the United Kingdom, Norway, the Netherlands and Sweden, and **managed by the United Nations Environment Programme as part of its Green Economy Initiative (GEI)**, seeks to draw attention to the global economic benefits of biodiversity, to highlight the growing costs of biodiversity loss and ecosystem degradation, and to draw together expertise from the fields of science, economics and policy to enable practical actions moving forward.

Prelims Grasp

Food Chain

1. With reference to food chains in ecosystems, consider the following statements:

1. A food chain illustrates the order in which a chain of organisms feed upon each other.
2. Food chains are found within the populations of a species.
3. A food chain illustrates the numbers of each organism which are eaten by others.

Which of the statements given above is/are correct?

- (a). 1 only
- (b). 1 and 2 only
- (c). 1, 2 and 3
- (d). None

2. Which one of the following is the correct sequence of a food chain?

- (a). Diatoms-Crustaceans-Herrings
- (b). Crustaceans-Diatoms-Herrings
- (c). Diatoms-Herrings-Crustaceans
- (d). Crustaceans-Herrings- Diatoms

Productivity

3. Which one of the following is the correct sequence of ecosystems in the order of decreasing productivity?

- (a) Oceans, lakes, grasslands, mangroves
- (b) Mangroves, oceans, grasslands, lakes
- (c) Mangroves, grasslands, lakes, oceans
- (d) Oceans, mangroves, lakes, grasslands

Succession

4. In the grasslands, trees do not replace the grasses as a part of an ecological succession because of:

- (a) insects and fungi
- (b) limited sunlight and paucity of nutrients
- (c) water limits and fire
- (d) None of the above

Mains Grasp

Ecosystem Services

What do you understand by ecosystem services? Enumerate the challenges faced by the major ecosystems in India in providing the ecosystem services. (15 Marks, 250 words)

Answers

1) a 2) c 3) c 4) c