SIVARAJAVEL IAS ACADEMY

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METIS

Mentoring and Enabling Through Intelligent Support system

ENVIRONMENT BIO DIVERSITY & DISASTER MANAGEMENT

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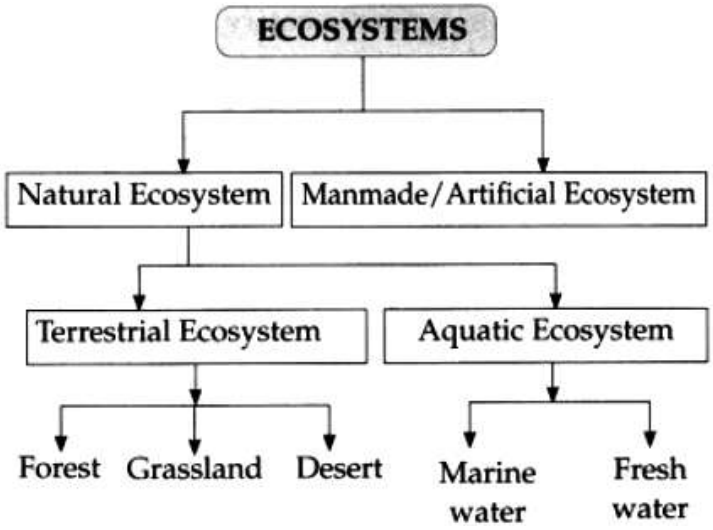
Ecosystem:

Types of Ecosystems:



Natural Ecosystems:

These ecosystems are capable of operating and maintaining themselves without any major interference by man.

A classification based on their habitat can further be made:

- **Terrestrial ecosystems:** forest, grassland, and desert.
- **Aquatic ecosystems:** freshwater ecosystem, viz. pond, lake, river, and marine ecosystems, viz. ocean, sea or estuary. Aquatic ecosystems are ecosystems present in a body of water**.**

These can be further divided into two types, namely:

- **Freshwater Ecosystem**
- **Marine Ecosystem**

Freshwater Ecosystem

- The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams, and wetlands.
- These have no salt content in contrast with the marine ecosystem.

Marine Ecosystem:

- The marine ecosystem includes seas and oceans.
- These have a larger salt content and greater biodiversity in comparison to the freshwater ecosystem.

Artificial Ecosystem:

These are maintained by man. These are manipulated by man for different purposes, e.g., croplands, artificial lakes and reservoirs, townships, and cities.

Ecology:

Ecology is the study of the relationships between living organisms, including humans, and their physical environment; it seeks to understand the vital connections between plants and animals and the world around them.

Also, Ecology also provides information about the benefits of ecosystems and how we can use Earth's resources in ways that leave the environment healthy for future generations.

The term **"ecology"** was coined by the **German zoologist, Ernst Haeckel, in 1866**

Also, ancient Indian texts have references to Ecological principles as follows:

The classical texts of the Vedic Period such as the Vedas, the Samhitas, the Brahmanas and the Aranyakas-Upanishads contain references to ecological concepts.

Further, a conceptual understanding of ecology is found in the broader details of study, including:

- life processes explaining adaptations.
- distribution and abundance of organisms
- the movement of materials and energy through living communities
- the successional development of ecosystems, and
- the abundance and distribution of biodiversity in context of the environment

Components:

Ecology mainly involves the study of biotic and abiotic factors with the environment.

Biotic components include the living factors of an ecosystem.

Examples include bacteria, animals, birds, fungi, plants, etc.

Abiotic components include the non-living chemical and physical factors of an ecosystem.

Examples include sunlight, soil, air, moisture minerals etc.

Types of Ecology:

Microbial Ecology:

Microbial ecology looks at the smallest fundamental levels of life, that is, the cellular level.

Here, the connections are made between microbes and their relationships with each other and their environments.

This is particularly important in the analysis of evolutionary connections and events leading to existence.

Organism/Behavioural Ecology:

This is the study of the organism at its fundamental levels and can encompass microbial ecology.

In this type of ecology, the main goal is to understand the organism's behaviours, adaptations for such behaviours, reason for those behaviours as explained through the lens of evolution, and the way all these aspects mesh together.

Population Ecology:

Population ecology focuses on the population, defined as a group of organisms of the same species living in the same area at the same time.

Here, attention is given to things such as population size, its density, the structure of the population, migration patterns, and the interaction between organisms of the same population.

Community Ecology:

Community ecology looks at the community, defined as all the populations that live in each area. This includes all the different species populations.

The focus here is usually on the interactions between the different species and how their numbers and sizes all mesh together and how change in one population change the dynamic of the whole community.

Ecosystem Ecology:

Ecosystem ecology makes a unique contribution to understanding ecology by adding abiotic (non-living) factors to the items analysed, alongside the biotic (living) factors involved.

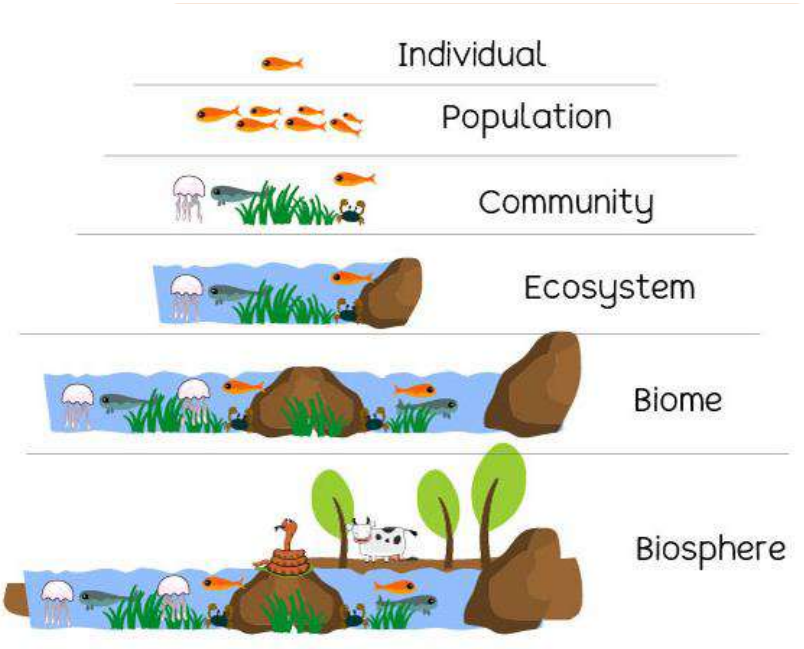
This interaction therefore involves all aspects of the environment and how they interact.

Global Ecology (Biosphere):

The global ecology is principally important in understanding all the ecosystems affecting the entire globe.

This includes all the different biomes, with considerations of aspects such as climate and other environmental geography.

Importance of Ecology:



Levels of organisation in an ecosystem

Levels of Organisation

- **Individual, Species, Organism**
  - Organism in this level can act or function independently.
  - Here, Individuals do not breed with individuals from other groups.
- **Population:**
  - A group of individuals of a given species that live in a specific geographic area at a given time.
  - Populations include individuals of the same species but may have different genetic makeup such as hair/eye/skin colour and size between themselves and other populations.
- **Community:**
  - It includes all the populations in a specific area at a given time. A community includes populations of organisms of different species.
  - These are generally named after the dominant plant species.
- **Ecosystem:**
  - Ecosystems include more than a community of living organisms (biotic) interacting with the environment (abiotic)
  - Everything that lives in an ecosystem is dependent on the other species and elements that are also a part of the ecological community.
- **Biome**
  - A Biome is a set of ecosystems sharing similar characteristics with their abiotic factors adapted to their environments.
- **Biosphere**
  - When we consider all the different biomes, each blending into the other, with all humans living in many different geographic areas, we form a huge community of humans, animals and plants, and micro-organisms in their defined habitats. A biosphere is the sum of all the ecosystems established on planet Earth.

Principles of Ecology:

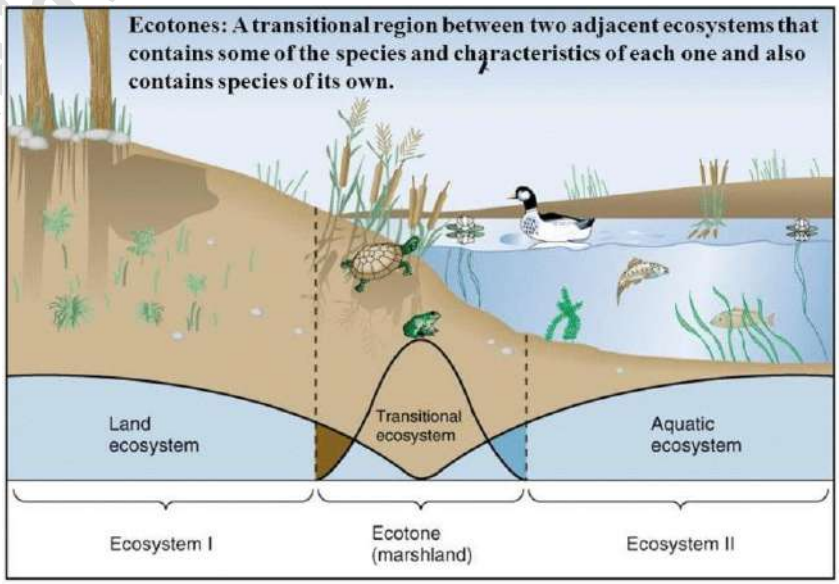
- **Evolution organizes ecological systems into hierarchies.**
  - Individual organisms combine into populations, populations combine into species, species combine into higher taxa like genera and phyla.
  - Each can be characterized by its abundance and diversity (number of kinds) in each ecosystem or study plot.
- **The sun is the ultimate source of energy for most ecosystems.**
  - Life runs on the carbon-rich sugars produced by photosynthesis; every ecosystem's sugar output depends on how much solar energy and precipitation it receives.
- **Organisms are chemical machines that run on energy.**
  - The laws of chemistry and physics limit the ways each organism makes a living and provide a basic framework for ecology.
  - The supply of chemical elements and the sugars needed to fuel their assembly into organisms limit the abundance and diversity of life.
- **Chemical nutrients cycle repeatedly while energy flows through an ecosystem.**

- The atoms of elements like Carbon, Nitrogen and Sodium go back and forth from spending time in living to spending time in dead parts of an ecosystem.
- But the photons of solar energy can be used only once before they are lost to the universe.

- **Organisms interact—do things to each other—in ways that influence their abundance.**
  - Individual organisms can eat one another, compete for shared resources, and help each other survive.
  - Each pair of species in an ecosystem can be characterized by the kind and strength of these interactions.
- **Ecosystems are organized into webs of interactions.**
  - The abundance of a population is influenced by the chains of interactions that connect it to the other species in its ecosystem.
  - This often leads to complex behaviour, and a key challenge in ecology is to determine what patterns of abundance and diversity can be predicted.
- **Human populations have an outsized role in competing with, preying upon, and helping other organisms.**
  - Humans are one of millions of species embedded in Earth's ecosystems. The ability of humans to change the planet, abetted by our large population size and technological prowess, increases our ability to shape the biosphere's future.
- **Ecosystems provide essential services to human populations.**
  - These include products like timber, fibre, and food, regulating water and air quality, and cultural benefits like recreation. A key goal of ecology is to use the above principles to preserve ecosystem services.

Ecotone:

- **An Ecotone is a transitional area of vegetation between two different plant communities, such as forest and grassland.**
  - **It has some of the characteristics of each bordering biological community and often contains species not found in the overlapping communities.**



Features:

- An ecotone can have a sharp vegetation transition, with a distinct line between two communities.
  - For example, a change in colours of grasses or plant life can indicate an ecotone.

- A change in physiognomy (physical appearance of a plant species) can be a key indicator.
  - Example, Water bodies, such as estuaries, can have a region of transition, and the boundary is characterized by the differences in heights of the plant species present in the areas because this distinguishes the two areas' accessibility to light.
- A change of species can signal an ecotone.
  - There will be specific organisms on one side of an ecotone or the other.
- The abundance of introduced species in an ecotone can reveal the type of biome or efficiency of the two communities sharing space.
  - Because an ecotone is the zone in which two communities integrate, many different forms of life must live together and compete for space.
  - Therefore, an ecotone can create a diverse ecosystem.
- An ecotone may exist along a broad belt or in a small pocket, such as a forest clearing, where two local communities blend together.
  - The influence of the two bordering communities on each other is known as the edge effect.

Examples of Ecotone:

- The Mangrove Forests represent an ecotone between Marine and Terrestrial ecosystem.
- The Grasslands represent an ecotone between desert and forest.
- The Estuaries represent an ecotone between saltwater and freshwater.

Significance of ecotones:

- Ecotones are the biological analogues of buffer states. They act as buffer regions when catastrophic conditions strike and protect the adjacent ecosystem from any prospective dangers.
  - For instance, if a tsunami hits a coast, it's usually the mangrove vegetation that acts as the shock absorbers. It prevents a massive amount of danger from infiltrating the terrestrial region.
- Ecotones act as biodiversity hotspots between two ecosystems. As such, this area is of high environmental and scientific importance.
  - Because this region borders two well-defined ecosystems, it promotes gene flow from one community to another, thereby giving rise to interesting variations. As such, ecotones hold evolutionary significance for researchers.

Ecological Niche:

- An ecological niche refers to the interrelationship of a species with all the biotic and abiotic factors affecting it.
- It describes how an organism or population responds to the distribution of resources and competitors (for example, by growing when resources are abundant, and when predators, parasites and pathogens are scarce) and how it in turn alters those same factors (for example, limiting access to resources by other organisms, acting as a food source for predators and a consumer of prey)
- A Niche is unique for a species, which means no two species have exact identical Niches.

Niche Formation:

- Both **abiotic and biotic factors** help shape the niche of an ecosystem.
  - Abiotic factors, such as temperature, climate, and soil type, of an ecosystem will help form the niches, while **natural selection** works to set which niches would be favoured and not.
  - Through time, the species eventually develop special features

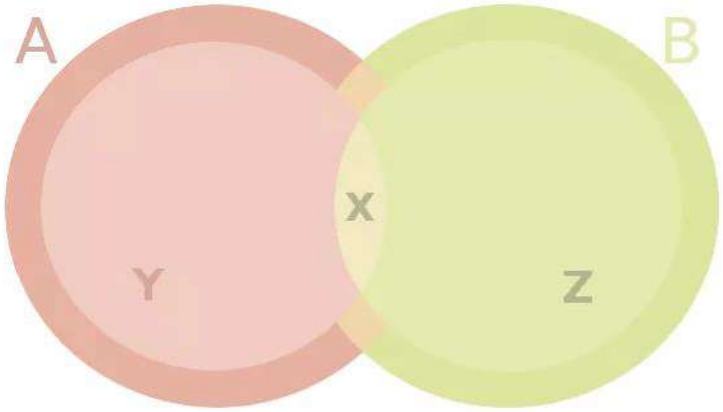


Figure 1: The different ecological niches. A and B represent the fundamental niches of species 1 and species 2, respectively. The *Y* refers to the realized niche of species 1 and the *Z* is the realized niche of species 2. The *X* represents the *niche overlap* wherein competition occurs among species.

that help them adapt to their environment.

Examples:

- **Xerophytic plants**
  - These have developed several adaptations to living in dry ecological niches.
  - The adaptations have evolved to help save water stored in the plant and to prevent water loss.
  - Other adaptations that xerophytic plants use include the ability to move or fold up their leaves, dropping their leaves during dry periods, a waxy coating to prevent evaporation (called the cuticle) and thick hairy leaf coverings.
  - Plants usually open their stomata during the day and close them at night. Succulents do the opposite to reduce water loss during the heat of the day.

Functions of Ecosystem:

- **Ecosystem functions** can be defined by "the ecological processes that control the fluxes of energy, nutrients and organic matter through an environment".
- 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 following aspects are considered:

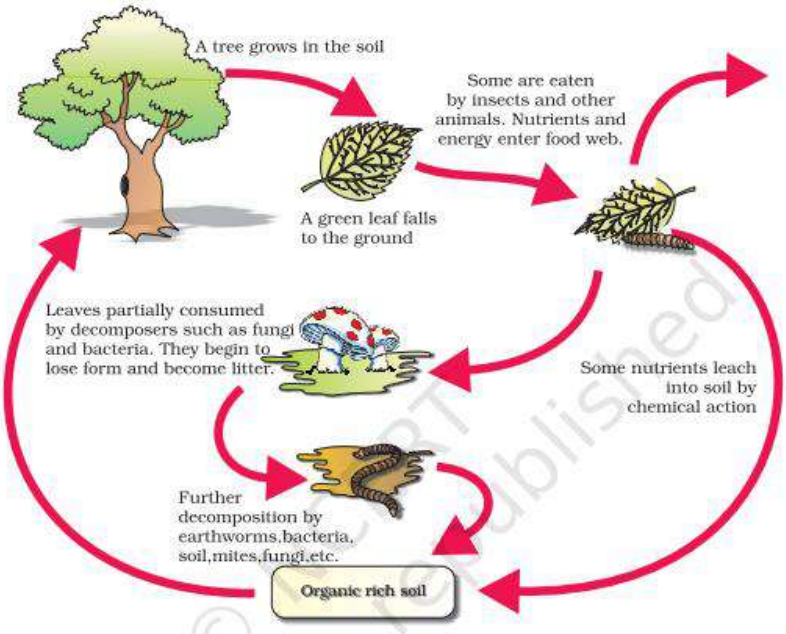
1. **PRODUCTIVITY:**

- A constant input of solar energy is the basic requirement for any ecosystem to function and sustain.
- **Primary production** is defined as the amount of biomass or organic matter produced per unit area over a time by plants during photosynthesis. It is expressed in terms of weight energy (kcal m^2).
  - The rate of biomass production is called **productivity.**
- It can be divided into
  - **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)

- 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. The annual net primary productivity of the whole biosphere is approximately 170 billion tons (dry weight) of organic matter.

2. **DECOMPOSITION:**
   1. Decomposers break down complex organic matter into inorganic substances like carbon dioxide, water and nutrients and the process is called decomposition.
   2. Dead plant remains such as leaves, bark, flowers and dead remain of animals, including faecal matter, constitute **detritus**, which are the raw material for decomposition.

- The important steps in the process of decomposition are fragmentation, leaching, catabolism, humification and mineralisation.
  1. Detritivores (e.g., earthworm) break down detritus into smaller particles. This process is called **fragmentation**.
  2. By the process of **leaching**, water soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts.
  3. Bacterial and fungal enzymes degrade detritus into simpler inorganic substances. This process is called as **catabolism.**
  4. Humification and mineralisation occur during decomposition in the soil.
- **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.
- The humus is further degraded by some microbes and release of inorganic nutrients occur by the process known as **mineralisation.**
- Decomposition is largely an oxygen-requiring process.
- **Temperature and soil moisture** are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes.

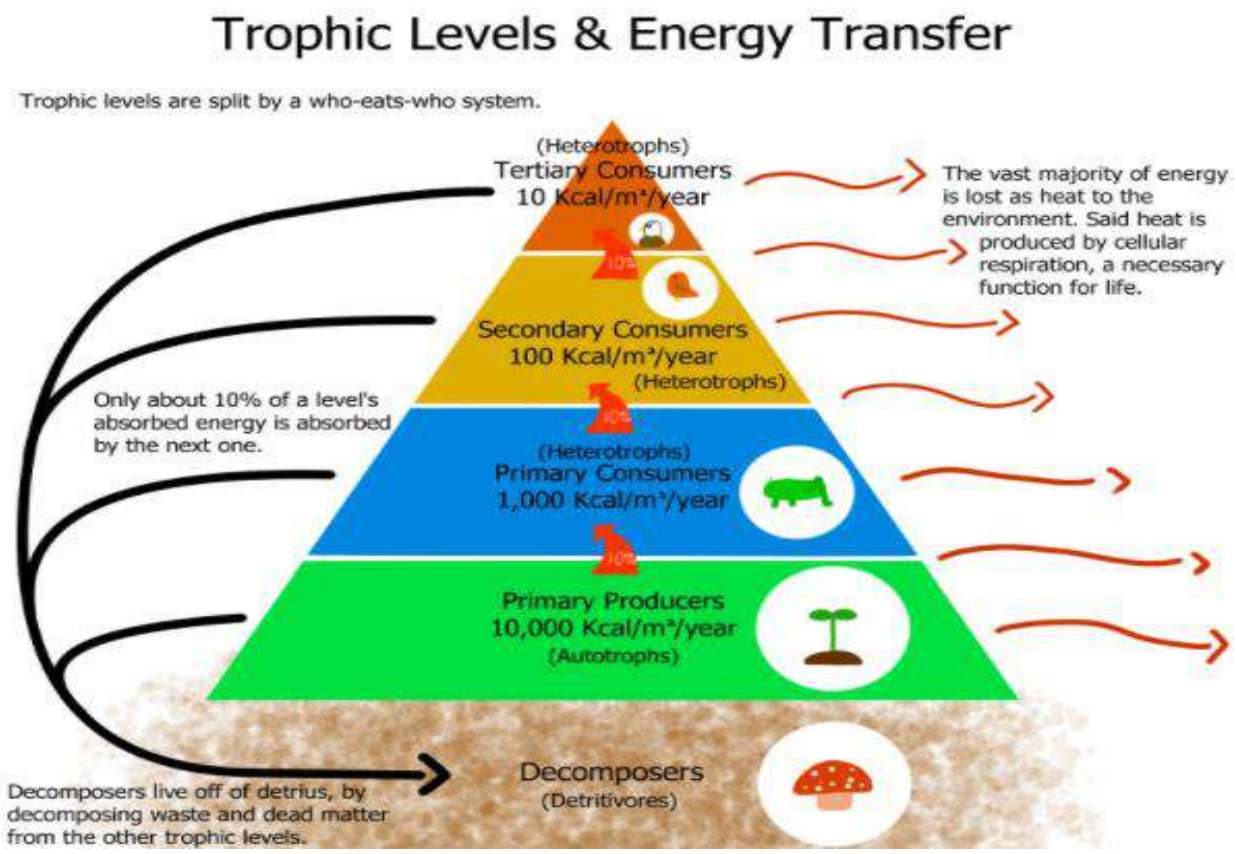


- **Warm and moist environment** favour decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build-up of organic materials

DECOMPOSITION IN TERRESTRIAL ECOSYSTEM

3.ENERGY FLOW:

- **Except for the deep-sea hydro-thermal ecosystem, Sun is the only source** of energy for all ecosystems on Earth.
- Of the incident solar radiation less than 50 per cent of it is **photosynthetically active radiation (PAR).**
  - Plants and photosynthetic bacteria (autotrophs), fix suns' radiant energy to make food from simple inorganic materials.
  - So, all organisms are dependent for their food on producers, either directly or indirectly.
  - Hence, there exists a unidirectional flow of energy from the sun to producers and then to consumers.
- Hence, starting from the plants (or producers) food chains or rather webs are formed such that an animal feeds on a plant or on another animal and in turn is food for another.
  - **The chain or web** is formed because of this **interdependency.**
- All animals depend on plants (directly or indirectly) for their food needs. They are hence called **consumers and also heterotrophs.**
- Further, 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.**

- In this perspective, Organisms occupy a place in the natural surroundings or in a community according to their feeding relationship with other organisms.
  - Based on the source of their nutrition or food, organisms occupy a specific place in the food chain that is known as their trophic level
  - Producers belong to the first trophic level, herbivores (primary consumer) to the second and carnivores (secondary consumer) to the third.
- The **important point** to note is that the amount of energy decreases at successive trophic levels. When any organism dies, it is converted to detritus or dead biomass that serves as an energy source for decomposers.
- Organisms at each trophic level depend on those at the lower trophic level for their energy demands.
  - 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.
- The number of trophic levels in the grazing food chain is restricted as the transfer of energy follows 10 per cent law – only 10 per cent of the energy is transferred to each trophic level from the lower trophic level.

ENERGY FLOW IN AN ECOSYSTEM

4.ECOLOGICAL PYRAMIDS:

- One gets the shape of a pyramid when food or energy relationship between organisms at different trophic level are expressed.
  - Thus, 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.
- This concept can be better understood by assessing the following pyramids:

Pyramid of number:

- The below diagram is that of a Grassland Ecosystem. Only the top-three carnivores are supported in an ecosystem, based on production of plants.

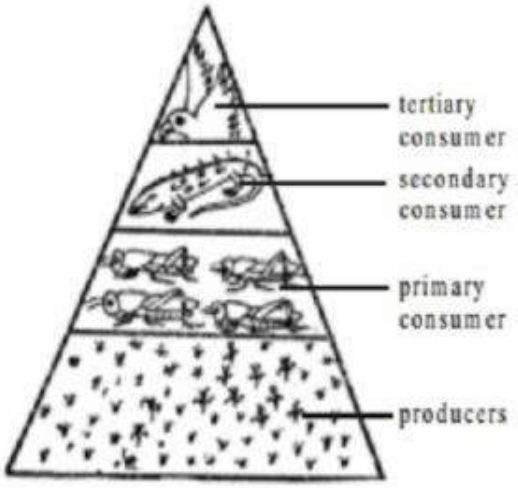


Fig. Pyramid of biomass in a grassland

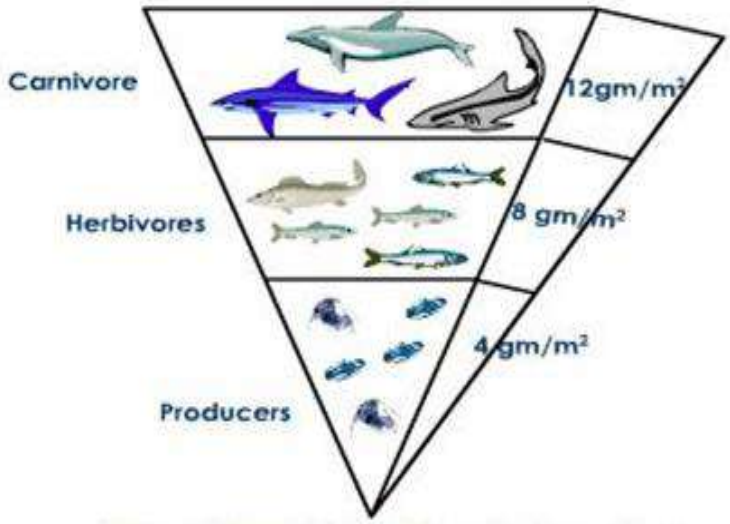
Pyramid of Biomass:

- This shows a sharp decrease in biomass at higher trophic levels.
- Biomass refers to the total weight of living matter per unit area. In an ecosystem the biomass decreases from the producer level to the consumer level

- In a grassland the biomass of grasses is the maximum and it gradually decreases towards the consumer level.

Inverted Pyramid:

- The pyramid of biomass is inverted in a pond or lake ecosystem.
- The biomass of phytoplankton is less as compared with that of the small herbivorous fish that feed on these producers.
- The biomass of large carnivorous fish that depends on small fishes is still greater.

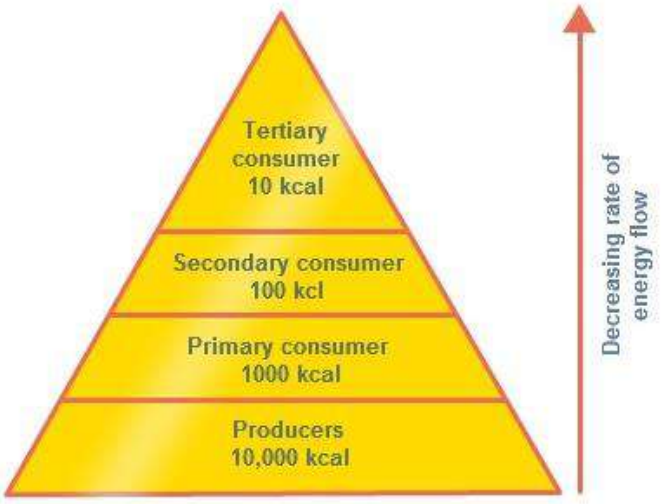


Inverted Pyramid in an Aquatic Ecosystem

Pyramid of energy:

- In an ecosystem, the energy flow from the producer to the consumer level will be decreasing. In a grassland, grass plants trap the maximum sun light energy.
- The energy gradually decreases towards the top consumer level.
- The chemical energy is transformed into kinetic energy.

However, there are **certain limitations** of ecological pyramids such as it does not consider the **same species** belonging to two or more trophic levels.



Pyramid of Energy

- It assumes a **simple food chain**, something that almost never exists in nature; it does not accommodate a food web.
- Moreover, **saprophytes** are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

Energy Flow:

Energy flow is the flow of energy through living things within an ecosystem.

The flow of energy in ecosystems is vitally important to the thriving of life on Earth.

Nearly all the energy in Earth's ecosystems originates within the Sun. Once this solar energy reaches Earth, it is distributed among ecosystems in an extremely complex manner.

Energy is the basic force responsible for all metabolic activities; and this flow from producer to top consumers is called energy flow and is unidirectional in nature.

The unidirectional flow of energy and the successive loss of energy as it travels up the food web, are patterns in energy flow that are governed by

thermodynamics, which is the theory of energy exchange between systems.

Producers are the energy gateway:

Plants, algae, and photosynthetic bacteria act as producers

Producers are autotrophs, or "self-feeding" organisms, that make their own organic molecules from carbon dioxide.

The energy stored in organic molecules can be passed to other organisms in the ecosystem when those organisms eat plants (or eat other organisms that have previously eaten plants)

In this way, all the consumers, or heterotrophs ("other feeding" organisms) of an ecosystem, including herbivores, carnivores, and decomposers, rely on the ecosystem's producers for energy.

If the plants or other producers of an ecosystem were removed, there would be no way for energy to enter the food web, and the ecological community would collapse.

That's because energy isn't recycled: instead, it's dissipated as heat as it moves through the ecosystem and must be constantly replenished.

Terms associated to understand the flow of Energy:

In ecology, productivity is the rate at which energy is added to the bodies of organisms in the form of biomass.

Biomass is simply the amount of matter that's stored in the bodies of a group of organisms.

Productivity can be defined for any trophic level or other group, and it may take units of either energy or biomass.

Gross primary productivity, or GPP, is the rate at which solar energy is captured in sugar molecules during photosynthesis (energy captured per unit area per unit time). Producers such as plants use some of this energy for metabolism/cellular respiration and some for growth (building tissues)

Net primary productivity, or NPP, is gross primary productivity minus the rate of energy loss to metabolism and maintenance. In other words, it's the rate at which energy is stored as biomass by plants or other primary producers and made available to the consumers in the ecosystem.

How does energy move between trophic levels?

Energy can pass from one trophic level to the next when organic molecules from an organism's body are eaten by another organism.

However, the transfer of energy between trophic levels is not usually very efficient.

Plants typically capture and convert about 1.3-1.6% of the solar energy that reaches Earth's surface and use about a quarter of the captured energy for metabolism and maintenance.

So, around 1% of the solar energy reaching Earth's surface (per unit area and time) ends up as net primary productivity.

On average, only about 10% of the energy stored as biomass in one trophic level (e.g., primary producers) gets stored as biomass in the next trophic level (e.g., primary consumers). Put another way, net productivity usually drops by a factor of ten from one trophic level to the next

energy transfer inefficient

There are several reasons.

One is that not all the organisms at a lower trophic level get eaten by those at a higher trophic level.

Another is that some molecules in the bodies of organisms that do get eaten are not digestible by predators and are lost in the predators' faeces. The dead organisms and faeces become dinner for decomposers.

Finally, of the energy-carrying molecules that do get absorbed by predators, some are used in cellular respiration (instead of being stored as biomass)

Trophic level:

In ecology, a trophic level pertains to a position in a food chain or ecological pyramid occupied by a group of organisms with similar feeding modes.

The trophic level of an organism is the number of steps it is from the start of the chain.

The concept of trophic level was developed by Raymond Lindeman (1942), based on the terminology of August Thienemann (1926)

The trophic levels are shown in a series or a succession to represent the flow of food energy and the feeding relationships between them.

Categories:

The trophic levels have two major categories: the autotrophs and the heterotrophs.

Autotrophs are organisms that can produce organic matter from inorganic matter.

Since they can make their own food and do not need to feed on other organisms, they are also referred to as the producers of an ecosystem.

Heterotrophs are organisms that obtain organic matter directly by consumption.

Unlike autotrophs, they do not have the ability to manufacture their food from inorganic sources. Thus, they hunt or gather food from other organisms. Hence, these are referred to as consumers.

Heterotrophs may be further grouped as:

Primary Consumers: These comprise the plant-eating organisms called herbivores.

Secondary Consumers: These feed on the primary consumers.

Tertiary Consumers: These feed on the secondary consumers and so on

Final Consumers: The final group called reducers feeds on dead organic matter. They include the detritivores and the decomposers.

Trophic Structure:

Trophic structure refers to the partitioning of biomass between different trophic levels.

It is controlled chiefly by the biomass of the primary producers.

The primary producers affect the transfer efficiency between trophic levels as they essentially provide the energy and the nutrient inputs.

Apart from them, another important factor is the top-down component.

This includes the predators.

Their consumption suppresses the lower trophic levels.

In a way, the predators help the primary producers by controlling or limiting excessive herbivory by predation. They serve as biological control of the lower trophic levels.

Trophic Level Pyramid:

An ecological pyramid is often depicted as a trophic level pyramid.

It is a graphical representation in the shape of a pyramid comprised of plants and animals in a certain ecosystem.

The shape indicates that the bottom trophic level is comprised of organisms that can make their own food through available sources from the environment.

They do not feed on other organisms to obtain their nutritional requirements.

Thus, they represent the base. This portion of the pyramid is comprised of producers.

As the trophic levels go up, it tapers towards the peak.

This pyramid shape depicts the biomass in each trophic level.

Biomass is the amount of living or organic matter in an organism. The base shows the largest biomass and then diminishes in amount as it moves up to the apex. This is the most common structure in ecosystems.

However, there are also instances wherein an inverted pyramid occurs.

The latter results when the combined weight of producers is smaller than the combined weight of consumers.

ENERGY_PYRAMID

Trophic level examples

Level 1: producers

This level comprises the primary producers and are found the base of an ecological pyramid.

They are found at the base of an ecological pyramid.

The fundamental feature of organisms in trophic level 1 is their ability to produce their own food from abiotic materials.

Level 2: primary consumers

In this level, the organisms occupying this level feed on the primary producers and are called primary consumers.

Animals that feed on plant materials are called herbivores.

They have anatomical and physiological features that make them adapt to a plant diet.

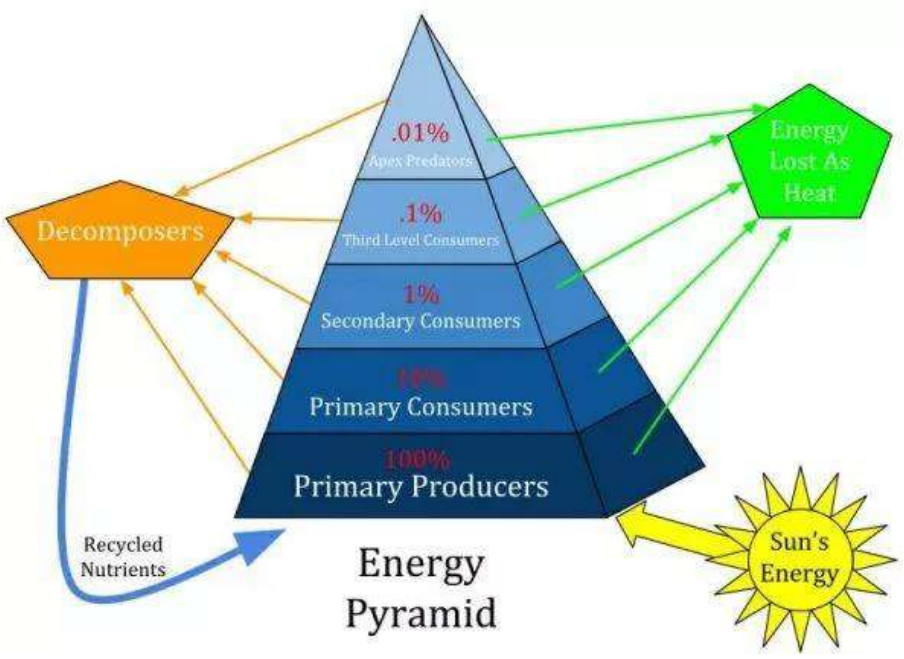
Examples of herbivores are horses, cattle, and goats.

Level 3: secondary consumers

Secondary consumers are comprised of animals that feed on primary consumers. Organisms that eat other animals are called carnivores (or predators)

Predation is an interaction in an ecosystem where a predator hunts or catches, kills, and eats prey. Thus, Predators are in turn, adapted anatomically and physiologically for an animal diet.

Examples of animals with a predator-prey relationship are spiders and flies, lion and zebra, bear and fish, and fox and rabbit.



Not all predators though have a diet exclusive of meat. Their diet may also

include plant materials. Animals that feed on both plants and animals are called omnivores.

Examples of omnivores are chimpanzees, orangutans, gorillas, pigs, most bears, etc.

Other trophic levels

The organism that feeds on a secondary consumer is called a tertiary consumer and the one that eats on a tertiary consumer is referred to as a quaternary consumer.

The tertiary consumers and the quaternary consumers occupy trophic levels 4 and 5, respectively.

Decomposers:

The last of the trophic level is occupied by decomposers, such as detritivores. They feed on dead plants and animal matter.

Detritivores are decomposers that specifically fragment to consume their food.

Examples of detritivores are worms, millipedes, dung flies, woodlice, and slugs. Other decomposers include fungi and bacteria.

Food Chain and Food Web:

- **Food chain** is a **feeding hierarchy** in which organisms in an ecosystem are grouped into **trophic (nutritional) levels** and are **shown in a succession** to represent the **flow of food energy** and the **feeding relationships** between them.
- A **food web** is the natural interconnection of food chains and a graphical representation of what-eats-what in an ecological community
- Food chains **intertwine** locally into a food web because most organisms consume more than one type of animal or plant.
- Major parts of Food Chain
  - **Sun:** This is the initial source of energy, which provides energy for everything on the planet
  - **Producers:** This is the first stage of Food Chain. These are any plant or other organisms that produce their own nutrients through photosynthesis.
  - **Consumers:** These are all organisms that are dependent on plants or other organisms for food. This is the largest part of a food web, as it contains almost all living organisms.
  - **Decomposers:** These are organisms that get energy from dead or waste organic material. This is the last stage in a food chain, and they convert organic waste materials into inorganic materials like nutrient-rich soil or land.
- Because energy, in the form of heat, is lost at each step, or trophic level, chains do not normally encompass more than four or five trophic levels.

Types of Food Chains:

- Two types of food chains are present in ecosystems:

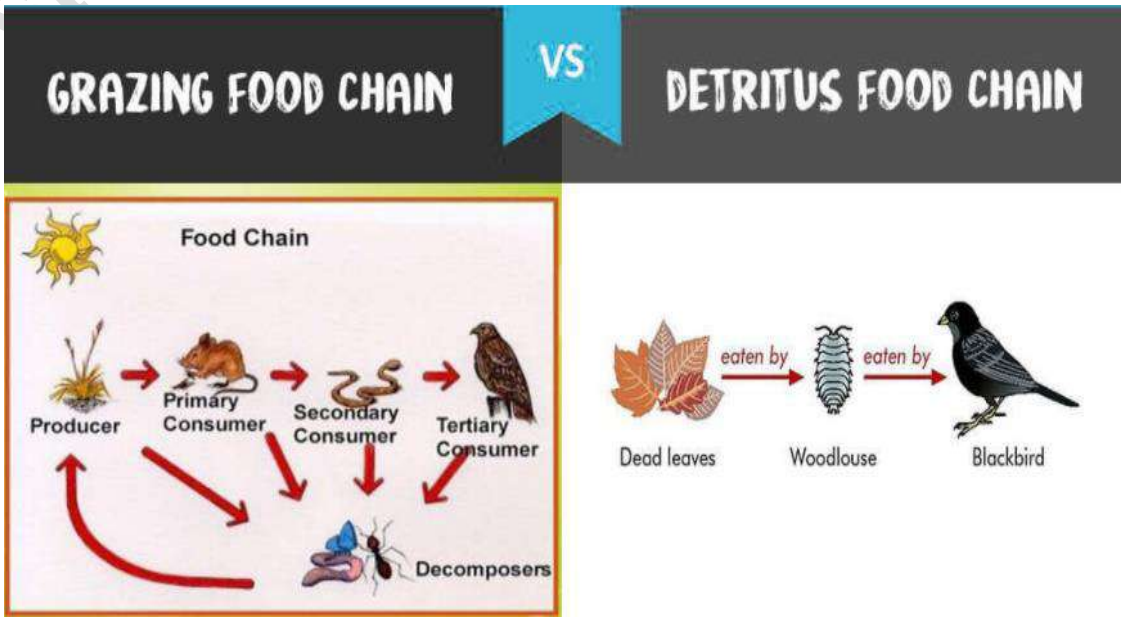
1. **Grazing food chain**
   - Grazing animals play an important role in the transfer of energy to the carnivores in this type of food chain, hence the name grazing food chain.
   - **Green plants** in the **terrestrial ecosystems** and **phytoplankton** in the **aquatic ecosystems** are the producers.
   - The **primary consumers** are the cattle, sheep, rabbits, deer, insects, and snails which feed on the green plants in the

terrestrial ecosystems and the zooplankton, fishes and animals which feed on phytoplankton in the aquatic ecosystems.

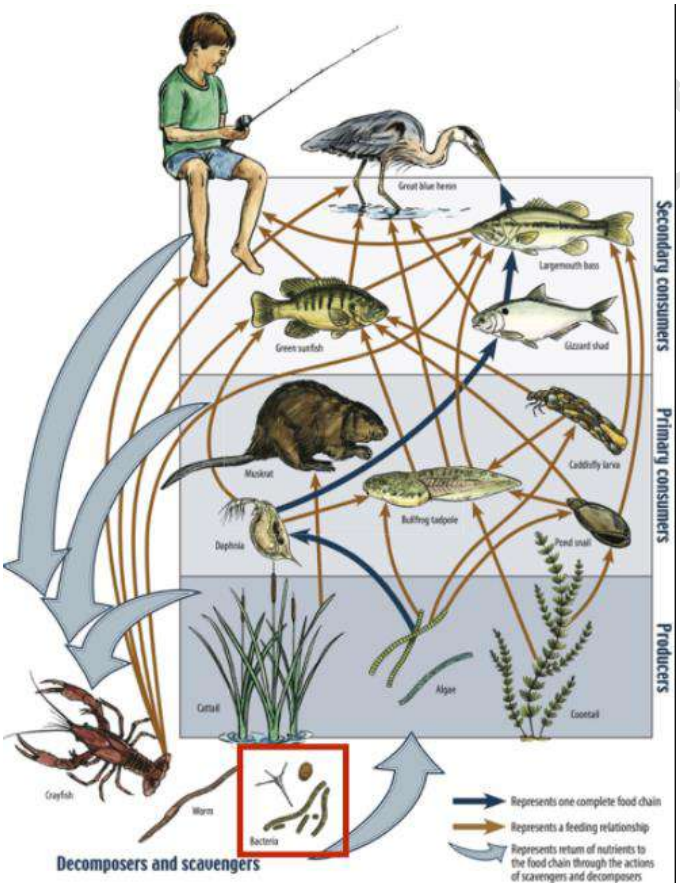
- In the soil the unconsumed dead organisms and biological wastes become the food for the detritivores of the detritus food chain.
- Herbivores (the primary consumers) are eaten by the secondary consumers or primary carnivores.
  - Similarly secondary consumers are eaten by the tertiary consumers or secondary carnivores.
- The **grazing food chains** are **linear** and are usually with 4 to 5 trophic levels in the chain.
- **Examples**
  - **In terrestrial Ecosystem**
    - Grass
    - Grass
  - **In aquatic Ecosystem**
    - Phytoplankton

2. **Detritus Food Chain**
   - It starts from dead organic matter of decaying animals and plant bodies consumed by the micro-organisms and then to detritus feeding organism called Detrivores or Decomposers and to other predators.
     - **Examples**
       - Litter → Earthworms→ Chicken → Hawak
- The **distinction** between these two food chains is the source of energy for the first level consumers.
  - In the grazing food chain, the primary source of energy is living plant Biomass, while in the detritus food chain the source of energy is dead organic matter or detritus.
- The two food chains are **linked** as well.
  - The initial energy source for detritus food chain is the waste materials and dead organic matter from the grazing food chain.

Food Web:



- A food web is a **graphical model** depicting the **many food chains** linked together to show the feeding relationships of organisms in an ecosystem.
- It **differs** from a food chain in a way that the latter is a linear system showing a succession of organisms whereby each species is eaten in turn by another species.
    - While **Food web** is a **more complex network** of what-eats-what in a particular ecosystem
- The diagram below shows an example of a food web.



- In food webs, arrows point from an organism that is eaten to the organism that eats it. As the food web above shows, some species can eat organisms from more than one trophic level.

Food Chain	Food web
It refers to a natural system by which energy is transmitted from one organism to another	It consists of a number of interconnected food chains.
Member of higher trophic level feed upon a single type of organism	Member of higher trophic level feed upon many organisms
It does not have any effect on improving the adaptability and competitiveness of the organism.	Food webs improves the adaptability and competitiveness of the organism.
Example- Carrots ---> rabbit --> snake --> eagle	Example- A hawk might also eat a mouse, a squirrel, a frog or some other animal. The snake may eat a beetle,

Energy transfer efficiency limits food chain lengths:

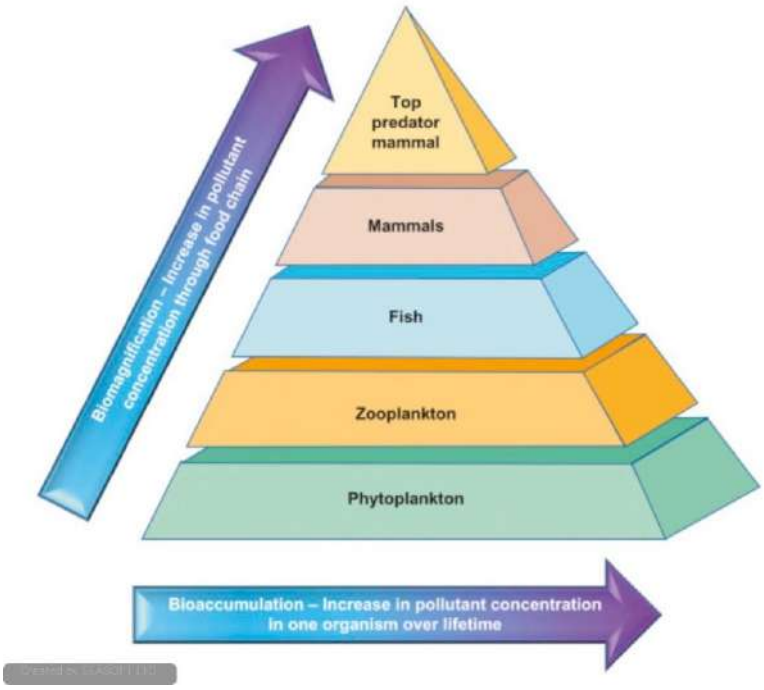
- Energy is transferred between trophic levels when one organism eats another and gets the energy-rich molecules from its prey's body. However, these transfers are **inefficient**, and this inefficiency limits the length of food chains.
- When energy enters a trophic level, some of it is stored as **biomass**, as part of organisms' bodies.
    - This is the energy that's available to the next trophic level since only energy storied as biomass can get eaten.
    - As a rule of thumb, only about 10% of the energy that's stored as biomass in one trophic level—per unit time—**ends up**

stored as biomass in the next trophic level—per the same unit time.

- This pattern of **fractional transfer** limits the length of food chains; after a certain number of trophic levels—generally three to six, there is too little energy flow to support a population at a higher level.

Bioaccumulation:

- **Bioaccumulation**s the gradual accumulation of substances, such as pesticides or other chemicals, in an organism
- It occurs when an organism absorbs a substance at a rate faster than that at which the substance is lost or eliminated by **catabolism and excretion.**
- Thus, the **longer the biological half-life** of a toxic substance, the greater the risk of chronic poisoning, even if environmental levels of the toxin are not very high.



Biomagnification:

- **Biomagnification**, also known as **bio amplification** or **biological magnification**, is any concentration of a toxin, such as pesticides, in the tissues of tolerant organisms at successively higher levels in a food chain.
- This increase can occur because of:
  - Persistence – where the substance cannot be broken down by environmental processes.
  - Food chain energetics – where the substance's concentration increases progressively as it moves up a food chain
  - Low or non-existent rate of internal degradation or excretion of the substance – mainly due to water-insolubility

Example:

- **Case of DDT**
  - When an animal consumes food having DDT residue, the DDT accumulates in the tissue of the animal by a process called **bioaccumulation**.
  - The higher an animal is on the food chain (e.g., tertiary consumer such as seals), the greater the concentration of DDT in their body because of a process called **biomagnification.**
- **Case of Indian Rivers**
  - India's 42 rivers have at least two toxic heavy metals beyond the permissible limit, says research conducted by Central Water Commission
  - Ganga, the national river, was found to be polluted with five heavy metals—chromium, copper, nickel, lead, and iron.
  - In this pursuance, the concentrations of toxic metals in

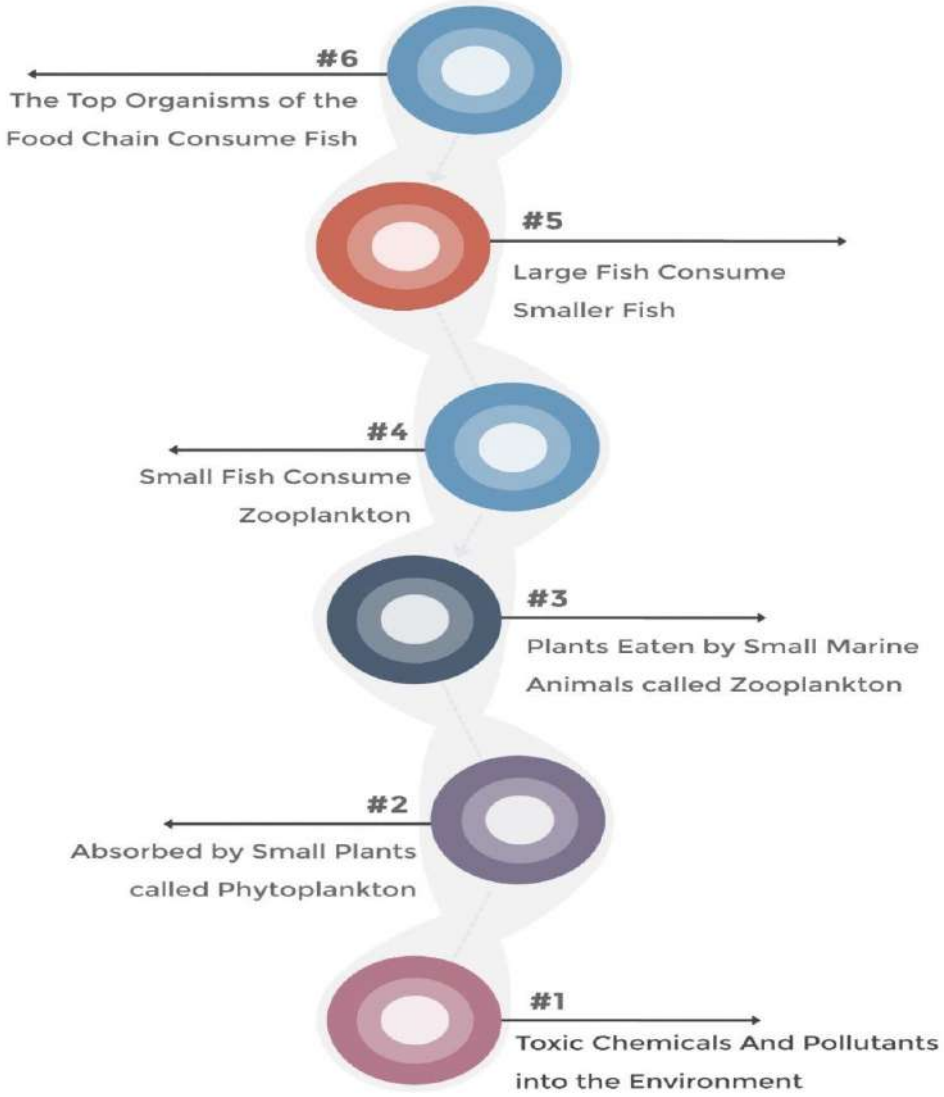
grains and vegetables have grown in contaminated soils and have increased at alarming rates.

- This poses a serious threat to humans and the environment because of its toxicity, non-biodegradability, and **bioaccumulation.**

Process of Bioaccumulation and Biomagnification

This is what happens:

- Small amounts of toxic substances – often pesticides or pollution from human activity – are absorbed by plants.
- These plants are eaten by **primary consumers** in low concentrations.
- The toxin cannot be excreted so when the primary consumers are eaten by secondary consumers all the toxin is **absorbed** by the secondary consumers.
- This repeats as **secondary consumers** are eaten by higher level consumers.
- At each **trophic level** of the food chain, the toxins remain in the tissues of the animals – so the concentration of toxin becomes most concentrated in the body tissues of the animals at the top of the food chain



Causes of Bioaccumulation / Biomagnification:

- **Agricultural Products**
  - The chemicals used in the agricultural sector contain highly toxic substances that mainly result in biomagnification.
  - These chemicals come from herbicides, pesticides, fungicides, and inorganic fertilizers.
  - These chemicals penetrate the soil where they accumulate to toxic levels and also find their way into the rivers and lakes through surface runoff.
- **Organic Contaminants**
  - Organic substances such as biosolids and manures have essential nutrients that are used by plants such as nitrogen, phosphorous, and carbon.
  - The biosolids that are used in agriculture farms are treated using toxic chemicals that may contain heavy metals.
  - When these organic substances are released into the farms, they release harmful substances that are

absorbed by the primary consumers and later accumulate in other organisms.

- **Plastic Pollution**
  - Disposal of plastic waste near or in water bodies may not only be directly harmful to aquatic organisms but also other animals up the trophic level in general.
    - The pollution in oceans caused by 'Ghost Nets' – these are fishing nets that have been abandoned, lost, or otherwise discarded in the ocean; are also contributing for the issue.
  - Research shows that plastic contains a harmful chemical called **Bisphenol A** which is one of the major contaminants released into the water bodies
- **Mining**
  - When mining substances such as zinc, copper, cobalt, lead, and other chemicals, these mineral deposits may be released into the aquatic and adjacent farm environment where their toxicity levels rise tremendously upon absorption by aquatic and farm animals or crops.
- **Toxic Gases and Air Pollution**
  - The release of gases into the environment can also contribute to Biomagnification. Exhaust gases from vehicles and industries that manufacture and refine oil into the air do not only cause air pollution, but they can be dissolved by the rainwater and fall as **acidic rain.**
  - The chemicals in the acid rain are absorbed by soil and water bodies. They are then absorbed by primary consumers and later find their way up the food chain.

Effects:

- **On Human Health**
  - In recent years, the consumption of seafood has been linked to certain types of **cancer**.
    - This is because of the accumulation of **mercury and the Polycyclic Aromatic Hydrocarbons** in the tissues of marine organisms.
  - In addition, consumption of plants or aquatic animals that have assimilated heavy metals and toxic substances may lead to long-term effects such as Kidney failure, respiratory disorders, brain damage, birth defects and heart diseases.
- **On aquatic animals**
  - The ingestion and subsequent accumulation of metals in the tissues of marine organisms have an adverse effect on their **development and reproduction**.
  - Consumption of heavy toxic metals in seabirds influences **egg production**.
    - The seabirds produce eggs with soft and thin shells which easily crashes as they try to incubate them.
  - Other cases that result from contamination of water bodies with toxic chemicals such as Selenium and mercury include effects on reproductive process of fish.
- **Disruption of Food Chain**
  - Accumulation of substances that cause Biomagnification can disrupt the natural food chain that

is essential for the survival of all animals in each biosphere.

- However, if a group of organisms was to die due to the toxic substances the natural flow of the food chains becomes disrupted. This may have a long-term effect which might not be noticed in the short term.

- **Destruction of Coral Reefs**
  - Cyanide that is used in leaching gold and fishing is the main cause of the destruction of coral reefs.
  - Their destruction affects the lives of many aquatic animals, as many of them depend on the coral habitats for their survival.

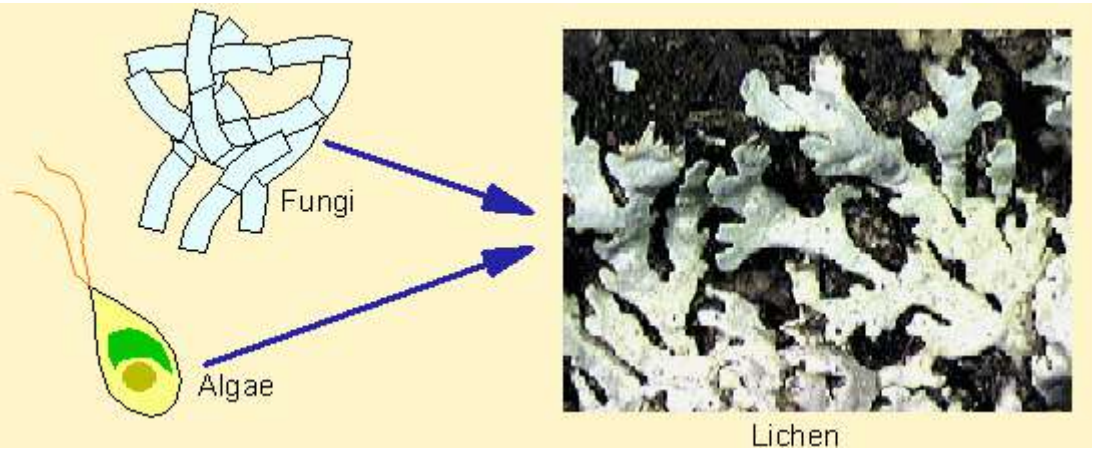
Biotic Interaction

Introduction:

- In ecology, a biological interaction is the effect that a pair of organisms living together in a community have on each other.
  - They can be either of the same species (intraspecific interactions), or of different species (interspecific interactions).
- These effects may be short-term, like pollination and predation, or long-term; both often strongly influence the evolution of the species involved.
- Interactions can be indirect, through intermediaries such as shared resources or common enemies.

Positive Interaction:

- This term is used for the types of interspecific relationships which are mutually beneficial and where one or both partners are benefited, and no one is harmed.
  - The benefit may be in terms of food, shelter, substratum, or transport.
- This is mainly divided into three categories.
  - **Mutualism**
    - It is mutually beneficial relationship between two organisms; here both species derive benefit.
    - The relationship may be compulsory(obligatory) or facultative(optional)
    - **Examples**
      - **Lichens**
        - The term means" living together".
        - This is an example where contact is close and permanent as well as obligatory.
        - The **fungus** provides moisture as well as minerals and

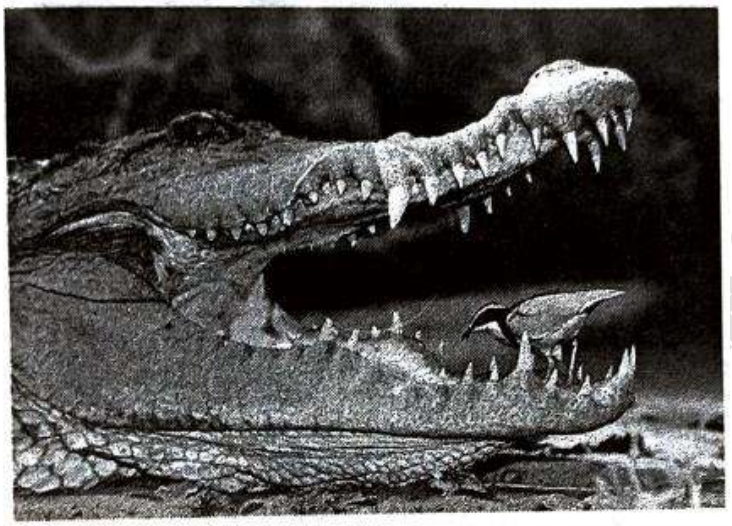


protection to **algae**, whereas alga manufactures food material

- Neither of the two can grow alone independently

Crocodile and Bird association

- Here the bird enters the mouth of crocodile and picks up leaches found between the teeth and feed on them.
- Thus, birds clean the teeth and crocodile is benefited, while the bird gets is nutritional requirement



1. **Commensalism:**
   - In this inter-specific relationship, one of the partners is benefited and another partner is neither benefited nor harmed
   - Here, the partner getting the benefit is called commensal.

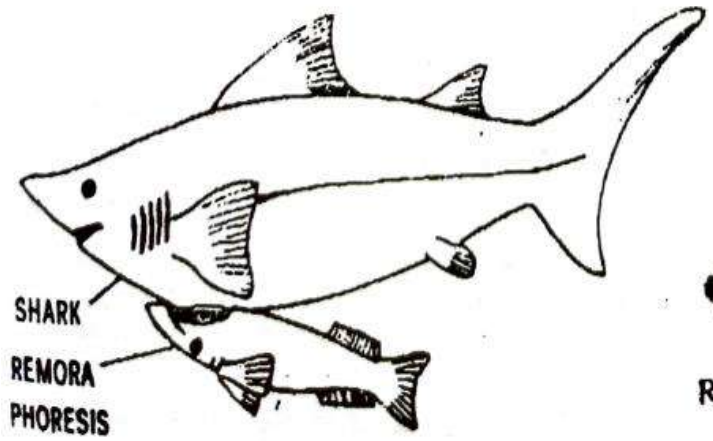
Ecto commensalism:

- Here, the commensal lives on the body of the other partner, which may be called host.

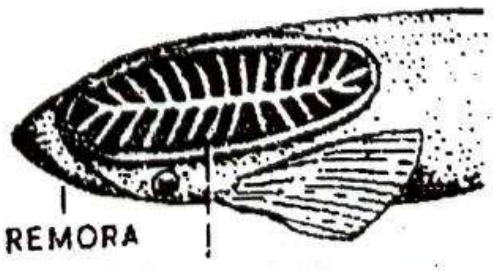
Association between suckerfish (or Remora or Echeneids) and shark:

- The sucker fish has the dorsal fin modified as a sucker (or adhesive) disc, with the help of which it is attached to the body of shark so that the suckerfish gets free transportation
- The sucker fish releases the attachment after some time and swims in search of food

- **Endo Commensalism:**
  - Here the commensal lives within the body of host
  - **Example**
    - **Association between saprophytic bacteria and fungi**
    - A variety of microorganisms, saprophytic bacteria and fungi and protozoans live within the tissues or



COMMENSALISM



ADHESIVE DISC (SUCKER)

cavities of higher plants and animals.
    - Many microorganisms like bacteria live as commensals in the digestive system of various animals. The microorganisms use undigested food for their nutritional requirements.
    - **coli** lives in the intestine of humans.
- **Protocooperation:**
    - Protocooperation is a form of mutualism, but the cooperating species do not depend on each other for survival.
    - **Example**
        - **Flowers and Insects**
        - The flowers of plants that re pollinated by insects and birds benefit from protocooperation.
        - The plants with colourful flowers, experience cross pollination because of insect activities
        - This is beneficial to the insect that has got its food supply as well.

Negative Interaction:

- These interactions include association where one or both individuals are **harmed**.
- The harm may be caused by eating other organism, competition for food, excretion of harmful wastes, etc.
- These have been sub-divided into

- **Exploitation:**
    - In this type of interaction, one species is benefited at the expense of another.
    - Predation is an interaction between organisms in which one organism captures biomass from another.
    - The term is used as a synonym for carnivory but in its widest definition includes all forms of one organism eating another, regardless of trophic level (e.g., herbivory), closeness of association (e.g., parasitism) and harm done to prey (e.g., grazing)
    - **Parasitism:**
        - This is an interaction between two organisms in which one (called parasite) derives synthesised food from another living organism (Called host).
        - A true parasite though obtains its food from the host, seldom kills it
        - **Examples**
            - Among the animals, ticks, mites, and lice are external parasites or ectoparasites.
            - The fungal parasites include Erysiphe (powdery mildew), Ustilago (smut), Puccinia (rust), etc; which cause diseases that result in serious losses of economically important crops.
    - **Predation:**
        - In contrast with a parasite which derives nourishment from its host without killing, a predator is **free living** which catches and kills another species for food or predator is a direct food relationship between two

individuals in which an animal that remains free living (called predator) catches and kills another animal (called prey) for food.

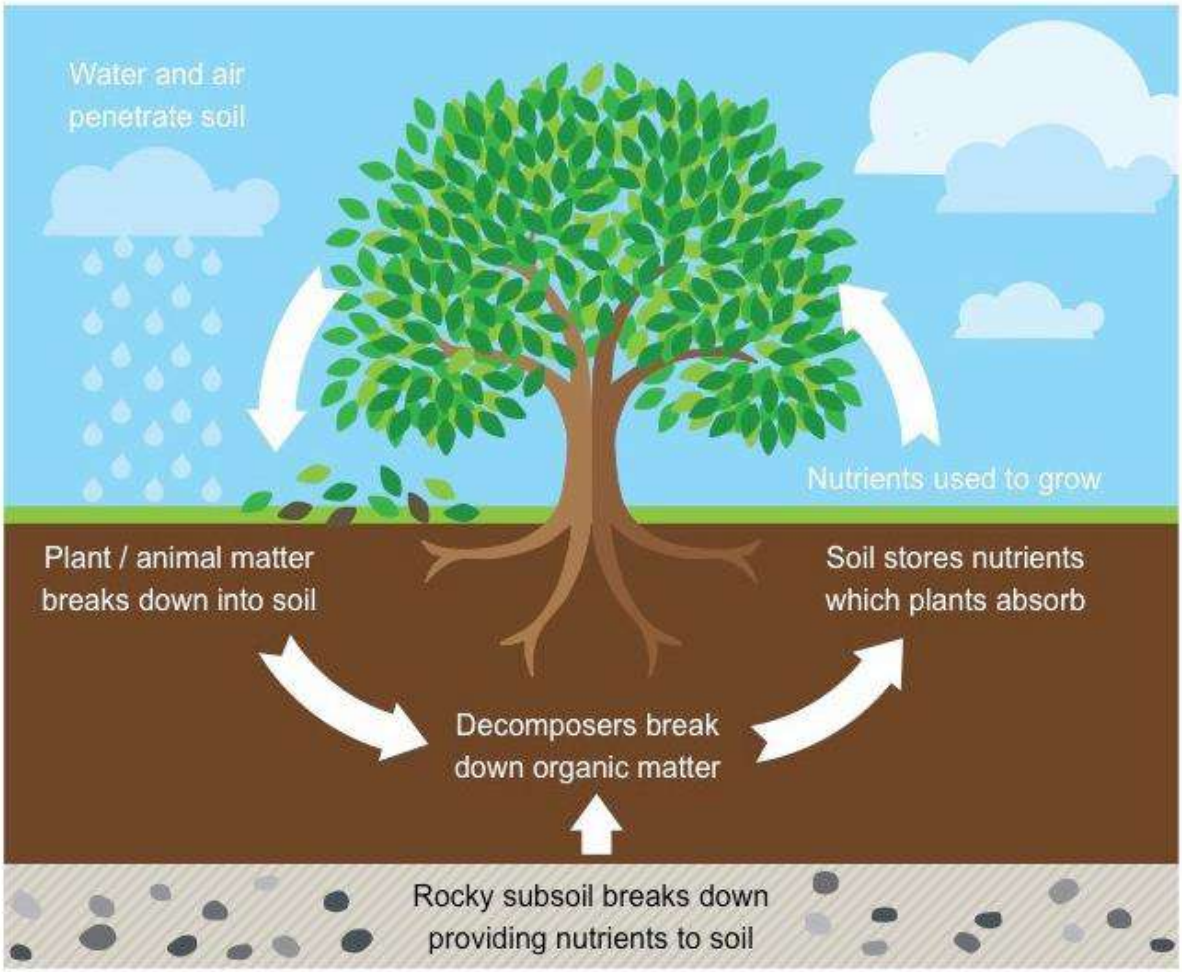
- **Examples**
  - Tiger (predator) eating deer (prey), frog eating insects.

- **Competition:**
  - Competition is an interaction between organisms or species in which both the organisms and species are harmed.
  - Limited supply of at least one resource (such as food. water and territory) used by both can be a factor.
  - Species compete in the following ways.

1. **By mechanism:**
   - Biologists typically recognize two of types of competition interference and exploitative competition.
   - During **interference** competition, organisms interact directly by fighting for scarce resources. For **example**, large aphids defend feeding sites on cottonwood leaves by ejecting smaller aphids from better sites.
   - In contrast, during **exploitative** competition, organisms interact indirectly by consuming scarce resources. For example, plants consume nitrogen by absorbing it into their roots, making nitrogen unavailable to nearby plants.
2. **By size asymmetry:**
   - Competition varies from **complete symmetric** (all individuals receive the same number of resources, irrespective of their size) to perfectly **size symmetric** (all individuals exploit the same amount of resource per unit biomass) to **size-asymmetric** (the largest individuals exploit all the available resource)
   - The degree of size asymmetry has major effects on the structure and diversity of ecological communities,
   - **Example**, in plant communities' size-asymmetric competition for light has stronger effects on diversity compared with competition for soil resources.
3. **By taxonomic relationship:**
   - Competition can occur between individuals of the same species, called **intraspecific** competition, or between different species, called **interspecific.**
   - Studies show that intraspecific competition can regulate population dynamics (changes in population size over time). This occurs because individuals become crowded as population grows.

- Since individuals within a population require the same resources, crowding causes resources to become more limited.
- Some individuals (typically small juveniles) eventually do not acquire enough resources and die or do not reproduce.
  - This reduces population size and slows population growth.
- **An example** among animals could be the case of Cheetah and lions since both species feed on similar prey, they are negatively impacted by the presence of the other because they will have less food, however they persist together, despite the prediction that under competition one will displace the other.

- **Antibiosis:**
  - This is a complete or partial inhibition of one organism by another either by secreting some substance or by modifying its immediate environment.
  - The substance or conditions produced by an organism are generally harmful for the other organism.
  - This phenomenon is very common in micro-organisms which secrete substance called **antibiotic.**
  - **Example**



  - Bacteria, actinomycetes and fungi produce several

antimicrobial substances which are widespread in nature.
    - Lichens as well as large number of higher plants produce substances that inhibit Molds and bacteria.

Nutrient Cycling

- A nutrient cycle is a repeated pathway of a particular nutrient or element from the environment through one or more organisms and back to the environment.
- **Energy flow** is a **unidirectional** and **noncyclic** path way, whereas the movement of **mineral** nutrients is **cyclic.**
- Hence, Nutrient cycling occurs as animals and plants consume nutrients found in the soil, and these nutrients are then **released back** into the environment via **death and decomposition.**
- Nutrient cycling is essential for life and is the vital function of the ecology of any region.
    - In any environment, to maintain an organism in a sustained manner, the nutrient cycle must be kept balanced and stable.

Nutrient Cycling

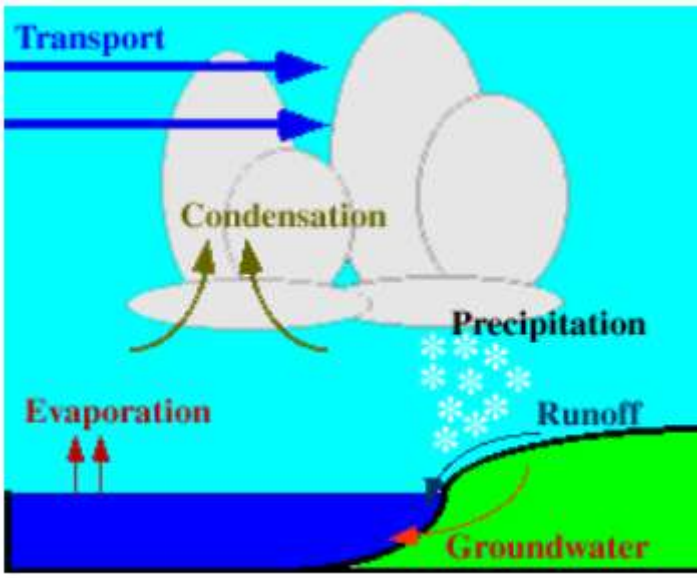
Types of Nutrient Cycle:

- Based on the **replacement period** a nutrient cycle is referred to as **Perfect or Imperfect Cycle**
    - A **perfect** nutrient cycle is one in which nutrients are replaced as fast as they are utilised. Most **Gaseous cycles** are considered as perfect cycles.
    - **Sedimentary** cycles are considered imperfect, as some nutrients are lost from the cycle and get locked into sediments and so become unavailable for immediate cycling.
- Based on **nature of the reservoir,** there are two types of cycles:
    - **Gaseous cycle –** where the reservoir is the atmosphere or the hydrosphere.
    - **Sedimentary cycle** – where the reservoir is the Earth's crust.

Gaseous Cycles:

- The most important gaseous cycles are – water, carbon, and nitrogen.

1. **Water Cycle (Hydrologic)**
    - The hydrologic cycle begins with the **evaporation** of water from the surface of the ocean. As moist air is lifted, it cools, and water vapour **condenses** to form clouds. Further, Moisture is transported around the globe until it returns to the surface as **precipitation.**
    - Once the water reaches the ground, one of two processes may occur.
        - some of the water may evaporate back into the atmosphere or
        - the water may penetrate the surface and become **groundwater.**
    - **Groundwater** either seeps its way to into the oceans, rivers, and streams, or is released back into the atmosphere through transpiration.
    - The balance of water that remains on the earth's surface is **runoff**, which empties into lakes, rivers and streams and is carried back to the oceans, where the cycle begins again.



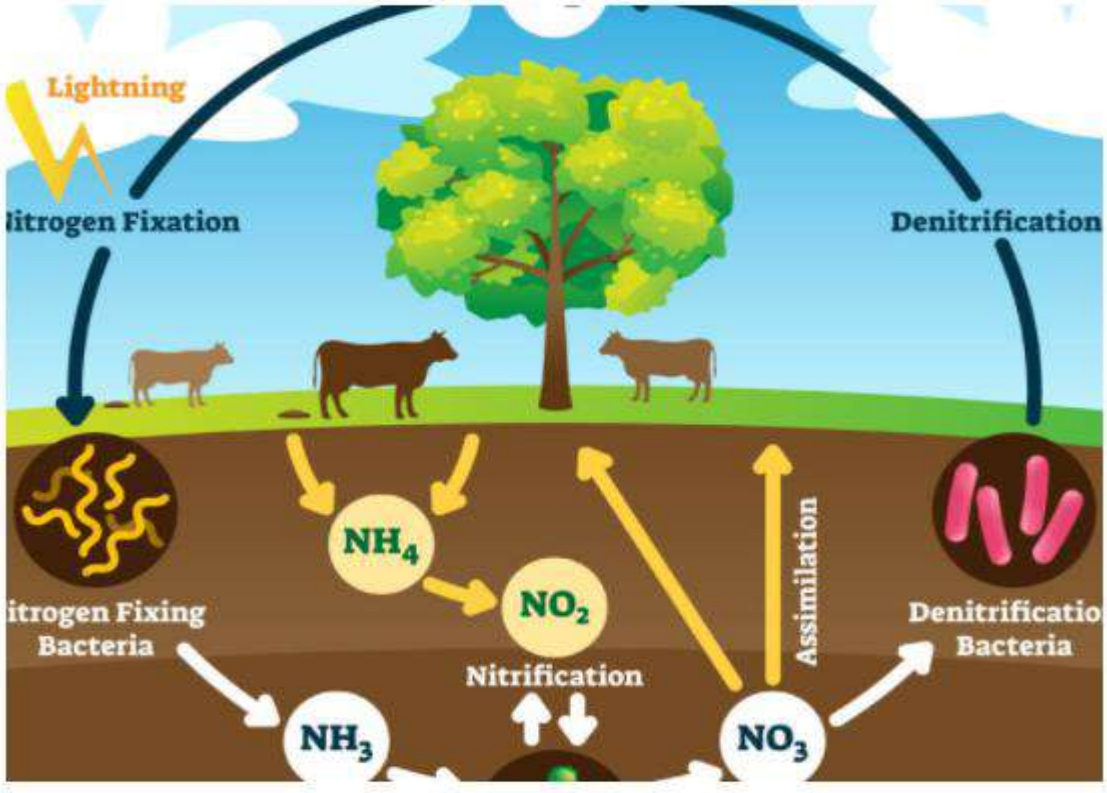
2. **Carbon Cycle**:
    - On Earth, the element carbon is a part of seawater, the atmosphere, rocks such as limestone and coal, soils, as well as all living things.
        - Carbon is able to move from one of these realms to another as a part of the carbon cycle.
    - Carbon moves from the **atmosphere to plants**. In the atmosphere, carbon is attached to oxygen in a gas called carbon dioxide (CO2).
        - Through the process of **photosynthesis**, carbon dioxide is pulled from the air to produce food made from carbon for plant growth.
    - Carbon moves from **plants to animals**.
        - Through food chains, the carbon that is in plants moves to the animals that eat them. Animals that eat other animals get the carbon from their food too.
    - Carbon moves from plants and animals to soils.
        - When plants and animals die, their bodies, wood and leaves decays bringing the carbon into the ground. Some is buried and will become fossil fuels in millions and millions of years.
    - Carbon moves from living things to the atmosphere.
        - Each time you exhale, you are releasing carbon dioxide gas (CO2) into the atmosphere.
        - Animals and plants need to get rid of carbon dioxide gas through a process called respiration.
    - Carbon moves from fossil fuels to the atmosphere when fuels are burned.
    - Further, Carbon moves from the atmosphere to the oceans. The oceans, and other bodies of water, absorb some carbon from the atmosphere. The carbon is dissolved into the water.
    - Carbon moves through our planet over longer time scales as well.
        - For example, over millions of years weathering of rocks on land can add carbon to surface water which eventually runs off to the ocean.
        - Over long-time scales, carbon is removed from seawater when the shells and bones of marine

animals and plankton collect on the sea floor. These shells and bones are made of limestone, which contains carbon.

- Also, the carbon can be released back to the atmosphere if the limestone melts or is metamorphosed in a subduction zone.

3. **Nitrogen Cycle**:
   - Nitrogen is one of the primary nutrients critical for the survival of all living organisms. Although nitrogen is very abundant in the atmosphere, it is largely inaccessible in this form to most organisms.
   - The processes in Nitrogen cycle can be explained as follows:
   - **Nitrogen fixation**
     - Nitrogen fixation is the process wherein N2 is converted to ammonium, or NH4+.
       - This is the only way that organisms can attain nitrogen directly from the atmosphere; the few that can do this are called nitrogen-fixing organisms.
     - Certain bacteria, including those among the genus Rhizobium, can fix nitrogen (or convert it to ammonium) through metabolic processes.
     - Nitrogen-fixing bacteria often form symbiotic relationships with host plants.
       - This symbiosis is well-known to occur in the legume family of plants (e.g., beans, peas, and clover).
       - In this relationship, nitrogen-fixing bacteria inhabit legume root nodules and receive carbohydrates and a favourable environment from their host plant in exchange for some of the nitrogen they fix.
     - In addition to nitrogen-fixing bacteria, high-energy natural events such as lightning, forest fires, and even hot lava flows can cause the fixation of smaller, but significant, amounts of nitrogen.

- **Nitrogen uptake**
  - The ammonium (NH4+) produced by nitrogen-fixing bacteria is usually quickly taken up by a host plant, the bacteria itself, or another soil organism and incorporated into proteins and other organic nitrogen compounds, like DNA.
- **Nitrogen mineralization**
  - After nitrogen is incorporated into organic matter, it is often converted back into inorganic nitrogen by a process called nitrogen mineralization, otherwise known as decay.
  - When organisms die, decomposers (such as bacteria and fungi) consume the organic matter and lead to the process of decomposition. During this process, a significant amount of the nitrogen contained within the dead organism is converted to ammonium.
  - Once in the form of ammonium, nitrogen is available for use by plants or for further transformation into nitrate (NO3-) through the process called nitrification.
- **Nitrification**
  - Nitrification requires the presence of oxygen, so nitrification can happen only in oxygen-rich environments like circulating or flowing waters and the surface layers of soils and sediments.
  - The process of nitrification has some important consequences. Ammonium ions (NH4+) are positively charged and therefore stick (are absorbed) to negatively charged clay particles and soil organic matter.
- **Denitrification**
  - Through denitrification, oxidized forms of nitrogen such as nitrate (NO3-) and nitrite



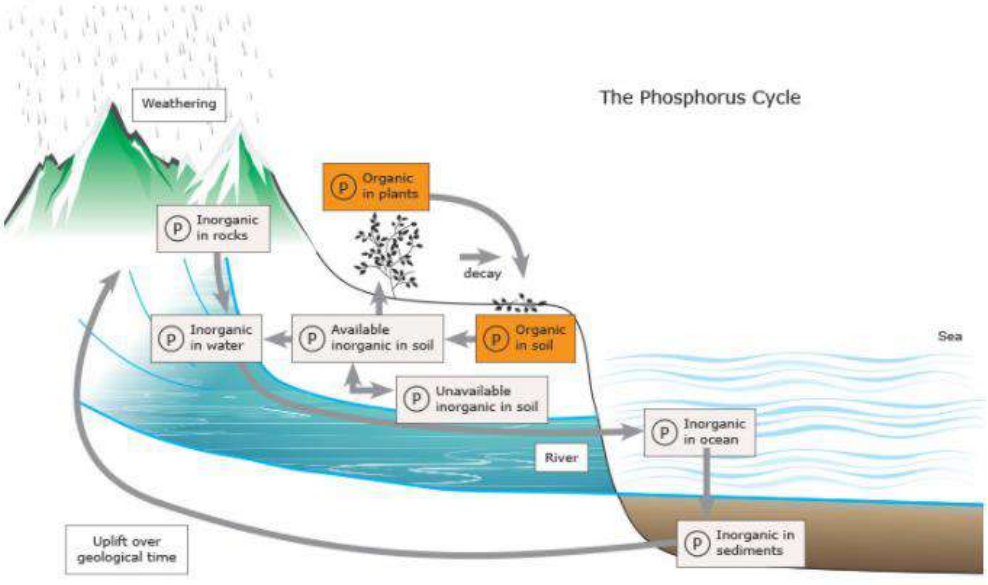
(NO2-) are converted to dinitrogen (N2) and, to a lesser extent, nitrous oxide gas (NO2)
    - Once converted to dinitrogen, nitrogen is unlikely to be reconverted to a biologically available form because it is a gas and is rapidly lost to the atmosphere.
    - Denitrification is the only nitrogen transformation that removes nitrogen from ecosystems (essentially irreversibly), and it roughly balances the amount of nitrogen fixed by the nitrogen fixer.
  - Thus, a large part of nitrogen is **fixed up and stored** in plants, animals, and microbes. Nitrogen leaves the living system in the same amount it is taken in from the atmosphere and the input and outflow of nitrogen are balanced in the ecosystem.

Sedimentary Cycles:

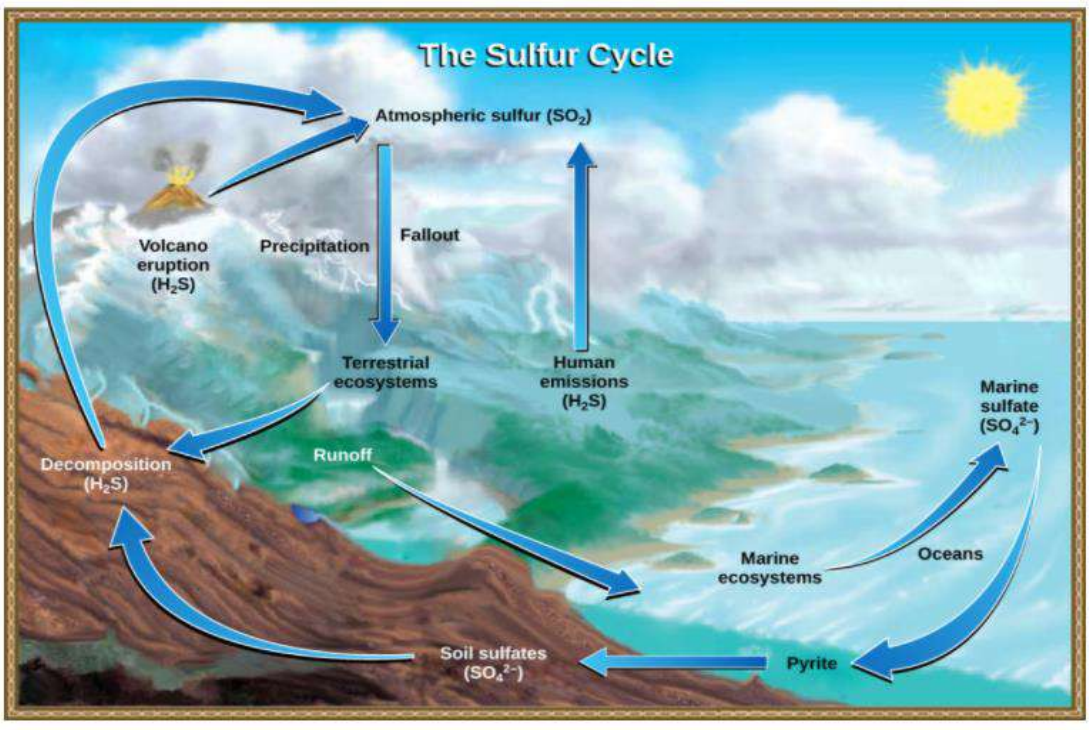
- Sedimentary cycles are a type of biogeochemical cycle, in which the reservoir is Earth's crust.

1. **Phosphorous cycle:**
    - Phosphorus moves in a cycle through rocks, water, soil and sediments and organisms.
    - Over time, rain, and weathering cause rocks to release phosphate ions and other minerals. This inorganic phosphate is then distributed in soils and water.
    - Plants take up inorganic phosphate from the soil. The plants may then be consumed by animals. Once in the plant or animal, the phosphate is incorporated into organic molecules such as DNA. When the plant or animal dies, it decays, and the organic phosphate is returned to the soil.
    - Within the soil, organic forms of phosphate can be made available to plants by bacteria that break down organic matter to inorganic forms of phosphorus. This process is known as mineralisation.
    - Phosphorus in soil can end up in waterways and eventually oceans. Once there, it can be incorporated into sediments over time.

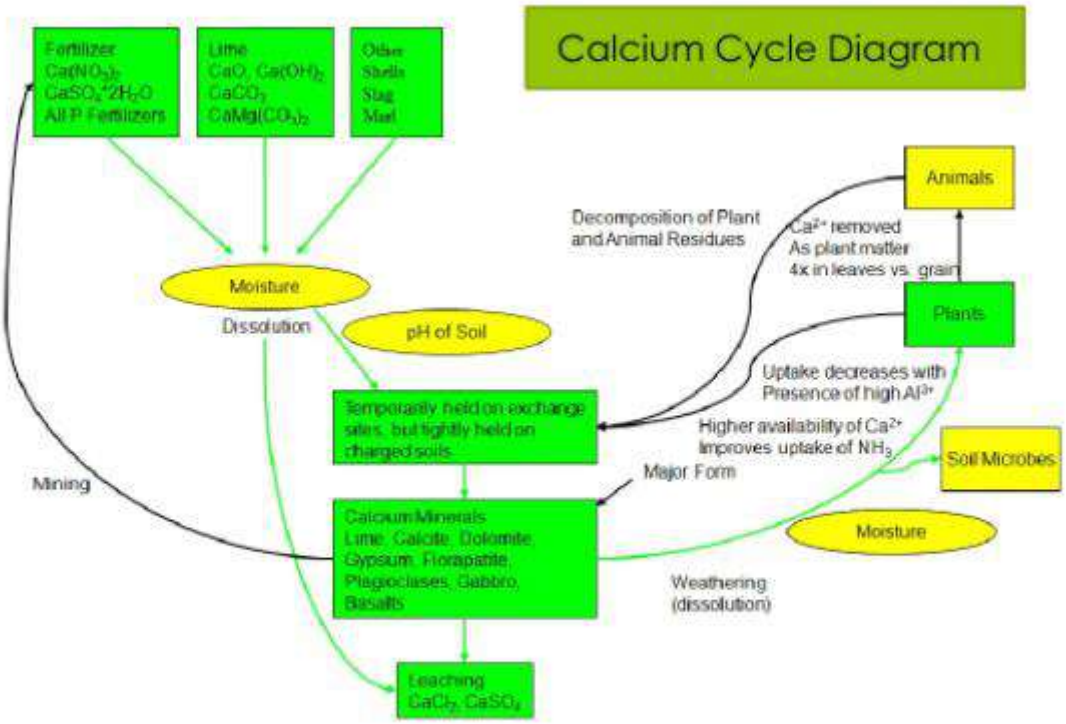
2. **Sulphur cycle**:
    - Most of the earth's sulphur is tied up in rocks and salts or buried deep in the ocean in oceanic sediments.



- Sulphur can also be found in the **atmosphere**. It enters the atmosphere through both natural and human sources.
- **Natural recourses** can be for instance volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms.
- When sulphur enters the atmosphere through **human activity**, this is mainly a consequence of **industrial processes** where sulphur dioxide (SO2) and hydrogen sulphide (H2S) gases are emitted on a wide scale.
  - When sulphur dioxide enters the atmosphere, it will react with oxygen to produce sulphur trioxide gas (SO3), or with other chemicals in the atmosphere, to produce **sulphur salts.**
  - Sulphur dioxide may also react with water to produce sulphuric acid (H2SO4).
    - Sulphuric acid may also be produced from demethylsulphide , which is emitted to the atmosphere by plankton species.
  - All these particles will settle back onto earth or react with rain and fall back onto earth as acid deposition.
    - The particles will then be absorbed by plants again and are released back into the atmosphere, so that the sulphur cycle will start over again**.**



3. **Calcium Cycle:**
    - Calcium is primarily present as rock, minerals or as structural calcium built into mineral crystal lattices of soil particles and is **not readily available**.
    - Calcium can also be added as fertilizer, lime, or by-products. Water can carry calcium into the soil through weathering and natural dissolution.
    - When in the soil, most of the calcium is in an **insoluble** form until it is 'weathered off' of minerals or when organic matter is broken down by microbes into **soluble calcium.**
        - However, some of the calcium are held loosely or tightly on soil's cation exchange complex (CEC) or in the soil solution and are available to plants and microorganisms.
    - When animals, microorganisms, or plants decay, their bodies **decompose,** and the **calcium is mineralized** and released back into the soil.
    - Roots also regularly leak minerals, sugars, and other compounds back into the soil including calcium.
    - Since calcium is a positively charged ion, it is adsorbed in the soil to the surface of clay and organic particles which are negatively charged. Positively charged ions (cations) adsorb to soil particles and are termed "exchangeable ions" because they can be exchanged by other ions present in the soil solution.
        - When absorbed by plants or microorganisms, calcium enters an organic phase. In this form, calcium is continually recycled between the plant roots, microorganisms, and soil.



- After a plant, animal, or soil fauna dies, decomposers break down the organism and calcium are released back to the soil in a soluble form.
  - Thus, Calcium **routinely moves back** and forth between the soluble (and available) and the insoluble (unavailable) phases.

Ecological Succession:

- An important characteristic of all communities is that their 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.
- These changes lead finally to a community that is in near equilibrium with the environment and that is called a **climax community.**
- The gradual and predictable change in the species composition of a given area is called **ecological succession.**
- The entire sequence of communities that successively change in each 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.
- Succession is hence 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 species that invade a bare area are called **pioneer species**. In primary succession on rocks these are usually lichens which can secrete acids to dissolve rock, helping in weathering and soil formation. These later pave the way to some very small plants like bryophytes, which can take hold in the small amount of soil.
- They are, with time, succeeded by bigger plants, and after several more stages, ultimately a stable **climax** forest community is formed.
- Secondary succession begins in areas where natural biotic communities have been destroyed such as in abandoned farmlands, burned or cut forests, lands that have been flooded. Since some soil or sediment is present, succession is faster than primary succession.
- **Based on the nature of the habitat** – whether it is water (or very wet areas) or 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 progresses from hydric to the mesic conditions.
- **Xerarch succession** takes place in dry areas and the series progress from xeric to mesic conditions.

BIODIVERSITY:

- It relates to the diversity among living organisms on the earth, including the diversity within and between the species and that within and between the ecosystems they form.

- The overall quantity and variety of species in a certain area or region is referred to as the region's biodiversity.
- It covers diversity within and between species as well as diversity in the ecosystem.
- The two main parts of biodiversity are species richness and species evenness. Whittaker carried out the biodiversity measurement.

Species Richness: Species richness refers to the variety of species found in a population. Alpha diversity, beta diversity, and gamma diversity are its three subtypes.

Species Evenness – The measure of species proportion at a particular site is species evenness.

IMPORTANCE OF BIODIVERSITY:

Biodiversity has contributed a lot to the development of human culture, and, in turn, human communities have played an important role in shaping the biodiversity at the genetic, species and ecological levels.

Biodiversity is important in the following ways:

- **Ecological role:** Species of many kinds perform some of the other functions in an ecosystem. Every organism, besides fulfilling its own needs, also contributes something useful to different other organisms in the environment. Species capture, store and utilise energy, produce and decompose organic materials, are part of cycles of water and nutrients throughout the ecosystem, fix gases in the atmosphere and help regulate the climate. Thus, they help in soil formation, reducing pollution, protection of land, water, and air resources. These functions of biodiversity are important for ecosystem functions and stability.
- **Ecosystem services:** Biodiversity underpins the basis of all the ecosystem services on the planet.
- **Provisioning Services:** Various plants, animals and microorganisms which form the biodiversity, provide us with foods such as cereals, fishes etc., fibre for our clothes such as cotton, wool etc., fuelwood for survival as well as pharmaceutical products such as neem, Tulsi etc.
- **Regulating services:** Biodiversity regulates the local as well as global climate, manages the global levels of oxygen, carbon dioxide and other gases, maintains freshwater quality by vegetation slowing runoff, absorbs carbon by acting as carbon sinks etc. Thus, biodiversity regulates the life and life processes on the planet.
- **Supporting services:** Biodiversity helps in pollination, nutrient cycling as well as recycling, greenhouse gas reduction by sequestration.
- **Social and cultural services:** Biodiversity provides us with aesthetic pleasure. It provides recreational avenues and rich biological diversity encourages tourism in the region. Many communities and cultures have co-evolved with the surroundings and the resources provided by a biologically diverse environment. Hence, it performs an important social role as well. Important services which are provided by biodiversity are: Recreation and relaxation Tourism especially ecotourism Art, Design and inspiration Spiritual experiences and a sense of place.

- **Food web maintenance:** Biodiversity helps in maintaining food webs as higher the diversity of an ecosystem, more complex is going to be the food webs because there are so many options to eat. Therefore, higher chances of survival of every species are there. This results in more stable food chains and food webs.
- **Scientific role:** Biodiversity help in scientific research, education, and monitoring. For example, research about new genetic materials with the help of gene pools. Biodiversity, thus, helps in understanding the functioning of life and the role that each species plays in sustaining ecosystems of which we humans are also a part.

TYPES OF BIODIVERSITY:

Based on the **three elements of biodiversity, that is, genes, species and ecosystems**, biodiversity is of **three types:**

- **Genetic diversity:** It can be understood as the diversity of genes within a particular species. This diversity **ensures that** some species can survive disruptions. Thus, genetic diversity gives us beautiful butterflies, roses, corals and fruits in myriad hues, sizes, and shapes.
- **Species diversity:** It refers to the variety of species within a particular geographical region. Species which are different from one another do not interbreed naturally However, closely associated species can have a lot of similarity in their hereditary characteristics. For example, humans and chimpanzees have about 98.4 percent genes which are the same. Species diversity is measured by **species richness**, which means the number of different species per unit area in a region, and species evenness equitably, which refers to the relative abundance of individuals of different species in an area.
- **Ecosystem or Community diversity:** It refers to the diversity of different biological communities or ecosystems like forests, deserts, lakes, corals etc. In a region or on the earth. As the ecosystem changes, species best adapted to that ecosystem becomes predominant. Thus, biodiversity also depends on the nature of the ecosystems.

MEASUREMENT OF BIODIVERSITY:

Measurement of biodiversity was done by **Whittaker**. Biodiversity can be measured by two major components: **Species Richness** and **Species Evenness**

- **Species Richness:** It refers to the measure of several species found in per unit area of a region or community. It has three components:
  - **Alpha diversity:** It refers to the diversity of species found in a particular area or ecosystem and is usually expressed by the number of species in that ecosystem.
  - **Beta diversity:** It refers to the comparison of the diversity of species between two or more ecosystems, usually measured as the change in the number of species between the ecosystems.
  - **Gamma diversity:** It is the measure of the overall diversity for the different ecosystems in a region. It is highly subjective because of different perceptions about the boundaries of the region.

- **Species Evenness:** It is the measure of relative abundance of individuals of different species in each region. Low evenness in general, means that a few species dominate the region or ecosystem.

LOSS OF BIODIVERSITY:

- The loss of species, ecosystems or genes is termed as a loss of biodiversity. The biological wealth of the planet is declining rapidly. The IUCN Red List documents the extinction of 784 species (including 338 vertebrates, 359 invertebrates and 87 plants) in the last 500 years. In the last 20 years alone, we have witnessed the loss of more than 30 species. As per the Living Planet report:
- The present rate of extinction of species is up to 100 to 1000 species extinction per 10,000 species in a duration of 100 years. This is almost 1000 times more than the natural rate of extinction.
- The living planet index, which measures the biodiversity abundance levels, is showing a persistent downward trend. On average, monitored species population has declined by 58% since the year 1970.
- In tropical forests, there has been a 40% decline of species since the year 1970.
- Whereas in temperate grasslands, species population has declined by 18% and in freshwater habitat, species population has declined by 81% since the year 1970.

Reasons for loss of Biodiversity:

- **Habitat loss and fragmentation:** This is a primary cause which drives animals and plants to extinction. The habitat loss and fragmentation have been through changes of land use the conversion of natural ecosystems to cropland, development of infrastructure projects like rails and roadways, increasing urbanisation and mining activities. As per the **Living Planet report**, there has been about a 30% decline in wetlands in the last 40 years. Wetlands have been primarily reclaimed for agriculture and urbanisation. Also, about 50% of the tropical and subtropical forests and 45% of the temperate grasslands have been converted for human use. Besides total loss, the degradation of many habitats by pollution also threatens the survival of many species. When large habitats are broken up into smaller fragments because of different human activities, mammals and birds which require large territories and certain animals with migratory habits are adversely affected, causing a decline in their population.
- **Over-exploitation of species:** Unsustainable use of ecosystems and over-exploitation of biodiversity are a major reason behind biodiversity loss. Over-hunting or poaching of species, overfishing, and overharvesting of plant products can quickly lead to a decline in biodiversity. Changing consumption patterns of humans is often cited as the key reason for this unsustainable exploitation of natural resources. Many species which got extinct in the past 5 centuries, like Steller's Sea cow, passenger pigeon, were subject to over-exploitation by humans.
- **Introduction of alien species:** Plants, animals and microorganisms transported deliberately or unintentionally from an

outside geographical region can cause great damage to native species by competing with them for food and shelter, spreading diseases unknown to them, causing genetic changes through the process of interbreeding with native species, and disrupting various aspects of their food chains and the physical environment. For example, in India Water hyacinth was introduced by the British for beautification. But over time, it has become an invasive species, clogging rivers, lakes, and other water bodies, thus not allowing any aquatic life to grow and survive.

- **Environmental pollution:** The accumulation of Pollution such phosphorus and nitrogen largely from excess fertilizers running off farmland, harmful chemicals firm urban and suburban runoff, industrial effluents etc. which are discharged into the natural water bodies. For example, oil spill off the port of Ennore in Chennai in 2017. Similarly, plastic pollution causes the death of animals. Also, air pollution from industries and vehicles has resulted in the death of many bird species in urban areas.
- **Global climate change:** Climate change is projected to become a progressively more significant threat to biodiversity in the coming decades. Already, changes in the flowering and migration patterns as well as in the distribution of various species have been observed throughout the world. These changes have altered food chains and created mismatches within ecosystems where different species have evolved synchronised inter-dependence.
- **Co-extinctions:** When a particular species becomes extinct, the plants and animals associated with it in an obligatory way also come under the danger of becoming extinct. For example, when a host fish species becomes extinct, its unique assemblage of parasites also meets the same fate.
- **Natural causes:** Like floods, earthquakes and other natural disasters also cause loss of biodiversity.

Biodiversity Hotspots in India:

India has six hotspots of biodiversity out of the 36 biodiversity hotspots, making it a country rich in biodiversity. With a great array of flora and animals in India (including endangered species). The Himalayas, the Indo-Burma region, the Terrai-duar Savannah, the Western Ghats, Sunderland, and the Sundarbans are among India's hotspots for biodiversity. India's Sundarbans is another UNESCO World Heritage Site. The following is a detailed summary of India's Hotspots for Biodiversity-

Himalayas:

One of the main Indian hotspots is the Eastern Himalayas. It encompasses the regions of Burma, Nepal, Bhutan, Sikkim, and Arunachal Pradesh. It has an evergreen forest with oak and alpine trees in it. The wildlife includes the fascinating western tragopan, clouded leopard, slow loris, snow cock, heron, tiger, white-winged wood duck, and Indian civet.

Terrai-duar Savannah:

The Terrai-duar Savannah extends to the Indo Gangetic plain of Bhutan, Nepal, and India after forming a brief sliver at the foot of the Himalayas. The Terrai-duar Savannah is home to some of the tallest, richest slits, and rarest grasslands in the entire globe. These perforations are left behind by powerful

monsoon floods each year. The one-horned rhinoceros, sloth bears, Asian elephants, and many more animals are among the Terrai-duar Savannah's most notable wildlife.

Indo-Burma region:

One of India's largest hotspots is the Indo-Burma region. The Ganga plains, parts of the Andaman and Nicobar Island, Thailand, Myanmar, Cambodia, Lao PDR, the Brahmaputra River basin, and other areas are also affected. Numerous plant and animal species, like the Annamite muntjac and grey-crowned crucial, can be found there, making it one of the most endangered places. But the region needs legislative protection due to growing dangers from humans.

Sundarbans:

In the Ganga-Brahmaputra delta, there are 104 islands collectively known as the Sundarbans. With the largest mangrove forest in the world, Sunderbans is one of India's UNESCO World Heritage Sites. The Royal Bengal tigers live there. Along with Gangetic dolphins and estuarine crocodiles, as well as several other fish, animal, and bird species, it is home to Royal Bengal tigers. But today, the rise in sea level brought on by global warming poses a serious threat to the local species.

Sundaland:

The Nicobar Islands are home to India's Sundaland hotspot, which reaches the tectonic plates beneath the Indian Ocean. Probscis monkeys, Javan and Sumatran rhinoceros, pig-tailed langurs, and orangutans are among the animals that call it home. Only the probosci's monkeys of this group are present in the Borneo region. Additionally, the Sundaland hotspot is home to the rafflesia, the largest bloom in the world (it measures one metres long).

Western Ghats:

Beyond India's west coast, the Western Ghats extends from north to south. With numerous highland tropical rainforests, it is also one of the UNESCO World Heritage Sites. A wide range of animals and plants can be found in these forests. Tigers, black panthers, and leopards are all part of it. The endangered shy lion-tailed macaques are part of the fauna in the southern Western Ghats. The strange pig-nosed purple frog is seen in the Western Ghats during monsoon season. In the dense forests, new species are continuously being found.

Importance of Biodiversity:

The ecological balance of the ecosystem is significantly maintained by biodiversity. It performs a crucial ecological, economic, and scientific role. The significance of biodiversity can be summed up as follows:

Ecological Role:

There will be a better possibility for a species to survive threats and adversity if the habitat is diversified. As a result, it helps to protect species and keep the ecological equilibrium. By absorbing and storing energy, creating, and digesting organic material, adding to the water cycle, and controlling the climate, it plays a crucial role in ensuring human survival.

Economic Role:

A resource that is vital to daily existence is biodiversity, particularly agro biodiversity. It is important for growing food crops, livestock, fish, and other initial materials for cosmetics, food production, and medicinal resources.

Scientific Role:

The species, whether extinct or still existing, aids in comprehending the idea of evolution. It aids in comprehending the function and role carried out by a species in a specific ecosystem and demonstrating their various relationships.

Other Roles:

In addition to these responsibilities, maintaining the food web, pollination,

nutrient cycling, lowering greenhouse gas emissions, soil formation, etc.

Threats to Biodiversity:

Changes to our land- and water-use:

Numerous diverse ecosystems exist on our land and in our oceans, and business activities have an impact on these ecosystems. For instance, when construction companies drain and fill in wetlands or marshes to make place for housing, they remove the area that normally collects extra rainwater during storms.

Excessive consumption and unsustainable exploitation:

While logging, farming, and fishing can all be done responsibly, they frequently involve overusing resources. The entire web of life in an area can disintegrate if too many species, or even just a few significant species, are removed from the ecosystem.

Climate change:

Already, we are experiencing hotter weather, warmer oceans, and more extreme storms. Since many animals can't adapt to these circumstances, their populations plummet.

Increase in pollution:

For many ecosystems, pollution of the air, soil, and water is a major issue. Fish, birds, and other marine creatures accumulate tiny plastic particles that are suspended in the ocean's water. Many species in rivers and lakes are wiped out by industrial poisons. The soil, leaves, and water are all contaminated by air pollution. Less species, less diversity, and weaker ecosystems are the end results of all of this.

Conservation Methods:

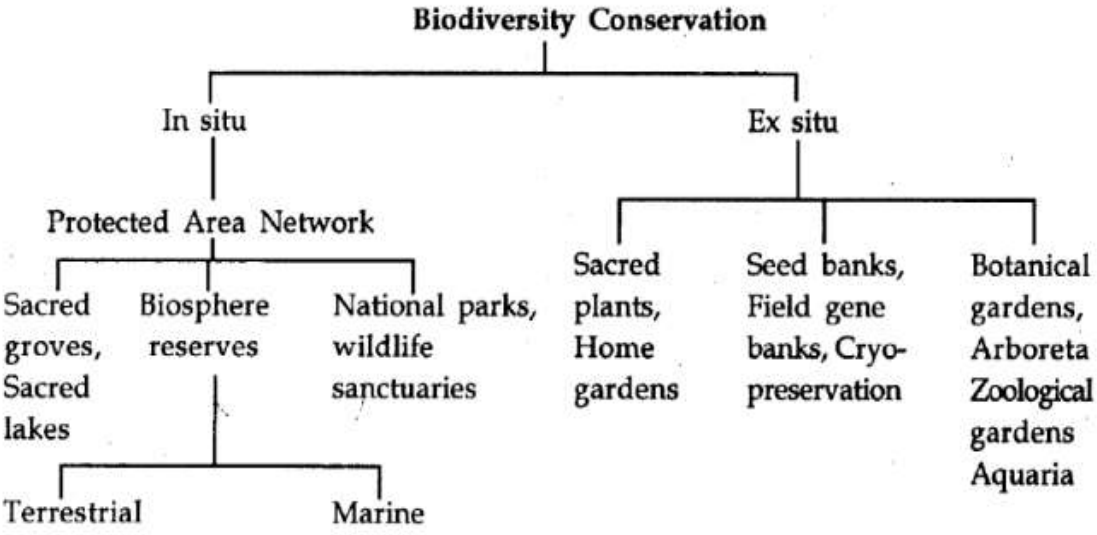


Fig. 1 The in-situ and ex-situ approaches of conserving biodiversity in India

In-situ conservation:

- It means conservation and management of genetic resources in their natural habitats. Here the plant or animal species are protected within the existing habitat. Forest trees, medicinal and aromatic plants under threat are conserved by this method. This is carried out by the community or by the State conservation which include wildlife, National Park, and Biosphere reserve. The ecologically unique and biodiversity rich regions are legally protected as wildlife sanctuaries, National parks, and Biosphere reserves. Megamalai, Sathyamangalam wildlife, Guindy and Periyar National Park, and Western ghats, Nilgiris, Agasthyamalai and Gulf of Mannar are the biosphere reserves of Tamil Nadu.

Sacred groves:

- These are the patches or grove of cultivated trees which are community protected and are based on strong religious belief systems which usually have a significant religious connotation for protecting community. Each grove is an abode of a deity mostly village God or Goddesses like Aiyanar or Amman. 448 grooves were documented throughout Tamil Nadu, of which 6 groves (Banagudi shola, Thirukurungudi and Udaiyankudikadu, Sittannnavasal, Puthupet and Devadanam) were taken up for detailed floristic and faunistic studies. These groves provide several ecosystem services to the neighbourhood like protecting watershed, fodder, medicinal plants, and microclimate control.

National Parks:

- They are the locations that the government has designated for the preservation of the environment.
- Compared to a wildlife sanctuary, a national park has additional restrictions.
- A national park's primary goals are to conserve biodiversity and the local natural environment.
- Their limits are set and clearly defined. No human activity is permitted here.
- Private tenancy rights and livestock grazing are prohibited in this area.
- Jim Corbett National Park (Uttarakhand), Kanha Tiger National Park (Madhya Pradesh), and Kaziranga National Park (Assam) are a few **examples**.

Wildlife Sanctuaries:

- Wildlife Sanctuaries are like national parks.
- Additionally, it is a protected area set aside for wildlife conservation. At wildlife sanctuaries, endangered species are given special attention.
- It also protects the plant species, allowing for the legalization of human activities like timber harvesting, small forest product production, and private property rights.
- In India, there are **543 wildlife sanctuaries,** 50 of which are Project Tiger-managed tiger reserves.
- In India, further initiatives include Project Rhino, Project Indian Bustard, and a few eco-developmental initiatives have been started.
- On April 1st, 1973, Kailash Sankhala introduced Project Tiger, one of the most effective conservation initiatives, to India.

Biosphere Reserves:

- Protection of wildlife and flora has become crucial. Although it can be difficult, protecting, and conserving animal and plant species is essential if humans are to survive.
- The term "biosphere reserve" refers to a protected area of land or a coastal environment where the land is divided into separate zones for a variety of uses.
- **Core Area:** Unaltered ecosystems are legally protected as part of the natural or core zone.
- **Buffer Zone:** The buffer zone encircles the core region. It supports a wide range of resource use tactics.
- **Transition Zone:** The transition zone is located at the very edge. It is a protected area for the local populations of animals, plants, and people.
- Nanda Devi (Uttarakhand), Manas (Assam), Dibru Saikhowa (Assam),

Great Nicobar, Sunderbans (West Bengal), and Pachmarhi (Madhya Pradesh) are few **examples** of India's biosphere reserves.

In-situ Conservation in Agriculture:

- Using in situ conservation strategies in agriculture is a successful strategy to enhance, preserve, and employ conventional or native kinds of crops.
- Such techniques connect farmers' experience and fieldwork with the beneficial results of scientific study.
- A variety's accessions from a germplasm bank and those that farmers have multiplied are first examined together in a producer's field and a lab, under various conditions and pressures.
- As a result, the scientific understanding of the native variety' production traits is improved.
- Later, reproducible conditions are used to cross, combine, and multiply the best tested accessions. Finally, the producers are given access to these improved accessions.
- So, instead of being encouraged to replace their own kinds with commercial ones or to give up on their crop, farmers are allowed to grow improved choices of their own variety.
- This method of agricultural biodiversity conservation works better in remote places where commercial varieties are impractical because of climatic and soil fertility restrictions, or where the flavor and cooking qualities of traditional varieties makeup for their lower yields.

In-situ Conservation – Advantages:

- **Cost Efficient:** In-situ conservation is an inexpensive and practical strategy to preserve biological variety.
- The species is allowed to develop in its native environment, where it has been developing for a long time, with the elimination of factors that are harmful to the species' survival.
- This significantly lowers the cost of conservation activities.
- **Protection of Entire Ecosystem:** We safeguard the complete ecosystem or natural habitat to guarantee the continued existence of the species.
- Naturally, the system needs enough herbivores to provide food for the predators to protect a population of carnivores.
- There must be plenty of green foliage for herbivores to eat to keep the number of herbivores stable.
- As a result, a high number of organisms are preserved via the process.
- **Free Play of Natural Agents: In a natural system, organisms not only survive and reproduce, but also change with time.**
- A natural ecosystem permits the free play of natural forces, such as drought, storms, snow, temperature fluctuations, heavy rain, fires, diseases, etc., which give organisms the chance to adapt to the environmental conditions and develop into better adapted living forms.

In-situ Conservation – Disadvantages:

- **Survival:** Fragmented endangered habitats may not have enough space to guarantee the survival of these species.
- **Decline in Genetic Diversity:** There may already be a significant decline in genetic diversity.
- **Diseases and Interspecific Competition:** There may still be diseases or interspecific competition,

for example, that threaten the local organisms.

- **Poaching And Tourism Activities:** The developing area can present a chance for poachers and ecotourists to do harm.

Ex-situ Conservation:

- This method involves removing threatened animals and plants from their native environment and relocating them to a designated location where they can be protected and given specialised care.
- This is accomplished by zoological parks, botanical gardens, wildlife safari parks, and seed banks.
- Many species of animals are nevertheless kept alive in zoological parks despite going extinct in the wild.
- Ex-situ conservation has recently gone beyond the preservation of vulnerable species.
- Now, utilizing cryopreservation technology, gametes of endangered species can be kept in viable and fertile form for extended periods of time.
- In vitro fertilization of eggs and tissue culture techniques for plant propagation are also possible.
- In seed banks, seeds of several genetic strains of commercially significant plants can be preserved for a long time.
- The key focus of the national gene bank at the National Bureau of Plant Genetic Resources (NBPGR), Delhi, is the long-term preservation of rare accessions as base collections for future generations, particularly in the form of seeds.

Ex-situ Conservation – Facilities:

Botanical Gardens:

- This is a technique for ex-situ conservation of endangered and threatened species in their local habitats.
- Governments at various levels, educational institutions, and international assistance are all involved in maintaining this.
- More than 80,000 species can be found in more than 1500 botanic gardens and arboreta around the globe.
- There are currently tissue culture labs, seed banks, and other ex-situ technologies at many of these botanical gardens.

Zoological Parks (Zoos):

- Around the world, there are more than 800 professionally run zoos that house around 3000 different species of mammals, birds, reptiles, and amphibians.
- These zoos frequently feature advanced captive breeding programmes.
- Breeders and genetic engineers have a ready source of genetic material thanks to the protection of crop plants', animals', or microbes' wild ancestors.
- Many tropical islands have many indigenous animal species, and they also have a highly spectacular record of agro biodiversity.

Wildlife Safari Parks:

- **A safari park, sometimes known as a wildlife park, is a zoo-like commercial is an ex-situ conservation technique.**
- A zoo-like establishment frequently referred to as a "wildlife park," a safari park is an example of ex-situ conservation.
- It is a drive-in tourist attraction where visitors can ride in vehicles provided by the establishment or drive their

own cars while watching animals roam freely.

- A safari park is bigger than a zoo and smaller than a game reserve. For instance, the 750-acre African Lion Safari in Hamilton, Ontario, Canada (3.0 km2).

Seed Banks:

- **Seeds are kept in seed banks to protect genetic variety for the future.**
- They often contain jars of seeds from various plant species and are vaults that are bomb, flood, and radiation proof.
- Seeds must be kept in storage for a variety of reasons. To boost crop output, disease resistance, drought tolerance, nutritional quality, flavor, and other traits, plant breeders need certain genes to be preserved.
- Another is to prevent the genetic diversity of rare or threatened plant species from being lost to ex situ conserve biodiversity.
- The seeds are normally stored in low humidity and cold (about -20°C) conditions.

Techniques for Plants:

Cryopreservation:

Seeds, pollen, tissue, and embryos are all stored in liquid nitrogen during plant cryopreservation. Compared to all other methods of ex situ conservation, this method allows for practically unlimited storage of the material without deterioration over a far longer time frame. Through cryoconservation of animal genetic resources, cryopreservation is also employed to conserve livestock genetics. Many species cannot be cryopreserved due to technical limits, but plants are the subject of several studies in the discipline of cryobiology, which is an area of ongoing research.

Seed Banking:

- The preservation of seeds in a setting with controlled humidity and temperature is called seed banking.
- For taxa with conventional seeds that can withstand desiccation, this method is employed.
- Facilities for seed banks range from climate-controlled walk-in freezers or vaults to sealed boxes.
- Normally, taxa with resistant seeds that cannot tolerate desiccation aren't kept in seed banks for a very long time.

Field Gene Banking:

- Field Gene Banking refers to a sizable open-air planting used to preserve the genetic variety of wild, domesticated, or forest species.
- In most cases, field gene banks conserve species that are either impossible or difficult to conserve in seed banks.
- Field gene banks can be used to cultivate and pick offspring of species preserved via various ex situ methods.

Cultivation Collections:

- Cultivation Collections refers to plants that are cared for horticulturally in a built landscape, usually a botanic garden or arboretum.
- Although plants are kept in their natural habitat, this method is comparable to field gene banks in that collections are often not as large or genetically varied.
- These collections are vulnerable to disease spread, genetic drift, artificial selection, and hybridization. Frequently, cultivated collections contain species that cannot be preserved using other ex situ methods.

Inter situ:

- Horticulture is used to take care of the plants, but the surroundings are kept as close to natural as possible.
- This happens in both semi-natural and restored habitats.
- This method is mainly applied to uncommon taxa or those that are found in severely degraded habitats.

Tissue Culture:

- In tissue culture, somatic tissue can be kept in vitro for a short while.
- This is carried out in a setting with controlled lighting and temperature to manage cell development.
- Tissue culture is mostly utilized for clonal growth of vegetative tissue or immature seeds as an ex-situ conservation strategy.
- This makes it possible for clonal plants to grow from a tiny amount of parent tissue.

Techniques for Animals:

- Similar methods are used to protect endangered animal species and breeds.
- **Gene Banks:** In genebanks, which are composed of cryogenic facilities used to store living sperm, eggs, or embryos, animal species can be conserved.
- **Cryopreservation:** For instance, the Zoological Society of San Diego has created a "frozen zoo" to retain such samples from more than 355 species, including mammals, reptiles, and birds, using cryopreservation techniques.
- **Interspecific Pregnancy:** Interspecific pregnancy is one such method that could help endangered species reproduce.
- It involves implanting embryos of an endangered species into a female of a related species and allowing to bring the embryo to term. For the Spanish ibex, it has been done.

Ex-situ Conservation – Advantages:

- Organisms are completely protected from predators and poachers.
- Individuals' health can be tracked, and medical assistance can be provided as required.
- Populations can be divided more effectively in the case of a disaster.
- Genetic diversity of the population can be measured.
- Selective breeding programmes can be implemented.
- Modern reproductive technology can increase the chances of reproductive success.
- Animals and plants can be bred to increase their numbers if they are in danger of extinction.
- Research on an endangered species' reproductive physiology, way of life, and ecology is made simpler.
- Funds for additional conservation efforts might be raised by using conservation sites as attractions.
- Educational activities can take place at conservation areas.

Ex-situ Conservation – Disadvantages:

- Genetic diversity in captive populations is minimal.
- As the creatures are residing outside of their normal habitat, nutritional problems could occur.
- Animals can be exposed to a wide variety of various diseases.
- Animals might not behave normally.
- Attempting to reproduce at times may become difficult.
- Appropriate environmental conditions for survival could be challenging to attain.
- Acceptance by the species' current wild members may present challenges.

Historic Movements to Conserve Biodiversity:

Chipko Movement:

- It is a social-ecological movement that used **hugging trees to stop them from falling** as a form of **peaceful resistance** and Gandhian satyagraha.
- Early in the 1970s, when awareness of rapid deforestation grew, the contemporary Chipko movement was born in Uttarakhand's Garhwal Himalayas.
- On March 26, 1974, a group of peasant women in Reni village, Hemwalghati, in Chamoli district, Uttarakhand, India, took action to stop the cutting of trees and reclaim their **traditional** forest rights that were threatened by the contractor system of the state Forest Department.
- This action is considered the turning point in this conflict.
- Numerous such acts were sparked by their deeds at the local level around the area.
- By the 1980s, the movement had **extended over all of India**, which helped to shape people-sensitive forest policies that ended open tree-cutting in places like Vindhyas and the Western Ghats.
- However, the first known instance of Chipko was in the village of Khejarli in the Jodhpur area in 1730 AD when 363 Bishnois under the leadership of Amrita Devi gave their lives to hug **green Khejri trees**, which were revered by the locals.

Appiko Movement:

- In India, the Appiko movement was a groundbreaking **environmental conservation** movement.
- The peasants of the district of **Karnataka** province in southern India started a similar initiative to safeguard their forests after being **inspired by the Chipko** movement in Himalayan Uttarakhand.
- Salkani men, women, and kids "hugged the trees" in Kalase forest in September 1983 (In Kannada, "hugging" is referred to as "appiko").
- Southern India saw a new consciousness because of the Appiko movement.

Biodiversity-related Conventions:

Several international conventions focus on biodiversity issues: the Convention on Biological Diversity (year of entry into force: 1993), the Convention on Conservation of Migratory Species, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975), the International Treaty on Plant Genetic Resources for Food and Agriculture (2004), the Ramsar Convention on Wetlands (1971), the World Heritage Convention (1972) and the International Plant Protection Convention (1952), the International Whaling Commission (1946).

Convention on Biological Diversity:

The objectives of the CBD are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from commercial and other utilization of genetic resources. The agreement covers all ecosystems, species, and genetic resources.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):

The CITES aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Through its three appendices, the Convention accords varying degrees of protection to more than 30,000 plant and animal species.

Convention on the Conservation of Migratory Species of Wild Animals:

The CMS, or the Bonn Convention aims to conserve terrestrial, marine and avian migratory species throughout their range. Parties to the CMS work together to conserve migratory species and their habitats by providing strict protection for the most endangered migratory species, by concluding regional multilateral agreements for the conservation and management of specific species or categories of species, and by undertaking co-operative research and conservation activities.

The International Treaty on Plant Genetic Resources for Food and Agriculture:

The objectives of the Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security. The Treaty covers all plant genetic resources for food and agriculture, while its Multilateral System of Access and Benefit-sharing covers a specific list of 64 crops and forages. The Treaty also includes provisions on Farmers' Rights.

Convention on Wetlands (popularly known as the Ramsar Convention):

The Ramsar Convention provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The convention covers all aspects of wetland conservation and wise use, recognizing wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities.

World Heritage Convention (WHC):

The primary mission of the WHC is to identify and conserve the world's cultural and natural heritage, by drawing up a list of sites whose outstanding values should be preserved for all humanity and to ensure their protection through a closer co-operation among nations.

International Whaling Commission (IWC):

The purpose of the IWC is to provide for the proper conservation of whale stocks and thus make possible the orderly development of the whaling industry.

Biodiversity Governance in India:

- The **Nagoya Protocol** sought to ensure commercial and research utilisation of genetic resources led to sharing its benefits with the government and the community that conserved such resources.
- India's Biological Diversity Act 2002 (BD Act) is in close synergy with the Nagoya Protocol.
- The BD Act was hailed as an important step towards preserving India's vast biodiversity, as it recognised the sovereign right of countries over its natural resources.
- Under the BD Act, an important regulatory mechanism was the emphasis on **ac cess and benefit sharing (ABS)** to local populations.
- The BD Act seeks to address issues of managing bio-resources in the most decentralised manner possible. The BD Act envisages **three layered structures**: the National Biodiversity Authority **(NBA)** at the national level, the state biodiversity boards **(SSBs)** at the state level and biodiversity management committees **(BMCs)** at the local level.
- It assumes significance because it imposes prohibitions on the transfer of genetic material originating from India without specific approval from competent authorities.

- The act also strengthens the country's stand with respect to anyone claiming an intellectual property right over biodiversity-related knowledge.

IUCN red list of threatened species:

- It is the world's most comprehensive **inventory of the global conservation status of plant and animal species.**
- ***How are species categorised?*** It uses a set of quantitative criteria to evaluate the extinction risk of thousands of species.

The IUCN Red List Categories:

- The IUCN Red List Categories define the extinction risk of species assessed. **Nine categories extend from NE (Not Evaluated) to EX (Extinct).**
- Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species are threatened with extinction.

The IUCN system uses a set of five quantitative criteria to assess the extinction risk of a given species. In general, these criteria consider:

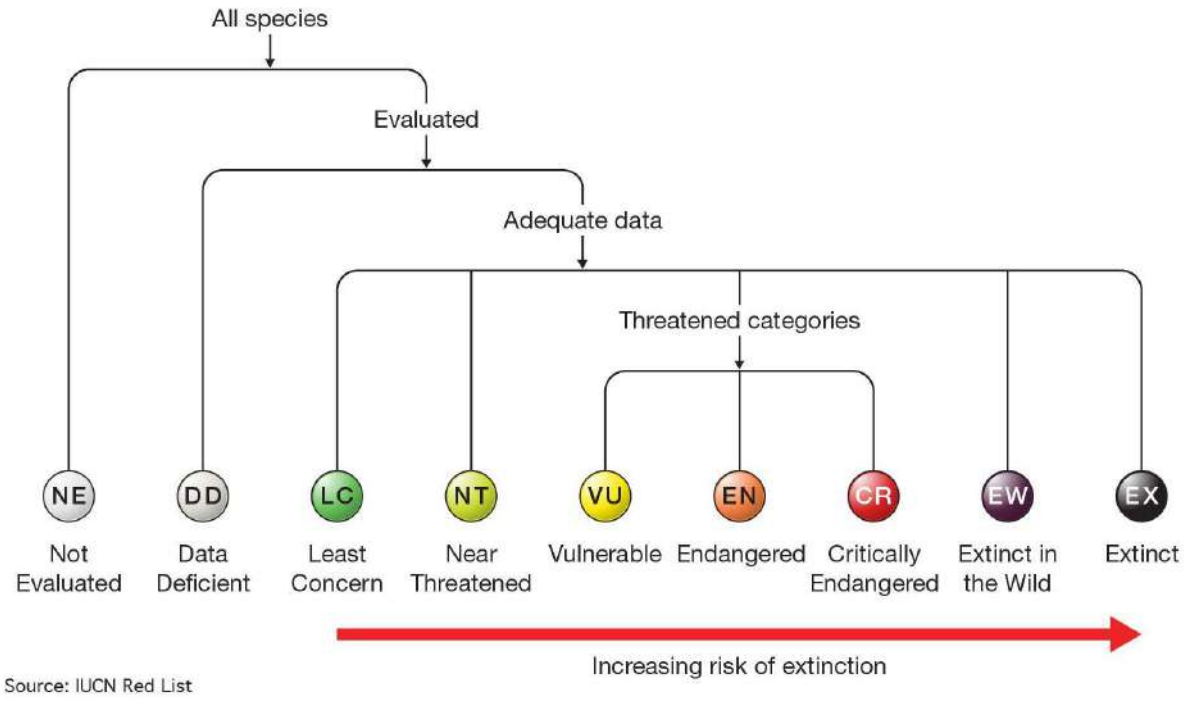
- The rate of population decline.
- The geographic range.
- Whether the species already possesses a small population size.
- Whether the species is very small or lives in a restricted area.
- Whether the results of a quantitative analysis indicate a high probability of extinction in the wild.

The Biological Diversity Act, 2002:

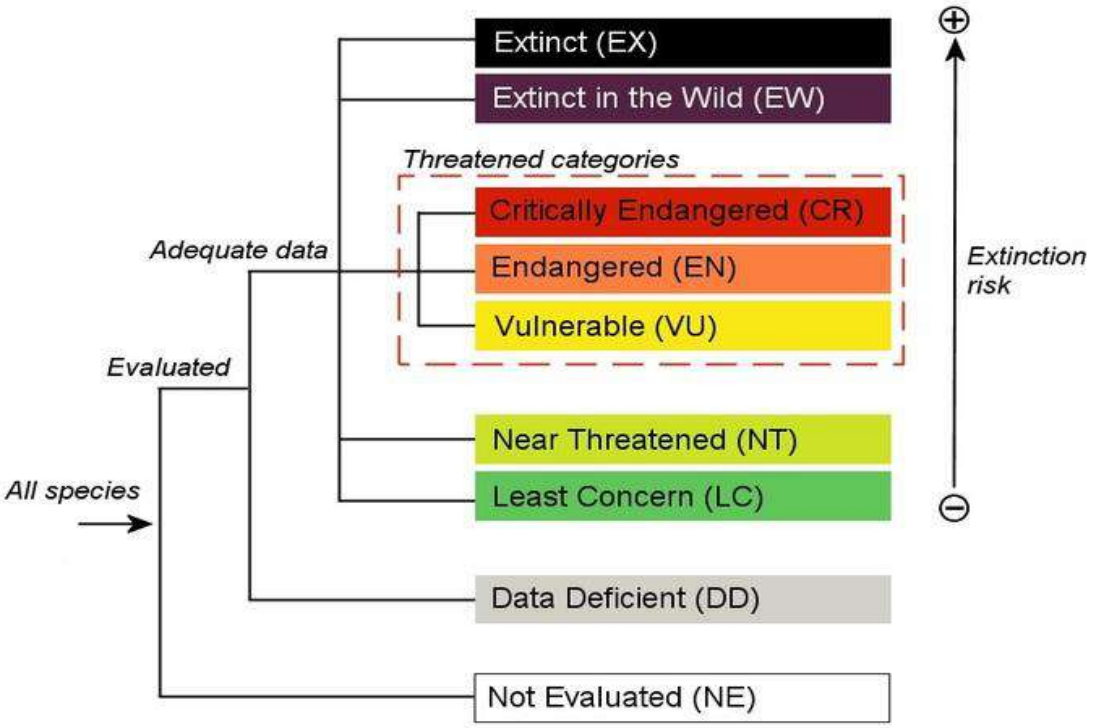
- The act was enacted in 2002, it **aims at the conservation of biological resources**, managing its **sustainable use** and **enabling fair and equitable sharing benefits** arising out of the use and knowledge of biological resources with the local communities.

Salient Features of the Act:

- The Act prohibits the following activities without the prior approval from the **National Biodiversity Authority:**
  - Any person or organisation (either based in India or not) obtaining any biological resource occurring in India for its research or commercial utilisation.
  - The transfer of the results of any research relating to any



Source: IUCN Red List



biological resources occurring in, or obtained from, India.
    - The claim of any intellectual property rights on any invention based on the research made on the biological resources obtained from India.
- The act envisaged a three-tier structure to regulate the access to biological resources:
    - **The National Biodiversity Authority** (NBA)
    - **The State Biodiversity Boards** (SBBs)
    - **The Biodiversity Management Committees** (BMCs) (at local level)
- The Act provides these authorities with special funds and a separate budget to carry out any research project dealing with the biological natural resources of the country.
    - It shall supervise any use of biological resources and the sustainable use of them and shall take control over the financial investments and their return and dispose of those capitals as correct.
- Under this act, the Central Government in consultation with the NBA:
    - Shall notify **threatened species** and prohibit or regulate their collection, rehabilitation, and conservation.
    - Designate institutions as repositories for different categories of biological resources
- The act stipulates all offences under it as **cognizable and non-bailable.**
- Any grievances related to the determination of benefit sharing or order of the National Biodiversity Authority or a State Biodiversity Board

under this Act, shall be taken to the National Green Tribunal (NGT).

The National Biodiversity Authority:

- The **National Biodiversity Authority (NBA)** was established in **2003** by the Central Government to implement India's Biological Diversity Act (2002).
- It is a **Statutory body** that performs facilitative, regulatory, and advisory functions for the Government of India on the issue of Conservation and sustainable use of biological resources.
- The NBA has its **Headquarters in Chennai,** Tamil Nadu, India.

Structure of the NBA:

- The National Biodiversity Authority consists of the following members to be appointed by the central government, namely:
  - **A Chairperson.**
  - **Three ex officio members,** one representing the Ministry dealing with Tribal Affairs and two representing the Ministry dealing with Environment and Forests.
  - **Seven ex-officio members** to represent respectively the Ministries of the Central Government dealing with:
    - Agricultural Research and Education
    - Biotechnology
    - Ocean Development
    - Agriculture and Cooperation
    - Indian Systems of Medicine and Homoeopathy
    - Science and Technology
    - Scientific and Industrial Research;
  - **Five non-official members** to be appointed from amongst specialists and scientists having special knowledge and experience in the required matters.

Functions of the NBA:

- Creating an enabling environment, as appropriate, to promote conservation and sustainable use of biodiversity.
- **Advising the central government, regulating activities** and **issuing guidelines** for access to biological resources and for fair and equitable benefit sharing in accordance with the Biological Diversity Act, 2002.
- Taking necessary **measures to oppose the grant of intellectual property rights** in any country outside India on any biological resource obtained from India or knowledge associated with such biological resources derived from India illegally.
- **Advising the State Governments** in the selection of areas of biodiversity importance to be notified as heritage sites and suggest measures for their management.

State Biodiversity Boards (SBBs):

- **The SBBs** are established by the State Governments in accordance with **Section 22** of the Act.
- **Structure:** The State Biodiversity Board consists of the following members:
  - **A Chairperson**
  - Not more than **five ex officio members** to represent the concerned Departments of the State Government
  - Not more than **five members from amongst experts** in matters relating to conservation

of biological diversity, sustainable use of biological resources and equitable sharing of benefits arising out of the use of biological resources.

- **All the members of the SBB are appointed by the respective State Governments.**

Functions of SBBs:

- **Advise the State Government,** subject to any guidelines issued by the Central Government, on matters relating to the conservation, sustainable use or sharing equitable benefits.
- **Regulate by granting approvals** or otherwise requests for **commercial utilisation or bio-survey and bio-utilisation** of any biological resource by people.

Biodiversity Management Committees (BMCs):

- According to **Section 41 of the Act,** every local body shall constitute the BMC within its area for the purpose of promoting conservation, sustainable use and documentation of biological diversity including:
  - Preservation of habitats
  - Conservation of Landraces
  - Folk varieties and cultivars
  - Domesticated stocks And breeds of animals
  - Microorganisms And Chronicling Of Knowledge Relating To Biological Diversity

Structure:

- It shall consist of **a chair person** and **not more than six persons** nominated by the local body.
  - Out of total members of a BMC, **not less than one third should be women** and not less than **18% should belong to the Scheduled Castes/ Scheduled Tribes.**
- The Chairperson of the Biodiversity Management Committee shall be elected from amongst the members of the committee in a meeting to be chaired by the Chairperson of the local body.
- The chairperson of the local body shall have the casting votes in case of a tie.

Functions:

- The main function of the BMC is to prepare **People's Biodiversity Register** in consultation with the local people.
- The register shall contain comprehensive information on availability and knowledge of local biological resources, their medicinal or any other use or any other.

Biodiversity Heritage Sites (BHS):

- **Under Section 37 of Biological Diversity Act, 2002** the State Government in consultation with local bodies may notify the areas of biodiversity importance as **Biodiversity Heritage Sites.**
- The Biodiversity Heritage Sites are the well defined areas that are unique, ecologically fragile ecosystems - **terrestrial, coastal and inland waters and, marine** having rich biodiversity comprising of any one or more of the following components:
  - richness of wild as well as domesticated species or intra-specific categories
  - high endemism
  - presence of rare and threatened species
  - keystone species

- species of evolutionary significance
- wild ancestors of domestic/cultivated species or their varieties
- past preeminence of biological components represented by fossil beds
- having significant cultural, ethical, or aesthetic values; important for the maintenance of cultural diversity (with or without a long history of human association with them)