

## Ecosystem

### **Introduction :**

An ecosystem is a geographic area where plants, animals, and other organisms, as well as weather and landscape, work together to form a bubble of life. Ecosystems contain biotic or living, parts, as well as abiotic factors, or nonliving parts. Biotic factors include plants, animals, and other organisms. Abiotic factors include rocks, temperature, and humidity. Every factor in an ecosystem depends on every other factor, either directly or indirectly. A change in the temperature of an ecosystem will often affect what plants will grow there, for instance. Animals that depend on plants for food and shelter will have to adapt to the changes, move to another ecosystem, or perish.

Ecosystems can be very large or very small. Tide pools, the ponds left by the ocean as the tide goes out, are complete, tiny ecosystems. Tide pools contain seaweed, a kind of algae, which uses photosynthesis to create food. Herbivores such as abalone eat the seaweed. Carnivores such as sea stars eat other animals in the tide pool, such as clams or mussels. Tide pools depend on the changing level of ocean water. Some organisms, such as seaweed, thrive in an aquatic environment, when the tide is in and the pool is full. Other organisms, such as hermit crabs, cannot live underwater and depend on the shallow pools left by low tides. In this way, the biotic parts of the ecosystem depend on abiotic factors. The whole surface of Earth is a series of connected ecosystems. Ecosystems are often connected in a larger biome. Biomes are large sections of land, sea, or atmosphere. Forests, ponds, reefs, and tundra are all types of biomes, for example. They're organized very generally, based on the types of plants and animals that live in them. Within each forest, each pond,

each reef, or each section of tundra, you'll find many different ecosystems.

The biome of the Sahara Desert, for instance, includes a wide variety of ecosystems. The arid climate and hot weather characterize the biome. Within the Sahara are oasis ecosystems, which have date palm trees, freshwater, and animals such as crocodiles. The Sahara also has dune ecosystems, with the changing landscape determined by the wind. Organisms in these ecosystems, such as snakes or scorpions, must be able to survive in sand dunes for long periods of time. The Sahara even includes a marine environment, where the Atlantic Ocean creates cool fogs on the Northwest African coast. Shrubs and animals that feed on small trees, such as goats, live in this Sahara ecosystem. Even similar-sounding biomes could have completely different ecosystems. The biome of the Sahara Desert, for instance, is very different from the biome of the Gobi Desert in Mongolia and China. The Gobi is a cold desert, with frequent snowfall and freezing temperatures. Unlike the Sahara, the Gobi has ecosystems based not in sand, but kilometers of bare rock. Some grasses are able to grow in the cold, dry climate. As a result, these Gobi ecosystems have grazing animals such as gazelles and even takhi, an endangered species of wild horse.

Even the cold desert ecosystems of the Gobi are distinct from the freezing desert ecosystems of Antarctica. Antarctica's thick ice sheet covers a continent made almost entirely of dry, bare rock. Only a few mosses grow in this desert ecosystem, supporting only a few birds, such as skuas.

### **The Components of an Ecosystem:**

At a basic functional level, ecosystem generally contains primary producers

(plants) capable of harvesting energy from the sun through the process called photosynthesis. This energy then flows through the food chain. Next come **consumers**. Consumers could be **primary consumers** (herbivores) or **secondary consumers** (carnivores). These consumers feed on the captured energy. Decomposers work at the bottom of the food chain. Dead tissues and waste products are produced at all levels. Scavengers, detritivores and decomposers not only feed on this energy but also break organic matter back into its organic constituents. It is the microbes that finish the job of decomposition and produce organic constituents that can again be used by producers.

There are four basic components of an ecosystem: abiotic substances, producers, consumers, and reducers, which are also known as decomposers.

### **Abiotic Substances –**

Abiotic means that a substance is devoid of life, it is physical and not derived from living organisms. With that being said, abiotic components include things such as carbon dioxide, sunlight, temperature, precipitation, water or moisture, soil, water chemistry etc. These components can be divided into two different groups: organic and inorganic. Abiotic substances can greatly affect an ecosystem. In fact, if one factor is changed even slightly, it can cause a disturbance.

### **Producers**

Producers, which are also referred to as autotrophs, are organisms that produce complex organic compounds from simple substances present in an ecosystem. This is completed using abiotic components, such as energy from sunlight. Examples of producers in an ecosystem include bacteria, algae or other green plants. Their ultimate responsibility in an ecosystem is to capture energy from non-organic sources, and then store them for future use.

### **Consumers**

Consumers, which are also known as heterotrophs, are organisms that cannot fix carbon from non-organic sources, so instead, they eat other living organisms. Several animals fall into this category, such as

herbivores (organisms that consume plants) and carnivores (organisms that eat other animals). Consumers are an essential component of any ecosystem.

### **Decomposers**

Decomposers can also be known as reducers. This is because these heterotrophic organisms break down dead animals and waste matter. Prime examples of decomposers include fungi and certain bacteria species. They are critical to any ecosystem. In fact, an ecosystem could not function very long without the presence of reducers. Without them, ecosystems would be littered with dead organisms.

### **Types of Ecosystem :**

There are basically three types of ecosystems under which any other sub-ecosystem falls. They are:

- **Terrestrial Ecosystem**
- **Freshwater Ecosystem**
- **Ocean Ecosystem**

In light of the fact that there are numerous different kinds of places on Earth, terrestrial ecosystems are many.

#### ***1. The Forest Ecosystems***

In forest ecosystems, a massive number of organisms can live in fairly small space. These are ecosystems in which you find a lot of flora. It suffices to say that the density of living organisms in forest ecosystems is pretty high.

A slight change in forest ecosystem can affect the entire balance, effectively killing the whole ecosystem. These ecosystems also feature a wide range of fauna. They can further be divided into Tropical evergreen forest, Tropical deciduous forest, temperate evergreen forest, temperate deciduous forest, and Taig.

## ***2. The Desert Ecosystem***

Desert ecosystems fall within regions that receive an annual rainfall not more than 25mm. The Earth is made of about 17 percent desert ecosystem. These ecosystems are characterized by intense sunlight, extremely high temperature, and low availability of water. What does this mean?

Flora and fauna are not only rare but also poorly developed. The plants feature stems and leaves that are modified in a bid to conserve as much water as possible. For instance, some common desert plants have succulent stems to store water, such as the spiny-leafed cactus.

Animals in this ecosystem are also adapted to various conditions that prevail in desert environments. The animals include reptiles, camels, birds, and insects.

## ***3. The Grassland Ecosystem***

Grassland ecosystems can be found in both the temperate and tropical regions across the globe, but with slight variations. These ecosystems mainly comprise grasses with a few trees and shrubs. Grasses are the main vegetation here, along with legumes, which belong to the composite family.

Grassland ecosystem is also home to a variety of grazing animals, herbivores, and insectivores. This ecosystem is further divided into savanna and prairies ecosystems.

## ***4. The Mountain Ecosystem***

Mountain land offers a dispersed and diverse range of habitats where various plants and animals can be found. The higher altitudes are characterized by harsh environmental conditions, which can only support the lives of treeless alpine vegetation. The animals found in this habitat have thick fur coats, which protect them from cold. At the lower slopes of the mountain environment, we mostly have coniferous forests.

**Freshwater Ecosystems :**

As the title suggests, freshwater ecosystems encompass freshwater environments and are divided into three basic categories:

- **Lentic**, which includes slow-moving or still water such as lakes, ponds, and pools. These are usually relatively small and contained. Most of the time they include various types of plants, amphibians and insects. Sometimes they include fish, but as these cannot move around as easily as amphibians and insects, it is less likely, and most of the time fish are artificially introduced to these environments by humans.
- **Lotic**, which includes fast-moving water like rivers and streams. Because rivers always link to the sea, they are more likely to contain fish alongside the usual plants, amphibians and insects. These sorts of ecosystems can also include birds because birds often hunt in and around water for small fish or insects.
- **Wetlands**, which include environments where the soil is saturated with water for a considerable period of time.

It is worth noting that freshwater ecosystems account for only 1.8 percent of the Earth's surface total, which makes it the smallest of the three main types of ecosystems. This ecosystem encompasses relatively small fish, amphibians, a variety of insects, as well as plants. Plankton is certainly the smallest living element of the food web in freshwater ecosystems. It is a tiny organism that is normally eaten by fish and other little creatures.

Freshwater ecosystems are those that are contained to freshwater environments. This includes, but is not limited to, ponds, rivers and other waterways that are not the sea (which is, of course, saltwater and cannot support freshwater creatures for very long). Freshwater ecosystems are actually the smallest of the three major classes of ecosystems, accounting for just 1.8% of the total of the Earth's surface. The ecosystems of freshwater systems include relatively small fish (bigger fish are usually found in the sea), amphibians (such as frogs, toads and newts), insects of various sorts and, of course,

plants. The absolutely smallest living part of the food web of these sorts of ecosystems is plankton, a small organism that is often eaten by fish and other small creatures.

### **Oceanic Ecosystems:**

Ocean ecosystems are amongst some of the most interesting in the world, especially in warm waters such as those of the Pacific Ocean. This is not least because around 75% of the Earth is covered by the sea, which means that there is lots of space for all sorts of different creatures to live and thrive. There are actually three different types of oceanic ecosystems: shallow waters, deep waters and the deep ocean surface. In two of these the very base of the food chain is plankton, just as it is in freshwater ecosystems.

These plankton and other plants that grow in the ocean close to the surface are responsible for 40% of all photosynthesis that occurs on Earth. From this there are herbivorous creatures that eat the plankton, such as shrimp, that are then themselves usually eaten by bigger creatures, particularly fish. Interesting, in the deep ocean, plankton cannot exist because photosynthesis cannot occur since light cannot penetrate that far into the ocean's depths. Down in the deepest depths of the ocean, therefore, creatures have adapted very strangely and are amongst some of the most fascination and the most terrifying and intriguing living creatures on Earth.

### **Bottom Line**

Living organisms cannot survive when separated from their non-living environments. This is because the non-living environments provide resources and energy for the survival of living organisms. Namely, there is an interrelationship between a biotic community and its environment geared to create a stable system – a natural self-sustaining unit that is called an ecosystem. Ecosystems are of three major types, and all of them have to comprise both biotic and abiotic components, the interactions, as well as a known source of energy.

### **Food Chain:**

Organisms of different species can interact in many ways. They can compete, or they can be symbionts—longterm partners with a close association. Or, of course, they can do what we so often see in nature programs: one of them can eat the other. That is, they can form one of the links in a food chain.

In ecology, a *food chain* is a series of organisms that eat one another so that energy and nutrients flow from one to the next. For example, if you had a hamburger for lunch, you might be part of a food chain that looks like this: grass→ cow→ human. But what if you had lettuce on your hamburger? In that case, you're also part of a food chain that looks like this: lettuce→human.

As this example illustrates, we can't always fully describe what an organism—such as a human—eats with one linear pathway. For situations like the one above, we may want to use a **food web** that consists of many intersecting food chains and represents the different things an organism can eat and be eaten by.

### **Autotrophs vs. Heterotrophs:**

What basic strategies do organisms use to get food? Some organisms, called *autotrophs*, also known as self-feeders, can make their own food—that is, their own organic compounds—out of simple molecules like carbon dioxide. There are two basic types of autotrophs:

- **Photoautotrophs**, such as plants, use energy from sunlight to make organic compounds—sugars—out of carbon dioxide in photosynthesis. Other examples of photoautotrophs include algae and cyanobacteria.
- **Chemoautotrophs** use energy from chemicals to build organic compounds out of carbon dioxide or similar molecules. This is called chemosynthesis. For instance, there are hydrogen sulfide-oxidizing chemoautotrophic bacteria found in undersea vent communities where no light can reach.

Autotrophs are the foundation of every ecosystem on the planet. That may sound dramatic, but it's no exaggeration! Autotrophs form the

base of food chains and food webs, and the energy they capture from light or chemicals sustains all the other organisms in the community. When we're talking about their role in food chains, we can call autotrophs *producers*.

**Heterotrophs**, also known as other-feeders, can't capture light or chemical energy to make their own food out of carbon dioxide. Humans are heterotrophs. Instead, heterotrophs get organic molecules by eating other organisms or their byproducts. Animals, fungi, and many bacteria are heterotrophs. When we talk about heterotrophs' role in food chains, we can call them *consumers*. As we'll see shortly, there are many different kinds of consumers with different ecological roles, from plant-eating insects to meat-eating animals to fungi that feed on debris and wastes.

Now, we can take a look at how energy and nutrients move through an ecological community. Let's start by considering just a few who-eats-who relationships by looking at a food chain.

A *food chain* is a linear sequence of organisms through which nutrients and energy pass as one organism eats another. Let's look at the parts of a typical food chain, starting from the bottom—the producers—and moving upward.

- At the base of the food chain lie the **primary producers**. The primary producers are autotrophs and are most often photosynthetic organisms such as plants, algae, or cyanobacteria.
- The organisms that eat the primary producers are called **primary consumers**. Primary consumers are usually **herbivores**, plant-eaters, though they may be algae eaters or bacteria eaters.
- The organisms that eat the primary consumers are called **secondary consumers**. Secondary consumers are generally meat-eaters—**carnivores**.
- The organisms that eat the secondary consumers are called **tertiary consumers**. These are carnivore-eating carnivores, like eagles or big fish.

- Some food chains have additional levels, such as **quaternary consumers**—carnivores that eat tertiary consumers. Organisms at the very top of a food chain are called **apex consumers**.

We can see examples of these levels in the diagram below. The green algae are primary producers that get eaten by mollusks—the primary consumers. The molluscs then become lunch for the slimy sculpin fish, a secondary consumer, which is itself eaten by a larger fish, the Chinook salmon—a tertiary consumer.

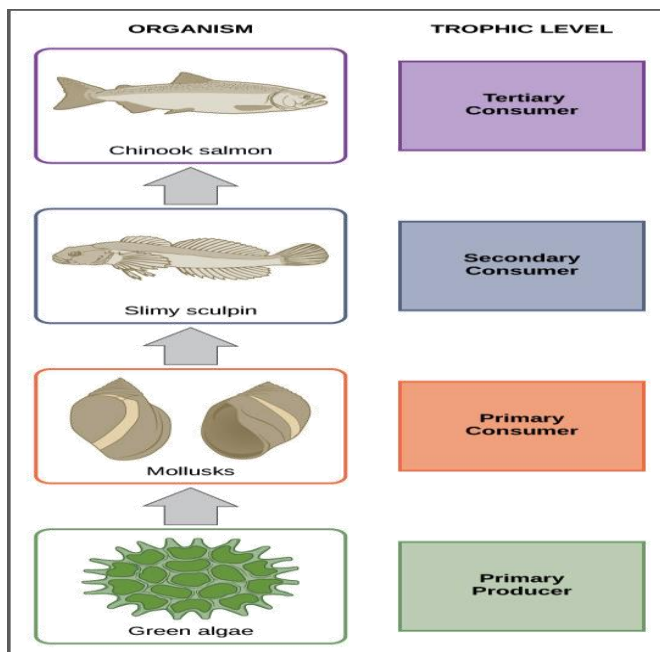


Image credit: *Ecology of ecosystems: Figure 3* by OpenStax College, Biology, CC BY 4.0

Each of the categories above is called a *trophic level*, and it reflects how many transfers of energy and nutrients—how many consumption steps—separate an organism from the food chain's original energy source, such as light. As we'll explore further below, assigning organisms to trophic levels isn't always clear-cut. For instance, humans are **omnivores** that can eat both plants and animals.

### Trophic Levels:

Organisms in food chains are grouped into categories called trophic levels. Roughly speaking, these levels are divided into producers (first

trophic level), consumers (second, third, and fourth trophic levels), and decomposers.

Producers, also known as autotrophs, make their own food. They make up the first level of every food chain. Autotrophs are usually plants or one-celled organisms. Nearly all autotrophs use a process called photosynthesis to create “food” (a nutrient called glucose) from sunlight, carbon dioxide, and water. Plants are the most familiar type of autotroph, but there are many other kinds. Algae, whose larger forms are known as seaweed, are autotrophic. Phytoplankton, tiny organisms that live in the ocean, are also autotrophs. Some types of bacteria are autotrophs. For example, bacteria living in active volcanoes use sulfur compounds to produce their own food. This process is called chemosynthesis.

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

Consumers can be carnivores (animals that eat other animals) or omnivores (animals that eat both plants and animals). Omnivores, like people, consume many types of foods. People eat plants, such as vegetables and fruits. We also eat animals and animal products, such as meat, milk, and eggs. We eat fungi, such as mushrooms. We also eat algae, in edible seaweeds like nori (used to wrap sushi rolls) and sea lettuce (used in salads).

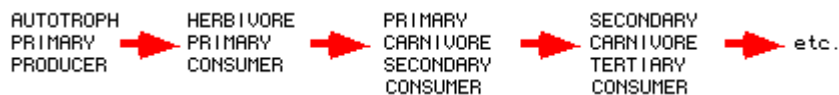
Detritivores and decomposers are the final part of food chains. Detritivores are organisms that eat nonliving plant and animal remains. For example, scavengers such as vultures eat dead animals. Dung beetles eat animal feces.

Decomposers like fungi and bacteria complete the food chain. They turn organic wastes, such as decaying plants, into inorganic materials,

such as nutrient-rich soil. Decomposers complete the cycle of life, returning nutrients to the soil or oceans for use by autotrophs. This starts a whole new food chain.

### Grazing Food Chain:

The Grazing food chain is a model that describes the general flow of energy in communities. For most ecosystems the model begins with the photosynthetic fixation of light, carbon dioxide, and water by plant autotrophs (primary producers) who produce sugars and other organic molecules. Once produced, these compounds can be used to create the various types of plant tissues. Primary consumers or herbivores form the second link in the grazing food chain. They gain their energy by consuming primary producers. Secondary consumers or primary carnivores, the third link in the chain, gain their energy by consuming herbivores. Tertiary consumers or secondary carnivores are animals that receive their organic energy by consuming primary carnivores. The illustration below models this process:



The various levels in the grazing food chain are linked to each other like links in a chain. The levels are often called trophic levels, and they suggest a particular order for the passage of energy through the food chain. Like many very simple models, the idea of a food chain only provides a simple abstraction of the nature of energy flow through communities. The ultimate disposition of the energy assimilated by consumers is by four routes: respiration, biomass accumulation, decay of organic matter by bacteria and other decomposer organisms, and consumption by consumers.

The actual amount of energy incorporated in the tissues of consumers at each trophic level is not determined by the gross amounts consumed. Instead, it is the amount of organic energy converted into actual biomass. Consumers lose significant amounts of consumed energy due to assimilation inefficiencies, morphological and physiological maintenance, reproduction, and the process of finding and capturing

food. The energy to perform the latter three processes is supplied by **respiration**.

Thus, the number of trophic levels that can be maintained in any ecosystem is finite. The limit is reached when consumers can no longer consume enough energy to balance the energy lost in the assimilation process, morphological and physiological maintenance, growth, reproduction, and in finding the food. Normally, ecosystems have about *four* or *five* trophic levels.

Finally, some ecosystems, like rivers and lakes, are characterized by large imports of biomass in the form of dead organic matter. This situation can cause consumer production to be higher than the **autotrophs** found in these systems.

### **Detritus Food Chain:**

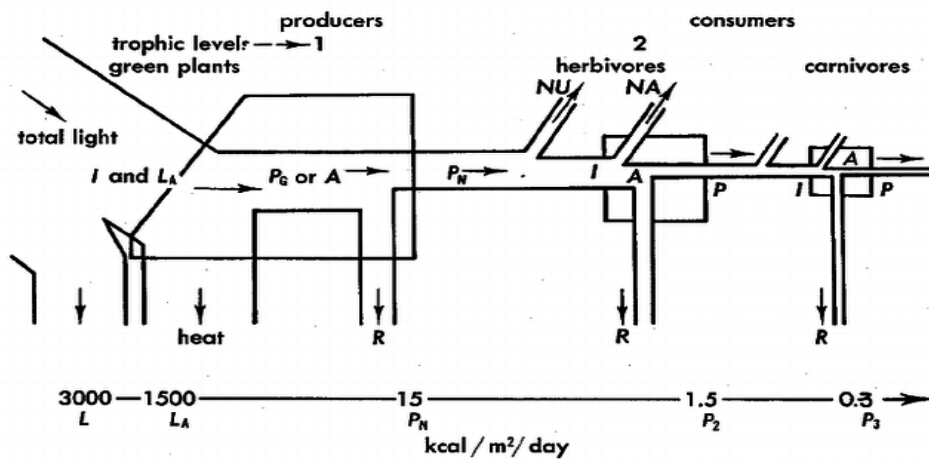
The **Detritus Food Chain** begins with dead organic matter. It is made up of **decomposers** which are heterotrophic organisms, mainly **fungi** and **bacteria**. They meet their energy and nutrient requirements by degrading dead organic matter or detritus. These are also known as **saprotrophs** (sapro: to decompose). Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.

Detritus food chain is the type of food chain in which the dead organic matter called detritus are utilized to maximum level and there is minimum wastage of organic material. Detritus food chains are vital in the ecosystem since the detritivores act upon the dead organic matter of grazing food chain and help in recycling the elements in the ecosystem. In detritus food chain the energy flow remains as a continuous passage rather than as a stepwise flow between discrete entities. Food is the basic source of energy for all organisms in the ecosystem. Due to 10% energy flow from each trophic level, any food chain cannot cross 5 trophic levels. Further steps include recycling of nutrient and flow of energy in Detritus food chain. However, the source of energy in Detritus food chain is dead organic matter.

### **Linear shaped Food chain:**

The principle of food chain and the working of the two laws of thermodynamics can be clarified by means of Single channel energy flow model. All biological activities need energy which they derived from the sun. The energy obtained from the sun is transformed into chemical energy by the process of photosynthesis. This energy is stored in plant tissue and transformed into heat energy during metabolic activities. The solar energy captured by autotrophs never revert back to sun, however, it passes to herbivores and that which passes to herbivores does not go back to autotrophs but passes to consumers. Thus, in biological system, the energy flows from the sun to plants and then to all heterotrophic organisms. The flow of energy is unidirectional and non-cyclic. Due to unidirectional flow of energy, the entire system would collapse if primary source of energy were cut off. At each trophic level there is progressive decrease in energy as heat in the metabolic reactions and also some of the energy is utilized at each trophic level. This one way flow of energy is governed by laws of thermodynamics which states: (a) Energy can neither be created nor be destroyed but may be transformed from one form to another. (b) During energy transfer there is degradation of energy from a concentrated form (mechanical, chemical etc.) to dispersed form (heat). (c) Energy transformation is never 100% efficient, it is always accompanied by some loss of energy in the form of heat. Therefore, all biological systems including ecosystems must required energy on a continuous Basis. The energy flow diagram (figure 2)) depicting three trophic levels (box 1, 2 and 3) in a linear food chain. Here the boxes represent the trophic level (producers, herbivores and carnivores) and the pipe depicts the energy flow in and out of each trophic level. There is loss of energy (represented as pipes) at every successive trophic level, there is also a corresponding decline in biomass (represented as box). However, it does not specify any correlation between the biomass and energy. The connection between biomass and energy content may vary according to different conditions. For

example, one gram of algae may be equivalent to several grams of forest leaves, due to the fact that the production rate of algae is higher than the forest leaves. The higher biomass of the organism does not necessarily indicate the higher productivity. Energy flow in the system balance the energy out flows as required by the First law of thermodynamics and each energy transfer is accompanied by loss of energy in the form of unavailable heat energy (respiration) as stated by second law of thermodynamics. The energy flow is significantly reduced at each successive trophic level. Thus, at each transfer of energy from one trophic level to another trophic level, major part of energy is lost in the form of heat or any other form. There is successive reduction in the energy flow whether we consider it in term of total flow (I+A) or secondary productivity and respiration component. Total of 3000 KCal of light falling upon green plants. 50% is absorbed (1500KCal), 1% is converted at first trophic level (15 KCal) Secondary productivity tend to about 10% at successive consumer level although efficiency may be up to 20% at the carnivores level.



A simplified energy flow diagram depicting three trophic levels in a linear food chain (E.P. Odum, 1971)

**Y shaped Food chain:**

The Y-shaped model indicates that the two food chains namely the grazing food chain and detritus food chain are in fact, under natural conditions, not completely isolated from one another. The grazing food chain beginning with green plant base going to herbivores and the detritus food chain beginning with dead organic matter acted by microbes, then passing to detritivores and their consumers.

For instance, dead bodies of small animals that were once part of the grazing food chain become incorporated in the detritus food chain as do the faeces of grazing food animals. Functionally, the distinction between the two is of time lag between the direct consumption of living plants and ultimate utilisation of dead organic matter. The importance of the two food chains may differ in different ecosystems, in some grazing is more important, in others detritus is major pathway.

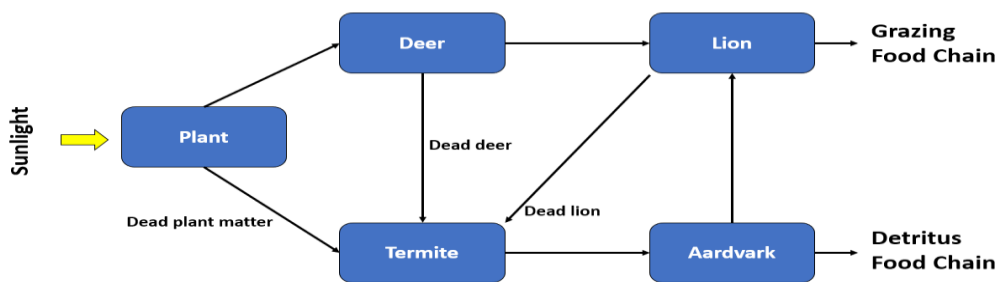
In Y-shaped energy flow, grazing and detritus food chain are sharply separated. It is more practical than simple linear chain energy model as:

- i) It confirms the basic stratified structure of ecosystem
- ii) It separates the grazing food chain from detritus food chain (Direct consumption of living plants and utilization of dead organic matter respectively) in both time and space.
- iii) Macroconsumer (animals) and microconsumers (bacteria & fungi) differ greatly in size-metabolism relations.

It must however, be remembered that these models depict the basic pattern of energy flow in ecosystem. In practice, under natural conditions, the organisms are interrelated in a way that several food chains become interlocked results into a complex food web. We have already referred to food webs in grassland and in pond ecosystems. The complexity of food web depends on the length of the food chains. Thus in nature there operates multi-channel energy flows, but in these

the channels belong to either of the two basic food chains i.e., will be either a grazing or a detritus food chain. Interlocking pattern of such several chains in food web of an ecosystem would lead to a multi-channel flow of energy. Thus in practice, under field conditions, we might face difficulties in measuring energetic of ecosystem.

The Y-shaped model further indicates that the two food chains are in fact, under natural conditions, not completely isolated from one another. For example, dead bodies of small animals that were once part of grazing food chain become incorporated in the detritus food chain as do the feces of grazing food animals. The importance of two food chains may differ in different ecosystem, in some cases, grazing is more important and in others, detritus is more important.



The Y-shaped model was originally proposed by H.T Odum (1956), but his brother E.P. Odum (1983) gave a generalized model of this relationship and called it the Universal model of flow of energy.

### **Food Web:**

A food web consists of all the food chains in a single ecosystem. Each living thing in an ecosystem is part of multiple food chains. Each food chain is one possible path that energy and nutrients may take as they move through the ecosystem. All of the interconnected and overlapping food chains in an ecosystem make up a food web.

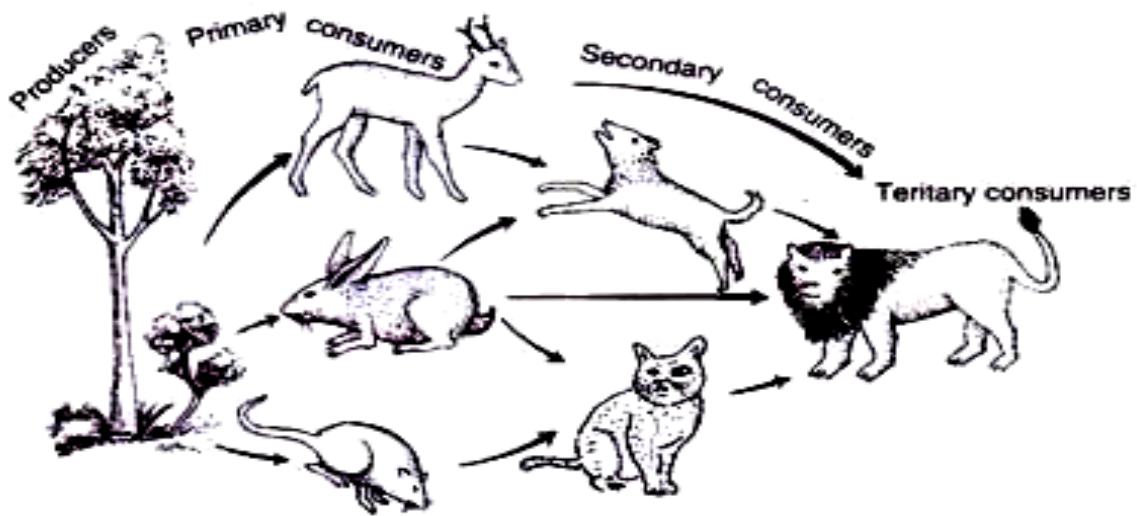
Food web is an important ecological concept. Basically, food web represents feeding relationships within a community (Smith and Smith 2009). It also implies the transfer of food energy from its

source in plants through herbivores to carnivores (Krebs 2009). Normally, food webs consist of a number of food chains meshed together. Each food chain is a descriptive diagram including a series of arrows, each pointing from one species to another, representing the flow of food energy from one feeding group of organisms to another. There are two types of food chains: the grazing food chain, beginning with autotrophs, and the detrital food chain, beginning with dead organic matter (Smith & Smith 2009). In a grazing food chain, energy and nutrients move from plants to the herbivores consuming them, and to the carnivores or omnivores preying upon the herbivores. In a detrital food chain, dead organic matter of plants and animals is broken down by decomposers, e.g., bacteria and fungi, and moves to detritivores and then carnivores.

Food web offers an important tool for investigating the ecological interactions that define energy flows and predator-prey relationship (Cain et al. 2008). Figure 1 shows a simplified food web in a desert ecosystem. In this food web, grasshoppers feed on plants; scorpions prey on grasshoppers; kit foxes prey on scorpions. While the food web showed here is a simple one, most feed webs are complex and involve many species with both strong and weak interactions among them (Pimm et al. 1991). For example, the predators of a scorpion in a desert ecosystem might be a golden eagle, an owl, a roadrunner, or a fox. The idea to apply the food chains to ecology and to analyze its consequences was first proposed by Charles Elton (Krebs 2009). In 1927, he recognized that the length of these food chains was mostly limited to 4 or 5 links and the food chains were not isolated, but hooked together into food webs (which he called "food cycles"). The feeding interactions represented by the food web may have profound effects on species richness of community, and ecosystem productivity and stability (Ricklefs 2008).

Similarly, in the food chain grass → mouse → snakes → owls, sometimes mice are not eaten by snakes but directly by owls. This type of interrelationship interlinks the individuals of the whole community. In this way, food chains become interlinked. A complex of interrelated food chains makes up a food web. Food web maintains the stability of the ecosystem. The greater the number of alternative

pathways the more stable is the community of living things. illustrates a food web in ecosystem.



**Fig. 3.10.** Food web in an ecosystem.

### **Energy flow in Ecosystem:**

Living organisms can use energy in two forms radiant and fixed energy. Radiant energy is in the form of electromagnetic waves, such as light. Fixed energy is potential chemical energy bound in various organic substances which can be broken down in order to release their energy content.

Organisms that can fix radiant energy utilizing inorganic substances to produce organic molecules are called autotrophs. Organisms that cannot obtain energy from abiotic source but depend on energy-rich organic molecules synthesized by autotrophs are called heterotrophs. Those which obtain energy from living organisms are called consumers and those which obtain energy from dead organisms are called decomposers.

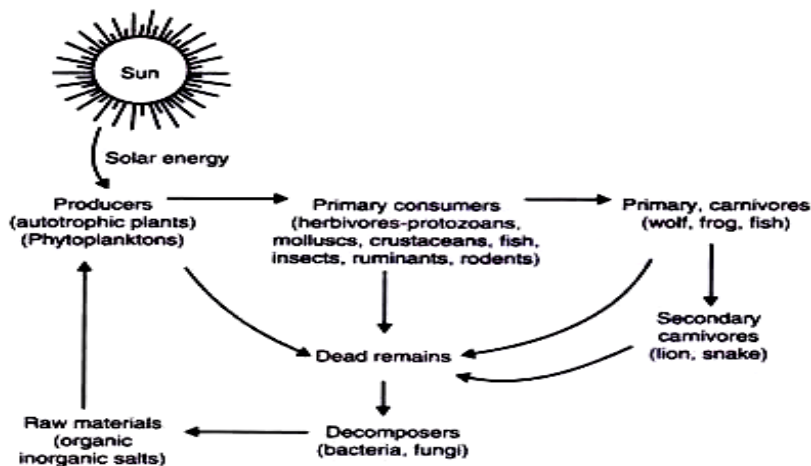


Fig. 3.7. Flow of energy at different levels of ecosystem.

When the light energy falls on the green surfaces of plants, a part of it is transformed into chemical energy which is stored in various organic products in the plants. When the herbivores consume plants as food and convert chemical energy accumulated in plant products into kinetic energy, degradation of energy will occur through its conversion into heat. When herbivores are consumed by carnivores of the first order (secondary consumers) further degradation will occur. Similarly, when primary carnivores are consumed by top carnivores, again energy will be degraded.

### **Ecological efficiency: the transfer of energy between trophic levels**

Large amounts of energy are lost from the ecosystem between one trophic level and the next level as energy flows from the primary producers through the various trophic levels of consumers and decomposers. The main reason for this loss is the second law of thermodynamics, which states that whenever energy is converted from one form to another, there is a tendency toward disorder (entropy) in the system. In biologic systems, this means a great deal of energy is lost as metabolic heat when the organisms from one trophic level are consumed by the next level. The measurement of energy transfer efficiency between two successive trophic levels is termed the trophic level transfer efficiency (TLTE) and is defined by the formula:

The low efficiency of energy transfer between trophic levels is usually the major factor that limits the length of food chains observed in a food web. The fact is, after four to six energy transfers, there is not enough energy left to support another trophic level.

Net consumer productivity is the energy content available to the organisms of the next trophic level. Assimilation is the biomass (energy content generated per unit area) of the present trophic level after accounting for the energy lost due to incomplete ingestion of food, energy used for respiration, and energy lost as waste. Incomplete ingestion refers to the fact that some consumers eat only a part of their food. For example, when a lion kills an antelope, it will eat everything except the hide and bones. The lion is missing the energy-rich bone marrow inside the bone, so the lion does not make use of all the calories its prey could provide.

Thus, NPE measures how efficiently each trophic level uses and incorporates the energy from its food into biomass to fuel the next trophic level. In general, cold-blooded animals (ectotherms), such as invertebrates, fish, amphibians, and reptiles, use less of the energy they obtain for respiration and heat than warm-blooded animals (endotherms), such as birds and mammals. The extra heat generated in endotherms, although an advantage in terms of the activity of these organisms in colder environments, is a major disadvantage in terms of NPE. Therefore, many endotherms have to eat more often than ectotherms to obtain the energy they need for survival. In general, NPE for ectotherms is an order of magnitude (10x) higher than for endotherms. For example, the NPE for a caterpillar eating leaves has been measured at 18 percent, whereas the NPE for a squirrel eating acorns may be as low as 1.6 percent.

The inefficiency of energy use by warm-blooded animals has broad implications for the world's food supply. It is widely accepted that the meat industry uses large amounts of crops to feed livestock. Because the NPE is low, much of the energy from animal feed is lost.

## **Ecological Pyramids :**

An ecological pyramid is a graphical representation of the relationship between the different living organisms at different trophic levels. The structure of ecosystems can be visualized with ecological pyramids, which were first described by the pioneering studies of Charles Elton in the 1920s. Ecological pyramids show the relative amounts of various parameters (such as number of organisms, energy, and biomass) across trophic levels. Ecological pyramids can also be called trophic pyramids or energy pyramids.

Pyramids of numbers can be either upright or inverted, depending on the ecosystem. A typical grassland during the summer has an upright shape since it has a base of many plants, with the numbers of organisms decreasing at each trophic level. However, during the summer in a temperate forest, the base of the pyramid consists of few trees compared with the number of primary consumers, mostly insects. Because trees are large, they have great photosynthetic capability and dominate other plants in this ecosystem to obtain sunlight. Even in smaller numbers, primary producers in forests are still capable of supporting other trophic levels.

Another way to visualize ecosystem structure is with pyramids of biomass. This pyramid measures the amount of energy converted into living tissue at the different trophic levels. Using the Silver Springs ecosystem example, this data exhibits an upright biomass pyramid, whereas the pyramid from the English Channel example is inverted. The plants (primary producers) of the Silver Springs ecosystem make up a large percentage of the biomass found there. However, the phytoplankton in the English Channel example make up less biomass than the primary consumers, the zooplankton. As with inverted pyramids of numbers, the inverted biomass pyramid is not due to a lack of productivity from the primary producers, but results from the high turnover rate of the phytoplankton. The phytoplankton are consumed rapidly by the primary consumers, which minimizes their biomass at any particular point in time. However, since phytoplankton reproduce quickly, they are able to support the rest of the ecosystem.

Pyramid ecosystem modeling can also be used to show energy flow through the trophic levels. Pyramids of energy are always upright, since energy is lost at each trophic level; an ecosystem without sufficient primary productivity cannot be supported. All types of ecological pyramids are useful for characterizing ecosystem structure. However, in the study of energy flow through the ecosystem, pyramids of energy are the most consistent and representative models of ecosystem structure.

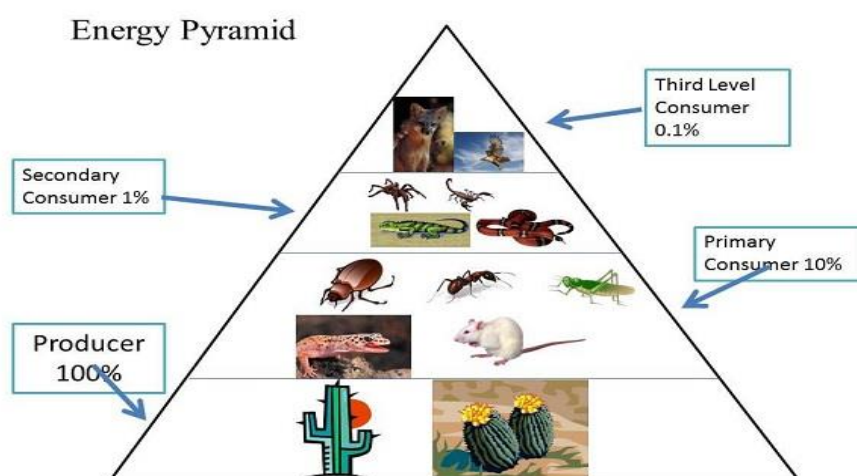
## Pyramid of Biomass

As the name suggests, the Biomass Pyramids show the amount of biomass (living or organic matter present in an organism) present per unit area at each trophic level. It is drawn with the producers at the base and the top carnivores at the tip.

Pyramid of biomass is generally ascertained by gathering all organisms occupying each trophic level separately and measuring their dry weight. Each trophic level has a certain mass of living material at a particular time called standing crop, which is measured as the mass of living organisms (biomass) or the number in a unit area.

## Upright Pyramid of Biomass

Ecosystems found on land mostly have pyramids of biomass with large base of primary producers with smaller trophic level perched on top, hence the upright pyramid of biomass.

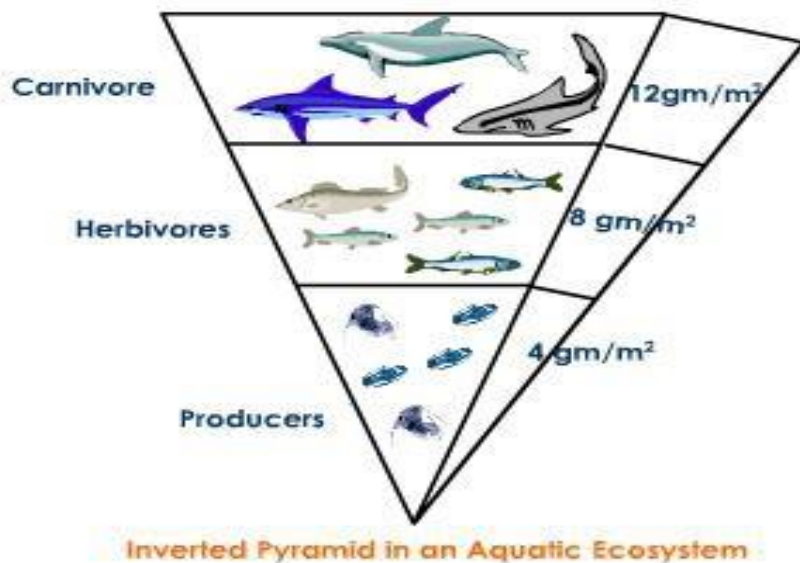


The biomass of autotrophs or producers is at the maximum. The biomass of next trophic level, i.e. primary consumers is less than the producers. Similarly, the other consumers such as secondary and tertiary consumers are comparatively less than its lower level respectively. The top of the pyramid has very less amount of biomass.

### **Inverted Pyramid of Biomass**

On the other hand, a reverse pyramidal structure is found in most aquatic ecosystems. Here, the pyramid of biomass may assume an inverted pattern. However, pyramid of numbers for aquatic ecosystem is upright.

In a water body, the producers are tiny phytoplankton that grow and reproduce rapidly. In this condition, the pyramid of biomass has a small base, with the producer biomass at the base providing support to consumer biomass of large weight. Hence, it assumes an inverted shape.



### **Pyramid of Numbers**

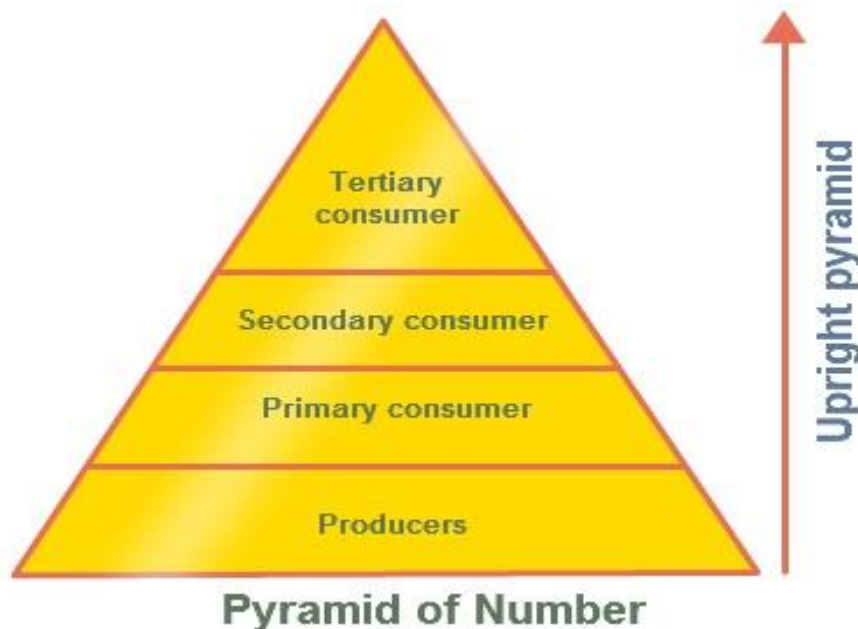
It is the graphic representation of number of individuals per unit area of various trophic levels. Large number of producers tend to form the base whereas lower number of top predators or carnivores occupy the

tip. The shape of the pyramid of numbers varies from ecosystem to ecosystem.

For example, in an aquatic ecosystem or grassland areas, autotrophs or producers are present in large number per unit area. The producers support a lesser number of herbivores, which in turn supports fewer carnivores.

### **Upright Pyramid of Numbers**

In upright pyramid of numbers, the number of individuals decreases from the lower level to the higher level. This type of pyramid is usually found in the grassland ecosystem and the pond ecosystem. The grass in a grassland ecosystem occupies the lowest trophic level because of its abundance.



Next comes the primary producers – the herbivores (for example – grasshopper). The number of grasshoppers is quite less than that of grass. Then, there are the primary carnivores, for example, the rat whose number is far less than the grasshoppers. The next trophic level is the secondary consumers such as the snakes who feed on the rats. Then, there are the top carnivores such as the hawks who eat snakes and whose number is less than the snakes.

The number of species decreases towards the higher levels in this pyramidal structure.

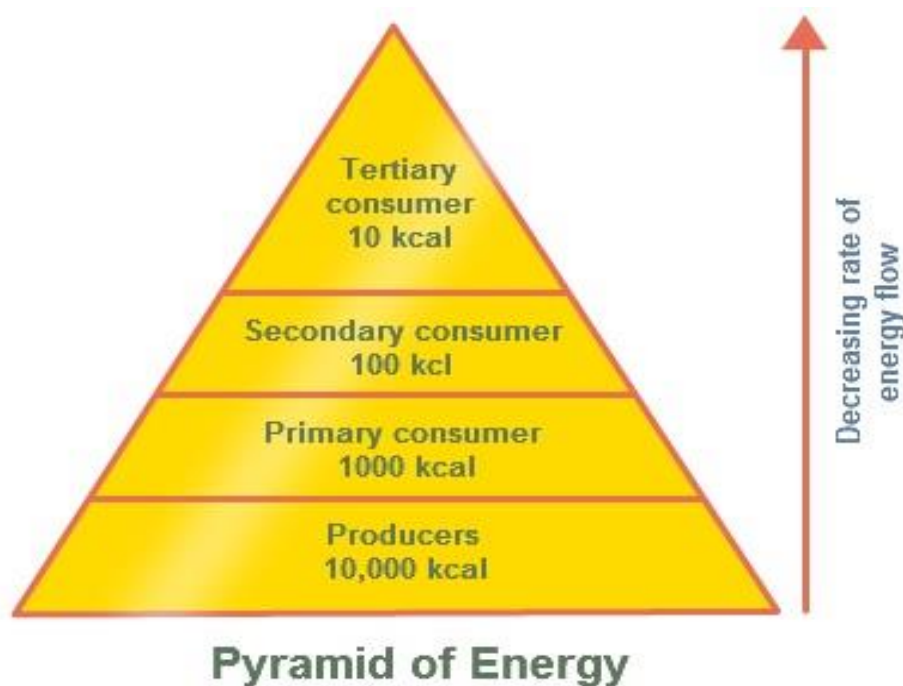
## Inverted Pyramid of Numbers

Here, the number of individuals increase from the lower level to the higher trophic level. For example, the tree ecosystem.

## Pyramid of Energy

It is a graphical structure representing the flow of energy through each trophic level of a food chain over a fixed part of the natural environment. An energy pyramid represents the amount of energy at each trophic level and loss of energy at each is transferred to another trophic level.

Energy pyramid, sometimes called trophic pyramid or ecological pyramid, is useful in quantifying the energy transfer from one organism to another along the food chain.



Energy decreases as one moves through the trophic levels from the bottom to the top of the pyramid. Thus, the energy pyramid is always upward.

## **Importance of Ecological Pyramid**

The importance of ecological pyramid can be explained in the following points:

1. They show the feeding of different organisms in different ecosystems.
2. It shows the efficiency of energy transfer.
3. The condition of the ecosystem can be monitored, and any further damage can be prevented.

## **Limitations of the Ecological Pyramid**

1. More than one species may occupy multiple trophic levels as in case of the food web. Thus, this system does not take into account food webs.
2. The saprophytes are not considered in any of the pyramids even though they form an important part of the various ecosystem.
3. These pyramids are applicable only to simple food chains, which usually do not occur naturally.
4. These pyramids do not deliver any concept in relation to variations in season and climate.
5. They do not consider the possibility of the existence of the same species at different levels.

## **Nitrogen Cycle :**

Nitrogen, or N, using its scientific abbreviation, is a colorless, odorless element. Nitrogen is in the soil under our feet, in the water we drink, and in the air we breathe. In fact, nitrogen is the most abundant element in Earth's atmosphere: approximately 78% of the atmosphere is nitrogen! Nitrogen is important to all living things, including us. It plays a key role in plant growth: too little nitrogen and plants cannot thrive, leading to low crop yields; but too much nitrogen can be toxic to plants. Nitrogen is necessary for our food supply, but excess nitrogen can harm the environment.

The delicate balance of substances that is important for maintaining life is an important area of research, and the balance of nitrogen in the environment is no exception. When plants lack nitrogen, they become yellowed, with stunted growth, and produce smaller fruits and flowers. Farmers may add fertilizers containing nitrogen to their crops, to increase crop growth. Without nitrogen fertilizers, scientists estimate that we would lose up to one third of the crops we rely on for food and other types of agriculture. But we need to know how much nitrogen is necessary for plant growth, because too much can pollute waterways, hurting aquatic life.

*Nitrogen* is essential to life because it is a key component of proteins and nucleic acids. Nitrogen occurs in many forms and is continuously cycled among these forms by a variety of bacteria. Although nitrogen is abundant in the atmosphere as diatomic nitrogen gas (N<sub>2</sub>), it is extremely stable, and conversion to other forms requires a great deal of energy. Historically, the biologically available forms NO<sub>3</sub><sup>-</sup> and NH<sub>3</sub> have often been limited; however, current anthropogenic processes, such as fertilizer production, have greatly increased the availability of nitrogen to living organisms. The cycling of nitrogen among its many forms is a complex process that involves numerous types of bacteria and environmental conditions.

### **Nitrogen Cycle:**

Nitrogen Cycle is a biogeochemical process through which nitrogen is converted into many forms, consecutively passing from the atmosphere to the soil to organism and back into the atmosphere. It involves several processes such as nitrogen fixation, nitrification, denitrification, decay and putrefaction.

The nitrogen gas exists in both organic and inorganic forms. Organic nitrogen exists in living organisms, and they get passed through the food chain by the consumption of other living organisms. Inorganic forms of nitrogen are found in abundance in the atmosphere. This nitrogen is made available to plants by symbiotic bacteria which can convert the inert nitrogen into a usable form – such as nitrites and nitrates. Nitrogen undergoes various types of transformation to maintain a balance in the ecosystem. Furthermore, this process

extends to various biomes, with the marine nitrogen cycle being one of the most complicated biogeochemical cycles.

**In general, the *nitrogen cycle* has five steps:**

1. ***Nitrogen fixation*** ( $N_2$  to  $NH_3$ /  $NH_4^+$  or  $NO_3^-$ )
2. ***Nitrification*** ( $NH_3$  to  $NO_3^-$ )
3. ***Assimilation*** (Incorporation of  $NH_3$  and  $NO_3^-$  into biological tissues)
4. ***Ammonification*** (organic nitrogen compounds to  $NH_3$ )
5. ***Denitrification*** ( $NO_3^-$  to  $N_2$ )

### **Nitrogen fixation**

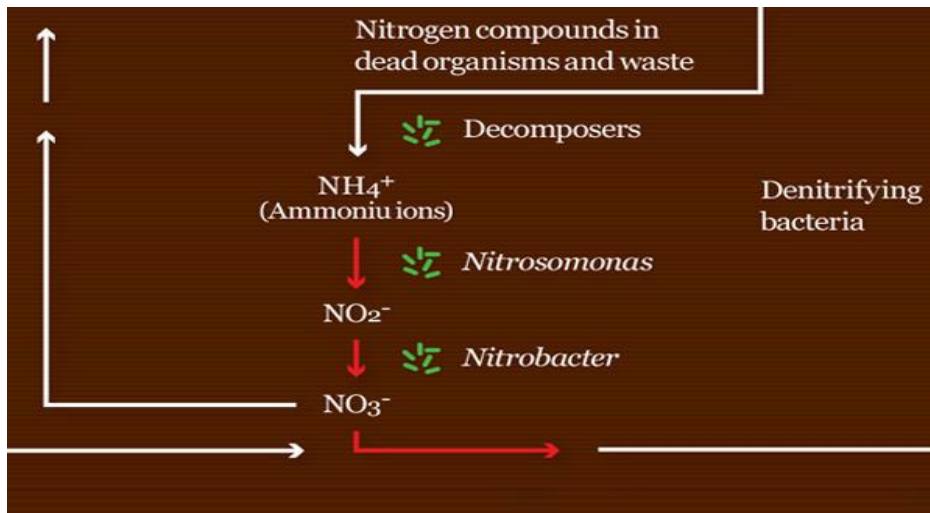
It is the initial step of the nitrogen cycle. Here, Atmospheric nitrogen ( $N_2$ ) which is primarily available in an inert form, is converted into the usable form -ammonia ( $NH_3$ ).

During the process of Nitrogen fixation, the inert form of nitrogen gas is deposited into soils from the atmosphere and surface waters, mainly through precipitation. Later, the nitrogen undergoes a set of changes, in which two nitrogen atoms get separated and combine with hydrogen to form ammonia ( $NH_4^+$ ).

The entire process of Nitrogen fixation is completed by symbiotic bacteria which are known as Diazotrophs. Azotobacter and Rhizobium also have a major role in this process. These bacteria consist of a nitrogenase enzyme which has the capability to combine gaseous nitrogen with hydrogen to form ammonia.

Nitrogen fixation can occur either by the atmospheric fixation- which involves lightening or industrial fixation by manufacturing ammonia under high temperature and pressure condition. This can also be fixed through man-made processes, primarily industrial processes that create ammonia and nitrogen-rich fertilisers.



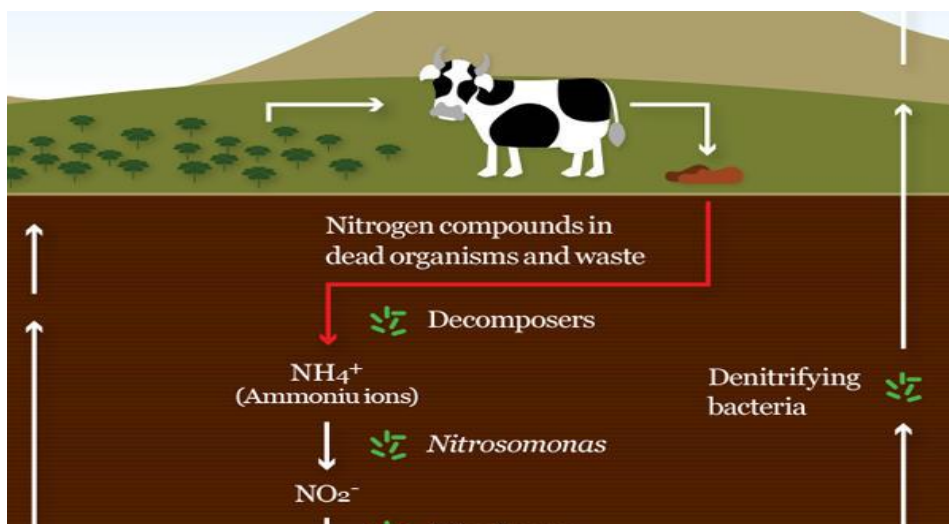


## Assimilation

Primary producers – plants take in the nitrogen compounds from the soil with the help of their roots, which are available in the form of ammonia, nitrite ions, nitrate ions or ammonium ions and are used in the formation of the plant and animal proteins. This way, it enters the food web when the primary consumers eat the plants.

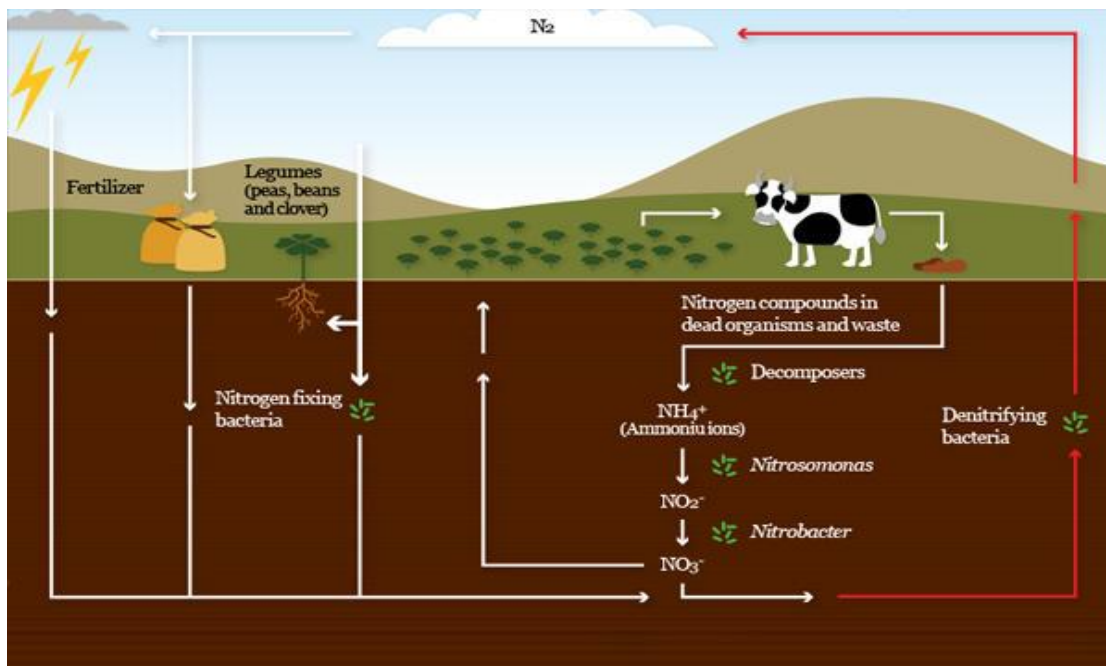
## Ammonification

When plants or animals die, the nitrogen present in the organic matter is released back into the soil. The decomposers, namely bacteria or fungi present in the soil, convert the organic matter back into ammonia. This process of decomposition produces ammonia, which is further used for other biological processes.



## Denitrification

Denitrification is the process in which the nitrogen compounds makes its way back into the atmosphere by converting nitrate ( $\text{NO}_3^-$ ) into gaseous nitrogen ( $\text{N}_2$ ). This process of the nitrogen cycle is the final stage and occurs in the absence of oxygen. Denitrification is carried out by the denitrifying bacterial species- *Clostridium* and *Pseudomonas*, which will process nitrate to gain oxygen and gives out free nitrogen gas as a byproduct.



## Nitrogen Cycle in Marine Ecosystem

The process of the nitrogen cycle occurs in the same manner in the marine ecosystem as in the terrestrial ecosystem. The only difference is that it is carried out by marine bacteria.

The nitrogen-containing compounds that fall into the ocean as sediments get compressed over long periods and form sedimentary rock. Due to the geological uplift, these sedimentary rocks move to land. Initially, it was not known that these nitrogen-containing sedimentary rocks are an essential source of nitrogen. But, recent researches have proved that the nitrogen from these rocks is released into the plants due to the weathering of rocks.

## **Importance of Nitrogen Cycle**

Importance of the nitrogen cycle are as follows:

1. Helps plants to synthesise chlorophyll from the nitrogen compounds.
2. Helps in converting inert nitrogen gas into a usable form for the plants through the biochemical process.
3. In the process of ammonification, the bacteria help in decomposing the animal and plant matter, which indirectly helps to clean up the environment.
4. Nitrates and nitrites are released into the soil, which helps in enriching the soil with necessary nutrients required for cultivation.
5. Nitrogen is an integral component of the cell and it forms many crucial compounds and important biomolecules.

Nitrogen is also cycled by human activities such as combustion of fuels and the use of nitrogen fertilisers. These processes, increase the levels of nitrogen-containing compounds in the atmosphere. The fertilisers containing nitrogen are washed away in lakes and rivers and results in eutrophication.