Chapter 02: Ecosystems – Part 1

A. UNDERSTANDING ECOSYSTEMS

Introduction:

Ecosystem: Meaning

Imagine a pond. It has fish, plants, insects and frogs, and it also has water, sunlight, air and soil. None of these live alone; they all depend on each other and on their surroundings. This whole set-up is what we call an **ecosystem**: living organisms (plants, animals, microbes) interacting with their non-living surroundings (air, water, soil, sunlight).

Two things keep an ecosystem running. **Energy flows** through it, and **nutrients keep cycling** between living things and the environment. Because of this, life continues and the area stays in ecological balance.

An ecosystem can be as small as a pond or as large as a forest, or even a whole biome like a desert or an ocean. It is **self-sustaining**, meaning it runs on its own. That is why the ecosystem is called the **structural and functional unit of life**.

Ecology vs Environment vs Ecosystem

These three terms are connected, but each has its own meaning.

- **Ecology** is a subject. It is the study of how organisms interact with their environment, and it focuses on the relationship between the two.
- **Environment** is the surroundings in which organisms live and interact, and here the focus is on the overall condition and quality of those surroundings.
- **Ecosystem** is a unit. It is a structural and functional unit in which living organisms interact with each other and with their physical surroundings, and the focus is on how closely everything is interconnected.

Ecology vs Environment vs Ecosystem

Term	Think of it as	Meaning
Ecology	*Study*	Study of interactions between organisms and their environment.
Environment	*Surroundings*	Surroundings in which organisms live and interact.
Ecosystem	*Unit*	Structural and functional unit where organisms interact with each other and their physical surroundings.

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Illustration:

ILLUSTRATION

A Walk Through a Forest

Imagine you are walking through a forest. You see tall trees, grass, birds, deer, insects and mushrooms. You also notice sunlight, air, water and soil.

Environment – The Surroundings: All the living and non-living things surrounding a deer, such as trees, grass, air, water and soil, form its environment.

Ecology – The Study: A student studies how deer feed on grass, how trees compete for sunlight and how birds depend on trees for shelter. The study of these interactions is ecology.

Ecosystem – The Working Unit: The forest, where all living organisms interact with one another and with non-living components, functions as an ecosystem.

Ecosystem Services

Humans get many benefits from nature, and these are called **ecosystem services**. They are essential for our well-being and come in four types.

PROVISIONING	Provisioning services give us physical products such as food, water, timber, fibre, medicinal plants and genetic resources. Forests give timber, and rivers and lakes give fish.
REGULATING	Regulating services control natural processes like climate, water purification, pollination and natural hazards. Wetlands, for instance, trap pollutants and sediments, so they act as natural water filters.
SUPPORTING	Supporting services are the base on which all other services stand. They include soil formation, nutrient cycling and photosynthesis.
CULTURAL	Finally, cultural services are the non-material gains: beauty, spiritual and cultural value, tourism and recreation such as hiking, birdwatching and photography.

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Key Takeaways:

ECOSYSTEM: MEANING	
MEANING	Ecosystem = living organisms (plants, animals, microbes) interacting with their non-living surroundings (air, water, soil, sunlight).
WHAT KEEPS IT RUNNING	Energy flows through it, and nutrients keep cycling between living things and the environment, so life continues and ecological balance is maintained.
SCALE	As small as a pond or as large as a forest or a whole biome (desert, ocean). It is self-sustaining: the structural and functional unit of life.
ECOLOGY VS ENVIRONMENT VS ECOSYSTEM	
ECOLOGY	Study – the study of interactions between organisms and their environment.
ENVIRONMENT	Surroundings – the surroundings in which organisms live and interact.
ECOSYSTEM	Unit – the structural and functional unit where organisms interact with each other and their physical surroundings.
ECOSYSTEM SERVICES	
MEANING	Ecosystem services are the many benefits humans get from nature; they are essential for our well-being.
FOUR TYPES	Provisioning (physical products), regulating (control of natural processes), supporting (the base for all other services) and cultural (non-material gains).
EXAMPLES	Forests give timber; rivers and lakes give fish; wetlands act as natural water filters; soil formation, nutrient cycling and photosynthesis support all other services; hiking and birdwatching are cultural services.

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UPSC PRELIMS PRACTICE MCQ

Q1. Consider the following statements:

1. A student's study of how trees in a forest compete for sunlight is an exercise in ecology, whereas the forest in which this competition occurs is an ecosystem.

2. The environment of a deer in a forest consists only of the non-living components around it, since trees and grass are part of the ecosystem and not of its environment.

3. A cropland, though created and managed by humans, can still be considered an ecosystem.

4. Because both energy and nutrients cycle continuously within an ecosystem, it can sustain itself without any external energy source.

How many of the statements given above are correct?

(a) Only one (b) Only two (c) Only three (d) All four

B. FUNCTIONING OF AN ECOSYSTEM

We have understood what an ecosystem is and how its living and non-living components interact. But have you ever wondered what keeps an ecosystem functioning? The answer is **energy**. Every organism needs energy to survive, grow and carry out its life processes. This energy flows from one organism to another through feeding relationships. So, how exactly does this energy flow, and how are different organisms connected through it? Let us understand this.

Energy Flow in the Ecosystem

Energy – Why do organisms need it?

Before understanding energy flow, we must understand what energy means.

DEFINITION

Energy is the capacity to do work. In simple terms, it is what organisms require to carry out their life activities. Every living organism needs energy for growth and development, movement and physical activities, respiration and other essential life processes.

Energy Flow – How does energy move in nature?

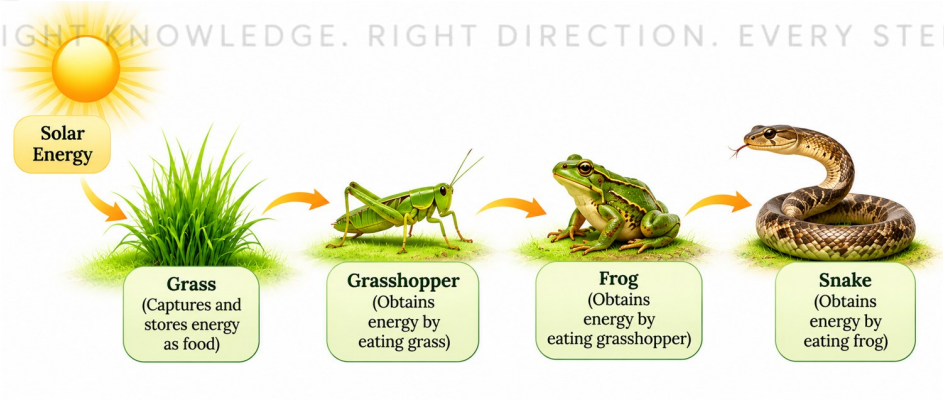
DEFINITION

Energy flow refers to the transfer of energy from one organism to another through feeding relationships in an ecosystem.

How does energy enter an ecosystem?

- The **Sun** is the primary source of energy for most ecosystems.
- Green plants, algae and certain bacteria capture solar energy through **photosynthesis**. They convert light energy into chemical energy and store it in the form of food.
- Animals obtain this stored energy by eating plants or other animals.
- Decomposers obtain energy from dead plants, animals and organic waste.

Let us understand energy transfer through an example



Thus, energy is transferred from one organism to another through feeding.

One important characteristic of energy flow is that energy flow is **unidirectional (one-way)**. Energy moves in one direction, from the Sun to producers and then to consumers. It does not return to the Sun or get recycled within the ecosystem.

10% Law – By Raymond Lindeman

Have you ever wondered what happens to the energy when one organism obtains it from another? Does an organism transfer all the energy it receives to the next organism, or does it use some of that energy for its own needs?

Let us understand this with the example we have already discussed:

Sun → Grass → Grasshopper → Frog → Snake

The grass captures energy from sunlight and stores it in the form of food. When a grasshopper eats the grass, does all the energy stored in the grass get transferred to the grasshopper? Similarly, when a frog eats the grasshopper, does all the energy present in the grasshopper pass on to the frog? The answer is no.

This is where Raymond Lindeman's 10% Law helps us understand how energy is transferred from one trophic level to another.

What does the 10% Law state?

DEFINITION

According to Lindeman's 10% Law, only about **10%** of the energy stored as biomass at one trophic level becomes available as new biomass at the next trophic level.

Let us understand how this happens.

When a grasshopper eats grass, it consumes the food material containing stored chemical energy. However, the entire food consumed does not become a part of the grasshopper's body. A portion of the food is digested and absorbed by the grasshopper. From the energy it assimilates, some is used to carry out its life processes, while a portion is converted into new body tissues through growth and development.

This newly formed body tissue represents **biomass**. It contains stored chemical energy. When a frog eats the grasshopper, it obtains energy from this biomass.

Similarly, when the frog is eaten by a snake, the energy stored in the frog's body becomes available to the snake.

Thus, energy is transferred to the next trophic level mainly through the consumption of the biomass formed at the preceding level. On average, only about 10% of the energy at one level is converted into new biomass that can be passed on to the next level.

What happens to the remaining 90%?

The remaining energy is not transferred to the next trophic level as new biomass. It is lost from this particular feeding pathway in different ways:

- **Energy used in life processes:** Organisms use a major portion of the energy they assimilate to carry out essential activities such as respiration, movement, growth, reproduction and maintenance of their bodies.
- **Heat released during respiration:** During respiration, organisms break down food to release energy required for their activities. A significant portion of this energy is released into the surroundings in the form of heat.
- **Undigested and unconsumed food:** Some parts of the food may not be digested or absorbed. Also, not every part of an organism is eaten by the next consumer. Such material may pass into the detritus food chain.

Therefore, only a small fraction of the energy is converted into new biomass and becomes available to the next trophic level.

(The 10% rule is an approximate ecological rule, not an exact fixed percentage.)

Trophic Levels

Now let's understand what is a trophic level?

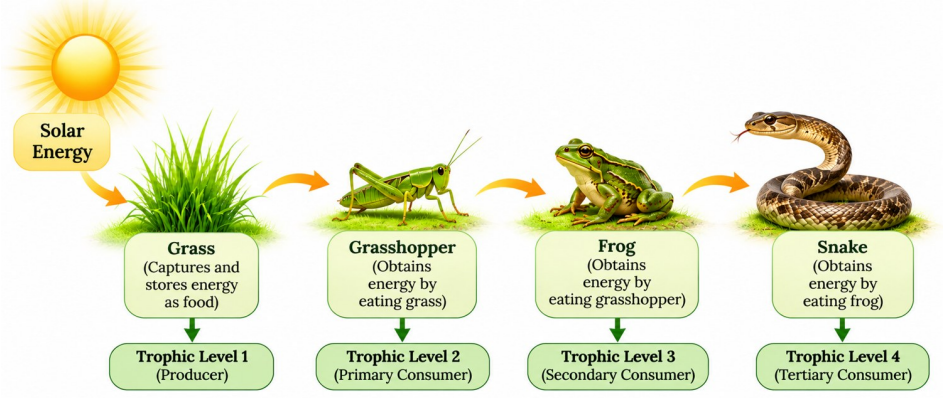
Trophic Levels – What position does an organism occupy?

Meaning of the term: As we have seen before, the word 'Trophic' comes from the Greek word Trophē, meaning nourishment or food and 'level' means a position or step.

So, a trophic level is the position occupied by an organism in the feeding relationship. In simple words, it tells us the position of an organism in the process of eating and being eaten.

Example: Grassland ecosystem

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Generally, producers occupy the first trophic level, primary consumers (herbivores) occupy the second trophic level, secondary consumers occupy the third trophic level, tertiary consumers occupy the fourth trophic level.

Important point to note: The trophic level of an organism depends on what it eats, not merely on its identity. For example, an omnivorous bird eating seeds occupies the second trophic level, whereas the same bird eating insects may occupy the third trophic level.

Illustration:

ILLUSTRATION

Energy's Journey Through an Ecosystem!

Think of energy as a traveller moving through an ecosystem! It starts its journey with the Sun, gets captured by green plants, and then passes from plants to herbivores and subsequently to carnivores. Energy Flow tells us the journey this energy takes, while Trophic Levels are the different stops along the way, showing the position occupied by each organism.

We have understood how energy flows through an ecosystem and how organisms occupy different trophic levels. Now, the interaction between these trophic levels can be understood through three important concepts:

- Food Chain
- Food Web
- Ecological Pyramids

In the next section, we will study these three concepts to understand how feeding relationships are organised and how energy is transferred and distributed within an ecosystem.

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Key Takeaways:

ENERGY FLOW IN THE ECOSYSTEM	
MEANING	Energy is the capacity to do work; energy flow is the transfer of energy from one organism to another through feeding relationships.
HOW IT WORKS	The Sun is the primary source; producers capture it through photosynthesis and store it as food; animals obtain it by eating plants or other animals; decomposers obtain it from dead matter and waste.
NATURE	Energy flow is unidirectional (one-way): from the Sun to producers and then to consumers; it does not return to the Sun or get recycled.
10% LAW – BY RAYMOND LINDEMAN	
STATEMENT	Lindeman's 10% Law: only about 10% of the energy stored as biomass at one trophic level becomes available as new biomass at the next trophic level.
THE REMAINING ~90%	Used in life processes (respiration, movement, growth, reproduction, maintenance), released as heat during respiration, or lost as undigested and unconsumed food, which may pass into the detritus food chain.
NOTE	It is an approximate ecological rule, not an exact fixed percentage.
TROPHIC LEVELS	
MEANING	A trophic level is the position occupied by an organism in the feeding relationship (the process of eating and being eaten).
LEVELS	Producers: first; primary consumers (herbivores): second; secondary consumers: third; tertiary consumers: fourth.
KEY POINT	The trophic level of an organism depends on what it eats, not merely on its identity.

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UPSC PRELIMS PRACTICE MCQ

Consider a grassland ecosystem in which the producers capture and store 20,000 kJ of energy in the form of biomass. The energy is then transferred through the following feeding sequence:

Grass → Grasshopper → Frog → Snake

Which one of the following best explains the expected pattern of energy transfer in this ecosystem?

(a) The grasshopper receives 2,000 kJ, the frog receives 200 kJ and the snake receives 20 kJ, as the remaining energy at each level is released entirely as heat.

(b) The grasshopper receives approximately 2,000 kJ in the form of food energy, but only a fraction becomes new biomass available to the frog, because some energy is used in life processes and some remains in unconsumed or undigested material.

(c) The grasshopper receives 10% of the energy stored in grass, and the remaining 90% is permanently destroyed, making it unavailable to any other organism or ecological process.

(d) The energy transferred to the grasshopper can eventually return to the grass through decomposition, allowing the same energy to be reused by producers.

C. FOOD CHAIN, FOOD WEB AND ECOLOGICAL PYRAMIDS

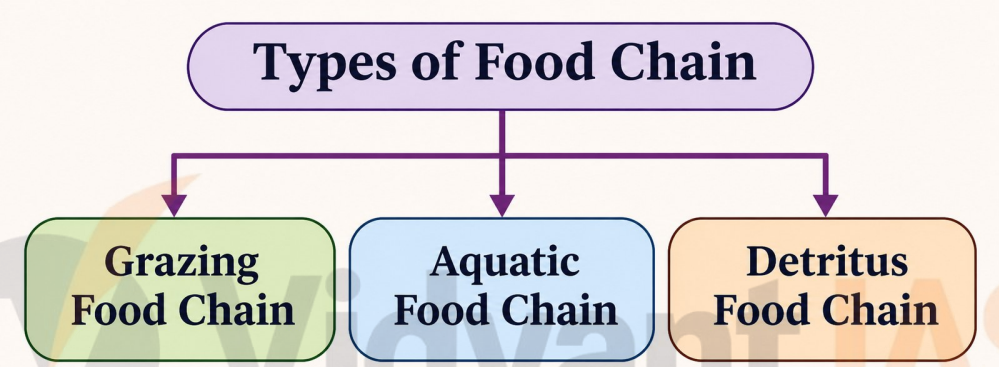
This section explains three important concepts related to ecosystem functioning: Food Chain, Food Web and Ecological Pyramids.

C.1 FOOD CHAIN

Every organism needs energy, and it gets that energy by eating. A **food chain** shows this as a straight line: who eats whom, and how energy and nutrients pass from one organism to the next. It is a simplified picture of the feeding relationships in an ecosystem.

Energy starts with the producers, passes to the consumers, and finally reaches the decomposers. Each step in this chain is called a **trophic level**, and higher levels always depend on the lower ones for their energy.

There are three types of food chains:



1. Grazing Food Chain

The grazing food chain begins with green plants. As producers, they use photosynthesis to turn sunlight, water and carbon dioxide into food (organic compounds), which makes them the main energy source of the ecosystem.

Herbivores eat these plants and are the primary consumers. Carnivores and omnivores that feed on herbivores are the secondary consumers, and the chain continues through tertiary consumers up to the top predators.

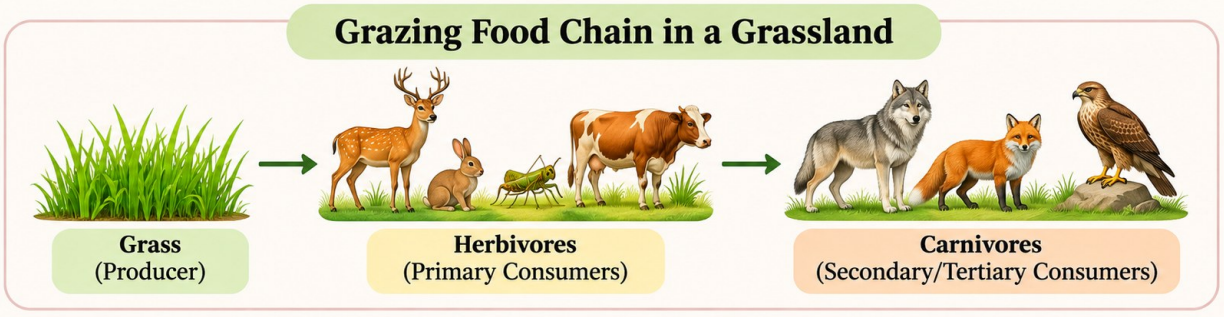
Illustration:

ILLUSTRATION

Grazing Food Chain

In a **grassland**, green grass is the starting point. It is eaten by herbivores like **deer, rabbits, grasshoppers and cattle**. These herbivores are then hunted by carnivores such as **wolves, foxes and birds of prey**.

Thus, energy moves step by step: plants → herbivores → carnivores.



2. Aquatic Food Chain

An aquatic food chain operates in water bodies such as rivers, lakes, ponds, seas and oceans. Its base is made up of producers, such as phytoplankton (microscopic algae), other algae and aquatic plants, which prepare their own food using sunlight and nutrients.

Next come the primary consumers, such as zooplankton and small herbivorous fish, which feed on these producers. They are then eaten by secondary consumers, such as larger fish and other aquatic predators. At the top are the tertiary consumers, which occupy the highest trophic levels and include large predatory fish, sharks, orcas and birds such as eagles.

Thus, energy moves from producers to primary consumers, then to secondary and tertiary consumers in an aquatic ecosystem.

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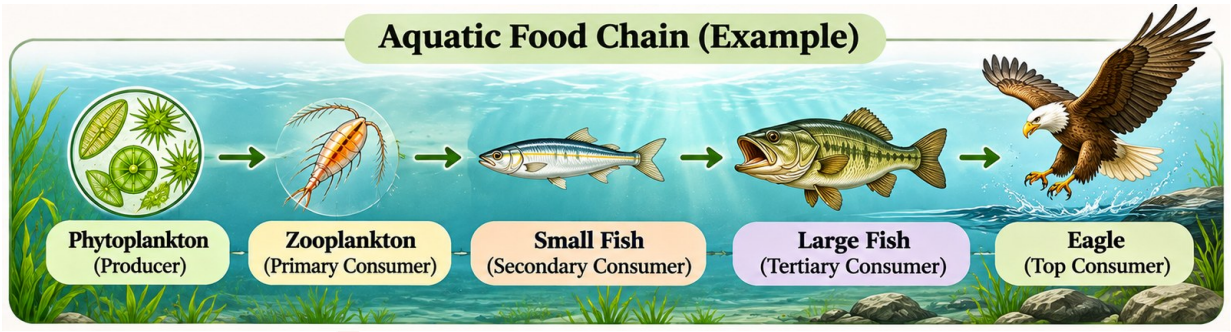
Illustration:

ILLUSTRATION

Aquatic Food Chain

A **tiny fish** is searching for its next meal, unaware that it is already part of a much larger food chain. It feeds on **zooplankton**, which in turn feed on microscopic **phytoplankton** floating in the water. But the tiny fish must stay alert too— a **larger fish** is searching for its prey. And that larger fish may eventually become food for an **eagle** hunting near the water.

This is how energy moves through an aquatic food **chain**, from microscopic producers to larger consumers.



3. Detritus Food Chain

What happens to fallen leaves, dead animals and faeces? They start the detritus food chain, also called the decomposer food chain. Dead organic matter (leaf litter, fallen branches, dead animals, faecal matter) is called **detritus**.

Detritus is food for two groups. **Decomposers**, mainly bacteria and fungi, are the most important on land. They release enzymes that break complex organic molecules into simple substances like carbon dioxide, water and minerals. **Detritivores** are organisms that eat detritus, such as earthworms, millipedes and certain insect larvae, and they work in both land and aquatic ecosystems.

As the dead matter breaks down, nutrients like nitrogen, phosphorus and carbon are released back into the ecosystem. Producers (plants, algae, bacteria) take them up again through **mineralization** (nutrients released from dead matter in inorganic form) and **immobilization** (nutrients taken into living tissue). So the cycle goes: dead matter, to decomposers, to inorganic nutrients, and back to producers.

Why is it important?

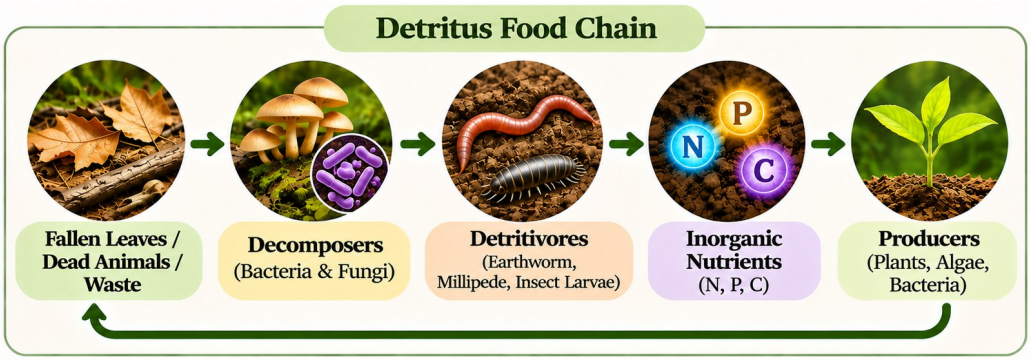
This chain is essential because it recycles matter, keeps the soil fertile and supports rich communities in soil and leaf litter, which adds to the productivity and stability of the ecosystem.

Illustration:

ILLUSTRATION

Detritus Food Chain

When leaves fall, animals die or produce waste, their remains don't go to waste. They become food for a special group of organisms, starting the **detritus food chain**— the nature's cleanup and recycling path.



Key Takeaways:

1. GRAZING FOOD CHAIN	
STARTS WITH	Green plants (producers), which use photosynthesis to make food and are the main energy source of the ecosystem.
CONSUMERS	Herbivores are primary consumers; carnivores and omnivores feeding on herbivores are secondary consumers; the chain continues through tertiary consumers up to the top predators.
EXAMPLE	Grass (producer) → herbivores such as deer, rabbits, grasshoppers and cattle → carnivores such as wolves, foxes and birds of prey.
2. AQUATIC FOOD CHAIN	
BASE	Producers such as phytoplankton (microscopic algae), other algae and aquatic plants, which prepare their own food using sunlight and nutrients.
CONSUMERS	Primary: zooplankton and small herbivorous fish. Secondary: larger fish and other aquatic predators. Tertiary: large predatory fish, sharks, orcas and birds such as eagles.
FLOW	Energy moves from producers to primary consumers, then to secondary and tertiary consumers in an aquatic ecosystem.
3. DETRITUS FOOD CHAIN	
STARTS WITH	Detritus: dead organic matter such as leaf litter, fallen branches, dead animals and faecal matter. Also called the decomposer food chain.
WHO ACTS ON IT	Decomposers (mainly bacteria and fungi) break complex molecules into simple substances using enzymes; detritivores (earthworms, millipedes, certain insect larvae) eat detritus.
WHY IMPORTANT	It recycles matter and returns nutrients (N, P, C) to producers through mineralization and immobilization, keeps the soil fertile and adds to the productivity and stability of the ecosystem.

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UPSC PRELIMS PRACTICE MCQ

Consider the following statements and choose the correct option that follows.

Assertion (A): In an aquatic ecosystem, top consumers such as large predatory fish and eagles are the main energy source for the whole ecosystem, because they occupy the highest trophic levels.

Reason (R): Each higher trophic level depends on the lower levels for its energy.

Select the correct answer:

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct, but R is incorrect.

(d) A is incorrect, but R is correct.

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C.2 FOOD WEB

DEFINITION

A **food web** is a network of interconnected food chains within an ecosystem. It shows how different organisms are connected to one another through multiple feeding relationships.

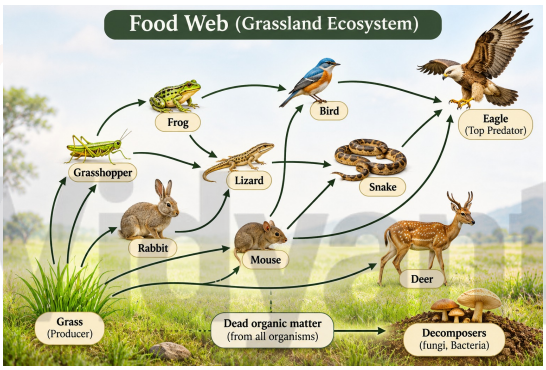
Unlike a food chain, which shows a single pathway of energy flow, a food web shows multiple pathways through which energy can flow. An organism may feed on more than one type of food and may also be consumed by different organisms.

Illustration:

ILLUSTRATION

Food Web (Grassland Ecosystem)

Imagine a grassland where different animals depend on one another for food. Grass provides food to grasshoppers, rabbits, mice and deer. A grasshopper may become a meal for a frog or a bird, while a rabbit or mouse may be hunted by a snake or an eagle. The frog and lizard may also become food for snakes. Thus, several food chains overlap and connect with one another, forming a food web.



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Important Features of a Food Web

- **Interconnected Food Chains:** Several food chains are linked together, forming a complex network of feeding relationships.
- **Multiple Feeding Pathways:** Organisms may have more than one food source and may be eaten by different predators. Therefore, energy can flow through different pathways.
- **Trophic Levels:** Organisms occupy different trophic levels depending on their feeding habits. Producers form the base, followed by primary, secondary and higher-level consumers.
- **Role of Decomposers and Detritivores:** They act on dead organic matter and help recycle nutrients by returning them to the environment.
- **Ecosystem Stability:** Since organisms may have alternative food sources, the disruption of one feeding pathway may not necessarily affect the entire food web. However, the removal of an important species can disturb several interconnected feeding relationships.

Key Takeaways:

MEANING	A food web is a network of interconnected food chains within an ecosystem, showing multiple feeding relationships among organisms.
VS FOOD CHAIN	A food chain shows a single pathway of energy flow; a food web shows multiple pathways, as an organism may feed on more than one type of food and be consumed by different organisms.
STABILITY	Alternative food sources mean the disruption of one pathway may not affect the whole web, but removing an important species can disturb several interconnected relationships.

UPSC PRELIMS PRACTICE MCQ

Consider the following two statements:

Assertion (A): A food web generally provides a more realistic representation of feeding relationships in an ecosystem than a single food chain.

Reason (R): In an ecosystem, an organism may depend on different food sources and may itself serve as food for more than one consumer.

Select the correct answer:

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct, but R is incorrect.

(d) A is incorrect, but R is correct.

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Meaning of Ecological Pyramids

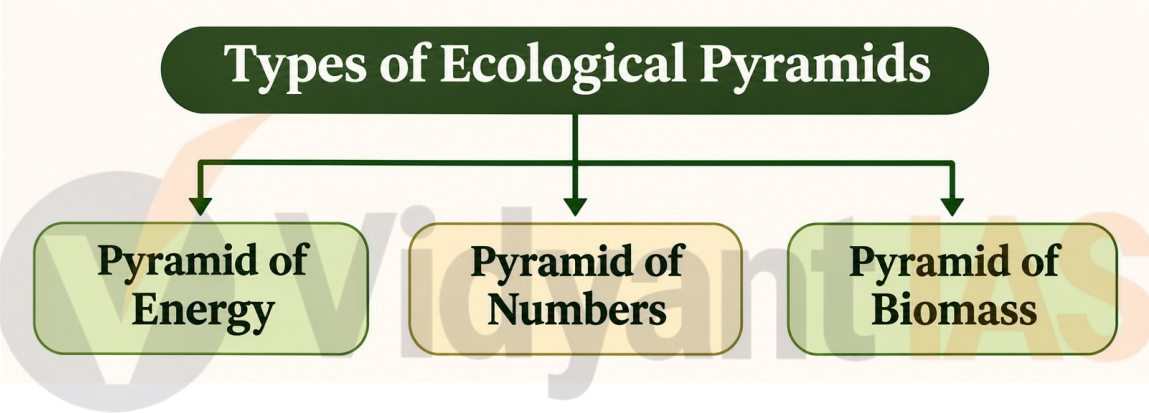
DEFINITION

An **ecological pyramid**, also known as a **trophic pyramid**, is a graphical representation of the distribution of organisms, biomass or energy at different trophic levels in an ecosystem.

It helps us understand how the quantity of organisms, the amount of living matter (biomass) and the available energy vary from producers at the base to consumers at higher trophic levels.

In a typical ecological pyramid:

- Producers form the base.
- Primary consumers occupy the next level.
- Secondary consumers occupy the level above them.
- Tertiary consumers generally occupy the higher levels.



1. Pyramid of Energy (Energy Pyramid)

A **pyramid of energy** represents the amount of energy available at each trophic level in an ecosystem.

It shows how energy is transferred from producers to consumers and how the available energy decreases at successive trophic levels.

Important features:

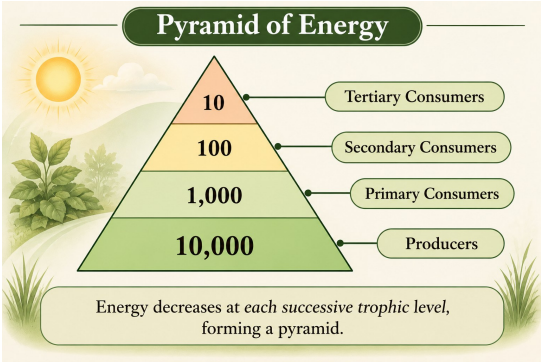
- **Producers form the base:** Green plants capture solar energy through photosynthesis and convert it into chemical energy stored in food.
- **Energy decreases at successive levels:** As studied before, when energy moves from one trophic level to the next, only a small fraction is transferred as new biomass. According to Lindeman's 10% Law, this is approximately 10%.
- **Energy is lost as heat:** A significant portion of assimilated energy is used for life processes such as respiration and movement, with energy released into the surroundings as heat.
- **Always upright:** The energy pyramid is always upright because the amount of energy available decreases at each successive trophic level.
- **Unidirectional flow:** Energy flows from producers towards consumers and is not recycled.

Illustration:

ILLUSTRATION

Pyramid of Energy

Imagine energy moving through an ecosystem, beginning with producers and passing to primary, secondary and tertiary consumers. The energy available at each successive level becomes smaller, giving the pyramid its characteristic shape.



2. Pyramid of Numbers

A **pyramid of numbers** represents the number of individual organisms present at each trophic level in an ecosystem.

Unlike the pyramid of energy, which measures the amount of energy, the pyramid of numbers simply counts the organisms present at each level.

Important features:

- It shows the number of producers, primary consumers, secondary consumers and higher-level consumers.
- The width of each level represents the number of organisms present at that trophic level.
- Depending on the ecosystem and feeding relationships, it can be upright, inverted or spindle-shaped.

Types of Pyramid of Numbers

A. Upright Pyramid

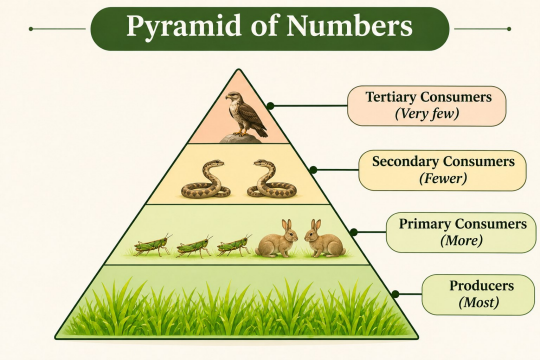
The number of organisms decreases as we move from producers towards higher consumers. It is commonly seen in grassland ecosystems.

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ILLUSTRATION

Grassland Ecosystem

Imagine a vast grassland filled with thousands of grass plants. They feed numerous grasshoppers and rabbits, which support fewer frogs, snakes and other predators. As we move up the food chain, the number of organisms gradually decreases, forming an upright pyramid.



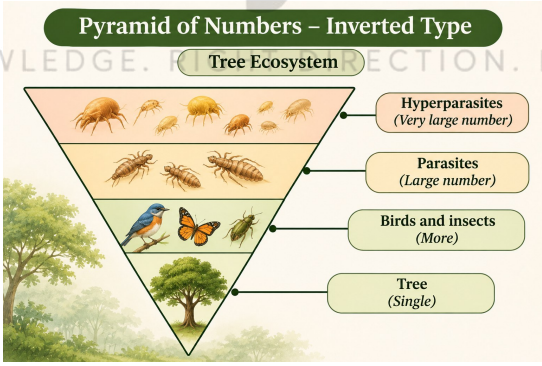
B. Inverted Pyramid

The number of organisms increases at successive higher trophic levels. It can be seen in a parasitic food chain.

ILLUSTRATION

Tree Ecosystem

Imagine a forest with a single large tree. The tree supports numerous birds and insects that feed on it. These organisms may further support thousands of parasites, such as lice and other parasitic organisms. The parasites may, in turn, support even smaller parasitic organisms. Thus, the number of organisms increases towards the higher trophic levels, resulting in an inverted pyramid.



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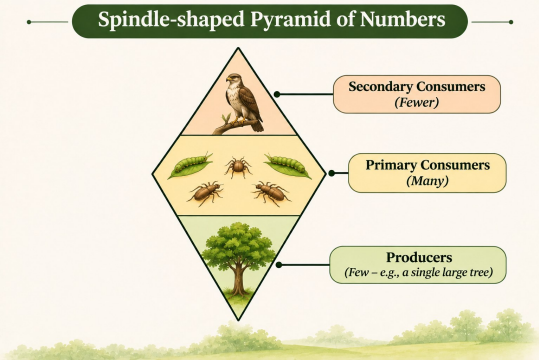
C. Spindle-shaped Pyramid

In some ecosystems, the number of organisms first increases and then decreases across successive trophic levels. This results in a spindle-shaped pyramid rather than a typical upright or inverted shape. It can be observed in certain tree-based ecosystems, where a small number of large producers support many herbivores, followed by fewer higher-level consumers.

ILLUSTRATION

Tree Ecosystem

Imagine a single large tree supporting numerous insects that feed on its leaves. These insects, in turn, provide food for a smaller number of insect-eating birds. Thus, the number of organisms first increases and then decreases across trophic levels, forming a spindle-shaped (funnel-shaped) pyramid.



3. Pyramid of Biomass

A **pyramid of biomass** represents the total biomass (total dry weight of living organisms) present at each trophic level in an ecosystem.

Unlike the pyramid of numbers, which counts individual organisms, the pyramid of biomass measures the total living matter present at each trophic level.

Biomass is generally expressed as dry mass per unit area, such as g/m², or per unit volume in aquatic ecosystems.

Important features:

- It considers the total dry weight of organisms at each trophic level.
- It helps overcome the size difference between organisms. For example, one large tree may have much greater biomass than thousands of small insects.
- Depending on the ecosystem, the pyramid of biomass can be either upright or inverted.

Types of Pyramid of Biomass

A. Upright Pyramid of Biomass

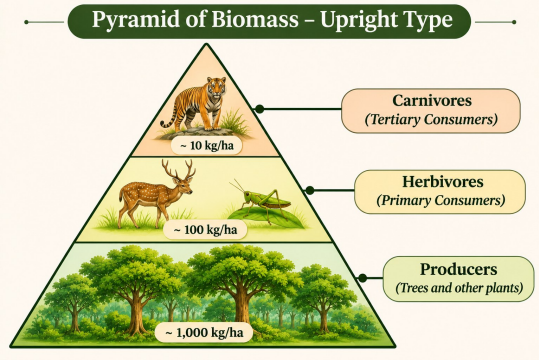
The biomass of producers is greater than that of primary consumers. The biomass generally decreases at successive higher trophic levels. It is commonly found in terrestrial ecosystems such as forests and grasslands.

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ILLUSTRATION

Forest Ecosystem

Imagine a forest filled with large trees. These trees collectively have a huge amount of biomass. They support herbivores such as deer and insects, whose total biomass is comparatively smaller. Carnivores such as tigers form an even smaller biomass at higher trophic levels. Thus, the biomass gradually decreases towards the top, forming an upright pyramid.



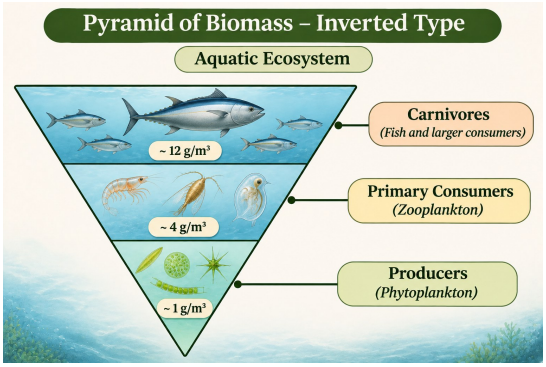
B. Inverted Pyramid of Biomass

The biomass of producers is smaller than that of consumers at a particular point in time. It is commonly observed in aquatic ecosystems such as oceans. This happens because microscopic producers such as phytoplankton have a very low standing biomass but reproduce rapidly and are continuously replaced.

ILLUSTRATION

Aquatic Ecosystem

Beneath the ocean surface, tiny phytoplankton constantly multiply and serve as food for zooplankton. Although phytoplankton reproduce rapidly, their total biomass at any given moment remains relatively low because they are continuously consumed. Surprisingly, the zooplankton may have a greater total biomass than the phytoplankton supporting them. This creates an inverted pyramid of biomass.



Ecological pyramids, thus, help us understand the structure and functioning of an ecosystem by showing the distribution of organisms, biomass and energy across different trophic levels. They provide a clear picture of feeding relationships and energy transfer, helping us understand the interdependence of organisms and the overall functioning of an ecosystem.

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Key Takeaways:

1. PYRAMID OF ENERGY (ENERGY PYRAMID)	
MEANING	A pyramid of energy represents the amount of energy available at each trophic level in an ecosystem.
SHAPE	Always upright, because the energy available decreases at each successive trophic level (approximately 10% passes on, as per Lindeman's 10% Law).
KEY POINT	Energy is lost as heat through respiration and other life processes; the flow is unidirectional and energy is not recycled.
2. PYRAMID OF NUMBERS	
MEANING	A pyramid of numbers counts the individual organisms present at each trophic level.
UPRIGHT	Numbers decrease from producers towards higher consumers; commonly seen in grassland ecosystems.
INVERTED	Numbers increase at successive higher trophic levels; seen in a parasitic food chain (one tree supporting many parasites).
SPINDLE-SHAPED	Numbers first increase and then decrease; seen in certain tree-based ecosystems (one large tree, many insects, fewer insect-eating birds).
3. PYRAMID OF BIOMASS	
MEANING	A pyramid of biomass represents the total biomass (total dry weight of living organisms) at each trophic level, usually expressed as dry mass per unit area (g/m^2) or per unit volume in aquatic ecosystems.
UPRIGHT	Producers have greater biomass than primary consumers and biomass decreases at higher levels; commonly found in forests and grasslands.
INVERTED	Producers have smaller biomass than consumers at a particular point in time; commonly observed in oceans, because phytoplankton have a very low standing biomass but reproduce rapidly and are continuously replaced.

UPSC PRELIMS PRACTICE MCQ

Q1. Consider the following ecological situations:

1. A grassland ecosystem has a large number of producers, followed by progressively fewer herbivores and carnivores.

2. A single large tree supports numerous insects, which further support a large number of parasites and hyperparasites.

3. In an aquatic ecosystem, the standing biomass of phytoplankton is lower than that of zooplankton at a particular point in time.

Which of the following correctly identifies the respective ecological pyramids?

Situation no.	Type of Pyramid
1.	Upright pyramid of numbers
2.	Inverted pyramid of numbers
3.	Inverted pyramid of biomass

Select the correct answer:

(a) Only one pair is correctly matched

(b) Only two pairs are correctly matched

(c) All three pairs are correctly matched

(d) None of the pairs is correctly matched

Q2. Consider the following two statements:

Assertion (A): The pyramid of energy is always upright, irrespective of whether the ecosystem is terrestrial or aquatic.

Reason (R): The amount of energy available at each successive trophic level decreases because only a fraction of energy is transferred to the next level.

Select the correct answer:

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct, but R is incorrect.

(d) A is incorrect, but R is correct.

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D. BIOACCUMULATION AND BIOMAGNIFICATION

We have already studied how energy flows through different trophic levels, from producers to primary consumers, secondary consumers and tertiary consumers. We have also studied food chains, food webs and ecological pyramids, which help us understand the feeding relationships between organisms and the transfer of energy across these trophic levels. But what happens when harmful chemical pollutants enter these food chains? Can these pollutants pass from one organism to another through feeding relationships, and can their concentration increase as we move towards higher trophic levels? The answer is yes. This brings us to two important ecological concepts: bioaccumulation and biomagnification.

1. Bioaccumulation

Definition

Bioaccumulation refers to the gradual increase in the concentration of a chemical pollutant within an individual organism over a period of time.

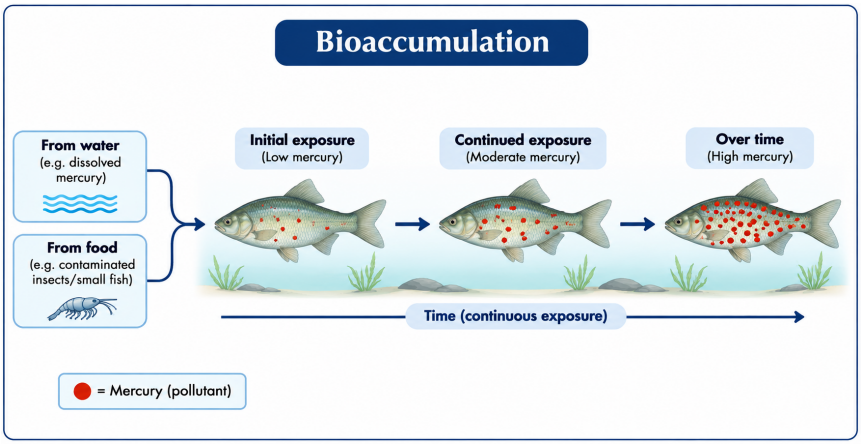
How does it happen?

- Pollutants such as pesticides and heavy metals enter the environment through agricultural activities, industrial discharge and other sources.
- These pollutants enter organisms through contaminated food, water or direct exposure to the surrounding environment.
- Certain pollutants are not easily broken down or eliminated from the body.
- When the rate of absorption of a pollutant exceeds its rate of elimination, it gradually accumulates within the organism. In simple terms, there is an imbalance between two processes: Uptake and Elimination: Uptake: The rate at which a chemical pollutant enters an organism through contaminated food, water, air or direct contact. Elimination: The rate at which the organism removes the pollutant through metabolism, breakdown or excretion.

Illustration:

ILLUSTRATION

Imagine a fish living in a lake contaminated with mercury. The fish continuously absorbs small quantities of mercury from the surrounding water and through the food it consumes. Its body cannot eliminate the entire amount that enters it. Over time, mercury accumulates in its tissues. This gradual accumulation within an individual organism is bioaccumulation.



2. Biomagnification (Biological Magnification)

Definition

Biomagnification refers to the progressive increase in the concentration of certain persistent chemical pollutants at successive higher trophic levels of a food chain.

How does it happen?

- Phytoplankton absorb small quantities of a persistent pollutant such as DDT from the surrounding water.
- Zooplankton feed on large numbers of phytoplankton and accumulate the DDT present in them.
- Small fish feed on zooplankton and accumulate the pollutants present in their bodies.
- Large predatory fish consume several smaller contaminated fish and may accumulate higher concentrations of DDT.
- Fish-eating birds consume contaminated fish and may accumulate still higher concentrations.

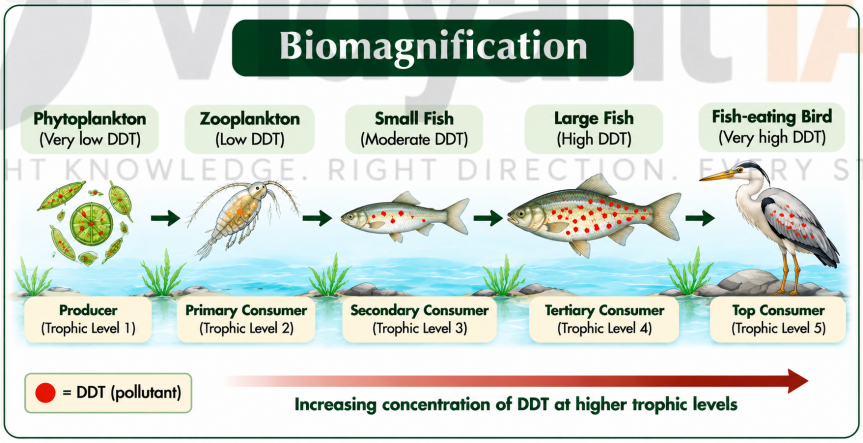
Thus, the concentration of the pollutant may progressively increase as we move from lower to higher trophic levels. This process is called biomagnification.

Illustration:

ILLUSTRATION

A tiny phytoplankton absorbs mercury from a contaminated lake. A hungry zooplankton eats several phytoplankton, a small fish feeds on the zooplankton, and a larger fish swallows several small fish. Finally, a fish-eating bird catches the larger fish.

With every step up the food chain, the mercury concentration increases. By the time it reaches the fish-eating bird, the pollutant concentration may be much higher than in the organisms at the bottom of the food chain. This is biomagnification.



Why do bioaccumulation and biomagnification occur?

Certain properties of chemical pollutants favour both bioaccumulation and biomagnification.

A. Common factors responsible for both

1. Persistence of pollutants: Certain chemicals do not break down easily and remain in the environment and organisms for a long time.

2. Fat solubility: Some pollutants dissolve in fats and tend to get stored in the fatty tissues of organisms, making their elimination difficult.

3. Slow metabolism and elimination: Some organisms cannot efficiently break down or eliminate these pollutants. As a result, the chemicals remain in their bodies for longer periods.

B. Additional factor responsible for biomagnification

4. Transfer through successive trophic levels: When a contaminated organism is consumed by another organism, the pollutant can enter the predator's body. As predators consume multiple contaminated prey over time, they may accumulate higher concentrations of the pollutant. This can result in an increase in pollutant concentration at successively higher trophic levels.

Examples of pollutants

- DDT – a persistent pesticide.
- Methylmercury – a toxic form of mercury that can biomagnify in aquatic food chains.
- PCBs (polychlorinated biphenyls) – persistent industrial chemicals.

Difference between bioaccumulation and biomagnification

Bioaccumulation	Biomagnification
Accumulation of pollutants within an individual organism over time.	Increase in pollutant concentration at successive higher trophic levels.
Takes place within an organism.	Takes place across a food chain.
Depends on the balance between pollutant absorption and elimination.	Depends on transfer and retention of pollutants through feeding relationships.
Example: mercury accumulating in a fish over time.	Example: higher mercury concentration in large predatory fish than in organisms at lower trophic levels.

Key Takeaways:

• Bioaccumulation occurs within an individual organism.
• Biomagnification occurs across successive trophic levels.
• Persistent pollutants such as DDT, methylmercury and PCBs can undergo biomagnification.
• Top predators may experience higher pollutant concentrations.
• Human beings may also be exposed to biomagnified pollutants through food.

UPSC PRELIMS PRACTICE MCQ

Question 1

Consider the following two statements:

Assertion (A): A chemical pollutant that undergoes bioaccumulation in an organism will necessarily undergo biomagnification in the food chain.

Reason (R): Biomagnification depends not merely on the accumulation of a pollutant within individual organisms, but also on its transfer through the food chain and its retention at successive trophic levels.

Select the correct answer using the code given below:

(a) Both A and R are correct, and R is the correct explanation of A.

(b) Both A and R are correct, but R is not the correct explanation of A.

(c) A is correct, but R is incorrect.

(d) A is incorrect, but R is correct.

Question 2

A freshwater lake receives continuous discharge of a persistent chemical pollutant. A particular species of fish absorbs this pollutant through its gills and contaminated food. Over several months, the pollutant concentration in the tissues of an individual fish increases, even though the fish is not moving to a higher trophic level. Further investigation reveals that the pollutant is poorly metabolised and is eliminated very slowly.

Which one of the following best explains the phenomenon described above?

(a) Biomagnification, because the pollutant concentration increases within the aquatic food chain.

(b) Bioaccumulation, because the pollutant builds up within an individual organism over time.

(c) Bioconcentration, because the pollutant enters the fish exclusively through the surrounding water.

(d) Trophic transfer, because the pollutant moves from one trophic level to another.

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