# Chapter 12: Ecosystem

## Exercises — Chapter-end Exercises

**Q1** Fill in the blanks.

(a) Plants are called as_____ because they fix carbon dioxide.

(b) In an ecosystem dominated by trees, the pyramid (of numbers) is_____ type.

(c) In aquatic ecosystems, the limiting factor for the productivity is_____.

(d) Common detritivores in our ecosystem are_____.

(e) The major reservoir of carbon on earth is_____.

### SOLUTION

(a) Plants are called producers (or autotrophs) because they fix carbon dioxide through photosynthesis, converting inorganic $CO_2$ into organic matter using solar energy.

(b) In an ecosystem dominated by trees, the pyramid of numbers is inverted type. A single large tree supports a very large number of insects (primary consumers), which in turn support smaller carnivores, and so on — so the base (producers) has the fewest individuals.

(c) In aquatic ecosystems, the limiting factor for productivity is light. In deeper water, light penetration is restricted, which limits photosynthesis by phytoplankton and other aquatic autotrophs.

(d) Common detritivores in our ecosystem are earthworms, millipedes, wood lice (isopods), and other soil-dwelling invertebrates. They break down detritus (dead organic matter) into smaller particles through fragmentation.

(e) The major reservoir of carbon on earth is the ocean (oceans/hydrosphere). Sedimentary rocks and fossil fuels also serve as large carbon reservoirs; among living systems, the atmosphere (as $CO_2$) is the primary immediate reservoir, but the largest overall reservoir is the ocean.

**Answer: (a) producers/autotrophs; (b) inverted; (c) light; (d) earthworms/millipedes; (e) oceans (hydrosphere/sedimentary rocks)**

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**Q2** Which one of the following has the largest population in a food chain?

(a) Producers

(b) Primary consumers

(c) Secondary consumers

(d) Decomposers

### SOLUTION

The correct answer is (d) Decomposers.

Although producers form the base of the grazing food chain and are large in number, decomposers (fungi and bacteria) are the most numerous organisms in any ecosystem. They are present in enormous quantities in soil, water, and on all dead organic matter, and they

outnumber both producers and consumers. They operate on detritus produced at every trophic level.

Note: Some textbooks accept (a) Producers as correct in the context of the grazing food chain pyramid of numbers. However, in a food chain that includes decomposers, decomposers have the largest population overall.

Answer: (d) Decomposers

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Q3 The second trophic level in a lake is
(a) Phytoplankton
(b) Zooplankton
(c) Benthos
(d) Fishes

SOLUTION

The correct answer is (b) Zooplankton.

In a lake (aquatic ecosystem), phytoplankton are the primary producers and occupy the first trophic level. Zooplankton feed on phytoplankton and therefore occupy the second trophic level (primary consumers). Fishes typically occupy the third or higher trophic levels as secondary or tertiary consumers.

Answer: (b) Zooplankton

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Q4 Secondary producers are
(a) Herbivores
(b) Producers
(c) Carnivores
(d) None of the above

SOLUTION

The correct answer is (d) None of the above.

There is no recognised category called 'secondary producers' in the classical ecological sense. Primary producers (autotrophs/plants) fix solar energy and produce organic matter. Consumers (herbivores, carnivores) are not producers — they only assimilate energy. The term 'secondary productivity' refers to the rate of formation of new organic matter by consumers (heterotrophs), but the organisms responsible are consumers, not producers. Hence, none of the options correctly identifies a group called 'secondary producers'.

Answer: (d) None of the above

Q5 What is the percentage of photosynthetically active radiation (PAR) in the incident solar radiation?
(a) 100%
(b) 50%
(c) 1-5%
(d) 2-10%

SOLUTION

The correct answer is (b) 50%.

Of the total incident solar radiation reaching the Earth's surface, less than 50 per cent of it is photosynthetically active radiation (PAR) — that is, the portion of the electromagnetic spectrum (400–700 nm) that plants can use for photosynthesis. Of this PAR, plants capture only 2–10 per cent for actual photosynthesis.

Answer: (b) 50%

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Q6 Distinguish between
(a) Grazing food chain and detritus food chain
(b) Production and decomposition
(c) Upright and inverted pyramid
(d) Food chain and Food web
(e) Litter and detritus
(f) Primary and secondary productivity

SOLUTION

(a) Grazing food chain vs Detritus food chain:
The grazing food chain (GFC) begins with living green plants (producers) and energy flows from producers to herbivores and then to carnivores. Example: Grass → Grasshopper → Frog → Snake → Hawk. In aquatic ecosystems, GFC is the major conduit for energy flow.
The detritus food chain (DFC) begins with dead organic matter (detritus) and is made up of decomposers (fungi, bacteria) that break down dead plant and animal material. In terrestrial ecosystems, a much larger fraction of energy flows through the DFC than through the GFC.

(b) Production vs Decomposition:
Production (primary productivity) is the rate at which producers (autotrophs) capture solar energy and synthesise organic matter through photosynthesis. It involves building up complex organic molecules from simple inorganic ones.
Decomposition is the process by which decomposers break down complex organic matter (detritus) into simple inorganic substances such as $CO_2$, water, and inorganic nutrients. It is essentially the reverse of production in chemical terms and releases nutrients back into the environment for reuse.

(c) Upright vs Inverted pyramid:
An upright ecological pyramid has a broad base (producers) tapering towards the apex (top

consumers), indicating that producers are most numerous/have the most biomass/energy, and these values decline at higher trophic levels. Most pyramids of number, biomass, and energy in terrestrial ecosystems are upright.

An inverted pyramid has a narrow base and widens towards the apex, meaning the higher trophic levels have more individuals, biomass, or energy than the lower. Example: pyramid of numbers in a tree ecosystem (one tree supports many insects) is inverted; pyramid of biomass in the sea is inverted (small standing crop of phytoplankton supports large biomass of zooplankton and fishes). The pyramid of energy is never inverted.

(d) Food chain vs Food web:

A food chain is a linear sequence of organisms in which each organism is eaten by the next — energy flows in one direction from producers to top consumers. Example: Grass → Deer → Tiger.

A food web is a network of interconnected food chains within an ecosystem. It represents the more realistic feeding relationships, where an organism may feed on multiple species and may itself be eaten by several others. Food webs show the complex interdependency of organisms in a natural ecosystem.

(e) Litter vs Detritus:

Litter refers to freshly fallen dead plant material such as leaves, bark, flowers, twigs, and other plant parts that accumulate on the soil surface. It is the recently deposited organic material that has not yet undergone significant decomposition.

Detritus is the broader term for all dead organic matter — including litter, dead animal remains, fecal matter, and any partially decomposed organic material. Litter is thus a component of (or precursor to) detritus. Detritus serves as the raw material for decomposition.

(f) Primary vs Secondary productivity:

Primary productivity is the rate of production of organic matter (biomass) by producers (autotrophs) through photosynthesis per unit area per unit time. It is subdivided into gross primary productivity (GPP — total photosynthesis) and net primary productivity (NPP = GPP − respiration losses). It is the energy available to all heterotrophs.

Secondary productivity is the rate of formation of new organic matter by consumers (heterotrophs). It represents the energy available at the consumer trophic levels after assimilation of food from the lower trophic level. Secondary productivity is always less than primary productivity due to energy losses at each trophic transfer.

Answer: Six paired distinctions covering food chain types, production vs decomposition, pyramid orientation, food chain vs food web, litter vs detritus, and primary vs secondary productivity.

Q7 Describe the components of an ecosystem.

SOLUTION

An ecosystem is a structural and functional unit of nature where living organisms interact among themselves and with the surrounding physical environment. Its components are broadly classified into abiotic (non-living) and biotic (living) components.

Abiotic Components:
These are the non-living, physical and chemical factors of the environment:
— Inorganic substances: $CO_2$, water, nitrogen, phosphorus, calcium, and other mineral nutrients present in the soil and water.
— Organic compounds: proteins, carbohydrates, lipids, and humic substances that link the biotic and abiotic components.
— Climatic factors: temperature, light, humidity, wind, and rainfall that regulate the rate of ecosystem processes.
In a pond ecosystem, the abiotic component includes water, dissolved inorganic and organic substances, and the rich soil deposit at the bottom. Solar input, temperature cycles, and day-length regulate the functioning of the whole system.

Biotic Components:
These are all the living organisms of the ecosystem, grouped into three functional categories:

1. Producers (Autotrophs): Green plants and photosynthetic bacteria that fix solar energy and synthesise organic compounds from inorganic raw materials. In terrestrial ecosystems, herbaceous and woody plants are the major producers; in aquatic ecosystems, phytoplankton, algae, and higher plants are the producers.

2. Consumers (Heterotrophs): Organisms that directly or indirectly depend on producers for food.
— Primary consumers (herbivores): Feed directly on producers. Examples: insects, deer, molluscs, zooplankton.
— Secondary consumers (primary carnivores): Feed on herbivores. Examples: frogs, small fish.
— Tertiary consumers (secondary carnivores): Feed on secondary consumers. Examples: large birds of prey, sharks.
— Omnivores: Feed on both plants and animals (e.g., humans, crows, cockroaches).

3. Decomposers (Saprotrophs/Detritivores): Fungi and bacteria that break down complex organic matter of dead organisms (detritus) into simple inorganic substances, releasing nutrients back into the environment for reuse by producers. In a pond, decomposers are especially abundant at the bottom. Detritivores (e.g., earthworms) mechanically fragment detritus into smaller particles.

These components interact through the processes of productivity, decomposition, energy flow, and nutrient cycling to form a self-sustaining unit.

Answer: Ecosystem components: (1) Abiotic — inorganic substances, organic compounds, climatic factors; (2) Biotic — producers (autotrophs), consumers (primary/secondary/tertiary), decomposers (saprotrophs/detritivores).

Q8 Define ecological pyramids and describe with examples, pyramids of number and biomass.

SOLUTION

Definition of Ecological Pyramids:
Ecological pyramids are graphical representations of the relationship between the number of organisms, their biomass, or the energy content at successive trophic levels of a food chain. The base of each pyramid represents the producers (first trophic level) and the apex represents the top-level consumers. Three types are studied: pyramid of number, pyramid of biomass, and pyramid of energy.

Pyramid of Number:
This represents the number of individual organisms at each trophic level.

Upright pyramid of number (grassland ecosystem):
In a grassland, there are millions of grass plants (producers) at the base, a large number of insects and other herbivores feeding on them, a smaller number of frogs and lizards, and very few top carnivores (e.g., hawks). The pyramid is upright — broadest at the base, narrowing at the top.
Example: Grass (millions) → Insects/Grasshoppers (thousands) → Frogs (hundreds) → Snake → Hawk (few)

Inverted pyramid of number (tree-dominated ecosystem):
When a single large tree (producer) supports a very large number of insects (primary consumers) feeding on it, which in turn support a smaller number of birds, the pyramid is inverted. The producer level (1 tree) has fewer individuals than the consumer levels.
Example: 1 tree → many insects → fewer birds → still fewer top carnivores

Pyramid of Biomass:
This represents the total dry weight (biomass) of all organisms at each trophic level.

Upright pyramid of biomass (terrestrial ecosystem):
In most terrestrial ecosystems, the biomass of producers is the largest, followed by decreasing biomass at each successive consumer level. The pyramid is upright.
Example: In a grassland — grass has the maximum biomass, herbivores less, carnivores least.

Inverted pyramid of biomass (aquatic ecosystem):
In an aquatic ecosystem such as the sea or a lake, the pyramid of biomass is generally inverted. The standing crop (biomass at a given time) of phytoplankton (producers) is very small — phytoplankton reproduce so rapidly that even a small standing crop can support a much larger biomass of zooplankton, and these support even greater biomass of fish. This apparent paradox is explained by the very high turnover rate of phytoplankton.
Example: Phytoplankton (small biomass) → Zooplankton → Fish (large biomass)

Limitations of ecological pyramids:
— They assume a simple food chain and do not accommodate food webs.
— An organism occupying more than one trophic level is not accounted for.
— Saprophytes (decomposers) are not given a place in ecological pyramids despite their vital role.

Answer: Ecological pyramids graphically represent number, biomass, or energy at successive trophic levels. Pyramid of number: upright in grasslands, inverted in tree ecosystems. Pyramid of biomass: upright in terrestrial systems, inverted in aquatic (sea) systems due to high phytoplankton turnover.

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Q9 What is primary productivity? Give brief description of factors that affect primary productivity.

SOLUTION

Definition of Primary Productivity:
Primary productivity is defined as the amount of biomass or organic matter produced per unit area over a time period by plants (producers) during photosynthesis. It is expressed in terms of weight (g $m^{-2}$) or energy (kcal $m^{-2}$) per year.

It is of two types:
— Gross Primary Productivity (GPP): The total rate of production of organic matter during photosynthesis, i.e., the total energy fixed by producers.
— Net Primary Productivity (NPP): The organic matter remaining after deducting the amount used by the plant itself in respiration. NPP = GPP − Respiration (R). NPP is the biomass available for consumption by heterotrophs (herbivores and decomposers).

The rate of biomass production is called productivity, expressed as g $m^{-2}$ $yr^{-1}$ or (kcal $m^{-2}$) $yr^{-1}$.

Factors Affecting Primary Productivity:

1. Plant species: The species composition of producers in an area influences productivity. Species with higher photosynthetic efficiency contribute more to productivity.

2. Environmental factors:
— Light: The availability of sunlight (PAR) directly determines photosynthetic rate. In aquatic ecosystems, light penetration into water is a major limiting factor.
— Temperature: Photosynthetic enzymes work optimally within a temperature range; extremes reduce productivity.
— Water: Availability of water is critical; it is a raw material for photosynthesis and also affects stomatal opening.

3. Availability of nutrients: Soil nutrients (especially nitrogen, phosphorus) are essential for the synthesis of photosynthetic pigments and enzymes. In oceans, nutrient availability is low despite occupying about 70% of Earth's surface, which is why oceanic productivity (55 billion tons/year) is much lower than terrestrial productivity even though the oceans are vast.

4. Photosynthetic capacity of plants: Plants differ in their photosynthetic pathways ($C_3$, $C_4$,

CAM) and inherent efficiency, which affects how much $CO_2$ they can fix per unit time.

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

Answer: Primary productivity is the rate of organic matter production by autotrophs via photosynthesis (GPP = total; NPP = GPP − respiration). Key factors: plant species, light, temperature, water, nutrient availability, and photosynthetic capacity.

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Q10 Define decomposition and describe the processes and products of decomposition.

SOLUTION

Definition of Decomposition:
Decomposition is the process by which decomposers (mainly fungi and bacteria) break down complex organic matter (detritus) into simpler inorganic substances such as carbon dioxide, water, and inorganic nutrients. Dead plant remains (leaves, bark, flowers) and dead animal remains including fecal matter constitute detritus, which is the raw material for decomposition.

Processes of Decomposition:
Decomposition involves five important steps that operate simultaneously:

1. Fragmentation: Detritivores (e.g., earthworms, millipedes) mechanically break down detritus into smaller particles, greatly increasing the surface area available for microbial action. This is the first step in decomposition.

2. Leaching: Water-soluble inorganic nutrients from the detritus go down into the soil horizon through leaching and get precipitated as unavailable salts. This removes soluble components from the detritus.

3. Catabolism: Bacterial and fungal enzymes degrade detritus into simpler inorganic substances through enzymatic (biochemical) breakdown. This is a chemical process that converts complex organic molecules into simple compounds.

4. Humification: This process leads to the accumulation of a dark-coloured, amorphous substance called humus. Humus is highly resistant to microbial action and decomposes at an extremely slow rate. Being colloidal in nature, it serves as a reservoir of nutrients and improves soil structure.

5. Mineralisation: Some microbes further degrade the humus, and inorganic nutrients are released in this process. This release of inorganic nutrients from organic matter is called mineralisation.

Products of Decomposition:
— $CO_2$ (carbon dioxide) — released back into the atmosphere.
— Water — released during breakdown of organic compounds.
— Inorganic nutrients — nitrogen, phosphorus, potassium, calcium, and other minerals returned to the soil/water, making them available for uptake by producers again.
— Humus — an intermediate stable product of decomposition, enriches soil with nutrients.

Factors Affecting Rate of Decomposition:
— Chemical composition of detritus: Detritus rich in lignin and chitin decomposes slowly; detritus rich in nitrogen and water-soluble sugars decomposes quickly.
— Temperature and soil moisture: Warm and moist conditions favour decomposition. Low temperature and anaerobic conditions (anaerobiosis) inhibit decomposition, leading to build-up of organic material.
— Decomposition is largely an oxygen-requiring (aerobic) process.

Answer: Decomposition breaks detritus into $CO_2$, water, and inorganic nutrients via five steps: fragmentation (detritivores), leaching (soluble salts), catabolism (enzyme action), humification (humus formation), and mineralisation (nutrient release). Rate depends on detritus chemistry and climatic factors (temperature, moisture).

Q11 Give an account of energy flow in an ecosystem.

SOLUTION

Energy flow in an ecosystem refers to the transfer of energy from one trophic level to the next, starting from the sun (the primary source) through producers and then through successive levels of consumers.

Source of Energy:
Except for deep-sea hydrothermal ecosystems, the sun is the only source of energy for all ecosystems on Earth. Of the total incident solar radiation, less than 50% is photosynthetically active radiation (PAR). Plants capture only 2–10% of this PAR for photosynthesis, and this small amount sustains the entire living world.

Unidirectional Flow:
Energy flow through an ecosystem is strictly unidirectional — from the sun to producers and then from producers to successive consumer trophic levels. Energy cannot flow back from consumers to producers. This is consistent with the Second Law of Thermodynamics: at each step of energy transfer, some energy is lost as heat to the environment and is not available for further use.

Trophic Levels and Energy Transfer:
Organisms are organised into trophic levels based on their source of nutrition:
— First trophic level: Producers (green plants, phytoplankton) — fix solar energy.
— Second trophic level: Primary consumers (herbivores) — feed on producers.
— Third trophic level: Secondary consumers (primary carnivores) — feed on herbivores.
— Fourth trophic level: Tertiary consumers (secondary carnivores) — feed on primary carnivores.

10 Per Cent Law (Lindeman's Law):
Only about 10% of the energy at any trophic level is transferred to the next higher trophic level. This is because the remaining 90% is used for the organism's own metabolic processes (respiration) and lost as heat. This severely limits the number of trophic levels in a grazing food

chain to about 4–5 levels.
Example from the energy pyramid: If producers fix 10,000 J from sunlight, primary consumers get 1,000 J, secondary consumers get 100 J, and tertiary consumers get only 10 J.

Grazing Food Chain (GFC) and Detritus Food Chain (DFC):
— GFC starts with living producers and passes energy through herbivores to carnivores. In aquatic ecosystems, GFC is the major conduit for energy flow.
— DFC starts with dead organic matter (detritus). Decomposers (fungi, bacteria) convert complex organic compounds to inorganic forms. In terrestrial ecosystems, a much larger fraction of energy flows through the DFC than through the GFC.
— The two food chains are interconnected: some organisms of the DFC are prey to GFC animals, forming a food web.

Standing Crop:
Each trophic level has a standing crop — the total mass of living organisms (biomass) or their number per unit area at a given time. Biomass decreases at successive trophic levels because energy is lost at each transfer.

Pyramid of Energy:
The energy pyramid is always upright — energy is always greatest at the producer level and decreases at each successive trophic level. It can never be inverted because some energy is always lost as heat at each step. Each bar in the energy pyramid represents the amount of energy (e.g., in joules) at that trophic level per unit area per unit time.

Summary: Energy enters ecosystems as sunlight, is fixed by producers, transferred through trophic levels with ~10% efficiency at each step, and is ultimately dissipated as heat. The flow is one-way and non-cyclic, unlike matter/nutrient cycles.

Answer: Energy flows unidirectionally: Sun → Producers → Consumers (via GFC) and Detritus → Decomposers (via DFC). Only ~10% of energy is transferred per trophic level (10% law); the rest is lost as heat. The pyramid of energy is always upright and can never be inverted.