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Step-by-step solutions, alternate methods & exam tips for Class 12 Biology

Chapter 12: Ecosystem

About this Chapter

An **ecosystem** is the structural and functional unit of nature where living **biotic** components interact with the non-living **abiotic** environment. This chapter walks you through productivity, decomposition, energy flow and ecological pyramids in the 2026-27 NCERT (Latest Edition, Coloured PDF) and answers every Exercise question for Class 12 Biology Chapter 12 with step-by-step reasoning, embedded source figures and exam-ready notes.

Topics covered: Ecosystem components • Productivity (GPP & NPP) • Decomposition • Energy flow • Food chains & food webs • Ecological pyramids

Quick Formula Sheet

NPP and GPP:
$\text{NPP} = \text{GPP} - R$

PAR of incident solar radiation:
$\approx 50\%$ (only 2–10% captured by plants)

Lindeman's 10% law (energy transfer):
Only $\sim 10\%$ of energy passes from one trophic level to the next.

Also see for this chapter: Revision Notes | Formula Sheet | Exemplar Solutions

Exercise: NCERT Biology Class 12 Chapter 12 Ecosystem

Q 12.1 **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

Concept used. A **producer** is an autotrophic organism that fixes inorganic carbon (CO_2) into organic matter through **photosynthesis**. The shape of a **pyramid of numbers** depends on how many individuals occupy each trophic level: it is *upright* when producers outnumber consumers, but *inverted* when a single large producer (like a tree) supports many small consumers. **Primary productivity** in water is limited mainly by sunlight penetration, since light dies out rapidly with depth. **Detritivores** are organisms that feed on dead organic matter (detritus), and the **carbon reservoirs** of the Earth are the oceans (dissolved CO_2 and carbonates), the atmosphere, and fossil fuels.

Step 1. **(a)** Plants take in atmospheric CO_2 and build sugars during photosynthesis; they are called **producers** (or autotrophs).

Step 2. **(b)** A single tree supports many herbivorous insects, which in turn feed birds. So one producer supports many primary consumers, making the pyramid of numbers **inverted** (or spindle-shaped).

Step 3. **(c)** In ponds, lakes and oceans, photosynthesising algae and phytoplankton can only grow where light reaches. Light intensity falls steeply with depth, so the limiting factor for productivity is **light (sunlight)**.

Step 4. **(d)** Earthworms, dung beetles, millipedes, woodlice and termites all break up dead leaves and faecal matter into smaller pieces. The common detritivore in Indian ecosystems is the **earthworm** (along with similar soil invertebrates).

Step 5. **(e)** About 71% of the global carbon is dissolved in the **oceans** as carbonates and bicarbonates; the oceans are therefore the largest active reservoir of carbon on Earth.

Final Answer: (a) Producers (b) Inverted (c) Light (d) Earthworms (e) Oceans

☞ **Exam Tip**

NEET and CUET routinely ask which reservoir holds the most carbon. Keep the order ranked: **oceans** > **fossil fuels** > **soil/biota** > **atmosphere**.

EXPERT'S SOLUTION : *Aanya Iyer, M.Sc Botany, Delhi University*

Quick reading. Treat each blank as a flag for one core ecosystem concept. The five blanks together cover trophic role (autotrophy), pyramid geometry, abiotic limiting factor, detritus food chain and biogeochemical cycling. Answering them well means naming the concept first, then giving the textbook word.

Step 1. Autotrophy (a). $CO_2 + H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} (CH_2O) + O_2$. Only organisms that can run this reaction fix carbon, so they sit at the base of every food chain: producers.

Step 2. Tree-based pyramid (b). One mango tree may host $\sim 10^4$ caterpillars, which feed $\sim 10^2$ birds, which feed ~ 10 hawks. Number of individuals *increases* for two levels before falling, giving an inverted (spindle) pyramid of numbers.

Step 3. Aquatic limiting factor (c). On land, water often limits productivity; in water, water is everywhere, so what's scarce is light. Below the photic zone (often ~ 200 m) photosynthesis stops.

Step 4. Detritivores (d). Detritus = dead leaves, faeces and remains. Fragmenting agents include termites, mites, millipedes and the all-purpose earthworm, which is called the "farmer's friend" for this very reason.

Step 5. Carbon reservoir (e). Carbon distribution by mass: oceans $\approx 71\%$, fossil fuels $\approx 22\%$, soils + living biota $\approx 6\%$, atmosphere $\approx 1\%$. The clear winner is the oceans.

Why this matters. Each blank links to a downstream chapter question (Q2–Q11), so memorising these one-word answers also unlocks the conceptual MCQs and the long-answer essay parts.

Final Answer: Producers · Inverted · Light · Earthworms · Oceans

Q 12.2 Which one of the following has the largest population in a food chain?

(a) Producers (b) Primary consumers (c) Secondary consumers (d) Decomposers

SOLUTION

Concept used. In any standard **grazing food chain**, energy passes from one trophic level to the next with heavy losses (see Lindeman's 10% law). Because energy thins out as we move up, each higher level can support fewer mouths than the one below it. So the *number* of individuals generally falls from producers to top carnivores in an upright **pyramid of numbers**.

Step 1. Producers (plants, phytoplankton) capture solar energy directly and use it to make biomass: they form the broadest base of the food chain.

Step 2. Primary consumers (herbivores) feed on producers. Because energy transfer is only $\sim 10\%$ efficient, herbivores must be fewer in number than the producers that feed them.

Step 3. Secondary consumers (small carnivores) and tertiary consumers (top carnivores) keep losing energy at every step, so their populations shrink further at each level.

Step 4. Decomposers can be locally abundant, but in a *food chain* (which traces energy flow from sun → producer → consumer) producers always outnumber any single consumer category. Hence the largest population is at the producer level.

Final Answer: (a) Producers

☞ Exam Tip

"Largest population in a *food chain*" always means **producers**. Decomposers are abundant in soil but are not counted in the grazing food chain because they consume detritus from every trophic level, not just one.

EXPERT'S SOLUTION *: Karan Reddy, Ph.D Molecular Biology, NCBS Bangalore*

Strategic angle. Read this MCQ as a test of two ideas at once: the energy-pyramid concept, and the discipline of staying within the question's frame ("in a food chain").

Step 1. The pyramid of numbers in a typical grassland or pond is upright, with producers at the broad base.

Step 2. Energy lost as heat at every transfer (per Lindeman's 10% rule) limits how many organisms a higher level can carry.

Step 3. Decomposers act on detritus from every trophic level, so they are not part of the linear grazing food chain implied here; the question is about the chain, not the whole web.

Step 4. Producers therefore hold the largest standing population.

Why this matters. This MCQ shows up in NEET almost every year. The trap option is decomposers, which can be numerous in soil but are off-chain.

Final Answer: (a) Producers

Q 12.3 The second trophic level in a lake is

(a) Phytoplankton (b) Zooplankton (c) Benthos (d) Fishes

SOLUTION

Concept used. A trophic level is the position an organism occupies in a food chain based on its feeding role. The *first* trophic level is the producer level. The *second* trophic level is the primary consumer (herbivore) level. In an aquatic ecosystem like a lake, the producers are tiny floating photosynthetic organisms called **phytoplankton**, and the primary consumers that graze on them are tiny drifting animals called **zooplankton**.

Step 1. In a lake, photosynthesis is carried out by phytoplankton (diatoms, green algae, cyanobacteria); they form the first trophic level (producers).

Step 2. Zooplankton (rotifers, copepods, daphnia, ciliates) feed on the phytoplankton; they are herbivores, so they occupy the second trophic level (primary consumers).

Step 3. Small fishes that eat zooplankton sit at the third trophic level (secondary consumers).

Step 4. Benthos refers to bottom-dwelling organisms (worms, molluscs, crustaceans); they are not defined by trophic position but by habitat, and they may feed on detritus or other benthic animals at varying levels.

Final Answer: (b) Zooplankton

✗ Common Mistake

Do not confuse *benthos* (a habitat-based term) with a trophic level. Benthos can be detritivores, herbivores or carnivores depending on what they eat at the lake floor.

EXPERT'S SOLUTION *: Vivaan Sharma, M.Sc Biotechnology, AIIMS Delhi*

Quick reading. Translate the question: "Who eats the producers in a lake?" That straight away rules out phytoplankton (they *are* the producers, level 1) and points at the primary consumers, which in a lake are zooplankton.

Step 1. **Lake food-chain skeleton.**
Phytoplankton $\rightarrow$ Zooplankton $\rightarrow$ Small fish $\rightarrow$ Large fish. Each arrow represents a single energy transfer between adjacent trophic levels.

Step 2. **Map levels to numbers.** Producer = level 1, herbivore = level 2, carnivore = level 3, top carnivore = level 4. So "second trophic level" in this chain is automatically the herbivore, which in a lake is the zooplankton.

Step 3. **Rule out the other options.** Phytoplankton sit at level 1 (producers). Small fish sit at level 3 (secondary consumers). Benthos is a habitat label, not a trophic-level label; benthic organisms can be detritivores, herbivores or carnivores depending on what they eat at the lake floor.

Step 4. **Conclusion.** Only zooplankton match all three filters (aquatic, primary consumer, distinct level-2 organism), so option (b) is the answer.

Why this matters. The same lake food-chain is the textbook example of an inverted biomass pyramid in Q8: phytoplankton standing crop is small but supports a far larger zooplankton standing crop at any instant because phytoplankton turn over every few days.

> **Final Answer:** (b) Zooplankton

Q 12.4 **Secondary producers are**

(a) Herbivores (b) Producers (c) Carnivores (d) None of the above

SOLUTION

Concept used. A **producer** is, by definition, an autotroph that synthesises organic compounds from inorganic ones using sunlight or chemical energy. *All* producers are primary producers; the term "secondary producer" is sometimes used loosely in older books to mean herbivores (which produce animal biomass from plant matter), but in strict NCERT usage there is no separate "secondary producer" category in the food chain.

Step 1. Producers fix carbon directly: they are the *only* producers in an ecosystem. There is no "second" producer rank because the next step (herbivores) does not fix carbon.

Step 2. Herbivores are primary *consumers*, not producers. They do produce new biomass, but using already-fixed energy.

Step 3. Carnivores are secondary or tertiary *consumers*.

Step 4. Therefore, no option (a)–(c) fits the strict definition of a "secondary producer". The correct option is (d).

> **Final Answer:** (d) None of the above

✗ Common Mistake

Older textbooks sometimes call herbivores "secondary producers" because they produce animal biomass. NCERT explicitly rejects that usage: in NCERT Class 12 Biology the only producers are autotrophs, and herbivores are primary *consumers*.

EXPERT'S SOLUTION : *Aditi Banerjee, Ph.D Molecular Biology, NCBS Bangalore*

Strategic angle. The trap option here is (a), because some older textbooks call herbivores "secondary producers". NCERT deliberately rejects that vocabulary, so the answer must be (d).

Step 1. Producers in NCERT = autotrophs only (plants, algae, cyanobacteria, chemosynthetic bacteria).

Step 2. Consumers in NCERT = heterotrophs (herbivores, carnivores, omnivores, detritivores).

Step 3. There is no "secondary producer" category in NCERT's food chain. Energy in animal biomass is *secondary productivity*, but the animals themselves are consumers.

Step 4. All of (a), (b), (c) fail, so (d) wins.

Why this matters. Read every MCQ option against the NCERT glossary, not your general impression. A small word like "producer" has a tight, defended meaning.

> **Final Answer:** (d) None of the above

Q 12.5 **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

Concept used. **Photosynthetically Active Radiation (PAR)** is the portion of the solar spectrum (wavelength 400–700 nm) that plants can absorb through chlorophyll for photosynthesis. Sunlight reaching the top of the atmosphere covers a much wider range (UV at one end, far-IR at the other), so only a fraction of it counts as PAR.

Step 1. Of all incident solar radiation that reaches a leaf, *about* 50% lies in the 400–700 nm band; this is the PAR portion.

Step 2. Of this PAR, plants actually capture only 2–10%, depending on species, leaf orientation, water availability and nutrients. This 2–10% is what fuels the entire living world via Net Primary Productivity.

Step 3. Reading the options carefully: option (d) is the capture-efficiency by plants, not the PAR fraction in sunlight. Option (b) is the PAR fraction itself.

Step 4. Therefore PAR $\approx 50\%$ of incident solar radiation.

Final Answer: (b) 50%

✗ **Two different numbers**

50% = PAR in incident solar radiation. 2–10% = how much of PAR is actually captured by plants. The MCQ asks the first.

EXPERT'S SOLUTION *: Pranav Mehta, Ph.D Condensed Matter Physics, TIFR Mumbai*

Quick reading. Three numbers float around in this section of NCERT: 50%, 2–10% and ~ 170 billion tonnes (global NPP). Match each number to its statement before answering.

Step 1. Solar spectrum at sea level: UV ($\sim 5\%$), visible ($\sim 50\%$), infrared ($\sim 45\%$).

Step 2. PAR overlaps with the visible band (400–700 nm), so PAR $\approx 50\%$ of total incident radiation.

Step 3. Plants then absorb a small slice of that PAR; conversion efficiency is only 2–10%.

Step 4. Hence option (b) is the answer; option (d) is a distractor for students who skim NCERT.

Why this matters. The 50% figure is the entry point to the entire chapter on productivity. Carrying it around saves time on both NEET MCQs and CUET fill-in-the-blank questions.

Final Answer: (b) 50% of incident solar radiation is PAR.

Q 12.6 **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

Concept used. Each pair below names two related but distinct ecological concepts. We list them side-by-side in compact tables. A **food chain** traces energy flow from one trophic level to the next; **productivity** measures the rate of biomass build-up; **decomposition** returns nutrients from dead matter to the abiotic pool; and ecological pyramids visualise number, biomass or energy across trophic levels.

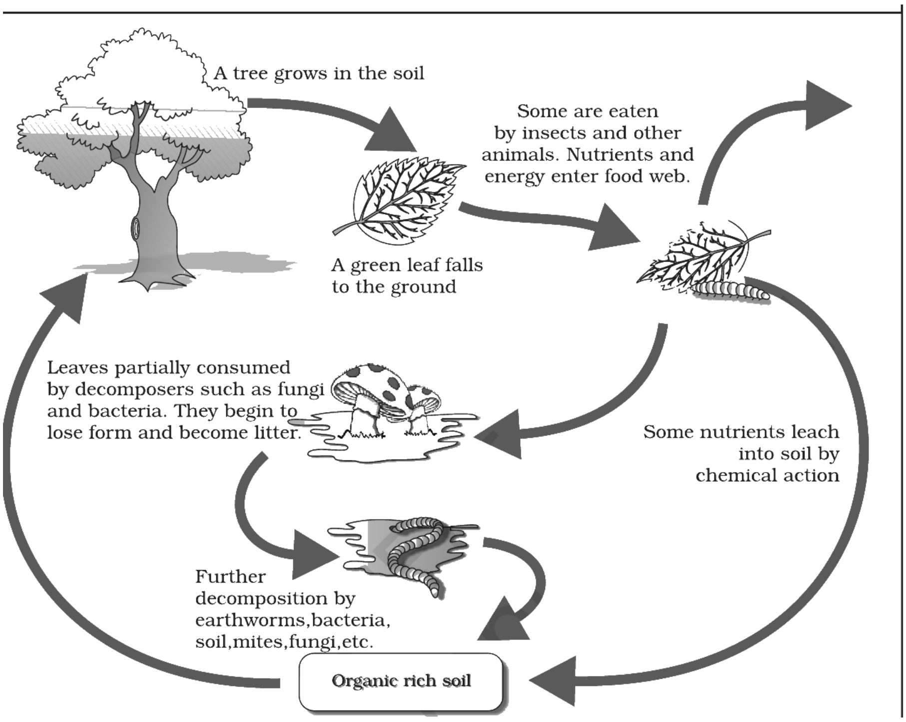

Fig. 12.1: Decomposition cycle in a terrestrial ecosystem. Source: NCERT Class 12 Biology, Chapter 12 (Ecosystem).

(a) Grazing food chain (GFC) vs Detritus food chain (DFC)

Grazing food chain	Detritus food chain
Starts with green plants (producers).	Starts with dead organic matter (detritus).
Energy enters as sunlight captured by producers.	Energy enters from the GFC via dead biomass.
Major energy route in terrestrial and aquatic ecosystems.	Dominant in forest floors and deep-sea ecosystems.
Example: grass → grasshopper → frog → snake.	Example: dead leaves → earthworm → bird.

(b) Production vs Decomposition

Production	Decomposition
Building of organic matter from inorganic substances.	Breakdown of organic matter into inorganic substances.
Carried out by producers (autotrophs).	Carried out by decomposers (fungi, bacteria).
Requires solar energy (anabolic).	Releases energy as heat (catabolic).
Increases O_2, decreases CO_2 in the atmosphere.	Increases CO_2, returns nutrients to soil.

(c) Upright vs Inverted pyramid

Upright pyramid	Inverted pyramid
Broad base (producers), narrow apex.	Narrow base, broad upper levels.
Number/biomass/energy decreases with trophic level.	Number or biomass increases with trophic level.
Typical of grasslands and ponds.	Pyramid of biomass in oceans (phytoplankton $\rightarrow$ zooplankton $\rightarrow$ fish).
Pyramid of energy is *always* upright.	Pyramid of energy is *never* inverted.

(d) Food chain vs Food web

Food chain	Food web
Linear, single-direction energy flow.	Network of many interlinked food chains.
Each organism eats only one type of food.	Each organism may have many food sources.
Less stable; loss of one link breaks the chain.	More stable; alternate routes if one link fails.
Example: grass $\rightarrow$ rabbit $\rightarrow$ fox.	Example: grassland web with many herbivores, carnivores, omnivores.

(e) Litter vs Detritus

Litter	Detritus
Fallen leaves, twigs and bark accumulating on the forest floor.	All dead plant and animal matter, including faeces and remains.
Usually surface layer, less broken down.	Includes litter plus dead bodies and excreta from any source.
Mostly plant-derived.	Plant + animal origin.
Foundation for the detritus food chain via fragmentation.	Acts as raw material for decomposers.

(f) Primary vs Secondary productivity

Primary productivity	**Secondary productivity**
Rate of biomass production by producers (autotrophs).	Rate of assimilation of food energy by consumers (heterotrophs).
Two forms: GPP (gross) and NPP (net).	Single estimate, no GPP–NPP split in NCERT.
Depends on plant species, sunlight, water, nutrients.	Depends on food availability, digestion efficiency, herbivore/carnivore type.
Units: g m^{-2} yr^{-1} or kcal m^{-2} yr^{-1}.	Same units.

Final Answer: Each pair compared with respect to source, direction, examples and ecological role above.

☞ Exam Tip

For 3-mark Board questions, tabulate each pair under three columns: **definition, mechanism, example**. Even if you only complete three of the six pairs (a, c, d are the safest), the tabular layout earns the full presentation mark.

EXPERT'S SOLUTION : *Sneha Kapoor, M.Sc Botany, Delhi University*

Structural observation. The six pairs form three clusters: flow concepts (a, d), rate concepts (b, f), and shape/material concepts (c, e). Reading them as clusters explains why the chapter chose these six and locks every pair into long-term memory.

Step 1. **Flow cluster (a, d).** GFC vs DFC contrast the *starting point* of energy: living producers vs dead organic matter. Food chain vs food web contrast *topology* of energy flow: linear single-route vs branching multi-route. Both pairs ultimately ask the same meta-question: "through how many channels can the same packet of energy travel?"

Step 2. **Rate cluster (b, f).** Production vs decomposition contrast *direction* of carbon transformation: small → large (anabolism) vs large → small (catabolism). Primary vs secondary productivity contrast *who* is building: producers (autotrophs, sunlight-driven) vs consumers (heterotrophs, food-driven). Both pairs share the same units (g m^{-2} yr^{-1} or kcal m^{-2} yr^{-1}) because rate concepts are always per unit area per unit time.

Step 3. **Material cluster (c, e).** Upright vs inverted pyramid contrast pyramid *shape*, which in turn reflects either body-size of the producer (numbers pyramid) or turnover-rate of the producer (biomass pyramid). Litter vs detritus contrast *composition*: litter is the leafy surface layer, detritus is the wider pool of dead matter from any source.

Step 4. Cross-chapter anchors. The only pyramid that can never be inverted is the energy pyramid (second law of thermodynamics). The only "producer" in NCERT is the autotroph. The only ecosystem with an inverted biomass pyramid named in NCERT is the open ocean (phytoplankton).

Step 5. Common trap. Examiners often word the question as "Differentiate between any *three* pairs". Pick the easiest three first (typically a, c, d) and save the harder rate-concept pairs (b, f) for the end of your writing time, when you can give them more thought.

Step 6. Worked memory hook for the flow cluster (a, d). Picture two diagrams: GFC starts with a *sun* and a *green plant*; DFC starts with a *pile of dead leaves*. Picture food chain as a *straight thread* connecting four beads (producer, herbivore, carnivore, top carnivore); picture food web as a *net* where every bead has many threads going in and out. These two pictures encode all four answers in the flow cluster.

Step 7. Worked memory hook for the rate cluster (b, f). Think of production as a factory *building* chairs from wood (sunlight + $CO_2 \rightarrow$ glucose), and decomposition as a recycling plant *taking apart* chairs back into wood and screws (glucose $\rightarrow CO_2$ + minerals). For the second pair, primary productivity is the wood-cutter's job (producer); secondary productivity is the carpenter's job (consumer assimilating already-cut wood).

Step 8. Worked memory hook for the material cluster (c, e). Pyramid shapes encode *body-size* (numbers pyramid) and *turnover rate* (biomass pyramid). Litter is the leafy carpet of the forest floor; detritus is the leafy carpet *plus* everything else that has died. Litter $\subset$ detritus.

Why this matters. Tabulating "source, mechanism, example" for each pair lets a student earn full marks even in a high-stakes 3-mark slot, and the cluster framing makes long-term recall painless.

> **Final Answer:** All six pairs distinguished by definition, mechanism and example, organised into flow (a, d), rate (b, f) and material (c, e) clusters.

Q 12.7 Describe the components of an ecosystem.

SOLUTION

Concept used. An **ecosystem** (e.g. forest, pond, desert, grassland) is the structural and functional unit of nature where physical surroundings and living organisms interact through energy flow and nutrient cycling. Its components are classified into two broad groups: **abiotic** (non-living) and **biotic** (living).

1. Abiotic components. These are the non-living physical and chemical factors that shape the ecosystem:

- **Climatic factors:** sunlight, temperature, rainfall, humidity, wind.
- **Edaphic factors (soil):** pH, texture, mineral content, moisture-holding capacity.
- **Inorganic substances:** CO_2, O_2, N_2, water, nitrates, phosphates, sulphates.
- **Organic substances:** proteins, lipids, carbohydrates, humus released by decomposition.

2. Biotic components. These are all the living organisms in the ecosystem, grouped by their nutritional role:

- **Producers (autotrophs):** green plants, algae, cyanobacteria. They fix solar energy by photosynthesis and synthesise organic compounds from CO_2 and water.
- **Consumers (heterotrophs):** animals that feed on producers or other consumers. Subdivided into primary consumers (herbivores), secondary consumers (small carnivores) and tertiary consumers (top carnivores).
- **Decomposers (saprotrophs):** fungi and bacteria that break down dead organic matter into simple inorganic substances, returning nutrients to the abiotic pool.

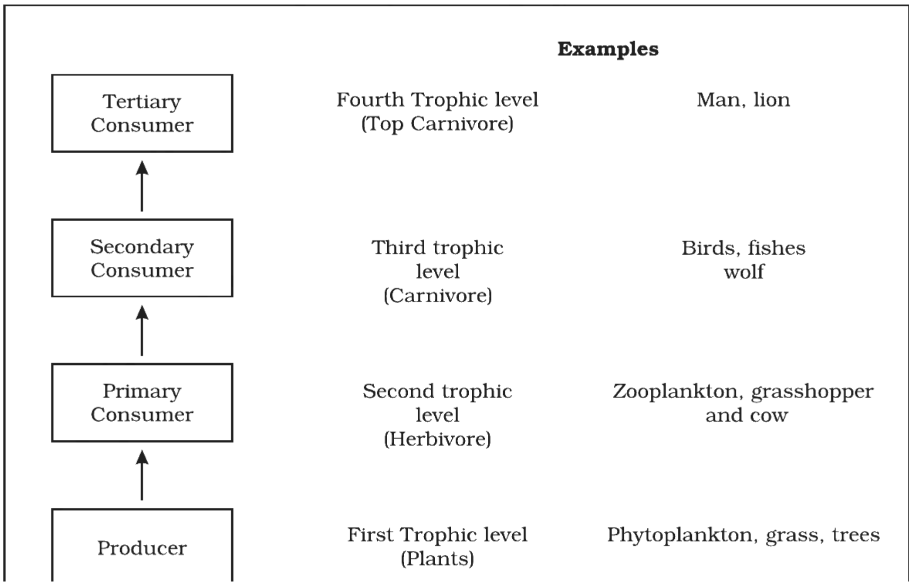

Fig. 12.2: Diagrammatic representation of trophic levels in an ecosystem. Source: NCERT Class 12 Biology, Chapter 12 (Ecosystem).

Functional aspects. The two component groups interact through four ecosystem processes: *productivity* (rate of biomass production), *decomposition* (return of dead matter to inorganic pool), *energy flow* (unidirectional, sunlight → producers →

consumers → decomposers) and *nutrient cycling* (repeated movement of N, P, C between abiotic and biotic stores). It is this interaction that turns a collection of organisms and air, soil and water into a functioning ecosystem.

> **Final Answer:** An ecosystem is built of **abiotic** components (climate, soil, inorganic/organic substances) and **biotic** components (producers, consumers, decomposers), linked by productivity, decomposition, energy flow and nutrient cycling.

♥ Why this question is asked

This is the canonical 3-mark NCERT Board question. Examiners want a clear two-pillar answer: name both groups, then list 2–3 entries under each. Adding the four functional processes as a closing line moves the answer to a 5-mark response.

EXPERT'S SOLUTION *: Riya Nair, M.Sc Zoology, Banaras Hindu University*

Picture-first. Visualise a small freshwater pond. The *water, dissolved gases and bottom soil* are abiotic; the *phytoplankton, fish, frogs and bacteria* are biotic. The ecosystem is not just these parts in isolation; it is the water, the soil, the organisms, and the *links between them* (food chains, decomposition, gas exchange, nutrient cycling). Hold the picture in mind throughout your answer.

- Abiotic = the stage and props of the play: sunlight, water, soil, atmospheric gases, temperature, minerals, organic residues like humus.
- Biotic = the actors of the play: producers (script-writers who turn sunlight into food), consumers (who eat each other in a defined order), decomposers (who recycle every fallen prop back into raw material).

Step 1. Structure - abiotic. Group the non-living factors into four sub-classes: (i) climatic (sunlight, temperature, rainfall, humidity, wind); (ii) edaphic or soil-based (pH, texture, mineral content, moisture-holding capacity); (iii) inorganic substances (CO_2, O_2, N_2, water, NO_3^-, PO_4^{3-}, SO_4^{2-}); (iv) organic substances released by decomposition (proteins, lipids, carbohydrates, humus).

Step 2. Structure - biotic. Group the living organisms by their nutritional role: (i) **producers** - autotrophs such as green plants, algae and cyanobacteria, which fix solar energy through photosynthesis; (ii) **consumers** - heterotrophs split into primary consumers (herbivores), secondary consumers (small carnivores), and tertiary consumers (top carnivores); (iii) **decomposers** - saprotrophs (fungi, bacteria) that break dead matter into simple inorganic substances.

Step 3. Function. Four ecosystem-level processes connect structure to function: (i) *productivity* - rate of biomass production; (ii) *decomposition* - return of dead matter to the inorganic pool; (iii) *energy flow* - unidirectional, sunlight →

producers → consumers → decomposers; (iv) *nutrient cycling* - repeated movement of N, P, C between abiotic and biotic stores.

Step 4. **Example - pond ecosystem.** Abiotic: pond water, sunlight reaching the surface, dissolved O_2 and CO_2, muddy bottom soil. Biotic: phytoplankton (producers), zooplankton and small fish (primary consumers), large fish (secondary consumers), bacteria and fungi (decomposers). The ecosystem is the pond *as a whole*, including the gas exchange at the surface and the nutrient release by mud bacteria.

Step 5. **Synthesis.** An ecosystem is not just a sum of parts; it is the *network* of interactions among parts. Remove the producers and consumers starve; remove the decomposers and nutrients lock up in dead matter; remove the abiotic substrate and no life is possible. Each component is necessary.

Why this matters. The same two-pillar (abiotic + biotic) schema reappears in Chapter 11 (Organisms and Populations) and Chapter 13 (Biodiversity and Conservation). Mastering it once pays off across the entire "Ecology" unit, and gives the full structure that examiners expect for any 5-mark essay on ecosystem composition.

> **Final Answer:** An ecosystem = abiotic components (climatic, edaphic, inorganic, organic) + biotic components (producers, consumers, decomposers), connected by productivity, decomposition, energy flow and nutrient cycling.

Q 12.8 **Define ecological pyramids and describe with examples, pyramids of number and biomass.**

SOLUTION

Concept used. An **ecological pyramid** is a graphical representation of the relationship between organisms at different trophic levels of a food chain in terms of their *number*, *biomass* or *energy*. The base of every pyramid represents the producers (first trophic level); successive tiers represent primary consumers, secondary consumers and so on. The three types of pyramids are pyramid of *numbers*, pyramid of *biomass* and pyramid of *energy*.

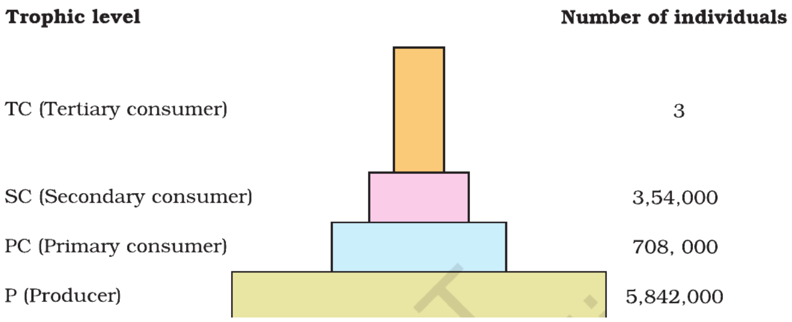

Fig. 12.4(a): Pyramid of numbers in a grassland ecosystem; only three top-carnivores are supported by ∼ 6 million producer plants. Source: NCERT Class 12 Biology, Chapter 12 (Ecosystem).

Pyramid of numbers. It plots the *number of individuals* at each trophic level.

Step 1. Grassland (upright). A grassland holds millions of grass plants, supporting thousands of grasshoppers, then hundreds of frogs, then a few snakes and only three top eagles. The pyramid is broad at the base and narrow at the apex.

Step 2. Tree-dominated (inverted/spindle). A single big tree supports thousands of leaf-eating insects, which support hundreds of insectivorous birds. Producer count is small but herbivore count is huge; the pyramid is inverted at the lower level.

Step 3. Parasitic chain (inverted). One large tree → many birds → many more lice/parasites on each bird. Numbers *increase* up the chain.

Step 4. In all forms, the pyramid *counts heads*, not size.

Pyramid of biomass. It plots the *dry weight per unit area* (biomass) at each trophic level.

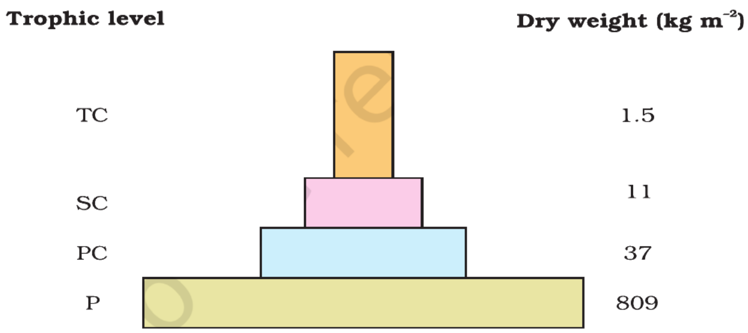

Fig. 12.4(b): Pyramid of biomass shows a sharp decrease in biomass at higher trophic levels (kg m^{-2}). Source: NCERT Class 12 Biology, Chapter 12 (Ecosystem).

Step 1. Grassland/forest (upright). Producer biomass ($\sim$ 809 kg m^{-2}) is far larger than herbivore ($\sim$ 37 kg m^{-2}), which is larger than carnivore ($\sim$ 11 kg m^{-2}) and top carnivore ($\sim$ 1.5 kg m^{-2}). Pyramid is upright.

Step 2. Ocean (inverted). A small standing crop of fast- reproducing phytoplankton supports a much larger standing crop of zooplankton and fish at any given moment. Pyramid is inverted, because phytoplankton turn over so quickly that their instantaneous biomass is tiny.

Step 3. Biomass is a *snapshot*; high turnover producers can look light on the snapshot while feeding a heavier consumer mass.

Limitations. Both pyramids ignore the same species occupying two trophic levels (e.g. a sparrow eating seeds and worms) and exclude saprophytes (decomposers).

> **Final Answer:** Ecological pyramids show numbers, biomass or energy across trophic levels; pyramids of numbers and biomass may be upright (grassland) or inverted (tree-dominated for numbers, ocean for biomass).

☞ **Pyramid of energy**

The pyramid of energy is *always upright*, because energy is lost as heat at every transfer (10% law).

EXPERT'S SOLUTION *: Ananya Pillai, M.Sc Microbiology, JNU*

Strategic angle. Three pyramids, two of which can flip. Hold two anchors in mind: "grassland is upright for all three pyramids", and "ocean flips the biomass pyramid because phytoplankton turn over in days while zooplankton and fish live for weeks or years". From those two facts every exception in the chapter can be reconstructed.

- Pyramid of numbers: counts individuals; shape depends on producer body-size.
- Pyramid of biomass: weighs standing crop in g or kg per unit area; shape depends on turnover rate of producers.
- Pyramid of energy: rate of energy transfer per unit time per unit area; always upright, no exception (second law of thermodynamics).

Step 1. **Define a pyramid.** A graphical representation of the trophic relationship between organisms in terms of number, biomass or energy. Base = producers; apex = top carnivore.

Step 2. **Pyramid of numbers (upright case).** In a grassland, millions of grass plants feed thousands of grasshoppers, which feed hundreds of frogs, which feed dozens of snakes, which feed only a few hawks. Producer count is the largest, top carnivore count is the smallest. Pyramid widens at the base and narrows at the apex.

Step 3. **Pyramid of numbers (inverted case).** On a single big tree, the producer count is 1, but it supports thousands of leaf-eating insects, which in turn support a few hundred birds. Producer count is tiny but herbivore count is huge. The same shape (spindle/inverted) shows up in parasitic chains:
1 tree → many birds → many more lice per bird.

Step 4. **Pyramid of biomass (upright case).** In grassland or forest, dry-weight per unit area falls from producer (~ 809 kg m^{-2}) to herbivore (~ 37) to carnivore (~ 11) to top carnivore (~ 1.5). Standing crop drops sharply at every transfer.

Step 5. **Pyramid of biomass (inverted case).** In open ocean, a small standing crop of phytoplankton (which divides every few days) supports a much larger standing crop of zooplankton and fish at any given instant. Biomass at level 2 is greater than biomass at level 1: pyramid is inverted. The key word is *standing crop*: it is a snapshot, not a sum over time.

Step 6. **Limitations.** Pyramids assume each species occupies one trophic level, but real organisms (e.g. sparrow eating both seeds and insects) span two. Pyramids also exclude saprophytes (fungi, bacteria) despite their central role in nutrient recycling.

Why this matters. The biomass-pyramid inversion in oceans is the single "exception" students forget under exam stress. Citing the phytoplankton turnover-rate explanation earns the second mark in a 3-mark Board answer and is the conceptual hinge for the entire Q8 response.

> **Final Answer:** Pyramids of numbers and biomass: defined, drawn for upright (grassland) and inverted (tree chain or ocean) cases, with their two limitations on multi-level species and excluded saprophytes.

Q 12.9 **What is primary productivity? Give brief description of factors that affect primary productivity.**

SOLUTION

Concept used. Primary productivity is defined as the amount of biomass (or organic matter) produced per unit area, per unit time, by plants during photosynthesis. It is expressed as weight (g m^{-2} yr^{-1}) or energy (kcal m^{-2} yr^{-1}). Productivity varies by ecosystem because the amount of fixed solar energy depends on which plants live there and on the abiotic conditions of light, water, temperature and nutrients.

Two important terms.

- **Gross Primary Productivity (GPP).** Total rate of production of organic matter (biomass) by producers, including what they later use for respiration. It is the gross capture of solar energy.

- **Net Primary Productivity (NPP).** The biomass left after producers spend some of their GPP on respiration (R):

$$\text{NPP} = \text{GPP} - R.$$

NPP is the new biomass available to herbivores and decomposers.

Factors that affect primary productivity.

Step 1. Plant species (variety). Different species fix carbon at different rates. **C_4 plants** (sugarcane, maize) have higher productivity than **C_3 plants** because of more efficient carbon fixation under high light and temperature.

Step 2. Environmental (climatic) factors. Light, temperature, precipitation, humidity and atmospheric CO_2 all directly change the rate of photosynthesis. Tropical rainforests are the most productive land ecosystems because all four factors are favourable year-round.

Step 3. Nutrient availability. Soil/water content of nitrogen, phosphorus, potassium and trace elements limits productivity in many ecosystems. In oceans, nitrogen and iron are the common limiting nutrients.

Step 4. Photosynthetic capacity of plants. Determined by chlorophyll content, leaf area index, root depth and overall physiology of the producer.

Step 5. Other ecosystem-specific limits. Light penetration limits aquatic productivity; water availability limits terrestrial productivity in deserts; latitude and altitude modulate both temperature and light.

Annual global figures. The annual net primary productivity of the whole biosphere is approximately **170** billion tonnes (dry weight) of organic matter; of this, the oceans contribute only ~ 55 billion tonnes despite covering 70% of Earth's surface.

> **Final Answer:** Primary productivity = biomass produced per unit area per unit time by plants. It depends on plant species, environmental factors (light, temperature, water, CO_2), nutrient availability and the photosynthetic capacity of producers.

☞ Exam Tip

For 3-mark Board questions, always state **GPP = NPP + R** and mention the global figure (~ 170 bn t y^{-1}). Both score "conceptual depth" marks.

EXPERT'S SOLUTION *: Ishaan Verma, M.Sc Biotechnology, AIIMS Delhi*

Quick reading. "Primary" tells you it is the producers' output. "Productivity" tells you it is a *rate*, not a stock. Combined: producers' biomass output per unit area per unit time. The question really asks for one tight definition plus a structured factor list, so plan the answer in three blocks: definition, GPP/NPP, factors.

- GPP: gross organic matter fixed by photosynthesis per unit area per unit time.
- Respiration (R): producers' own metabolic cost of staying alive.
- NPP: GPP $-$ R, the leftover available to herbivores and decomposers.

Step 1. **Definition.** Primary productivity is the rate of capture of solar energy and its conversion to organic matter per unit area per unit time by autotrophs (producers). It is the foundation on which every consumer in the ecosystem feeds.

Step 2. **Units and forms.** Mass form: g m^{-2} yr^{-1}. Energy form: kcal m^{-2} yr^{-1}. GPP includes respiratory loss; NPP excludes it. The relationship is NPP $=$ GPP $-$ R.

Step 3. **Factor 1 - plant species (variety).** C_4 plants (sugarcane, maize, sorghum) outperform C_3 plants (rice, wheat) at high light and temperature because their PEP- carboxylase enzyme has a higher affinity for CO_2, which suppresses photorespiration.

Step 4. **Factor 2 - environmental (climatic) factors.** Sunlight intensity, day length, temperature, rainfall, soil moisture, humidity and atmospheric CO_2 all directly affect the rate of photosynthesis. Tropical rainforests are the most productive land ecosystems precisely because all these factors are favourable year-round.

Step 5. **Factor 3 - nutrient availability.** Nitrogen, phosphorus, potassium and trace elements (Fe, Mg, Mn) limit photosynthetic rate when in short supply. In open oceans, the limit is usually iron or nitrogen; in farmland, often phosphorus.

Step 6. **Factor 4 - photosynthetic capacity of plants.** Determined by chlorophyll content per unit leaf area, leaf area index (LAI), root depth, stomatal density and overall plant physiology.

Step 7. **Factor 5 - other ecosystem-specific limits.** Light penetration limits aquatic productivity below the photic zone; water availability limits terrestrial productivity in deserts; latitude and altitude modulate both light and temperature.

Step 8. **Global context.** Annual NPP of the entire biosphere is ~ 170 bn t y^{-1} dry weight; oceans contribute only ~ 55 bn t y^{-1} despite covering 70% of the planet, because most of the open ocean is nutrient-poor.

Why this matters. GPP, NPP and the factor list are the backbone of every productivity-themed CUET/NEET MCQ in the chapter and they thread directly into the energy-flow story of Q11. The 170 bn t figure earns a "conceptual depth" mark on Board essays.

Final Answer: Primary productivity = rate of biomass production by producers; NPP = GPP − R; controlled by plant species (C_3/C_4), climate, nutrients, photosynthetic capacity, and ecosystem-specific limits.

Q 12.10 **Define decomposition and describe the processes and products of decomposition.**

SOLUTION

Concept used. **Decomposition** is the breakdown of complex organic matter (detritus) into simpler inorganic substances like CO_2, water and nutrients (NO_3^-, PO_4^{3-}, SO_4^{2-}) by decomposers (mainly fungi and bacteria, together with detritivores like earthworms). The substrate for decomposition is detritus, which includes dead plant parts (leaves, bark, flowers), dead animals and faecal matter.

Processes of decomposition. Decomposition proceeds in five overlapping steps:

Step 1. **Fragmentation.** **Detritivores** (earthworms, mites, millipedes) physically break detritus into smaller pieces, vastly increasing its surface area.

Step 2. **Leaching.** Water-soluble inorganic nutrients (sugars, ions) seep down through the soil with rainwater and become unavailable for the next step (or get adsorbed on soil particles).

Step 3. **Catabolism.** Bacterial and fungal *enzymes* (cellulases, ligninases, proteases) chemically break the fragmented detritus into smaller organic compounds.

Step 4. **Humification.** Partly degraded matter accumulates as **humus**, a dark amorphous, colloidal substance resistant to further attack. Humus stores nutrients and is slowly mineralised.

Step 5. **Mineralisation.** Humus and any remaining organic compounds are finally converted by microbes into inorganic nutrients: CO_2, water, NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}.

Products of decomposition. The final products are CO_2, water and a pool of inorganic plant nutrients (NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}, K^+, Ca^{2+}), which become available again for producers, closing the nutrient cycle.

Factors that affect decomposition rate.

- **Chemistry of detritus.** Detritus rich in nitrogen and soluble sugars decomposes fast; detritus rich in lignin and chitin decomposes slowly.
- **Climate.** Warm and moist conditions favour decomposition; cold or dry conditions slow it.
- **Oxygen.** Decomposition is largely an aerobic process; anaerobic (water-logged)

conditions stall it and lead to organic accumulation (peat bogs).

> **Final Answer:** Decomposition = enzymatic breakdown of detritus into CO_2, water and inorganic nutrients by decomposers; five processes (fragmentation, leaching, catabolism, humification, mineralisation) are favoured by warm, moist, aerobic conditions and nitrogen-rich substrates.

✗ Common Mistake

Many students confuse *humification* (formation of humus) with *mineralisation* (release of inorganic ions from humus). They are sequential, not interchangeable.

EXPERT'S SOLUTION *: Diya Joshi, Ph.D Organic Chemistry, IISc Bangalore*

Structural observation. Five steps, two end-products, three controlling factors. If you can rattle off "5–2–3" you can rebuild the whole answer from memory, even under exam pressure.

Step 1. **Define the substrate and the agent.** Detritus is the substrate for decomposition: dead leaves, twigs, bark, flowers, dead animals and faecal matter. The agents are *decomposers* (saprophytic fungi and bacteria), assisted by *detritivores* (earthworms, mites, millipedes, termites) that physically fragment the detritus.

Step 2. **Step 1 - fragmentation.** Detritivores break detritus into smaller particles, increasing the surface area available for microbial attack. Earthworms swallow soil and detritus together, grinding it in their gizzards. This is a purely physical process.

Step 3. **Step 2 - leaching.** Water-soluble inorganic nutrients (sugars, simple ions) are washed down through the soil profile by rainwater. Some get adsorbed on clay particles and become temporarily unavailable.

Step 4. **Step 3 - catabolism.** Bacterial and fungal enzymes (cellulases for cellulose, ligninases for lignin, proteases for proteins) chemically degrade the fragmented detritus into smaller organic compounds. This is the heart of decomposition.

Step 5. **Step 4 - humification.** Partially degraded matter accumulates as **humus**, a dark, amorphous, colloidal substance highly resistant to microbial attack. Humus is a slow-release reservoir of nutrients and improves soil structure.

Step 6. **Step 5 - mineralisation.** Some microbes continue to attack humus, releasing inorganic ions: NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}, K^+, Ca^{2+}. These return to the soil pool for plant uptake.

Step 7. **Two end-products.** (i) CO_2 + water released to the atmosphere and soil; (ii) the inorganic nutrient pool ready for re-absorption by producers. The nutrient cycle is thereby closed.

Step 8. **Three controlling factors.** (i) Detritus chemistry: high lignin or chitin slows decomposition, high nitrogen or soluble sugars speeds it up. (ii) Climate: warm and moist conditions favour decomposition; cold or dry conditions slow it. (iii) Oxygen: decomposition is largely aerobic; anaerobic (water-logged) conditions stall it and lead to organic accumulation in peat bogs and marshes.

Why this matters. The same five-step list shows up in CUET fill-ins ("humus is produced during ____") and in 6-mark Board essays on nutrient cycling. Remembering the order also makes drawing the carbon cycle easier and earns a separate mark for "mineralisation" as a distinct final step.

Final Answer: Decomposition: enzymatic conversion of detritus to CO_2, water and inorganic nutrients via fragmentation, leaching, catabolism, humification and mineralisation; rate set by detritus chemistry, climate and oxygen.

Q 12.11 Give an account of energy flow in an ecosystem.

SOLUTION

Concept used. **Energy flow** in an ecosystem is the one-way movement of energy from the Sun through producers, consumers and decomposers, with energy lost as heat at every transfer. It is governed by two laws: the *first law of thermodynamics* (energy is neither created nor destroyed, only transformed) and the *second law of thermodynamics* (every transfer increases entropy, releasing some energy as unusable heat). The chapter highlights three quantitative anchors: $\approx 50\%$ of incident solar radiation is PAR; plants capture only 2–10% of PAR; and only about 10% of energy passes from one trophic level to the next (**Lindeman's 10% law**).

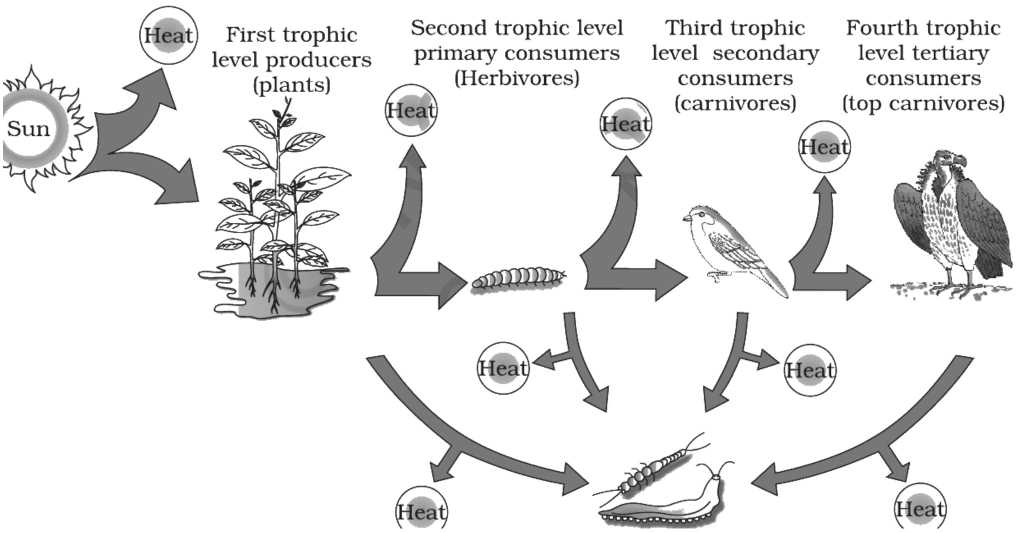

Fig. 12.3: Energy flow through different trophic levels; "Heat" bubbles indicate energy lost at every step. Source: NCERT Class 12 Biology, Chapter 12 (Ecosystem).

Sequence of energy flow.

Step 1. Solar input. The Sun is the only source of energy for almost every ecosystem. Of the total radiation that reaches Earth, $\sim 50\%$ falls in the **Photosynthetically Active Radiation (PAR)** band (400–700 nm).

Step 2. Producer capture. Producers (plants, algae) absorb PAR and convert it to chemical energy in glucose. Capture efficiency is only 2–10% of PAR; this fixed energy is the **Gross Primary Productivity (GPP)**.

Step 3. Producer respiration. Producers spend part of GPP on their own respiration (R). What is left is the **Net Primary Productivity**: NPP = GPP − R. NPP is the energy available to the next trophic level.

Step 4. Transfer to herbivores. Primary consumers eat producers and assimilate only about 10% of the energy. Roughly 90% is lost as heat in respiration, undigested material and metabolic waste.

Step 5. Transfer to carnivores. Secondary and tertiary consumers again carry only $\sim 10\%$ of the energy of the previous level. So a chain plant $\to$ herbivore $\to$ carnivore $\to$ top carnivore with 1000 J at the producer level retains roughly 100 J at herbivore, 10 J at carnivore and 1 J at top-carnivore.

Step 6. Decomposers. Dead bodies and faecal matter from every trophic level enter the detritus food chain. Decomposers (fungi, bacteria) break it down and release the last available chemical energy as heat while recycling nutrients.

Key features of energy flow.

- **Unidirectional.** Energy moves Sun $\rightarrow$ producers $\rightarrow$ consumers $\rightarrow$ decomposers $\rightarrow$ heat. It never flows backwards.
- **Non-cyclic.** Once dissipated as heat, energy cannot be reused by the ecosystem (unlike nutrients).
- **Decreasing at each level.** Only $\sim 10\%$ of energy is passed to the next level; the rest is lost as heat. This is why pyramid of energy is *always upright*.
- **Limits chain length.** Because of the 10% rule, food chains are usually only 3–5 trophic levels long; beyond that, available energy is too low to support another level.

Worked numerical (10% law). If a grassland fixes $10\,000$ kcal m^{-2} yr^{-1} at the producer level, then approximately:

- Herbivores receive $\sim 10\,000 \times 0.10 = 1\,000$ kcal m^{-2} yr^{-1}.
- Carnivores receive $\sim 1\,000 \times 0.10 = 100$ kcal m^{-2} yr^{-1}.
- Top carnivores receive $\sim 100 \times 0.10 = 10$ kcal m^{-2} yr^{-1}.

> **Final Answer:** Energy flow is unidirectional, non-cyclic, and decreases by $\sim 90\%$ at every trophic transfer; from the Sun's PAR ($\sim 50\%$ of incident radiation), plants fix only 2–10%, and $\sim 10\%$ of that energy reaches each next trophic level (Lindeman's 10% law).

♥ Why energy flow is one-way

Nutrients cycle (atoms are conserved). Energy doesn't (the second law of thermodynamics turns each transfer into heat that radiates to space). So ecosystems need a steady solar input to keep going.

EXPERT'S SOLUTION *: Yash Chatterjee, Ph.D Physics, IISc Bangalore*

Picture-first. Draw a horizontal arrow from the Sun, hitting a green leaf, then jumping right to a grasshopper, a sparrow, an eagle. Beside each jump write "-90%". That single diagram is the whole answer in one frame. The rest of this Expert Solution unpacks the physics behind each arrow.

Step 1. **Source.** The Sun is the only energy input for almost every ecosystem on Earth. Of the total solar radiation that reaches a leaf, $\approx 50\%$ lies in the **Photosynthetically Active Radiation (PAR)** band (400–700 nm). The other $\sim 50\%$ is UV or infrared and is not used in photosynthesis.

Step 2. **Producer capture.** Producers absorb PAR through chlorophyll and convert it to chemical energy stored in sugars during photosynthesis. Conversion efficiency is only 2–10% of PAR, depending on species, water and nutrient availability. The fixed energy is called **Gross Primary Productivity (GPP)**.

Step 3. Respiration loss at the producer. Producers spend a substantial fraction of GPP on their own respiration (R) - roughly $20–40\%$ in most plants. What is left is the **Net Primary Productivity**: NPP $=$ GPP $-$ R. Only NPP is available to the next trophic level.

Step 4. Pathway. Sun $\rightarrow$ producers (GPP, then NPP) $\rightarrow$ herbivores $\rightarrow$ carnivores $\rightarrow$ top carnivores $\rightarrow$ decomposers $\rightarrow$ heat radiated to space. Energy flows in one direction; it never goes back up the chain.

Step 5. 10% law (Lindeman, 1942). Energy at trophic level $n + 1$ is $\approx 10\%$ of energy at level n. The other 90% is lost as heat in respiration, in undigested faeces and in body parts not consumed. The law applies on average across many ecosystems; real-world efficiencies range from 5% to 20%.

Step 6. Numerical illustration. If producers fix $10\,000$ kcal m^{-2} yr^{-1} as NPP, then: herbivores receive $10\,000 \times 0.10 = 1\,000$ kcal m^{-2} yr^{-1}; carnivores receive $1\,000 \times 0.10 = 100$ kcal m^{-2} yr^{-1}; top carnivores receive $100 \times 0.10 = 10$ kcal m^{-2} yr^{-1}. After four transfers only 1 kcal m^{-2} yr^{-1} remains, which is why ecosystems cannot support more than $4–5$ trophic levels.

Step 7. Why pyramid of energy is always upright. Each higher level holds less energy than the level below it - no exception is possible because the second law of thermodynamics guarantees energy loss at every transfer. Numbers and biomass pyramids can flip; energy pyramid never can.

Step 8. Role of decomposers. Dead bodies, shed parts and faecal matter from every trophic level feed the detritus food chain. Decomposers (saprophytic fungi and bacteria) extract the last chemical energy and release it as heat while returning the atoms (C, N, P, S) to the abiotic pool for producers to reuse.

Step 9. Two thermodynamic anchors. The first law (energy is conserved) explains why ecosystems must have a steady solar input to keep running. The second law (entropy always increases) explains why energy is degraded to heat at every transfer and cannot be reused. Together they make energy flow *one-way* and *non-cyclic*, unlike nutrient cycles which are closed loops.

Why this matters. Two-mark CUET questions ask for the laws of thermodynamics behind energy flow; four-mark Board questions ask for the 10% law with a numerical; six-mark essays ask for unidirection, loss at each transfer and the short-chain consequence. This Expert Solution covers all three levels in one structured walk-through.

Final Answer: Energy flow: unidirectional, non-cyclic, governed by the two laws of thermodynamics; $\sim 50\%$ of solar radiation is PAR, plants capture 2–10%, and $\sim 10\%$ passes between successive trophic levels (Lindeman's law), making the pyramid of energy always upright and food chains short (≤ 4–5 levels).

Key Takeaways

- An **ecosystem** is the structural and functional unit of nature, with abiotic and biotic components linked by four processes: productivity, decomposition, energy flow and nutrient cycling.
- **Primary productivity** (NPP = GPP $-R$) is the rate of biomass production by producers; it depends on plant species, light, temperature, water, CO_2 and nutrients.
- **Decomposition** converts detritus to CO_2, water and inorganic nutrients through fragmentation, leaching, catabolism, humification and mineralisation.
- **Energy flow** is unidirectional and non-cyclic. About 50% of incident solar radiation is PAR; plants capture 2–10% of PAR; only $\sim 10\%$ of energy passes between successive trophic levels (Lindeman's 10% law).
- **Ecological pyramids** (numbers, biomass, energy) can be upright or inverted. Pyramid of energy is *always* upright; pyramid of biomass is inverted in oceans because of the high turnover of phytoplankton.

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