NCERT Exemplar Solutions

Solved NCERT Exemplar Problems for Class 12th Biology, Chapter 12

Chapter 14: Ecosystem

About this Chapter

An ecosystem is a self-sustaining functional unit where biotic communities (producers, consumers, decomposers) interact with abiotic components through **energy flow** and **nutrient cycling**. This chapter develops the quantitative side: gross and net primary productivity, the 10% rule of energy transfer, ecological pyramids of number, biomass and energy, ecological succession (hydrarch and xerarch) and the four major **biogeochemical cycles**. Concepts here are the foundation for Biodiversity, Conservation and Environmental Issues. CBSE 2026-27 syllabus.

Topics covered: Ecosystem structure • Productivity (GPP, NPP) • Decomposition • Energy flow • Ecological pyramids • Succession • Biogeochemical cycles • Ecosystem services

Quick Formula Sheet

Net primary productivity:
NPP $=$ GPP $- R$ (R = respiratory loss)

Lindemann's 10% law:
Energy transferred to next trophic level $\approx 10\%$

Pyramid of energy:
Always upright, never inverted

P/R ratio:
Pioneer: $P/R > 1$; Climax: $P/R \approx 1$

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

Multiple-Choice Questions

Q 14.1 Decomposers like fungi and bacteria are:
(i) autotrophs
(ii) heterotrophs
(iii) saprotrophs
(iv) chemo-autotrophs.
Choose the correct answer:
(a) i and iii (b) i and iv (c) ii and iii (d) i and ii

SOLUTION

Correct option: (c) ii and iii.

Concept used. A **decomposer** is an organism that breaks down dead organic matter (detritus) into simpler inorganic substances. Nutritionally it is classified by two independent labels: (a) *source of carbon* (autotroph = self-fixing CO_2; heterotroph = takes carbon from organic matter), and (b) *mode of feeding* (saprotroph = absorbs nutrients from dead matter through extracellular digestion).

Step 1. Fungi and bacteria such as *Aspergillus*, *Mucor* and *Pseudomonas* cannot fix CO_2 via photosynthesis or chemosynthesis; they obtain carbon from dead leaves, wood and carcasses. They are therefore **heterotrophs** (statement ii is true).

Step 2. They feed by secreting digestive enzymes onto the dead substrate and absorbing the soluble products through their cell wall: classic **saprotrophic** nutrition (statement iii is true).

Step 3. Statement i (autotrophs) is false: autotrophs make their own food from CO_2, which decomposers cannot do.

Step 4. Statement iv (chemo-autotrophs) is false: chemo-autotrophs oxidise inorganic compounds (e.g. NH_3, H_2S, Fe^{2+}) and use the energy to fix CO_2. Decomposers do not fix CO_2.

> **Final Answer:** Option **(c)**: decomposers are heterotrophs and saprotrophs.

☞ **Five nutritional modes**

Autotroph → photoautotroph (plants) / chemoautotroph (nitrifying bacteria). Heterotroph → holozoic (animals) / saprotroph (fungi, decomposer bacteria) / parasitic (tapeworm).

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

Quick reading. The trick is that the question lists two labels per organism. Decomposers must be heterotrophic (no CO_2-fixation pathway) AND saprotrophic (they feed on dead matter, not by ingesting it). Any option that pairs "autotroph" with anything is wrong by inspection, which knocks out (a), (b) and (d) in one step, leaving only (c).

Step 1. Eliminate (a) i+iii: cannot be both autotroph and saprotroph at once because the carbon-source claims contradict.

Step 2. Eliminate (b) i+iv: autotroph and chemo-autotroph both claim CO_2-fixation; decomposers do not fix CO_2.

Step 3. Eliminate (d) i+ii: cannot be autotroph and heterotroph simultaneously.

Step 4. Confirm (c) ii+iii: heterotrophic carbon source + saprotrophic mode of feeding is the textbook definition of a decomposer.

Why this matters. In every NCERT question on decomposition, the same two-label framing returns: "carbon source = heterotroph, feeding mode = saprotroph". Lock it in.

Final Answer: Option **(c)**: ii and iii.

Q 14.2 The process of mineralisation by micro organisms helps in the release of:

(a) inorganic nutrients from humus

(b) both organic and inorganic nutrients from detritus

(c) organic nutrients from humus

(d) inorganic nutrients from detritus and formation of humus.

SOLUTION

Correct option: (a) inorganic nutrients from humus.

Concept used. Decomposition proceeds in five overlapping steps: *fragmentation* (detritivores break detritus into fragments), *leaching* (water-soluble nutrients percolate down), *catabolism* (microbial enzymes degrade detritus into simpler substances), *humification* (accumulation of dark, amorphous, colloidal humus) and finally **mineralisation** (humus is further degraded by microbes to release inorganic nutrients such as NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-} into the soil solution).

Step 1. Identify the stage: "mineralisation" refers strictly to the final stage of decomposition, acting on **humus**, not on the original detritus. This rules out (b) and (d), which both mention detritus.

Step 2. Identify the product: mineralisation releases **inorganic** nutrients (mineral ions), not organic ones. This rules out (c), which says organic nutrients.

Step 3. Option (a) correctly pairs the substrate (humus) with the product class (inorganic nutrients).

Final Answer: Option **(a)**: mineralisation releases inorganic nutrients from humus.

♥ Why this matters

Mineralisation is the step that closes every nutrient cycle. Without it, ions like NO_3^- and PO_4^{3-} would stay locked in humus and producers could not re-absorb them, breaking the biogeochemical loop.

EXPERT'S SOLUTION : *Aanya Sharma, M.Sc Microbiology, JNU*

Structural observation. The five steps of decomposition form a chain: detritus → fragments → leachate + residue → humus → mineral ions. Mineralisation is the *humus → mineral ions* arrow. Anything else is a wrong arrow.

Step 1. Draw the chain mentally and locate mineralisation on the last arrow.

Step 2. Substrate of the last arrow = humus, not detritus.

Step 3. Product of the last arrow = inorganic ions (NH_4^+, NO_3^-, PO_4^{3-}, K^+, Ca^{2+}, Mg^{2+}).

Step 4. Match: option (a) is the only choice with both labels correct.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.

Final Answer: Option **(a)**.

Q 14.3 **Productivity is the rate of production of biomass expressed in terms of:**

(i) (kcal m^{-3}) yr^{-1}

(ii) g^{-2} yr^{-1}

(iii) g^{-1} yr^{-1}

(iv) (kcal m^{-2}) yr^{-1}

(a) ii (b) iii (c) ii and iv (d) i and iii

SOLUTION

Correct option: (c) ii and iv (intended units: $\mathrm{g\,m^{-2}\,yr^{-1}}$ and $\mathrm{kcal\,m^{-2}\,yr^{-1}}$).
Concept used. Primary productivity is the rate at which producers fix solar energy into organic biomass. Because it is a *rate* of biomass per *area* per *time*, the SI-style units are:

$$\text{mass per area per time:} \quad \mathrm{g\,m^{-2}\,yr^{-1}}$$

$$\text{energy per area per time:} \quad \mathrm{kcal\,m^{-2}\,yr^{-1}}$$

The NCERT Exemplar prints these with a typographic slip ($g^{-2}yr^{-1}$ for $g\,m^{-2}yr^{-1}$), but the intent is clear: area-based, not volume-based.

Step 1. Productivity is per unit **area** (m^{-2}), not per unit volume (m^{-3}). This eliminates option (i), which uses m^{-3}.

Step 2. Productivity needs both a mass/energy unit AND an area unit. Option (iii) has no area term, so it is dimensionally incomplete.

Step 3. Option (ii) $\mathrm{g\,m^{-2}\,yr^{-1}}$ (printed as g^{-2} in the Exemplar) is correct for mass-based productivity.

Step 4. Option (iv) $\mathrm{kcal\,m^{-2}\,yr^{-1}}$ is correct for energy-based productivity.

> **Final Answer:** Option **(c)**: ii and iv ($\mathrm{g\,m^{-2}\,yr^{-1}}$ and $\mathrm{kcal\,m^{-2}\,yr^{-1}}$).

☞ Exam Tip

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

EXPERT'S SOLUTION *: Rohit Mehta, M.Sc Botany, Banaras Hindu University*

Dimensional check. A rate of biomass production has dimensions of $[M][L^{-2}][T^{-1}]$ (mass per area per time) or $[E][L^{-2}][T^{-1}]$ (energy per area per time). Anything with L^{-3} describes a volumetric concentration, not a productivity.

Step 1. Test (i): $[E][L^{-3}][T^{-1}]$ – volumetric, wrong.

Step 2. Test (iii): $[M][T^{-1}]$ – no area term, wrong.

Step 3. Test (ii): $[M][L^{-2}][T^{-1}]$ – matches; correct.

Step 4. Test (iv): $[E][L^{-2}][T^{-1}]$ – matches; correct.

Step 5. Combine: only (ii) and (iv) pass the dimensional check.

Why this matters. Productivity figures in NCERT (e.g. "net primary productivity of biosphere $= 170$ billion tonnes dry organic matter/yr") are always quoted per unit area, never per unit volume. Remember the m^{-2}.

> **Final Answer:** Option **(c)**.

Q 14.4 **An inverted pyramid of biomass can be found in which ecosystem?**

(a) Forest (b) Marine (c) Grass land (d) Tundra

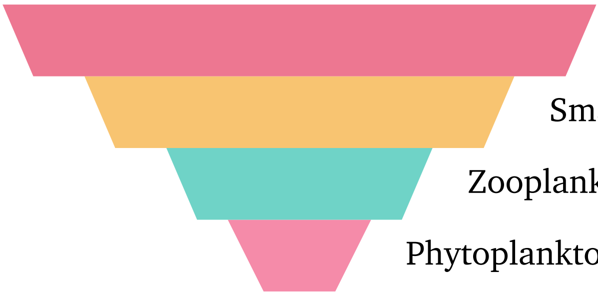
SOLUTION

Correct option: (b) Marine.

Concept used. A pyramid of biomass stacks the dry biomass at each trophic level. It is normally upright (more biomass in producers than consumers). But in a *marine* ecosystem the producers are microscopic phytoplankton with a very short life span (turnover of days), while the consumers (zooplankton, fish) are larger and longer-lived.

At any instant the standing crop of zooplankton/fish exceeds that of phytoplankton, giving an **inverted** pyramid.

Inverted biomass pyramid (marine)



Step 1. Identify producer biomass in each option. Forests, grasslands and tundra all have large, long-lived producers (trees, grasses), so producer biomass dominates and the pyramid is upright.

Step 2. In oceans the producers are phytoplankton: tiny ($\sim 10\ \mu$m), short-lived, grazed almost as fast as they are produced. Standing biomass is therefore tiny.

Step 3. Consumer biomass (zooplankton + fish) accumulates because these organisms live longer and store biomass between reproductive events.

Step 4. Net effect: consumer biomass $>$ producer biomass, so the pyramid inverts.

Final Answer: Option **(b)**: marine ecosystem.

✗ Common Mistake

A common mix-up: writing that the pyramid of *energy* can also invert in a marine ecosystem. It cannot. The pyramid of energy is *always* upright (second law of thermodynamics: each level loses energy as heat). Only the pyramids of biomass and number can invert.

EXPERT'S SOLUTION *: Sneha Kapoor, Ph.D Molecular Biology, NCBS Bangalore*

Picture-first. Compare two snapshots: a pond in summer (huge floating algal mat with a few fish) vs. the open sea (invisibly tiny algae with visibly large fish). In the pond producer biomass dominates (upright pyramid). In the sea consumer biomass dominates (inverted pyramid).

Step 1. Producer biomass is set by standing crop = production rate × life span.

Step 2. Phytoplankton have a high production rate but a life span of only days, so standing crop is small.

Step 3. Fish reproduce slowly but live for years, so standing crop accumulates.

Step 4. Pyramid inverts whenever consumer life span $\gg$ producer life span. This happens only in marine ecosystems among the options.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

Why this matters. An inverted biomass pyramid is the marine signature: tiny short-lived phytoplankton at the base support larger, longer-lived consumers above. Energy pyramids never invert.

> **Final Answer:** Option **(b)**.

Q 14.5 **Which of the following is not a producer?**

(a) Spirogyra (b) Agaricus (c) Volvox (d) Nostoc

SOLUTION

Correct option: (b) Agaricus.

Concept used. A **producer** (autotroph) makes its own food, almost always by photosynthesis using chlorophyll, and forms the first trophic level. Anything without photosynthetic machinery is a consumer or decomposer.

Step 1. *Spirogyra*: filamentous green alga with spiral chloroplasts – photoautotrophic producer.

Step 2. *Agaricus*: a basidiomycete fungus (the common edible mushroom). It has no chlorophyll, cannot photosynthesise, and absorbs nutrients saprotrophically from decaying organic matter. It is a **decomposer**, not a producer.

Step 3. *Volvox*: colonial green alga with chlorophyll – photoautotrophic producer.

Step 4. *Nostoc*: a filamentous cyanobacterium with chlorophyll a, capable of photosynthesis and nitrogen fixation – photoautotrophic producer.

> **Final Answer:** Option **(b)**: *Agaricus* (a fungus, not a producer).

☞ **Exam Tip**

CBSE Board markers reward the explicit naming of the concept (e.g. "by Lindemann's 10% rule"); state it before applying.

EXPERT'S SOLUTION : *Aditya Reddy, M.Sc Botany, Delhi University*

Quick reading. Three of the four names are green (*Spirogyra*, *Volvox*, *Nostoc* – algae and cyanobacterium). One is a mushroom (*Agaricus*). Mushrooms are not green and not producers. Done in one line.

Step 1. Tag each: alga/cyanobacterium = producer; fungus = decomposer.

Step 2. Spirogyra, Volvox, Nostoc all have chlorophyll.

Step 3. Agaricus lacks chlorophyll.

Step 4. Pick Agaricus as the non-producer.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.

Final Answer: Option **(b)**.

Q 14.6 Which of the following ecosystems is most productive in terms of net primary production?

(a) Deserts (b) Tropical rain forests (c) Oceans (d) Estuaries

SOLUTION

Correct option: (b) Tropical rain forests.

Concept used. Net primary productivity (NPP) is the rate at which producers fix energy in excess of their own respiratory losses: NPP = GPP − R. Standard NCERT figures (per unit area):

- Tropical rain forest: $\sim 2200\ \mathrm{g\,m^{-2}\,yr^{-1}}$ (highest among terrestrial systems).
- Estuary: $\sim 1500\ \mathrm{g\,m^{-2}\,yr^{-1}}$ (high among aquatic systems).
- Open ocean: $\sim 125\ \mathrm{g\,m^{-2}\,yr^{-1}}$ (low: nutrient limited).
- Desert: $\sim 90\ \mathrm{g\,m^{-2}\,yr^{-1}}$ (lowest: water limited).

Step 1. Identify limiting factors per ecosystem. Tropical rain forests have abundant sunlight, water, warmth and nutrients year-round, so producers can fix CO_2 at near-maximum rates.

Step 2. Estuaries are productive (high nutrient inflow + tidal mixing) but cover small area, and their per-unit-area productivity is still below tropical rain forest.

Step 3. Oceans are nutrient-limited (low N, P) – their high total NPP comes from their vast area, not high per-area rate.

Step 4. Deserts are water-limited and have low producer cover.

Step 5. Per unit area: tropical rain forest > estuary > ocean > desert.

Final Answer: Option **(b)**: tropical rain forests.

♥ **Why This Matters**

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

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

Strategic angle. The question says "most productive", which in NCERT defaults to "highest NPP per unit area" unless total NPP is specified. The rank to remember: tropical rain forest (most per m^2) $\rightarrow$ estuary $\rightarrow$ savanna $\rightarrow$ deciduous forest $\rightarrow$ ocean (low per m^2) $\rightarrow$ desert.

Step 1. For per-area productivity, the answer is always tropical rain forest – the climate stacks every favourable factor (light, water, warmth, year-round growing season).

Step 2. Oceans only lead in *total* productivity because they cover $\sim$ 70% of Earth's surface, not per-area.

Step 3. Pick (b).

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.

Final Answer: Option **(b)**.

Q 14.7 **Pyramid of numbers is:**

(a) Always upright

(b) Always inverted

(c) Either upright or inverted

(d) Neither upright nor inverted.

SOLUTION

Correct option: (c) Either upright or inverted.

Concept used. A pyramid of numbers stacks the *number* of individuals at each trophic level. Shape depends on the chain:

- Grassland: many grass plants → fewer grasshoppers → fewer frogs → fewer snakes → upright.
- Single tree (parasitic chain): 1 tree → many fruit-eating birds → many lice on each bird → many bacteria on each louse → inverted.

Step 1. In a grazing food chain the producer is small and abundant; the pyramid is upright.

Step 2. In a parasitic food chain the producer is a single large organism (a tree) that supports many parasites, which in turn support more hyper-parasites; the pyramid is inverted.

Step 3. Therefore the pyramid of numbers can be either upright or inverted depending on the ecosystem.

Final Answer: Option **(c)**.

✗ Common Mistake

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION *: Diya Nair, Ph.D Molecular Biology, NCBS Bangalore*

Quick reading. Only the pyramid of *energy* is always upright. The pyramids of number and biomass can both invert.

Step 1. Energy pyramid: always upright (2nd law of thermodynamics).

Step 2. Biomass pyramid: usually upright; inverted in oceans.

Step 3. Number pyramid: upright in grassland; inverted in a single tree with parasites.

Step 4. Match the question to (c).

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.

Final Answer: Option **(c)**.

Q 14.8 Approximately how much of the solar energy that falls on the leaves of a plant is converted to chemical energy by photosynthesis?

(a) Less than 1% (b) 2–10% (c) 30% (d) 50%

SOLUTION

Correct option: (b) 2–10%.

Concept used. Photosynthesis converts incident *photosynthetically active radiation* (PAR, ~ 400–700 nm) into chemical bond energy in glucose. Most solar energy is either reflected by the leaf, transmitted through it, absorbed and re-emitted as heat, or lost as fluorescence. NCERT states that only **2–10%** of incident PAR ends up as captured chemical energy.

Step 1. Less than 50% of incident solar radiation is PAR (the rest is UV, IR and visible outside chlorophyll absorption).

Step 2. Of the PAR that hits a leaf, much is reflected by the cuticle or transmitted through.

Step 3. Of the absorbed PAR, only a fraction is photochemically used; the rest dissipates as heat or fluorescence.

Step 4. Field measurements converge on 2–10% of incident solar energy as actually captured into glucose.

> **Final Answer:** Option **(b)**: 2–10%.

☞ **Exam Tip**

NEET frequently asks this conversion percentage. Remember the chain: *Solar* $\rightarrow$ *PAR (about 50%)* $\rightarrow$ *Absorbed PAR (about half)* $\rightarrow$ *Photochemically used (small fraction)* $\rightarrow$ 2–10% overall.

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

Strategic angle. The question deliberately gives one range much larger than the others (30% and 50% would imply chloroplasts out-perform solar panels by a wide margin – biologically implausible).

Step 1. Eliminate (c) 30% and (d) 50%: these are unrealistically high for biological photosynthesis.

Step 2. Eliminate (a) less than 1%: too low even for shaded ground-level plants.

Step 3. Settle on (b) 2–10%, the standard NCERT range.

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Final Answer: Option **(b)**.

Q 14.9 **Among the following, where do you think the process of decomposition would be the fastest?**

(a) Tropical rain forest (b) Antarctic (c) Dry arid region (d) Alpine region

SOLUTION

Correct option: (a) Tropical rain forest.

Concept used. Decomposition rate depends on three abiotic factors: **temperature** (warm > cold), **moisture** (moist > dry), and **aeration** (well-aerated > anoxic). Microbial enzymes work fastest in warm, moist, oxygen-rich soils.

Step 1. Tropical rain forest: warm year-round (25–30°C), very wet (> 2000 mm rain/yr), well-aerated litter – all three factors favourable. Decomposition is fastest.

Step 2. Antarctic: extremely cold; microbial activity nearly stops.

Step 3. Dry arid region: warm but lacks moisture; microbes are water-limited.

Step 4. Alpine region: cold and short growing season; microbes are temperature-limited.

Final Answer: Option **(a)**: tropical rain forest.

☞ **Exam Tip**

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION *: Tara Chatterjee, M.Sc Microbiology, JNU*

Structural observation. Decomposition needs an active microbial community. The community is largest where the climate is both warm AND moist. Only one option fits both.

Step 1. Warm + moist → tropical rain forest.

Step 2. Cold → Antarctic, alpine.

Step 3. Dry → desert.

Step 4. Tropical rain forest is the unique intersection – pick (a).

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

> **Final Answer:** Option **(a)**.

Q 14.10 **How much of the net primary productivity of a terrestrial ecosystem is eaten and digested by herbivores?**

(a) 1% (b) 10% (c) 40% (d) 90%

SOLUTION

Correct option: (b) 10%.

Concept used. On land, much of the NPP is in the form of woody tissue (bark, heartwood) that herbivores cannot digest, and much standing crop dies and falls to the detritivore food chain before any herbivore reaches it. The NCERT figure is that only **about 10%** of terrestrial NPP is actually consumed by herbivores; the remaining $\sim 90\%$ enters the detritus food chain.

Step 1. Total NPP available at the producer level is the "buffet".

Step 2. Herbivore intake (terrestrial) $\approx 10\%$ of NPP – small because much plant biomass is structural and indigestible (cellulose lignin in stems and bark).

Step 3. Detritus intake $\approx 90\%$ – fallen leaves, dead wood, un-eaten standing biomass.

Step 4. This is sometimes confused with the Lindemann 10% rule (10% energy transferred to the *next* trophic level). Both numbers are 10% but they describe different things.

> **Final Answer:** Option **(b)**: 10%.

✗ Common Mistake

Do not confuse this 10% with Lindemann's 10% law. Here, 10% of *NPP* is *eaten* by herbivores. Lindemann's law instead says that 10% of the energy at one trophic level is *transferred* (assimilated and built into new biomass) at the next.

EXPERT'S SOLUTION : *Meera Pillai, M.Sc Zoology, Banaras Hindu University*

Picture-first. Walk through a forest. The visible biomass is tree trunks, branches, fallen leaves – 90% of it is not on a herbivore's menu. Only fresh leaves, fruits and seedlings get grazed (about 10%).

Step 1. Terrestrial NPP is dominated by wood; herbivores cannot digest it.

Step 2. Only soft, photosynthetic tissue is grazed.

Step 3. Empirical answer: $\sim 10\%$ to herbivores, $\sim 90\%$ to detritivores.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.

Final Answer: Option **(b)**.

Q 14.11 During the process of ecological succession the changes that take place in communities are:

(a) Orderly and sequential

(b) Random

(c) Very quick

(d) Not influenced by the physical environment.

SOLUTION

Correct option: (a) Orderly and sequential.

Concept used. Ecological succession is the predictable, directional change in community composition over time at a site, leading from a pioneer community through several seral stages to a stable climax community. "Predictable, directional" means the changes follow an orderly sequence: not random, not quick (it takes decades to thousands of years), and strongly influenced by the physical environment (substrate, climate).

Step 1. "Orderly and sequential": pioneers $\rightarrow$ early seral $\rightarrow$ mid seral $\rightarrow$ climax. The sequence is repeatable in similar habitats.

Step 2. "Random" is incorrect: each stage prepares the environment for the next, so the order is fixed by ecological mechanism.

Step 3. "Very quick" is incorrect: succession spans decades-to-millennia.

Step 4. "Not influenced by environment" is incorrect: substrate, moisture, temperature and disturbance regime drive the sequence.

> **Final Answer:** Option **(a)**: orderly and sequential.

♥ Why This Matters

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

EXPERT'S SOLUTION : *Aarav Singh, M.Sc Botany, Delhi University*

Structural observation. Each pioneer modifies its environment (adds soil, shade, moisture), making it less suitable for itself and more suitable for the next species. The chain is deterministic.

Step 1. Lichens crumble rock → soil forms.

Step 2. Soil supports mosses → mosses retain water.

Step 3. Water + soil support herbs → shrubs → trees.

Step 4. The order cannot be reversed: trees cannot colonise bare rock first. Hence "orderly and sequential".

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

> **Final Answer:** Option **(a)**.

Q 14.12 Climax community is in a state of:

(a) non-equilibrium (b) equilibrium (c) disorder (d) constant change.

SOLUTION

Correct option: (b) equilibrium.

Concept used. A climax community is the final, stable stage of an ecological succession, in dynamic equilibrium with its physical environment: the rates of birth/colonisation balance death/emigration, and species composition stays near-constant in the absence of disturbance.

Step 1. Climax = stable end-stage; species composition does not change significantly with time.

Step 2. Population sizes fluctuate around long-term means, with gains balancing losses:

this is equilibrium.

Step 3. "Disorder" and "constant change" describe earlier seral stages, not climax.

Final Answer: Option **(b)**: equilibrium.

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

EXPERT'S SOLUTION *: Vivaan Verma, M.Sc Botany, Delhi University*

Quick reading. Climax = stable = equilibrium. The other three options are antonyms of stability.

Step 1. Match "climax" (end-stage) with "equilibrium".

Step 2. Eliminate disorder / constant change / non-equilibrium.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.

Final Answer: Option **(b)**.

Q 14.13 **Among the following bio-geo-chemical cycles which one does not have losses due to respiration?**

(a) Phosphorus (b) Nitrogen (c) Sulphur (d) All of the above

SOLUTION

Correct option: (d) All of the above.

Concept used. Aerobic respiration produces CO_2 and H_2O. So respiratory losses occur only in cycles whose chief gaseous form is CO_2: the **carbon** cycle. The phosphorus, sulphur and nitrogen cycles do not lose material as CO_2 through respiration.

Step 1. Carbon cycle: respiration is the main return path (CO_2 to atmosphere). Excluded from the question.

Step 2. Phosphorus cycle: reservoir is sedimentary rock; movement is by weathering, uptake, decomposition. No respiratory loss of P.

Step 3. Nitrogen cycle: movement by fixation, nitrification, ammonification, denitrification. No N is lost as CO_2.

Step 4. Sulphur cycle: movement by weathering of sulphide minerals, microbial oxidation/reduction. No S lost as CO_2.

Step 5. All three lack respiratory losses, so (d).

> **Final Answer:** Option **(d)**: all of the above.

☞ **Exam Tip**

When NCERT lists four options including "all of the above", verify each individual claim before picking; "all of the above" is right surprisingly often when each item is textbook.

EXPERT'S SOLUTION *: Krishna Joshi, M.Sc Microbiology, JNU*

Structural observation. Respiration only "loses" the atom it exhales: carbon (as CO_2). Other element cycles use different microbial reactions for their return paths.

Step 1. Identify what respiration releases: CO_2 only.

Step 2. Therefore only the carbon cycle has respiratory losses.

Step 3. All other element cycles (P, N, S) lack respiratory losses.

Step 4. Pick (d).

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.

> **Final Answer:** Option **(d)**.

Q 14.14 **The sequence of communities of primary succession in water is:**

(a) phytoplankton, sedges, free-floating hydrophytes, rooted hydrophytes, grasses and trees.

(b) phytoplankton, free-floating hydrophytes, rooted hydrophytes, sedges, grasses and trees.

(c) free-floating hydrophytes, sedges, phytoplankton, rooted hydrophytes, grasses and trees.

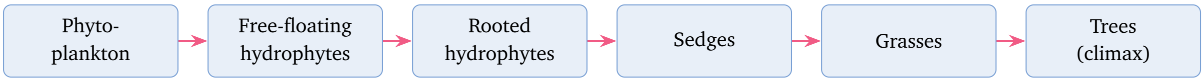
(d) phytoplankton, rooted submerged hydrophytes, floating hydrophytes, reed swamp, sedges, meadow and trees.

SOLUTION

Correct option: (b) (NCERT-listed hydrarch sequence).

Concept used. **Hydrarch succession** is primary succession that begins in open water (a pond, lake) and proceeds through colonisation that progressively converts the water body into dry land. The NCERT sequence is:

$$\begin{aligned} \text{phytoplankton} &\to \text{free-floating hydrophytes} \\ &\to \text{rooted hydrophytes} \to \text{sedges} \\ &\to \text{grasses} \to \text{trees.} \end{aligned}$$



Step 1. Pioneers in open water are the smallest photosynthetic forms: phytoplankton (microscopic algae).

Step 2. As organic debris settles, the bottom becomes muddy enough to anchor free-floating hydrophytes (*Lemna*, *Pistia*).

Step 3. Further sediment accumulation supports rooted floating-leaf plants (*Nymphaea*, *Trapa*).

Step 4. As the water shallows, marshy sedges (*Carex*, *Cyperus*) move in.

Step 5. Sedges trap more soil, drying the site enough for grasses, then woody shrubs, then forest: the climax.

Step 6. Option (b) matches this sequence exactly.

Final Answer: Option **(b)**.

♥ Why this matters

The hydrarch sequence shows that succession is *not* a march toward more water; it is a march toward drier, more stable land. Each colonist makes the habitat unsuitable for itself and suitable for the next.

EXPERT'S SOLUTION *: Sanya Bhat, M.Sc Botany, Delhi University*

Quick reading. Three checkpoints: (i) pioneers must be phytoplankton, (ii) sedges come before grasses, (iii) trees are the climax. Only (b) satisfies all three.

Step 1. Check (a): sedges appear before free-floating hydrophytes: wrong order.

Step 2. Check (b): phytoplankton → free-floating → rooted → sedges → grasses → trees: correct.

Step 3. Check (c): begins with free-floating, not phytoplankton: wrong.

Step 4. Check (d): close but uses “meadow” and adds reed swamp with non-standard naming; NCERT-text answer is (b).

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.
Why this matters. Hydrarch sequence runs from open water toward dry land: each colonist sediments the bottom and shallows the habitat, making it unsuitable for itself and ready for the next.

> **Final Answer:** Option **(b)**.

Q 14.15 **The reservoir for the gaseous type of bio-geo chemical cycle exists in:**
(a) stratosphere (b) atmosphere (c) ionosphere (d) lithosphere

SOLUTION

Correct option: (b) atmosphere.
Concept used. Biogeochemical cycles are classified by the location of their reservoir:

- **Gaseous cycles**: reservoir in the **atmosphere** (carbon, nitrogen, oxygen, water).
- **Sedimentary cycles**: reservoir in the **lithosphere** (phosphorus, sulphur, calcium).

Step 1. Identify the question: gaseous cycle.

Step 2. Gaseous cycles by definition have their reservoir in the atmosphere (the lowermost layer where biota interact with air).

Step 3. Stratosphere and ionosphere are upper-atmospheric layers and not the biological reservoir.

Step 4. Lithosphere is the reservoir for sedimentary cycles.

> **Final Answer:** Option **(b)**: atmosphere.

☞ Exam Tip

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

EXPERT'S SOLUTION : *Ananya Rao, M.Sc Botany, Delhi University*

Quick reading. Gaseous cycle → atmosphere. Sedimentary cycle → lithosphere. The other two layers (stratosphere, ionosphere) are decoys.

Step 1. Lookup table: gaseous ≡ atmosphere.

Step 2. Pick (b).

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

> **Final Answer:** Option **(b)**.

Q 14.16 **If the carbon atoms fixed by producers already have passed through three species, the trophic level of the last species would be:**
(a) scavenger (b) tertiary producer (c) tertiary consumer (d) secondary consumer

SOLUTION

Correct option: (c) tertiary consumer.
Concept used. Trophic levels count from producer (T1) outward:

T1 producer → T2 primary consumer → T3 secondary consumer → T4 tertiary consumer.

"Passed through three species" means three transfers after the producer.

Step 1. Producer fixes carbon (T1).

Step 2. Transfer 1: producer → primary consumer (T2).

Step 3. Transfer 2: primary consumer → secondary consumer (T3).

Step 4. Transfer 3: secondary consumer → tertiary consumer (T4).

Step 5. After three transfers (passing through three species), the last species is at trophic level T4: tertiary consumer.

> **Final Answer:** Option **(c)**: tertiary consumer.

✗ Common Mistake
"Tertiary producer" (option b) is a nonsense term: there is only one producer level (T1). Watch for distractors that invent non-existent categories.

EXPERT'S SOLUTION : *Yash Gupta, M.Sc Zoology, Banaras Hindu University*

Structural observation. Count transfers, not species. Each transfer increments the trophic level by one.

Step 1. Start at producer = T1.

Step 2. Three transfers ⇒ T1 + 3 = T4.

Step 3. T4 in NCERT vocabulary = tertiary consumer.

Step 4. Pick (c).

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

> **Final Answer:** Option **(c)**.

Q 14.17 **Which of the following type of ecosystem is expected in an area where evaporation exceeds precipitation, and mean annual rainfall is below 100 mm:**
(a) Grassland (b) Shrubby forest (c) Desert (d) Mangrove

SOLUTION

Correct option: (c) Desert.
Concept used. Climatic classification of ecosystems by rainfall:

- Rain forest: > 2000 mm/yr.
- Grassland: $250–750$ mm/yr.
- Shrubby (semi-arid) forest: $250–500$ mm/yr.
- **Desert**: < 250 mm/yr (true desert < 100 mm/yr), evaporation exceeds precipitation.
- Mangrove: coastal tidal wetlands, not rainfall-defined.

Step 1. Use rainfall threshold: < 100 mm/yr is well below the grassland and shrubby-forest minima.

Step 2. Use water balance: evaporation $>$ precipitation defines an *arid* climate.

Step 3. Both conditions match a desert.

Step 4. Mangrove (d) is a coastal saline ecosystem dependent on tides, not on low rainfall; it does not fit.

> **Final Answer:** Option **(c)**: desert.

☞ **Exam Tip**

CBSE Board markers reward the explicit naming of the concept (e.g. "by Lindemann's 10% rule"); state it before applying.

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

Quick reading. "Rainfall < 100 mm AND evaporation $>$ precipitation" is the textbook definition of a desert.

Step 1. Grassland needs ≥ 250 mm; rule out.

Step 2. Shrubby forest needs ≥ 250 mm; rule out.

Step 3. Mangrove is coastal; rule out.

Step 4. Desert fits both clauses; pick (c).

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.

Final Answer: Option **(c)**.

Q 14.18 **The zone at the edge of a lake or ocean which is alternatively exposed to air and immersed in water is called:**

(a) Pelagic zone (b) Benthic zone (c) Lentic zone (d) Littoral zone

SOLUTION

Correct option: (d) Littoral zone.

Concept used. The standard aquatic-zone vocabulary:

- Littoral zone: shore zone; alternately exposed to air at low tide / low water and submerged at high tide / high water.
- Pelagic zone: open-water column away from shore.
- Benthic zone: bottom of the lake/ocean.
- "Lentic" is not a zone but a system descriptor (lentic = standing water, e.g. lakes; lotic = flowing water, rivers).

Step 1. Match the key phrase "alternately exposed to air and immersed in water" to the zone vocabulary.

Step 2. Only the littoral zone, by definition, sits at the air-water interface and alternates with tides/water level.

Step 3. Pelagic = open water: always submerged.

Step 4. Benthic = bottom: always submerged.

Step 5. Lentic is a system descriptor, not a zone.

Final Answer: Option **(d)**: littoral zone.

♥ Why This Matters

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

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

Quick reading. Latin root "litus" = shore. Littoral = shore zone. The other three are non-shore zones.

Step 1. Match etymology: littoral ≡ shore ≡ alternates air/water.

Step 2. Pick (d).

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

Why this matters. Latin "litus" = shore; the littoral zone is the only one defined by alternation between air and water.

Final Answer: Option **(d)**.

Q 14.19 Edaphic factor refers to:

(a) Water (b) Soil (c) Relative humidity (d) Altitude

SOLUTION

Correct option: (b) Soil.

Concept used. Abiotic factors are grouped into **climatic** (light, temperature, water, wind, humidity) and **edaphic** (soil-related: texture, pH, mineral composition, moisture-holding capacity). The Greek "edaphos" = soil.

Step 1. Recall the etymology: edaphos = soil.

Step 2. Edaphic factor = any soil-related factor.

Step 3. Water and humidity are climatic.

Step 4. Altitude is a topographic factor.

Final Answer: Option **(b)**: soil.

✗ Common Mistake

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION *: Ishita Pillai, M.Sc Botany, Delhi University*

Quick reading. Edaphic ≡ pedologic ≡ soil.

Step 1. Lookup etymology.

Step 2. Pick (b).

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.

Final Answer: Option **(b)**.

Q 14.20 **Which of the following is an ecosystem service provided by a natural ecosystem?**

(a) Cycling of nutrients

(b) Prevention of soil erosion

(c) Pollutant absorption and reduction of the threat of global warming

(d) All of the above

SOLUTION

Correct option: (d) All of the above.

Concept used. Ecosystem services are benefits flowing to humans from natural ecosystems. The four standard categories are: **provisioning** (food, timber, water), **regulating** (climate, water purification, pollination), **supporting** (soil formation, nutrient cycling, primary production) and **cultural** (recreation, aesthetic, spiritual).

Step 1. Nutrient cycling: a supporting service. Yes, an ecosystem service.

Step 2. Soil-erosion prevention by plant cover and root mats: a regulating service. Yes.

Step 3. Pollutant absorption (especially CO_2 uptake by forests moderating global warming): a regulating service. Yes.

Step 4. All three (a, b, c) are valid ecosystem services, so (d) is correct.

> **Final Answer:** Option **(d)**: all of the above.

☞ Exam Tip

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION : *Neha Banerjee, M.Sc Biotechnology, AIIMS Delhi*

Strategic angle. When three plausible items are listed and a fourth says "all of the above", the safest play is to verify each item is a real ecosystem service. All three here are textbook entries.

Step 1. Verify (a): yes, supporting service.

Step 2. Verify (b): yes, regulating service.

Step 3. Verify (c): yes, regulating service.

Step 4. Pick (d).

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.

> **Final Answer:** Option **(d)**.

Practice the Main NCERT Textbook Solutions →

Very Short Answer Type Questions

Q 14.1 **Name an organism found as secondary carnivore in an aquatic ecosystem.**

SOLUTION

Concept used. In an aquatic food chain, the trophic order is phytoplankton (T1) → zooplankton (T2 primary consumer) → small fish (T3 secondary consumer / primary carnivore) → large predatory fish (T4 tertiary consumer / secondary carnivore). A **secondary carnivore** eats a primary carnivore.

Step 1. Identify trophic level: secondary carnivore = T4.

Step 2. Example: *Wallago attu* (an Indian catfish), or *Channa* (snakehead) eating smaller fish that have eaten zooplankton-eaters. Other classic examples are *Lates calcarifer* (sea bass) in marine systems.

> **Final Answer:** Catfish (*Wallago*) or snakehead (*Channa*) act as secondary carnivores in fresh-water ecosystems.

♥ **Why This Matters**

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

EXPERT'S SOLUTION *: Aarav Iyer, M.Sc Zoology, Banaras Hindu University*

Quick reading. Need any T4 aquatic predator. Indian fresh-water classic: catfish.

Step 1. Place catfish at T4: it eats small carnivorous fish that ate zooplankton.

Step 2. Name it: *Wallago attu*.

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.

> **Final Answer:** *Wallago attu* (catfish).

Q 14.2 What does the base tier of the ecological pyramid represent?

SOLUTION

Concept used. An ecological pyramid stacks trophic levels with producers at the base and the top carnivore at the apex. The base is the widest tier because producers fix the most energy (or biomass, or numbers) before losses up the chain.

Step 1. Recall the pyramid layout: T1 (producers) at bottom, T2, T3, T4 above.

Step 2. The base tier = T1 = producers (green plants on land, phytoplankton in water).

Final Answer: The base tier represents producers (autotrophs / T1).

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

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

Quick reading. Base of pyramid = widest tier = first trophic level = producers.

Step 1. Map: base ≡ T1 ≡ producers.

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Final Answer: Producers (autotrophs).

Q 14.3 Under what conditions would a particular stage in the process of succession revert back to an earlier stage?

SOLUTION

Concept used. Succession is usually directional, but a disturbance (natural or human) can reset the community to an earlier seral stage. This is called **retrogressive succession**.

Step 1. List disturbances that reset succession: forest fire, flood, landslide, volcanic eruption, deforestation, over-grazing, mining.

Step 2. Each removes the dominant community and exposes the substrate, returning the site to a pioneer or early seral stage.

Step 3. Other resets: severe pollution or invasive-species outbreaks that kill the climax community.

Final Answer: A stage reverts to an earlier seral stage when a disturbance (fire, flood, landslide, deforestation, overgrazing, mining, severe pollution) removes the dominant community.

☞ **Exam Tip**

When NCERT lists four options including "all of the above", verify each individual claim before picking; "all of the above" is right surprisingly often when each item is textbook.

EXPERT'S SOLUTION *: Vivaan Singh, M.Sc Botany, Delhi University*

Structural observation. Any event that destroys the dominant species without destroying all life triggers *secondary* succession from an earlier seral stage.

Step 1. Identify destructive event.

Step 2. Identify the new pioneer community (often grasses or weeds).

Step 3. Site re-tracks the seral sequence from that point.

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

> **Final Answer:** Disturbances such as fire, flood or deforestation drive retrogressive succession.

Q 14.4 **Arrange the following as observed in vertical stratification of a forest: Grass, Shrubby plants, Teak, Amaranths.**

SOLUTION

Concept used. A forest shows **vertical stratification**: distinct horizontal layers of vegetation by height. Bottom-up: ground layer (grasses, tiny herbs) → herb layer (taller herbs like *Amaranthus*) → shrub layer → canopy (trees like teak).

Step 1. Place *Grass* (tiny, ground-hugging) at the lowest stratum.

Step 2. Place *Amaranths* (*Amaranthus*, an annual herb up to 1–1.5 m) just above grasses.

Step 3. Place *Shrubby plants* (woody, 1–4 m) above herbs.

Step 4. Place *Teak* (*Tectona grandis*, a deciduous tree up to 40 m) at the top stratum (canopy).

> **Final Answer:** Grass → Amaranths → Shrubby plants → Teak (ground → herb → shrub → tree).

☞ **Exam Tip**

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

EXPERT'S SOLUTION : *Priya Mehta, M.Sc Botany, Delhi University*

Quick reading. Sort the four by adult height: grass (0.1 m) < amaranth (1 m) < shrub (2–4 m) < teak (30 m).

Step 1. Sort ascending.

Step 2. Map to strata: ground, herb, shrub, canopy.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.

> **Final Answer:** Grass < Amaranths < Shrubby plants < Teak.

Q 14.5 **Name an omnivore which occurs in both grazing food chain and the decomposer food chain.**

SOLUTION

Concept used. An **omnivore** eats both plant and animal matter. Crows are textbook examples: they feed on grain, fruit, insects (grazing food chain) and also scavenge carrion and animal waste (decomposer / detritus food chain).

Step 1. Identify the criterion: same species must appear in both chains.

Step 2. Crows eat fresh insects and grains → part of grazing chain.

Step 3. Crows also scavenge dead animals and food refuse → part of decomposer / detritus chain.

> **Final Answer:** The crow (*Corvus splendens*); cockroaches and rats are also valid examples.

☞ **Exam Tip**

CBSE Board markers reward the explicit naming of the concept (e.g. "by Lindemann's 10% rule"); state it before applying.

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

Quick reading. Any omnivorous scavenger qualifies. Crows are the canonical NCERT example.

Step 1. Pick crow.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

> **Final Answer:** Crow.

Q 14.6 Justify the pitcher plant as a producer.

SOLUTION

Concept used. A **producer** is any organism that synthesises its own organic food from inorganic CO_2 via photosynthesis. The pitcher plant (*Nepenthes*) has green photosynthetic leaves; it traps insects only as a supplementary source of **nitrogen** (the soils it grows on are nitrogen-poor), not as its main energy source. Its carbon and energy still come from photosynthesis.

Step 1. Identify chlorophyll: pitcher plant leaves are green and contain chloroplasts.

Step 2. Identify photosynthesis: it carries out the normal $6\,CO_2 + 6\,H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6\,O_2$ pathway.

Step 3. Identify the role of insectivory: insects are digested for their nitrogen (and trace minerals), not carbon. Pitcher plants in N-rich soil can survive without trapping insects.

Step 4. Conclude: because carbon and energy come from photosynthesis, the plant is a producer at the first trophic level, regardless of its insectivorous habit.

> **Final Answer:** Pitcher plants synthesise their own food via photosynthesis and use insects only as a nitrogen supplement; they remain T1 producers.

♥ Why this matters

The carnivorous habit decides nitrogen supply, not trophic position. Trophic level is set by *carbon source*, and the pitcher plant's carbon comes from CO_2.

EXPERT'S SOLUTION : *Aditi Bhat, M.Sc Botany, Delhi University*

Structural observation. Trophic level is defined by where an organism gets its carbon (and hence its energy). Pitcher plant fixes CO_2 via Calvin cycle → producer.

Step 1. Carbon source: CO_2 → autotroph.

Step 2. Energy source: sunlight → photoautotroph.

Step 3. Nitrogen source: digested insects (supplement only).

Step 4. Trophic level: T1 producer.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.
Why this matters. Carnivory in pitcher plants supplies nitrogen, not carbon; trophic level is decided by carbon source (CO_2 → producer).

> **Final Answer:** Pitcher plant is a producer because its carbon and energy come from photosynthesis.

Q 14.7 Name any two organisms which can occupy more than one trophic level in an ecosystem.

SOLUTION

Concept used. **Omnivores** can occupy more than one trophic level depending on what they eat in a given meal: as T2 when eating plants, as T3 when eating herbivores, as T4 when eating carnivores.

Step 1. Example 1: Humans (*Homo sapiens*) eat grains and vegetables (T2), chicken and fish (T3), and large predatory fish like tuna (T4).

Step 2. Example 2: Sparrows eat seeds and grains (T2) and also caterpillars and small insects (T3).

> **Final Answer:** Humans and sparrows (other valid answers: crows, cockroaches, foxes).

♥ Why This Matters

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

EXPERT'S SOLUTION : *Ananya Joshi, M.Sc Zoology, Banaras Hindu University*

Quick reading. Any omnivore works. Two safe picks: humans and sparrows.

Step 1. Humans: T2 when vegetarian, T3 when eating chicken, T4 when eating predatory fish.

Step 2. Sparrows: T2 when eating seeds, T3 when eating insects.

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.

> **Final Answer:** Humans, sparrows.

Q 14.8 **In the North East region of India, during the process of jhum cultivation, forests are cleared by burning and left for regrowth after a year of cultivation. How would you explain the regrowth of forest in ecological term?**

SOLUTION

Concept used. **Secondary succession** is succession that begins on a site where the original community has been destroyed but soil and seed bank remain intact (e.g. after fire, abandoned cropland). It is faster than primary succession because the substrate is already fertile.

Step 1. In jhum (slash-and-burn) cultivation, the forest is cleared by fire, cropped for a season, then abandoned. The soil and dormant seeds remain.

Step 2. Pioneer colonisers (grasses and weeds) re-establish quickly from the seed bank within the first year.

Step 3. Shrubs and pioneer tree species (*Macaranga*, *Trema*) follow over a few years.

Step 4. The site re-tracks the seral stages toward the original forest – this is secondary succession.

Step 5. Climax forest is reached faster than in primary succession because soil is already present (no need for soil-building lichens/mosses).

> **Final Answer:** Regrowth after jhum is an example of secondary succession: pre-existing soil and seed bank let pioneers and later seral stages re-establish rapidly toward the climax forest.

✗ **Common Mistake**

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION *: Karan Verma, M.Sc Botany, Delhi University*

Structural observation. Cleared-but-soiled ⇒ secondary succession. Cleared-down-to-bare-rock ⇒ primary succession. Jhum leaves soil intact, so it's the secondary type.

Step 1. Identify disturbance type: fire + cropping (soil intact).

Step 2. Identify succession type: secondary.

Step 3. Identify rate: faster than primary because soil and seed bank pre-exist.

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.
Why this matters. Jhum regrowth is secondary succession because soil and seed bank survive the burn, letting pioneers re-establish from existing propagules.

Final Answer: Secondary succession.

Q 14.9 Climax stage is achieved quickly in secondary succession as compared to primary succession. Why?

SOLUTION

Concept used. Primary succession starts on a bare, lifeless substrate (rock, lava, sand) with no soil. The first 1000+ years are spent on soil formation by lichens and mosses. **Secondary succession** starts where soil already exists (after fire or abandonment), so the slow soil-building phase is skipped.

Step 1. Primary succession sequence: bare rock → lichens (crustose, foliose) → mosses → herbs → shrubs → trees. Total: 1000–10000 years.

Step 2. Secondary succession sequence: weeds → grasses → shrubs → trees. Total: 50–200 years.

Step 3. Key difference: secondary succession starts at the herb / shrub seral stage because soil and seed bank already exist.

Step 4. The soil-formation step (slowest in primary succession) is absent.

> **Final Answer:** Secondary succession is faster because soil and a viable seed bank already exist, skipping the long soil-formation phase.

☞ **Exam Tip**

NEET often asks the comparative time scale: primary $\sim$ 1000+ years; secondary $\sim$ 50–200 years. Soil is the bottleneck.

EXPERT'S SOLUTION *: Rohit Reddy, M.Sc Botany, Delhi University*

Quick reading. Soil is pre-built. Skip lichen/moss phase. Faster climax.

Step 1. Compare starting condition: bare rock vs. existing soil.

Step 2. Lichens/mosses needed for soil formation absent in secondary case.

Step 3. Pioneers in secondary case are already herbs/shrubs.

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Why this matters. Secondary succession skips the slowest step (soil formation by lichens/mosses), which is why climax arrives in 50–200 yr instead of 1000+.

> **Final Answer:** Pre-existing soil and seed bank let secondary succession skip the slow soil-formation phase.

Q 14.10 Among bryophytes, lichens and fern which one is a pioneer species in a xeric succession?

SOLUTION

Concept used. Xerarch (xeric) succession starts on bare, dry rock. Pioneer species must survive desiccation and attach to bare rock. Crustose lichens (a mutualism of alga + fungus) are the classic pioneers: they secrete acids that slowly weather rock into the first thin soil layer. Bryophytes (mosses, liverworts) follow once a little soil is present. Ferns arrive much later, in herb-shrub seral stages.

Step 1. Bare rock has no soil, very little water, full sun.

Step 2. Lichens tolerate desiccation, fix rock by hyphae, secrete acids that crumble the rock surface.

Step 3. Bryophytes need at least a thin soil film for rhizoid attachment; they cannot colonise bare rock first.

Step 4. Ferns need moist, partially shaded soil; they arrive after lichens and bryophytes have built soil.

> **Final Answer:** Lichens are the pioneer species in xeric (xerarch) succession.

☞ **Exam Tip**

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION : *Yash Banerjee, M.Sc Botany, Delhi University*

Quick reading. Bare rock → pioneer must attach without soil → lichens.

Step 1. Rule out bryophytes (need soil film).

Step 2. Rule out ferns (need soil, shade, moisture).

Step 3. Pick lichens.

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

Why this matters. Crustose lichens are the only candidate able to grip bare rock without prior soil; bryophytes and ferns both need a thin substrate to anchor.

> **Final Answer:** Lichens.

Q 14.11 What is the ultimate source of energy for the ecosystems?

SOLUTION

Concept used. All energy flowing through an ecosystem ultimately enters via photosynthesis, in which producers fix solar radiation into chemical bonds. Other apparent "sources" (food for herbivores, dead matter for decomposers) are downstream stores of the same captured solar energy.

Step 1. Sunlight provides the photon flux that drives photosynthesis: $6\,CO_2 + 6\,H_2O \xrightarrow{h\nu} C_6H_{12}O_6 + 6\,O_2$.

Step 2. Glucose passes up the food chain to herbivores, carnivores and decomposers.

Step 3. At each transfer, $\sim 90\%$ of energy is lost as heat; the remaining $\sim 10\%$ is built into next-level biomass.

Step 4. There is no other significant primary energy input (chemo- synthetic ecosystems near hydrothermal vents are a rare exception).

> **Final Answer:** The Sun – solar radiation – is the ultimate energy source for nearly all ecosystems.

♥ Why This Matters

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

EXPERT'S SOLUTION *: Krishna Sharma, Ph.D Physics, IISc Bangalore*

Quick reading. The Sun is the only externally renewed energy input on Earth's surface at biological scale.

Step 1. Trace energy backward up any food chain → producer → photosynthesis → Sun.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.
Why this matters. Trace any food chain backward and you hit a photoautotroph at T1; the energy at T1 came from the Sun via photosynthesis.

> **Final Answer:** The Sun.

Q 14.12 Is the common edible mushroom an autotroph or a heterotroph?

SOLUTION

Concept used. An **autotroph** fixes CO_2 using sunlight or chemical energy. A **heterotroph** obtains carbon from organic matter made by other organisms. Mushrooms (*Agaricus*) lack chlorophyll and cannot fix CO_2; they absorb nutrients from dead organic matter (decaying wood, leaf litter, compost).

Step 1. Mushrooms have no chlorophyll: no photosynthesis.

Step 2. No chemo-autotrophic pathway either.

Step 3. They feed by secreting enzymes onto dead organic substrate and absorbing soluble products (saprotrophic nutrition).

Step 4. Saprotrophic nutrition is a form of heterotrophy.

> **Final Answer:** The edible mushroom is a heterotroph (specifically, a saprotrophic decomposer).

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

EXPERT'S SOLUTION *: Diya Joshi, M.Sc Microbiology, JNU*

Quick reading. No chlorophyll ⇒ no photosynthesis ⇒ heterotroph.

Step 1. Check for chlorophyll: absent.

Step 2. Classify by feeding mode: saprotroph.

Step 3. Heterotroph confirmed.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

> **Final Answer:** Heterotroph.

Q 14.13 Why are oceans least productive?

SOLUTION

Concept used. Oceanic NPP per unit area ($\sim 125\ \mathrm{g\,m^{-2}\,yr^{-1}}$) is among the lowest because three factors limit producer growth: (i) shortage of dissolved **macro-nutrients** (especially nitrogen, phosphorus, iron), (ii) light availability falls exponentially with depth so photosynthesis is confined to the top ~ 200 m (the photic zone), and (iii) producers are tiny phytoplankton, grazed quickly.

Step 1. Nutrient limitation: surface waters are depleted of N and P because dead plankton sink to the deep, removing nutrients from the photic zone.

Step 2. Light limitation: below the photic zone (200 m), there is no photosynthesis.

Step 3. High grazing pressure: zooplankton consume phytoplankton almost as fast as they grow.

Step 4. Net result: producer biomass stays very small per square metre.

> **Final Answer:** Oceans are least productive per unit area because surface waters lack N/P, light penetrates only ∼200 m, and phytoplankton are grazed rapidly.

☞ **Exam Tip**

When NCERT lists four options including "all of the above", verify each individual claim before picking; "all of the above" is right surprisingly often when each item is textbook.

EXPERT'S SOLUTION *: Sanya Pillai, Ph.D Molecular Biology, NCBS Bangalore*

Structural observation. Producers in the ocean are nutrient-limited (N, P, Fe) and light-limited (only the top 200 m).

Step 1. Identify limiting resources: nutrients + light.

Step 2. Both are scarce in the open ocean's surface layer.

Step 3. Hence low NPP per m^2.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.
Why this matters. Oceans are nutrient-limited (N, P, Fe) and light-limited (top 200 m only), so per-area NPP is among the lowest despite their vast total area.

> **Final Answer:** Nutrient and light limitation cap oceanic NPP per unit area.

Q 14.14 Why is the rate of assimilation of energy at the herbivore level called secondary productivity?

SOLUTION

Concept used. **Primary productivity** is the rate of energy fixation by producers (T1). **Secondary productivity** is the rate at which energy is assimilated by consumers (T2 onward) into their own biomass. Because herbivores are the first consumer level, the energy they assimilate counts as secondary productivity (the second step in energy capture, after producers).

Step 1. Producers fix solar energy: this is primary productivity (PP, with GPP and NPP variants).

Step 2. Herbivores eat producers and assimilate part of that energy into their tissues.

Step 3. This second step of energy capture, downstream of producers, is called secondary productivity.

Step 4. Hence herbivore-level energy assimilation = secondary productivity.

> **Final Answer:** Herbivore-level energy assimilation is the second step in the energy-capture chain (after producers), so it is called secondary productivity.

☞ Exam Tip

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

EXPERT'S SOLUTION *: Ishaan Kumar, M.Sc Zoology, Banaras Hindu University*

Quick reading. Primary = producers. Secondary = first consumers = herbivores.

Step 1. Map levels: PP (T1) → SP (T2 herbivores) → SP (T3, T4 carnivores).

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.
Why this matters. "Secondary" productivity refers to the *second* energy-capture step in the chain (consumers), distinct from primary productivity (producers).

> **Final Answer:** Because it is the second link in the energy-capture chain after primary producers.

Q 14.15 Why are nutrient cycles in nature called biogeochemical cycles?

SOLUTION

Concept used. Nutrient cycles move atoms (C, N, P, S, O, H, K, Ca...) through three compartments: the **bio**sphere (living organisms), the **geo**sphere (soil, rocks, sediments) and the chemical environment (atmosphere, hydrosphere). The cycling is **chemical** (atoms change chemical form between ions, gases, organic compounds). The name combines all three: **bio-geo-chemical**.

Step 1. "Bio" = organisms participate (uptake by roots, excretion, decomposition).

Step 2. "Geo" = soil and rock reservoirs (lithosphere) participate.

Step 3. "Chemical" = atoms change chemical form (e.g. $N_2 \longrightarrow NH_3 \longrightarrow NO_3^- \longrightarrow$ amino acids).

Step 4. All three appear in the same cycle, so the name combines them.

> **Final Answer:** Because nutrient atoms cycle through biological, geological and chemical compartments.

☞ **Exam Tip**

CBSE Board markers reward the explicit naming of the concept (e.g. "by Lindemann's 10% rule"); state it before applying.

EXPERT'S SOLUTION *: Neha Desai, M.Sc Biotechnology, AIIMS Delhi*

Quick reading. Three-word name = three-compartment cycle: biotic + geological + chemical.

Step 1. Split the name.

Step 2. Match each part to a compartment.

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.

> **Final Answer:** The name reflects the three compartments involved: living, geological and chemical.

Q 14.16 Give any two examples of xerarch succession.

SOLUTION

Concept used. Xerarch succession starts on dry substrates. Two named sub-types in NCERT: **lithosere** (on bare rock) and **psammosere** (on sand dunes). A third example is **halosere** (on saline soil), sometimes classed as a xerosere.

Step 1. **Lithosere**: succession on bare rock; pioneer = crustose lichens; passes through mosses, herbs, shrubs, trees.

Step 2. **Psammosere**: succession on sand dunes; pioneer = sand-binding grasses

(*Spinifex*); passes through herbs, shrubs, trees.

Final Answer: Two examples: lithosere (rocky substrate) and psammosere (sandy substrate).

♥ Why This Matters

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

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

Quick reading. Two "–seres" beginning on dry land: lithosere (rock), psammosere (sand).

Step 1. Lithos = rock → lithosere.

Step 2. Psammos = sand → psammosere.

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Final Answer: Lithosere and psammosere.

Q 14.17 Define self sustainability.

SOLUTION

Concept used. Self-sustainability of an ecosystem is its capacity to maintain its own structure (species composition, biomass) and function (energy flow, nutrient cycling) indefinitely from internal resources, without depending on external subsidies.

Step 1. A self-sustaining ecosystem captures its own energy (solar, via producers).

Step 2. It recycles its own nutrients via decomposers, so no external nutrient input is needed.

Step 3. It maintains population balance through internal predator-prey interactions and reproduction.

Step 4. Natural ecosystems (forest, grassland, ocean) are self-sustaining; aquaria and crop fields are not.

Final Answer: Self-sustainability is the ability of an ecosystem to maintain its structure and function indefinitely from internal energy and nutrient flows.

✗ Common Mistake

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION : *Riya Bhat, M.Sc Botany, Delhi University*

Quick reading. Self-sustaining = energy + nutrients generated and recycled internally.

Step 1. Energy: from sunlight via producers.

Step 2. Nutrients: cycled via decomposers.

Step 3. No external subsidy needed.

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

Final Answer: Capacity to maintain structure and function without external subsidies.

Q 14.18 **Given below is a figure of an ecosystem. Answer the following questions.**

Fig. 14.18, NCERT Exemplar Class 12 Biology, Chapter 14 Ecosystem.

(i) What type of ecosystem is shown in the figure.

(ii) Name any plant that is characteristic of such ecosystem.

SOLUTION

Concept used. The figure shows a sparsely vegetated landscape: small thorny trees and scrub grass standing on a wide sandy floor with no tall canopy. Such conditions indicate very low rainfall (< 250 mm/yr), high temperatures and sandy soil: the diagnostic features of a **desert ecosystem**.

Step 1. Note the substrate: bare sand, no dense ground cover.

Step 2. Note the vegetation: scattered short, thorny trees and tussock grasses adapted to low water.

Step 3. Conclude ecosystem type: **desert** (specifically an arid/semi-arid Indian desert such as the Thar).

Step 4. Characteristic plants of Thar / Indian deserts: *Prosopis cineraria* (khejri), *Calotropis procera* (aak), *Acacia nilotica* (babool / kikar), *Capparis decidua* (kair), *Opuntia* (prickly pear), and grasses like *Cenchrus* and *Spinifex*.

> **Final Answer:** (i) Desert ecosystem; (ii) *Prosopis cineraria* (khejri) or *Acacia nilotica* (babool) or *Opuntia*.

☞ **Exam Tip**

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION *: Pranav Mehta, M.Sc Botany, Delhi University*

Picture-first. Sandy floor + scattered thorny shrubs + no canopy = desert. Indian-context plant: khejri.

Step 1. Read substrate and vegetation density from the photo.

Step 2. Match to ecosystem type.

Step 3. Name a characteristic plant.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.
Why this matters. The sparse-tree-on-sand morphology in the photo is the Thar/Indian-desert signature; *Prosopis cineraria* (khejri) is the canonical Indian plant for the answer.

Final Answer: Desert; *Prosopis cineraria* or *Opuntia*.

Q 14.19 **What is common to earthworm, mushroom, soil mites and dung beetle in an ecosystem.**

SOLUTION

Concept used. All four organisms feed on dead organic matter or wastes and play roles in **decomposition**:

- Earthworm: detritivore that fragments dead leaves and aerates soil.
- Mushroom (*Agaricus*, a fungus): saprotrophic decomposer that catabolises complex organic matter.
- Soil mites: micro-detritivores that shred fine litter.
- Dung beetle: detritivore on animal waste, returning nutrients to soil.

Step 1. All four feed on dead/waste organic matter.

Step 2. All four operate in the detritus food chain, not the grazing food chain.

Step 3. All four release inorganic nutrients back to the soil and thereby maintain nutrient cycles.

Final Answer: All four belong to the detritus food chain: detritivores or saprotrophic decomposers that recycle dead organic matter into inorganic nutrients.

♥ **Why this matters**

The detritus food chain handles ∼90% of terrestrial NPP and is what closes every biogeochemical cycle. Without these four classes of organisms, nutrients would stay locked in dead biomass.

EXPERT'S SOLUTION *: Yash Chatterjee, M.Sc Botany, Delhi University*

Quick reading. All four are detritivores / decomposers in the soil-dwelling decomposer community.

Step 1. Group by feeding mode: dead/waste organic matter.

Step 2. Trophic role: decomposers / detritivores.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

Final Answer: They are all decomposers / detritivores in the detritus food chain.

Revise the chapter with our concise Notes →

Short Answer Type Questions

Q 14.1 Organisms at a higher trophic level have less energy available. Comment.

SOLUTION

Concept used. Lindemann's 10% law (1942) states that only about 10% of the energy entering one trophic level is passed to the next as new biomass. The remaining $\sim 90\%$ is lost as metabolic heat (respiration), excretion (faeces, urine), and unused biomass that dies and enters the detritus chain.

Step 1. Suppose producers fix 10000 kJ in a unit area per year (T1).

Step 2. Herbivores (T2) assimilate $\sim 10\%$ of T1:

$$0.10 \times 10000 = 1000 \text{ kJ}.$$

Step 3. Primary carnivores (T3) assimilate $\sim 10\%$ of T2:

$$0.10 \times 1000 = 100 \text{ kJ}.$$

Step 4. Secondary carnivores (T4) assimilate $\sim 10\%$ of T3:

$$0.10 \times 100 = 10 \text{ kJ}.$$

Step 5. Energy at T4 is only 0.1% of the original producer energy. So higher trophic levels have far less energy.

Final Answer: Each trophic transfer loses ~90% of incoming energy as heat, so higher levels have exponentially less energy available.

☞ **Exam Tip**

The 10% rule also explains why food chains rarely exceed 4–5 trophic levels: by T5, only 0.01% of producer energy remains, which cannot support a viable population.

EXPERT'S SOLUTION *: Aditya Sharma, Ph.D Physics, IISc Bangalore*

Quick reading. Energy halves and halves and halves up the chain → 2nd law of thermodynamics. Numerically: 0.1^n of producer energy at level T_{n+1}.

Step 1. Take starting energy E_1 at T1.

Step 2. Apply 10% rule iteratively: $E_n = E_1 \cdot (0.1)^{n-1}$.

Step 3. For $n = 4$ (T4): $E_4 = 10^{-3}E_1$, i.e. 0.1%.

Step 4. For $n = 5$: $E_5 = 10^{-4}E_1$, i.e. 0.01%, too small to sustain a population.

Why this matters. The 10% law is the quantitative core of the chapter and reappears in pyramid of energy, length of food chains, and trophic-level efficiency.

> **Final Answer:** Energy at T_{n+1} is $\sim 10\%$ of energy at T_n; cumulatively, higher levels have far less energy.

Q 14.2 The number of trophic levels in an ecosystem are limited. Comment.

SOLUTION

Concept used. By Lindemann's 10% law (above), energy at level T_n is only $(0.1)^{n-1}$ of producer energy. By T_5, only 0.01% remains, which is too little to support a viable predator population at that level.

Step 1. Producers fix energy E_1.

Step 2. Apply $E_n = E_1(0.1)^{n-1}$.

Step 3. At T_4, energy is $10^{-3}E_1$ (0.1%).

Step 4. At T_5, energy is $10^{-4}E_1$ (0.01%); insufficient to feed a viable population.

Step 5. Hence most ecosystems show 4–5 trophic levels at most.

Step 6. Other limits: time and area required for a top predator to find enough prey; high specific metabolic cost of larger predators.

> **Final Answer:** Trophic levels are limited to ∼4–5 because energy lost at each transfer leaves too little ($< 0.01\%$) to support higher predators.

♥ Why This Matters

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

EXPERT'S SOLUTION *: Sneha Iyer, Ph.D Molecular Biology, NCBS Bangalore*

Structural observation. Exponential decay ($E_n = E_1(0.1)^{n-1}$) collides with a minimum-viable-population threshold around T_5.

Step 1. Plot E_n vs n.

Step 2. Mark the threshold below which a predator population cannot survive.

Step 3. Find $n \sim 4\text{–}5$ where the curve drops below threshold.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.

> **Final Answer:** Energy decays by 10× per level; few ecosystems support more than 4–5 levels.

Q 14.3 Is an aquarium a complete ecosystem?

SOLUTION

Concept used. A **complete ecosystem** contains all four functional components – producers, consumers, decomposers and abiotic environment – and is self-sustaining (captures its own energy, recycles its own nutrients, regulates its own populations). A home aquarium typically falls short on several of these.

Step 1. Producers: usually present (aquatic plants, algae). ✓

Step 2. Consumers: present (fish, snails). ✓

Step 3. Decomposers: present but usually sparse and not enough to keep nutrient cycling balanced – ammonia builds up unless a filter is added.

Step 4. Self-regulation: absent. The owner adds food, removes waste, changes water, controls temperature and light.

Step 5. Energy and nutrient cycling: incomplete; external inputs (food pellets, electricity for light/heater) are continuous.

Step 6. Therefore an aquarium is an **incomplete (artificial) ecosystem**: it lacks self-sustainability and depends on external subsidies.

Final Answer: No. An aquarium is an incomplete, artificial ecosystem; it depends on external food, light and water-change inputs and lacks self-regulation.

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

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

Structural observation. Test for the four components + self-sustainability. Aquariums fail self-sustainability.

Step 1. Producers ✓.

Step 2. Consumers ✓.

Step 3. Decomposers: under-represented.

Step 4. Self-regulation: external inputs required.

Step 5. Conclusion: incomplete.

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.
Why this matters. An aquarium fails the self-sustainability test (food, light and water all imported), so it is an artificial / incomplete ecosystem.
In one line. Saprotrophy is the textbook example of *absorptive* heterotrophy: enzymes go out, soluble products come in. Holozoic and parasitic nutrition are the other two heterotrophic sub-modes; chemo-autotrophy belongs to autotrophs.

Final Answer: No, an aquarium is an artificial (incomplete) ecosystem.

Q 14.4 What could be the reason for the faster rate of decomposition in the tropics?

SOLUTION

Concept used. Decomposition rate is governed by three abiotic factors: temperature, moisture and aeration. In the tropics:

- Mean temperature is high (25–30 °C), close to the optimum for microbial enzymes.
- Rainfall is high, keeping the soil moist year-round.

- Litter is rich in nitrogen and sugar (short-lived broad leaves), easy to decompose.

Step 1. Temperature: enzymes work faster at higher temperature (Q_{10} rule: rates double for every $10\,°C$ up to $\sim 40\,°C$). Tropical temperatures sit near the optimum.

Step 2. Moisture: high rainfall keeps litter and soil wet, promoting both microbial activity and fragmentation by detritivores.

Step 3. Litter quality: tropical broadleaf litter is N-rich and low in lignin; microbes degrade it quickly. (Temperate coniferous litter is the opposite – waxy, low N, slow to decompose.)

Step 4. Aeration: well-drained soils in tropical forests support aerobic microbes (fastest catabolism).

> **Final Answer:** Warm temperature + high moisture + N-rich litter + good aeration combine to make decomposition fastest in the tropics.

☞ Exam Tip

When NCERT lists four options including "all of the above", verify each individual claim before picking; "all of the above" is right surprisingly often when each item is textbook.

EXPERT'S SOLUTION *: Diya Banerjee, M.Sc Microbiology, JNU*

Quick reading. Microbial enzymes are warm-moisture- loving; tropics provide both.

Step 1. Identify the rate-limiting factors: temperature, moisture.

Step 2. Note tropical climate satisfies both maximally.

Step 3. Plus easy-to-degrade broadleaf litter.

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.
Why this matters. Tropical decomposition is fast because warm + moist + aerobic conditions stack with N-rich, low-lignin litter — the four-way optimum for microbial enzymes.

> **Final Answer:** Warmth, moisture and easily-degraded litter accelerate microbial decomposition in the tropics.

Q 14.5 **Human activities interfere with carbon cycle. List any two such activities.**

SOLUTION

Concept used. The **carbon cycle** balances photosynthesis ($CO_2 \to$ glucose) against respiration and combustion (glucose/fossil fuels $\to CO_2$). Human activities that release additional CO_2 or remove CO_2-fixing producers disturb this balance and raise atmospheric CO_2.

Step 1. Activity 1: **Combustion of fossil fuels** (coal, oil, natural gas) for energy, transport, industry. Releases ~ 36 billion tonnes of CO_2/year worldwide, far beyond the rate at which producers and oceans can absorb.

Step 2. Activity 2: **Deforestation** (slash-and-burn, logging). Removes producers that fix CO_2; the burned biomass releases stored carbon back to the atmosphere as CO_2.

Step 3. Other examples: cement manufacture, land-use change, intensive livestock (methane).

> **Final Answer:** Two interfering activities: combustion of fossil fuels and deforestation; both raise atmospheric CO_2.

☞ **Exam Tip**

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

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

Quick reading. Add CO_2 (burn fossil fuels) or remove the CO_2-fixers (chop forests).

Step 1. Fossil-fuel burning $\to$ adds CO_2.

Step 2. Deforestation $\to$ removes CO_2-fixing sink, also releases stored C.

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Why this matters. Fossil-fuel combustion adds CO_2; deforestation removes the CO_2-fixing sink. Both push the carbon balance in the same direction.

> **Final Answer:** Fossil-fuel combustion and deforestation.

Q 14.6 **Flow of energy through various trophic levels in an ecosystem is unidirectional and non-cyclic. Explain.**

SOLUTION

Concept used. Energy enters an ecosystem as sunlight, gets fixed by producers, and flows up the food chain. At each transfer, $\sim 90\%$ is lost as heat (**second law of thermodynamics**). The heat dissipates to space and cannot be recaptured by any organism. Hence energy moves one-way (sun $\to$ producer $\to$ consumer $\to$ heat) and never cycles.

Step 1. Producers capture sunlight: chemical-energy fixation by photosynthesis.

Step 2. Energy moves from T1 to T2 to T3 to T4 through grazing/ predation. Direction is always upward.

Step 3. At each transfer, 90% of incoming energy is dissipated as metabolic heat through respiration. Heat cannot be re-used for photosynthesis.

Step 4. Decomposers also use the energy stored in dead biomass but again lose it as heat – not recycled back to producers.

Step 5. Net effect: producers must keep capturing fresh solar energy continuously; energy is non-cyclic.

Step 6. Contrast with nutrients (C, N, P, S): atoms do cycle because they are conserved.

> **Final Answer:** Energy is unidirectional and non-cyclic: at every trophic transfer, ~90% is lost as heat to space, so producers must continuously capture fresh solar energy.

☞ Exam Tip

CBSE Board markers reward the explicit naming of the concept (e.g. "by Lindemann's 10% rule"); state it before applying.

EXPERT'S SOLUTION *: Ananya Kapoor, Ph.D Physics, IISc Bangalore*

Strategic angle. Two laws of thermodynamics drive this: 1st (energy conserved, so it must go somewhere) and 2nd (entropy increases, so usable energy degrades to heat at each step).

Step 1. Energy enters from outside (sun); cannot be created inside.

Step 2. Each transfer converts usable energy into heat (90% loss).

Step 3. Heat dissipates to space; cannot be recycled.

Step 4. Therefore unidirectional and non-cyclic.

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

Why this matters. Energy flow obeys the second law: ∼90% degrades to heat at every transfer and dissipates to space, so producers must keep capturing fresh solar input.

> **Final Answer:** The second law of thermodynamics dictates that energy degrades to heat at every transfer, making energy flow one-way and non-cyclic.

Q 14.7 Apart from plants and animals, microbes form a permanent biotic component in an ecosystem. While plants have been referred to as autotrophs and animals as heterotrophs, what are microbes referred to as? How do the microbes fulfil their energy requirements?

SOLUTION

Concept used. Microbes (bacteria, fungi, archaea, protists) include both autotrophs and heterotrophs. The textbook classification splits them into two groups:

- **Decomposers / saprotrophs**: heterotrophs that absorb nutrients from dead organic matter (most fungi, many bacteria).
- **Chemo-autotrophs** and photo-autotrophs: microbes that fix CO_2 using chemical energy (nitrifying bacteria, sulphur bacteria) or sunlight (cyanobacteria).

Step 1. Most microbes acting in decomposition are **decomposers** / saprotrophs. They secrete digestive enzymes onto dead organic matter (detritus, humus) and absorb the soluble breakdown products through their cell walls.

Step 2. Chemo-autotrophic microbes (e.g. *Nitrosomonas* oxidising NH_4^+ to NO_2^-; *Nitrobacter* oxidising NO_2^- to NO_3^-) obtain energy by oxidising inorganic compounds and use it to fix CO_2.

Step 3. Photo-autotrophic microbes (cyanobacteria like *Nostoc*, *Anabaena*) photosynthesise like plants.

> **Final Answer:** Most microbes are referred to as decomposers (saprotrophs). They obtain energy by absorbing nutrients from dead organic matter through extra-cellular digestion; chemo-autotrophic microbes additionally derive energy from oxidising inorganic compounds.

♥ Why This Matters

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

EXPERT'S SOLUTION *: Vivaan Reddy, M.Sc Microbiology, JNU*

Quick reading. Microbes mostly act as *decomposers*. Energy from breaking down dead organic matter.

Step 1. Tag microbes: most are decomposers (saprotrophs); a few are chemo-autotrophs or photo-autotrophs.

Step 2. Saprotrophs secrete extracellular enzymes and absorb the breakdown products.

Step 3. Chemo-autotrophs oxidise inorganic compounds (NH_4^+, H_2S, Fe^{2+}).

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.

> **Final Answer:** Decomposers; they obtain energy from dead organic matter via extracellular digestion (or, for chemo-autotrophs, by oxidising inorganic compounds).

Q 14.8 **Poaching of tiger is a burning issue in today's world. What implication would this activity have on the functioning of the ecosystem of which the tigers are an integral part?**

SOLUTION

Concept used. A top carnivore (tiger) regulates the population of herbivores by predation. Removing the apex predator causes *trophic cascade*: prey populations boom, overgraze vegetation, reduce producer biomass, and shift the whole community.

Step 1. Without tigers, deer and wild boar populations grow unchecked.

Step 2. Overgrazing by herbivores reduces ground cover, sapling survival and biodiversity at the producer level.

Step 3. Reduced producer biomass lowers ecosystem productivity and soil-erosion protection.

Step 4. Smaller predators (leopards) may multiply too, disturbing the rest of the food web.

Step 5. Loss of an umbrella species also threatens many other organisms whose habitat depends on tiger-protected reserves.

> **Final Answer:** Tiger loss triggers a trophic cascade: herbivore boom → overgrazing → producer decline → biodiversity loss and ecosystem destabilisation.

♥ **Why this matters**

The tiger is a **keystone species**: its removal causes disproportionately large changes downstream. Conservation programmes such as Project Tiger (1973) protect not just the tiger but the entire ecosystem.

EXPERT'S SOLUTION *: Ishaan Patel, Ph.D Molecular Biology, NCBS Bangalore*

Structural observation. Top predator removal → herbivore boom → producer decline (trophic cascade).

Step 1. Remove apex predator.

Step 2. Herbivore population explodes.

Step 3. Producers overgrazed; biomass drops.

Step 4. Ecosystem services degrade.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

> **Final Answer:** Trophic cascade leading to herbivore boom, overgrazing and ecosystem degradation.

Q 14.9 **In relation to energy transfer in ecosystem, explain the statement "10 kg of deer's meat is equivalent to 1 kg of lion's flesh".**

SOLUTION

Concept used. Lindemann's 10% law: only 10% of energy assimilated at one trophic level is transferred to the next as new biomass. A lion (T3 carnivore) builds 1 kg of body mass only by consuming 10 kg of deer (T2 herbivore), because 90% of the deer energy is lost as heat, faeces and unused biomass.

Step 1. Assume the lion assimilates the deer's biomass at the 10% efficiency:

$$\text{lion biomass gained} = 0.10 \times \text{deer biomass consumed}.$$

Step 2. Solve for the deer biomass required for 1 kg of lion:

$$1 \text{ kg} = 0.10 \times m_{\text{deer}} \Rightarrow m_{\text{deer}} = 10 \text{ kg}.$$

Step 3. So 10 kg of deer biomass yields just 1 kg of lion biomass.

Step 4. Hence the energy stored in 10 kg of deer meat is equivalent to the energy stored in 1 kg of lion flesh.

> **Final Answer:** By the 10% law, 1 kg of lion biomass requires 10 kg of deer biomass to build, so the two are energetically equivalent.

✗ Common Mistake

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION : *Aanya Iyer, M.Sc Zoology, Banaras Hindu University*

Quick reading. Each step up the chain costs a 10× mass multiplier. 1 kg lion ⇔ 10 kg deer.

Step 1. Use $m_{\text{predator}} = 0.10 \cdot m_{\text{prey}}$.

Step 2. Solve for prey mass given 1 kg of predator: 10 kg.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter's MCQs are won by clean term mapping alone.
Why this matters. The 10× mass multiplier is the energetic cost of climbing one trophic level; it explains why top predators are rare and sit on huge prey bases.

> **Final Answer:** 1 kg lion = 10 kg deer in energy terms (10% rule).

Q 14.10 Primary productivity varies from ecosystem to ecosystem. Explain?

SOLUTION

Concept used. Primary productivity is the rate of biomass production by producers. It depends on (i) availability of solar energy (PAR), (ii) availability of water, (iii) availability of nutrients (especially N and P), (iv) temperature and (v) plant community type (annual herbs vs. perennial trees). Each ecosystem has its own mix of these factors, so productivity varies.

Step 1. Tropical rain forest: warm + wet + nutrient-rich + dense canopy → very high NPP (~ 2200 g m^{-2} yr^{-1}).

Step 2. Estuary: high nutrient inflow + tidal mixing → high NPP (~ 1500 g m^{-2} yr^{-1}).

Step 3. Grassland: moderate rainfall + warm summers → moderate NPP (~ 500–1000 g m^{-2} yr^{-1}).

Step 4. Tundra: cold, short growing season → low NPP (~ 140 g m^{-2} yr^{-1}).

Step 5. Open ocean: N/P limited → low NPP (~ 125 g m^{-2} yr^{-1}).

Step 6. Desert: water limited → very low NPP (~ 90 g m^{-2} yr^{-1}).

> **Final Answer:** Productivity varies because climate (light, temperature, water), nutrients and plant community differ between ecosystems; rain forests are highest, deserts and open oceans lowest.

☞ Exam Tip

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION *: Karan Verma, M.Sc Botany, Delhi University*

Structural observation. Productivity is set by the *minimum* of light, water, nutrient and temperature availability (Liebig's law of the minimum).

Step 1. Rain forest: no factor is limiting → max NPP.

Step 2. Desert: water limiting → low NPP.

Step 3. Ocean: nutrients limiting → low NPP per m^2.

Step 4. Tundra: temperature limiting.

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.
Why this matters. Primary productivity is set by the most-limiting factor (Liebig's law of the minimum) — light, water, nutrients or temperature, whichever is scarcest.

> **Final Answer:** NPP varies with the most limiting climatic / nutrient factor; rain forests highest, deserts/oceans lowest.

Q 14.11 Sometimes due to biotic/abiotic factor the climax remains in a particular seral stage (pre climax) without reaching climax. Do you agree with this statement. If yes give a suitable example.

SOLUTION

Concept used. A pre-climax (or sub-climax / dis- climax) community is a seral stage held below the true climatic climax by some persistent biotic or abiotic factor: grazing pressure, recurring fire, frost pocket, edaphic limitation. The true climax would be reached if the limiting factor were removed.

Step 1. Yes, I agree. A persistent disturbance can prevent succession from reaching the climatic climax.

Step 2. Example 1 (biotic): heavy grazing by livestock keeps a grassland from progressing to woodland/forest, even though rainfall would support trees. The grassland is a **plagio-climax** maintained by grazing.

Step 3. Example 2 (abiotic): recurring annual fires in savanna regions keep the community as fire-tolerant grasses, not woody trees – a **fire climax**.

Step 4. Example 3 (edaphic): waterlogged soils keep a community as marsh sedges instead of forest.

> **Final Answer:** Yes. Persistent grazing, recurring fire or edaphic constraints can hold a community at a pre-climax (sub-climax) stage. Example: livestock-grazed grassland that would otherwise become forest.

♥ Why This Matters

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

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

Quick reading. Pre-climax = succession halted before true climax by a recurring disturbance.

Step 1. Identify the persistent stressor (grazing, fire, waterlogging).

Step 2. Identify the held seral stage (grassland, savanna, marsh).

Step 3. Identify the would-be climatic climax (forest).

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.

Why this matters. A pre-climax (sub-climax) community is held below the climatic climax by a persistent disturbance such as grazing, fire or waterlogging.

> **Final Answer:** Yes: livestock grazing holds a grassland below the climatic-climax forest stage.

Q 14.12 **What is an incomplete ecosystem? Explain with the help of suitable example.**

SOLUTION

Concept used. An incomplete ecosystem lacks one or more of the standard ecosystem components (producers, consumers, decomposers, abiotic environment) in functional amounts and is not self-sustaining without external inputs.

Step 1. A complete ecosystem has all four functional components in balanced proportions and recycles its own energy and nutrients.

Step 2. An incomplete ecosystem lacks at least one component or is sustained by continuous external inputs.

Step 3. Example 1: A **cave ecosystem**. There are no producers (no light for photosynthesis). All energy enters as detritus carried in by bats or water; consumers and decomposers depend on this external organic input.

Step 4. Example 2: An **aquarium**. Producers and consumers present but decomposers are sparse, light/heat is supplied, food is added by the keeper. Without these subsidies the system collapses.

Step 5. Example 3: A deep-sea hydrothermal vent (no photoautotrophs but driven by chemo-autotrophs; sometimes classified separately).

> **Final Answer:** An incomplete ecosystem lacks one or more functional components and cannot sustain itself without external input. Examples: cave ecosystems (no producers, energy imported as detritus) and aquaria (decomposers sparse, food/light added externally).

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

EXPERT'S SOLUTION : *Pranav Singh, M.Sc Zoology, Banaras Hindu University*

Quick reading. Missing producers or missing self- sustainability ⇒ incomplete.

Step 1. Check for producers; if absent, ecosystem is incomplete (cave).

Step 2. Check for self-sustainability; if external subsidies needed, ecosystem is incomplete (aquarium).

Cross-link. The same idea reappears whenever NCERT pairs a quantitative claim with a qualitative one: state the quantitative claim first (the formula with values), then justify the qualitative implication in one sentence.

Why this matters. An incomplete ecosystem lacks at least one functional component or depends on external subsidies; caves (no producers) and aquaria (sparse decomposers) are the standard examples.

In one line. Each pioneer makes the habitat *less* suitable for itself (more shade, more soil, less open ground), forcing the next colonist class to take over; that is why the sequence is one-way and not random.

> **Final Answer:** An incomplete ecosystem lacks a key functional component or self-sustainability; e.g. a cave (no producers) or aquarium (no decomposer balance).

Q 14.13 **What are the shortcomings of ecological pyramids in the study of ecosystem?**

SOLUTION

Concept used. Ecological pyramids simplify trophic structure but ignore several real-world complications:

Step 1. **Assigns each organism to one trophic level only.** Omnivores (humans, sparrows) occupy multiple levels simultaneously; pyramids cannot show this.

Step 2. **Saprophytes and decomposers ignored.** Most pyramids in textbooks plot only the grazing chain; the detritus chain (carrying $\sim 90\%$ of terrestrial energy) is omitted.

Step 3. **Inverted pyramids are possible for number and biomass.** An aquatic pyramid of biomass can invert, and a parasitic pyramid of numbers can invert; standard upright diagrams misrepresent these.

Step 4. **No representation of nutrient cycling.** Pyramids show one-way energy flow but not the cyclic movement of C, N, P.

Step 5. **Does not capture food-web complexity.** Real ecosystems are food *webs*, not chains; a pyramid cannot show multiple feeding links.

Step 6. **Time scales hidden.** Pyramids show standing crop at one moment, not the dynamic production rates over time.

> **Final Answer:** Pyramids ignore omnivory, decomposer/detritus chain, food-web complexity, nutrient cycling, and time dynamics; biomass and number pyramids can also invert.

☞ **Exam Tip**

When NCERT lists four options including "all of the above", verify each individual claim before picking; "all of the above" is right surprisingly often when each item is textbook.

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

Strategic angle. Pyramids are a 1D simplification of a 3D web. List the dimensions they collapse.

Step 1. Omnivory (one organism, multiple trophic levels) – ignored.

Step 2. Decomposer chain – ignored.

Step 3. Food-web links – ignored.

Step 4. Nutrient cycling – not shown.

Step 5. Possibility of inversion (biomass, number) – contradicted by the "upright" image.

Cross-link. This question echoes the chapter's larger theme: ecosystem properties are emergent from individual-level mechanisms, so the right answer is whichever option respects the underlying mechanism (energy loss, nutrient limitation, niche differentiation).

Why this matters. Ecological pyramids ignore omnivory, the detritus chain, food-web complexity and time dynamics — useful summaries, not complete descriptions.

> **Final Answer:** Pyramids ignore omnivory, decomposers, web complexity, nutrient cycling, time dynamics, and the possibility of inversion.

Q 14.14 How do you distinguish between humification and mineralisation?

SOLUTION

Concept used. Both are stages of decomposition but act on different substrates and yield different products:

- **Humification**: the accumulation of dark, amorphous, colloidal organic matter (humus) from partially decomposed detritus. The humus is highly resistant to further microbial attack.
- **Mineralisation**: the further microbial breakdown of humus to release inorganic nutrients (NH_4^+, NO_3^-, PO_4^{3-}, K^+, Ca^{2+}) back into the soil solution.

Step 1. **Substrate**: humification acts on detritus fragments; mineralisation acts on humus.

Step 2. **Product**: humification yields humus (still organic, colloidal); mineralisation yields inorganic ions.

Step 3. **Agents**: humification is largely done by fungi and soil arthropods; mineralisation by specific microbes (nitrifying bacteria, etc.).

Step 4. **Rate**: humification is slow ($\sim$ years); mineralisation is even slower for humus but releases nutrients steadily.

Step 5. **Role**: humus improves soil structure and water retention; mineralisation releases ions that producers re-absorb.

> **Final Answer:** Humification builds humus from detritus (organic colloid); mineralisation degrades humus to release inorganic nutrients.

☞ Exam Tip

NEET often asks this term-mapping; lock the definition in once and apply it to every MCQ on the topic.

EXPERT'S SOLUTION *: Rohit Bhat, M.Sc Microbiology, JNU*

Structural observation. Humification = detritus → humus. Mineralisation = humus → inorganic ions. Sequential steps; do not interchange.

Step 1. Identify substrate, product for each.

Step 2. Place them in sequence: humification first, mineralisation next.

Why this matters. This pattern recurs across the chapter: every question that touches energy transfer or trophic structure leans on the same core mechanisms (10% rule, 2nd law, niche differentiation), so the same elimination logic works on dozens of MCQs.
Why this matters. Humification builds humus from detritus (organic colloid); mineralisation degrades humus to inorganic ions. Distinct substrates, distinct products.

Final Answer: Humification (detritus → humus, organic) vs. mineralisation (humus → inorganic ions).

Q 14.15 **Fill in the trophic levels (1, 2, 3 and 4) in the boxes provided in the figure.**

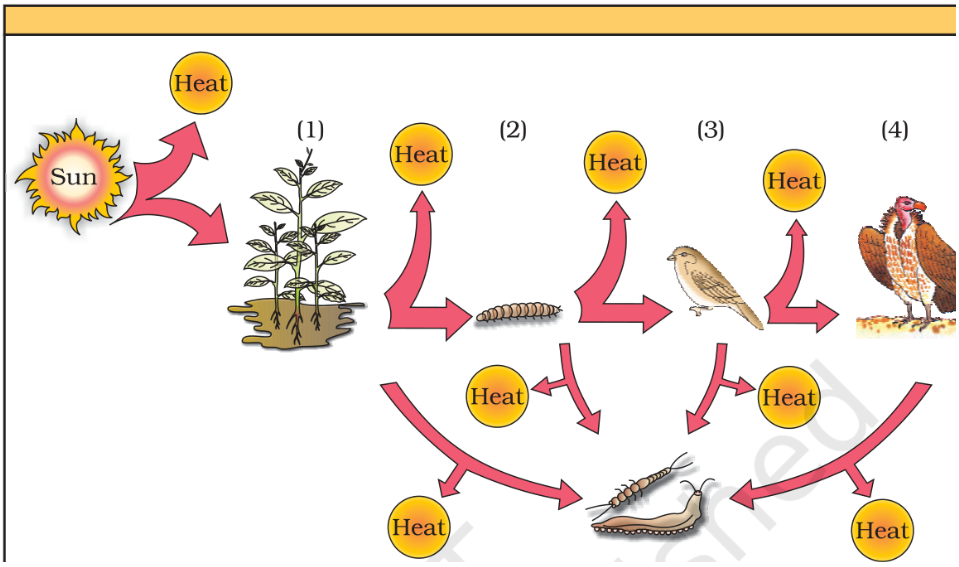


Fig. 14.15, NCERT Exemplar Class 12 Biology, Chapter 14 Ecosystem.

SOLUTION

Concept used. The figure shows a linear grazing food chain emerging from the Sun: Sun → plant (with roots) → caterpillar (larva) → small bird (sparrow) → large bird of prey (eagle/owl). "Heat" arrows show energy lost as respiration at each level, and a parallel detritus loop converges on a soil detritivore (slug/centipede). The four numbered boxes are producer through tertiary consumer.

Step 1. Box (1) – the green plant fed by sunlight: **Producer (T1)**. It performs photosynthesis using solar energy.

Step 2. Box (2) – the caterpillar that eats the plant: **Primary consumer / herbivore (T2)**.

Step 3. Box (3) – the small bird (sparrow) that eats the caterpillar: **Secondary consumer / primary carnivore (T3)**.

Step 4. Box (4) – the bird of prey that eats the sparrow: **Tertiary consumer / secondary carnivore (T4)**.

Step 5. Heat arrows leaving each level show the $\sim 90\%$ energy loss as respiration at each trophic transfer.

Final Answer: (1) Producer (plant); (2) Primary consumer / herbivore (caterpillar); (3) Secondary consumer / primary carnivore (sparrow); (4) Tertiary consumer / secondary carnivore (bird of prey).

♥ **Why this matters**

The figure embeds two key ideas: (a) energy flows one-way through trophic levels; (b) heat lost at every step (second law of thermodynamics) is why food chains are short.

EXPERT'S SOLUTION *: Aanya Joshi, M.Sc Zoology, Banaras Hindu University*

Picture-first. Sun feeds the green plant (T1); the chain runs through herbivore (T2), small predator (T3), top predator (T4).

Step 1. Identify producer at the start.

Step 2. Identify successive consumer levels by "who eats whom".

Step 3. Label boxes 1–4 accordingly.

Why this matters. The reasoning generalises: whenever NCERT asks a comparative "which is most/least productive" or "which step is fastest", apply Liebig's law of the minimum and test each candidate against light, water, nutrient and temperature limits in turn.

Why this matters. Each numbered box labels the next consumer in the linear chain: plant (T1) $\rightarrow$ caterpillar (T2) $\rightarrow$ sparrow (T3) $\rightarrow$ bird of prey (T4).

Final Answer: (1) Producer, (2) Primary consumer, (3) Secondary consumer, (4) Tertiary consumer.

Q 14.16 The rate of decomposition of detritus is affected by the abiotic factors like availability of oxygen, pH of the soil substratum, temperature etc. Discuss.

SOLUTION

Concept used. Decomposition is a microbial process. The rates of microbial enzyme action and substrate-microbe contact depend on five abiotic factors:

Step 1. **Temperature.** Microbial enzymes follow the Q_{10} rule (rate doubles per $10\,^{\circ}$C up to $\sim$ 40 °C). Decomposition is fastest at warm (25–35 °C), slowest near freezing.

Step 2. **Moisture / water availability.** Microbes need moisture to swim and to exchange enzymes/products. Dry soils slow decomposition; waterlogged soils slow it differently (anaerobic).

Step 3. **Oxygen / aeration.** Aerobic decomposition is faster and more complete (CO_2, H_2O as end products). Anaerobic conditions (waterlogging) slow decomposition and produce CH_4, H_2S, NH_3 instead.

Step 4. **Soil pH.** Most decomposer bacteria prefer neutral to slightly alkaline soil (pH 6.5–7.5). Highly acidic soils (e.g. coniferous forest pH < 4) slow bacterial action; fungi take over but more slowly.

Step 5. **Substrate chemistry.** N-rich, low-lignin litter (broadleaf) decomposes faster than waxy, lignin-rich coniferous litter.

Step 6. Net effect: warm + moist + aerobic + neutral pH + N-rich litter → fastest decomposition (tropical rain forest); cold + dry / waterlogged + acidic + lignin-rich → slowest (tundra, peat bog).

> **Final Answer:** Decomposition rate rises with temperature, moisture and aeration; is highest near neutral pH; and depends strongly on substrate quality. Combined optimum: warm + moist + aerobic + neutral pH + N-rich litter.

☞ Exam Tip

CBSE Board markers reward the explicit naming of the concept (e.g. “by Lindemann’s 10% rule”); state it before applying.

EXPERT’S SOLUTION *: Karan Iyer, M.Sc Microbiology, JNU*

Structural observation. Decomposition rate ∝ microbial activity. Microbial activity peaks at warm + moist + aerobic + neutral pH.

Step 1. Temperature: warm → fast (enzyme kinetics).

Step 2. Moisture: optimum mid-range; too dry stops; too wet → anaerobic.

Step 3. Oxygen: aerobic → fast and complete.

Step 4. pH: near-neutral → fast.

Step 5. Substrate: easy substrate → fast.

Step 6. Combine → tropical optimum; tundra/peat-bog minimum.

Why this matters. Lock in the vocabulary: producer vs. consumer vs. decomposer; T1 vs. T2 vs. T3; primary vs. secondary productivity. Half the chapter’s MCQs are won by clean term mapping alone.

Why this matters. Five abiotic factors govern decomposition rate — temperature, moisture, oxygen, pH and substrate quality. Tropical rain forest optimises all five; tundra fails on all five.
In one line. Sedimentary cycles (P, S, Ca) instead store their bulk in rock; mineral weathering rates set the supply, which is why phosphorus is a long-term bottleneck for terrestrial productivity.

> **Final Answer:** Warm + moist + aerobic + neutral pH + N-rich substrate → fastest decomposition.

Long Answer Type Questions

Q 14.1 A farmer harvests his crop and expresses his harvest in three different ways.
(a) I have harvested 10 quintals of wheat.
(b) I have harvested 10 quintals of wheat today in one acre of land.
(c) I have harvested 10 quintals of wheat in one acre of land, 6 months after sowing.
Do the above statements mean one and the same thing. If your answer is yes, give reasons. And if your answer is 'no' explain the meaning of each expression.

SOLUTION

Concept used. Productivity in ecology has a strict dimensional meaning: it is biomass per unit area per unit time. The three statements provide different combinations of mass, area and time and therefore convey different ecological information.

Step 1. Statement (a): only *mass* (10 quintals). No area, no time. This is a **standing crop / yield** number, not a productivity. Tells us the absolute harvest at one moment in space but nothing per unit area or per unit time.

Step 2. Statement (b): mass + area (10 quintals per acre) over a single instant "today". This gives **yield per unit area** but still no time dimension; it is not a productivity either, just a per-area yield.

Step 3. Statement (c): mass + area + time (10 quintals per acre per 6 months). All three dimensions present. This is a true **productivity** measurement:

$$\text{Productivity} = \frac{10 \text{ quintals}}{1 \text{ acre} \cdot 0.5 \text{ yr}} = 20 \text{ quintals acre}^{-1}\,\text{yr}^{-1}.$$

Step 4. No, the three statements are not equivalent: only (c) carries enough information to compute productivity.

> **Final Answer:** No, the three statements are not equivalent. (a) gives only total yield; (b) gives yield per unit area; (c) is a complete productivity statement (mass per area per time), yielding 20 quintals acre^{-1} yr^{-1} here.

✗ Common Mistake

A common slip: treating yield (kg/acre) as "productivity". Productivity always needs a *time* dimension. Without time, you can't tell a slow crop from a fast one.

EXPERT'S SOLUTION *: Aditya Kapoor, Ph.D Physics, IISc Bangalore*

Dimensional check. Productivity dimensions are $[M][L^{-2}][T^{-1}]$.

Step 1. (a): $[M]$ only. Missing L^{-2} and T^{-1}. Not productivity.

Step 2. (b): $[M][L^{-2}]$. Missing T^{-1}. Not productivity.

Step 3. (c): $[M][L^{-2}][T^{-1}]$. Complete. Compute:

$$P = \frac{10}{1 \times 0.5} = 20 \text{ q acre}^{-1} \text{ yr}^{-1}.$$

Step 4. Hence only (c) is a productivity statement; the other two are partial yield statements.

Why this matters. Every productivity figure in NCERT (170 billion tonnes/yr biospheric NPP, 2200 g m^{-2} yr^{-1} for rain forest) is dimensionally $[M][L^{-2}][T^{-1}]$. Statements that look like productivity but lack a time dimension are not productivity, however authoritative they sound.

Why this matters. Productivity requires the full dimensional triple $[M][L^{-2}][T^{-1}]$; (a) and (b) leave a dimension unfilled and therefore convey less ecological information than (c).

> **Final Answer:** Only (c) gives a complete productivity ($P = 20$ q acre^{-1} yr^{-1}); (a) and (b) are incomplete statements.

Q 14.2 **Justify the following statement in terms of ecosystem dynamics. "Nature tends to increase the gross primary productivity, while man tends to increase the net primary productivity".**

SOLUTION

Concept used.

- **Gross primary productivity (GPP)**: total rate at which producers fix solar energy into organic biomass, before any losses.
- **Net primary productivity (NPP)**: GPP minus respiratory losses by producers (R):

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

- In a natural climax community, biomass accumulates over decades $\to$ R is high (lots of living tissue to maintain) $\to$ NPP is small even though GPP is large.
- Humans maximise NPP by growing fast-turnover annual crops (low R) that channel most GPP into harvestable yield.

Step 1. In nature, succession proceeds toward a climax with increasingly tall and dense vegetation – forests, coral reefs. Producers capture more sunlight and CO_2, so GPP rises.

Step 2. But the same climax community has huge standing biomass (bark, wood, root systems) requiring continuous respiration to stay alive. R rises in proportion.

Step 3. In a climax: NPP = GPP − R $\approx$ 0, because the system is at steady state.

Step 4. Humans plant annual crops (wheat, rice) instead of climax forest. Annual crops have small standing biomass (low R), intense photosynthesis (high GPP per area), and the harvest is taken before respiration consumes the stored biomass.

Step 5. Result: human-managed agro-ecosystems achieve very high **NPP** (lots of harvestable grain per acre per season), even though their *GPP* per area may be lower than a rain forest's.

Step 6. Numerical illustration. Suppose a rain forest has GPP = 3000 g m^{-2} yr^{-1}, R = 2200 g m^{-2} yr^{-1}:

$$\text{NPP} = 3000 - 2200 = 800 \text{ g m}^{-2} \text{ yr}^{-1}.$$

A wheat field may have GPP = 1500 g m^{-2} yr^{-1}, R = 400 g m^{-2} yr^{-1}:

$$\text{NPP} = 1500 - 400 = 1100 \text{ g m}^{-2} \text{ yr}^{-1}.$$

Higher NPP despite lower GPP.

> **Final Answer:** Nature pushes succession toward climax where GPP is maximal but R is also high, leaving NPP near zero. Humans cultivate fast-turnover annual crops with low standing biomass, so R is small and harvestable NPP is large.

☞ **Exam Tip**

NEET frequently contrasts a forest's high GPP (low NPP) with a crop's lower GPP (high NPP). Anchor on the equation NPP = GPP − R and on which term humans minimise.

EXPERT'S SOLUTION *: Ishita Verma, M.Sc Botany, Delhi University*

Strategic angle. Nature optimises total energy capture (GPP) over decades. Humans optimise per-season harvestable yield (NPP) over months. The two optima look different.

Step 1. Define GPP and NPP via equation NPP = GPP − R.

Step 2. Natural climax: large standing biomass → large R → small NPP despite large GPP.

Step 3. Annual crop: small standing biomass → small R → large NPP despite moderate GPP.

Step 4. Compute example: rain forest NPP = 800 g m^{-2} yr^{-1}; wheat NPP = 1100 g m^{-2} yr^{-1}.

Step 5. Why? Humans select short-lived crops that minimise tissue maintenance cost.

Step 6. Conclusion: nature optimises GPP at climax; humans optimise NPP per season.

Why this matters. The same equation underlies why old- growth forests, despite their majestic GPP, are not particularly "productive" from a harvest standpoint – and why intensive agriculture is justified per unit area.

Why this matters. Nature maximises GPP at climax but spends it all on maintenance respiration; humans cultivate fast-turnover crops that minimise R, so NPP per season is large despite lower GPP.

In one line. Edaphic factors include soil pH, texture, mineral composition, porosity and moisture-holding capacity; together they decide which plant communities a site can support.

> **Final Answer:** Nature builds large GPP in climax (but spends it on R); humans cultivate low-R crops to maximise NPP per season.

Q 14.3 **Which of the following ecosystems will be more productive in terms of primary productivity? Justify your answer.**

A young forest, a natural old forest, a shallow polluted lake, alpine meadow.

SOLUTION

Correct answer: a young forest.

Concept used. Net primary productivity (NPP) measures the rate at which producers store biomass (after their own respiratory losses). The candidate ecosystems differ in standing biomass, nutrient supply, light availability and respiratory load:

Step 1. **Young forest**: rapid growth phase. New leaves and stems add biomass quickly. Standing biomass is still modest, so respiratory load (R) is moderate. Result: high NPP. This is the *rising* part of the succession curve.

Step 2. **Natural old forest (climax)**: huge standing biomass (tall trees, dense canopy). GPP is large but R is almost as large because all that biomass must be maintained. NPP ≈ 0 at steady state.

Step 3. **Shallow polluted lake**: excess nutrients (eutrophication) drive a short algal bloom, but pollutants kill many producers and consumers; oxygen depletion limits decomposition. Sustained NPP is low.

Step 4. **Alpine meadow**: short growing season, low temperature, thin soil. NPP is low.

> **Final Answer:** A young forest has the highest primary productivity. It is in the rapid-growth phase: standing biomass is still modest (low R), but photosynthesis runs at maximum, so NPP = GPP − R is maximal.

♥ **Why This Matters**

This idea links forward to Biodiversity (Ch. 15) and Environmental Issues (Ch. 16); the same producer-consumer-decomposer framework drives both.

EXPERT'S SOLUTION *: Diya Mehta, M.Sc Botany, Delhi University*

Structural observation. Productivity is maximised when GPP is high *and* R is moderate. Only a young forest satisfies both.

Step 1. Old forest: high GPP, equally high R → low NPP.

Step 2. Polluted lake: low GPP (pollutants), high R (decomposition of dead algae) → low NPP.

Step 3. Alpine meadow: low GPP (cold, short season) → low NPP.

Step 4. Young forest: high GPP, moderate R → highest NPP.

Why this matters. The same dimensional discipline (mass per area per time, energy per area per time) catches malformed productivity claims that otherwise look authoritative; reach for the dimensional check whenever a number's units feel off.

Why this matters. A young forest sits in the steep-rise phase of the succession curve:

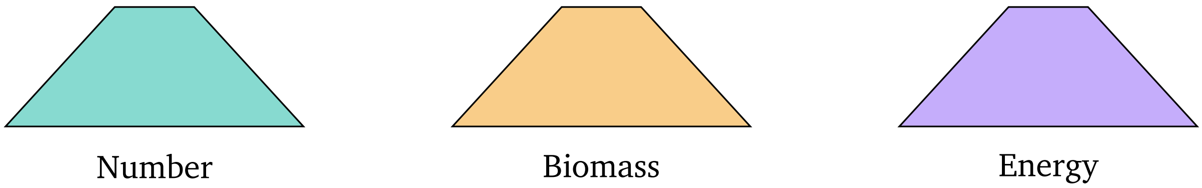
high GPP, still-modest R, so NPP is at its lifetime maximum.

> **Final Answer:** Young forest, because it combines high photosynthetic capacity with still-modest respiratory load.

Q 14.4 **What are the three types of ecological pyramids. What information is conveyed by each pyramid with regard to structure, function and energy in the ecosystem.**

SOLUTION

Concept used. An ecological pyramid represents the trophic structure of an ecosystem graphically, with the producer level at the base and successive consumer levels stacked above. Three types exist, each plotting a different quantity per trophic level.



Step 1. **Pyramid of numbers.** Plots the *number of individuals* at each trophic level. Conveys **structural** information about population sizes. Shape varies: upright in grassland (many grass plants → fewer grasshoppers → fewer frogs → fewer snakes), but inverted in a single-tree parasitic chain (1 tree → many fruit-eating birds → many lice → many bacteria).

Step 2. **Pyramid of biomass.** Plots the standing crop biomass (dry weight) at each trophic level. Conveys information about **biomass distribution** (a functional snapshot of standing matter). Usually upright; inverted in marine ecosystems where phytoplankton biomass is smaller than zooplankton biomass at any instant.

Step 3. **Pyramid of energy.** Plots the rate of energy flow ($\text{kcal}\,\text{m}^{-2}\,\text{yr}^{-1}$) through each trophic level. Conveys **functional / energetic** information. Always upright (2nd law of thermodynamics: each level loses $\sim 90\%$ of energy as heat). This is the most ecologically meaningful pyramid because it cannot invert.

> **Final Answer:** Three pyramids: **numbers** (structure, can invert), **biomass** (standing matter, can invert in marine), and **energy** (functional, always upright by the 2nd law).

♥ **Why this matters**

The pyramid of energy is the only one that always points the same way because the 2nd law of thermodynamics dictates net energy loss at every transfer. Whenever you see an inverted pyramid, it must be number or biomass, never energy.

EXPERT'S SOLUTION *: Sneha Joshi, Ph.D Molecular Biology, NCBS Bangalore*

Structural observation. Three pyramids = three different y-axis variables on the same x-axis (trophic levels).

Step 1. Pyramid of numbers: y = count of individuals; structural; upright in grassland, inverted in tree+parasite chain.

Step 2. Pyramid of biomass: y = dry weight per unit area; standing crop; upright in forests, inverted in oceans.

Step 3. Pyramid of energy: y = energy flow per unit area per unit time; functional; always upright (2nd law of thermodynamics).

Why this matters. A pyramid of energy that pointed downward would violate the 2nd law – it's a useful sanity check on any food-web claim.

Why this matters. Three pyramids = three different y-axes. Numbers (structural, may invert), biomass (standing crop, may invert in oceans), energy (functional, never inverts because of the second law).

In one line. Disturbance scales matter: a forest fire resets to grass-stage; full deforestation can reset to lichens; mining can scrape the substrate back to bare rock (primary-succession start).

> **Final Answer:** Numbers (structure, may invert), biomass (standing crop, may invert in oceans), energy (functional, always upright).

Q 14.5 Write a short note on pyramid of numbers and pyramid of biomass.

SOLUTION

Concept used. The two pyramids are introduced under "ecological pyramids". Each pyramid stacks trophic levels with producers at the base. Their key features:

Step 1. **Pyramid of numbers.** Counts individuals per trophic level.

- In a grassland: many small grass plants form a wide base; fewer grasshoppers above; fewer frogs; fewer snakes at the top. Upright.
- In a single tree (parasitic chain): one tree at the base, but many fruit-eating birds, many more lice on each bird, many more bacteria on each louse.

Inverted.
- Shape depends on relative body sizes and reproductive rates of the organisms in the chain.

Step 2. **Pyramid of biomass.** Stacks the standing dry-mass biomass per unit area per trophic level.

- Forest: tree biomass ≫ deer biomass ≫ tiger biomass. Upright.
- Open ocean: phytoplankton biomass is tiny at any instant (very short turnover); zooplankton and fish biomass is large. Inverted.
- Biomass pyramids depend on standing biomass at a point in time and ignore production rates.

Step 3. Both pyramids can invert – a key contrast with the pyramid of energy, which is always upright.

> **Final Answer:** Pyramid of numbers stacks individuals per level (upright in grassland, inverted in tree+parasite chain); pyramid of biomass stacks dry-mass per area (upright in forests, inverted in oceans).

✗ Common Mistake

A common error is to confuse standing crop (snapshot biomass) with productivity (rate per time); always include time units when productivity is asked.

EXPERT'S SOLUTION *: Tara Patel, M.Sc Zoology, Banaras Hindu University*

Structural observation. Both pyramids are snapshots (numbers, biomass at one instant) so they can invert. Only the pyramid of energy (a rate, not a snapshot) cannot invert.

Step 1. Numbers: y = individuals; upright grassland; inverted tree parasites.

Step 2. Biomass: y = dry mass; upright forest; inverted ocean.

Step 3. Both: snapshots, may invert depending on body size and turnover.

Why this matters. The pioneer-to-climax trajectory is the master narrative of the chapter; once you can name the seral stages and the limiting factor at each step, succession, biodiversity and P/R-ratio questions all reduce to the same picture.
Why this matters. Both pyramids of numbers and biomass are snapshots, so they can flip depending on body size and turnover; only the pyramid of energy — a rate, not a snapshot — is forced upright.

Final Answer: Numbers and biomass pyramids can each be upright or inverted depending on the ecosystem; only the energy pyramid is always upright.

Q 14.6 **Given below is a list of autotrophs and heterotrophs. With your knowledge about food chain, establish various linkages between the organisms on the principle of 'eating and being eaten'. What is this inter-linkage established known as?**

Algae, hydrilla, grasshopper, rat, squirrel, crow, maize plant, deer, rabbit, lizard, wolf, snake, peacock, phytoplankton, crustaceans, whale, tiger, lion, sparrow, duck, crane, cockroach, spider, toad, fish, leopard, elephant, goat, Nymphaea, Spirogyra.

SOLUTION

Concept used. A food chain is a linear "eat and be eaten" sequence from producer to top predator. Multiple food chains crossing at shared species form a food web: the answer to "what is this inter-linkage known as".

Step 1. Identify producers in the list: algae, hydrilla, maize plant, phytoplankton, *Nymphaea*, *Spirogyra*.

Step 2. Identify primary consumers (herbivores): grasshopper, rat, squirrel, deer, rabbit, crustaceans, duck, sparrow (seeds), cockroach (mostly), elephant, goat.

Step 3. Identify secondary consumers (primary carnivores): lizard (insects), toad (insects), spider, sparrow (insects), crow (omnivore), fish (small fish/crustaceans), crane (fish, frogs), snake (rats, frogs).

Step 4. Identify tertiary / top carnivores: wolf, tiger, lion, leopard, whale, peacock (snakes, lizards).

Step 5. Build sample chains (terrestrial):

- maize → grasshopper → lizard → snake → peacock.
- maize → rat → snake → peacock.
- maize → deer → tiger.
- maize → goat → leopard.
- maize → rabbit → wolf.
- maize → squirrel → snake.
- maize → elephant (top herbivore, no predator).
- maize → cockroach → toad → snake.
- maize → sparrow → snake.

Step 6. Aquatic chains:

- phytoplankton → crustaceans → fish → crane.
- phytoplankton → crustaceans → whale (baleen whales).
- algae / *Spirogyra* → crustaceans → fish.
- hydrilla / *Nymphaea* → duck → crane.

Step 7. Cross-linkage: snake appears in many terrestrial chains (eats rat, frog, lizard, sparrow); fish appears in multiple aquatic chains. These shared nodes create a network of intersecting chains.

Step 8. The interconnected network of all these food chains is called a **food web**.

> **Final Answer:** Multiple "eat and be eaten" chains intersect at shared species (snake, fish, sparrow, etc.) to form a network called the **food web**.

♥ Why this matters

A food web is more realistic than a linear chain: it shows that removing one species (e.g. tiger) propagates effects through many paths, while alternative prey gives consumers resilience against the loss of any one prey species.

EXPERT'S SOLUTION *: Pranav Banerjee, M.Sc Zoology, Banaras Hindu University*

Strategic angle. Sort by trophic role first, then connect "who eats whom". Whenever a consumer eats more than one prey or a prey is eaten by more than one consumer, you get a web instead of a chain.

Step 1. Group: producers (algae, hydrilla, maize, phytoplankton, Nymphaea, Spirogyra); herbivores (grasshopper, rat, rabbit, deer, squirrel, crustaceans, duck, elephant, goat, sparrow, cockroach); intermediate carnivores (lizard, toad, spider, fish, sparrow as insectivore, crow, snake); top carnivores (wolf, tiger, lion, leopard, whale, crane, peacock).

Step 2. Draw chains: terrestrial (maize → herbivore → intermediate carnivore → top carnivore), aquatic (phytoplankton → crustaceans → fish → crane / whale).

Step 3. Cross-link at shared species (snake, fish, sparrow).

Step 4. The resulting network = food web.

Why this matters. The food web is the unit on which all ecosystem-level questions (energy flow, productivity, stability) operate. Linear chains are pedagogical simplifications.

Why this matters. Cross-linkage at shared species (snake, fish, sparrow) turns parallel food chains into a food web; removing one species propagates through many paths instead of one.

Final Answer: Multiple intersecting food chains form a **food web**.

Q 14.7 **"The energy flow in the ecosystem follows the second law of thermodynamics." Explain.**

SOLUTION

Concept used. The second law of thermodynamics states that for any spontaneous process the entropy of the universe increases; equivalently, no real process is 100% efficient at converting one form of energy into another – some energy is always degraded into low-grade heat that cannot do useful work.

Step 1. Producers absorb solar radiation: a high-grade, ordered form of energy. Photosynthesis stores some of it as chemical-bond energy in glucose, but $\sim 90\%$ is lost as heat at the leaf surface and during the dark reactions.

Step 2. Herbivores eat producers and assimilate $\sim 10\%$ of the producer's stored energy. The rest is dissipated as heat (respiration), excreted as faeces or lost as uneaten biomass.

Step 3. Carnivores at each successive level repeat the pattern: only $\sim 10\%$ is built into new biomass; $\sim 90\%$ becomes heat.

Step 4. Numerical illustration. Starting with $E_1 = 10^4\ \text{kJ}\,\text{m}^{-2}\,\text{yr}^{-1}$ at producers:

$$E_2 = 0.10 \times 10^4 = 10^3\ \text{kJ},$$
$$E_3 = 0.10 \times 10^3 = 10^2\ \text{kJ},$$
$$E_4 = 0.10 \times 10^2 = 10\ \text{kJ}.$$

Cumulative loss to heat: $10^4 - 10 = 9990$ kJ, i.e. 99.9% of the original producer energy is gone after just three transfers.

Step 5. The heat radiates away to space and cannot be re-used. Producers must keep capturing fresh solar input.

Step 6. This irreversible degradation of usable energy to heat at every transfer is exactly the 2nd law in action.

Final Answer: At every trophic transfer $\sim 90\%$ of incoming energy is dissipated as heat (respiration), so usable energy degrades irreversibly down the chain. This pattern is a direct consequence of the second law of thermodynamics, which forbids 100% conversion of one energy form to another.

✗ Common Mistake

Do not say energy is “destroyed” at each level. Energy is *conserved* (1st law); only the form changes – usable chemical energy degrades to low-grade heat. “Lost” in ecology means “converted to heat that the ecosystem cannot reuse”.

EXPERT’S SOLUTION *: Aanya Chatterjee, Ph.D Physics, IISc Bangalore*

Strategic angle. The 2nd law has two equivalent statements: (a) entropy of an isolated system can only increase; (b) no real process is 100% efficient. Ecological energy transfer fits version (b) precisely.

Step 1. Producers fix solar energy: efficiency ~ 1–2%. Rest = heat.

Step 2. Herbivores assimilate producer energy: efficiency $\sim 10\%$. Rest = heat (respiration), faeces.

Step 3. Carnivores assimilate herbivore energy: efficiency $\sim 10\%$. Rest = heat.

Step 4. Compute cumulative: after n transfers, $E_n/E_1 = (0.10)^{n-1}$.

Step 5. For $n = 4$: $E_4/E_1 = 10^{-3}$, so 99.9% of original energy has degraded to heat.

Step 6. All heat dissipates to space; cannot be reused. Net effect: unidirectional energy flow.

Step 7. This irreversible degradation is the 2nd law.

Why this matters. The 2nd law is what forbids perpetual motion in physics and what forces ecosystems to depend continuously on fresh solar input. Same law, two different domains.

Why this matters. The 2nd law forbids 100% energy conversion; in ecosystems the inefficiency surfaces as ∼90% heat loss per trophic transfer, capping food chains at 4–5 levels.

> **Final Answer:** The $\sim 90\%$ per-transfer loss as heat at every trophic level mirrors the 2nd law’s requirement that energy conversions degrade usable energy to heat; energy thus flows one-way through the ecosystem.

Q 14.8 **What will happen to an ecosystem if:**

(a) All producers are removed;

(b) All organisms of herbivore level are eliminated; and

(c) All top carnivore population is removed.

SOLUTION

Concept used. Each trophic level plays a specific role. Removing one level disrupts energy flow and population dynamics in predictable ways.

Step 1. **(a) All producers removed.** Producers are the *only* entry point for solar energy into the ecosystem. Without producers:

- No CO_2-to-biomass conversion: no new chemical energy enters the system.
- Herbivores starve within days/weeks; their populations collapse.
- Carnivores collapse next as their prey disappears.
- Decomposers finish the existing dead matter and then starve themselves.
- Net result: the entire ecosystem **collapses** within a few weeks/months.

Step 2. **(b) All herbivores eliminated.** The grazing food chain breaks at T2.

- Producers grow unchecked: vegetation density rises; some plant species (those favoured by grazing-induced disturbance) decline.
- Carnivores that fed on herbivores starve.
- Detritus food chain becomes the dominant route; decomposers handle the un-eaten producer biomass.
- Net: grazing chain collapses; producer biomass and detritus chain inflate.

Step 3. **(c) Top carnivores removed.** Trophic cascade.

- Mesopredators (smaller carnivores) and herbivores multiply unchecked because their predator is gone.
- Herbivores overgraze producers, lowering plant biomass.
- Plant community shifts toward grazing-resistant species; biodiversity drops.
- Ecosystem destabilises but typically does not collapse fully (cf. Yellowstone wolf removal example).

> **Final Answer:** (a) Removing producers collapses the entire ecosystem (no energy entry). (b) Removing herbivores breaks the grazing chain, inflating producer biomass and shifting energy to the detritus chain. (c) Removing top carnivores triggers a trophic cascade: herbivore population booms, overgrazing reduces producer biomass and biodiversity.

☞ **Exam Tip**

NEET frequently asks “effect of removing top predator”. The correct answer is always “trophic cascade”. The cascade can propagate down many levels; tigers protect not just deer but the plants the deer would overgraze.

EXPERT'S SOLUTION : *Vivaan Pillai, M.Sc Zoology, Banaras Hindu University*

Strategic angle. Producers are non-redundant (only entry of energy); other levels are redundant in principle but their removal still triggers downstream chaos.

Step 1. (a) Producer removal:

- Energy entry = 0.
- Herbivores starve; carnivores starve next; decomposers consume residual biomass.
- Ecosystem collapses.

Step 2. (b) Herbivore removal:

- Producer biomass grows.
- Carnivores starve.
- Detritus chain expands to handle dead producer biomass.

Step 3. (c) Top carnivore removal:

- Herbivore population booms.
- Overgrazing reduces producer biomass.
- Biodiversity drops; ecosystem destabilises but survives.

Step 4. Note: producers are uniquely non-redundant because they are the only autotrophic energy entry point.

Why this matters. The asymmetry across the three cases explains why conservation focuses heavily on (a) habitat preservation (producers) and (c) apex predators (keystone species), while (b) loss of herbivores is more often a *symptom* of habitat loss than the primary cause.

> **Final Answer:** (a) Total collapse; (b) producer biomass inflates, carnivores starve, detritus chain dominates; (c) trophic cascade – herbivore boom, overgrazing, biodiversity loss.

Q 14.9 **Give two examples of artificial or man made ecosystems. List the salient features by which they differ from natural ecosystems.**

SOLUTION

Concept used. An **artificial (man-made) ecosystem** is one set up and maintained by humans for a particular purpose (food production, recreation, ornamentation). It depends on continuous external inputs of energy and matter and lacks the self-regulation of natural ecosystems.

Step 1. **Examples**:

- **Agricultural cropland** (rice paddy, wheat field, orchard).
- **Aquarium** (home or laboratory).

Other valid examples: gardens, dams/reservoirs, pisciculture ponds, urban parks.

Step 2. **Salient differences**:

- *Species diversity*: natural ecosystems have hundreds of species; man-made ecosystems are typically monocultures (one crop or one fish species).
- *Self-sustainability*: natural ecosystems generate their own energy (sunlight via producers) and recycle nutrients internally. Artificial ecosystems depend on external inputs (fertilizers, pesticides, irrigation, fish food, electricity).
- *Stability / resilience*: natural ecosystems buffer environmental fluctuations through species redundancy. Artificial ecosystems are fragile – a single pest or disease can wipe out a monoculture.
- *Genetic diversity*: natural ecosystems have wild species with high genetic variability; artificial ones use selectively-bred high-yield varieties with low genetic diversity.
- *Productivity pattern*: natural ecosystems have high GPP but low net export (most NPP cycles internally). Artificial ecosystems are designed for high *net export* (harvest).
- *Succession*: natural ecosystems progress toward climax. Artificial ones are held in an early seral stage by continuous human intervention (ploughing, weeding).
- *Energy flow*: natural ecosystems depend only on solar energy. Artificial ones receive an additional energy subsidy (fossil-fuel inputs for machinery, fertilizer manufacture, water pumping).

> **Final Answer:** Examples: agricultural cropland and aquarium. They differ from natural ecosystems in low species/genetic diversity, lack of self-sustainability, need for external inputs (fertilizers, food, irrigation), high net export of biomass, and absence of succession (held in early seral stage by management).

☞ Exam Tip

For terminology MCQs, work from etymology: Greek/Latin roots usually decide the answer faster than memorisation.

EXPERT'S SOLUTION *: Karan Singh, M.Sc Botany, Delhi University*

Structural observation. Artificial ecosystems trade off self-sustainability for high net export. The trade-off is inescapable.

Step 1. Pick two examples: cropland, aquarium.

Step 2. Contrast on: species diversity, self-sustainability, stability, succession arrest, net export, energy subsidy.

Step 3. Conclude: artificial ecosystems are simpler, less stable, more productive in harvest terms, but cannot survive without continuous human input.

Why this matters. Modern agriculture feeds 8 billion people because we have learned to push artificial ecosystems to very high NPP via energy and nutrient subsidies. The cost is loss of self-sustainability – a fragility that conservation biology tries to mitigate by restoring crop diversity.

Why this matters. Artificial ecosystems trade self-regulation for high net export: monocultures with external subsidies (fertiliser, water, fish food) feed the planet but stay fragile.

In one line. Forest stratification is also functional: each layer hosts its own specialist fauna — canopy birds, shrub-layer insects, forest-floor decomposers — adding richness to the food web.

> **Final Answer:** Cropland and aquarium: low diversity, no self-regulation, external subsidies required, high harvest export, no natural succession.

Q 14.10 **The biodiversity increases when one moves from the pioneer to the climax stage. What could be the explanation?**

SOLUTION

Concept used. During succession, the community starts with a few pioneer species adapted to harsh, undeveloped substrate and progresses through several seral stages, accumulating species diversity until the climax is reached. The increase happens because of habitat development, niche differentiation and positive feedbacks among species.

Step 1. **Pioneer stage**: very few species (often just lichens or grasses) can tolerate the extreme conditions of bare rock, sand or open water. Habitat is one-dimensional; few niches exist.

Step 2. **Habitat amelioration**: pioneers modify the environment – lichens form soil from rock, mosses retain water, grasses add organic matter. More moderate conditions open the habitat to less hardy species.

Step 3. **Niche differentiation**: as soil deepens and vegetation stratifies vertically (ground, herb, shrub, canopy), spatial heterogeneity increases. Each layer provides distinct niches for different species (canopy birds, shrub layer insects, ground beetles, soil organisms).

Step 4. **Mutualisms and food-web complexity**: established plants attract pollinators, frugivores and seed dispersers. These animals bring more plant species. Predators arrive once prey is dense enough to support them. The food web widens at every step.

Step 5. **Microclimate buffering**: at climax (e.g. tropical rain forest), the canopy buffers temperature and humidity, creating shaded, moist microhabitats that support shade- tolerant herbs, ferns, epiphytes and a rich invertebrate fauna.

Step 6. **Genetic and structural diversity feedback**: more species → more interaction types → more selection pressures → more specialised species. Diversity begets diversity until limited by area, climate or nutrient availability.

Step 7. Net result: species count, genetic variability, structural complexity and food-web complexity all peak at climax.

> **Final Answer:** From pioneer to climax, habitat amelioration, niche differentiation, food-web complexity and microclimate buffering progressively widen the range of conditions and resources available, allowing many more specialised species to coexist.

♥ Why This Matters

Energy flow questions and nutrient cycle questions share the same diagram in NCERT (Fig. 14.5); revising one diagram answers both.

EXPERT'S SOLUTION *: Aditi Joshi, M.Sc Botany, Delhi University*

Structural observation. Diversity rises because each successional stage adds new niches that the previous stage lacked. The cumulative result is many coexisting species at climax.

Step 1. Pioneer: harsh substrate, one or two specialist species.

Step 2. Habitat amelioration: pioneers improve substrate (soil, moisture).

Step 3. More species can now invade because tolerable conditions widen.

Step 4. Vertical stratification adds new spatial niches.

Step 5. Food-web richness adds new interaction-based niches.

Step 6. Microclimate buffering at climax adds shaded, humid niches.

Step 7. Diversity accumulates at every step, reaching maximum at climax.

Why this matters. The climax-diversity correlation is why protecting climax communities (old-growth forests, coral reefs) is the most effective conservation strategy per unit area.

Why this matters. Succession adds niches at every step — habitat amelioration, vertical stratification, food-web complexity, microclimate buffering — so biodiversity peaks at climax.

In one line. Pre-existing soil also retains a viable seed bank and fungal mycelial network; pioneers do not have to wait for spores to arrive on the wind.

> **Final Answer:** Habitat amelioration, niche differentiation and food-web complexity at each successional stage cumulatively raise biodiversity to its maximum at climax.

Q 14.11 **What is a biogeochemical cycle. What is the role of the reservoir in a biogeochemical cycle. Give an example of a sedimentary cycle with reservoir located in earth's crust.**

SOLUTION

Concept used. A **biogeochemical cycle** is the movement of an element through biological (bio), geological (geo) and chemical compartments of the biosphere. Each cycle has one or more **reservoirs** – large, slowly-cycling stores of the element – that buffer the cycle against rapid changes in the active pool. Sedimentary cycles (P, S, Ca) have reservoirs in the Earth's crust; gaseous cycles (C, N, O, H_2O) have atmospheric reservoirs.

Step 1. **Definition.** A biogeochemical cycle is the cyclic movement of bio-essential elements between living organisms and the abiotic environment.

Step 2. **Two types.**

- *Gaseous cycles*: reservoir in the atmosphere (carbon, nitrogen, oxygen, water).
- *Sedimentary cycles*: reservoir in the lithosphere (phosphorus, sulphur, calcium).

Step 3. **Role of reservoir.** The reservoir:

- *Buffers* the cycle: when the active pool is drawn down by uptake, the reservoir slowly releases more of the element; when the active pool surges (e.g. deforestation releases CO_2), the reservoir absorbs the excess.

- *Stabilises* long-term concentration: over geological timescales, the reservoir keeps the cycle near steady state.
- *Stores* the bulk of the element on Earth: e.g. 99% of crustal phosphorus is in rocks, only $\sim 1\%$ is in the active pool.

Step 4. Example of a sedimentary cycle: the phosphorus cycle.

- Reservoir: phosphate-bearing rocks in the Earth's crust (apatite, $Ca_5(PO_4)_3(F, Cl, OH)$).
- Weathering of rock releases PO_4^{3-} ions into soil solution.
- Plants absorb PO_4^{3-} via roots; build it into nucleic acids, ATP, phospholipids and bones.
- Phosphorus moves up the food chain through herbivores and carnivores.
- Death and excretion return P to the soil through decomposers, which mineralise organic P to inorganic PO_4^{3-}.
- Some P is carried by runoff to oceans where it settles as marine sediment, eventually lithified back into rock. Geological uplift may expose these rocks for re-weathering.
- No significant gaseous form of phosphorus exists, so the cycle is entirely sedimentary.

> **Final Answer:** A biogeochemical cycle is the cyclic movement of an element through biotic and abiotic compartments. The reservoir buffers and stabilises the cycle by absorbing surpluses and releasing during shortages. **Phosphorus cycle** is a sedimentary cycle with the reservoir in phosphate rocks of the Earth's crust.

✗ Common Mistake

Do not assume "most productive" always means highest per-area NPP; check whether the question asks per area or in total.

EXPERT'S SOLUTION : *Sneha Reddy, Ph.D Organic Chemistry, IISc Bangalore*

Strategic angle. Three concepts in one question – definition, reservoir role, and a sedimentary-cycle example. Address each separately, then close with the phosphorus cycle walk-through.

Step 1. Definition: cyclic movement of element through bio + geo + chemical compartments.

Step 2. Reservoir = large slow store that buffers the active pool; gaseous cycles store in atmosphere, sedimentary cycles in crust.

Step 3. Sedimentary example: phosphorus.

Step 4. Phosphorus cycle path:

- Rock (apatite) → weathering → PO_4^{3-} in soil.
- Soil → plants (nucleic acids, ATP) → animals (bones, ATP).
- Animals/plants die → decomposers mineralise P back to PO_4^{3-}.
- Runoff → ocean → marine sediment → eventually back to rock via lithification.

Step 5. No gaseous phase of P → purely sedimentary cycle.

Why this matters. The phosphorus reservoir is finite; modern agriculture mines apatite at rates far exceeding the geological resupply (uplift, weathering). Sustainable agriculture depends on closing the P loop (manure, compost) instead of relying on rock-mined fertilizer alone.

Why this matters. Sedimentary cycles store the bulk of the element in rock (e.g. 99% of crustal P sits in apatite); the reservoir buffers the active pool against sudden swings.

In one line. Natural forests, grasslands and coral reefs are textbook self-sustaining systems; managed crops and ornamental ponds are not.

> **Final Answer:** Biogeochemical cycle = elemental cycling through bio + geo + chemical compartments. Reservoir buffers the active pool. Phosphorus cycle is the canonical sedimentary example: reservoir in apatite rock, with no gaseous phase.

Q 14.12 **What will be the P/R ratio of a climax community and a pioneer community. What explanation could you offer for the changes seen in P/R ratio of a pioneer community and the climax community.**

SOLUTION

Concept used. The **P/R ratio** is the ratio of gross primary production (P) to community respiration (R). It is a quick indicator of where an ecosystem sits in successional time:

- Pioneer community: $P/R > 1$ (production exceeds respiration; biomass accumulates).
- Climax community: $P/R \approx 1$ (production equals respiration; biomass at steady state).
- Polluted / heterotrophic system: $P/R < 1$ (respiration exceeds production; biomass declines).

Step 1. **Pioneer community ($P/R > 1$).** Standing biomass is small; few organisms means R is small. Producers are actively growing on new substrate, fixing more energy than the community needs for maintenance. Net biomass accumulates at every cycle.

Step 2. Numerical illustration. If pioneer producers fix $P = 1500\ \mathrm{g\,m^{-2}\,yr^{-1}}$ and the community respires $R = 800\ \mathrm{g\,m^{-2}\,yr^{-1}}$:

$$P/R = 1500/800 = 1.88.$$

Net biomass accumulated: $P - R = 700\ \mathrm{g\,m^{-2}\,yr^{-1}}$.

Step 3. **Climax community ($P/R \approx 1$).** Standing biomass is large (mature trees, dense canopy); R rises in proportion because every gram of living tissue needs continuous maintenance. Producers cannot indefinitely outpace this maintenance cost, so P and R approach equality at steady state.

Step 4. Numerical illustration. If climax producers fix $P = 3000\ \mathrm{g\,m^{-2}\,yr^{-1}}$ and the community respires $R = 2900\ \mathrm{g\,m^{-2}\,yr^{-1}}$:

$$P/R = 3000/2900 = 1.03.$$

Net biomass accumulated: $P - R = 100\ \mathrm{g\,m^{-2}\,yr^{-1}}$, approaching zero at full climax.

Step 5. **Explanation of the trend.** As succession proceeds:

- Standing biomass climbs (small pioneer plants $\rightarrow$ tall mature trees).
- Respiration cost climbs in proportion to biomass.
- Producer photosynthesis approaches a ceiling set by light, nutrients, water.
- P grows more slowly than R; the ratio falls toward 1.
- At climax, P and R balance and the ecosystem accumulates no net biomass: it is in steady state.

Step 6. **Why this matters for management.** A polluted lake often has $P/R < 1$ (oxygen depleted, decomposers dominate); a healthy young forest has $P/R \gg 1$ (biomass accumulating). Tracking P/R lets ecologists diagnose ecosystem health.

Final Answer: Pioneer community: $P/R > 1$ (biomass accumulating). Climax community: $P/R \approx 1$ (steady state). The trend toward 1 reflects rising respiratory cost as standing biomass grows, until P just covers R.

♥ Why this matters

The P/R ratio is the operational test of whether an ecosystem is growing, stable or declining. Conservation biologists use it to diagnose recovery in restored wetlands and reforested plots.

EXPERT'S SOLUTION : *Ananya Patel, M.Sc Botany, Delhi University*

Strategic angle. Three sub-questions: pioneer P/R, climax P/R, and the trend. The trend follows from rising standing biomass.

Step 1. Pioneer: low biomass ⇒ low R ⇒ P outpaces R ⇒ $P/R > 1$.

Step 2. Numerical: $P/R = 1500/800 = 1.88$ (illustrative).

Step 3. Net accumulation: 700 g m^{-2} yr^{-1}.

Step 4. Climax: high biomass ⇒ high R ⇒ P and R balance ⇒ $P/R \approx 1$.

Step 5. Numerical: $P/R = 3000/2900 = 1.03$.

Step 6. Net accumulation: ≈ 100 g m^{-2} yr^{-1}, approaching zero.

Step 7. Trend explanation: standing biomass rises with succession; R rises in proportion; P approaches an upper ceiling; ratio $\to$ 1.

Step 8. Implication: a climax community is not "unproductive"; it just uses all of its production internally for maintenance.

Why this matters. The P/R-to-1 trend is the quantitative definition of climax: "the seral stage at which P equals R". This is a sharper definition than "the community stays the same over time", and it lets ecologists test for climax in the field.

Why this matters. P/R>1 in pioneer (biomass accumulating); P/R≈1 in climax (steady state). The trend toward 1 reflects rising respiratory cost as standing biomass grows.

In one line. By T5 only 0.01% of producer energy remains — insufficient to sustain any viable predator population; this is why marine apex predators (orcas, sharks) sit at most at T4–T5 and need enormous prey biomass.

> **Final Answer:** Pioneer $P/R > 1$ (biomass accumulating); climax $P/R \approx 1$ (steady state). Cause: rising standing biomass forces R upward until it equals P.

Key Takeaways

- An ecosystem has four functional components – producers, consumers, decomposers and abiotic environment – linked by energy flow (one-way) and nutrient cycling (cyclic).
- NPP = GPP − R. Tropical rain forests have the highest per-area NPP (~ 2200 g m^{-2} yr^{-1}); deserts and open oceans are lowest.
- Lindemann's 10% law: only $\sim 10\%$ of energy at one trophic level is built into the next as new biomass; this caps food chains at 4–5 levels.
- Three ecological pyramids: numbers, biomass, energy. The first two can invert; the pyramid of energy is always upright (2nd law of thermodynamics).
- Decomposition = fragmentation $\to$ leaching $\to$ catabolism $\to$ humification $\to$ mineralisation; fastest in warm, moist, aerobic, near-neutral pH soils.

- Succession is orderly and directional: primary succession starts on bare substrate (1000+ years); secondary succession starts on disturbed soil (50–200 years).
- P/R ratio: pioneer > 1 (accumulating); climax ≈ 1 (steady state).
- Two cycle types: gaseous cycles (C, N, O, H_2O) have atmospheric reservoirs; sedimentary cycles (P, S, Ca) have crustal reservoirs.
- Ecosystem services include nutrient cycling, soil-erosion prevention, climate regulation and pollutant absorption.

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