

Nutrient cycles and populations

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Read first: [Energy flow, food chains and food webs](#), [Plant nutrition](#), [Respiration](#)

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What you need to know

This topic follows two elements, carbon and nitrogen, as they are passed round and round between the air, the soil and living things, and then looks at how the number of organisms in a population changes over time. It comes up on every paper: one-mark multiple-choice questions on Papers 1 and 2 (usually two or three per paper), and parts of longer questions on Papers 3 and 4, often a carbon cycle diagram, a nitrogen cycle diagram or a growth curve for bacteria or yeast. Outcomes marked **Extended only** are tested on Papers 2 and 4 only. By the end of this topic you should be able to:

Nutrient cycles

1. Describe the **carbon cycle** using six processes: **photosynthesis**, **respiration**, **feeding**, **decomposition**, **formation of fossil fuels** and **combustion**.
2. **Extended only**: describe the **nitrogen cycle**: decomposition of plant and animal protein to **ammonium ions**; **nitrification**; **nitrogen fixation** by **lightning** and by **bacteria**; **absorption of nitrate ions** by plants; the **production of amino acids and proteins**; **feeding and digestion** of proteins; **deamination**; and **denitrification**.
3. **Extended only**: state what **microorganisms** do in the nitrogen cycle: **decomposition**, **nitrification**, **nitrogen fixation** and **denitrification**. (You don't need the names of particular bacteria.)

Populations

4. Describe a **population**, a **community** and an **ecosystem**.
5. Identify and state the factors that affect how fast a population grows: **food supply**, **competition**, **predation** and **disease**.
6. Identify the **lag**, **exponential (log)**, **stationary** and **death** phases of the **sigmoid curve** of population growth, for a population growing where resources are limited.
7. Interpret graphs and diagrams of population growth.
8. **Extended only**: explain what causes each phase of the sigmoid curve, using the idea of **limiting factors** where it fits.

Exam questions on the carbon cycle often go on to ask how burning fossil fuels and cutting down forests change the carbon dioxide in the air. That link is part of Human influences on ecosystems; "How to do it" gives the points you need.

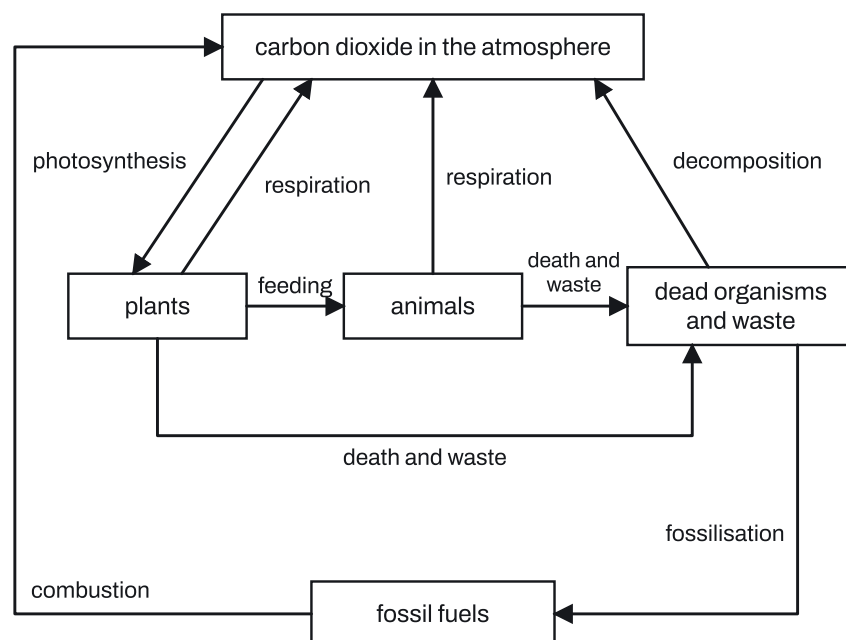
Understand it

Why elements have to be recycled

Living things are built from a handful of elements. Carbon is in every carbohydrate, fat and protein; nitrogen is in every amino acid, protein and DNA molecule. The Earth doesn't get new supplies of these elements, so the same atoms have to be used again and again. When an organism dies, its body is broken down and the elements go back into the air or the soil, where plants can take them up once more. The paths the atoms follow are the **nutrient cycles**.

The carbon cycle

Carbon moves between **carbon dioxide in the atmosphere** (about **0.04%** of the air) and the **carbon compounds** in living things, dead remains and fossil fuels.



The six processes, and what each one does to the carbon:

Process	Carbon moves from	to	Carbon dioxide in the air
photosynthesis	the atmosphere	plants (glucose, then starch, cellulose, proteins, fats)	removed
respiration	plants, animals and decomposers	the atmosphere	added
feeding	plants (or animals)	the animals that eat them	no change
decomposition	dead organisms and waste	the atmosphere (decomposers respire)	added

Process	Carbon moves from	to	Carbon dioxide in the air
formation of fossil fuels	dead organisms	coal, oil and natural gas	no change
combustion	fossil fuels (and wood)	the atmosphere	added

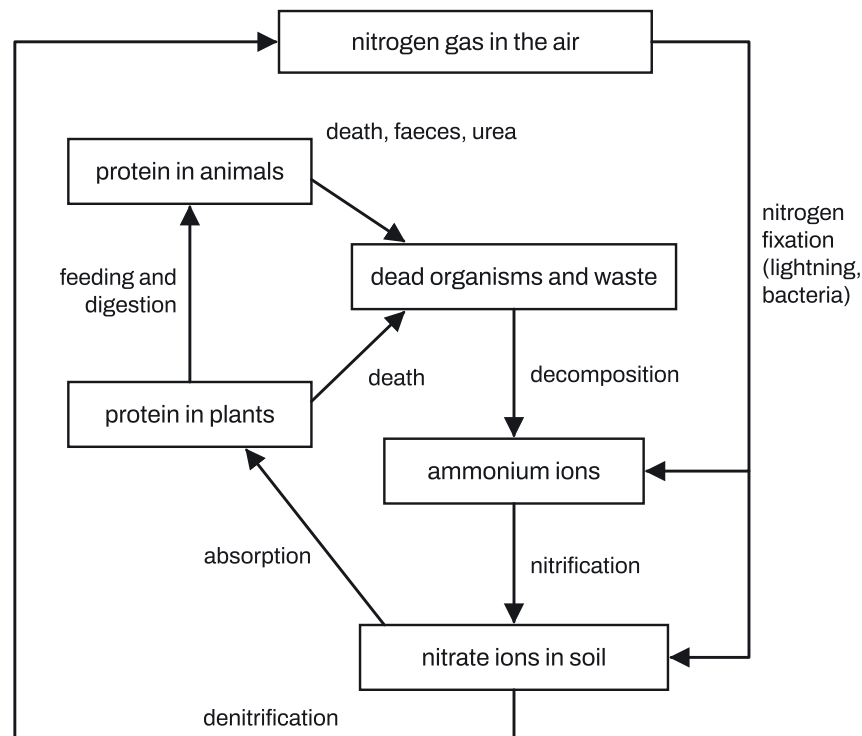
A few things are worth seeing clearly:

- **Photosynthesis is the only process that takes carbon dioxide out of the air.** Three processes put it back: **respiration**, **decomposition** and **combustion**. Feeding and fossil fuel formation move carbon between compounds without touching the air.
- **Plants do both.** A plant respire all the time, day and night, giving out carbon dioxide. In the light it also photosynthesises, faster than it respire, so overall it takes carbon dioxide in and gives oxygen out. In the dark it only respire, so it gives carbon dioxide out and takes oxygen in. A plant's carbon cycle diagram has **two** arrows between the plant and the air, one each way.
- **Decomposition** is done by **decomposers** (bacteria and fungi). They feed on dead organisms, faeces and other waste and **respire**, so the carbon goes back to the air as carbon dioxide. That is why mark schemes accept "decomposition" or "respiration" for this arrow.
- **Fossil fuels** form when dead organisms are buried before they can decompose and are squashed and heated over millions of years into coal, oil and natural gas. The carbon in them was taken from the air by photosynthesis long ago. **Combustion** (burning) releases it as carbon dioxide in a few moments.

Energy flows through an ecosystem in one direction and is lost as heat; carbon, by contrast, goes round a cycle and is used again.

The nitrogen cycle

Extended only. Air is about 78% nitrogen gas (N_2), but plants and animals can't use it: the two atoms are held together too strongly. Plants take their nitrogen from the soil as **nitrate ions** (NO_3^-), and animals get theirs by eating plants or other animals. Most of the steps that turn one form of nitrogen into another are done by **bacteria**.



Follow a nitrogen atom round the cycle:

1. **Absorption by plants.** Root hair cells take in **nitrate ions** from the soil by **active transport** (the soil usually has fewer nitrate ions than the root, so energy from respiration is needed).
2. **Making amino acids and proteins.** The plant joins the nitrogen from the nitrate to sugars made in photosynthesis to make **amino acids**, then joins amino acids to make **proteins** (for enzymes, membranes and growth). Using absorbed substances to build the body like this is called **assimilation**.
3. **Feeding and digestion.** An animal eats the plant. **Proteases** digest the protein to **amino acids**, which are absorbed and built into the animal's own proteins.
4. **Deamination.** The animal can't store spare amino acids. In the **liver**, the **nitrogen-containing part** of each surplus amino acid is removed and turned into **urea**, which the kidneys excrete in urine.
5. **Decomposition.** When plants and animals die, and when animals produce faeces and urine, **decomposers** (bacteria and fungi) break down the protein, amino acids and urea, releasing **ammonium ions** (NH_4^+) into the soil.
6. **Nitrification.** **Nitrifying bacteria** in the soil turn **ammonium ions** into **nitrite ions** (NO_2^-) and then into **nitrate ions**, which plants can absorb again. They need oxygen, so this happens in well-aired soil.
7. **Denitrification.** **Denitrifying bacteria** turn **nitrate ions** back into **nitrogen gas**, which goes into the air. They thrive where there is little oxygen, in **waterlogged** (flooded) soil, so such soils lose nitrates.
8. **Nitrogen fixation.** Turning nitrogen gas into compounds that living things can use. It happens in two ways:
 - **lightning:** the energy of a lightning flash makes nitrogen and oxygen combine; the rain washes the products into the soil as **nitrate ions**;
 - **nitrogen-fixing bacteria:** some live free in the soil and some live in **root nodules** of plants such as peas and beans (legumes). They turn nitrogen gas into **ammonium** compounds; the bean plant uses these to make amino acids, so it needs less nitrate from the soil.

So the microorganisms have four jobs: **decomposition** (protein → ammonium), **nitrification** (ammonium → nitrate), **nitrogen fixation** (nitrogen gas → ammonium) and **denitrification** (nitrate → nitrogen gas). Only denitrification returns nitrogen to the air; only fixation (by bacteria or lightning) takes it out.

Populations, communities and ecosystems

- A **population** is a group of organisms of **one species**, living in the **same area**, at the **same time**. All the zebras in one national park this year are a population. "All the birds in a forest" is not (many species), and "all the zebras that have ever lived in Africa" is not (different times).
- A **community** is **all the populations of different species** in an ecosystem: the zebras, lions, grasses, acacia trees, dung beetles and bacteria in that park.
- An **ecosystem** is a **unit** containing the **community of organisms and their environment, interacting together**: the community **plus** the soil, water, air, temperature and light. A pond, a forest or a coral reef is an ecosystem.

What makes a population grow or shrink

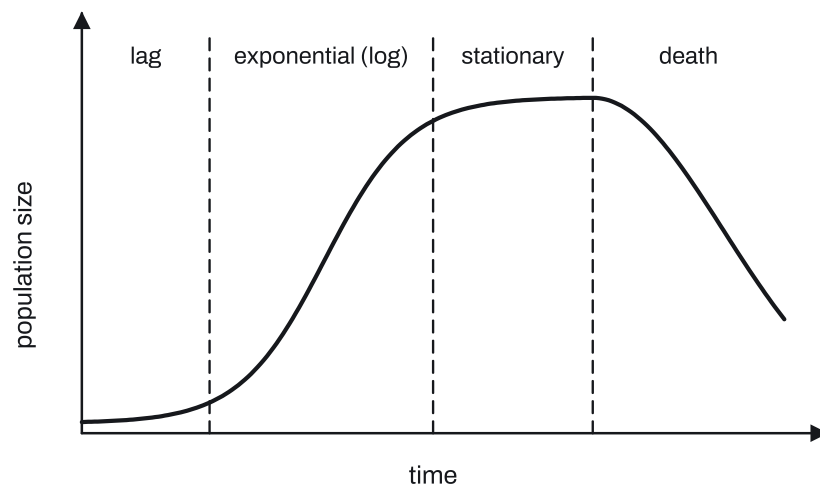
A population grows when more individuals are **born** (or arrive) than **die** (or leave). Four factors decide how fast:

- **food supply**: more food means more individuals survive and breed;
- **competition**: individuals compete for food, water, space, light (plants), mates and nesting sites; more competition means fewer survive;
- **predation**: more predators (or more hunting and fishing) means more are killed;
- **disease**: a disease that spreads through the population raises the death rate.

A factor that stops the population growing any faster because it is in short supply is called a **limiting factor**.

The sigmoid growth curve

Put a few bacteria or yeast cells into a flask of nutrient solution, or let a new species arrive on an island, and count them over time. The graph of numbers against time is S-shaped: this is the **sigmoid curve**. In a closed container, where the food runs out and waste builds up, it ends with a fall.



Phase	What the curve does	Births and deaths
lag	low and almost flat	births only just more than deaths
exponential (log)	rises steeply; numbers double in equal times	births much more than deaths
stationary	high and flat	births equal deaths
death	falls	deaths more than births

Extended only: why each phase happens.

- **Lag phase.** There are only **a few individuals** to reproduce, and they are **adjusting** to their new surroundings (bacteria and yeast make the enzymes they need to use the new food; animals find mates and nest sites) before they breed. So numbers rise slowly.
- **Exponential (log) phase.** Resources are **plentiful**: lots of food, oxygen and space, little **competition**, and few predators or diseases. Every individual can reproduce, so the birth rate is far above the death rate and numbers double again and again.
- **Stationary phase.** A resource becomes a **limiting factor**: food (nutrients), oxygen or space runs short, so **competition** rises. Toxic waste starts to build up, and predators and disease increase as the population gets crowded. The birth rate falls until it **equals** the death rate, so the number stays level: this is the most the environment can support.
- **Death phase.** In a closed flask or fermenter, the **nutrients run out** and **toxic waste** (such as carbon dioxide, alcohol from yeast, or acids that lower the pH) builds up. The death rate is now **higher** than the birth rate, so numbers fall. In the wild, a death phase can be caused by a new disease or predator, overhunting, pollution or losing the habitat.

The **human** population of the world is growing **exponentially**. Its graph shows a long **lag** phase (for most of history) followed by the **exponential** phase over the last few hundred years; it has **not** reached a stationary or death phase.

Key facts and formulas

"Learn it" means you must remember it: the exam gives no formulas for this topic.

Formula	Status
Carbon dioxide is removed from the air only by photosynthesis; it is added by respiration, decomposition and combustion	Learn it
Carbon dioxide is about 0.04% of the air	Learn it
Extended only: decomposition: protein, amino acids, urea → ammonium ions	Learn it
Extended only: nitrification: ammonium ions → nitrite ions → nitrate ions	Learn it
Extended only: denitrification: nitrate ions → nitrogen gas	Learn it
Extended only: nitrogen fixation: nitrogen gas → ammonium or nitrate, by lightning or bacteria	Learn it
Extended only: deamination: removal of the nitrogen-containing part of amino acids to make urea, in the liver	Learn it
Population: one species, same area, same time. Community: all the populations in an ecosystem. Ecosystem: community + environment, interacting	Learn it
Sigmoid curve phases, in order: lag, exponential (log), stationary, death	Learn it
Percentage change = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$	Learn it
One cell dividing n times gives 2^n cells; the increase is $2^n - 1$	Learn it

How to do it

We tagged 121 questions for this topic (2021–2025, Papers 1–4; 10 are the same question on two or more papers). 120 of them fall into the types below, and 20 of those mix types, so the counts add up to 144. The last one, [0610/12/O/N/25 Q33](#), asks for a pyramid of numbers: that belongs to Energy flow, food chains and food webs, so practise it with that note.

Question type	Questions
Carbon cycle processes	34
Nitrogen cycle processes and bacteria	26

Question type	Questions
Phases of the sigmoid growth curve	23
Population, community and ecosystem	19
Explaining population changes	16
Human activities and carbon dioxide	12
Recycling the nitrogen in protein	7
Population calculations from data	7

1. Carbon cycle processes (34 questions)

- Read every box** on the diagram and decide what kind of carbon it holds: carbon dioxide in the air, carbon compounds in plants, animals, dead organisms (or decomposers) or fossil fuels.
- Name each arrow from where it starts and where it ends**, using the table in "Understand it":
 - air → plants: **photosynthesis**;
 - plants, animals or decomposers → air: **respiration**;
 - plants → animals (or animal → animal): **feeding**;
 - plants or animals → dead organisms: **death** (and for animals, egestion and excretion of waste);
 - dead organisms → air: **decomposition** (respiration by decomposers is also accepted);
 - dead organisms → fossil fuels: **formation of fossil fuels** (fossilisation);
 - fossil fuels → air: **combustion**.
- Use the exact name. Write **combustion**, not "burning"; **respiration**, not "breathing" or "exhaling"; **feeding**, not "digestion" or "predation".

Variations you will meet:

- "Which processes release carbon dioxide?"** Respiration, decomposition and combustion: **three**. **"Which remove it?"** Photosynthesis only. Feeding and fossilisation do neither.
- Draw an arrow** for respiration in plants (from the plant box **to** the air) or for herbivores feeding (from the plant box **to** the animal box). Always put the arrowhead on.
- Count arrows**: on a diagram without arrowheads, count how many lines should point **into** the carbon dioxide box. Go round every box and ask whether it gives carbon dioxide to the air (every living group respire; fossil fuels are burned).
- Day and night**: in the light a plant takes in carbon dioxide and gives out oxygen (photosynthesis is faster than respiration); in the dark it gives out carbon dioxide and takes in oxygen (respiration only).
- Which processes involve producers?** Photosynthesis, respiration, feeding (they are eaten), decomposition and fossil fuel formation (after they die).
- Molecules in plants that contain carbon**: carbohydrates (glucose, starch, cellulose), fats and oils, proteins, DNA.
- Processes in both cycles**: decomposition and feeding (also excretion).

- **The ocean:** phytoplankton are producers, so they remove carbon dioxide by photosynthesis; animals in the sea return it by respiration.

2. Nitrogen cycle processes and bacteria (26 questions)

Extended only.

1. **Find the forms of nitrogen** in the boxes: nitrogen gas, protein in plants or animals, dead organisms and waste, ammonium ions, nitrate ions.
2. **Name each arrow from its two ends:**
 - nitrogen gas → ammonium or nitrate: **nitrogen fixation** (lightning, or nitrogen-fixing bacteria in soil and root nodules);
 - protein, dead organisms or waste → ammonium: **decomposition** (by decomposers);
 - ammonium → (nitrite →) nitrate: **nitrification** (nitrifying bacteria);
 - nitrate → nitrogen gas: **denitrification** (denitrifying bacteria);
 - nitrate in soil → plant: **absorption** (by **active transport** into root hair cells);
 - amino acids → protein: **assimilation** (making amino acids and proteins);
 - plant protein → animal protein: **feeding and digestion**;
 - amino acids → urea: **deamination** (in the **liver**).
3. **Say which organism does it** if asked: bacteria (and fungi) for decomposition; bacteria only for nitrification, fixation and denitrification; lightning for the non-living kind of fixation.

Variations you will meet:

- **"State two ways nitrogen fixation occurs":** lightning and **nitrogen-fixing bacteria**. "Root nodules" on their own isn't enough; say the bacteria in them.
- **"Which process removes nitrogen gas from the air?"** Nitrogen fixation. **"Which releases it?"** Denitrification. **"Which bacteria make soil short of nitrates?"** Denitrifying bacteria.
- **Experiments and conditions.** Work out which bacteria were affected. Heating soil kills its bacteria, so ammonium added to it is **not** turned into nitrate (the nitrifying bacteria are dead). Waterlogged or acidic soil favours the anaerobic denitrifying bacteria, so **more nitrogen gas** is released and nitrates fall.
- **Which organisms remove nitrate ions from the soil?** Plants (absorbing them) and denitrifying bacteria.
- **What compound comes out of decomposition?** Ammonia, or ammonium ions.

3. Phases of the sigmoid growth curve (23 questions)

1. **Find the four shapes** on the graph: low and flat (**lag**), steep rise (**exponential** or **log**), high and flat (**stationary**), fall (**death**).
2. **Match letters or numbers** to phases in order from the left. A graph may show only some phases, or the phases may be lettered out of order, so check each one's shape.
3. **Birth and death rates:** births = deaths in the **stationary** phase; births > deaths in the lag and exponential phases; deaths > births in the death phase.

4. Name the whole curve: **sigmoid**.

Variations you will meet:

- **A graph of the world's human population** (or any graph that only rises, slowly then steeply) shows **lag** and **exponential** phases only. The **stationary** and **death** phases are not shown.
- **"Where is the population limited by resources?"** The stationary phase.
- **A fermenter or flask of bacteria, yeast or fungi**: the same four phases; the examiner may call the axes "biomass" or "number of cells per cm³".
- **Pests, introduced species or the number of animals caught**: if the numbers are rising faster and faster, the population is in the exponential phase.
- **Mark a point** (with a letter X or Y) on a graph: put it clearly **inside** the phase, not on the boundary.

4. Population, community and ecosystem (19 questions)

1. **Population**: one **species**, same **area**, same **time**. All three are needed for the mark.
2. **Community**: **all the populations** of **different species** in an **ecosystem**.
3. **Ecosystem**: a **unit** containing the **community** and its **environment**, **interacting** together.

Variations you will meet:

- **Multiple choice "which is a population?"**: the right answer names **one species** (all the three-spined sticklebacks in a lake, all the red deer in a forest). Reject answers with a group of many species (all the fish, all the birds, all the plants), different places, or different times ("all the lions that lived from 1950 to 2000").
- **Match terms to descriptions**: a species is a group that can breed to produce fertile offspring; a trophic level is a position in a food chain; don't confuse these with population or community.
- **Community** (Paper 4): say "different species" and "in an ecosystem" or "in an area"; one species is a population.

5. Explaining population changes (16 questions)

1. **Describe** what the graph does in that part, with a figure or two from the axes.
2. **State the phase** and the **balance of births and deaths**.
3. **Explain with a named factor**: food supply, competition, predation, disease (and for microorganisms: oxygen, space, toxic waste, pH, temperature).

Variations you will meet:

- **"State factors that increase a population"**: more food, fewer predators, less disease, less competition, more births. **Decrease**: the opposite, plus pollution, hunting or fishing, habitat loss and natural disasters.
- **Extended only: why the lag phase happens**: few individuals to breed; they are adjusting to the conditions (making enzymes, finding mates).
- **Extended only: why the curve levels off** (stationary): a resource becomes limiting, so competition increases; births = deaths.

- **Why bacteria die after a few days in a fermenter** (death phase; Core Paper 3 also asks for one reason, such as not enough nutrients): nutrients or oxygen run out; toxic waste builds up; the pH changes; deaths > births.
- **Why a graph dips at one point**: something raised the death rate (predators added, disease, hunting) or lowered the birth rate.
- **Describe and explain** a curve from a new species arriving (Paper 4): rises slowly then steeply (births > deaths, plenty of resources, no competition or predators), then slows and levels off (resources become limited, competition, predation or disease increase, births and deaths become equal). Aim for 5 points with data.

6. Human activities and carbon dioxide (12 questions)

1. **Combustion of fossil fuels** (in power stations, vehicles, industry) **adds** carbon dioxide to the air.
2. **Deforestation** (cutting down forests) raises carbon dioxide in three ways: **less photosynthesis** so less carbon dioxide is removed; the felled trees are **burned** (combustion); and the wood left behind is **decomposed**, and decomposers respire. Always give the reason, not just "it increases".
3. **Replanting trees** (reforestation) takes carbon dioxide out of the air, by photosynthesis.
4. **The effect**: carbon dioxide is a **greenhouse gas**. It traps **infrared** (heat) radiation given off by the ground, so more of it gives an **enhanced greenhouse effect**, leading to **climate change** (global warming).

Variations you will meet:

- **"Another gas with the same effect"**: **methane** (from cattle, rice fields, decaying waste). Water vapour and nitrous oxide are also accepted.
- **"Complete the sentences"**: combustion **increases** the concentration of carbon dioxide; this causes an **enhanced** greenhouse effect and leads to **climate change**.
- **"Which activities raise carbon dioxide?"**: burning fossil fuels and deforestation; replanting forests lowers it.
- **The usual concentration** of carbon dioxide: about **0.04%**.
- **A natural process that adds carbon dioxide** besides fires: respiration or decomposition (also volcanoes). "Breathing out" is not accepted: say **respiration**.

7. Recycling the nitrogen in protein (7 questions)

Extended only. These are Paper 4 "describe" questions worth 3–6 marks; each step below is a marking point.

1. **Decomposers** (bacteria and fungi) **break down** the protein (in dead organisms, faeces or manure) into **amino acids**, using **proteases**.
2. The amino acids are **deaminated** and **ammonium ions** are released (ammonia).
3. **Nitrifying bacteria** turn the ammonium ions into **nitrite** and then **nitrate ions**: this is **nitrification**.
4. **Plants absorb** the nitrate ions through their root hair cells by **active transport**, and use them to make **amino acids** and **proteins**.

Variations you will meet:

- **"Why do plants need nitrate ions?"**: to make **amino acids**, and so **proteins** (for enzymes, membranes, growth).
- **"Describe deamination"**: removing the **nitrogen-containing part** of amino acids, forming **urea**, in the liver.
- **Complete a flow chart** of one route round the cycle: fill each gap with the process or the ion (lightning or root nodules; nitrate; urea; nitrate; denitrification...).
- **"Advantage of plants with many root nodules"**: their nitrogen-fixing bacteria supply nitrogen compounds, so the farmer needs to add **less fertiliser**, and the plants grow better.

8. Population calculations from data (7 questions)

1. **Read the values** off the graph carefully, using the scale (check whether the axis says "thousand" or "million").
2. **Percentage increase** = $\frac{\text{new} - \text{original}}{\text{original}} \times 100$. For example, from 15 000 to 45 000: $\frac{45\,000 - 15\,000}{15\,000} \times 100 = 200\%$. A **percentage decrease** is the same with (original – new).
3. **Round** only at the end, to the number of figures asked.

Variations you will meet:

- **Difference**: new – original, with units.
- **Doubling or halving time**: find a value, find where the population is twice (or half) that value, and read the time between them. During the exponential phase the doubling time stays the same.
- **Bacteria dividing**: each division doubles the number. One bacterium dividing every 30 minutes for 2 hours divides $120 \div 30 = 4$ times, giving $2^4 = 16$ bacteria, an **increase** of $16 - 1 = 15$. Read the question: "number" or "increase".
- **Reading sentences off a graph**: the year of the largest population, a population in a given year, or a second year with the same size as the first.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
 - **A1** accuracy mark: for a correct answer; it needs the M mark before it.
 - **B1** mark for a correct result on its own, with no method needed.
-

Example 1

A diagram of the carbon cycle has five boxes: carbon dioxide in the atmosphere, carbon compounds in plants, carbon compounds in animals, carbon compounds in dead organisms, and carbon compounds in fossil fuels. Its arrows are:

- **P**: from carbon dioxide in the atmosphere to plants;
- **Q**: from plants to animals;
- **R**: from dead organisms to carbon dioxide in the atmosphere;
- **S**: from dead organisms to fossil fuels;
- **T**: from fossil fuels to carbon dioxide in the atmosphere.

(a) Name the processes P, Q, R, S and T. **[5]**

(b) State how many of the processes P to T add carbon dioxide to the atmosphere. **[1]**

(c) Describe the arrow you would add to show respiration by animals. **[1]**

(d) Explain how cutting down a large area of forest affects the concentration of carbon dioxide in the atmosphere. **[3]**

(a) P photosynthesis **B1**; Q feeding **B1**; R decomposition (or respiration by decomposers) **B1**; S formation of fossil fuels **B1**; T combustion **B1**.

(b) Two (R and T) **B1**.

(c) An arrow from carbon compounds in animals to carbon dioxide in the atmosphere, with the arrowhead at the atmosphere **B1**.

(d) The carbon dioxide concentration increases **B1**. There are fewer trees to photosynthesise, so less carbon dioxide is removed from the air **B1**. The felled trees are burned (combustion) or decomposed by decomposers, which respire, adding carbon dioxide **B1**.

Example 2

Extended only. A farmer ploughs the remains of a bean crop into a field. The remains contain protein.

(a) Describe how the nitrogen in this protein becomes available to the next crop. **[5]**

(b) Bean plants have root nodules. State two ways in which nitrogen fixation can happen. **[2]**

(c) After heavy rain the field is waterlogged for several weeks. Explain why the soil then contains fewer nitrate ions. **[2]**

(a) Decomposers (bacteria and fungi) break down the protein **B1** into amino acids **B1**, which are deaminated to release ammonium ions **B1**. Nitrifying bacteria convert the ammonium ions to nitrite and then nitrate ions (nitrification) **B1**. The next crop absorbs the nitrate ions by active transport and uses them to make amino acids and protein **B1**.

(b) Lightning **B1**; nitrogen-fixing bacteria (in the soil or in the root nodules) **B1**.

(c) Waterlogged soil has little oxygen **B1**, so anaerobic denitrifying bacteria increase and turn nitrate ions into nitrogen gas, which escapes into the air (denitrification) **B1**. (Nitrifying bacteria also need oxygen, so fewer new nitrate ions are made.)

Example 3

A few yeast cells were put into a flask of sugar solution and kept at 25 °C. The table shows the number of yeast cells.

Time / hours	0	4	8	12	16	20	24	28	32	36	40	44
Yeast cells / thousand per cm ³	2	2	4	8	16	32	44	48	48	48	36	20

(a) Name the phase of population growth between 0 and 4 hours, between 12 and 20 hours, between 28 and 36 hours and between 36 and 44 hours. **[2]**

(b) State the doubling time of the yeast population between 8 and 20 hours. **[1]**

(c) Calculate the percentage increase in the number of yeast cells between 12 hours and 20 hours. **[2]**

(d) **Extended only.** Explain the change in the number of yeast cells between 24 hours and 36 hours. **[3]**

(e) Calculate the percentage decrease between 36 hours and 44 hours. Give your answer to the nearest whole number. **[2]**

(a) 0–4 h lag; 12–20 h exponential (log); 28–36 h stationary; 36–44 h death. All four **B2**; two or three **B1**.

(b) The number doubles every **4 hours** (4 → 8 → 16 → 32 thousand at 8, 12, 16 and 20 hours) **B1**.

(c) $\frac{32 - 8}{8} \times 100$ **M1** = 300% **A1**

(d) The growth slows and the number levels off at 48 thousand per cm³ **B1**. The sugar (a nutrient) becomes a limiting factor / there is more competition for sugar and oxygen **B1**, and toxic waste such as alcohol builds up, so the birth rate falls until it equals the death rate **B1**.

(e) $\frac{48 - 20}{48} \times 100 = 58.33 \dots$ **M1** = 58% **A1**

Common mistakes

- **Confusing nitrification and nitrogen fixation.** Fixation starts with nitrogen **gas**; nitrification starts with **ammonium ions**. Many candidates call the first step "nitrification". Check what the arrow starts from.
- **Writing denitrification for deamination** (or the reverse). In animals, deamination happens in the **liver** and makes **urea**; decomposers also deaminate amino acids in the soil, releasing **ammonium ions**. Denitrification happens in **soil** and makes **nitrogen gas**.

- **"Root nodules" without bacteria.** It is the **nitrogen-fixing bacteria** inside the nodules that fix nitrogen. Naming nitrifying bacteria for fixation is also wrong.
- **Vague or wrong process words.** Examiners want **combustion**, not "burning"; **respiration**, not "breathing out"; **decomposition**, spelled so it can be recognised. For plant uptake of nitrate, say **active transport**, not osmosis.
- **Mixing up urea and urine.** Urea is the nitrogen compound made by deamination; urine is the liquid that carries it out.
- **A population with more than one species.** "All the fish in a lake" or "all the organisms in a lake" is a community, not a population. A population is one species, in one area, at one time.
- **Not knowing the phase names.** Some candidates invent names ("growth phase", "decline"). Learn **lag**, **exponential (log)**, **stationary**, **death**, and don't choose exponential or stationary for the slow start: that is the lag phase.
- **Explaining deforestation with only one side.** "Deforestation increases carbon dioxide" earns little. Say **why**: less photosynthesis, and burning or decomposing of the felled trees.
- **Giving fewer reasons than marks.** A 2-mark "suggest" needs two different reasons.
- **Percentage change from the wrong base.** Always divide by the **original** (earlier) value, and subtract before dividing.

How to get the marks

- **"State" or "name":** one word or phrase is enough, but it must be the exact biological term: photosynthesis, combustion, nitrification, denitrification, deamination, lag phase.
- **"Describe" a cycle or process:** give the steps in order, each with the correct term and what is changed into what (ammonium ions → nitrate ions). The mark schemes reward about one mark per correct step, so a 5-mark answer needs five separate steps.
- **"Explain":** give the reason as well as the effect, linked with "because" or "so": "less photosynthesis, **so** less carbon dioxide is removed".
- **Graph questions:** quote figures with units ("levels off at 48 thousand cells per cm³"), and name the phase. "Describe and explain" needs both what happens and why.
- **Calculations:** show the working ($\frac{32-8}{8} \times 100$). A method mark is given for the correct values and calculation, then an accuracy mark for rounding as asked. If you read the graph wrongly, the later marks can still be earned from your values.
- **Diagrams:** when asked to draw an arrow, start and finish it at the right boxes and add the arrowhead; without it, the mark is lost.
- **Multiple choice:** work through the cycle one arrow at a time, and cross out options that include a process going the wrong way.

Quick check

1. Which of these is a population: (A) all the insects in a meadow, (B) all the oak trees of one species in a wood this year, (C) all the plants and animals in a pond, (D) all the robins that have ever lived in Europe? Say why the others are wrong.
2. From photosynthesis, respiration, feeding, decomposition, formation of fossil fuels and combustion, list the processes that add carbon dioxide to the atmosphere, and the process that removes it.
3. **Extended only.** Name the process, and the type of microorganism that does it, for each change: (a) ammonium ions to nitrate ions; (b) nitrate ions to nitrogen gas; (c) nitrogen gas to ammonium compounds in a root nodule.
4. A bacterium divides every 20 minutes. Starting with one bacterium in ideal conditions, how many bacteria are there after 3 hours, and what is the increase?
5. A population of deer grew from 250 to 400 in five years. Calculate the percentage increase, and state two factors that could stop the population growing.

Answers

1. **B.** A has many species of insect; C is a community (many species); D includes different times.
2. Added by **respiration**, **decomposition** and **combustion**; removed by **photosynthesis**. Feeding and formation of fossil fuels do neither.
3. (a) nitrification, by nitrifying bacteria; (b) denitrification, by denitrifying bacteria; (c) nitrogen fixation, by nitrogen-fixing bacteria.
4. 3 hours = 180 minutes, so $180 \div 20 = 9$ divisions. $2^9 = 512$ bacteria, an increase of $512 - 1 = 511$.
5. $\frac{400 - 250}{250} \times 100 = 60\%$. Any two: shortage of food, competition, predation (or hunting), disease.

Past questions to try

- [0610/42/O/N/24 Q6](#): complete a flow chart through the nitrogen cycle.
- [0610/43/O/N/23 Q5](#): a fermenter growth curve with phases, halving time and a describe-and-explain.
- [0610/32/F/M/23 Q6](#): carbon cycle processes, then the greenhouse effect.
- [0610/13/O/N/25 Q39](#): bacteria dividing in ideal conditions.