

Organisms and their environment revision notes

Organisms do not live alone. They depend on energy from the Sun and on each other for food. This topic looks at how energy flows through ecosystems along food chains and food webs, how nutrients are cycled, and how populations change in size.

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

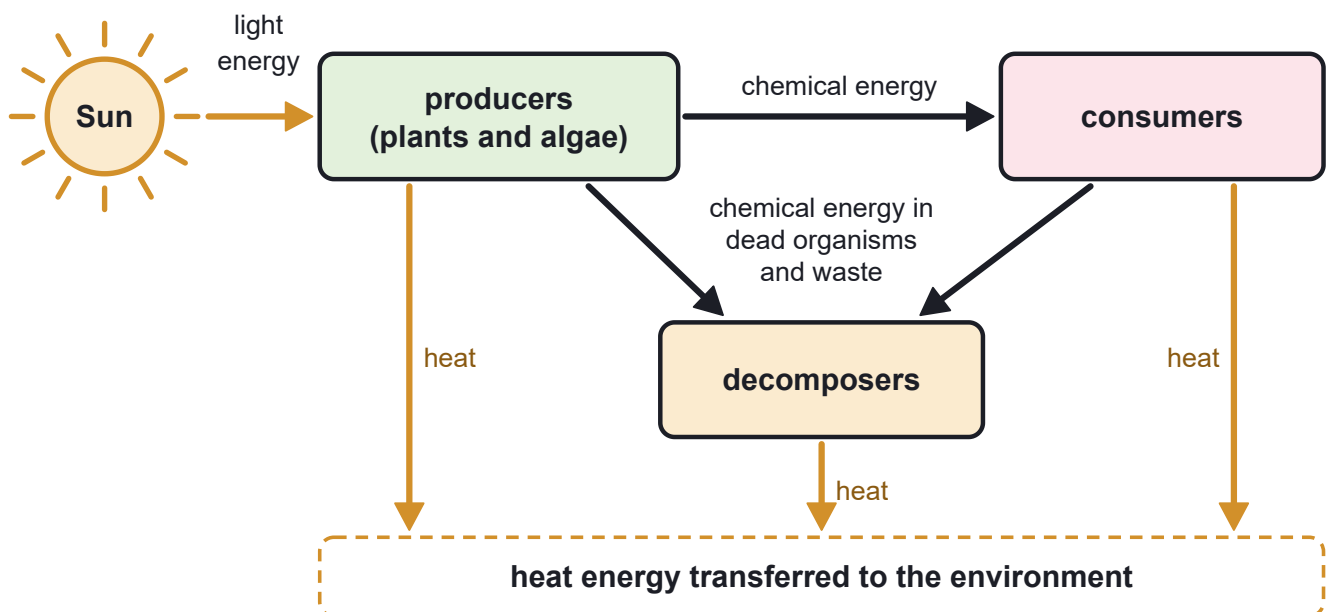
1 Energy flow, food chains and food webs Spec 19.1, 19.2.1-19.2.10

Energy flow Spec 19.1.1, 19.1.2

The **Sun** is the principal source of energy input to biological systems. Without light from the Sun there would be almost no energy entering living things.

Energy does not go round in a cycle. It **flows through** living organisms in one direction and is eventually transferred to the environment.

1. Light energy from the Sun is absorbed by green plants and algae. They transfer it to **chemical energy** in organic nutrients (such as glucose) by photosynthesis.
2. Chemical energy passes to animals when they eat plants, and to other animals when they eat those animals.
3. Chemical energy passes to decomposers when they feed on dead organisms and waste.
4. At every stage, organisms transfer energy by respiration. Much of it is eventually transferred to the environment as **heat**.



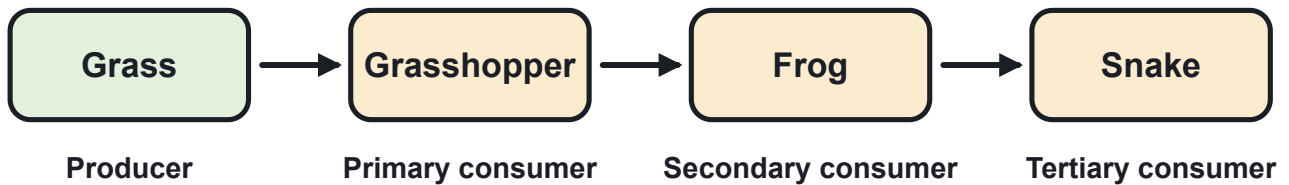
Energy **flows in one direction** through organisms and is not recycled: it ends up as heat in the environment.

Exam tip: Name the forms of energy: light energy from the Sun, chemical energy in organisms, and heat lost to the environment. Do not say that energy is 'used up' or 'destroyed'.

Food chains and food webs Spec 19.2.1, 19.2.2, 19.2.3, 19.2.10

Food chain	Shows the transfer of energy from one organism to the next, beginning with a producer.
Food web	A network of interconnected food chains.

In a **food chain** the arrows show the **transfer of energy**. Each arrow points from the organism that is eaten to the organism that eats it. The chain always begins with a producer.



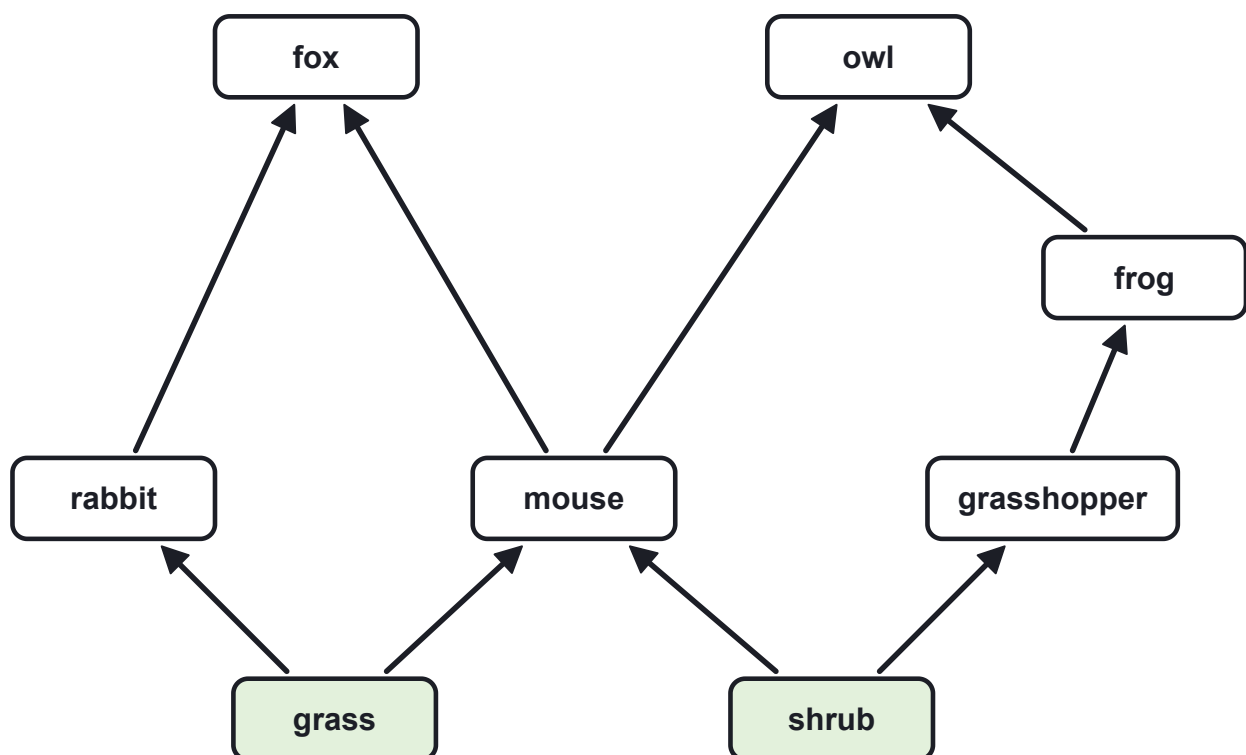
A food chain. The arrows show the **transfer of energy** from each organism to the one that eats it.

Common mistake: Arrows point from the food to the feeder. Grass → rabbit means the rabbit eats the grass and energy passes to the rabbit.

Food webs

Most organisms eat more than one type of food, and are eaten by more than one type of predator. A **food web** shows these links as a network of interconnected food chains.

To interpret a food web, trace each food chain from a producer, following the arrows. You can then say what an organism eats, what eats it, and what might happen if one population changes.



A food web. Arrows point from the food to the feeder. The owl is a secondary consumer when it eats mice and a tertiary consumer when it eats frogs.

Human impact on food chains and food webs

Food chains and food webs can be used to describe the impact humans have on an ecosystem.

- **Overharvesting** of a food species, such as overfishing, reduces the population of that species. Predators that feed on it have less food, so their populations may fall. Species that the harvested species eats may increase in number.
- **Introducing foreign species** to a habitat adds a new organism to the food web. It may eat native species, so their numbers fall, or compete with them for food, so those species have less food and their populations fall.

Exam tip: For 'what happens if' questions, work along the arrows. Say what happens to the organisms that eat it (less food) and to those it eats (fewer eaten, so more of them). Mention that effects can be indirect.

Producers, consumers and decomposers Spec 19.2.4, 19.2.5, 19.2.6, 19.2.7, 19.2.8, 19.2.9

Producer	An organism that makes its own organic nutrients, usually using energy from sunlight, through photosynthesis.
Consumer	An organism that gets its energy by feeding on other organisms.
Herbivore	An animal that gets its energy by eating plants.
Carnivore	An animal that gets its energy by eating other animals.
Decomposer	An organism that gets its energy from dead or waste organic material.

Consumers are classed by their position in a food chain.

Classes of consumer		
Class	What it eats	Example
Primary consumer	Producers (so it is a herbivore)	Grasshopper
Secondary consumer	Primary consumers (a carnivore)	Frog
Tertiary consumer	Secondary consumers (a carnivore)	Snake
Quaternary consumer	Tertiary consumers (a carnivore)	Eagle

Decomposers, such as bacteria and fungi, feed on dead organisms and waste. They get their energy from dead or waste organic material, and they return nutrients to the soil.

*Exam tip: Learn the definitions word for word. A producer makes its own **organic nutrients**, usually by photosynthesis. Do not just say that it 'makes its own food'.*

Quick check

1. State the principal source of energy input to biological systems.
2. What does a food chain show?
3. What is a food web?
4. Define a consumer.
5. Define a decomposer.

2 Trophic levels and ecological pyramids Spec 19.2.11-19.2.19

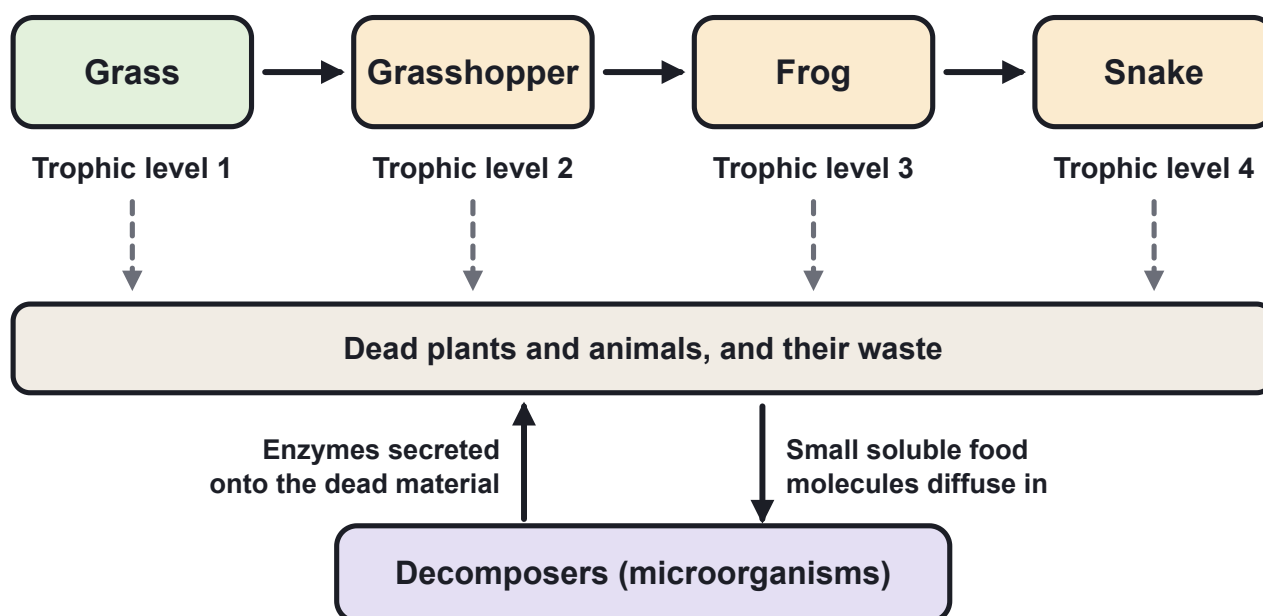
Trophic levels Spec 19.2.13, 19.2.14

Trophic level The position of an organism in a food chain, food web or ecological pyramid.

Trophic levels are numbered from the **producer** at the start of the chain. The same names are used in food webs, food chains and ecological pyramids.

Trophic levels		
Trophic level	Name	Example
1	Producers	Grass
2	Primary consumers	Grasshopper
3	Secondary consumers	Frog
4	Tertiary consumers	Snake
5	Quaternary consumers	Eagle

An organism in a food web may be at **more than one trophic level**. For example, an animal that eats both plants and herbivores is a primary consumer in one food chain and a secondary consumer in another. Decomposers feed on the dead remains from every trophic level.



Every trophic level ends up as dead material or waste, which decomposers feed on.

Common mistake: Producers are trophic level 1, so the primary consumer is level 2 and the secondary consumer is level 3. Do not count from the first animal.

Pyramids of numbers and biomass Spec 19.2.11, 19.2.12

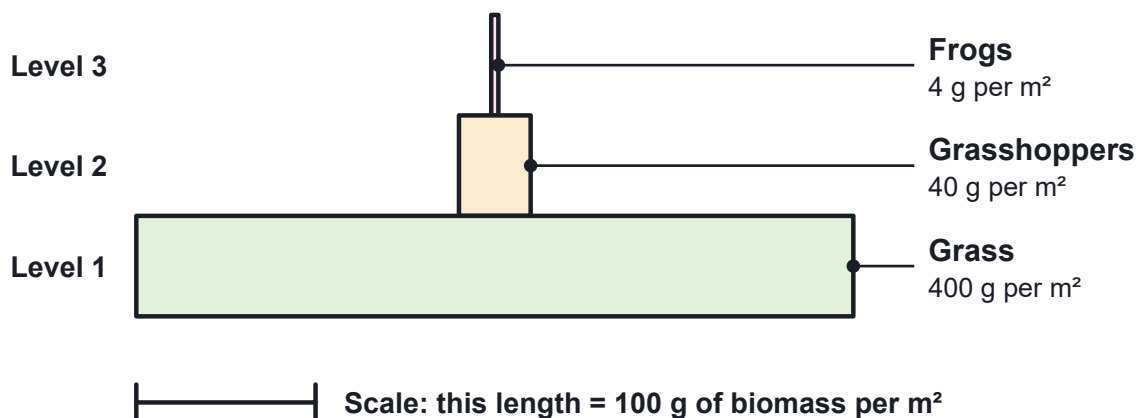
An ecological pyramid has one horizontal bar for each trophic level, with the producers at the bottom. The length of each bar is drawn to scale.

- A **pyramid of numbers** shows the number of organisms at each trophic level.

- A **pyramid of biomass** shows the mass of living material (biomass) at each trophic level, for example in g per m².

Drawing a pyramid

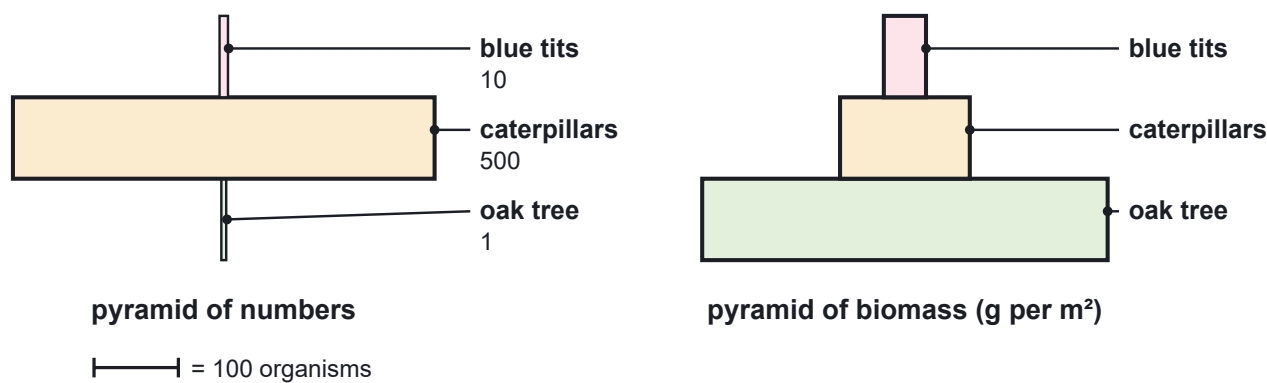
1. Choose a scale so that the longest bar fits on the page.
2. Draw a bar for each trophic level, with the producers at the bottom. Make the length of each bar proportional to its value.
3. Centre the bars on a vertical line and label each bar with the organism.



A pyramid of biomass for grass, grasshoppers and frogs, drawn to scale.

Pyramids of numbers can be the wrong shape

A pyramid of numbers does not always get narrower. One large oak tree can support hundreds of caterpillars, so the bar for the producers is shorter than the bar above it. The pyramid is not pyramid-shaped and is often described as **inverted**. The size of the organisms is ignored.



The same food chain: the **pyramid of numbers** is an odd shape because one large tree supports many caterpillars, but the **pyramid of biomass** is pyramid-shaped.

Advantage of a pyramid of biomass

A pyramid of biomass is usually a better way to represent a food chain than a pyramid of numbers, because:

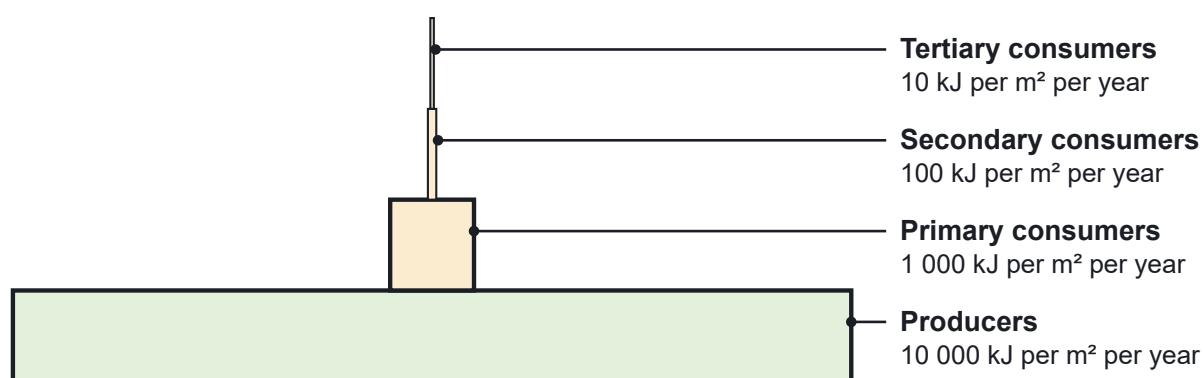
- it takes the **size of the organisms** into account, so one large tree is not shown as equal to one tiny insect;
- it is usually **pyramid-shaped**, because there is less biomass at each higher trophic level.

Exam tip: To explain an odd-shaped pyramid of numbers, say that the producer is one very large organism that supports many smaller consumers. Say that numbers ignore the size of organisms but biomass does not.

Pyramids of energy Spec 19.2.15, 19.2.16 Supplement

A **pyramid of energy** shows the **amount of energy** that flows through each trophic level in a given area over a period of time, for example in kJ per m² per year. It is drawn in the same way as the other pyramids, with the producers at the bottom and bars drawn to scale.

Example data for a pyramid of energy (practice values)	
Trophic level	Energy / kJ per m ² per year
Producers	10 000
Primary consumers	1 000
Secondary consumers	100
Tertiary consumers	10



— Scale: this length = 1 000 kJ per m² per year

A pyramid of energy is always pyramid-shaped. In this example only a tenth of the energy passes on to each higher trophic level.

Advantages of a pyramid of energy

- It is always **pyramid-shaped**, because energy is lost at each trophic level. It cannot be inverted.
- It takes into account the **size of the organisms**, unlike a pyramid of numbers.
- It shows the **rate** of energy flow, over a period of time. A pyramid of biomass shows only the mass at one moment (a pyramid of biomass can be inverted if organisms grow and reproduce quickly, for example algae in the sea).
- Different tissues contain different amounts of energy per gram (fat contains more than carbohydrate), so equal biomass does not always mean equal energy. A pyramid of energy compares the energy directly.
- It allows the efficiency of energy transfer between trophic levels to be compared.

Exam tip: Write the units as energy per area per time, such as kJ per m² per year. A pyramid of energy never has an inverted shape.

Why energy transfer is inefficient Spec 19.2.17, 19.2.18, 19.2.19 Supplement

Only a small fraction of the energy at one trophic level is transferred to the next. The transfer of energy from one trophic level to another is often not efficient, because energy is lost in these ways:

- Not all of an organism is eaten. Some parts, such as bones, roots and fur, are left uneaten.
- Some of what is eaten is not digested and is lost as **faeces** (egestion).
- Energy is lost in **excretion**, for example in urine.
- Energy is released by **respiration** to power life processes such as movement and, in mammals and birds, keeping warm. Much of this is lost as heat to the environment.

efficiency of energy transfer (%) = energy transferred to the next level ÷ energy available at the previous level × 100

Efficiency of energy transfer

The grass in a field stores 20 000 kJ of energy per m² per year. The cattle that eat it gain 1 600 kJ per m² per year. Calculate the efficiency of energy transfer from the grass to the cattle.

1. Efficiency = energy transferred ÷ energy available × 100
2. = 1 600 ÷ 20 000 × 100
3. = 8%

Answer: 8%

Food chains are short

Energy is lost at each trophic level, so less energy is available at each step. By the fourth or fifth trophic level there is too little energy left to support another population. This is why food chains usually have **fewer than five trophic levels**.

Eating plants or eating livestock

Humans can eat crop plants directly, or feed the crops to livestock and eat the livestock. It is more energy efficient to eat crop plants, because:

- there are **fewer trophic levels** in the food chain, so less energy is lost to the environment before it reaches humans;
- much of the energy in the crop fed to livestock is lost, for example in respiration, movement and keeping warm, and in faeces and urine, and is not stored in the meat or milk;
- so more people can be fed from the same area of land growing crops than from the same area used to grow food for livestock.

Common mistake: Do not say energy is 'lost' or 'used up' without saying how. Name the losses: heat from respiration, faeces, urine and parts not eaten.

Quick check

1. Define a trophic level.
2. Which trophic level do tertiary consumers occupy?
3. State one advantage of a pyramid of biomass over a pyramid of numbers.
4. **Supplement** State one advantage of a pyramid of energy over a pyramid of biomass.
5. **Supplement** Why do food chains usually have fewer than five trophic levels?

3 Nutrient cycles Spec 19.3

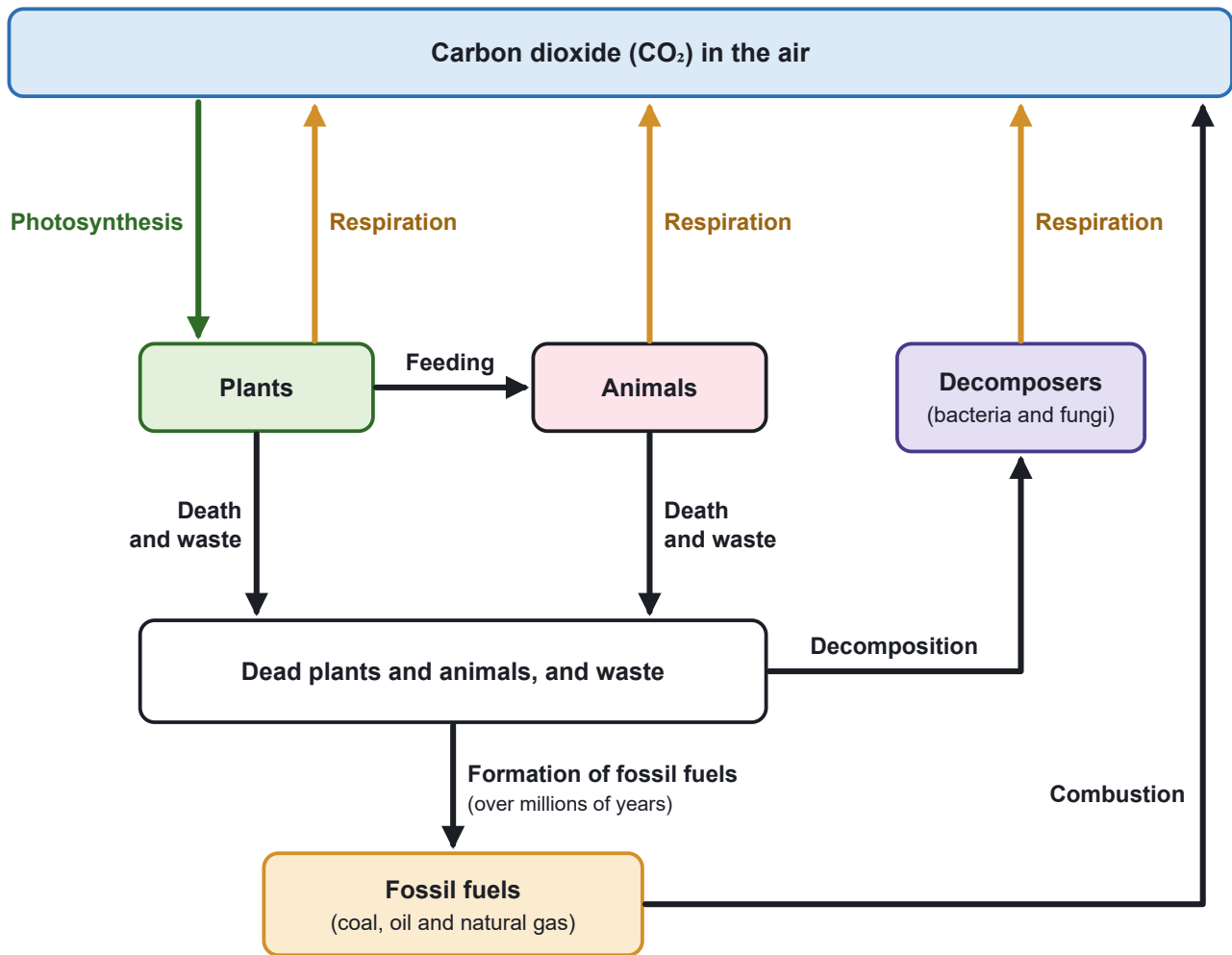
The carbon cycle Spec 19.3.1

All living things are made of carbon compounds, such as carbohydrates, proteins and fats. The carbon cycle moves carbon between the air, living organisms, dead material and fossil fuels. It makes sure carbon dioxide is available for plants to use in photosynthesis again.

1. Plants and algae take carbon dioxide from the air and use it in **photosynthesis** to make carbon compounds such as glucose, starch and proteins.
2. The carbon compounds pass along the food chain by feeding, when animals eat plants and other animals.
3. Plants, animals and decomposers all release carbon dioxide into the air by **respiration**.
4. When organisms die, and when they produce waste, **decomposers** (bacteria and fungi) break down the material. They release carbon dioxide into the air by respiration.
5. Over millions of years, some dead organisms are buried and do not decompose fully. They form **fossil fuels** (coal, oil and natural gas).
6. When fossil fuels, wood or other fuels are burned, **combustion** releases carbon dioxide into the air.

Processes in the carbon cycle

Process	Effect on carbon dioxide in the air
Photosynthesis	Removes carbon dioxide from the air
Respiration (plants, animals, decomposers)	Adds carbon dioxide to the air
Decomposition	Adds carbon dioxide to the air, because decomposers respire
Combustion	Adds carbon dioxide to the air
Feeding	Passes carbon compounds from one organism to the next; no change in the air
Formation of fossil fuels	Locks carbon away in coal, oil and gas



The carbon cycle. **Photosynthesis** removes carbon dioxide from the air; **respiration**, **decomposition** and **combustion** return it.

Exam tip: Name the process at every arrow. Photosynthesis takes carbon dioxide in. Respiration, decomposition and combustion put it back. Do not write 'breathing' for respiration.

The nitrogen cycle Spec 19.3.2, 19.3.3 Supplement

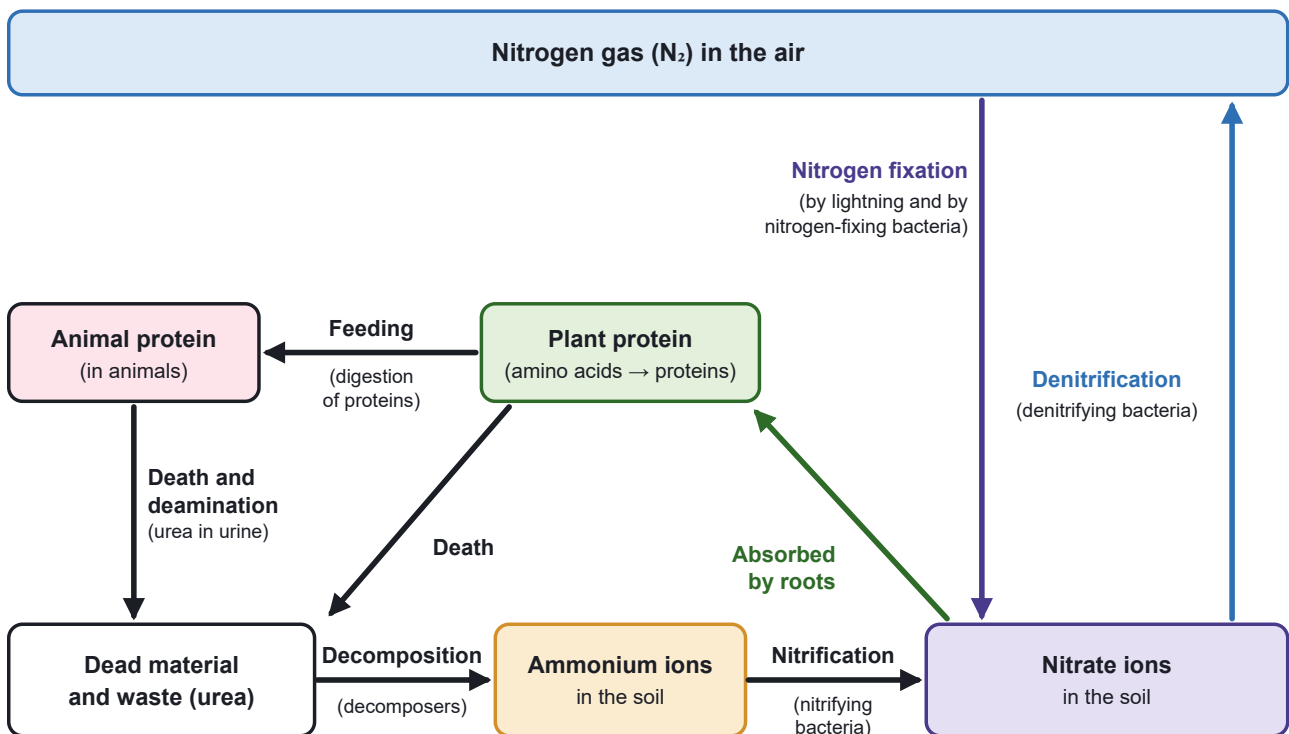
Plants need nitrogen to make amino acids and then proteins. Nitrogen gas makes up most of the air, but plants cannot use it. They absorb nitrate ions from the soil through their roots. The nitrogen cycle shows how nitrogen is moved between the air, the soil and living things.

1. Plants absorb nitrate ions from the soil. They combine them with carbohydrates to make amino acids, and then join the amino acids to make proteins.
2. Animals get proteins by feeding on plants or other animals. They digest the proteins to amino acids and use these to make their own proteins.
3. Excess amino acids cannot be stored. In the liver, **deamination** removes the nitrogen-containing part of the amino acids to form urea. Urea is excreted in urine.
4. Decomposers (bacteria and fungi) break down the proteins in dead plants and animals, and the urea in waste, to **ammonium ions** in the soil. This is decomposition.
5. Nitrifying bacteria change ammonium ions into nitrate ions. This is **nitrification**. Plants can absorb the nitrate ions again.
6. **Nitrogen fixation** changes nitrogen gas into nitrogen compounds that plants can use. It is done by nitrogen-fixing bacteria in the soil and in root nodules, and by lightning. The energy of lightning

makes nitrogen in the air combine with oxygen to form nitrogen oxides. These dissolve in rain and reach the soil as nitrates.

7. Denitrifying bacteria change nitrates in the soil back into nitrogen gas. This is **denitrification**. It lowers the amount of nitrate available to plants.

Roles of microorganisms in the nitrogen cycle		
Process	Role of microorganisms	Effect on nitrate in the soil
Decomposition	Decomposers break down proteins in dead material, and urea, to ammonium ions	Supplies ammonium ions for nitrification
Nitrification	Nitrifying bacteria change ammonium ions to nitrate ions	Increases nitrate
Nitrogen fixation	Nitrogen-fixing bacteria change nitrogen gas into nitrogen compounds	Increases the nitrogen compounds available to plants
Denitrification	Denitrifying bacteria change nitrates to nitrogen gas	Decreases nitrate



The nitrogen cycle. Microorganisms carry out **decomposition**, **nitrification**, **nitrogen fixation** and **denitrification**.

Common mistake: Nitrogen fixation turns nitrogen gas into nitrogen compounds. It is not the same as decomposition, which makes ammonium ions from dead material. You do not need the names of individual bacteria.

Exam tip: Link each step to a microorganism: decomposers (ammonium ions), nitrifying bacteria (nitrates), nitrogen-fixing bacteria (nitrogen compounds), denitrifying bacteria (nitrogen gas).

Quick check

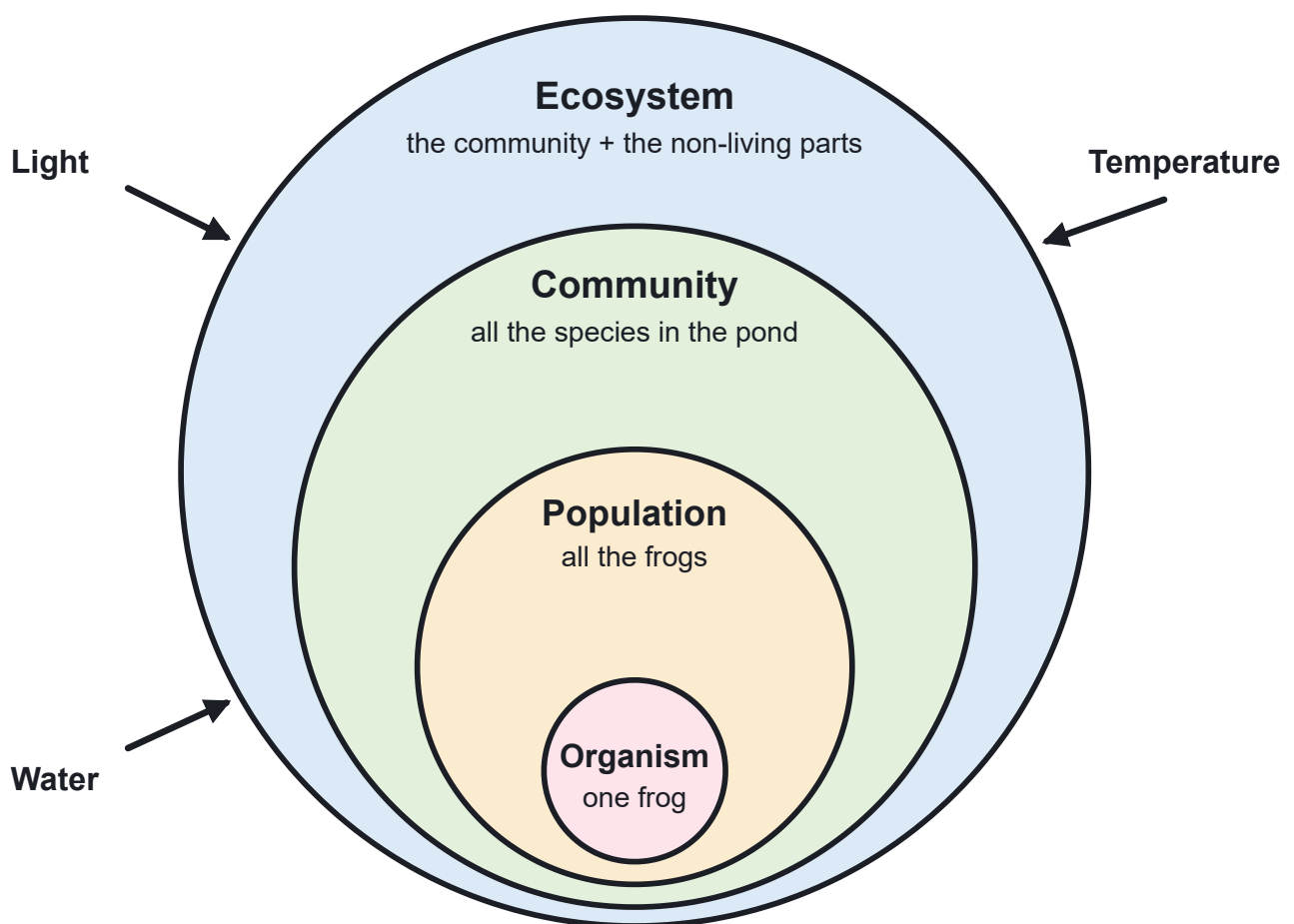
1. Which process removes carbon dioxide from the air?
2. Name three processes that add carbon dioxide to the air.
3. How are fossil fuels formed?
4. **Supplement** What do nitrifying bacteria do?
5. **Supplement** Name two ways nitrogen gas is fixed.

4 Populations Spec 19.4

Populations, communities and ecosystems Spec 19.4.1, 19.4.2, 19.4.3, 19.4.4

Population	A group of organisms of one species, living in the same area, at the same time.
Community	All of the populations of different species in an ecosystem.
Ecosystem	A unit containing the community of organisms and their environment, interacting together.

Levels of organisation, using a pond as the example		
Level	Meaning	Pond example
Organism	A single living thing	One frog
Population	One species, in the same area, at the same time	All the frogs in the pond
Community	All the populations of different species in the ecosystem	All the plants, animals and microorganisms in the pond
Ecosystem	The community and its environment, interacting together	The pond community plus the water, light and temperature



Each level contains the one before it. The **ecosystem** is the community plus its environment.

Factors affecting the rate of population growth

The rate at which a population grows depends on four factors: **food supply**, **competition**, **predation** and **disease**.

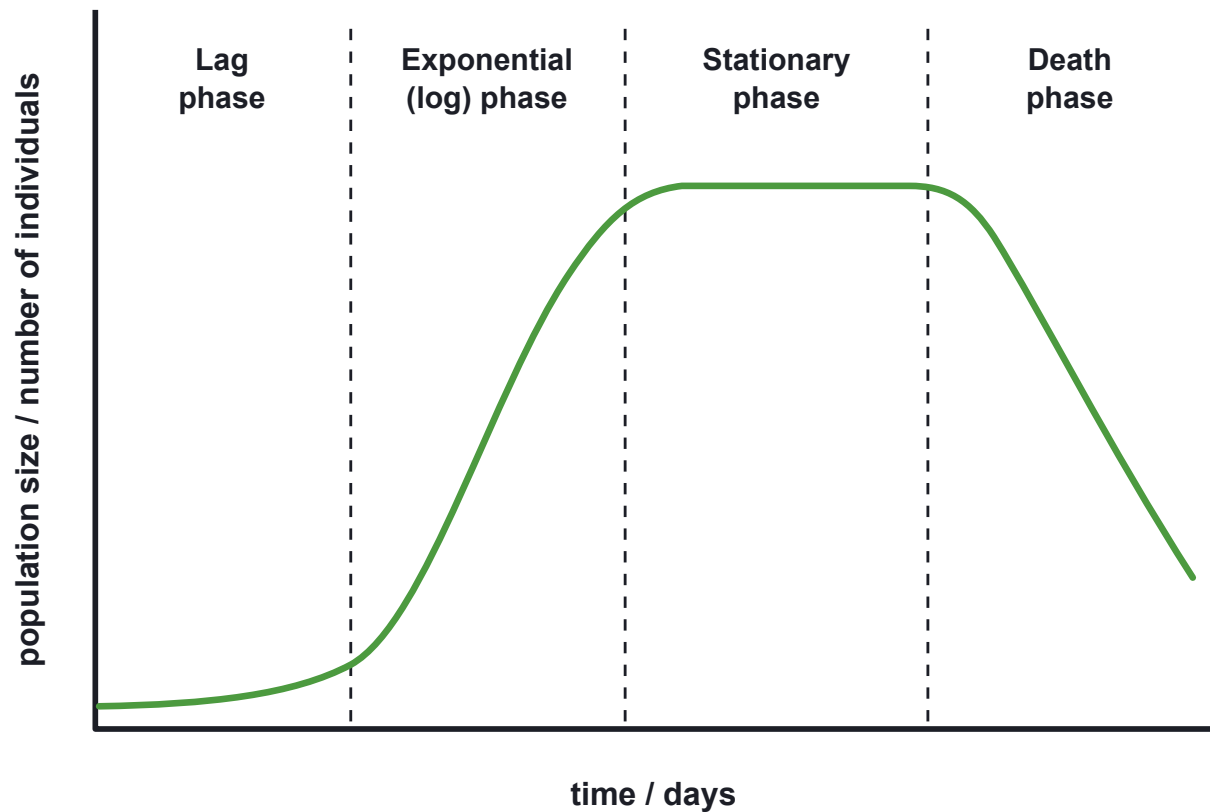
Factors affecting population growth	
Factor	Effect on population growth
Food supply	More food means more organisms survive and reproduce, so the population grows faster. Less food slows growth or makes the population fall.
Competition	Organisms compete for limited resources such as food, water, light and space. The more competition, the slower the growth.
Predation	Predators eat prey, so more predators slow the growth of the prey population.
Disease	Pathogens can kill or weaken organisms, so disease slows growth or reduces numbers.

Common mistake: A population is one species only. If an answer includes different species living together, it is describing a community. Always include 'at the same time' in the definition of a population.

The sigmoid population growth curve Spec 19.4.5, 19.4.6, 19.4.7

When a small population enters an environment with limited resources, its growth follows an S-shaped curve called the **sigmoid curve**. It has four phases.

The four phases of the sigmoid growth curve	
Phase	What the graph shows
Lag phase	Slow growth at the start, with few individuals
Exponential (log) phase	Rapid growth, with the curve getting steeper
Stationary phase	No overall growth; the curve levels off and the population stays roughly constant
Death phase	The population falls



The **sigmoid curve**: lag, exponential (log), stationary and death phases.

Supplement

Explaining the phases

Supplement

Why each phase happens

Phase	Explanation
Lag phase	There are few individuals to reproduce, and the organisms are adjusting to the environment. The birth rate is low, so growth is slow.
Exponential (log) phase	Food and space are plentiful, and there is little competition, predation or disease. The birth rate is much higher than the death rate, and more individuals reproduce, so growth speeds up.
Stationary phase	Limiting factors such as food supply, space and the build-up of waste restrict growth. Birth rate equals death rate , so the population stays constant.
Death phase	Resources run out or waste and disease build up. The death rate is higher than the birth rate, so the population falls.

Exam tip: When describing a graph, name the phase, quote figures from the axes with units, and say whether the population is rising, constant or falling.

Supplement

Common mistake: In the stationary phase, organisms are still being born and are still dying. The population is constant because the birth rate equals the death rate. When explaining any phase, link it to a limiting factor.

Quick check

1. Define a population.
2. Define a community.
3. State the four factors that affect the rate of population growth.
4. Name the four phases of the sigmoid growth curve in order.
5. **Supplement** Why does a population level off in the stationary phase?

Quick check answers

Energy flow, food chains and food webs

1. The Sun.
2. The transfer of energy from one organism to the next, beginning with a producer.
3. A network of interconnected food chains.
4. An organism that gets its energy by feeding on other organisms.
5. An organism that gets its energy from dead or waste organic material.

Trophic levels and ecological pyramids

1. The position of an organism in a food chain, food web or ecological pyramid.
2. Trophic level 4.
3. It takes the size of the organisms into account, and is usually pyramid-shaped.
4. It shows the rate of energy flow over time, and is always pyramid-shaped.
5. Energy is lost at each level, so too little remains to support more.

Nutrient cycles

1. Photosynthesis.
2. Respiration, decomposition and combustion.
3. From dead organisms that were buried and did not decompose fully, over millions of years.
4. They change ammonium ions into nitrate ions.
5. By lightning and by nitrogen-fixing bacteria.

Populations

1. A group of organisms of one species, living in the same area, at the same time.
2. All of the populations of different species in an ecosystem.
3. Food supply, competition, predation and disease.
4. Lag, exponential (log), stationary and death.
5. Limiting factors mean the birth rate equals the death rate.