REVISION GUIDE

Every species has a *job*

Ecological niches

No two species can do exactly the same job in the same place for long. Here is how living things get their energy, how they eat and avoid being eaten, how plants fight for light, and why a species rarely lives everywhere it could.

13 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ib-biology-b4-2-ecological-niches

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By the end you can

- [ ] Describe the ecological niche of a species as its role, with its biotic and abiotic interactions B4.2.1
- [ ] Distinguish obligate anaerobes, facultative anaerobes and obligate aerobes by their tolerance of oxygen B4.2.2
- [ ] Outline photosynthesis as the mode of nutrition of plants, algae and some prokaryotes B4.2.3
- [ ] Describe holozoic nutrition: ingestion, digestion, absorption and assimilation B4.2.4
- [ ] Explain mixotrophic nutrition in protists such as Euglena, obligate and facultative B4.2.5
- [ ] Explain how saprotrophic fungi and bacteria feed, and their role as decomposers B4.2.6
- [ ] Outline the three energy sources archaea use to make ATP B4.2.7
- [ ] Infer the diet of hominids from the features of their teeth and skulls B4.2.8
- [ ] Describe adaptations of herbivores for eating plants, and of plants for resisting them B4.2.9
- [ ] Describe chemical, physical and behavioural adaptations of predators and their prey B4.2.10
- [ ] Explain how forest plants reach light: canopy trees, lianas, epiphytes, stranglers and shade plants B4.2.11
- [ ] Distinguish a fundamental niche from a realized niche, with barnacles on a rocky shore B4.2.12
- [ ] Explain competitive exclusion, and the two outcomes of competition between species B4.2.13

Tick each one when you can do it without the book.

01 A habitat is an address; a niche is a *job*

B4.2.1 ECOLOGICAL NICHE AS THE ROLE OF A SPECIES IN AN ECOSYSTEM

The **ecological niche** of a species is its role in the ecosystem: where it lives, when it is active, what it eats and how it gets it, what eats it, what it competes with, and the range of temperature, salinity or light it can stand. Some of these are **biotic** interactions, with other living things. Others are **abiotic**, with the physical and chemical conditions. Together they decide how well the species grows, survives and reproduces.

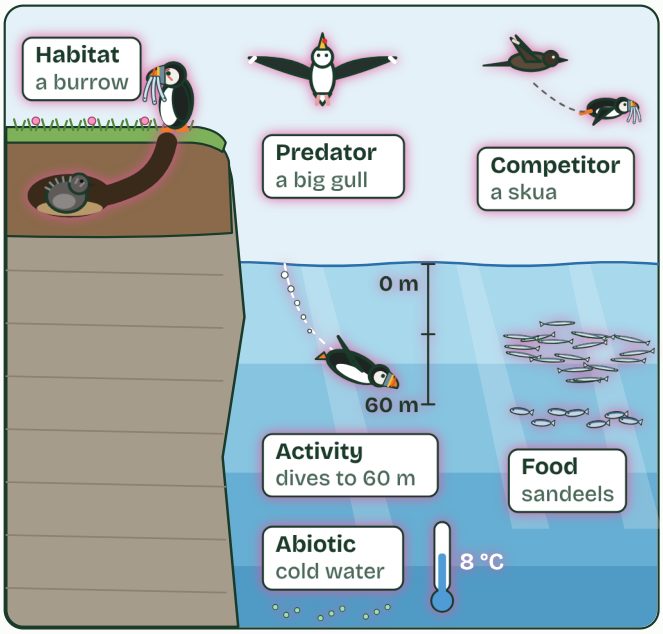
Take the Atlantic puffin (*Fratercula arctica*). It nests in burrows on grassy cliff tops in the North Atlantic, dives up to about 60 m for sandeels and sprats, carries a row of fish crosswise in its beak back to its single chick, is hunted by great black-backed gulls and has its fish stolen by skuas. It needs cold, productive water near land. All of that, together, is its niche. Its habitat is only one part: the cliff.

KEY POINTS

- Niche: the **role** of a species in its ecosystem.
- It includes **biotic** interactions (food, predators, competitors, parasites, mutualists) and **abiotic** ones (temperature, water, light, oxygen).
- Both affect its **growth, survival and reproduction**.
- The habitat is only **where** it lives; the niche is how it lives there.

KEY TERMS

ecological niche
The habitat a species lives in, together with its role there: everything it needs, everything it does, and all its interactions with other species and with abiotic factors.



Habitat Puffins nest in burrows dug into the soil of grassy cliff tops and islands in the North Atlantic, out of reach of foxes and rats. Each pair raises a single chick.

Predator Great black-backed gulls catch adult puffins, especially as they land or leave their burrows.

Interactions An Arctic skua chases puffins in the air until they drop their fish, then takes it: kleptoparasitism. Puffins also compete with seabirds such as kittiwakes, and with fishing boats, for sandeels.

Food A puffin catches sandeels and young sprats and herring underwater. It can carry a row of ten or more fish crosswise in its beak back to its chick.

Activity Puffins feed by day, diving from the surface and using their wings to swim, down to about 60 m. They spend the winter far out at sea and come to land only to breed, from about April to August.

Abiotic factors Puffins need cold, nutrient-rich water mixed by currents near land, where plankton feed the fish they eat. Warming seas have cut sandeel numbers and puffin breeding success in parts of their range.

PREDICT

Two species of bird live in the same oak wood. Which statement must be true?

(A) They share the same niche, because they share one and the same habitat in the wood

(B) They share a habitat, but their niches differ in some way, such as food or feeding place

(C) One of the two species must be in the process of dying out from the wood altogether

Decide before you look. Answer on page 36.

REMEMBER IT

What goes into a niche

H	A	R	I
Hungry	Ants	Raid	Insects
Habitat	**Activity**	**Resources**	**Interactions**
where it lives	when and how it is active	food, water, nest sites	predators, prey, competitors, partners

02 Oxygen: *needed*, optional or poison

B4.2.2 OBLIGATE ANAEROBES, FACULTATIVE ANAEROBES AND OBLIGATE AEROBES

Oxygen is one abiotic factor that splits microbes into three groups. **Obligate aerobes** need it: they respire aerobically and cannot make enough ATP without it. *Mycobacterium tuberculosis* is one, which is why tuberculosis grows best in the well-aired lungs.

Facultative anaerobes use oxygen when it is there and switch to anaerobic respiration when it is not, though they grow faster with it. Yeast (*Saccharomyces cerevisiae*) and *Escherichia coli* in your gut are both facultative. **Obligate anaerobes** are poisoned by oxygen: they lack the enzymes that break down the reactive forms of oxygen, which damage their cells. *Clostridium tetani*, which causes tetanus, lives in soil and grows only in deep, closed wounds.

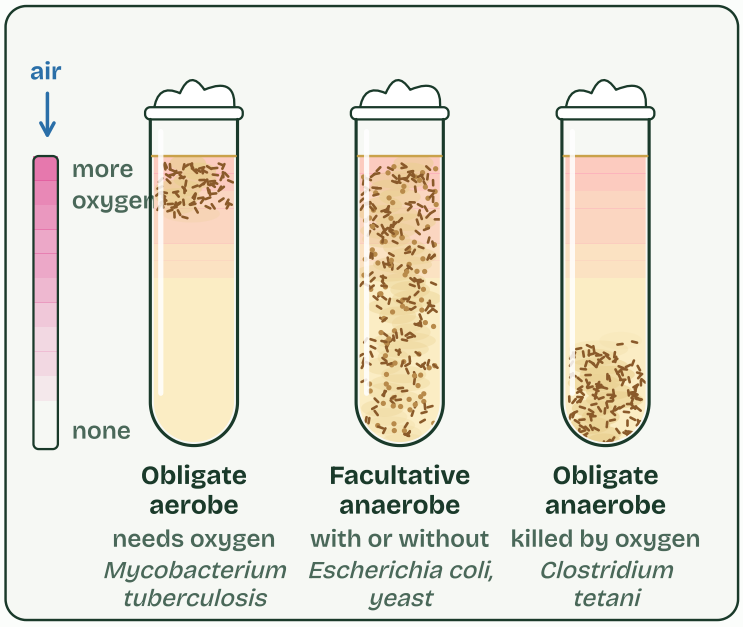
Grow each in a tube of broth that is open to the air at the top, and the oxygen falls with depth. Where each one grows in the tube shows which group it is in.

KEY TERMS

obligate aerobes
An organism that needs oxygen to survive, because it can only make enough ATP by aerobic respiration.

facultative anaerobes
An organism that respires aerobically when oxygen is present and switches to anaerobic respiration or fermentation when it is not.

obligate anaerobes
An organism that cannot survive in the presence of oxygen, because oxygen and the reactive forms it produces damage its cells.



PREDICT

A bacterium grows all the way down a tube of broth, but most thickly near the top. Which is it?

(A) An obligate aerobe that needs oxygen to make every single molecule of its ATP

(B) An obligate anaerobe, killed off wherever there is any oxygen dissolved in the broth

(C) A facultative anaerobe, growing without oxygen but faster with it near the top

Decide before you look. Answer on page 36.

IN THE EXAM

Keep to **tolerance of oxygen**:

1. Obligate aerobe: needs oxygen.
2. Facultative anaerobe: grows with or without oxygen.
3. Obligate anaerobe: cannot grow, or dies, where oxygen is present.

B4.2.3 PHOTOSYNTHESIS AS THE MODE OF NUTRITION IN PLANTS, ALGAE AND SEVERAL GROUPS OF PHOTOSYNTHETIC PROKARYOTES

03 Making food from *light*

An **autotroph** makes its own carbon compounds from carbon dioxide and other simple inorganic substances. Most do it by **photosynthesis**: light energy, captured by pigments such as chlorophyll, is used to make glucose from carbon dioxide and water, and oxygen is given off. From that glucose, with nitrate, phosphate and other mineral ions, the autotroph builds every carbon compound in its body.

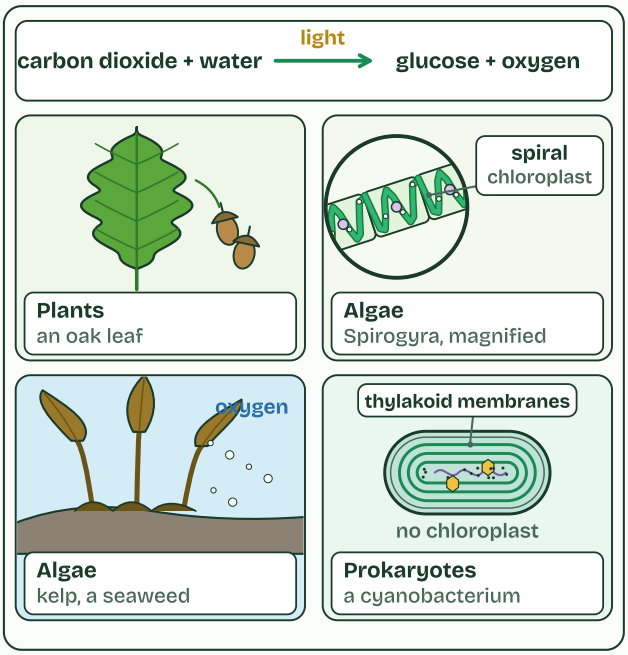
Photosynthesis feeds three groups: **plants**, **algae** (from single cells such as *Chlamydomonas* to the filaments of *Spirogyra* and the giant kelps) and several groups of **prokaryotes**. The best known are the **cyanobacteria**, such as *Anabaena*: they have no chloroplasts, but their chlorophyll sits on folded membranes in the cytoplasm. Cyanobacteria began releasing oxygen over 2.4 billion years ago, and a cyanobacterium taken in by an early eukaryote became the first chloroplast.

KEY POINTS

- **Autotroph**: makes its own carbon compounds from inorganic ones.
- **Photosynthesis**: light energy used to make glucose from carbon dioxide and water; oxygen released.
- Done by **plants**, **algae** and some **prokaryotes**, such as cyanobacteria.
- Prokaryotes photosynthesise **without chloroplasts**.

KEY TERMS

autotroph
An organism that makes its own carbon compounds from simple inorganic substances such as carbon dioxide, using energy from light or from chemical reactions.



PREDICT

Why are photosynthetic organisms called producers in a food chain?

(A) They make the carbon compounds, from carbon dioxide and light, that every other organism depends on

(B) They produce all of the oxygen that every other living organism on Earth needs for respiration

(C) They produce the most offspring of any of the organisms in an ecosystem, year after year

Decide before you look. Answer on page 36.

04 Swallow it, then *break it down*

B4.2.4 HOLOZOIC NUTRITION IN ANIMALS

Every animal is a **heterotroph**: it gets its carbon compounds ready-made from other organisms. Animals do it by **holozoic nutrition**. Food is taken into the body whole or in pieces (**ingestion**), broken down inside the gut by enzymes into small soluble molecules (**digestion**), taken across the gut wall into the blood or cells (**absorption**), and used to build the animal's own molecules and tissues (**assimilation**). Whatever cannot be digested passes out of the gut as faeces (**egestion**).

The key word is *internal*. A fungus digests its food outside itself and absorbs the products (chapter 6). An animal takes the food in first, so the digestive enzymes work in a closed space, the gut, where they are not wasted and the products are not lost to other organisms.

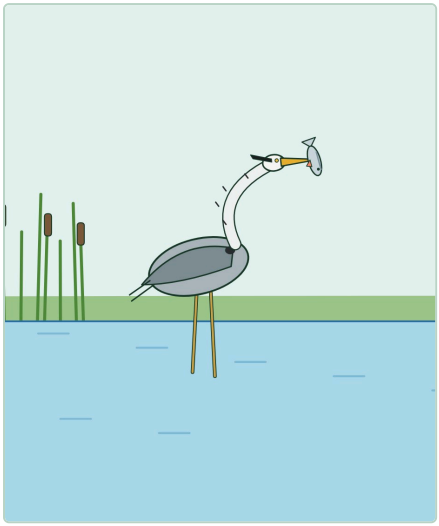
KEY TERMS

heterotroph
An organism that obtains its carbon compounds from other organisms, living or dead, rather than making them itself.

holozoic nutrition
Nutrition in which food is taken into the body, digested internally, absorbed and assimilated.

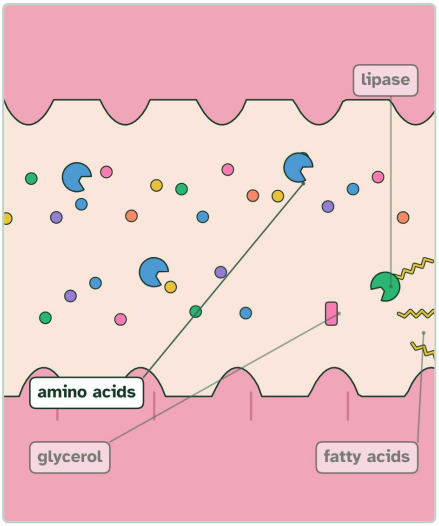
ANIMATION · FROM MOUTH TO CELL
6 MOMENTS

1 INGESTION



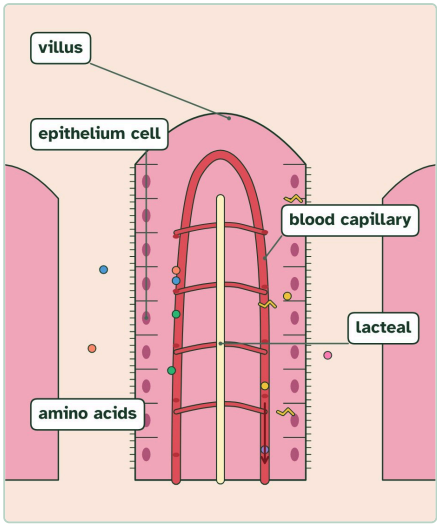
Ingestion. A grey heron spears a fish and swallows it whole: the food is taken into its gut.

2 DIGESTION



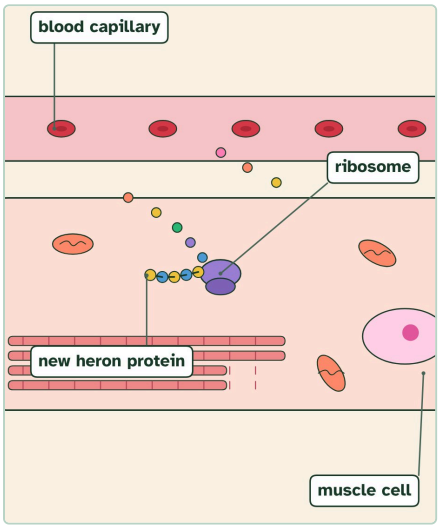
Digestion. Inside the gut, enzymes cut the large molecules of the fish into small, soluble ones: proteins into amino acids, fats into fatty acids and glycerol.

3 ABSORPTION



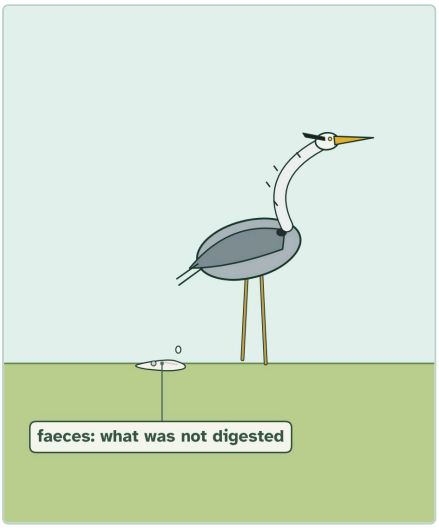
Absorption. The small molecules cross the wall of the intestine, through the cells of each villus, into the blood.

4 ASSIMILATION



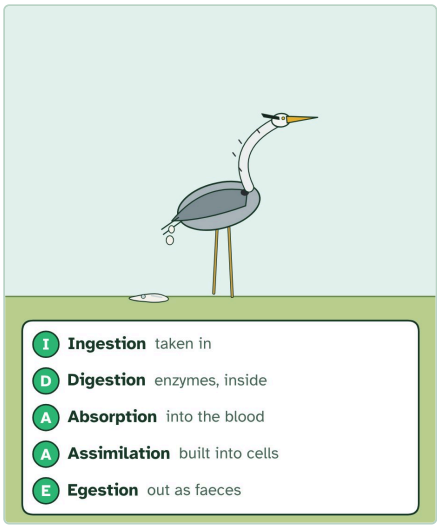
Assimilation. The blood carries them to the body cells, which use them to build their own molecules: here, a muscle cell joins amino acids into heron protein.

5 EGESTION



Egestion. What could not be digested leaves the body as faeces. Herons also cough up pellets of bones and scales.

6 HOLOZOIC NUTRITION



Holozoic nutrition: food is taken in, then digested inside the body. **I** Despise **A**ll **A**lgebra **E**xams.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#holozoic

PREDICT

A Hydra catches a water flea with its tentacles, pushes it through its mouth and digests it in its body cavity. Which step of holozoic nutrition is the pushing through the mouth?

(A) Assimilation, because the flea becomes part of the Hydra's own body

(B) Ingestion, because the food is taken into the body before it is digested

(C) Absorption, because the flea passes from outside to inside the animal

Decide before you look. Answer on page 36.

REMEMBER IT

The order of holozoic nutrition

I	D	A	A	E
I	Despise	All	Algebra	Exams
Ingestion	**D**igestion	**A**bsorption	**A**ssimilation	**E**gestion
taken into the gut	enzymes, inside	across the gut wall	built into the body	the undigested left

05 Both at *once*

B4.2.5 MIXOTROPHIC NUTRITION IN SOME PROTISTS

A **mixotroph** can feed both ways: as an autotroph and as a heterotroph. *Euglena gracilis*, a single-celled protist of ponds and ditches, has chloroplasts and photosynthesises in the light, swimming towards it with its flagellum and steering with a red eyespot. In the dark it absorbs carbon compounds from the water, and some species take in food particles. Kept in the dark long enough, it can lose its chloroplasts and live as a heterotroph alone.

Euglena is a **facultative** mixotroph: it can live by either mode alone, and uses both when it can. **Obligate** mixotrophs need both to grow. Many are in the ocean plankton: some dinoflagellates and ciliates photosynthesise but must also eat prey, sometimes to steal its chloroplasts, and cannot grow on light alone or on food alone.

KEY POINTS

- **Mixotroph**: both autotrophic and heterotrophic.
- *Euglena*: photosynthesises in light, absorbs or ingests food in the dark.
- **Facultative** mixotroph: can live by either mode alone.
- **Obligate** mixotroph: needs both modes to grow; common in ocean plankton.

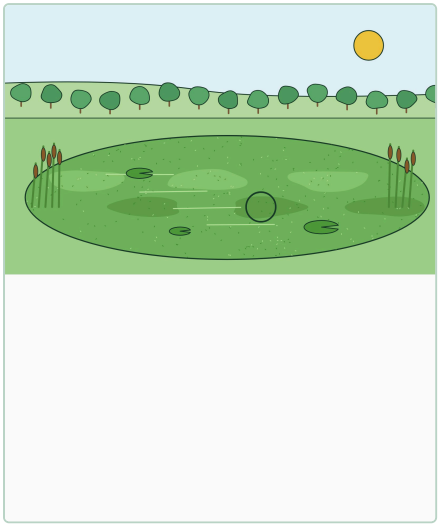
KEY TERMS

mixotroph
An organism that can obtain its carbon compounds both by autotrophic nutrition, such as photosynthesis, and by heterotrophic nutrition.

ANIMATION · EUGLENA, LIGHT AND DARK

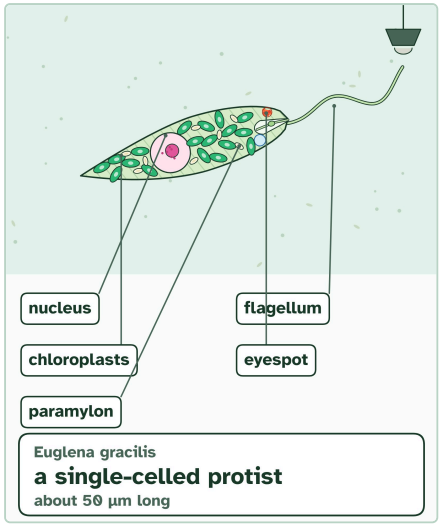
6 MOMENTS

1 A GREEN POND



A pond turned green in summer. The colour is a bloom of **Euglena**, single cells far too small to see one by one.

2 ONE CELL



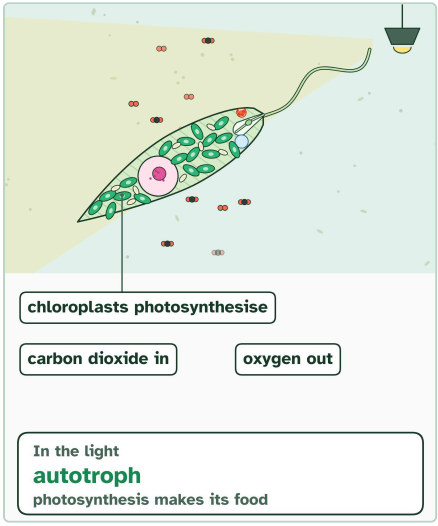
One cell of *Euglena gracilis*, about 50 µm long: a **flagellum** to swim, an **eyespot**, **chloroplasts**, and grains of **paramylon**, its stored carbohydrate.

3 LAMP ON



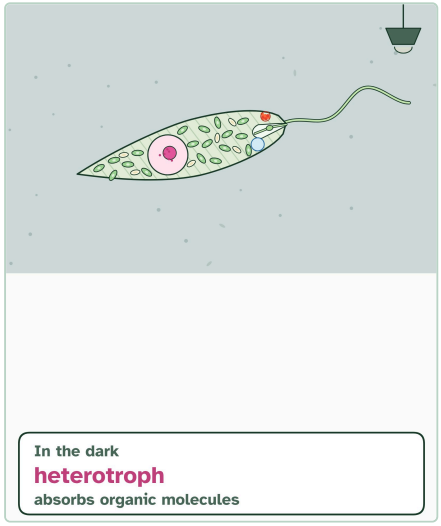
Lamp on. The eyespot shades a light sensor at the base of the flagellum, so the cell steers **towards the light**.

4 AUTOTROPH



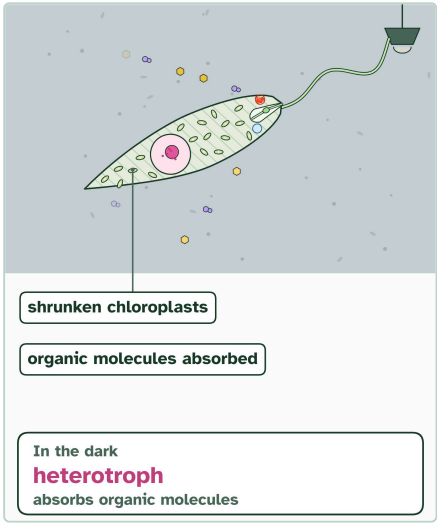
In the light it photosynthesises: **carbon dioxide** in, **oxygen** out. It makes its own carbon compounds: an **autotroph**.

5 LAMP OFF



Lamp off. With no light the chloroplasts shrink and pale, and the paramylon store is used up.

6 HETEROTROPH



In the dark it absorbs **organic molecules** from the water and respires them: a **heterotroph**. Able to do both, it is a **facultative mixotroph**.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#mixotroph

PREDICT

A protist in a lake photosynthesises in the light and eats bacteria. Grown in the light with no bacteria, it dies. What kind of nutrition does it have?

(A) Facultative mixotrophic, since it can switch to photosynthesis once the bacteria run out

(B) Obligate mixotrophic, since it needs both photosynthesis and food to grow and survive

(C) Holozoic only, since photosynthesis is not enough to keep it alive in the lake water

Decide before you look. Answer on page 36.

06

B4.2.6 SAPROTROPHIC NUTRITION IN SOME FUNGI AND BACTERIA

Digesting from the *outside*

A **saprotroph** lives on dead organic matter: fallen leaves, dead wood, dung, corpses. It cannot swallow anything. Instead it secretes digestive enzymes onto the food, which digest it outside the body, and then absorbs the small, soluble products. This is **extracellular digestion**.

A fungus such as the oyster mushroom (*Pleurotus ostreatus*) grows through a dead log as a mesh of thin threads, the **hyphae**, which give a huge surface for secreting and absorbing; the mushroom is only its fruiting body. Bacteria in soil do the same at a smaller scale. Together these **decomposers** release the nutrients locked in dead matter, such as nitrogen, phosphorus and carbon dioxide, so that producers can use them again. Without them, nutrients would stay locked in dead bodies.

KEY TERMS

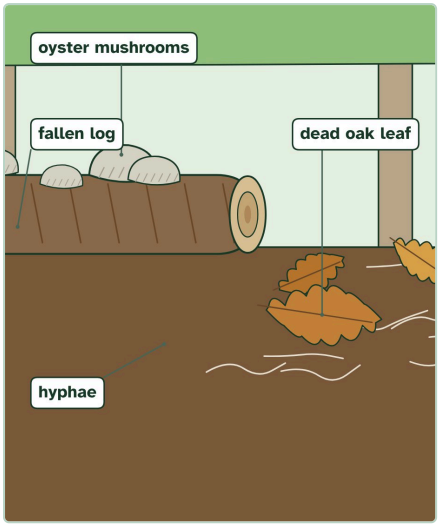
saprotroph
An organism that feeds on dead organic matter by secreting digestive enzymes onto it and absorbing the products of digestion.

decomposers
Saprotrophic fungi and bacteria that break down dead organic matter and release its inorganic nutrients.

ANIMATION · DIGESTING FROM THE OUTSIDE

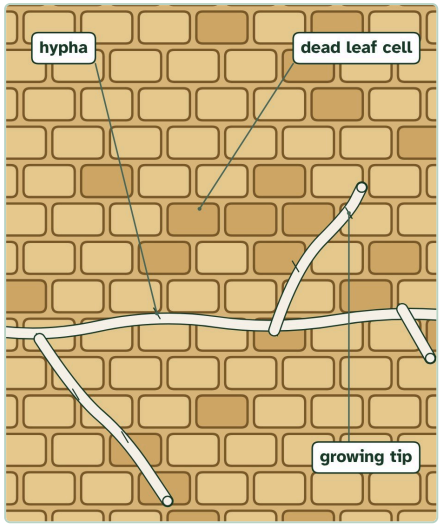
5 MOMENTS

1 A FALLEN LOG



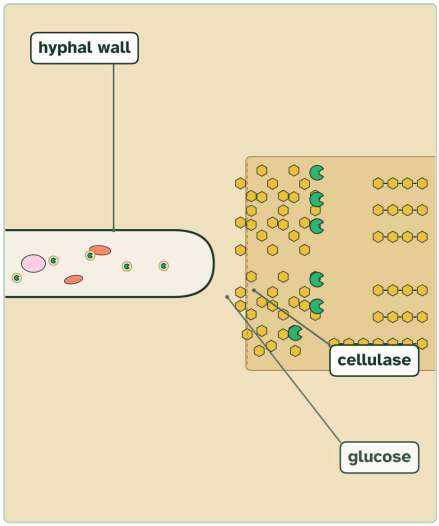
Oyster mushrooms on a fallen log. The mushrooms are only the fruiting bodies: the fungus itself is a web of fine threads, **hyphae**, through the dead wood and leaves.

2 GROW INTO THE FOOD



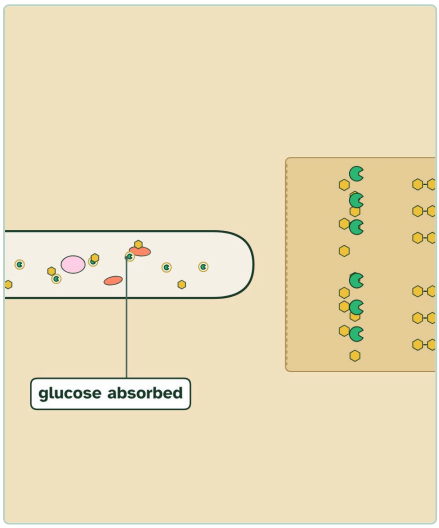
Grow into the food. Hyphae grow into a dead leaf, branching between and through its cells.

3 DIGEST OUTSIDE



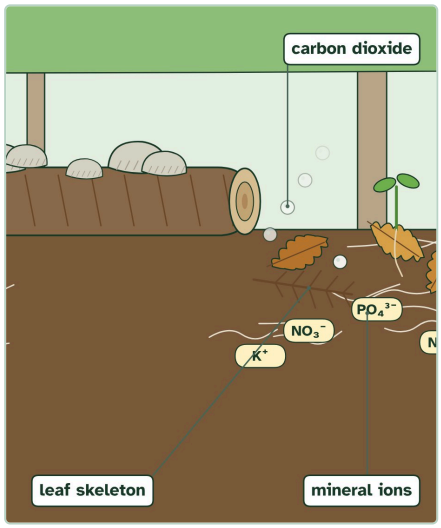
Secrete enzymes; digest outside. The hyphal tip releases enzymes onto the dead matter: cellulase cuts cellulose into glucose, outside the fungus.

4 ABSORB



Absorb. The small, soluble products, glucose and amino acids, are absorbed through the hyphal wall and carried back along the hypha.

5 RECYCLE



Recycle. The leaf crumbles away. Respiring the sugars releases carbon dioxide, and mineral ions are left in the soil for plants: saprotrophs are decomposers.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#sapro

PREDICT

What is the main difference between how a fungus and how an animal digests its food?

(A) The fungus uses no enzymes, since it absorbs its food whole across its cell walls

(B) The fungus digests its food inside its cells, while an animal digests it in the gut

(C) The fungus digests its food outside its body, while an animal digests it once inside

Decide before you look. Answer on page 36.

07 The third domain, and its *three* fuels

B4.2.7 DIVERSITY OF NUTRITION IN ARCHAEA

Living things fall into three domains: **bacteria**, **archaea** and **eukaryotes**. Archaea are prokaryotes, but their membranes, their cell walls and the way they copy and read their genes differ from bacteria. First found in hot springs and salt lakes, they are now known to live everywhere, from soil and the open ocean to the human gut.

For their nutrition, archaea are the most varied of all. To make ATP, different species use one of three energy sources:

Light. Some absorb light with a pigment in their membrane, without chlorophyll, and use it to make ATP.
The oxidation of inorganic chemicals, such as hydrogen, hydrogen sulfide, ammonia or iron ions. Some of these live at deep-sea vents, far from any light.
The oxidation of carbon compounds, taken from their surroundings, as heterotrophs.

Some use their energy to fix carbon dioxide into carbon compounds, as autotrophs; others take carbon compounds ready-made. The methane-producing archaea in cattle guts, rice paddies and marshes are among them, and so behind some of the methane in chapter 1 of D4.3.

ANIMATION · THREE WAYS TO POWER A CELL

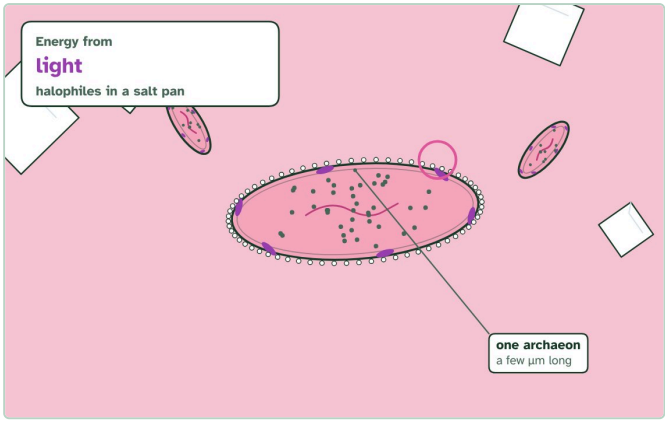
9 MOMENTS

1 LIGHT



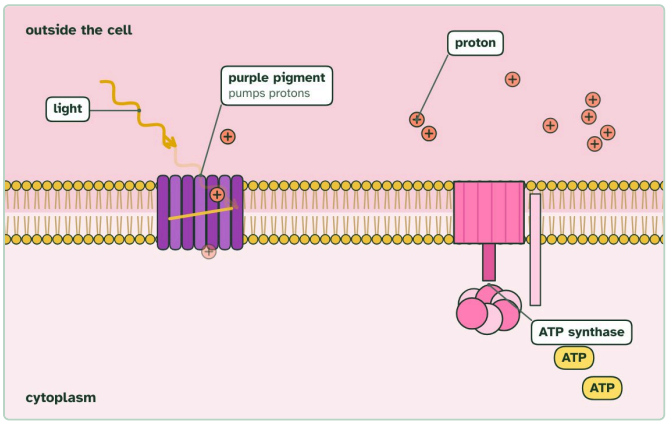
A salt pan, ten times saltier than the sea. The water is pink with **archaea** that live nowhere less salty.

2 LIGHT



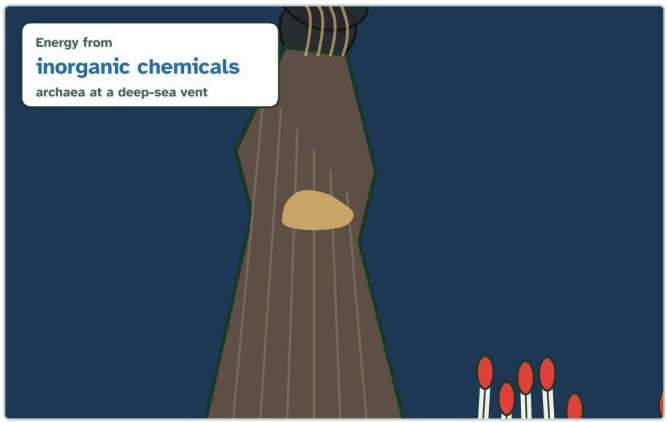
One archaeon among the salt crystals. Its membrane carries patches of a **purple pigment**.

3 LIGHT



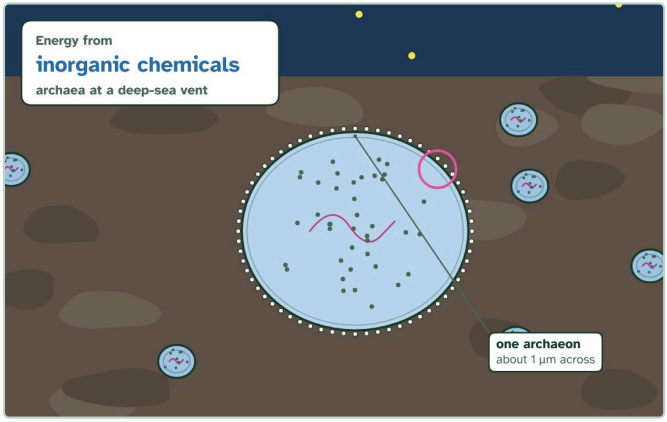
Light hits the pigment, which pumps a **proton** out of the cell. The protons flow back in through **ATP synthase**, which makes **ATP**.

4 INORGANIC CHEMICALS



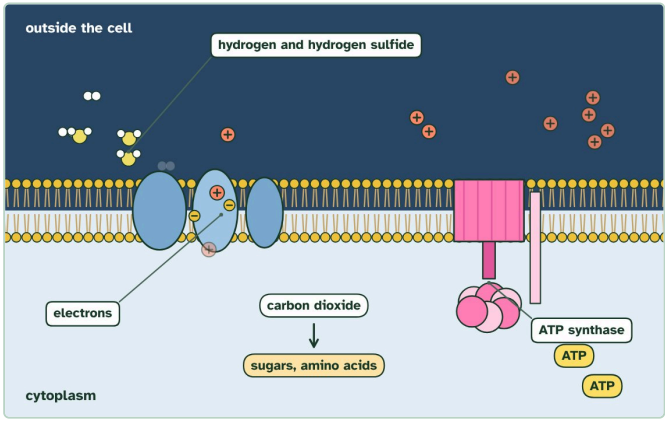
A black smoker on the deep sea floor: no light at all, and water at over 300 °C full of hydrogen sulfide.

5 INORGANIC CHEMICALS



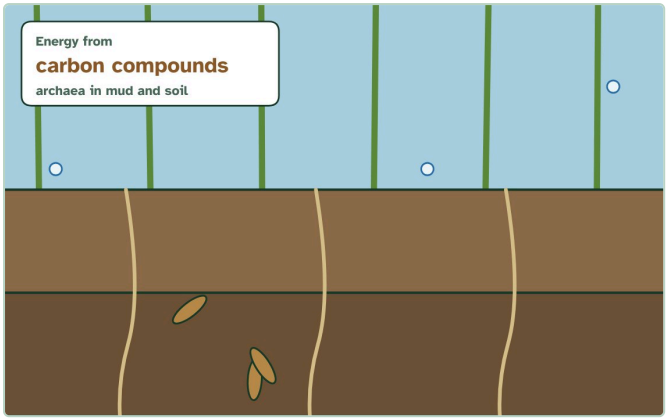
Archaea coat the chimney. They live on the **inorganic chemicals** pouring out of it.

6 INORGANIC CHEMICALS



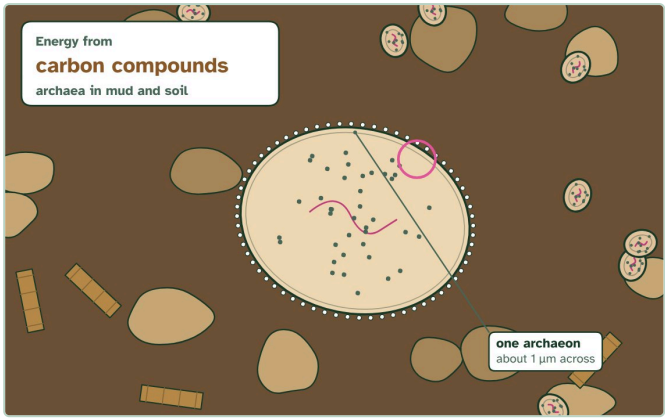
They **oxidise** hydrogen and hydrogen sulfide. The electrons pass along the membrane, pumping protons out, and ATP synthase makes **ATP**. With it they fix carbon dioxide.

7 CARBON COMPOUNDS



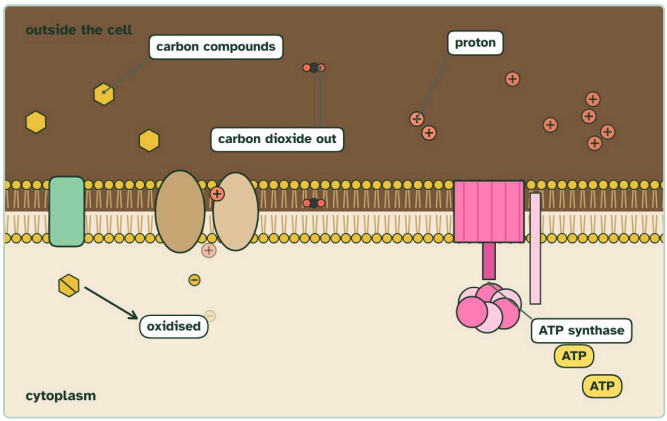
Mud at the bottom of a marsh, full of dead leaves and roots, and no oxygen.

8 CARBON COMPOUNDS



Archaea live among the grains, next to the dead matter that feeds them.

9 CARBON COMPOUNDS



They take in **carbon compounds** and **oxidise** them to carbon dioxide. The electrons pump protons out, and ATP synthase makes **ATP**.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#archaea

PREDICT

An archaean lives in a hot spring rich in hydrogen sulfide, in complete darkness, with almost no organic matter. Where does its energy most likely come from?

(A) From light, absorbed by a pigment in its membrane and used to make ATP

(B) From the oxidation of inorganic chemicals, such as the hydrogen sulfide

(C) From the oxidation of carbon compounds that it takes in from the water

Decide before you look. Answer on page 36.

IN THE EXAM

You do not need to name archaea. Learn the **three energy sources** for ATP:

1. light;
2. oxidation of inorganic chemicals;
3. oxidation of carbon compounds.

B4.2.8 RELATIONSHIP BETWEEN DENTITION AND THE DIET OF OMNIVOROUS AND HERBIVOROUS MEMBERS OF THE FAMILY HOMINIDAE

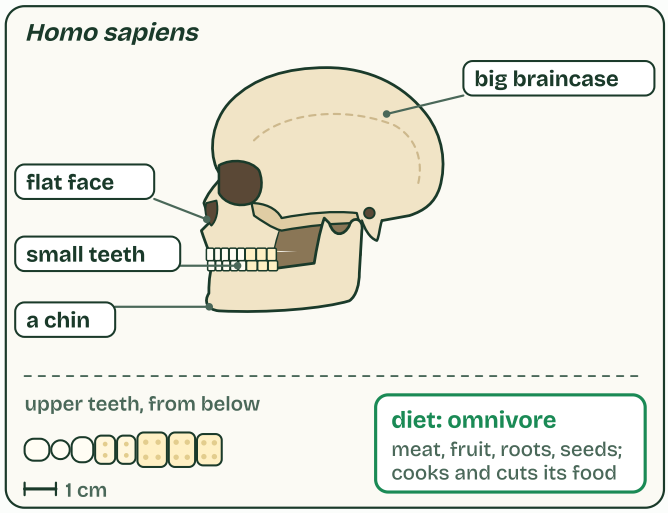
08 Reading a diet in the *teeth*

Teeth are the hardest part of a skeleton and the commonest fossils of our relatives. Watching living mammals, biologists built a theory: **herbivores** have broad, flat, thickly enamelled molars for grinding tough plants, and big jaw muscles; **carnivores** have sharp teeth for slicing; **omnivores** have a mix. From that theory, the diet of an extinct species can be **deduced** from its teeth and skull.

Paranthropus robustus, from South Africa about 2 to 1 million years ago, had small front teeth but enormous premolars and molars with very thick enamel, a deep, heavy jaw, wide cheekbones and a bony crest along the top of the skull, the **sagittal crest**, where huge chewing muscles attached. It ground tough plant food: seeds, nuts, roots and tubers. *Homo sapiens* has small molars, small canines and no crest: the teeth of an **omnivore** that cuts its food with tools and cooks it. *Homo floresiensis*, the small hominid of the island of Flores, Indonesia, had teeth like ours in shape, and its cave holds stone tools and the bones of young pygmy elephants (*Stegodon*): an omnivore too.

KEY POINTS

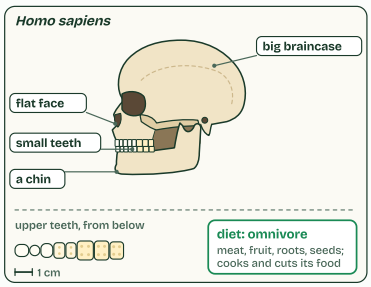
- **Herbivore** features: large, flat molars and premolars, thick enamel, heavy jaw, sagittal crest.
- **Omnivore** features: smaller molars, varied teeth for biting and grinding, no crest.
- **NOS**: theory from living mammals lets us **deduce** the diet of extinct ones.



SWITCH IT

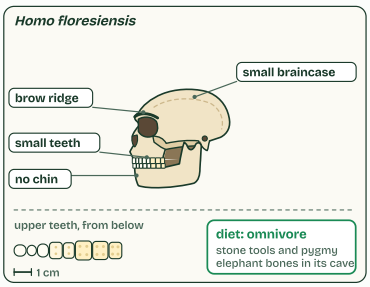
3 SETTINGS

1



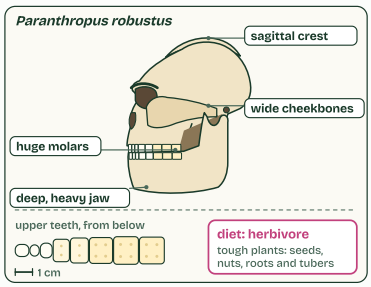
H. sapiens

2



H. floresiensis

3



P. robustus

PREDICT

A fossil hominid skull has a sagittal crest and molars four times the area of a modern human's. What do these suggest?

(A) A diet of mostly meat, torn and sliced by the large teeth and jaws

(B) A diet of tough plant food, ground for long periods by large molars

(C) A diet of soft cooked food, which needs only small chewing muscles

Decide before you look. Answer on page 36.

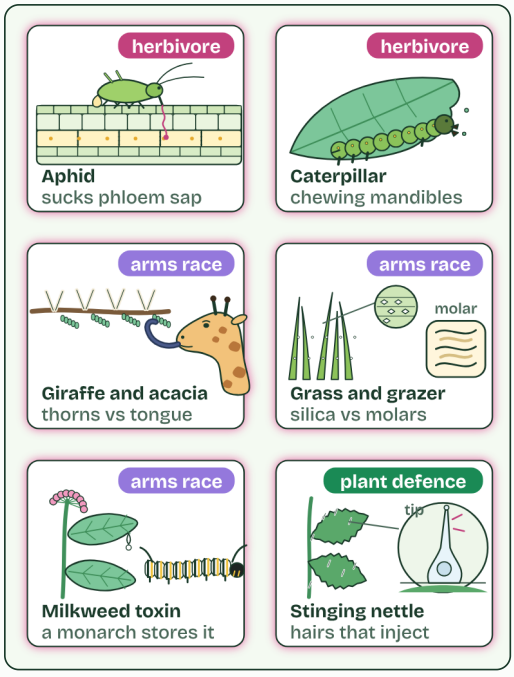
B4.2.9 ADAPTATIONS OF HERBIVORES FOR FEEDING ON PLANTS AND OF PLANTS FOR RESISTING HERBIVORY

09 An arms race over *leaves*

Plants cannot run away, so they defend themselves where they stand, and herbivores evolve ways round the defences. Leaf-eating insects have mouthparts shaped to their food. A caterpillar's **chewing mouthparts** are a pair of hard mandibles that cut and crush leaf tissue. An aphid's **piercing mouthparts** are a fine, flexible stylet that slips between plant cells into a phloem tube and drinks the sugary sap.

Plants resist with **physical** defences: thorns on acacias, spines on cacti, stinging hairs on nettles, and leaves toughened with silica in grasses. They also make **toxic secondary compounds**, often stored in seeds and leaves: nicotine in tobacco, caffeine in coffee and tea, cyanide-releasing compounds in cassava, and cardenolides, which stop the heart, in milkweeds.

Some herbivores have **metabolic adaptations** that detoxify or survive the toxins. Monarch butterfly caterpillars (*Danaus plexippus*) eat milkweed: a changed form of the protein the cardenolides attack makes them resistant, and they store the toxins, so birds that eat a monarch are sick. Koalas break down the toxins of eucalyptus leaves in their liver.



Piercing mouthparts An aphid pushes a fine, flexible stylet between the plant cells into a phloem sieve tube and drinks the sugary sap under pressure. It passes the extra sugar out as honeydew.

Thorns and a long tongue Acacias grow long, sharp thorns that deter most browsers (a physical defence). A giraffe has a tough, prehensile tongue about 45 cm long and thick saliva, and strips leaves from between the thorns.

Chewing mouthparts A caterpillar has a pair of hard mandibles that cut and crush leaf tissue, working along the leaf edge. Many beetles and grasshoppers chew too.

Silica and ridged teeth Grasses stiffen their leaves with silica, which wears teeth down (a physical defence). Grazers such as horses and cows have broad molars with folded ridges of hard enamel that grind it, and in horses the teeth keep growing as they wear.

Toxic secondary compounds Milkweed makes cardenolides, which stop the heart, and bleeds sticky latex where it is bitten. Monarch caterpillars are resistant: a changed form of the protein the cardenolides attack. They store the toxins, which then protect them from birds. Koalas detoxify eucalyptus leaves in their liver.

Stinging hairs Each hair is a hollow cell with a brittle tip of silica. A touch snaps the tip off and the hair injects irritants, including histamine, like a syringe. Thorns, spines and hairs are physical defences; the irritants are chemical.

PREDICT

Why does a plant store toxins in its seeds as well as its leaves?

(A) Seeds use the toxins as a food store when they begin to germinate

(B) Seeds hold the embryo and its food, so losing them costs the plant offspring

(C) Seeds are where all the plant's secondary compounds are first made

Decide before you look. Answer on page 37.

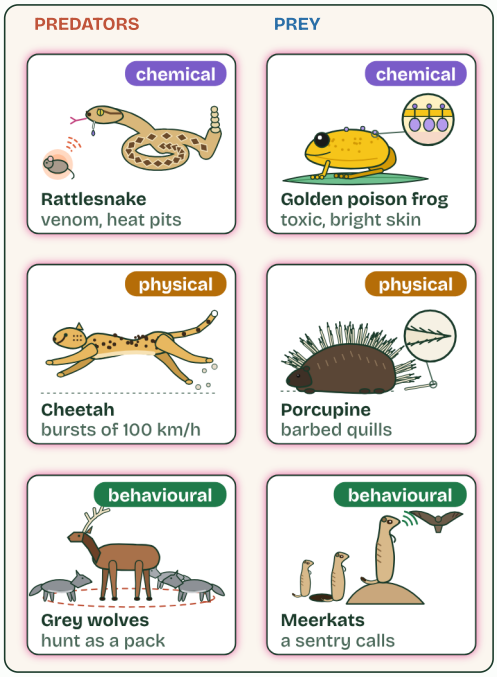
B4.2.10 ADAPTATIONS OF PREDATORS FOR FINDING, CATCHING AND KILLING PREY AND OF PREY ANIMALS FOR RESISTING PREDATION

10 Hunters and the *hunted*

A predator must **find**, **catch** and **kill** its prey, and each step has its adaptations. Each can be **chemical**, **physical** (a structure) or **behavioural**.

	Predator	Prey
Chemical	Rattlesnakes kill with venom. A pit viper also tastes the air with its forked tongue to follow a trail.	Poison dart frogs (*Phyllobates terribilis*) carry toxins in their skin, advertised by bright colours.
Physical	Pit organs between a pit viper's eyes and nostrils sense the infrared from warm prey in the dark. A cheetah's long legs and flexible spine reach about 100 km/h.	Porcupine quills; the armour of an armadillo; the camouflage of a stick insect.
Behavioural	Wolves hunt in packs, wearing down and surrounding large prey such as elk.	Meerkats post a sentry that gives alarm calls; zebras gather in herds; Virginia opossums play dead.

Each side's adaptations select for the other's: faster cheetahs select for faster gazelles. This keeps predator and prey in a long arms race.



Rattlesnake Pit organs between the eyes and nostrils sense infrared from warm prey in the dark (physical); the forked tongue tastes the trail; venom kills and starts to digest the prey (chemical).

Cheetah Long legs, a flexible spine and grippy claws give bursts of about 100 km/h to catch gazelles (physical).

Golden poison frog Phyllobates terribilis carries batrachotoxin in glands in its skin, gathered from the small insects it eats (chemical). Its bright colour warns predators away.

Porcupine Thousands of barbed quills that come away in an attacker (physical). Armadillo armour and the camouflage of stick insects are physical defences too.

Wolves Hunt in packs, wearing down and surrounding prey much larger than one wolf, such as elk (behavioural).

Meerkats One stands guard and gives alarm calls when a hawk or jackal appears (behavioural). Herding in zebras and playing dead in opossums are behavioural too.

PREDICT

A monarch butterfly stores milkweed toxins and is brightly coloured. Is this a chemical, physical or behavioural adaptation against predators?

(A) Behavioural, since the monarch chooses to feed on the milkweed

(B) Chemical, with the bright colour as a physical warning sign of it

(C) Physical, since the bright colour is what keeps the birds away

Decide before you look. Answer on page 37.

11

B4.2.11 ADAPTATIONS OF PLANT FORM FOR HARVESTING LIGHT

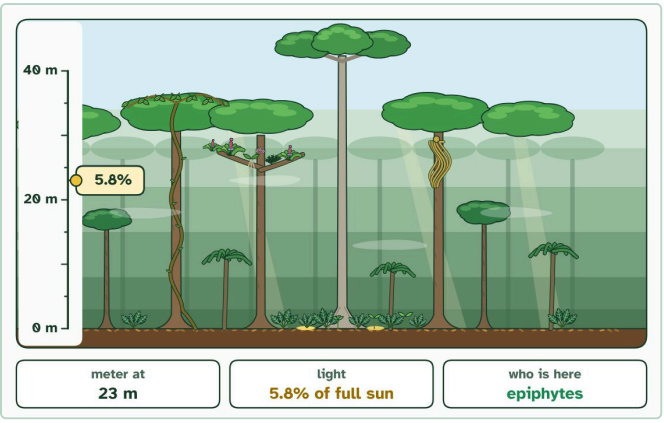
Racing for the *light*

In a tropical rainforest, water and warmth are plentiful all year. Light is the factor in short supply: the canopy absorbs nearly all of it, and the forest floor gets only about 1 to 2% of the light at the top. Plants reach it in five ways.

Canopy trees grow tall, straight trunks and spread their leaves in the full sun at the top, 30 to 50 m up. They shed their shaded lower branches, which would cost more to keep than they make.
Lianas are woody climbers rooted in the soil. They use trees as their support, so they put little into a trunk and grow up quickly to spread their leaves over the canopy.
Epiphytes, such as orchids, bromeliads and ferns, grow on the branches of trees, high up in the light, with no roots in the soil. Their seeds and spores arrive by wind or birds. They catch water and nutrients from rain and falling debris, some with tanks of leaves or roots that soak up water.
Strangler figs start as epiphytes from a seed left by a bird in a high branch. They send roots down to the soil, and the roots thicken and fuse round the trunk of the host. The fig's crown shades the host's, and its roots stop the trunk growing, until the host dies and rots, leaving a hollow lattice of fig.
Shade-tolerant shrubs and herbs live on the floor in the dim light, with large, thin leaves rich in chlorophyll. They make the most of sunflecks, the patches of sun that move across the floor.

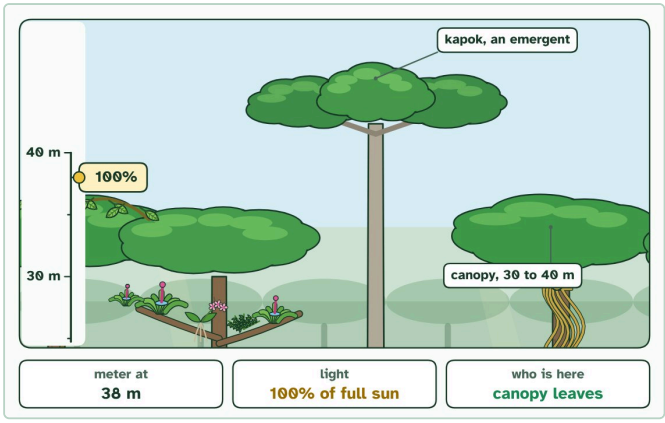
ANIMATION · RACING FOR THE LIGHT
7 MOMENTS

1 23 M: 5.8% OF FULL SUN



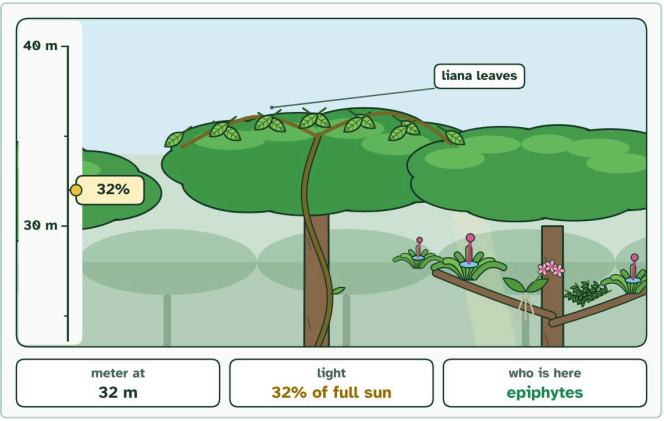
A lowland rainforest. Full sun falls on the top of the canopy, but only 1 to 2% of it reaches the floor.

2 38 M: 100% OF FULL SUN



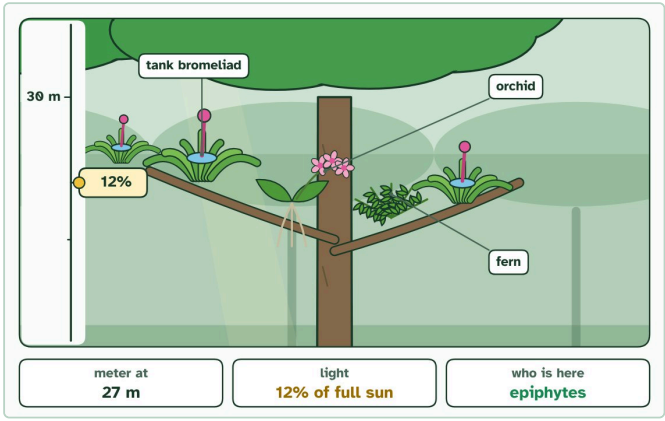
Canopy trees grow tall, straight trunks fast and spread their leaves in full sun, 30 to 50 m up. A kapok breaks through as an emergent.

3 32 M: 32% OF FULL SUN



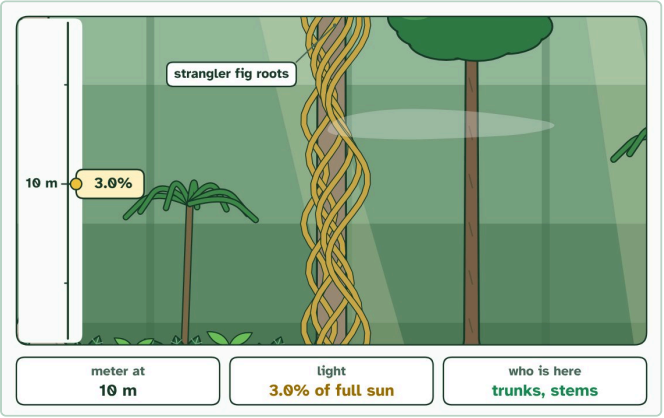
A **liana**, rooted in the soil, climbs a tree for support instead of building its own trunk, and spreads its leaves over the canopy.

4 27 M: 12% OF FULL SUN



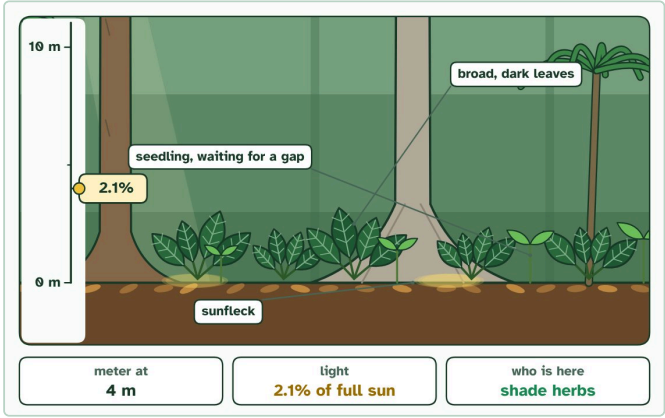
Epiphytes such as bromeliads, orchids and ferns grow on the branches, high in the light, with no roots in the soil.

5 10 M: 3.0% OF FULL SUN



A **strangler fig** starts as a seed on a branch and sends its roots down to the soil. They fuse round the host, which dies.

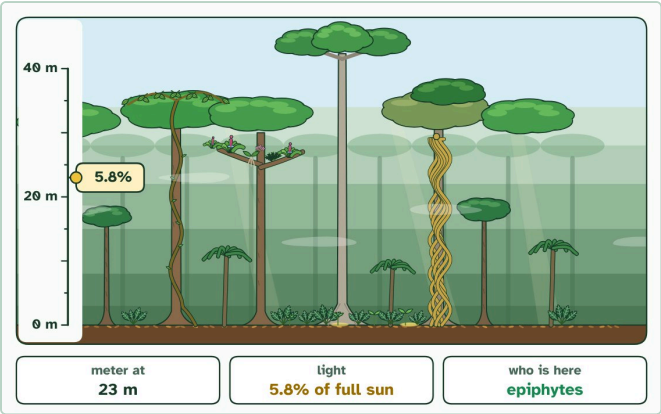
6 4 M: 2.1% OF FULL SUN



Shade-tolerant herbs on the floor have broad, dark leaves to catch the 1 to 2% of light there, and use the moving sunflecks.

7

23 M: 5.8% OF FULL SUN



Each plant has its own way to reach the light it needs.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#light

PREDICT

Why does a liana not need a thick trunk of its own?

(A) It takes its water and its sugars straight out of the host tree it climbs

(B) It climbs a tree for support, so it can put more into growing upwards

(C) It grows only on the forest floor, where there is no wind to blow it over

Decide before you look. Answer on page 37.

REMEMBER IT

Five ways to reach the light

C Can	L Little	E Elves	S Steal	H Herbs
Canopy trees tall trunks	**Lianas** climb the trees	**Epiphytes** sit on branches	**Stranglers** grow down, then kill	**Shade herbs** tolerate the dark

12

B4.2.12 FUNDAMENTAL AND REALIZED NICHES

Where it *could* live, and where it does

The **fundamental niche** of a species is everything it could do and everywhere it could live, set by its adaptations and its tolerance limits, if no other species got in its way. The **realized niche** is what it actually does and where it actually lives, when it competes with other species. The realized niche is usually smaller, and part of the fundamental one.

Joseph Connell showed this with barnacles on a rocky shore in Scotland, in 1961. Two species settle as larvae across the shore. *Chthamalus stellatus* lives higher up, where the rock dries out at low tide; *Semibalanus balanoides* lives lower down, and dies of drying out if it settles too high. Connell scraped *Semibalanus* off some rocks. Where it was gone, *Chthamalus* survived right down the shore. Where it stayed, the faster-growing *Semibalanus* smothered, undercut or crushed the young *Chthamalus*. So the fundamental niche of *Chthamalus* reaches down the shore, but its realized niche is only the upper band.

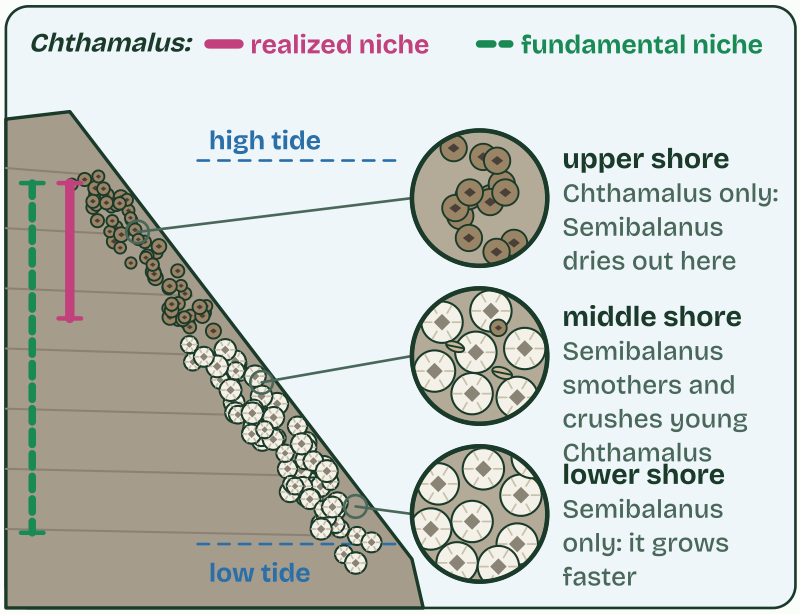
KEY POINTS

- **Fundamental niche**: the potential niche, from adaptations and tolerance limits.
- **Realized niche**: the actual niche, with competition from other species.
- The realized niche is **part of** the fundamental niche.
- Connell's barnacles: *Chthamalus* can live low on the shore, but *Semibalanus* excludes it there.

KEY TERMS

fundamental niche
The full range of conditions and resources in which a species could survive and reproduce, set by its adaptations and tolerance limits, with no competition from other species.

realized niche
The part of its fundamental niche that a species actually occupies, because of competition and other interactions with other species.



PREDICT

What sets the upper limit of *Chthamalus* on the shore?

(A) Competition with *Semibalanus*, which grows faster everywhere on the rock

(B) Its tolerance of drying out, an abiotic factor that limits its fundamental niche

(C) Predation by dog whelks, which hunt it right across the top of the shore

Decide before you look. Answer on page 37.

13 No two species can share a *niche*

B4.2.13 COMPETITIVE EXCLUSION AND THE UNIQUENESS OF ECOLOGICAL NICHES

When two species need the same limited resource, they compete. If their niches are the same, one will always be a little better at getting the resource, or reproduce a little faster, and in time it removes the other from that place. This is the **competitive exclusion principle**. It explains why every species' niche is **unique**.

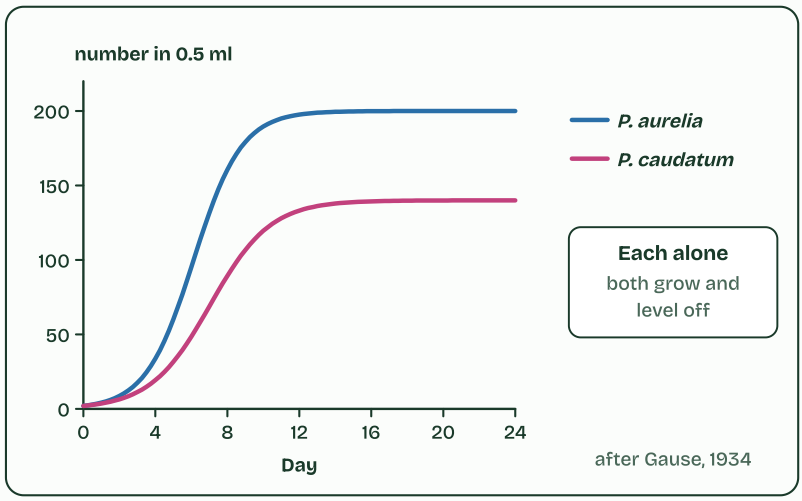
In the 1930s the Russian ecologist Georgii Gause grew two species of *Paramecium* on the same bacteria. Alone, each grew to a steady population. Together, *P. aurelia* grew faster and *P. caudatum* died out in about two to three weeks. Competition between two species can end in one of two ways:

Elimination: one species is excluded from the place, as *P. caudatum* was. **Restriction**: both survive, each kept to part of its fundamental niche, so they divide the resources between them. This is **resource partitioning**. When Gause grew *P. caudatum* with *P. bursaria*, both survived: *P. bursaria* fed on yeast cells settled at the bottom, and *P. caudatum* fed on bacteria in the liquid above.

Robert MacArthur found five species of warbler feeding on insects in the same spruce trees in Maine, in 1958. Each fed mostly in its own part of the tree: the top, the outer twigs, the inner branches or the base. Partitioning lets similar species share a habitat.

KEY TERMS

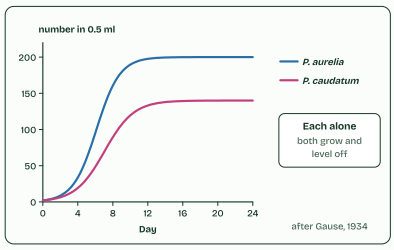
competitive exclusion principle The principle that two species cannot coexist indefinitely in the same place if they occupy the same niche: one will outcompete and eliminate the other.



SWITCH IT

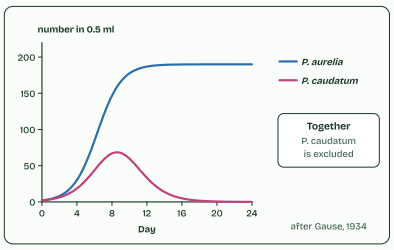
3 SETTINGS

1



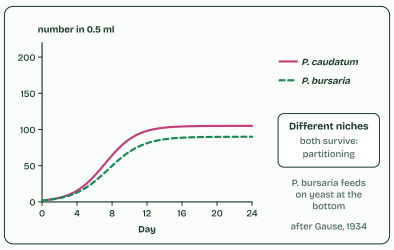
Each alone

2



Aurelia with caudatum

3



Caudatum with bursaria

PREDICT

Two species of Paramecium are grown together and both survive for months. What is the most likely reason?

(A) They have the same niche, but there is so much food that they never compete

(B) Their niches differ, such as in where they feed, so they partition the resources

(C) They are not really two species, since they can interbreed in the culture flask

Decide before you look. Answer on page 37.

Key terms

Every term this guide defines, A to Z, with the chapter it is in. Cover the right-hand side and test yourself.

autotroph 03
An organism that makes its own carbon compounds from simple inorganic substances such as carbon dioxide, using energy from light or from chemical reactions.

competitive exclusion principle 13
The principle that two species cannot coexist indefinitely in the same place if they occupy the same niche: one will outcompete and eliminate the other.

decomposers 06
Saprotrophic fungi and bacteria that break down dead organic matter and release its inorganic nutrients.

ecological niche 01
The habitat a species lives in, together with its role there: everything it needs, everything it does, and all its interactions with other species and with abiotic factors.

facultative anaerobes 02
An organism that respires aerobically when oxygen is present and switches to anaerobic respiration or fermentation when it is not.

fundamental niche 12
The full range of conditions and resources in which a species could survive and reproduce, set by its adaptations and tolerance limits, with no competition from other species.

heterotroph 04
An organism that obtains its carbon compounds from other organisms, living or dead, rather than making them itself.

holozoic nutrition 04
Nutrition in which food is taken into the body, digested internally, absorbed and assimilated.

mixotroph 05
An organism that can obtain its carbon compounds both by autotrophic nutrition, such as photosynthesis, and by heterotrophic nutrition.

obligate aerobes 02
An organism that needs oxygen to survive, because it can only make enough ATP by aerobic respiration.

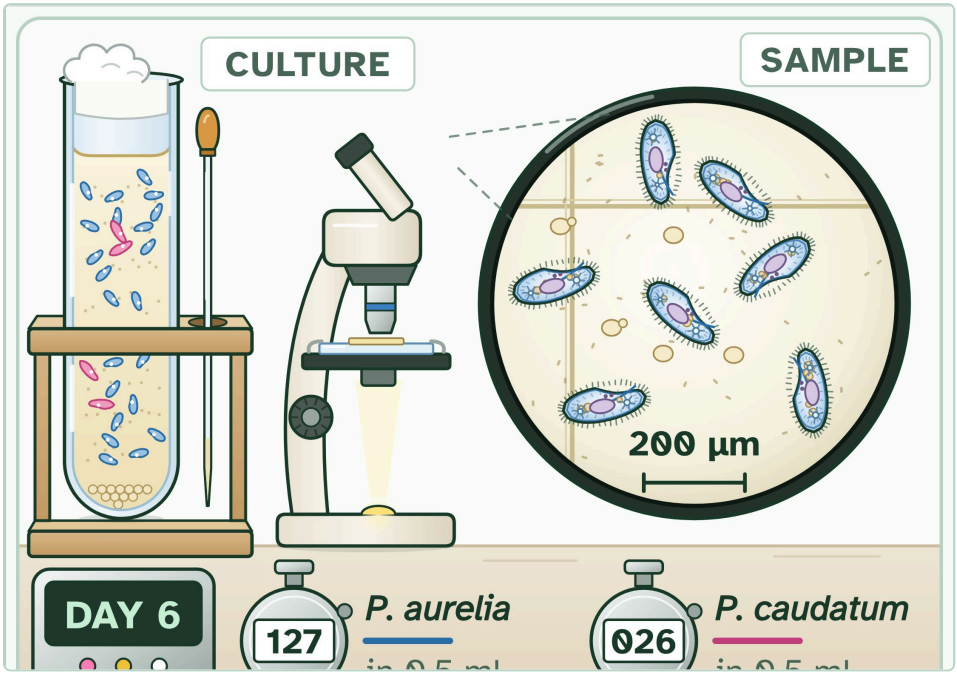
obligate anaerobes 02
An organism that cannot survive in the presence of oxygen, because oxygen and the reactive forms it produces damage its cells.

realized niche 12
The part of its fundamental niche that a species actually occupies, because of competition and other interactions with other species.

saprotroph 06
An organism that feeds on dead organic matter by secreting digestive enzymes onto it and absorbing the products of digestion.

Dry lab: *Paramecium in a tube*

Repeat Gause's experiment. Grow species of Paramecium alone and in pairs, count them every day for 24 days, and find out when two species can share a tube and when one wins.



Run it online: change the variables, run the trials, and the table and graph fill in as you go. `biologybybradford.com/guides/ib-biology-b4-2-ecological-niches#lab`

Your question

What happens when two species of Paramecium that eat the same bacteria are grown together, and is it different for a pair that feed in different parts of the tube? In the 1930s Georgii Gause grew them in tubes of culture medium and counted them each day.

What you can change

Which species go in the tube: Paramecium aurelia, P. caudatum or P. bursaria, alone or two together. The food supply: low, normal or high.

What to record

The number of each species in a 0.5 ml sample on every day. The graph plots each population over the 24 days. Repeat a pairing to see how far it varies, and download the CSV to plot your own.

Find out

- **Each alone.** Grow each species on its own with normal food. Which reaches the highest number, and how long does each take to level off?
- **Aurelia and caudatum.** Grow them together three times. Which species dies out, on which day, and does it always happen?
- **Caudatum and bursaria.** Grow them together. Do both survive? Compare their numbers on day 24 with the numbers they reached alone.
- **More food.** Repeat aurelia with caudatum with high food. Does exclusion still happen, and is it faster or slower?

Record

- The species, the food and the number of each species in 0.5 ml on day 24 for every run.
- The day any species died out.
- For repeated runs, the mean and the range of the day-24 numbers.
- Download the CSV to plot each population against day yourself.

Your question What happens when two species of Paramecium that eat the same bacteria are grown together, and is it different for a pair that feed in different parts of the tube? In the 1930s Georgii Gause grew them in tubes of culture medium and counted them each day.**What you can change**Which species go in the tube: Paramecium

aurelia, P. caudatum or P. bursaria, alone or two together. The food supply: low, normal or high.**What to record**The number of each species in a 0.5 ml sample on every day. The graph plots each population over the 24 days. Repeat a pairing to see how far it varies, and download the CSV to plot your own.

Back to niches

Gause's tubes are the classic evidence for competitive exclusion. Use your runs to explain the principle, and why *P. caudatum* could share a tube with *P. bursaria* but not with *P. aurelia*.

QUESTIONS ON THE LAB

QUESTION 1

Grown alone, *P. caudatum* levels off at about 130 in 0.5 ml. Grown with *P. aurelia*, it dies out. What does this show about its niche?

(A) That its fundamental niche is empty, since it cannot live in the tube with any food at all

(B) That its fundamental niche includes the tube, but with aurelia there it has no realized niche

(C) That aurelia must be a predator of caudatum, since one species cannot otherwise remove another

Answer on page 37.

QUESTION 2

***P. caudatum* and *P. bursaria* both survive together. Why do they not exclude each other?**

(A) They are both too slow at reproducing for either one to win the competition

(B) Bursaria feeds on yeast at the bottom and caudatum on bacteria above: different niches

(C) There is always more than enough food in the tube for any two species to share it

Answer on page 37.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on B4.2 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=B4.2&level=SL&paper=quiz&marks=15&src=ep

Answers

PREDICTIONS IN THE CHAPTERS

01 Two species of bird live in the same oak wood. Which statement must be true?

B **They share a habitat, but their niches differ in some way, such as food or feeding place**

Sharing a **habitat** is common; sharing a whole **niche** is not. Great tits and blue tits both nest in holes in oak woods, but blue tits are lighter and take more insects from thin twigs at the ends of branches. Chapter 13 explains why two species with identical niches cannot both stay.

02 A bacterium grows all the way down a tube of broth, but most thickly near the top. Which is it?

C **A facultative anaerobe, growing without oxygen but faster with it near the top**

Growing at every depth means it survives without oxygen, so it is not an obligate aerobe. Growing best near the top means oxygen helps it, so it is not an obligate anaerobe: aerobic respiration makes far more ATP from each glucose. It is a **facultative anaerobe**.

03 Why are photosynthetic organisms called producers in a food chain?

A **They make the carbon compounds, from carbon dioxide and light, that every other organism depends on**

Producers bring carbon and energy into the food web: they fix carbon dioxide into sugars using light. Every **heterotroph** lives on carbon compounds made, at the start of the chain, by an autotroph. Oxygen is a by-product, and not every organism needs it (chapter 2).

04 A Hydra catches a water flea with its tentacles, pushes it through its mouth and digests it in its body cavity. Which step of holozoic nutrition is the pushing through the mouth?

B **Ingestion, because the food is taken into the body before it is digested**

Ingestion is taking food in. Absorption comes after digestion, when small molecules such as amino acids cross into the cells. Assimilation is last: those molecules are built into the Hydra's own proteins.

05 A protist in a lake photosynthesises in the light and eats bacteria. Grown in the light with no bacteria, it dies. What kind of nutrition does it have?

B **Obligate mixotrophic, since it needs both photosynthesis and food to grow and survive**

It photosynthesises, so it is not simply holozoic, but light alone cannot keep it alive. It needs both: an **obligate mixotroph**. A facultative mixotroph such as Euglena would survive on light alone.

06 What is the main difference between how a fungus and how an animal digests its food?

C **The fungus digests its food outside its body, while an animal digests it once inside**

Both use enzymes. A saprotroph secretes them **outside** its body and absorbs the products. An animal ingests the food first and digests it **internally**, in its gut.

07 An archaean lives in a hot spring rich in hydrogen sulfide, in complete darkness, with almost no organic matter. Where does its energy most likely come from?

B **From the oxidation of inorganic chemicals, such as the hydrogen sulfide**

With no light and almost no organic matter, the only fuel is the **inorganic** hydrogen sulfide. Oxidising it releases energy for ATP: this is chemosynthesis.

08 A fossil hominid skull has a sagittal crest and molars four times the area of a modern human's. What do these suggest?

B **A diet of tough plant food, ground for long periods by large molars**

Broad, flat molars grind; a sagittal crest anchors big temporalis muscles for powerful, long chewing. Together they point to tough **plant** food, as in *Paranthropus*. Meat-eaters have slicing teeth, and cooked food needs little chewing.

09 Why does a plant store toxins in its seeds as well as its leaves?

B **Seeds hold the embryo and its food, so losing them costs the plant offspring**

A seed is the next generation, packed with food that makes it a rich meal. A seed that is eaten is an offspring lost, so defending seeds raises the plant's **reproductive success**.

10 A monarch butterfly stores milkweed toxins and is brightly coloured. Is this a chemical, physical or behavioural adaptation against predators?

B **Chemical, with the bright colour as a physical warning sign of it**

The defence is **chemical**: the stored toxins make a predator sick. The bright colour is **warning colouration**, which teaches predators to leave the species alone. Adaptations often work together.

11 Why does a liana not need a thick trunk of its own?

B **It climbs a tree for support, so it can put more into growing upwards**

A liana is not a parasite: it has its own roots and leaves. It uses the tree only as a **support**, so the energy a tree spends on a trunk goes into growing up to the light.

12 What sets the upper limit of *Chthamalus* on the shore?

B **Its tolerance of drying out, an abiotic factor that limits its fundamental niche**

At the top of the shore, *Semibalanus* cannot survive, so it is not competition. *Chthamalus* is stopped by **desiccation**, its tolerance limit: the edge of its fundamental niche. The lower limit of its realized niche is set by **competition**.

13 Two species of Paramecium are grown together and both survive for months. What is the most likely reason?

B **Their niches differ, such as in where they feed, so they partition the resources**

By competitive exclusion, two species with the same niche cannot both persist. Long-term coexistence means their niches differ: they **partition** the resources, by food, place or time.

QUESTIONS ON THE DRY LAB

Q1 Grown alone, *P. caudatum* levels off at about 130 in 0.5 ml. Grown with *P. aurelia*, it dies out. What does this show about its niche?

B **That its fundamental niche includes the tube, but with aurelia there it has no realized niche**

Alone, caudatum thrives in the tube, so the tube is in its **fundamental niche**. With aurelia, which uses the same bacteria faster, it is **excluded**: it has no realized niche there. Neither species eats the other.

Q2 *P. caudatum* and *P. bursaria* both survive together. Why do they not exclude each other?

B **Bursaria feeds on yeast at the bottom and caudatum on bacteria above: different niches**

Their niches differ: they feed on different food in different parts of the tube, so they compete only a little. This is **resource partitioning**. Both numbers are lower than alone, because they still share some resources.

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.

Written and drawn for Biology by Bradford, biologybybradford.com. Free to print and share with a class.