



Ecosystems (Form and function) revision notes

This group looks at how the form of organisms fits the place where they live and the role they play there. It covers habitats, adaptations and ranges of tolerance, coral reefs and terrestrial biomes, then ecological niches, modes of nutrition, feeding adaptations, and how competition shapes fundamental and realized niches.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

1 Adaptation to environment Spec B4.1

Habitats and adaptations to the abiotic environment Spec B4.1.1, B4.1.2

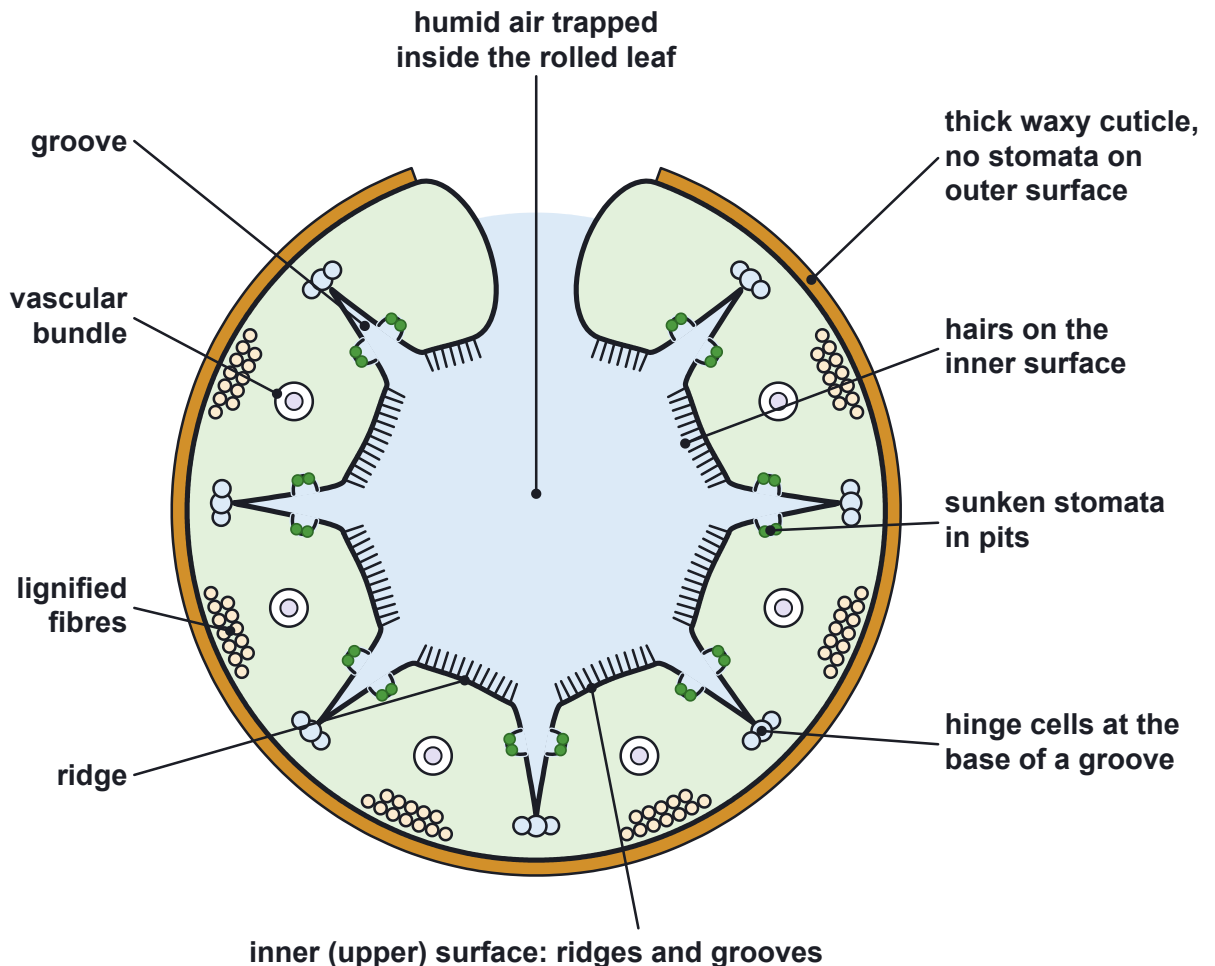
A **habitat** is the place in which a community, species, population or organism lives. Describing a habitat can include its **geographical location** (for example the coast of north-west Europe), its **physical location** (the upper beach and foredunes) and the **type of ecosystem** (a sand dune system).

Every habitat has abiotic (non-living) conditions such as temperature, water availability, light, salinity, oxygen and soil type. An **adaptation** is a feature of structure, physiology or behaviour that increases the chance of survival and reproduction in those conditions.

A grass adapted to sand dunes: marram grass (*Ammophila arenaria*)

Sand dunes are dry because rain drains quickly through sand, windy, exposed to salt spray and constantly shifting. Marram grass is the main dune-building plant: it traps blown sand and thrives where sand keeps arriving.

- Leaves **roll up** in dry conditions, with the stomata on the inner surface. Humid air is trapped inside the roll, so less water is lost by transpiration.
- Stomata sit in **pits** and the inner surface has **hairs**, which trap still, moist air next to the stomata.
- **Hinge cells** lose turgor when water is short, which makes the leaf roll.
- A **thick waxy cuticle** on the outer surface reduces water loss.
- **Long roots and vertical rhizomes** reach water deep in the sand and anchor the plant. When sand buries the plant, the rhizomes grow upwards, so the grass keeps pace with the growing dune.



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Rolling traps **humid air** next to the sunken stomata on the inner surface, which reduces transpiration.

A tree adapted to mangrove swamps: red mangrove (*Rhizophora mangle*)

Mangrove swamps grow in the intertidal zone of tropical coasts. The mud is soft, waterlogged and low in oxygen, and it is flooded by salt water twice a day.

- **Stilt (prop) roots** arch out from the trunk and anchor the tree in soft mud.
- The aerial parts of the roots have **lenticels** that let oxygen diffuse in, because the waterlogged mud is anoxic.
- Roots **exclude most salt** as water is taken up, and salt that does build up is stored in older leaves that are then shed.
- Seeds germinate while still on the parent tree (**vivipary**). The seedling (propagule) drops and floats, then roots quickly in mud.

Exam tip: Always link each adaptation to the abiotic factor it deals with: "rolled leaves trap humid air, reducing transpiration in a dry habitat" earns the mark; "rolled leaves" alone does not.

Abiotic variables and range of tolerance Spec B4.1.3, B4.1.4

The distribution of a species depends on abiotic variables. Each species has adaptations that suit it to a certain set of conditions, and these give it a **range of tolerance** for each variable.

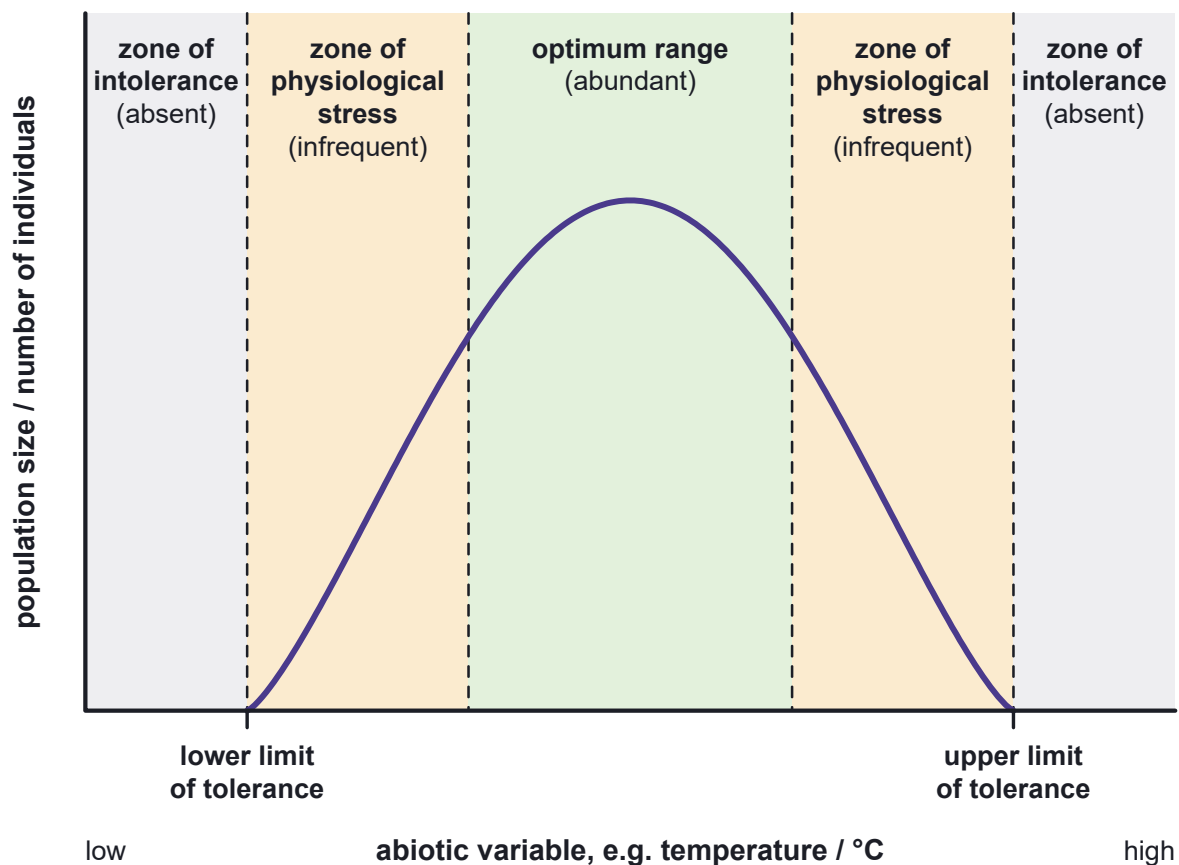
Examples of abiotic variables affecting distribution	
Organisms	Abiotic variables
Plants	Light intensity, temperature, water availability, soil pH, mineral nutrients in the soil, salinity, wind exposure
Animals	Temperature, water availability, dissolved oxygen (aquatic animals), salinity, pH of water, shelter and substrate type

Range of tolerance of a limiting factor

Plotting how well a species does (for example population density) against an abiotic variable gives a bell-shaped tolerance curve.

- **Optimum range:** conditions where the species grows and reproduces best, so it is most abundant.
- **Zones of physiological stress** on either side: individuals survive but grow and reproduce less, so they are fewer.
- **Zones of intolerance** at the extremes: the species cannot survive, so it is absent.

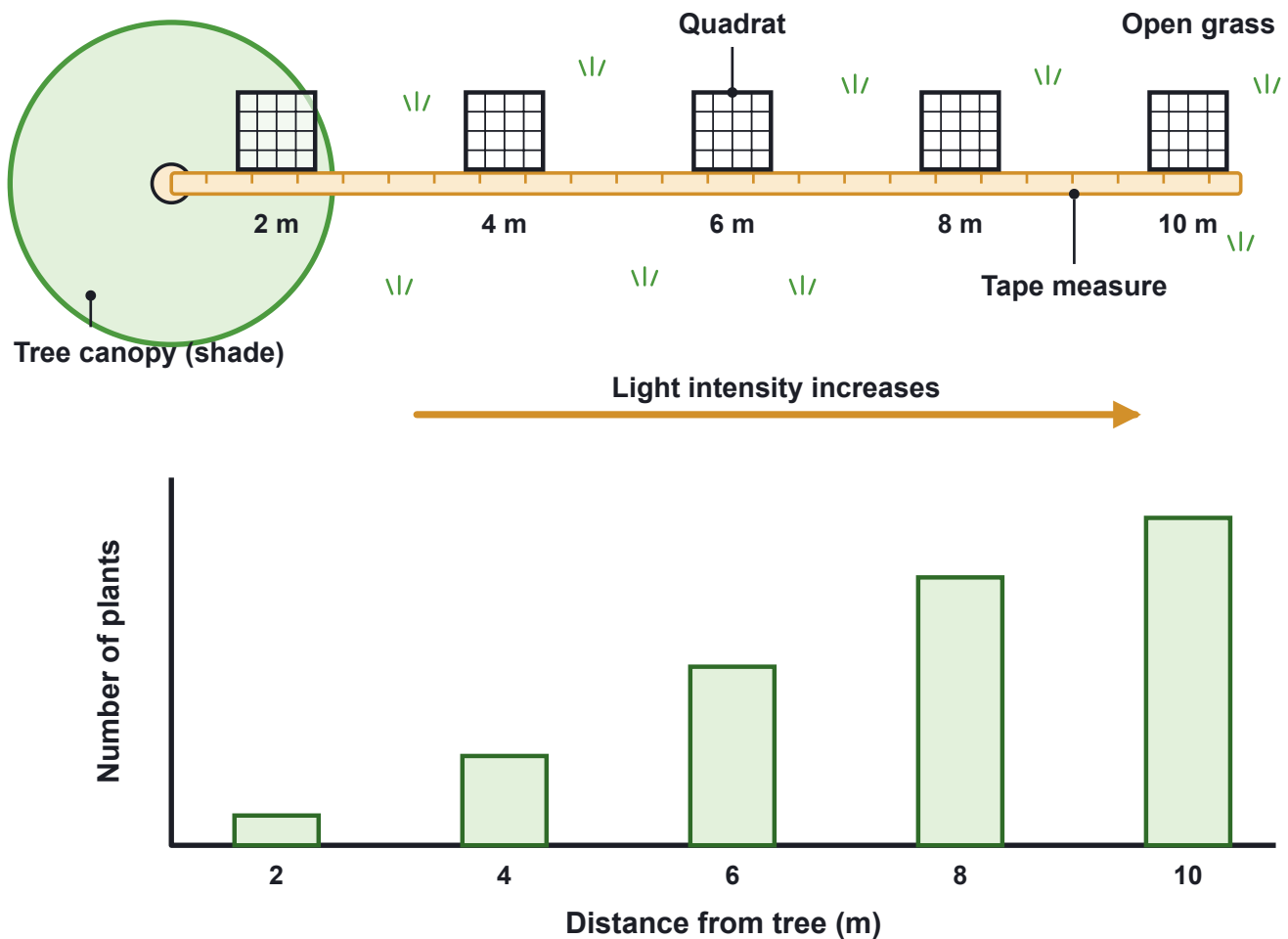
A **limiting factor** is the variable that restricts the distribution or abundance of a species because it lies closest to, or beyond, the limits of tolerance. For example, a plant may be absent from a shaded woodland floor because light intensity is below its tolerance, even though soil and water are suitable.



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A species is **most abundant in its optimum range**, infrequent in the zones of physiological stress and absent beyond its limits of tolerance.

Practical skill: Use a line or belt transect from a natural or semi-natural habitat (influenced by humans but dominated by wild, not cultivated, species). Place quadrats at regular intervals, record abundance (percentage cover or counts) and measure the abiotic variable at each quadrat with sensors such as a light meter, temperature probe or soil pH probe.



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Quadrats placed at regular intervals along a tape across a light gradient (an interrupted **belt transect**). Abundance in each quadrat is plotted against distance; for IB, measure the abiotic variable (here light intensity, with a sensor) at each quadrat too.

Mean percentage cover along a transect

At 6 m along a transect, three replicate quadrats gave 40%, 35% and 30% cover of a grass species. Light intensity there was 5200 lux. At 2 m, the mean cover was 10% and light intensity was 1100 lux. Calculate the mean cover at 6 m and describe the relationship.

1. $\text{Mean} = (40 + 35 + 30) \div 3$

2. $= 105 \div 3 = 35\%$

3. Higher light intensity (5200 lux) goes with higher cover (35%) than lower light intensity (1100 lux, 10%).

Answer: Mean cover is 35%. Cover is positively correlated with light intensity (practice data).

Maths skill: A scatter graph of abundance against the abiotic variable shows correlation; a correlation coefficient (for example Spearman's rank) measures its strength. Correlation does not prove the variable causes the distribution.

Conditions required for coral reef formation Spec B4.1.5

Coral reefs are a marine ecosystem built by colonies of small animals called **coral polyps**. Each polyp secretes a skeleton of **calcium carbonate**, and over thousands of years these skeletons build the reef. Reef-building corals live in a mutualistic relationship with photosynthetic algae (**zooxanthellae**) inside their cells, which supply most of the coral's carbon compounds.

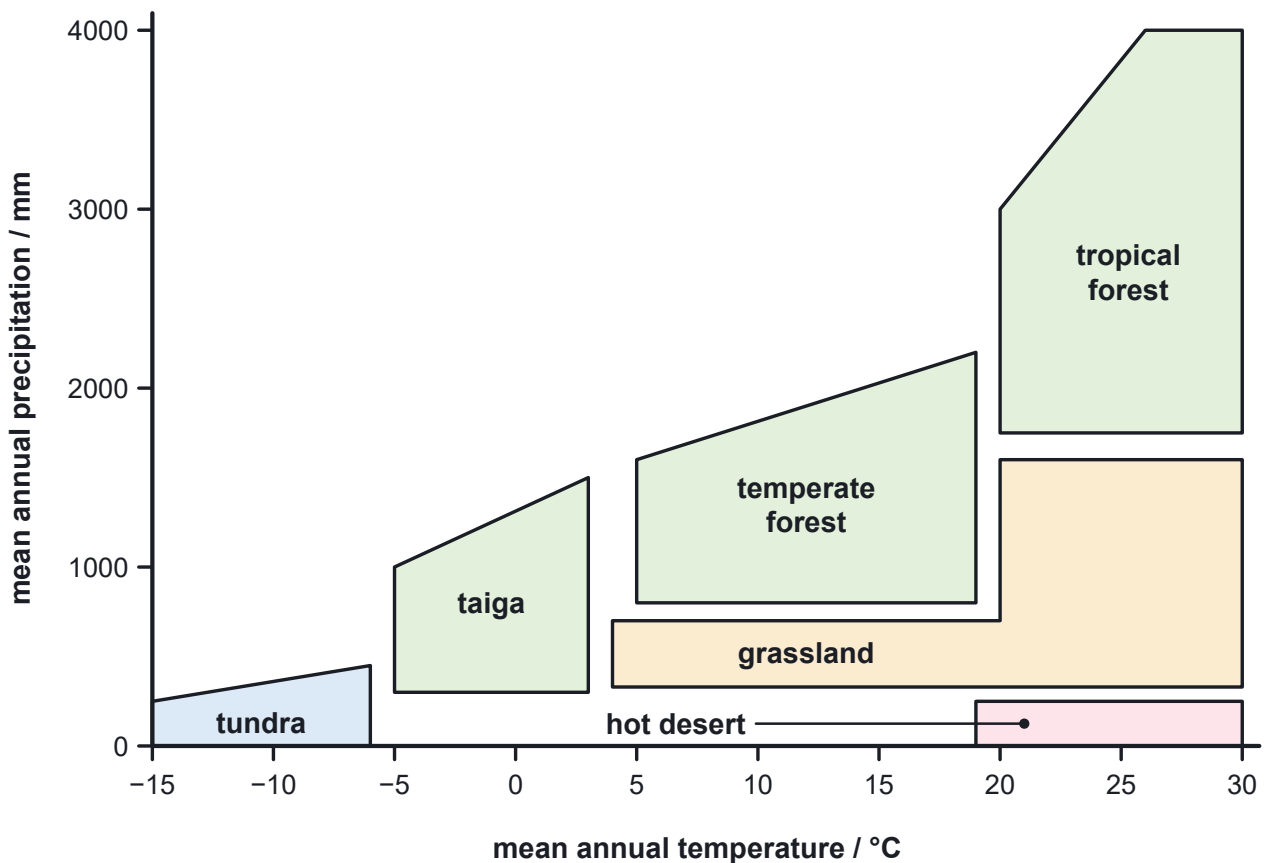
Abiotic conditions needed for coral reef formation (approximate values)		
Factor	Condition needed	Reason
Water depth	Shallow: most reefs grow in water less than about 30 m deep, and few reef-building corals live below about 50 m	Light for photosynthesis by zooxanthellae falls off rapidly with depth
Clarity	Clear water with little suspended sediment	Turbid water absorbs and scatters light, and sediment can smother polyps
Temperature	Warm: best growth at about 23–29 °C; reefs rarely form where water falls below about 18 °C	In colder water, growth and calcification are too slow; water that stays above the usual summer maximum makes corals expel their zooxanthellae (bleaching)
Salinity	Normal seawater, about 32–42 parts per thousand	Corals tolerate only a narrow range, so reefs are absent near river mouths
pH	Slightly alkaline, about pH 8 (roughly 7.8–8.4; surface seawater is about 8.1)	Lower pH reduces the carbonate ions available to build calcium carbonate skeletons

Because corals have a narrow range of tolerance for each factor, reefs occur mainly in shallow tropical seas. Ocean acidification (falling pH as seawater absorbs more CO₂) and rising sea temperatures both threaten reefs.

Exam tip: Linking question: is light essential for life? Reef corals depend on light indirectly through their photosynthetic zooxanthellae, which is why depth and clarity matter.

Terrestrial biomes Spec B4.1.6, B4.1.7

Abiotic factors are the determinants of terrestrial biome distribution. The two most important are **temperature** and **rainfall**. For any given temperature and rainfall pattern, **one natural ecosystem type is likely to develop**.



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Temperature and rainfall together decide which biome develops. Boundaries are approximate and illustrative.

A **biome** is a group of ecosystems with similar communities due to similar abiotic conditions and **convergent evolution**. Unrelated species in different continents face the same selection pressures, so they evolve similar adaptations. For example, cacti in American deserts and spurges (*Euphorbia*) in African deserts are not closely related, yet both have water-storing green stems, spines and reduced leaves.

Climate conditions of six terrestrial biomes		
Biome	Temperature	Rainfall
Tropical forest	High all year (monthly means about 25-27 °C), little seasonal change	Very high (often over 2000 mm per year), spread through the year
Temperate forest	Warm summers and cool to cold winters; clear seasons	Moderate (roughly 750-1500 mm), through the year
Taiga (boreal forest)	Long, very cold winters; short, cool summers	Low to moderate, much falling as snow
Grassland	Warm to hot summers; temperate grasslands have cold winters	Low to moderate, with a dry season; too dry for forest
Tundra	Very cold, below 0 °C for most of the year; permafrost	Very low (often under 250 mm), short growing season
Hot desert	Very hot by day, cool at night: large daily range	Very low (under 250 mm), unpredictable

Common mistake: A biome is not a single ecosystem. It is a group of ecosystems in different places that share similar communities because their climate is similar.

Adaptations to hot deserts and tropical rainforest Spec B4.1.8

Hot deserts

Named desert species		
Species	Adaptation	How it helps
Saguaro cactus (<i>Carnegiea gigantea</i>)	Leaves reduced to spines; photosynthesis in the green stem	Small surface area for water loss; spines deter herbivores and shade the stem
Saguaro cactus	Pleated stem that swells to store water	Stores water taken up after rare rain
Saguaro cactus	Shallow, widespread roots	Absorb rainwater quickly before it evaporates
Saguaro cactus	CAM photosynthesis: stomata open at night	CO ₂ is taken in when it is cool, so less water is lost
Dromedary camel (<i>Camelus dromedarius</i>)	Body temperature can rise by several °C during the day	Less water is used for sweating; heat is lost in the cool night
Dromedary camel	Very concentrated urine and dry faeces	Reduces water loss in excretion and egestion
Dromedary camel	Fat stored in the hump, not spread under the skin; thick fur on the back	Heat is lost easily from the rest of the body; fur insulates against the sun

Tropical rainforest

Named rainforest species		
Species	Adaptation	How it helps
Kapok tree (<i>Ceiba pentandra</i>)	Very tall trunk that emerges above the canopy	Reaches full sunlight above competing trees
Kapok tree	Buttress roots	Support a tall tree in shallow, nutrient-poor soil
Many rainforest trees	Leaves with drip tips and a waxy surface	Rain runs off quickly, so fewer fungi, algae and mosses grow on the leaf
Spider monkey (<i>Ateles geoffroyi</i>)	Long limbs and a prehensile tail	Swings and grips branches to move and feed in the canopy
Strawberry poison frog (<i>Oophaga pumilio</i>)	Toxic alkaloids in the skin with bright warning colours	Predators learn to avoid it, allowing it to be active by day

Exam tip: The guide asks for named species. Either the common or the scientific name is accepted, but the adaptation must be explained, not just listed.

Quick check

- 1 . Define habitat.
- 2 . Why does marram grass roll its leaves?
- 3 . Name two factors needed for coral reef formation.
- 4 . Which two abiotic factors mainly determine terrestrial biome distribution?
- 5 . Why do mangrove stilt roots have lenticels?

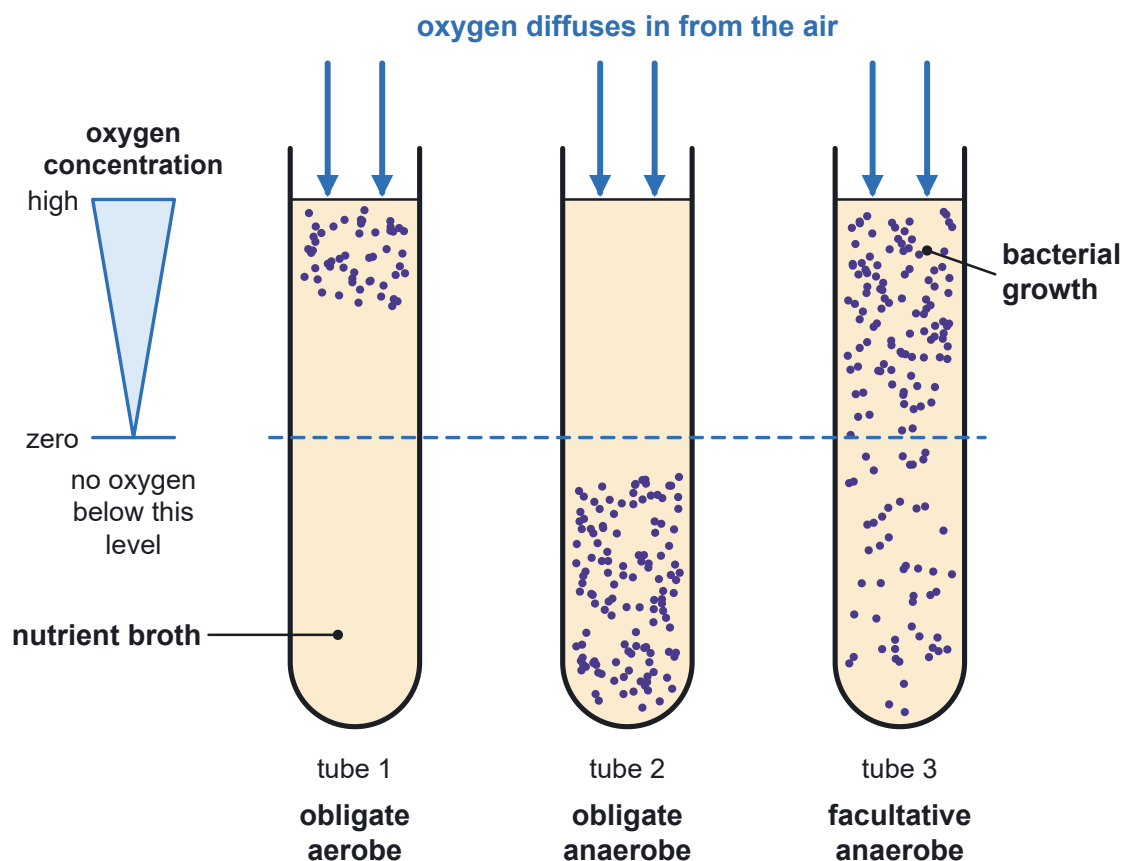
2 Ecological niches Spec B4.2

Ecological niche and tolerance of oxygen Spec B4.2.1, B4.2.2

An **ecological niche** is the role of a species in an ecosystem. It includes all the **biotic interactions** (food, predators, competitors, parasites, mutualists) and **abiotic interactions** (temperature, water, oxygen, light) that influence the growth, survival and reproduction of the species, including **how it obtains food**.

One abiotic part of a niche is whether a species can live with or without oxygen gas. Organisms fall into three groups.

Tolerance of oxygen		
Group	Tolerance of oxygen	Where found / example
Obligate anaerobe	Cannot survive in the presence of oxygen; oxygen is toxic to them	Anoxic sediments, deep soil, the gut; e.g. <i>Clostridium</i> bacteria
Facultative anaerobe	Can live with or without oxygen; respire aerobically when it is present and anaerobically when it is absent	Wide range of habitats; e.g. yeast (<i>Saccharomyces cerevisiae</i>), <i>Escherichia coli</i>
Obligate aerobe	Cannot survive without oxygen; needs it for aerobic respiration	Oxygenated air, water and soil; e.g. most animals and plants



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Where bacteria grow in a broth shows their **tolerance of oxygen**.

Common mistake: Facultative means "optional", obligate means "must". A facultative anaerobe does not need to avoid oxygen; it simply copes without it.

Photosynthesis and mixotrophic nutrition Spec B4.2.3, B4.2.5

Photosynthesis is the mode of nutrition in **plants, algae** and **several groups of photosynthetic prokaryotes** such as cyanobacteria. These organisms are **autotrophs**: they use light energy to make their own carbon compounds from carbon dioxide and other simple inorganic substances.

Mixotrophic nutrition

A **mixotroph** is an organism that is both autotrophic and heterotrophic. Some protists do this. *Euglena* is a well-known freshwater example: it has chloroplasts and photosynthesises in the light, but it can also absorb carbon compounds such as sugars from its surroundings. Many other mixotrophic species form part of oceanic plankton.

- **Obligate mixotrophs** need both modes of nutrition to grow and survive.
- **Facultative mixotrophs** can survive using either mode alone, switching to heterotrophy when light is short or to autotrophy when food is scarce. *Euglena* can live heterotrophically in the dark.

Exam tip: Linking question: what are the relative advantages of specificity and versatility? A facultative mixotroph is versatile, surviving changes in light or food that would kill a strict autotroph or heterotroph.

Holozoic and saprotrophic nutrition, and archaea Spec B4.2.4, B4.2.6, B4.2.7

Heterotrophs obtain carbon compounds from other organisms. **All animals are heterotrophic**, and their mode of nutrition is **holozoic nutrition**.

1. **Ingestion**: food is taken into the gut.
2. **Digestion**: large molecules are broken down by enzymes inside the body (internal digestion).
3. **Absorption**: small digested molecules pass across the gut wall into body cells and the blood.
4. **Assimilation**: absorbed molecules are taken up by body cells and become part of the organism's own cells and tissues.

Saprotrophic nutrition

Some fungi and bacteria are **saprotrophs**. They secrete digestive enzymes onto dead organic matter, digest it **outside** their cells (extracellular digestion), then absorb the products. Fungi and bacteria with this heterotrophic mode of nutrition are called **decomposers**: they release mineral nutrients from dead matter for reuse.

Holozoic and saprotrophic nutrition compared		
Feature	Holozoic	Saprotrophic
Organisms	Animals	Some fungi and bacteria
Food source	Other organisms, living or dead, ingested	Dead organic matter
Where digestion happens	Internally, in the gut	Externally, outside the cells
Ingestion	Yes	No; products are absorbed directly

Diversity of nutrition in archaea

Archaea are one of the **three domains of life**, alongside bacteria and eukaryotes. They are very varied in how they obtain energy for ATP production. Different species use **light**, the **oxidation of inorganic chemicals** or the **oxidation of carbon compounds** as their energy source. Archaea that use light do not photosynthesise with chlorophyll: they absorb light with a different pigment, which pumps protons across the membrane, and the proton gradient drives ATP synthase. Many live in extreme habitats, but archaea are also common in ordinary soils and oceans.

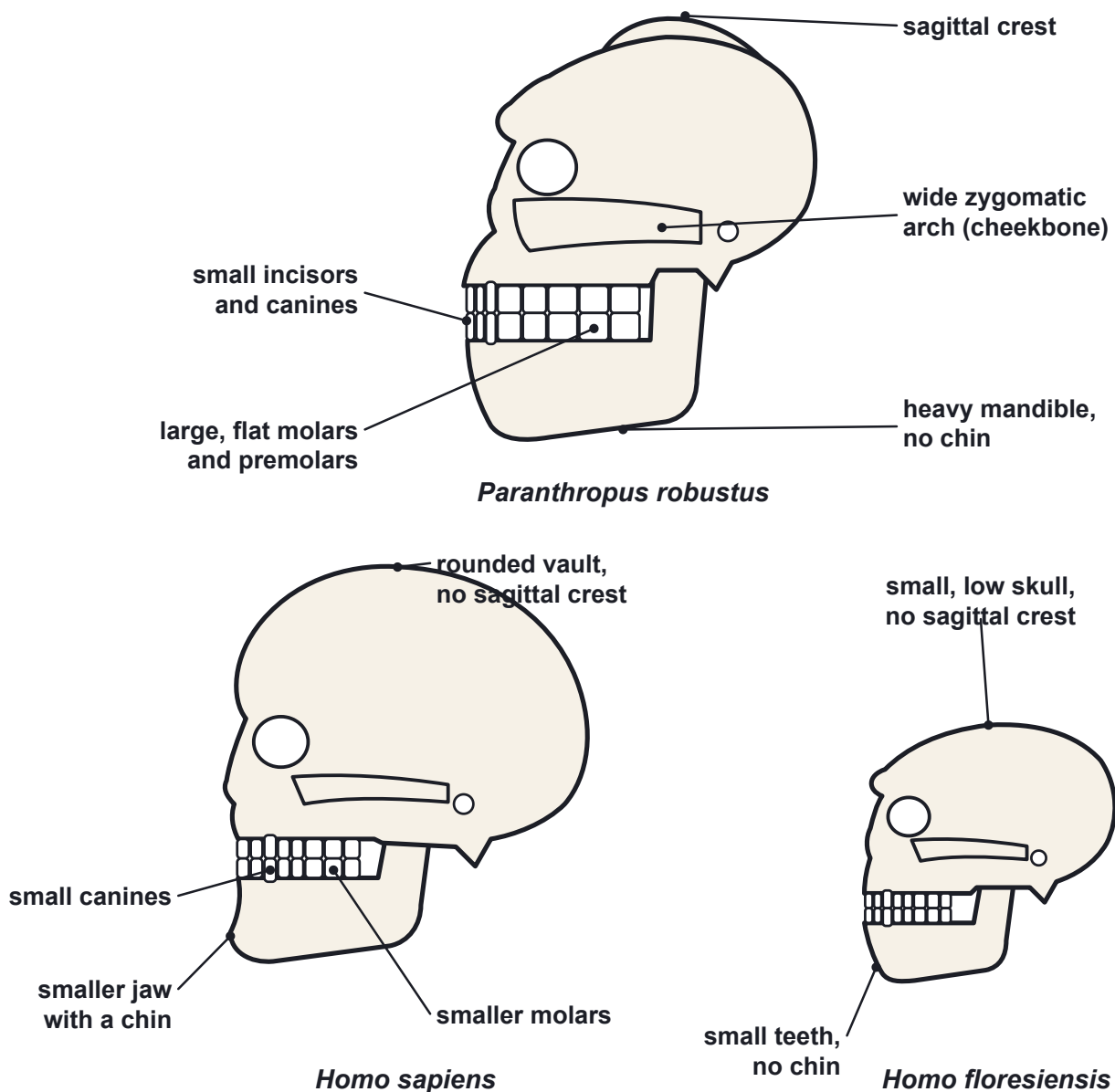
Exam tip: You do not need to name archaea species. Do know the three possible energy sources, since a question may ask you to outline their metabolic diversity. No archaea are known to carry out chlorophyll-based photosynthesis.

Dentition and diet in the Hominidae Spec B4.2.8

The family **Hominidae** includes humans and their extinct relatives. Comparing teeth and skulls lets biologists infer what each species ate.

Dentition and inferred diet of three hominids		
Species	Dentition and skull features	Inferred diet
<i>Homo sapiens</i> (humans)	Small incisors and canines; moderate premolars and molars; smaller jaw and no sagittal crest	Omnivorous: meat and plants, much of it cooked or processed
<i>Homo floresiensis</i>	Small skull; small but robust jaw with no chin; small canines; small molars with features like those of later <i>Homo</i> , including modern humans; no sagittal crest	Omnivorous: small, unspecialised teeth suit a mixed diet, and stone tools and cut-marked bones of <i>Stegodon</i> (a dwarf elephant relative) in the same cave show that meat was eaten, probably often scavenged
<i>Paranthropus robustus</i>	Very large, flat molars and premolars with thick enamel; small incisors and canines; heavy jaw, wide cheekbones and a sagittal crest for large chewing muscles	Herbivorous: tough, hard plant material such as seeds, roots and tubers, ground by the large molars

Large grinding surfaces and powerful chewing muscles point to a diet that needed a lot of grinding. Smaller molars, no sagittal crest and, in fossils, evidence such as stone tools and cut-marked animal bones point to a mixed diet including meat.



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Inferring diet from dentition: **large grinding teeth and a sagittal crest** suggest tough plant food. Outlines are schematic, not to scale.

Practical skill: Examine models or digital collections of skulls. Note the size of each type of tooth, the thickness of enamel, jaw size and any sagittal crest, then infer the diet from these anatomical features.

Exam tip: Nature of science: observing living mammals led to theories relating dentition to herbivorous or carnivorous diets. These theories allow the diet of extinct species to be deduced.

Adaptations for herbivory and predation Spec B4.2.9, B4.2.10

Herbivores and plants

- **Chewing mouthparts:** leaf-eating insects such as caterpillars and locusts have hard mandibles that bite off and grind leaf tissue.
- **Piercing mouthparts:** insects such as aphids have a needle-like stylet that pierces leaf tissue to reach and suck phloem sap.
- **Physical defences of plants:** **thorns**, spines and other physical structures such as stinging or tough hairs deter herbivores.

- **Chemical defences of plants:** plants produce **toxic secondary compounds** in seeds and leaves, such as alkaloids (nicotine in tobacco leaves) and cyanogenic glycosides.
- **Metabolic adaptations of herbivores:** some animals can **detoxify** these toxins. Koalas break down the toxic compounds in eucalyptus leaves using liver enzymes, so they can feed on a food few others can eat.

Predators and prey

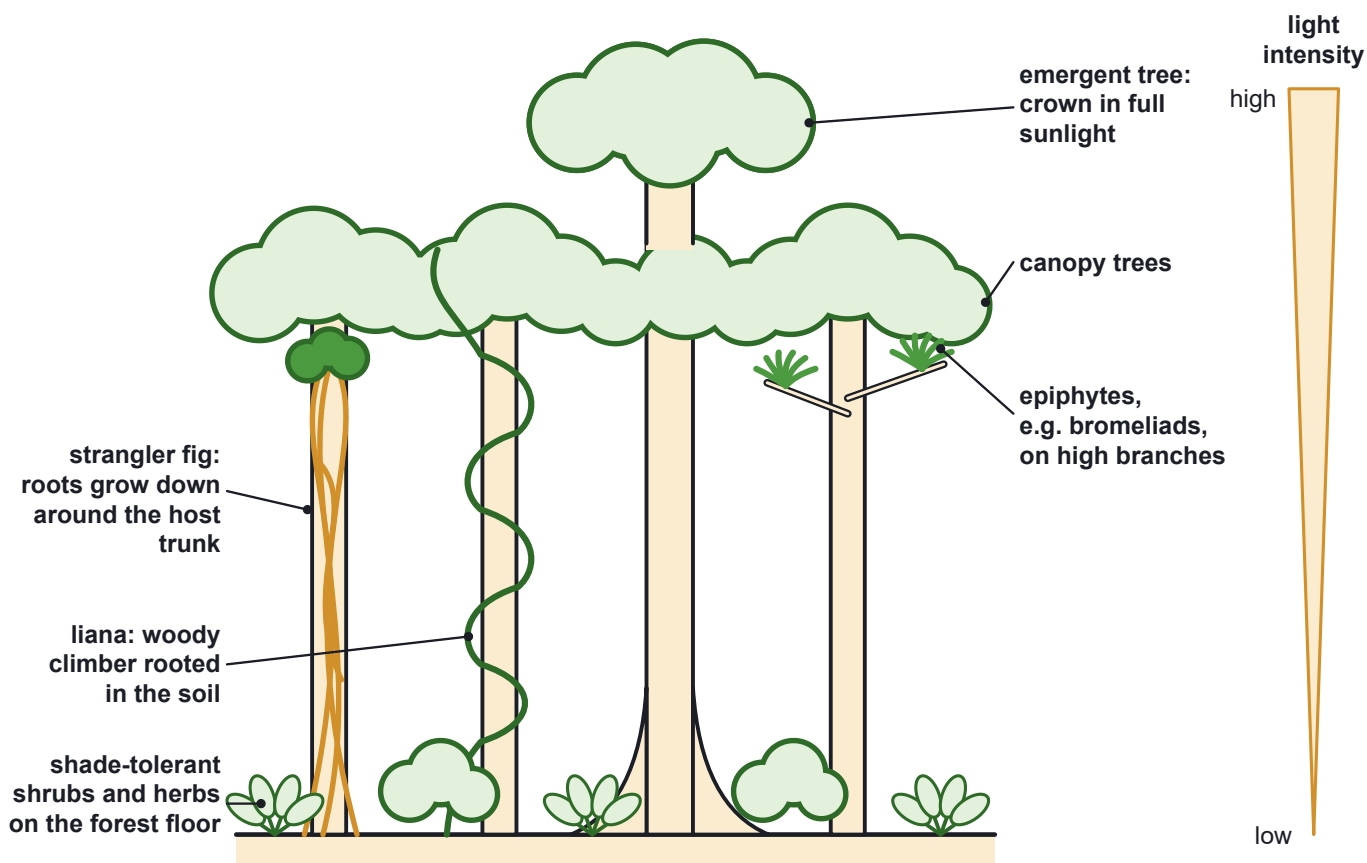
Chemical, physical and behavioural adaptations		
Type	Predators: finding, catching and killing	Prey: resisting predation
Chemical	Venom to kill or paralyse prey (e.g. rattlesnakes); detecting the scent of prey	Toxins and distasteful chemicals (e.g. poison frogs); defensive sprays (e.g. skunks)
Physical	Sharp teeth and claws; speed (e.g. cheetah); forward-facing eyes for judging distance; camouflage for ambush	Camouflage; spines or shells (e.g. porcupines, tortoises); speed; warning colours
Behavioural	Hunting in packs (e.g. wolves); ambush; stalking	Living in herds or shoals; alarm calls; fleeing; playing dead

Exam tip: If a question asks for chemical, physical and behavioural adaptations, give one clear example of each and say how it helps the predator or prey survive.

Adaptations of plant form for harvesting light Spec B4.2.11

Light is the main resource plants compete for in a forest. Very little light reaches the forest floor, so each plant growth form has its own strategy to **reach light sources**.

Strategies for harvesting light in forests	
Plant form	Strategy
Trees that reach the canopy	Invest in a tall, woody trunk to lift leaves above competitors into full sunlight
Lianas	Woody climbers rooted in the soil that use other trees for support, reaching the canopy without building a thick trunk
Epiphytes	Grow on the branches of trees, high up where light is brighter, with no roots in the soil; they obtain water from rain and humid air
Strangler epiphytes	Start as epiphytes on a branch, then send roots down to the soil; the roots thicken and enclose the host tree, which may die (e.g. strangler figs, <i>Ficus</i>)
Shade-tolerant shrubs and herbs	Grow on the forest floor; large, thin leaves with a high chlorophyll content for their mass, and low respiration rates giving a low light compensation point, let them photosynthesise in dim light



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Plants reach light in different ways: **tall trunks, climbing, growing on branches** or tolerating shade on the forest floor.

Common mistake: Epiphytes are not parasites. They grow on trees for support and light but take no nutrients from the host.

Fundamental and realized niches, and competitive exclusion Spec B4.2.12, B4.2.13

Fundamental niche	The potential niche of a species, based on its adaptations and tolerance limits, in the absence of competition.
Realized niche	The actual extent of a species' niche when it is in competition with other species. It is usually smaller than the fundamental niche.

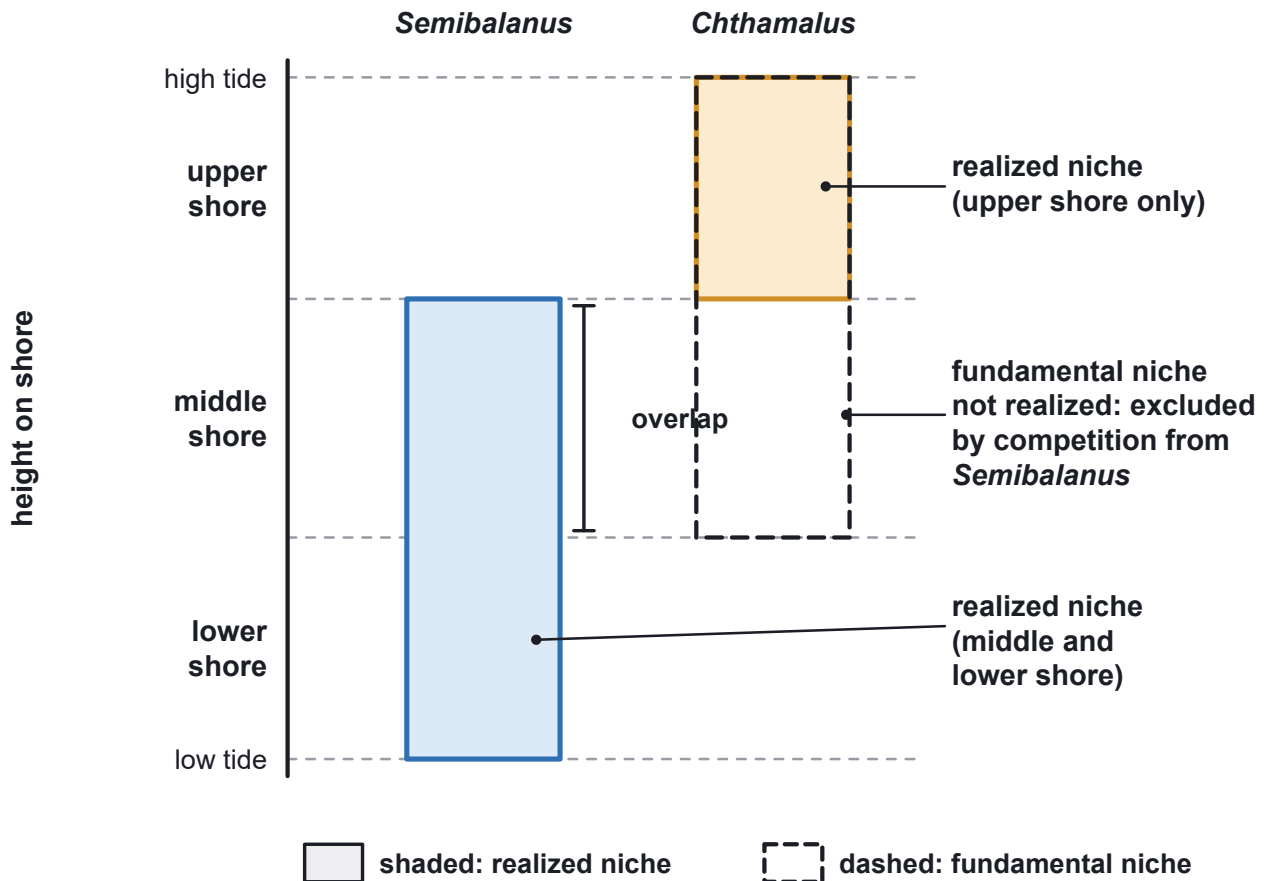
Example: on rocky shores two barnacle species, *Chthamalus stellatus* and *Semibalanus balanoides* (formerly *Balanus*), grow at different heights. *Chthamalus* can survive lower on the shore when its competitor is removed, so its fundamental niche is larger than its realized niche. Where both are present, faster-growing *Semibalanus* crowds it out of the lower zone, and *Chthamalus* is restricted to the upper shore, where it tolerates drying out better.

Competitive exclusion

The **competitive exclusion principle** states that two species with the same niche cannot coexist indefinitely in the same place. When two species compete, there are two possible outcomes:

- **Elimination** of one of the competing species from the area, because the other uses the shared resources more efficiently.
- **Restriction of both** species to a part of their fundamental niche, so that each uses a slightly different part of the resources (their realized niches no longer overlap fully).

So **each ecological niche is unique**: no two species in an ecosystem occupy exactly the same niche.



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Competition from *Semibalanus* restricts *Chthamalus* to a **realized niche** smaller than its fundamental niche.

Exam tip: When data show a species spreading after a competitor is removed, say the species had moved from its realized niche towards its fundamental niche.

Quick check

1. Define ecological niche.
2. What is a facultative anaerobe?
3. List the four stages of holozoic nutrition in order.
4. Name an example of a mixotrophic protist.
5. State two possible outcomes of competition between two species.

Quick check answers

Adaptation to environment

1. The place in which a community, species, population or organism lives.
2. To trap humid air around the stomata on the inner surface, reducing transpiration.
3. Any two: shallow water, clear water, warm temperature, normal seawater salinity, slightly alkaline pH.
4. Temperature and rainfall.
5. The waterlogged mud is anoxic, so oxygen diffuses into the roots from the air through lenticels.

Ecological niches

1. The role of a species in an ecosystem, including the biotic and abiotic interactions that influence its growth, survival and reproduction.
2. An organism that can live with or without oxygen, respiring aerobically when oxygen is present and anaerobically when it is absent.
3. Ingestion, digestion, absorption, assimilation.
4. Euglena.
5. One species is eliminated, or both are restricted to part of their fundamental niche.