REVISION GUIDE

# Built for *where* it lives

## Adaptation to environment

Marram grass holds a dune together where nothing else can grow, and a mangrove stands in salt water on stilts. Run a transect from the sea inland, read a plant's range of tolerance, watch carbon dioxide stop a coral growing, and find the biome any climate will give you.

5 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ib-biology-b4-1-adaptation-to-environment

# Contents


| | | |
|---|---|---|
| 01 | A place to live | 3 |
| 02 | Only so far, and no further | 5 |
| 03 | What a reef needs | 7 |
| 04 | Climate decides the biome | 11 |
| 05 | Too dry, too wet | 13 |
| | Key terms | 18 |
| | Dry lab: A transect across a dune | 19 |
| | Check yourself | 20 |
| | Answers | 21 |


## By the end you can

- [ ] Describe the habitat of a species by its place, its physical conditions and its type of ecosystem B4.1.1
- [ ] Explain the adaptations of marram grass to sand dunes and of a mangrove tree to salt swamps B4.1.2
- [ ] Give abiotic variables that affect the distribution of plants and of animals B4.1.3
- [ ] Explain a range of tolerance, and use transect data to link a species' distribution to an abiotic variable B4.1.4
- [ ] State the conditions a coral reef needs: depth, pH, salinity, clarity and temperature B4.1.5
- [ ] Explain how temperature and rainfall decide which biome develops, using a climate graph B4.1.6
- [ ] Describe the climates of six biomes, and explain their similar communities by convergent evolution B4.1.7
- [ ] Explain adaptations of named plants and animals to hot deserts and tropical rainforest B4.1.8

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

B4.1.1 B4.1.2 HABITAT AS THE PLACE IN WHICH A COMMUNITY, SPECIES, POPULATION OR ORGANISM LIVES ADAPTATIONS OF ORGANISMS TO THE ABIOTIC ENVIRONMENT OF THEIR HABITAT

# 01 A place to *live*

A **habitat** is where an organism lives. A full description gives three things: where it is on the map (the coasts of north-west Europe), the physical conditions there (loose sand, salt spray, strong wind) and the type of ecosystem (sand dunes). The word fits any level: the habitat of one plant, of a population, of a whole species or of a community.

Each habitat has its own **abiotic** (non-living) conditions, and the organisms that live there have **adaptations** that suit them to it. The IB asks for two plants.

**Marram grass** (*Ammophila arenaria*) grows on the dunes behind a beach, where the sand is dry, salty and blowing. Its leaves roll up in dry weather, so the stomata, sunk in grooves on the inner surface among hairs, open into still, moist air and lose little water; the outer surface has a thick waxy cuticle. Its roots reach metres down to water, and its underground stems (rhizomes) spread sideways. Buried by blown sand, it grows up through it: marram does best where fresh sand keeps arriving, and its roots bind the dune.

**Red mangrove** (*Rhizophora mangle*) grows between the tides on tropical coasts, in salt water over soft mud that has almost no oxygen. Arching **prop roots** brace it in the mud, and pores in them (lenticels) take in air when the tide is out. Its roots keep most of the salt out as they take up water; salt that gets in is stored in older leaves, which are shed. Its seeds germinate on the tree, so a seedling drops ready-grown into the mud.

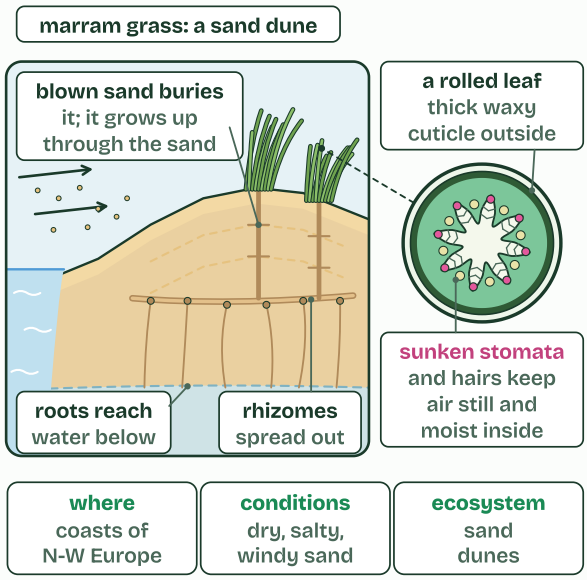
KEY POINTS

- Habitat: location, physical conditions and ecosystem type.
- Marram: rolled leaves, sunken stomata and hairs, thick cuticle, deep roots and rhizomes.
- Mangrove: prop roots, lenticels, salt kept out or shed in old leaves, seedlings grown on the tree.

KEY TERMS

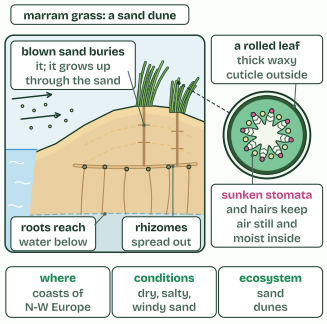
**habitat**
The place where an organism, population, species or community lives, described by its location, its physical conditions and the type of ecosystem it is part of.

**adaptations**
A heritable feature that makes an organism better suited to survive and reproduce in its environment, shaped by natural selection.



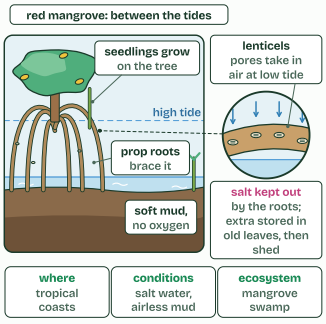

SWITCH IT 2 SETTINGS

1




Marram grass

2




Red mangrove

PREDICT

**On a dry, windy day, a marram leaf rolls up tightly. Why does this cut its water loss?**

(A) The rolled leaf closes all of its stomata at once, so no water at all can leave the leaf until it unrolls again

(B) The stomata face inwards into still, humid air, so the water vapour gradient from inside the leaf is much smaller

(C) The rolled leaf takes up less light, so it photosynthesises less and has no need to open its stomata during the day

Decide before you look. Answer on page 21.

B4.1.3 B4.1.4 ABIOTIC VARIABLES AFFECTING SPECIES DISTRIBUTION RANGE OF TOLERANCE OF A LIMITING FACTOR

# 02 Only so far, and *no further*

Where a species is found depends on abiotic variables. For plants: light, temperature, water, soil pH, minerals, salinity and wind. For animals: temperature, water, oxygen (in water especially), salinity and shelter. Each species copes with a set span of each one.

That span is its **range of tolerance**. In the middle is the **optimum**, where the population is largest. Either side are **zones of stress**, where individuals survive but grow and reproduce less. Beyond the lower and upper **limits** are the **zones of intolerance**, where the species cannot survive at all. The factor that sets the edge of a species' range is a **limiting factor**. A species' adaptations decide where its limits fall.

To see this in the field, ecologists run a **transect**: a line across a habitat where conditions change, such as from a beach inland. At set intervals along it they place a quadrat, record each species, and measure the abiotic factors, with sensors where they can (a probe for soil pH, a light meter, an anemometer for wind). A **kite diagram** shows each species as a band whose width is its abundance at each point.

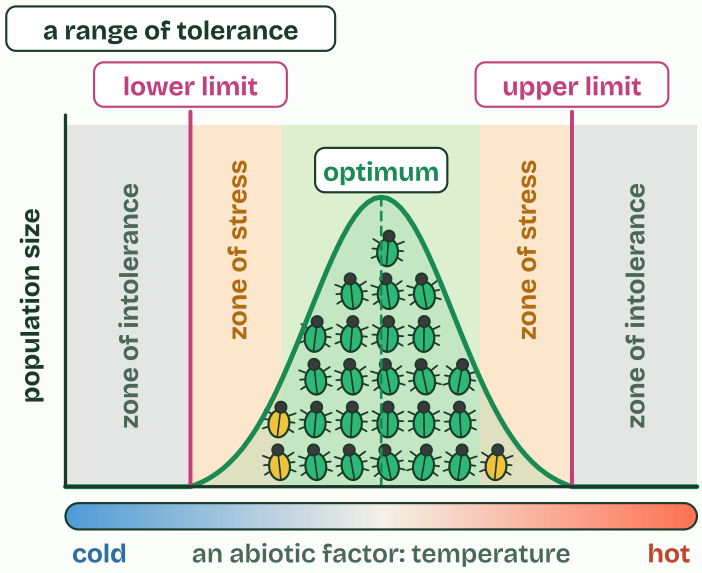
KEY POINTS

- Range of tolerance: optimum, zones of stress, limits, zones of intolerance.
- A limiting factor sets the edge of a species' distribution.
- Transect: sample at intervals along a line; plot species as a kite diagram.

KEY TERMS

**range of tolerance**
The span of values of an abiotic factor within which a species can survive, from a lower limit to an upper limit, with an optimum where it does best.

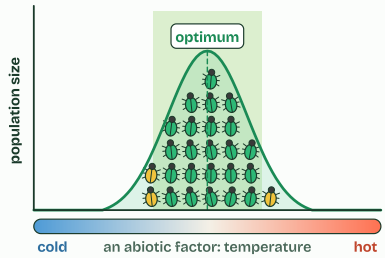
**transect**
A line across a habitat, along which samples are taken at set intervals to show how organisms and abiotic factors change from place to place.



STEP BY STEP

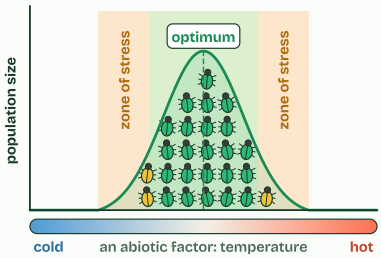
3 STEPS

1



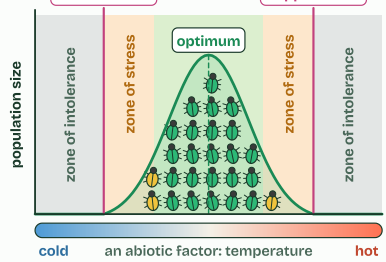

A species does best at its **optimum** for a factor such as temperature.

2




Either side are **zones of stress**: individuals survive but grow and breed less.

3




Beyond the **lower and upper limits** it cannot survive: **zones of intolerance**.

WATCH OUT

A transect shows **correlation**. Along a dune, wind, salt, pH and humus all change together, so a plant correlates with all of them. Which one actually limits it needs an experiment, such as growing it in sand of different salinity.

PREDICT

**On the dune transect (the Dry lab), which plant would you expect to grow nearest the sea?**

(A) Heather, because its tough woody stems stand up to the strong wind blowing straight in off the sea

(B) Marram grass, because it is the plant that needs a regular covering of fresh, salty sand to grow

(C) Sand couch, because it tolerates more salt in the sand than either of the other two plants can

Decide before you look. Answer on page 21.

B4.1.5 CONDITIONS REQUIRED FOR CORAL REEF FORMATION

# 03 What a reef *needs*

A coral reef is built by tiny animals, coral polyps, that lay down skeletons of calcium carbonate, layer on layer, over thousands of years. Inside their cells live **zooxanthellae**, algae that photosynthesise and give the coral most of its food. So a reef forms only where both partners can thrive:

**Depth:** shallow enough for light to reach the algae, mostly less than 50 m.
**Temperature:** warm, about 23 to 29 °C, which is why reefs lie in the tropics.
**Salinity:** full-strength sea water; fresh water from rivers breaks a reef.
**Clarity:** clear water, with little mud to block the light or smother the polyps.
**pH:** slightly alkaline, about 8.2, with plenty of carbonate ions for skeletons.

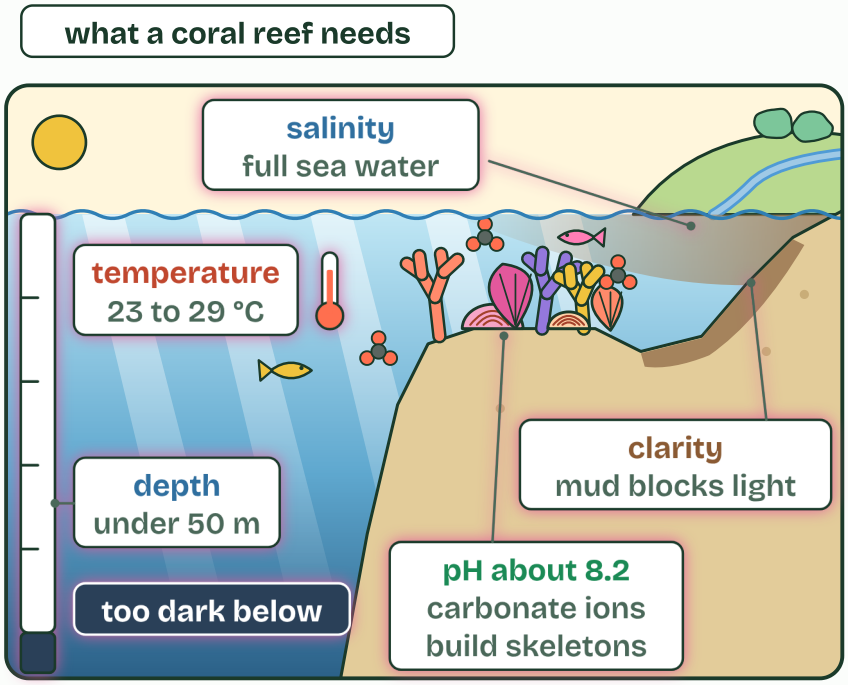
The last condition is changing. The oceans have taken up about a quarter of the carbon dioxide released by burning fossil fuels. It reacts with water to make carbonic acid, so the sea's pH falls: **ocean acidification**. The hydrogen ions released take up carbonate ions, and corals then struggle to build skeleton. Play the film below at today's level and at two futures.

KEY POINTS

- Reefs need light (shallow), warmth, full salinity, clear water and a pH about 8.2.
- $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$; $H^+ + CO_3^{2-} \rightarrow HCO_3^-$.
- Less carbonate: slower skeleton growth.

KEY TERMS

**ocean acidification**
The fall in the pH of sea water as it takes up carbon dioxide from the air, which also lowers the concentration of carbonate ions that corals and shellfish need.



Depth: the zooxanthellae in a coral's cells need light to photosynthesise, so reefs grow only where enough sunlight reaches, mostly in the top 25 m and rarely below about 50 m.

Salinity: corals need full-strength sea water, about 32 to 42 g of salt in a litre. Fresh water from rivers upsets their water balance, so reefs have gaps opposite river mouths.

pH: slightly alkaline water, rich in carbonate ions, lets corals lay down their calcium carbonate skeletons. Ocean acidification lowers both the pH and the carbonate (the film below).

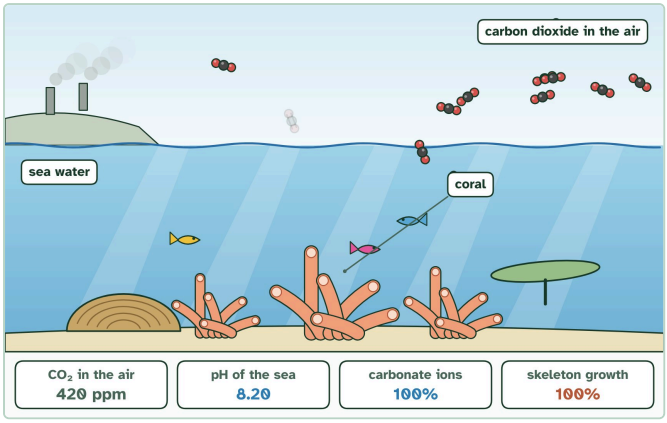
Temperature: reef corals grow best between about 23 and 29 °C, so reefs lie in the tropics. Colder water slows them; a few weeks above about 30 °C and they bleach, expelling their algae.

Clarity: the water must be clear. Mud washed from the land, or stirred up by dredging, blocks the light and smothers the polyps.

ANIMATION · WATCH IT HAPPEN: CARBON DIOXIDE AND CORAL

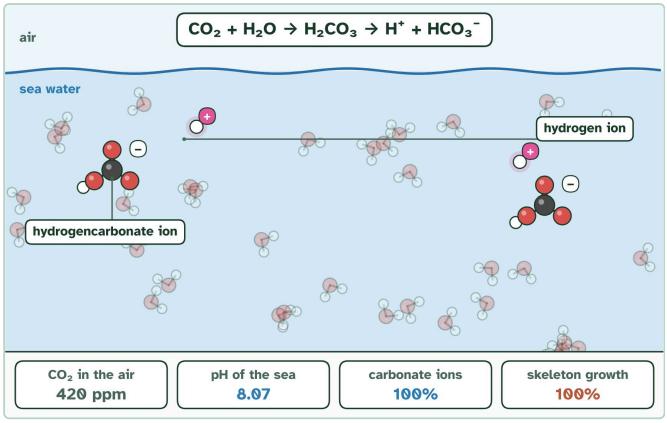
5 MOMENTS

1 420 PPM: THE REEF



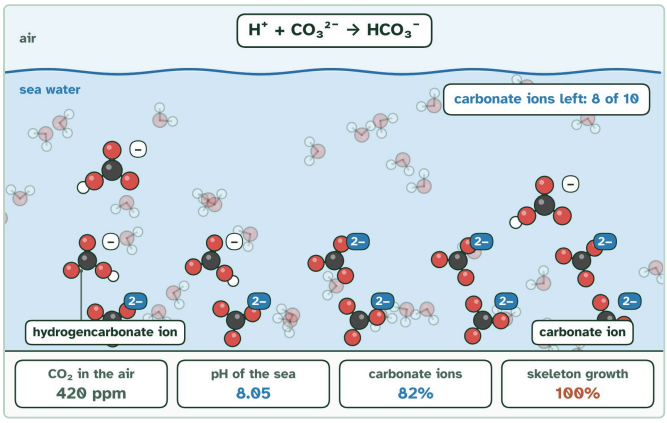

The air now holds 420 ppm of carbon dioxide, up from 280 in 1750. The oceans take up about a quarter of what we release, so more dissolves than comes back out.

2 420 PPM: SURFACE WATER



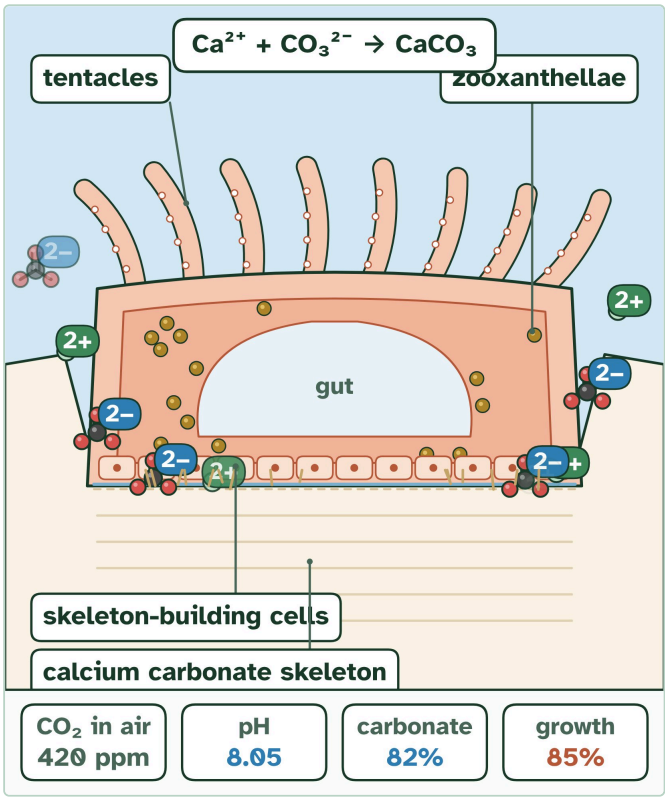

Zoom into the surface water. Dissolved carbon dioxide reacts with water to make **carbonic acid**, which releases **hydrogen ions**. More hydrogen ions means a lower pH: down from about 8.2 to 8.05. The sea is still alkaline, but less so: **ocean acidification**.

3 420 PPM: CARBONATE IONS




Hydrogen ions combine with **carbonate ions**, turning them into hydrogencarbonate ions. About 18% of the carbonate is gone.

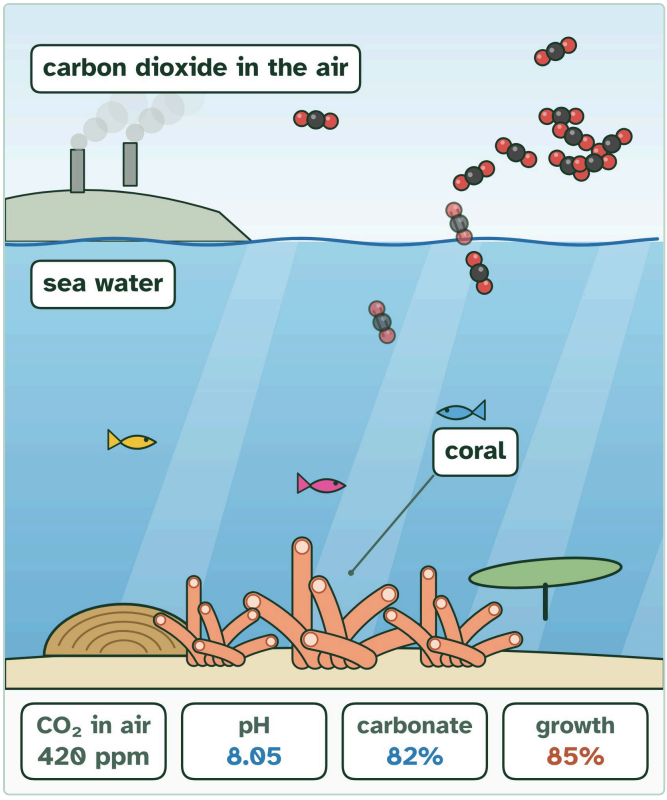
4 420 PPM: ONE POLYP




A coral polyp, cut open. The cells at its base take **calcium** and **carbonate ions** from the sea water and lay down **calcium carbonate** skeleton. With less carbonate it grows more slowly, about 85% of the old rate.

5

420 PPM: THE REEF




Acidification adds to warming, which bleaches corals. A reef that grows more slowly than waves and animals wear it down shrinks.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-1-adaptation-to-environment#reef

PREDICT

**Why do coral reefs not grow in the warm, shallow water at the mouth of the Amazon?**

(A) The river water is too warm for the zooxanthellae, which leave the corals' cells and stop photosynthesising there

(B) The river brings fresh water and mud, so the sea there is too low in salt and too cloudy for light to reach the bed

(C) The river water is too alkaline, so the corals' calcium carbonate skeletons cannot form until they are further offshore

Decide before you look. Answer on page 21.

B4.1.6 B4.1.7 ABIOTIC FACTORS AS THE DETERMINANTS OF TERRESTRIAL BIOME DISTRIBUTION BIOMES AS GROUPS OF ECOSYSTEMS WITH SIMILAR COMMUNITIES DUE TO SIMILAR ABIOTIC CONDITIONS AND CONVERGENT EVOLUTION

# 04 Climate decides the *biome*

On land, two abiotic factors matter more than any others: **temperature** and **rainfall** (precipitation). For any combination of the two, one natural type of ecosystem is likely to develop. Plot mean yearly temperature against yearly precipitation and the world's ecosystems fall into regions: these are **biomes**.

**Tropical forest:** hot all year (about 25 to 28 °C) and wet, over 2,000 mm.
**Temperate forest:** mild, four seasons, rain all year; deciduous broadleaved trees.
**Taiga:** long cold winters, short summers; conifers.
**Grassland:** too dry for forest; hot summers and cold winters, or a long dry season.
**Tundra:** very cold, a short cool summer, frozen ground; no trees.
**Hot desert:** under about 250 mm of rain a year; hot days, cold nights.

Ecosystems in the same biome on different continents look alike even though their species are unrelated. The same conditions select for the same solutions: **convergent evolution**. The cacti of the American deserts and the euphorbias of the African deserts are in different families, yet both have swollen, pleated green stems that store water and spines in place of leaves.

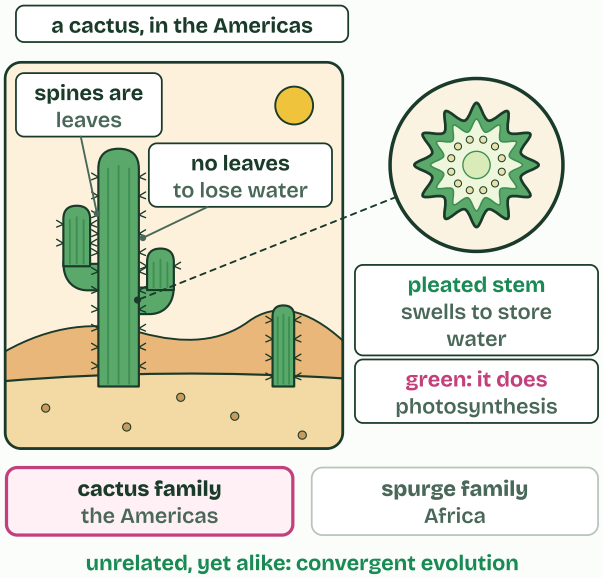
KEY POINTS

- Temperature and rainfall decide which biome develops.
- Six biomes: tropical forest, temperate forest, taiga, grassland, tundra, hot desert.
- Similar conditions select similar adaptations: convergent evolution.

KEY TERMS

**biomes**
A group of ecosystems in different parts of the world with similar communities, because they have similar abiotic conditions, especially temperature and rainfall.

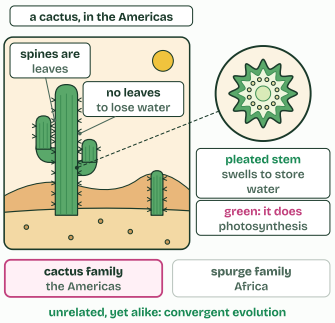
**convergent evolution**
The evolution of similar features in unrelated groups of organisms, because they face similar selection pressures in similar environments.



SWITCH IT

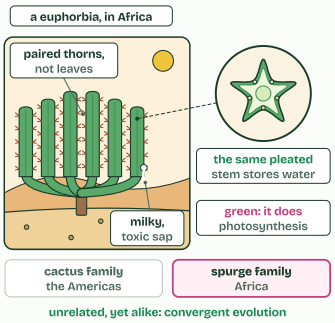
2 SETTINGS

1

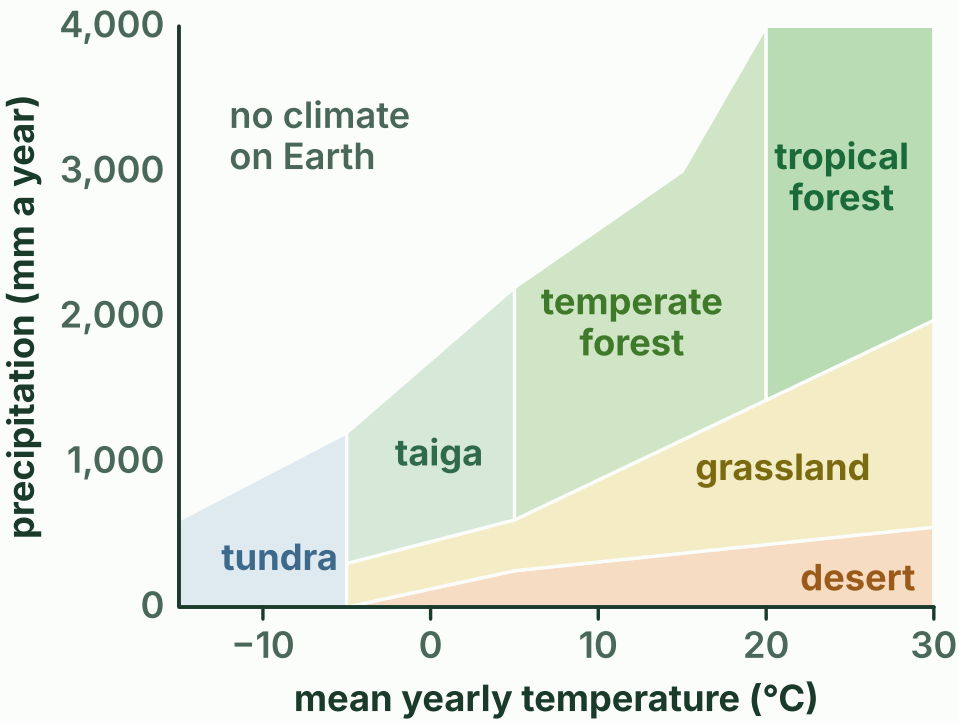



Cactus

2




Euphorbia




Temperature and precipitation decide which biome develops: for any climate on the chart, one natural ecosystem type is most likely.

PREDICT

**A place has a mean temperature of 12 °C and 500 mm of rain a year. In the biome finder below, which biome do you expect?**

(A) Temperate forest, because 12 °C is a mild temperature with four seasons in the year

(B) Grassland, because 500 mm a year is too dry for forest but wetter than a desert

(C) Hot desert, because any place with less than 1,000 mm of rain a year is a desert

Decide before you look. Answer on page 21.

# 05 Too dry, too *wet*

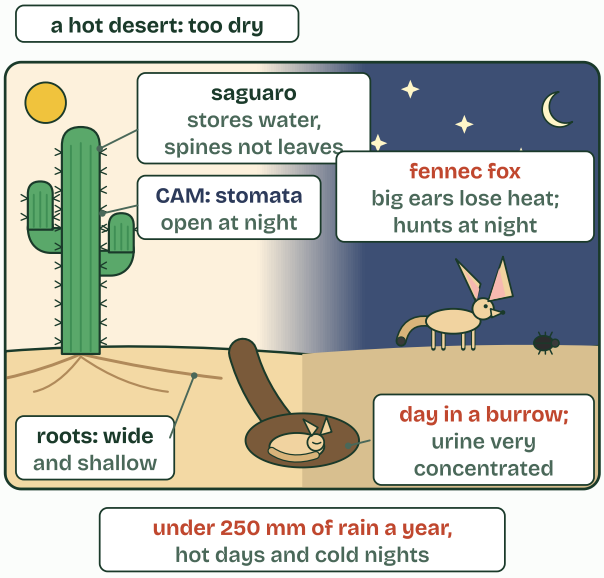
B4.1.8 ADAPTATIONS TO LIFE IN HOT DESERTS AND TROPICAL RAINFOREST

In a **hot desert** the problem is water, and heat. The **saguaro cactus** (*Carnegiea gigantea*) of the Sonoran Desert stores water in a stem that swells like a concertina after rain; its leaves are spines, so it loses little water and is protected from animals that would drink from it. Its shallow roots spread wide to catch rain before it evaporates. It photosynthesises by **CAM**, opening its stomata only in the cool night to take in carbon dioxide. The **fennec fox** (*Vulpes zerda*) of the Sahara loses heat through its huge ears, hunts at night and spends the day in a burrow, has fur on the soles of its feet against hot sand, and its kidneys make very concentrated urine, so it can go without drinking.

In a **tropical rainforest** water and warmth are plentiful; the competition is for light, and the rain is heavy. The **kapok tree** (*Ceiba pentandra*) grows up above the canopy into full sun, held up in thin soil by huge buttress roots. Many rainforest leaves end in a **drip tip** that sheds water quickly, so a film of water does not cut gas exchange or grow fungi. The **three-toed sloth** (*Bradypus*) lives on leaves, a poor food, with a very slow metabolism; it hangs from branches by long curved claws, and green algae grow in its fur, hiding it from eagles.

KEY POINTS

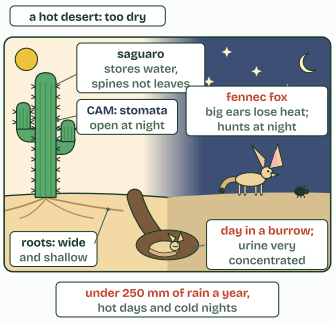
- Saguaro: water-storing pleated stem, spines, wide shallow roots, CAM.
- Fennec fox: big ears, nocturnal, burrows, concentrated urine.
- Kapok: emergent, buttress roots. Drip tips. Sloth: slow metabolism, claws, algae camouflage.



SWITCH IT

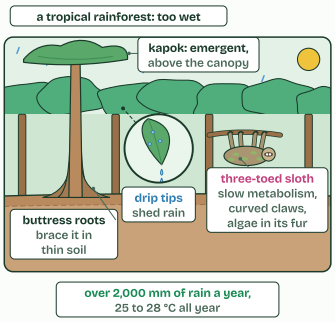
2 SETTINGS

1




**Hot desert**

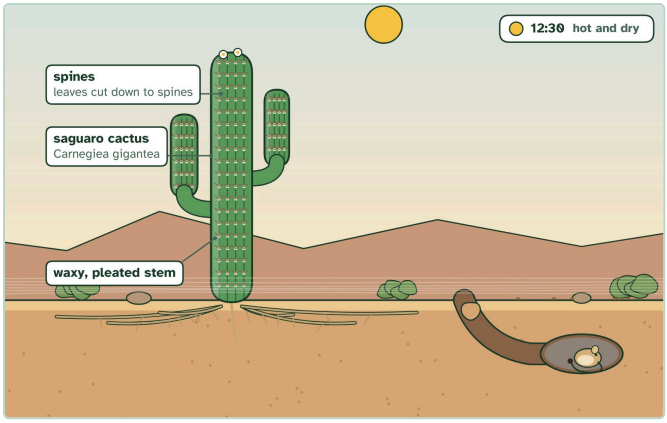
2




**Rainforest**

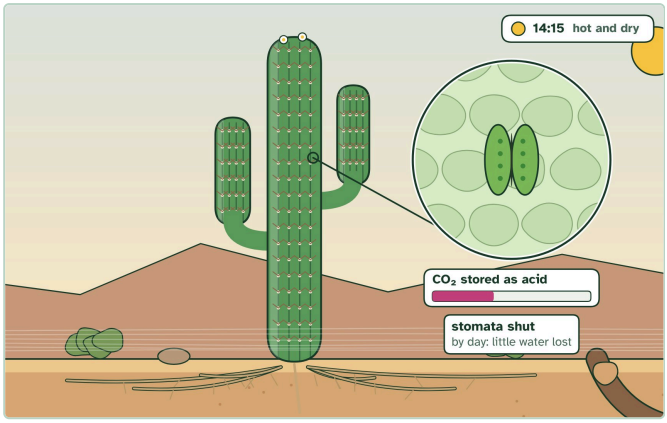
ANIMATION · A DAY IN TWO BIOMES
8 MOMENTS

1 MIDDAY



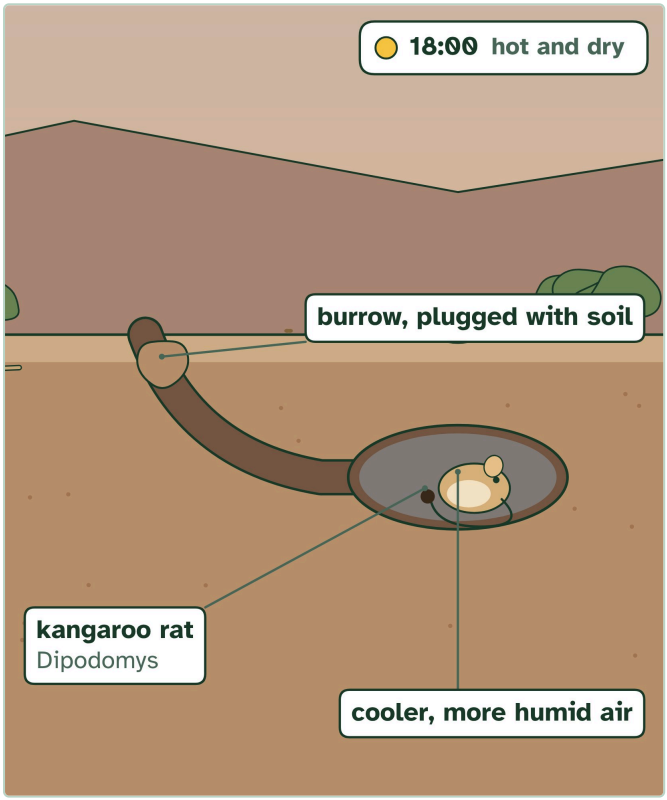

**Hot desert**, midday in the Sonoran Desert of Arizona. Months can pass with no rain, and the air is hot and dry. The problem is **water**.

2 STOMATA SHUT



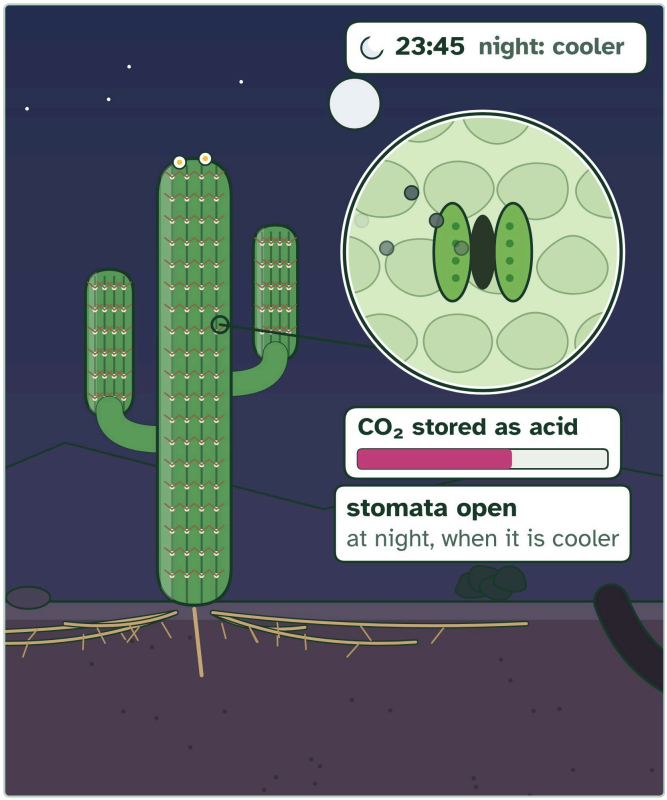

The **saguaro cactus** keeps its **stomata shut by day**, so little water evaporates. Its leaves are **spines**, and a waxy skin covers the green stem.

3 THE BURROW



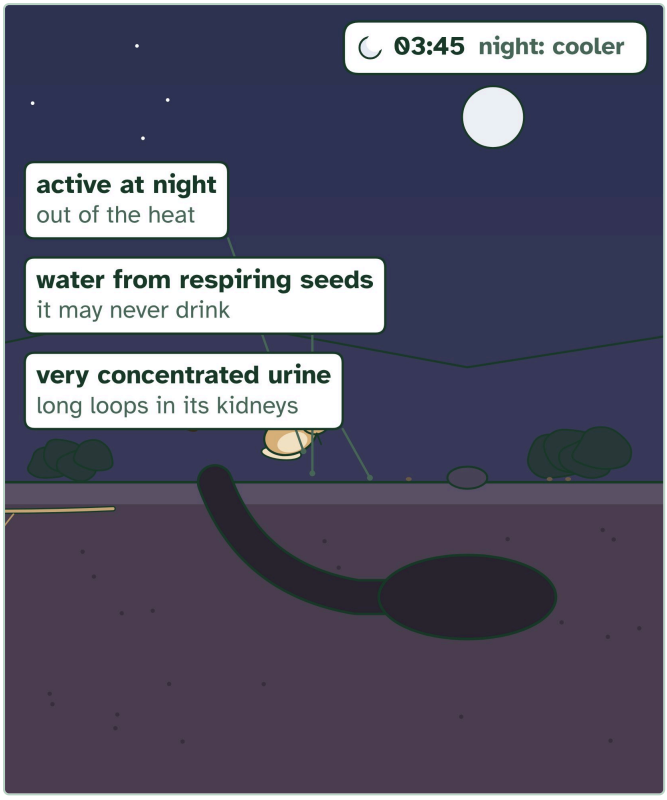

A **kangaroo rat** spends the hot day in its **burrow**, plugged with soil, where the air is cooler and more humid. The fennec fox of the Sahara does the same.

4 NIGHT



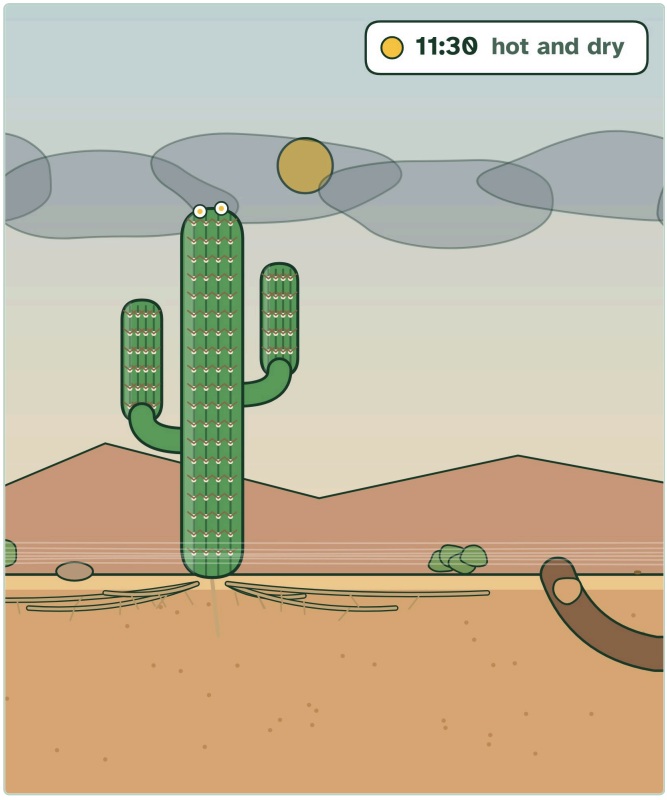

**At night** the air is cooler and less dry. The saguaro **opens its stomata** and stores the carbon dioxide as an acid, to use in daylight: **CAM**.

5 OUT FOR SEEDS



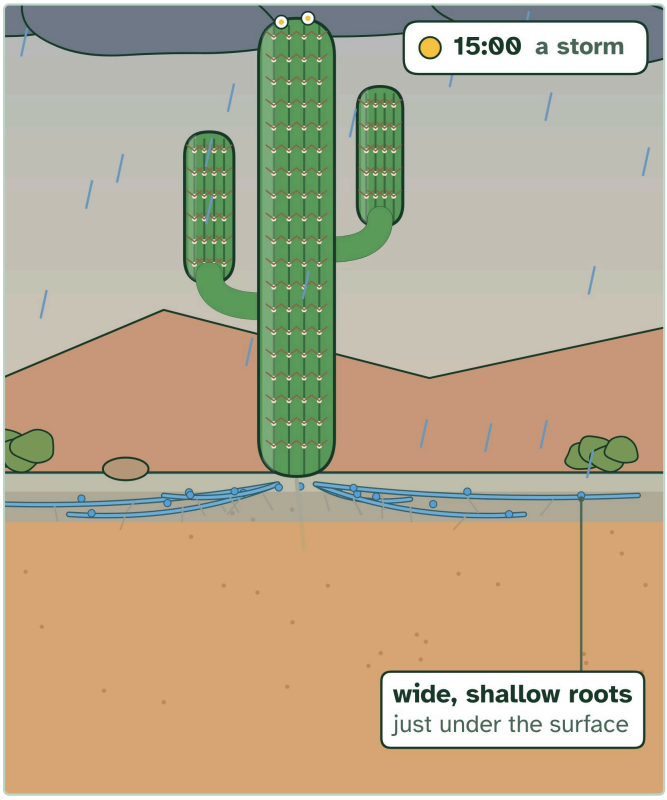

The kangaroo rat comes out at night for seeds. It rarely drinks: it gets water by **respiring its food**, and its kidneys make very **concentrated urine**.

6 A STORM



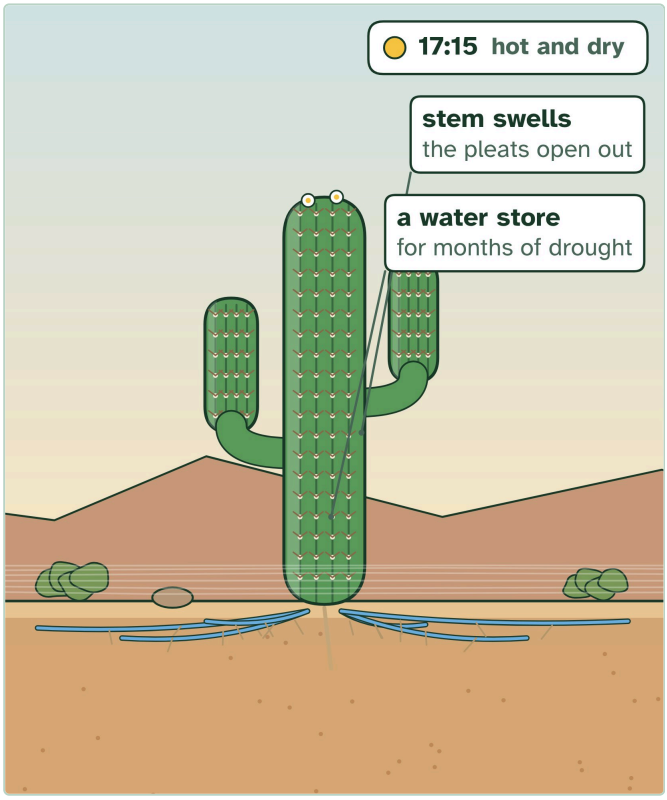

Another hot day. In summer, **storms** bring a little rain, all at once.

7 SHALLOW ROOTS




The saguaro's **roots spread wide and shallow**, just under the surface, to soak up the rain before it evaporates.

8 THE STEM SWELLS




The **pleated stem swells like a concertina** as it fills with water: a store to last the dry months ahead.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-b4-1-adaptation-to-environment#extremes

PREDICT

**A saguaro opens its stomata at night and closes them by day. How does this help it in the desert?**

(A) It can photosynthesise in the dark, because the light reflected by the sand at night is enough for its chloroplasts

(B) It avoids taking in the hot daytime air, which would kill the cells of its stem if it reached them through the stomata

(C) It loses far less water, because the night air is cool and humid, and it stores the carbon dioxide to use in daylight

Decide before you look. Answer on page 21.

# Key terms

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

**adaptations** 01
A heritable feature that makes an organism better suited to survive and reproduce in its environment, shaped by natural selection.

**biomes** 04
A group of ecosystems in different parts of the world with similar communities, because they have similar abiotic conditions, especially temperature and rainfall.

**convergent evolution** 04
The evolution of similar features in unrelated groups of organisms, because they face similar selection pressures in similar environments.

**habitat** 01
The place where an organism, population, species or community lives, described by its location, its physical conditions and the type of ecosystem it is part of.

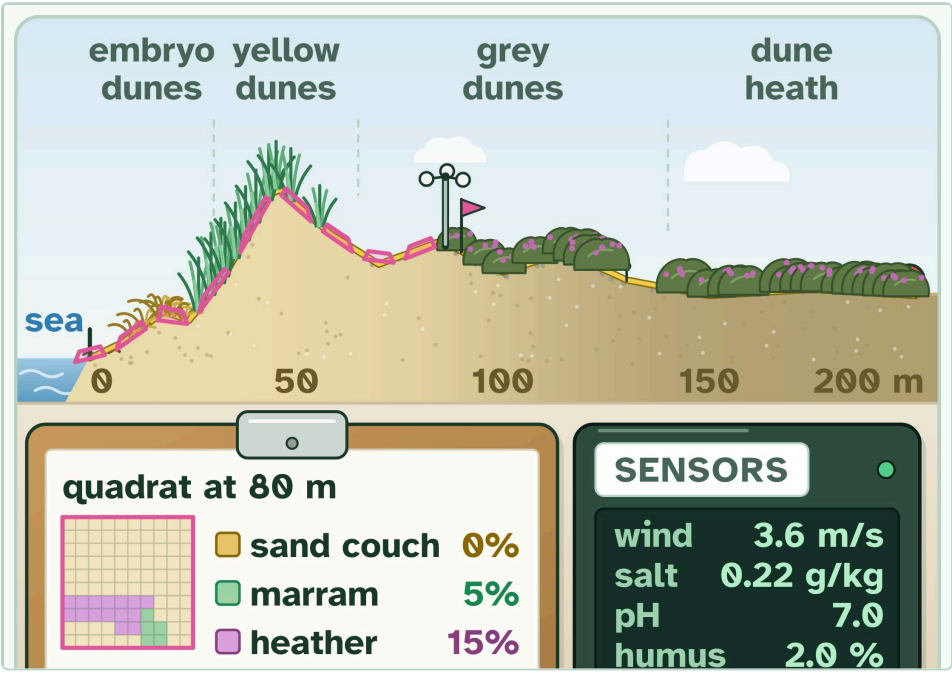
**ocean acidification** 03
The fall in the pH of sea water as it takes up carbon dioxide from the air, which also lowers the concentration of carbonate ions that corals and shellfish need.

**range of tolerance** 02
The span of values of an abiotic factor within which a species can survive, from a lower limit to an upper limit, with an optimum where it does best.

**transect** 02
A line across a habitat, along which samples are taken at set intervals to show how organisms and abiotic factors change from place to place.

# Dry lab: *A transect across a dune*

Run a 200 m tape from the strandline inland and put a quadrat down at every station. Record three plants and four abiotic factors, draw the kite diagram, and find each plant's range of tolerance.




Run it online: change the variables, run the trials, and the table and graph fill in as you go. `biologybybradford.com/guides/ib-biology-b4-1-adaptation-to-environment#lab`

### Your question

How do three dune plants, sand couch, marram grass and heather, change from the sea inland, and which abiotic factor sets where each one grows? Predict first: which plant will grow nearest the sea, and which furthest inland?

### What you can change

The sampling interval: a station every 10, 20 or 40 m. Then what you plot: the kite diagram, one abiotic factor along the transect, or one plant's cover against one factor.

### What to record

At each station, the percentage cover of each plant, wind speed, salt in the sand, soil pH and humus. The dune is a model with invented numbers; the pattern is what real transects across dunes show.

## Find out

- **The pattern.** Sample every 10 m from the strandline to 200 m. Read the kite diagram: where does each plant grow, and where is it most abundant?
- **The gradients.** Show each abiotic factor in turn. Which rise inland, which fall, and where does each change fastest?
- **The range of tolerance.** For each plant, plot its cover against each factor and show the range. Which factor best explains where each plant stops?
- **The interval.** Start again and sample every 40 m. Which plant is easiest to miss, and why?
- **Back to biology.** Use your transect to explain how a range of tolerance sets where each plant grows, and why a transect cannot show which factor is limiting.

## Record

- A table of distance against the cover of each plant and the four abiotic factors.
- A kite diagram of the three plants, drawn to scale.
- For each plant: the factor you chose, its lower and upper limits and its optimum on this transect.
- Download the CSV to keep every reading.

**Your question**How do three dune plants, sand couch, marram grass and heather, change from the sea inland, and which abiotic factor sets where each one grows? Predict first: which plant will grow nearest the sea, and which furthest inland?**What you can change**The sampling interval: a station every 10, 20 or 40 m. Then what you plot: the kite diagram, one abiotic factor along the transect, or one plant's cover against one factor.**What to record**At each station, the percentage cover of each plant, wind speed, salt in the sand, soil pH and humus. The dune is a model with invented numbers; the pattern is what real transects across dunes show.

Back to biology

Use your transect to explain how a range of tolerance sets where each plant grows, and why a transect cannot show which factor is limiting.

## QUESTIONS ON THE LAB

### QUESTION 1

**Heather grows well only where the soil pH is below about 7. On the dune, where does that put it?**

(A) Close to the sea, where shell fragments in the sand make the soil the most acidic along the whole transect

(B) Far inland, where rain has leached the shell out of the sand and rotting plants have built up acid humus

(C) On the tall yellow dunes, where the strongest winds blow the alkaline salt spray away from the plants

Answer on page 21.

### QUESTION 2

**Sand couch, marram and heather all correlate with distance from the sea. Why can the transect not show which factor limits each one?**

(A) Because the quadrats are too small to hold a whole plant of each species, so cover is only an estimate

(B) Because the abiotic factors were each measured only once at every station along the line of the transect

(C) Because every factor changes along the transect at once, so a plant correlates with all of them together

Answer on page 21.

### QUESTION 3

**You sample every 40 m instead of every 10 m. What happens to the kite diagram?**

(A) Nothing important, because the same three plants are on the dune and will be found whatever the interval

(B) A plant in a narrow band near the sea can be missed entirely, and the edges of every zone become less precise

(C) Every plant appears in more of the quadrats, because each quadrat now stands for a longer stretch of the dune

Answer on page 22.

## Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on B4.1 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=B4.1&level=SL&paper=quiz&marks=15&src=ep

# Answers

## PREDICTIONS IN THE CHAPTERS

**01** On a dry, windy day, a marram leaf rolls up tightly. Why does this cut its water loss?

**B The stomata face inwards into still, humid air, so the water vapour gradient from inside the leaf is much smaller**

Water leaves a leaf by diffusion, down a gradient of water vapour. Rolled up, the stomata open into a pocket of still, moist air that the wind cannot sweep away, so the gradient, and the loss, are small. The hairs trap the air further.

**02** On the dune transect (the Dry lab), which plant would you expect to grow nearest the sea?

**C Sand couch, because it tolerates more salt in the sand than either of the other two plants can**

Sand couch tolerates the salt spray and salty sand of the embryo dunes, so it grows first. Marram takes over on the taller, windier yellow dunes, where blown sand buries it. Heather needs acid soil rich in humus, found only far inland.

**03** Why do coral reefs not grow in the warm, shallow water at the mouth of the Amazon?

**B The river brings fresh water and mud, so the sea there is too low in salt and too cloudy for light to reach the bed**

The Amazon pours out vast amounts of fresh, muddy water. Corals need full-strength sea water and clear water for their algae, so reefs are broken wherever big rivers reach the coast.

**04** A place has a mean temperature of 12 °C and 500 mm of rain a year. In the biome finder below, which biome do you expect?

**B Grassland, because 500 mm a year is too dry for forest but wetter than a desert**

At 12 °C a forest needs roughly a thousand millimetres a year; 500 mm supports grass but not trees, so it is temperate grassland, like the prairies of Kansas. A desert has under about 250 mm.

**05** A saguaro opens its stomata at night and closes them by day. How does this help it in the desert?

**C It loses far less water, because the night air is cool and humid, and it stores the carbon dioxide to use in daylight**

Water loss depends on the gradient between the leaf and the air. At night the air is cooler and less dry, so opening the stomata then costs far less water. The carbon dioxide taken in is stored overnight and used in photosynthesis next day, with the stomata closed.

## QUESTIONS ON THE DRY LAB

**Q1** Heather grows well only where the soil pH is below about 7. On the dune, where does that put it?

**B Far inland, where rain has leached the shell out of the sand and rotting plants have built up acid humus**

Fresh dune sand is full of shell, calcium carbonate, so it is alkaline (pH 8 or more). Inland, older sand has had its shell washed out and humus added, so the pH falls to about 5: heather's side of its limit.

**Q2** Sand couch, marram and heather all correlate with distance from the sea. Why can the transect not show which factor limits each one?

**C Because every factor changes along the transect at once, so a plant correlates with all of them together**

Wind, salt, pH and humus all change with distance, so they are tangled together. The transect suggests which factor matters; an experiment that changes one factor and holds the rest constant tests it.

**Q3** You sample every 40 m instead of every 10 m. What happens to the kite diagram?

**B** **A plant in a narrow band near the sea can be missed entirely, and the edges of every zone become less precise**

Sand couch grows thickly in a band only about 25 m wide. Stations at 0 and 40 m can both fall outside it. A shorter interval costs more time but shows narrow zones and sharp edges.

---

**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.