



Adaptation to environment

Revision notes • Habitats, adaptations to abiotic factors, ranges of tolerance, coral reef conditions and the biomes set by temperature and rainfall. IB Biology B4.1.

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

Adaptation to environment Spec B4.1

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

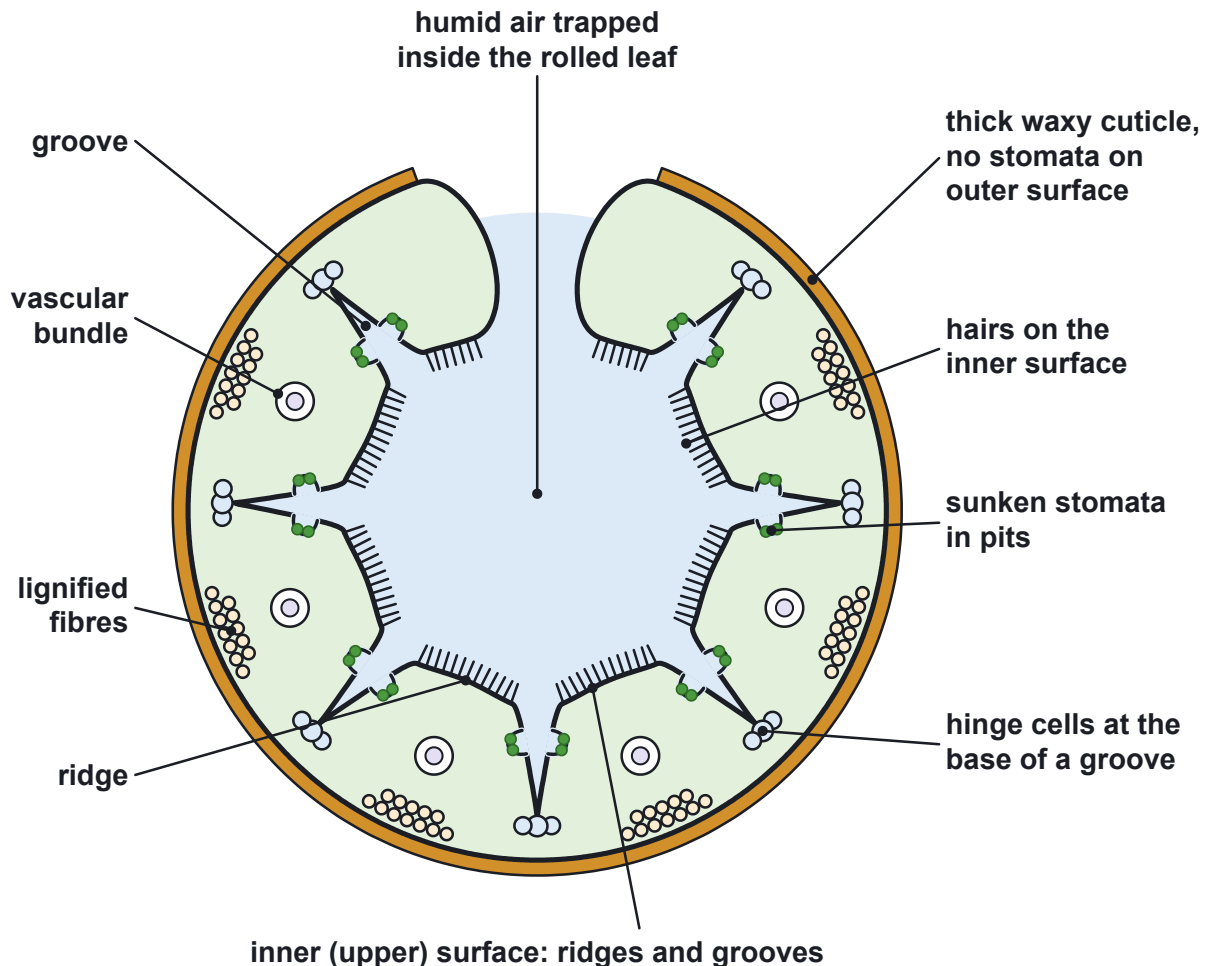
A **habitat** is the place in which a community, species, population or organism lives. Describing a habitat can include its **geographical location** (for example the coast of north-west Europe), its **physical location** (the upper beach and foredunes) and the **type of ecosystem** (a sand dune system).

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

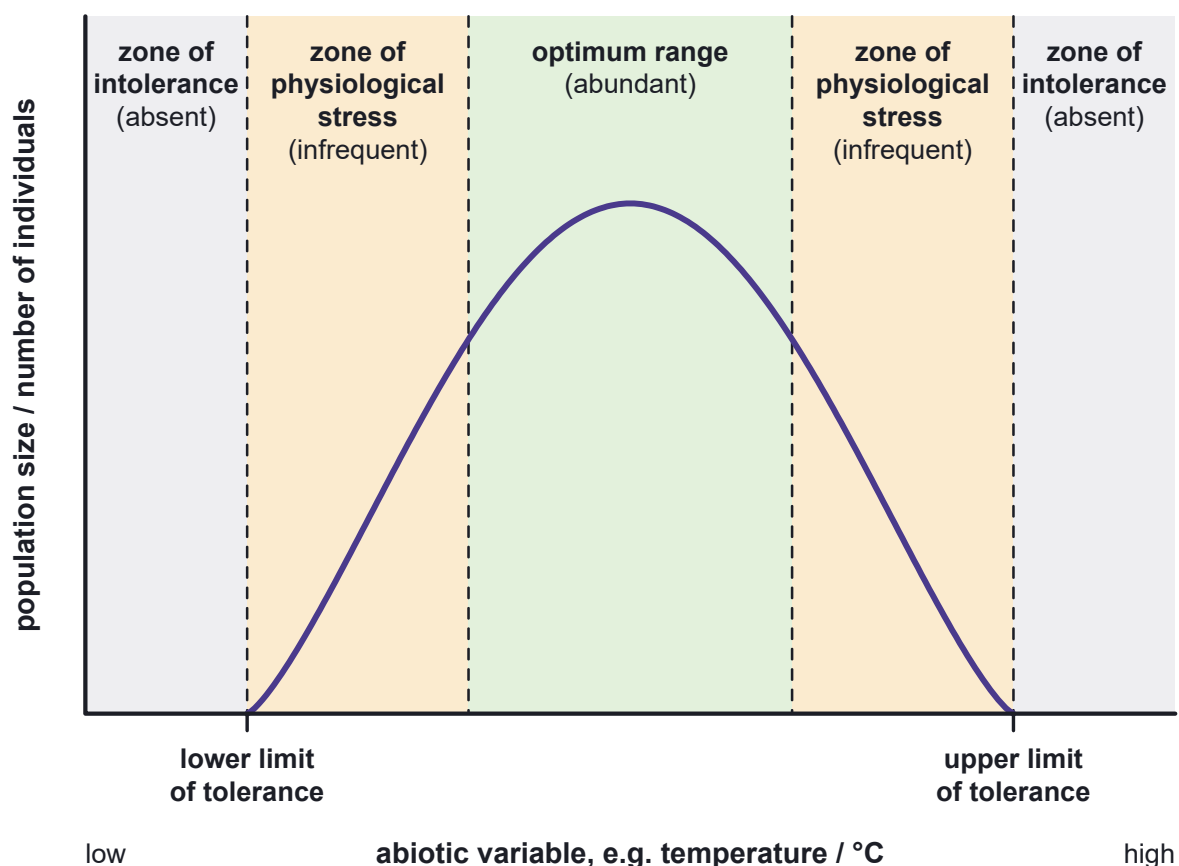
Organisms	Abiotic variables
Plants	Light intensity, temperature, water availability, soil pH, mineral nutrients in the soil, salinity, wind exposure
Animals	Temperature, water availability, dissolved oxygen (aquatic animals), salinity, pH of water, shelter and substrate type

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.

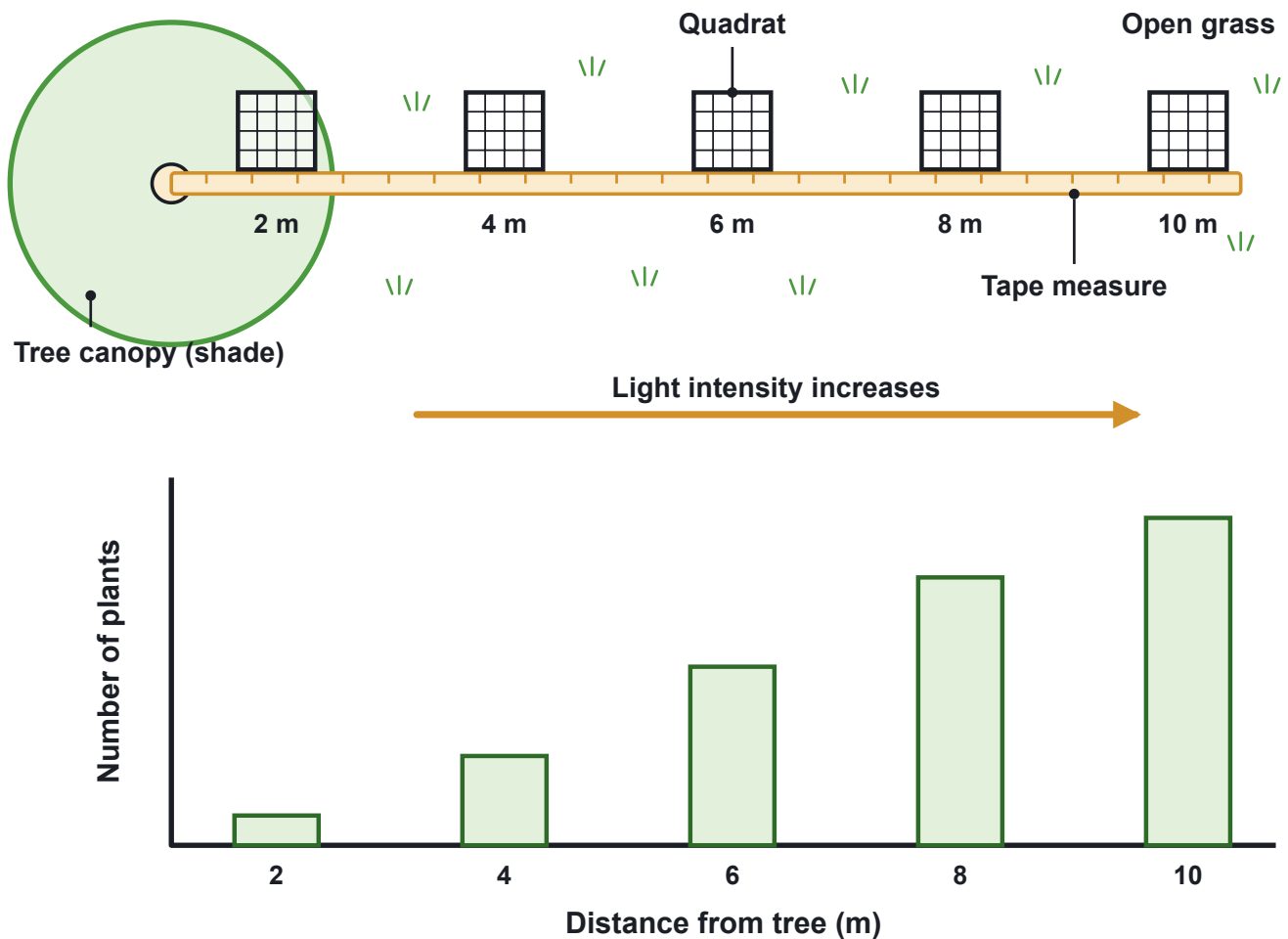
A **limiting factor** is the variable that restricts the distribution or abundance of a species because it lies closest to, or beyond, the limits of tolerance. For example, a plant may be absent from a shaded woodland floor because light intensity is below its tolerance, even though soil and water are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

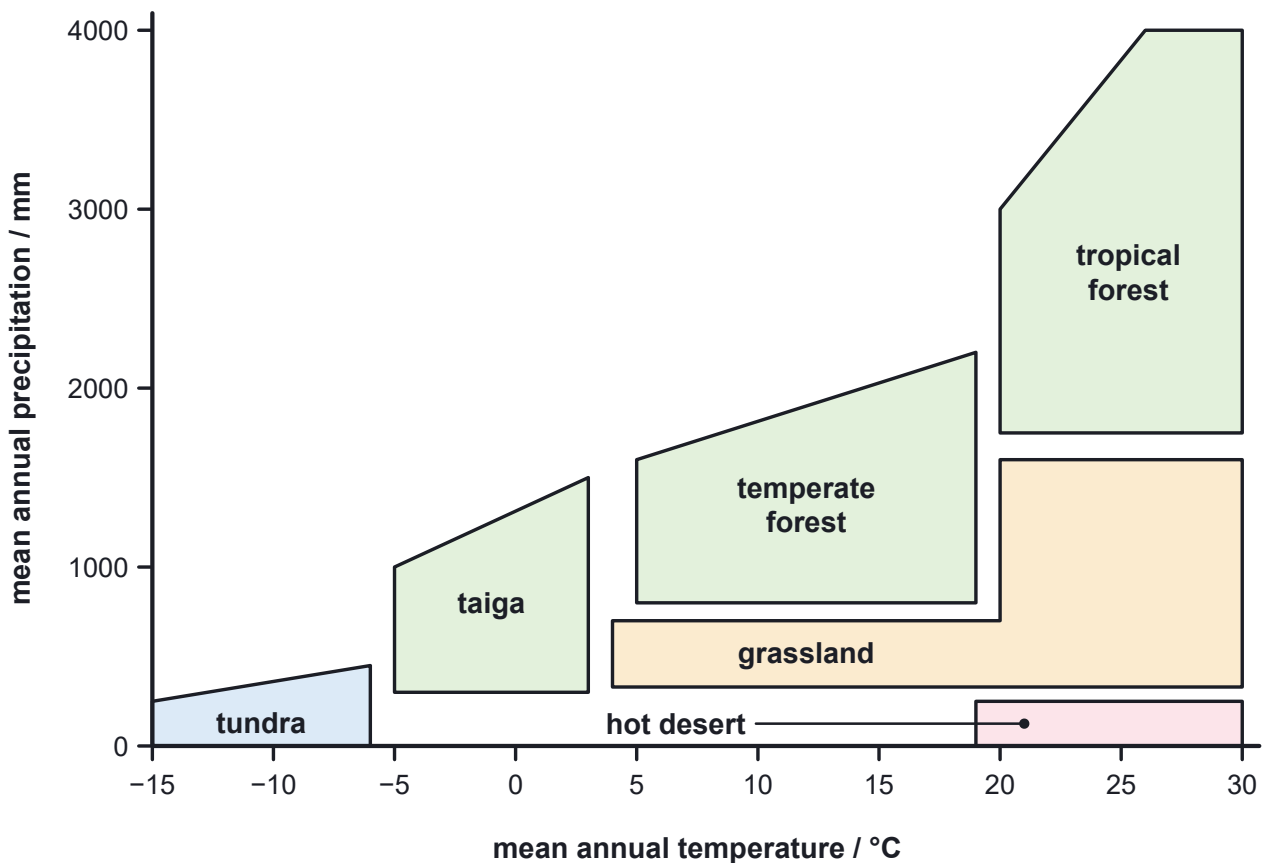
Abiotic conditions needed for coral reef formation (approximate values)		
Factor	Condition needed	Reason
Water depth	Shallow: most reefs grow in water less than about 30 m deep, and few reef-building corals live below about 50 m	Light for photosynthesis by zooxanthellae falls off rapidly with depth
Clarity	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?

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.