Adaptation to environment

B4.1 · SL and HL

Wet mud and dry sand create different problems

B4.1: the same full content for SL and HL

A dune grass must conserve water in drying wind; a mangrove must manage salt and obtain oxygen in waterlogged mud.

Trace condition → effect → mechanism → benefit and cost. Cover habitat, abiotic limits, transects, reef formation, biomes and named species.

All numerical datasets and climate regions are invented teaching models, not measured values for the named species.

Describe where an organism lives before explaining its traits

Location and environmental conditions are different information

Habitat can combine a geographical region, ecosystem and physical position: exposed seaward dune sand differs from the sheltered interior.

Abiotic variables include water, light, temperature, pH, salinity and oxygen. Competitors and predators are biotic influences.

A neighbour is biotic but its shade alters abiotic light. A place name alone does not identify a limiting mechanism.

Separate evolutionary adaptation from an immediate response

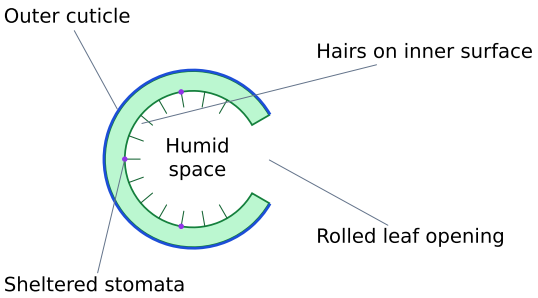
An inherited capacity can produce reversible individual change

An adaptation is a heritable feature contributing to survival or reproduction in context; selection acts across generations.

One grass leaf can roll as water status changes. Its inherited response system is an adaptation, while rolling that afternoon is a physiological response.

The plant does not evolve a new species-level feature because it needs one during a dry afternoon.

Inspect the sheltered stomatal surface



Marram grass (Ammophila arenaria) rolls its leaf around a sheltered humid space.

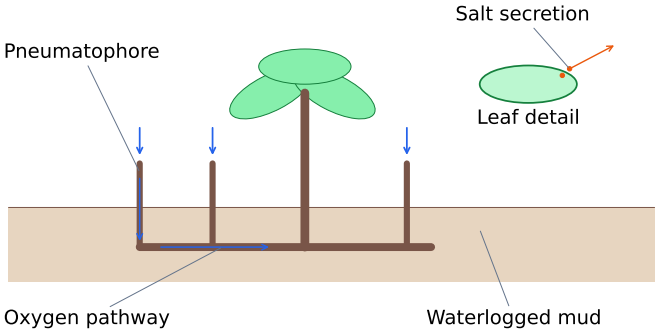
Explain how each feature addresses a condition

Feature	Mechanism and limit
Rolling, hairs and grooves	Restrict airflow near stomata; retain humid air and reduce water-vapour gradient
Outer cuticle	Limits loss across the exposed surface
Rhizomes	Anchor and spread below moving sand; support new shoots
Trade-off	Restricted carbon dioxide entry can limit photosynthesis; no feature stops all water loss

Compare benefit and cost with the same baseline

1. **Invented responses.** Water loss $10 \rightarrow 4$ mg per square centimetre per hour; assimilation index $12 \rightarrow 6$.
2. **Relative decreases.** Water loss: $6/10 \times 100 = 60\%$. Assimilation: $6/12 \times 100 = 50\%$.
3. **Evaluate.** Water conservation is accompanied by less carbon gain. Growth/reproduction and environmental conditions are needed before calling one response optimal.

Trace oxygen and salt by separate pathways



Grey mangrove (Avicennia marina) has exposed breathing roots and leaf salt glands with different roles.

A wet environment can still restrict water uptake

Problem	Mechanism
Saline surroundings	Low external water potential makes uptake difficult; root exclusion limits salt entry
Salt entering the plant	Leaf glands secrete some salt; handling has limits and costs
Oxygen-poor mud	Exposed pneumatophores allow air entry and internal oxygen movement for root respiration
Changing tide	Submergence can restrict atmospheric access; species differ in root and salt-handling traits

Name the function whose tolerance is measured

Survival, reproduction and occupied distribution can differ

A limiting factor restricts performance under the circumstances, even when other requirements are suitable.

Survival for a short exposure does not establish successful reproduction or a persistent population.

Field absence may reflect dispersal, competition, predation or disturbance rather than physiological intolerance.

Related variables can act together

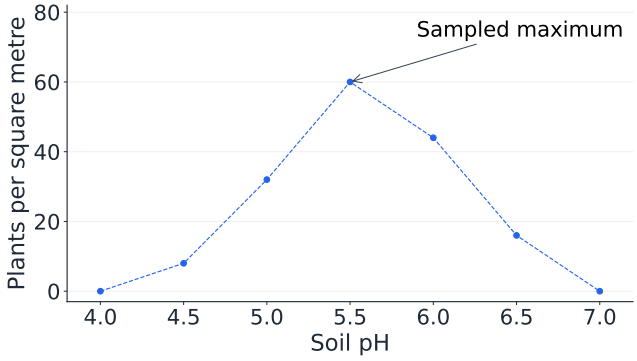
A temperature association need not identify the only mechanism

Soil water and salinity affect a plant's water supply. Light and temperature also influence performance.

For brown trout (Salmo trutta), water temperature and dissolved oxygen influence oxygen demand and supply.

Warmer water generally holds less dissolved oxygen at equilibrium, while metabolic demand can rise within a tolerable range. Other conditions and life stages matter.

Read the shape before choosing a linear model



Plant P density rises and falls across sampled pH values; field observations do not establish lethal limits.

Convert quadrat counts to comparable densities

1. **Invented equal areas.** Each quadrat is 0.25 square metre. At pH 5.5 there are 15 plants; at pH 6.0 there are 11.
2. **Density.** $15/0.25 = 60$ and $11/0.25 = 44$ plants per square metre.
3. **Interpretation.** Recorded occurrence is pH 4.5–6.5, with sampled maximum at 5.5. Sparse sampling and confounding prevent exact tolerance-limit claims.

Repeat independent gradients and measure confounders

The investigation must match the claim

Use permitted natural or semi-natural habitat, a stated transect-selection method, equal quadrat areas and consistent counts at stated intervals.

Calibrate pH sensors, standardize soil preparation/depth, and record moisture and light. Light/temperature sensors also need consistent positions and timing.

Several adjacent positions on one line are not independent whole habitats. Repeat transects/sites or seasons as required; field correlation alone is not causal isolation.

Explain each condition through a process

Condition	Connection to shallow reef formation
Depth and clarity	Affect light for photosynthetic symbionts; sediment can smother
Temperature	Suitable warmth supports tropical growth; sustained excessive heat can disrupt symbiosis
Salinity	Must remain within tolerable marine conditions; freshwater input can stress colonies
pH and carbonate chemistry	Lower pH can reduce carbonate availability and calcification even above pH 7

Corals are animals; not every coral is a shallow tropical builder

Construction must exceed erosion and dissolution

Many shallow reef-building corals receive organic products from photosynthetic symbionts. Cold-water corals also exist.

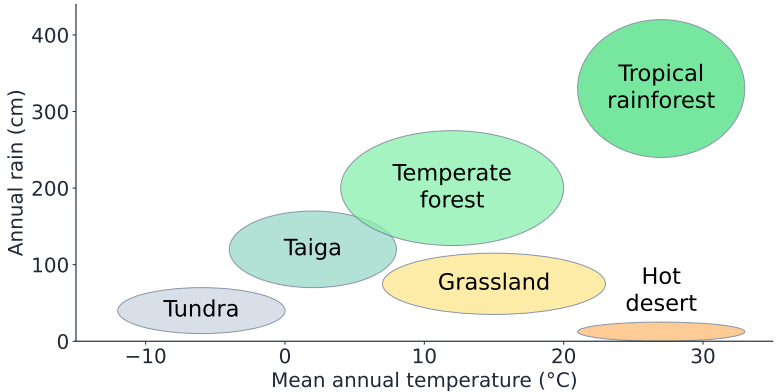
Many tropical builders grow well around 23–29°C, but species/history differ. Bleaching is loss of symbionts or pigments; it does not always mean immediate animal death.

Favourable light, water chemistry, salinity and temperature must work together. One suitable factor cannot guarantee reef accretion.

Distinguish cover change from colony mortality

1. **Invented monitoring.** Live cover falls from 30% to 18%.
2. **Two comparisons.** Decrease = 12 percentage points; relative decrease = $12/30 \times 100 = 40\%$.
3. **Limits.** This is area cover, not 40% of each colony dying. Heat, storms, disease and survey differences require separate evidence.

Use two climate variables to describe broad possibilities



Climate patterns guide predictions; local conditions modify them.

Compare cold and temperate biomes

Biome	Climate and vegetation
Tundra	Cold, short growing season; low vegetation; permafrost important in many Arctic areas
Taiga / boreal forest	Long cold winters, short growing season; conifers prominent
Temperate forest	Moderate, seasonal temperatures and adequate water; deciduous or evergreen forms occur

Compare grassland, hot desert and tropical forest

Biome	**Climate and vegetation**
Grassland	Water/seasonality plus fire and grazing can constrain tree cover
Hot desert	Low water relative to evaporative demand; sparse drought-tolerant vegetation
Tropical forest	Warm conditions and substantial rain; rainforest usually has a long growing season

Similar climate can favour convergent functional traits

Similar growth form does not mean identical species

Different lineages can evolve similar responses to similar abiotic pressures; biome similarity does not erase shared ancestry or require the same species.

Annual means hide rainfall timing, freezing and drought. Soil, drainage, altitude, fire, grazing and land use also matter.

A broad temperature–rainfall diagram is a model of potential patterns, not an exact map of every ecosystem.

Connect named desert organisms to their environment

Species	Features, mechanism and limit
Saguaro (Carnegiea gigantea)	Pleated water-storing stem expands; shallow spreading roots exploit wetting; tissue investment and seedling stress remain
Fennec fox (Vulpes zerda)	Large ears permit heat transfer under a suitable gradient and detect prey; nocturnal activity/foot fur reduce daytime exposure

Connect named forest organisms to structure and resources

Species	**Features and mechanism**
Kapok (Ceiba pentandra)	Tall crown accesses canopy light; buttresses support the trunk and distribute loads, without removing wind risk
Geoffroy's spider monkey (Ateles geoffroyi)	Long limbs and a prehensile tail support arboreal movement; gripping can leave limbs available for feeding

Tripling length changes total area and the ratio differently

1. **Cube relations.** Surface area $= 6s^2$; volume $= s^3$; **surface area to volume ratio** $= 6/s$.
2. **Sides 1 and 3 cm.** Areas 6 and 54 cm^2; volumes 1 and 27 cm^3; ratios 6 and 2 per cm.
3. **Interpretation.** Ratio falls to one third even though total area increases ninefold. Gradients, insulation, shape, circulation and behaviour affect actual exchange.

Geometry alone does not predict body temperature

1. **Invented body model.** Area 400 cm^2, volume 2,000 cm^3: ratio 0.20 per cm.
2. **Compare.** 0.20 is one tenth of 2.0 per cm: less exposed area per unit internal volume.
3. **Limit.** Lower exchange per volume is conditional on comparable conditions. Reduced heat loss can be disadvantageous in heat; specialized surfaces and behaviour matter.

Attempt the full thirteen-question handout set

Explain the causal step and evaluate evidence

Compare marram and mangrove challenges; distinguish adaptation, response and physiological tolerance.

Interpret plant P density and range, design replicated transects, and explain all reef conditions and six biome climates.

Calculate cube ratios, cover changes and leaf water-loss rates; use named species and discuss trade-offs.

Check areas, percentages and measured rates

1. **Field and reef data.** pH 6.0: 44 plants per square metre; recorded range 4.5–6.5, sampled maximum 5.5. Cover 40% $\rightarrow$ 28%: 12 points, 30% relative decrease.
2. **Cubes.** Sides 2/6 cm: areas 24/216 cm^2, volumes 8/216 cm^3, ratios 3/1 per cm. Body model $300/1500 = 0.20$, one fifth of 1.0.
3. **Leaves.** 15 min $= 0.25$ h; 30/12 mg divided by 10×0.25 gives 12/4.8 mg per cm^2 per hour: 60% less loss. Assimilation 20 $\rightarrow$ 12: 40% less.

Check yourself

Specify species, condition, mechanism and comparison

Field occurrence is not an exact physiological range; correlation is not causal isolation.

Abiotic climate filters and convergence can explain similar communities without identical species.

Keep percentage points separate from relative percentages and geometric ratios separate from complete exchange predictions.