
# ECOPHYSIOLOGY

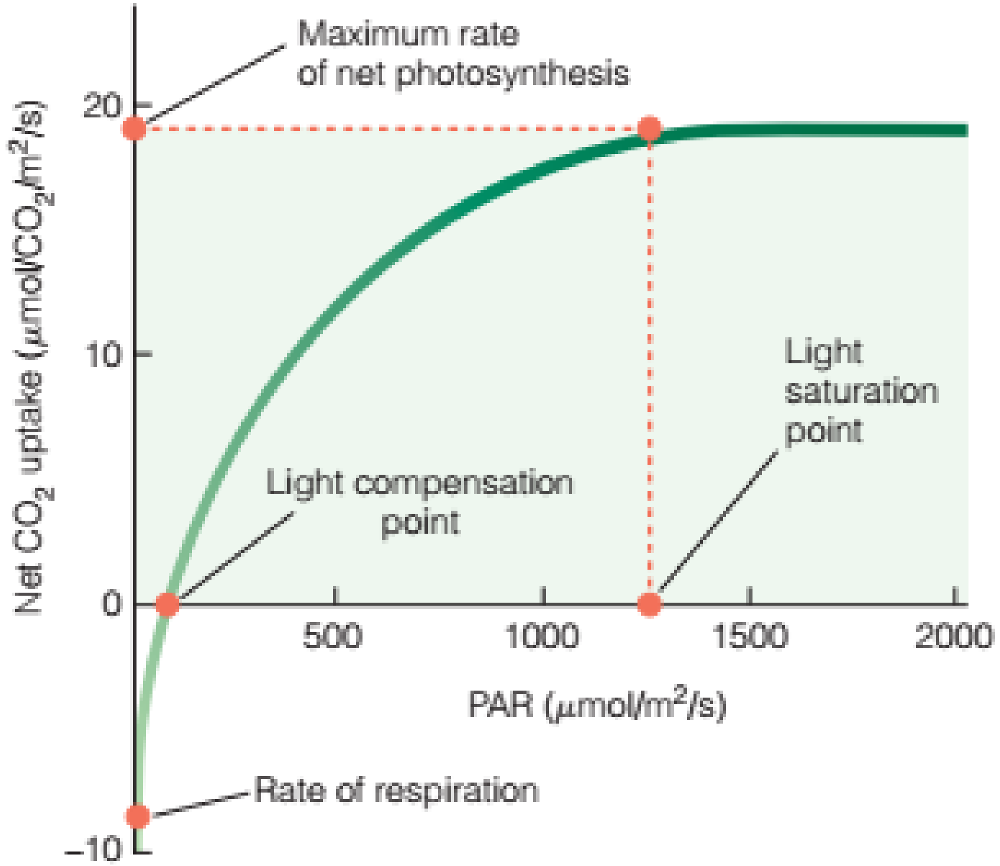
# Ecophysiology

- Ecophysiology (from Gr. oikos – "house(hold)", physis – "nature, origin", and -logia – "study of"), Also known as **environmental physiology** or **physiological ecology**, it is the branch of biology that examines how an organism's physiology responds to environmental conditions.
- It is broadly divided into:
  - Plant Ecophysiology
  - Animal Ecophysiology
- **Adaptation:** A genetically determined trait that enhances an organism's ability to survive and reproduce in a specific environment. It involves the acquisition of heritable traits that improve performance or survival over successive generations.
- **Acclimatisation:** Physiological, anatomical, or morphological adjustments within an individual organism that enhance performance or survival in response to environmental change. It occurs over a short period (days to weeks) within the organism's lifetime.

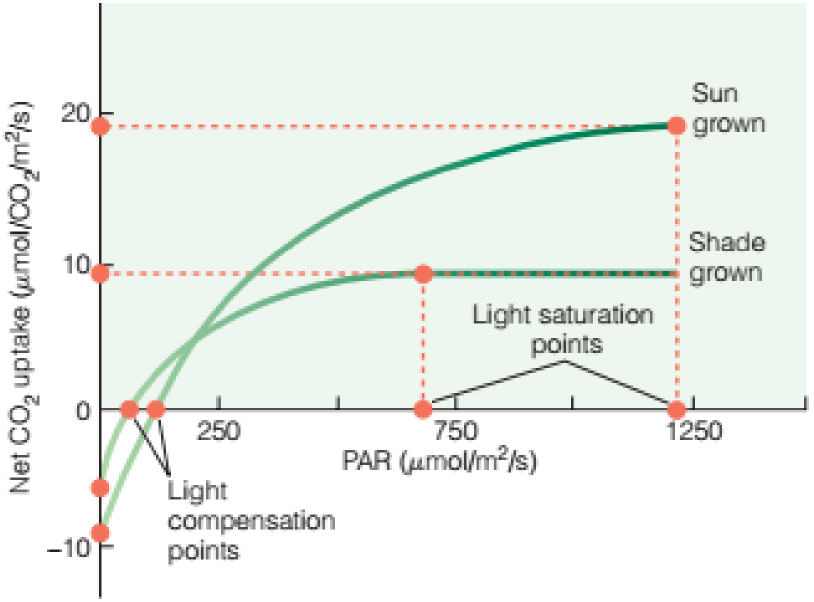
# PLANT ECOPHYSIOLOGY

# Photosynthetic Responses to Light

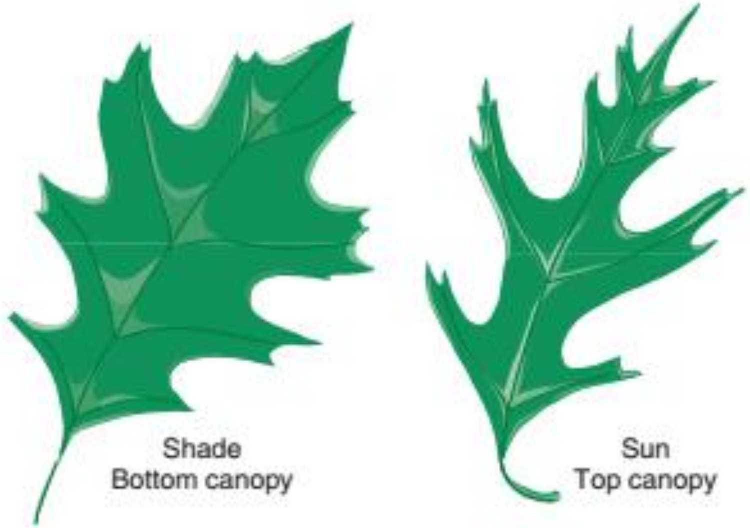
- **Compensation Point:** The light intensity at which the rate of photosynthesis equals the rate of respiration.
- **Light Saturation Point:** The **PAR** (Photosynthetically Active Radiation) value beyond which no further increase in photosynthesis occurs.
- **Shade-adapted Plants (Sciophytes):** Reach saturation at low PAR.
- **Sun-adapted Plants (Heliophytes):** Reach saturation at high PAR.
- **Photoinhibition:** In some shade-adapted plants, photosynthetic rate decreases when light intensity exceeds the optimum level.
- **Euphotic Zone:** The photosynthetically active layer of a water body.



# Photosynthetic Responses to Light




Shade-grown plants typically have a lower light compensation point and a lower light saturation point than do sun-grown plants.




Red oak *(Quercus rubra)* leaves vary in size and shape from the top to the bottom of the tree.
**Top leaf:** Narrow, more lobed and thick
**Bottom leaf:** Less lobed, broad

# Photoperiodism

- Flowering plants use photoreceptor proteins such as **phytochrome** and **cryptochrome** to detect seasonal changes in **night length (photoperiod)**, which serve as cues for flowering.
- **Obligate Photoperiodic Plants:** Require a specific long or short night before flowering.
- **Facultative Photoperiodic Plants:** Flower more readily under one photoperiodic condition but can flower otherwise as well.
- **Long-day Plants:** Flower when night length falls **below the critical photoperiod**. Usually, flower in **late spring or early summer**, as days become longer.
- **Short-day Plants:** Flower when night length **exceeds the critical photoperiod**. Do not flower under short nights or if **night is interrupted by artificial light**. **Moonlight or lightning** is insufficient to affect flowering.

# Light

1. Production of chlorophyll
2. Transpiration
3. Stomatal regulation
4. Plant distribution
5. Photoperiodism
6. Photosynthetic efficiency

# Temperature Hazards and Plant Responses

**High Temperature:**

- Causes **protein denaturation**, **heat shock**, and **ROS production**.
- Induces synthesis of **heat shock proteins (HSPs)**.
- Leads to **membrane fluidity increase** and **metabolic imbalance**.

**Low Temperature:**

- Results in **enzyme inactivation**, **slow catalysis**, and **membrane rigidity**.
- Triggers production of **antifreeze proteins** and **dehydrins**.
- Causes **freezing injury** and **reduced membrane transport**.

# Temperature Hazards and Plant Responses

Common Effects and Adaptations:

- **Reactive Oxygen Species (ROS)** build up under temperature stress; neutralised by **antioxidant systems**.
- Membrane Composition Adjustment:
  - More **unsaturated fatty acids** in cold conditions.
  - More **saturated fatty acids** in hot conditions.
- Overheating Avoidance:
  - Reduced sunlight absorption using **reflective hairs, scales, and waxes**.
  - **Wind and transpiration** enhance cooling.
  - Some species (e.g. *Macroptilium purpureum*) display **paraheliotropism** to avoid direct sun.
- Cold avoidance
  - **Microclimate modification**, e.g. *Raoulia* ("vegetable sheep") forms **compact cushions** to insulate tissues and resist cooling winds.

*Raoulia eximia*

# Water Stress in Plants

**Water Deficit (Drought):**

- Insufficient water causes **tissue dehydration** and may lead to plant death.
- **Root structure** and **root cell water potential** determine water uptake efficiency (Soil–Plant–Atmosphere Continuum).
- Under low soil moisture, plants adjust their **water potential** to sustain water flow from roots to leaves.
- **Stomata close** to minimise transpiration, often regulated by **abscisic acid** (ABA) from roots.
- Prolonged drought causes **loss of turgor pressure and wilting**.
- Adaptive responses include:
  - Osmotic adjustment (lowering cell water potential)
  - Increased root growth
  - Xerophytic adaptations to conserve or protect water.

# Water Stress in Plants

**Waterlogging and Anoxia**

- Excess soil water leads to **anoxic (low-oxygen)** conditions that can **kill roots within days**.
- Some species transport **oxygen from aerial tissues to roots** through internal air spaces (**aerenchyma**).
- **Specialised surface roots** develop near the soil–air interface to aid gas exchange.
- Surviving roots may shift to **less oxygen-dependent respiration**.
- Plants frequently submerged (e.g. **mangroves**) form **aerial roots (pneumatophores)** to maintain root oxygen levels.

# Xerophytes

Plants that grow in **dry or xeric conditions** are called **xerophytes**.

- **Types of Xerophytic Habitats:**
  - **Physical Dryness:**
    Soil contains very little water due to **low rainfall** or **poor water-holding capacity**.
  - **Physiological Dryness:**
    Water is present but **unavailable to plants**, e.g. in **saline or acidic soils**.

**Classification of Xerophytes (Based on Adaptive Features)**

- **Ephemeral Annuals (Drought Escapers):**
  - Complete life cycle before dry season; not true xerophytes.
  - *Example: Argemone mexicana*
- **Succulents (Drought Endurers):**
  - Store water in stems, roots, or leaves; remain internally hydrated.
  - *Examples: Aloe*, *Opuntia*
- **Non-succulent Xerophytes (Drought Resisters):**
  - Withstand external and internal dryness; true xerophytes.
  - *Examples: Calotropis procera*, *Casuarina equisetifolia*

*Argemone mexicana*

*Aloe*

*Casuarina equisetifolia*

# $CO_2$ Uptake and Water Loss

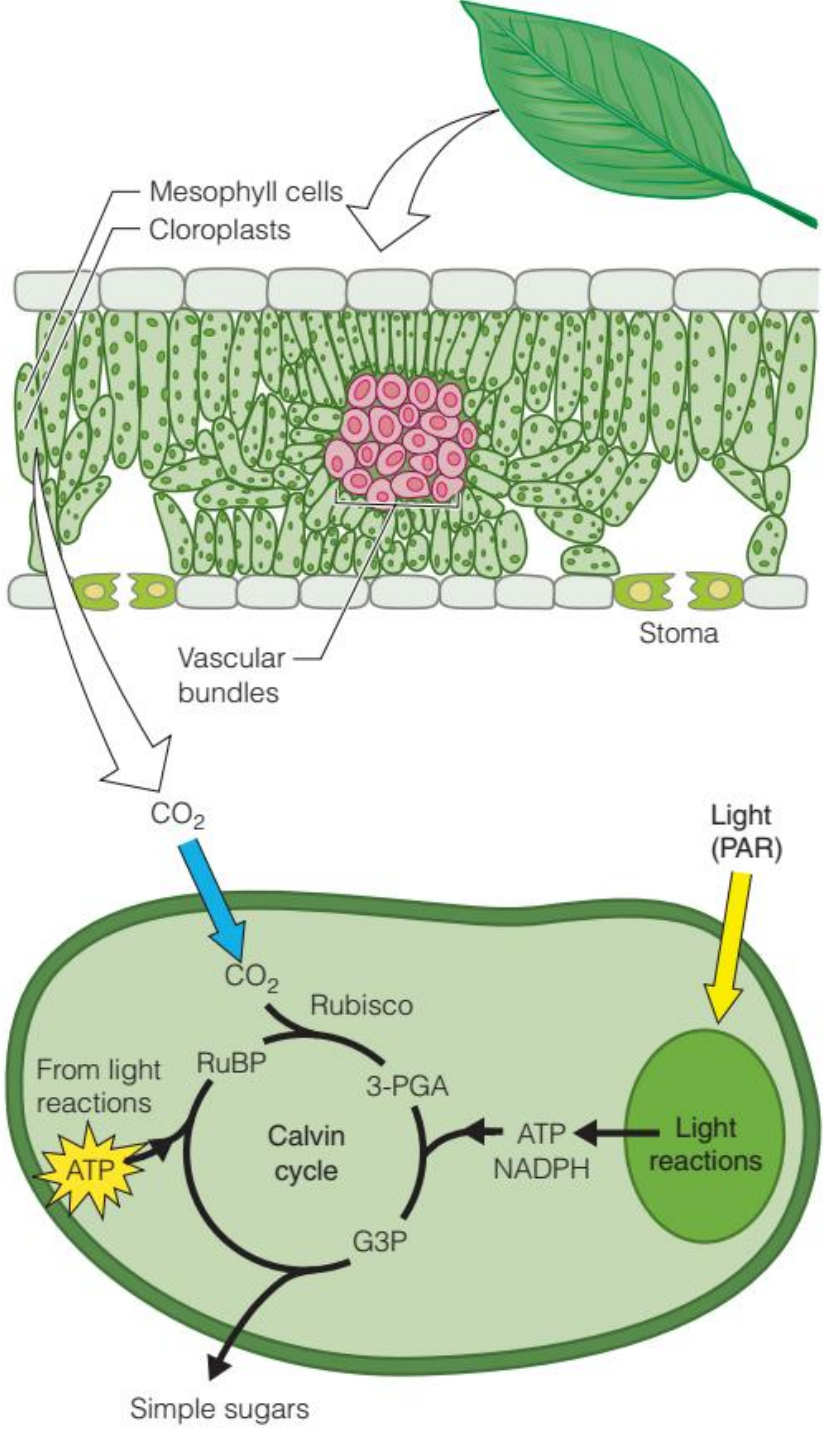
- Plants absorb **$CO_2$** through **stomatal pores** on their leaves.
- As $CO_2$ enters, **water vapour escapes**, creating a trade-off between $CO_2$ gain and water loss — vital for plant productivity.
- The trade-off intensifies because **Rubisco**, the $CO_2$-fixing enzyme, works efficiently only at **high internal $CO_2$ concentrations**.
- Some plants overcome this by concentrating $CO_2$ via **$C_4$ carbon fixation** or **Crassulacean Acid Metabolism (CAM)**.
- Most plants use **$C_3$ carbon fixation**, keeping stomata open during photosynthesis for $CO_2$ uptake.

# C3 Pathway (Calvin Cycle)

- $CO_2$ is fixed when **RuBP (ribulose-1,5-bisphosphate)** combines with $CO_2$ to form **two molecules of 3-PGA (3-phosphoglycerate)**.
- This **carboxylation reaction** is catalysed by **Rubisco** (ribulose bisphosphate carboxylase-oxygenase).
- **3-PGA** is converted into **G3P (glyceraldehyde-3-phosphate)** using **ATP and NADPH** from the light reactions.
- **G3P** is used to:
  - Produce **glucose ($C_6H_{12}O_6$)**, starch, and other carbohydrates.
  - Regenerate **RuBP** for the next cycle (requires additional ATP).
- **Light dependency:** ATP and NADPH availability links **dark reactions** to **light intensity**.

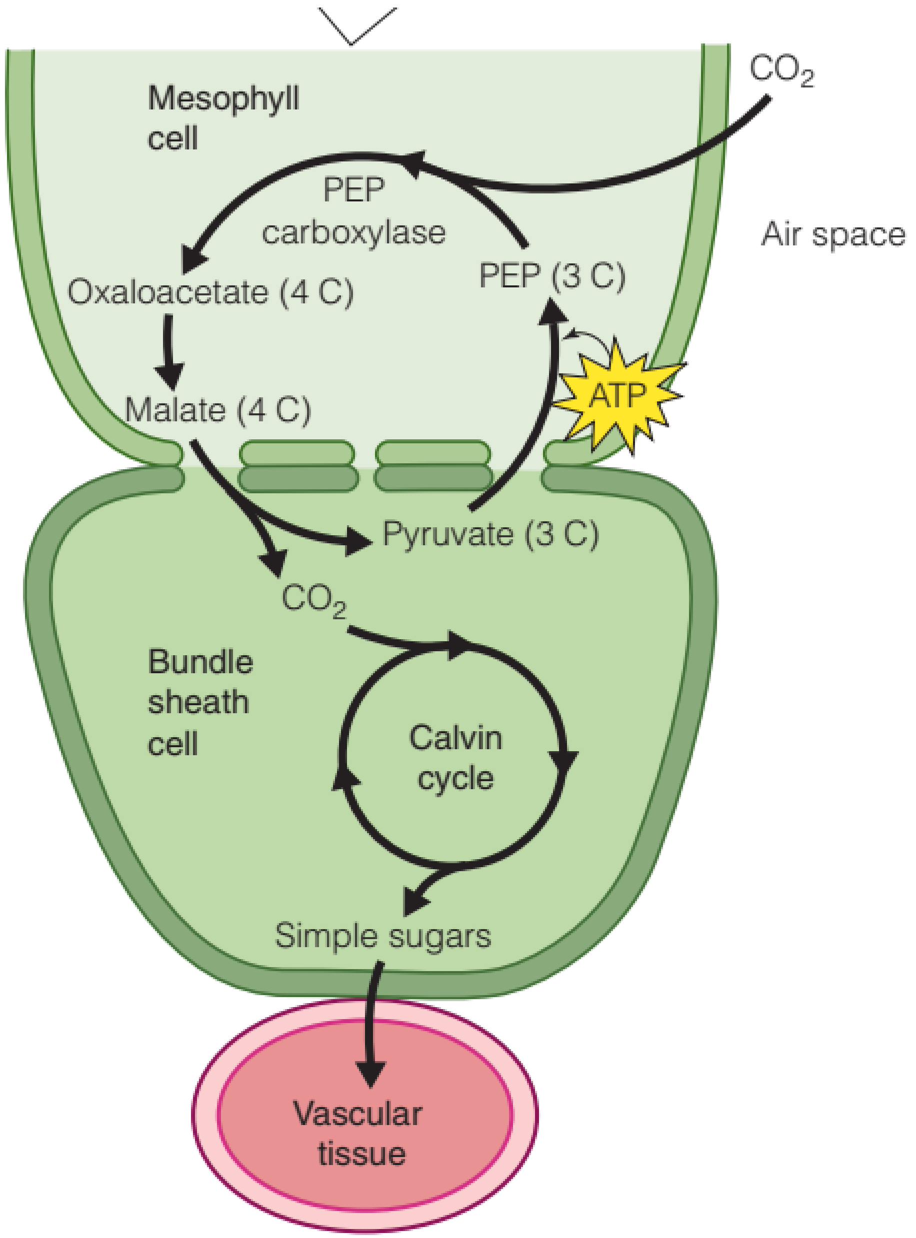
**Drawback:**

- **Rubisco also acts as an oxygenase**, catalysing $O_2$ with RuBP.
- This **oxygenation reaction** releases $CO_2$ and **reduces C3 photosynthesis efficiency**.



# C4 Pathway

- **$CO_2$ fixation:** $CO_2$ combines with **PEP (phosphoenolpyruvate)** in **mesophyll cells**, catalysed by **PEP carboxylase**, forming **OAA (oxaloacetate)**.
- **Formation of C4 acids:** OAA is converted into **malate and aspartate** (four-carbon compounds).
- **Transport to bundle sheath:** C4 acids move to **bundle sheath cells**.
- **$CO_2$ release and C3 cycle:** Enzymes release **$CO_2$** from the C4 acids, which enters the **C3 pathway** using **RuBP and Rubisco** to produce sugars.
- **Distribution:**
  - Mostly **grasses** in tropical/subtropical regions.
  - Some **shrubs** in arid or saline environments.
  - **Absent** in algae, bryophytes, ferns, gymnosperms, and primitive angiosperms.



# C4 Pathway

**Advantages of C4 Photosynthesis**

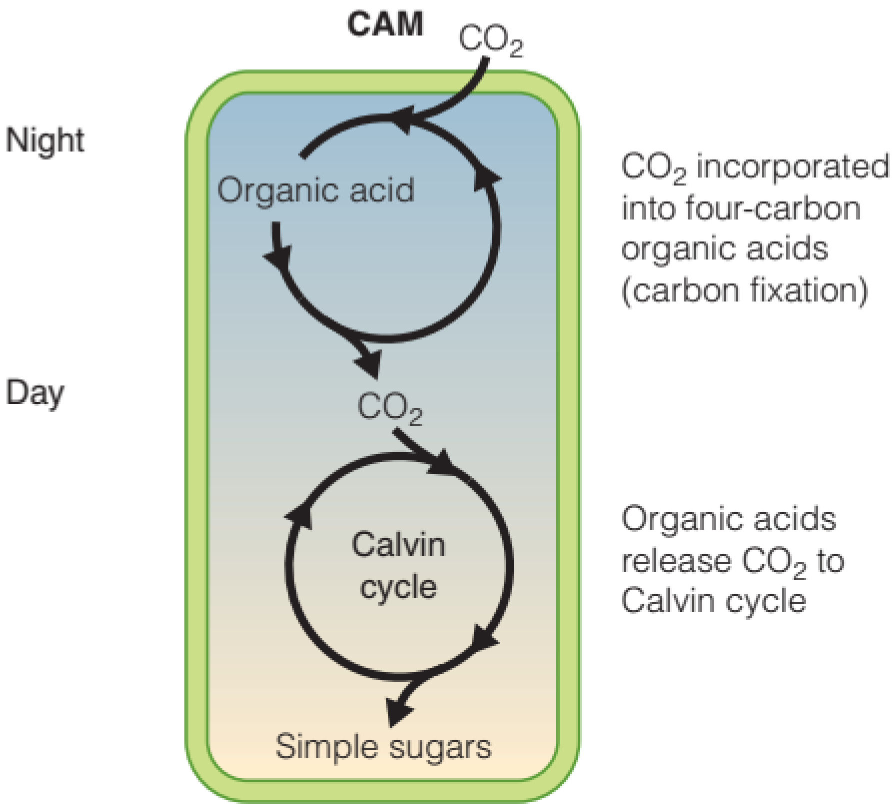
- **Avoids photorespiration:** PEP does not react with $O_2$, unlike RuBP, eliminating $CO_2$ loss from Rubisco oxygenation.
- **$CO_2$ concentration:** Malate and aspartate release $CO_2$ in **bundle sheath cells**, raising $CO_2$ levels and increasing Rubisco efficiency.
- **Higher photosynthetic rate:** C4 plants generally achieve **higher maximum photosynthesis** than C3 plants.
- **Greater water-use efficiency:** More carbon is fixed per unit of water lost, an advantage in **hot, dry climates**.

**Drawback**

- **Energy cost:** Requires additional ATP to regenerate PEP and operate **PEP carboxylase**.

# CAM Pathway (Crassulacean Acid Metabolism)

- Found in **desert succulents** (e.g., *Cactaceae*, *Euphorbiaceae*, *Crassulaceae*).
- Similar to **C4 pathway**, but both steps occur in the **mesophyll cells** at **different times**.
- **Night:**
  - Stomata open to take up $CO_2$.
  - $CO_2$ is fixed with **PEP** into **malic acid**, stored in mesophyll cells.
- **Day:**
  - Stomata close to conserve water.
  - Malic acid is converted back to $CO_2$ for fixation via the **C3 cycle**.
- **Advantages:**
  - Greatly **reduces water loss** by nocturnal stomatal opening.
  - Increases **water-use efficiency** in hot, arid environments.
- **Limitations:**
  - $CO_2$ fixation is **slower and less efficient** than in C3 or C4 plants.



# Comparison between C3, C4 and CAM

| Feature | C3 Pathway | C4 Pathway | CAM Pathway |
|---|---|---|---|
| **Main $CO_2$ Fixation Enzyme** | Rubisco | PEP carboxylase (initial), then Rubisco | PEP carboxylase (night), then Rubisco (day) |
| **First Stable Product** | 3-Phosphoglycerate (3C) | Oxaloacetate (4C) → Malate/Aspartate | Oxaloacetate (4C) → Malic acid |
| **Site of $CO_2$ Fixation** | Mesophyll cells | Mesophyll (initial) & Bundle sheath (final) | Mesophyll cells (both steps, but at different times) |
| **Separation Type** | No separation | Spatial separation | Temporal separation |
| **Photorespiration** | High | Negligible (avoids it) | Negligible |
| **Water-use Efficiency** | Low | High | Very high |
| **Optimum Conditions** | Cool, moist, moderate light | High light, warm temperature | Hot, arid environments |
| **Examples** | Wheat, Rice, Barley, Oat | Maize, Sugarcane, Sorghum | Cactus, Pineapple, Agave |
| **Advantages** | Simple, less energy demand | Avoids photorespiration; high photosynthetic rate | Minimises water loss; survives extreme drought |
| **Limitations** | Loses $CO_2$ via photorespiration | Requires extra ATP for PEP regeneration | Slow $CO_2$ fixation; low productivity |

# Effects of Wind on Plants

- **Mass & Energy Exchange:** Renews air around leaves through convection, influencing **evaporation, $CO_2$ uptake,** and **heat transfer**.
- **Signal Response (Thigmomorphogenesis):** Acts as a mechanical signal triggering **growth modification**, **structural strengthening**, and **wind hardening**.
- **Physical Damage:** Causes **leaf abrasion**, **branch or stem breakage**, **tree uprooting (windthrow)**, and **crop lodging**.

# Effects of Wind on Plants

**Exchange of Mass and Energy**

- **Boundary Layer Effect:** In still air, a moist boundary layer forms around leaves, insulating them from heat and water loss.
- **Wind Influence:** Increased wind disrupts this layer, linking the leaf microclimate with the surrounding air — enhancing cooling but increasing water loss.
- **Leaf Adaptations:** Fine hairs (trichomes) and specific leaf or canopy structures help maintain the boundary layer and regulate heat and moisture exchange.

**Acclimation (Thigmomorphogenesis)**

- **Wind Signal Response:** Higher wind speeds inhibit shoot elongation and promote radial growth and root development.
- **Outcome:** Produces shorter, sturdier plants with stronger stems and improved anchorage — a process known as wind hardening.

# ANIMAL ECOPHYSIOLOGY

# Homeostasis

- Homeostasis is the property of a living organism to regulate its internal environment to maintain a stable, constant condition under varying environmental conditions.

# Thermoregulation in Animals

- **Poikilotherms:** Cannot maintain a constant body temperature; body temperature varies with the environment.
  *Examples:* Insects, fishes, reptiles.
- **Homeotherms:** Maintain a constant body temperature through metabolic regulation, irrespective of environmental fluctuations.
  *Examples:* Birds, mammals.
  - **Cold Climate:** Increase metabolic rate or improve insulation to retain heat.
  - **Hot Climate:** Reduce heat production and enhance heat loss through sweating or panting.

**TABLE 6-1** Terms associated with body temperature homeostasis

| | |
|---|---|
| Homeothermy | Maintenance of a constant body temperature, usually warmer than that of the environment (hence "warm-blooded")* |
| Endothermy | Use of elevated metabolism in response to body cooling to maintain homeothermy |
| Ectothermy | Reliance on external sources of heat (solar radiation, conduction of heat from warm surfaces) to maintain an elevated body temperature |
| Poikilothermy | Failure to regulate body temperature; hence, conformance to environmental temperature ("cold-blooded")† |
| Heterothermy | Facultative reduction in body temperature by an endothermic animal |
| Facultative endothermy | Increase in body temperature of an ectothermic animal by means of some physiological process |

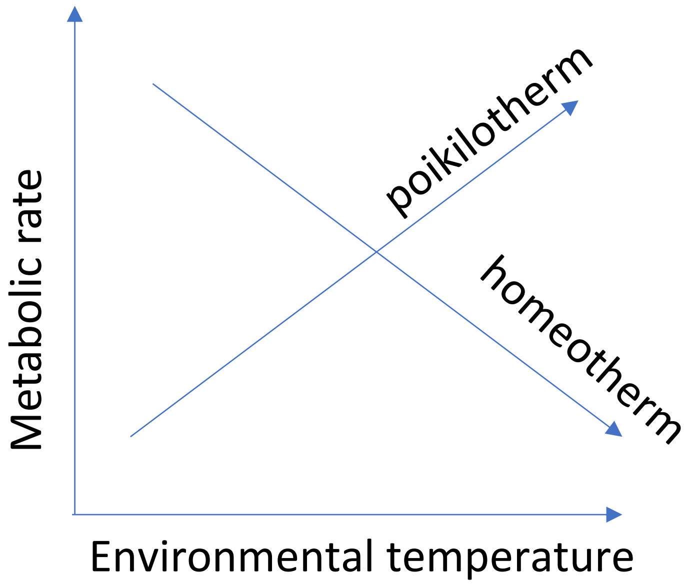
# Thermoregulation in Animals

**Poikilotherms**

- **Energy Use:** Low metabolic rate; conserve energy.
- **Survival Strategy:** Can **shut down activity** during resource scarcity (food, water, oxygen).
- **Cold Tolerance:**
    - **Freeze-tolerant:** Survive extracellular ice formation.
    - **Freeze-susceptible:** Cannot survive freezing.
- **Advantage:** Can survive long periods with minimal energy expenditure.

**Homeotherms**

- **Energy Use:** High metabolic rate; metabolically "extravagant."
- **Activity:** Maintain activity even when resources are limited.
- **Temperature Regulation:** Adjust metabolism, insulation, or cooling mechanisms to maintain constant body temperature.
- **Trade-off:** Excellent performance in **resource-rich environments**, but high energy demands can be a disadvantage under scarcity.



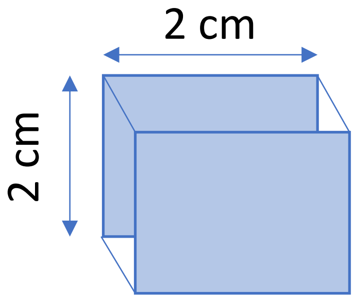
# Influence of Temperature on Animal Size

**Small Animals**

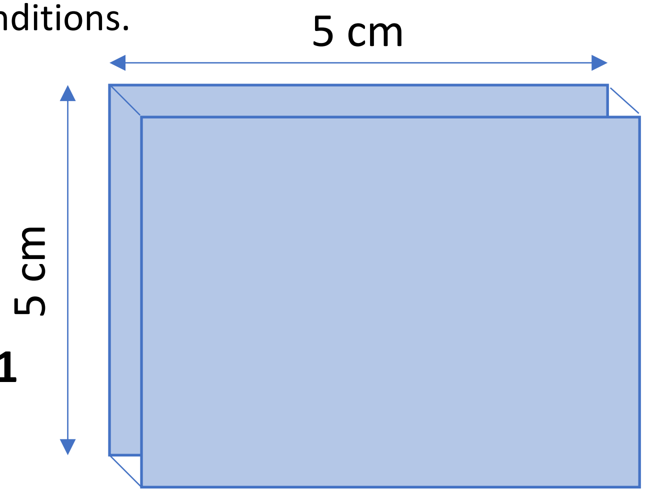
- **Surface Area:** Large relative to volume.
- **Heat Generation:** Less metabolically active tissue per unit surface area.
- **Effect of Cold:** Lose heat rapidly and are more vulnerable to low temperatures.

**Large Animals**

- **Surface Area:** Small relative to volume.
- **Heat Retention:** Cool down slowly in cold environments.
- **Advantage:** Better resistance to heat loss in cold conditions.




**Cube 1: 2 × 2 × 2 cm**
**Surface Area (SA):** 24 $cm^2$
**Volume (V):** 8 $cm^3$
**SA:V ratio** = SA ÷ V = 24 ÷ 8 = **3:1**




**Cube 2: 5 × 5 × 5 cm**
**Surface Area (SA):** 150 $cm^2$
**Volume (V):** 125 $cm^3$
**SA:V ratio** = SA ÷ V = 150 ÷ 125 = **1.2:1**

# Temperature–Body Size Relationships

Polar bear showing a big  body size

**Bergmann's Rule**

- **Definition:** In endothermic vertebrates, body size correlates with environmental temperature.
- **Principle:** Individuals in **cooler climates** tend to be **larger** than those in **warmer climates**.
- **Reason:** Larger bodies have **lower surface area-to-volume ratio**, reducing heat loss.
- **Memory Trick: "Bergmann = Bigger in the cold"**

**Allen's Rule**

- **Definition:** Extremity size in endothermic animals correlates with climate.
- **Principle:** Animals in **colder climates** have **shorter extremities** (ears, tails) than those in **warmer climates**.
- **Reason:** Shorter extremities reduce heat loss; longer extremities in warmth help heat dissipation.
- **Memory Trick: "Allen = Appendages adjust"**

Bigger appendages of Desert fox

# Hibernation (Winter Sleep)

- Observed in certain mammals. The warm-blooded animals that hibernate in winter are called **heterotherms**.
- The shelter used for hibernation is known as the **hibernaculum**.
- As winter approaches, these homeothermic animals temporarily behave like poikilotherms, thereby **reducing metabolic activity and conserving energy**.
- However, they differ from true poikilotherms — when the temperature of their hibernaculum nears freezing, **they increase heat production** to prevent body freezing.

💡 *Hibernate to save energy, but never freeze!*

# Shelford’s law of tolerance

- A species can survive only **within a certain range (limits) of environmental conditions**.
- **Upper and lower tolerance limits** define the boundaries of survival for that species.
- Species vary in their **degree of tolerance** to different factors:
  - **Steno-** → Narrow range of tolerance
  - **Eury-** → Wide range of tolerance

💡 **Trick to Remember:**
🔷 *“Steno = Strict, Eury = Easy”*

| Factor | Narrow tolerance | Wide tolerance |
|---|---|---|
| **Temperature** | Stenothermal | Eurythermal |
| **Water** | Stenohydric | Euryhydric |
| **Salinity** | Stenohaline | Euryhaline |
| **Food** | Stenophagic | Euryphagic |
| **Habitat selection** | Stenoecious | Euryecious |

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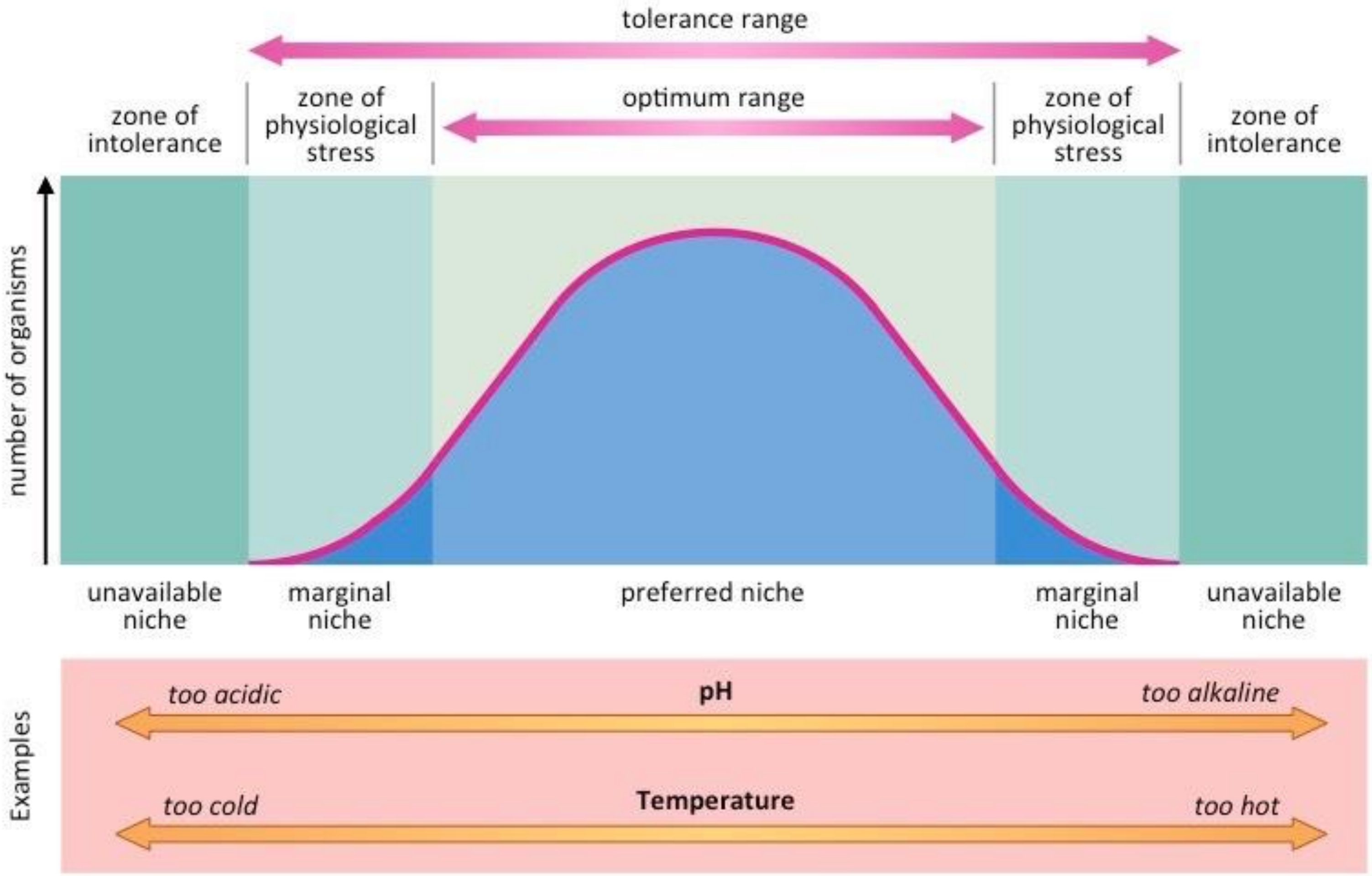

# Ecological Laws and Rules of Adaptation

**Leibig's Law of Minimum**

- Proposed by **Justus von Liebig**.
- Growth or productivity is controlled by the **most limiting factor** among all essential environmental requirements.
- Even if other factors are optimal, **deficiency in one limits growth**.
- *Example:* A plant short of nitrogen cannot grow further even with abundant sunlight and water.

💡 **Trick to Remember:**
*"Growth stops where the least is dropped."*

**The minimum available resource limits the maximum growth.**

**Gloger's Rule**

- Proposed by **C. W. L. Gloger (1833)**.
- Among **endothermic animals**, **darker pigmentation** occurs in **warm and humid regions**, whereas **lighter colouration** dominates in **cold or dry areas**.
- *Example:* Tropical species of birds and mammals show darker plumage or skin tones than those in temperate zones.

💡🌞 **Trick to Remember:**
*"Gloger = Glow near the equator."*

More **humidity and heat → more melanin → darker colouration.**