

Plant structures and their functions

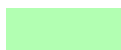
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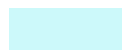
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Endothermic reaction

- a reaction that takes in energy from the surroundings (here, light energy).

Define Inverse square law

- light intensity is inversely proportional to the square of the distance from the source.

Define Xylem

- lignified dead cells that transport water and mineral ions up the plant.

Define Lignin

- the waterproof substance that strengthens xylem walls and kills the cells.

Define Translocation

- the transport of sucrose in the phloem, from source to sink.

Define Guard cell

- one of a pair of cells that change shape to open and close a stoma.

Define Phototropism

- a growth response of a plant to light.

Define Auxin

- a plant hormone that controls growth by cell elongation, causing tropisms.

Define Photosynthesis

- the endothermic reaction using light energy to react carbon dioxide and water to produce glucose and oxygen.

Define Limiting factor

- the factor in shortest supply, which is holding back the rate of a process.

Define Root hair cell

- a root epidermal cell with a long extension that absorbs water and mineral ions.

Define Phloem

- living cells that use energy to transport sucrose around the plant.

Define Transpiration

- the loss of water vapour from the leaves, which pulls water up through the plant.

Define Stoma (plural stomata)

- a pore in the leaf epidermis for gas exchange, through which water vapour is also lost.

Define Cuticle

- the waxy waterproof layer on the leaf surface that reduces water loss.

Define Gravitropism

- a growth response of a plant to gravity.

6.1–6.2 Photosynthesis, producers and biomass

- Photosynthetic organisms — plants and algae — are the **main producers** of food and therefore of **biomass** (6.1); nearly all other organisms depend on them.
- It happens in **chloroplasts**, which contain **chlorophyll**, the pigment that absorbs light energy.
- Photosynthesis is **endothermic**: light energy is taken in and stored in glucose (6.2). Without light the reaction stops.

WATCH OUT

"Photosynthesis is exothermic because the plant gains energy."
No — energy is *taken in* as light and stored, so photosynthesis is **endothermic**. Respiration, which releases it, is the exothermic one. Plants respire *day and night*.

NOTE

WHAT THE GLUCOSE IS USED FOR

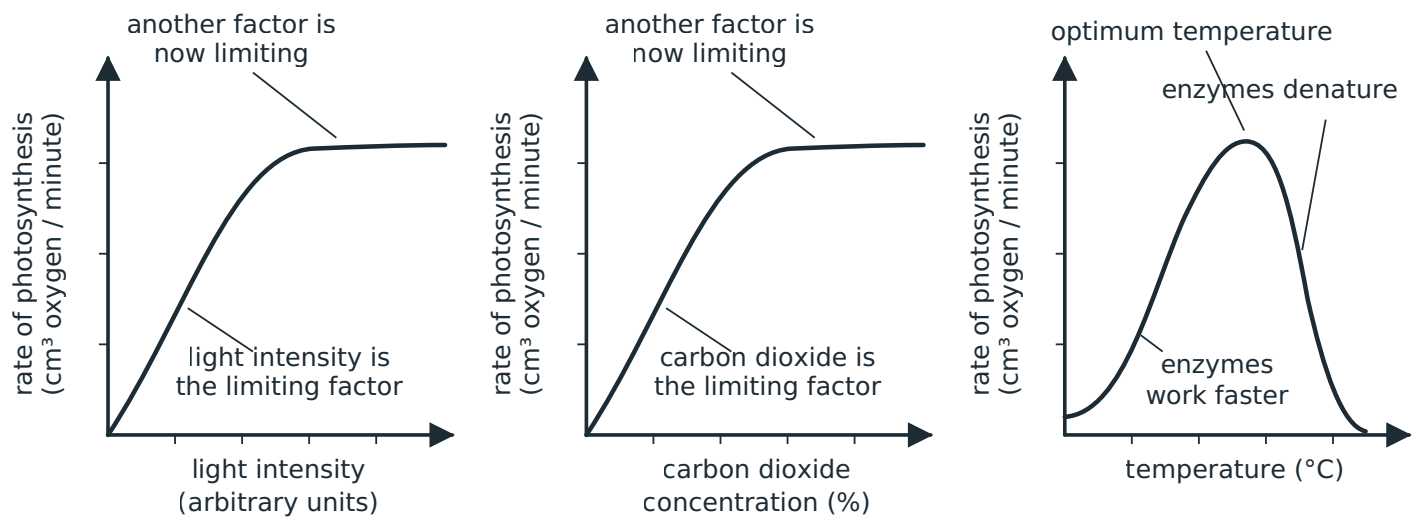
Glucose is respired for energy; converted to **starch** for storage; converted to **sucrose** for transport in the phloem; used to make **cellulose** for cell walls; combined with nitrate ions to make **amino acids** and proteins; and stored in seeds as **lipids**. These products are why photosynthesis builds biomass (6.1).

6.3–6.4 Limiting factors on the rate of photosynthesis

The rate is controlled by whichever factor is in shortest supply — the **limiting factor** (6.3).

- **Light intensity** — the rate rises as intensity rises, then levels off when another factor becomes limiting.
- **Carbon dioxide concentration** — the rate rises, then levels off. CO₂ is often limiting in a sealed greenhouse on a sunny day.
- **Temperature** — the rate rises because molecules and enzymes have more kinetic energy, but above the optimum it falls **sharply** as the enzymes are **denatured** (active sites change shape). Note the difference: light and CO₂ graphs *plateau*; the temperature graph *peaks then falls*.

Limiting factors and the rate of photosynthesis



ANALOGY

LIMITING FACTORS

Making tomato sandwiches with 50 slices of bread, 50 slices of cheese and only 5 tomatoes: you can make just 5. The tomatoes are the limiting factor, and buying more bread changes nothing. Get plenty of tomatoes and something else becomes the limit.

HIGHER TIER

HT ONLY 6.4 Interactions of the three factors

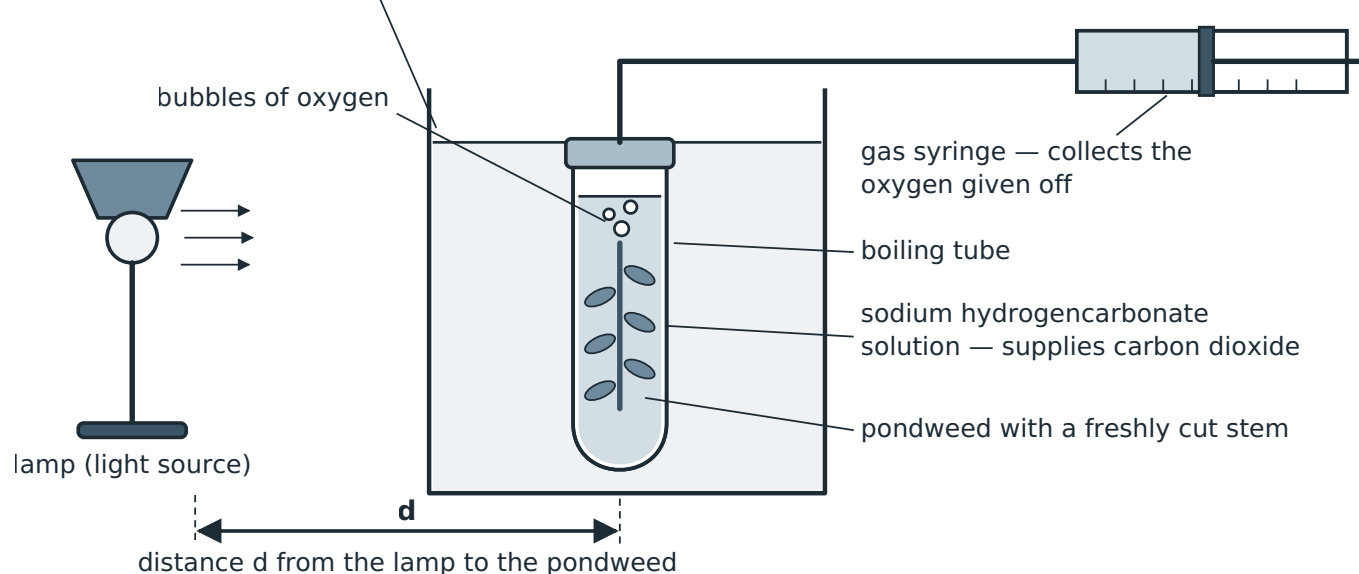
HT ONLY You must explain **combinations** of factors from a graph (6.4):

- Two curves at different CO₂ concentrations run together at low light (light is limiting for both) and separate at higher light, where CO₂ becomes limiting — so the higher-CO₂ curve plateaus higher.
- If increasing a factor gives no increase in rate, that factor was **not** limiting; the plateau shows a *different* factor is now limiting.
- At the plateau of a light-intensity curve, the limiting factor is CO₂ concentration or temperature.
- Greenhouse growers control all three (lamps, heaters, CO₂ enrichment) so that none is limiting, balancing the cost against the extra yield.

6.5 Core Practical — light intensity and the rate of photosynthesis

Alternative apparatus for Core Practical 6.5, using pondweed to measure the rate of photosynthesis

large beaker of water — a heat shield: it absorbs heat from the lamp so the temperature stays constant



independent variable — distance d of the lamp from the pondweed (this changes the light intensity)

dependent variable — volume of oxygen collected in one minute (or bubbles counted per minute)

control variables — temperature (kept constant by the water bath), carbon dioxide concentration, the same piece of pondweed, the same time for each reading

HT ONLY 6.6 Light intensity and the inverse square law

HIGHER TIER

HT ONLY When light is the limiting factor, the rate of photosynthesis is **directly proportional to light intensity**, and light intensity is **inversely proportional to the square of the distance** from the source (6.6). Doubling the distance gives **one quarter** the intensity; trebling it gives **one ninth**.

6.7 Root hair cells

Root hair cells are epidermal cells on young roots, adapted to absorb water and mineral ions (6.7):

- A **long thin extension** gives a large surface area and reaches between soil particles into the water film.
- **No chloroplasts** — they are underground.
- A **thin wall and membrane**, so a short pathway for water to cross.
- **Water** enters by **osmosis** through the partially permeable membrane, down a concentration gradient.
- **Mineral ions** are usually more concentrated inside the cell than in the soil, so they enter by **active transport** against the gradient — hence **many mitochondria** to supply the energy.

6.8 Xylem and phloem

Feature	Xylem (6.8a)	Phloem (6.8b)
Transports	Water and mineral ions	Dissolved sucrose
Direction	One way, roots to leaves	Both ways, source to sink
Cells	Dead , hollow, no end walls — a continuous tube	Living sieve tube elements with perforated sieve plates, plus companion cells
Walls	Thickened with lignin in rings and spirals	Thin cellulose walls, no lignin
Energy	None needed — driven by transpiration pull	Energy needed , supplied by companion cells

- Xylem cells lose their contents and end walls as lignin is laid down, leaving an open waterproof pipe; the lignin also stops the vessel collapsing under tension and supports the plant.
- Phloem sieve tubes lose most organelles, so neighbouring **companion cells** respire to supply the energy for loading and unloading sucrose.

6.9 Transpiration and the stomata

Transpiration is the loss of water vapour from the leaves, and it drives the movement of water and mineral ions through the plant (6.9).

1. Water is absorbed from the soil by **osmosis** through root hair cells.
2. It crosses the root into the **xylem**.
3. It is pulled up the xylem as a continuous column — the **transpiration stream**.
4. It **evaporates** from the surfaces of spongy mesophyll cells into the air spaces.
5. Water vapour **diffuses out through the open stomata** into the drier air outside.

Structure and function of the stomata - A **stoma** is a pore in the lower epidermis between two **guard cells**. Open stomata let **CO₂ in** and **O₂ out**, but water vapour is lost at the same time — the compromise the plant must manage. - Guard cells have **unevenly thickened walls**: the inner wall beside the pore is thicker than the outer wall. - In the light, water enters the guard cells by osmosis and they become **turgid**; the thin outer wall stretches more, so the cells curve apart and the stoma **opens**. - When water is short, guard cells become **flaccid** and straighten, so the stoma **closes** — saving water but stopping CO₂ uptake. - Most stomata are on the **lower** surface, which is shaded and cooler, reducing water loss.

ANALOGY

TRANSPIRATION PULL

Drinking through a straw: you do not push the drink up, you lower the pressure at the top and the drink is *pulled* up as one unbroken column. Evaporation from the leaves is the suck at the top; water molecules stick to one another so the whole column moves up the xylem. An air bubble breaks the column and it stops — which is why a shoot is cut under water for a potometer.

6.10 Translocation

- **Translocation** is the transport of **sucrose** around the plant in the **phloem** (6.10).
- It moves from a **source** (photosynthesising leaves, or a storage organ in spring) to a **sink** (growing root tips, fruits, seeds, tubers).
- It can move **up or down**, and one organ can be a source at one time of year and a sink at another.
- It **requires energy from respiration**, unlike transport in the xylem.

Transpiration in the xylem and translocation in the phloem

Rate of transpiration increases when:

- the temperature increases
- air movement increases
- light intensity increases
- humidity decreases

xylem — carries water and mineral ions from the roots up to the leaves; this flow is the transpiration stream

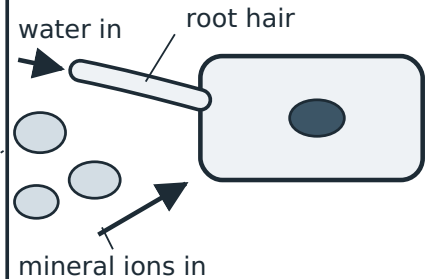
roots — covered in root hair cells that absorb from the soil

water evaporates from the leaf and diffuses out through the stomata

phloem — carries dissolved sugars from the leaves to the rest of the plant; this is called translocation

Root hair cell

adapted for uptake of water by osmosis and mineral ions by active transport

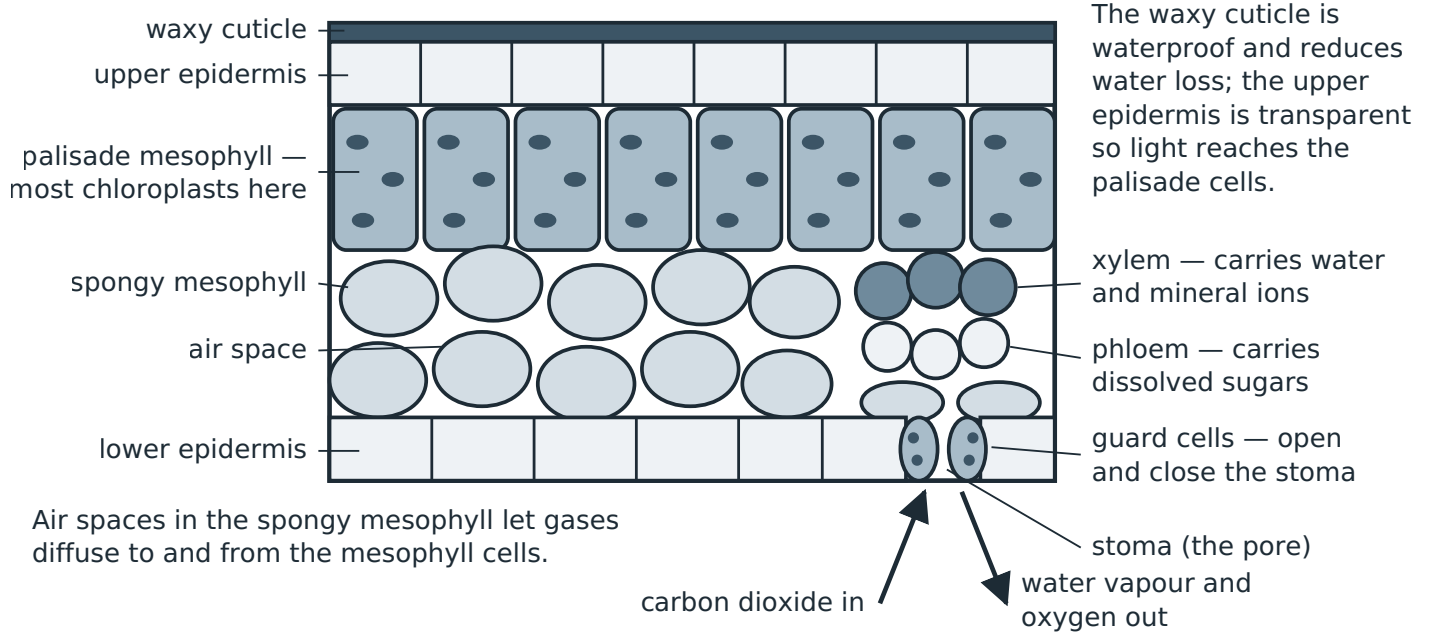


BIOLOGY ONLY 6.11B Structure of the leaf

BIOLOGY ONLY How each part is adapted for photosynthesis and gas exchange (6.11B):

- **Waxy cuticle** — transparent so light passes through, and waterproof so it reduces water loss.
- **Upper epidermis** — thin and transparent, letting light reach the layer below.
- **Palisade mesophyll** — tall column-shaped cells packed near the top with **many chloroplasts**, absorbing most of the light; most photosynthesis happens here.
- **Spongy mesophyll** — loosely packed cells with large **air spaces**, giving a big surface area and letting CO₂ diffuse quickly to the palisade cells.
- **Stomata and guard cells** in the lower epidermis — control entry of CO₂ and exit of O₂ and water vapour.
- **Veins** — xylem brings water and mineral ions, phloem carries sucrose away.
- **Broad, flat and thin** — large surface area for light, short diffusion distance for gases.

Cross-section of a leaf



6.12 Environmental factors and the rate of water uptake

Transpiration, and therefore water uptake, is increased by (6.12):

- **Light intensity** — brighter light opens the stomata for photosynthesis, so more water vapour escapes; in the dark most stomata close.
- **Air movement (wind)** — moving air removes the humid air just outside the stomata, keeping the concentration gradient steep, so diffusion out is faster.
- **Temperature** — warmer molecules have more kinetic energy, so evaporation from mesophyll cells and diffusion out of the stomata are both faster.
- Higher **humidity** has the opposite effect: a smaller concentration gradient, so slower transpiration.

NOTE

A **potometer** measures water *uptake*, a good estimate of transpiration but not identical to it — a little water is used in photosynthesis and to keep cells turgid.

6.13 Rate calculations for transpiration

BIOLOGY ONLY 6.14B Plants in extreme environments

BIOLOGY ONLY Adaptations for surviving where water is scarce (6.14B):

- **Small leaves or spines** (cactus) — a much smaller surface area, so far less water lost; spines also deter herbivores.
- **Thick waxy cuticle** — a stronger waterproof barrier against evaporation.
- **Fewer stomata**, and stomata **sunken in pits** or surrounded by hairs — trapping humid air by the pore, reducing the concentration gradient; some open only at night.
- **Rolled leaves** (marram grass) — trapping humid air inside and sheltering stomata from wind.
- **Water storage tissue** in fleshy stems, and wide shallow or very deep root systems.

BIOLOGY ONLY 6.15B Plant hormones and tropisms

BIOLOGY ONLY Plant hormones control and coordinate growth and development (6.15B). **Auxins** are made in the growing tips of shoots and roots, move back from the tip, and cause cells behind it to **elongate**.

- **Phototropism** — a growth response to light. Shoots are **positively phototropic**: auxin moves to the shaded side, those cells elongate more, and the shoot bends **towards the light**, so leaves capture more light.
- **Gravitropism** — a growth response to gravity. In a horizontal root, auxin gathers on the lower side, but in roots high auxin **inhibits** elongation, so the upper side grows more and the root bends **downwards** (positively gravitropic) towards water and anchorage.
- A horizontal shoot is **negatively gravitropic**: auxin on the lower side makes those cells elongate more, so the shoot bends **upwards**.
- The key exam point: the same auxin **promotes** elongation in shoots but **inhibits** it in roots.

WATCH OUT

Plants do not bend because they "want" light. Bending is unequal *growth* caused by unequal auxin distribution — cells on one side get longer than the other.

BIOLOGY ONLY HT ONLY 6.16B Commercial uses of plant hormones

HIGHER TIER

BIOLOGY ONLY HT ONLY You must describe these commercial uses (6.16B):

- **a Auxins**
- **Selective weedkillers** — broad-leaved weeds absorb far more synthetic auxin and grow uncontrollably fast until they use up their resources and die, while narrow-leaved grasses and cereals survive.
- **Rooting powders** — a cutting dipped in auxin powder grows roots quickly, cloning many identical plants cheaply from one parent.
- **b Gibberellins**
- **Germination** — they end seed dormancy, so seeds germinate out of season and all at the same time, giving an even crop.
- **Fruit and flower formation** — used to make plants flower early or out of season, and to produce larger fruit.
- **Seedless fruit** — applied to unpollinated flowers so fruit develops without fertilisation (e.g. seedless grapes).
- **c Ethene**
- **Fruit ripening** — ethene is a gas that stimulates ripening. Fruit is picked and transported **unripe** so it is firm and does not bruise or spoil, then ethene is added in storage or transport so it ripens just before sale. This cuts waste and controls when fruit reaches the shops.