

Cambridge OCR GCSE Biology A — Biology

Topic B2

Scaling up

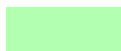
Specification J247 · Cambridge OCR

Free edition

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 Osmosis

- the movement of water from a higher to a lower water potential through a partially permeable membrane.

Define Active transport

- movement of substances against a concentration gradient, using energy from respiration.

Define Mitosis

- the stage in which chromosomes move to opposite ends of the cell and the nucleus divides, giving two identical cells.

Define Stem cell

- an undifferentiated cell that can divide and differentiate into other cell types.

Define Surface area : volume ratio

- surface area divided by volume; it falls as an organism gets larger.

Define Double circulatory system

- one in which blood passes through the heart twice for each circuit of the body.

Define Translocation

- movement of dissolved food molecules through the phloem, from source to sink.

Define Diffusion

- the net movement of particles from a higher to a lower concentration; passive.

Define Water potential

- how likely water is to move out of a solution; pure water has the highest, a concentrated solution the lowest.

Define Cell cycle

- cell growth, DNA replication, further growth, then division of the nucleus by mitosis.

Define Differentiation

- the process by which a cell becomes specialised for a particular function.

Define Meristem

- plant tissue at root and shoot tips where cells divide and can differentiate throughout the plant's life.

Define Exchange surface

- a surface adapted to move substances into or out of an organism quickly.

Define Transpiration

- loss of water vapour from the leaves, mainly through the stomata, which pulls water up the xylem.

Define Potometer

- apparatus that measures the rate of water uptake by a leafy shoot.

B2.1 Supplying the cell

Cells transport many substances across their membranes by diffusion, osmosis and active transport. Stem cells are found in both plants and animals; they divide, differentiate and become specialised to form tissues, organs and organ systems.

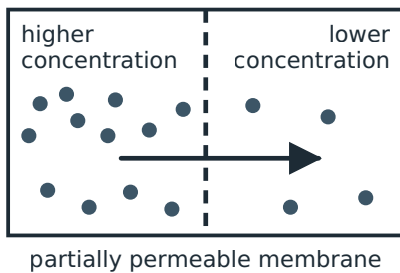
Movement across membranes (B2.1a)

The cell membrane is a **selective barrier**. Substances cross it in three ways.

	Diffusion	Osmosis	Active transport
What moves	Any dissolved solute or gas	Water only	Dissolved ions and molecules
Direction	Down the gradient, high to low	Higher to lower water potential	Against the gradient, low to high
Membrane	Not needed	Partially permeable	With carrier proteins
Energy from respiration	No — passive	No — passive	Yes
Examples	Oxygen and carbon dioxide at the alveoli; carbon dioxide into a leaf	Water into root hair cells and into red blood cells	Mineral ions into root hair cells; sugars into the phloem

Diffusion, osmosis and active transport across a cell membrane.

Diffusion



Moves:

any substance in solution, or a gas — e.g. oxygen, carbon dioxide, urea

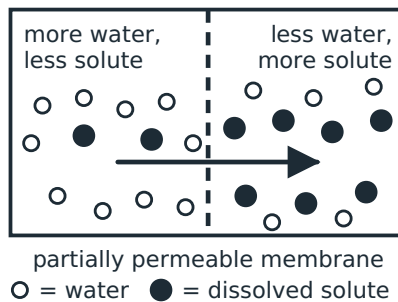
Direction:

down the concentration gradient, from a higher to a lower concentration

Energy from respiration:

not needed — it is passive

Osmosis



Moves:

water only, through a partially permeable membrane

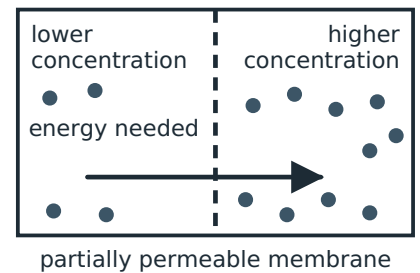
Direction:

from a dilute solution to a more concentrated solution

Energy from respiration:

not needed — it is passive

Active transport



Moves:

dissolved substances — mineral ions into root hair cells, sugar from the gut into the blood

Direction:

against the concentration gradient, from a lower to a higher concentration

Energy from respiration:

yes — energy is needed

- **Water potential** describes the direction of osmosis: water moves from a **higher water potential** (dilute) to a **lower** one (concentrated). No mathematical use of water potential is required.
- Active transport needs **energy released in respiration**, so cells that do much of it — root hair cells, gut lining cells — contain many mitochondria.

ANALOGY

Osmosis — the crowded corridor. A turnstile lets through people carrying nothing but blocks those carrying big boxes. One side is packed with box-carriers (concentrated solution), the other has mostly free people (dilute solution). Free people drift both ways at random, but more drift towards the crowded side simply because there are more free people on the dilute side to set off — a **net movement of water** into the concentrated solution. Nothing pushes the water; it is the turnstile plus random motion.

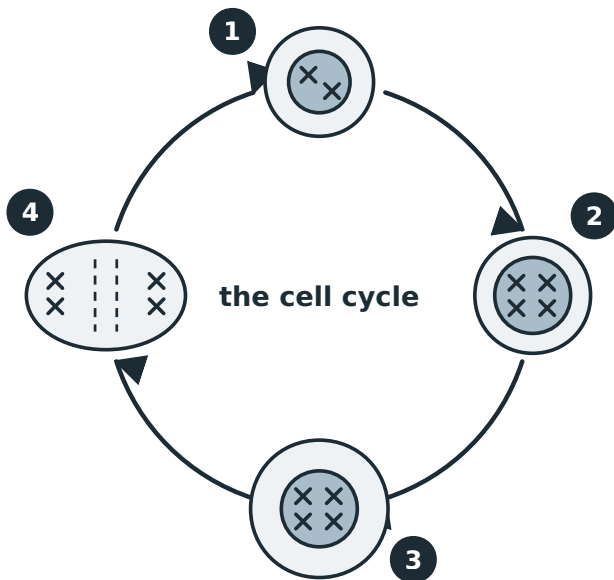
Mitosis and the cell cycle (B2.1b)

The **cell cycle** produces new cells for **growth** and repair. Its stages are:

1. **Cell growth** — the cell enlarges and the number of sub-cellular structures such as ribosomes and mitochondria increases.
2. **DNA replication** — every chromosome is copied.
3. **More cell growth** — the cell continues to grow and prepares to divide.
4. **Mitosis** — the copied **chromosomes are moved** to opposite ends of the cell and the nucleus divides; the cytoplasm and membrane then divide.

The two daughter cells are **genetically identical** to each other and to the parent cell.

The stages of the cell cycle, ending in two genetically identical cells.



1 Cell growth

The cell grows and the number of sub-cellular structures — ribosomes, mitochondria — increases.

2 DNA replication

Every chromosome is copied, so the cell now holds two identical copies of each one.

3 More cell growth

The cell keeps growing and prepares to divide.

4 Movement of chromosomes (mitosis)

One copy of each chromosome is pulled to each end of the cell and the nucleus divides; the cytoplasm and membrane then divide into two cells.

B2.1b names four stages: growth, DNA replication, more cell growth, movement of chromosomes. The cycle produces two genetically identical cells, for growth, development and repair.

	Mitosis	Meiosis
Divisions	One	Two
Daughter cells	2, genetically identical	4, all genetically different
Chromosome number	Kept the same	Halved
Purpose	Growth, repair, asexual reproduction	Making gametes for sexual reproduction

NOTE

Only **mitosis** is required in Topic B2; meiosis belongs to Topic B5 (Inheritance), examined on Paper 2 / Paper 4. The comparison is given here only because the two are so often confused.

Cell differentiation (B2.1c)

- **Differentiation** produces **specialised cells**, letting an organism become **more efficient**: each cell type does one job extremely well instead of every cell doing everything adequately.
- Examples: **sperm cell** (tail, many mitochondria, enzymes in the head); **nerve cell** (long axon, branched endings); **muscle cell** (contracting fibres, many mitochondria); **red blood cell** (biconcave, no nucleus, full of haemoglobin); **root hair cell** (large surface area, many mitochondria); **xylem vessel** (dead, hollow, lignified); **palisade cell** (packed with chloroplasts).

Specialised cells and the features that adapt each of them to its function.



Sperm cell

tail to swim; many mitochondria for energy; enzymes in the head to digest into the egg



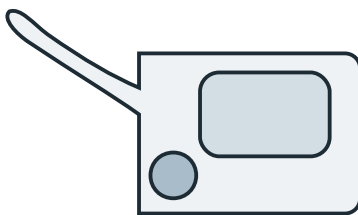
Nerve cell

long and thin to carry electrical impulses a long way; branched ends join other cells



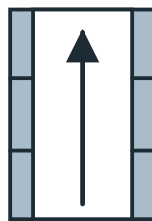
Muscle cell

contracts and relaxes; many mitochondria to release the energy needed to contract



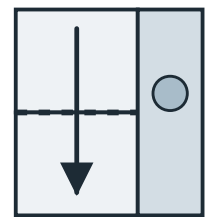
Root hair cell

long, thin hair gives a large surface area to absorb water and mineral ions from the soil



Xylem vessel

hollow dead cells joined end to end, no end walls — carries water; lignin strengthens walls



Phloem cell

sieve plates with pores let cell sap flow; companion cells supply the energy needed

Stem cells (B2.1d–f)

- Stem cells are present in embryonic and adult animals, and in meristems in plants (B2.1d).
- They divide to produce a range of different cell types for development, growth and repair (B2.1e): adult stem cells in bone marrow replace blood cells continuously, and meristems produce new plant tissue for the whole life of the plant.

	Embryonic stem cells	Adult stem cells
Source	Early embryo	Bone marrow and other adult tissues
Range	Can become any type of cell	A limited range only
Role	Development of the whole organism	Replacement and repair

- Plant **meristems** keep the ability to produce **any** plant cell type throughout life, which is why a cauliflower floret or a cutting can be cloned into a whole new plant (B2.1d–e; B2.1f is about the difference between **embryonic and adult stem cells in animals**).

WATCH OUT

Learners are commonly confused about **where stem cells are found and what they do**. They are not only in embryos: adults have them in bone marrow and other tissues, and plants have them in **meristems**. A stem cell is defined by what it can do — divide and **differentiate** — not by being an "early" cell, and in animals a differentiated cell cannot normally go back.

B2.2 The challenges of size

When organisms become multicellular, the need arises for highly adapted structures, including gaseous exchange surfaces and transport systems, so that living processes can be performed effectively.

Surface area : volume ratio (B2.2a)

A single-celled organism exchanges everything across its own surface and no part of it is far from that surface. As an organism grows, its **volume increases faster than its surface area**, so the ratio **falls** and diffusion distances become too long — hence the need for **exchange surfaces** and a **transport system**.

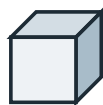
How the surface area : volume ratio falls as a cube gets larger.

Working it out

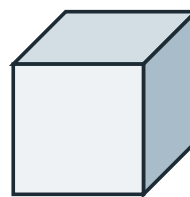
surface area = $6 \times \text{side} \times \text{side}$

volume = $\text{side} \times \text{side} \times \text{side}$

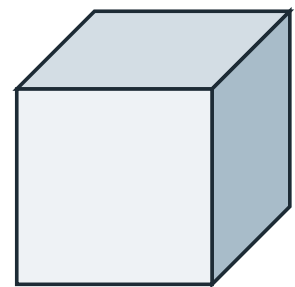
ratio = surface area $\div$ volume,
written in the form $n : 1$



side 1 cm



side 2 cm



side 3 cm

surface area (cm ²)	$6 \times 1 \times 1 = 6$	$6 \times 2 \times 2 = 24$	$6 \times 3 \times 3 = 54$
volume (cm ³)	$1 \times 1 \times 1 = 1$	$2 \times 2 \times 2 = 8$	$3 \times 3 \times 3 = 27$
surface area : volume	$6 : 1$	$24 : 8 = 3 : 1$	$54 : 27 = 2 : 1$

As an organism gets bigger, its surface area : volume ratio falls, so diffusion alone is too slow — it needs specialised exchange surfaces and a transport system.

ANALOGY

Surface area : volume — sugar cubes in tea. A whole sugar cube dissolves slowly; crushed, the same mass dissolves almost at once, because crushing creates far more surface for the same volume. A mouse is crushed sugar, an elephant the whole cube: the mouse loses heat fast through its relatively huge surface and must eat constantly, while the elephant struggles to lose heat and needs large ears to add surface area.

WATCH OUT

Learners commonly get **surface area : volume ratio the wrong way round**, assuming a larger animal has a *larger* ratio because it obviously has more surface. It has more surface in total but far more volume, so the **ratio is smaller**. Always work out both numbers and divide.

The human circulatory system (B2.2c)

- The circulatory system links every cell to the exchange surfaces, working **with the gaseous exchange system**: blood reaching the alveoli is low in oxygen and high in carbon dioxide, and the two gases diffuse in opposite directions across the thin, moist alveolar surface.
- Mammals have a **double circulatory system** — blood passes through the heart **twice** per circuit: the **pulmonary circuit** (right side → lungs → left side) and the **systemic circuit** (left side → body → right side).
- Vessels are always arranged artery → arteriole → **capillary** (where exchange happens) → venule → vein.

Substances transported (B2.2b)

- **Oxygen** in for aerobic respiration, and out of plants in daylight; **carbon dioxide** out as a respiratory waste product, and into leaves for photosynthesis.
- **Water** in through roots, food and drink; out in urine, sweat, breath and by transpiration.
- **Dissolved food molecules** — glucose and amino acids from the gut, and sugars translocated in the phloem.
- **Mineral ions** — nitrate for amino acids, magnesium for chlorophyll, taken up by active transport.
- **Urea** — made in the liver from excess amino acids, carried in the blood to the kidneys and excreted.

The heart and the blood vessels (B2.2d)

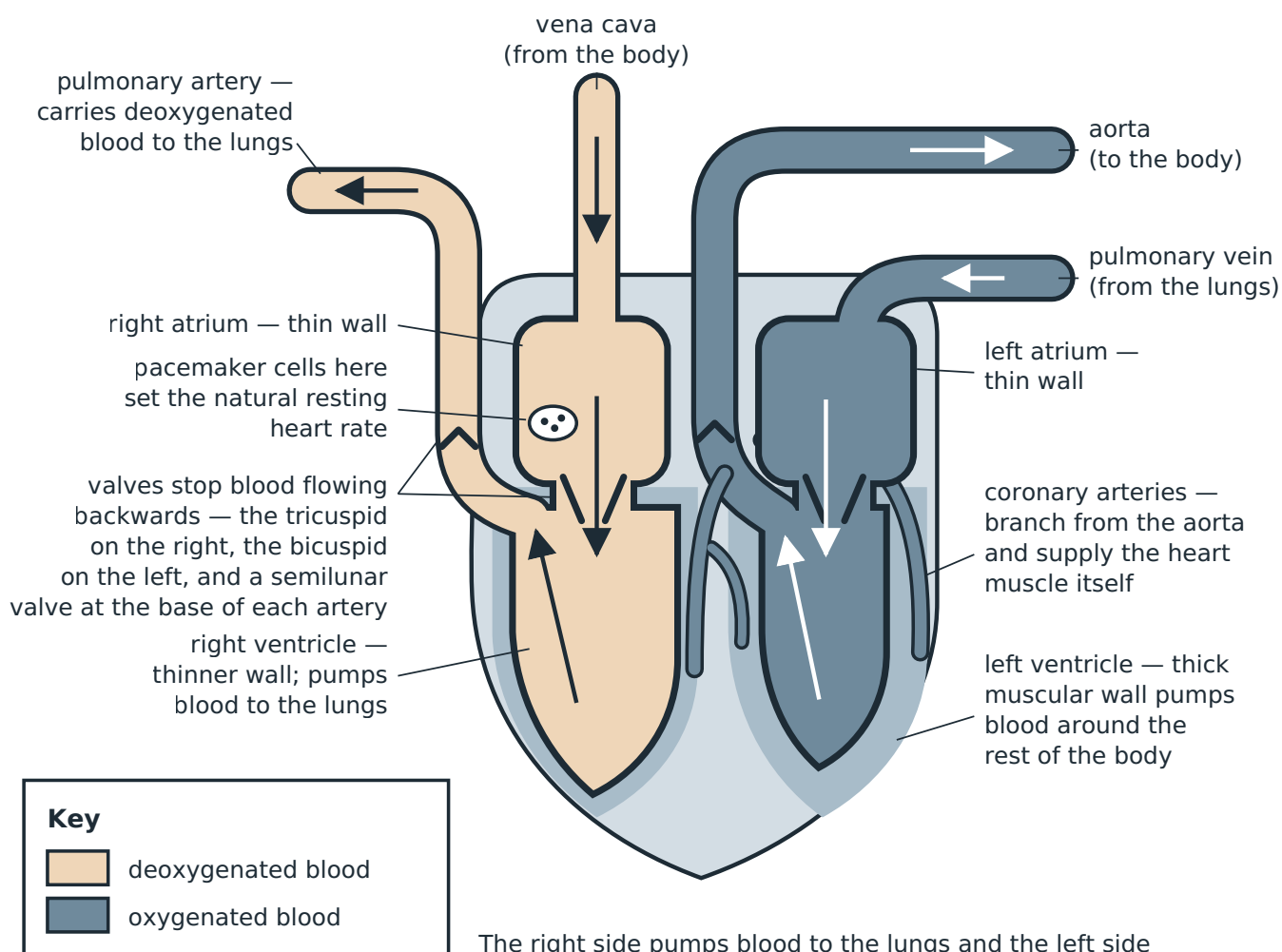
The heart is made of **cardiac muscle**, which contracts continuously without tiring.

- Blood enters the **right atrium** from the **vena cava** and the **left atrium** from the **pulmonary vein**.
- The atria contract; blood passes the **atrioventricular valves** (tricuspid right, bicuspid left) into the **ventricles**.
- The ventricles contract, forcing blood past the **semilunar valves** into the **pulmonary artery** (to the lungs) and the **aorta** (to the body). Valves prevent backflow, so blood flows one way only.
- The **left ventricle wall is much thicker** than the right, because it must generate enough pressure for the whole body while the right pumps only to the lungs.

ANALOGY

Double circulation — two short bus routes, not one long one. A single circulation is one bus on a huge loop: by the time it has crawled through the lungs it has lost its speed and dawdles round the body. A double circulation uses the heart as an interchange halfway, re-pressurising blood after the lungs so it reaches the body fast — fast enough for a mammal's high metabolic rate, which a fish's single circulation cannot support.

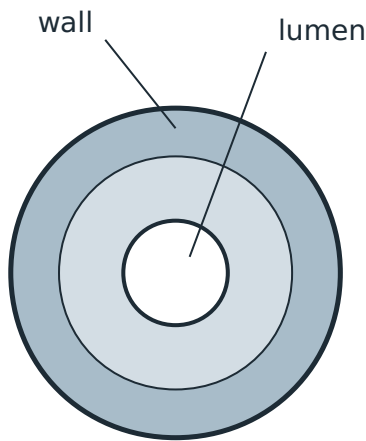
The chambers, the four named valves and the vessels of the mammalian heart.



The right side pumps blood to the lungs and the left side pumps it to the rest of the body — a double circulatory system. The left ventricle wall is thickest because it has to push blood the furthest.

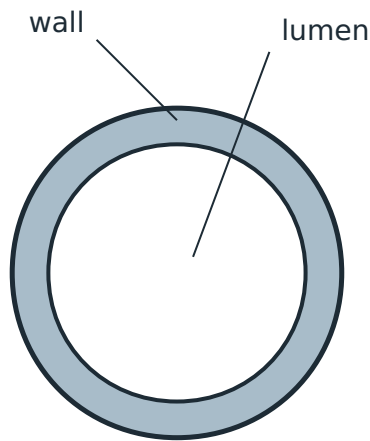
	Artery	Vein	Capillary
Direction	Away from the heart	Towards the heart	Links arterioles to venules
Wall	Thick, muscular, elastic	Thin, little muscle	One cell thick
Lumen	Narrow	Wide	One red blood cell wide
Valves	None, apart from those leaving the heart	Present , preventing backflow	None
Pressure	High, pulsing	Low	Falling
Adapted for	Withstanding and smoothing high pressure	Low-pressure return, helped by body muscles	Exchange — short diffusion distance

The walls, lumens and valves of an artery, a vein and a capillary.



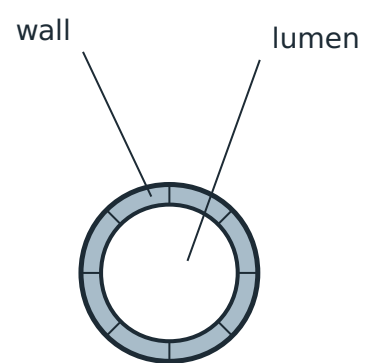
Artery

thick wall of muscle
and elastic fibres
narrow lumen
no valves
carries blood away from
the heart at high pressure



Vein

thin wall — little muscle
or elastic tissue
large lumen
valves present
carries blood back to the
heart at low pressure



Capillary

wall only one cell thick
very narrow lumen
no valves
walls are permeable
lets substances diffuse
into and out of cells

Longitudinal section of a vein



(the three cross-sections are not drawn to the same scale)

WATCH OUT

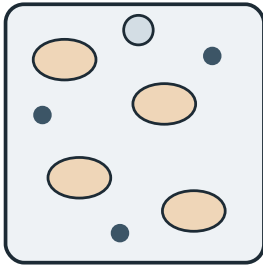
Learners assume blood flows slowly in capillaries **because they are narrow**. It is not the diameter of one capillary but the **total cross-sectional area** of all of them together — about **1000 times greater than that of the aorta**. The same volume of blood spread across a much wider total channel must move more slowly, and that slow flow is what allows **time for exchange by diffusion**.

Red blood cells and plasma (B2.2e)

- **Red blood cells** are **biconcave discs**, giving a large surface area and short diffusion path; they have **no nucleus**, leaving more room for **haemoglobin**, which binds oxygen in the lungs as oxyhaemoglobin and releases it in respiring tissue; they are flexible enough to squeeze through capillaries.
- **Plasma** is the straw-coloured liquid carrying everything else in solution: carbon dioxide, **urea**, glucose and amino acids, mineral ions, hormones, antibodies and heat, plus the cells and platelets themselves.

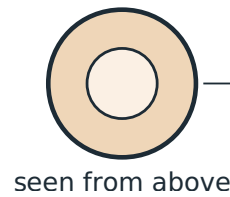
The components of the blood and how each is adapted to its transport function.

Plasma

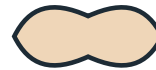


- straw-coloured liquid
- transports carbon dioxide, urea and hormones
- transports the soluble products of digestion
- the blood cells and platelets are carried suspended in it

Red blood cell



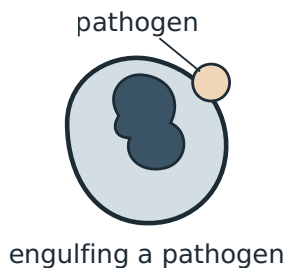
seen from above



seen in section

- no nucleus, so there is more room for haemoglobin
- biconcave disc shape gives a large surface area for diffusion
- haemoglobin joins with oxygen in the lungs and carries it to the cells

White blood cell



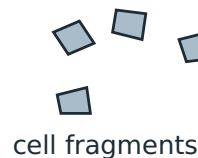
engulfing a pathogen



large nucleus
(unlike a red cell)

- has a nucleus
- some engulf and digest pathogens
- some make antibodies
- some make antitoxins
- they defend the body

Platelets



cell fragments



a clot plugs a wound

- small fragments of cells, with no nucleus
- help the blood to clot at a wound
- clotting stops blood loss and stops pathogens getting in

Water and mineral uptake by roots (B2.2f)

- **Water** enters root hair cells by **osmosis**, the soil solution having the higher water potential.
- **Mineral ions** such as nitrate are usually more concentrated inside the cell than in the soil, so they enter by **active transport**.
- The **root hair cell** is adapted for both: a long thin extension giving a **very large surface area**, a thin wall and membrane giving a **short diffusion distance**, and **many mitochondria** to supply energy for active transport.

Transpiration, translocation and stomata (B2.2g)

- **Transpiration** is the loss of water vapour from the leaf: water evaporates from mesophyll cell surfaces and diffuses out through the **stomata**, pulling a continuous column of water up the xylem — the transpiration stream.
- **Stomata** are pores, mostly on the lower epidermis, each controlled by two **guard cells**. Turgid guard cells open the pore, letting carbon dioxide in and water vapour out; when water is short they go flaccid and the pore closes, conserving water but stopping photosynthesis. Stomata are generally open by day and closed at night.
- **Translocation** is the movement of **dissolved food molecules**, mainly sugars, through the **phloem** from a **source** (a leaf) to a **sink** (a root, fruit or storage organ). Unlike transpiration it can move in **either direction** and requires energy.

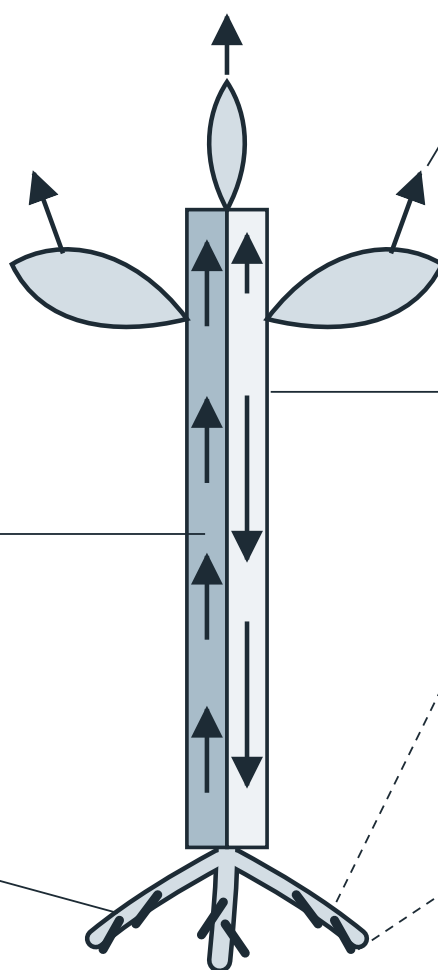
The transpiration stream in the xylem and translocation in the phloem.

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

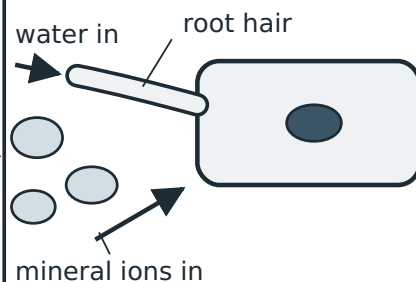


water evaporates from the leaf and diffuses out through the stomata

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



Xylem and phloem (B2.2h)

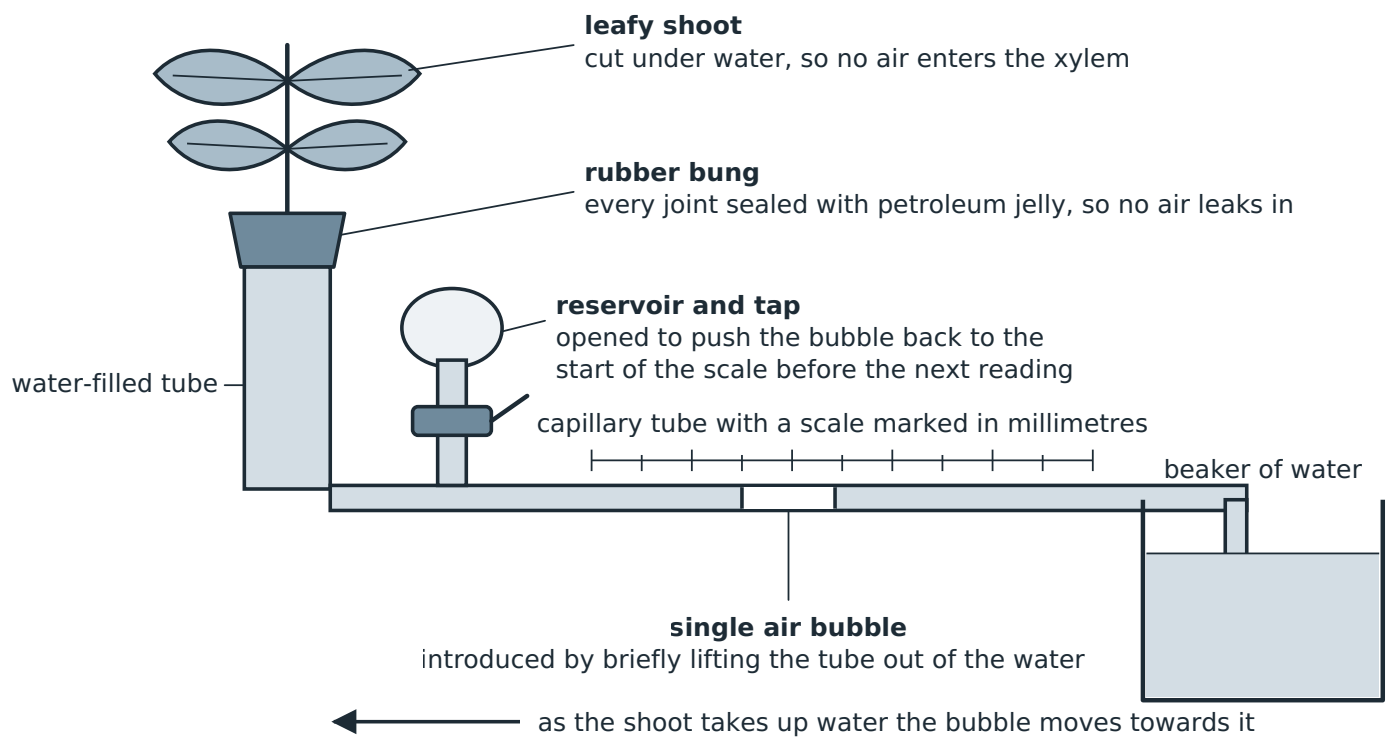
	Xylem	Phloem
Transports	Water and mineral ions	Dissolved sugars
Direction	Upwards only, roots to leaves	Both ways, source to sink
Cells	Dead , hollow, no end walls	Living sieve tubes with perforated end walls, plus companion cells
Walls	Strengthened with lignin	Thin, not lignified
Extra role	Support for the stem	Companion cells supply the energy needed

Environmental factors affecting water uptake (B2.2i)

- **Light intensity** — brighter light opens the stomata, so water uptake increases; in darkness they close and the rate falls to a minimum.
- **Air movement** — wind removes the humid air trapped by the leaf, keeping the concentration gradient steep, so the rate increases.
- **Temperature** — more kinetic energy means faster evaporation and diffusion out of the stomata.
- Higher **humidity** does the opposite of wind: it reduces the gradient and slows transpiration.

The potometer (B2.2j)

A simple potometer, used to measure the rate of water uptake by a leafy shoot.



rate of water uptake = distance moved by the bubble ÷ time taken; volume taken up = $\pi \times r^2 \times \text{distance moved}$