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Exchange surfaces, a real gill and a diagram, active transport, root hair cells

1. Getting substances in and out

Cells need substances such as oxygen, water, sugar (glucose) and mineral ions. Plants take in their water and mineral ions from the soil. Cells must get rid of waste, such as carbon dioxide. Substances move into and out of cells in three ways:

- **diffusion** (B1 L8 Diffusion)
- **osmosis**, for water only (B1 L9 Osmosis)
- **active transport** (this lesson).

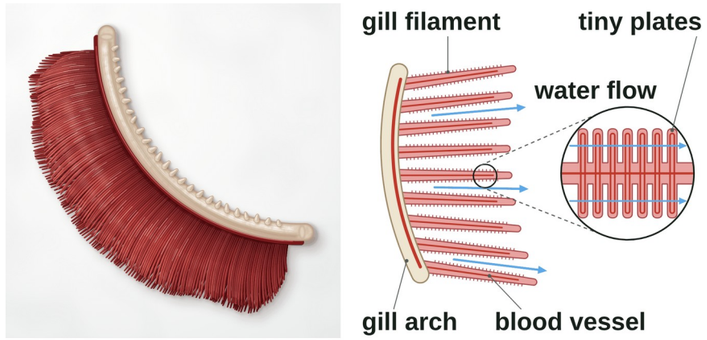
An **exchange surface** is a surface specialised for substances to move into or out of an organism, such as the alveoli or the gills.

A fish's **gills** are the organs it uses to take in oxygen from water and get rid of carbon dioxide. Each gill has a curved, bony **gill arch** that holds two rows of **gill filaments**: many thin, feathery strands, covered in tiny plates, which give a large surface area.

2. A real gill and a diagram

Exam pictures of gills are usually **diagrams**. A diagram is simplified on purpose:

- **Colour:** real gills are deep red all over, from the blood in their many capillaries. A diagram is pale, with thin red lines for the blood vessels.
- **Number:** a real gill has hundreds of filaments. A diagram shows a few.



A real gill **A diagram**

Real gills are deep red because they are full of blood. The diagram is simplified.

- **Tiny plates:** these are too small to see without a microscope. A diagram draws them big, in an enlarged circle.
- **Two rows:** a real gill has two rows of filaments. A diagram usually shows one.
- **Water flow:** in a living fish, the gills sit under a bony flap, the gill cover, and water flows over them. A diagram shows the flow with arrows.

Both show a bony gill arch that supports many thin gill filaments.

3. Active transport

Active transport is the movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.

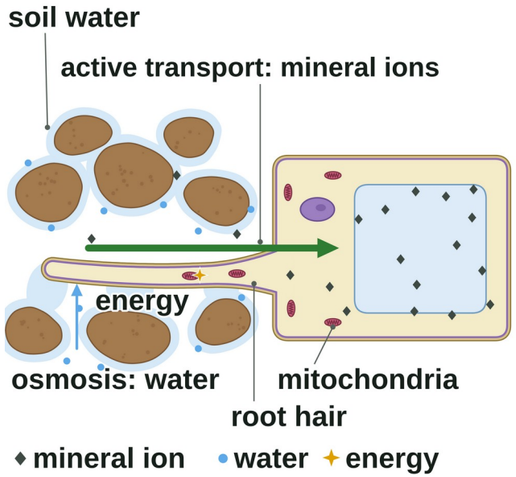
- It moves substances from a **lower** to a **higher** concentration.
- The energy is released by **respiration**, which happens in the **mitochondria**.
- Cells that do a lot of active transport have **many mitochondria**.

> **Watch out:** only active transport goes against a concentration gradient. Diffusion and osmosis go the other way and need no energy from respiration.

4. Root hair cells

Plants need **mineral ions**, such as nitrate, to stay healthy. The water in the soil is a very dilute solution of mineral ions, so there are more ions inside a root hair cell than in the soil water.

- Diffusion would move the ions **out** of the cell. So the root hair cell uses **active transport** to move mineral ions in, against the concentration gradient.
- Root hair cells have many mitochondria to release the energy.
- Root hair cells take in water from the soil by osmosis (B1 L9 Osmosis). Osmosis needs no energy.
- The long, thin root hair gives a large surface area (B1 L5 Specialised cells).



> **Watch out:** water enters root hair cells by osmosis; mineral ions enter by active transport. Not the other way round.

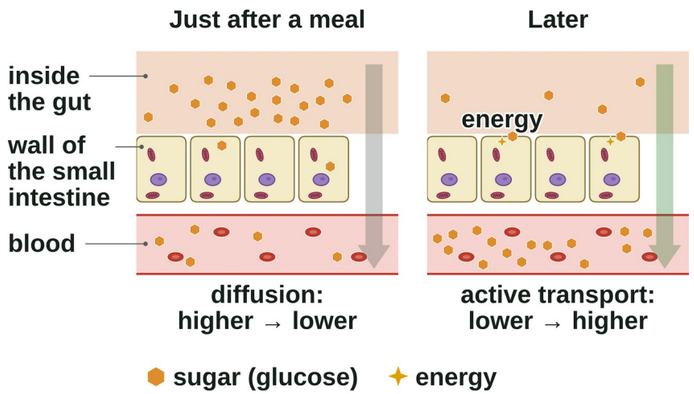
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The gut, comparing the three processes, surface area to volume ratio

5. Active transport in the gut

Digested food in the small intestine includes sugar (glucose). It is absorbed into the blood, which carries it to the body's cells for respiration.

- Just after a meal, there is more sugar in the gut than in the blood, so sugar **diffuses** into the blood.
- Later, the gut has less sugar than the blood. **Active transport** keeps moving sugar into the blood, against the gradient, so very little sugar is left in the gut. The gut wall cells have many mitochondria to release the energy.



The wall of the small intestine is folded into **villi** (B2 L2 The digestive system), which give a large surface area.

Watch out: sugar is absorbed by diffusion **and** by active transport. Active transport lets absorption carry on when the gut has less sugar than the blood.

6. Diffusion, osmosis and active transport

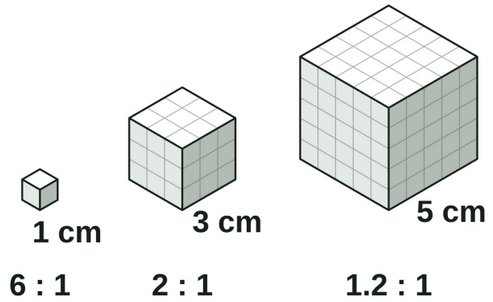
	Diffusion	Osmosis	Active transport
What moves	particles of a gas or a dissolved substance	water only	substances such as mineral ions and sugar
Which way	higher → lower concentration	dilute → more concentrated solution	lower → higher concentration
Energy from respiration?	no	no	yes
Membrane	not always needed (in cells: the cell membrane)	partially permeable	a cell membrane
Example	oxygen into the blood in the gills	water into a root hair cell	mineral ions into a root hair cell

Watch out (section 6): osmosis and active transport can both be described as "from a dilute solution to a more concentrated solution". In osmosis, **water** moves. In active transport, the **dissolved substance** (such as mineral ions) moves, from where there is less of it to where there is more.

7. Surface area to volume ratio

Surface area is the total area of the outside of an object (in cm²). **Volume** is the space inside it (in cm³).

The **surface area to volume ratio** is the surface area of an object compared with its volume, written as a ratio such as 6 : 1.



For a cube: surface area = 6 × side × side; volume = side × side × side

Side of cube	Surface area	Volume	Ratio
1 cm	6 cm²	1 cm³	6 : 1
3 cm	54 cm²	27 cm³	2 : 1
5 cm	150 cm²	125 cm³	1.2 : 1

Worked example: a cuboid, 5 cm × 2 cm × 1 cm.

It has 6 faces: two of 5 × 2, two of 5 × 1 and two of 2 × 1.

Surface area = 2 × (10 + 5 + 2) = **34 cm²**.

Volume = length × width × height = 5 × 2 × 1 = **10 cm³**.

Ratio = 34 : 10. Divide both numbers by 10: **3.4 : 1**. Check: 3.4 × 10 = 34 ✓

Watch out: a bigger cube has more surface area **in total**, but less surface area for each cm³ of volume. Put surface area first and simplify the ratio (54 : 27 = 2 : 1).

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Size and exchange, the four features, gills, exchange surfaces in animals and plants

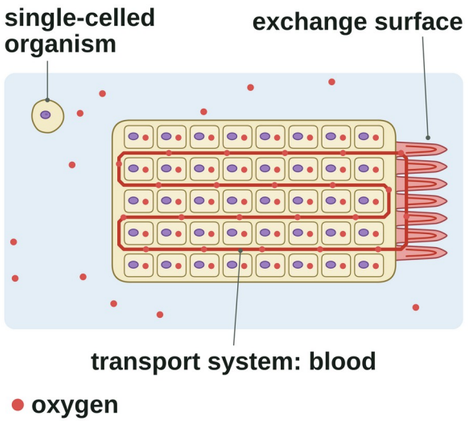
8. Why big organisms need exchange surfaces

A **single-celled organism** (an organism made of only one cell, such as a bacterium) has a large surface area to volume ratio. Every part of it is close to the surface, so diffusion across its surface meets its needs.

A **multicellular organism** (an organism made of many cells, such as a human or a tree) has a much smaller surface area to volume ratio, and most of its cells are far from the surface. Diffusion alone would be far too slow.

So multicellular organisms need:

- **exchange surfaces**, to take substances in and get rid of waste
- a **transport system**, to carry substances to and from every cell (in animals, the blood: B2 L6 The heart and circulation; in plants, the xylem and phloem: B2 L13 Plant transport: xylem and phloem).



9. Effective exchange surfaces

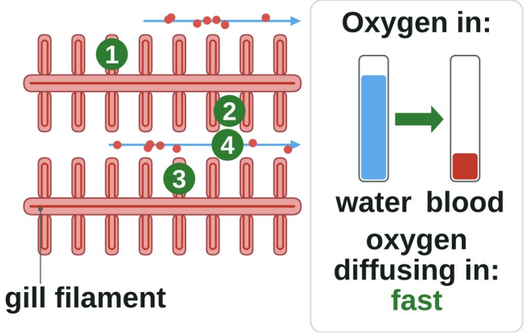
Feature	How it helps
1. A large surface area	More substances can move across at the same time.
2. A thin membrane	A short diffusion path, so substances cross quickly.
3. An efficient blood supply (animals)	Blood carries substances away, so the concentration gradient stays steep.
4. Ventilation (animals, for gas exchange)	Fresh air or water keeps the concentration gradient steep.

Watch out: "thin" means a short diffusion path, often only one cell thick. Do not just write "thin": say what it does.

10. Gills

Gills have all four features:

1. Many thin **gill filaments**, each covered in tiny plates, give a huge surface area.
2. The plates are very thin, so oxygen has a short diffusion path into the blood.
3. Each plate has a good blood supply. Flowing blood carries oxygen away, so the blood arriving always has less oxygen than the water.



4. The fish keeps water flowing over its gills, in through the mouth and out under the gill cover. This brings fresh oxygen and keeps the gradient steep.

Out of water, the filaments stick together. The surface area becomes much smaller, so the fish cannot take in enough oxygen.

11. Exchange surfaces in animals and plants

Exchange surface	What is exchanged	Adapted by
Gills (fish)	oxygen in, carbon dioxide out	many thin filaments with tiny plates; a good blood supply; water flowing over them
Lungs	oxygen in, carbon dioxide out	many alveoli with thin walls, capillaries and breathing (B2 L9 Lungs and gas exchange)
Small intestine	sugar and other food molecules in	villi: a large surface area, a thin wall and a good blood supply (B2 L2 The digestive system)
Roots	water and mineral ions in	root hair cells give a large surface area
Leaves	carbon dioxide in, oxygen out (in the light)	flat and thin; stomata; air spaces inside (B2 L12 Leaf tissues and stomata)

Watch out: plants have no blood. A leaf's features are being flat and thin, its stomata and its air spaces.

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Key words, exam tips and check yourself

Key words

Active transport: the movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.

Concentration gradient: the difference in concentration between two areas.

Diffusion: the net movement of particles from an area of higher concentration to an area of lower concentration.

Exchange surface: a surface specialised for substances to move into or out of an organism, such as the alveoli or the gills.

Gill filaments: the many thin, feathery strands of a gill, covered in tiny plates, which give it a large surface area.

Gills: the organs a fish uses to take in oxygen from water and get rid of carbon dioxide.

Mineral ions: substances from the soil, such as nitrate, that a plant needs to stay healthy.

Mitochondria (one **mitochondrion**): the structures in the cytoplasm where aerobic respiration happens, releasing energy for the cell.

Osmosis: the diffusion of water from a dilute solution to a concentrated solution through a partially permeable membrane.

Respiration: a chemical reaction in every living cell that releases energy.

Stoma (plural **stomata**): a tiny hole (pore) in the surface of a leaf that lets gases diffuse in and out.

Surface area: the total area of the outside of an object.

Surface area to volume ratio: the surface area of an object compared with its volume, written as a ratio such as 6 : 1.

Villi (one **villus**): tiny finger-shaped parts that stick out from the inside wall of the small intestine and give it a large surface area.

Exam tips

- For active transport, say "against the concentration gradient" **and** "uses energy from respiration".
- Water enters root hair cells by osmosis; mineral ions enter by active transport.
- Energy is **released** by respiration. Never write that energy is "made".
- Ratios: surface area first, then volume. Simplify to "something : 1". Use cm^2 and cm^3 in your working.
- A bigger object has a **smaller** surface area to volume ratio.
- Link each feature of an exchange surface to its effect: "thin, so a short diffusion path".

Check yourself

Cover the answers, then check.

1. What is active transport?
2. Give two places where active transport happens.
3. Some hours after a meal, the gut has less sugar than the blood. Why can diffusion not absorb this sugar?
4. Give one way a diagram of a gill is different from a real gill.
5. Calculate the surface area to volume ratio of a cube with sides of 8 cm.
6. Explain why a large multicellular organism needs exchange surfaces and a transport system.
7. Give the four features of an effective exchange surface.
8. Give two ways a leaf is adapted for exchanging gases.

Answers

1. The movement of substances from a more dilute solution to a more concentrated solution (against a concentration gradient), which requires energy from respiration.
2. Root hair cells (taking in mineral ions) and the small intestine (absorbing sugar into the blood).
3. Diffusion only moves particles from a higher to a lower concentration. Here the blood has more sugar than the gut, so active transport is needed, using energy from respiration.
4. Any one: it is pale, not deep red; it shows a few filaments, not hundreds; it draws the tiny plates big; it shows one row of filaments, not two; it shows the water flow with arrows.
5. $6 \times 8 \times 8 = 384\ cm^2$; $8 \times 8 \times 8 = 512\ cm^3$; 384 : 512 = 0.75 : 1.
6. It has a small surface area to volume ratio, and most of its cells are far from the surface, so diffusion across its outer surface would be too slow to supply them.
7. A large surface area; a thin membrane (a short diffusion path); an efficient blood supply (in animals); ventilation (in animals, for gas exchange).
8. Any two: it is flat and thin; it has stomata; it has air spaces inside.