Gas Exchange

GAS EXCHANGE refers to the process by which oxygen (O_2) is taken in from the external environment and carbon dioxide (CO_2) is expelled from an organism.

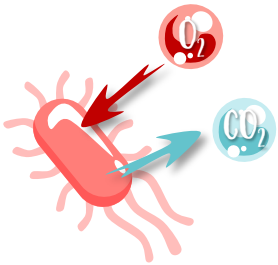
Aerobic organisms:
Require oxygen to metabolize energy from organic substances such as glucose. They can include;

I. Unicellular organisms
e.g. bacteria

II. Multicelluar organisms
e.g. animals and plants
- A. MAMMALS
- B. FISH
- C. PLANTS

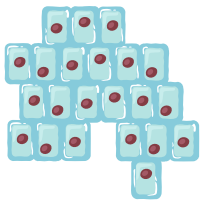
I. GAS EXCHANGE IN SINGLE CELLED ORGANISMS

Occurs directly with the atmosphere as the gases can freely diffuse in and out of the cell. This is due to their large surface area to volume ratio.



II. GAS EXCHANGE IN MULTICELLULAR ORGANISMS

Cannot occur freely with the atmosphere (some cells if not the majority are **NOT** in direct contact with the atmosphere). And their surface area to volume ratio is too small (thus inefficient)



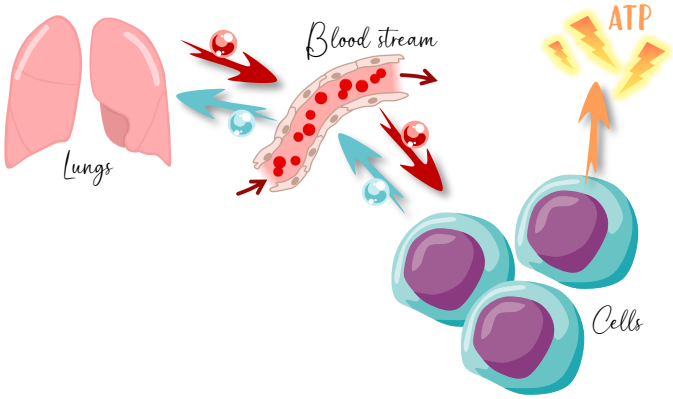
The cells are usually well organised and compact. This prevents them from all being in contact with the atmosphere (realise also this is 3D)

A. MAMMALS

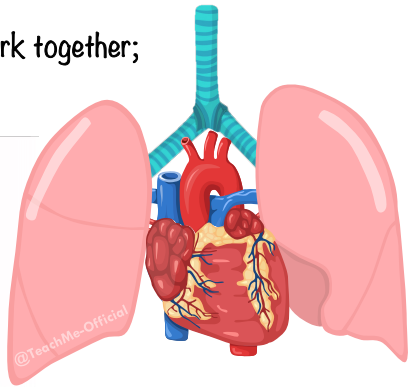
Why do we even need gas exchange?

ATP

For **ENERGY!** Oxygen is needed for our cells to create ATP (energy) during the process of **CELLULAR RESPIRATION** (learned in topic C1.2) to function. In the process, carbon dioxide is created as a waste product and must then be excreted in exchange for new oxygen.



Two body systems work together;



RESPIRATORY SYSTEM
(lungs)

Helps bring air (containing oxygen) into our body and into the blood stream*.

CARDIOVASCULAR SYSTEM
(heart and vessels)

Helps us distribute the blood (containing nutrients, oxygen and carbon dioxide) to all the cells of our body, and back to the lungs to dispose of the waste (carbon dioxide).

* You will learn in section B3.2 more about the circulation of blood between the lungs and the heart.

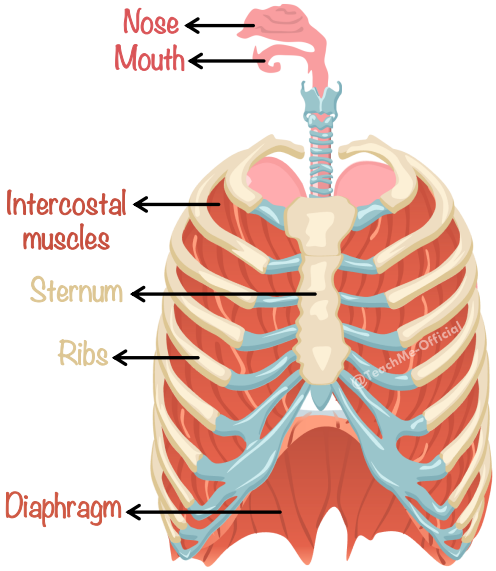
Gas Exchange

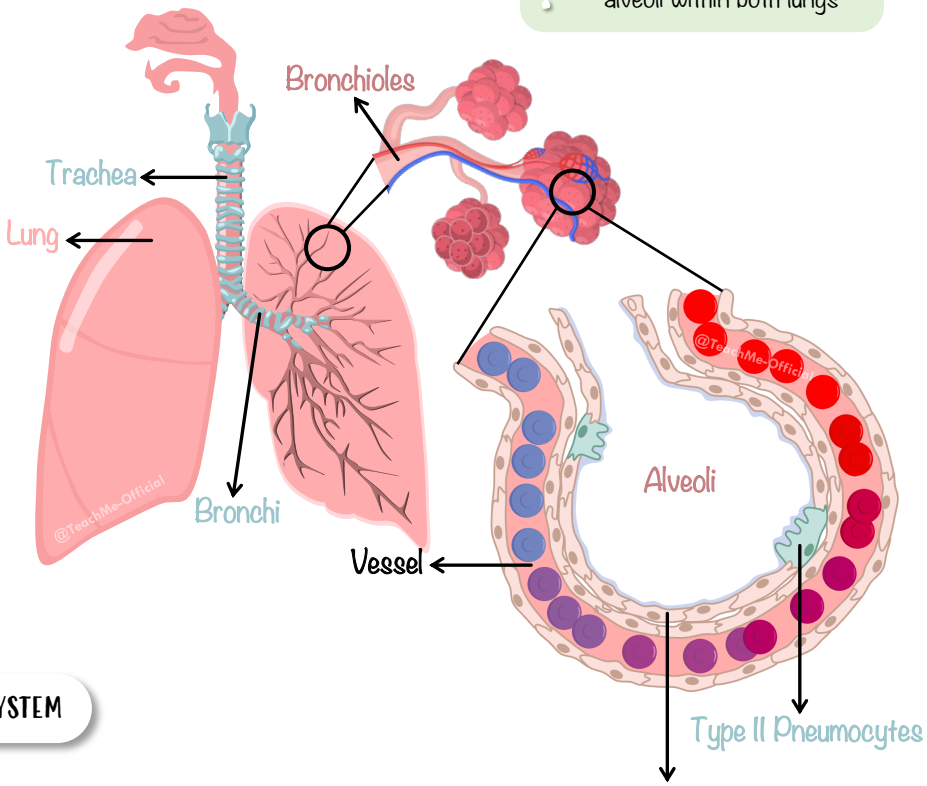
Anatomy (structure) of the respiratory system

It is located in the thorax (more simply known as the chest)

Did you know?

We have around 300,000,000 alveoli within both lungs



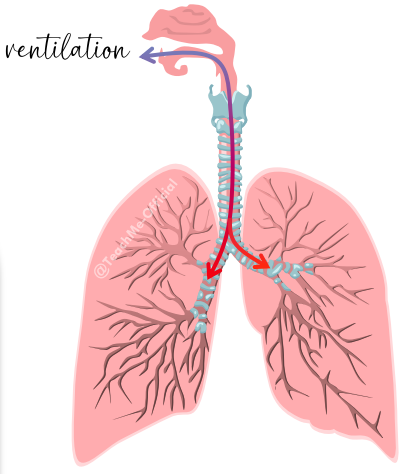


Function of the respiratory system

1. Ventilation – The process of bringing air in and out of the lungs (inhaling brings air in, exhaling brings air out).

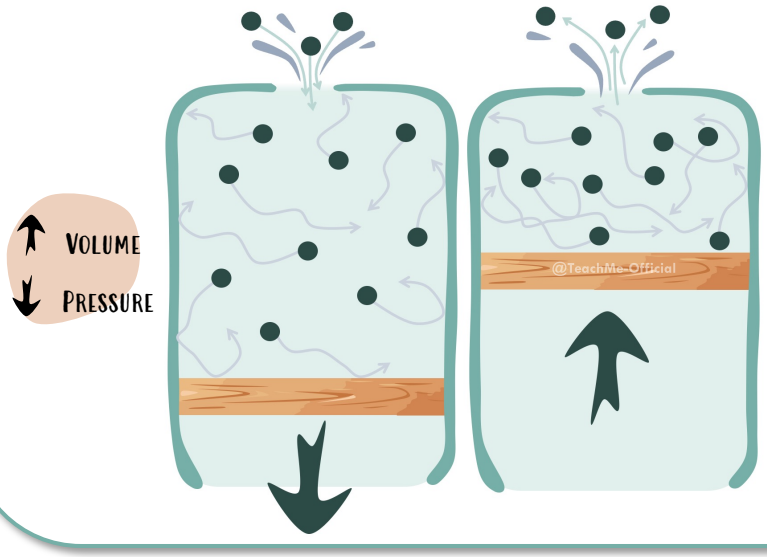
BUT the lungs themselves don't contain muscles to expand and deflate, they require the action of:

Diaphragm **Intercostal muscles** Abdominal muscles Antagonizing muscle groups

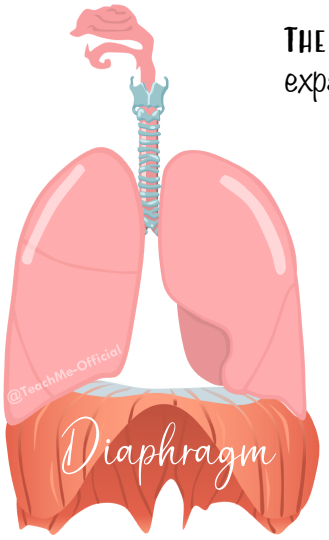


Boyle's law

An increase in volume will lead to a decrease in pressure, and vice versa.



Gas Exchange



The diaphragm – a large muscle that sits under the lungs. It's contraction and relaxation expand and reduce the volume of the chest cavity for breathing (Boyle's Law).

Inhalation (inflate lungs)

Contract (become flat)

↓

Increase lung volume (reduce pressure)

↓

High pressure outside, low inside (pressure gradient)

↓

Air flows into the lungs

Exhalation (deflate lungs)

Relax (become dome)

↓

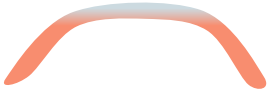
Decrease lung volume (Increase pressure)

↓

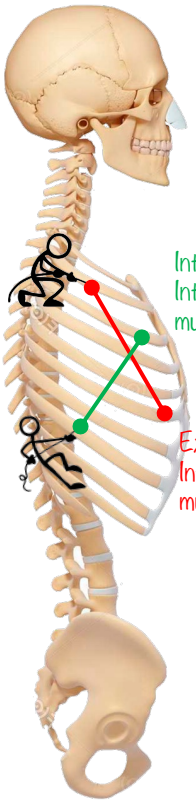
Low pressure outside, high inside (pressure gradient)

↓

Air flows out of the lungs



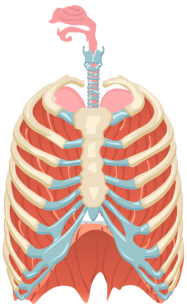
The Intercoastal muscles – Muscles found between the ribs; there are two kinds: the **internal intercoastal muscles** and the **external intercoastal muscles**.

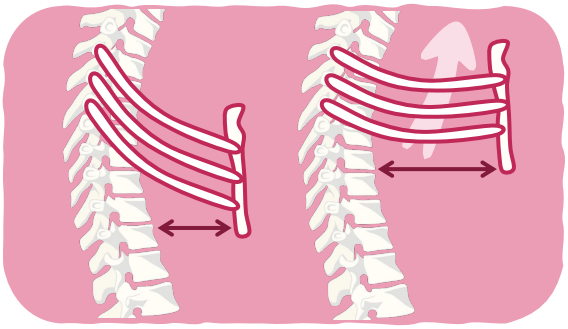


External Intercostal muscles

Contract → Raise ribs → Inhale
Relax → Depress ribs → Exhale

The orientation of the muscles fibres go down and inwards towards the midline (like hands in your pockets)



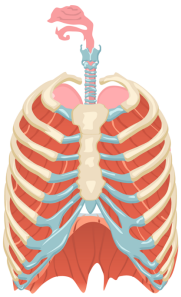


Notice how when the ribs rise, the volume increased in the lung.

Internal Intercostal muscles

Contract → Depress ribs → Exhale
Relax → Raise ribs → Inhale

The orientation of the muscles fibres go down and outwards away from the midline



Inhalation (inflate lungs)

Contract (raise ribs)

↓

Increase lung volume (reduce pressure)

↓

High pressure outside, low inside (pressure gradient)

↓

Air flows into the lungs

Exhalation (deflate lungs)

Relax (Depress ribs)

↓

Decrease lung volume (Increase pressure)

↓

Low pressure outside, high inside (pressure gradient)

↓

Air flows out of the lungs

Inhalation (inflate lungs)

Relax (raise ribs)

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Air flows into the lungs

Exhalation (deflate lungs)

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Decrease lung volume (increased pressure)

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High pressure inside, low outside (pressure gradient)

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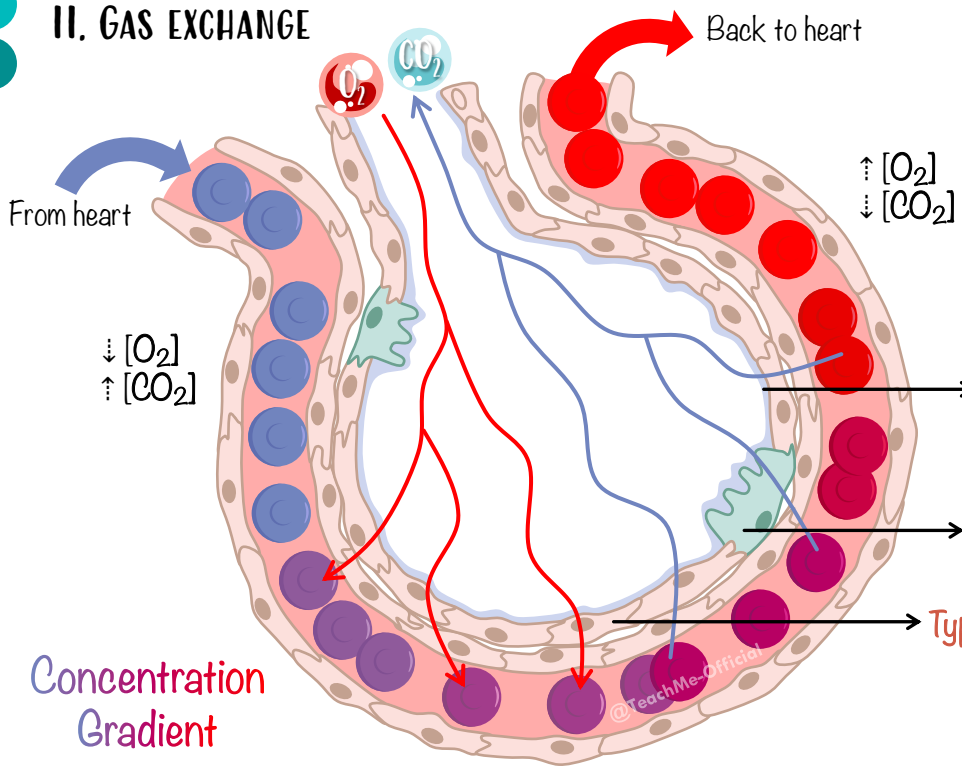
Air flows out of the lungs

Gas Exchange

II. Gas Exchange



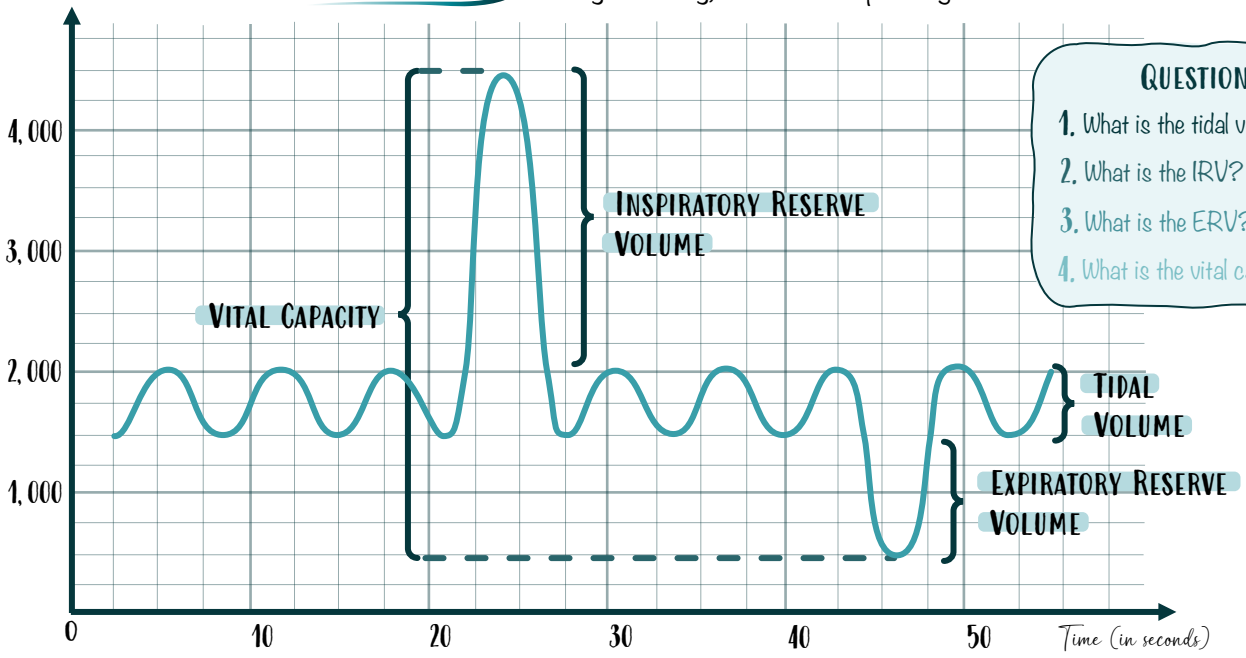
Alveolar Cells

Thin walls – Small diffusion distance
Blood supply – Efficient collection
Surface area – Maximum diffusion
Tightly joint cells - Prevent fluid enter

Type I pneumocyte	Type 2 pneumocyte
Majority (95%)	Minority (5%)
Smaller (flat) - Small diffusion distance	Larger (cube) - More space for organelles such as secretory vesicles
Gas exchange	Secretes surfactant
Can't divide	Can divide to replace type I

Spirometry

Used to measure the amount of air that is exchanged during breathing, as well as respiratory rate.



Questions

1. What is the tidal volume?
2. What is the IRV?
3. What is the ERV?
4. What is the vital capacity?

Answers: 1. 500 mL, 2. 2,500 mL, 3. 1,000 mL, 4. 4,000 mL

Gas Exchange

Tidal Volume – The volume of air that is inhaled AND exhaled during a typical cycle when a person is at rest. "Tidal" volume comes from the idea of an ocean tide coming in and out.

Inspiratory Reserve Volume – The maximum volume of air that a person can **inhale** (from the maximum point of the tidal volume).

Expiratory Reserve Volume – The maximum volume of air that a person can **exhale** (from the minimum point of the tidal volume).

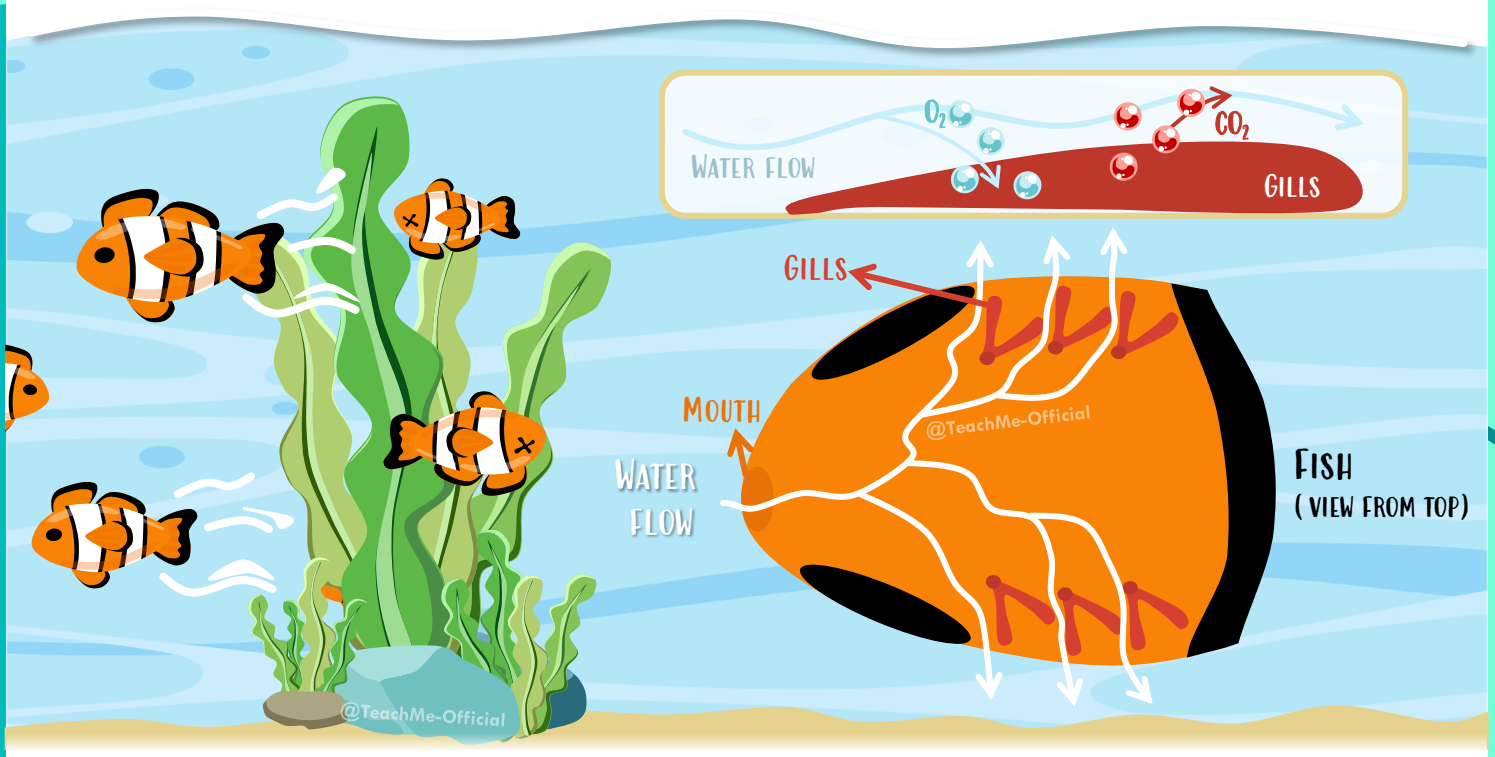
Vital Capacity – The sum of inspiratory reserve volume, tidal volume and the expiratory reserve volume. In other the maximum volume that you can inhale, and exhale added together.

B. Fish

Fish do not use lungs to oxygenate their blood – they rather use **GILLS**.

Did you know?

Fish might die if they stop swimming as the lack of water flow prevents oxygenation of the blood

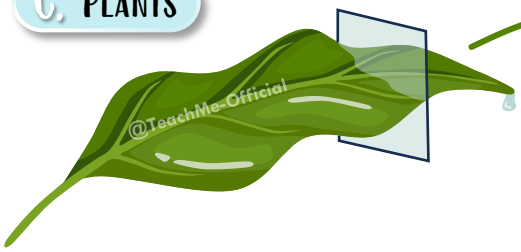


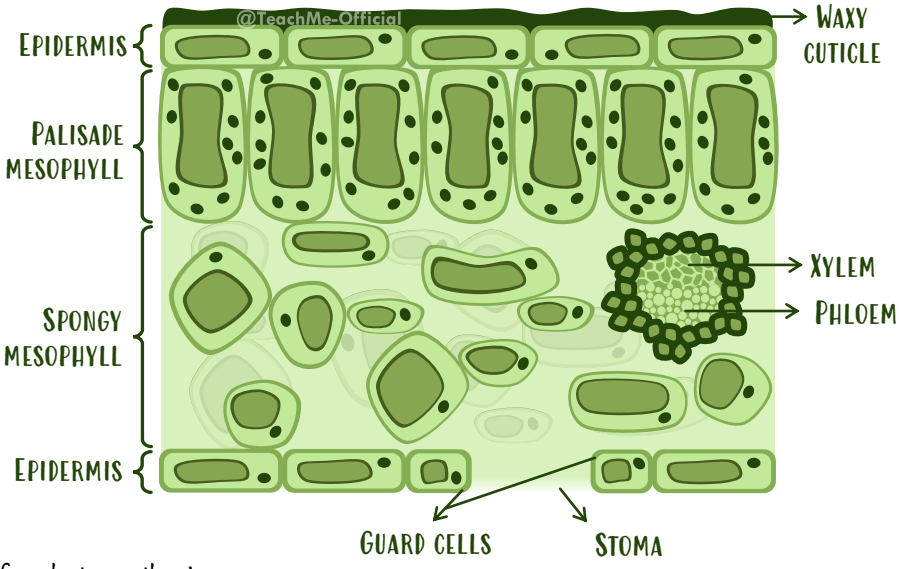
Water flows through the fish's mouth, past the gills and back out. **Gills** are filament structures filled with capillaries (blood).

Oxygen in the water diffuses down a concentration gradient across the gills membrane into the fish's blood stream.
Carbon dioxide in the fish's blood stream diffuses down a concentration gradient across the gills membrane into the water.

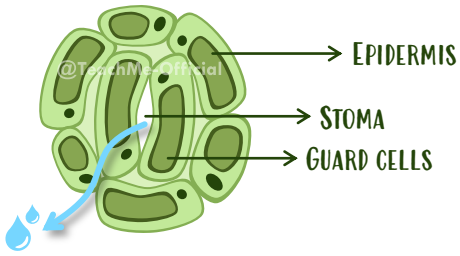
Gas Exchange

C. Plants

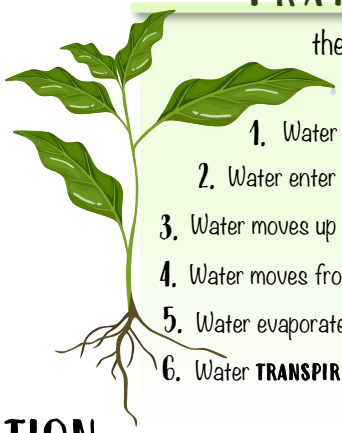




- **Epidermis** – Secrete waxy cuticle.
- **Waxy cuticle** – Lipid layer covering the surface of leaves to prevent uncontrolled/excessive water loss by evaporation.
- **Palisade mesophyll** – Densely packed cells in upper portion of the leaf, containing many chloroplasts and are specifically located near top surface to receive maximum sunlight for photosynthesis.
- **Spongy mesophyll** – Loosely packed cells located below the palisade mesophyll, and above the stomata. Contain few chloroplasts and many air spaces for gas exchange (large surface area).
- **Veins** – Contain phloem and xylem (fluid transport tubes). Responsible for transport of water and nutrients.
- **Stomata (singular stoma)** – Imbedded in the lower epidermis. These are microscopic openings on the surface of the leaves, controlled by two guard cells. When open, three gases (water vapor, oxygen and carbon dioxide) can diffuse in or out. Located on lower surface limits water loss by transpiration (lower surface have lower temperature) compared to upper surface).



Transpiration



the loss of water vapour from the leaves and stems of plants

1. Water uptake occurs at the root.
2. Water enter the xylem (a type of vascular bundle)
3. Water moves up the xylem.
4. Water moves from the xylem to leaf cells.
5. Water evaporates into empty spaces in the leaves.
6. Water **transpires** out of stomata into the air.

Factors Affecting Transpiration

Factor	Effect on transpiration	Reason
Increased Light	Increase	Light stimulates guard cells to open stomata. In addition, more light increases photosynthesis rate. Therefor stomata open to let in more carbon dioxide in and more oxygen out.
Increased Temperature	Increase	It causes increased movement (kinetic energy), and therefore more evaporation of water.
Increased Wind	Increase	It removes water vapor around the stomata, thereby increasing the water vapor gradient between the inside and the outside of the leaf.
Increased Humidity	Decrease	Higher humidity lessens the water concentration gradient between the inside and the outside of the leaf.

notes