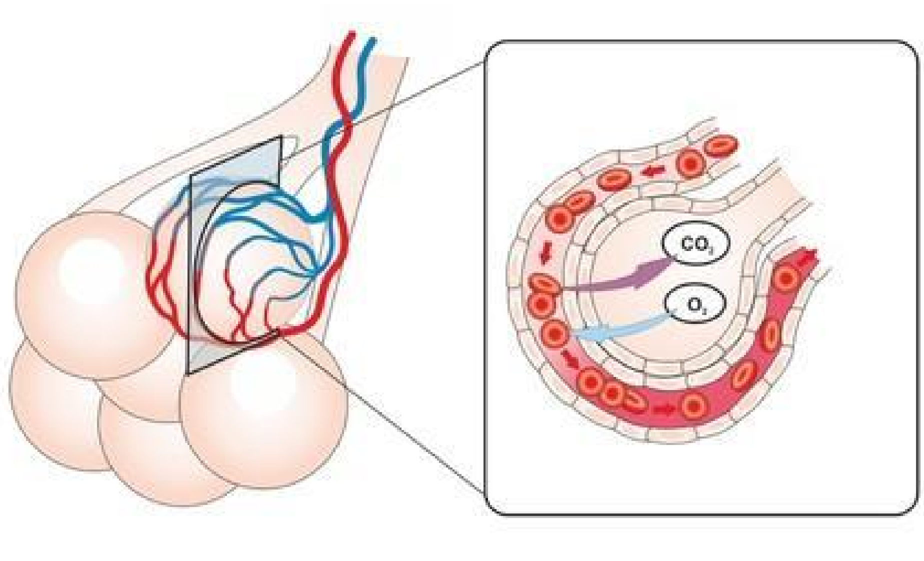
Year 12 HL

IB BIOLOGY

B3.1 Gas Exchange



Name:

Teacher: Mr Trent

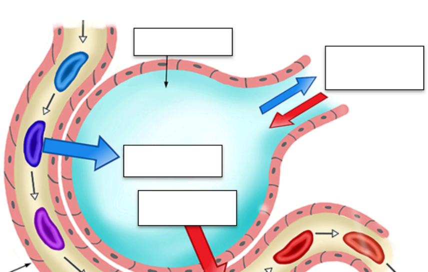
B3.1 Gas Exchange

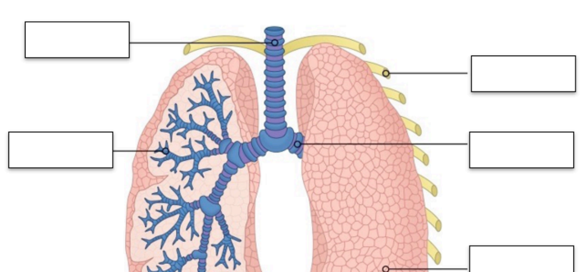
How are multicellular organisms adapted to carry out gas exchange?
What are the similarities and differences in gas exchange between a flowering plant and a mammal?
B3.1.1—Gas exchange as a vital function in all organisms
B3.1.2—Properties of gas-exchange surfaces
B3.1.3—Maintenance of concentration gradients at exchange surfaces in animals
B3.1.4—Adaptations of mammalian lungs for gas exchange
B3.1.5—Ventilation of the lungs
B3.1.6—Measurement of lung volumes
B3.1.7—Adaptations for gas exchange in leaves
B3.1.8—Distribution of tissues in a leaf
B3.1.9—Transpiration as a consequence of gas exchange in a leaf
B3.1.10—Stomatal density

NOS: Reliability of quantitative data is increased by repeating measurements. In this case, repeated counts of the number of stomata visible in the field of view at high power illustrate the variability of biological material and the need for replicate trials.

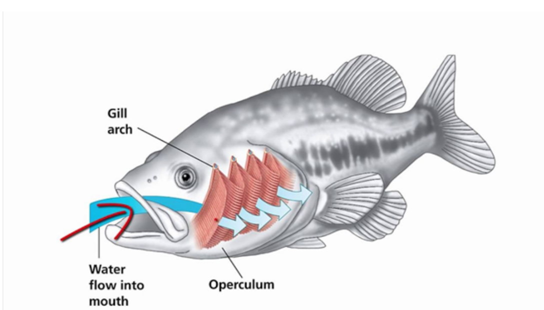
AHL
B3.1.11—Adaptations of fetal and adult haemoglobin for the transport of oxygen
B3.1.12—Bohr shift
B3.1.13—Oxygen dissociation curves as a means of representing the affinity of haemoglobin for oxygen at different oxygen concentrations

B3.1.1—Gas exchange as a vital function in all organisms

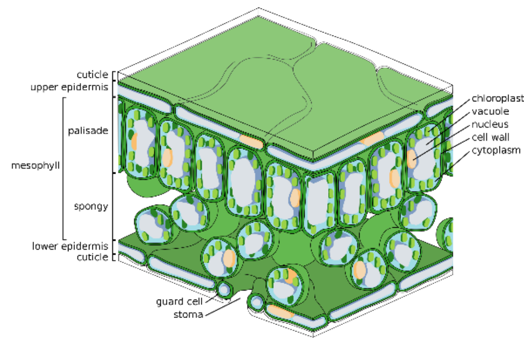




Gas exchange takes place directly through the cell membrane via simple diffusion. Nutrients, gases, and waste products are exchanged across the cell membrane due to concentration gradients.

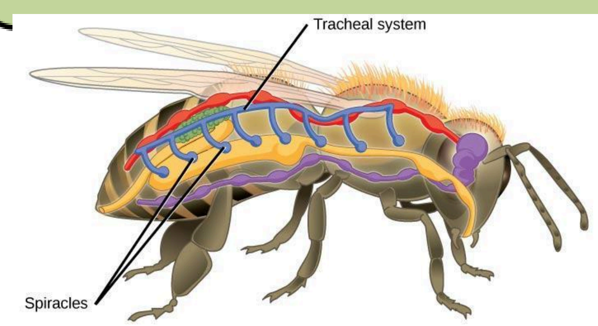


Many aquatic organisms, such as fish and amphibians, respire through gills. Gills are specialized structures that contain thin, filament-like structures with a rich network of blood vessels. Oxygen from the water diffuses into the bloodstream while carbon dioxide is expelled.



Gas exchange in plants occurs through small openings called stomata present on the surface of leaves and stems. Carbon dioxide enters the leaf through the stomata, while oxygen exits. Additionally, plants also carry out gas exchange during photosynthesis, where they absorb carbon dioxide and release oxygen

Insects have a network of tiny tubes called tracheae that transport oxygen directly to tissues. Air enters the body through openings called spiracles and then diffuses through the tracheal system, reaching the cells for gas exchange.



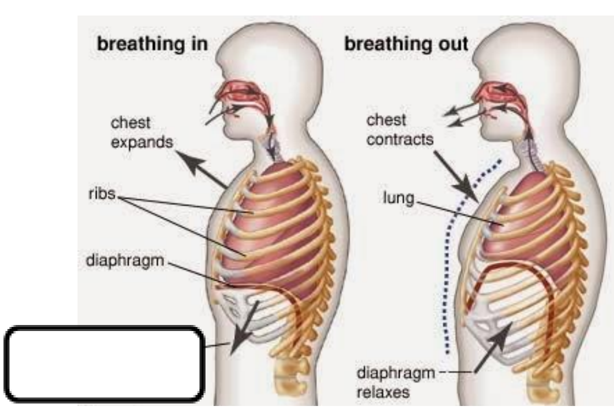
B3.1.2—Properties of gas-exchange surfaces

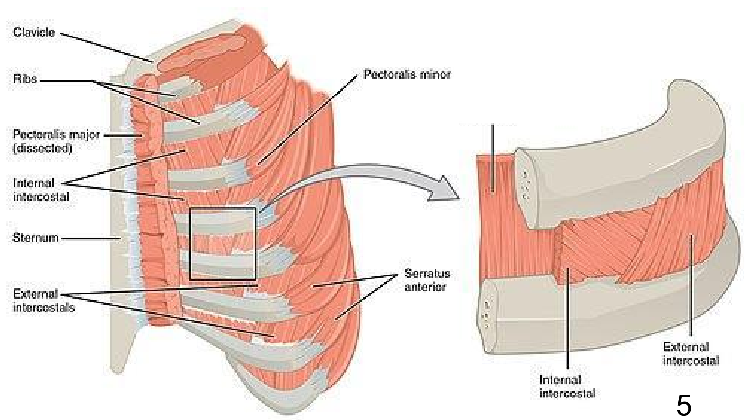
Term		**Definition**
Permeability		The presence of water or other liquid, typically in small amounts, on the surface or within a substance or material.
Thin tissue layer		A delicate or thin layer of specialized cells that forms a structural component of an organ or body part.
Moisture		A significant extent of surface or outer area relative to the volume, providing increased contact or interaction space.
Large surface area		The property of a material or membrane to allow the passage of substances, such as liquids, gases, or solutes, through it.

B3.1.3—Maintenance of concentration gradients at exchange surfaces in animals
B3.1.5—Ventilation of the lungs

Ventilation:		The release of energy (ATP) from organic molecules – it is enhanced by the presence of oxygen (aerobic)
Gas Exchange:		The exchange of oxygen and carbon dioxide between the alveoli and bloodstream (via passive diffusion)
Cell Respiration:		The exchange of air between the atmosphere and the lungs – achieved by the physical act of breathing

	Inspiration	Expiration
Pressure change		
Volume change		
Ribcage movement		
External intercostal muscles		
Internal intercostal muscles		
Diaphragm		
Abdominal muscles		





Describe and draw antagonistic muscles

B3.1.4—Adaptations of mammalian lungs for gas exchange

Presence of Surfactant: Surfactant is a substance composed of lipids and proteins that coats the inner surface of the alveoli (tiny air sacs in the lungs). It reduces the surface tension of the alveolar walls, preventing them from collapsing during exhalation. Surfactant helps to maintain the stability of the alveoli and ensures efficient gas exchange by keeping the alveoli open.

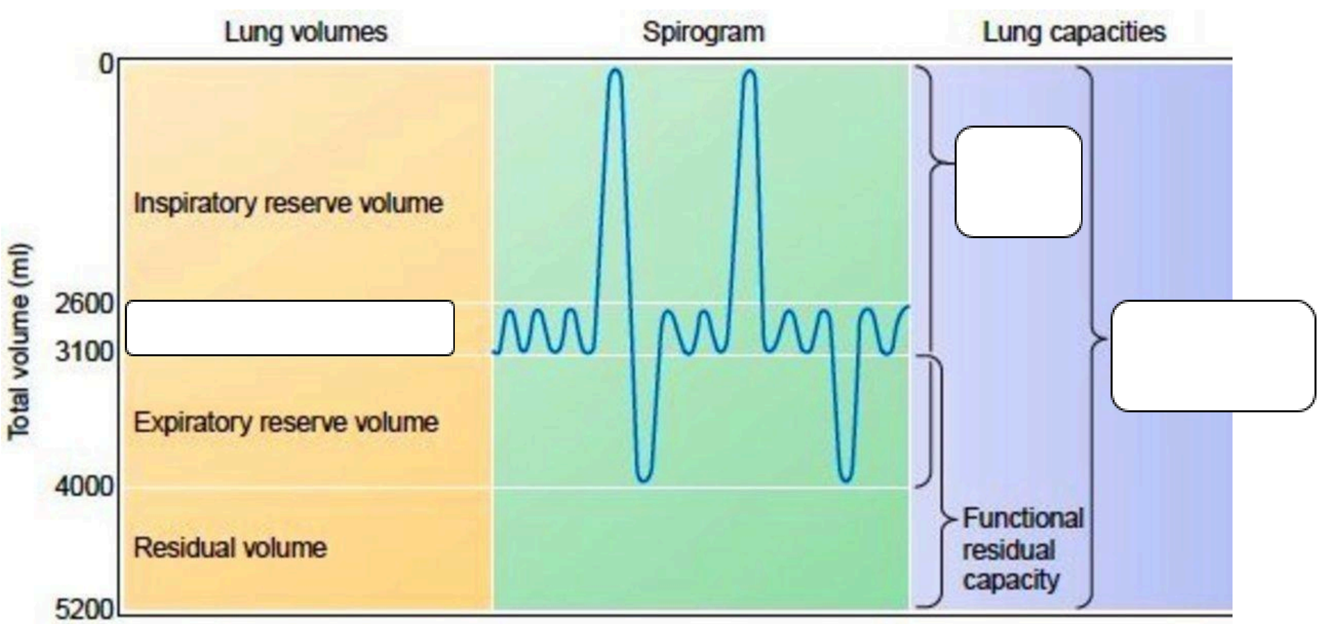
Branched Network of Bronchioles: The bronchioles are small airways that branch out from the main bronchi, eventually leading to the alveoli. The bronchioles form a highly branched network, allowing for the distribution of air to a large number of alveoli. This branching structure ensures that air reaches all areas of the lungs, maximizing the surface area available for gas exchange.

Extensive Capillary Beds: Capillaries are tiny blood vessels with thin walls that surround the alveoli. The alveolar walls and the capillary walls are in close proximity, creating a short diffusion distance for gases. The extensive network of capillaries increases the contact between the alveolar walls and the blood, facilitating the exchange of oxygen and carbon dioxide between the air in the alveoli and the blood in the capillaries.

High Surface Area: The alveoli provide an extensive surface area for gas exchange. The combined surface area of all the alveoli in the lungs is significantly large, increasing the overall area available for oxygen to diffuse into the bloodstream and for carbon dioxide to diffuse out of the bloodstream. This large surface area ensures efficient gas exchange and allows for the uptake of sufficient oxygen and removal of waste carbon dioxide.

Adaptation	**Reason**

B3.1.6—Measurement of lung volumes

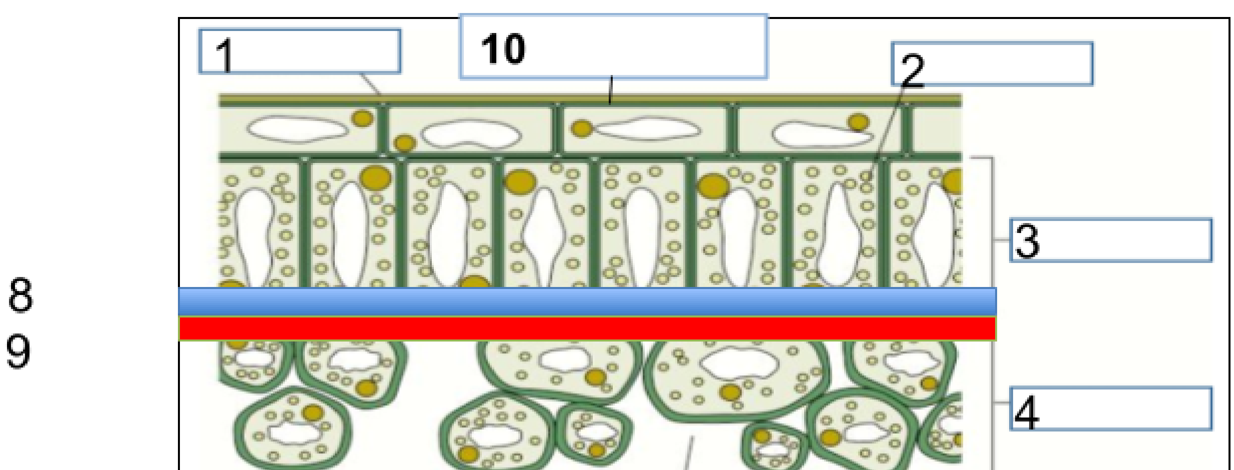


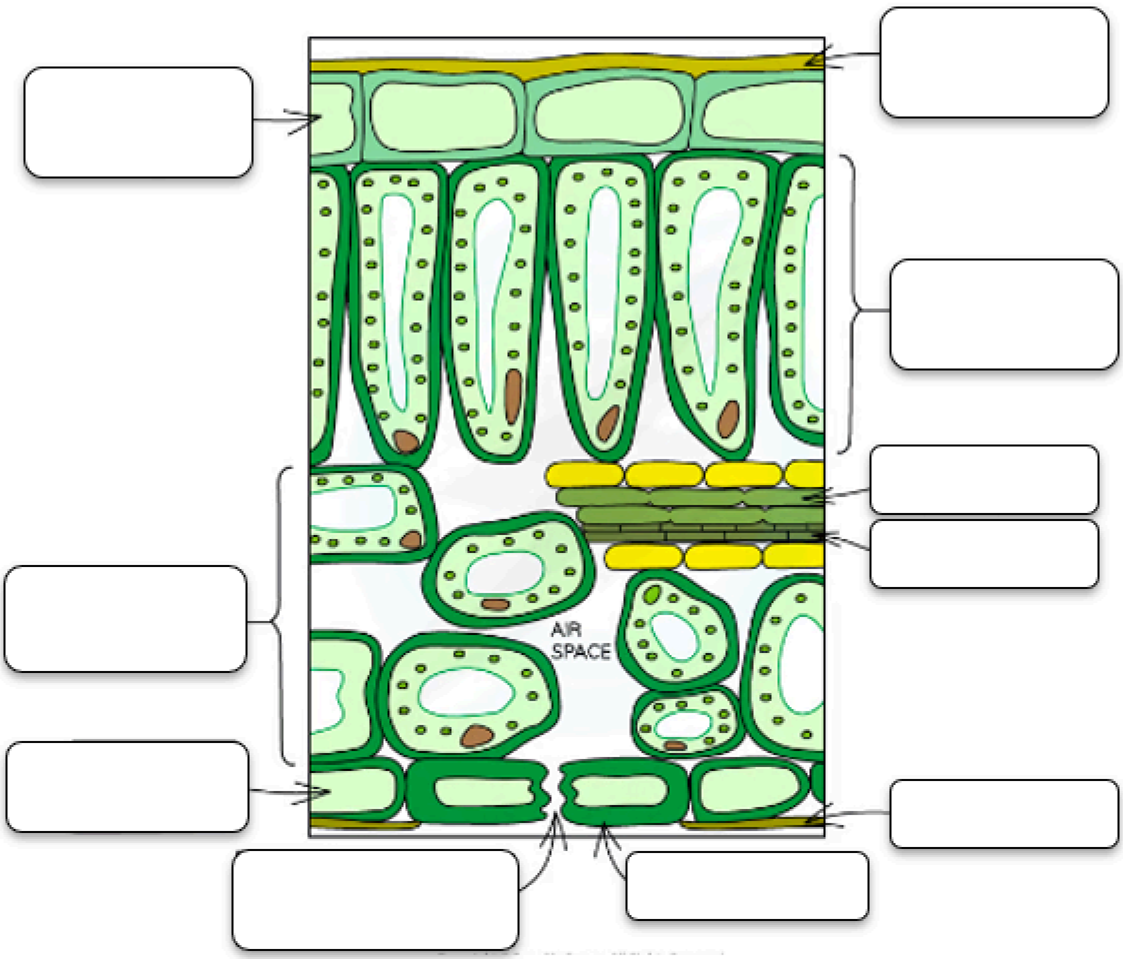
Draw and label a spirometry reading.

Application of skills: Students should make measurements to determine tidal volume, vital capacity, and inspiratory and expiratory reserves.

B3.1.7—Adaptations for gas exchange in leaves

B3.1.8—Distribution of tissues in a leaf



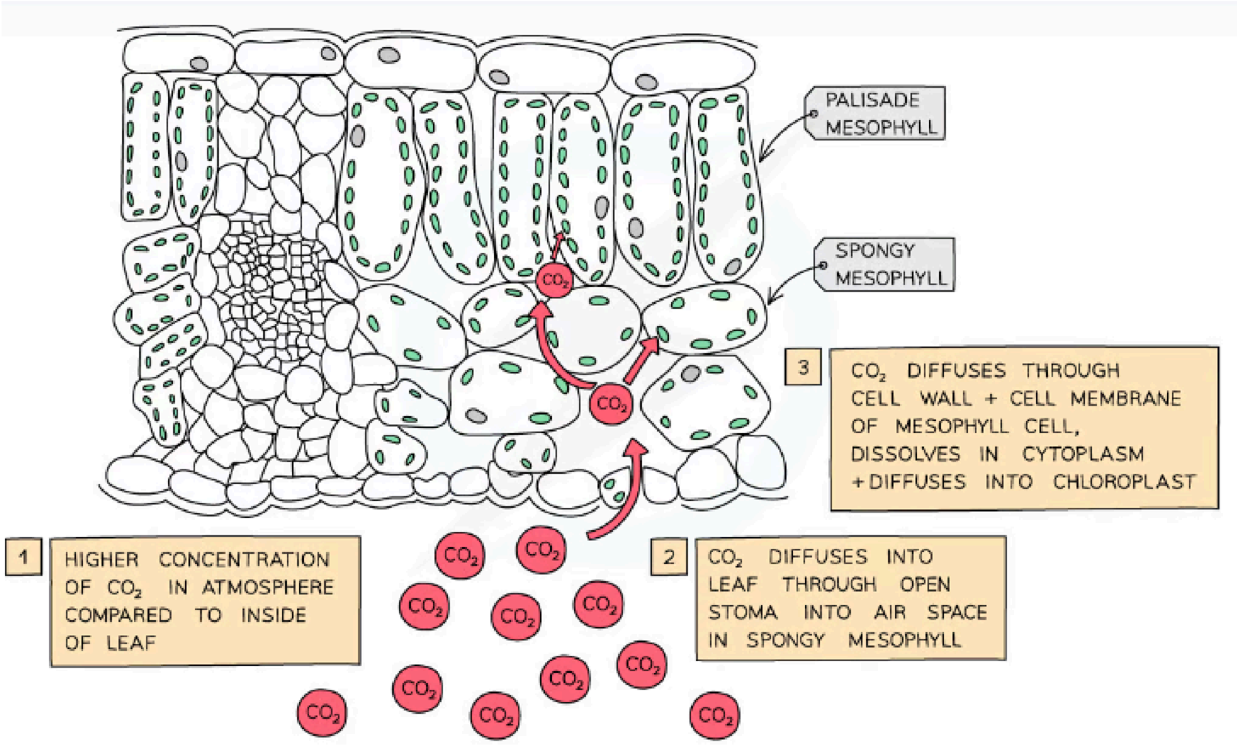


There are 3 key gases:

1. ________________ - released in respiration but used in photosynthesis

2. ______________- released in photosynthesis but used in respiration

3. ____________________ - released in respiration and transpiration



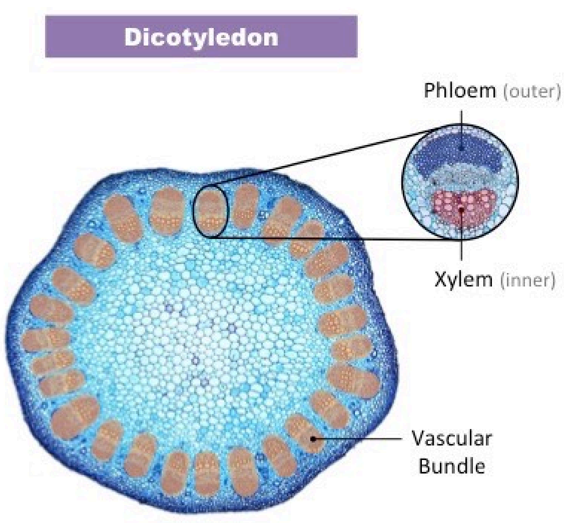
Adaptations of leaves to maximise gas exchange:

- They are _________ which gives a ____________ diffusion distance
- They are flat which provides a _________ surface area to volume ratio

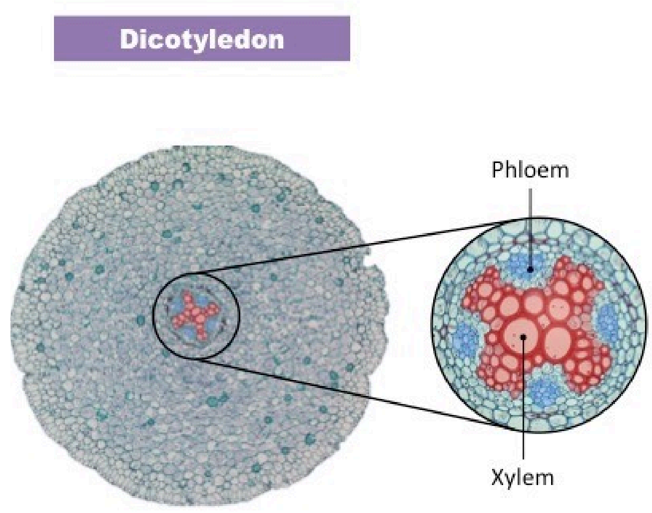
They have many ____________ which allow movement of gases in and out of the air spaces inside the leaf to maintain a steep concentration ____________.

Dicotyledon Leaf

Dicotyledon Stem



Dicotyledon Root



B3.1.9—Transpiration as a consequence of gas exchange in a leaf
Define *transpiration*.

Outline gas exchange that occurs through leaf stomata.

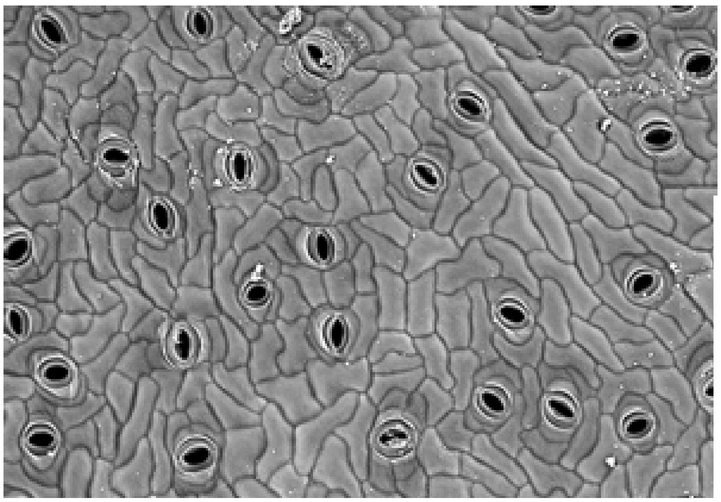
- There is ________________ water in the roots of the plant that in the leaves.
- Water moves via o_______________ from a ________________ concentration in the roots to a ___________ concentration in the leaves.
- Plants continually lose water to the air. This is called __________.
- Water is constantly lost from the l__________________- this occurs due to e_________________ due to heat + water loss from the s___________________
- Transpiration happens much more quickly in hot, ___ and windy conditions.
- Most plants have a waxy layer called the ________ on their leaves. This prevents too much water loss from the leaves.
- The cuticle is much thicker in plants that live in drier areas. Water lost through transpiration is mainly lost through the _______.
- The _____ cells control the size of the stomata, so can regulate the amount of water lost by transpiration.
- If plants are losing water faster than they are gaining it, the stomata ______.
- Without this happening, the plants will ____ – and may die.

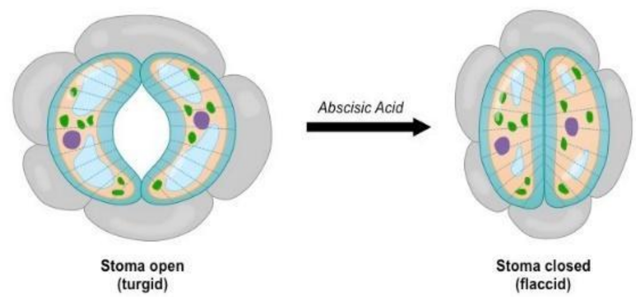
Wilt evaporation dry stomata cuticle guard transpiration close osmosis more low high leaves

Controlling W___________ Loss

Count how many stoma (more than one stomata) you can see in the image.
_____________ stoma (more than one stomata)

How many guard cells are there?

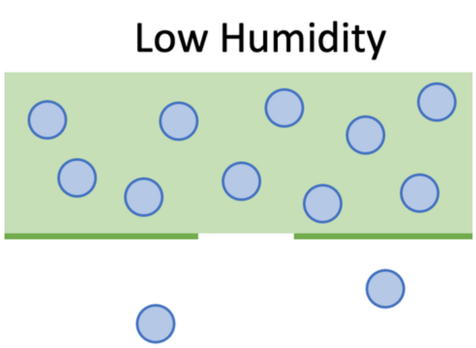


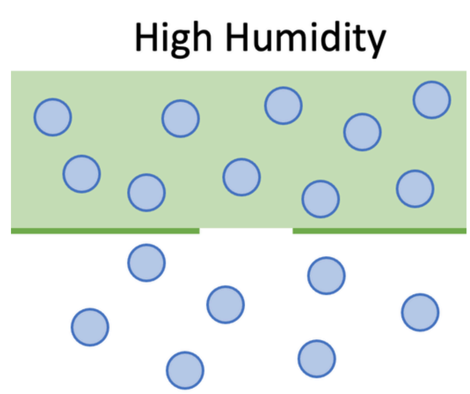


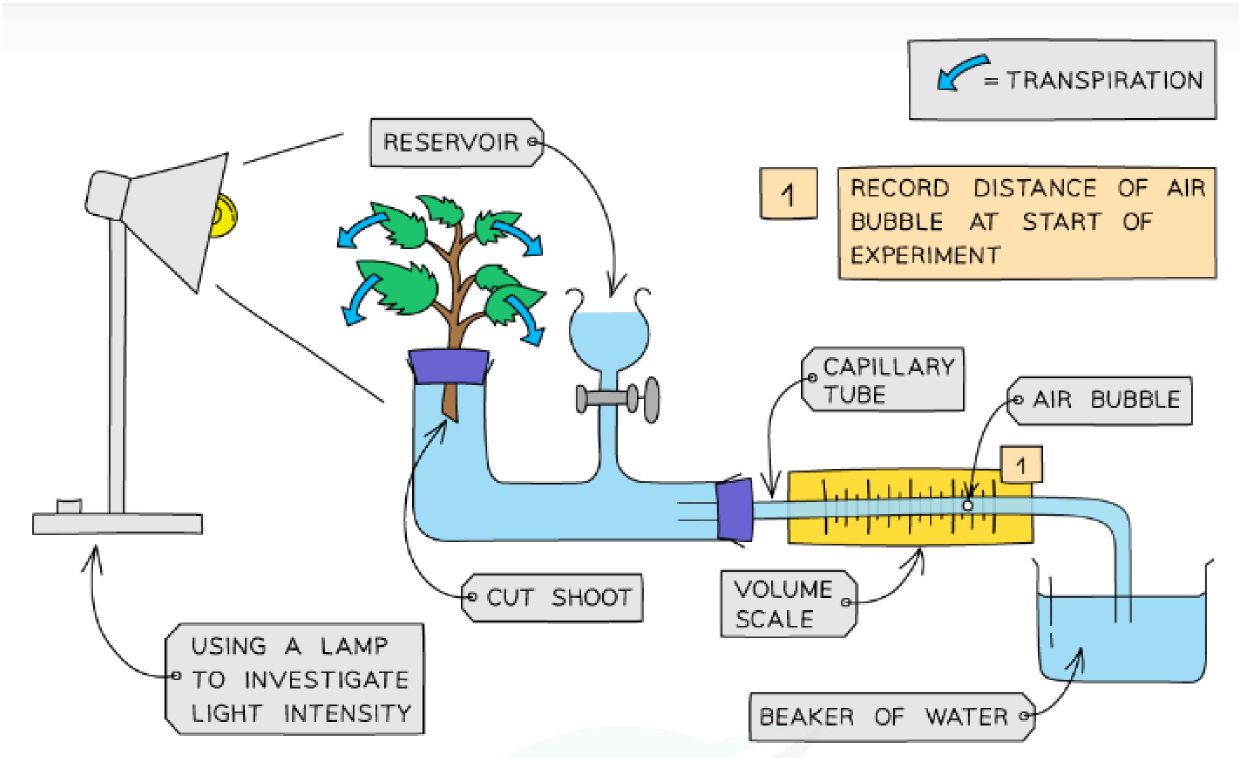
- The _____________ cells control the size of the stomata, so can regulate the amount of water _________ by t_____________________.
- If plants are losing water faster than they are gaining it, the stomata ____________.
- Without this happening, the plants will wilt – and may ______.
- ____________acid triggers the ______________ (exit) of potassium from guard cells, decreasing water pressure within the cells (lose ___________)
- A loss of __________ makes the stomatal pore close, as the guard cells become flaccid and block the opening

Complete the table to explain how the following **abiotic factors** affect the rate of transpiration:

	Effect	Reason
Temperature		
Light		
Wind		
Humidity		






= TRANSPIRATION
RESERVOIR
1
RECORD DISTANCE OF AIR BUBBLE AT START OF EXPERIMENT
CAPILLARY TUBE
AIR BUBBLE
1
CUT SHOOT
VOLUME SCALE
USING A LAMP TO INVESTIGATE LIGHT INTENSITY
BEAKER OF WATER

B3.1.10—Stomatal density

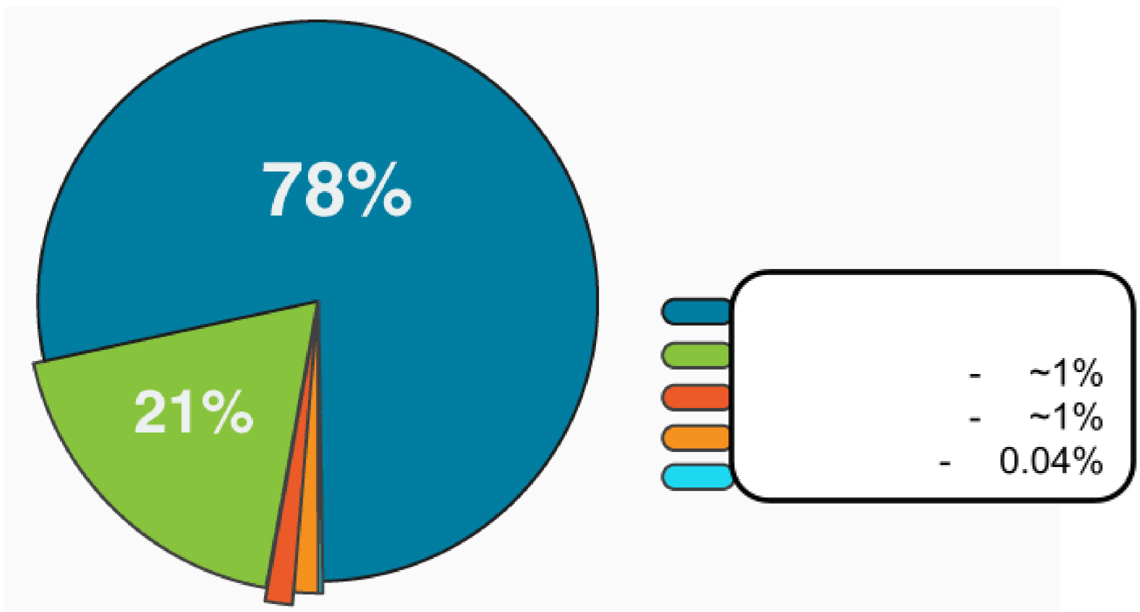
NOS: Reliability of quantitative data is increased by repeating measurements. In this case, repeated counts of the number of stomata visible in the field of view at high power illustrate the variability of biological material and the need for replicate trials.

Design an investigation on stomatal density in plant leaves.

Spiderwort
Geranium:
Coleus
Cabbage
Lily

AHL

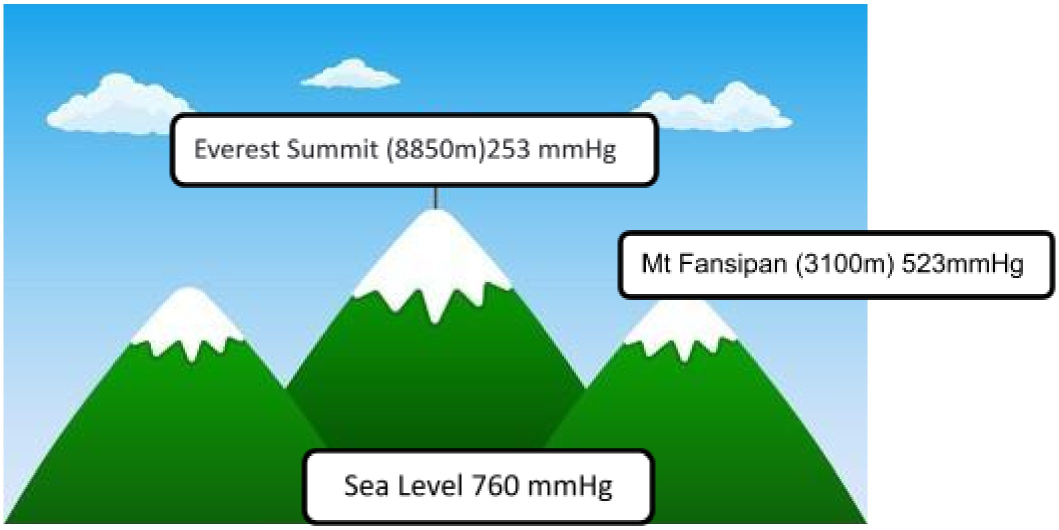
B3.1.13—Oxygen dissociation curves as a means of representing the affinity of haemoglobin for oxygen at different oxygen concentrations



Define partial pressure:

What are the units of partial pressure: ______________________________ (mmHg),

Total atmospheric pressure (all gasses combined, at sea level) = 760 mm Hg



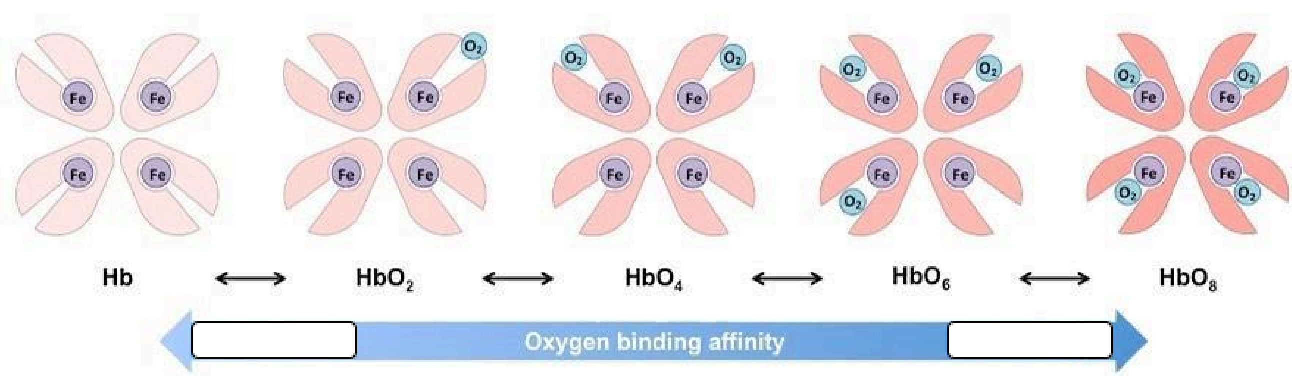
Calculate the partial pressure of oxygen at each level

Define affinity:

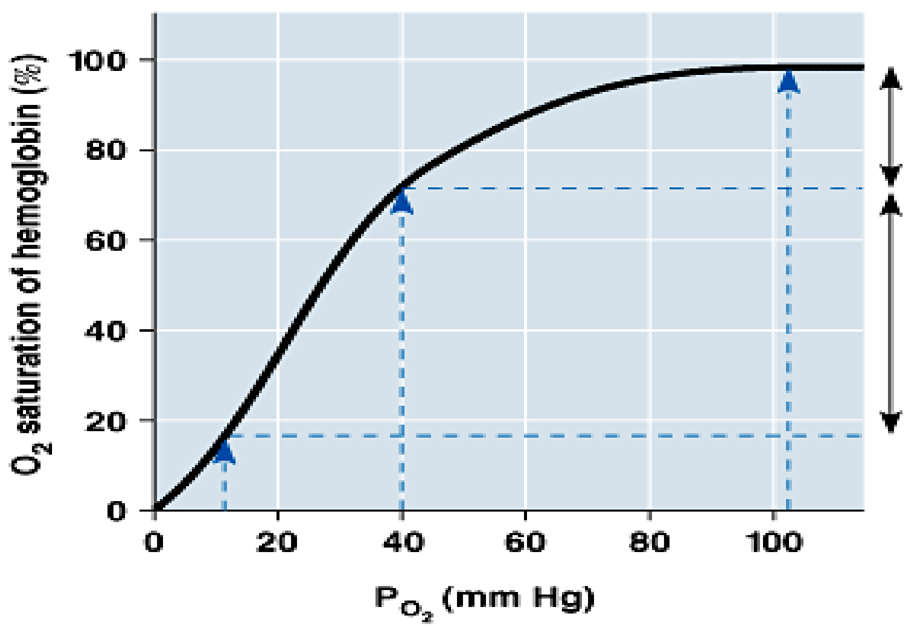
Cooperative binding of haem groups refers to the binding of one oxygen molecule to a heme group facilitates the binding of subsequent oxygen molecules, resulting in enhanced oxygen uptake and delivery.

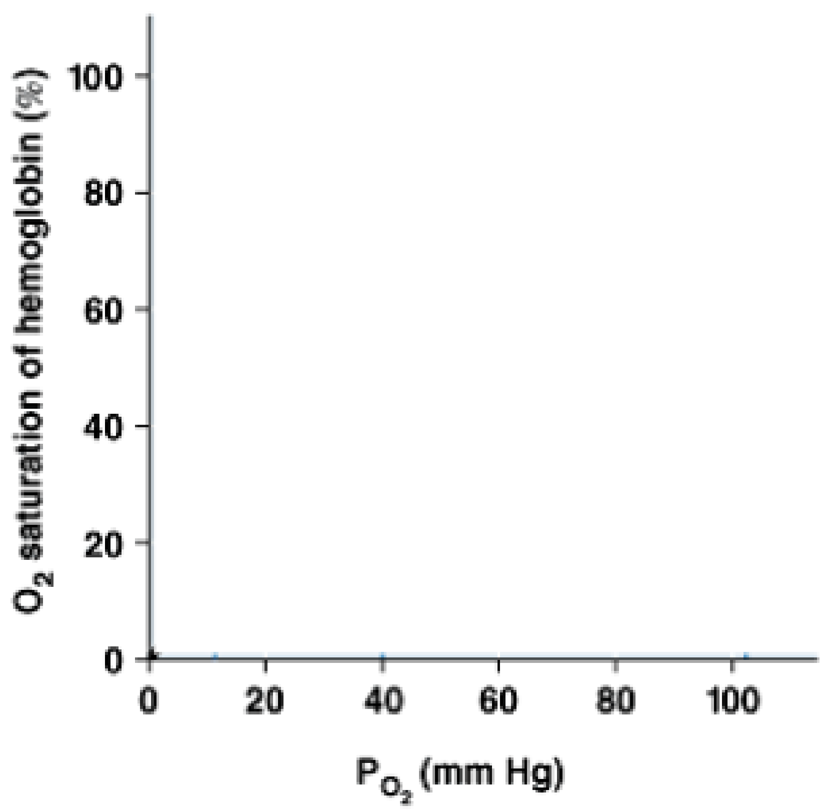
Tense (T) and Relaxed (R) States: In the T state, the hemoglobin subunits have a lower affinity for oxygen, making it difficult for the initial oxygen molecule to bind. In the R state, the affinity for oxygen is higher, promoting oxygen binding.

Label the Tense (T) state and Relax ® state below:



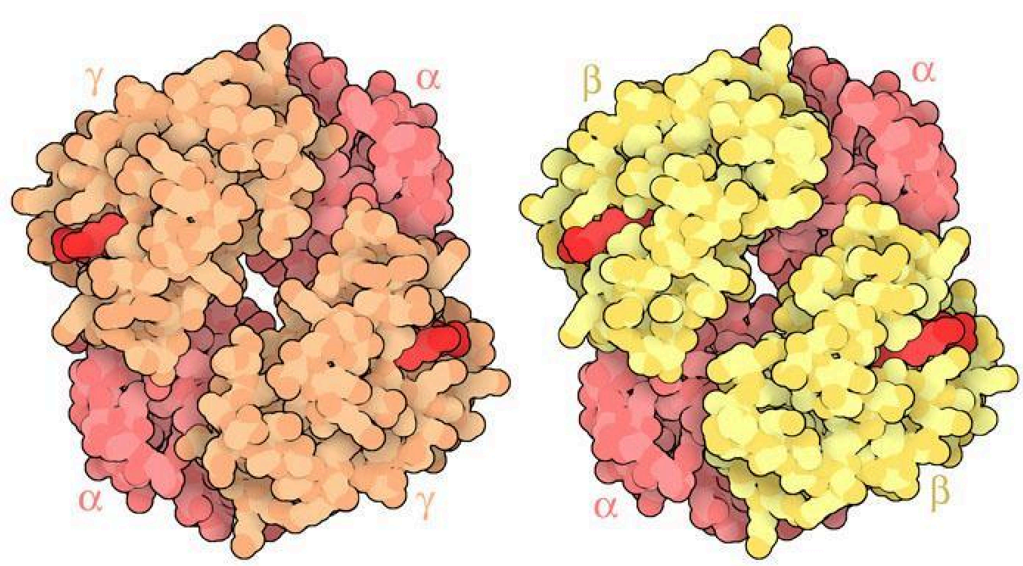
When the first oxygen molecule binds to a heme group in one subunit, it induces a ________________ change, shifting that subunit from the _______ state to the ________ state. This conformational change increases the __________ of the other subunits for oxygen, making it _________ for subsequent oxygen molecules to bind to the remaining heme groups.





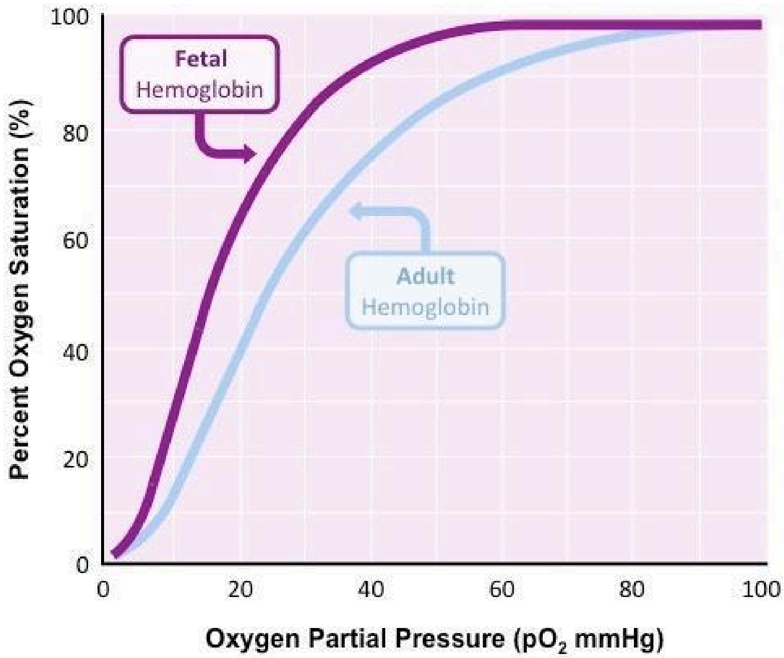
B3.1.11—Adaptations of fetal and adult haemoglobin for the transport of oxygen

________________________ haemoglobin has a different subunit composition than ____________ hemoglobin. It consists of two alpha-globin chains and two gamma-globin chains (α2γ2) instead of the two alpha-globin chains and two beta-globin chains (α2β2) found in adult hemoglobin. The gamma chains in fetal hemoglobin contribute to its _____________ oxygen affinity.



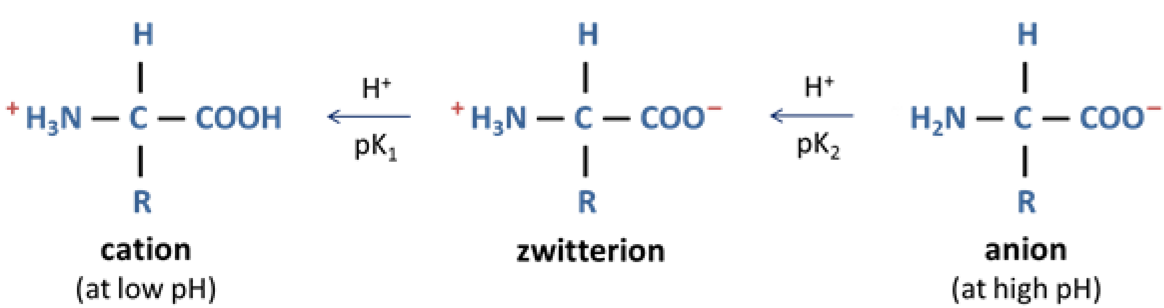
This _____________affinity allows the fetal hemoglobin to readily pick up oxygen from the mother's blood across the ______________, where oxygen concentration is lower. The higher affinity ensures efficient oxygen transfer to the developing fetus.

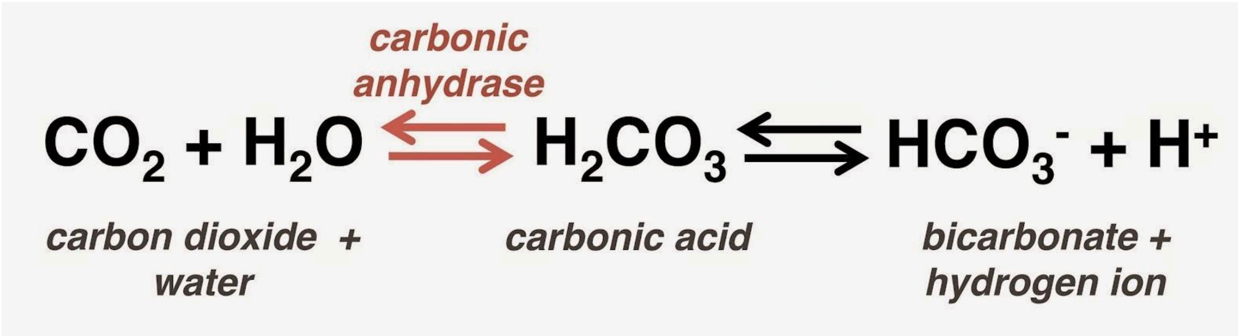
Annotate the graph below



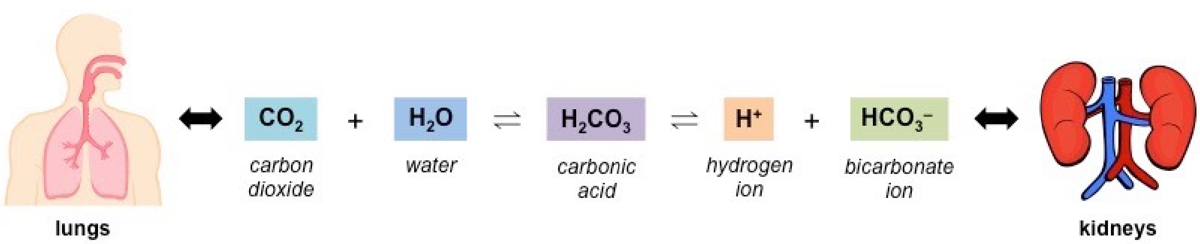
B3.1.12—Bohr shift

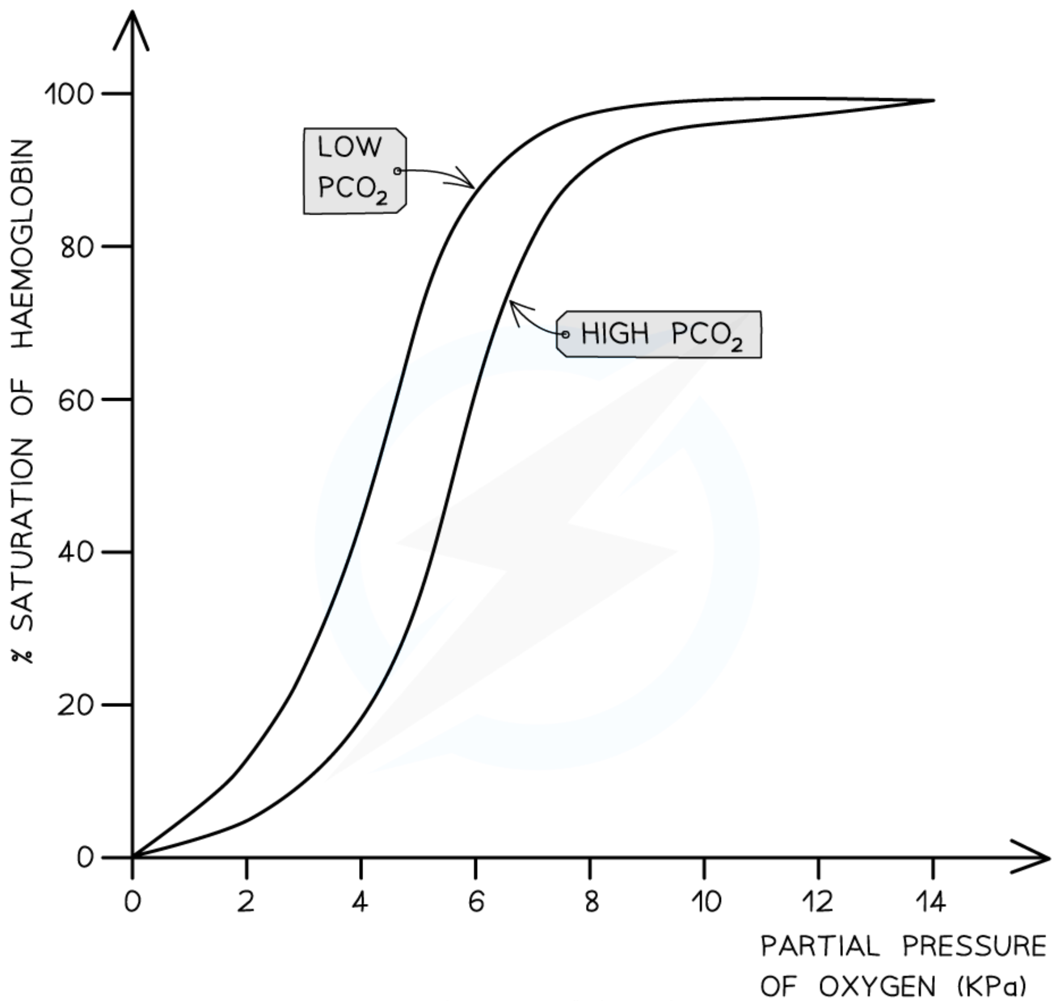
- The pH of blood is required to stay within a very narrow tolerance range (________ – ___________) in order to avoid the onset of disease.
- This pH range is, in part, maintained by plasma proteins which act as __________
- A buffering solution resists changes to pH by removing excess H+ ions (↑ acidity) or OH– ions (↑ alkalinity)
- Amino acids are **zwitterions** – they may have both a positive and negative charge and hence can buffer changes in pH
- The amine group may take on H+ ions while the carboxyl group may release H+ ions (which form water with OH– ions)





- Carbon dioxide reacts with ___________________ forming _____________ acid, which causes a _______________ the pH of the blood. This in turn, triggers __________________ to release its _________________ (by decreasing pH and binding to allosteric site of haemoglobin).
- This is known as the **___________ effect** – a decrease in pH shifts the oxygen dissociation curve to the___________________ and in turn releasing more _____________ for respiring tissues.
- Cells with increased metabolism (i.e. respiring tissues) release _____________amounts of carbon dioxide (product of cell respiration).





100
80
60
40
20
0
% SATURATION OF HAEMOGLOBIN
LOW PCO2
HIGH PCO2
0
2
4
6
8
10
12
14
PARTIAL PRESSURE OF OXYGEN (KPa)

Past Paper Question

1. What normally prevents the membranes of the alveoli from sticking together during expiration?

A. The thickness of the single-cell layer of alveoli membranes

B. The secretion of fluids in the inner surface of the alveoli

C. The pressure within the thoracic cavity

D. The dense net of capillaries covering the alveoli

(Total 1 mark)

2. What feature of alveoli adapts them to efficient gas exchange?

A. They have muscles which pump air in and out regularly.

B. Their membranes are more permeable to gases than water.

C. A constant blood supply flows through them.

D. A dense network of capillaries surrounds them.

(Total 1 mark)

3. Which muscle action is associated with an increase in the volume of the thoracic cavity during inspiration?

A. The diaphragm contracts.

B. The external intercostal muscles relax.

C. The internal intercostal muscles contract.

D. The abdominal muscles contract.

(Total 1 mark)

4. Capillaries surround the alveoli in the lungs. Which pair of statements correctly describes the concentrations of oxygen and carbon dioxide in the lungs?

	Oxygen	**Carbon dioxide**
A.	Higher in the capillaries	Higher in the alveoli
B.	Lower in the capillaries	Higher in the alveoli
C.	Lower in the alveoli	Higher in the capillaries
D.	Higher in the alveoli	Higher in the capillaries

(Total 1 mark)

5. What change occurs to the pressure and volume of the lungs when the external intercostal muscles contract?

A. Both pressure and volume increase.

B. Pressure increases and volume decreases.

C. Pressure decreases and volume increases.

D. Both pressure and volume decrease.

(Total 1 mark)

6. Explain the mechanisms involved in the ventilation of the lungs.

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7. Draw a labelled diagram of a mitochondrion as seen in an electron micrograph (4)

8. A supply of oxygen is needed for aerobic respiration in mitochondria. Describe the features of alveoli in human lungs that adapt them for efficient absorption of oxygen (6)

9. Explain the mechanism of ventilation of human lungs (8)

1. Explain the oxygen dissociation curves of adult hemoglobin and fetal hemoglobin. [4]
2. **Explain how the increase in CO2 concentration affects the release of oxygen to respiring cells. [2]**
3. **Explain the role of the Bohr shift during vigorous exercise. [2]**
4. **Outline the changes in the partial pressures of carbon dioxide and oxygen as altitude increases. [2]**
5. **Outline how CO2 interacts with haemoglobin once it enters erythrocytes. [1]**

1. Hemoglobin is composed of four polypeptide chains, each containing an iron containing team group that oxygen may bind to. The configuration of the hemoglobin changes and students oxygen molecule binds to it.
In adult hemoglobin, there is low saturation of oxygen under low pressure, but the saturation level grows exponentially as oxygen is added. Adult hemoglobin has the highest affinity for oxygen when it is bound to 3 oxygen.
Fetal hemoglobin has a different molecular composition adult hemoglobin. The dissociation curve moves to the left because it has a higher affinity for oxygen. This is so that oxygen the move from adult hemoglobin to fetal hemoglobin in the capillaries of the uterus.

2. a. increased levels of CO lower the pH of the blood
b. «which results in» decreased affinity of the hemoglobin for oxygen / greater release of oxygen
c. this shifts the oxygen dissociation curve to the right/Bohr shift

6. both pO_2 and pCO_2 fall with increasing altitude;
above certain altitude there is little change in alveolar pO_2 / pO_2 remains close to 37 mm Hg over a wide range of altitudes;
Pco_2 changes over the entire range of altitudes;
the pO_2 is always higher than pCO_2;

3. a. more CO is produced which lowers the pH of the blood;
b. hemoglobin releases more oxygen (at lower pH) for same partial pressure of oxygen;
c. more oxygen is available to respiring tissues;

1. B

[1]

2. D

[1]

3. A

[1]

4. D

[1]

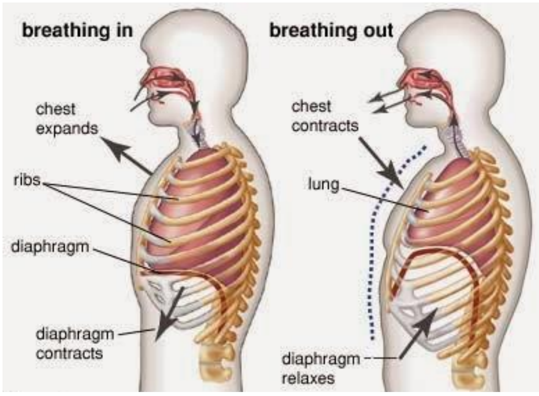
5. C

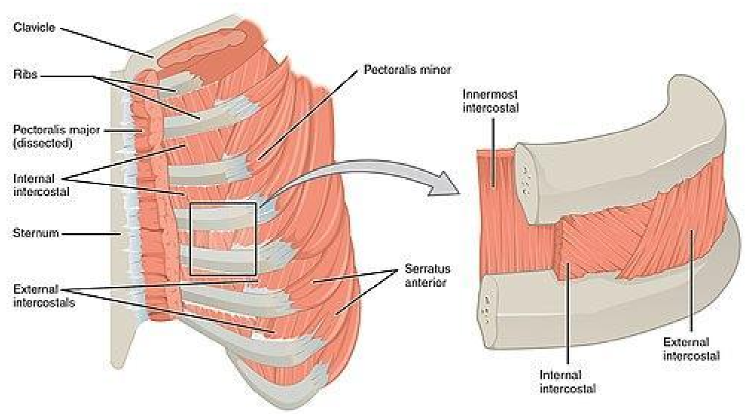
[1]

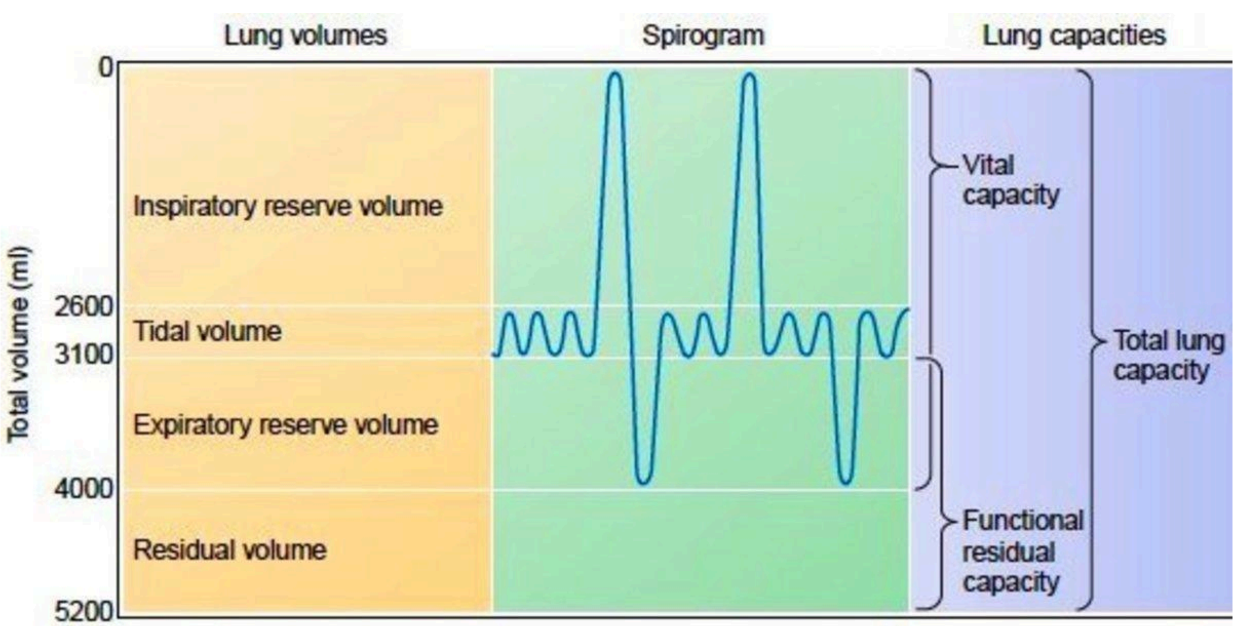
6. external intercostal muscles contract;
internal intercostal muscles relax;
pulling the rib cage upwards;
diaphragm contracts and flattens;
increase in volume of thoracic cavity;
this reduces pressure;
so air enters the lungs;
internal intercostal muscles contract / external intercostal muscles relax;
diaphragm relaxes;
abdominal muscles/organs/liver push diaphragm upwards;
decrease in volume of thoracic cavity;
increases the pressure;
so air leaves the lungs;
Award any of the above points if clearly drawn in a diagram. 8 max

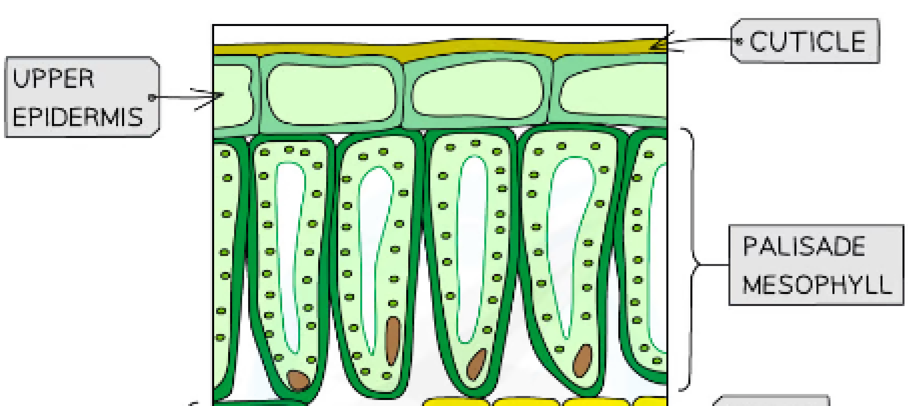
[8]

7.
outer membrane – drawn as a continuous line;
inner membrane – showing folding to create cristae;
cristae – shown as distinct infoldings of inner membrane;
matrix;
intermembrane space – shown as continuous space between outer and inner membranes;
(70S) ribosomes – shown as small dots in proportion with organelle, not too large;
(naked) loop of DNA;


breathing in
breathing out
chest expands
chest contracts
ribs
lung
diaphragm
diaphragm contracts
diaphragm relaxes


Clavicle
Ribs
Pectoralis minor
Pectoralis major (dissected)
Internal intercostal
Sternum
External intercostals
Serratus anterior
Innermost intercostal
External intercostal
Internal intercostal


Lung volumes
Spirogram
Lung capacities
Total volume (ml)
0
2600
3100
4000
5200
Inspiratory reserve volume
Tidal volume
Expiratory reserve volume
Residual volume
Vital capacity
Total lung capacity
Functional residual capacity


CUTICLE
UPPER EPIDERMIS
PALISADE MESOPHYLL

Select a plant species with readily observable stomata on the lower surface of the leaves. It's important to choose leaves of the same species to minimize variations.

Prepare the experimental setup by arranging the light sources at different distances or intensities. Ensure that the light sources cover the leaves evenly and provide a range of light intensities.

Start with a control group by exposing a leaf to natural light conditions. This will serve as a baseline for comparison.

Choose a leaf from the control group and apply a thin layer of clear nail polish to the lower surface. Allow it to dry completely. This technique, known as peel or nail polish replication, creates an imprint of the stomata for observation.

Repeat step 4 for the leaves exposed to different light intensities, ensuring that each leaf represents a specific light condition.

Carefully remove the dried nail polish layer from each leaf using a sharp blade or tweezers, and mount it on a microscope slide with a drop of mounting medium. Place a coverslip on top.

Examine the slides under a microscope at a suitable magnification. Count the number of stomata in a specific area (e.g., number of stomata per mm2). Alternatively, capture images of stomata for later analysis using image analysis software.

Repeat steps 4-7 for multiple leaves from each light intensity condition to obtain sufficient data for statistical analysis.

Analyze the data by calculating the average stomatal density for each light intensity condition. You can use statistical tests (e.g., t-test or ANOVA) to determine if there are significant differences between the groups.

Record and present the results, including the average stomatal density for each light intensity condition, along with any statistical analyses conducted.