NAME _____ CLASS _____ DATE _____

IB BIOLOGY · B3.1

Gas exchange

Notes to fill in alongside the guide. Each numbered block matches a chapter of the guide, and of the lesson slides. Write in the gaps, answer the cues, annotate the figures, and sum up each section in your own words.

BY THE END YOU CAN

- [ ] Explain why every organism exchanges gases, and why being bigger makes it harder B3.1.1
- [ ] Describe the four properties of a gas-exchange surface and why each one matters B3.1.2
- [ ] Explain how a leaf's waxy cuticle, epidermis, air spaces, spongy mesophyll, guard cells and veins suit it to gas exchange B3.1.7
- [ ] Draw and label a plan diagram of a leaf in transverse section from a micrograph B3.1.8
- [ ] Explain why transpiration is the price of gas exchange, and how light, temperature, humidity and wind change its rate B3.1.9
- [ ] Find a leaf's stomatal density from a leaf cast or a micrograph, and explain why repeated counts make it more reliable B3.1.10
- [ ] Explain how blood flow and ventilation keep the gradient steep at an animal's exchange surface, with air for lungs and water for gills B3.1.3
- [ ] Relate the branching airways, the alveoli, the capillary beds, the surface area and the surfactant of a mammal's lungs to gas exchange B3.1.4
- [ ] Explain how the diaphragm, ribs, intercostal and abdominal muscles change the volume and pressure of the chest to ventilate the lungs B3.1.5
- [ ] Measure tidal volume, vital capacity and the two reserve volumes, and say what makes a result reliable B3.1.6
- [ ] Explain how cooperative binding and the binding of carbon dioxide suit haemoglobin, adult and foetal, to carrying oxygen B3.1.11
- [ ] Explain how more carbon dioxide makes haemoglobin release more oxygen (the Bohr shift) and why that helps working tissue B3.1.12
- [ ] Read an oxygen dissociation curve for affinity and explain its S shape B3.1.13

01 Every cell needs a way in

B3.1.1 B3.1.2

CUES

Predict: The 4 cm cube is squashed into a sheet 16 cm by 16 cm and 0.25 cm thick, with the same volume. Compared with the cube, how quickly is every part of it supplied?

What is meant by gas exchange?

What is meant by diffusion?

NOTES

1 So almost every organism has to take oxygen in and get rid of carbon dioxide, all the time. That swap is _____.

2 Gases cross a surface by _____, from where they are more concentrated to where they are less.

3 But as anything grows, its volume grows faster than its surface, so its _____ falls, and its centre ends up further from the outside.

4 A _____ has four properties.

What is meant by surface area to volume ratio?

What is meant by gas-exchange surface?

5 It is _____, so oxygen and carbon dioxide can pass through it.

6 It is _____, often one layer of cells, so the gases have only a short way to go.

7 As an organism gets bigger, its _____ falls and the distance from its centre to the outside rises.

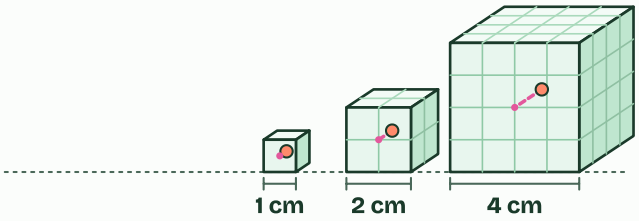
8 A _____ is permeable, thin, moist and large.

Your own notes

ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 6 cm², 1 cm³; 2 3 : 1; 3 1.5 : 1; 4 falls, rises.

Bigger cube, smaller ratio

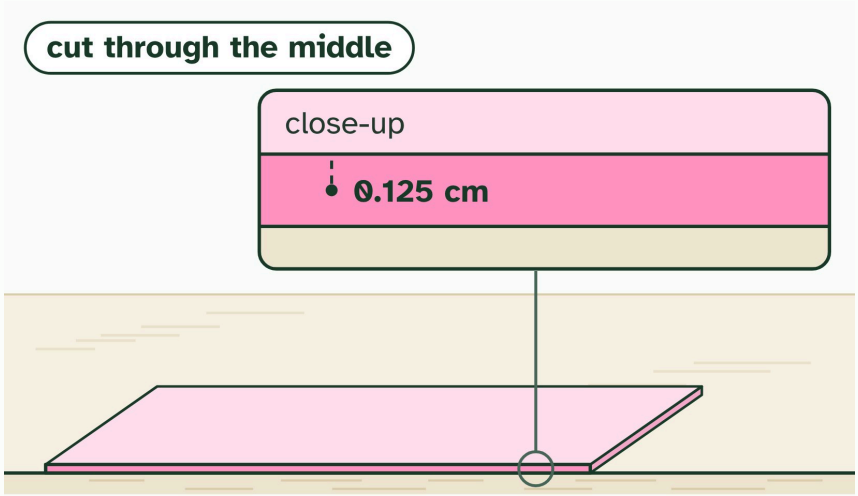


	1 cm	2 cm	4 cm
surface area	6 cm²	24 cm²	96 cm²
volume	1 cm³	8 cm³	64 cm³
ratio	6 : 1	3 : 1	1.5 : 1
centre to face	0.5 cm	1 cm	2 cm

the ratio falls ↓ the distance rises ↑

ANNOTATE THE FIGURE

Annotate this still from the animation (Bigger bodies, slower supply): what is happening, and why?



shape	cube	sheet
surface area / cm^2	96	528
volume / cm^3	64	64
surface area : volume	1.5 : 1	8.25 : 1
centre to nearest face / cm	2	0.125
middle after soaking	pale	dyed

REMEMBER IT

The four properties of a gas-exchange surface

T Too	M Many	P Pink	L Leaves
T	M	P	L

SPOT THE MISTAKE

A student writes: “Plants photosynthesise instead of respiring.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 01 in two or three sentences of your own.

02 A leaf is built for gas exchange

B3.1.7

CUES

Predict: Why are most of a leaf's stomata in its lower surface?

What is meant by waxy cuticle?

What is meant by stomata?

What is meant by guard cells?

What is meant by mesophyll?

NOTES

1 The _____, one layer of tightly fitted cells with few or no chloroplasts, makes a _____ over itself.

2 The wax keeps water in, but it keeps carbon dioxide out too, so gases need a way through: the _____ (one is a stoma), each a pore between two _____ that can open or close it (chapter 4).

3 Under the upper surface is the _____, tall cells packed with chloroplasts, where most of the light is caught.

4 Below it, the cells of the _____ are loosely packed, and the _____ between them join up from every stoma to every cell.

5 The moist walls of these _____ cells are the real gas-exchange surface: carbon dioxide dissolves in the film of water on them and diffuses into the cells, and oxygen leaves the same way.

6 The _____ and the epidermis keep water in, and keep gases out too.

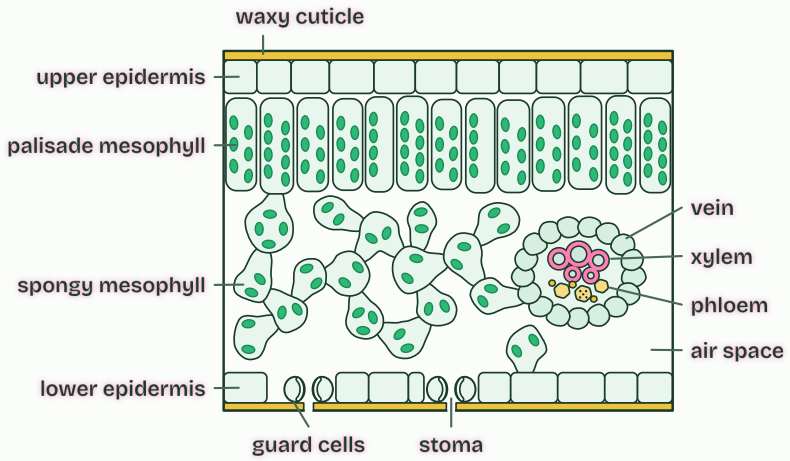
7 _____ let gases through the epidermis, and guard cells open and close them.

8 Air spaces carry gases from the _____ to every mesophyll cell; the moist walls of those cells are the exchange surface.

Your own notes

ANNOTATE THE FIGURE

Label each part and say what it does: air spaces, spongy mesophyll, palisade mesophyll, vein, xylem, phloem, upper epidermis, lower epidermis, guard cells, waxy cuticle.



REMEMBER IT

The layers of a leaf, top to bottom

C Cats	U Usually	P Purr	S Softly	L Lazily
C	U	P	S	L

SPOT THE MISTAKE

A student writes: "Gas exchange happens across the whole surface of the leaf." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 02 in two or three sentences of your own.

03 Drawing a leaf in plan

B3.1.8

CUES

Predict: A plan diagram shows where each tissue of an organ is. A student draws every palisade cell in their plan of a leaf. What is wrong?

What is meant by plan diagram?

What is meant by micrograph?

What is meant by transverse section?

NOTES

1 A _____ shows where the tissues are, not what their cells look like.

2 You draw the outline of each tissue as one region, in the same proportions and positions as in the _____ or slide you are drawing from, and no single cells.

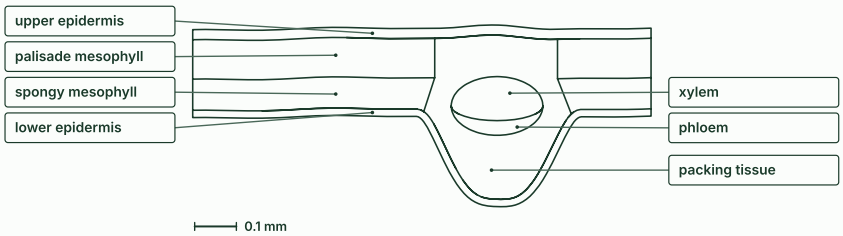
3 In a _____ of the leaf of a dicotyledonous plant (a dicot: a flowering plant with two seed leaves and net-veined leaves), the tissues lie in layers.

4 Proportions and positions as the _____ shows them, not as a textbook does.

Your own notes

ANNOTATE THE FIGURE

Number the 2 steps on the figure and note what happens at each.



Plan diagram: transverse section of a dicotyledonous leaf, through the midrib

SPOT THE MISTAKE

What do students often get wrong about distribution of tissues in a leaf? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 03 in two or three sentences of your own.

04 Guard cells open and close the door

B3.1.7

CUES

Predict: A plant in bright sunshine runs short of water. What do its stomata do?

What is meant by turgid?

What is meant by flaccid?

What is meant by osmosis?

What is meant by abscisic acid?

NOTES

1 When the guard cells take in water they swell and become _____.

2 When they lose water they become _____, straighten, and the pore closes.

3 In the light, guard cells take up potassium ions (K^+) from the cells around them. That raises the concentration of solutes inside them, and water follows by _____.

4 The signal is a plant hormone, _____.

5 A guard cell's wall is thickest on the pore side, so _____ guard cells bow apart and open the stoma.

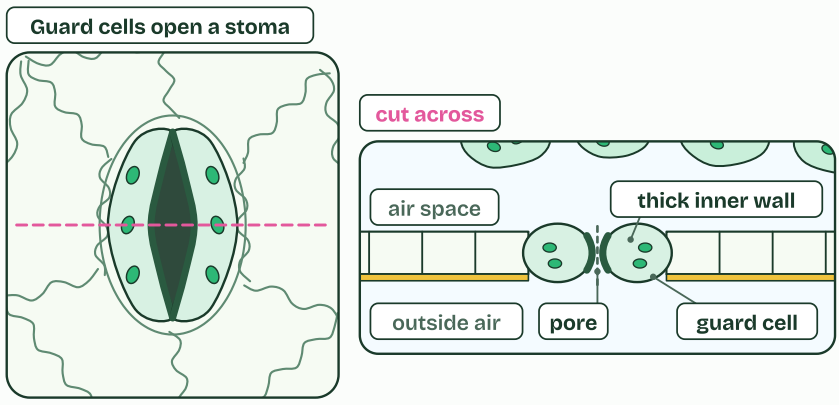
6 Potassium ions taken up in the light draw water in by _____; losing them lets the water out and closes the pore.

7 _____ closes the stomata when the plant is short of water, even in the light.

Your own notes

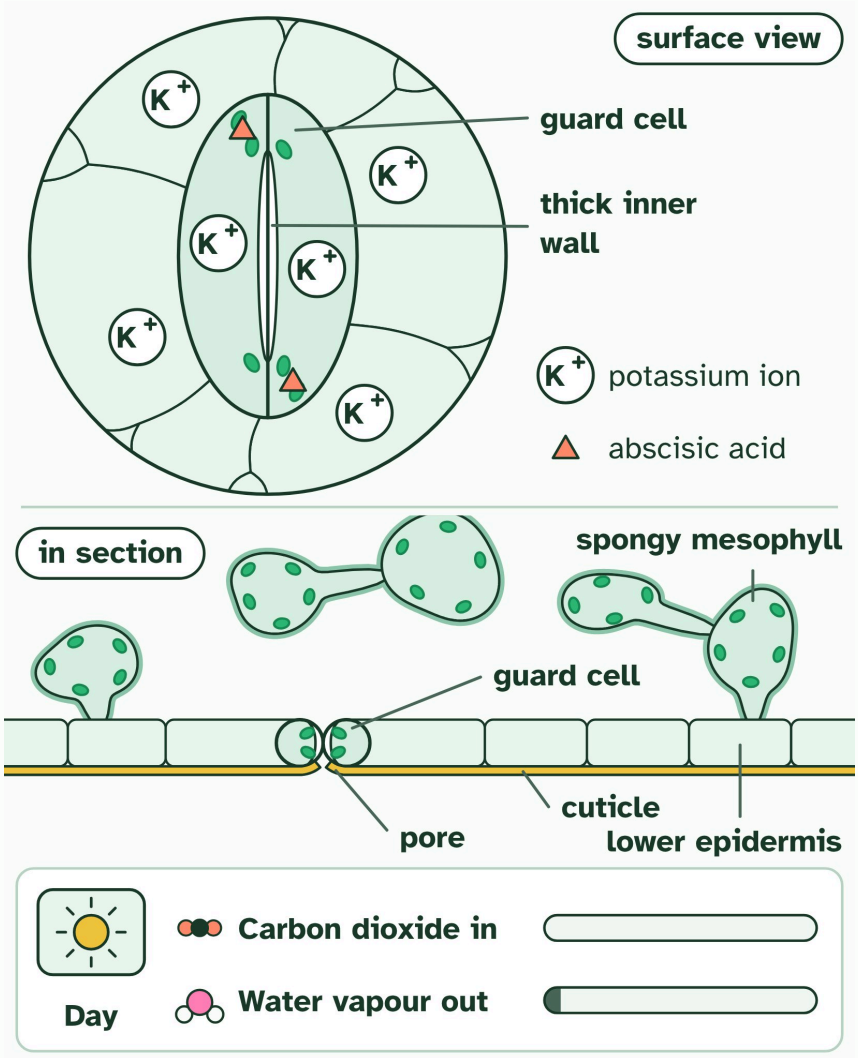
ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Annotate this still from the animation (Open, closed, and the price of each): what is happening, and why?



SPOT THE MISTAKE

A student writes: "Guard cells pull the pore open like muscles." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 04 in two or three sentences of your own.

05 Counting stomata

B3.1.10

CUES

Predict: Why count five fields, chosen at random, instead of one?

What is meant by stomatal density?

What is meant by field of view?

What is meant by stage micrometer?

NOTES

1 _____ is the number of stomata in a unit area of leaf surface, usually given per mm².

2 You can find it from a micrograph that has a scale, or from a _____: paint a thin layer of clear nail varnish on the leaf, let it dry, press clear tape onto it, peel the varnish off with the tape and stick it on a slide.

3 Decide before you start what to do with a stoma cut by the edge of the _____ (one rule, the one used here: count it only if more than half of it is inside) and keep to it.

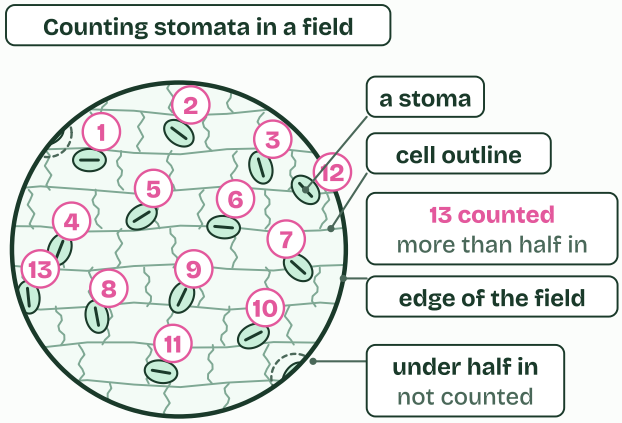
4 Measure its diameter with a _____, a slide ruled in hundredths of a millimetre, or measure it at low power against a clear ruler and divide by how many times more the high-power objective magnifies.

5 _____ = mean number of stomata per field ÷ area of the field (πr²), usually per mm².

Your own notes

ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 edge of the field; 2 more than half, 13; 3 0.45 mm, 0.159 mm²; 4 82 stomata per mm².

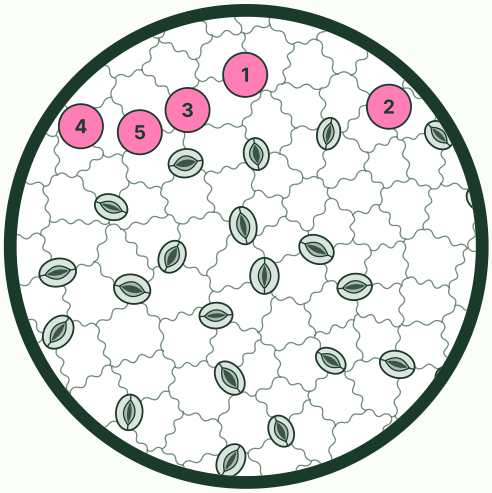


field across: 0.45 mm
so r = 0.225 mm
area = π × 0.225²
= 0.159 mm²

five fields: 12, 15, 11, 14, 13
mean 13
density = 13 ÷ 0.159
≈ 82 per mm²

ANNOTATE THE FIGURE

Label the key parts and add a note on what it shows.



Count a stoma only if more than half of it is inside the circle.

Field	Leaf	Surface	Stomata	Density / mm^{-2}

SPOT THE MISTAKE

What do students often get wrong about stomatal density? Write the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 05 in two or three sentences of your own.

06 The price of gas exchange: transpiration

B3.1.9

CUES

Predict: One leaf on a plant in sunshine has its lower surface smeared with petroleum jelly. Compared with a leaf left alone, it becomes...

What is meant by transpiration?

What is meant by potometer?

NOTES

1 _____ is the loss of water vapour from the leaves and stems of a plant.

2 The rate depends on that gradient, and on how open the stomata are. _____ opens the stomata, so transpiration is fastest by day and slows right down at night.

3 A higher _____ speeds up evaporation and diffusion, and the warmer air spaces hold more vapour before they are saturated, so the gradient to the outside air is steeper. _____ air already holds a lot of vapour, so the gradient is shallower and the rate falls. _____ carries away the humid layer of air next to the leaf, which keeps the gradient steep.

4 To measure the rate, use a _____: a leafy shoot sealed into a tube of water, with an air bubble that moves along a scale as the shoot takes water up.

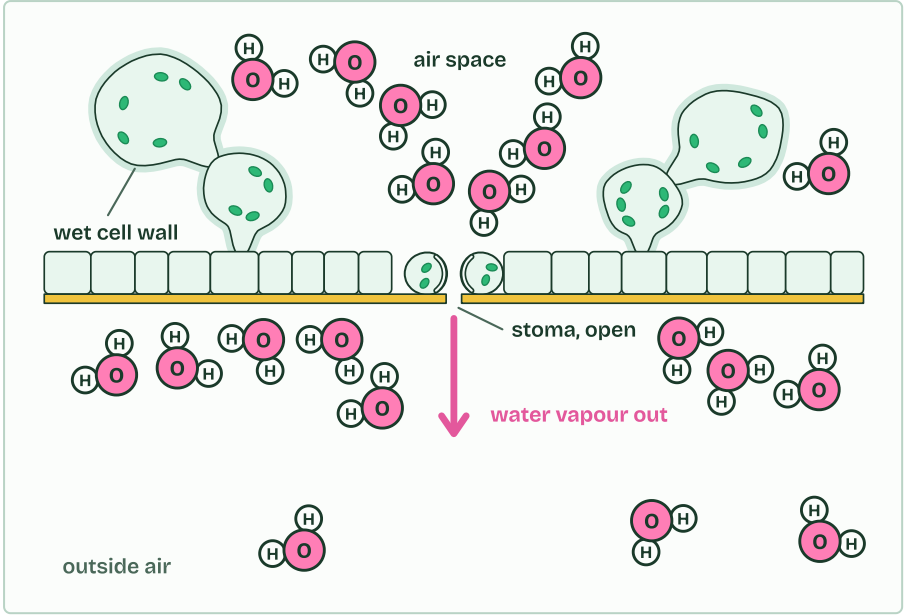
5 _____ is the loss of water vapour from leaves and stems, a consequence of the open stomata that gas exchange needs.

6 A _____ measures water uptake, which is close to the water lost.

Your own notes

ANNOTATE THE FIGURE

The figure shows it as Still air, Humid air, Windy, Warm and Dark. Note what changes each time.



REMEMBER IT

Four factors that change the rate of transpiration

L Lazy	T Teens	H Hate	W Wednesdays
L	T	H	W

SPOT THE MISTAKE

A student writes: "Transpiration stops in the dark." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 06 in two or three sentences of your own.

07 Keeping the gradient steep

B3.1.3

CUES

Predict: The blood in a capillary beside an alveolus stops flowing, but breathing carries on. What happens to the gradient across the wall?

What is meant by concentration gradient?

What is meant by ventilation?

What is meant by gills?

NOTES

1 That makes it cheap, but it only works while there is a _____: more oxygen on the air side of the wall than on the blood side, and more carbon dioxide on the blood side than in the air.

2 _____ is not gas exchange.

3 Its _____ are rows of thin filaments, each packed with capillaries, and the fish pumps water over them in a one-way stream, in through the mouth and out under the gill covers.

4 An exchange surface: _____ in an alveolus over a wall two flat cells thick, and a _____ under it.

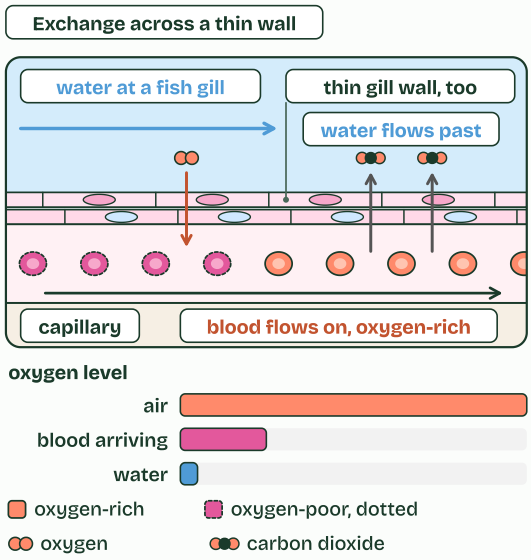
5 Oxygen diffuses _____ across the wall, down its gradient, and carbon dioxide diffuses _____. The bars show the oxygen level either side.

6 The blood keeps _____: it carries each load of oxygen away and brings blood low in oxygen to the wall, so the gradient stays steep.

Your own notes

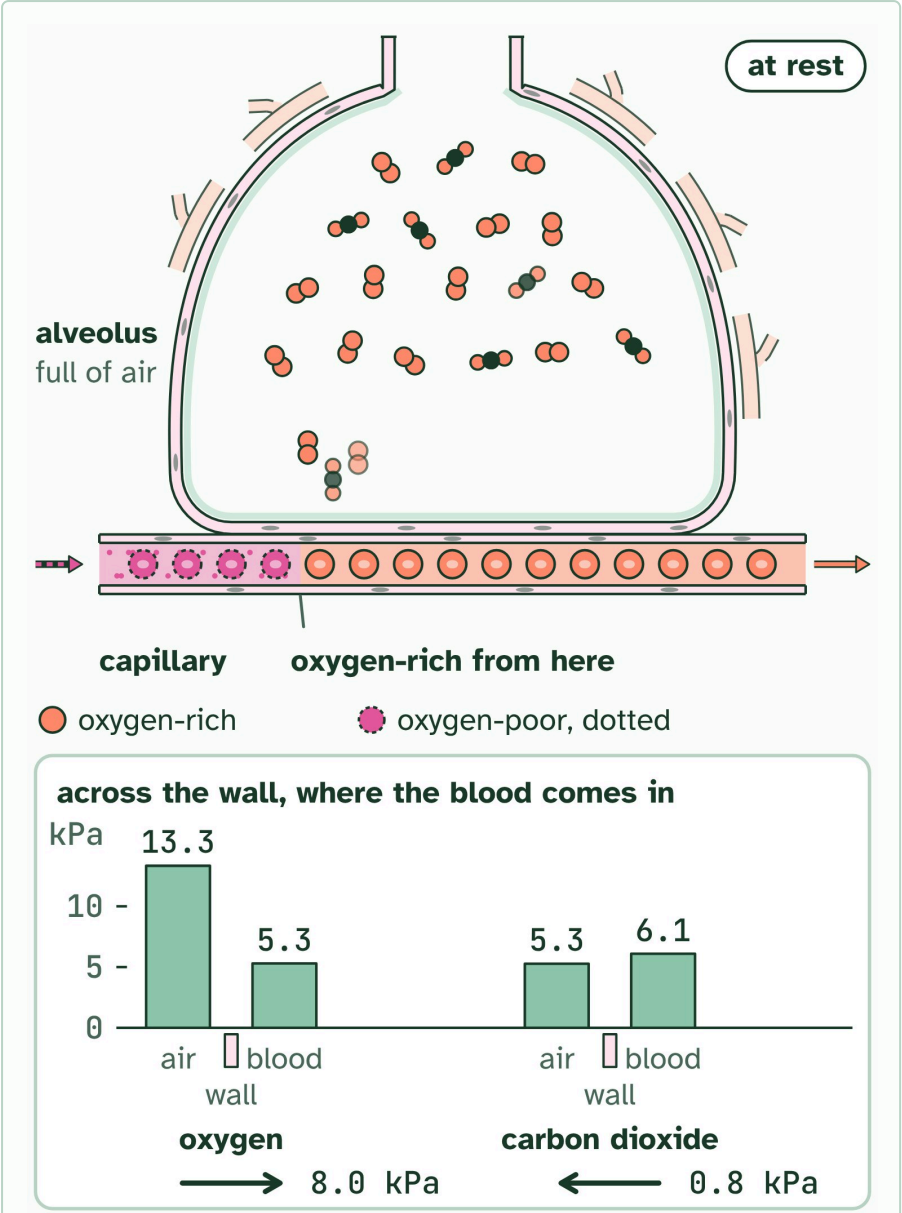
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each: 1 air, capillary; 2 in, out; 3 flowing; 4 Ventilation; 5 gill.



ANNOTATE THE FIGURE

Annotate this still from the animation (Keeping the gradient steep): what is happening, and why?



REMEMBER IT

The three things that keep the gradient steep

V Very	F Fast	V Vans
V	F	V

SPOT THE MISTAKE

A student writes: “Breathing is gas exchange.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 07 in two or three sentences of your own.

08 Down the branching tree

B3.1.4

CUES

Predict: A lung is a tree of ever narrower tubes ending in millions of tiny sacs, not one big bag. What does this gain?

What is meant by trachea?

What is meant by bronchi?

What is meant by bronchioles?

What is meant by alveoli?

What is meant by capillary bed?

NOTES

1 Air comes in through your nose or mouth, down the throat and into the _____, the windpipe, which C-shaped rings of cartilage hold open as the pressure inside it changes.

2 In the chest it divides into two _____, one to each lung.

3 Inside the lung each bronchus divides, and divides again, over twenty times in all, into ever narrower _____.

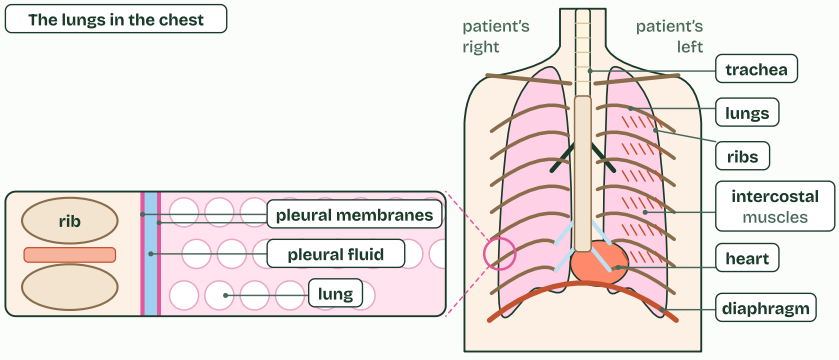
4 The finest end in clusters of tiny air sacs, the _____, like bunches of grapes on their stalks.

5 Every alveolus is wrapped in capillaries, so the lungs hold an extensive _____: the third adaptation the IB lists.

Your own notes

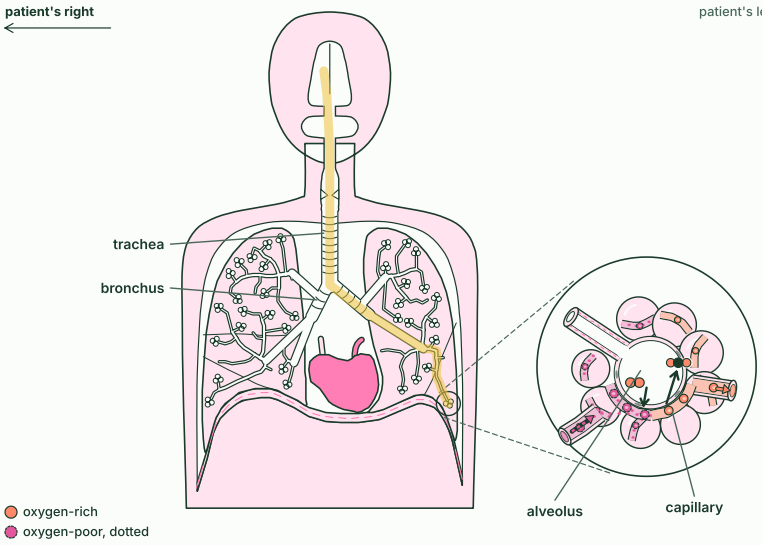
ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 lungs, diaphragm, trachea, heart; 2 ribs, intercostal muscles; 3 pleural membranes, pleural fluid.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 frontal plane; 2 pharynx, larynx, trachea, bronchi, bronchioles, alveoli, capillaries; 3 oxygen, carbon dioxide.



SPOT THE MISTAKE

A student writes: "Gas is exchanged all along the airways." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 08 in two or three sentences of your own.

09 One alveolus, close up

B3.1.4

CUES

Predict: A baby is born weeks early with too little surfactant. What goes wrong in its alveoli when it breathes out?

What is meant by surfactant?

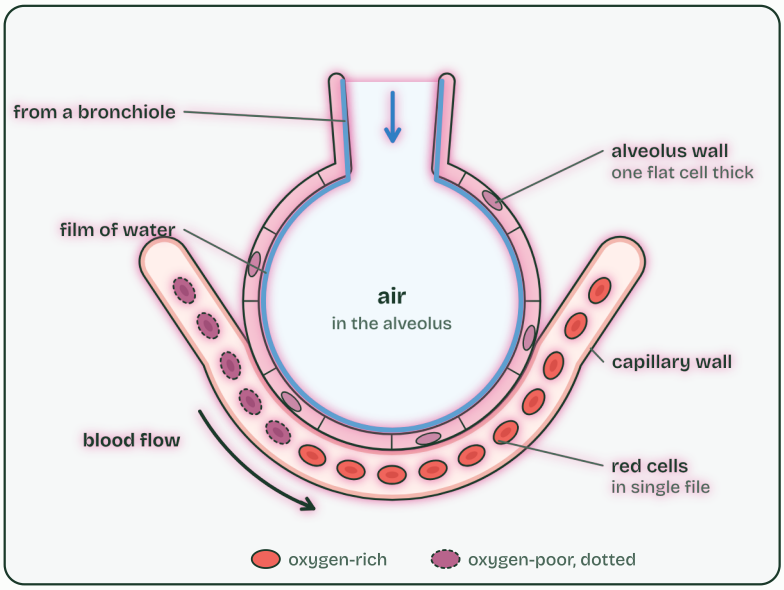
NOTES

1 _____ is the fourth adaptation the IB names.

Your own notes

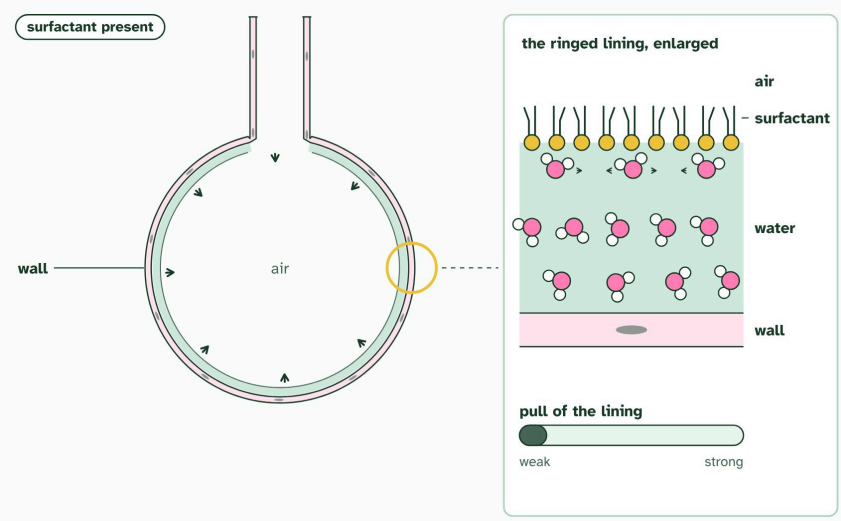
ANNOTATE THE FIGURE

Label each part and say what it does: the capillary wall, red blood cells, air in the alveolus, the alveolus wall, a film of water, the way in, the blood keeps flowing.



ANNOTATE THE FIGURE

Annotate this still from the animation (Why the alveoli stay open): what is happening, and why?



SPOT THE MISTAKE

A student writes: "Surfactant is a soap that cleans the lungs." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 09 in two or three sentences of your own.

10 Pressure moves the air

B3.1.5

CUES

Predict: The diaphragm contracts. What does that do to the pressure of the air in the lungs, and so to the air?

What is meant by diaphragm?

What is meant by external intercostal muscles?

NOTES

1 Your lungs have no muscle that can expand them. They sit in a sealed chest, floored by the _____ and walled by the ribs, and they are stretched with it.

2 _____ (inspiration).

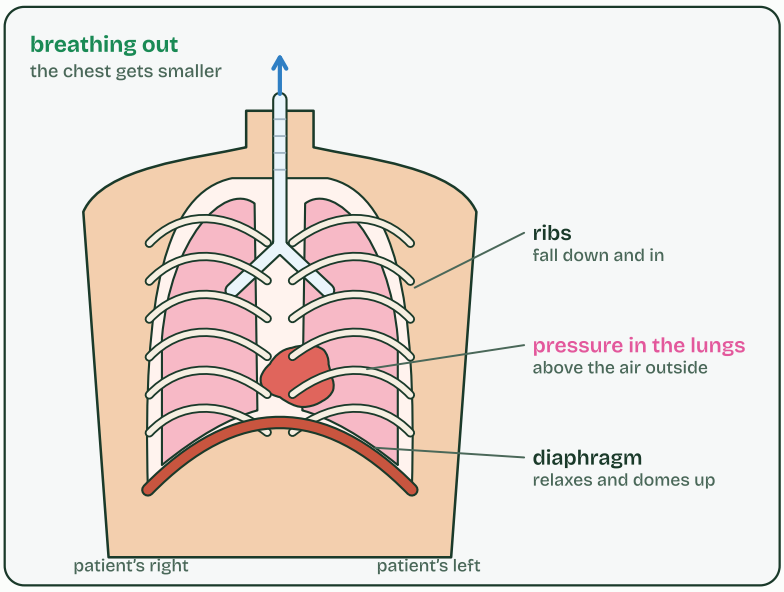
3 The _____, between the ribs, contract and lift the ribs up and out.

4 _____ (expiration).

Your own notes

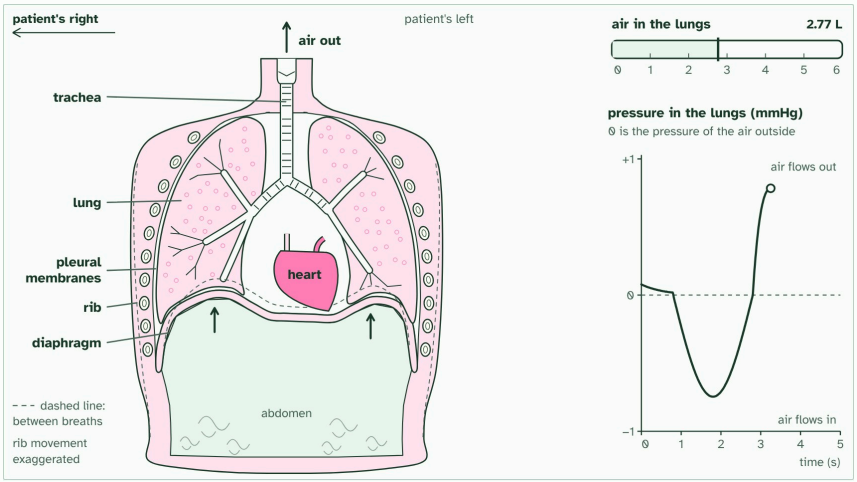
ANNOTATE THE FIGURE

Number the 4 steps on the figure and note what happens at each: 1 syringe; 2 lower pressure; 3 diaphragm, external intercostals; 4 relax.



ANNOTATE THE FIGURE

Annotate this still from the animation (Breathing in and out at rest): what is happening, and why?



REMEMBER IT

Breathing in, in order

D Drop	L Lift	W Widen	F Fill
D	L	W	F

SPOT THE MISTAKE

A student writes: "The diaphragm rises when you breathe in." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 10 in two or three sentences of your own.

11 Working harder

B3.1.5

CUES

Predict: Quiet breathing out uses no muscle effort. In a sprint, which extra muscles help you breathe out?

What is meant by antagonistic pair?

NOTES

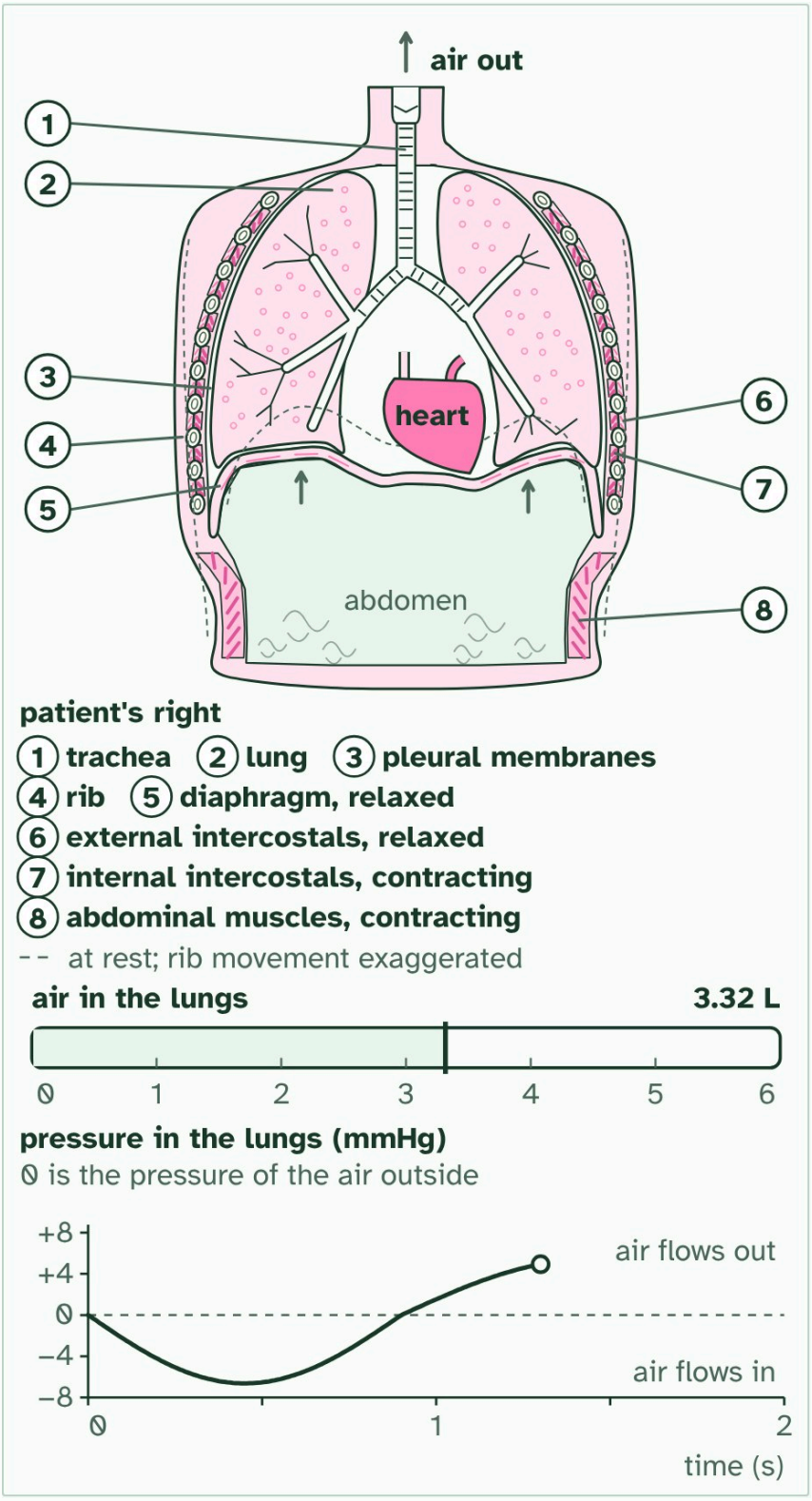
1 Muscles can only pull, so each one that moves the ribs one way has a partner that moves them back: an _____.

2 _____ (exercise, a cough, blowing out a candle). The internal intercostals contract and pull the ribs down and in; the abdominal muscles contract and push the diaphragm up. Breathing out is now active.

Your own notes

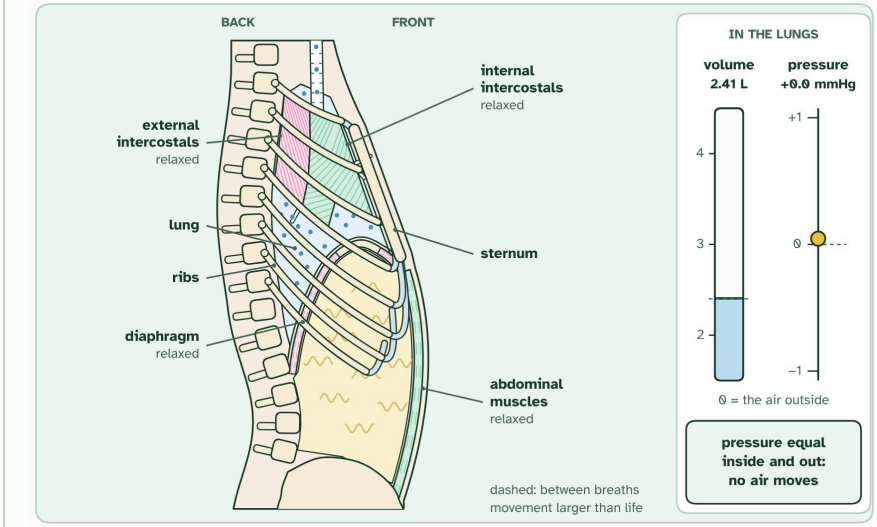
ANNOTATE THE FIGURE

Annotate this still from the animation (Breathing hard): what is happening, and why?



ANNOTATE THE FIGURE

Annotate this still from the animation (Four muscles, one breath): what is happening, and why?



REMEMBER IT

IEEI: Inhale External, Exhale Internal

I I E	E E I
I	E

SPOT THE MISTAKE

A student writes: "You breathe in with muscles and out by relaxing, always." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 11 in two or three sentences of your own.

12 How much air?

B3.1.6

CUES

Predict: After an ordinary breath out you push out as much more air as you can. Which volume is that extra air?

What is meant by spirometer?

What is meant by tidal volume?

What is meant by inspiratory reserve volume?

What is meant by expiratory reserve volume?

What is meant by vital capacity?

What is meant by ventilation rate?

NOTES

1 A _____ measures how much air you move.

2 Count the breaths in a minute and you have the _____ : about 12 to 16 at rest in an adult, with a tidal volume of about half a litre (0.5 dm^3: a litre is 1 dm^3, the unit the IB writes volumes in).

3 _____: the air moved in or out in one ordinary breath.

4 _____: the extra you can breathe in after an ordinary breath in.

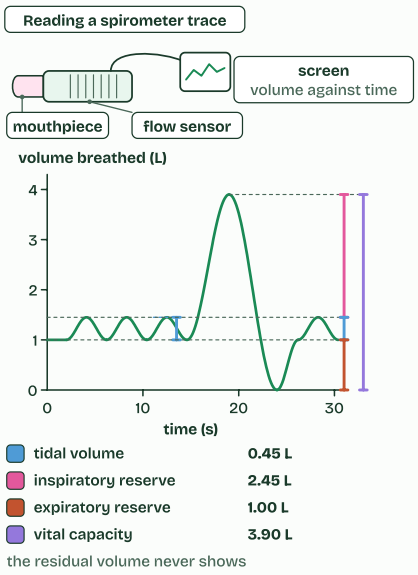
5 _____: the extra you can breathe out after an ordinary breath out.

6 _____: the most air you can move in one breath, from the deepest breath in to the hardest breath out: the other three added together.

Your own notes

ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each.

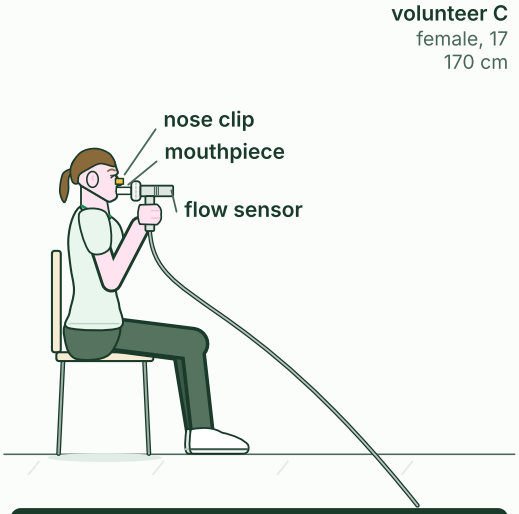


tidal volume	0.45 L
inspiratory reserve	2.45 L
expiratory reserve	1.00 L
vital capacity	3.90 L

the residual volume never shows

ANNOTATE THE FIGURE

Label the key parts and add a note on what it shows.





Trial	TV / dm³	IRV / dm³	ERV / dm³	VC / dm³
1	----------	----------	----------	----------
2	----------	----------	----------	----------
3	----------	----------	----------	----------
mean	----------	----------	----------	----------

SPOT THE MISTAKE

A student writes: "Vital capacity is all the air in the lungs." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 12 in two or three sentences of your own.

13 A carrier with four hands

B3.1.11 HL

CUES

Predict: A haemoglobin has four haem groups. What does the first oxygen to bind do to how easily the others bind?

What is meant by haemoglobin?

What is meant by haem group?

What is meant by cooperative binding?

What is meant by allosteric?

NOTES

1 Almost all of it travels bound to _____, which packs every red blood cell.

2 A haemoglobin molecule is four polypeptide chains held together, each folded round a _____ with an iron ion at its centre, and each iron binds one oxygen molecule.

3 That is _____.

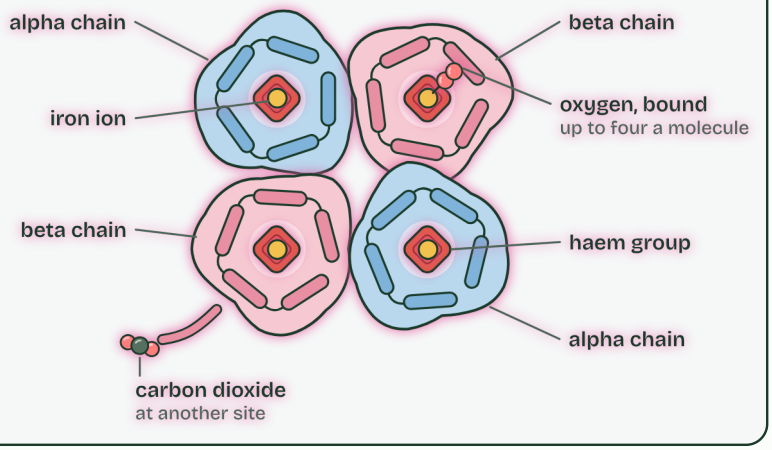
4 Binding at a site other than the one a molecule works at is called _____ binding, "another site".

Your own notes

ANNOTATE THE FIGURE

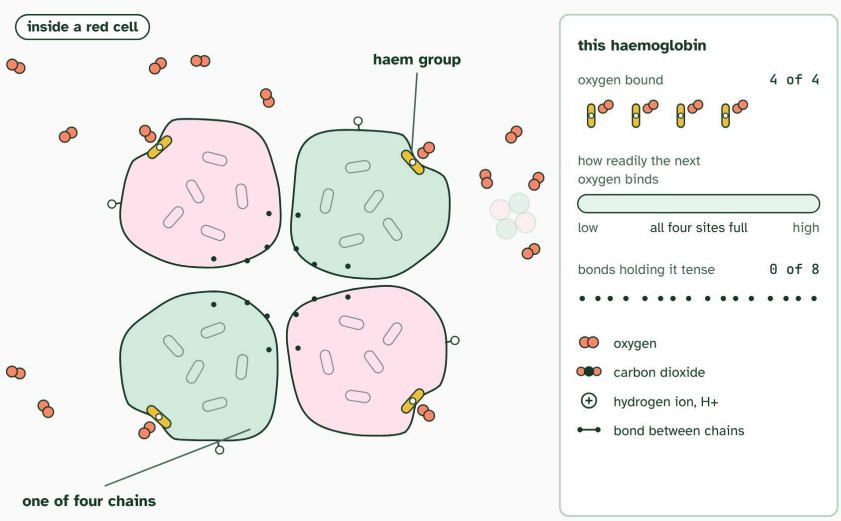
Label each part and say what it does: an alpha chain, a beta chain, a beta chain, an alpha chain, another site, a haem group, the iron ion, oxygen, bound.

One haemoglobin, drawn flat



ANNOTATE THE FIGURE

Annotate this still from the animation (One haemoglobin takes up oxygen): what is happening, and why?



SPOT THE MISTAKE

A student writes: "Each red cell carries one oxygen." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 13 in two or three sentences of your own.

14 The S-shaped curve

B3.1.13 HL

CUES

Predict: The curve is shallow at low pO2, steep in the middle and flat at the top. What makes the middle so steep?

What is meant by oxygen dissociation curve?

What is meant by saturation?

What is meant by partial pressure?

NOTES

1 An _____ shows it.

2 Up the side is the _____: the percentage of the haem groups carrying oxygen.

3 Along the bottom is the _____ of oxygen, pO_2, in kilopascals (kPa): how much oxygen there is.

4 Four measurements of blood at different partial pressures of oxygen (pO_2), plotted as the percentage of its haemoglobin carrying oxygen: its _____.

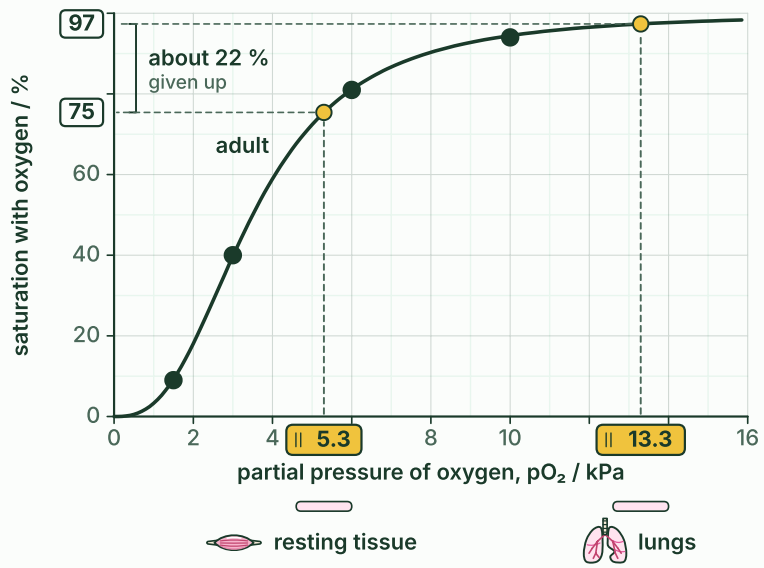
5 The curve through them is _____: shallow at the lowest pO_2, steep in the middle, flat at the top. This is the oxygen dissociation curve of adult haemoglobin.

6 Read it: blood leaving the _____ (13.3 kPa) is about 97 % saturated; blood leaving _____ (5.3 kPa) about 75 %. About 22 % of the haemoglobin gave up its oxygen there.

Your own notes

ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each: 1 saturation; 2 S-shaped; 3 lungs, resting tissue.



REMEMBER IT

Which way the curve moves

L Left	R Right
L	R

SPOT THE MISTAKE

A student writes: "The y-axis is the amount of oxygen in the blood." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 14 in two or three sentences of your own.

15 Foetal against adult

B3.1.11 HL

CUES

Predict: In the placenta the mother's blood and the foetus's blood are both at low oxygen levels. For oxygen to pass to the foetus, what must be true of foetal haemoglobin?

What is meant by foetal haemoglobin?

NOTES

1 _____ is built from different chains: two of the same alpha chains as an adult's, but two gamma chains in place of the adult's beta chains.

2 The mother's haemoglobin, at this low pO_2, _____ some of its oxygen, which diffuses towards the barrier.

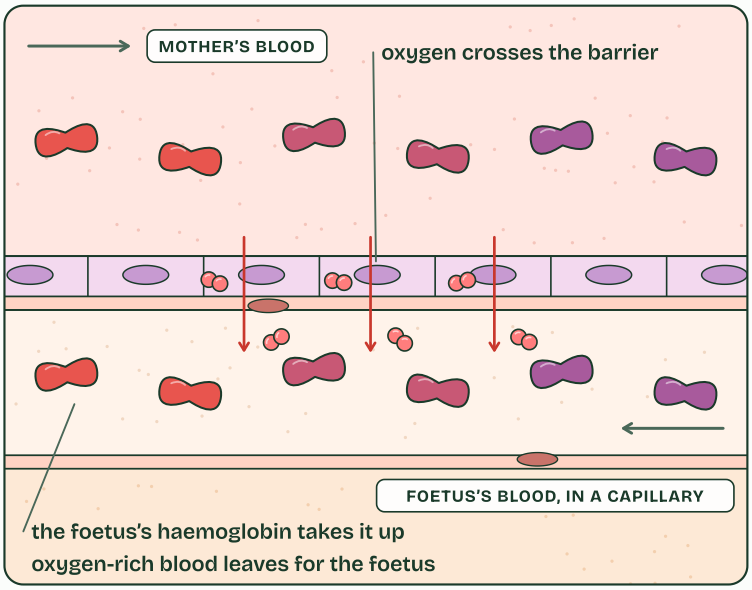
3 The oxygen crosses, and the foetus's haemoglobin _____ at the low pO_2 there: it holds oxygen more tightly than the mother's. Its red cells leave oxygen-rich, for the foetus.

4 Foetal haemoglobin's curve lies to the _____ of the adult curve: at the same pO_2 it is more saturated. It has a higher _____ for oxygen.

Your own notes

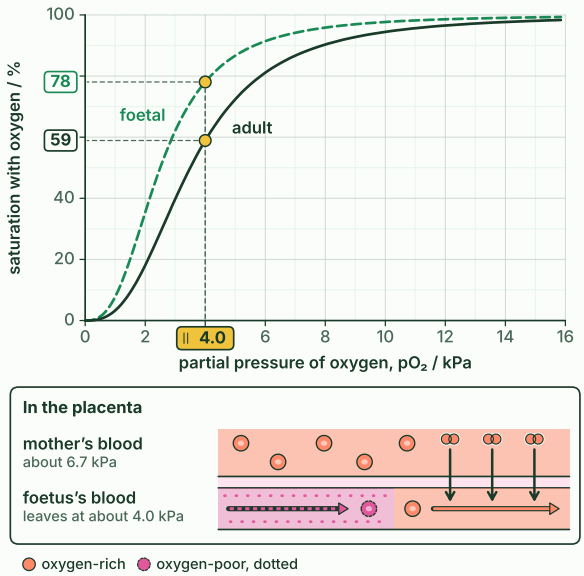
ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



SPOT THE MISTAKE

A student writes: "The foetus's blood is its mother's." Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 15 in two or three sentences of your own.

16 More carbon dioxide, more oxygen delivered

B3.1.12 HL

CUES

Predict: A muscle is working hard and its carbon dioxide is high. At the same pO2, what does this do to the haemoglobin passing through?

What is meant by bohr shift?

NOTES

1 That move of the curve to the right is the _____.

2 Carbon dioxide, and the hydrogen ions made from it in the cell, bind to the haemoglobin at their own sites. Its grip on oxygen loosens: its _____, and the first oxygen goes.

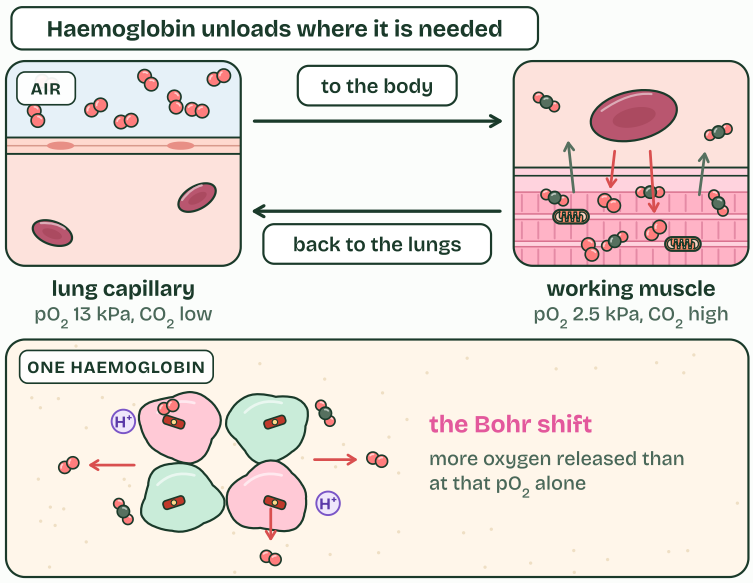
3 So it releases _____ than it would at that pO_2 alone, into the muscle that needs it most: the Bohr shift. The cell goes back to the lungs oxygen-poor, where the carbon dioxide leaves and it loads again.

4 With the carbon dioxide of blood in working muscle (pCO_2 about 8.5 kPa) the curve moves to the _____: a lower affinity for oxygen. This is the _____.

Your own notes

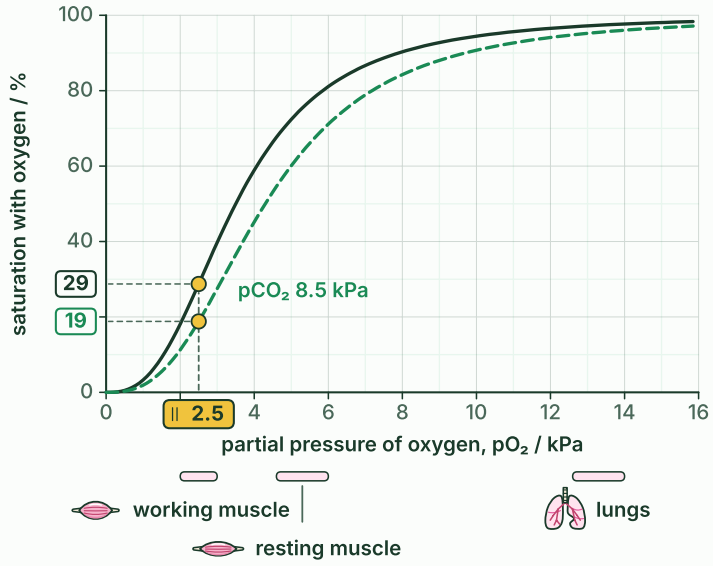
ANNOTATE THE FIGURE

Number the 5 steps on the figure and note what happens at each.



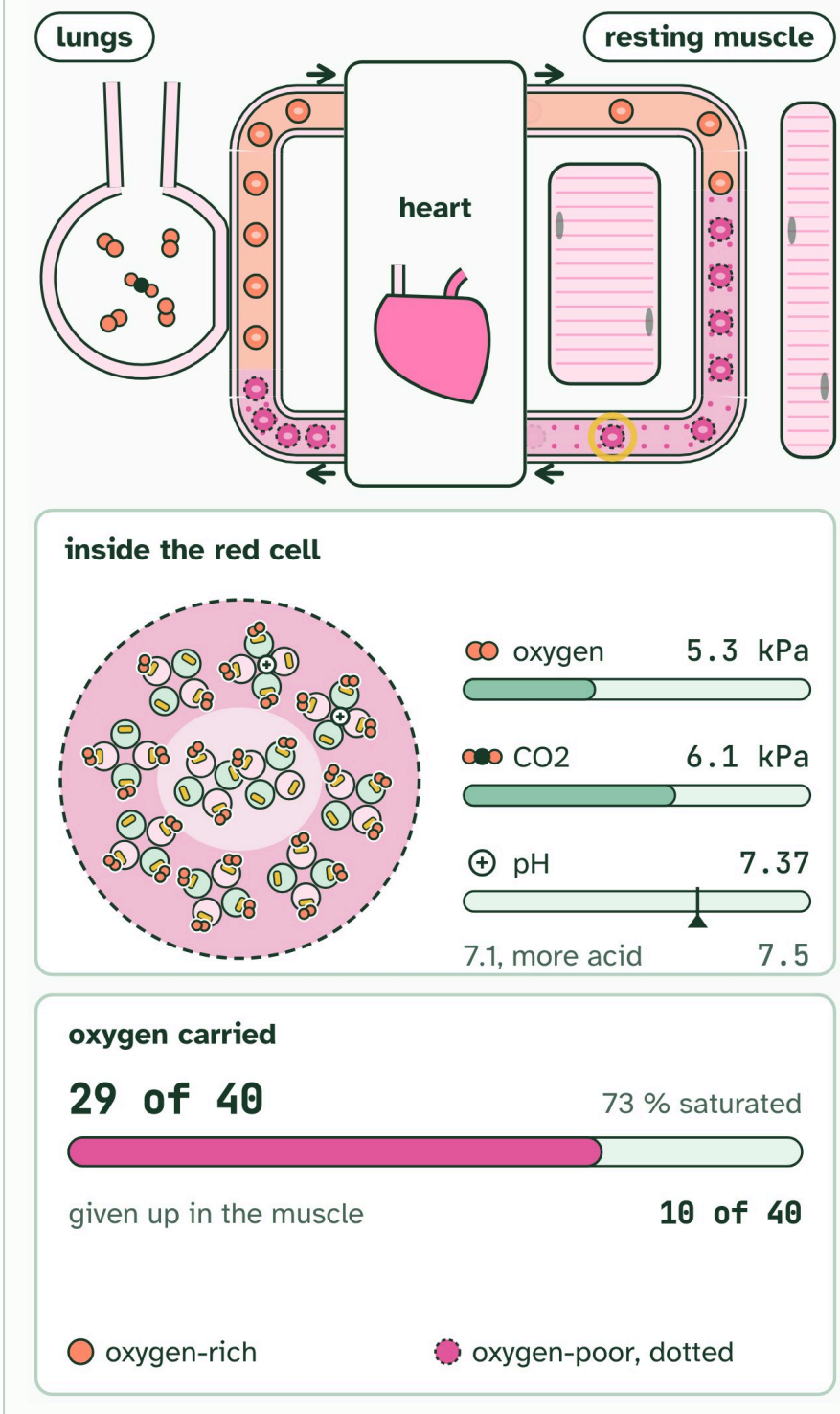
ANNOTATE THE FIGURE

Number the 3 steps on the figure and note what happens at each.



ANNOTATE THE FIGURE

Annotate this still from the animation (From lung to working muscle): what is happening, and why?



SPOT THE MISTAKE

A student writes: “The curve moves right, so haemoglobin takes up more oxygen.” Spot the mistake, then put it right.

The mistake

Put it right

SUMMARY

Sum up section 16 in two or three sentences of your own.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on B3.1 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=B3.1&level=HL&paper=quiz&marks=15&src=ep

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.