St. Ambrose College

A Level Biology (Year 12)

Knowledge Organiser: Unit 3 Organisms exchange (3.1-3.3)

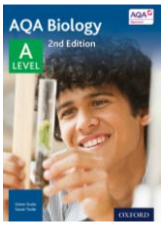
3.1 Surface area to volume ratio

3.2 Gas exchange

3.3 Digestion and absorption

For every 1 hour A Level Biology lesson you are expected to spend at least 1 hour independently reviewing the subject content. The following resources should be referred to regularly to support your independent work.

You have been provided with a printed copy of the full subject specification (also available on the AQA website https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402/specification-at-a-glance). Use this to follow the learning in lessons…track your progress and be aware of what is still to come.



kerboodle

Use the textbook on www.kerboodle.com after every lesson to develop your understanding. Read the relevant pages, add detail to your class notes and complete the summary tasks. Create your own summary notes/flashcards for future use in the run up to exams.

Unit 3 Organisms exchange on pages 128-199 Surface area to volume ratio (pg130-132) Gas exchange (pg133-150) Digestion and absorption (pg151-160)

SENECA www.senecalearning.com

Use regularly between lessons to review basic content and to become more familiar with key terminology. https://senecalearning.com/en-GB/

PMT •resources•tuition•courses

Access detailed revision notes, key definitions, flash cards, past paper questions and mark schemes. https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/

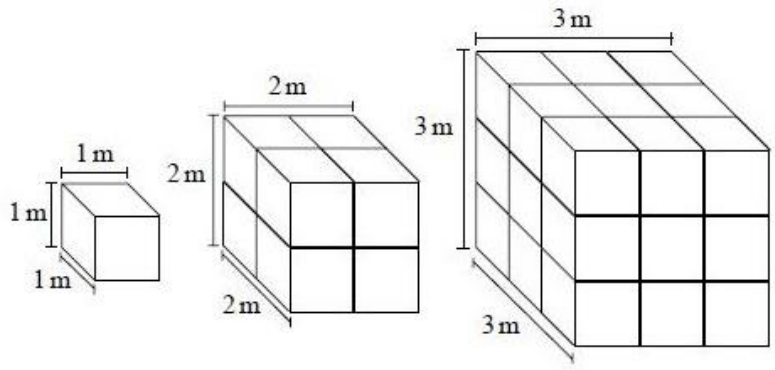
As an A Level student you are expected to take a proactive approach to your studies; arrive to lessons fully equipped and prepared for what you will be learning about (read ahead in the specification/textbook), focus and participate in lessons, ask for help/clarification when you are unsure and spend time after the lesson consolidating/embedding new learning.

3.1 Surface area to volume ratio

- Surface area = area of exposed/outer surface
- Volume = amount of space an object takes up

Relationship between the size of organism and its SA:V

- Smaller objects tend to have a higher SA:V than larger objects.
- This can be seen in organisms eg. hippo vs. mouse
- The relationship between SA and V can be calculated and proven mathematically:



surface area	$6m^2$	$24m^2$	$54m^2$
volume	$1m^3$	$8m^3$	$27m^3$
surface area: volume	6:1	3:1	2:1

Relationship between SA:V (and thus the size of an organism) and metabolic rate

- Rate of heat loss / heat lost per unit body mass increases as SA:V increases
- i.e. more heat lost per unit body mass in smaller animals with a high SA:V
- so they need a higher metabolic rate / faster respiration
- to generate enough heat to maintain a constant body temperature i.e. replace lost heat

Adaptations to facilitate exchange as this ratio reduces in larger organisms include changes to body shape and the development of systems

- Larger organisms need a specialised surface / organ for gaseous exchange e.g. lungs
- because they have a smaller SA:V and a long diffusion pathway (and skin is waterproof / gas tight)
- as well as having a high demand for oxygen and to remove carbon dioxide

3.2 Gas Exchange

Adaptations of gas exchange surfaces shown by gas exchange…

Across the body surface of a single-celled organism

- **Thin, flat** shape
    - **Large SA(:V)**
    - **Short diffusion pathway**/distance (all parts of cell are a small distance away from exchange surfaces)
- For rapid diffusion e.g. oxygen / carbon dioxide

In the tracheal system of an insect

1. Air moves through **spiracles** (pores) on the surface of the insect
2. Air moves through **tracheae**
3. Gas exchange at **tracheoles** directly to/from cells
    - Oxygen diffuses down conc. gradient to respiring cell
    - Carbon dioxide diffuses down conc. gradient from respiring cells

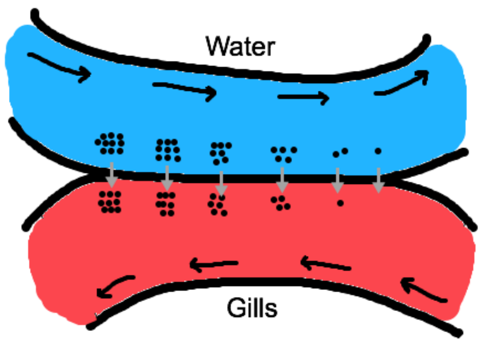
Adaptations: lots of thin, branching tracheoles → short diffusion pathway and SA(:V) → rapid diffusion

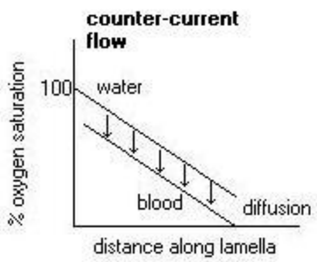
Note: *rhythmic abdominal movements increase the efficiency of gas exchange by increasing the amount of air/oxygen entering → maintains greater concentration gradient for diffusion*

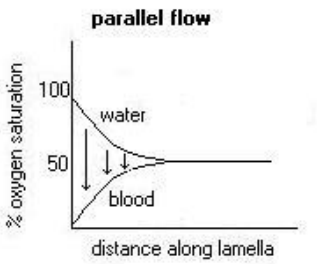
Across the gills of fish

- Each gill is made of lots of gill filaments (thin plates) which are covered in many lamellae
- Gill filaments provide a large surface area, lamellae increase surface area even more
- Vast network of capillaries on lamellae → remove oxygen to maintain a concentration gradient
- Thin/flattened epithelium → shorter diffusion pathway between water and blood

- ## Counter current flow
    - Blood flows through lamellae and water flows over lamellae in opposite directions
    - Always a higher concentration of oxygen in water than the blood it is near
    - Hence, a concentration gradient of oxygen between the water and blood is maintained along the whole length of lamellae (/gill plate) → **equilibrium not met**
    - Maximising diffusion of oxygen







Note: *if the current was parallel, equilibrium would be met, so a concentration gradient wouldn't be maintained and oxygen wouldn't diffuse into the blood along the whole gill plate*

Adaptations of gas exchange surfaces shown by gas exchange…
By the leaves of dicotyledonous plants

- Process of gas exchange in leaves
  - Carbon dioxide / oxygen diffuse through the stomata
  - Stomata opened by guard cells
  - Carbon dioxide / oxygen diffuse into mesophyll layer into air spaces
  - Carbon dioxide / oxygen diffuse down concentration gradient
- Adaptations
  - Lots of stomata (small pores) that are close together
    - Large surface area for gas exchange / unimpaired movement of gases / gases do not have to pass through cells to reach mesophyll
  - Interconnecting air space in mesophyll layers (exchange surface)
    - Gases come into contact with mesophyll cells
  - Mesophyll cells have a large surface area
    - Rapid diffusion of gases
  - Thin
    - Short diffusion pathways

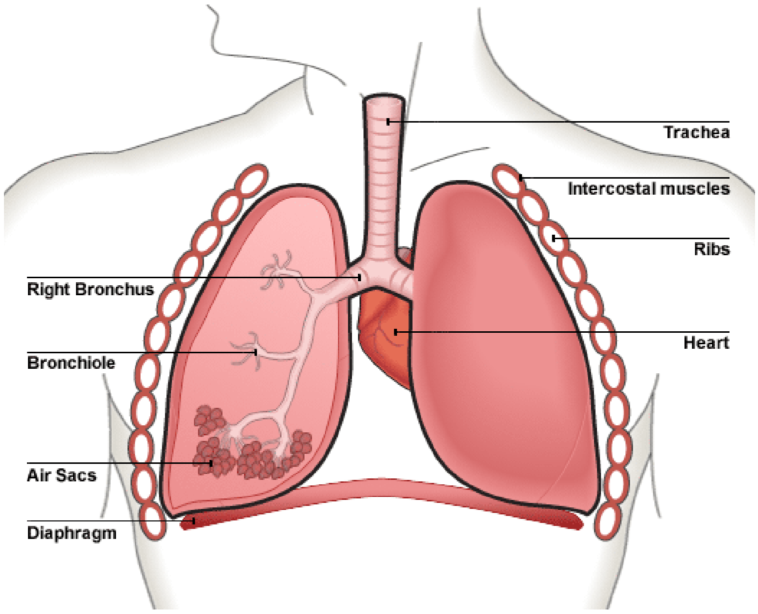
Structural and functional compromises between the opposing needs for efficient gas exchange and the limitation of water loss shown by:
Xerophytic plants

- Thick waxy cuticle
  - Increases diffusion distance → less evaporation
- Stomata in pits/grooves
  - 'Trap' water vapour → water potential gradient decreased → less evaporation
- Rolled leaves
  - 'Trap' water vapour → water potential gradient decreased → less evaporation
- Spindles/needles
  - Reduces surface area to volume ratio
- Hairs
  - 'Trap' water vapour → water potential gradient decreased → less evaporation

Structural and functional compromises between the opposing needs for efficient gas exchange and the limitation of water loss shown by:
Terrestrial insects

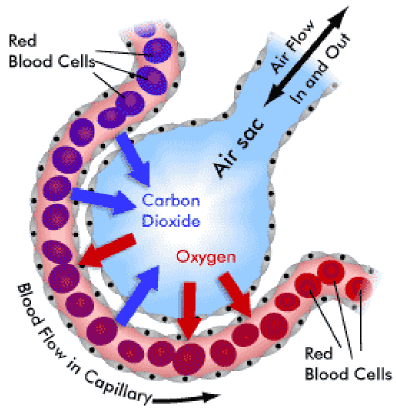
- Thick waxy cuticle
  - Increases diffusion distance → less evaporation
- Spiracles can open and close
  - Open to allow oxygen in, close when water loss too much

The gross structure of the human gas exchange system



- Trachea (windpipe)
- Splits into two bronchi
- Each bronchus branches into smaller tubes called bronchioles
- Bronchioles end in air sacs called alveoli

Features of the alveolar epithelium (gas exchange surface)



- Squamous epithelium = thin/one cell thick
  - Short diffusion pathway → fast diffusion
- Large surface area to volume ratio
  - Fast diffusion
- Permeable
- Good blood supply from network of capillaries
  - Maintains concentration gradient
- Elastic tissue allows it to recoil after expansion
- Surfactant

How does gas exchange occur in the alveoli?

- Oxygen diffuses from air in the alveoli
- Down its concentration gradient
- Across the alveolar epithelium
- Across the capillary endothelium
- Into the blood (binds to haemoglobin in RBCs)

- Carbon dioxide diffuses from capillary (from plasma and RBCs)
- Down its concentration gradient
- Across the capillary endothelium
- Across the alveolar epithelium
- Into the air in the alveoli

How are the lungs adapted for efficient/rapid gas exchange?

- Many alveoli/capillaries
  - Large surface area → fast diffusion
- Alveoli/capillary walls are thin / short distance between alveoli and blood
  - Short diffusion distance → fast diffusion
- Ventilation/circulation
  - Maintains concentration gradient → fast diffusion

Example exam questions

Forced expiration volume (FEV1) is the volume of air a person can breathe out in 1 second. Emphysema is a lung disease which results in a reduction in FEV1. Emphysema is mainly caused by long-term cigarette smoking.

Scientists investigated the effects of ageing and long-term cigarette smoking on FEV1 and on the development of emphysema.

Figure 7 shows their results:

(a) *Scientists determined the mean FEV1 value of 25-year-olds in the population.*
Suggest two precautions that should have been taken to ensure that this mean FEV1 value was reliable. ***(2 marks)***

- ✓ *Large sample size*
- ✓ *Individuals chosen at random*
- ✓ *Are healthy*
- ✓ *Equal number of males and females (accept: same sex)*
- ✓ *Repeat readings*

(b) ***Explain the importance of determining a mean FEV1 value of 25-year-olds in this investigation.*** ***(2 marks)***

- ✓ *(For) comparison*
- ✓ *To see the effect of age/emphysema/smoking*
  OR
  Takes into account outliers / anomalous results

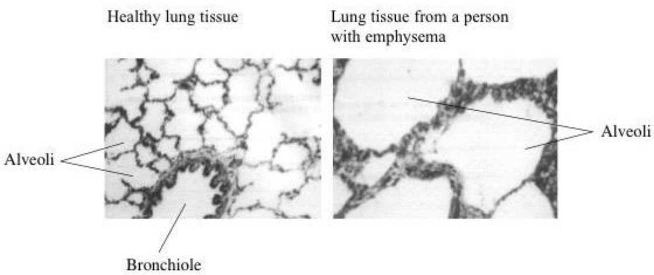
(c) *The mean FEV1 value of non-smokers decreases after the age of 30.* ***Use your knowledge of ventilation to suggest why.*** ***(1 mark)***

- ✓ *Internal intercostal muscle(s) less effective*
- ✓ *Less elasticity (of lung tissue)*

(d) *One of the severe disabilities that results from emphysema is that walking upstairs becomes difficult.*
Explain how a low FEV1 value could cause this disability. ***(3 marks)***

- ✓ *Less carbon dioxide removed (accept: carbon dioxide increases)*
- ✓ *Less oxygen (uptake/in blood)*
- ✓ *Less (aerobic) respiration/ ATP*
  OR
  (More) anaerobic respiration

Emphysema is a disease that affects the alveoli of the lungs and leads to the loss of elastic tissue. The photographs show sections through alveoli of healthy lung tissue and lung tissue from a person with emphysema.
Both photographs are at the same magnification.



Using the evidence given above and your own knowledge, explain why a person with emphysema is unable to do vigorous exercise. ***(4 marks)***

- ✓ *Not enough O2*
- ✓ *For increased respiration / for ATP needed for exercise*
- ✓ *Reference to decreased surface area of alveoli / longer diffusion pathway*
- ✓ *Less gas exchange / diffusion / less oxygen passes into the blood*
- ✓ *OR*
- ✓ *Reference to decreased elasticity / reduced elastic recoil*
- ✓ *Meaning breathing becomes more difficult / lungs do not empty*

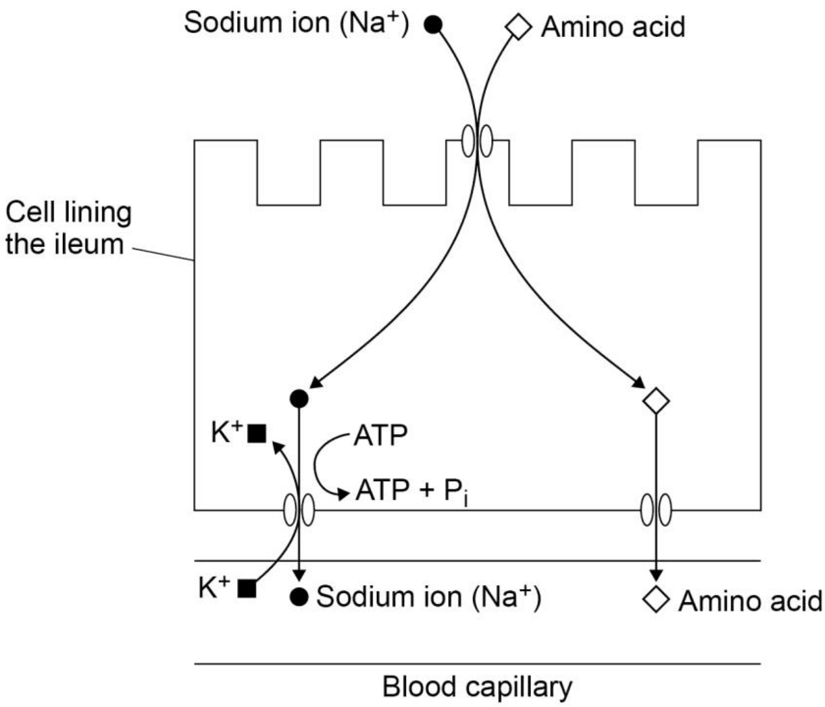
Mechanisms for the absorption of the products of digestion by cells lining the ileum of mammals, to include co-transport mechanisms for the absorption of amino acids and of monosaccharides

1. Sodium ions **actively** transported out of epithelial cells lining the ileum, into the blood, by the sodium-potassium pump. Creating a concentration gradient of sodium (higher conc. of sodium in lumen than epithelial cell)
2. Sodium ions and glucose move by facilitated diffusion into the epithelial cell from the lumen, via a co-transporter protein
3. Creating a concentration gradient of glucose – higher conc. of glucose in epithelial cell than blood
4. Glucose moves out of cell into blood by facilitated diffusion through a protein channel

Example exam question

Figure 1 shows the co-transport mechanism for the absorption of amino acids into the blood by a cell lining the ileum.

The addition of a respiratory inhibitor stops the absorption of amino acids.
Use figure 1 to explain why. *(3 marks)*



✓ *No/less ATP produced*
OR
No active transport
✓ *Sodium (ions) not moved (into/out of cell) / sodium ions increase in cell*
✓ *No diffusion gradient for sodium (to move into cell with amino acid)*
OR
No concentration gradient for sodium (to move into cell with amino acid);

Mechanisms for the absorption of the products of digestion by cells lining the ileum of mammals, to include the role of micelles in the absorption of lipids

- Monoglycerides and fatty acids diffuse out of micelles (in lumen) into epithelial cell
  - Because lipid soluble
- Monoglycerides and triglycerides recombine to triglycerides which aggregate into globules
- Globules coated with proteins to form chylomicrons
- Leave via exocytosis and enter lymphatic vessels
- Return to blood circulation

Design and carry out investigations into the effect of a pH or bile salts on the rate of reaction catalysed by a digestive enzyme

Example exam question:

Students investigated the digestion of lipids in milk by lipase. They set up three test tubes.
- *In tube A, milk was incubated with lipase only*
- *In tube B, milk was incubated with lipase and bile salts*
- *In tube C, milk was incubated with bile salts only*

The results are shown in the table

	Mean pH		
Time / minutes	A Lipase only	B Lipase and bile salts	C Bile salts only
0	8.5	8.5	8.5
10	8.0	7.7	8.5
20	7.6	7.0	8.5
30	7.3	6.5	8.5
40	7.0	6.5	8.5
50	6.5	6.5	8.5
60	6.5	6.5	8.5

(a) The pH changed in test tube A. ***Explain why.*** **(2 marks)**
- ✓ *Production of fatty acids*
- ✓ *(Fatty) acids (produced) cause fall in pH*

(b) The pH did not fall below a value of 6.5 in tube A. ***Suggest one reason why.*** **(1 mark)**
- ✓ *Substrate/lipids all used up*
- ✓ *Equilibrium reached*
- ✓ *(pH) denatures enzymes*

(c) The rate at which the pH fell in tube A was different from the rate at which the pH fell in tube B. ***Explain why pH fell at a different rate.*** **(2 marks)**
- ✓ *Bile salts produce many small lipid droplets/emulsifies lipids*

(d) ***Explain why test tube C set up.*** **(1 mark)**
- ✓ *To show that lipase has to be present for pH to change/reaction to take place / to show that bile salts do not digest lipids*

Note: Visking tubing can be used to model the absorption of the products of digestion - synthetic selectively permeable membrane