AS Biology OCR

Unit F211: Cells, Exchange & Transport

Module 2.1 Exchange Surfaces & Breathing

Notes & Questions
1.2.1

Explain, in terms of surface area:volume ratio, why multicellular organisms need specialised exchange surfaces and single-celled organisms do not.

- **Uni-cellular Organisms**
  - They are only 1 cell in size
  - They have a surface area that is large in comparison to their small internal volume
    - We therefore say that they have a large surface area : volume ratio.
  - This means;
    - They have a large surface to absorb the small amounts of substances that they require to survive and also remove waste.
    - These include;
      - Essential substances such as; Oxygen, Water, nutrients
      - Waste substances such as; carbon dioxide & waste.
    - They do not require a highly specialised exchange surface, they just absorb what they need across their outer surfaces.
    - Their surface barrier is thin and the absorbed substances do not need to travel very far to where they are required, nor does waste for it to be removed.

- **Multi-cellular Organisms**
  - As multi-cellular organisms become larger their volume increases rapidly while their surface area although increasing does so to a much lesser effect
  - In other words the increases in the surface area of the organism are smaller than the increases in the volume of the organism
    - We refer to the organism having a smaller surface area : volume ratio.
  - This means;
They have a small surface to absorb the large amounts of substances that they require to survive and also remove waste.

These include:
- Essential substances such as; Oxygen, Water, nutrients
- Waste substances such as; carbon dioxide & waste.

They do require a highly specialised exchange surface, as they cannot just absorb what they need across their outer surfaces.

Their outer surface barrier is many cells deep making diffusion slow, again a reason why they require a specialised exchange surface which is very thin.

The absorbed substances need to travel far to where they are required, and so does waste for it to be removed. This means that their exchange surface is always associated with a circulatory system.

They have large demands on the essential substances.

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**Surface Area : Volume (SA:V) Ratio**

<table>
<thead>
<tr>
<th>Total surface area (height x width x number of sides x number of boxes)</th>
<th>6</th>
<th>150</th>
<th>750</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total volume (height x width x length x number of boxes)</td>
<td>1</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>Surface-to-volume ratio (surface area / volume)</td>
<td>6</td>
<td>1.2</td>
<td>6</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>Uni-cellular Organism</th>
<th>Multi-cellular Organism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demands on nutrition</strong></td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Surface Area</strong></td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>Small</td>
<td>Large</td>
</tr>
<tr>
<td><strong>SA : V Ratio</strong></td>
<td>Large</td>
<td>Small</td>
</tr>
<tr>
<td><strong>How it obtains nutrition</strong></td>
<td>Simple diffusion</td>
<td>Simple diffusion</td>
</tr>
<tr>
<td><strong>Diffusion distance</strong></td>
<td>short</td>
<td>Large</td>
</tr>
<tr>
<td><strong>Diffusion time</strong></td>
<td>short</td>
<td>Long</td>
</tr>
<tr>
<td>Specialised exchange surface</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td><img src="image" alt="Diagram" /> scale: 0.075 mm</td>
<td><img src="image" alt="Diagram" /> A</td>
<td><img src="image" alt="Diagram" /> B</td>
</tr>
<tr>
<td>surface area / mm²</td>
<td>0.28</td>
<td>3.1</td>
</tr>
<tr>
<td>volume / mm³</td>
<td>0.02</td>
<td>0.59</td>
</tr>
<tr>
<td>surface area to volume ratio</td>
<td>14:1</td>
<td>2:1</td>
</tr>
</tbody>
</table>

- Why do multi-cellular organisms require a specialised exchange surface?
  - Size
  - Multi-cellular larger / AW;
  - Large demands on essential substances
  - Cells are deep in the body;
  - Regions requiring materials separated by a distance that is too great
  - Need to get materials to all parts / AW;
  - Diffusion alone is too slow / AW;

Describe the features of an efficient exchange surface, with reference to diffusion of oxygen and carbon dioxide across an alveolus.

- Features of an efficient exchange surface
  - Increase the surface area to provide enough space for molecules to pass through
    - Often achieved by folding walls and membranes
    - Many alveoli with internal walls
  - Provide a thin barrier to reduce the diffusion distance
    - Alveoli walls are made of squamous epithelial cells (<0.5µm thick)
    - Capillary walls are made of squamous epithelial cells (<0.5µm thick)
- **The diffusion distance between the alveoli and the capillary is less than 1µm thick**

  - Maintain a diffusion gradient by
    - Providing a fresh supply of molecules on one side to keep the concentration high
    - *Inspiration and expiration keeps the concentration of oxygen in the alveoli high and carbon dioxide low.*
    - *The heart beating keeps the blood flowing keeping the concentration of oxygen in the blood low and the carbon dioxide high.*

  - Removal of required molecules on the other side to keep the concentration low.
  - Associated with a circulatory system to transport essential substance to all cells quickly and remove waste molecule quickly from all cells.

- **Examples of specialised exchange surfaces**
  - Small intestines
  - Liver
  - Root hari cells
  - Fungal hyphae
  - Alveoli

**Describe the features of the mammalian lung that adapt it to efficient gaseous exchange.**

- **Large Surface Area**
  - Created by many many alveoli
  - They all have internal surfaces which increase the surface area to the size of 70m²

- **Barrier permeable to Oxygen & Carbon Dioxide**
  - Created by plasma membranes that surround the very thin squamous epithelial cells

- **Thin barrier to reduce diffusion distance.**
  - The alveoli wall (Not cell wall as they are animal cells) is extremely thin
  - The capillary wall is also extremely thin
  - The diffusion distance between the alveoli and the capillary is less than 1µm thick

- **Maintaining a diffusion distance**
  - Inspiration and expiration keeps the concentration of oxygen in the alveoli high and carbon dioxide low.
  - The heart beating keeps the blood flowing keeping the concentration of oxygen in the blood low and the carbon dioxide high.
Describe, with the aid of diagrams and photographs, the distribution of cartilage, ciliated epithelium, goblet cells, smooth muscle and elastic fibres in the trachea, bronchi, bronchioles and alveoli of the mammalian gaseous exchange system.

Describe the functions of cartilage, cilia, goblet cells, smooth muscle and elastic fibres in the mammalian gaseous exchange system.
• **Outer Layer - Trachea & Bronchi**
  o Cartilage
    ▪ Structural – hold airways open.
    ▪ Incomplete ring – flexibility

• **Middle Layer – Trachea, Bronchi & Bronchioles**
  o Smooth Muscle
    ▪ Contract – constricts the airway
    ▪ Especially effective in the bronchioles.
  o Elastic Fibres
    ▪ Recoil – allows airways to dilate after smooth muscle relaxes.
  o Glandular tissue
    ▪ Under the epithelium
    ▪ Secrete mucus – traps tiny particles in air

• **Inner Layer - Epithelium**
• Ciliated Epithelium – Trachea, Bronchi & Bronchioles
  o Epithelium – tissue that covers the outside of a structure
  o Cilia – Tiny hair-like structures.
    - Move in synchrony to waft mucus to back the throat.
• Squamous Epithelium – Alveoli
  o Epithelium – tissue that covers the outside of a structure.
    - Very thin, flat cells that provide a very short diffusion distance
What?

Alveoli
Outline the mechanism of breathing (inspiration and expiration) in mammals, with reference to the function of the rib cage, intercostal muscles and diaphragm.

- Inspiration (Inhalation)
  - Diaphragm contracts
  - Diaphragm flattens and moves down
  - Intercostal muscles between the ribs contract
  - The intercostal muscles lift the rib cage up and out
  - The volume in the chest cavity increases
  - This increase in volume decreases the air pressure in the lungs below atmospheric
  - Air is drawn into the lungs down a pressure gradient.

- Expiration (Exhalation)
  - Diaphragm relaxes
  - Diaphragm curves and moves up into chest cavity
  - Intercostal muscles between the ribs relax
  - The rib cage falls down and in under its own weight
  - The volume in the chest cavity decreases
  - This decrease in volume increases the air pressure in the lungs above atmospheric
  - Air is forced out of the lungs down a pressure gradient.

Explain the meanings of the terms tidal volume and vital capacity.

- Tidal Volume
  - The volume of air moved in and out of the lungs with each breath when a person is at rest.

- Vital Capacity
  - The largest volume of air that can be moved into and out of the lungs in any one breath.
Describe how a spirometer can be used to measure vital capacity, tidal volume, breathing rate and oxygen uptake.
1.2.1

**Inspiratory Reserve Volume**
- How much air can be inspired over and above the tidal volume

**Expiratory Reserve Volume**
- How much air can be expired over and above the tidal volume
Analyse and interpret data from a spirometer.

- Below is a spirometer trace
- Can you calculate;
  - Breathing rate?
  - Tidal volume?
  - Vital capacity?
  - Oxygen consumption per minute?
volume of air in spirometer / dm³

X

1.2.1

Andy Todd
1. A student investigated how the surface area of a single-celled organism is related to its volume. The student used two spheres, A and B, as models of two organisms. The surface area and volume of each sphere was calculated.

The results are shown in the table below.

<table>
<thead>
<tr>
<th></th>
<th>sphere A</th>
<th>sphere B</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter / cm</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>surface area / cm$^2$</td>
<td>3.14</td>
<td>28.27</td>
</tr>
<tr>
<td>volume / cm$^3$</td>
<td>0.52</td>
<td>14.14</td>
</tr>
</tbody>
</table>

(i) The student calculated the surface area: volume ratio of sphere B as 2:1.

Calculate the surface area: volume ratio of sphere A. Show your working.

.......................................................................................................................... [2]

(ii) How does the surface area: volume ratio of sphere B differ from that of sphere A?

................................................................................................................................................... [1]
(iii) Single-celled organisms generally have a surface-area to volume ratio more like that of sphere A than sphere B.

Explain why.

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[2]
[Total 5 marks]

2. Outline how the diaphragm and intercostal muscles cause inspiration.

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[Total 4 marks]
3. Explain, using the term surface area to volume ratio, why large, active organisms need a specialised surface for gaseous exchange.

[Total 2 marks]

4. Fig. 1 (a) is a diagram of a part of a mammalian lung.

Fig. 1 (b) is an enlargement of part of the lining of the bronchus.
1.2.1

(i) Name the two types of cell, A and B, shown lining the bronchus.

A .................................................................

B .................................................................

(ii) Describe how cell types A and B work together to keep the lung surface clear of dust and other particles.

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(iii) The bronchus wall also contains smooth muscle fibres.

State the function of the smooth muscle fibres.

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[Total 6 marks]
5. The diagram below is a drawing of an alveolus together with an associated blood capillary.

(i) State a feature, **visible in the diagram**, which shows that squamous epithelial cells are eukaryotic.

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[1]

(ii) State why squamous epithelium is described as a tissue.

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[1]

(iii) State **two** features of a gas exchange surface, such as the lining of the alveolus.

1 ......................................................................................................................................................

2 ......................................................................................................................................................

[2]

[Total 4 marks]
6. State three features of the lung, visible in the photograph below, that permit efficient exchange of gases.

1. 
2. 
3. 

[Total 3 marks]
7. The lungs in the mammalian body are well developed to allow effective exchange of gases.

Describe the features of the lungs that make them effective organs for the exchange of gases.

*In your answer, you should use appropriate technical terms, spelled correctly.*

[Total 5 marks]
8. The figure below is a diagram of a spirometer, a piece of apparatus used to measure some aspects of breathing, such as breathing rate and vital capacity.

(a) (i) Outline the mechanism of inspiration.

In your answer you should use appropriate technical terms, spelt correctly.

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[3]
(ii) A person breathes through the mouthpiece of a spirometer.

State what happens to the air chamber in the figure above during inspiration.

........................................................................................................................................ [1]

(iii) Chamber T contains a chemical that absorbs carbon dioxide.

Suggest a chemical that could be used in chamber T to absorb carbon dioxide.

........................................................................................................................................ [1]

(b) Explain why a person using the spirometer to measure their vital capacity should wear a nose clip.

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........................................................................................................................................ [2]

(c) State two other precautions that should be taken when using a spirometer to measure vital capacity.

1 ........................................................................................................................................ [2]
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2 ........................................................................................................................................ [2]
........................................................................................................................................ [2]
[Total 9 marks]