Chapter 13
Gaseous exchange and exercise

Worksheet: Lung microscopy

*Practical 1: Investigating the mammalian gaseous exchange system (1)

*Practical 2: Investigating the mammalian gaseous exchange system (2)

*Practical 3: Investigating breathing volumes

End-of-chapter worksheet

Marking scheme: Worksheet

Marking scheme: End-of-chapter worksheet

*includes Guidance for teachers
Worksheet

Lung microscopy

Higher level

The diagrams below show the structure of the trachea, the bronchus and a bronchiole.

1. Use your books to locate and label the following structures on each diagram, as appropriate:
   - ciliated epithelium
   - air space
   - cartilage
   - smooth (involuntary) muscle
   - elastic fibres
   - goblet cell
   - mucus gland

TS of part of the trachea
TS of a bronchus

TS of a bronchiole
2 Complete the table below to show the distribution and functions of the different tissues in the trachea, bronchus, bronchioles and alveoli.

<table>
<thead>
<tr>
<th></th>
<th>Trachea</th>
<th>Bronchus</th>
<th>Bronchioles</th>
<th>Alveoli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliated epithelium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squamous epithelium</td>
<td></td>
<td></td>
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<tr>
<td>Cartilage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elastic fibres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[23]

Total: $\frac{37}{37}$  Score:  %
Practical 1

Investigating the mammalian gaseous exchange system (1)

Apparatus and materials
• lungs and trachea of sheep or pig
• scissors
• forceps
• blunt seeker
• scalpel
• dissection board
• surgical gloves

Introduction
In this practical you will carry out a dissection of the lungs and bronchial system of a mammal in order to investigate the structure of the mammalian gaseous exchange system. (In Practical 2 you will extend this investigation by examining microscope slides of some of the organs and tissues of the gaseous exchange system.)

Safety
See CLEAPSS Student Safety Sheets and Laboratory Handbook for further details when carrying out a risk assessment for this practical.

Procedure
1 Lay out the lungs on the dissection board and arrange them on either side with the curved surface facing upwards and the long ‘tubes’ towards the top of the board. Straighten out the tubes. You should now be looking at the dorsal surface of the lungs, i.e. from the back of the animal.

2 Examine the external appearance of the organs. In order to see all of them you will have to turn over the lungs so you can see them from the ventral view. You should be able to identify the following:
• the lobes of the left and right lungs;
• trachea;
• larynx;
• oesophagus;
• dorsal aorta;
• diaphragm;
• nerves.

You may also have the heart attached to the lungs. If so, see if you can trace the pathway taken by blood as it flows from the heart to the lungs and from the lungs back to the heart.

3 Answer these questions:
   a  How many lobes of the lungs are there?
   b  Describe what happens to the trachea as it passes between the lungs.
   c  How can you tell the difference between the trachea and the oesophagus?

4 Examine the trachea and run your finger, or a blunt seeker, down its length.

5 Cut open the trachea from the top with a pair of scissors and examine the inside surface.

6 Follow the trachea down as far as you can by cutting it open, and find the points at which it branches into the lobes of the lung. Continue cutting into the lung tissue to follow these airways into the lungs. Examine the surface of these airways.
7 Make two cuts across the middle of the trachea either side of one of the hard bands that you will have found.

8 Answer these questions:
   a Describe the internal surface of the trachea.
   b How many major branches of the trachea have you found?
   c Where do these branches go? What are they called?
   d Describe the arrangement of the hard material in the wall of the trachea. What is it made of? Is the material arranged in the same way in the airways inside the lungs as in the trachea? If not, describe the differences.

9 Cut through the lung tissue and examine its appearance. Look for small tubes that have a different appearance from the airways that you have been following. These are blood vessels. The small white vessels are arteries, the small pink vessels are veins. If it is attached, try tracing these back to the heart (you will find it easier to locate some veins on the surface of the lungs and start from there).

10 Answer these questions:
   a Describe the appearance of the lung tissue. Explain why it is like this.
   b What is the name given to the arteries in the lungs? What type of blood flows through them?
   c What is the name of the veins in the lungs? What type of blood flows through them?

11 When you have finished, dispose of the dissected material as instructed, wash the dissection board and place the instruments into disinfectant. Wash your hands thoroughly.
Guidance for teachers

If there is time, students may continue with Practical 2.

Always refer to the departmental risk assessment before carrying out any practical work. See the Part 3 Notes on practical activities, found in the Additional resources section, for additional guidance.
Practical 2

Investigating the mammalian gaseous exchange system (2)

Apparatus and materials
- microscope
- slide of transverse section of trachea
- slide of mammalian lung
- eyepiece graticule
- stage micrometer

Introduction
In this practical you will examine microscope slides of some of the organs and tissues of the gaseous exchange system.

Safety
Not applicable.

Procedure
1. Examine the slide of a cross-section of a trachea, using the low power of your microscope. If you have carried out Practical 1, compare what you can see with your observations when you dissected the trachea.
2. Make a plan drawing of the trachea to show the arrangement of the tissues. Use figure 13.1a in Biology 1 (page 174) to help you identify these. Do not draw individual cells. Look at page 18 of Biology 1 to remind yourself what a plan drawing should look like. Label your drawing.
3. Remove the slide from the microscope and measure the diameter of the trachea. Add this information as a scale to your drawing.
4. Annotate your drawing to show how the structure of the trachea is related to its function.
5. Now examine the section of trachea under high power. Look carefully at the tissue closest to the lumen (central air space). You should be able to find two cell types. Make a drawing of a small number of cells from this tissue. Use labels to identify the cells that you have drawn. Annotate your drawing to show how these structures are stained.
6. Examine the prepared slide of lung tissue under low power. Search the slide for the following structures:
   bronchi, bronchioles, alveoli, arteries, veins.
   You may need to look at several slides to find all of these structures. Look at figure 13.1b and c (page 174) of Biology 1 to help you identify these structures.
7. Make a drawing of three or four adjacent alveoli. Label your drawing and use annotations to explain how alveoli are adapted for gaseous exchange.
8. Use an eyepiece graticule to measure the distance between the air in an alveolus and a blood vessel. If you cannot do this, then measure the distance using figure 13.3 in Biology 1 (page 175). Note that the diameter of a red blood cell is 7 \( \mu \text{m} \). This should help you to calculate the distance that gases have to diffuse from air to blood.
9. Answer these questions:
   a. How can you tell the difference between sections of trachea, bronchi and bronchioles when they are viewed through the microscope?
   b. How can you tell the difference between arteries and veins in the lung tissue when they are viewed through the microscope?
Guidance for teachers

Students will find it easier to understand the sections of trachea and lung that they see through the microscope and in photographs if they can dissect some material as described in Practical 1.

Always refer to the departmental risk assessment before carrying out any practical work. See the Part 3 Notes on practical activities, found in the Additional resources section, for additional guidance.
Practical 3

Investigating breathing volumes

Apparatus and materials
• spirometer
• kymograph

Introduction
In this practical you will use a spirometer to measure some breathing volumes.

Safety
See CLEAPSS Student Safety Sheets and Laboratory Handbook for further details when carrying out a risk assessment for this practical. Between subjects, mouthpieces should be washed in dilute bleach solution followed by two washes in distilled water.

Procedure
1. Set up the spirometer with the water tank filled to the mark with water (see diagram). Open the air tubes to the mouthpiece and fill the floating lid about three-quarters full with water, by gently raising the lid. Close the tubes from the tank to the mouthpiece, so that the air is trapped in the lid.
2. Ask the person who is going to be the experimental ‘subject’ to wear a nose clip and to practise breathing through their mouth for a few minutes.
3. Now ask them to practise breathing into the spirometer mouthpiece, but with the tubes open to the outside air.
4. After a few minutes, switch the tap to connect the subject to the air in the spirometer. Allow them to breathe in and out for about ten breaths, and record the tidal volumes on the kymograph drum.
5. At the end of a normal expiration, ask the subject to take as deep an inspiration as they can manage, followed by as deep an expiration as possible. The recordings of these lung volumes can be used to find the vital capacity (see figure 13.5 in Biology 1 on page 176).
6 Ask the subject to return to normal breathing. After a few breaths the subject should breathe out and the tubes should be opened to the outside air again.

7 Calibrate the spirometer trace using the volume indicator attached to the lid of the spirometer. Allow the lid to fall slowly, stopping it at 0.5 dm³ intervals and marking the trace with the volumes.

8 If you have time, try to record tidal volumes and vital capacities of further experimental subjects. You could try to answer these questions:
   a Do boys have a greater tidal volume or vital capacity than girls?
   b Is there a correlation between vital capacity and body mass?

9 If the speed of revolution of the drum is known, you can calculate the average number of tidal breaths per minute.

10 The tidal volume of a person, when measured using a spirometer, is usually an overestimate. Can you think why this might be?
**Guidance for teachers**

If required, the inspiratory and expiratory reserve volumes may also be calculated from the differences between the tidal volume and vital capacity when inspiring or expiring. It is not necessary to use medical grade oxygen in the spirometer, but if air is used, it will not be possible to connect the subject to the spirometer for very long before the oxygen in the tank is depleted. However, there will be plenty of air to allow recording of the lung volumes.

Always refer to the departmental risk assessment before carrying out any practical work. See the Part 3 *Notes on practical activities*, found in the Additional resources section, for additional guidance.
End-of-chapter worksheet

1 State the word or phrase that best describes the following:
   a Membranes surrounding the lungs and lining the thoracic cavity. They contain
      a fluid that reduces friction.
   b The type of muscle present in the bronchioles.
   c Cells that secrete mucus into the trachea and bronchi.
   d A type of white blood cell that ‘patrols’ the surfaces of the airways, scavenging
      bacteria and dust particles.
   e The air remaining in the lungs after a forced exhalation.

2 a A man has a tidal volume of 0.36 dm$^3$ and a breathing rate of 18 breaths min$^{-1}$.
   Calculate his ventilation rate. Show your working.
   b A woman has a pulse rate of 62 and a stroke volume of 75 cm$^3$.
   Calculate her cardiac output. Show your working.

3 a Explain the difference between systolic and diastolic blood pressure.
   b When the heart ventricles relax, the diastolic blood pressure does not fall to
      zero. Give two reasons why this does not happen.
   c What effect does hardening of a person’s arteries have on the diastolic
      pressure? Explain why this is the case.
   d State four causes of long-term hypertension (high blood pressure).

4 Copy and complete the following description of events taking place during exercise.
   Before exercise, release of the hormone ________ causes the heart and
   ventilation rates to increase. Arterioles in the skin and gut ________ and those in
   the muscles ________. The liver converts the storage carbohydrate ________
   into glucose for energy, and ________ are released from fat stores in the body.
   During the period of exercise, the muscle cells respire to make the compound
   ________, which provides the energy for muscle contraction. Oxygen is supplied
   by the red blood cells, which transport it as ________, while some oxygen is
   stored in the muscle cells, combined with the pigment _________. During
   vigorous exercise the supply of oxygen is inadequate for aerobic respiration, and
   the cells respire anaerobically, producing the compound ________.

5 Explain what is meant by an oxygen debt. State four reasons why an oxygen debt
   needs to be ‘repaid’.
6 \( \dot{V}_{O_2}\text{max} \) is a measure of the maximum rate at which a person can absorb and utilise oxygen. It is measured by finding a person’s oxygen uptake while they exercise on a treadmill. The table below shows the oxygen uptake of an athlete at different levels of intensity of exercise.

<table>
<thead>
<tr>
<th>Intensity of exercise (arbitrary units)</th>
<th>Oxygen uptake (dm(^3) min(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>2</td>
<td>3.9</td>
</tr>
<tr>
<td>3</td>
<td>5.2</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>6.1</td>
</tr>
<tr>
<td>6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

a  Plot a graph of the oxygen uptake against the intensity of exercise.  

b  From the graph, estimate the athlete’s \( \dot{V}_{O_2}\text{max} \).

c  \( \dot{V}_{O_2}\text{max} \) is sometimes referred to as the ‘aerobic ceiling’. What do you think is meant by this term?

d  \( \dot{V}_{O_2}\text{max} \) can also be measured in cm\(^3\) kg\(^{-1}\) min\(^{-1}\) (volume per kg of body mass per minute). Suggest an advantage to be gained by using this unit of measurement, rather than dm\(^3\) min\(^{-1}\).

7 Write down five ways in which regular exercise can benefit the heart and circulatory system.

Total: \( \frac{45}{45} \)  Score:  \%
Any 14 correct labels [14]
<table>
<thead>
<tr>
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<th>Bronchus</th>
<th>Bronchioles</th>
<th>Alveoli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliated epithelium</td>
<td>Lining of trachea; beating of cilia carries mucus and dust, bacteria etc. towards mouth [2]</td>
<td>Lining of bronchus; beating of cilia carries mucus and dust, bacteria etc. towards mouth [2]</td>
<td>Lining of bronchioles; beating of cilia carries mucus and dust, bacteria etc. towards mouth [2]</td>
<td>-</td>
</tr>
<tr>
<td>Squamous epithelium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Forms walls of alveoli; thin lining provides short distance between air and blood for efficient diffusion of gases [2]</td>
</tr>
<tr>
<td>Cartilage</td>
<td>C-shaped rings in outer wall; prevents trachea collapsing [2]</td>
<td>Irregular blocks in outer wall; prevents bronchus from collapsing [2]</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Muscle</td>
<td>Some smooth muscle present in wall that can contract or relax to adjust the diameter of the airways [2]</td>
<td>Some smooth muscle present in wall that can contract or relax to adjust the diameter of the airways [2]</td>
<td>Surrounded by smooth muscle that can contract or relax to adjust the diameter of the airways [2]</td>
<td>-</td>
</tr>
</tbody>
</table>
Marking scheme

End-of-chapter worksheet

1 a Pleural (membranes)
b Smooth (muscle)
c Goblet (cells)
d Macrophage
e Residual volume [5]

2 a $0.36 \text{ dm}^3 \text{ breath}^{-1} \times 18 \text{ breaths min}^{-1} = 6.48 \text{ dm}^3 \text{ min}^{-1}$ [1]
b $62 \text{ beats min}^{-1} \times 0.075 \text{ dm}^3 \text{ beat}^{-1} = 4.65 \text{ dm}^3 \text{ min}^{-1}$ [1]

3 a Systolic pressure is the maximum pressure at which the blood leaves the heart during ventricular contraction; diastolic pressure is the minimum pressure in the arteries (as the ventricles relax); (both refer to the systemic circuit). [2]
b The semilunar valve in the aorta closes; elastic recoil of the aorta/large arteries maintains pressure. [2]
c Increases; arteries less elastic. [2]
d Smoking; excessive alcohol intake; obesity; salt in the diet; genetic factors. [max. 4]

4 Before exercise, release of the hormone adrenaline causes the heart and ventilation rates to increase. Arterioles in the skin and gut constrict and those in the muscles dilate. The liver converts the storage carbohydrate glycogen into glucose for energy, and fatty acids are released from fat stores in the body. During the period of exercise, the muscle cells respire to make the compound ATP, which provides the energy for muscle contraction. Oxygen is supplied by the red blood cells, which transport it as oxyhaemoglobin, while some oxygen is stored in the muscle cells, combined with the pigment myoglobin. During vigorous exercise the supply of oxygen is inadequate for aerobic respiration, and the cells respire anaerobically, producing the compound lactate. [9]

5 An oxygen debt is the volume of oxygen that a person needs to use after a period of exercise:

(it is needed for) respiration of lactate (in the liver); reoxygenation of myoglobin (in the muscles); reoxygenation of haemoglobin (in the blood); the increased metabolic rate of many organs. [5]

6 a axes labelled/units; suitable scale; all points plotted correctly; curve drawn. [4]
b $6.2 \text{ dm}^3 \text{ min}^{-1}$ [1]
c Exercise at a level above that which utilises $V_{O_2 \text{max}}$ will result in anaerobic respiration. [1]
d It allows for better comparison between individuals. [1]

7 Lowers resting heart rate;
increases stroke volume;
increases cardiac output;
increases heart size/amount of heart muscle;
decreases resting systolic and diastolic blood pressures;
improves blood supply to muscles during exercise;
more powerful heart beat; [max. 5]