Activity 7A: Gas exchange in animals

1. Describe the requirements of any gas exchange surfaces in animals.
2. For animals, distinguish between the following:
   a. respiration and gas exchange
   b. breathing and gas exchange.
3. Describe the location of gas exchange surfaces in animals.
4. Explain the need for maintaining a high concentration gradient for O_2 and CO_2 in gas exchange surfaces in animals.
5. Explain why most gas exchange surfaces in animals are closely associated with circulatory systems.
6. Explain why most multi-cellular animals need a gas-exchange system.
7. Compare and contrast the tracheal gas-exchange system of insects with the lung gas-exchange system of mammals.
8. Compare and contrast the lung gas-exchange system of mammals with the gill gas-exchange system of fish.
9. The metabolic processes of cells require a constant supply of oxygen and constant removal of carbon dioxide. Discuss the ways in which the animals of three named taxonomic or functional groups have solved the problem of obtaining and removing these gases.
10. Select three different taxonomic or functional groups, and, using named animals as examples, discuss the structure of their gas-exchange systems and the reasons for their differences. In your answer:
    - describe the system for each of the named animals
    - explain how each of these systems operates
    - explain the differences in the systems in relation to the different ways of life of the three animals.

Activity 7A answers: Gas exchange in animals

1. Gas exchange surfaces need to be *thin*, *moist* and have *a large surface area*.
2. a. Respiration is a *chemical* process that occurs in cells to *release energy*; gas exchange is a *physical* process (diffusion) in which the gases *O_2 and CO_2 are exchanged* across a semipermeable membrane / cell membrane.
   b. Breathing is a *physical* process, involving *muscular movements* to facilitate the movement of gases to and from a gas exchange surface; gas exchange is a *physical process* (*diffusion*), in which the gases O_2 and CO_2 are exchanged across a semipermeable membrane / cell membrane.
3. Gas exchange surfaces are located between the environment (air, water) and the body (e.g. alveoli, gills, skin) *and* between the transport system and the cells.
4. High concentration gradients are needed for O_2 and CO_2 to diffuse in the correct direction / O_2 in and CO_2 out. The *higher the concentration gradient the more rapid the diffusion* of the two gases, and this will increase/maximise the rate of respiration / release of energy.
5. The gas exchange system is closely associated with the circulatory system, because the circulatory system is the transport system for the body and transports both O_2 and CO_2 around the body to all the cells for/from respiration. In large multi-cellular

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animals, the direct diffusion of O_2 and CO_2 into/out of the body and from cell to cell is too slow to meet the respiratory/energy demands of the animal. A transport/circulatory system is needed to ensure that the gases are rapidly taken to and from the cells and to maximise respiration/energy release.

6. A gas exchange system is needed to obtain O_2 from the surrounding medium/environment and take it into the body rapidly while removing CO_2 from the body and returning it to the surrounding medium/environment. A system is needed because most multi-cellular animals are large, with their cells forming complex tissues and systems that are removed from contact with the surrounding medium. Therefore, multi-cellular animals cannot use simple diffusion to obtain O_2 and remove CO_2; it is too slow and the skin of the animal is typically impervious to gases (exception: earthworms and some amphibians). A gas exchange system is needed, and usually is associated with, a circulatory system, to transport the gases throughout the body (an exception is insects).

7. *Comparisons* of the two systems could include the following.

- Both have closable openings to air (spiracles in insects, mouth/nose in mammals).
- Both systems have branching tubes that penetrate the body (trachea in insects, trachea and bronchi in mammals), and get smaller and smaller (tracheoles in insects, and bronchioles in mammals).
- Large air tubes have strengthening bands to keep them open (chitin in insects, cartilage in mammals).
- Gas-exchange process is diffusion (across SPMs), dependent on the concentration gradient; O_2 diffuses inwards, CO_2 diffuses outwards. Gas-exchange surfaces are kept moist.
- Muscular 'breathing' movements facilitate movement of gases into and out of the body.

Contrasts of the two systems could include the following.

- Insects use a tracheal system; mammals use a lung system.
- Insect tracheal system transports gases directly to/from cells; mammals need a circulatory system to transport gases to/from cells.
- Oxygen-carrying pigment present (haemoglobin) in mammals.
- In insects, the finest air tubes pass between the cells for direct gas exchange; in mammals, the finest tubes end in air sacs (the alveoli), which exchange gases with the capillaries of the blood. Alveoli provide a large SA for gas exchange with the blood capillaries.
- 'Breathing' in insects is by pumping muscular movements of the abdomen; in mammals, breathing is by muscular movements of the intercostal muscles of the ribcage, along with muscular movements of the diaphragm.
- Tracheal system of insects is a factor that limits their size (insects all small); lung system with circulatory system for transport allows for development of large body size in mammals.

Correct terms should be used in all answers (e.g. trachea, not 'air tubes'; alveoli, not 'air sacs').

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8. *Comparisons* of the two systems could include the following.

- Both systems are closely connected with the circulatory system, which transports the gases.
- Both have a large SA (gill filaments, alveoli) for gas exchange with the blood capillaries.
- Numerous blood capillaries are in close contact with the gills/alveoli to increase gas exchange.
- Haemoglobin in RBCs transports O_2 in both systems.
- 'Breathing' movements facilitate the movement of gases into and out of the body.
- Gas-exchange process is diffusion (across SPMs), dependent on the concentration gradient; O_2 diffuses inwards, CO_2 diffuses outwards.

Contrasts of the two systems could include the following.

- Fish system is external (gills lie free in the water), mammal system is internal (lungs contained in chest cavity).
- Gas exchange occurs between gill filaments and capillaries in fish, between alveoli and capillaries in mammals. Both filaments and alveoli provide a large SA for gas exchange.
- Gills are supported by bony structures, gills are protected by bony operculum. Trachea and bronchi in mammals are supported by bands of cartilage.
- Counter-current system exists between blood and gills in the fish – maximises a concentration gradient for the gases, to facilitate diffusion (needed because O_2 content of water lower than that of air).
- 'Breathing' – fish gulp in water and force it over the gills by closing their mouth, mammals draw air in and out using muscular contractions of the intercostal muscles of the ribcage together with the muscles of the diaphragm.

Correct terms should be used in all answers (e.g. trachea, not 'air tubes'; alveoli, not 'air sacs').

9. Three clearly different taxonomic (e.g. earthworms, insects, mammals) or functional groups (e.g. tracheal system, gill system, lung system) need to be selected. For *each* group:

- *Describe* the ways in which the animals *obtain and transport the gases* to/from the cells. Include the *structures* concerned – e.g. lungs, gills, trachea, alveoli, muscles, diaphragm, blood vessels, RBCs, oxygen-carrying pigments or plasma.
- *Explain* the ways in which the animals *obtain and transport the gases* to/from the cells. Include how the structures *function* (e.g. requirements of a gas-exchange surface – moist, thin, large surface area) and the *purpose* of these, how the gases are transported (the role of blood and RBCs and haemoglobin), where oxygenation/deoxygenation of blood occurs and how (diffusion and concentration gradients), and the need for breathing and how it occurs.
- *Discuss* the ways in which the animals *obtain and transport the gases* to/from the cells. This *compares* the groups of animals and gives *reasons for similarities and differences* – e.g. whether the animals are aquatic or terrestrial, whether they obtain oxygen from water or air and different gas-exchange sites and structures, comparative activity levels of the animals, and comparative size of the animals.

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10. Three clearly different taxonomic (e.g. earthworms, insects, mammals) or functional groups (e.g. tracheal system, gill system, lung system) need to be selected.

For *each* group, the *structures* associated with the *obtaining and transport of gases* to/from cells need to be *described fully and carefully*, *using correct terms*, e.g. the following.

- Detailed descriptions of gills (fish), lungs (mammals), trachea (insects), skin (earthworms), etc., and their location.
- A description of the circulatory system relevant to the transport of gases; RBCs and respiratory pigments.
- How the surface area is maximised for gas exchange.
- How air tubes are kept open.
- How breathing occurs.

For *each* group, *how* these structures perform their particular function needs to be *explained*, e.g. the following.

- Diffusion and concentration gradients, counter-currents, SA.
- The role of respiratory pigments/haemoglobin and RBCs.
- The need for breathing.
- The process of respiration – the need for O_2, the production of CO_2.

For *each* group, reasons for *differences* between the groups need to be *explained*, e.g. the following.

- Why tracheal systems meet the needs of insects but would not meet the needs of mammals.
- Why a gill system meets the needs of fish, but mammals need a lung system.
- Differences in the role of the blood in carrying O_2 and CO_2 (e.g. insects compared with mammals); why some groups have haemocyanin as their oxygen-carrying pigment (e.g. molluscs), while most animal groups have haemoglobin.
- These differences need to be related to differences in habitat (e.g. aquatic or terrestrial), activity levels of the animals (high or low), size of the animals (large or small), or ecological niches (specific adaptations to their habitat and lifestyle).

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