# Biology 2.3

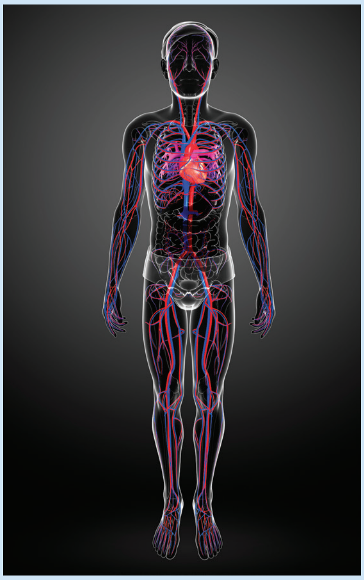
**Internally assessed**
**3 credits**

## Demonstrate understanding of adaptation of plants or animals to their way of life

### Internal transport in mammals

The structure and function of the transport system is essentially the same for all mammals. The circulatory system is a double, closed system; blood is transported in *vessels* – **arteries** take blood away from the heart, **veins** return blood to the heart, **capillaries** exchange materials with cells of lungs, liver, small intestine, muscles, etc. Blood is pumped through the vessels by a four-chambered **heart**.

Within the chordate phylum (which include the classes: fish, amphibians, reptiles, birds, mammals), the heart has evolved from the simple S-shaped structure in fish to a complex four-chambered pump in birds and mammals; the circulatory system has evolved from a simple, single system in fish to a complete, double system in birds and mammals. The chordate classes – fish, amphibians, reptiles, birds and mammals – provide a good basis for comparative study of internal transport across taxonomic groups.



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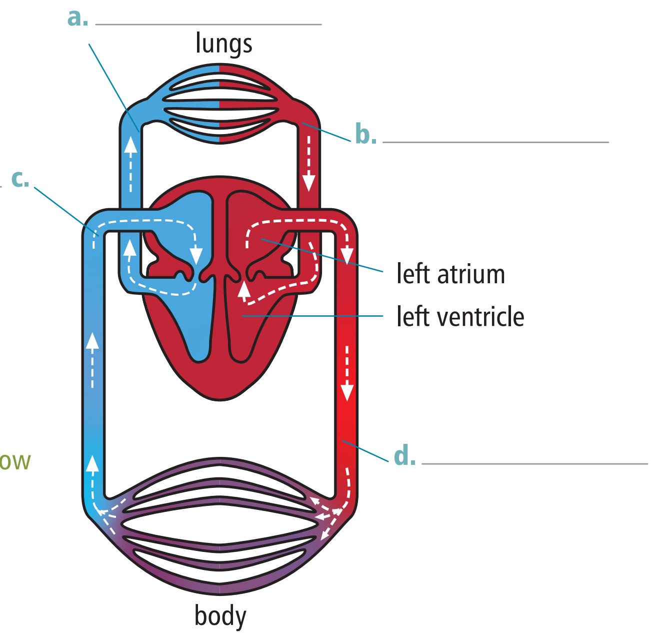
## *Mammal circulatory system*

Answers p. 29

1. Say why the mammal system is a *closed* (rather than an open) system.

2. Explain why the mammal system is a complete *double* system.

3. On the circulation diagram, label the blood vessels: aorta | pulmonary artery | pulmonary vein | vena cava




Double-loop, four-chambered heart circulatory system of mammals and birds; arrows show the direction of blood flow

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4. Gases are exchanged between the alveoli of the lungs and the blood capillaries. Name these gases, and explain why they need to be exchanged. Where do they come from / go to in the body? Why?

5. Do some research to name substances, with reasons, that are likely to be exchanged between the capillaries and:

a. cells of small intestine

b. cells of liver

c. cells of muscles

## Heart structure and function

The two top chambers of the heart are the *atria* (singular: atrium), which collect blood, while the two lower chambers are the *ventricles,* which pump blood. The two sides of the heart are divided by the *septum*. Large blood vessels connect to each of the four chambers. *Valves* occur between the atria and the ventricles, the ventricles and the arteries.

### *Heart dissection*

Hearts from sheep or cows can usually be bought from meat suppliers or supermarkets. Using disposable gloves, open up a heart and examine it; for example:

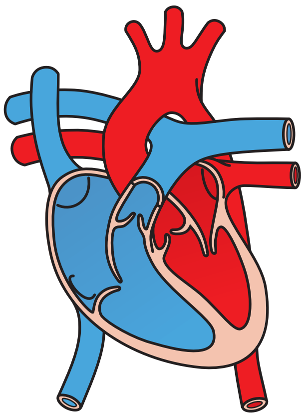
- compare the walls of atria and ventricles, right and left ventricle – explain differences
- compare the walls of the large veins and arteries – explain differences
- find the valves between atria and ventricles – describe structure; try to push a finger up and down one of the two large arteries – explain any difference
- look for blood vessels on the outside of the heart – name these and give their function.

A heart dissection may be part of the examination of a 'full pluck', described for gas exchange on page 18.

## *Heart structure and function (1)*

Answers p. 29

1. On the heart diagram:
   a. label the *right atrium* and *left atrium*, *right ventricle* and *left ventricle*, *septum*
   b. circle each of the four valves
   c. label the *pulmonary arteries* and *pulmonary veins*, the two *venae cavae* (singular: vena cava) and the *aorta.*



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2. The left ventricle has a much more muscular wall than the right ventricle does. Explain why.

3. Give the function of the heart valves.

4. Say why the pulmonary vein carries oxygenated blood, whereas the pulmonary artery carries deoxygenated blood.

The heart is made of *cardiac muscle*, which differs from skeletal muscle. A small bundle of nerves called the *pacemaker* located in the right atrium provides an electrical impulse that spreads across the heart causing the muscles (atria first, ventricles second) to contract. The pacemaker is under the (unconscious) control of the brain. $CO_2$ (released in cellular respiration) levels in the blood are monitored; increasing levels increase the rate of contraction of the heart. The release of the 'fight or flight' hormone *adrenalin* also increases heart contraction rate.

## *Heart structure and function (2)*

Answers p. 29

1. Do some quick research and give the essential difference(s) between cardiac and skeletal muscle.

2. Say why the heart needs large amounts of oxygen and glucose and produces large amounts of $CO_2$.

3. Give the reasons for the increase and decrease of $CO_2$ in the blood, and relate these to the increase and decrease in the rate of contraction of the heart.

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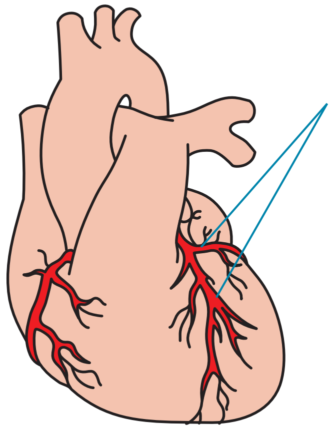
4. The diagram shows the coronary arteries that supply the heart with nutrients and remove wastes.

Formation of *plaque* in the coronary arteries places limitations on the functioning of the heart. Find out the factors that promote plaque build-up, and explain how plaque may limit the effective functioning of the heart. Discuss your findings with your class and teacher, then write a summary here.




## Blood pressure and pulse

Blood leaves the heart under pressure. **Blood pressure** is given as systole/diastole (e.g. 120/80). The top figure is the pressure of the blood when the heart is pumping, the lower figure is the blood pressure when the heart is between beats. High blood pressure (*hypertension*) can damage the heart and lead to death. Blood is under high pressure in arteries, low pressure in the veins. Blood spurts or pulses out of the heart with each contraction. The elastic artery walls act to even out the flow. In certain places (where arteries can be pressed against bone), the heart beat can be detected as a **pulse**. The main sites are the neck (carotid artery) and inside wrist.

### *Your blood pressure*

If your school has a *sphygmomanometer* you may be able to get a reading of your blood pressure.

### *Your pulse*

1. Sitting quietly, take your pulse from your neck (the carotid artery):
   - place the fingertips of one hand in the hollow alongside the windpipe and count the beats per minute (or for 15 seconds multiply by 4 for beats per minute)
   - repeat to get three readings then average – this is your *resting pulse*, and it should be between 60 and 100 beats per minute.
2. Stand up and take another reading. If there is a difference to that of the resting pulse, say why.
3. Take some gentle exercise (e.g. jog on the spot for 5 minutes) and then take your pulse. If there is a difference to that of the resting pulse, say why.

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## *Blood pressure and pulse*

Answers p. 29

Do some research and discuss with your partner or class to come up with good answers to these questions.

1. Find out and give:
   a. normal blood pressure for a person your age ______________________
   b. reasons for, and problems associated with, high blood pressure (hypertension)

   ______________________

   ______________________

   ______________________

   c. reasons for, and problems associated with, low blood pressure (hypotension).

   ______________________

   ______________________

   ______________________

2. a. Find out and give the normal pulse for a person your age. ______________________
   b. Give reasons for, and problems associated with, high resting pulse rate (tachycardia).

   ______________________

   ______________________

   ______________________

   ______________________

   ______________________

   c. Give reasons for, and advantages and disadvantages associated with, low resting pulse rate (bradycardia).

   ______________________

   ______________________

   ______________________

   ______________________

   ______________________

### Blood vessels

The diagrams show cross-sections through a large artery and a large vein. Blood is under high pressure in arteries, low pressure in veins.

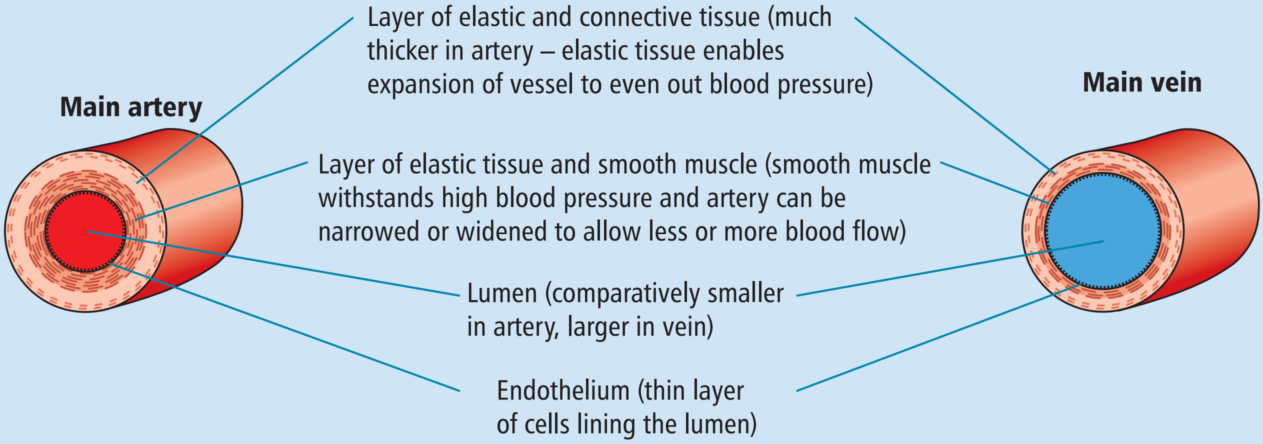


Diagram of cross-sections through a main artery and a large vein

**Valves** are present in veins. Blood returns to the heart as a result of residual blood pressure, contraction of body muscles squeezing veins, action of valves.

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## Blood vessels

Answers p. 29

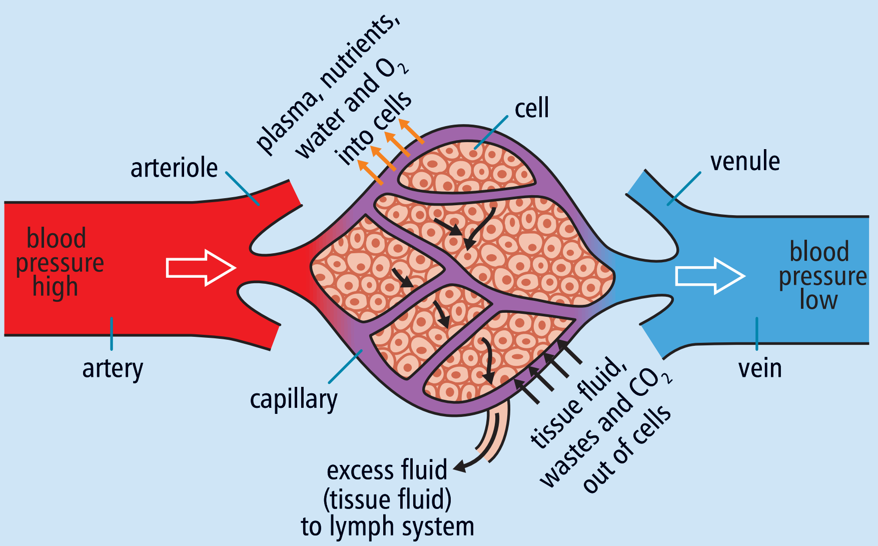
1. Compare the structure of both types of blood vessel, and relate differences to their function.

2. When arteries lose their elasticity, hypertension results. Find out the factors that cause arteries to lose their elasticity and the results of hypertension. Write your findings up on your own paper and show your answer to your teacher for their feedback.
3. Describe how the valves assist the return of blood to the heart.

4. Valves may malfunction and be 'leaky', resulting in *varicose veins*. Describe how this malfunction may limit blood return to the heart.

### Exchange of materials between capillaries and cells

Arteries get smaller and smaller forming *arterioles* as they branch, becoming tiny **capillaries** (walls are only one cell thick) which pass between cells. Capillaries join up to form *venules*, which in turn join to form the large veins. Capillaries exchange materials with surrounding cells. Blood pressure can force fluid and materials out of capillaries; movement of substances across the membranes of cells and capillaries occurs in the processes of diffusion and osmosis (refer to pages 76 and 80 of the hard-copy book for details on these processes).




Blood movement through, and fluid movement into and out of, a capillary system

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**Blood composition** – an adult of 75 kg has about 5.5 L of blood.

**Plasma** is the fluid part (about 55% by volume) of the blood and is mainly water with a large variety of substances dissolved in it (e.g. glucose, amino acids, mineral ions, vitamins, carbon dioxide, urea, hormones). The composition of plasma constantly changes as substances enter and leave the capillaries from and to the surrounding cells.

The remaining 45% of the blood is blood cells.

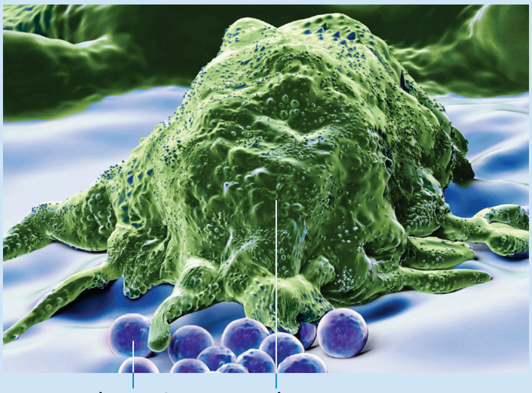
Getty Images: AlexLMX

**Red blood cells** (about 5 million per mL of blood) are biconcave discs containing the protein *haemoglobin* which binds to oxygen to transport it around the body from its point of entry, the lungs. Carbon dioxide is transported in the form of hydrogen carbonate ions, $HCO_3^-$, dissolved in the plasma.


Getty Images: rasslava

Red blood cells

**White blood cells** are much less common (about 7 500 per mL of blood) and serve to fight off pathogens by directly engulfing them or by producing antibodies against them.



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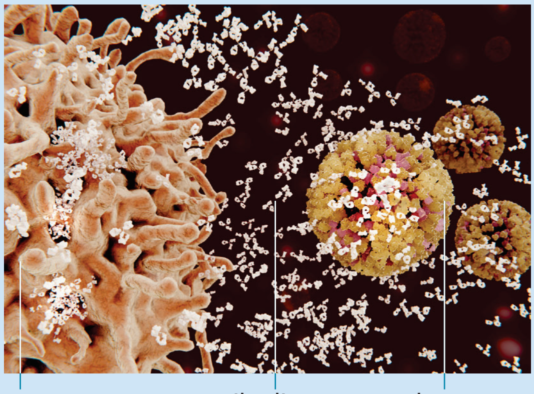

Getty Images: JUAN GAERTNER/SCIENCE PHOTO LIBRARY

**Platelets** are involved in the clotting mechanism when a vessel is damaged and leaks blood.

Fluid 'leaks out' from the capillaries and surrounds the cells. The **lymph system** acts to drain excess fluid and return it to the blood system (by emptying into the superior vena cava near the heart). Lymph is similar to plasma but does not contain cells. Lymph vessels are similar to veins – lymph circulates in these vessels in a similar way, using one-way valves and the contraction of body muscles.

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## *Exchange of materials between capillaries and cells*

Answers p. 29

1. Find out the main function(s) of each of these organs, then describe the main change(s) in composition of the blood as the capillaries pass among the cells of the:

   a. lungs

   b. small intestine

   c. liver

   d. kidneys

2. Describe how the processes of *osmosis* and *diffusion* operate in the exchange of *named* substances between cells and capillaries (refer to pages 76 and 80 of the hard-copy book for help with this).

3. a. Explain how red blood cells (RBCs) are adapted to carrying oxygen (refer to pages 95–97 of the hard-copy book for help with this).

   b. Haemoglobin is the most common oxygen-carrying pigment. Do some research, then:

      i. Give the benefit to mammals of having haemoglobin in their red blood cells.

      ii. Give the problems of having low levels of haemoglobin in the blood.

4. Explain why the lymph system is essential for correct body functioning.

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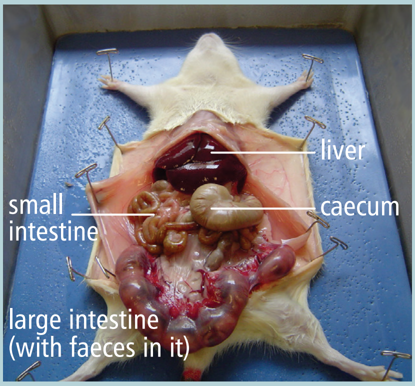
### *Rat dissection*

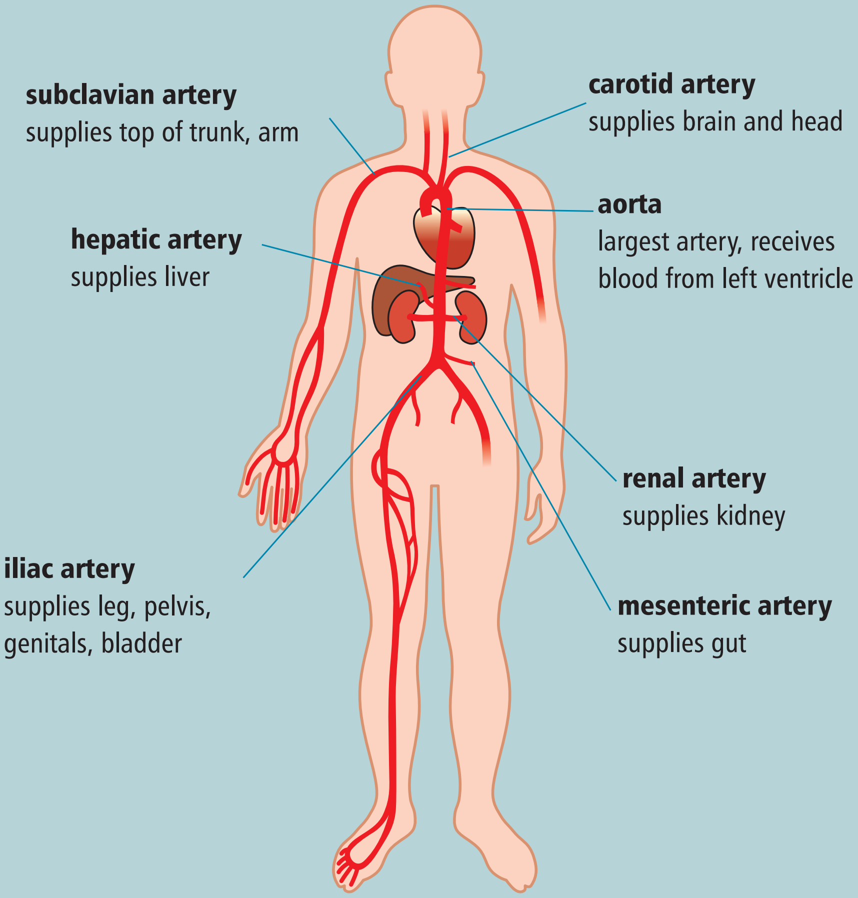
A rat may be dissected to display aspects of the digestive, transport, and gas exchange systems. Your teacher will give you full instructions for this. It is recommended that a pair of sharp, pointed scissors are used (*not* a scalpel – it is too easy to cut through organs, as well as yourself). Wear disposable gloves and *use your fingers* to separate out the organs to reduce risk of damaging the organs – the gut is likely to have partially processed food and wastes and if cut will spill these out and make it very difficult to view other organs. Cover the rat with water to float the organs so that they are more easily displayed.
A mammal is always dissected from the ventral (front) surface by cutting through the skin and muscle. *Make all cuts shallow.*
A hand lens / magnifying glass / tripod lens may be useful for detail.

You should be able to display and identify the following organs: oesophagus and trachea, heart enveloped in the lungs, diaphragm across the body beneath the heart/lungs, stomach with the pyloric sphincter which closes it off from the small intestine, pancreas and liver, small intestine and large intestine with the caecum at the start, rectum. The intestines are held together with membranes (mesenteries) which have blood vessels running through them. These can be carefully broken to unravel the intestines. Measure the length of the small and large intestines and caecum – how do they reflect the diet? Beneath the intestines, the kidneys can be found and some of the large blood vessels from heart to organs can be located – aorta, vena cava (renal and iliac should be able to be seen).




Wikimedia: Wittayayut

To help identify the large blood vessels for the rat dissection and as information to help with *Practice assessment – Internal transport system of mammals*, a diagram of the major arteries of the human circulatory system follows.




Major arteries of the human circulatory system

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## Practice assessment – Internal transport system of mammals

Answers p. 30

1. Discuss how the transport system is adapted (structurally, physiologically) to allow mammals to successfully live an active lifestyle. Include in your discussion any limitations of the system.
   Show your answer to your teacher for their feedback.
2. Discuss how the transport system and digestive system are connected and work together so that mammals are successful in their way of life.
   Show your answer to your teacher for their feedback.
3. Discuss how the gas exchange and transport systems are connected and work together so that mammals are successful in their way of life.
   Show your answer to your teacher for their feedback.

# Gas exchange

With a few exceptions, all multicellular animals respire *aerobically* to release energy to fuel their life processes. **Aerobic respiration** requires oxygen, $O_2$, from the atmosphere and releases carbon dioxide, $CO_2$, as a waste product. The build-up of $CO_2$ is toxic to the body, therefore $CO_2$ needs to be released into the atmosphere.

*These two gases, $O_2$ and $CO_2$, are exchanged across thin, moist, semi-permeable membranes.*

Aerobic respiration takes place in the mitochondria of cells. Cells in tissues associated with high energy demands (such as muscles) will have large numbers of mitochondria. Therefore large quantities of gas exchange will occur in these tissues with $O_2$ and $CO_2$ diffusing across the thin moist membranes of the cells and their mitochondria. The mitochondria are elongated and their inner membranes (the cristae) folded to increase surface area and facilitate rapid diffusion of the gases. (Refer to pages 114 and 115 of the hard-copy book for detail on the mitochondria.)

## Gas exchange

Answers p. 30

Use any prior knowledge (you will find the content of AS91156 (Biology 2.4) pages 114 and 115 helpful) plus any extra research to answer the following questions.

1. Describe the process of aerobic respiration, stating where it occurs. Write a word and symbol equation for the process, and give the energy conversion that occurs.

2. Name important cell/life processes that require energy, indicating those which have high energy demands.

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3. $O_2$ and $CO_2$ are exchanged across thin, moist, semi-permeable membranes.
   a. Explain the process by which the two gases cross membranes.

   b. Explain why the membranes need to be *thin* and *moist* for gas exchange to occur.
      i. Thin:
      ii. Moist:

   c. Gas exchange membranes occur in *large quantities* within cells and organisms – explain the purpose of this.

4. Animals may need to **breathe** (also known as *ventilation*) to facilitate gas exchange. The terms *respiration*, *breathing* and *gas exchange* are often confused and used indiscriminately. However, each refers to a distinct process. If necessary, do some research, then write definitions for each of these processes.

   Respiration:

   Breathing:

   Gas exchange:

When oxygen enters the body, it is typically transported to the cells and tissues using an *internal transport system*; carbon dioxide is also transported away from the cells and tissues in the transport system. Therefore, the gas exchange system and transport system (also referred to as the *circulatory system* or *blood system*) are in close contact; the notable exception to this is the gas exchange system in terrestrial insects.

The gas exchange systems in three different taxonomic groups – insects, fish, mammals – follow. The three groups display marked differences in lifestyle, the environments they inhabit and consequently the way in which they are adapted for gas exchange.

## Gas exchange in insects

Insects are invertebrates and the most numerous and diverse group of all animals. They have evolved to inhabit all environments (with the exception of the sea) and are the only group of animals (apart from birds) that have evolved flight. They have an exoskeleton made of the protein chitin and an internal body cavity (the coelom) containing the 'blood' which bathes the body organs. There are no blood vessels and a simple tubular heart lies dorsally surrounded by the blood; circulation is sluggish. All insects are small – the giant wētā of New Zealand is amongst the largest of insects.

Unlike all other animal groups, the gas exchange system of insects is independent of the circulatory/transport system.


Sid Mosdell
Giant wētā

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Insects have a **tracheal system** for gas exchange. Valves called **spiracles** open along each side of the abdomen. **Trachea**, bound with **chitin**, lead from the spiracles and branch as they penetrate the body. The finest branches, the **tracheoles**, lack chitin and have fluid-filled ends that pass between individual body cells. It is in the tracheoles that gas exchange occurs. **Air sacs** may be present to increase the efficiency of the trachea. Muscular pumping of the abdomen assists the movement of gases into and out of the body and along the trachea.

## *Practical activity – Gas exchange in insects*

Crickets are common insects in New Zealand late summer and autumn and are easily caught and kept in the laboratory.

Crickets allow for a variety of observations on structural and behavioural adaptations. Try putting a large cricket in a clean test tube (or similar) and stopper the test tube with cotton wool. Lie the tube on its side and observe the cricket with a hand lens / tripod lens / binocular microscope – you should be able to identify the spiracles along the abdomen and observe regular pulsations of the abdomen as the insect 'breathes'.

Jennifer Dymock

The photo following is of three spiracles on abdominal segments.

Troy Bartlett

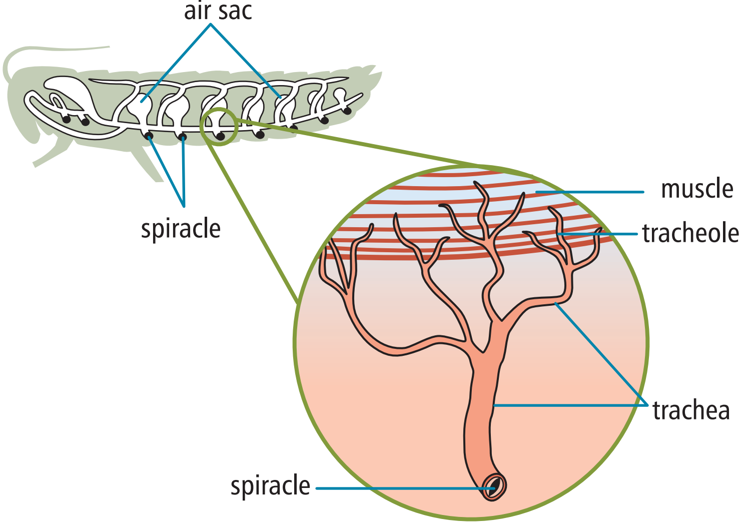
Your school may have preserved specimens of insects such as grasshoppers; if so, these may be used to view the spiracles and also to dissect out the tracheal system under a binocular microscope.

## *Gas exchange in insects*

Answers p. 30

1. The blood of insects does not contain any oxygen-carrying pigments (such as haemoglobin) and consequently is a creamy colour. Therefore, if you were to squash an insect that had landed on your leg and produced a red smear, what could you deduce?

2. The following diagrams show the insect tracheal system.

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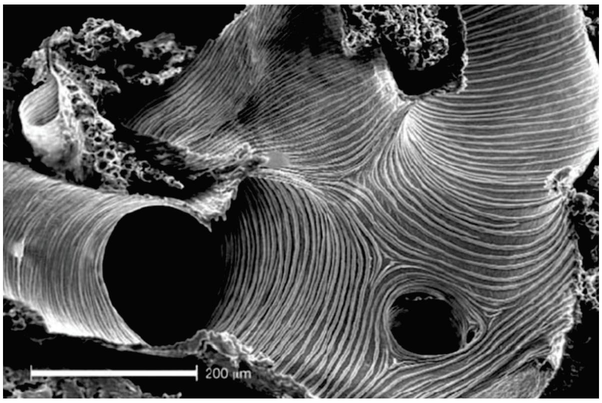
Describe the location and function of the spiracles, and explain the advantage of their being able to open and close.

3. The diagram shows chitin bands of insect trachea. Chitin is a hard, flexible and non-porous.
   a. Give the function of the chitin bands.




Petz, Brodschneider and Stabentheiner (University of Graz)

   b. Explain why tracheoles lack chitin bands.

4. Air sacs form part of the gas exchange system in insects. Give the function of air sacs.

5. Explain why insect tracheoles are narrow, fluid-filled, membrane-bound tubes.

6. Explain how and why the insect tracheal system provides a large surface area.

7. Some insects are able to ‘breathe’. Explain how and why this happens.

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8. Insects inhabit all terrestrial environments on the planet. Many insects are able to fly (e.g. all flies, moths, butterflies, bees and wasps, dragonflies). All insects are small.

Discuss how the structure of the gas exchange system, including its separation from the transport system, is an advantage for insects but also sets limitations on them.

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The use of the transport system in gas exchange in both fish and mammals removes them from the size constraints of insects.

## Gas exchange in fish

Fish are vertebrates, adapted to life in an aquatic (both marine and freshwater) environment. Insects and mammals extract oxygen from the air; fish extract oxygen from water. Oxygen concentrations are much higher in air (about 21% oxygen) than in water (less than 1% dissolved oxygen). The amount of oxygen in water varies – dependent on temperature, pressure, salinity, presence of photosynthesisers and current. Oxygen dissolves better the colder, more pressurised, and less saline the water.

*Since the content of oxygen in water is very much less than in air, fish have to pump through their gills a very great amount of the medium (water) to extract sufficient oxygen to sustain themselves. Water, being much more dense than air, requires a lot more energy to move it than does air.* Water may therefore be considered a 'risky' gas exchange medium when compared with air.

**Gills** are the gas exchange surface between the water and the blood/transport system of fish. The gills lie free in the water and are composed of many thin **filaments**, further divided into thin foldings called **lamellae**. Fish breathe by 'gulping' in water then closing their mouths to force the water over the gills.

In the *bony fish* (e.g. snapper, tarakihi, tuna, salmon) gills are protected by a bony cover (the **operculum**) and the gill filaments (and associated blood capillaries) are supported by bony **gill arches**. **Gill rakers** attached to the arches prevent food particles from exiting the gills as water flows through them.


Shutterstock: Daniel Petrescu

## *Practical activity – Gas exchange in fish*

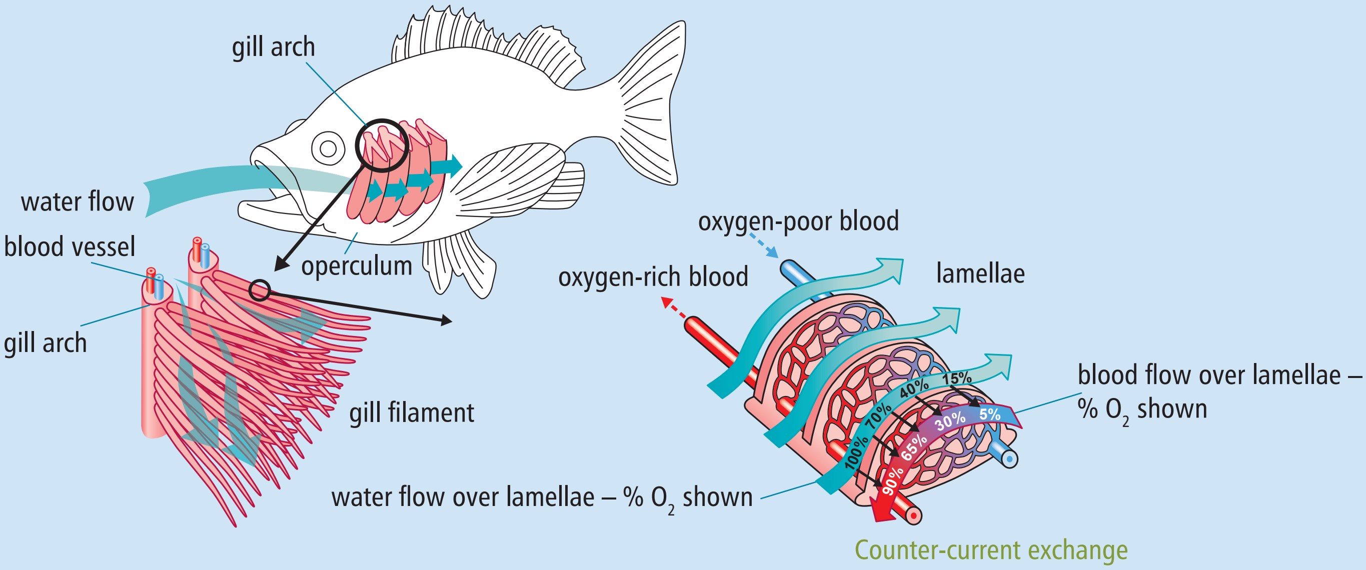
Next time you catch a fish or get a fish from the local fish shop or supermarket, bring the fish into the lab and examine and dissect out the gills – you should easily be able to identify all the structures described above. A hand lens or binocular microscope will enable you to get a detailed look at the filaments.

In the *cartilaginous fish* (sharks and rays), the gills open to the surrounding seawater via slits and water is forced over the gills by the movement of the fish through the water.

Gills are dependent on the buoyancy of water for their support; in air, the gills collapse.

Gills are very rich in blood capillaries. The flow of blood in the gills is *opposite* to the flow of water over the gills – known as a **counter-current exchange system**. The counter-current system maximises the **concentration gradient**, facilitating gas exchange. If oxygen-rich water and oxygen-deficient blood flowed in the same direction (concurrent flow), the concentration gradient would reach an equilibrium such that the maximum amount of oxygen diffusing into the blood would be 50%. However, in a counter-current flow, where oxygen-rich water and oxygen-deficient blood flow in *opposite* directions, a continuous concentration gradient is maintained such that the maximum amount of oxygen diffusing into the blood reaches 90%.

## Summary – gas exchange in fish

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## *Gas exchange in fish*

Answers p. 30

1. a. Describe the structure of the gills and explain why they are red in colour.

   b. Explain how and why gas exchange occurs in fish, including a definition of the term 'concentration gradient'. Refer to pages 76–80 of the hard-copy book for help with this.

   c. Explain why the gas exchange surfaces of fish, like all organisms, are thin.

   d. Explain how and why in fish the gas exchange surfaces have been maximised.

2. Explain how and why fish breathe.

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3. Explain why fish die when removed from the water.

4. Discuss the ways in which fish are adapted for gas exchange in water that has low oxygen content.

## Gas exchange in mammals

Mammals are very active *homeotherms* (homeotherm means 'warm blooded' – both insects and fish are 'cold blooded' or poikilotherm) so mammals have a high oxygen demand. They evolved a complex internal lung system for gas exchange which is closely connected to their closed, double-circuit transport/circulatory system.

Air enters the body through the moist, hair-lined **nasal cavity** where the air is also warmed. Air is taken into the chest cavity by the large, cartilage-banded air tubes, the **trachea**. This is lined with **mucus**-secreting cells and lined with **cilia**. Within the chest cavity, the trachea branches to form two **bronchi** (singular *bronchus*), which enter the lungs and further divide to become very thin membranous **bronchioles**. Bronchioles continue to divide, ending in millions of tiny moist membranous air sacs, the **alveoli** (singular *alveolus*). The surface area of all your alveoli combined measures about 100 $m^2$. Each alveolus is wrapped in a network of capillaries – it is here that gas exchange between the air and the body occurs.

Beneath the lungs is a sheet of muscle, the **diaphragm**. The diaphragm works together with the **rib cage** in breathing.

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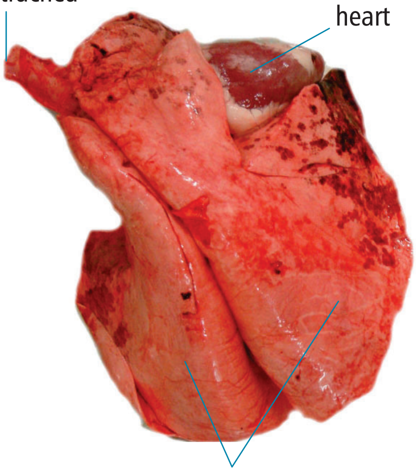
## Practical activity – Gas exchange in mammals

If you can obtain a 'full pluck' (the intact heart and lungs) of a sheep from a butcher or meat supplier (even a friendly farmer), you will be able to examine the trachea, bronchi and bronchioles (use a pair of scissors to cut down the trachea, along one bronchus and into its branches).

- Feel how bendy the cartilage bands are. (What is their function?)
- Compare the heart and lungs. Size? Colour? Texture?

Remember that the heart is a muscle, while the lungs are full of air sacs. Compare these differences with their function. If the lungs are intact, and being mindful of health and safety, you may be able to inflate the lungs by blowing down the (intact!) trachea using a suitable tube. Notice the extent of inflation possible (this is effectively what happens in mouth-to-mouth resuscitation) and any changes in the colour of the lungs (explain this). If internal transport is being studied, then this dissection may be done in association with the heart dissection described on page 2.

The dissection of a rat – described on page 9, may also be done at this point.




DISSECT

## Gas exchange in mammals

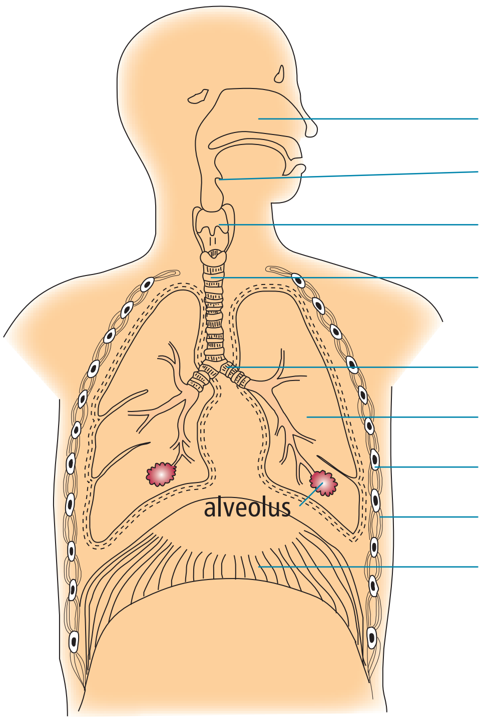
Answers p. 31

Do some research on the human gas exchange system, and then answer the following questions.

1. **Chest cavity and organs**

   a. The diagram shows the main structures in the gas exchange system. Label the structures indicated using the following words:

   bronchus diaphragm epiglottis larynx lung nasal cavity trachea rib rib (intercostal) muscles




Chest cavity and organs

   b. Give the purpose of the nasal cavity:

      i. being moist ______________________________

      ______________________________

      ii. being lined with hairs ______________________________

      ______________________________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iii. warming the air. ______________________________________________

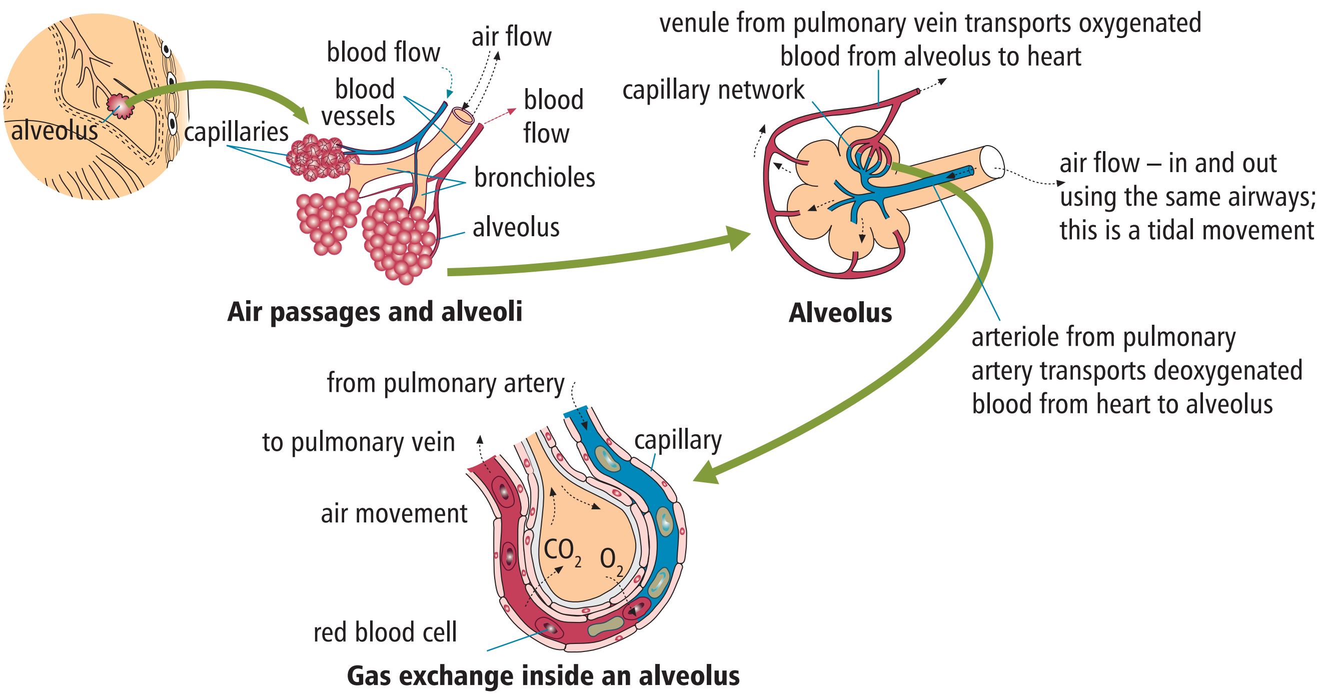
c. Explain why the trachea is:

i. banded with cartilage ______________________________________________

ii. lined with mucus cells ______________________________________________

iii. lined with cilia. ______________________________________________

2. The following diagram relates to the alveolus from the *Chest cavity and organs* diagram in question 1.




Gas exchange between alveoli and capillaries

Discuss how the alveoli are adapted for gas exchange. In your discussion, describe alveoli, explain the process of gas exchange, and link this to the adaptations of alveoli.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**Breathing** is essential to get air into and out of the lungs. Breathing results from the combined action of the diaphragm and ribcage. The rate of breathing is controlled by the **respiratory centre** in the brain which monitors the amount of $CO_2$ in the blood.

Getty Images: martin-dm

## *Breathing in humans*

Research, discuss in class, then write a report on the process of breathing in humans. You will need to:

- explain how both inhalation and exhalation occur (define these two terms); support your explanation with suitable diagrams
- explain what is meant by 'tidal movement' and give its limitations
- identify activities that increase and decrease the rate of breathing and account for how the rate of breathing is monitored by the body and controlled by the body
- account for the fact that breathing is not very efficient – only about 25% of inhaled oxygen enters the pulmonary vein.

Hand your report to your teacher for their feedback.

## *Practice assessment – Gas exchange*

Answers p. 31

Compare and contrast the gas exchange systems of three taxonomic groups of animals and relate differences to differences in their way of life. You may use annotated diagrams to support your comparisons. Consider the adaptations (structural, behavioural, physiological) of the different systems and give reasons for these differences. Support your discussion with named examples. Show your answer to your teacher for feedback.

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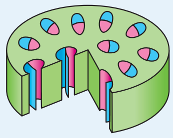
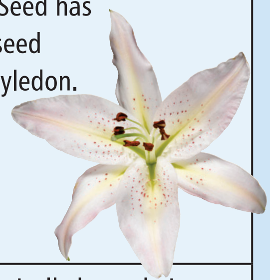
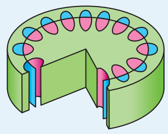
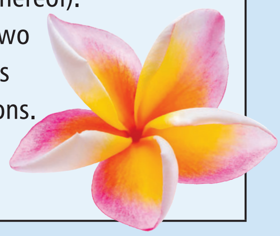
## Transport in angiosperms

Angiosperms are large, multicellular plants fully adapted to a terrestrial existence (the *hydrophytes*, e.g. water lilies, have subsequently returned to an aquatic existence).

There are two main groups of angiosperms: the **monocotyledons** (e.g. all grasses, lilies, orchids) and the **dicotyledons** (most of our common garden plants; shrubs and trees). The main differences between the groups are shown on the following table.

| Angiosperm | Leaves | Stems | Flowers |
|---|---|---|---|
| **Monocotyledons**<br>Includes all the grasses, lilies, orchids. | Leaves are typically long and thin, with parallel veins (the transporting xylem and phloem) along their length.  | Vascular bundles (of xylem and phloem) are scattered throughout the width of the stem, and there is rarely secondary growth of the stem.  | Flowers typically have parts arranged in threes (or multiples of three). Seed has only one seed leaf or cotyledon.  |
| **Dicotyledons**<br>Most of the angiosperms. | Leaves are typically broad and have a network of veins.  | Vascular tissue is arranged in a circle around the stem, and secondary growth of the stem occurs.  | Flowers typically have their parts in fours or fives (or multiples thereof). Seed has two seed leaves or cotyledons.  |

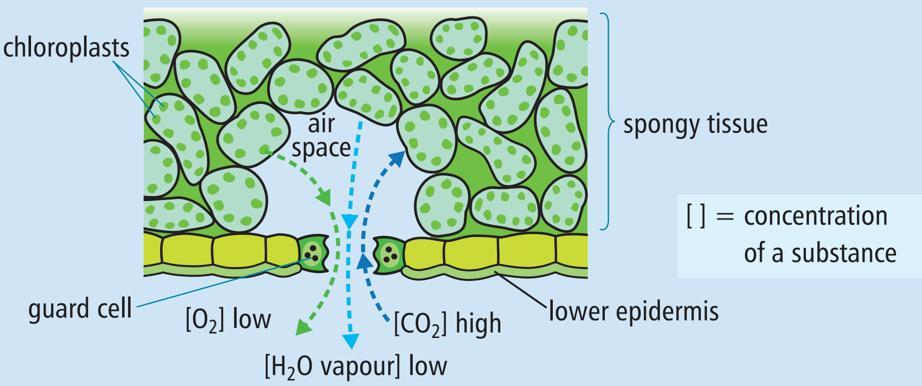


Angiosperms are dependent on a **transport system** to move the essential substances of *glucose*, *water* and *mineral ions* around the plant from where they are produced or enter the plant to where they are needed/stored or exit the plant. Aspects of the transport system also assist support of the plants, e.g. the very thick, lignified walls of xylem vessels.

Transport into / out of the plant and cells involve the processes of *active transport*, *osmosis*, *diffusion*, *transpiration*.

Transport systems are *not* needed for carbon dioxide and oxygen – they *diffuse* directly from the air into and out of a leaf through stomata. The direction of movement of $O_2$ and $CO_2$ depends on their *concentration gradient*. Water vapour diffuses out of the leaf in the process of *transpiration*. Cell membranes need to be kept moist as gases need to be in solution to diffuse across a membrane.

Details on transport into / out of cells is covered in AS91156 (Biology 2.4). Refer to pages 76–78, 80 and 91 of the hard-copy book.




Section through lower part of leaf, showing diffusion pathways of $CO_2$, $O_2$ and $H_2O$ vapour in response to their concentration gradients

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## *Movement of substances (1)*

Answers p. 31

1. Name the cell process that needs $CO_2$ and releases $O_2$, and state where and when it occurs.

2. Name the cell process that needs $O_2$ and releases $CO_2$, and state where and when it occurs.

3. Explain what causes the movement of $O_2$ and $CO_2$ into and out of the leaf, and account for the variation in the direction of movement depending on the time of day.

4. State what a plant needs water for, and give the ways in which water loss is reduced. Give the environmental conditions that may cause stomata to be closed.

5. Define each of the following terms, and give an example of each (refer to AS91156 (Biology 2.4) pages 63 onwards of the hard-copy book for help):

   a. semi-permeable membrane (SPM)

   b. diffusion

   c. osmosis

   d. transpiration

   e. concentration gradient

   f. active transport

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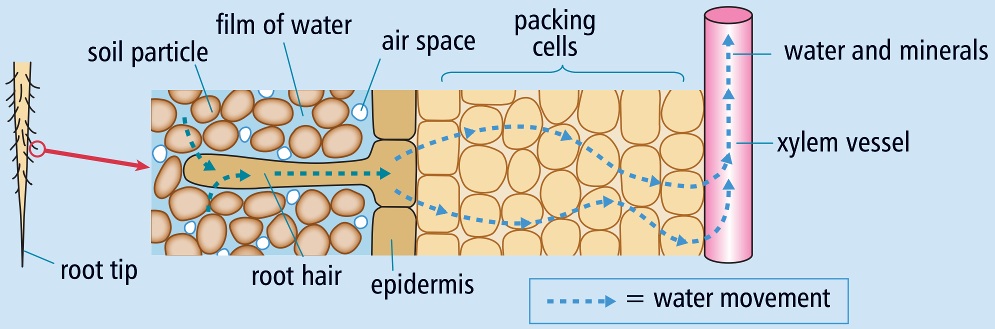
Water and mineral ions enter the plant through the *root hairs* from the soil water.




## *Movement of substances (2)*

Answers p. 31

1. Referring to the diagram above, describe how the root hairs are adapted to the uptake of water and minerals.

2. To answer the following questions, use your knowledge from AS91156 (Biology 2.4) (refer to pages 63 onwards of the hard-copy book).
   a. Describe how water enters the root.

   b. Describe how mineral ions enter the root (two possible processes).

   c. Describe the movement of water and ions from soil to xylem.

3. Name three mineral ions that are important to plants, and state why each is important.

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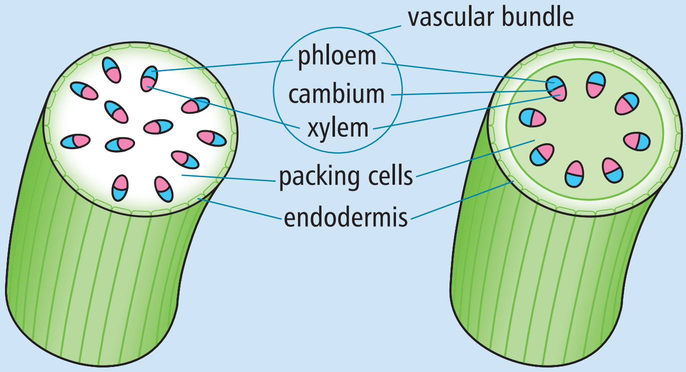
## Vascular tissue – xylem and phloem

Water travels to the leaves in **xylem vessels**. Mineral ions travel in solution in the water. Xylem is found with the **phloem tubes** in the **vascular bundles** in roots and stems (and the **veins** in leaves). Glucose, made in photosynthesis, travels from the leaves in the phloem tubes. The arrangement of the vascular bundles is different in monocotyledons and dicotyledons – this is shown in the following diagram:




Section of monocotyledon stem (ryegrass) showing scattered vascular bundles

Young dicotyledon stem – vascular bundles distinct and in a circle

### *Dicotyledon stems*

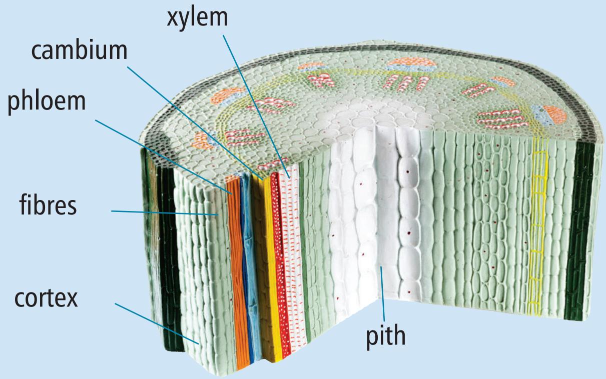
As a dicotyledon stem thickens, the vascular bundles join to form a complete circle of xylem (inside) and phloem (outside). The xylem and phloem are separated by a cell layer called the *cambium*, which is able to divide to form new cells, allowing the stem to thicken. Supportive *fibres* are typically found in conjunction with vascular bundles in both monocotyledon and dicotyledon stems.

Xylem cells die and become joined end-to-end with their end walls broken down so that the cells now form a hollow tube with a large lumen. The tubes are continuous from roots to leaves, and may be many metres in length. The walls are strengthened by *lignin*, which typically forms bands or spirals.

Phloem is living cells with little cytoplasm and no nuclei. They are mainly hollow and joined end-to-end to form tubes. The cell walls are normal thickness but the end walls become perforated forming *sieve plates* (phloem tubes are also known as *sieve tubes*). Alongside the phloem cells are small living cells called *companion cells* – these cells have much higher numbers of mitochondria and ribosomes than 'normal' cells of similar size and provide the metabolic needs of the phloem tube cells.

### Stem cross-section

A cross-section of a stem from a common plant such as a geranium may be made, stained with toluidine blue, and viewed under a microscope to display the location and structure of cells and tissues, including xylem and phloem (refer AS91160 (Biology 2.8), pages 295 to 297 of *Level 2 Biology Learning Workbook*, for guidance with preparing slides, staining, and using a microscope). This activity may contribute towards assessment for AS91160 (Biology 2.8).




Xylem cells ('wood') showing lignin bands



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## *Vascular tissue: xylem and phloem*

Answers p. 31

1. Describe and compare the structure of xylem and phloem, relating differences to their function.

2. Give the function of companion cells, and explain why they have large numbers of ribosomes and mitochondria.

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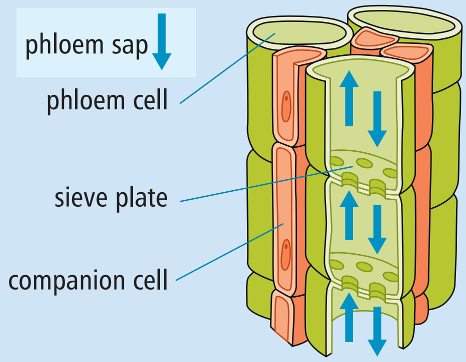
## Methods of transport

How transport occurs in xylem and phloem is not completely understood.




Organic materials ('phloem sap') are transported in phloem tubes. The sugar sucrose (a compound of glucose and fructose), dissolved in water, makes up about ⅓ of phloem sap (making it very thick and viscous). Hormones and amino acids may also be present in the water for transport. The transport of these organic materials is called **translocation**.

Movement of sap in phloem is partially explained by *pressure flow*. The high concentration of sugars at source (e.g. in the leaf from photosynthesis) in the phloem creates a diffusion gradient which draws water into the phloem. Pressure (turgor) is created, which pushes sap along a phloem tube from a *sugar source* to a *sugar sink* (e.g. root where stored). In spring and summer growth periods, the storage areas are sugar sources while the upper areas of plant/leaf area are sugar sinks, so mass flow is upwards rather than downwards – to fuel new growth. Movement of material in phloem may be multidirectional and sap may be moving upwards in one phloem tube and downwards in an adjacent phloem tube (in xylem, movement is only unidirectional – upwards). Movement of sap is active, i.e. requires energy.

## *Movement in phloem*

Answers p. 31

1. a. Define *translocation*. ______

   b. Describe the composition of the *phloem sap*. ______

   ______

   c. Give, with examples, the difference between a *sugar source* and a *sugar sink*.

   ______

   ______

   ______

   d. Describe *pressure flow*. ______

   ______

2. Explain why movement in phloem may be both up and down the plant, while movement in xylem is always upwards.

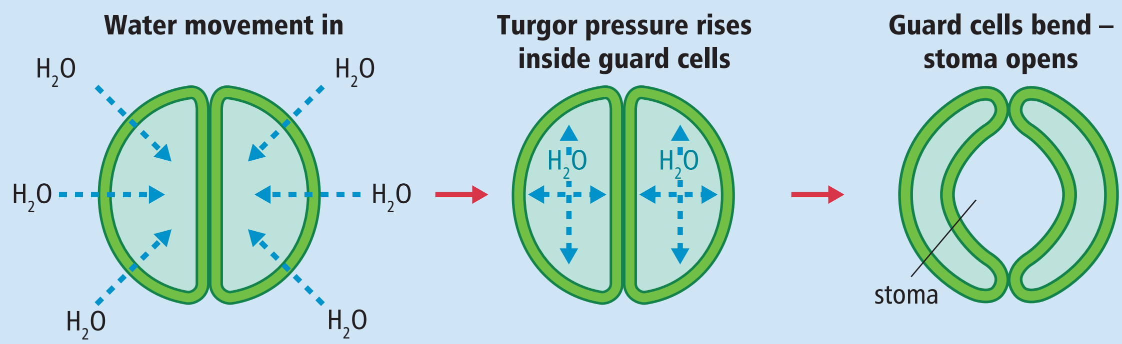
   ______

   ______

   ______

## Transpiration

**Transpiration** is the loss of water from the leaves of the plant by evaporation out of the stomata. Water leaving the xylem vaporises in the air spaces in the leaf and diffuses out of the leaf in response to a concentration gradient. Water loss may be controlled by closing stomata. Stomata are opened and closed by changes in turgor pressure of the guard cells as water enters and leaves. During the day, photosynthesis in the guard cells increases the solute level in vacuoles/cytoplasm, drawing in water and increasing turgor pressure. The inner walls of the guard cells are thickened, therefore the increase in turgor pressure (refer to page 89 of the hard-copy book) causes the cells to bend and separate so forming/opening the stomata. $CO_2$ enters; $H_2O$ vapour, $O_2$ leave. At night, or when temperature increases the transpiration rate, the guard cells may lose turgor and collapse, closing the stomata.

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## *Movement in xylem*

Answers p. 32

1. a. Define *transpiration*.

b. Do some research to explain how transpiration will be affected by increases in:

i. environmental temperature

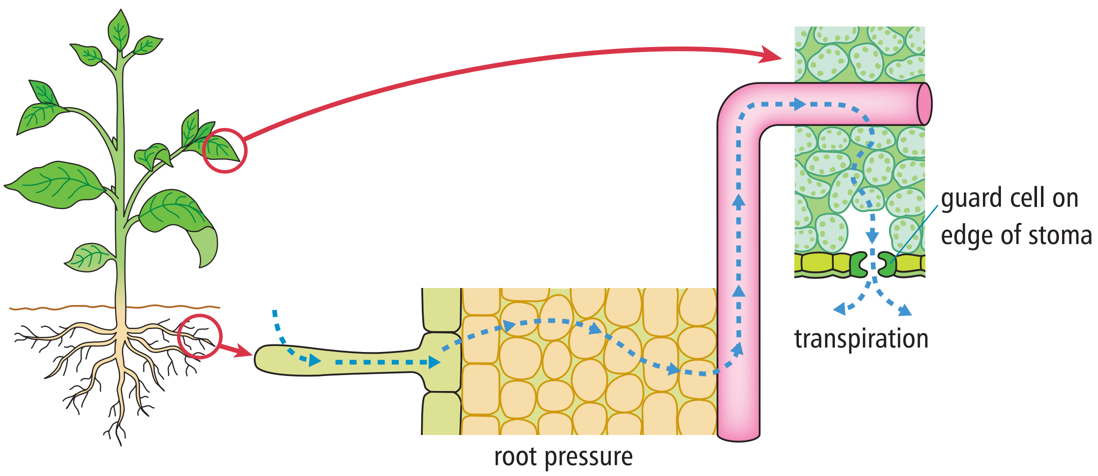
ii. wind speed

iii. humidity

iv. light intensity

2. a. Explain the opening and closing of stomata during 24 hours (one day) of 'normal' environmental conditions.

b. Explain why stomata close during times of high environmental temperature.




Relationship between roots, stem and leaves in the transpiration stream

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3. Transpiration acts as a pull force (*transpiration pull*) to transport water up the xylem vessels to the leaf. The movement of water up the xylem results from a combination of forces – *root pressure* pushes water up the xylem; *capillary action*, *cohesion* and *transpiration* all pull water up the xylem.
   Do some research, then describe the relation between each of these terms and the transport of water.
   a. capillary action
   b. cohesion
   c. transpiration pull
4. Describe how push and pull forces work together to transport water up the xylem from roots to leaves.
5. Discuss why angiosperms need to conserve water and how this is achieved. Explain how the need to conserve water may limit the process of photosynthesis.

## *Practice assessment – Transport in angiosperms*

Answers p. 32

1. Write a summary of transportation in angiosperms. In your summary:
   - name the substances that need transportation, state why they are needed by the plant, and say where they are transported from/to
   - name the processes involved, and explain their role in transportation
   - describe the tissues involved in transportation, and say how they are adapted to perform their function(s)
   - give any limitations associated with the structures or processes.

   Show your summary to your teacher for feedback.
2. Discuss how the nutrition and transport systems in angiosperms connect and work together to allow the plants to be successful in their terrestrial lifestyle. Support your answer with named examples. Show your account to your teacher for feedback.

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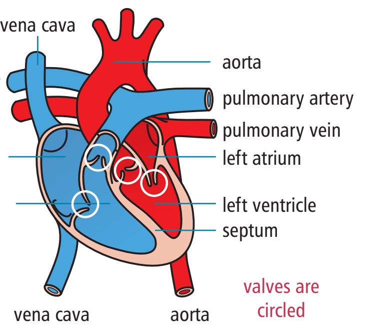
# ANSWERS

## Mammal circulatory system (page 1)

1. Blood carried in (blood) vessels rather than open cavity (e.g. insects' system).
2. Heart has four separate chambers (two collecting atria and two pumping ventricles); right ventricle pumps to loop to lungs (only), left ventricle pumps to separate loop to rest of body.
3. a. pulmonary artery
   b. pulmonary vein
   c. vena cava
   d. aorta
4. *Oxygen* (by diffusion) enters blood capillaries from alveoli; *carbon dioxide* (by diffusion) moves in the reverse direction. Oxygen is needed for cellular respiration; carbon dioxide is the waste product of respiration (respiration occurs in all cells, especially cells of working muscles). Carbon dioxide needs removing as it makes blood (plasma) acidic.
5. a. Glucose, amino acids, mineral ions, vitamins from digestion enter blood capillaries for transport to where processed/needed/stored. Small intestine receives oxygen (for cellular respiration) and nutrients for cell processes / growth in return.
   b. Liver receives glucose and amino acids (plus vitamins, minerals) for processing (e.g. deamination) or storage (e.g. glycogen from glucose), toxins for detoxification, oxygen for respiration. Blood gets carbon dioxide (from respiration), urea (from deamination), glucose (from glycogen storage) from liver for transport to where needed/eliminated.
   c. Muscles receive oxygen for respiration (to release energy to contract) plus needed nutrients for cell processes / growth and release carbon dioxide from respiration to blood for removal at lungs.

## Heart structure and function (1) (page 2)

1.




2. The left ventricle is much more muscular than the right ventricle as it has to pump blood around the body; right ventricle has to pump the blood only to the lungs, a much shorter distance/loop.
3. Valves prevent backflow of blood, ensuring flow is directional (from atria to ventricles, then from ventricles to arteries).
4. Pulmonary vein carries oxygenated blood as the blood has a high concentration of oxygen – since the blood was received from the alveoli of the lungs and it is now being taken to the heart for pumping around the body. Pulmonary artery carries deoxygenated blood as the blood has a high concentration of carbon dioxide (and low oxygen concentration) from body cells – this blood is now being transported to the alveoli of the lungs for removal of $CO_2$ from the body.

## Heart structure and function (2) (page 3)

1. Cardiac muscle doesn't tire (beats throughout an individual's life, which could be 100+ years); skeletal muscle tires comparatively quickly. Skeletal muscle under conscious control, cardiac muscle cannot be consciously controlled.
2. Heart is a muscular organ contracting regularly to pump blood. Contraction needs large amounts of energy from (aerobic) cellular respiration, hence needs large amounts of oxygen and glucose and produces large amounts of $CO_2$ in the process.
3. Levels of $CO_2$ in blood relate to rate of respiration in cells of organs. Higher rate means higher levels of $CO_2$ in plasma (and vice versa). $CO_2$ causes the blood to increase in acidity (lowers pH from neutral) – this lower pH will cause damage to cells/membranes/processes. Brain receptors monitor blood acidity and increase heart and breathing rate to speed up removal of $CO_2$ (by lungs) to return blood pH to 7.35–7.45.
4. *Class discussion / teacher feedback*.

***Your blood pressure***

*Answer from own research or measurements* (with sphygmomanometer) – likely to be in vicinity of 120/80.

***Your pulse***

*Answer from own measurement and research*.

## Blood pressure and pulse (page 5)

1. a. *Answer from own research or measurement*.
   b. Hypertension may have no known cause, or may be caused by lifestyle factors (e.g. diet rich in saturated fats) that cause narrowing of the arteries (from plaque build-up) making the heart work much harder to pump blood around the body (e.g. by having to force blood through narrowed arteries) – heart disease/failure or stroke may result.
   c. Hypotension is most commonly caused by low blood volume. The brain does not get sufficient oxygen/nutrients and the individual becomes dizzy or may faint or pass out (may be associated with sitting up or standing up suddenly).
2. a. *Answer from own research or measurement*.
   b. The sinus node is the impulse-generating tissue (*pacemaker*) in the right atrium – and causes contraction of the cardiac muscle. *Tachycardia* occurs when heart contractions exceed the normal resting beat (>100 bpm in people 15+ years). It can be caused by action of hormones (e.g. adrenalin) and stimulants (e.g. cocaine), hyperthyroidism and hypertension, fever and severe infections (these raise metabolic demands of the body). The heart pumps less efficiently and provides less blood flow to the body, including the heart. Increased workload and oxygen demand by the heart occur, which can lead to heart disease.
   c. *Sinus bradycardia* occurs when the heart contractions are < 60 bpm. *Benign bradycardia* is common in a conditioned athlete – and is advantageous as the conditioned heart muscle has a higher stroke volume and therefore needs fewer contractions to circulate the same volume of blood. Bradycardia resulting from 'sick' sinus syndrome, however, may be caused by certain drugs, electrolytic imbalance or hypothyroidism. Reduced oxygen transport may occur and if the oxygen supply to the heart is too low, cardiac arrest may result.

## Blood vessels (page 6)

1. *Arteries* have thick, muscular, elastic walls – thickness helps withstand high blood pressure, muscle contraction and elasticity help to even out blood flow. *Veins* have less muscular and relatively inelastic walls, as blood is under low pressure and flow is even, not spurting. Lumen is relatively larger, to enable easier blood flow back to the heart. Valves are present to stop backflow of blood and maintain directional flow to heart.
2. *Teacher feedback*.
3. Muscular contraction (skeletal muscles as well as vein muscle) squeezes vein wall, opening a valve and pushing blood through. The muscles relax and valve closes, preventing backflow of blood. Contraction cycle repeats, moving blood towards the heart.
4. Faulty valves allow blood to flow backwards and to accumulate, which puts pressure on veins. Veins may enlarge and become painful (a varicose vein). Movement of blood is restricted, so circulation is less efficient.

## Exchange of materials between capillaries and cells (page 8)

1. a. Concentration of oxygen increases while carbon dioxide decreases.
   b. Concentration of nutrients (glucose, amino acids, minerals, vitamins) and carbon dioxide increases. Concentration of oxygen decreases.
   c. Concentration of oxygen, amino acids, glucose, toxins decreases. Concentration of urea and carbon dioxide increases.

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d. Concentration of oxygen and urea decreases as does (excess) water and mineral ions. Concentration of carbon dioxide increases.

2. *Osmosis* is the process in which water passes through membranes of capillaries and surrounding cells; the direction of movement is determined by water potential – from higher to lower – e.g. from capillaries into kidney tubule cells. *Diffusion* is the process by which oxygen and carbon dioxide (also glucose and amino acids) move across membranes of alveoli, capillaries, cells – the direction of movement is determined by concentration (from high to low – e.g. oxygen higher in alveoli moves to lower concentration in surrounding capillaries).

3. a. RBCs are biconcave discs, thinner at their centre. This gives more surface area (membrane) than a sphere, increasing the SA : Vol ratio. This allows rapid uptake of oxygen which binds with the oxygen-carrying pigment haemoglobin contained in the RBCs so the oxygen can be transported about the body.

   b. i. Presence of haemoglobin to bind with oxygen increases the oxygen-carrying capacity of the blood – greater quantities of oxygen are transported per unit volume than if there were no haemoglobin.

   ii. Low levels of haemoglobin mean less oxygen can be transported which reduces rate of cellular respiration. An individual is likely to lack energy (e.g. for movement), experiencing undue fatigue.

4. Lymph system is the body's 'drainage system'. Capillaries are 'leaky' and lose fluid/plasma/water (which can accumulate and cause swelling (e.g. lower legs) – this may put strain on the heart. The fluid needs to be collected and returned to the blood to maintain fluid levels and prevent dehydration.

## Practice assessment – Internal transport system of mammals (page 10)

1. *Teacher feedback*.
2. *Teacher feedback*.
3. *Teacher feedback*.

## Gas exchange (page 10)

1. Aerobic respiration occurs in the mitochondria of cells. In the process, glucose (chemical energy) is broken down into water and carbon dioxide using oxygen to release energy in the form of ATP (chemical energy). ATP is then used to fuel all cell/life processes.

glucose + oxygen ⟶ carbon dioxide + water (+ ATP + heat energy)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6O_2 + 6H_2O \text{ (+ ATP + heat energy)}$$

2. Processes include DNA replication, cell division, protein synthesis, secretion, transport, movement, growth. Cells that are carrying out these processes have high energy demands (i.e. need lots of ATP). Muscle cells which are involved in movement (e.g. cardiac muscle cells) will have large numbers of mitochondria to release the large quantities of energy needed. Therefore, these cells (and organelles) will have a very high rate of gas exchange.

3. a. Process is **diffusion**. Both $O_2$ and $CO_2$ **freely diffuse** across membranes (as they are both small neutral (or non-polar) molecules) in response to their **concentration gradients**. $O_2$ always diffuses *in,* as $O_2$ is always in higher concentration outside than inside a cell (as $O_2$ used in respiration), while $CO_2$ *always diffuses out* across the cell membrane, as $CO_2$ is always in higher concentration inside the cell (as $CO_2$ is produced in respiration).

   b. i. Membranes are thin so that the *diffusion pathway is short*. Therefore diffusion (hence entry and exit of gases) is rapid.

   ii. Membranes need to be moist to allow the gases to *dissolve*. Both $O_2$ and $CO_2$ need to be *in solution* so that they can diffuse across membranes.

   c. Large quantities of membranes provide a large *surface area* for gas exchange. Therefore, $O_2$ and $CO_2$ can enter/exit a cell in large quantities per unit time.

4. Respiration is a *chemical* process that occurs in the mitochondria of body cells to release energy.

   Breathing is a *physical* process involving muscular movements to take $O_2$ and $CO_2$ to and from gas exchange surfaces.

   Gas exchange is the physical process of **diffusion** in which the gas $O_2$ (needed for respiration) is exchanged with $CO_2$ (released in respiration) across a semi-permeable membrane.

## Gas exchange in insects (page 12)

1. The insect must have been an (ecto) parasite feeding off your blood, e.g. mosquito, sandfly, flea. The red smear is your blood; any whitish fluid would have been the insect's blood.

2. Spiracles are valves along either side of the abdomen. Spiracles open and close to allow entry of $O_2$ and the exit of $CO_2$ from the gas exchange / tracheal system during breathing (see answer to Question 7.). Spiracles are also able to close to conserve water – the end of the tracheoles is moist to allow gases to dissolve so they can diffuse across the membranes into / out of cells. If the tracheoles dry out, gas exchange will not be able to occur and insects die.

3. a. Chitin bands keep the air tubes / trachea open at all times so that both $O_2$ and $CO_2$ can diffuse freely along the tubes to and from the gas exchange surfaces. Chitin bands are flexible so they are not damaged / closed off by movements of the insect.

   b. Tracheoles are the site of gas exchange with body cells. They need to be membranous and moist so that gases can **diffuse freely** into and out of the cells – this would not occur if they were made of chitin.

4. Air sacs assist the trachea by acting as a reservoir of air; when the spiracles close to conserve water, air in the sacs can be used to supply $O_2$ / store $CO_2$.

5. See answer to 3. b.

6. A large surface area is provided by numerous tiny tracheoles which pass between body cells. This allows for large amounts of gas exchange to occur per unit time – large quantities of $O_2$ are delivered to the cell membranes / transported across the membrane, while large amounts of $CO_2$ are removed from the cell / transported across the membrane.

7. Breathing forces air/$O_2$ into and along the trachea, making movement of gases more rapid. This is achieved by muscular pulsations/movements of the abdomen. *However, it is the simple process of diffusion that is mainly responsible for bringing the gases to and from and across the gas exchange surfaces.*

8. The tracheal system directly delivers gases to and from the gas exchange surfaces; the system does not rely on a transport system to deliver the gases. This is an advantage for insects as they do not need transporting proteins such as haemoglobin in their blood (the synthesis of materials and energy). Also, the blood circulation is sluggish as it lacks vessels and a strong heart – blood occurs in the general body cavity and circulates via weak pumping of the dorsal heart. This would be inefficient at supplying $O_2$ to cells and $CO_2$ away from cells. Therefore, the tracheal system is more efficient at gas exchange for insects (many insects fly; flight has huge demands on energy, therefore a high need for oxygen). However, the movement and transport of gases is mainly by the process of diffusion which is not rapid – the gases mainly diffuse along the trachea into/from the tracheoles, though assisted to some extent by breathing movements. This limits the length of trachea and therefore limits the size that insects can grow to – all insects are thus small as a result of their tracheal system of gas exchange (as well as their exoskeleton of chitin).

## Gas exchange in fish (page 16)

1. a. The gills are composed of many thin *filaments*, which are further folded into thin *lamellae*. They are supported by bony gill arches.

   Gills are red in colour as they are rich in blood capillaries – the blood gives them their colour.

   b. Gas exchange occurs between water and the gill filaments. Both $O_2$ and $CO_2$ diffuse across the gas exchange surfaces/membranes in response to a concentration gradient (the difference in concentration of each gas on either side of a membrane). $O_2$ diffuses into the filaments and their blood capillaries as it is in higher concentration in the surrounding water than in the blood capillaries – therefore it is transported away to the cells and used in respiration. $CO_2$ is produced in respiration so is in higher concentration in the cells and the blood capillaries of the filaments than in the surrounding water. It therefore diffuses out into the water from the capillaries of the filaments.

   c. Gases diffuse across the membranes; the thinner the membrane, the shorter the diffusion pathway, therefore the faster the rate of diffusion.

   d. The surface area is increased by the folding of the gills into filaments then the folding of the filaments into lamellae. This allows for the diffusion of much larger quantities of gases into / out of the gills per unit time than if the (extensive) folding did not occur.

2. Fish breathe by gulping in water then closing their mouths so that the water is forced over the gills back into the surrounding water. This makes for rapid transport of dissolved $O_2$ to the gills and $CO_2$ from the gills to the surrounding water. The counter-current flow maximises the concentration gradients. As a result, the rate of gas exchange is increased.

3. Their gills no longer have the buoyancy of water and collapse in air. This results in the fish suffocating.

4. Fish are adapted for gas exchange by having thin, membranous, much-folded gills supported by gill arches and protected by a bony operculum. The gills are surrounded by water containing dissolved oxygen. Fish gulp in water which is then forced out over the gill filaments. The filaments are rich in blood capillaries. $O_2$ and $CO_2$ are exchanged across the membranes of the filaments and capillaries. Both gases freely diffuse across the membranes in response to their concentration gradients – $CO_2$ is in higher concentration in capillaries so diffuses into surrounding water, while $O_2$ is in higher concentration in water so diffuses into the capillaries. The membranes involved are thin to provide a short pathway for rapid diffusion and many-folded to provide a large surface area for diffusion of large quantities of gases per unit time. The water flow over the filaments is in the opposite direction to the flow of blood within the capillaries, known as counter-current flow. This maximises the concentration gradient so that diffusion is efficient. If the flow was


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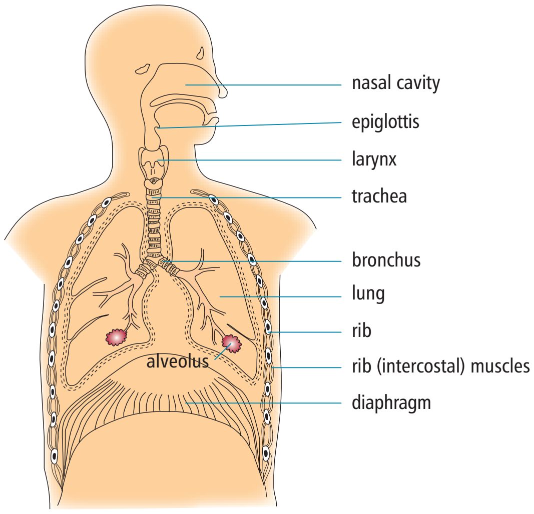
in the same direction, a maximum of 50% of available oxygen would diffuse into the blood; with counter-current flow, a maximum of 90% of the available oxygen in the water diffuses into the blood. Blood transports $O_2$ to the cells/tissues where it diffuses into the cells for respiration, and $CO_2$ from respiration diffuses out; the rapid flow of blood also maximises the concentration gradient for both gases, so enhancing diffusion into and out of the surrounding water.

## Gas exchange in mammals (page 18)

1. a.




b. i. Humidifies the air to prevent dryness of the lining of the lungs and bronchial tubes.
ii. Hairs acts to trap dust and other particles that enter the nasal cavity as air is inhaled, keeping the air passages and alveoli free of potentially blocking particles.
iii. Warm air is more humid, so holds more water to help prevent dryness of the lining of the lungs and bronchial tubes. Also, warm air assists in maintaining the core body temperature.

c. i. Cartilage bands keep the trachea (and bronchi) open at all times so that air can pass freely along these air tubes.
ii. Mucus is sticky so traps dust and other particles that enter the air passages (i.e. particles that haven't been trapped in the nose).
iii. Cilia line the air tubes and beat back towards the trachea to the throat, where mucus-trapped particles are removed by swallowing (to be digested by stomach acid and digestive juices).

2. Alveoli are tiny air sacs made of thin moist membranes. Wrapped in a network of blood capillaries, each alveolus is a hollow sac that allows entry of a comparatively large volume of air (air contains about 21% $O_2$). Blood in the capillaries has a much lower % of $O_2$ – a concentration gradient exists. $O_2$ dissolves in the moisture on the cells of an alveolus then freely diffuses across the thin alveolar cell membranes into the blood capillaries (vice versa for $CO_2$). A thin membrane provides a short diffusion pathway so diffusion is rapid. The huge numbers of alveoli in each lung provide a large surface area for gas exchange, allowing for large quantities of gas exchange per unit time. The capillary network allows for the transport of large quantities of $O_2$ and $CO_2$ per unit time and the rapid flow of blood acts to maximise the concentration gradient for maximising the rate of diffusion.

## Practice assessment – Gas exchange (page 20)

*Teacher feedback.*

## Movement of substances (1) (page 22)

1. Photosynthesis – occurs in chloroplasts of leaf cells during daylight hours only.
2. Respiration (aerobic) – occurs in mitochondria of all (living) cells all the time (24/7).

> During daylight hours, the amount of photosynthesis taking place 'masks' respiration. It is only during night-time that the occurrence of respiration becomes apparent when concentrations of $CO_2$ and $O_2$ are measured.

3. Direction of movement is dependent on the *concentration gradient* of each gas; direction of movement is from an area of high concentration to an area of low concentration. In daylight hours, photosynthesis occurs, which uses $CO_2$ and produces $O_2$. Therefore:
   - the concentration of $CO_2$ is lower in the leaf than in surrounding air, so the gas diffuses into the leaf
   - the concentration of $O_2$ is higher in the leaf than in surrounding air, so the gas diffuses out of the leaf.

   Photosynthesis does not occur during night-time. Respiration continues in the leaf, using $O_2$ and producing $CO_2$. Direction of movement of the two gases into and out of the leaf is therefore reversed as the concentration gradients of each gas are reversed.
4. Water is needed to keep membranes moist for gas exchange, keep leaf cells cool, allow for transport in xylem and phloem, and is an essential raw material for photosynthesis. Water loss is controlled by the presence of the waxy cuticle on the upper epidermis, location of stomata on lower epidermis and not the upper epidermis, closing of stomata in times of high temperature / high light intensity / high wind speed – during these conditions evaporation/transpiration increases so excess loss of water may occur.
5. a. SPM is a membrane that allows the passage through it of only certain (usually small) molecules, e.g. glucose, oxygen. Plasma (cell) membrane, organelle membranes (e.g. chloroplast, mitochondria) are SPMs.
   b. Diffusion is movement of substances from an area of high concentration to an area of low concentration, e.g. movement of $CO_2$ from air into leaf during photosynthesis.
   c. Osmosis is movement of water across an SPM from an area of high water potential to an area of low water potential, e.g. movement of water from soil water into root hairs.
   d. Transpiration is the loss of water (vapour) from the leaves by evaporation.
   e. Concentration gradient is the difference in concentration of a substance in different areas, often on either side of an SPM, e.g. difference in concentration of $CO_2$ outside/inside leaf, and outside/inside chloroplast.
   f. Active transport is the movement of substances across an SPM against a concentration gradient, a process that requires energy. Mineral ions may move into root hairs from soil water by active transport.

## Movement of substances (2) (page 23)

1. Root hairs are long, thin extensions of the cell membrane of the epidermal cells of a root. This give them a large surface area (high SA : Vol ratio) to allow rapid entry of water (and dissolved ions). Large numbers of root hairs (in a small area) increase the capacity for water/ion uptake.
2. a. Entry is by osmosis from soil water. Water has higher water potential in soil than in root hairs, so moves into root hairs across the SPM.
   b. Mineral ions in soil water may enter by diffusion across the SPM of root hairs if in higher concentration in soil than in root hair. Entry may otherwise be by active transport if the ions are in lower concentration in root hair than in soil.
   c. Water passes from soil water into root hairs, then from cell to cell in the process of osmosis to reach and enter the xylem for transport to leaves. Direction of movement is from higher to lower water potential, maintained by the constant movement of water up the xylem. Mineral ions move in solution in water, diffusing (or moving by active transport) across membranes then up the xylem.
3. Plants need many different mineral ions, some only in small amounts (trace elements, e.g. Mg). Important ones needed in larger quantities include nitrates, $NO_3^-$, phosphates, $PO_4^{3-}$, sulfates, $SO_4^{2-}$; all needed for protein and nucleic acid synthesis.

## Vascular tissue: xylem and phloem (page 25)

1. Xylem resemble drainage pipes, transporting the large quantities of water needed by the plant (especially for photosynthesis), and cater for transpiration pull, especially upwards (against gravity) to the leaves. Lumen is large, walls are thick and strengthened (bands/spirals of lignin) to withstand the pressure of transporting water often over large distances from roots to leaves. Transport of water is a physical process, so cells no longer need to be living (this allows them to be hollow, giving much more space for water transport). Phloem cells, in contrast, are living cells; cell walls are not thick and strengthened as transport of the organic compounds/sugars is mainly downwards (i.e. not against gravity) and no significant pressure is involved. Phloem do not form long hollow tubes as end walls are present, but have perforations (sieve plates) for cell-to-cell transport of sugars. They have reduced cytoplasm/organelles, facilitating flow of sap; no nucleus, as companion cells provide metabolic needs.
2. Companion cells provide the metabolic needs of the phloem cells, e.g. provide them with needed energy, proteins, nutrients. A companion cell needs large numbers of mitochondria (to release energy for both the phloem and itself) and large numbers of ribosomes (as it synthesises proteins for both the phloem and itself).

## Movement in phloem (page 26)

1. a. The transport of organic material in phloem.
   b. Made up of about two-thirds water, with the remaining third mainly being the sugar sucrose, along with various hormones and amino acids.
   c. *Sugar source* – an area where sugar is produced (e.g. leaves when sugar is produced in photosynthesis, roots when sugar is released from (storage) starch). *Sugar sink* – an area that needs/stores food (e.g. roots when sugar is stored as starch, leaves / upper plants when buds/flowers/seeds/fruits are formed).

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d. The flow of sap in phloem resulting from pressure (turgor) differences between sugar sources and sugar sinks.

2. Movement in phloem is both up and down the plant as sugar is produced/needed in both leaves (upper part of plant) and roots (lower part of plant). Movement of water in xylem is only upwards as water is sourced in roots and needed in leaves.

## Movement in xylem (page 27)

1. a. Loss of water vapour from the leaves by evaporation.
   b. i. Increases evaporation of water (change from liquid to vapour), so increases transpiration.
      ii. Speeds up removal of water vapour from leaves, so gives high concentration gradient from air spaces in leaf to surrounding air, therefore increases transpiration.
      iii. More water in surrounding air, which lowers the concentration gradient for water between leaf and air, therefore decreases transpiration.
      iv. Increasing light intensity is associated with increasing temperature, so same effect as i.
2. a. Photosynthesis occurs in daylight only. Solutes produced increase in concentration in guard cells, lowering the water potential. Water enters guard cells, increasing turgor pressure. Guard cells bend around thickened inner wall, so opening stomata during daylight hours. Photosynthesis cannot occur at night, so solutes concentrations decrease. Water leaves guard cells which collapse, closing stomata during hours of darkness.
   b. High temperatures increase evaporation of water from leaves; water is drawn from guard cells (water potential is lower outside cells). Loss of turgor pressure causes collapse of guard cells, closing stomata (thereby conserving water).
3. a. Capillary action occurs when water is in narrow tubing (e.g. capillary tubing, xylem vessels). Adhesive forces between water molecules and the sides of the tube mean water wants to 'move along' (i.e. 'up') the tube. As it does this, water moving against gravity is being 'torn apart'. It is only in thin tubes that water tension of the water is strong enough that the water is *not* 'torn apart'.
   b. Cohesion occurs between water molecules as water is a polar molecule (the two H have a slightly positive charge while the O has a slightly negative charge). The charges attract adjacent molecules which form (weak) hydrogen bonds. Water tends to form a column (with tensile strength) as a result, which assists the upward pull (from transpiration).
   c. Transpiration pull occurs from the evaporation of water from leaves. More water moves up the xylem to replace that lost, pulling the column of water upwards.
4. Movement of water into the xylem from the soil creates a push force – water moves up the xylem. This is assisted by water molecules 'holding onto' one another, and the adhesive forces between water molecules and the sides of the xylem. The loss of water in transpiration from the leaves creates a pull force that acts on the column to draw it up to the leaves.
5. Plants need to conserve water to ensure they do not dehydrate, e.g. membranes must remain moist to allow for gas exchange. Transpiration acts as a pull force to draw water up from the roots. Photosynthesis needs water as a raw material. Water is needed for transport of sugars and minerals. Water is also needed to support a plant (turgor pressure in cells/cell vacuoles) and to stop wilting. Water also acts to cool a plant (by evaporation). Water is conserved by having a waxy waterproof cuticle on the leaf upper epidermis, having the stomata on the lower epidermis and closing stomata when excess water loss is likely (e.g. when temperatures are high). However, closing stomata means that $CO_2$ needed for photosynthesis cannot enter the leaf so photosynthesis will stop. Also, the transport of water from the roots will be limited over time, which may also limit the occurrence of photosynthesis. If stomata are closed during the day for any length of time, photosynthesis will cease as one or both raw materials cannot be provided.

## Practice assessment – Transport in angiosperms (page 28)

1. *Teacher feedback.*
2. *Teacher feedback.*

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