BIOZONE

QCE | BIOLOGY UNITS 1&2

FREE SAMPLE for classroom trial

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UNIT 1
Topic 1

Prokaryotic and Eukaryotic Cells

Activity number

Key terms

biological molecule
cell wall
centrioles
chloroplast
cilia
cytoplasm
electron micrograph
electron microscope
endoplasmic reticulum (ER)
eukaryotic cell
flagella
Golgi
light (=optical) microscope
lysosome
magnification
mitochondrion
nucleolus
nucleus
organelles
pigment
plasma membrane
prokaryotic cell
resolution
ribosome
rough ER (rER)
smooth ER (sER)
stain
vacuole

Cells are the unit of life

Key skills and knowledge

☐ 1 Recognise cells as the basic unit of life on Earth and outline the basic principles of the cell theory. 47

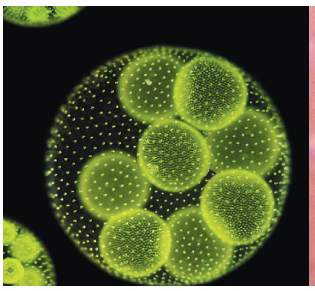
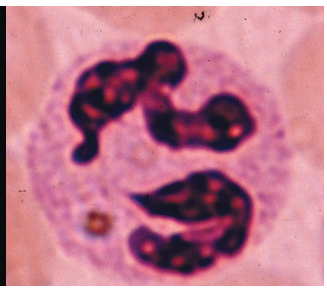
☐ SHE Link the history of the cell theory to the development of microscopes. 47

☐ 2 Recognise the requirements of all cells for survival, including sources of energy, gases, and nutrients, and removal of wastes. 48 49

☐ 3 Recognise the features that prokaryotic and eukaryotic cells have in common. Explain how these commonalities are the result of their shared ancestry. 50 51

☐ 4 Describe the range of cell sizes. Express cell sizes in different units of measurement (mm, µm, nm). 52

☐ 5 Recall the distinguishing features of prokaryotic cells, including small size (relative to eukaryotic cells), lack of a nucleus and membrane-bound organelles, and the presence of a single, circular chromosome. Prokaryotes usually exist as single cells but may be colonial, with some specialization of function (e.g. 50

Eukaryotic cells have specialised organelles

Key skills and knowledge

☐ 6 Understand that eukaryotic cells have specialised organelles and describe the role of these in the functioning of the cell and the organism, including: 53 55
- chloroplasts and plastids other than chloroplasts
- mitochondria
- rough and smooth endoplasmic reticulum (rER and sER)
- Golgi
- lysosomes

☐ 7 Identify which of the above organelles are present in plant cells, animal cells, or both plant and animal cells. 53 55

☐ 8 Identify chloroplasts, mitochondria, rough endoplasmic reticulum, and lysosomes in electron micrographs. 54 56

☐ 9 Use drawings and electron micrographs to compare and contrast the structure of prokaryotic cells and eukaryotic cells. 50 54 56 58

Studying eukaryotic cells

Key skills and knowledge

☐ 10 Understand the structure and basic principles of light (optical) microscopes. Contrast light and electron microscopy in terms of magnification and resolution. 59

SKILL Construct a wet mount for viewing with a light microscope. Use a light microscope to locate prepared material and focus images. 59 60 61

☐ 11 PRAC Prepare wet mounts and use a light microscope to observe cells and identify structures and organelles in microorganisms, plants, and animals (cytoplasm, cell wall, cell membrane, chloroplasts,nucleus). Calculate magnification and field of view. 59-63

☐ 12 PRAC Use electron micrographs to identify organelles in cells. 54 56

32 Investigating Diffusion

Key Idea: Dialysis tubing can be used to model the diffusion of glucose down its concentration gradient.

Diffusion through a partially permeable membrane can be modelled using dialysis tubing. The pores of the dialysis tubing determine the size of the molecules that can pass through. The experiment described below demonstrates how glucose will diffuse down its concentration gradient from a high glucose concentration to a low glucose concentration.

The aim

To demonstrate diffusion through a selectively permeable membrane.

Hypothesis

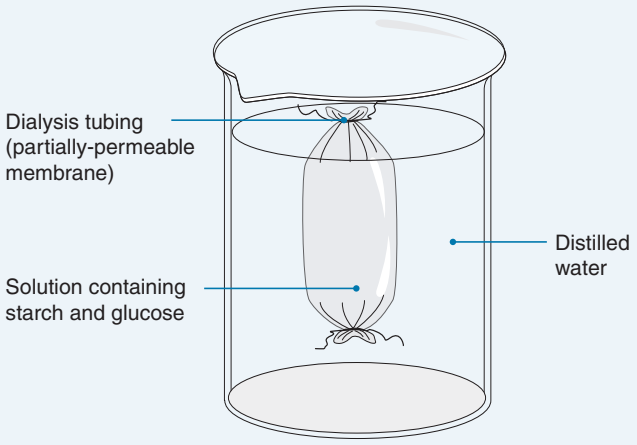
If there is no glucose outside the dialysis tubing, then glucose will diffuse down its concentration gradient from the dialysis tubing into the distilled water until the glucose concentrations are equal.

Background

Dialysis tubing acts as a partially (or selectively) permeable membrane. It comes in many pore sizes and only allows molecules smaller than the size of the pore to pass through.

Lugol's indicator contains iodine, and turns blue/black in the presence of starch.

The presence of glucose can be tested using a glucose dipstick test. If glucose is present, the indicator window will change colour. The colour change can be compared against a reference to determine the concentration of glucose present.



Method

Dialysis tubing was filled with 5 cm^3 each of a 1% starch solution and a 10% glucose solution. A 1 cm^3 sample was removed and tested for the presence of starch using Lugol's indicator, and glucose using a glucose dipstick.

The dialysis tubing was tied, and the outside of the tubing washed with distilled water to remove any starch or glucose that spilled on to the outer surface during filling. The tubing was placed into a beaker of distilled water.

After 30 minutes, the solution inside the dialysis tubing and the distilled water were tested for the presence of starch and glucose.

1. Why was it important to wash the dialysis tubing before placing it into the beaker of distilled water? _____

_____

2. What part of a cell does the dialysis tubing represent?

_____

3. The results for the experiment are tabulated right.

	Dialysis tubing start	Beaker start	Dialysis tubing end	Beaker end
Starch	++	-	++	-
Glucose	++	-	+	+

(a) In the spaces provided (below, right) draw the distribution of starch and glucose at the start and at the end of the experiment. Use the coloured symbols shown under the table to represent starch and glucose:

Starch Glucose

Dialysis tubing start	Beaker start

Dialysis tubing end	Beaker end

(b) Describe why glucose has moved across the partially permeable membrane during the experiment:

_____

_____

_____

_____

(c) Why was there no starch present in the beaker at the end of the experiment?

_____

_____

_____

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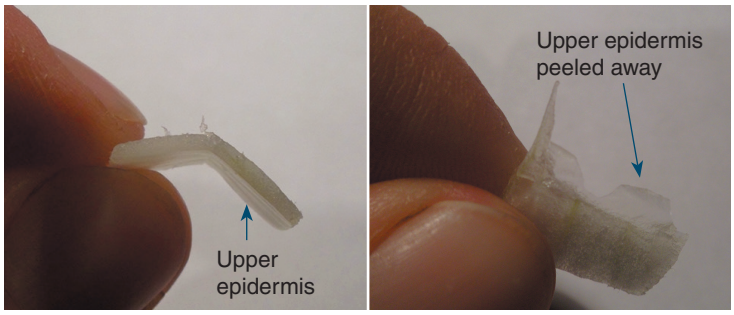
62 Preparing a Slide

Key Idea: Correctly preparing and mounting a specimen on a slide are important if structures are to be seen clearly under a microscope. A wet mount is suitable for most slides.

Specimens are usually prepared in some way before viewing in order to highlight features and reveal details. A wet mount is a temporary preparation in which a specimen and a drop of fluid are trapped under a thin coverslip. Wet mounts are used to view thin tissue sections, live microscopic organisms, and suspensions such as blood. A wet mount improves a sample's appearance and enhances visible detail. Sections must be made very thin for two main reasons. A thick section stops light shining through making it appear dark when viewed. It also ends up with too many layers of cells, making it difficult to make out detail.

Preparing a specimen

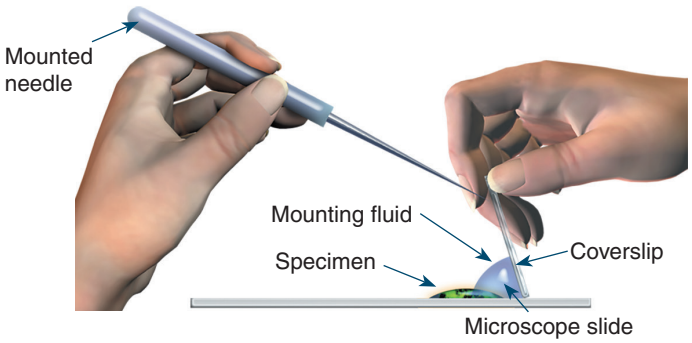


These photos KP

Onions make good subjects for preparing a simple wet mount. A square segment is cut from a thick leaf of the bulb. The segment is then bent towards the upper epidermis and snapped so that just the epidermis is left attached. The epidermis can then be peeled off to provide a thin layer of cells for viewing.

Sections through stems or other soft objects are made with a razor blade or scalpel and must be very thin. Cutting at a slight angle produces a wedge shape with a thin edge. Ideally, specimens should be set in wax before sectioning. This stops crushing and makes it easy to cut the specimen.

Mounting a specimen



The thin layer is placed in the centre of a clean glass microscope slide and covered with a drop of mounting liquid (e.g. water, glycerol, or stain). To cover it for viewing, a mounted needle is used as support and the coverslip is lowered gently over the specimen. This avoids including air in the mount.

Viewing

Locate the specimen or region of interest at the lowest magnification. Focus using the lowest magnification first, before switching to the higher magnifications.

1. Why must sections viewed under a microscope be very thin? _____

_____

2. Why do you think the specimen is covered with a coverslip? _____

_____

_____

3. Why would no chloroplasts be visible in an onion epidermis cell slide? _____

_____

4. Why is it necessary to focus on the lowest magnification first, before switching to higher magnifications? _____

_____

_____

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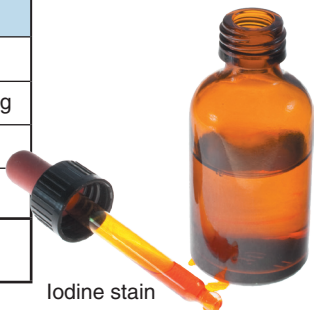
63 Staining a Slide

Key Idea: Staining material to be viewed under a microscope can make it easier to distinguish particular cell structures.

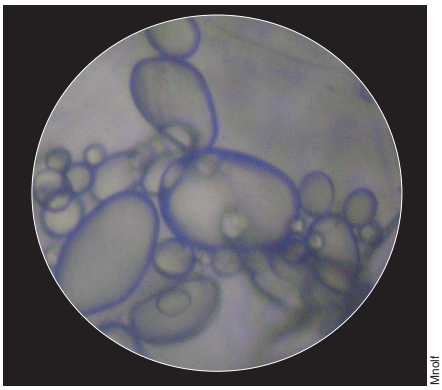
Stains and dyes can be used to highlight specific components or structures. Most stains are **non-viable**, and are used on dead specimens, but harmless **viable stains** can be applied to living material. Stains contain chemicals that interact with molecules in the cell. Some stains bind to a particular molecule making it easier to see where those molecules are. Others cause a change in a target molecule, which changes their colour, making them more visible.

Some commonly used stains

Stain	Final colour	Used for
Iodine solution	blue-black	Starch
Crystal violet	purple	Gram staining
Aniline sulfate	yellow	lignin
Methylene blue	blue	Nuclei
Hematoxylin and eosin (H&E)	H=dark blue/violet E=red/pink	H=Nuclei E=Proteins

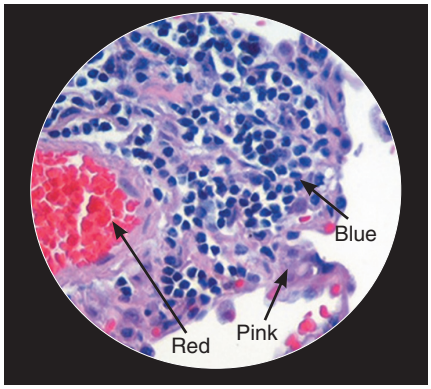


Iodine stain



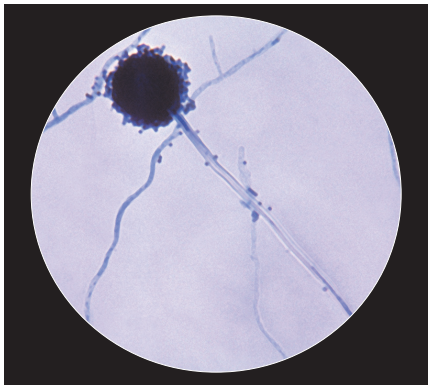
Mnolf

Iodine stains starch-containing organelles, such as potato amyloplasts, blue-black.



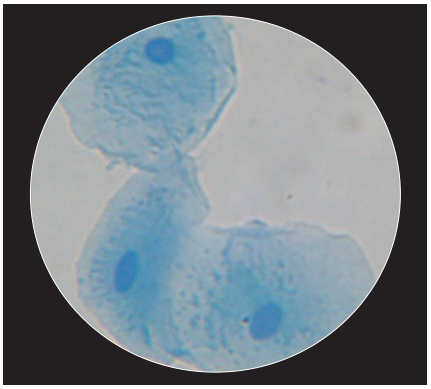
PloS

H&E stain is one of the most common stains for animal tissues. Nuclei stain dark blue, whereas proteins, extracellular material, and red blood cells stain pink or red.



Mnolf

Vital (viable) stains do not immediately harm living cells. Trypan blue is a vital stain that stains dead cells blue but is excluded by live cells. It is also used to study fungal hyphae.

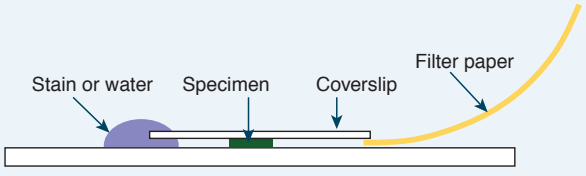


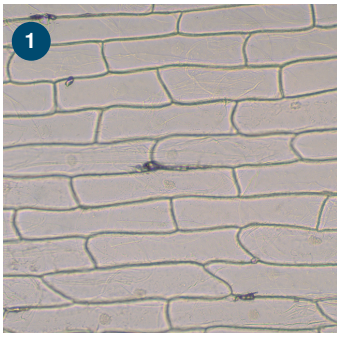
CDC: Dr Lucille K. Georg

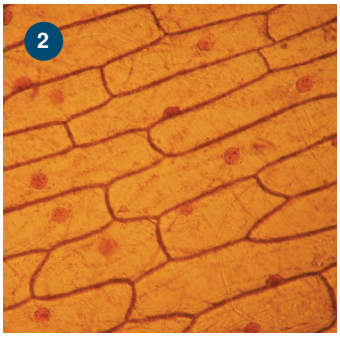
Methylene blue is a common temporary stain for animal cells, such as these cheek cells. It stains DNA and so makes the nuclei more visible.

How to apply a simple stain

If a specimen is already mounted, a drop of stain can be placed at one end of the coverslip and drawn through using filter paper (below). Water can be drawn through in the same way to remove excess stain.







The light micrographs 1 and 2 (above) illustrate how the use of a stain can enhance certain structures. The left image (1) is unstained and only the cell wall is easily visible. Adding iodine (2) makes the cell wall and nuclei stand out.

1. What is the main purpose of using a stain? _____

_____

2. What is the difference between a viable and non-viable stain? _____

_____

3. Identify a stain that would be appropriate for distinguishing each of the following:

(a) Live vs dead cells: _____ (c) Lignin in a plant root section: _____

(b) Red blood cells in a tissue preparation: _____ (d) Nuclei in cheek cells: _____

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69 Investigating Enzyme Activity

Key Idea: The factors affecting peroxidase activity can be measured using the indicator guaiacol.

Enzymes control all the metabolic activities required to sustain life. Changes to environmental conditions (e.g. pH or temperature) may alter an enzyme's shape and functionality. This may result in decreased activity or complete loss of activity if the enzyme is denatured. In this activity you will use the information provided and your own understanding of enzymes to design an experiment to investigate factors affecting enzyme activity.

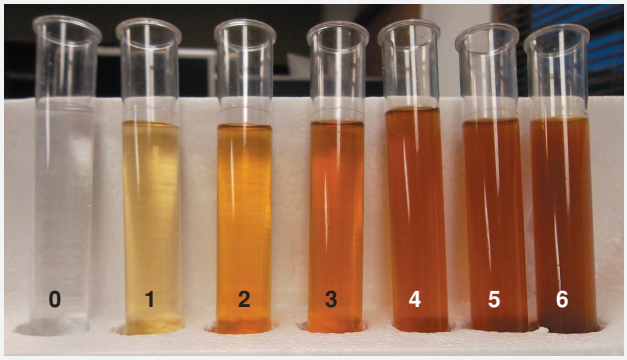
Background

Peroxidase breaks down hydrogen peroxide (H_2O_2), a toxic metabolic by-product of respiration, into water and oxygen.

Hydrogen peroxide $\xrightarrow{\textit{Peroxidase}}$ Water + Oxygen

Like all enzymes, peroxidase activity is highest within specific ranges of pH and temperature, and activity drops off or is halted altogether when the conditions fall outside of the optimal range. The conversion of H_2O_2 is also influenced by other factors such as the levels of substrate and enzyme.

The effect of turnip peroxidase on H_2O_2 breakdown can be studied using the indicator guaiacol. **Guaiacol** has a high affinity for oxygen. In solution, guaiacol binds oxygen and forms tetraguaiacol, which is a brown colour. The greater the amount of oxygen produced, the darker brown the solution becomes (right). The colour palette provides a standard way to measure relative oxygen production (and therefore peroxidase activity).



Increasing levels of oxygen production over time (minutes)

The students were provided with a reference colour palette (above) against which to compare their results. The palette was produced by adding a set amount of peroxidase to a solution containing hydrogen peroxidase and water. The colour change was measured after set time points (0-6 minutes).

Determining the effect of pH on peroxidase activity

Students examined the effect of pH on peroxidase activity using the following procedure:

- **Substrate tubes** were prepared by adding 7 mL of distilled water, 0.3 mL of 0.1% H_2O_2 solution, and 0.2 mL of prepared guaiacol solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- **Enzyme tubes** were prepared by adding 6.0 mL of prepared buffered pH solution (pH 3, 5, 6, 7, 8, 10) and 1.5 mL of prepared turnip peroxidase solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- The substrate and enzyme tubes were combined, covered in parafilm, mixed and placed back into a test tube rack at room temperature. Timing began immediately. Students took photos with their phones to record the colour change (relative to the reference colour palette) every minute from time 0-6 minutes. Results are provided in Table 1.

Table 1. Effect of pH on peroxidase activity

	Colour reference number					
	0 min	1 min	2 min	3 min	4 min	5 min
pH 3	0	2	2	3	3	3
pH 5	0	2	4	5	6	6
pH 6	0	3	3	3	3	3
pH 7	0	3	4	4	4	4
pH 8	0	3	3	3	3	3
pH 10	0	0	0	0	0	0

1. Graph the students' results on the grid (right).

2. (a) Describe the effect of pH on peroxidase activity:

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(b) No colour change was recorded at pH 10. Explain why and relate this finding to the enzyme's structure and the way it interacts with its substrate:

3. The colour palette (previous) shows the relative amounts of tetraguaiacol formed when oxygen binds to guaiacol. How can this be used to determine enzyme activity?

4. In the pH experiment, the students measured the rate of enzyme activity by comparing their results against a colour palette. How could they have measured the results quantitatively?

5. How might the results be affected if the students did not begin timing immediately after mixing the enzyme and substrate tubes together?

6. Why is peroxidase written above the arrow in the equation for enzymatic breakdown of H_2O_2?

7. Using the information provided, design an experiment to test the effect of concentration of turnip peroxidase on oxygen production. In the space below, summarise your method as step by step instructions. Note how you will record and display the data as well as any limitations or sources of potential error with your design:

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78 Investigating Photosynthetic Rate

Key Idea: Measuring the production of oxygen provides a simple means of measuring the rate of photosynthesis.

The rate of photosynthesis can be investigated by measuring the substances involved in photosynthesis. These include measuring the uptake of carbon dioxide, the production of oxygen, or the change in biomass over time. Measuring the rate of oxygen production provides a good approximation of the photosynthetic rate and is relatively easy to carry out.

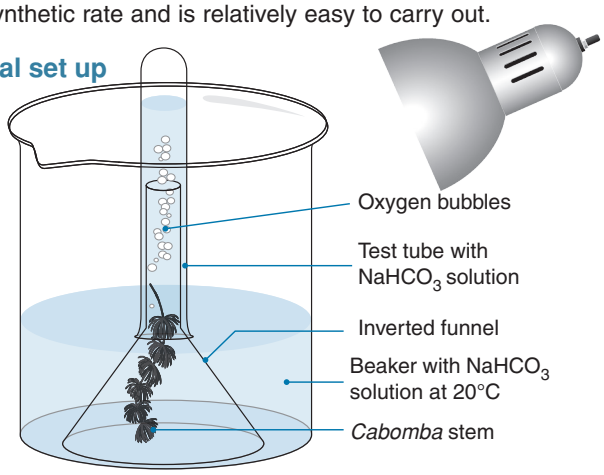
The aim

To investigate the effect of light intensity on the rate of photosynthesis in an aquatic plant, *Cabomba aquatica*.

The method

- 0.8-1.0 grams of *Cabomba* stem were weighed on a balance. The stem was cut and inverted to ensure a free flow of oxygen bubbles.
- The stem was placed into a beaker filled with a solution containing 0.2 mol L^{-1} sodium hydrogen carbonate (to supply carbon dioxide). The solution was at approximately 20°C. A funnel was inverted over the *Cabomba* and a test tube filled with the sodium hydrogen carbonate solution was inverted on top to collect any gas produced.
- The beaker was placed at distances (20, 25, 30, 35, 40, 45, 50 cm) from a 60W light source and the light intensity measured with a lux meter at each interval.
- Before recording data, the *Cabomba* stem was left to acclimatise to the new light level for 5 minutes. Because the volumes of oxygen gas produced are very low, bubbles were counted for a period of three minutes at each distance.

Experimental set up



The results

Light intensity (lx) (distance)	Bubbles counted in three minutes	Bubbles per minute
5 (50 cm)	0	
13 (45 cm)	6	
30 (40 cm)	9	
60 (35 cm)	12	
95 (30 cm)	18	
150 (25 cm)	33	
190 (20 cm)	35	

1. Complete the table above by calculating the rate of oxygen production (bubbles of oxygen gas per minute):
2. Use the data to draw a graph of the bubble produced per minute vs light intensity:
3. Although the light source was placed set distances from the *Cabomba* stem, light intensity in lux was recorded at each distance rather than distance *per se*. Explain why this would be more accurate:

4. The sample of gas collected during the experiment was tested with a glowing splint. The splint reignited when placed in the gas. What does this confirm about the gas produced?

5. What could be a more accurate way of measuring the gas produced in the experiment? _____

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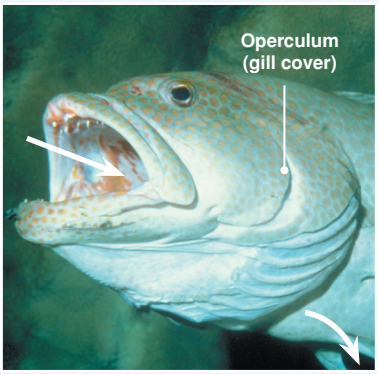
99 Gas Exchange in Fish

Key Idea: Fish gills are thin, vascular structures just behind the head. Countercurrent flow enables efficient exchange of gases between the water and the blood in the gill capillaries.

Fish obtain the oxygen they need from the water using gills, which are membranous structures supported by cartilaginous or bony struts. Gill surfaces are very large and as water flows over the gill surface, respiratory gases are exchanged between the blood and the water. The percentage of dissolved oxygen in a volume of water is much less than in the same volume of air. Air is 21% oxygen, whereas in water, dissolved oxygen is about 1% by volume. Active organisms with gills must therefore be able to extract oxygen efficiently from the water. In fish, high oxygen extraction rates are achieved using countercurrent exchange and by pumping water across the gill surface (most bony fish) or swimming continuously with the mouth open (sharks, rays, and some bony fish, e.g. tuna).

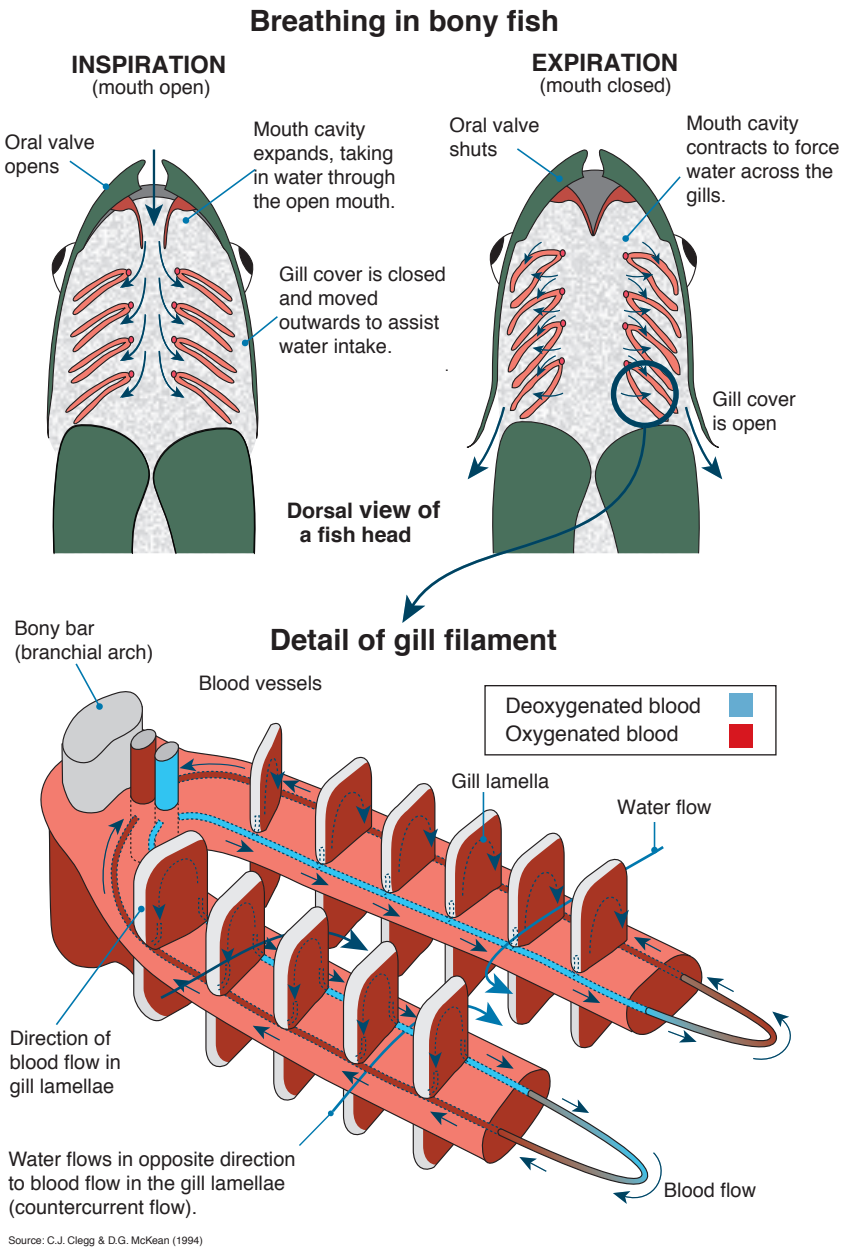
Fish gills

The gills of fish are very thin, filamentous structures, with individual filaments supported and kept apart from each other by the water. This gives them a high surface area for gas exchange. The outer surface of the gill is in contact with the water, and blood flows in vessels inside the gill. Gas exchange occurs by diffusion between the water and blood across the gill membrane and capillaries. The operculum (gill cover) permits exit of water and acts as a pump, drawing water past the gill filaments. The gills of fish are very efficient and achieve an 80% extraction rate of oxygen from water; over three times the rate of human lungs from air.



Ventilation of the gills

Most bony fish ventilate the gills by opening and closing the mouth in concert with opening and closing the operculum. The mouth opens, increasing the volume of the buccal (mouth) cavity, causing water to enter. The operculum bulges slightly, moving water into the opercular cavity. The mouth closes and the operculum opens and water flows out over the gills. These pumping movements keep oxygenated water flowing over the gills, maintaining the concentration gradient for diffusion. Other fish (e.g. sharks and tuna) must swim continuously to achieve the same gill ventilation.



Source: C.J. Clegg & D.G. McKean (1994)

1. Describe three features of a fish gas exchange system (gills and related structures) that facilitate gas exchange:

   (a) _____

   (b) _____

   (c) _____

2. Why do fish need to ventilate their gills? _____

   _____

   _____

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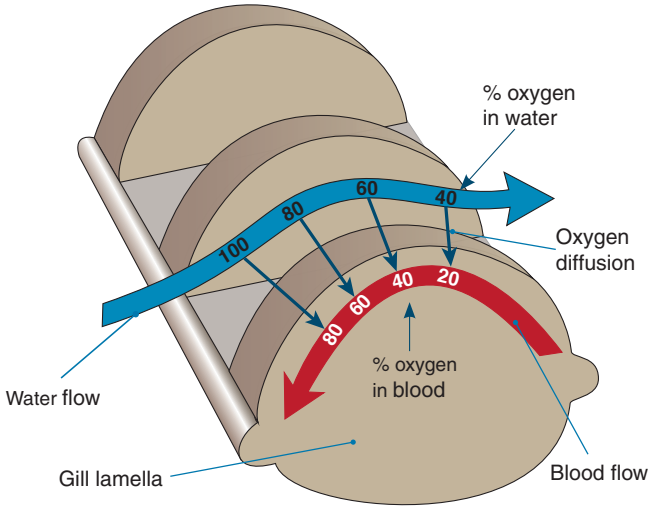
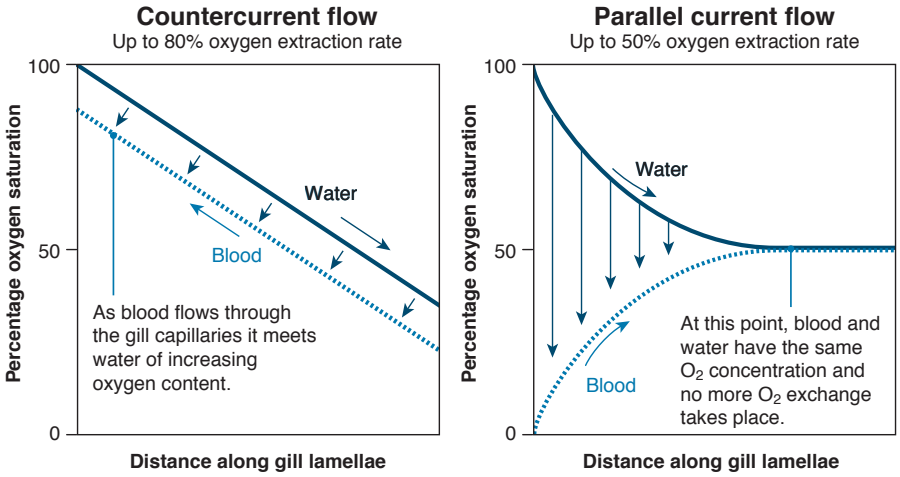
Countercurrent flow

- The structure of fish gills and their physical arrangement in relation to the blood flow maximises gas exchange rates. A constant stream of oxygen-rich water flows over the gill filaments in the opposite direction to the blood flowing through the gill filaments.
- This is called countercurrent flow (below left) and it is an adaptation for maximising the amount of O_2 removed from the water. Blood flowing through the gill capillaries encounters water of increasing oxygen content.



The concentration gradient (for oxygen uptake) across the gill is maintained across the entire distance of the gill lamella and oxygen continues to diffuse into the blood (CO_2 diffuses out at the same time).

A parallel current flow could not achieve the same oxygen extraction rates because the concentrations across the gill would quickly equalise (far right).



3. Describe how fish achieve adequate ventilation of the gills through:

   (a) Pumping (mouth and operculum): _____

   _____

   (b) Continuous swimming (mouth open): _____

   _____

4. Describe countercurrent flow: _____

   _____

   _____

5. (a) How does the countercurrent system in a fish gill increase the efficiency of oxygen extraction from the water?

   _____

   _____

   _____

   (b) Explain why parallel flow would not achieve the same rates of oxygen extraction: _____

   _____

   _____

6. In terms of the amount of oxygen available in the water, explain why fish are very sensitive to increases in water temperature or suspended organic material in the water:

   _____

   _____

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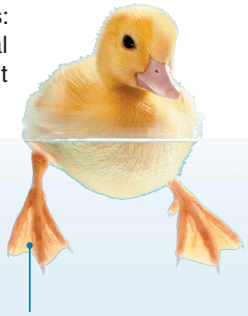
154 Mechanisms of Thermoregulation

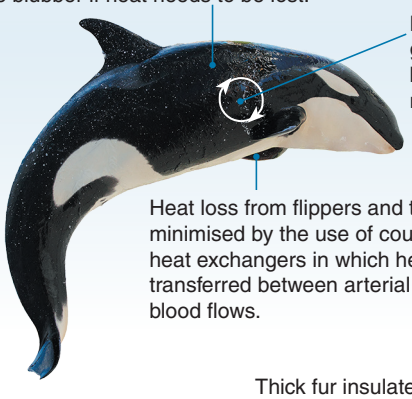
Key Idea: Endotherms regulate their body temperature to within narrow limits by controlling heat exchanges with the environment and generating heat from metabolism. This is termed thermoregulation.

Heat exchanges with the environment occur via **conduction** (direct heat transfer), **radiation** (indirect heat transfer), and **evaporation**. To maintain a relatively constant body temperature, endotherms must balance heat losses and gains. Thermoregulation is achieved through a variety of mechanisms: structural (physical attributes of the body), behavioural (the way an organism behaves), and physiological (mechanisms at the metabolic level). These mechanisms, which operate to different degrees at different times, allow an organism to maintain a body temperature that is optimum for functioning.



Aquatic birds have heat exchangers in their webbed feet that transfer heat from the outgoing arterial blood to the incoming blood in the veins. Their feet are therefore close to the ambient temperature of the water and they reduce heat loss to the environment.

Water has a much greater capacity than air to transfer heat away from organisms, so aquatic mammals have heavily insulated surfaces of vascularised fat called blubber (up to 60% of body thickness). Blood is diverted to the outside of the blubber if heat needs to be lost.



Mammals generate their body heat through metabolism.

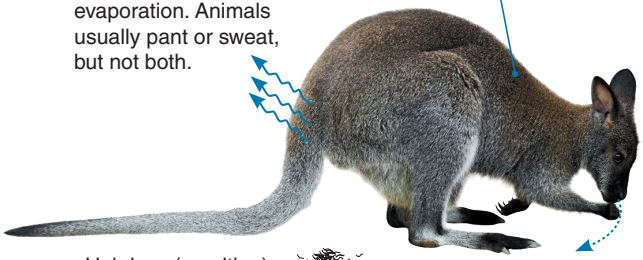
Heat loss from flippers and tail flukes is minimised by the use of countercurrent heat exchangers in which heat is transferred between arterial and venous blood flows.

Temperature regulation mechanisms in water

- Heat generation from metabolic activity
- Insulation layer of blubber
- Changes in circulation patterns when swimming
- Large body size
- Heat exchange systems in limbs or high activity muscle

Thick fur insulates better because it traps a thicker layer of air.

Sweating cools by evaporation. Animals usually pant or sweat, but not both.



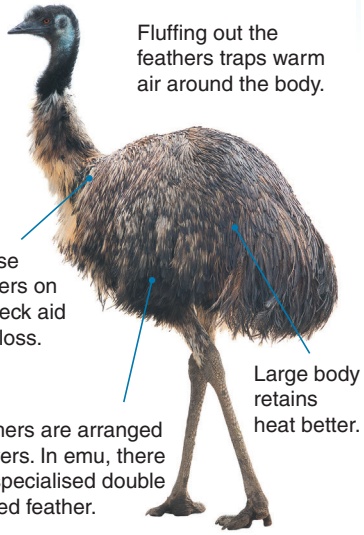
Hair loss (moulting) in warmer months assists cooling.

Panting and licking poorly insulated parts of the body aid evaporative heat loss.

Temperature regulation mechanisms in air

- Behavior or habitat choice
- Heat generation from metabolic activity, including shivering.
- Insulation (fat, fur, feathers)
- Circulatory changes including constriction and dilation of blood vessels
- Large body size
- Sweating and panting
- Tolerance of fluctuation in body temperature

Fluffing out the feathers traps warm air around the body.



Sparse feathers on the neck aid heat loss.

Large body retains heat better.

Feathers are arranged in layers. In emu, there is a specialised double layered feather.

For most mammals, the thickness of the fur or hair varies around the body. Thermoregulation is assisted by adopting body positions that expose or cover areas of thin fur and help regulate heat loss or gain.

In birds, short, fluffy feathers (down) provide insulation against cold. Aquatic birds have waterproof, tightly packed feathers to reduce water entry and aid insulation. In the emu, the black tipped feathers capture heat while lighter feathers underneath insulate the body. This allows the bird to be active in the hot parts of the day without overheating.

1. Endotherms use a number of different mechanisms to thermoregulate, although not every mechanism is present in every species. Determine if the following are structural, behavioural, or physiological mechanisms:

   (a) Seeking shade: _____

   (b) Countercurrent heat exchange systems: _____

   (c) Presence of fur, feathers or hair: _____

   (d) Presence of a blubber layer: _____

   (e) Generation of heat through metabolism: _____

   (f) Panting: _____

   (g) Alternation of circulation pattern (countercurrent exchanges): _____

   (h) Reduced activity at hot temperatures: _____

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166 Investigating Stomatal Density

Key Idea: The density and distribution of leaf stomata in different plant species is related to the rate of water loss.

Different plant species have different leaf shapes and structures and these can be correlated with the environment in which they are found. Comparing the leaf area and stomatal density of different plant species helps to explain observed differences in transpiration rate but factors in the environment, such as shading and wind, are also important.

Plant species show different leaf shapes and structures associated with their environments

Aloe (agave)
A succulent

Tropical species with thick, fleshy leaves. Physiology allows it to fix CO_2 during the night and keep stomata closed during the day.

Pine
A conifer

Temperate species with thin, needle like leaves and a thick waxy leaf cuticle. Stomata are sunken into pits.

Eucalyptus
An Australian gum tree

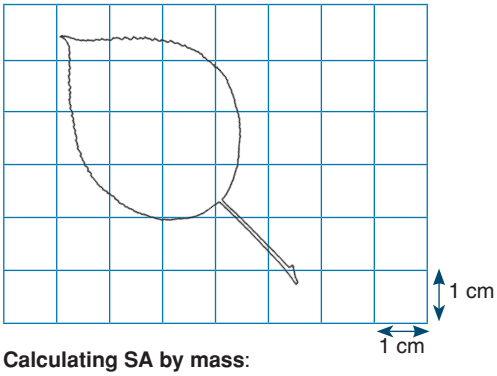
Sub-tropical drought tolerant species with a deep root systems and waxy leaves that hang downwards.

Sunflower
A perennial dicot with large leaves

Widespread cultivated North American dicot with a showy flower head and very large soft leaves.

Measuring leaf area

Leaf area can be measured by tracing the leaves onto graph paper and counting the squares, or by tracing or photocopying the leaves onto a paper of a known mass per area, then cutting out the shapes and weighing them. For both methods, multiply by 2 for both leaf surfaces.

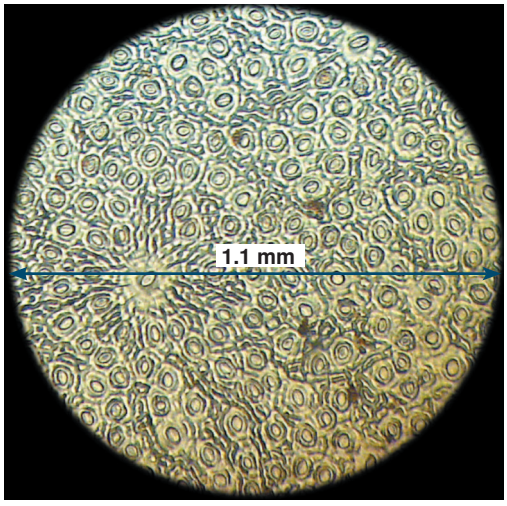


Calculating SA by mass:
Photocopying leaves onto paper with a known gsm (grams per square meter) allows you to calculate the surface area from the mass of paper they cover.

Calculating SA by leaf trace method:
Count entire squares covered by the leaf. Estimate the area of the partial squares by counting those that are at least half covered by the leaf and disregarding those that are less than half covered.

Determining the number of stomata per mm^2

The number of stomata per mm^2 on the surface of a leaf can be determined by counting the stomata visible under a microscope. Painting clear nail polish over the surface of a leaf and leaving it to dry creates a layer with impressions of the leaf surface. This can be peeled off and viewed under the microscope to count stomata (below).



1. (a) Determine the area of the leaf traced onto the blue grid above: _____

   (b) Twenty leaves from plant A were taped to paper and photocopied on to 80 gsm paper. The shapes were cut out and weighed on a digital balance. The total weight of shapes was 3.21 grams. Calculate the surface area of the leaves.

   _____

2. Calculate the number of stomata per square millimetre in the microscope view of the leaf above: _____

   _____

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The aim

To evaluate the relationship between transpiration rate and stomatal density by examining a variety of plant species.

Background

Plants lose water all the time by evaporation from the leaves and stem. This loss, mostly through pores in the leaf surfaces, is called **transpiration**. Despite the adaptations of plants to reduce water loss (e.g. waxy leaf cuticle), 99% of the water a plant absorbs from the soil is lost by evaporation. Different species of plant are adapted to different physical conditions. These conditions may affect the number of stomata per mm^2 of leaf and the transpiration rate of the plant.

The method

Six plant species from a range of habitats were chosen for use. The stems of several specimens of each species were cut while submerged and set up in a potometer similar to that described earlier but with a larger capacity. The temperature was measured at 21°C. The plants were left to transpire in still air at 70% relative humidity for 2 hours and the volume of water transpired was recorded. The surface area of the leaves was also determined as was the number of stomata per mm^2.

3. Write a hypothesis for the investigation: _____

_____

Table 1: Water loss in various plant species over 2 hours

	Total leaf area (cm^2)	Total water lost (μL)	Transpiration rate ($\mu L\ cm^{-2}\ h^{-1}$)	Number of stomata per mm^2 upper surface	Number of stomata per mm^2 lower surface	Total number of stomata per mm^2
Sunflower: *Helianthus annus*	2000	6081		71	172	
Busy Lizzie: *Impatiens sultani*	620	3017		29	143	
Geranium: *Pelargonium zonale*	3800	3721		19	52	
Garden bean: *Phaseolus vulgaris*	1340	4147		40	250	
Caster oil plant: *Ricinus communis*	860	3609		52	121	
Corn: *Zea mays*	4100	6402		60	101	

4. Complete the table by calculating the transpiration rate and total number of stomata per mm^2 for each plant in table 1:

5. (a) Which plant has the highest transpiration rate? _____

   (b) Which plant has the lowest transpiration rate? _____

6. (a) Which plant has the highest stomatal density? _____

   (b) Which plant has the lowest stomatal density? _____

7. (a) Is there a relationship between the number of stomata per mm^2 and the transpiration rate?

   _____

   _____

   (b) Explain your answer: _____

   _____

   _____

   _____

8. (a) Where are the majority of stomata located In a typical dicot leaf? _____

   (b) Suggest why this might be the case: _____

   _____

   _____

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