BIOZONE

HSC | BIOLOGY
MODULES 5 - 8

FREE SAMPLE
for classroom trial
This sample packet may be photocopied and trialled in the classroom.

CHAPTER 3

Cell Function

Key terms

acetyl coA
activation energy
active site
ATP
ATP synthase
Calvin cycle
catalyst
cellular respiration
chlorophyll
chloroplast
cristae
denaturation
electron transport chain
enzyme
glucose
glycolysis
grana
Krebs cycle
light dependent phase
light independent phase
link reaction
matrix
metabolic pathway
metabolism
mitochondrion
NAD/NADH
NADP/NADPH
oxidative phosphorylation
photolysis
photosynthesis
photosystem
pyruvate
RuBisCo
stroma
substrate level phosphorylation
thylakoid discs
triose phosphate

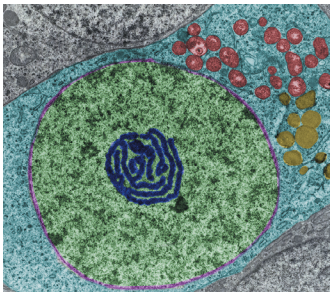
Inquiry question: *How do cells coordinate activities within their environment?*

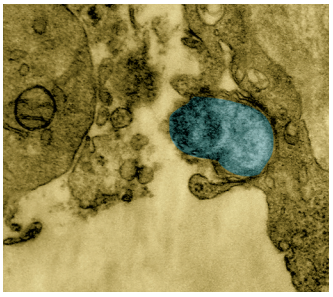
Activity number

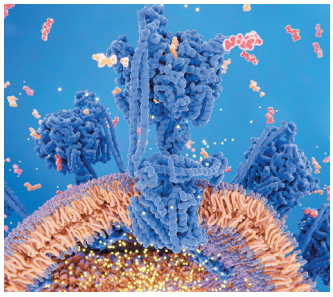
The movement of materials into and out of cells

Key skills and knowledge

☐	1	Describe how cells exchange substances by diffusion (including facilitated diffusion) and osmosis. Relate the exchange of materials across membranes to the surface area-volume ratio, concentration gradient, and the characteristics of the materials being exchanged. Explain how cells overcome the limitations to cell size.	32-35 37 39 44
☐	2	PRAC Investigate diffusion across membranes using a model system.	32
☐	3	PRAC Investigate the effect of cell size on the rate and efficiency of diffusion.	36
☐	4	PRAC Investigate the effects of solutions of different solute concentration on plant cells. Use your results to estimate the osmolarity of a cell, e.g. a potato cell.	38
☐	5	Examine the role active transport (including ion pumps, cotransport, and exo- and endocytosis). What distinguishes active transport mechanisms from forms of passive transport and why is active transport important, despite its energetic costs.	40-44







Cell requirements

Key skills and knowledge

☐	6	Understand that cells exchange matter and energy with their environment. Describe the general requirements of cells, including but not limited to:	31 45 46
	i	The need for energy, including light and chemical energy in complex molecules.	
	ii	The need for matter, including nutrients, gases, and ions.	
	iii	The need to remove waste materials. What types of waste materials are produced by cells, what is their origin, and how do cells get rid of them?	

Investigating biochemical processes in cells

Key skills and knowledge

☐	7	Explain the role of ATP in cells and describe its central role in biochemical processes.	47 48
☐	8	Describe cellular respiration, including the inputs, outputs, and location of glycolysis, the Krebs cycle, and the electron transport chain, and the events occurring in those stages.	49 51-52
☐	9	PRAC Use a simple respirometer to measure respiration in a simple organism.	50
☐	10	Analyse data from a simple model system to investigate factors affecting respiration rate.	53
☐	11	Describe photosynthesis, including the main inputs, outputs, and location of the light dependent and light independent reactions, and the events occurring in those phases.	54 55 57
☐	12	PRAC Use a simple system to investigate factors affecting rate of photosynthesis.	56
☐	13	PRAC Use simple chromatography to isolate and visualise photosynthetic pigments.	58
☐	14	Describe how enzymes work to control biochemical processes in cells, including removal of cellular products and wastes, such as hydrogen peroxide.	60-63
☐	15	PRAC Using turnip peroxidase, investigate factors affecting enzyme activity in cells.	64

64 Investigating Peroxidase 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 a reduction or loss of activity. In this exercise you will use the information provided and your own understanding of enzymes to investigate the effect of pH on enzyme activity and then design an experiment to investigate the effect of inhibitors on enzyme function.

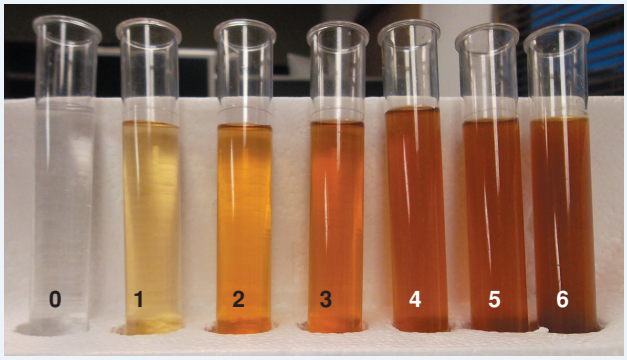
Background

Hydrogen peroxide (H_2O_2) is a toxic by-product of respiration and must be broken down in order to avoid cellular damage. The enzyme **peroxidase** acts in the presence of naturally occurring organic reducing agents (electron donors) to catalyse the breakdown of H_2O_2 into water and oxidised organic substrates.

$$2H_2O_2 + 2AH_2 \xrightarrow{\textit{Peroxidase}} 4H_2O + A_2$$

Like all enzymes, the activity of peroxidase 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 peroxidase on H_2O_2 breakdown can be studied using a common reducing agent called guaiacol. Oxidation of guaiacol (as in the equation above) forms tetraguaiacol, which is a dark orange colour. The rate of the reaction can be followed by measuring the intensity of the orange colour as a function of time.



Increasing levels of oxygen production over time (minutes)

A time-colour palette is shown above. You can use it as a reference against which to compare your own results from the investigation below. The palette was produced by adding a set amount of peroxidase to a solution containing hydrogen peroxide and water. The colour change was recorded at set time points (0-6 minutes).

Investigation 3.7 Investigating peroxidase activity

See appendix for equipment list.

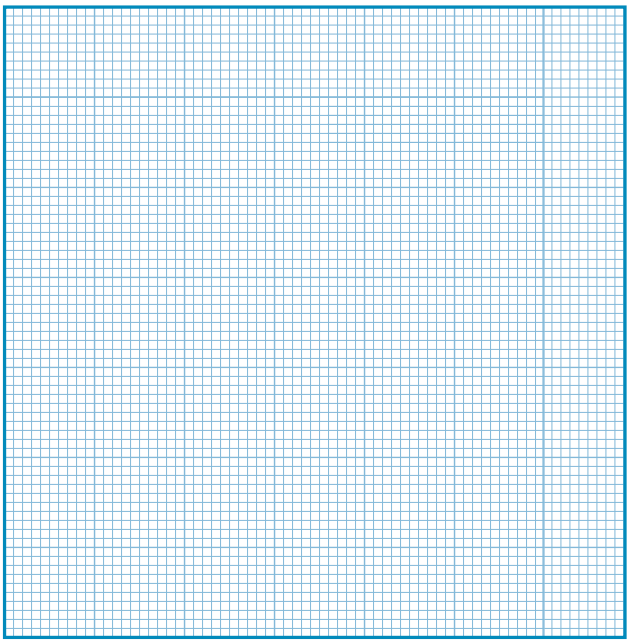
1. Prepare six substrate tubes by adding to a boiling tube 7 mL of distilled water, 0.3 mL of 0.1% H_2O_2 solution, and 0.2 mL of prepared guaiacol solution. Cover the tubes with parafilm and mix.
2. Prepare six enzyme tubes by adding 6.0 mL of prepared buffered pH solution (one of pH 3, 5, 6, 7, 8, and 10) and 1.5 mL of prepared turnip peroxidase solution. Cover the tubes with parafilm and mix.
3. Combine the contents of substrate and enzyme tubes and cover with parafilm. Mix and place back on the rack.
4. Begin timing immediately. Record the colour change every minute (1-6 based on the colour palette above).
5. You can take photos with your phones or keep a written record of the colour changes.

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

1. The colour palette (above) shows the relative amounts of tetraguaiacol formed when guaiacol is oxidised. How can this be used to determine enzyme activity?

ISBN: 978-1-98-856654-2

2. Graph your results on the grid (right).



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

(b) Was there a colour change at pH 10? Explain the result at this pH and relate it to the enzyme's structure and the way it interacts with its substrate:

4. In your experiment, the rate of enzyme activity is measured by comparing against a ranked colour palette. How could you have measured the results more quantitatively?

5. How might the results be affected if you did not begin timing immediately after mixing the contents of 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. Based on the information provided and your answer to question 4, design an experiment to investigate the effect of lead nitrate (an enzyme inhibitor) on the activity of turnip peroxidase. Summarise your method as step by step instructions below. Note how you will record and display the data and calculate the reaction rate. Include reference to any limitations or sources of potential error in your design:

ISBN: 978-1-98-856654-2

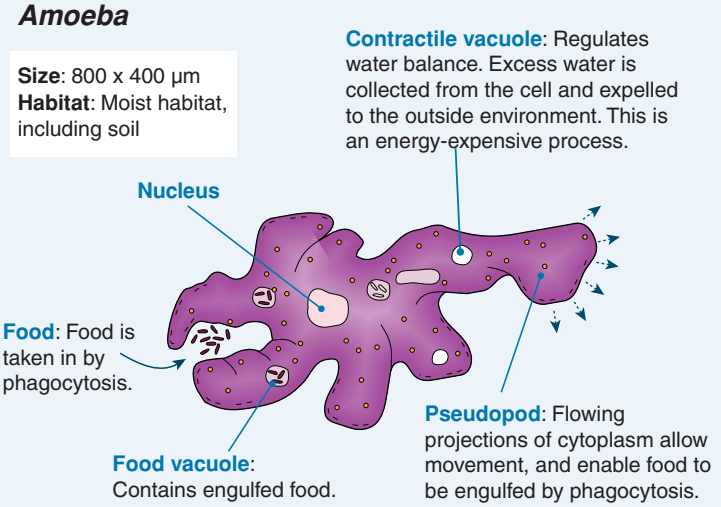
67 Unicellular Eukaryotes

Key Idea: Unicellular eukaryotes show great variation in the ways in which they carry out the functions of life.

Most of life is unicellular (single-celled) prokaryotes (e.g. bacteria). Unicellular organisms must have all the structures needed for independent survival. Unicellular eukaryotes are much larger than prokaryotes and show some features typical of generalised eukaryotic cells, as well as specialised, often unique, features. The genera below are representative of a group of single-celled eukaryotes called protists. Even within the genera below there is considerable variation in size and appearance. *Amoeba* and *Paramecium* are both heterotrophic, ingesting food, which accumulates inside a vacuole. *Chlamydomonas* is an autotrophic alga. Its flagella help it stay in the sunlit parts of a pond.

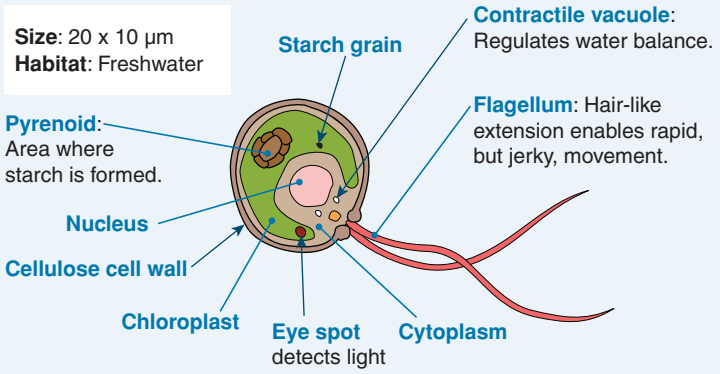
Amoeba

Size: 800 x 400 µm
Habitat: Moist habitat, including soil



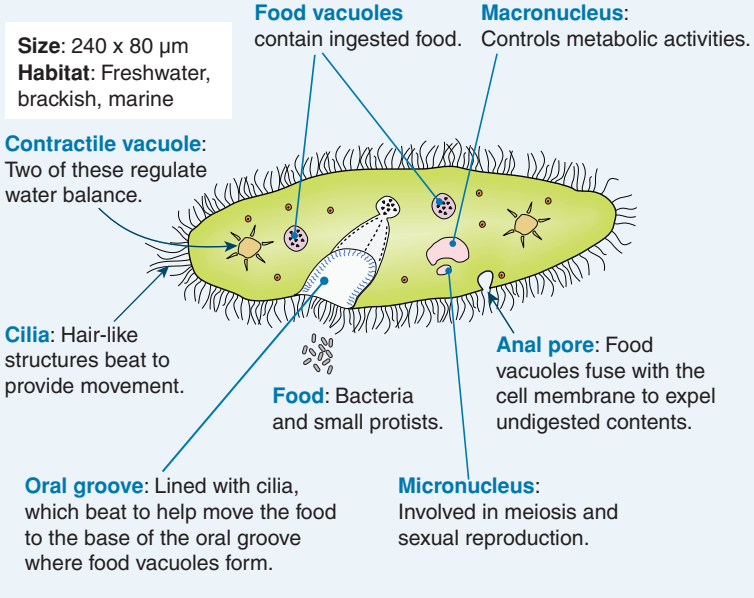
Chlamydomonas

Size: 20 x 10 µm
Habitat: Freshwater



Paramecium

Size: 240 x 80 µm
Habitat: Freshwater, brackish, marine



1. List the three organisms shown in the diagram in order of size (largest first):

   i _____

   ii _____

   iii _____

2. Why would an autotroph have an eye spot?

   _____

   _____

   _____

3. For each of the organisms pictured left, identify the organelles or structures with a role in each of the life functions identified below and describe what they do:

   (a) Nutrition: _____

   _____

   _____

   _____

   _____

   _____

   _____

   _____

   (b) Water balance: _____

   _____

   _____

   _____

   _____

   (c) Movement: _____

   _____

   _____

   _____

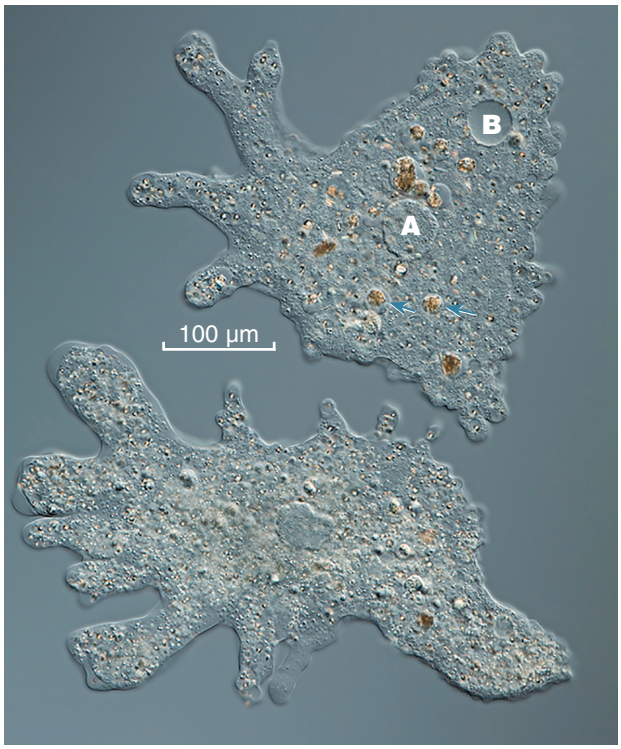
   _____

   _____

   _____

   _____

ISBN: 978-1-98-856654-2



istock

4. (a) Identify the structure labelled **A**:

(b) Circle the same structure in the unlabelled specimen:

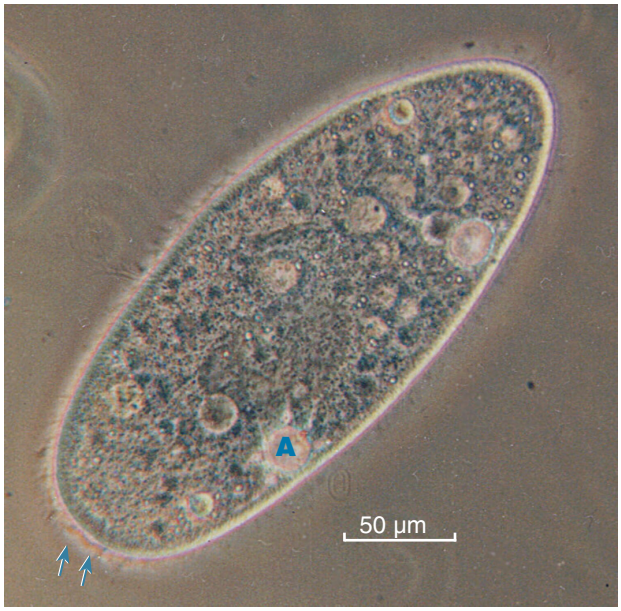
(c) What feature(s) helped you identify this organelle?

(d) Identify the structure labelled **B**:

(e) Describe the function of this structure:

(f) Identify the structures labelled with arrows:

(g) Describe the function of these structures:



Barfooz CC 3.0

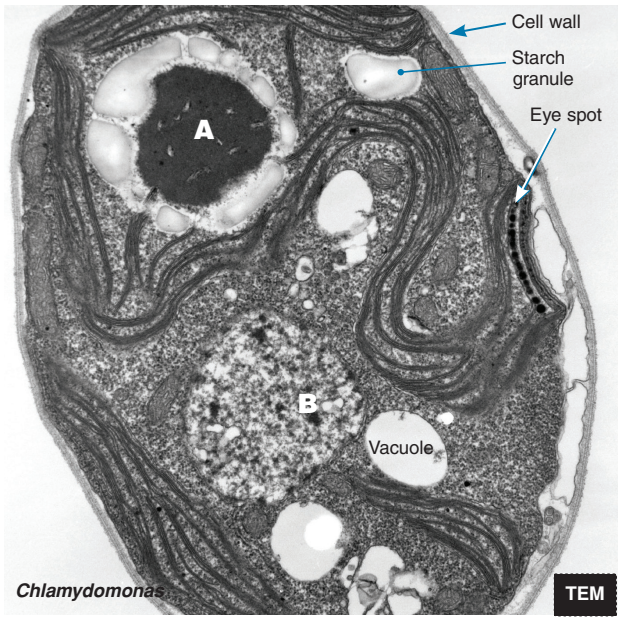
5. (a) Identify this organism:

(b) What feature(s) helped you make your identification?

(c) Identify the organelle labelled **A**:

(d) Circle another organelle with the same function:

(e) Identify the structures indicated by the arrows and describe their purpose:



Dartmouth College

6. (a) Identify the organelle labelled **A**:

(b) Describe the function of this organelle:

(c) Identify the organelle labelled B. What is the dark granular material you can see?

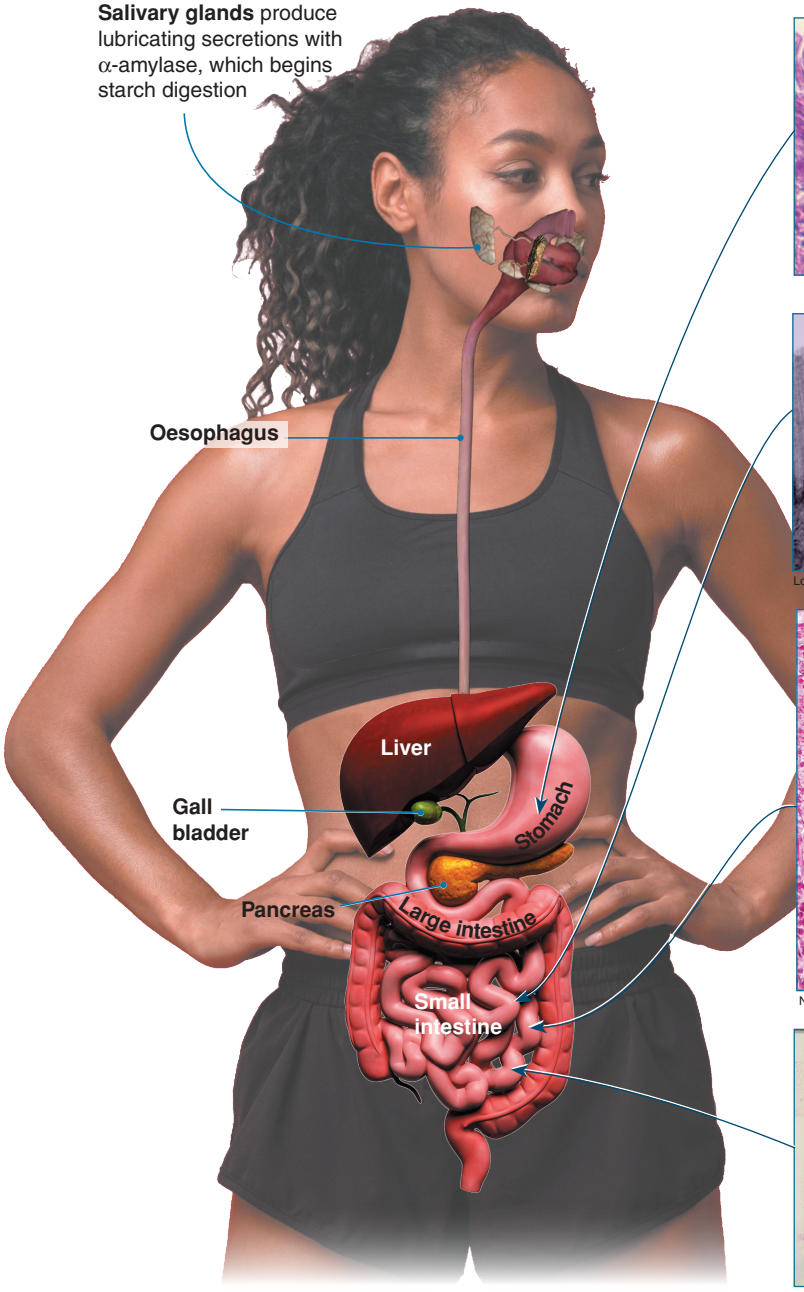
(d) Identify the ribbon-like structures in this image, and explain how you came to your conclusion about what they are:

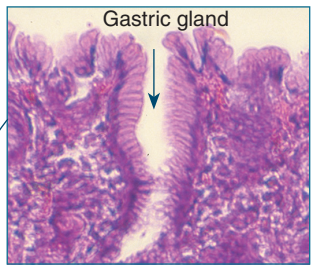
ISBN: 978-1-98-856654-2

90 The Digestive System

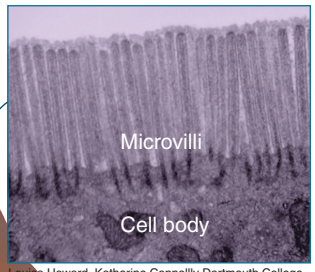
Key Idea: The digestive tract is specialised to maximise the digestion of food, absorption of nutrients, and elimination of undigested material.

The human digestive system (gut) is a tubular tract, which is regionally specialised into a complex series of organs and glands. These work in sequence to maximise the efficiency with which food is processed. Collectively, the organs of the digestive tract carry out the physical and chemical breakdown (digestion) of food, absorption of nutrients, and elimination of undigested material. The gut is a hollow, open-ended, muscular tube, and the food within it is essentially outside the body, having contact only with the cells lining the tract. Several accessory organs and glands lie external to the digestive tract. These secrete enzyme-rich fluids to the food to aid digestion.



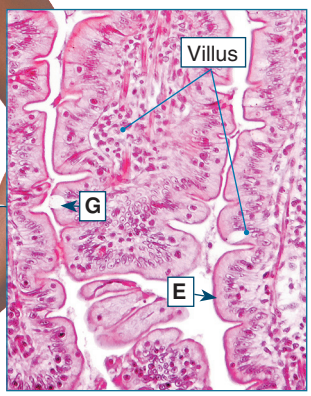


In the stomach, gastric glands contain parietal cells, which produce hydrochloric acid, and chief cells, which produce a protein-digesting enzyme. Scattered endocrine cells secrete a hormone to regulate gastric activity.



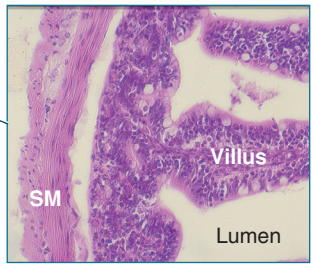
Louise Howard, Katherine Connollly Dartmouth College

Cells lining the walls on the small intestine (the intestinal epithelium) have microscopic extensions of the plasma membrane called microvilli. These form a brush border that increases the surface area for absorption of food molecules. Under lower power microscopy, it appears as a fuzzy edge.



Nephron

In the small intestine, the intestinal epithelial cells (E) and mucus-producing goblet cells (G) make up the epithelium lining the gut wall. The wall is folded into finger like projections called villi (*sing.* villus). These further increase the surface area of the intestine.



EII

The entire gastrointestinal tract is supported by underlying connective tissue. Two layers of smooth muscle (SM), one running lengthwise and one running around the gut, encircle the tube, contracting in waves to move food through the gut. This process is called **peristalsis**.

1. (a) How are villi formed? : _____

   _____

   (b) What is the purpose of microvilli _____

   _____

2. What is the purpose of the smooth muscle surrounding the intestine? _____

   _____

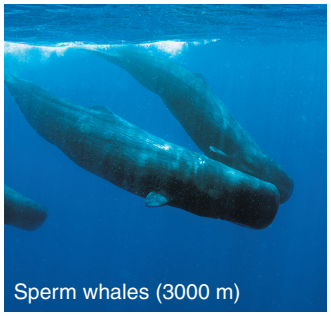
   _____

ISBN: 978-1-98-856654-2

119 Adaptations for Diving

Key Idea: Diving animals have adaptations that allow them to stay active while submerged for extended periods of time.

All air breathing animals that dive must maintain an oxygen supply to the tissues while submerged. This is a problem for mammals and birds in particular because their metabolic rates and oxygen demands are high. In addition, resurfacing from dives of 20 m or more carries a risk of decompression sickness, where dissolved gases in the blood produce bubbles as pressure reduces. Primates (including humans) are one of the few orders of mammals without diving representatives.


Sperm whales (3000 m)


Weddell seals (1000 m)

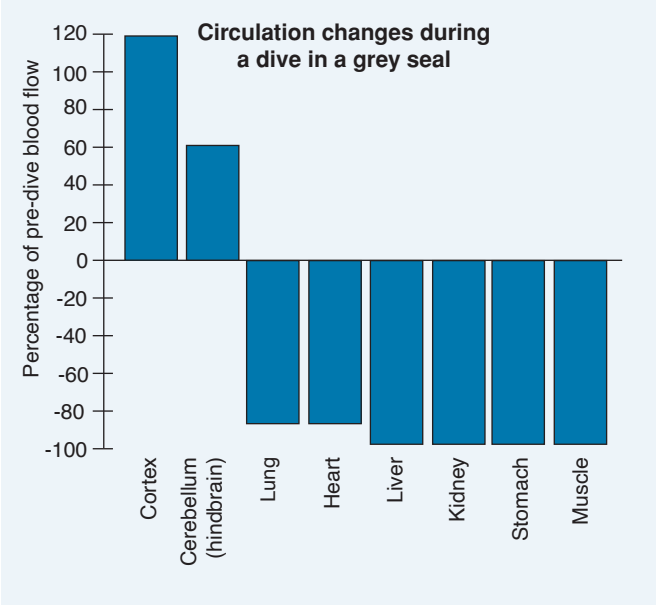

Pantropical spotted dolphins (300 m)

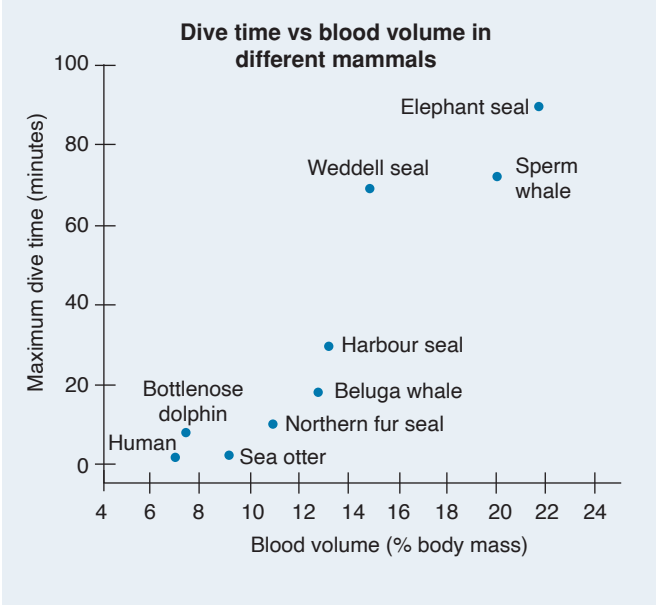

Dugong (10 m)

Diving mammals have physiological adaptations that enable them to stay underwater

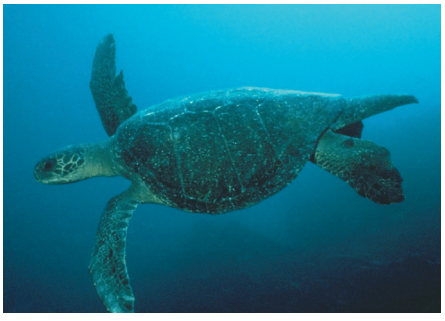
Dolphins, whales, seals, and to a lesser extent dugongs (Australia) and manatees (Northern Hemisphere), are among the most well adapted diving animals. They exhale before diving, expelling most of the air from their lungs. In deep divers, the flexible rib cage allows the lungs to be compressed at depth so that only the trachea contains air. This stops nitrogen entering the blood and prevents decompression sickness ("the bends") when surfacing. During dives, heart rate slows and blood flow is redistributed to critical organs (plot, below left). Most diving mammals have high levels of myoglobin, an oxygen-binding protein found in skeletal muscle (plot, opposite page). Sperm whales are the deepest divers (3000 m) and Weddell seals dive to 1000 m for 40 minutes or more (plot below, right). During these dives, heart rate drops to 4 or 5 beats per minute (4% of the rate at the surface).

Dugongs and manatees, which graze on the ocean floor, are also well adapted for diving, but their dives are generally shallow feeding dives (~3 m) and their muscles do not contain the high concentrations of myoglobin typical of deep divers.





Diving birds
Penguins show many of the adaptations typical of diving birds. During dives, their heart rate slows, and blood is diverted to the head, heart, and eyes.



Diving reptiles
Sea turtles such as the green sea turtle have low metabolic rates, and tolerate low oxygen. They use the lining of the mouth and the cloaca for gas exchange and can overwinter at 10-15 m depth for several months.

Bony fish
Fish don't dive like air breathing animals. However bony fish do experience the effects of pressure. They use an air filled swim bladder to adjust their buoyancy. If they surface too quickly, the swim bladder can expand like balloon.

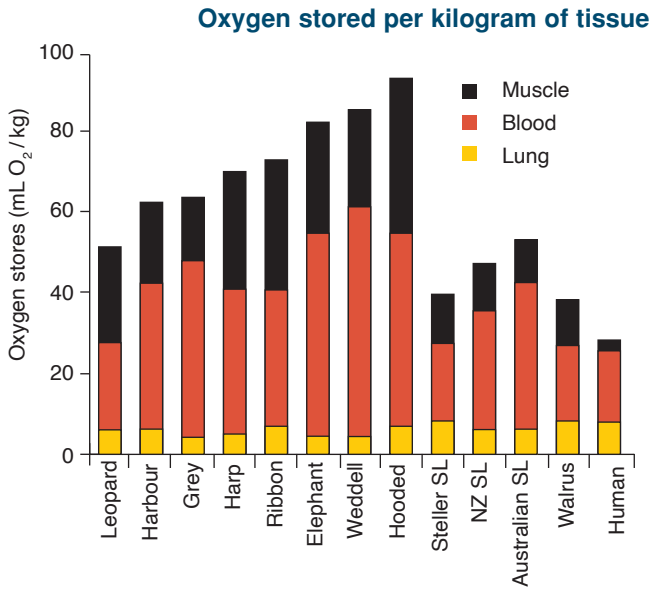
ISBN: 978-1-98-856654-2

1. Unlike humans, mammals that have evolved adaptations for diving exhale before they dive (humans inhale). How might this be an advantage to diving mammals?

2. What is the relationship between blood volume as a percentage of body mass and the maximum dive time in mammals with adaptations for diving?

3. Describe the blood flow in a seal during a dive: _____

4. The ability to remain submerged for long periods of time depends on the ability to maintain the oxygen supply to the tissues. This depends on oxygen stores. The graph below compares the amount of oxygen in different regions of the body during a dive in various seal and sea lion (SL) species and a human (not on scuba).



(a) Describe how seals store oxygen in their body: _____

(b) How does this compare to a human? _____

(c) The seals are more specialised for a life in water than the eared sea lions. Does the evidence above support this?

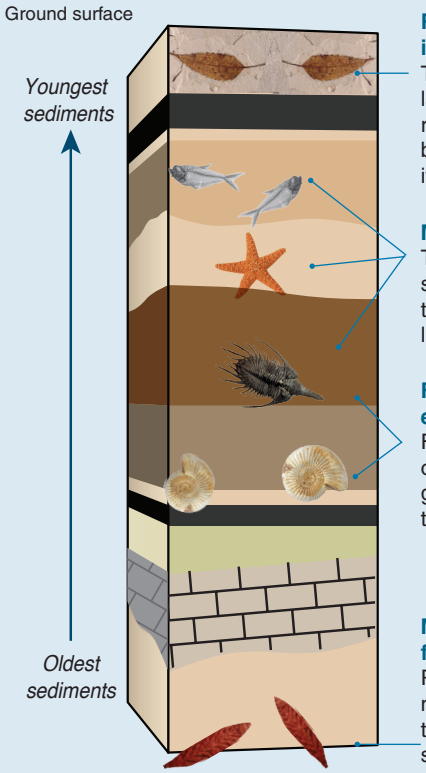
ISBN: 978-1-98-856654-2

148 Relative Dating and the Fossil Record

Key Idea: Fossils found in rock at the bottom of a rock profile are older than those found at the top of the rock file.

Relative dating establishes the sequential (relative) order of past events in a rock profile, but it cannot provide an absolute date for an event. Each rock layer (**stratum**) is unique in terms of the type of rock (sedimentary or volcanic) and the type of fossils it contains. Rock layers (**strata**) are arranged in the order that they were deposited, with the oldest layers at the bottom (unless disturbed by geological events). This is called the **law of superposition**. Strata from widespread locations with the same fossils or characteristics can thus be correlated, even when their absolute date is unknown.

Profile with sedimentary rocks containing fossils



Recent fossils are found in more recent sediments
The more recent the layer of rock, the more resemblance there is between the fossils found in it and living forms.

Many extinct species
The number of extinct species is far greater than the number of species living today.

Fossil types differ in each stratum
Fossils in any given layer of sedimentary rock are generally quite different to fossils in other layers.

More primitive fossils are found in older sediments
Phyla are represented by more generalised forms in the older layers, and not by specialised forms (such as those alive today).

What is relative dating?

Relative dating is a way to determine the relative order of past events without necessarily determining absolute (chronometric) age. The same rocks and fossils can then be used to correlate stratigraphic records in different places. Material that can't be dated using absolute methods can therefore be correlated with the same material elsewhere for which an absolute date may be available.

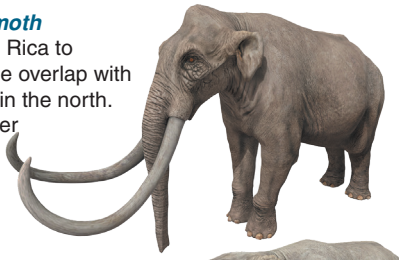
New fossil types mark changes in environment

In the rocks marking the end of one geologic period, it is common to find many new fossils that become dominant in the next. Each geologic period had an environment very different from those before and after. Their boundaries coincided with drastic environmental changes and the appearance of new niches. New selection pressures resulted in new adaptive features as species responded to the changes. An absolute age can be assigned to fossils, usually by dating the rocks around them. Most often, this involves radiometric dating (e.g. radiocarbon, K-Ar).

The fossil record of proboscidea

African and Asian elephants have descended from a diverse group known as **proboscideans** (named for their long trunks). The first pig-sized, trunkless members of this group lived in Africa 40 million years ago. From Africa, their descendants invaded all continents except Antarctica and Australia. As the group evolved, they became larger, an effective evolutionary response to deter predators. Examples of extinct members of this group are illustrated below:

Columbian mammoth
Pleistocene, Costa Rica to northern US. Range overlap with woolly mammoths in the north.
~4 m at the shoulder



Deinotherium
Miocene-Pleistocene, Asia, Africa
~4 m at the shoulder

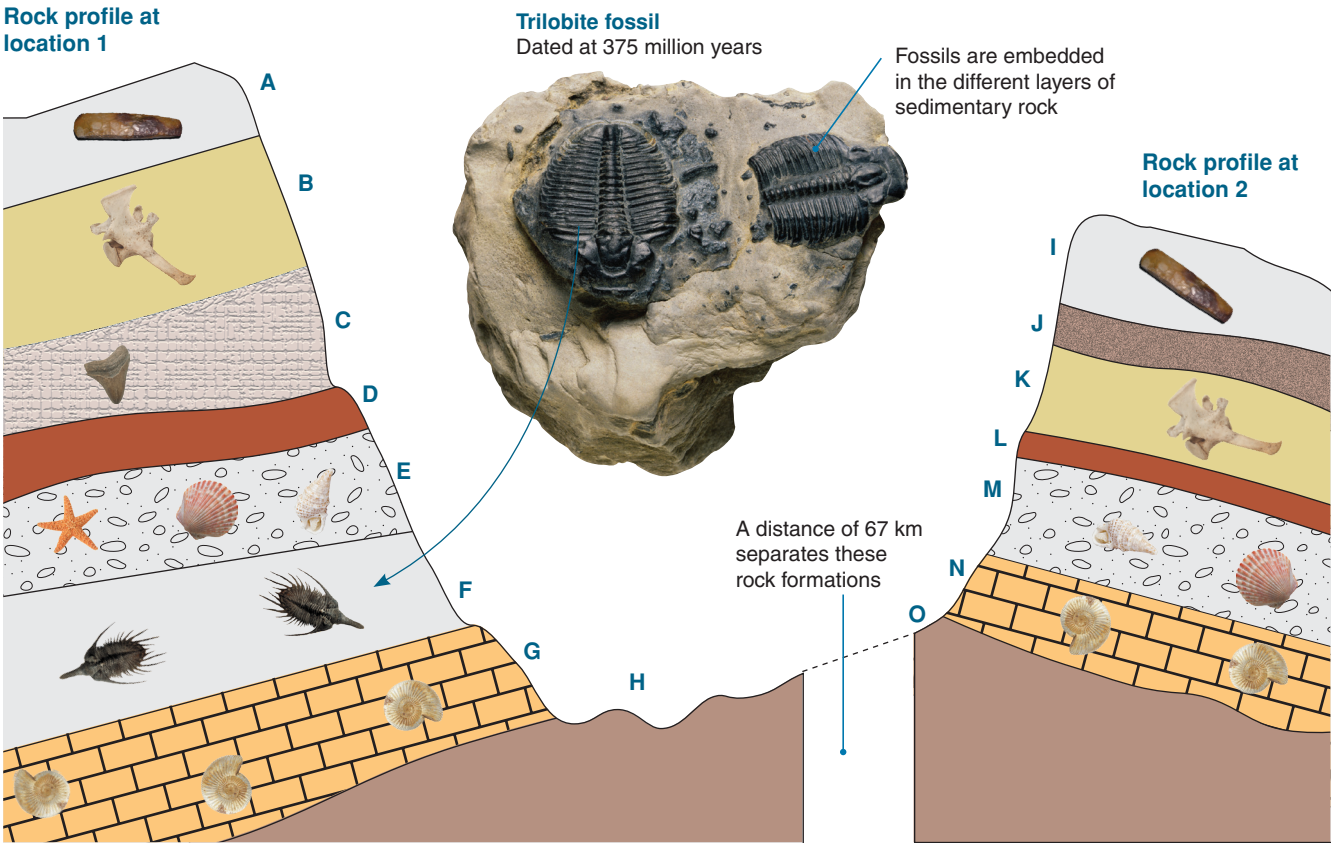
Gomphotherium
Miocene, Europe, Africa
~ 3 m at the shoulder

Platybelodon
One of several genera of shovel-tuskers. Middle Miocene, Northern Asia, Europe, Africa
~3 m at the shoulder

- **Modern day species can be traced:** The evolution of many present-day species can be very well reconstructed. For instance, the evolutionary history of the modern elephants is exceedingly well documented for the last 40 million years. The modern horse also has a well understood fossil record spanning the last 50 million years.
- **Fossil species are similar to but differ from today's species**: Most fossil animals and plants belong to the same major taxonomic groups as organisms living today. However, they do differ from the living species in many features.

1. Explain the importance of fossils in relative dating: _____

ISBN: 978-1-98-856654-2



The questions below relate to the diagram above, showing a hypothetical rock profile from two locations separated by a distance of 67 km. There are some differences between the rock layers at the two locations. Apart from layers D and L which are volcanic ash deposits, all other layers comprise sedimentary rock.

2. Assuming there has been no geologic activity (e.g. tilting or folding), state in which rock layer (A-O) you would find:

   (a) The youngest rocks at location 1: _____ (c) The youngest rocks at location 2: _____

   (b) The oldest rocks at location 1: _____ (d) The oldest rocks at location 2: _____

3. (a) State which layer at location 1 is of the same age as layer M at location 2: _____

   (b) Explain the reason for your answer above: _____

   _____

4. The rocks in layer H and O are sedimentary rocks. Explain why there are no visible fossils in these layers:

   _____

   _____

5. (a) State which layers present at location 1 are missing at location 2: _____

   (b) State which layers present at location 2 are missing at location 1: _____

6. Using radiometric dating, the trilobite fossil was determined to be approximately 375 million years old. The volcanic rock layer (D) was dated at 270 million years old, while rock layer B was dated at 80 million years old. Give the approximate age range (i.e. greater than, less than, or between given dates) of the rock layers listed below:

   (a) Layer A: _____ (d) Layer G: _____

   (b) Layer C: _____ (e) Layer L: _____

   (c) Layer E: _____ (f) Layer O: _____

7. Suggest why gaps in the fossil record can make it difficult to determine an evolutionary history? _____

   _____

   _____

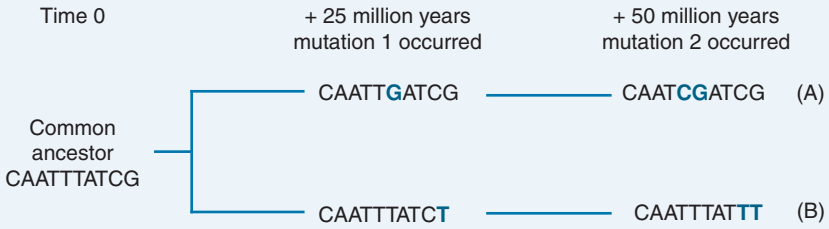
ISBN: 978-1-98-856654-2

161 The Molecular Clock Theory

Key Idea: The molecular clock hypothesis proposes that mutations occur at a steady rate and that changes in DNA sequences between species can determine phylogeny.

The molecular clock hypothesis states that mutations occur at a relatively constant rate for any given gene. The genetic difference between any two species can indicate when two species last shared a common ancestor and can be used to construct a phylogenetic tree. The molecular clock for each species, and each protein, may run at different rates, so molecular clock data is calibrated with other evidence (e.g. morphological) to confirm phylogeny. Molecular clock calculations are carried out on DNA or amino acid sequences.

In a theoretical example, the DNA sequence for a gene in two species (A & B, right) alive today differs by four bases. The mutation rate for the gene is approximately one base per 25 million years. Based on this rate, it can be determined that the common ancestor for these two species lived 50 mya.

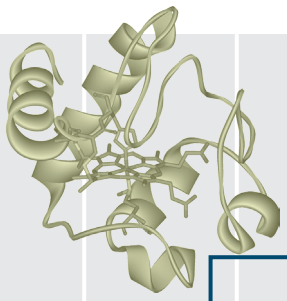


Cytochrome *c* and the molecular clock theory

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Human		Gly	Asp	Val	Glu	Lys	Gly	Lys	Lys	Ile	Phe	Ile	Met	Lys	Cys	Ser	Gln	Cys	His	Thr	Val	Glu	Lys
Pig												Val	Gln			Ala							
Chicken				Ile						Val		Val	Gln			Ala							
Dogfish										Val		Val	Gln			Ala							Asn
Drosophila	<<									Leu		Val	Gln	Arg		Ala							Ala
Wheat	<<		Asn	Pro	Asp	Ala		Ala				Lys	Thr	Arg		Ala						Asp	Ala
Yeast	<<		Ser	Ala	Lys			Ala	Thr	Leu		Lys	Thr	Arg		Glu	Leu						

This table shows the N-terminal 22 amino acid residues of human cytochrome c, with corresponding sequences from other organisms aligned beneath. Sequences are aligned to give the most position matches. A shaded square indicates no change. In every case, the cytochrome's heme group is attached to the Cys-14 and Cys-17. In *Drosophila*, wheat, and yeast, arrows indicate that several amino acids precede the sequence shown.

The sequence homology of cytochrome c (right), a respiratory protein, has been used to construct a phylogenetic tree for some species. Overall, the phylogeny aligns well to other evolutionary data, although the tree indicates that primates branched off before the marsupials diverged from other placental mammals, which is incorrect based on other evidence. Highly conserved proteins, such as cytochrome c, change very little over time and between species because they carry out important roles and if they changed too much they may no longer function properly.



1. How can using molecular clocks help to establish evolutionary relationships (phylogenies) between organisms?

ISBN: 978-1-98-856654-2

181 The Effect of Keystone Species?

Key Idea: When mulgara were excluded from a fenced area, the number of smaller dasyurid species present reduced.

Two species of mulgara (*Dasycercus* genus) are found in Australia, the brush-tailed mulgara and the crest-tailed mulgara. Mulgara are nocturnal marsupials belonging to the family Dasyuridae, which includes the Tasmanian devil and the quolls. Both mulgara species are small (30 cm long from head to tail) and weigh up to 190 g.

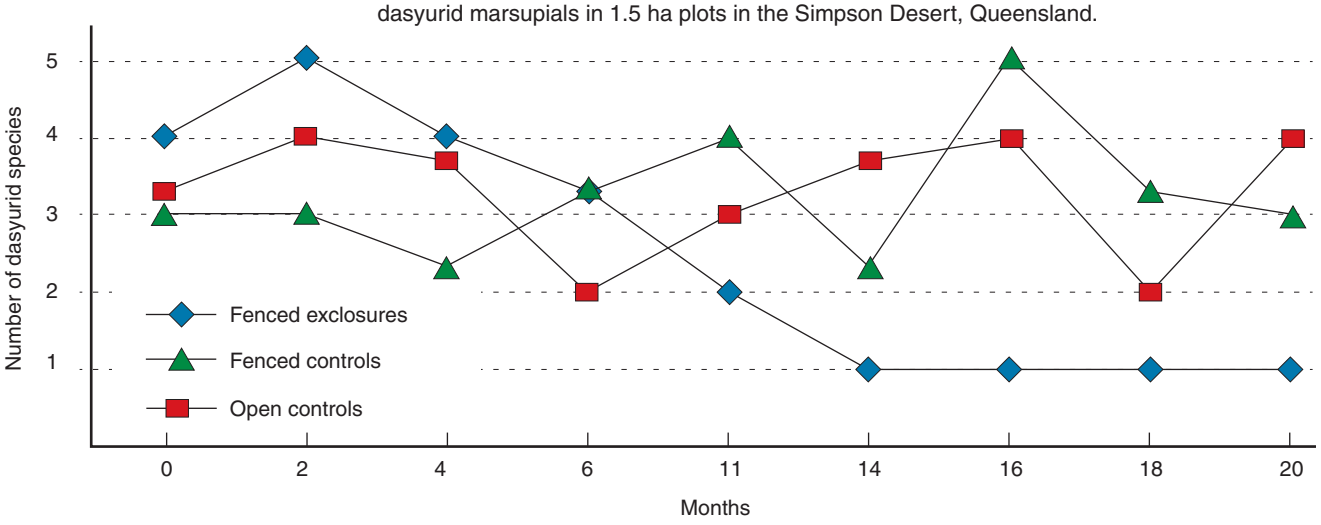
Mulgaras live in arid central Australia, and burrow 50 cm under the surface to avoid the heat. While the brush-tailed mulgara has an extensive range through the middle of Australia, the crest-tailed mulgara is found only in a small part of the Simpson Desert within Queensland's borders.


Crest-tailed mulgara

Bobby Tamayo CC 4.0

The effect of the crest-tailed mulgara (*Dasycercus cristicauda*) as a keystone species was tested by excluding them from a 1.5 ha plot of land. Fenced exclosures were established 10 months after sampling began. All dasyurid species (except mulgara) could access the site. Fenced controls and open controls were established at the same time. All dasyurid species (including mulgara) could access these plots. The results are shown in the graph below.

Effects of crest-tailed mulgara (*Dasycercus cristicauda*) on the number of smaller dasyurid marsupials in 1.5 ha plots in the Simpson Desert, Queensland.



Data source: Dickman in Attiwell, P. and Wilson, B (2003) Ecology: An Australian Perspective.

1. Describe what happens to species numbers after the fences were established (at 10 months) for each of the following:

   (a) Fenced exclosures: _____

   (b) Fenced controls: _____

   (c) Open controls: _____

2. Describe the difference in species numbers between the fenced exclosure and the:

   (a) Fenced control: _____

   (b) Open control: _____

3. (a) Based on the data presented above, do you think the crest-tailed mulgara acts as a keystone species? _____

   (b) Explain your answer: _____

   _____

   _____

   _____

4. Why do you think the researchers included a fenced control and open control? _____

   _____

   _____

ISBN: 978-1-98-856654-2

BIOZONE Learning Media Australia
3/45 Township Drive, Burleigh Heads, Queensland, 4219, AUSTRALIA
PHONE 07 5535 4896
EMAIL sales@biozone.com.au

www.BIOZONE.com/au