Antarctica
–
unique marine environment

A sequence of learning for Grade 11 Life Science (Marine) students

Created by Jane MacDonald

Adelie penguins on snow (Photo © ACE CRC)

Produced by the Tasmanian Department of Education with the support of Antarctic Tasmania, Department of Economic Development

Tasmania
Explore the possibilities

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Purposes and learning activities

This learning sequence is designed for use with Grade 11 Life Science (Marine) classes. The intended purposes and learning activities are as follows:

1. To engage all students in the class, through an initial hands-on visual / kinaesthetic activity. This introduces the Antarctic food web via colouring a diagram published in *New Scientist* in 1983. The potential for updating the information in the diagram is part of the learning sequence (see 4).

   To encourage students to discover the interconnectedness of organisms in the food chain, by answering a set of questions based on the diagram.

   Activity: *Food web of the Antarctic*

2. To introduce the students to the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) website, and, through limited navigation around the site and linked sites, and answering questions, lead them to the understandings that:

   a. CCAMLR aims to regulate impacts on the Antarctic food web, through international agreements.

   b. Hobart is an important international centre for Antarctic-related activity.

   Activity: *Introducing CCAMLR*

3. To introduce students to some changes in our understanding of the Antarctic food web since 1983 and changes in the dynamics of the ecosystem, through readings taken from sources such as the ABC Radio National website (Science Show interview transcripts),

   New Scientist website archives, BBC website, *National Geographic* website and other resources available on the Internet.

   Activity: *What's new in the Antarctic food web?*

4. To have students create a product demonstrating their understanding of the chosen article /s, and linking this understanding to the original 1983 food web. This is most likely to be a poster of the student's own design, showing the relevant links and trends. However, the product is the student's choice.

   Activity: *Assessment task*

Note from the author

In the lead-up to this learning sequence, my students had completed experiments of their own design, to investigate the effects of salinity and temperature on the density of water, using salt, water from hot and cold taps, food colouring, and glassware and methods of their choice.

They also watched a DVD of the program, *Future Focus: The Gulf Stream and the next ice age*, shown on SBS on 29.4.07, which is an excellent introduction to the concept of thermohaline circulation. Even though the DVD focuses on the Gulf Stream, the explanation of global thermohaline circulation is clear and relevant to the whole planet.

Immediately before beginning the learning sequence described here, my class had visited the Islands to Ice exhibition at the Tasmanian Museum and Art Gallery (TMAG), guided by the education officer. This visit was especially focused on underlying factors driving the Antarctic system: the Southern Ocean, the circumpolar current, global heat transfers and thermohaline circulation.

Two more visits to the museum followed, one for the students to 'free range' and study the exhibits at their own pace, and finally, one using the studio space, for hands-on activities with krill, baleen etc. This was also facilitated by an education officer.

A follow-on topic could explore adaptations possessed by Antarctic and other organisms. There is an excellent segment on humpback whales feeding on krill in the David Attenborough's *Life in the freezer* program, and a question sheet for this is also included with this learning sequence (see Additional resource 1). Both structural and behavioural feeding adaptations of humpback whales are shown. Other adaptations of whales and other marine mammals are an interesting topic for further study.

Study of adaptations may lead on to the topic of evolution, by considering how the various adaptations have evolved in response to the organism's environment. The evolution of marine mammals from land mammals is a fascinating story. A further resource provided is an extensive set of questions on the episode *Return to the Water* from David Attenborough's *Life of Mammals* series. This program looks at a range of adaptations in marine mammals worldwide and discusses their ancestry (see Additional resource 2).

Acronyms, abbreviations and key words

AAD	Australian Antarctic Division
ACE CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
CAML	Census of Antarctic Marine Life
CAMLR	Conservation of Antarctic Marine Living Resources convention.
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources, established under Article IX of the convention.
CEMP	CCAMLR Ecosystem Monitoring Program, established in 1985.
IASOS	Institute of Antarctic and Southern Ocean Studies, based at the University of Tasmania
IUU	illegal, unregulated and unreported (fishing)
SCAR	Scientific Committee on Antarctic Research
carnivore	a flesh eater
commercialism	the tendency to attempt to generate profit from things
demersal fish	fish which feed in deep water or on the seabed
herbivore	a plant eater
krill	a small, shrimp-like crustacean which is a major food item for species such as penguins, seals, albatrosses and whales
pelagic fish	mobile or migratory fish which often occupy the open waters between the coast and the continental shelf in depths from twenty to four hundred metres
trophic level	feeding position within a food chain such as primary producer, herbivore or carnivore

The food web of Antarctica

The diagram which follows is taken from an article published in *New Scientist* magazine on 1 September 1983. Since this article was published some details of the feeding interactions shown have been updated. However, the diagram remains a very good illustration of the complex feeding relationships between organisms in a food web.

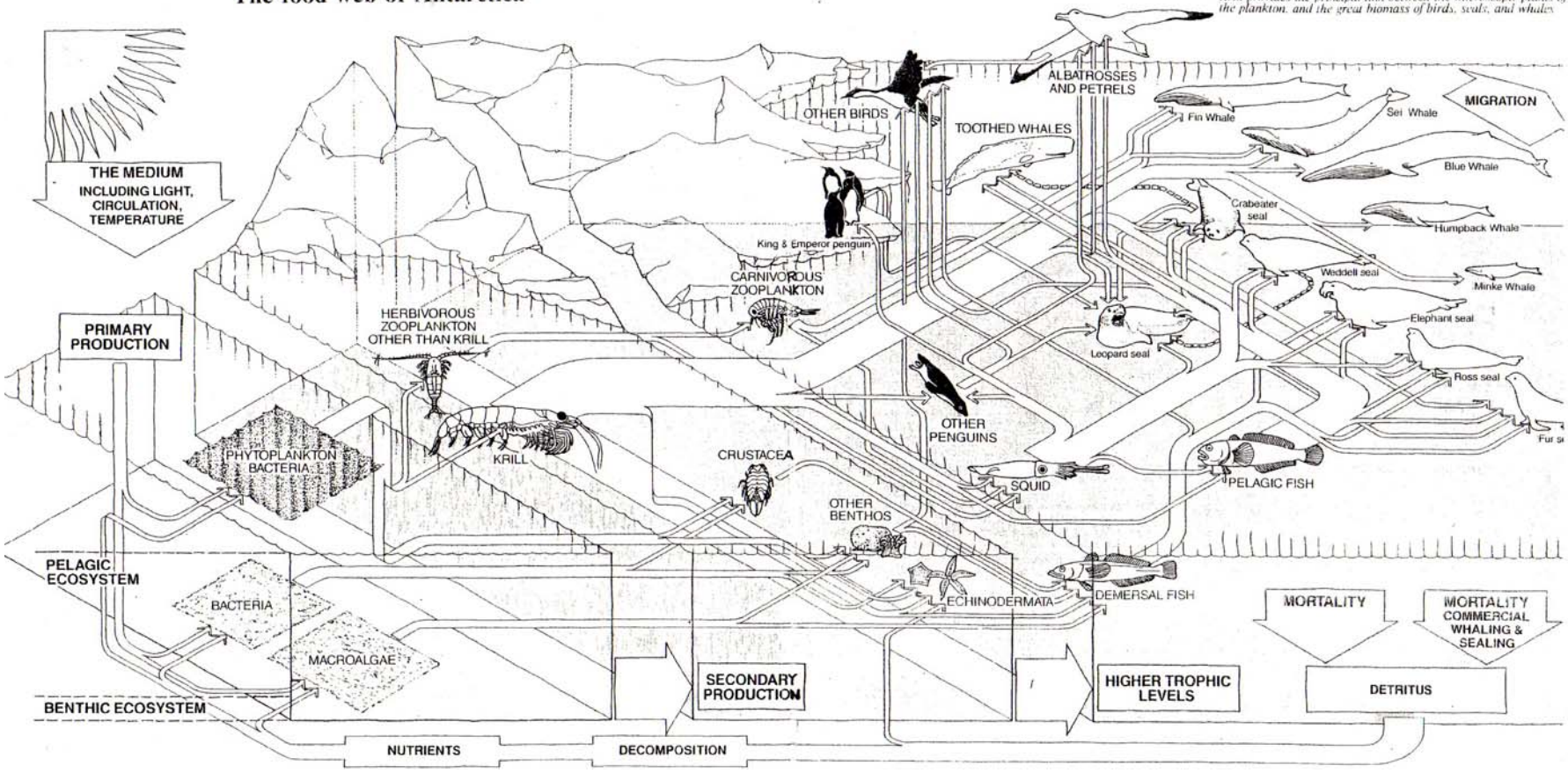
Starting on the left of the diagram (phytoplankton, bacteria and macroalgae), colour your food web to make it easier to see the feeding relationships. To do this, shade a type of organism (e.g. macroalgae) in one colour. In the same colour, shade every branch of the arrow leading away from that organism, to show which other organisms eat it. You can colour non-living components of the diagram if you wish.

Questions

1. When you have completed colouring the Antarctic food web diagram, why is it that you have not coloured the whales, elephant seal, leopard seal, Ross seal and fur seal, or 'other birds'?
2. In relation to question 1, do you think the situation depicted would be completely realistic at all times? Discuss briefly, and suggest a type of organism that is missing from this food web diagram.
3. What are the main producers in the food web shown?
4. Which of the organisms shown feed directly on (i) krill, and (ii) squid?
5. How many trophic levels are shown within the plankton?
6. List the herbivores (primary consumers)
7. List the omnivores.
8. List the top carnivores.
9. List all the animals consumed by the leopard seal.
10. Write out the longest food chain you can find in this food web.
11. How might the harvesting of krill by humans affect this ecosystem?
12. How might hunting of the large whale species in the past have affected seal numbers? Explain.
13. How might human hunting of fur seals have affected the numbers of the other seals? Explain.
14. Explain the role of mortality as shown in the diagram.
15. Why has the sun been included as part of the diagram?

The food web of Antarctica

Krill provides the principal link between the microscopic plants of the plankton, and the great biomass of birds, seals, and whales



Introducing CCAMLR

'At the beginning of 1982, a far-sighted convention came into force to protect the living resources of the Antarctic seas. The convention for the Conservation of Antarctic Marine Living Resources (CAMLR) applies to an area with natural boundaries – that is to say, the area within the Antarctic Convergence. The convergence is a physical boundary where there is an abrupt change in temperature.'

These words are taken from the beginning of an article titled *Antarctica:: convergence of life* in the 1 September 1983 edition of *New Scientist* magazine whose front cover headline was, 'Antarctic wildlife: only here for the krill.' The Antarctic food web you have just studied came from this article.

At the time the article was written, there were no websites. However, CCAMLR had just been established, and it still exists today. This activity involves a brief exploration of the CCAMLR website, to learn more about the Southern Ocean, Antarctica, CCAMLR and the species it focuses on most.

CCAMLR online research

Google CCAMLR, and navigate to the official CCAMLR website. Then navigate around the site in order to answer the following questions in your own words, wherever possible.

1. Where is the headquarters of CCAMLR?
2. What, exactly, is the Southern Ocean?
3. What, exactly, is the Antarctic Convergence?
4. What does CCAMLR stand for?
5. When did CCAMLR come into effect?
6. What was the main reason for establishing CCAMLR?
7. What is IUU fishing?
8. Does CCAMLR include whales and seals? Explain.
9. When did hunting and fishing begin in the Southern Ocean?
10. Which fish species have been targeted in the Southern Ocean, since the 1970s?
11. How have long line fishing techniques improved in recent years, and why were these improvements necessary?
12. Explain what is meant by 'the precautionary approach'.
13. Why does CCAMLR use the precautionary approach, instead of waiting until full scientific investigation has provided a complete picture of Antarctic wildlife and answered every question with certainty?
14. How big is the Southern Ocean?
15. What is CEMP, and when was it set up?

16. What are CEMP's aims?
17. Follow the links to SCAR (Scientific Committee on Antarctic Research), and navigate from Sitemap -> Antarctic information -> Antarctica in pictures. Find pictures showing the collapse of the Larsen B ice shelf.
18. When did the Larsen B ice shelf collapse?
19. How thick was the part of the Larsen B ice shelf that collapsed?
20. What happened to all the ice that was in the Larsen B ice shelf?
21. Navigate around the linked sites and find five interesting pieces of Antarctic information to report to the class, and at least one interesting image to share, using the data projector. You need to be able to explain the image and / or give some basic information about it.

Emperor Penguins (Photo © ACE CRC)

What's new in the Antarctic food web?

When biologists first began to study the Antarctic, they were impressed by the whales, seals and penguins. They soon noticed the vast numbers of krill in Antarctic waters, and krill were regarded as the key organism in the food web. The krill feed on plankton, and so a general understanding of the Antarctic food web developed, which looked like this:

phytoplankton -> zooplankton -> krill -> whales, seals, penguins

Many Antarctic food chains and food webs shown on the internet are almost as simple as this.

However, as you have already seen from your first Antarctic food web activity, squid and fish are also very important. In fact, they are important to humans as well as wildlife, and there is now a very large squid fishery in Antarctic waters.

In recent years, the importance of the microbial food web has been realised. It now seems that perhaps 50% of the sun's energy trapped by phytoplankton gets as far as protozoans (microscopic animals) in the zooplankton, and then passes on to bacteria, which decay the dead protozoans. This microbial food web acts as a 'loop' beneath the big web featuring the familiar Antarctic animals. Because of the microbial food web, around 50% of the sunlight energy trapped by phytoplankton never goes on to the krill, fish, squid and larger animals.

Antarctic salps have been studied in recent years. These are gelatinous creatures with cylindrical bodies a few cm long, which feed on phytoplankton. As far as is known so far, nothing in the Antarctic food web eats salps, so they simply eat phytoplankton, die and decompose, passing the energy in their bodies to bacteria in the food web.

Squid and salps seem to be taking over from krill to an extent, as the numbers of krill have declined significantly. There are several possible reasons for the decline in krill, but it is not certain which are the most important.

Viruses are also involved in the Antarctic web of life, but their role is not understood. However, there are vast numbers of marine viruses, and they have a significant biomass in Antarctic waters.

A significant factor in the Antarctic food web is the reduction in ice algae**.** Ice algae live under the sea ice, and are grazed by krill. In areas where the sea ice is melting sooner, salps are beginning to dominate, but in areas with plenty of sea ice, krill still dominate the food chain. The highest concentrations of krill are found in the waters south of Argentina and around the Antarctic Peninsula – far more than in Australian Antarctic waters. The least sea ice is found off the coast of Casey station, and this area has less krill than in many other parts of the Southern Ocean.

Here is a selection of pertinent articles. Keep looking for new resources from sources such as CAML and *National Geographic*.

Antarctic reveals treasure trove of life 17/5/07
http://www.abc.net.au/science/news/stories/2007/1925590.htm

Antarctic 'treasure trove' found 16/5/07
http://news.bbc.co.uk/go/pr/fr/-/2/hi/science/nature/6661987.stm

Ice collapse exposes Antarctic beauty 26/2/07
http://www.abc.net.au/science/news/stories/2007/1856913.htm

Life in a frozen lattice: The white, frozen worlds of the polar ice fields are virtually devoid of life. Yet below the ice, as David Thomas and Gerhard Dieckmann found out, are rich ecosystems with plenty of lessons for the planet 11 June 1994 *New Scientist*
http://www.newscientist.com/article

Antarctic food web under pressure 3/11/04
http://news.bbc.co.uk/2/hi/science/nature/3979833.stm

Science Show transcripts from ABC Radio National:

Krill biology and behaviour
http://www.abc.net.au/rn/scienceshow/stories/2006/1672855.htm

Squid
http://www.abc.net.au/rn/scienceshow/stories/2001/305244.htm

Antarctic ice flow and Arctic sea ice 7/4/07
http://www.abc.net.au/rn/scienceshow/stories/2007/1890777.htm

Deep ocean currents 20/5/00
http://www.abc.net.au/rn/scienceshow/stories/2000/131912.htm

More ABC news in science stories:

Global warming makes seal pups go hungry 5/5/05
http://www.abc.net.au/science/news/stories/s1360603.htm

Fishing plan to get seabirds off the hook 17/3/04
http://www.abc.net.au/science/news/stories/s1066355.htm

Penguins sign up as ocean spies 13/7/06
http://www.abc.net.au/science/news/stories/s1685899.htm

Octopuses evolved as Antarctica froze 21/7/06
http://www.abc.net.au/science/news/stories/s1691737.htm

Antarctica: she's breaking up 20/3/02
http://www.abc.net.au/science/news/stories/2002/508154.htm
Faster westerlies threaten Antarctica 14/7/06
http://www.abc.net.au/science/news/stories/s1686723.htm

Caught: Antarctic glaciers on the move 23/2/01
http://www.abc.net.au/science/news/stories/2001/250408.htm

Antarctic glaciers going, going, gone 23/9/04
http://www.abc.net.au/science/news/stories/2004/1205516.htm

Information sheets from the Antarctic Climate and Ecosystems Cooperative Research Centre:

Antarctic sea ice
Oceans, carbon & acidification
www.acecrc.org.au

Leopard seal (Photo by Adrian Boyle)

Assessment task

Tasmanian Certificate of Education Life Science (Marine) criteria assessed are:

- Criterion 3. Plan, organise and complete activities
- Criterion 5. Communicate ideas and information
- Criterion 7. Demonstrate knowledge and understanding of biodiversity and the interrelationships of organisms
- Criterion 6. Demonstrate knowledge and understanding of the impact of science on society and the environment (if applicable, which would depend on which topic you choose and how you tackle it)

The task

Research one or more examples of changes taking place in the Antarctic food web, *or* changes in our scientific understanding of the Antarctic food web. Your task is to produce a piece of work to demonstrate your knowledge and understanding of the chosen topic, in any way you like. This may be a poster, a written assignment, a PowerPoint presentation, or some other product of your choice. There should, ideally, be some form of visual representation of the topic. However, it is up to you to decide how best to communicate your knowledge and understanding.

You can use the information given above, internet research (try websites such as Australian Antarctic Division; CCAMLR; *National Geographic*; the ABC, especially ABC Radio National *Science Shows* and *Catalyst* TV shows – transcripts are usually available; BBC; *New Scientist* and others).

Hints for teachers

Likely 'What's new?' topics, with easy-to-find information currently available on the internet would include:

- new discoveries about Antarctic organisms. Keep an eye on CAML, the Census of Antarctic Marine Life, throughout the International Polar Year in 2007 and 2008. Under CAML amazing new discoveries of Antarctic marine species can be expected.
- new insights / understandings on the biology, interactions and evolution of Antarctic organisms
- effects of climate change / global warming on Antarctic organisms
- especially, the impact of reductions in sea ice on krill, and flow-on effects of this throughout the food web
- effects of ozone depletion on Antarctic organisms, especially plankton
- effects of ocean acidification as a result of increasing levels of dissolved carbon dioxide forming carbonic acid

- issues around exploitation of Patagonian toothfish resources, and methods used by CCAMLR in an attempt to control illegal fishing
- issues around seabird bycatch (especially albatrosses) in the Southern Ocean, and new methods to minimize this.

Adelie penguins (Photo © ACE CRC)

Additional resource 1

Video 919.89LIF, ABC 1994 - Life in the Freezer

This is a BBC documentary, narrated and presented by David Attenborough. In this 5-minute excerpt (12 minutes into the video), we see humpback whales feeding. The following questions are to help you remember information about humpback whale features, especially their structural and behavioural adaptations for feeding on krill.

1. Krill are described in the film as 'the most numerous animal on earth.' What kind of animal are they?
2. These scenes are filmed in the Antarctic. In what season of the year do humpbacks feed in the Antarctic?
3. How many nostrils does a humpback whale have?
4. What type of whale is a humpback – toothed or baleen?
5. Describe the way humpbacks feed on krill near the surface. Sketches would be good.
6. Humpbacks have throat pleats – what is their function?
7. Sketch a humpback's dorsal fin (the one on its back).
8. Describe and sketch a humpback's tail flukes.
9. Describe and sketch a humpback's pectoral (side) fins.
10. When krill are dispersed in the sea, humpbacks often cooperate to catch them. How do they do this? Sketches would be good.
11. During the Antarctic winter, humpbacks move to tropical waters. Do they feed in these waters?
12. Approximately what weight do humpbacks reach?
13. Write down any other points of interest from the video.

Additional resource 2

Video: Return to the Water, Life of Mammals – BBC TV, David Attenborough

This 49 minute video looks at the mammals whose ancestors, after evolving on the land, returned to the water. These animals have evolved into the aquatic mammals we see today. After a look at the elephant and a small shrew-related animal that hunts for its prey in streams, David Attenborough introduces us to the following mammals:

- Sea otters, off the coast of California and Alaska (USA)
- Sea lions
- True seals (ringed seals, hooded seals, harp seals) (Arctic and Antarctic)
- Manatees ('sea cows') (Florida, USA)
- Ganges River dolphin (India)
- Dolphins on the coastline of Georgia and the Carolinas (USA)
- Common dolphins in the open ocean
- Blue whale
- Humpback whale
- Southern Right whale

The questions below are intended to help focus your attention, and give you a record of information from this video.

1. What proportion of the Earth's surface is covered by seas?
2. What animals are believed to have been the ancestors of sea otters?
3. What adaptations do sea otter feet have, to help in swimming?
4. What is the habitat of the sea otter?
5. How has the fur of the sea otter evolved, to prevent heat loss?
6. What behavioural adaptation does the sea otter show, to prevent heat loss?
7. Why / how did humans almost drive sea otters to extinction?
8. In what ways are the limbs of a sea lion more extremely adapted for swimming than those of a sea otter?
9. Besides fur, what other adaptation do sea lions have, to prevent heat loss?

Sea lions are not true seals, as they have not evolved to quite such extremes as true seals, to suit their marine habitat.

1. What feature would you notice, somewhere around a sea lion's head, that would tell you this was not a true seal? A sketch would be good.

2. The front legs of a sea lion are stout, and can act as props when it is out of the water. The hind legs can swivel back and forward, to allow it to move on land. Sketch the hind leg in its forward position.

Sea lions give birth on islands, where they are safe from land predators. Good breeding areas are scarce, and tend to be very crowded. This enables beachmaster males to gather harems of numerous females. The beachmaster males will mate with the females in their harem as soon as they have given birth, and they will fight off any other males who come near.

1. Females have very rich milk, to help their pups to grow as fast as possible. What is the fat content of a mother sea lion's milk?

The video next shows true seals, in the Antarctic.

1. What kind of animal is believed to have been a common ancestor for seals and sea lions?
2. In what way is the head of a true seal more streamlined than that of a sea lion?
3. How do the hind limbs of true seals differ from those of sea lion?
4. Explain why the seals shown do not have harems dominated by the males.

David Attenborough then takes us to the Arctic (the northern polar region), to show more seals.

1. Name two predators of seal pups in the arctic.
2. Why do these land predators threaten the arctic seal pups, when the Antarctic seals were free of this danger?
3. How do the female seals try to protect their young pups?
4. Which seal is the staple diet of the polar bear, during the seal's breeding season?
5. How do the polar bears detect the presence of seal pups?
6. Describe and sketch the hind flippers of the ringed seal shown swimming under the ice.

The next species shown is the hooded seal. This seal breeds far away from land, on the ice. These seals also mate soon after giving birth.

1. What reason was suggested to explain why these seals mate soon after giving birth?
2. What adaptation do male hooded seals have to attract the females?
3. What behaviour do male harp seals show during their mating season – behaviour which is unusual for seals?

The next aquatic mammals shown are herbivores (plant eaters). These are the manatees, or sea cows. Their ancestors began living in the water about 35 million years ago. Their habitat is warm, clear, freshwater creeks in Florida: they are not marine creatures.

1. What animals are believed to be the ancestors of manatees?
2. Sketch and describe the manatee's front flippers and how they are used.
3. Sketch the tail of a manatee.

The Ganges River dolphin is a freshwater species that swims in the turbid (murky) waters of the Ganges, in India

1. Comment on the eyesight of the Ganges River dolphin.
2. How does the Ganges River dolphin find its food?
3. Along the coast of Georgia and the Carolinas in the USA, some dolphins have developed an extraordinary hunting method. Describe what they do – sketches would be great.

This hunting method involves teamwork, communication and high intelligence.

1. It has been observed that one team member will push its head out of the water before the final surge – why?
2. Explain why the dolphins all turn their heads in the same direction as they beach.
3. Next, we are shown hundreds of common dolphins in the open ocean. Explain their hunting strategy for catching sardines.

Next – the blue whale (a baleen whale). Almost twice as heavy as the biggest known dinosaur, it is 30m long, has a tongue as big as an elephant, lungs with 500 times our capacity for air, a heart the size of a small family car, 10 tonnes of blood and 1 million miles of blood vessels!

1. The blue whale has two isolated fragments of bones buried in muscle – what are these the remains of?
2. Why is there no land animal anywhere near the blue whale's size?
3. What types of mammal are believed to have been the ancestors of the blue whale?
4. How long ago did the blue whale's ancestors begin living in the sea?
5. With one blast from its nostrils, a blue whale can exhale 90% of the spent air from its lungs. How does this compare with most land animals?
6. A blue whale can dive for half an hour or more. Where does it store oxygen during this time?
7. A blue whale's blubber can be 50cm thick. How does this adaptation help the blue whale to survive in its ocean habitat?
8. The humpback whale is the next animal shown.
9. Humpback whales communicate using sound. Compare the way sound travels through water and through air.
10. Describe the songs of the humpback whale.

The final species shown and described is the Southern Right Whale, seen off the coast of Patagonia (South America).

1. Sketch the flippers (pectoral fins) of the southern right whale, and briefly explain how they differ from the pectorals of the humpback.
2. The penis of the southern right whale is 4m long and highly mobile. How does the female try to avoid mating before she is ready?
3. How big are the testes of a southern right whale?
4. Although several males may mate with a single female southern right whale, it is likely that the last male to mate with her will be the father of her calf. Explain why this is so.

The mammals shown in the video have all evolved adaptations to deal with the following problems:

- The need to breathe air, since they are mammals not fish, and do not have gills
- The need to maintain their body heat, since mammals are warm blooded
- The need for a body well adapted for swimming in water, instead of walking on land.

We also saw or heard about behavioural and structural adaptations for: hunting and feeding in the aquatic environment; navigation; mating; communication.

1. On a separate sheet, make a table summarising the adaptations possessed by each of the ten mammals featured in the video (e.g. column 1 could be names of mammals; 2 could be breathing adaptations; 3 could be adaptations to conserve heat; 4 could be swimming adaptations; 5 could be other adaptations).

Krill (Photo © ACE CRC)