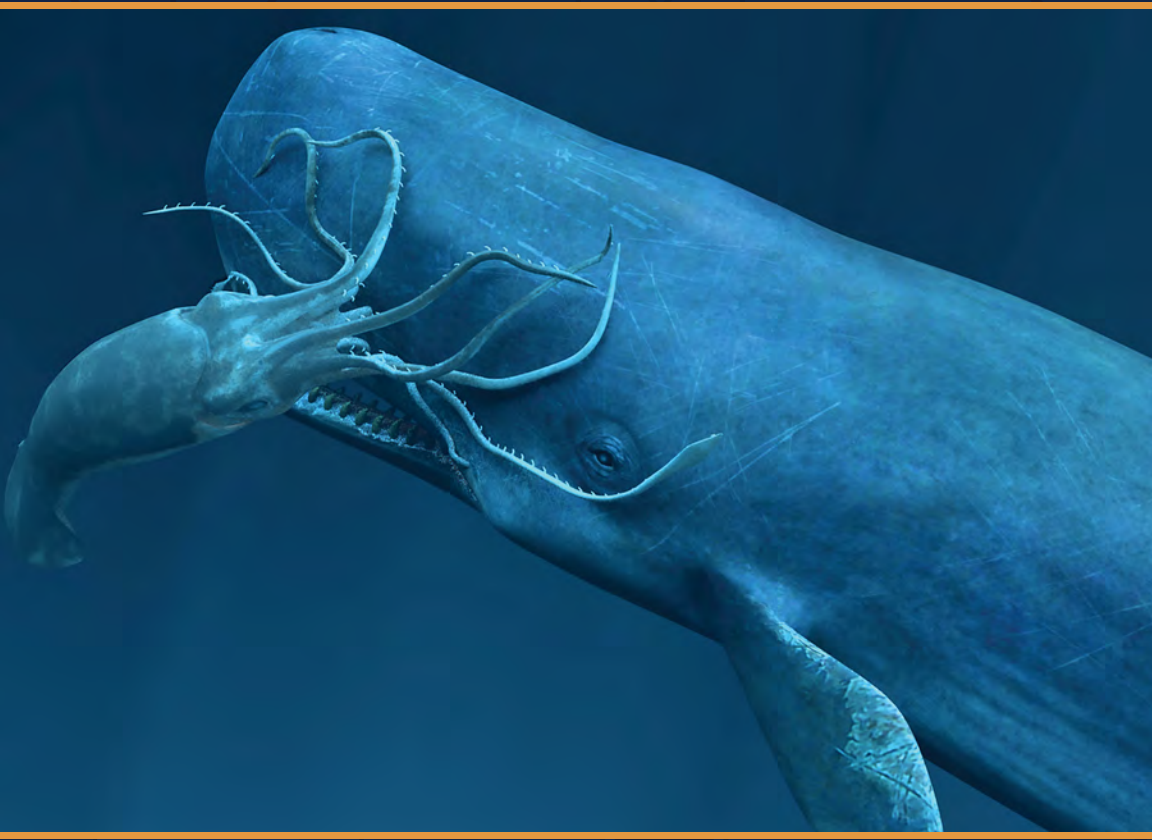
BATTLE DEEP: SPERM WHALES

A SCIENCE 3D ADVENTURE

MIDDLE SCHOOL



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KEY WORDS

ADAPTATION

BALEEN

BIOLUMINESCENCE

CETACEANS

CONSUMER

DECOMPOSER

ECHOLOCATION

ELECTROMAGNETIC WAVE

ENERGY

EXTINCT

HYDROPHONE

MAMMAL

MATRIARCH

MATTER

MECHANICAL WAVES

MYSTICETES

NUTRIENTS

ODONTOCETES

PHOTOSYNTHESIZE

PHYTOPLANKTON

PRODUCER

SCAVENGER

WARM-BLOODED

WAVE

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INTRODUCTION

Imagine what it would be like to be able to hold your breath underwater for almost two hours. Imagine if your body could survive the crushing pressure of having a kilometer (.62 mi) of water on your back. Imagine if you were able to "see" in the pitch black of the deep ocean using sounds that you produce. Imagine being able to survive in near-freezing water. And imagine if you could win a battle with a giant squid!

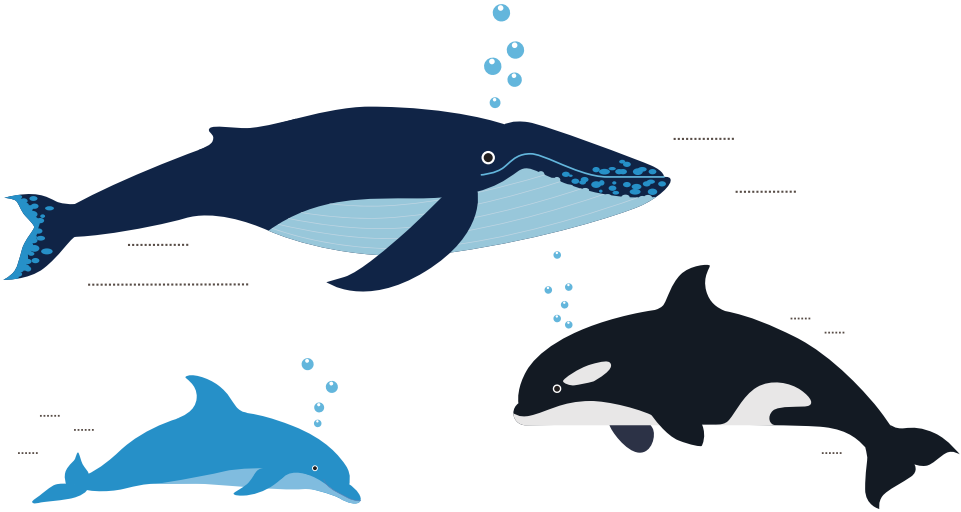
It may sound impossible, but sperm whales can do it all! With all those incredible abilities, you might think that sperm whales (*Physeter macrocephalus*) must live an easy life that is free of worries. But even with all their unique abilities, intelligence, and family ties, sperm whales still face many challenges.

Sperm whales are the largest toothed predators on the planet.

THE CETACEAN FAMILY

As **mammals**, sperm whales breathe air, give birth to their calves, and feed their calves milk when they are babies. They are also **warm-blooded**, so they can keep their bodies warm even in frigid waters. But they need lots of **energy** to stay warm, fuel their body systems, and move around their habitats.

Whales, dolphins, and porpoises are part of a group called **cetaceans**. Cetaceans are found in all of the world's oceans, from the equator to the waters of the Arctic and Antarctica. Some are even found in rivers.



There are about 90 species of cetaceans alive today. All living cetaceans have a common ancestor that lived on land more than 50 million years ago. It looked a bit like a small dog with hooves. Over time, these land animals adapted to life in the ocean. They lost most of their hair. Their bodies became streamlined. This means their hind legs disappeared, and their forelimbs became flippers. They developed powerful flukes to propel their bodies and the ability to hold their breath for long periods of time. They developed thick layers of blubber to stay warm. Even their teeth transformed. These **adaptations** all helped them survive in an aquatic environment.

How do scientists know there is a link between today's cetaceans and past land animals that look nothing like them? First, they look at the skeletons of ancient and modern cetaceans and compare them to both living and **extinct** land animals. There is a good fossil record that shows the path from land mammal to cetacean. Paleontologists use fossils of plants and other animals and the types of rocks near ancient skeletons to recreate whale ancestor environments.

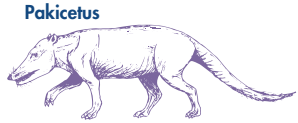
Today scientists can look at genes of different groups of animals and see which animals living on land are most closely related to cetaceans. It turns out it is hoofed mammals! Hippopotamuses are another mammal that has adapted to life in the water, even though they feed on land. Hippos are closely related to cetaceans.

HOW LAND ANIMALS EVOLVED TO BECOME MODERN WHALES AND DOLPHINS

Modern hippos

Freshwater, semi-aquatic habitat, thick, bony wall around middle ear

Pakicetus

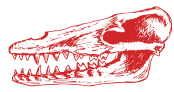


Brackish water habitat, strong, powerful tail, shorter legs, fat pad in jaw for hearing

Ambulocetus

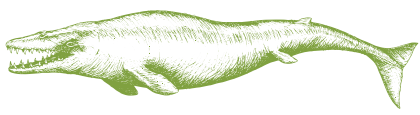
Saltwater habitat, nasal opening shifted back eyes on side of head

Rodhocetus



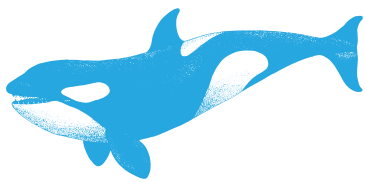
Tail flukes, very small hind legs, nasal opening further back

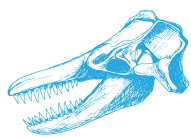
Dorudon



Complete loss of hind legs, nasal opening in modern blowhole position

Odontocetes: modern toothed whale





Echolocation for hunting

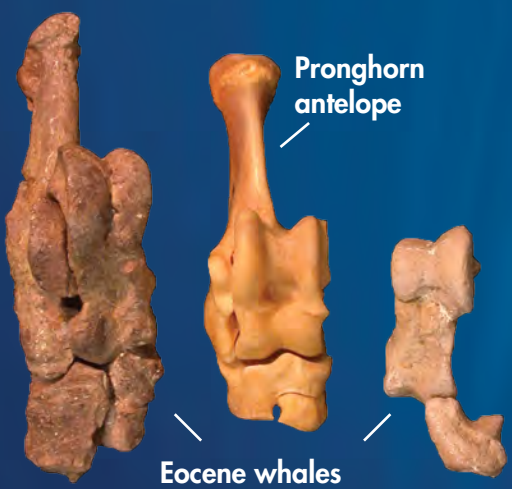
Baleen for filtering food

Mysticetes: modern baleen whale

FOSSIL & GENETIC EVIDENCE

Fossil evidence and genetic evidence help scientists construct the relationships between species of cetaceans.

Scientists look at specific traits of fossils and modern animals to determine relationships. For example, there are similarities between the ankle bones of modern pronghorn antelope and ancient whales.



There are two major groups of living cetaceans: the toothed whales (**Odontocetes**) and the **baleen** whales (**Mysticetes**). Baleen whales don't have teeth. Instead, their upper jaws have baleen plates made of keratin. Keratin is what makes up your fingernails. Blue whales and humpback whales are baleen whales. Baleen whales may be huge, but they eat small prey. They can gulp schools of small fish or swarms of small shrimp-like creatures called krill. Others, like right whales, swim through the water with their mouths open and skim prey from the water. Most baleen whales live alone, and calves stay with their mothers for around two years. However, humpback whales can be more social. Some even cooperate to feed.

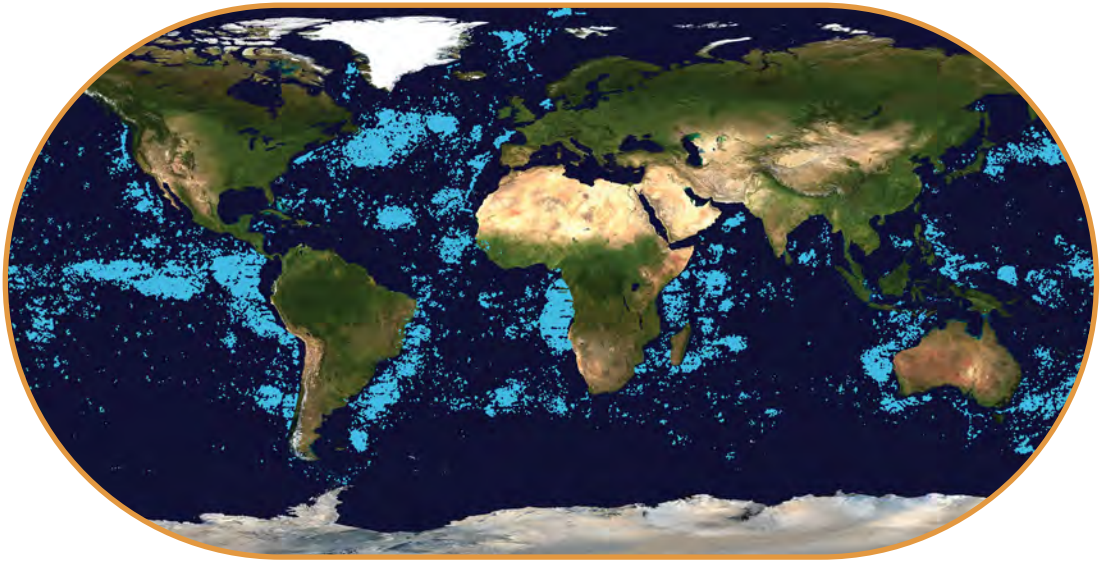
Sperm whales, beaked whales, dolphins, and porpoises are toothed whales. They eat their prey one at a time. Some species eat small fish and squid. Other species, like killer whales, can eat huge prey, including other dolphins and whales. Some toothed whales live in shallow, coastal waters, or even in rivers. Others never come close to shore. Many toothed whales are highly social and live in groups that range from several to more than a thousand individuals!

Baleen whales

A group of humpback whales (*Megaptera novaeangliae*) feeding on herring. Their lower jaws can dislocate to form a huge scoop. Prey are trapped in their mouths while the whales push the water out through their baleen plates.

WHERE DO SPERM WHALES LIVE?

Sperm whales are found throughout the world's oceans. They can be spotted in the frigid waters of the Arctic and the Antarctic but also in warmer tropical waters near the equator. But seeing sperm whales isn't easy. They spend most of their lives underwater and live in water that is very deep (sometimes kilometers deep). That means that they usually are far from shore. But in a few special places, where the waters drop off quickly, you can find sperm whales close to land.



Sperm whales are found around the world in deep waters. During some times of the year, males and females are found in different areas. Each dot on the map shows where people have seen sperm whales.

THE WORLD'S LARGEST TOOTHED PREDATOR

Sperm whales are the largest toothed predators in the world. Females grow to be around 11 m (36 ft) and weigh around 14,000 kg (30,865 lbs). Fully grown males can grow to more than 18 m (59 ft) and over 51,000 kg (112,436 lbs). That's more than ten elephants! Sperm whales are mammals, so they are warm-blooded. That means that they have to eat lots of food to maintain body temperatures higher than the water around them.

An adult male whale may need an average of around 1,000 kg (2,200 lbs) of food per day. But because they are so big, they don't have to eat that much every day to survive. Instead, they can go days without eating and live off of the energy stored in their layers of fat, called blubber. That is one reason that sperm whales can live in open ocean waters where prey can be scarce. In these areas, sperm whales have to search over large expanses for rare patches of prey. When they find it, they eat tons!

Sperm whales mainly eat deep-sea fish and squid. They will even eat deep-sea sharks. Their most common prey is large squid. When they get a chance, they will even take on the giant squid. In some places, giant squid are their most common prey, even though they are not easy to catch. They can deploy ink clouds to escape, have sharp parrot-like beaks, and have hooked barbs on their suckers that can inflict nasty wounds.

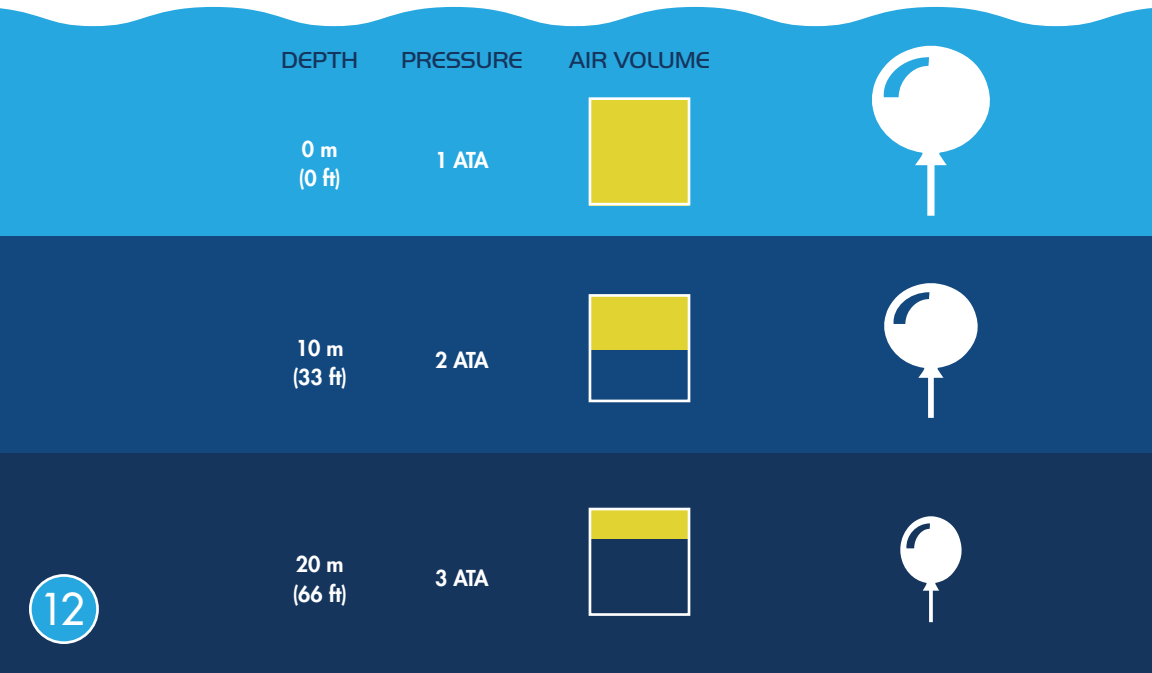
To grab a meal, sperm whales have to dive deep. They can dive down more than 2,000 m (6,562 ft). One whale was recorded holding its breath for more than two hours! Usually, though, they don't have to dive that far or long. After 45 minutes in the cold waters of the deep sea, they have to rest at the surface to recharge their oxygen and warm up before they are ready to dive again.

People realized that sperm whales might eat giant squid after finding beaks of squid in the stomachs of whales that were stranded on beaches. They also saw the scars that squid left on whales from the hooks on their suckers. This figure depicts a computer animator's idea of what the battle may look like.

UNDER PRESSURE

Most animals couldn't survive a dive to the extreme depths that sperm whales hunt. First, it is very cold – often near 3°C (37°F). Sperm whales are large, so they lose heat slowly, and a thick layer of blubber (fat) stores the heat. Sperm whales also constrict blood flow to their extremities when they dive, which keeps them from losing heat.

Deep underwater dives cause tremendous pressure on an organism's body. For every 10 m (33 ft) of depth, there is another atmosphere of pressure. At sea level there are about 6 kg (13 lbs) of pressure per square inch of your body. Imagine 100 times that amount of pressure! The big problem for sperm whales is that the pressure could squash air bubbles out of their lungs and into their bloodstream. This can cause major health problems, or even death. That is why sperm whales don't take air down with them when they dive. Instead, their lungs can collapse, and they dive with virtually no air in their lungs. A lot of oxygen is carried in their red blood cells to fuel their body when they dive.



Another challenge of feeding in the deep ocean is that there is virtually no light. Light travels as an **electromagnetic wave**. **Waves** are disturbances that transfer energy from one place to another. Unlike other waves, light waves don't have to travel through **matter**. When light encounters matter, it can be transmitted, absorbed, reflected, or refracted. Clear objects transmit all the different colors of light. Colored objects reflect the color that we perceive and absorb the other colors of light. So, an organism that is green reflects green light but absorbs other colors of light.

As light travels through the water, its energy is scattered or absorbed. By 200 meters (656 ft) there isn't enough light for plants and algae to **photosynthesize**. By 1,000 meters (3,281 ft) there is no sunlight at all. Not all colors of light disappear at the same time. Red is the first to go, and blue and violet travel the furthest. Many deep-sea creatures are red when viewed with light at the surface. This is because they reflect red light. At the depths they live, there is little or no red light to reflect. Because their bodies absorb the other colors, they are almost impossible to see. Many deep-sea animals do not appear to have the ability to see red light.

Many deep-sea creatures are red. This may help them avoid being seen.

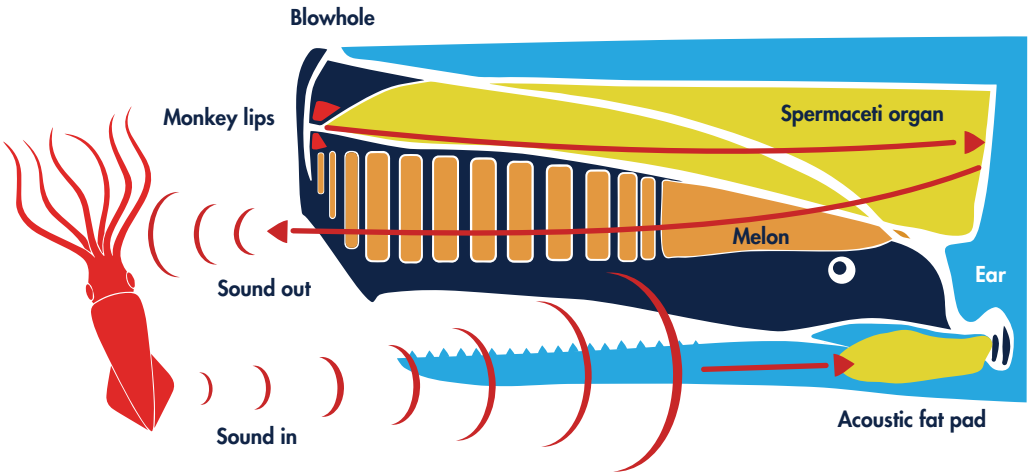
BIOLUMINESCENCE

There is still some light in the deep sea, but it doesn't come from the sun. It comes from organisms that produce light called **bioluminescence**. This still isn't enough light for sperm whales to see their prey easily.

This deep-sea anglerfish uses a bioluminescent lantern to attract prey.

SOUND OVER SIGHT

How do sperm whales find and catch their prey in the darkness of the deep sea? They use sounds called **echolocation**. Like light, sound travels as a wave. Unlike light waves, sound waves are **mechanical waves**. They have to travel through matter. They are produced by the vibration of particles. That means that matter with different densities transmit sound at different speeds. The speed of sound is much faster in water than in air because the molecules in water are packed together more tightly. That means the sound wave is transmitted faster. Sound in water can travel very far if it is the right frequency and volume. The loud call of a blue whale might be heard across an entire ocean! When sounds hit another object, they can be absorbed by the object, transmitted through the object, or reflected. Echolocation takes advantage of reflected sound waves. Here's how it works:



Whales produce echolocation clicks in their head. The clicks move into the environment. When the sound hits an object – like a squid – it bounces back to the whale. The reflected sound waves travel through the lower jaw and into the ear. The whale's brain decodes the information to know what the object looks like and how far away it is. It's like seeing with sound!

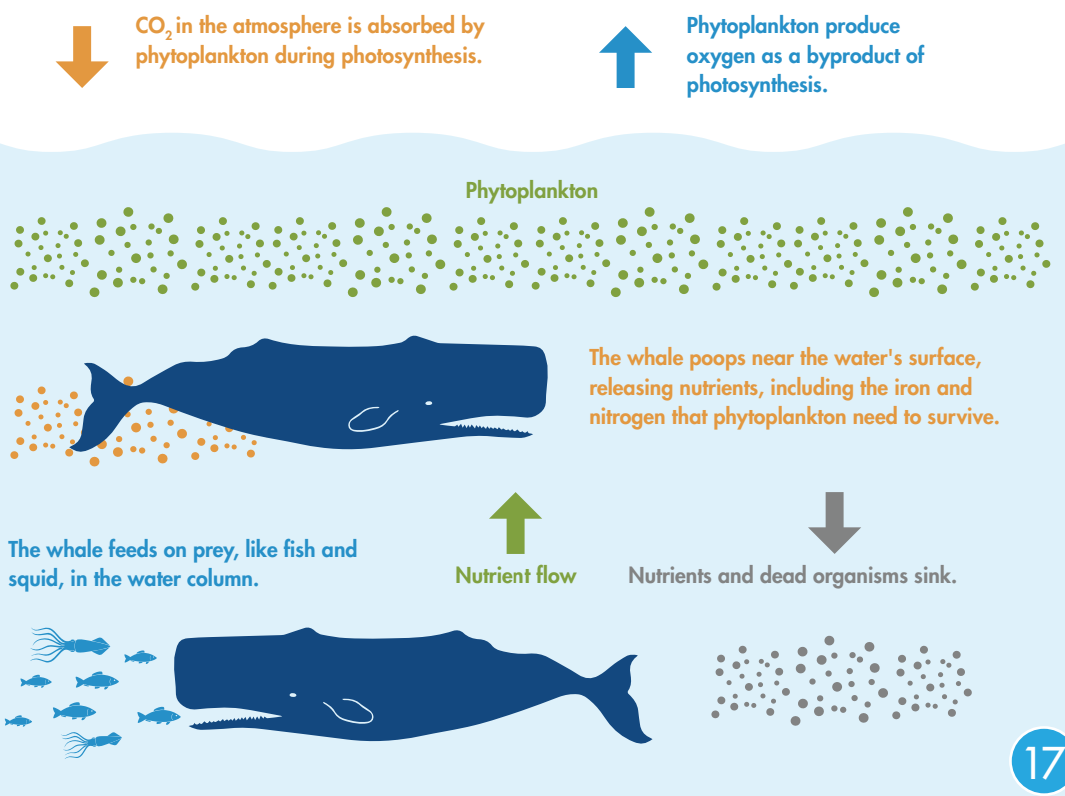
Other animals use echolocation. The most well-known are bats and dolphins. People have developed sonar that uses sound in the same way. A machine produces a ping of sound that bounces off of objects and returns to a receiver. A computer then uses the echoes to create a picture of the bottom of the ocean, fish, and other objects in the water.

THE POOP PUMP

Open ocean and deep-sea habitats are sometimes referred to as "deserts of the ocean." Why do you think they are referred to in this way? Life is much less common in these places than in other habitats. There are very few tiny producers, called **phytoplankton**, which makes the waters very clear. These **producers** need light energy from the sun, carbon dioxide, and water to make sugars that store energy (and release oxygen in the process) through photosynthesis. They also need **nutrients** and other matter to build their bodies. Producers (and **consumers** that have eaten producers to get matter and energy) break down the sugar using oxygen to release energy (as well as carbon dioxide and water). Matter and energy are not destroyed; they just change form. Cycles of nutrients like carbon, nitrogen, iron, and phosphorus are important for sustaining organisms and ecosystems.

In surface waters of the open ocean, there is plenty of light for photosynthesis, but they lack nutrients that sink to the bottom. Because the water is deep, wind and waves don't bring nutrients back up to the surface. So how do the phytoplankton get their nutrients? Some come from the whale "poop pump." Here is how it works. Sperm whales dive deep underwater. They eat deep sea creatures. Then they come up to the surface to release poop. This provides nutrients and other matter for producers to use. Fewer whales would mean less plankton. Less plankton would mean fewer fish.

So where does the energy come from in the deep sea? Nutrients fall down from above, but there isn't enough light from photosynthesis for producers. That means that the energy in the deep sea has to come from producers that live near the surface. The food and energy in the deep sea mostly come from organisms that die and sink. They may be the tiny producers or even whales. Deep sea organisms eat these as they fall to the bottom or once they land on the bottom. "Whale falls," a process in which dead whales sink to the bottom, are an important source of energy and matter for many deep sea organisms. This includes **scavengers**, like hagfish, crabs, and sixgill sharks. It also includes **decomposers**, like bacteria. Another way energy and matter get to the deep sea is movement of organisms. Every night, in the biggest migration on the planet, huge numbers of deep-sea organisms swim toward the surface to feed. Before dawn, and the arrival of enough light for predators to be able to see them, these organisms swim back into the depths, where it is safer.



GROWING UP SPERM WHALE

Sperm whale mothers are pregnant for 14 to 16 months and give birth to a single calf at a time. Sperm whale babies are huge! They are 4 m (13 ft) long, and they weigh 1,000 kg (2,200 lbs).

Calves start nursing almost as soon as they are born. Sperm whale milk is rich in fat. Cow's milk is 4% fat. Sperm whale milk is 36% fat. The fat helps baby sperm whales grow fast. Even though sperm whales grow quickly, they depend on mom's milk for a long time. Most nurse for two to four years. But one whale that was 13 years old was seen nursing!

Besides needing to grow, sperm whales rely on mom for their food for a long time because it takes years for young whales to be able to dive deep enough to hunt for themselves. That means that mother whales have to leave their calves when they need to eat. But sperm whale calves aren't left to fend for themselves. Other whales will stay at the surface to babysit until the mothers return.

Baby sperm whales are part of social groups, in which females stay together for life.

SPERM WHALE SOCIAL LIVES

Sperm whales can live to be at least 70 years old. Females live in the same family groups for life. These groups are led by an old female (a **matriarch**). Her daughters, their calves, and young males live with them. Female groups stay in warmer waters near the equator all year. Food in these warm waters can be hard to find. That means that the whales need to keep on the move to find places where there is good hunting before the prey move somewhere else.

Can you think of any land animals that live within societies, or family groups, similar to sperm whales? Elephants! Sperm whales and elephants have adapted to similar challenges. Both need to protect their vulnerable young from predators. Also, they need the intelligence and experience of grandmothers to lead the groups of females and calves. Older female sperm whales know where to lead the group to find food based on their lifetimes of experience. For elephants, when bad droughts hit, they rely on the matriarch's memory of where to find good water holes.

Family groups of elephants and sperm whales benefit from the knowledge of females that have lived a long time. Grandma knows best.

Male sperm whales don't stay in their mother's group for life. After 4 to 20 years, they strike off on their own. Young males may group together in "bachelor groups" that live in the warmer waters until they are big enough to make it fully on their own.

Adult males are too big to be able to get enough food in the warm waters of the tropics year-round. In the summer they move into the waters of the Arctic or Antarctic. They do this because there is a lot more food there during summer. In the winter they move to the warm waters to travel with groups of females and calves to find mates. Because they are able to put on enough fat when they are feeding in the Arctic or Antarctic, they can survive for months in the warmer waters with less food. They use the energy stored in their blubber.

Because sperm whales have to eat so much, they spend a lot of their time foraging for food. But they also spend time socializing with other whales. They may rub against each other or jump out of the water (breach). They also produce social sounds. Codas are a type of call sperm whales tend to make when they are socializing. You can sort groups of sperm whales based on their codas. These "vocal clans" are made up of many of the small family groups in which sperm whales live. But the family groups may not be related to one another. One cool thing about codas is that even though the codas of a clan are very similar, each individual's sound is a little bit different. Also, one individual may produce a variety of codas.

Different sperm whale groups have their own unique calls, called codas.

SPERM WHALE DANGERS

Sperm whales face many challenges to survival. First, their prey in the warmer waters where females and calves live can be hard to find. It may disappear from an area for a while. That means that sperm whales have to be able to travel far and wide to find food.

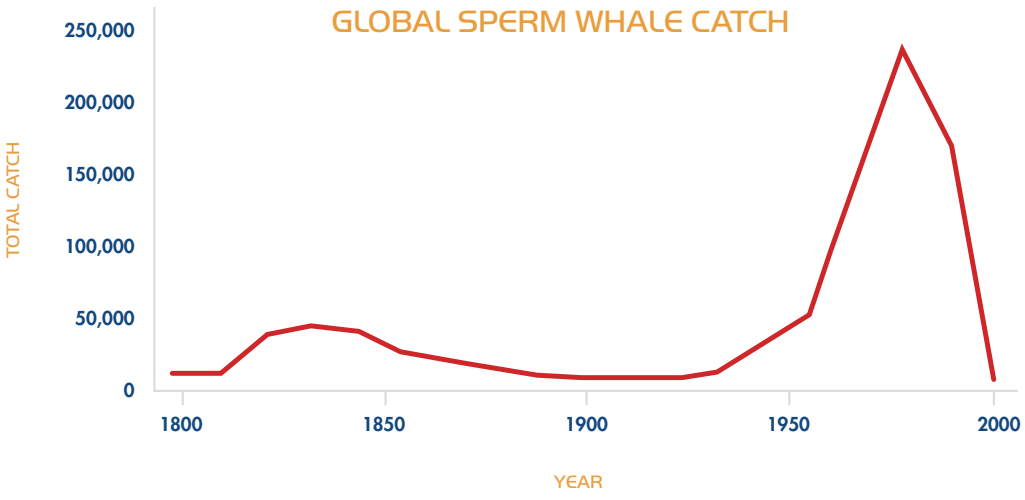
Many people think that sperm whales are at the top of the food chain, since they are the largest predator with teeth. However, this is not true! Killer whales will eat sperm whales. Given their large size and ability to work as a team, killer whales are a threat to sperm whale adults and especially calves.

Some types of killer whales only eat fish. Others prefer to eat whales, seals, and sea lions. These mammal-eating whales are a big threat to sperm whales.

But sperm whales have ways to protect themselves. When killer whales are around, sperm whales will put the babies in the middle of the group to defend them. The adults will form a circle around the calves. Their heads face the calves, and their tails point out where they can smash a killer whale that gets too close. Sometimes sperm whales will line up to face a threat with their jaws open to try to scare a predator away.

Pilot whales can't eat sperm whales, but they can be nasty. Scientists have seen pilot whales harassing sperm whales until the sperm whales vomited their food. Then the pilot whales ate the regurgitated food! In some places pilot whales and sperm whales are rarely seen together. Are sperm whales avoiding pilot whale harassment?

Even though sperm whales are not hunted today, they used to be a favorite target for whalers. The oil from their spermaceti organ, a large organ in their head, was very valuable. So were their teeth and blubber.

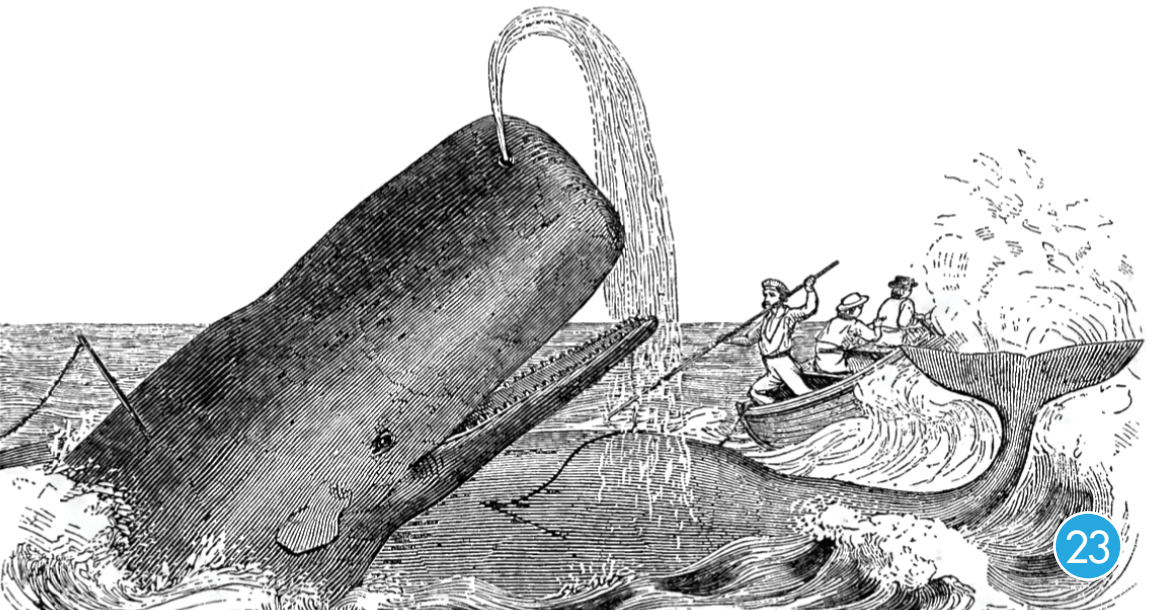


Sperm whales were heavily hunted until their populations crashed, and they were protected. Today there are other threats.

Catching sperm whales was very dangerous for people in the 1800s, and sperm whales' aggressive protection of their calves and group members inspired the novel *Moby Dick*. Even so, people killed so many sperm whales that their population numbers plummeted around the world. It takes so long for sperm whales to be old enough to reproduce and females only give birth every few years, so sperm whale numbers have still not fully recovered from whaling.

Now sperm whales face different threats from people. Getting tangled in nets and being hit by ships are big dangers for sperm whales. Also, chemicals used to protect crops from insects and other types of pollution can end up in the food chain. These chemicals get concentrated in top predators like sperm whales. Some of these chemicals can harm the whales by making them sick or making it harder to reproduce.

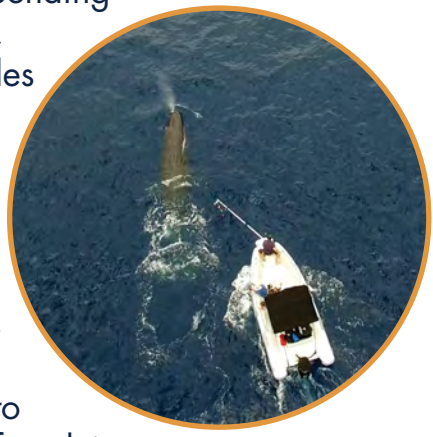
Another human threat to sperm whales is plastic in the ocean. Plastic bags probably look like squid or jellyfish to sperm whales, turtles, and other marine animals. They can die after eating plastic bags that they mistake for prey. Can you think of a way that you might be able to help keep sperm whales safe from this threat?



STUDYING SPERM WHALES

How have we learned so much about sperm whales? How will we find out more about them? Much of what scientists first learned about sperm whales was from examining whales that had died. They looked at what was in their stomachs and noticed the scars on their bodies from battles with giant squid.

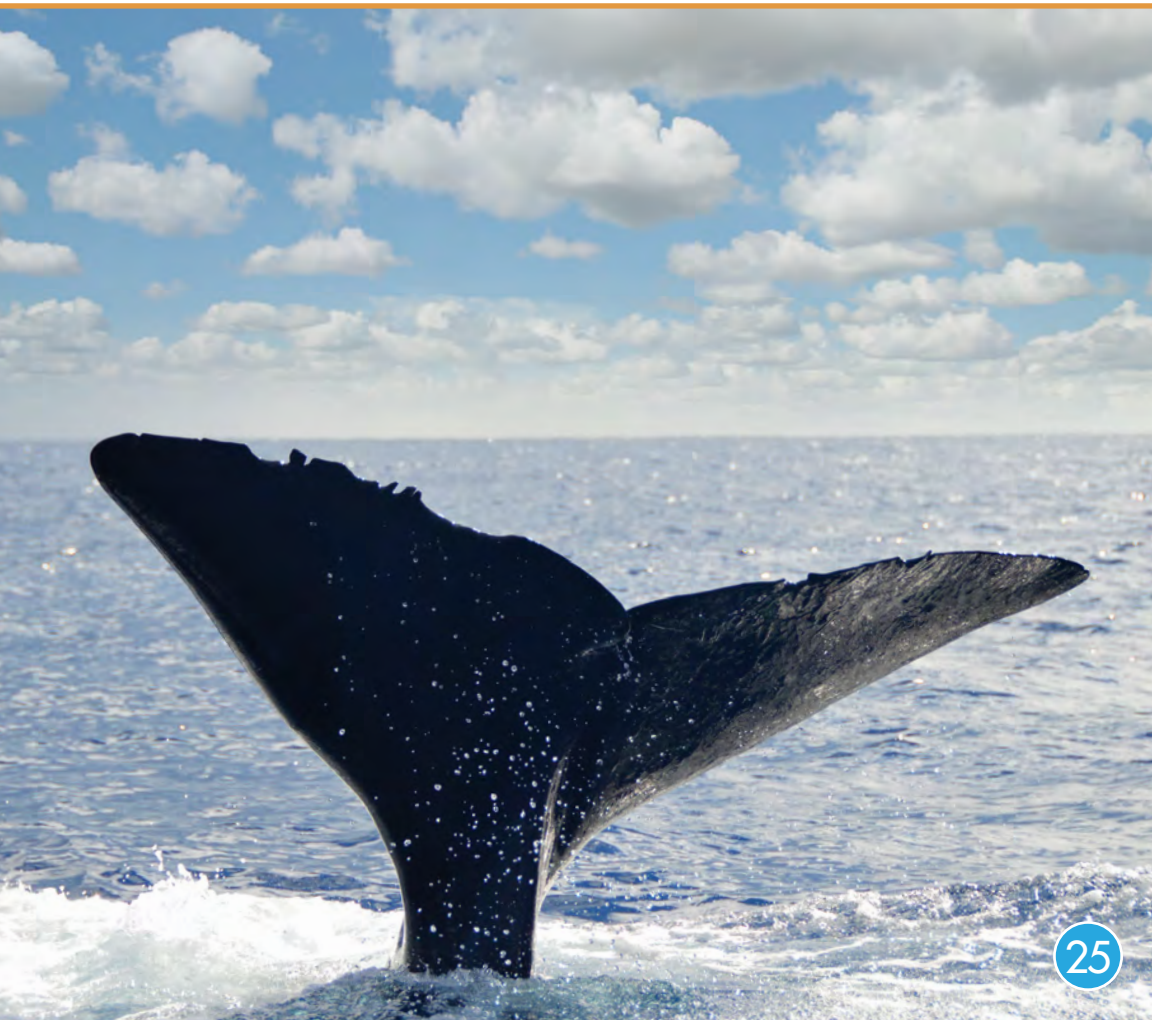
Eventually some scientists decided that a better way to study whales was to live with them. By spending weeks or months on sailing vessels, they were able to observe the whales and get to know where they spent their time and how they lived. They learned to tell individuals apart using the shape and color patterns on their flukes and markings on their bodies. Scientists use **hydrophones**, special underwater microphones, to listen to sperm whale sounds. After years of studying the same whale groups, they learned about their societies, how they move through the oceans, and how they protect themselves from predators.



One big challenge for scientists has been how to study what sperm whales do when they aren't near the surface. Engineers have greatly helped to solve this problem. They have designed special systems that use sonar, which works like echolocation of the whales, to measure the squid and fish in the deep sea. They have designed tags that can be attached to whales with suction cups. These tags can tell the temperature and depth of where the whale swims. They also can record sound. The newest tags even have a camera and a GPS tracker. A big challenge was finding a way to prevent the tags from being crushed by the pressure at the depths in which the sperm whales dive.

Scientists also use chemistry to study whales. One way is to collect skin samples that the whales shed. They also use a special dart to take a small sample of skin and blubber. The genetic material in the samples is then used to determine how many whales are in an area or how different individuals are related to one another. The carbon and nitrogen in the skin and blubber tells scientists how high in the food chain the whales eat and where they might feed.

Every year we learn more about sperm whales, but there are still many mysteries to solve. Now that you have been introduced to them, you are ready to join a mission studying sperm whales!



Dr. Mike Heithaus attaches a camera to a whale with a suction cup. The suction cup does not hurt the whale. It stays attached to the whale for several hours or more. When it falls off, it floats to the surface. Scientists use radio tracking devices to find the camera. Then they can see what the whales have been doing – maybe even battling a giant squid!

GLOSSARY

ADAPTATION
a trait of an organism that helps it survive in its environment

BALEEN
a series of plates found in the upper jaw of a baleen whale. Baleen is made of keratin, which also makes up fingernails and hair

BIOLUMINESCENCE
light emitted by organisms

CETACEANS
the group of mammals that includes whales, dolphins, and porpoises

CONSUMER
an organism that feeds on plants or animals for energy

DECOMPOSER
an organism that feeds on and breaks down organic material

ECHOLOCATION
the use of reflected sound to locate objects

ELECTROMAGNETIC WAVE
wave made up of changing electrical and magnetic fields

ENERGY
the capacity of a physical system to perform work

HYDROPHONE
a microphone that detects sound waves underwater

MAMMAL
a warm-blooded vertebrate distinguished by hair or fur, presence of milk in females, and (typically) the birth of live young

MATRIARCH
an older female that is the head of a family or group

MATTER
physical substance that occupies space and has mass

MECHANICAL WAVES
oscillation of matter that travel through a medium

MYSTICETES
baleen whales; part of the cetacean group that includes right whales, bowhead whales, humpbacks, and blue whales

NUTRIENTS
substances that provide nourishment essential for growth and life

ODONTOCETES
toothed whales; part of the cetacean group that includes dolphins, porpoises, beaked whales, and sperm whales

PHOTOSYNTHESIZE
when producers convert sunlight, water, and carbon dioxide into sugars and oxygen

PHYTOPLANKTON
small or microscopic plants floating in the water

PRODUCER
an organism (like a plant) that uses photosynthesis or another process to make its own food

SCAVENGER
an animal that feeds on dead animals

WARM-BLOODED
an animal that can generate its own heat and maintain a constant body temperature

WAVE
a disturbance that transfers energy through space and water

PHOTO CREDITS

Abbreviation Key: SS = Shutterstock.com; NASA = National Aeronautics and Space Administration; NOAA = National Oceanic and Atmospheric Administration

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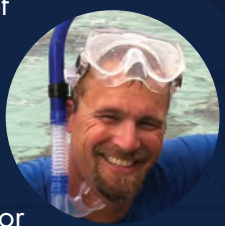
Thanks for learning about sperm whales with us. Our science adventures take us around the world to uncover secrets of the most amazing animals and places. Our mission and passion are to share these scientific discoveries with you. There are so many cool things to see out there, even in your own backyard, so get outside and explore!

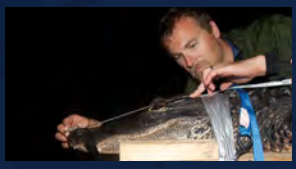
MIKE HEITHAUS, Ph.D.



Dr. Mike Heithaus is an explorer, author, educator, and television host. He is a professor of biology and Dean of the College of Arts, Sciences & Education at Florida International University. Mike and his students study sharks, whales, sea turtles, and other large marine animals around the world. They also work with people to help protect these species. Mike loves sharing his work with others. He has written textbooks and helped create programs for students in elementary, middle, and high school. He has been on television programs on PBS, National Geographic, and Discovery Channel's Shark Week.

PATRICK GREENE

As a wildlife filmmaker, Patrick has always had a passion for animals. He started to draw pictures of sharks and whales when he was just five years old. Later he went to college to become a marine biologist and learned a lot about science. Then he got a job in television and learned how to make videos too. Since then he's gone all over the world studying and filming wild animals. He's made shows for National Geographic, PBS, and ABC, and even won an Emmy Award. He loves making videos to teach students about science and about the many creatures that share our world.



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