# SHARK WORLD

## A SCIENCE 3D ADVENTURE

MIDDLE SCHOOL

By MIKE HEITHAUS Ph.D

symbio education

# KEY WORDS

BIOLUMINESCENCE

CELL MEMBRANE

COMMENSALISM

ENZYME

HETEROCERCAL TAIL

HYDROPHONE

INNATE BEHAVIOR

LATERAL LINE

MULTICELLULAR ORGANISMS

MUTUALISM

ORGAN

ORGAN SYSTEM

OSMOSIS

PARASITE

SENSOR

SYMBIOSIS

TISSUE

VERTEBRATE

# TABLE OF CONTENTS

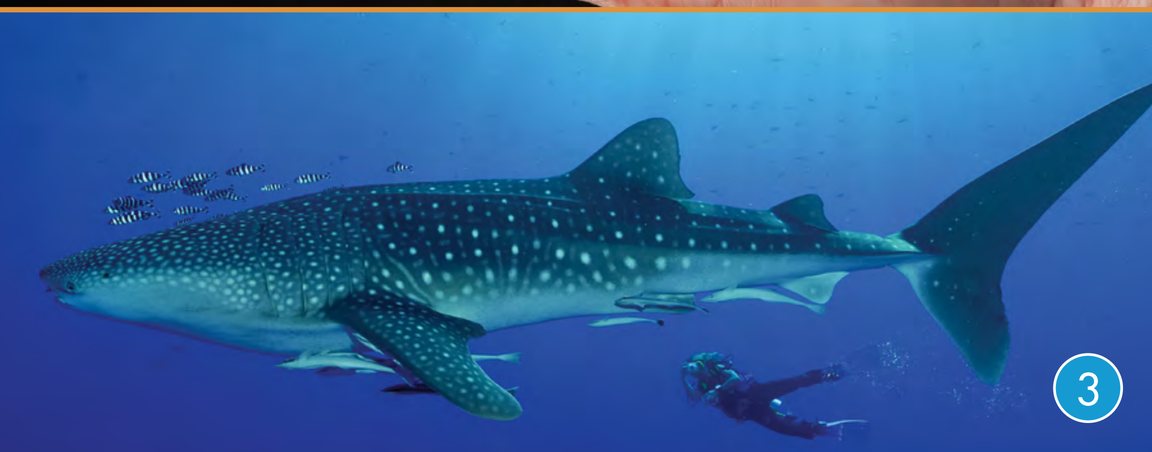
# MANY SHARKS

When most people think of sharks, they probably imagine the large size and scary big teeth of a great white shark (*Charcharodon carcharias*). However, great white sharks are just one of more than 500 species of sharks. In fact, scientists are still discovering new species of sharks! Some have been hiding in plain sight. Even though certain sharks looked very similar, scientists were able to discover they were different species by studying their genetic makeups.

# MANY SIZES

Sharks come in a wide range of sizes. The smallest is the dwarf lantern shark. It has a maximum length of 20 cm (8 in) and can fit in the palm of your hand! The largest shark is the whale shark. It can grow over 12.5 m (40 ft) long and weigh over 21 tons! The extinct Megalodon was even bigger. It reached around 18 m (60 ft) long! And, unlike the whale shark, which eats small prey, Megalodon ate whales, dolphins, sharks, and other very large prey.

Lifespans of sharks vary a lot too. Some sharks may only live a few years, but others live for centuries! Scientists recently used the chemical composition of a Greenland shark's eye lens to determine that it had lived almost 400 years! That makes it the oldest known vertebrate.



# MANY HABITATS

Sharks are found in many different habitats, ranging from the oceans in the tropics to the very cold waters of the Arctic. They are also found from the surface down to depths of more than 1,500 m (5,000 ft). Some species found only in the deep sea are adapted to the cold, dark waters where the pressure on their bodies is very intense. Other sharks may swim from surface waters to deeper waters to feed. Other sharks spend most of their time deep underwater but follow their prey to the surface at night.

**Tiger sharks are common top predators in coastal oceans of the tropics. They are also found far out to sea. Recent studies show that they can dive hundreds of meters deep!**

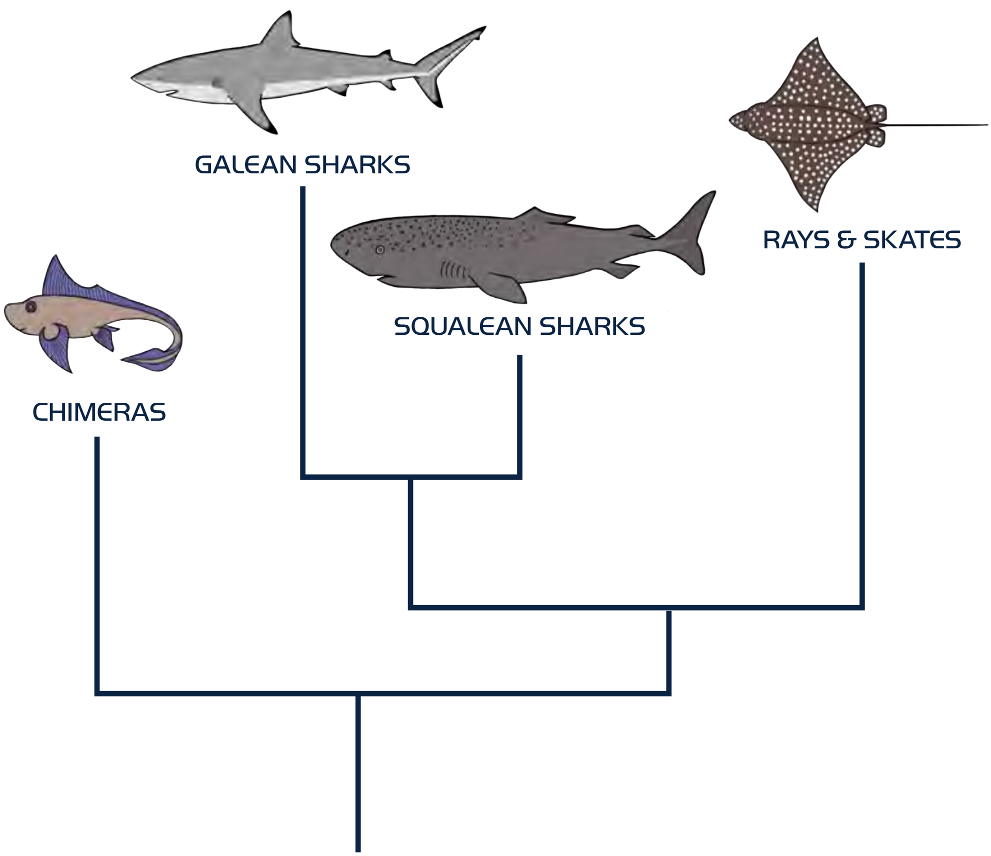
Sharks are also found in rivers and lakes in some parts of the world. The bull shark has been found thousands of kilometers upstream in the Amazon and Mississippi Rivers as well as Lake Nicaragua. Several species of river sharks are found in northern Australia and Asia. Unfortunately, many of these freshwater sharks are threatened by overfishing and habitat degradation.

**Bull sharks are found in fresh water, estuaries, and oceans.**

# THE RISE OF SHARKS

Sharks are part of the group of cartilaginous fish known as "elasmobranchs." This group also includes skates, rays, and chimeras (also known as ghost sharks). The first sharks appeared around 400 million years ago. Modern sharks first evolved around 100 million years ago. Since that time, they have diversified to thrive in the many habitats described above.

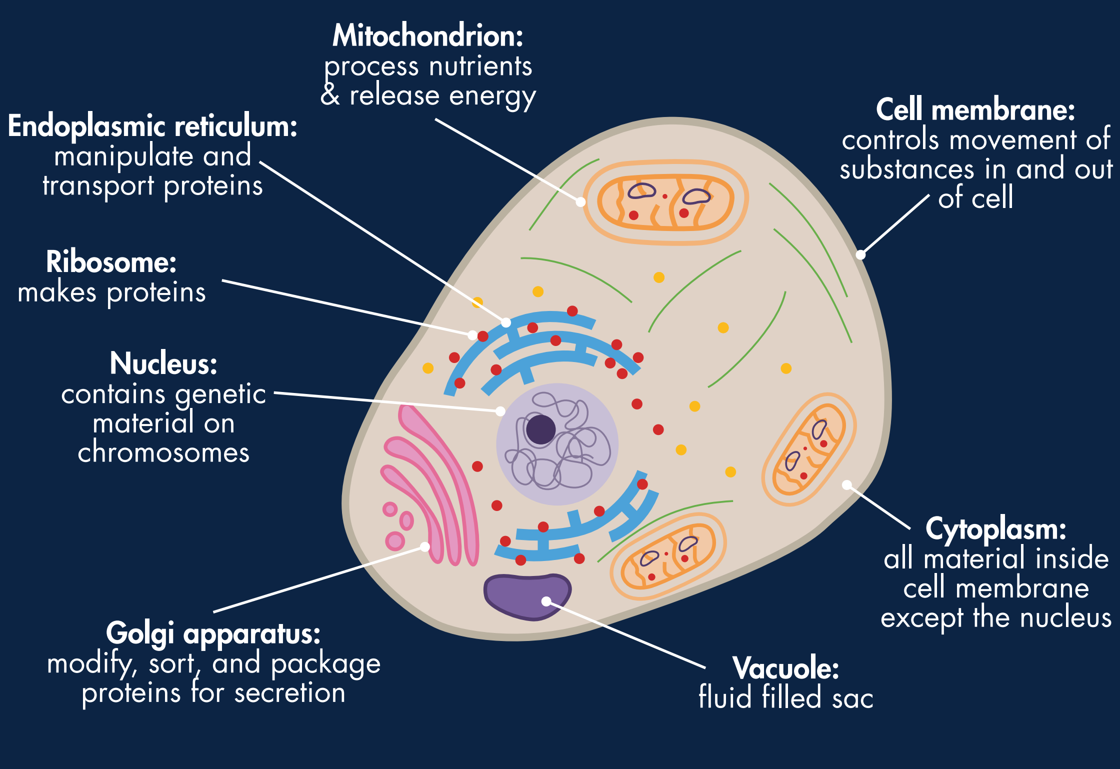
There is no question that sharks are built for success. But what makes the perfect ocean predator? Let's start from the beginning.




Scientists use morphological traits and genetic information to map the relationships among elasmobranch fish. Check out the "tree of life" of these incredible animals at www.sharksrays.org.

# BUILDING BLOCKS

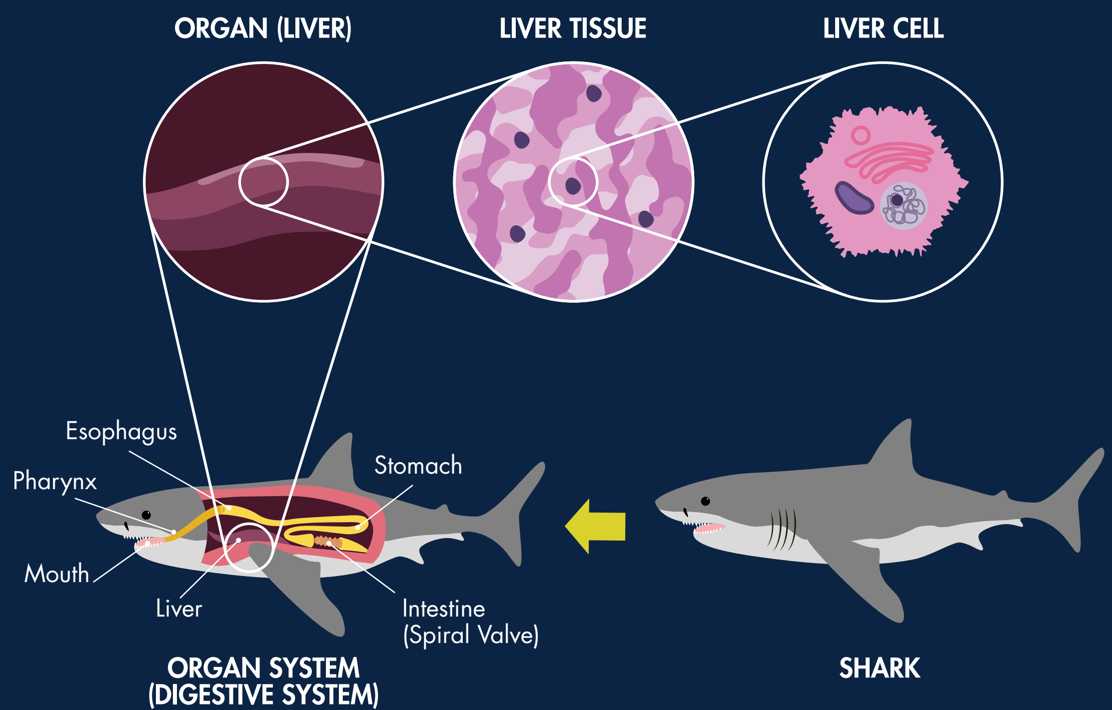
From dwarf lantern sharks to whale sharks, bacteria to redwood trees, cells are the building blocks of all life. Sharks, like other **multicellular organisms**, have many different types of cells. The structure of these cells is linked to their function. For example, muscle cells are built to contract while other cell types have a special hair that detects the movement of water. Even cells with different functions and appearances have some similarities. These are shown in the picture of the cell. Cells have to store and process information, gather energy and matter from the environment, and get rid of waste. Different parts of the cell are responsible for each of these functions. Because they are animals, each cell of a shark is surrounded by a **cell membrane.**




**A basic eukaryotic cell (a cell with a nucleus).**

The next level of organization in sharks is **tissue**. Tissue is a collection of cells that, together, perform a specific function. For example, muscle tissue in sharks is made up of cells that work together to contract, enabling motion.

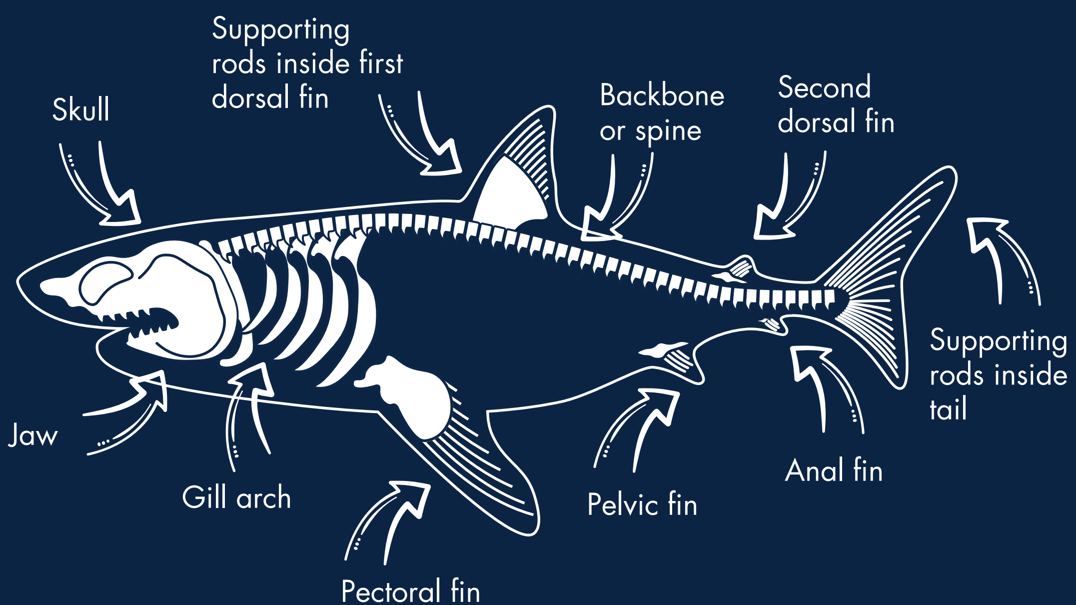
When more than one type of tissue work together to complete a particular function, they are called an **organ**. Shark gills are organs that extract oxygen from the water and release carbon dioxide from the body. An **organ system** is a group of organs and other structures that work together. The heart and blood vessels are part of the circulatory system. All the organ systems need to work together to help an organism function. Let's look at how the functions of the organ systems and **sensory systems** work together to build a shark.




**Levels of organization: Cells of the same type form tissues. Tissues form organs. Groups of organs that work on the same function form an organ system. Multiple organ systems work together to enable a body to run and respond to its environment.**

# SHARK STRUTS (SKELETAL SYSTEM)

The skeletal system of a shark is an endoskeleton, which means it provides support from the inside. Shark skeletons are made up of cartilage and connective tissue. Sharks do not have bones like most fish, amphibians, reptiles, birds and mammals. Cartilage is more flexible and less dense than bone. Unlike many other **vertebrates**, sharks do not have a rib cage.



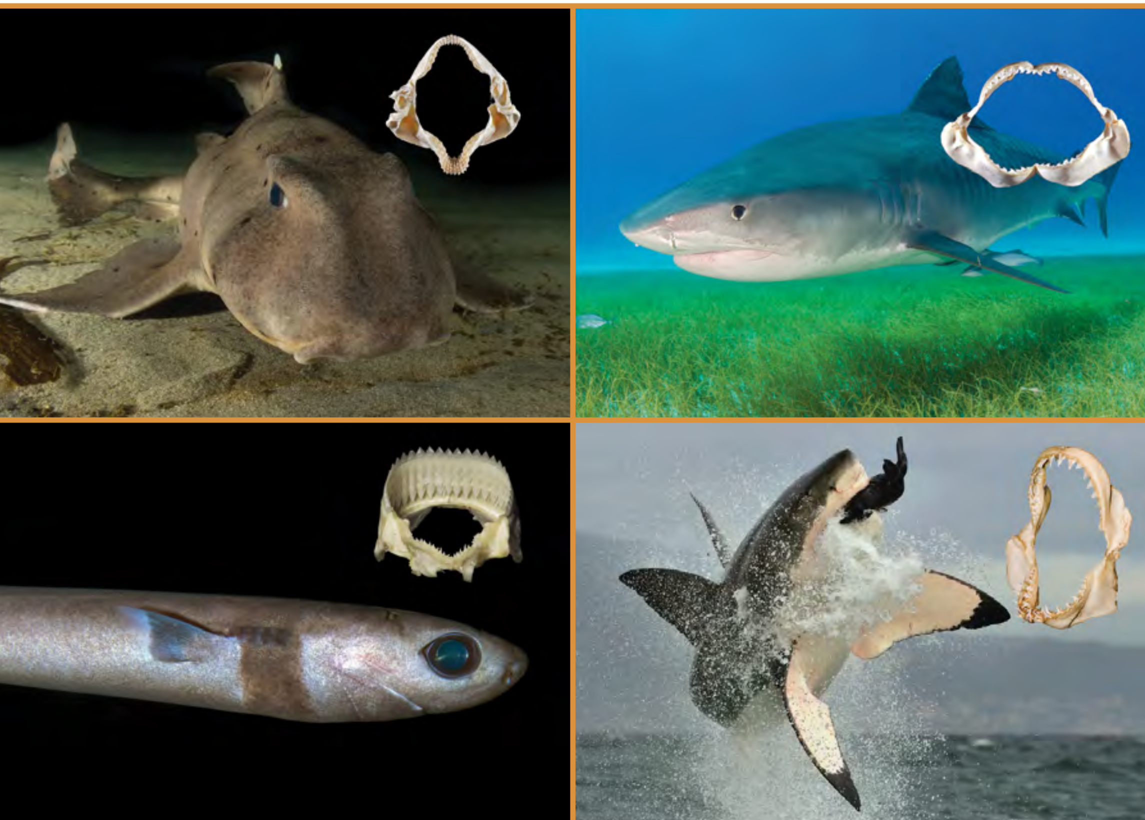

**The skeletal system of a shark.**

Because they undergo a lot of stress, the jaws of sharks have special reinforcements that makes them strong. The jaw is not attached to the rest of the skeleton. This lets the shark move its jaw forward when it bites. Shark teeth sit in the gums rather than in the jaw. There are multiple rows of teeth in the jaw groove. These rows are positioned one behind the other. When a tooth is lost, another one slides into place, like a conveyor belt.

Different types of sharks eat different types of prey. The structure of a shark's jaw and the shape and size of its teeth reflect what it eats. Some sharks, such as the horn shark, eat shellfish like bivalves and crabs. These sharks have strong narrow jaws. They have small, flat teeth that work with the jaw to crush hard prey. Sharks that eat fish and squid tend to have pointy teeth that are built to grab and hold onto slippery prey until they can be swallowed whole.

Tiger sharks eat big prey, including sea turtles. They have broad, heavy jaws and curved teeth with serrations like a steak knife. This combination allows them to easily grab large prey and even cut through bone and turtle shells by shaking their head back and forth. Their teeth work like a saw. Cookie cutter sharks may be small, but they have incredible teeth and fleshy lips. These enable them to suck onto their prey, including whales, dolphins, seals, and fish, and then bite and twist their bodies to remove scoops of tissue. They leave marks that look like cookie cutters, which gives them their name! The biggest sharks have tiny teeth. Whale sharks and basking sharks don't need teeth to eat tiny prey.

## TYPES OF SHARK JAWS



**The horn shark (upper left), tiger shark (upper right), cookie cutter shark (below left), and white shark (below right) eat different foods. They each have the right jaws and teeth for the job.**

# SHARK FUEL PROCESSING (DIGESTIVE AND EXCRETORY SYSTEMS)

Sharks eat many different kinds of prey. Most sharks eat fish and squid. Some eat shellfish. Small deep-sea sharks eat small fish and shrimp. Some large sharks, like hammerhead, tiger, bull, and white sharks eat big bony fish, rays, and other sharks. Large white sharks eat seals and sea lions. Many sharks scavenge dead fish or dead whales. The biggest sharks (whale sharks, basking sharks, and megamouth sharks) eat the smallest prey. They dine on fish and coral eggs, small shrimp-like creatures, and sometimes small schooling fish.

A shark's **digestive system** breaks down its food. This is important because sharks get the energy they need to survive from their food. Sharks don't spend much time chewing their food with their teeth. Sometimes they cut pieces off before swallowing if the prey is large. Alternatively, cows spend eight hours a day chewing to break down food!

**The biggest sharks, like whale sharks, filter water to feed on tiny prey, like plankton.**

Once shark food is swallowed, digestive **enzymes** in the stomach chemically break it down. Some sharks throw up large items, like turtle shells, that can't be digested. They can even turn their stomachs inside out to get rid of things they can't digest! Most food, though, is broken down into smaller particles by enzymes and then moves into the intestine. There, nutrients that have been broken down from the food are absorbed. Sharks have a "spiral valve" intestine. The spiral adds more surface area on which nutrients can be absorbed, so sharks have shorter intestines than mammals.

Not all of the matter from food is digested and used by the body. After nutrients are absorbed, animals get rid of waste products through the **excretory system**. The kidneys and liver help remove toxins and waste from the blood. Solid waste moves through the intestine. The gills are the part of the excretory system that gets rid of carbon dioxide. In land animals, lungs serve this function.

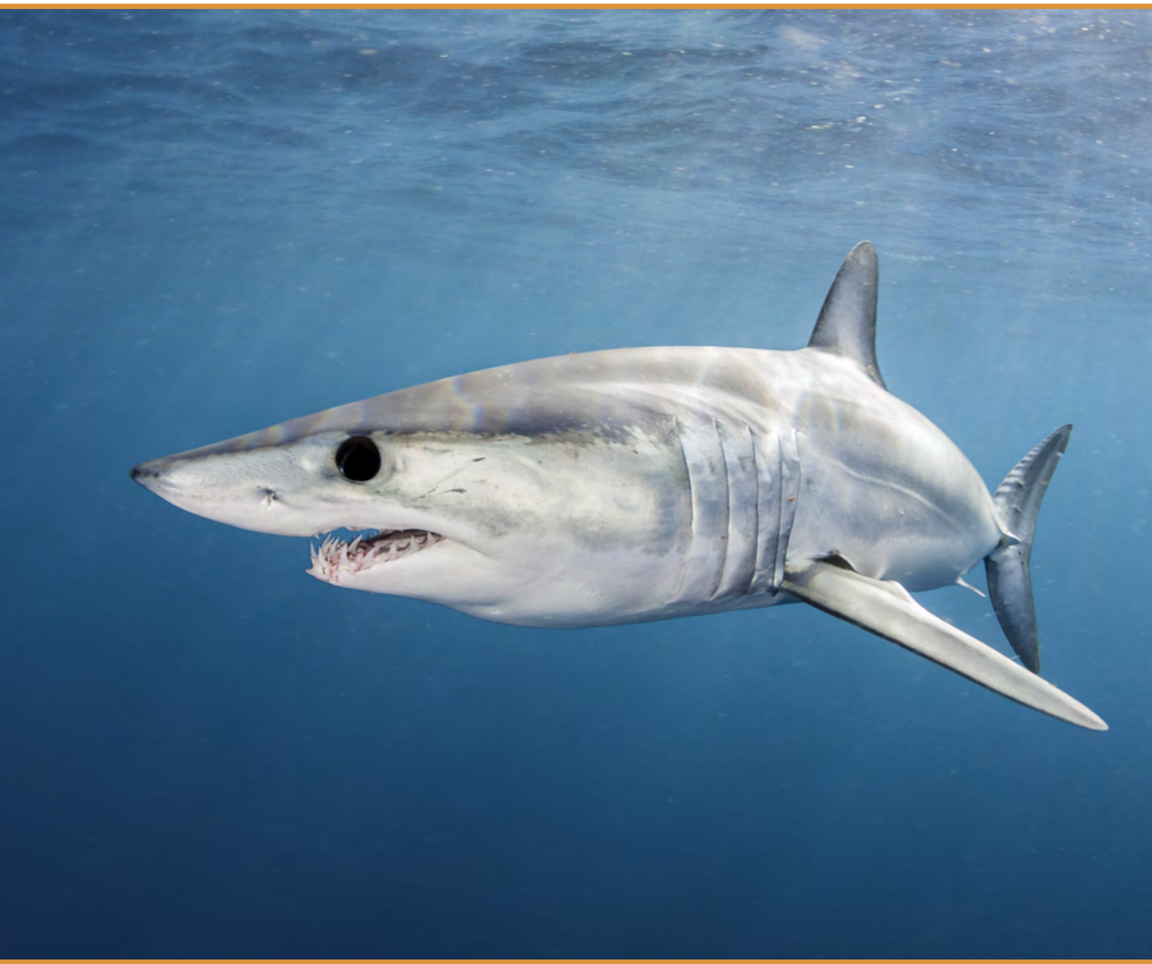
**Once a shark eats food, its digestive system breaks it down and extracts nutrients. The excretory system gets rid of waste.**

# SHARK FUEL INJECTION (RESPIRATORY AND CIRCULATORY SYSTEMS)

All organisms need energy to run their bodies. Consumers, like sharks, get this energy from their food, but they also need oxygen to release that energy through the process of **cellular respiration**. In sharks, the gills extract oxygen dissolved in the water. Gills are one way to tell the difference between sharks and bony fish. Bony fish have one gill opening on each side. Sharks have five to seven gill slits. To get enough oxygen, water has to flow across the gills. Many sharks have to swim constantly to get enough oxygen to survive. Some species, like nurse and whitetip reef sharks, rest on the bottom and suck water in through their mouths and over their gills.

Nurse sharks can lie motionless on the bottom and pump water over their gills.

Nutrients from food and oxygen extracted by the gills, are carried to cells by the **circulatory system**. The circulatory system of sharks includes the heart and blood vessels. Sharks have a two-chambered heart. Cells that make up tissue in the heart have protein fibers that let them stretch and contract. The cells that make up cardiac tissue have a structure that allows them to contract together. Oxygen-rich blood flows out to the body in arteries. Oxygen-poor blood flows from the body to the heart in veins and then is pumped to the gills to be re-oxygenated.



**Most sharks cruise slowly at around 2-3 km per hour (1-2 mph). Some species are capable of incredible speed. The shortfin mako shark, found in offshore waters around the world, can swim in bursts of around 65 km per hour (40 mph)!**

# SHARK PROPULSION (MUSCULAR SYSTEM)

The **muscular system** drives animal movement. Muscles are bundles of muscle cells that contract when signaled by the nervous system. This contraction shortens the muscle, which moves whatever the muscle is attached to, like cartilage. Some muscles, like those sharks use to swim or move their eyes, are under voluntary control. Others, like internal organs including the heart, are not voluntarily moved.

Sharks and humans both have red and white muscles. Red muscles contract slowly but don't get tired easily. They are used for slower movements over long periods of time. White muscles contract and tire quickly. They can give sharks amazing bursts of speed. In general, sharks have a higher proportion of muscle than land animals. Much of this muscle tissue is white muscle. How does this benefit sharks? Think about whether a shark is a better sprinter or long-distance swimmer.

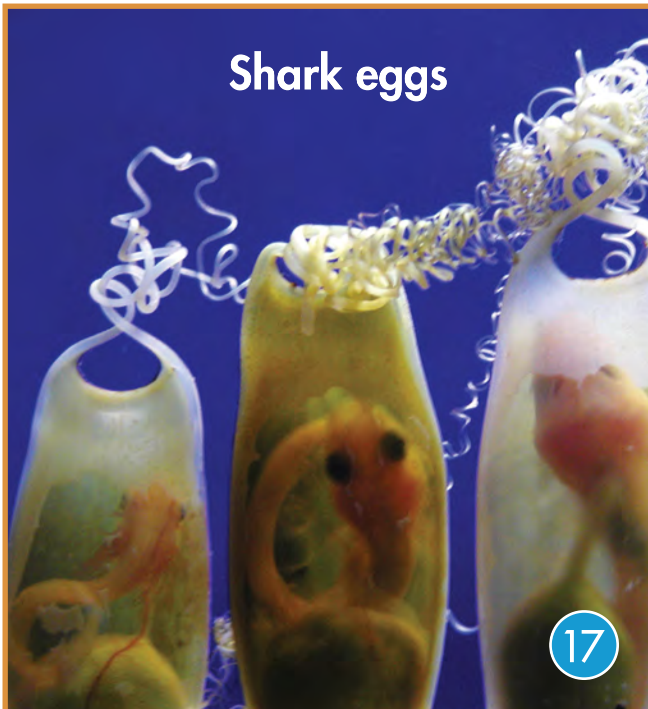
**The muscular system of a white shark helps it swim fast enough to breach and catch speedy prey like sea lions!**

# SHARK FACTORY (REPRODUCTIVE SYSTEM)

The **reproductive system** produces and transports reproductive cells. In females, it provides the environment for the development of eggs or embryos. Sharks have internal fertilization. Males have modified pelvic fins with claspers that are used in mating. In some species, males bite onto female's pectoral fins or bodies during mating. This can leave "mating scars," but these scars heal quickly.

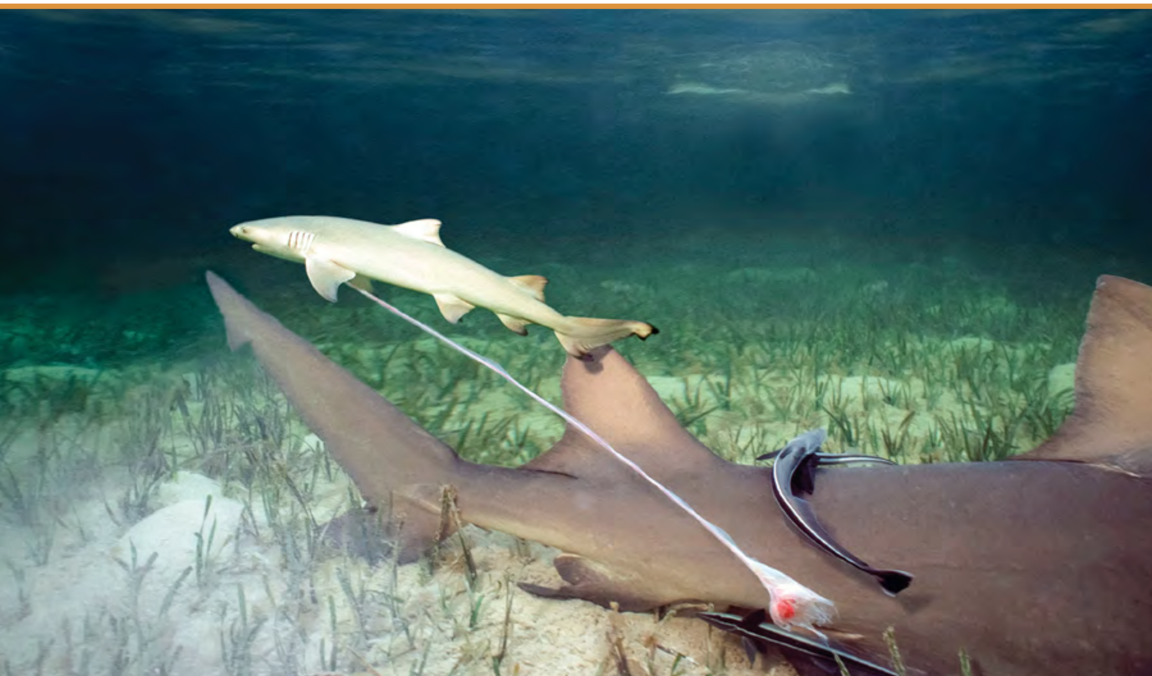
There are different types of shark reproduction. Some species, like catsharks and horn sharks, lay eggs. In other species, the egg hatches inside the mother before the baby is born. In both of these types of reproduction, baby sharks are nourished by a yolk sac inside the egg. Once young tiger sharks use up the yolk supply, they get nourishment from fluid secreted inside the mother until they are born. In some species, like white sharks, the young sharks inside their mother eat other eggs that have not hatched. Sand tiger shark pups will cannibalize other pups while still inside their mothers!

The young of many species of sharks, including blacktip sharks and hammerheads, develop inside their mothers without an egg case. Some of these species have a placental connection to their mothers, through which they provide their babies with nutrients and energy. These babies are born alive.



Sharks reproduce slowly. Some species may be more than 20 or 30 years old before they start reproducing. They also have few young. For species that give birth to live young, a female shark may only reproduce once every two years and give birth to relatively few pups. What sharks lack in numbers they make up for in size. Regardless of whether they hatch or are born alive, baby sharks are fully formed and ready to fend for themselves. Despite their size, they are not at risk from most predators in the ocean. Babies of some shark species are also born with large livers. The energy in their livers is used to keep them alive while they learn to feed for themselves.

Bony fish reproduce very differently than sharks. They use external fertilization. Females release eggs into the water where they are fertilized by males. They also may produce thousands of eggs when they reproduce. But, each baby bony fish is tiny and its chances of survival are poor. Bony fish tend to grow quickly and are ready to reproduce at an early age.



**Birth of a baby lemon shark. You can still see the connection that the pup had to its mother when it was inside her.**

# SHARK DEFENSES (IMMUNE SYSTEM)

The **immune system** defends organisms from parasites, diseases, and infections. It has to be able to tell the difference between a threat and its own body's tissue. Then, it has to be able to respond. The immune system includes many different structures and processes. People are very interested in the shark immune systems because they don't get cancer very often. Some people think that sharks don't get cancer at all and that taking pills made of ground up shark cartilage will make them healthy. Neither of these myths are true! But that doesn't mean that sharks don't have amazing immune systems. In fact, scientists are studying them to help better understand how to improve treatment of human diseases.

Studying shark immune systems may even help cure diseases in humans.

# SHARK CENTRAL (NERVOUS SYSTEM)

The **nervous system** has to collect sensory information from the external and internal environment, interpret this information, and then respond to it. The brain and spinal cord make up the central nervous system. The nerves of the spinal cord bring information from the peripheral nervous system to the brain. The brain uses that information to make memories or respond.

Sensory systems bring information into the nervous system. The five main senses are sight, smell, hearing, touch, and taste. Sharks have another special sense that lets them detect electric fields. Sharks use different senses at different distances to help them navigate, find food and mates, and respond to their environment.

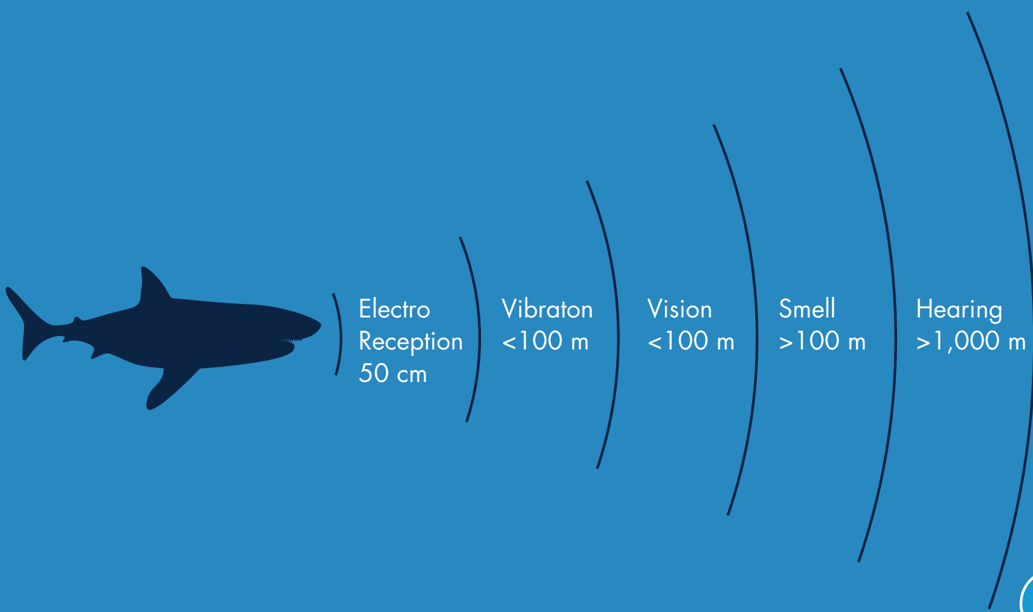
**Grey reef sharks in Fakarava Atoll, French Polynesia gather each night to prey on fish. Feeding at night requires many sensory systems to find prey, catch a meal, and interact with other sharks.**

## HEARING

Sound travels incredibly far in the ocean. It moves more than four times faster in the ocean than it does through the air. Can you believe that loud sounds, like the call of a blue whale, might be heard across an entire ocean? Sharks appear to have good hearing. More research is needed to learn more about this sense, but it is clear that they can hear loud sounds from many kilometers away. Hearing is probably the sense that they use at the farthest distances.

## SMELL

Sharks are famous for their sense of smell. They can detect one drop of blood in a million drops of water! That's around 100 liters or 30 gallons of water. If there is enough blood or other scent in the water, sharks can detect the direction of the smell by swimming back and forth across a trail of scent. That is one way that some sharks, like white sharks, are able to quickly find dead whales and feast. Sharks can follow trails of scent for long distances, especially if they are caught in currents. The oils from a floating carcass, for example, may extend for kilometers.



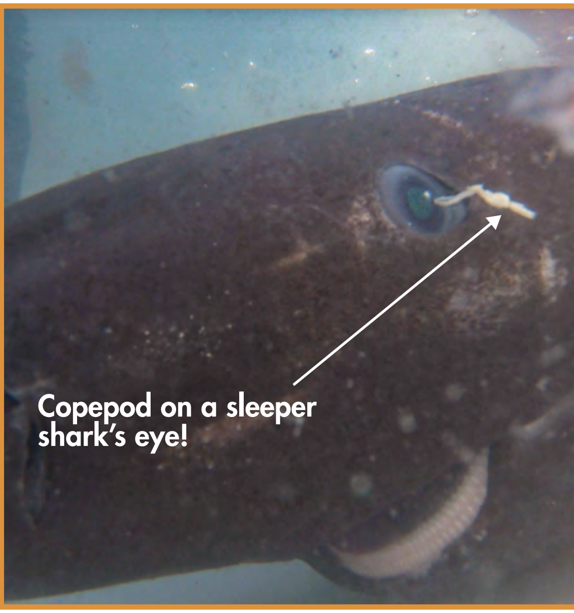
# VISION

Many think that all animals see the same way as people. But, many animals have eyes that are tuned to different wavelengths (colors) of light. It is still unknown exactly how well different sharks see, but many are colorblind or do not see the same range of colors as people. However, sharks have adaptations in their eyes to help them see very well in low light. Some species are better at low light vision than others. Some sharks have another adaptation, called a nictitating membrane that covers the eye to protect it when the shark attacks prey.

**Different species of sharks have different eyes and different ways of seeing the world. To protect their eyes, some sharks can cover them with a special membrane.**

Based on their behaviors, some sharks probably use vision to navigate and hunt. White sharks and tiger sharks look for their swimming prey's silhouettes at the surface and ambush them from below. Deep-sea sharks probably use **bioluminescence** in the water and on other organisms to find prey and identify other sharks. Recently, scientists found that some sharks look very different when viewed with the wavelengths of light that sharks see. They appear to glow and stand out from their surroundings. Maybe this color helps them find other sharks of their species. There is still a lot to learn about shark vision.

Scientists used special biofluorescent cameras to see the world the way a shark would! This is what chain catshark biofluorescence looks like.

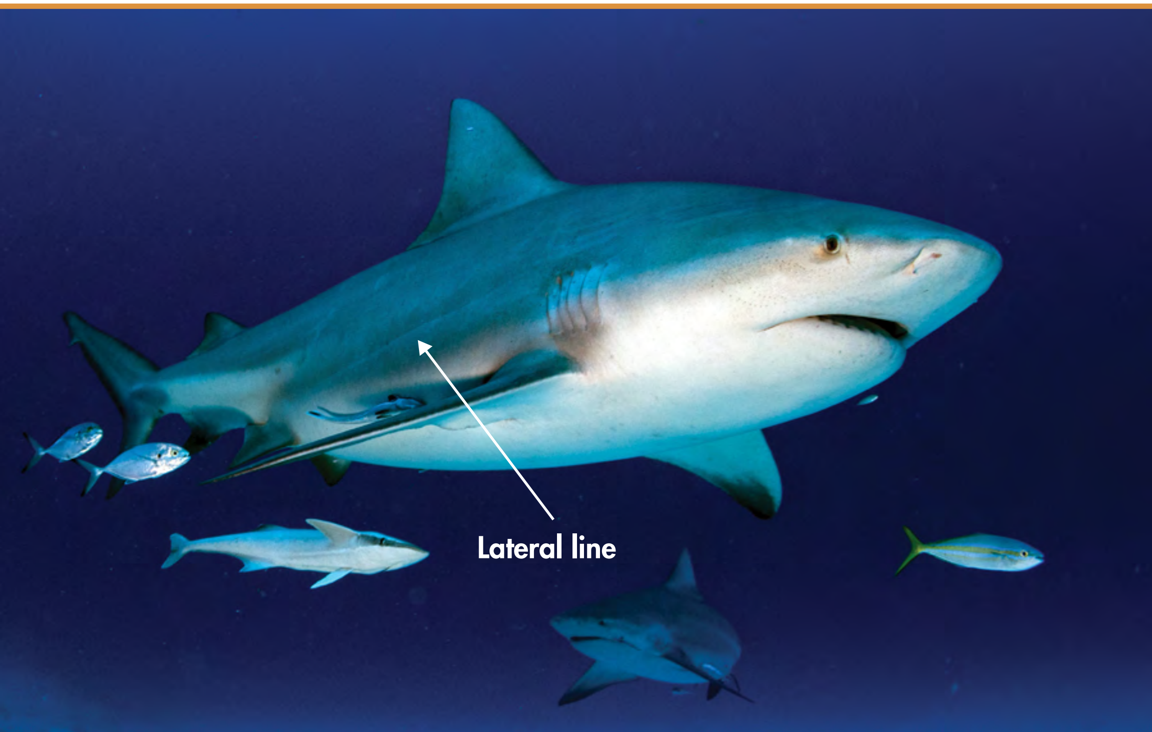


Copepod on a sleeper shark's eye!

Other sharks probably don't heavily rely on vision. Some species live in waters that are so murky they wouldn't be able to see very far at all. The Greenland shark may be mostly blind. Some even have parasitic copepods that cling to their eyes. **Parasites** are animals that live in or on another organism and harm them. Some animals live in or on other organisms without hurting or helping them. This relationship is called **commensalism**. Parasitism and commensalism are both types of **symbiosis**, which occurs when organisms live in close association.

## TOUCH/LATERAL LINES

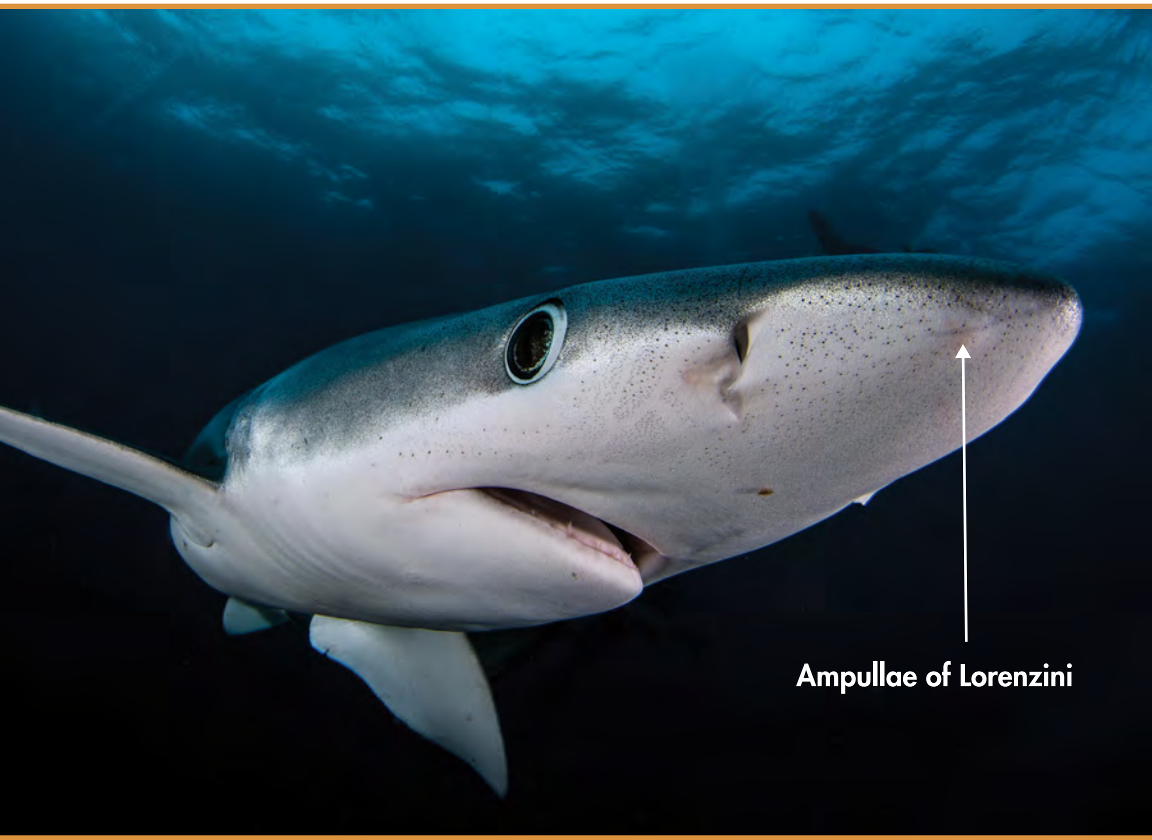
Sharks and other aquatic vertebrates have a **lateral line** made of sensory organs that run along the body. They detect vibrations and movement in the environment. This includes disturbances in the water. Sharks use their lateral line to find and attack prey and to detect movements of other sharks.




**Schooling sharks may be able to detect and respond to the movements of other sharks using their lateral lines.**

# ELECTRORECEPTION

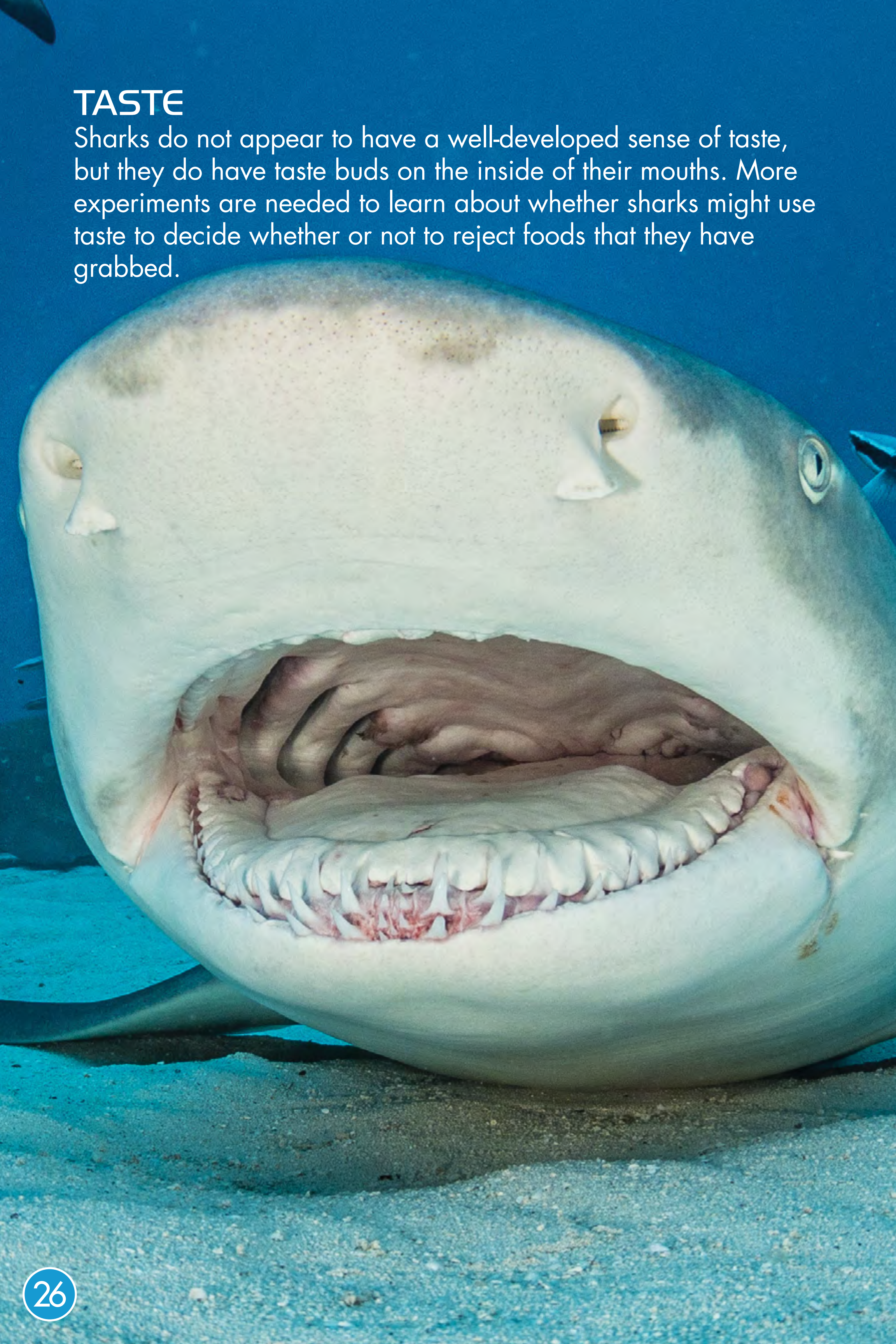
Saltwater is a good conductor of electricity. Sharks and many other aquatic organisms have the ability to detect electric fields. This ability is called electroreception. Sharks have small jelly-filled pits on the underside of their snouts and around their heads that can detect electric fields. These are called the Ampullae of Lorenzini. Using the Ampullae, sharks can detect their prey's electric fields. This helps them find prey buried in the ground or make the final attack when they lose sight of their prey as they open their mouths. Sharks can also detect magnetic fields generated by the earth. Scientists think they may use these magnetic fields to navigate across the expanse of featureless oceans with amazing accuracy!




**Blue sharks, like other sharks, have an amazing ability to detect electric fields using small pores called Ampullae of Lorenzini.**

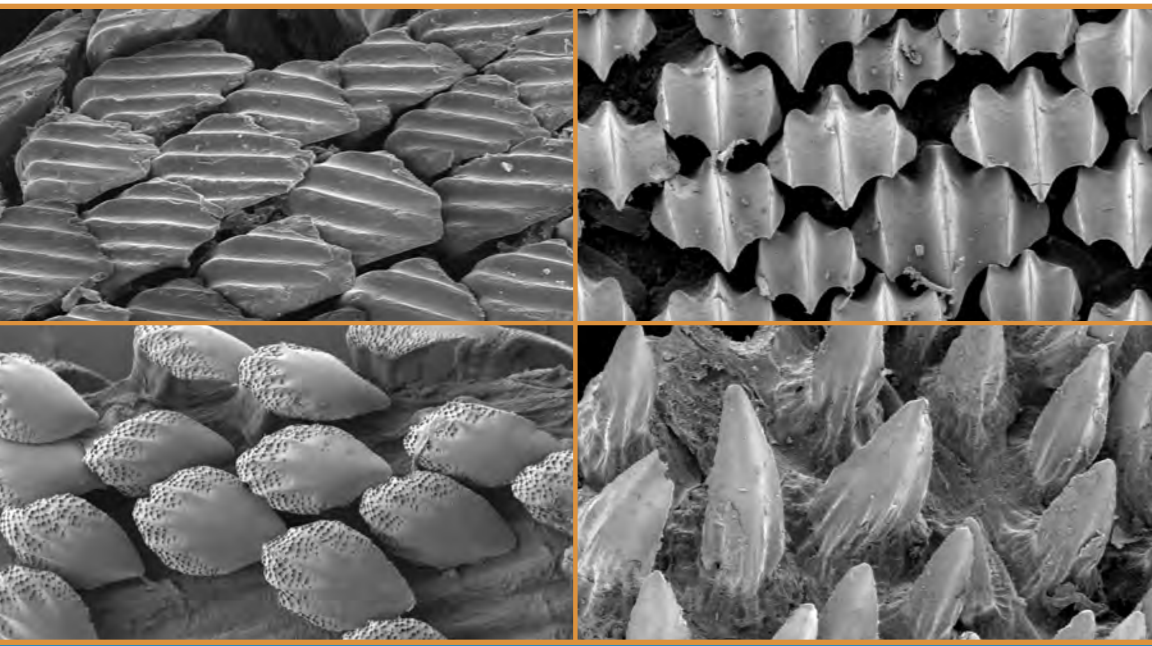
# TASTE

Sharks do not appear to have a well-developed sense of taste, but they do have taste buds on the inside of their mouths. More experiments are needed to learn about whether sharks might use taste to decide whether or not to reject foods that they have grabbed.



# SHARK WRAPS (INTEGUMENTARY SYSTEM)

Skin is the largest organ in people and some animals. It protects the animal from the outside world and transports materials in and out of the animal. Shark skin is covered by scales called dermal denticles. The scales of sharks are very different than those of bony fishes. Shark scales look like little teeth. They make shark skin feel very rough. Some might think that rough skin would slow a shark down. But, shark dermal denticles are very good at reducing the water's resistance, helping the shark move with less energy. Shark dermal denticles are so efficient that they were used as a model for high-tech swimsuits used by Olympic swimmers. The advantages the full body suits provided athletes were so large that they were banned from some competitions!



**These are shark scales seen through a high-powered microscope. The scales of different sharks can have very different shapes. Some look like small teeth!**

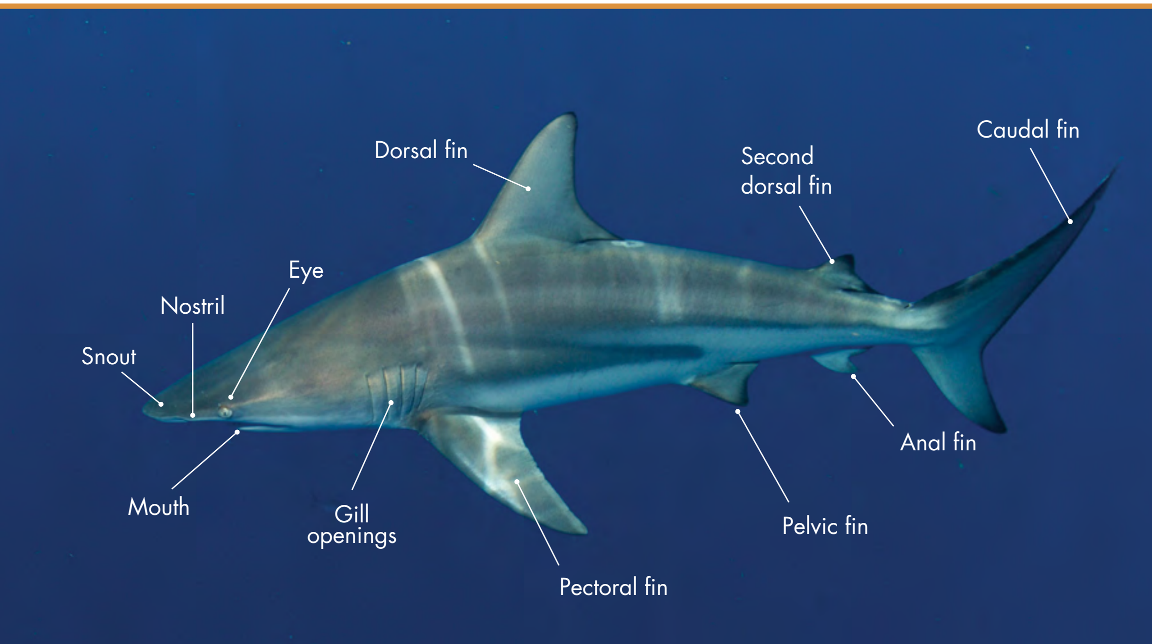
A number of sharks in the deep sea have special organs in their skin called photophores that help them create light. They glow in the dark! Many organisms in the deep sea can create their own light or have bacteria on their skin that glows. Why would a shark want to glow? It might help them blend in with the background glow in the deep sea. Having special patterns might help sharks find other members of their species, attract prey, and warn predators. Velvet belly lantern sharks have spines near their dorsal fins that are lit up with bioluminescence.

Sharks that live closer to the surface may not glow, but their color patterns are functional. Many sharks and other species that live in the open ocean have a pattern known as "countershading." Sharks have a darker color on their dorsal surface and a lighter color on their ventral surface. This helps the shark blend into the dark waters below when viewed from above and into the bright surface waters when viewed from below.

**Some deep sea sharks use bioluminescence (top). Shark colors can help them blend into the water (bottom).**

# SHARK SHAPES

There are hundreds of species of sharks that have "typical shark" shapes, including bull sharks, white sharks, lemon sharks, and blacktip sharks. But upon closer look, even these sharks have differences that help them adapt to their particular environments. The basic shark shape, when combined with their muscular system and dermal denticles, is perfect for efficiently slipping through the water. The **heterocercal tail**, in which the upper lobe is longer than the lower lobe, helps to keep the shark from sinking. The sharks' pectoral fins were thought to provide lift to prevent sinking, but Dr. Cheryl Wilga found out that this is not true. Rather than provide lift, they help the shark maneuver vertically. Some sharks have tails (called caudal fins) that have similar-sized upper and lower lobes. This helps them swim faster, but they are less efficient for cruising. Others have long upper lobes and almost no lower lobe. These species swim slowly and spend a lot of time on the bottom.




**The basic body plan of a shark.**

Some sharks have weird body shapes that are adapted to their environments. The sawshark has a long snout with teeth on the outside. Angel sharks and wobbegongs look like sharks that have been run over by a steamroller. Their flattened bodies help them hide buried in the sand or squeeze under ledges on coral reefs. Their coloration and the tassels around their mouths provide camouflage. Thresher sharks have tails with incredibly long upper lobes. They use it to hit and stun their prey before they eat it. Hammerhead sharks get their names from the shape of their heads. Scientists still don't know exactly why their heads are shaped that way. Maybe it helps them detect their prey or the environment. Maybe it helps them quickly maneuver to capture prey. The craziest looking sharks existed a long time ago. Some extinct shark relatives had lower jaws that looked like band saws and others had bizarre projections on their heads.

**Wobbegong sharks have flat bodies and a color pattern that helps them blend in to the reef!**

**Thresher sharks use the long upper lobe of their caudal fin to stun prey.**

# SYSTEM CHECKS

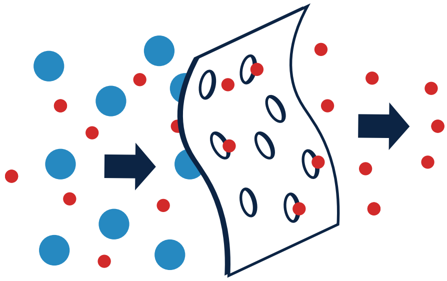
## BUOYANCY

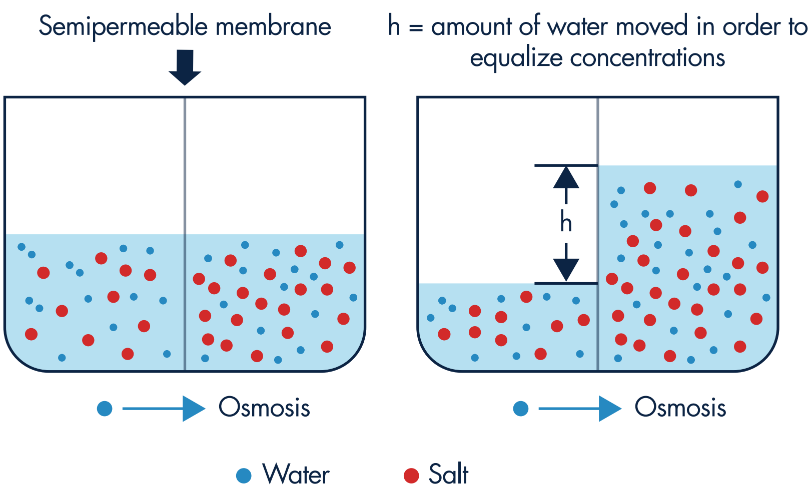
Maintenance of swimming depth is important for ocean animals. Bony fish have air-filled sacs called swim bladders. They can move air in and out of their bladder to rise, descend, or stay at one depth. Sharks don't have swim bladders and they are denser than seawater. This causes them to sink! Sharks have adapted by having large livers with a lot of oil. This keeps them from being too dense, but they still sink if they don't swim. When they swim, their tails and body angle create lift, so they can stay at the same depth. Although sharks sink if they stop swimming, lacking a swim bladder has benefits. Air expands as depth decreases, so bony fish cannot change depths too rapidly or their swim bladder will over inflate. Because they don't have air-filled sacs, sharks can easily move across a large depth range. Sand tiger sharks gulp air at the surface and keep it in their stomachs. This special trick enables them to "hover" in the water.

**Sand tiger sharks gulp air to be able to "hover" in the water instead of sink.**

## WATER BALANCE

One might think it's easy for ocean animals to keep enough water in their bodies since they live in the ocean. But, **osmosis** makes it a major challenge for marine organisms. Osmosis is the process of water moving from areas of low salt concentration to areas of high salt concentration. For most organisms living in saltwater, they have fewer salts in their body than are in the saltwater. That means water tends to leave their bodies to move towards the higher concentration of salts found in saltwater. Sharks solve this problem with a chemical called urea in their bodies. Urea keeps their bodies in balance with the seawater so they don't lose any freshwater.






In osmosis, water moves across membranes from areas with lower concentrations of salt to areas with higher concentrations. Eventually, the concentrations on each side will be similar.

## TEMPERATURE CONTROL

Most fish, including sharks, are cold-blooded. That means that their bodies are the same temperature as the water around them. This is one reason many species of sharks are found in warmer waters. To increase their body temperatures, sharks can spend time in areas with warmer waters. To decrease their body temperatures, they can move into areas with colder waters. The bigger they are, the slower they lose heat. That means large sharks can spend more time in deeper and cooler waters without cooling down too much.

A few types of sharks are warm-blooded. That means that their metabolism keeps their bodies at a temperature warmer than their environments. Some species may have body temperatures more than 11°C (20°F) above the water temperature. Warm-blooded sharks can spend more time in colder waters and be more active. However, this comes at a cost. Warm-blooded sharks need more food to keep their bodies going. White sharks, mako sharks, and salmon sharks are some of the warm-blooded shark species.

**Salmon sharks can live in cold waters because they are warm-blooded. Most sharks are cold-blooded and can't live in these temperatures.**

# SHARK BEHAVIOR

For animals, success isn't just about having the right form for a specific function. Although form is a great starting point, behavior is critical to success. Animal behavior is adapted to the environment, just like body structures. Some behaviors are **innate**, or happen automatically. Others are learned and require experience. Many people think that sharks are unintelligent and their behavior must all be innate. But, scientists have shown that sharks can be pretty smart. Lemon sharks have been taught to navigate a maze! They also quickly learn the locations where food is plentiful. In some places, humans take advantage of this by feeding sharks. The sharks learn when and where to show up for food where people can view them. In some situations, this is good and beneficial. Tourists can view sharks and learn about why they are important to oceans. People can make money without hurting sharks. However, it can be dangerous if sharks, like more aggressive bull sharks, are attracted to areas where people are dumping garbage or scraps.

**People feed great hammerhead sharks in the Bahamas to let people see them up close. Hammerheads are not dangerous to people. In many places, people have found that tourists will pay money to see sharks in the wild, and they are worth much more alive than dead. Live shark tourism may be worth millions of dollars to the economy every year!**

# GROWING UP SHARK

Baby sharks are ready to swim and fend for themselves as soon as they hatch or are born. But that doesn't mean that they aren't at risk. Many large sharks, like tiger sharks, white sharks, bull sharks, and hammerhead sharks, love to eat smaller sharks. Because of this, many species of sharks that live near coasts grow up in nursery areas. These are shallow waters where big sharks can't catch them and there is enough food for them to grow. When they are big enough, which may take five years, they leave the nursery areas and move into adult habitats. Shallow waters can be dangerous when there are major storms, like hurricanes. But, baby sharks can sense the approach of the storm and move into deeper waters until the storm has passed.

**Baby blacktip reef sharks in French Polynesia in the Pacific Ocean. These sharks spend their early life in the shallow waters of lagoons until they are big enough to survive on the coral reef.**

# FEEDING

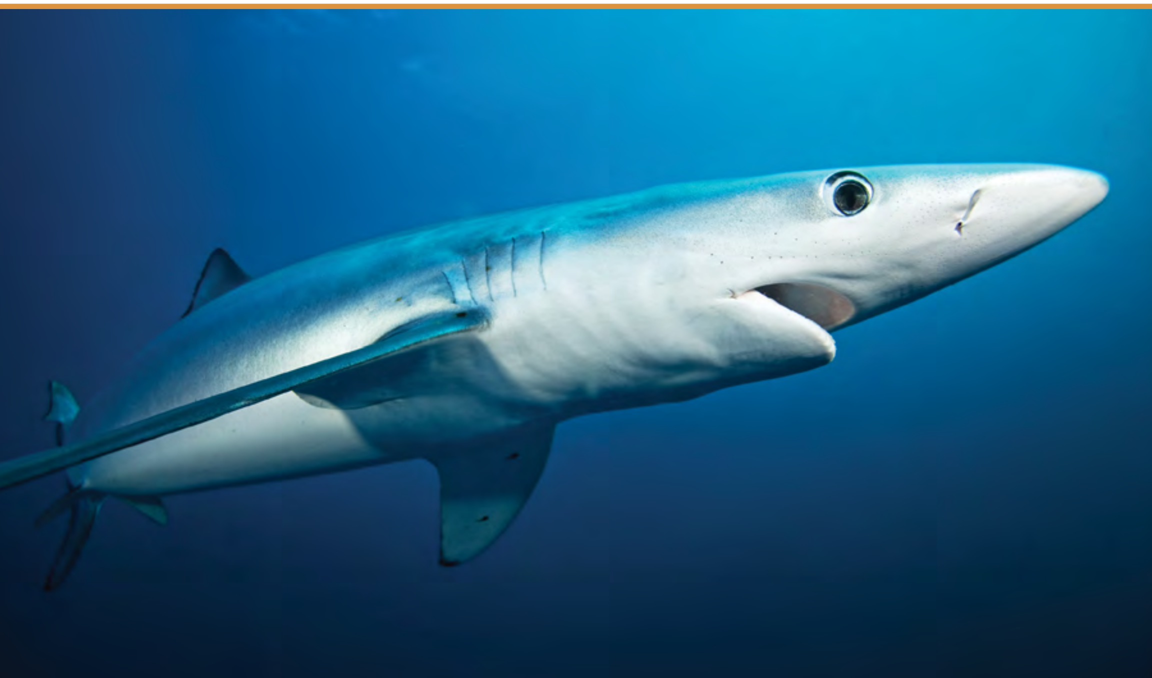
Different shark species have very different diets and strategies for capturing food. The biggest sharks eat tiny prey. Basking, whale, and megamouth sharks eat tiny shrimp-like creatures, fish and coral eggs, and sometimes small fish. Whale and basking sharks usually feed by swimming through the water with their mouths open. They filter prey from the water. The prey is captured on filter pads before the water passes out of the gills. Megamouth sharks approach a large swarm or school of prey and take a large "bite" out of the prey swarm.

Most sharks eat one prey item at a time and feed alone. Some sharks cruise through the ocean, looking for prey. Tiger sharks in Australia swim over seagrass beds looking for sea turtles, sea cows, and sea snakes to eat. Other sharks may eat prey packed into big schools. Several types of sharks feed from "bait balls" that they have herded together. Sometimes it isn't just sharks that have herded the prey. It is common to see sharks feeding from bait balls that dolphins, tuna, or sea lions have herded. Sharks swim through the tightly packed school to grab prey. Sometimes they get lucky and grab a couple fish at once. Some bottom-dwelling sharks are sit-and-wait predators. They ambush their prey. White sharks ambush fur seals by attacking from below. Angel sharks bury themselves in the sand and then lunge at passing prey. Some sharks may even lure prey. The bioluminescent lips of megamouth may attract their prey.

# SHARK TRACKS - MOVEMENTS AND MIGRATION

One thing that scientists want to know about sharks is how far and fast they move. For many years, scientists learned about shark movements by putting tags with numbers on them. When the shark was caught again, they knew where it was caught and how long it took for it to be captured again. Now, scientists use different tracking devices to study shark movements. Acoustic tracking devices emit a "ping" at a particular frequency. These pings are picked up by **hydrophones** (an underwater microphone), and computers tell what tracking device is being detected. In some studies, scientists use hydrophones mounted to the bottom to listen for tagged sharks that swim by. In other studies, scientists have hydrophones on the boat that help them determine which direction the shark is from the boat. They can follow the shark and track its movement. Scientists can also attach satellite transmitters to the shark. These devices send information to satellites that can be used to calculate where the shark is no matter where it swims on earth. The positions aren't as accurate as the ones obtained from following a tagged shark, but they work over much greater distances. Like any other object, the speed of a shark is calculated by dividing the distance it travels by the time it took to swim that distance. This is the same as the slope of a line on a graph that plots distance traveled by time.

What have scientists learned by tagging sharks? Some sharks are homebodies; they spend long periods of time in relatively small areas. Other sharks make seasonal migrations to find the right water temperatures, to take advantage of abundant prey, or to reproduce. For example, blacktip sharks move from waters of the northeast United States along the coast to the waters of Florida and the Caribbean during the fall and return north in spring. White sharks spend time along the Pacific coast of the United States feeding on seals and sea lions during the summer and fall then move to the "white shark café" for the spring and winter. The café, located in offshore waters not far from Hawaii, is where sharks go to feed on deep-sea organisms. Other sharks wander widely throughout the year, sometimes across entire oceans. Tiger sharks have been recorded crossing the Indian Ocean and Atlantic Ocean. Blue sharks move across the entire North Atlantic Ocean throughout their lives. The different movements of sharks help them successfully find food, survive, and reproduce.





**Blue sharks can swim across an entire ocean.**

## SHARK "PERSONALITIES"

Different species of sharks have different traits. Some are physical while others are behavioral. Most people think that individuals of a particular species all behave in basically the same way. But, pet owners know that their dog or cat has unique behaviors that make it different from other dogs or other cats. Scientists have learned that sharks of the same species may have different "personalities" too!

For example, in coastal rivers of southern Florida, there are some bold baby bull sharks. They go to areas where there is a lot of food even if they are at risk of being eaten by bigger sharks. Other individuals never take these risks even if they don't get as much food. Individuals show the same type of behavior over years.

**Tagging studies of baby bull sharks have revealed that they have unique "personalities." Here, a baby bull shark with an orange tag is released.**

## SHARK SOCIAL LIVES

Many sharks are solitary. They don't mix with other sharks of their species unless it is for reproduction or they show up at a food source that they share, like a whale carcass or a huge school of fish. Other species form large groups. Schools of thousands of blacktip sharks and spinner sharks migrate together north and south along the east coast of the United States every fall and spring. Could the groups help them stay safe from great hammerhead sharks that hunt them during the migration? Groups of scalloped hammerhead sharks gather around seamounts during the day and head out individually to feed at night. Around coral reefs, whitetip reef sharks may hunt in groups. They may also hunt in groups with up to hundreds of gray reef sharks. As soon as one sharks sees prey, all the sharks in the area can lock on and attack. Sharks, similar to people, may have social networks. Sevengill sharks attack sea lions in groups. Are the sharks cooperating or just independently competing? More research is needed to be certain.


**Hammerhead sharks form large schools during the day near underwater mountains called seamounts. They approach fish that will clean them of parasites. The sharks don't attack the cleaners! Do the sharks in these schools have social relationships? We still don't know.**

## STAYING CLEAN

Sharks, like other animals, need to stay clean. Small crustaceans called copepods are often found on and even in the mouths of sharks. To stay clean, sharks often rely on other species. Some visit cleaning stations where small fish pick parasites off their skin. The interaction between cleaner fish and sharks is an example of **mutualism**. Both species benefit. In this case, fish get food and sharks get cleaned! Remoras, that hitch along with sharks for a ride, also help clean off parasites, especially copepods. There is still a lot to learn about how sharks keep from getting hurt by parasites.

# DISAPPEARING SHARKS?

Sharks may be amazing predators, but they are in trouble in many places around the world. Some populations have declined by 90% or more. The biggest reason for their decline is overfishing. Because sharks take years to mature and produce few offspring, it can be easy for too many sharks to be caught. People use sharks for their meat and for shark fin soup. Some countries, like the United States and Australia have regulations to limit the number of sharks caught. Other places, like The Bahamas and French Polynesia, protect all sharks from being caught. There, people pay to see live sharks up close. People work with countries that consume sharks, like China, to ensure they only consume sustainably caught sharks. Protecting sharks is important for both the livelihoods of people that catch them or rely on them for food and also for the health of oceans.

# SHARKS ARE IMPORTANT

Many people are afraid of sharks but most species are no risk to people. Even for dangerous species (like white, bull, tiger, and oceanic whitetip sharks) most individuals are too small or timid to be a threat. Usually, a person is much less likely to be bitten by a shark than to get in a major car accident driving to the beach. But, even though they are not a big threat to people, there are sometimes calls to reduce their populations. Is this a good idea? Not for ocean ecosystems.

Sharks are important for maintaining balance in ecosystems. Like other top predators, the largest shark species can help limit prey populations. If sharks did not exist, prey populations could get too big and they could eat too many of their prey. The whole ecosystem could collapse. If tiger sharks disappeared, sea turtles and sea cows might eat too much seagrass. Seagrass is essential for ecosystems and people. It is home to small fish, shrimp and crabs that are important resources for the fishing industry.

# SHARK STUDIES

For years, studying sharks in their natural environment has been very difficult because sharks can move long distances and live deep underwater. Most knowledge came from dissecting sharks that fishermen caught or putting plastic tags on sharks' fins. If the shark was caught again, people notified scientists about the location. Now, technology enables scientists to learn more about sharks than ever before. Video cameras, computers, sonar, and boats and aircraft without captains or pilots have all helped scientists understand more about sharks. Even satellites in space are used to study sharks and their environments.

Cameras can be placed on drones that fly above sharks and film their behavior. They can also be placed in packages that ride along on the shark, like remora fish. These shark cameras give a shark's-eye view of the world. They can help people learn how sharks interact with each other, their habitats, and how they feed. Shark-cam tags can also have sensors that measure the conditions in the environment and details on how the shark moves. These data can be used to study details of shark body systems, energy use, and behavior.

**Drones are used to count shark numbers from above.**

Scientists also use sound to study sharks. Engineers have built machines that use sound to make images, called sonar. Scientists use sonar to count shark prey and map where on the bottom sharks spend time. Sometimes they do this with sonar mounted on self-driving boats!

Now are you ready for your mission studying the Great Shark Migration?

# GLOSSARY

**BIOLUMINESCENCE**
light emitted by organisms

**CELL MEMBRANE**
a membrane that separates the interior of a cell from the outside environment

**COMMENSALISM**
a relationship in which one species benefits and the other is not affected

**ENZYME**
a chemical produced by organisms that speeds up biochemical reactions

**HETEROCERCAL TAIL**
a tail in which the upper lobe is longer than the lower lobe

**HYDROPHONE**
a microphone that detects sound waves underwater

**INNATE BEHAVIOR**
a behavior that does not have to be learned; is automatic

**LATERAL LINE**
a line of sensory organs along the body of a shark that detects movement and vibrations

**MULTICELLULAR ORGANISM**
an organism that is made up of more than one cell

**MUTUALISM**
an interaction in which both species benefit

**ORGAN**
a group of tissues that work together to perform a specific function

**ORGAN SYSTEM**
a group of organs and other structures that work together

**OSMOSIS**
the movement of water across a membrane from an area of low salt concentration to high salt concentration

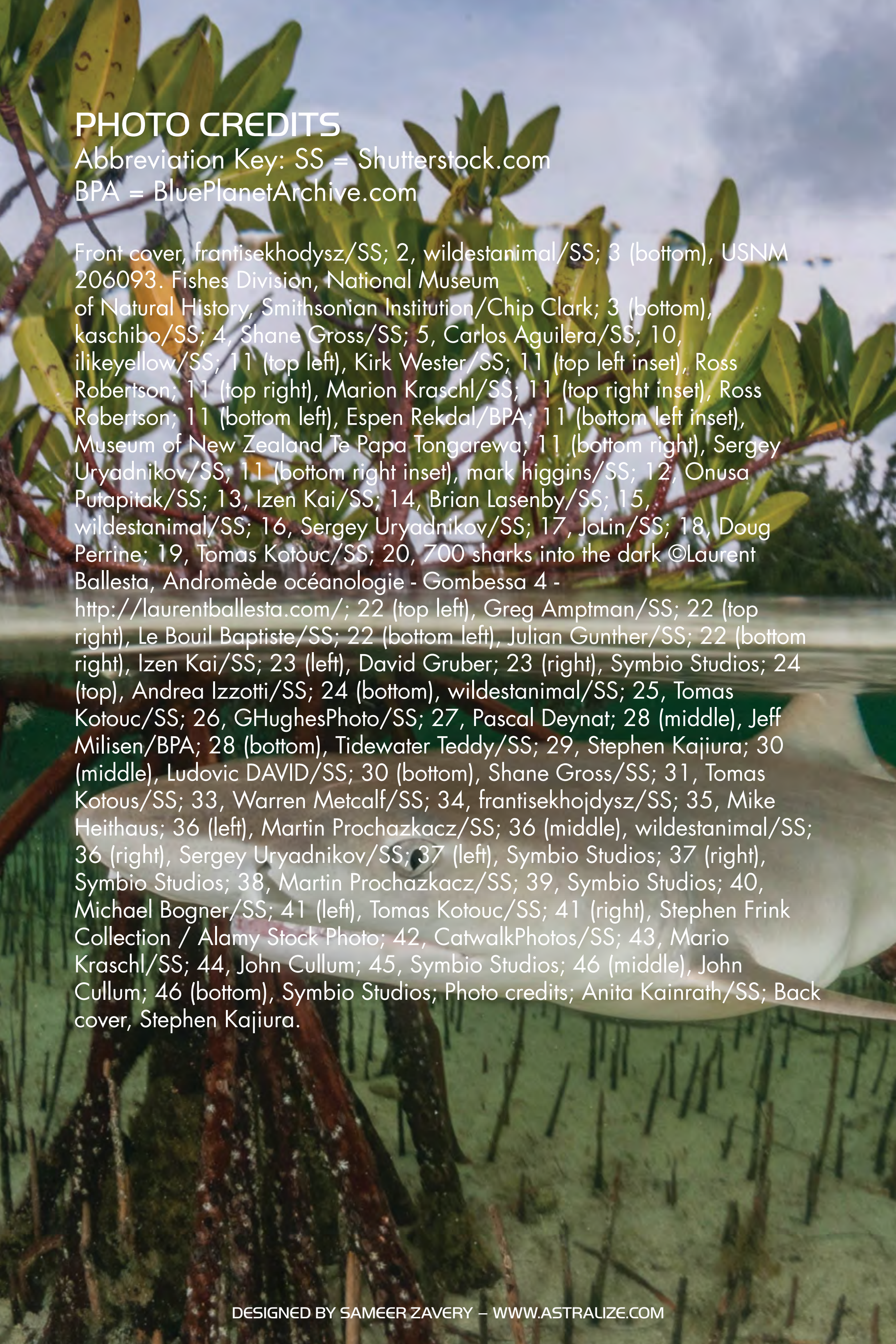
**PARASITE**
an organism that lives off of and harms another host species

**SENSOR**
a device that measures or detects a physical property

**SYMBIOSIS**
an interaction between two organisms that live close together

**TISSUE**
a group of cells that work together to perform a specific function

**VERTEBRATE**
an animal with a backbone



# PHOTO CREDITS

Abbreviation Key: SS = Shutterstock.com
BPA = BluePlanetArchive.com

Front cover, frantisekhodysz/SS; 2, wildestanimal/SS; 3 (bottom), USNM 206093. Fishes Division, National Museum of Natural History, Smithsonian Institution/Chip Clark; 3 (bottom), kaschibo/SS; 4, Shane Gross/SS; 5, Carlos Aguilera/SS; 10, ilikeyellow/SS; 11 (top left), Kirk Wester/SS; 11 (top left inset), Ross Robertson; 11 (top right), Marion Kraschl/SS; 11 (top right inset), Ross Robertson; 11 (bottom left), Espen Rekdal/BPA; 11 (bottom left inset), Museum of New Zealand Te Papa Tongarewa; 11 (bottom right), Sergey Uryadnikov/SS; 11 (bottom right inset), mark higgins/SS; 12, Onusa Putapitak/SS; 13, Izen Kai/SS; 14, Brian Lasenby/SS; 15, wildestanimal/SS; 16, Sergey Uryadnikov/SS; 17, JoLin/SS; 18, Doug Perrine; 19, Tomas Kotouc/SS; 20, 700 sharks into the dark ©Laurent Ballesta, Andromède océanologie - Gombessa 4 - http://laurentballesta.com/; 22 (top left), Greg Amptman/SS; 22 (top right), Le Bouil Baptiste/SS; 22 (bottom left), Julian Gunther/SS; 22 (bottom right), Izen Kai/SS; 23 (left), David Gruber; 23 (right), Symbio Studios; 24 (top), Andrea Izzotti/SS; 24 (bottom), wildestanimal/SS; 25, Tomas Kotouc/SS; 26, GHughesPhoto/SS; 27, Pascal Deynat; 28 (middle), Jeff Milisen/BPA; 28 (bottom), Tidewater Teddy/SS; 29, Stephen Kajiura; 30 (middle), Ludovic DAVID/SS; 30 (bottom), Shane Gross/SS; 31, Tomas Kotous/SS; 33, Warren Metcalf/SS; 34, frantisekhojdysz/SS; 35, Mike Heithaus; 36 (left), Martin Prochazkacz/SS; 36 (middle), wildestanimal/SS; 36 (right), Sergey Uryadnikov/SS; 37 (left), Symbio Studios; 37 (right), Symbio Studios; 38, Martin Prochazkacz/SS; 39, Symbio Studios; 40, Michael Bogner/SS; 41 (left), Tomas Kotouc/SS; 41 (right), Stephen Frink Collection / Alamy Stock Photo; 42, CatwalkPhotos/SS; 43, Mario Kraschl/SS; 44, John Cullum; 45, Symbio Studios; 46 (middle), John Cullum; 46 (bottom), Symbio Studios; Photo credits; Anita Kainrath/SS; Back cover, Stephen Kajiura.

DESIGNED BY SAMEER ZAVERY – WWW.ASTRALIZE.COM

Thanks for exploring with us! Our science adventures take us around the world to uncover secrets of the most amazing animals and places. Our mission and passion is 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 a scientist, explorer, author, 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 text books and helped create programs for students in elementary, middle, and high school. He has been on television programs including 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.

# SHARK WORLD

A SCIENCE 3D ADVENTURE

symbio education

LEXILE® LEVEL

950L

ISBN: 978-1-954681-04-0



WWW.SCIENCE3D.EDUCATION