SHARK DISSECTION

FOR THE TEACHER:

Discipline
Biology

Themes
Evolution; Scale and Structure

Key Concept
Sharks have been well adapted for their ocean habitat since before the time of the dinosaurs and this evolutionary success is due in part to their reproductive and feeding strategies, hydrodynamic body plan and keen senses.

Synopsis
Students work in small groups to dissect a shark and investigate its structure and how all the parts function together to allow the shark to be so well adapted to its habitat and lifestyle.

Science Process Skills
observing, communicating, comparing, classifying, relating, inferring

Social Skills
checking for understanding

Vocabulary
chondrichthys, evolution, oviparous, ovoviviparous, viviparous

MATERIALS
INTO:
- Large sheet of poster paper and colored markers
- Graph paper or large graph drawn on the board for the Shark Survey
- Optional: shark video such as "***Sharks***" from National Geographic.

THROUGH:

- Shark(s): ***you may want to do this dissection as a demonstration in which case you will need one shark; otherwise order enough sharks for students to work in small groups of 5-6. Sharks are available from Scientific supply houses such as Carolina Biological Supply Co. (800)547 - 1733 or (800)334 - 5551. Order the sharks described as P1302PS, Dogfish, pregnant; "Caropak" single packed; double injected; they cost approximately $8.03/shark. (The sharks from Carolina Biological are "incidental takes" meaning that they were caught accidentally in the nets with the target fish and would otherwise have been thrown overboard dead). It may take 4 or more weeks for delivery so plan ahead! Alternatively, you may want to make arrangements with your local seafood store to save any fresh sharks that they receive. They can be frozen indefinitely. Remember that the fresh sharks will not be injected with latex colors nor will you be assured of pregnant females, however the color of the organs will be more life-like.***
- Tray or newspaper for shark
- Gloves, if using preserved shark
- Newspaper covered tables
- Dissection scissors and probes
- Student worksheet of dissected shark (distribute after dissection)

INTRODUCTION

Of the 368 species of sharks now known, only about twenty are known "Maneaters" or more correctly "person biters". The sharks are possibly the most maligned of all animals Their reputation for ferocity is much overplayed. The vast majority of sharks are scavengers just looking for a meal and would never bother a human. The few that have been implicated in attacks on humans are not the least bit adapted to eat people. Their feeding strategies were well in place millions of years before mans nearest relative was accidentally squashed under the foot of a dinosaur. The sharks first showed up in the Devonian Period (the Age of Fishes). By the end of the Cretaceous period 135-165 million years ago, all of the modern groups of sharks had been established. This is the time that Tyrannosaurus rex might have been the major terrestrial predator. Man showed up on the scene about 2.2 million years ago.

The evolutionary success of the sharks can be attributed in part to their reproductive strategies. Most bony fish lay millions of eggs (oviparous) and have an extremely high mortality rate. Sharks, on the other hand, have internal fertilization and retain their young for extended periods of time, either intrauterine or in camouflaged eggs that have large yolks. The newborns are fairly large and well toothed at birth which helps to reduce predation. Most species of sharks are ovoviviparous, that is the young have a large yolk sac and

are retained within the body of the mother. The longest gestation period of any animal known is the Spiny Dogfish shark. This shark gives birth 20-24 months after fertilization!

The largest living shark is the Whale Shark, an egg layer (oviparous) whose fully formed embryo is only 14 inches long at hatching. This small size is characteristic of egg laying sharks due to the small quantity of yolk that is available within the eggcase. The embryo of some ovoviviparous sharks such as the Sand Tiger (also probably Mako and White Sharks) will actually eat unfertilized ova when their own yolk is used up. Intrauterine cannibalism is suspected when only two large very well developed offspring are produced. This would be the ultimate in survival of the fittest at the embryonic level. Some species of sharks have entered freshwater streams and rivers and a well established population is known in Lake Nicaragua in Central America. These Bull sharks have a particularly nasty disposition and are implicated in many attacks on humans every year. White sharks have wandered upstream and attacked people on a few occasions.

Sharks belong to the Class Chondrichthys - the cartilaginous fish. Sharks have little true bone, present only in the base of their teeth and scales. Their spinal column is highly calcified and is now being used to study seasonal growth rings like those found in trees, fish ear bones (otoliths), whorls of snails and mammalian teeth.

These cartilaginous fish have been commercially exploited over the years mainly for the high Vitamin A content in the oil from their liver (cod liver oil) and their fins used for shark fin soup. A new market arose after the movie "Jaws" was released and White Shark teeth have been sought for souvenirs. White sharks are at the top of the food web and thus are probably not numerous and the species cannot withstand exploitation in this manner. Many biologists are concerned that this majestic creature will go the way of the symbol on the California State flag, the grizzly bear and numerous other predators that man has not tolerated.

INTO THE ACTIVITIES

Turn on a shark video (turn down the sound completely) and allow the students to quietly discuss what they see in small groups.

Partner Parade

Think about our five senses and how we use our senses to understand and discover things about the world around us.

1. Our senses work well to perceive our environment, do you think they would work just as well if we lived in the ocean?

2. How might our senses have to change if we lived in the ocean?
Sharks are extremely successful in their ocean environment - they were around for over 200 million years before the dinosaurs.
3. What are the first things that come to mind when you think about sharks?
4. In what ways are we similar to sharks, and how are we different?
Think about what you've heard about sharks or seen in movies or on TV. Two statements I've heard: "Sharks must always swim"; "All sharks are bloodthirsty"
5. What do you think of these statements? What other ones have you heard? Do you think they are true? Why or why not.

Have students sit with their last partner and list or draw as many things as they can remember from the Tea Party (at least five items). Lead a class discussion about the group's ideas and do "free word association" asking the students to say the one word that comes to mind when you say the word sharks. Write each word down on a large shark shaped piece of paper where all can see.

"Think, Pair, Share" and Anticipatory Chart
1. Have students each take a piece of paper and divide it lengthwise into 3 columns and label them as shown below. Have each student "**Think**" about each of the first 2 columns ("What we think we know" and "What we would like to find out") and jot down or illustrate some of their ideas.

Anticipatory Chart
"What we think we know about sharks"

"What we would like to know about sharks"

"What we know to be true about sharks"

2. Now have each student "**Pair**" up with another and compare/discuss their ideas. They can add to their lists after discussions with their partner if they like.
3. Finally, have each pair "**Share**" their answers with another pair of students.
4. After all the pairs have had a chance to share their ideas, complete the first two columns of the Anticipatory Chart as a class and refer back to their ideas as you do the activity.

Shark Survey
Have students complete the shark survey below (adapted from **Coastal Capers**, University of North Carolina) and plot the results on a bar graph. At the end of the dissection, again have the students complete this survey and compare the results. The survey can be completed with a show of hands or written out on the board.
Answer yes, no or don't know for each statement or question below:
1. All sharks are dangerous to people. (NO)
2. Sharks have been around since before the time of the dinosaurs.(YES)
3. People are the greatest enemies of sharks.(YES)
4. Sharks have a well-developed sense of smell.(YES)
5. Have you seen a living shark?
6. Would you be afraid to swim in the ocean because of sharks?
7. Do you want to learn more about sharks?

Sketch a Shark
Have students work in small groups to create a poster of a shark, labeling any parts they already know. Tell them that if they don't know the "right" word for a part, they should make up a word that describes what it is for or what it looks like.

ASSESSMENT:
Participation in Tea Party and "Free word association"
At least 5 items recorded from the Tea Party
Participation in "Think, Pair ,Share" including individual recording of "Think"
Group poster of Sketch a Shark with labels
Observation of Checking for Understanding

THROUGH
THE ACTIVITIES

Dissection of Spiny Dogfish, **Squalus acanthias**, female.

Prelude to Any Dissections
Before the shark or tools are distributed, discuss with students the sanctity of life, referring back to the video and the activities they saw the shark engaging in and their beauty as they swam. Describe that these sharks were caught as "incidental takes". Stress that all of your instructions must be followed exactly so that they can get the most out of the dissection and see all of the parts. Also, no one is to use a tool until directed to do so and under no circumstances should they poke the shark. Do not make any student participate in the dissection if they are really concerned or squeamish. Allow them to sit in the group and participate when they feel ready. Fresh air circulation in the room helps a lot!

EXTERNAL ANATOMY

FINS AND BODY SHAPE:

Sharks have long thin torpedo-shaped bodies. Their movement through the water can be compared to the hydrodynamics of submarines or even the aerodynamics of airplanes. The spiny dogfish has paired pectoral fins, 1st and 2nd dorsal fins, paired pelvic fins, and a tail or caudal fin.

The caudal or tail fin acts as the thrust in a jet or the propeller of a submarine. The tail is heterocercal with the upper lobe larger than the lower lobe. This causes the shark to be pushed through the water unequally, in effect constantly pushing the shark down into deeper water. In order to counteract this downward trend the pectoral fins act as wings to plane and lift.
The dorsal fins keep the shark from veering from the line of motion and the direction it is headed even as the power stroke of the caudal fin goes from side to side. The dorsal fins also keep the shark from rolling.

Unlike bony fish, sharks cannot swim backwards or hover, mainly because the structure of their pectoral fins. They cannot beat their pectorals like wings and they are negatively buoyant due to their lack of a swim bladder. If the shark stops swimming...it will sink, not die, necessarily!! Most species of sharks can lie motionless with no ill effects.

The dorsal spines as in spiny dogfish are used by the male as an anchoring device for positioning during mating. The spines are said to be slightly venomous to humans, but have been removed in the preserved sharks to avoid puncturing the bag.

SKIN:

Run a hand over the skin from the tail to the head in order to feel the abrasiveness of the skin of the shark. This abrasiveness is used by the shark to remove cells from prey items or carrion in order to smell or "taste" whether or not it is an appropriate food item. People have used the skin of sharks for thousands of years for "sand paper" (not any more), for Japanese samurai sword handle grips (the grip wouldn't get slippery even when soaked with blood!) and still even today for the longest lasting leather purses, shoes and wallets. The tanning process is a traditional secret that has never been mastered outside of Japan. The abrasiveness of the skin is caused by very small scales called dermal denticles (a type of placoid scale) that are embedded in the skin. These denticles are very tooth-like. In fact the teeth of the shark are merely enlarged scales attached loosely to the second gill arch of the jaw. These dermal denticles vary in size and structure on different parts of the body but are species specific and can be used as definitive species characteristics.

Ampullae of Lorenzini:
These sensory organs are found on the rostrum around the mouth and lower jaw. ***Squeeze the sharks face and a small amount of gel will ooze from each pore.*** These sensory organs can pick up short range, weak electrical impulses in the range of 1 microvolt (the electrical impulse given off by a fishes heart) and are used to detect bottom dwelling fish even if they are buried in the sand. Ampullae of Lorenzini continue down the length of the body and are considered to be the lateral line system for sensing vibrations in the water like those given off by a struggling fish or a thrashing swimmer.

EYES:
The eyes are large and relatively efficient in perceiving the contrast between light and dark. Some species of shark, have a nictitating membrane (eyelid) that comes from below to protect the eye during feeding. The White Shark though simply rolls its eyes backwards so that only the sclera or white shows during feeding. Both of these mechanisms protect the eye from being gouged while feeding on live potentially dangerous prey. The spiny dogfish simply has a membrane called the conjunctiva, which covers their eyeball much like that seen in humans.

NOSTRIL:
The nostrils or external nares are only for olfaction and play no role in respiration.

GILLS:
Five pairs of gill slits are present in almost all species of sharks with the exception of the more primitive six & seven gill sharks (called the cow sharks) and the Frill shark. As a shark swims, oxygen rich water is allowed in through the mouth and passes over the gills and out through the gill slits. Unlike bony fish, sharks have no bony operculum over their gills for protection and to aid in pumping the gills. This is a very vulnerable part of a shark. Many species of shark can pump these gill covers to keep water flowing over the gills even if the shark isn't swimming.

SPIRACLES:
The spiracles are a pair of openings just behind the eyes on the top of the head. Sharks have ventral mouths and a shark lying on the bottom would have its mouth in the sand or silt where clean silt-free water is not available. The spiracles draw clean, fresh seawater from above to avoid the problem of turbid water possibly fouling the gills. These spiracles can also be found in the bottom-dwelling skates and rays.

INTERNAL ANATOMY

DIGESTIVE SYSTEM (Part 1):

The mouth is the beginning of the digestive system with all vertebrates. Sharks bite off chunks of flesh and swallow the chunks whole without chewing. A shark will bite a large food item clamping its jaws shut with tremendous force for their size (18 tons per square inch) and shake their head side to side using their entire body for leverage. The bite removed in this manner is generally spherical in shape and approximately the size of the mouth. However, the bite size can vary due to the flexibility of the cartilaginous jaws. Teeth are often dislodged because they are only loosely attached in the jaws and don't have any roots. (Remember they were formed from dermal denticles).

Dissection Technique:

Insert the scissors at the cloaca behind the pelvic fins and cut by lifting up under the muscle and skin only. Don't cut deeply or damage will occur to the internal organs. Cut ventrally along the midline all the way to between the gills. When approaching the gills be prepared for cutting through the tough pectoral girdle that is made of cartilage. More pressure will be needed here and possibly two hands. From this midline, cut dorsally through the gills on one side to the spinal column. Cut along the spinal column for the length of the animal until you reach the cloaca. Cut from the cloaca to the spinal column and remove that entire side of the shark. The internal organs are now exposed.

The Liver:

The organ that occupies most of the body cavity is the large, soft, oily, grey-green, two-lobed liver. The extremely large liver seen in the shark may comprise 25-30% of its entire weight and is utilized by the shark in several ways, the most important of which is as an energy storehouse. Oil stores can comprise up to 90% of the weight of the shark liver. These fatty oils are used by the shark during extended periods of fasting, especially with large oceanic species where food may be unavailable for long periods of time. The liver shrinks in size as these reserves are being tapped. There is also some evidence to indicate that liver reserves may be used during a feeding inhibition of mating males and pupping females.

Another important aspect of the liver is that the oil acts as a buoyancy compensator since its specific gravity is less than seawater. The more oil in the liver the more buoyancy the shark has and the less effort it has to put out to avoid sinking. Sharks have almost no fatty reserves in their muscle tissue and therefore are considered to be a dry fish for human consumption.

On the back of one lobe of the liver is the green gall bladder in which bile is stored after it is produced by the liver. As in humans, this important glandular secretion aids in the breakdown of fats in food. This is why people can have

their gall bladder removed and have few ill effects. They just can't digest fatty foods easily.

The human liver is five-lobed and very important as a filter for removing toxins from the body. Unfortunately, many of these toxins, such as alcohol are stored in the liver and can damage it over extended periods of time.

Digestive System (Part 2):
After observing the liver and gall bladder, gently remove them and then the stomach and intestine will become obvious. The mouth of the preserved dogfish will be difficult to open. The jaws may be cut apart to show the teeth if preservation of the jaws is not a concern. Start cutting at the enlarged portion of the stomach, called the cardiac stomach, up towards the mouth until the esophagus is reached. The esophagus is characterized by having fingerlike projections called papillae on the inner surface. The cardiac stomach has folds called rugae. Both papillae and rugae increase the surface area for absorption of nutrients. The cardiac stomach is where partially digested food items, rocks, coins, hooks, and parasitic worms can be found.

Posterior (towards the tail) to the cardiac portion of the stomach is the pyloric portion which turns 180 on itself giving the entire stomach a J shape. This terminates with the pylorus that controls the rate at which the partially digested material continues into the intestine. After the pylorus, the digestive system continues as a short duodenum, where fat is broken down by bile coming from the gall bladder. Partially digested food would then enter the large spiral valve for further digestion.

The spiral valve is characteristic in having many veins and arteries as a human intestine would. It is also notable that in a six foot shark the entire intestine may be only two feet long unlike a human that would have 32 feet of intestine. The length of human intestines is necessary to allow sufficient surface area to absorb nutrients. The shark has a very short intestine with many folds or a spiral which increases surface area without sacrificing the internal space of the shark. The spiral valve empties into the colon which descends to the rectum and anus and then into the cloaca. The cloaca is the common chamber in which the digestive, urinary and reproductive tracts open to the outside. The portion of the digestive system found around the pylorus is the glandular tissue of the pancreas where insulin is produced to aid in the breakdown of sugars. In people, aberration with this gland can result in diabetes. As with bile, the pancreatic secretions enter the duodenum.

Not part of the digestive system but attached to it is the heart-shaped very enlarged spleen. This lymphatic gland is generally brown or red and is thought to be the primary area for the production of red blood corpuscles since sharks have no bone marrow, the usual site of blood cell production. In humans this

organ produces red blood corpuscles only in the fetal form. In adults, the spleen produces white blood cells to destroy old red blood cells as well as act as a reservoir for extra blood to be used in an emergency. Sharks probably use the spleen for all of these functions. The spleen can be removed from humans with little ill effect.

Near the rectum is a small finger-like organ called the rectal gland that acts as a salt gland. It removes excess salt from the blood and helps to keep the salinity constant in the shark whether in salt, brackish or freshwater. A few species of sharks and rays spend their entire lives in fresh water rivers and lakes.

The entire digestive system can now be removed to expose the reproductive system.

The female urogenital tract:
The paired ovaries are found at the anterior end of the body cavity dorsal to the liver. They are large and granular and often have large ovum at the surface. The eggs are released from the ovary and pass to the ostium at the beginning of the oviduct that runs the length of the body. After the ostium is the slightly enlarged, and often hard to find shell gland. The shell gland secretes a membrane over the fertilized egg that in some species will form the egg case or shell. This is not the case with the ovoviviparous spiny dogfish. The fertilized ova are covered with a protective membrane. The membrane and the eggs together make up a candle and can contain 2-4 embryos. The shell gland area of the ostium is the sight of sperm storage for fertilization of the eggs.
The embryo and yolk sac proceeds down the oviduct to the enlarged thin-walled uterus where it is nourished by the yolk for nearly 2 years. This is the longest gestation of any known animal. Depending on the size of the mother, the embryos will be about 5 inch long miniature adults at full term. They can be easily sexed (males have miniature claspers on their pelvic fins) and the umbilical scar will be obvious.

The fetuses (usually 4 per uterus) can be found just inside the uterus. Sometimes unfertilized ovum make their way down, but most of these are reabsorbed at the ovary.

The paired uteri join together at a chamber, the vagina, which opens into the cloaca.

Remove both the uteri and ovaries. Running the length of the spine is the dorsal aorta. The kidneys are on either side of this artery. The kidneys drain by paired ureters which unite into the urinary sinus that opens into the cloaca.

HEART:
The circulatory system of the shark and of fish in general consists of a two-chambered heart with two accessory chambers which receive venous blood from the body and pumps it to the gills for oxygenation. The human heart has four chambers, like all birds and mammals and is much more efficient than the sharks.

Cut one side of the lower jaw and lay open the throat to the incision made at the beginning of the dissection through the gills. This cut will expose the heart. The branching of the dorsal aorta leading to the gills will be apparent.

Remove the heart and cut it in half to show the thin-walled sac-like atrium and the thick-walled muscular ventricle. Black liquid in the heart is coagulated blood.

BRAIN:
Place the shark on its belly. Use strong scissors to cut the cartilage. Cut at the back of the eye socket directly through the skull to the other eye. Crack the skull by holding the head in one hand and pushing down on the rostrum (nose). The eyes will be exposed also. Take a pair of scissors and snip 1 to 1 1/2 inches back as shown creating a "pop-top". Peel this back to observe the brain.

The smooth two-lobed fore portion is the cerebral hemisphere. This is the part of the brain so enlarged in dolphins, apes and humans and indicative of intelligence. The slightly smaller portion on top (yellowish) is the cerebellum, the portion of the brain associated with instinctual behavior. Draw your own conclusions, but sharks probably don't philosophize much.

EYE:
The eye is now exposed and should be removed by clipping the optic nerve and the muscles surrounding it. Cut into the eyeball with the point of the scissors exposing vitreous humor (clear, viscous, liquid ooze).
The circular hard lens will be obvious. It is milky white from preservation instead of clear as in life.

The lens is suspended inside the eyeball by a gelatinous ligament and muscles. At rest, the eye of the dogfish is focused on distant objects and when the lens is pulled toward the cornea, images of near objects come into focus.
The black layer in the back of the eyeball is the retina. Within the retina is the tapetum lucidum, an adaptation that many nocturnal animals have to increase visual acuity in low light levels. Light entering the eye passes through the retina and is then reflected back through the retina a second time by the tapetum lucidum, thus doubling the apparent brightness of the light. The

sharks tapetum structure is very unique in that it is perhaps the most efficient in the animal kingdom (twice as efficient as a cats).

Activities After the Dissection

1. Watch the video again having students take turns narrating what they think is happening in each scene, pointing out parts of the body and how it is using it to be successful. You may want to watch the video a third time, however this time have the sound turned up.

2. Have students complete the last column of the Anticipatory Chart "What we know to be true about sharks" and as a whole class decide if there are any answers they would like to change in the other two columns. Are there still questions for which we don't have answers? How might we find out the answers?

3. Have the students again take the Shark Survey and discuss the results as a class. How do these results compare with the first time the Survey was taken?

ASSESSMENT:

Distribute the student worksheets and have the students fill in as many of the blanks as they can. Be sure to keep all of the charts and information up around the room so they can be used as references.

Have students do "Tape Recorder Dyads" reporting on what their partner tells them about: "Everything you know about parts of the shark" and then trade places and have the other student report on "Everything you know about behavior of the shark".

Participation in dissection, video narration and Anticipatory Chart completion
Observation of Checking for Understanding

BEYOND
THE ACTIVITIES

Debriefing

Have students debrief their favorite/least favorite part of the activity. What did they learn the most from? What was a waste of time? How would they change the activity if they were the teacher? Would they like to do more dissections or could they have learned enough from the other parts of this activity?

Field Trip

Take a field trip to Steinhart Aquarium in San Francisco's Golden Gate Park, and visit the "Roundabout" to see large sharks swimming continuously and the "Coral Reef Sharks" to see many small active sharks. Many other aquariums also have shark exhibits.

Student Posters
Have each group select one of the following topics to discuss and represent graphically on a poster. Have students share their poster with the rest of the class.

Compare fish and sharks. How are they alike? What adaptations do they have in common? In what ways are they different? On what basis could you group them together? Why would you put them in separate groups?
Why have sharks been hunted in such great numbers around the world? Do you think these are good reasons? Why or why not? What factors caused this to happen?

What do shark hunters need to know about sharks in order to capture them in great enough numbers to be successful? What should they keep in mind so that they can continue to capture them every year? What might affect the number they capture from year to year?

The marine mammal population, especially the elephant seals, has been increasing off the coast of California ever since the Marine Mammal Protection Act was passed in 1972. What affect do you think this has had on the Great White Shark population? What do you think surfers think of this? What about shark researchers? What do you think we should do about the situation?
Discuss the "bad" reputation of sharks and how people stereotype sharks. How can a movie like "Jaws" affect people's attitudes?

Consequence Charts
Have students work in cooperative groups to complete charts in which they describe consequences over time given the following scenario:
What would be the immediate, short term, medium term, and long term consequences on marine mammals, fish, and invertebrates if Great White Sharks were hunted to extinction around islands where marine mammals haul out? What terrestrial predator in California could they be compared with? (Grizzly Bear). What arguments can you give to support your prediction?

Shark Survey
Have students design a Shark Survey to distribute to the rest of the school. What can they infer from the data? Are there many preconceptions and misconceptions about sharks?

Library Research
Have students research how sharks are caught by different countries, where the major shark fisheries are located and what parts of the shark are used. (It was just recently made illegal for Japan to capture sharks, cut off their fins and throw them back alive).

Have students research different species of sharks and then make presentations to the class.