There's Something Fishy Here: Jaws, Scales and Many Kinds of Fishes

Note: These links do not work. Use the links within the outline to access the images in the popup windows. This text is the same as the scrolling text in the popup windows.

I. What are the characteristics of fish? (Page 1)

Subgroups:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_popups/subgroups.html

Fish form a very large and diverse group of vertebrates. They can be divided into three main subgroups: the jawless fish, the jawed fish with a cartilaginous skeleton (that is, the sharks and the rays), and the jawed fish with a bony skeleton. Most modern fish are in the third group.

Notochord:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_popups/notochord.html

Here we see two vertebrae within the vertebral column of a shark and a bony fish. As in most fish, the hard vertebrae have surrounded the notochord which can still be seen as a small spot within the center of each vertebra. In many bony fish, the notochord is large between the vertebrae and constricted within them. All vertebrae have a dorsal arch that forms a canal to house and protect the nerve cord (now usually called the spinal cord). Note also the attachment of ribs to the shark vertebrae.

Vertebrae:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_popups/vertebrae.html

This is a real shark vertebra within the tail region of a shark. Note the location of the spinal cord and remnant of the notochord.

Muscles:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_popups/muscles.html

Here is the entire tail section from a shark. Thick muscles are attached to the vertebrae and the skin. The muscles on either side contract alternately to provide a side-to-side swimming motion.

Caudal Fin:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_popups/caudal_fin.html

Fish typically have a large tail fin that sweeps back and forth to provide most of the forward thrust for swimming. Three shapes of fish tails are shown here.

Propulsive Force:
http://courses.ncsu.edu/zo495x/common/zo155_site-wrap/fish/fish_bigimages/propulsive_force.html

Note how the posterior end (tail) of the body moves back and forth in a sinuous pattern as this shark
swims. The tail fin extends the tail and provides a broad surface to push against the water.

Entire Body Used During Propulsion:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_bigimages/entire_body.html
The eel lacks a large tail fin. Note how the entire body moves in sinuous curves to generate propulsive force. This type of swimming is relatively slow and requires a great deal of energy.

**Brain:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/brain.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/brain.html)

The roof of the skull has been removed from this shark head to reveal the brain. Fish have a large brain with nerve tracts extending to the nasal sacs, eyes, and other anterior sense organs.

**Gills:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/gills.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/gills.html)

The simple pharyngeal slits of the lancelets and tunicate larvae have been modified into complex respiratory organs in fish. As in the simple chordate animals, water enters the pharynx through the mouth, then exits via slits. In fish, gills lie between the slits. As water flows over the gills, oxygen is absorbed and enters blood vessels within the gills. It is then carried throughout the body by a closed circulatory system typical of all vertebrates.

**Stabilization:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/stabilization.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/stabilization.html)

Most jawed fish have a large pair of pectoral fins in the anterior body region and a much smaller pair of pelvic fins near the tail. The pectoral fins are used as stabilizers while swimming to prevent the fish from rolling. They can also be used to change direction in all three dimensions and are sometimes used as brakes. The pelvic fins can also act as stabilizers, but are much less important than the pectoral fins.

**Fins:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/fins.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/fins.html)

The pectoral fins are smaller in this perch than in the shark previously seen. The pelvic fins are located more anteriorly as is the case in many of the bony fish. Most fish have one or two dorsal fins and a ventral, anal fin located along the central axis of the body. These fins assist the fish in swimming a straight course and in maintaining a vertical body position.

**Ancestors:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/ancestors.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/ancestors.html)

Recall that the Ostracoderm ancestors of modern fish had bony armor plating over much of their body. As fish evolution progressed, these bony plates became thinner and shrank to the size of scales.

**Scales:**  [http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/scales.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/scales.html)

Here are several types of scales found in modern fish. Shark scales, upper left, are embedded in the skin. A point projects up and backward from each tiny scale making the skin feel rough, but decreasing drag as the fish swims. Gar scales, bottom left, touch one another and are covered with a layer of enamel-like mineral. Most modern bony fish have overlapping scales that are covered with a thin layer of skin. The skin secretes mucus which makes the fish slippery and decreases drag.
While swimming, these types of scales are shown in on the right. The upper scales are from an Australian lung fish and the lower ones from a salmon.

Layer of Bone:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/layer_of_bone.html

The upper diagram shows the composition of Ostracoderm armor. Note that it contains two thick layers of bone and is covered by a thin layer of enamel-like substance. In most modern bony fish, he scales retain a very thin layer of bone derived from these ancestors, but have added a fibrous plate that makes the scale strong, but flexible.

I. What are the kinds of fish? (Page 2-4)

Separate Classes:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/separate_classes.html

All vertebrate animals have a hard skull that surrounds and protects the brain and they should have a vertebral column as well. Both hagfish and lampreys have a skull composed of cartilage, but neither has a vertebral column to stiffen the body. Instead, both of these jawless fish retain a large notochord as the sole supporting structure. Both hagfish and lampreys do have cartilaginous arches over the notochord to protect the nerve cord, but these are present only in the tail region of hagfish. Thus, the full vertebral column is indicated as originating within the line of jawless fish leading to lampreys. If you are interested in class names, the hagfish are Class Myxini and the lampreys Class Cephalaspidomorphi.

Sea Bottom:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sea_bottom.html

Hagfish search the sea floor for carcasses and small invertebrates. They contribute to the process of keeping the ocean free of decaying animal matter. Hagfish often reside in burrows or rock crevices.

Hagfish:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/hagfish.html

The hagfish body has one pair of gill openings and a row of openings from slime glands.

Tongue:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/tongue.html

Within the mouth of the hagfish resides a toothed tongue that resembles the radula of molluscs and is used to bore into a carass or to pull small invertebrates into the mouth. A hagfish can circulate water through the pharynx and gills while feeding, since water enters through a nostril on the dorsal side of the head.

Pores:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/pores.html

The pores from which slime is secreted are easily seen along the body of this preserved specimen.

Slime:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/slime.html
The hagfish secretes two kinds of slime. One is a clear mucous, but the other is thick and very sticky. The viscous slime can be seen as it is secreted from the hagfish in this photograph. The protein composition of slime is somewhat like that of egg white and is said to be usable in cooking. Perhaps that is what this student from British Columbia is trying to demonstrate by dangling hagfish slime above his mouth.

Knot:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/knot.html

Too much slime can clog the nostril of a hagfish. To remove the slime, the hagfish ties itself into a knot and moves the knot forward over the head, scraping off the slime as it goes. This maneuver may also be used during feeding to gain leverage for pulling off pieces of meat, as illustrated in the diagram.

Lampreys:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/lampreys.html

This lamprey is resting on a lake bottom, although lampreys can swim well enough to locate and attach to a fish. Note that, unlike hagfish, lampreys have seven pairs of gill openings and a large, disc-shaped mouth. In the section from a preserved lamprey, the large notochord can be seen. Note also, the absence of a vertebra around the notochord.

Mouth Cavity:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mouth_cavity.html

Observe the teeth that surround the mouth opening in these two species of lamprey. The teeth and cup-like shape of the mouth cavity allow lampreys to attach tightly to their host.

Game Fish:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/game_fish.html

This lake trout is host for two lamprey. Fish often die from parasitization, especially if more than one lamprey is attached. An average-sized lamprey of the Great lakes causes the loss of 20 kg of fish per year, explaining why fishermen in the region despise lampreys. This lamprey species originated in Lake Ontario, but spread throughout the Great Lakes and their tributaries when construction of the Welland canal provided access to Lake Erie. Lampreys are currently threatening the $2 billion dollar economy based on sport fishing.

Larva:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/larva.html

The lamprey larva resembles a lancelet, but has fewer pharyngeal slits. It also feeds like a lancelet, burying its tail in the stream bed and using the pharyngeal slits to filter tiny organisms from the water. Upon metamorphosis, members of parasitic lamprey species move to a large body of fresh water or into the sea. In non-parasitic species, the adult remains in the stream, does not feed and lies immediately after spawning.

Adult:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/adult.html
This adult lamprey is from Ohio. It lives in a large river as a parasite and returns to an adjacent stream to reproduce.

**Larval Stages:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/larval_stages.html

Note the similarity of these three larvae. The idea that a tunicate larva acquired the ability to reproduce, leading to the first cephalochordate animal, gained credence with the discovery of the arvacean tunciates. Review this section of the Chordates topic if you have forgotten that this tunicate is known to be a reproductive “larva”.

**Lampreys for Sale:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_bigimages/lamprey_sale.html

**Sharks:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sharks.html

The jaws of sharks differ from those of most vertebrates in that the upper jaw is not fused to the skull. Since both jaws are movable, sharks can open their mouth very wide when feeding. Each jaw bears several rows of teeth: two rows are clearly visible within the lower jaw of this specimen.

**Rows:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/rows.html

Several rows of teeth can be seen in this close-up view of a shark jaw. Each tooth has a triangular shape with serrated edges. Since fish teeth lack roots, they are loosely attached and fall out after a short time. The teeth pointing upward in this jaw are the teeth currently in use. When one is lost, it is immediately replaced by a tooth in the row behind.

**Replaced:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/replaced.html

This diagram of a shark lower jaw, illustrates the relationship between teeth and scales. Scales, are loosely embedded within the skin of the body just as teeth are embedded the covering of the jaw. Both scales and teeth have a triangular process extending outward, although is much larger and sharper in teeth. The jaw covering moves slowing forward, allowing a new tooth to replace an old one, when it reaches the edge of the jaw and falls out. Since new teeth are continuously formed in the back of the jaw, the shark is provided with an unending series of teeth throughout its life. Both scales and teeth consist of hard layers of dentine and enamel, similar to the teeth of other vertebrates including mammals. It is believed that all vertebrate teeth, as well as fish scales, are derived from the bony armor of Ostracoderm ancestors.

**Open Wide:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/open_wide.html

Since the upper jaw of sharks is not fused to the skull, it can slide forward while opening. This allows the jaws to open wide in spite of the overhanging snout.
The streamlined body and powerful jaws of sharks are well suited to a predatory lifestyle. The best known sharks are those that cruise the sea and utilize their sharp teeth to capture prey.

Capture Fish:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/capture_fish.html

The fast-swimming sharks typically capture fish which are often swallowed whole.

Other Prey:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/other_prey.html

Other prey includes seals and sea birds that are captured from the ocean surface. If prey is too large to swallow whole, the shark tears off bite-size pieces.

Filter-Feeders: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/filter-feeders.html

Not all sharks are hunters. Some, like the megamouth shark shown here, are filter-feeders. Water containing plankton is pulled into the mouth and enters the pharynx. As water passes through the pharyngeal gill slits and out over the gills, plankton is retained within the pharynx. Thus these large sharks use the same basic feeding style as their small chordate ancestors.

Mouth: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mouth.html

The basking shark is a very large filter-feeder, reaching a length of 30 feet. It swims with its mouth open while feeding, so that water is continuously pushed through the mouth and into the pharynx. The skeletal supports of the pharynx can be seen by looking into the wide mouth of this shark.

Angel Shark:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/angel_shark.html

The angel shark has an unusual, flattened body shape. It lies in the sand or mud on the sea floor with only its head exposed and captures crustaceans, molluscs, and bottom-dwelling fish.

Parasite: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/parasite.html

This small cookie-cutter shark is less than two feet long. It uses its circular, mouth and extremely sharp teeth to attach to whales and dolphins, then cuts out round chunks of living flesh. Wounds from the cookie-cutter have also been found on large, slow-moving fish such as the megamouth shark.

Bizarre Species:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/bizarre_species.html
These odd looking sharks have been extinct for 250 million years. They are typical of the many bizarre shark species found as fossils in ancient sea beds.

**Protrusions:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/protrusions.html

One group of ancient sharks had fantastic structures protruding from the dorsal side of the head. This shark has an anvil shaped protuberance topped with teeth-like bristles. The function of these odd structures is not known.

**Megalodon:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/megalodon.html

This reconstruction of a megalodon shark reveals an awesome predator. Megalodon reached a length of 60 feet, more than twice that of the great white shark, and had immense teeth to match. If a megalodon shark were alive today, it could swallow a human whole.

**Goblin Shark:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/goblin_shark.html

This shark lives in very deep water and is seldom seen. It resembles some of the bizarre extinct sharks and was, in fact, thought to have been extinct for 100 million years. To the vast surprise of zoologists, the first living goblin shark was found off the coast of Japan in 1898.

**Whale Shark:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/whale_shark.html

The whale shark can attain a length of 45 feet and a weight of 30,000 pounds. It is not only the largest living shark, but the largest fish. The name “whale” is misleading, since whales are mammals, not fish. The whale shark is a filter-feeder like the basking shark and also swims with its mouth open. It is a gentle shark, harmless to humans.

**Dogfish Shark:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/dogfish_shark.html

This spiny dogfish shark should be recognized by anyone who has taken a course in vertebrate anatomy. It is a small and very abundant shark, making it a good choice for dissection when earning fish anatomy in the laboratory. Spines are present in front of both dorsal fins of this shark. They are mildly poisonous, but not considered harmful to humans.

**Hammerhead:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/hammerhead.html

The hammerhead shark can be recognized by its broad, uniquely-shaped head. The eyes and nostrils are located on the sides of the head, providing an extended range for these senses. Although hammerhead sharks seldom attack humans, they are large active predators, and thus
The black-tipped reef shark is about 6 feet long. It does well in captivity, so is often found in aquariums. The mako shark is the fastest swimmer, achieving speeds that exceed 40 mph. It sometimes leaps out of the water and has been seen to land in boats! The thresher shark has a tail hat is half the length of its body. This 10 foot tail is used to herd and stun small fish. The nurse shark is a bottom dweller. It sleeps by day and hunts at night. The bull shark is thought to be the third most dangerous shark to humans. It can enter fresh water and has been found 2500 miles up the Amazon river. The tiger shark has a striped body and a temper to match its name. It is the second most dangerous shark to humans. The great white shark is responsible for the most shark attacks on humans and is considered the most dangerous shark. Great white sharks average 12 feet in length but can grow up to 20 feet long with a weight of 3,000 pounds. Unlike most sharks, the great white can lift its head out of the water while swimming. It frequently breaches as shown in the photograph on the right.

Shark Attacks:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/shark_attacks.html

The potential for shark attacks provides plentiful material for jokesters, but of course, it is really a serious subject.

Shark Bites:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/shark_bites.html

Shark bites can be fatal, but relatively minor injuries, such as shown here are more common.

Human Population:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/human_population.html

As this chart indicates, the frequency of shark attacks along the Florida coast has increased in proportion to the state’s population. During the last decade, attacks averaged 16 per year, or 1 per million Florida residents.

Rays:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/rays.html

Rays have a distinctive appearance with a flat body, long thin tail, and broad pectoral fins that move up and down to create a slow, gliding type of locomotion.

Bottom-dwelling:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/bottom-dwelling.html

Rays and skates are well adapted for life on the ocean floor. With a flat shape and camouflage coloration, they blend into the background and can rest comfortably on the sea bed.
The Head:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/the_head.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/the_head.html)

Since rays and skates spend much of their time on the sea floor, it is advantageous to take water in through the dorsal side of the head, rather than the ventrally located mouth. A pair of openings called spiracles allow water to enter the pharynx (and thus the gills) without passing through the mouth.

Mouth and Gills:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mouth_and_gills.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mouth_and_gills.html)

The ventral surface of this ray is clearly visible as it swims up the side of an aquarium. Note the location of the mouth and gills.

Teeth:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/teeth.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/teeth.html)

The mouth of this ray is open. Observe the broad, flat teeth that are used to crush invertebrates on which the ray feeds.

Sawfish:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sawfish.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sawfish.html)

The sawfish is another unusual shark that spends much time resting on the sea bottom. It uses the saw-like protuberance to probe the substrate for small invertebrates which it lifts out of the sand by using its saw like a rake. The saw may also be used by some sawfish as they swim through schools of fish to stun or injure small fishes which are then consumed.

Electric Rays:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/electric_rays.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/electric_rays.html)

These rays have an electric organ that consists of non-contracting muscle cells. It can generate a current as high as 220 volts. The electric shock is used to stun prey or to discourage predators.

Skates:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/skates.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/skates.html)

In this frontal view, the skates are difficult to distinguish from rays.

Pelvic Fins:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/pelvic_fins.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/pelvic_fins.html)

In a dorsal view, two differences between rays and skates can be seen. Only the skates have a divided pelvic fin, and only rays have a barb in their tail.

Stinging Barb:
[http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/stinging_barb.html](http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/stinging_barb.html)

The barb of a ray is used for self defense. If threatened, or stepped on by an unwary human, the tail whips upward and the barb injects venom into the skin, causing a painful sting.
This strange looking fish has been named “chimera” after the mythical Greek monster that had a lion’s head, a goat’s body, and a serpent’s tail. The chimeras have some characteristics of both sharks and rays, but differ from other cartilaginous fish in that their upper jaw is fused to the skull.

In this typical fish skeleton, the skull, vertebral column, ribs and fin rays can be seen. The skull, like the other parts of the skeleton is composed of bone.

Water that has passed over the gills leaves the pharynx through slits (shown by arrows) in both the cartilaginous and the bony fish. However, the gills of bony fish are covered by a flap of tissue called the operculum, leaving only a single, curved opening for water exit. The operculum seals his opening as water is pulled into the pharynx through the mouth, then raises to allow water to escape as it leaves the gill chambers.

The three lines of bony fishes and their relationship to one another is illustrated in this chart. Note also the close relationship of lungfish to amphibians.

The fin rays are clearly visible within the dorsal fins of this perch.

The fish shown at the top, a yellow perch, has the classic shape and fins of a bony fish that allow several types of swimming styles. The other four fish show features that are optimized for specific life styles. The long, streamlined body of the pike is designed for rapid accelerations when large chasing prey. The broad tail fin gives additional thrust during acceleration. Fish like the tuna, that feed on schools of small fish or plankton, have a massive elongated body designed for cruising at moderate speed. The tail fin, dorsal fin, and anal fins are large, but thin to minimize turbulence and reduce side-to-side body motion during continuous swimming. Fish that live in restricted areas, such as coral reefs or weedy bottoms, need maneuvering ability more than speed. Like the sunfish shown here, they have short bodies and generate most forward thrust with their oar-like pectoral fins. Flatfish, such as the flounder, have a very thin body with a rounded shape and both eyes on one side to facilitate lying flat on the sea floor. Their dorsal and anal fins extend around the edge of the
Sturgeons: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sturgeons.html

There are 24 species of sturgeons, found in both fresh and salt waters of the northern hemisphere. A Pacific sturgeon can reach a length of 20 feet, weigh 400 pounds, and live more than 100 years. The most famous sturgeon is the beluga which is found in the Caspian sea and prized for its caviar.

Paddlefish: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/paddlefish.html

The paddlefish was discovered by Hernando de Soto in the 16th century while he was exploring the Mississippi river for Spain. There are only two living species of paddlefish. One is found in the Mississippi and its tributaries and the other in China’s Yangtze river. The fish shown here was caught in Wisconsin. The paddle-like snout is used to gather sensory data such as odors, tastes, and the electrical fields of other aquatic animals.

Rivers: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/rivers.html

Paddlefish can reach a length of 15 feet. They filter-feed by swimming with their mouth open. Note the resemblance to filter-feeding sharks.

Gars: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/gars.html

Gars are freshwater fish found in the warmer rivers and lakes throughout the world. They have diamond-shaped scales covered with enamel, and long, slender jaws that bear needle-like teeth.

Bowfin: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/bowfin.html

There is only one living species of bowfin. It is an American fish, found mainly in the Great Lakes and Mississippi River basin. Although bowfin are ravenous feeders, they can go without eating for nearly a year due to a low metabolism.

Flying Fish: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/flying_fish.html

The flying fish has long pectoral fins that allow it the jump from the water and glide for short distances through the air. In the waters around Barbados, flying fish are so abundant that they are sold at markets for prices as low as 8 fish for a dollar.

Glide: http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/glide.html

This flying fish has its pectoral fins spread and is gliding through the air. The smaller pelvic fins are also extended.

Puffer Fish:
There are 120 species of puffer fish. They can greatly expand the body when threatened by swallowing water. They lack ribs and have an elastic skin to allow expansion. The puffers at the bottom of this image are inflated.

**Fugu:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/fugu.html

Some puffer fish are extremely poisonous. Their skin and certain internal organs contain a substance that is 10,000 times more toxic than cyanide. In Japan, these fish are called fugu and are considered a delicacy. Although specially trained chefs prepare fugu and remove the poisonous parts, about 100 diners per year still die from eating the fish.

**Eels:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/eels.html

Eels are found in fresh and salt water throughout the world. They have a long dorsal fin and swim by undulating the entire body.

**Gourmet Treat:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/gourmet_treat.html

Eels are popular food items in many parts of the world, although not in the USA. The eel shown here is the species recommended for the Asian dish “spicy eel”.

**Moray Eel:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/moray_eel.html

This inquisitive moray eel was filmed in an aquarium. Note the large head and jaws and the lack of pectoral fins which are characteristic of this eel species.

**Electric Eel:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/electric_eel.html

This electric eel was photographed in the waters of Northern California. Electric eels discharge an average of 350-400 volts when defending themselves or stunning prey. In large eels, a discharge as high as 650 volts has been measured. The mechanism of electricity production is similar to that of the electric ray, previously described.

**Sea Horses:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/sea_horses.html

All sea horses are marine. Those shown here are called sea dragons. They are colored to blend into the algae-covered rocks of their habitat. The green sea horse is a leafy sea dragon. It has exotic, leaf-like projections from its body that resemble the plants in its environment.

**Anchor:**  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/anchor.html

This fish has the typical horse-shaped head and neck that gave sea horses their name. Observe how
The sea horse has anchored itself by wrapping its tail around a plant stem.

**Lion Fish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/lion_fish.html

There are several venomous fish that can cause great pain to a human who picks one up or steps on it. You have previously learned of the venomous stonefish as well as the stingray. The lion fish shown here is an exotic-looking fish with venomous spines.

**Scorpion Fish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/scorpion_fish.html

The scorpion fish has venomous spines extending from its dorsal fin. The person holding this fish has been careful to grasp the underside of the fish’s body.

**Lobe-finned Fish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/lobe-finned_fish.html

The lobe-finned fish have long, strong lateral fins as shown in this diagram of a living lobe-fin. The many lobe-finned species now extinct lived in fresh water and probably used their muscular pectoral fins to drag themselves overland to a new body of water, when the old one dried up or became stagnant. The fossil of an extinct species of lobe-fin is shown in the bottom panel.

**Coelocanths:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/coelocanths.html

Two representatives of the surviving lobe-finned fish species are shown here. Unlike most of the extinct coelocanths, that lived in fresh water, these fish are marine and have vestigial lungs that are non-functional. They appear to be descendents of lobe-fins that moved into the sea at some point during their evolution.

**Australian Lungfish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/lungfish.html

This Australian lungfish was filmed in an aquarium. Note its resemblance to the lobe-finned fish to which it is closely related. Like all lungfish it has both lungs and gills, but gills are the major respiratory organ in this river-dwelling species.

**African Lungfish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/african_lungfish.html

The African lungfish makes extensive use of its lungs and in fact would drown if held under the water. The swamps in which it lives periodically dry up. To avoid desiccation, the lungfish burrows into the mud, secretes a cocoon of mucous, and drops its metabolic rate to a very low level. While in this dormant state, which can last as long as two years, it acquires oxygen from the air stores within its lungs.
II. How do fish perform the basic life processes? (Page 5)

Digestive System:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/digestive_system.html

Fish have a digestive tract with mouth and anus, typical of vertebrate animals. Food passes through the pharynx before entering the stomach and then the intestine where digestion and absorption of nutrients occurs. Structures called “gill rakers”, located near the internal pharyngeal slits, prevent food from escaping the pharynx and clogging the gills.

Spiral Valve:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/spiral_valve.html

This diagram of a dissected shark, illustrates the digestive system of cartilaginous fish. It differs from that of teleosts by the presence of a large, spiral structure within the intestine. This spiral valve slows down the passage of food and provides additional time and surface area for nutrient absorption. Note also the extremely large liver that fills most of the body cavity. In sharks, the liver stores oils that provide buoyancy, as previously mentioned.

Tubular Heart:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/tubular_heart.html

All fish, except lungfish, have a tubular heart comprised of four contractile chambers in a line. Veins bring blood from the body into the sinus venosus of the heart. Blood passes through an atrium and ventricle, then leaves the heart via the conus. Note that the heart is located beneath the pharynx, in the anterior region of the body.

Blood Flow Through the Gills:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/the_gills.html

Blood leaving the heart, immediately passes through the gills where it is oxygenated. The blood then enters a large blood vessel, the dorsal aorta, that carries it to tissues in the fish’s body and tail.

Kidney:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/kidney.html

All fish have long, thin kidneys located in the dorsal region of the body cavity. Both the kidney and the gonad discharge their products through a urogenital pore located just behind the anus.

Dilute Urine:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/dilute_urine.html

This diagram of a freshwater fish illustrates the regulation of salt and water balance. Since the fish’s blood and tissue fluids have a higher salt concentration than the surrounding environment, water enters unprotected surfaces of the body (mainly the gills) by osmosis and salts diffuse out. To correct these problems, the kidney excretes a large volume of water and the gills pump salts back into the bloodstream from the surrounding water.
Concentrated Urine:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/concentrated_urate.html

In marine fish, the salt concentration of blood and tissue fluids is less than sea water. Thus, water leaves the unprotected surfaces of the body by osmosis and the fish is in danger of dehydration. To overcome this problem, the kidney produces a very concentrated urine, thus retaining as much water as possible. The fish drinks a large volume of sea water and excretes excess salts through the gills. Since kidney function is reduced, the gills of most fish have acquired the ability to pump out metabolic wastes as well.

Reproduction:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/reproduction.html

The tuna shown in the upper corner have aggregated are preparing to spawn together. Other fish that reproduce by mass spawning are the sardines, whitefish and certain shads. The salmon shown below are also spawning. They have migrated from the sea into streams, where mating occurs after a ritualized “mating dance”. The female scoops out a nest where she deposits her eggs. Her mate fertilizes them, and the female then covers them with gravel. After mating, the exhausted salmon lie. Hatchling salmon remain in the stream for as long as two years, before eventually returning to the sea as adults.

Courtship:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/courtship.html

These colorful mandarins engage in courtship. On the morning of mating, males frequently fight. Later in the day, elaborate courting behavior begins. Eventually the courting couple embrace and spawn. The externally fertilized eggs sink to the bottom and the fish go their separate ways.

Mating of Seahorses:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mating.html

Male seahorses can be distinguished from females by the presence of a belly sac, indicated by the arrow. Seahorses court by swimming around one another. During mating, the female takes the lead and deposits her sperm in the belly sac of her partner. The male fertilizes the eggs and retains them in his sac, thus becoming “pregnant”. When the eggs hatch, a cloud of tiny seahorses is emitted from the belly sac. This gives the appearance of a male giving birth.

Mouth Brooding:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/broods.html

Some fish carry the cluster of fertilized eggs beneath their body until hatching, while others (like this tilapia) are mouth brooders. Note the developing eggs held within the fish’s mouth for safekeeping.

Hatchlings:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/hatchlings.html
This Amazonian demon fish provides a safe haven for her hatchlings by taking them into her mouth when danger threatens.

**Copulation:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/copulation.html

These sharks are copulating. The male, on the left, is holding the female by grasping her pectoral fin in his jaws. He is maneuvering his pelvic fins into position to deposit sperm. Note the elongated structure a called clasper extending from the male’s pelvic fin.

**Guppies:** http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/guppies.html

Guppies are notorious for giving birth to large numbers of young. An adult guppy and three newborns are shown here.

**IV. What type of sense organs do fish have? (Page 6)**

**Olfactory Sacs:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/olfactory_sacs.html

The nostrils of a shark are illustrated in this diagram. They open into small, blind sacs that contain olfactory receptors. Water flows into the sac on one side of the nostril and out on the other side of the nostril. Sharks can scent blood in the water from a great distance and use their sense of smell to locate wounded prey.

**Inner Ear:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/inner_ear.html

The inner ear of fish is embedded within the skull. The structure of the inner ear closely resembles that of mammals. The sac-like structure is a gravity sensor and the three semi-circular canals detect acceleration and rotational movements of the head.

**Neuromasts:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/neuromasts.html

The neuromast consists of hair cells covered by a gelatinous mass. Neuromasts are located near the skin surface. The gelatinous mass either projects into the surrounding water or lies just beneath the skin. Water currents press against the gelatinous mass which bends it and stimulates the hairs within. Thus the neuromast is a type of touch receptor, specific for water movements.

**Lateral Lines:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/lateral_lines.html

The lateral line canals are prominent structures in most fish. Canals and pits in the head region are characteristic of the cartilaginous fish as illustrated here in the chimera.
Fish Orienting:
These smokey catfish are oriented with their heads pointing into a gentle current within the aquarium.

**School of Fish:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/school.html

Along with eyes, the lateral line system allows fish to perceive the location and movements of their neighbors within a school. Thus fish can keep an appropriate spacing, and the school often responds as a unit when moving or turning.

I. Why are lungs and swim bladders important? (Page 7)

**Air Sacs:** http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/air_sacs.html

This diagram illustrates the arrangement of air sacs in several fish. In lungfish, a pair of sacs are attached to the pharynx at the point where it becomes the esophagus. These air sacs function as lungs and are filled when the fish rises to the surface, gulps air, and swallows. In the three ray-finned fish shown here, the air sacs function as swim bladders. The Bowfin and carp retain a connection to the pharynx, whereas in most teleosts the bladder is completely detached from the digestive tract.

**Duct:** http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/duct.html

In this tarpon, a duct that connects the swim bladder and pharynx is present. Fish that retain this connection, called the pneumatic duct, must rise to the surface periodically to fill the bladder by swallowing air. Their swim bladders also function as lungs to one degree or another.

**Swim Bladder:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/swim_bladder.html

This salmon has been opened from the ventral side. Most internal organs have been removed to reveal the dorsally located swim bladder. The bladder usually deflates at death, but can be re-inflated by inserting a soda straw and blowing gently, as shown in the bottom photograph. When filled with air, the bladder can be floated in a bowl of water. In a fish, the inflated bladder makes the body buoyant. Depending upon the species of fish, it may be filled with nitrogen or oxygen with small amounts of carbon dioxide.

**Neutral Buoyancy:**
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/neutral_buoyancy.html

The swim bladder provides the fish with neutral buoyancy. That is, it can hang motionless in the water with little expenditure of energy. Observe how this motionless piranha maintains its position without rising or sinking.

**Hear:** http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/hear.html
In this tarpon, small extensions from the swim bladder extend to the skull near the location of the inner ear. Water vibrations cause the bladder to vibrate, and these vibrations are then transmitted to the ear as sound.

Vocalize:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/vocalize.html

In some fish, muscles attached to the swim bladder contract to make thumping sounds or force air back and forth between chambers within the bladder to produce a croaking noise. Such vocalizations are used for communication. The two fish shown here were named for the sounds that they make.

Early Amphibians:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/early_amphibians.html

The relationship between lungfish and amphibians can be seen by comparing the lungs of a salamander to those of an African lungfish. Both have relatively small lungs and inflate them by swallowing air.

Mudskipper:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/mudskipper.html

The mudskippers can travel quite rapidly across the mud flats using their pectoral fins. They hunt small creatures, such as insects, and spend more time on land than in the water. When a mudskipper’s body begins to dry out, it enters a nearby puddle and rolls.

Walking Catfish:
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/walking_catfish.html

The walking catfish can live in almost in body of fresh water, including brackish or swampy regions. It spends most of its time lying on the bottom, but periodically rises to the surface to gulp air. While not a true lungfish, the walking catfish is able to use its swim bladder as a lung to a limited extent. If its environment becomes inhospitable, this fish can walk across land to locate a new home.

Florida:  
http://courses.ncsu.edu/zo495x/common/zo155_site/wrap/fish/fish_popups/florida.html

The walking catfish is native to Asia and was introduced to Florida in the 1960’s, when some aquarium brood stock escaped. Fish used the interconnecting series of canals as well as their ability to walk on land to rapidly spread across much of the state. They tend to drive out native fish and sometimes invade aquaculture facilities where they eat large numbers of young fish. The walking catfish has been banned from the USA and can be imported only with a license.