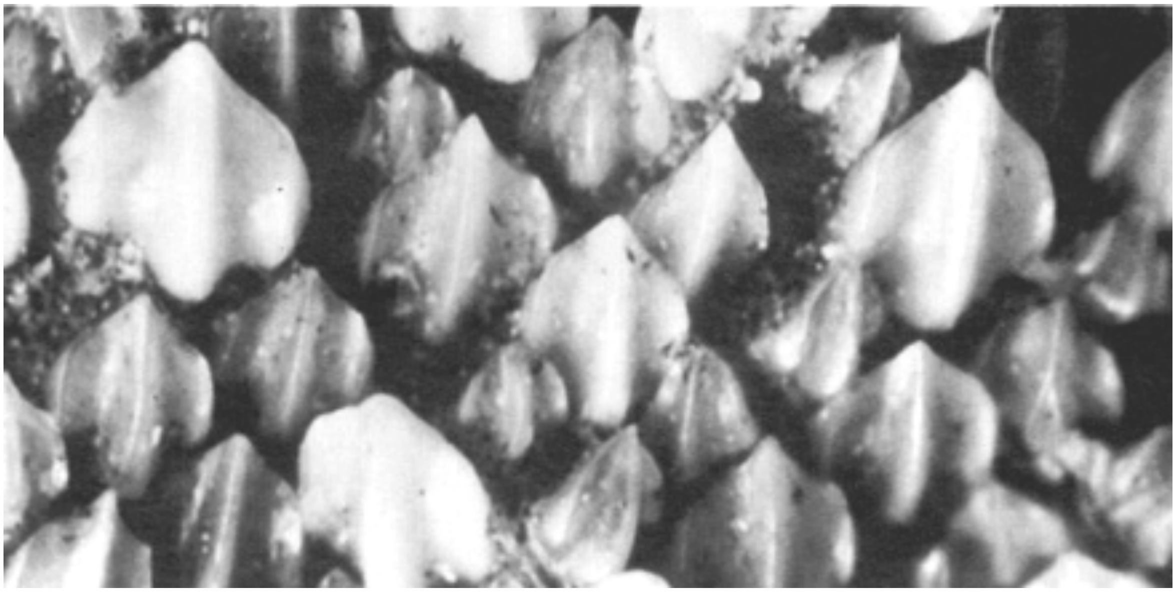
F. Scales.

1. Sharks and batoids have placoid scales, also called dermal denticles (dermal=skin, denticles=teeth). Placoid scales have the same structure as a tooth, consisting of three layers: an outer layer of vitro-dentine (an enamel), dentine, and a pulp cavity. Placoid scales are arranged in a regular pattern in sharks and an irregular pattern in batoids.



A placoid scale has the same structure as a shark's tooth.

2. Unlike other types of scales, placoid scales do not get larger as the fish grows. Instead, the fish grows more scales.

3. Like teeth, the shape of the scales is variable among species and can be used to identify the species.

4. Placoid scales gave rise to teeth, stingrays' spines, and the dorsal spines of horn sharks (*Heterodontus* spp.) and dogfishes (family Squalidae).

5. As a shark or batoid swims, placoid scales may create a series of vortices or whirlpools behind each scale. This enables a shark to swim efficiently.

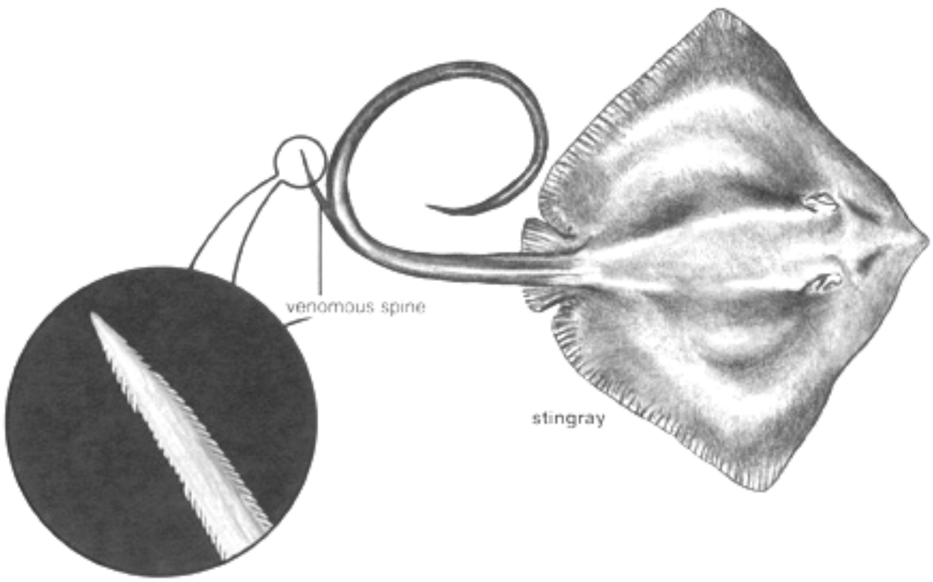
6. European cabinetmakers used the rough skin of a shark as sandpaper, called shagreen. With the denticles removed, shark skin is also used for leather.

G. Spines

1. Most rays (order Myliobatiformes) have one or more venomous spines on the tail. Spines are an adaptation for defending the animal against predators and are not used aggressively. Shallow-water species do, however, pose a risk to unwary bathers because if a ray is disturbed, its natural reflex is to lift its spine.

2. Skates (family Rajidae) and guitarfish (family Rhinobatidae) may have rows of short spines or prickles on the back.

3. Some shark species, such as horn sharks (family Heterodontidae) and dogfishes, have spines associated with their dorsal fins. These spines are an adaptation for defense against predators.



Most rays have one or more venomous spines on the tail, for defense.

IV. Senses.

A. Acoustic senses.

1. Hearing.

   a. Sharks have only an inner ear, which consists of three chambers and an ear stone called an otolith. A shark's inner ear detects sound, acceleration, and gravity.

   b. Sharks use sound to locate food.

      (1) Sound is often the first sense a shark relies on to detect prey.

      (2) Under water, sound travels faster and farther than on land.

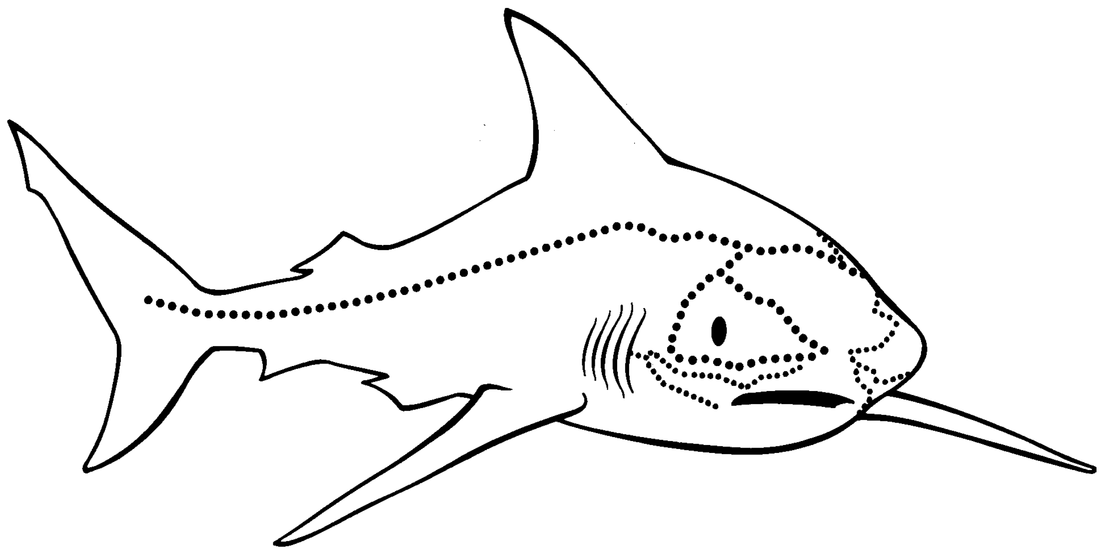
      (3) Sharks are attracted to low-frequency pulsed sounds, similar to those wounded or ill prey would emit. Most attractive sounds are in the frequency of 25 to 100 Hz. Some sharks are attracted to sound sources from distances as great as 250 m (820 ft.).

2. Lateral line.

   a. The lateral line system is a series of fluid-filled canals just below the skin of the head and along the sides of the body. The canal is open to the surrounding water through tiny pores.

b. The lateral line canals contain a number of sensory cells called neuromasts. Tiny hairlike structures on the neuromasts project out into the canal. Water movement created by turbulence, currents, or vibrations displaces these hairlike projections and stimulates the neuromasts. This stimulation triggers a nerve impulse to the brain.

c. Like the ear, the lateral line senses low-frequency vibrations. It functions mainly in distance perception and detecting low-frequency vibrations and directional water flow.



The lateral line system is a series of fluid-filled canals. It senses low-frequency vibrations.

B. Eyesight.

1 . Sharks have a basic vertebrate eye, but it is laterally compressed. The lens is large and spherical.

2. Although the threshold of a shark's visual acuity has not been demonstrated, it is apparent that they are well-suited for seeing in dim light. Their eyes are particularly sensitive to moving objects.

a. Sharks have a large proportion of rods, which are highly sensitive to changes in light intensity, making sharks sensitive to contrasts of light and shadow.

b. The eye has a layer of reflecting plates called the tapetum lucidum behind the retina. These plates act as mirrors to reflect light back through the retina a second time. The tapetum lucidum of a shark is twice as effective as that of a cat.

3. Unlike those of other fishes, a shark's pupil can dilate and contract.

4. Cone cells are present, indicating that sharks may have some sort of color vision.

5. In clear water, a shark's vision is effective at a distance up to about 15 m (50 ft.).

C. Taste.

Sharks and batoids have taste buds inside their mouths. These taste buds have not been studied extensively. Taste may be responsible for a shark's final acceptance or rejection of prey items.

D. Smell.

1. Paired external nostrils with an incurrent and an excurrent opening lead to ventral olfactory organs (organs which function in smelling). Olfactory organs are blind sacs which are not connected with the mouth.

2. Sharks have an acute sense of smell. They are well-known for their ability to detect minute quantities of substances such as blood in water. Sharks can detect a concentration as low as one part per billion of some chemicals, such as certain amino acids. A shark's sense of smell functions up to hundreds of meters away from the source.

E. Ampullae of Lorenzini.

1. The ampullae of Lorenzini form a complex and extensive sensory system around a shark's head.

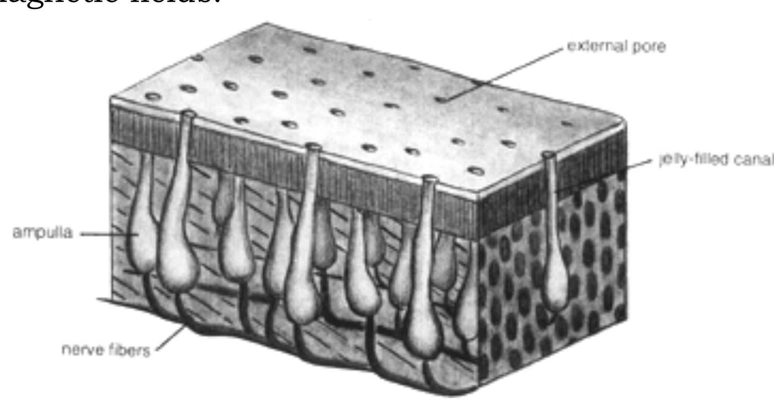
2. External pores cover the surface of a shark's head. Each pore leads to a jelly-filled canal that leads to a membranous sac called an ampulla. In the wall of the ampulla are sensory cells innervated by several nerve fibers.

3. The ampullae detect weak electrical fields at short ranges. All living animals produce electric fields.

4. Ampullae of Lorenzini are effective only within inches, as they sense bioelectrical fields in the final stages of prey capture.

5. Mainly considered electroreceptors, it is possible that the ampullae of Lorenzini may also detect temperature, salinity, changes in water pressure, mechanical stimuli, and magnetic fields.

External pores on the surface of a shark's head lead to membranous sacs connected to nerve fibers. Called the ampullae of Lorenzini, these organs detect weak electrical fields at close range.



F. Sensory pits.

1. A sensory pit is formed by the overlapping of two enlarged placoid scales guarding a slight depression in the skin. At the bottom of the pit is a sensory papilla: a small cluster of sensory cells that resembles a taste bud.

2. Sensory pits are distributed in large numbers on the back, flank, and lower jaw.

3. The precise function of sensory pits has not been determined. They are most likely sense organs that are stimulated by physical factors such as water current.

V. Behavior.

A. Daily activity cycle.

Recordings of the movements of tagged sharks suggest that most sharks undergo daily activity rhythms. Their greatest activity occurs during the twilight and dark hours.

B. Social behavior.

Although sharks and batoids are basically asocial, many species demonstrate various degrees of social behavior. For instance, hammerhead sharks commonly school.

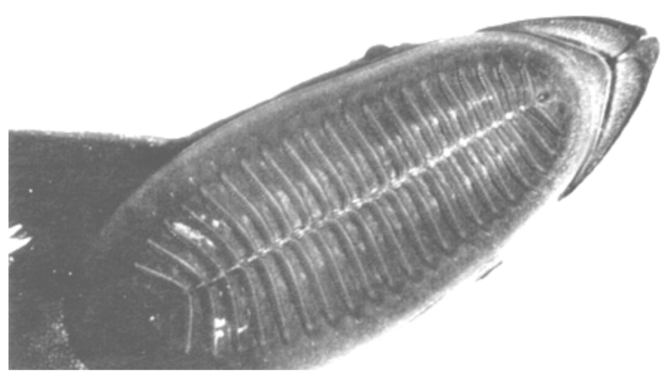
C. Symbiotic relationships.

1. Pilotfish (usually *Naucrates ductor*, but there are others) often travel with sharks, for unclear reasons. This relationship may be due to the natural schooling behavior of pilotfish, or the pilotfish may conserve energy by riding the hydrodynamic bow wake of the shark. Pilotfish also eat small amounts of food scraps released as the shark feeds.

2. Several species of small fishes, notably the cleaner wrasse (*Labroides dimidiatus*), are "cleaners" that pick debris and parasites from sharks.

3. Remora (several species in the family Echeneidae) commonly attach themselves to sharks and batoids or ride their hydrodynamic bow wakes. In addition, they may eat parasites of sharks and batoids.

A remora's dorsal fin has evolved into a sucking disc, which it uses to attach itself to sharks, large batoids, sea turtles, and whales.



4. Parasites of sharks and batoids are mainly copepods (small crustaceans) and flatworms.

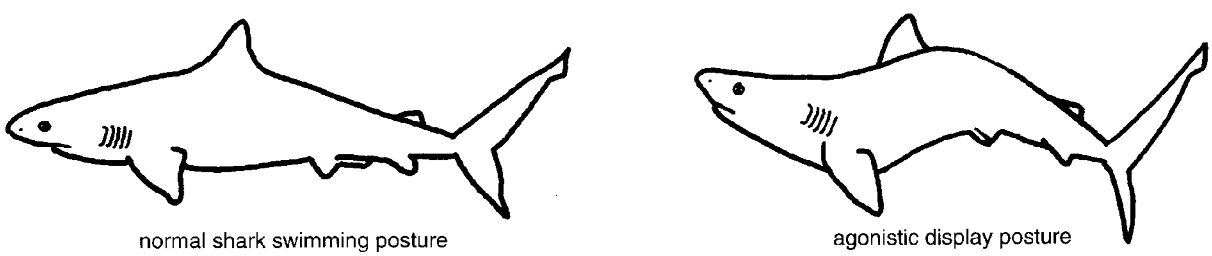
D. Shark attack.

1. Only 32 species of sharks have been identified with attacks on humans or boats. These species have three features in common: they prey on fish or marine mammals, grow to a large size, and frequent warmer coastal waters where swimmers are apt to be.

2. In 1958, the U.S. Office of Naval Research and the American Institute of Biological Sciences set up the Shark Research Panel-a union of scientists that gathered documentation on shark attacks and compiled the information into the Shark Attack File. The Shark Research Panel documented the following:

   a. Humans become prey by accident. Most shark attacks involve people handling hooked or snared sharks or spearfishermen handling wounded fish. Through sight or sound, a shark may confuse swimmers or divers for prey.

   b. Sharks may also attack from a territorial drive, with no intention to feed. A characteristic swimming pattern called agonistic display usually precedes attacks out of territoriality. The shark shakes its head and swims erratically with a hunched back, pectoral fins pointing down, and snout pointing up.



A characteristic swimming pattern called agonistic display usually precedes attacks out of territoriality.

3. An analysis of 1,000 recent shark attacks world-wide showed that well over 50% of the attacks were not feeding-related.

4. Up to 60% of shark attack injuries are slashes of the upper jaw teeth. This behavior is typical of courtship advances by some male sharks.

5. Sharks may also injure victims by bumping them vigorously, but most sharks move in cautiously when attacking.

6. A great white shark (*Carcharodon carcharias*) rushes towards its prey, attacking from beneath and behind. These sharks rely on stealth and surprise to prey on seals, sea lions, and other marine mammals.