INTRODUCTION: THE SHARK AND MAN

"Who can open the jaws of his face?
His teeth are terrible round about."
Job, 41:6

The very mention of the word shark has from ancient times instilled within man an almost irrational fear. Yet, at the same time, the cunning, strength, tenacity, and grace of movement of the animal have never ceased to fascinate him.

Sharks have in the past been studied by ichthyologists alone. Today, with the popularity of such films as *Jaws I* and *Jaws II* and the publication of numerous paperbacks on the subject, even the person without a science background is aware of the more dramatic aspects of shark behavior.

The present day popular interest in sharks can be traced to the wartime experiences of the armed forces. The sinking of troop transport ships and the shooting down of aircraft over the open seas often ended in carnage resulting from shark attacks upon those who had survived the guns and torpedoes.

This led to the founding of the *Shark Research Panel* as a joint venture of the U.S. Navy and the American Institute of Biological Science (AIBS). Its aims include:

(1) To keep an up-to-date record of shark attacks throughout the world, and to compile annual statistics of these accidents, published as a list with an analysis of the attack and the conditions under which it occurred.

(2) To promote and to follow up all basic research by coordinating studies carried out in all parts of the world on systematics, migrations, general biology, anatomy, and physiology of sharks.

(3) To study the methods and results of shark repellent investigations.

SHARKS AND FISH

Biologically, sharks are fish belonging to the phylum *Chordata* and the subphylum *Vertebrata*. However, sharks and their relatives, the rays and skates, are unique amongst fish in that their skeletons are made entirely of cartilage, not bone. This places them in the class *Chondrichthyes*, subclass *Elasmobranchii*.

The bony fish, the *Osteichthyes*, possess a gas-filled *swim bladder* by means of which they can regulate their buoyancy allowing the fish to "float" at various depths under water. Sharks have no swim bladders. They are somewhat heavier than the water they displace. Thus, once a shark ceases to move, it sinks. Coastal species rest on the sea floor in shallow water. However, the sharks of the deeper oceans must continue moving from the moment of birth to the moment of death! If they were to stop swimming, they would sink and be crushed by the pressure of the deep below.

Regulation of *osmotic pressure* in marine sharks differs from that of their bony relatives. They retain a high concentration of urea and other solutes in their body fluids, a concentration of salts higher than that in the surrounding sea water. There is therefore no need for sharks to drink.

Fertilization is *internal*, and most shark "pups" hatch internally, to continue their development within the *uterus* of the mother. After a period of gestation (up to two years in the spiny dogfish, *Squalus acanthias*, the

longest of any vertebrate!) they are born alive as a smaller version of the adult. This method of reproduction is called *ovoviviparous*. The number of "pups" in a litter varies from two in some species to sixty in others. Some sharks are *oviparous*, laying large eggs enclosed in shells, or egg-cases, consisting of a hornlike material. They are usually flat and quadrangular shaped with long tendrils which serve to anchor the eggs to seaweed or other objects.

While there are close to 20,000 living species of fish, only about 300 of these are sharks. They are divided into nineteen families, with five families making up 75 per cent of the known species.

Sharks range in size from a species only six inches long when mature to the 35-foot basking shark and to the largest of all fish, the *whale-shark*, reaching 50 feet in length and weighing over ten tons. Contrary to popular belief, these two largest of sharks are quite inoffensive beasts, deriving most of their nourishment from minute planktonic animals (those which float in the upper layers of the sea).

SPINY DOGFISH SHARK

The spiny dogfish, genus and species names *Squalus acanthias*, of the family Squalidae, is our dissection specimen. The species name "acanthias" calls attention to the animal's mildly poisonous *spines*, one in front of each dorsal fin. It is a relatively small shark, attaining about 3½ feet in length and weighing about 15 pounds. The absence of an anal fin is characteristic of the entire family.

It is distributed worldwide, from the temperate to the subpolar regions, from the shallow waters of the seashore to depths of 100 fathoms (600 feet).

They are voracious eaters, feeding on fish, crustaceans, squid, gastopods, jelly fish, and even red and brown algae. The spiny dogfish, as most other sharks, is *omnivorous*, devouring both plant and animal matter.

It is an abundant species. On this side of the Atlantic it is infamous for its disruptive activities to fishing operations. It is destructive of fishing gear; hook and line, nets are bitten and their catch devoured and freed. This results in a high animal loss to the fishing industry. Except as laboratory specimens, no economic use has been found for them.

In northern Europe and the British Isles, the spiny dogfish shark is similarly destructive but is there counted as a food fish species. Known as the *spurdog* or *piked dogfish*, a great deal of it is served in fish and chips shops.

Tagging studies indicate that the animal has a life span of 25-30 years. The male reaches sexual maturity at the age of 11, the female at 19. Litters are small, generally four to seven pups. The excessively long gestation period, two years, longest of any other vertebrate, has already been mentioned.

In the laboratory they serve two functions. Firstly, they serve as dissection specimens, illustrating many primitive vertebrate features, and thus useful in tracing these features through the higher vertebrates to man. Secondly, their relatively small size is a convenience in housing and caring for live specimens in a broad range of physiological research situations, such as human cardiology and immunology.

Man, *Homo sapiens*, belongs to the class *Mammalia*, whose members:

— Possess milk producing glands in the female (mammary glands) for nursing the young;

— Have skin covered with hair or fur.

The dogfish shark is a comparatively large dissection specimen. Its muscles and internal organs are clearly visible. Its nerves and blood vessels are readily traced.

The photographs and diagrams accompanying each chapter are for your use as learning tools. Identify and learn the names of the structures of your specimen by repeated referrals to the photographs.

ANATOMICAL TERMINOLOGY

Some basic biological terminology should be studied at this time. Familiarize yourself with the following words and learn to use them in referring to the location of the body parts of your specimen.

DIRECTIONS OR POSITIONS

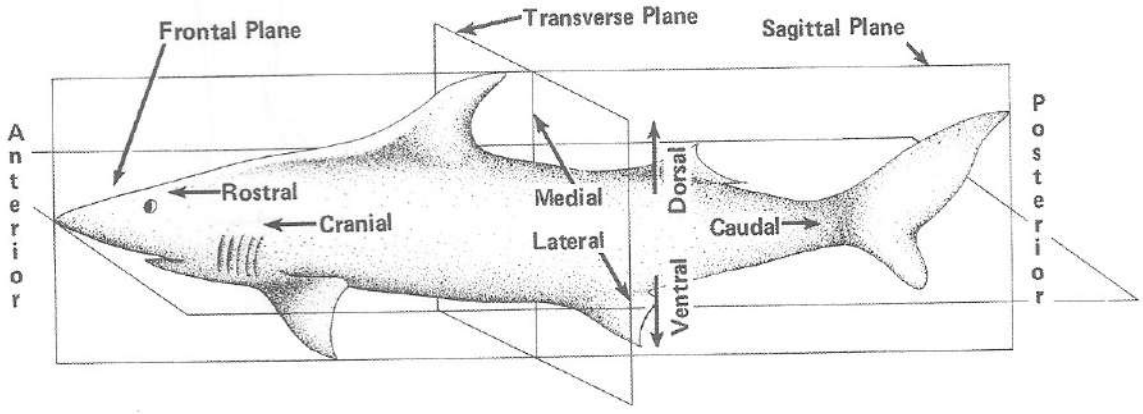
Anterior (Cranial)	– toward the head
Posterior (Caudal)	– toward the tail
Dorsal (Superior)	– toward the backbone
Ventral (Inferior)	– toward the belly
Lateral	– toward the side
Medial	– toward the midline
Proximal	– lying near the point of reference
Distal	– lying further from the point of reference

Note: The terms in parentheses are synonymous when referring to a fish-like animal such as the shark or to a quadruped such as a cat. In man these terms have different meanings (see diagram at the end of this section).

PLANES OR SECTIONS THROUGH THE BODY

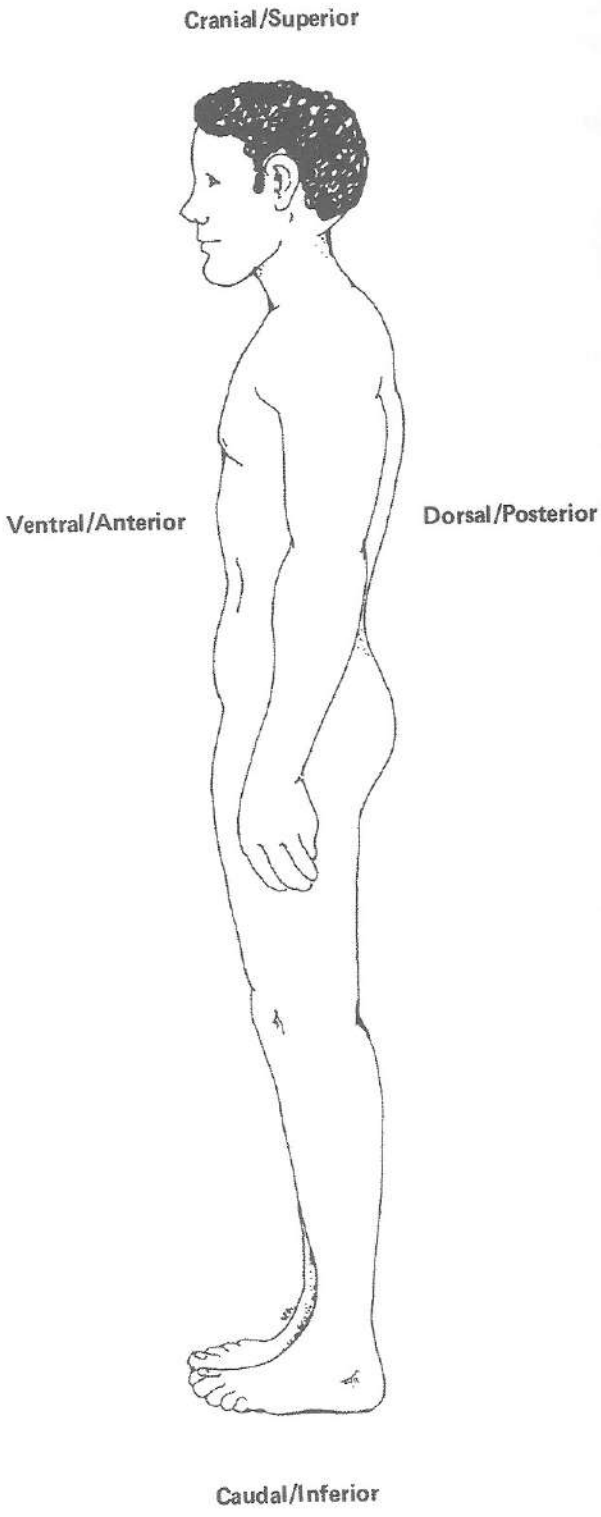
Transverse (Cross Section)	– perpendicular to the long axis of the body
Sagittal	– a longitudinal section separating the body into right and left sides
Frontal (Coronal)	– a longitudinal section dividing the specimen into dorsal and ventral parts

DIRECTIONAL TERMS for the Shark and Man



In man, the *anterior* and *ventral* surfaces are identical; both terms refer to a person's front or belly side. Similary, the terms *posterior* and *dorsal* are identical, referring to a person's back surface, the area near the spinal cord.

Other terms indicating position or direction will appear in the text. For example, the terms *superficial* (or external) and *deep* (or internal) will be used when describing muscles. The terms *pelvic* and *pectoral* will describe different fins of the shark.



EXTERNAL FEATURES

Specimens of dogfish shark generally come individually packed in large plastic bags together with about a pint of preservative solution. Prepare a large dissection pan and some paper towels. Open the bag and carefully remove the animal onto the pan. Do not discard the preservative. It should remain in the bag during the entire dissection. Examine your specimen.

OVERALL DESCRIPTION

The shark is gracefully elongated and streamlined. The body shape is known as *fusiform*, built for swimming in the sea with least possible resistance.

The student should now refer to the first photo.

The body is divided into three readily identifiable areas:

The head (cranial) – from the pointed snout-like *rostrum* to the *pectoral fins*. This includes the *gill* region.

The trunk – from the *pectoral fins* to the *pelvic fins*.

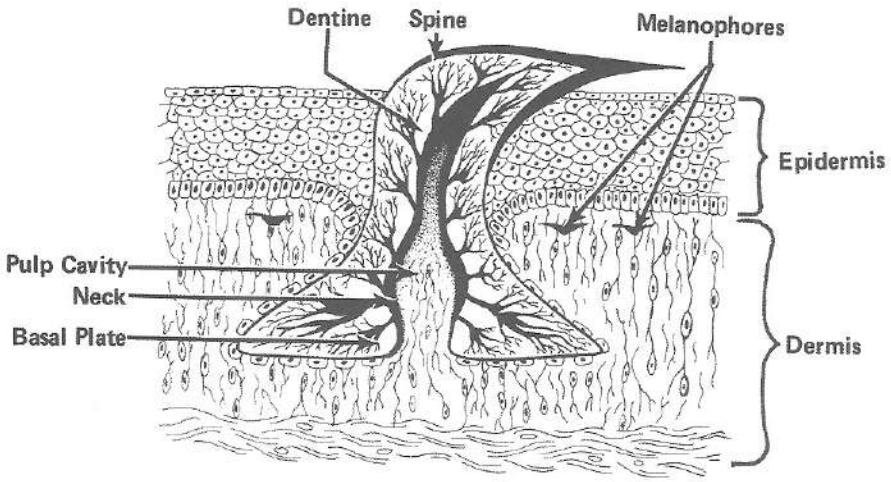
The tail (caudal) – from the *pelvic fins* to the end of the *caudal fin*.

THE SKIN

Run your hand over the body of the shark from head to tail and feel its smooth texture. Now, run your hand in the opposite direction and you will detect a rough, sandpaper-like texture. As a matter of fact, shark skin has been used as an abrasive in the manufacture of furniture for hundreds of years. It was also used as a covering for sword handles and tools to prevent them from slipping from one's hand.

The entire skin of the shark is covered by minute, sharp, tack-like *placoid scales* embedded in the skin pointing caudally. These scales differ considerably from the oval overlapping transparent scales of most bony fish. They are modifications of teeth; thus their name, *dermal denticles*. Their structure and mode of development are similar to the teeth of higher vertebrates and man. See diagram below.

SKIN STRUCTURE



Like true teeth, the placoid scales have a base of *dentine* which contains a *pulp cavity* filled with connective tissue. Both scales and teeth have a spinous process covered by *enamel* which protrudes through the skin.

The shark's body is colored dark gray above and much lighter, almost white, below. This distribution of pigment is referred to as *counter shading* and is common amongst aquatic vertebrates. It tends to neutralize the effects of natural lights, which, coming from above, highlights the back and casts a shadow on the underside. It tends to make the animal less conspicuous.

Extending laterally, along the sides of the body, somewhat nearer to the dorsal than to ventral surface, look for a narrow, light-colored horizontal stripe. Observe carefully along this line with a magnifying glass or low power dissection microscope and note the pores along its length. This is part of the *lateral line system*. Below the skin, nerve receptors called *neuromasts* run along a *lateral line canal* with pores opening to the surface. They carry impulses to the central nervous system. These receptors, found only in fish and some aquatic amphibians, are sensitive to the mechanical movement of water, to disturbances in the water, and to sudden changes of pressure. They warn the shark of vibrations and movements even in murky water, where visibility is reduced.

In the area of the head the lateral line canal branches to form several communicating canals. These will be described in the chapter on the Nervous System, page 106.

Note patches of pores upon the head in the areas of the eyes, snout, and nostrils. These are the openings of the *ampullae of Lorenzini*, sense organs which are sensitive to changes in temperature, water pressure, electrical fields, and salinity. Press firmly upon the skin near the nares (nostrils). Note the jelly-like material you have squeezed out of the pores. These will be examined further in the chapter on the Nervous System, page 106.

THE HEAD

Examine the head of the shark and note each of the following:

ROSTRUM — This is the pointed snout at the anterior end. This streamlined tapered tip at the anterior end helps overcome water resistance in swimming. See the first three photos at the end of this chapter.

NARES — These are the openings for the external nostrils. They are located on the underside (ventral surface) of the rostrum anterior to the jaws. Water is drawn into the nares to moisten the sensory cells of the olfactory sac. A *nasal flap* can be seen clearly in the photo of the ventral surface of the head, page 11, which separates the *incurrent aperture* from the *excurrent aperture*. Water passes into and out of the olfactory sac, permitting the shark to detect the odors of the water. The ability of the sharks to detect blood and injured flesh at great distances from their source is legendary and is a major attractant and subsequent cause of shark attacks.

JAWS — The opening to the mouth of sharks is always on the underside. The great powers of the shark's jaws have been retold by mariners for generations. Recently a testing device, the *gnathodynamometer*, was used to measure the force exerted by the jaws of a typical eight-foot shark. It was an extraordinary eighteen tons per square inch!

Examine the *teeth*. They are sharp and pointed. They are formed of the same material and develop similarly to the smaller *placoid scales* distributed over the shark's entire body. Besides the visible teeth, several rows of flattened teeth lie behind the upright set ready to replace them when worn out or lost. It has been estimated that the great white shark has about 400 teeth.

EYES — These are very prominent in sharks, and as our later dissection and photo will reveal, see pages 104 and 108, they are very similar to the eyes of man.

A transparent *cornea* covers and protects the eye.

A darkly pigmented *iris* can be seen below the cornea. Its contraction and relaxation adjusts the amount of light entering. In its center is the opening to the interior of the eyeball, the *pupil*.

Upper and lower eyelids protect the eye. Just inside the lower lid, a membrane may be seen, the *conjunctiva*. It extends over the surface of the eye to cover the cornea.

SPIRACLES — These large openings posterior and dorsal to the eyes are actually reduced first gill slits in the jawed fish. A *pseudobranch*, false gill, is a reduced first gill which may be seen within the spiracle. A fold of tissue, the *spiracular valve*, permits the opening and closing of the external spiracular pore. The spiracle serves as an incurrent water passageway leading into the mouth. Thus water can be brought in for respiration even when the shark's mouth is closed or when he is feeding.

GILL SLITS — Most sharks have five external gill slits. They are located laterally, posterior to the mouth, in front of the pectoral fins. Water taken in by the mouth is passed over the internal gills, oxygen is removed and carbon dioxide excreted. The water is then forced out to the external environment by way of the gill slits. The structure of the gills, their cartilaginous support and blood supply will be discussed in later chapters.

ENDOLYMPHATIC PORES — Look at the top of the head between the spiracles with a hand lens. You will see a pair of tiny *endolymphatic pores*, one on each side of the midline. They are continuations of the *endolymphatic ducts* which lead into the *inner ear* which, in turn, serves primarily as an organ of equilibrium.

THE FINS

The spiny dogfish shark possesses two single dorsal fins, a caudal fin, and two pairs of ventral fins.

DORSAL FINS — The anterior dorsal fin is larger than the posterior dorsal fin. When sharks are seen near the surface of the water, the telltale sign is the triangular anterior dorsal fin projecting ominously above the surface of the water.

A feature peculiar to our specimen, the spiny dogfish, is the presence of two *spines*, one immediately anterior to each dorsal fin. When captured, these sharks will arch their backs and attempt to pierce their captor with these long sharp spines. Besides the puncture wounds these can inflict, the spines also carry a poison secreted by glands at their base. The structures and origins of these spines are similar to those of the tiny dermal placoid scales and teeth.

CAUDAL FIN (Tail Fin) — This fin is divided into two lobes; the larger *dorsal lobe*, and smaller *ventral lobe*. Note that the tapering body axis passes upwards into the dorsal lobe. This type of tail is known as a *heterocercal* tail, as opposed to the single-lobed, fan-shaped symmetrical tail of the bony fish known as a *homocercal* tail.

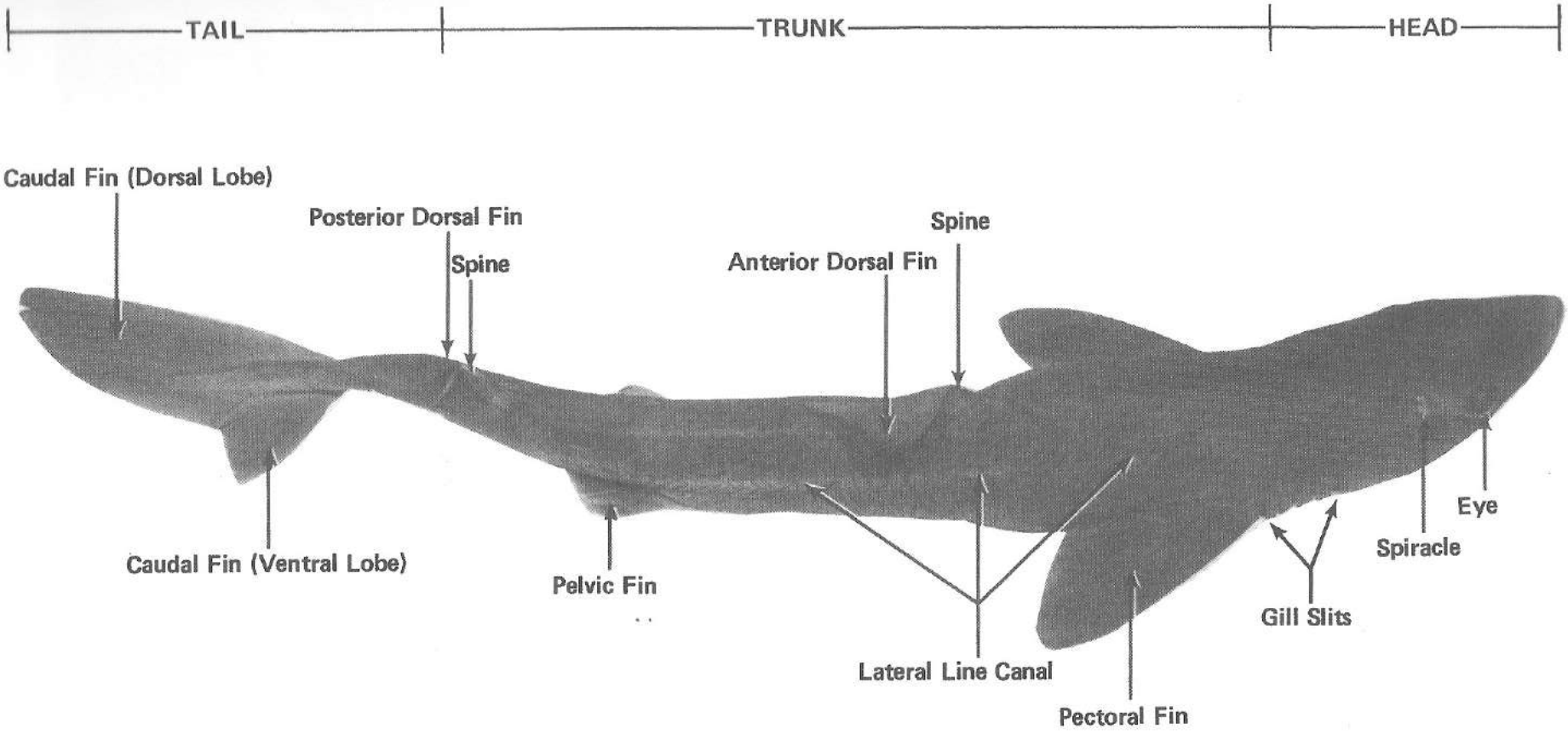
PECTORAL FINS — The asymmetry of the shark's tail fin creates a problem. As the tail is moved back and forth, the larger dorsal lobe causes the shark to be propelled forward and downward in the water. To offset the downward tendency, the paired pectoral fins act to deflect water downward and thus provide the lift needed at the crucial end to keep the shark moving in a horizontal direction.

PELVIC FINS — These paired ventral fins are located on either side of the cloacal aperture. They are different in males and females; see photos, pages 12 and 13. Those of the female are undifferentiated while those of the male are specialized for use in the transfer of sperm to the female during copulation or mating.

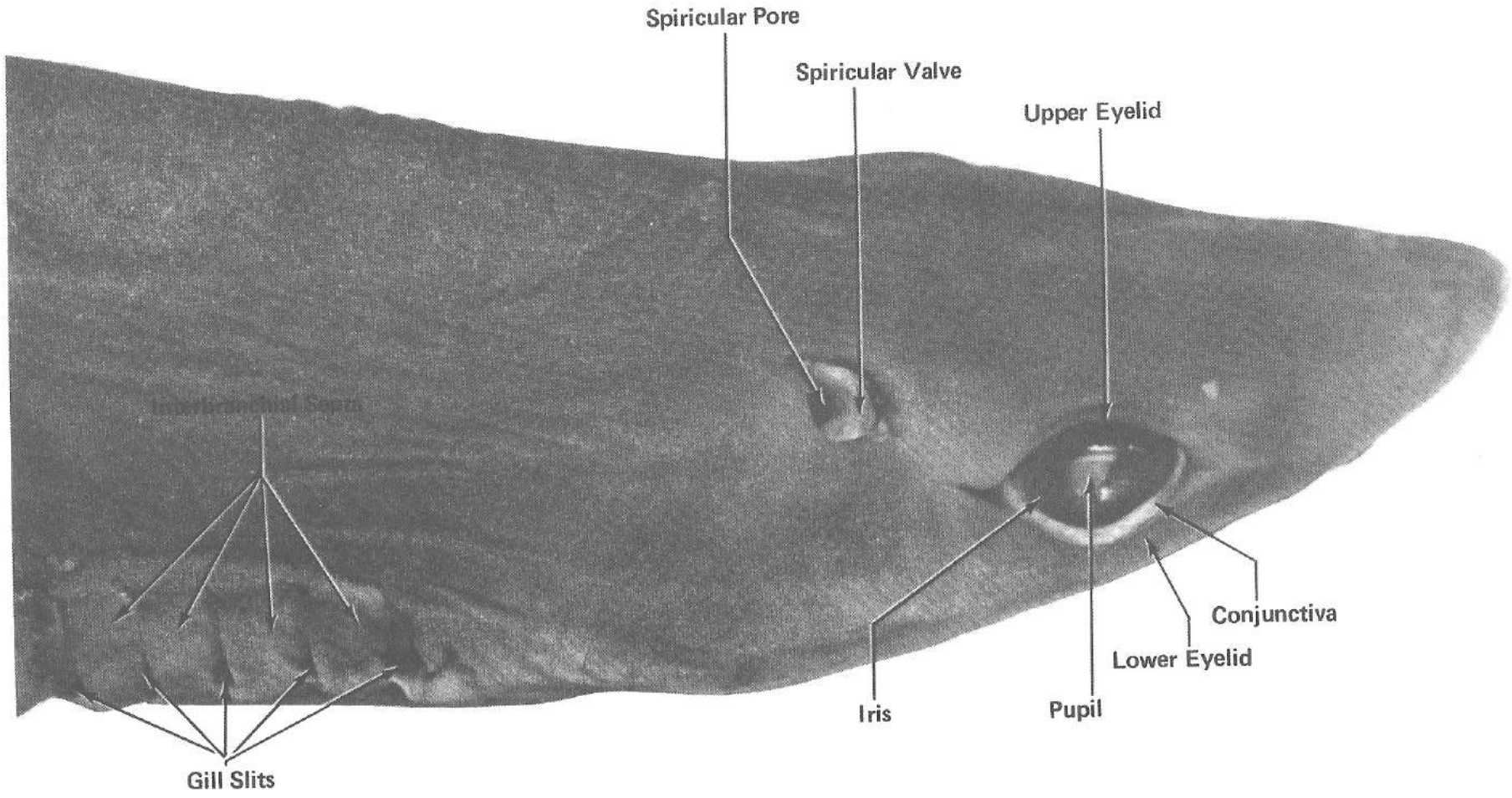
THE CLOACA — This name is given to the chamber on the ventral surface between the pelvic fins. It receives the products of the intestine, the urinary and the genital ducts. The name, meaning sewer, seems quite appropriate. A closer look within the cloaca will reveal the *urinary papilla*. Also visible, especially in mature female specimens, are the *abdominal pores*. These will be discussed later; see page 47.

CLASPERS — Males have stout, grooved copulatory organs called *claspers* on the medial side of their pelvic fins. Fertilization in the dogfish shark is internal. During copulation, one of the claspers is inserted into the oviduct orifice of the female. The sperm proceed from the cloaca of the male along the groove on the dorsal surface of the clasper toward the female.

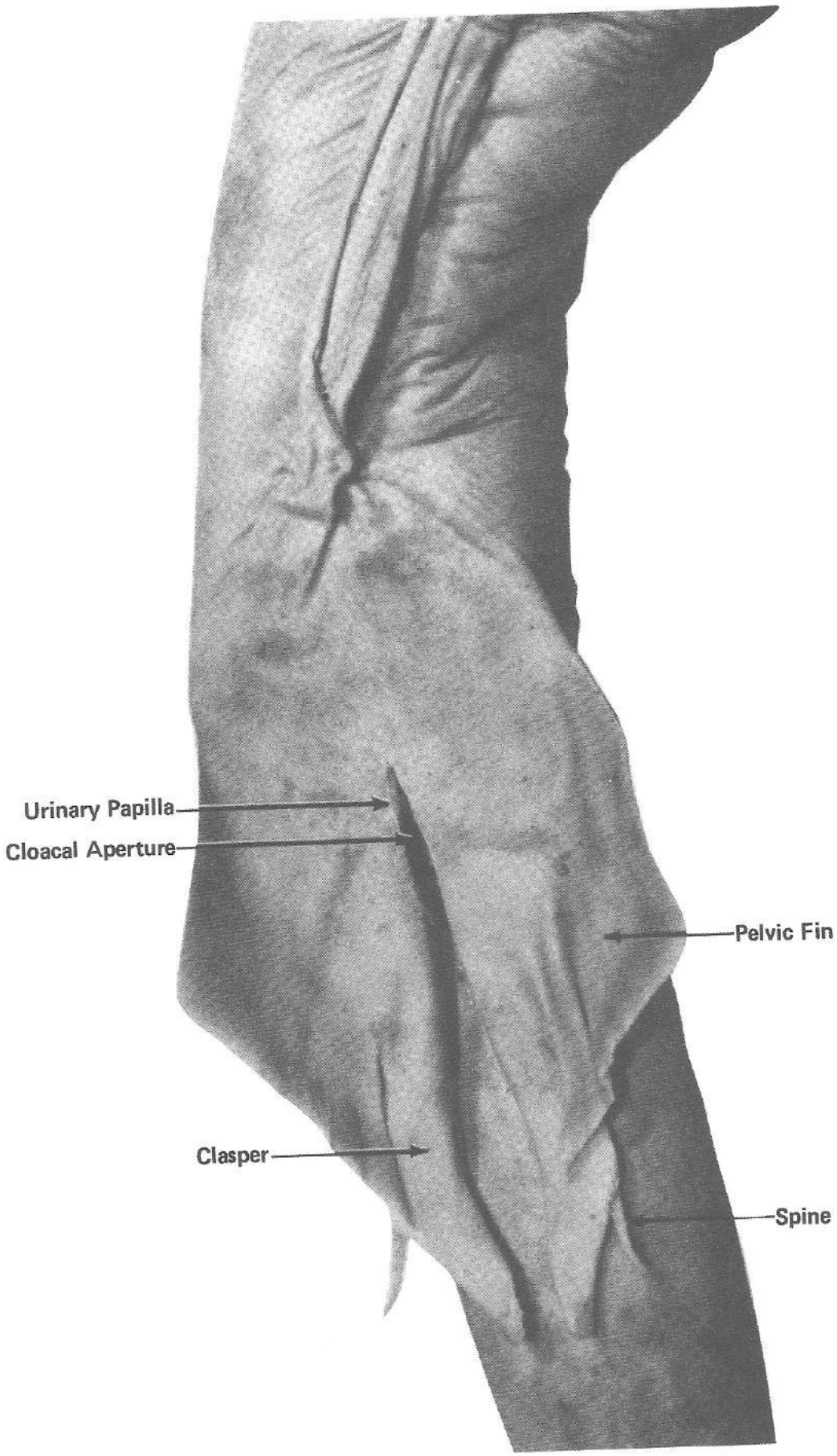
Associated with the claspers of the male are accessory structures such as the *siphons* and in some specimens *lateral spines* and *ventral hooks* may be present near the end of the claspers. The relationship of the pelvic fins to the cloacal openings as well as some of the accessory structures in males and females are better seen in the photos in the chapter on The Reproductive System, pages 82 and 86.



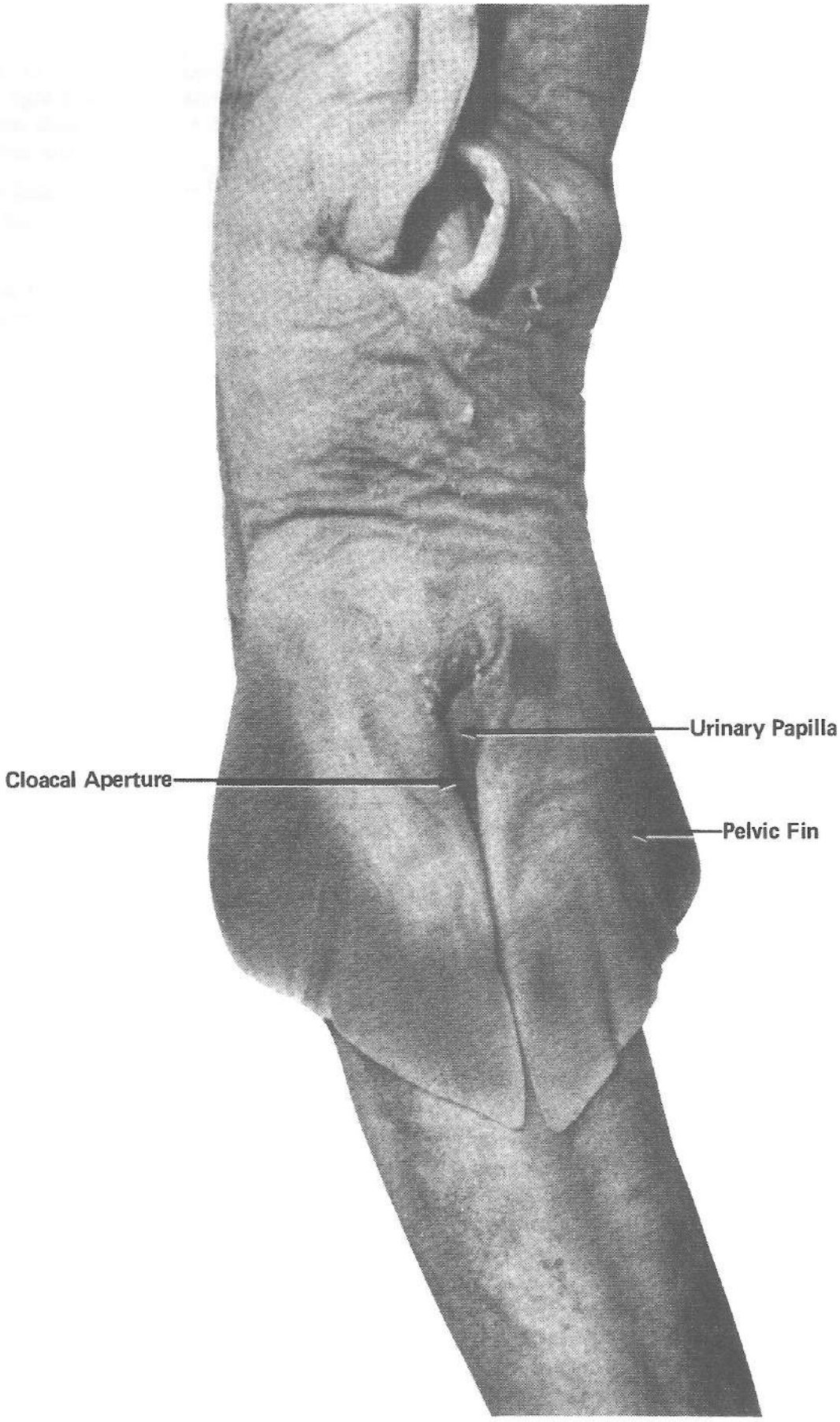
EXTERNAL FEATURES



HEAD – LATERAL VIEW



PELVIC REGION – MALE



PELVIC REGION – FEMALE