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ABSTRACT

This document provides science curriculum instructional material relating to marine biology. Items presented relate to live animal exhibits seen during visits to Sea World marine aquarium exhibits; however, all materials are also useful for in-class instruction without visits to Sea World displays. Ideally, material should be reviewed immediately prior to a Sea World exhibit. This unit has a theme of adaptation and includes transparencies and information sheets on sharks and adaptation for survival. (SL)

SEA WORLD Curriculum Guide

Program Theme: ADAPTATIONS 4-8

A SEA WORLD EDUCATIONAL PUBLICATION
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SHARK INFORMATION SHEETS

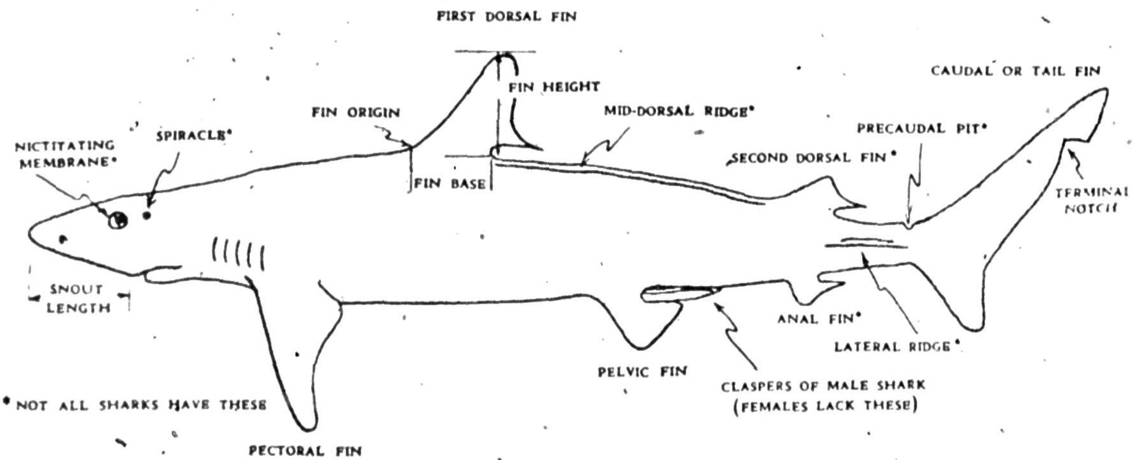
SEA WORLD EDUCATION DEPARTMENT

Sharks inhabited the earth long before humans did. Present-day sharks represent a very primitive group of vertebrates of which the first record appears in the Devonian period 265 million years ago. Although sharks have specialized, the basic characteristics of the modern shark evolved 140-170 million years ago during the Jurassic period.

Today between 250-300 species of sharks inhabit the world's waters. They are found in tropical and temperate seas as well as in freshwater lakes of South America and Africa. Sharks range in size from the giant 45-foot long whale shark, the largest fish in the world, to the tiny Midwater shark, measuring only 6 to 8 inches. The sharks (Selachians) together with the skates and rays (Batoideii) make up the order Elasmobranchi.

external anatomy

Sharks have an extremely efficient body plan. Each body part and each sense is designed to help them function in their role as top marine predators. Sharks often benefit their prey by consuming its weak and inferior members, thus strengthening the prey's breeding stock. Because sharks are an important part of the marine ecosystem, their senseless capture or slaughter would upset the delicate balance of marine life.



body shape

The slim, torpedo-like shape of most sharks requires less energy for swimming than would a non-streamlined body form. This energy savings is important to sharks, especially to those species which must swim continuously in order to breathe.

skeleton

Sharks, skates and rays have a skeleton of cartilage, the same substance which makes up the end of the human nose. Their skeletal material distinguishes them from the majority of fish species which depend on bone for body support.

spiracles and gill slits

Sharks get their oxygen from water passing over their gills. In pelagic sharks, water enters the gill chamber through the mouth. Because they have to move in order to pass this water over the gills, these sharks swim continuously with their mouth slightly ajar. In some shark species, this continual swimming is not necessary and they will rest on the bottom. Water enters the bodies of these sharks through spiracles, small openings behind the eyes, and is pumped over the gills. In both groups of sharks, water is expelled through each of the five to seven gill slits after its oxygen is absorbed by the blood.

fins

Unlike the bony fishes, sharks have fins which cannot be folded against their body but may be rotated during swimming and atagonistic display. The tail, or caudal fin, is used in an oarlike motion to propel the shark forward. This tail movement tends to drive the body downward while the pectoral fins and the angle of the snout provide lift. The balance of these two forces keeps the shark from swimming into the bottom. In males, the pelvic fin is modified into paired claspers, used in reproduction.

senses

hearing range measured to several thousand yards

Experiments have shown that sharks are attracted to an area when low-frequency pulsed sounds are produced. These sounds are similar to those a wounded prey would transmit. Because sound travels rapidly underwater, and over long distances, sound reception is thought to be the first sense sharks rely on in locating their prey.

The hearing system of sharks differs widely from man's. They lack a middle and outer ear, having only an inner ear. This inner part has three ear chambers in which are located hairlike sensory cells and a calcified ear stone (otolith). Sound causes vibrations between the otoliths and sensory hairs, which are conducted to the brain by the auditory nerve.

The upper portion of the inner ear also helps the shark maintain its balance. As it pitches and rolls, the movement of the otoliths against the sensory hairs conveys nerve impulses to the brain which then activates the muscles controlling the fins and eyes.

smelling range extends for hundreds of yards

Two-thirds of the shark's brain weight is devoted to the function of smell. This extremely acute sense in the shark allows it to detect minute quantities of substances such as fish body juices and blood in the water. Smells are picked up by olfactory (smelling) cells located in sacs within the shark's nostrils. The nostrils are found on the underside of the shark's snout, ahead of the mouth, and do not open into the mouth. Because sharks swim continuously, the olfactory cells are constantly bathed with new smells.

vibrations are sensed from hundreds of feet to within inches

Highly developed in sharks is the ability to sense vibrations and disturbances in the water around them. One of the ways they can do this is through a lateral line system. This system consists of fine canals, filled with fluid, that lie below the skin of the head and along the body sides. The canals open to the surrounding water through pores. Any vibration in the water causes movement of the canal fluid. This then triggers sensory cells in the canal to fire nerve impulses, alerting the shark to the outside disturbance.

When vision is impaired at night or in the moment of bite, sharks use their ampullae of Lorenzini. These are small pits containing mucus and sensory cells which pepper the snout. The ampullae function as electroreceptors in detecting electrical currents generated by prey. It is also thought that these can be used to detect the earth's magnetic field, thus aiding the shark in navigation.

vision most useful up to fifty feet

Since sharks' eyes are highly sensitive to dim light, they are able to pick out objects against a background, particularly moving ones. The reason for this is that the eye retina has a large number of rods, cells highly sensitive to contrasts of light and shadow. The eye is also lined with a layer of silvery plates which act as mirrors to reflect light back to the retina. Sharks lack the ability to see objects in sharp detail. This is because their eyes have few bipolar or ganglion cells for transmitting light impulses to the brain. It is thought that sharks also do not see color because they have no cones, those cells perceiving color.

shark teeth seize and cut prey

For their role as predators in the sea, most sharks are equipped with a formidable arsenal of teeth used in two basic actions: seizing and cutting food. Some shark species may have as many as five or more rows of teeth. A small number of species have molarlike teeth adapted for crushed prey.

extra teeth lie in wait inside the mouth

Lining the shark's jaw are rows of reserve teeth lying flat against the inside of the mouth. As teeth are broken off and lost, new teeth move up and into place. This is possible since the teeth are not firmly rooted in the jaw bone, but set loosely in the gums. New teeth continually develop in reserve rows, increasing in size as the shark grows.

size and shape of teeth vary

Each of the over 250 species of sharks has a characteristic tooth shape. These variations may be extreme within a shark family or very slight. For example, the great white shark has triangular, serrated teeth much different from the long, pointed teeth of the closely related mako shark. Interestingly enough, the two largest sharks, the whale shark and basking shark, do not have teeth at all, but strain large amounts of tiny plankton from the water with their modified gill rakers.

shark skin is covered with tiny teeth

The rough sandpaper feel of a shark's skin is due to its unique scales. Unlike those of bony fishes, shark scales are modified teeth called dermal denticles. Each is made of dentine and has an inside pulp cavity and an outer enamel coating. The shape and size of these denticles vary widely among shark species.

Internal Anatomy

heart and circulatory system

The heart of a shark is small in proportion to its body size and is located forward of the pectoral fins near the gill chambers. De-oxygenated blood returning from the body is circulated once through the two-chambered heart, and then pumped into the gills. There it picks up oxygen before being distributed throughout the body.

In most sharks the internal body temperature is the same as that of the surrounding water. Normal body processes warm the blood, but when the blood flows to the gills, it loses heat rapidly. As this blood circulates around the body, it cools the tissues.

Some sharks, such as the mako, porbeagle, and the great white, have a body temperature as much as 10 degrees warmer than the water. In a process called countercurrent heat exchange, the heat from blood flowing out to the body surfaces is transferred to cooler blood flowing into the body from the gill chambers. Since the heat is not lost, but retained in the body, a temperature higher than that of the surrounding water is maintained. This warmer body temperature increases the power of the muscles and speeds the transmission of nerve impulses - important assets for fast-swimming, predatory sharks living in temperate seas.

liver

A Shark's liver is extremely large, making up almost 25% of the total body weight, and acts as a storage reservoir for fatty acids. These fat reserves are used to provide energy when food is unavailable. The high fat content of the liver also provides some buoyance to the shark which, unlike bony fishes, has no gas filled swim bladder.

stomach

The stomach of a shark is shaped like a bag in a J or U form. The inside is rough and expandable. Stomach contents empty into a short, thick spiral valve which functions as the shark's intestine. Because this spiral-shaped organ has a large amount of absorptive space, long intestinal loops are unnecessary. The rate of digestion in most sharks has not been measured, but the digestive juices have been found to be so strong that even metal is dissolved.

reproduction

Shark eggs are fertilized internally as opposed to external fertilization in most bony fishes, and in many species, the eggs develop within the shark's uterus. When born, the young sharks are fully formed and physically able to fend for themselves. Bony fish can produce several million young but few survive. Because shark pups have a better chance for survival, the number of sharks produced in a litter is rarely over a hundred with the majority of species bearing far fewer pups.

development of young

On the basis of how their eggs develop, most sharks can be assigned to one of three groups: oviparous, viviparous or ovoviviparous.

oviparous These sharks lay external eggs encased in thick, rubbery shells which are then left to develop on their own. Embryos are nourished by the egg yolk and, depending on the species and water temperature, hatch within six to ten months. Horn sharks, swell sharks and whale sharks belong to this group.

viviparous The eggs of these species hatch internally in the oviducts. After the embryo consumes its egg yolk, a placental connection develops between the embryo and the mother. Her blood then provides food to the growing pup during the last stages of its development. In this group are blue sharks, hammerhead sharks, and some smooth dogfishes.

ovoviviparous As in the above group, the eggs of these sharks also hatch in the oviduct. The embryo gains nourishment only from its egg yolk until it is born. However, in some species, like the sand tiger shark, after the embryo consumes its egg yolk, it feeds on addditional eggs produced by the mother. Tiger sharks, makos and thresher sharks are examples of this group.

great white shark <u>Carcharodon</u> <u>carcharias</u>

This shark is known worldwide as an extremely dangerous and aggressive animal. However, little else has been discovered about the great white's reproduction, behavior patterns and numbers.

size

The largest recorded great white shark was taken off Cuba in the mid-1940s. It weighed 7100 pounds (more than the weight of three small cars) and measured a length of 21 feet.

range

Great whites live in cool and warm seas throughout the world and are found nearshore and in the open ocean.
They have been sighted along the entire length of California, particularly off the central coast, both in the winter and in the summer.

feeding habits

Labeled as the perfect eating machine, the great white shark's large size, speed, sharp teeth and powerful jaws make it an awesome enemy of ocean animals.
It swallows small prey whole and is known to tear large chunks of flesh from larger prey, such as whales and elephant seals.

teeth

Their imposing array of large, triangular, serrated teeth set great white sharks apart from the other members of their family. These teeth slope backward and are arranged in rows around the jaws. When teeth are broken off, they are replaced by others which lie in reserve against the inside surface of the jaws.

a top ocean predator

Great white sharks play an important role as a major predator in the ocean food chain. In many cases they consume sick or inferior animals which serves to strengthen the breeding stocks of their prey. The senseless capture of great whites is therefore harmful to the delicate balance of marine life.

Great White Shark *Carcharodon carcharias*

To the best or our knowledge, this is the largest great white shark ever taken off the Pacific Coast of North America.

It was taken on June 14th, 1976 southeast of Catalina Island, by the Ventura based, commercial swordfish boat Commanche, operated by Hans Weeren and Larry Mansur.

Preliminary studies conducted by Sea World's scientists have revealed the following:

Sex: female

Length: 18 feet ½ inch

Weight: 4,150 pounds

Girth: 10 feet 2 inches at the mid-section

Teeth: 2 inches (51 mm.) long. The teeth are triangular shaped with serrated edges, set in multiple rows.

Heart: 10 pounds. The relatively small heart was located just behind the gullet, close to the gills, where blood is oxygenated before being circulated through the body.

Liver: 575 pounds. Extremely large, the trilobate liver constituted nearly 15% of the total body weight. Fatty acids stored in the liver provide energy reserves and buoyancy.

Intestine: The single spiral valve intestine weighing 74 pounds, was removed and sent to parasitologist, Dr. Murray Dailey, of Long Beach State for analysis.

Stomach: It contained the remains of one large female elephant seal. Examination of other great white shark stomachs have revealed the remains of seals, sea lions, sea otters, other sharks, and bony fishes.

Extensive future studies of sharks have been planned.

Tissue samples from internal organs are taken from all sharks brought to Sea World, and are subjected to intensive microscopic study. They are analyzed for bacteria, enzymes and cell structure, as well as for the presence of internal parasites, pesticides and heavy metal traces. All organs are weighed, measured, tagged and frozen, and are available for future study by scientists throughout the country.

Opportunities to study the great white shark have been few and infrequent. A Sea World Exhibit and Research Facility, allowing for the husbandry and scientific study of living sharks, is now being designed and will be completed in the near future.

great white shark — *Carcharodon carcharias*

Collected September 7, 1975 by a commercial fisherman 7 miles southeast of Anacapa Island off the Southern California coast.

Preliminary studies conducted by Sea World scientists have revealed the following:

Sex: female
Length: 16 feet 3 1/2 inches
Weight: 3,440 pounds
Girth: 10 feet

External parasites: Parasitic copepods, commonly found on sharks, were collected from around the pectoral, pelvic, anal, dorsal and keel fins as well as from the tail.

Teeth: The largest tooth of the shark, measuring 1 3/4 inches, was removed from the front of the shark's upper jaw. The teeth are triangular shaped with sharp, serrated edges and are set in multiple rows.

Heart: Weighing approximately 5 1/2 pounds, the relatively small heart was located just behind the gullet, close to the gills where blood is oxygenated before being circulated through the body.

Liver: The extremely large, trilobate liver weighed 599 pounds (almost 1/5 of the total body weight). Fatty acids stored in the liver provide energy reserves and buoyancy to the shark.

Stomach Contents: A young female elephant seal weighing approximately 500 pounds was found partially digested in the shark's stomach.

Intestine: The single spiral valve intestine was removed and sent to parasitologists for study.

Extensive studies of this shark are underway.

Tissue samples from internal organs were taken for study. These will be analyzed for bacteria, enzymes and cell structure and for the presence of internal parasites, pesticide residues, heavy metal concentrations and other substances.

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Adaptations for Survival

The animals that live in the oceans of the world have evolved through thousands of years, so that they are specifically adapted for survival in their own particular eco-niches in a water environment. These adaptations enable them to successfully survive and reproduce; to eat and avoid being eaten.

MARINE MAMMAL ADAPTATIONS

Students will first learn how marine mammals have evolved special adaptations for living all or part of their lives in the water. Their bodies have become adapted for:

Breathing: They instinctively hold their breath and are able to remain submerged for relatively long periods of time. Some breathe through a blowhole located on the top of the head.

Swimming: They have streamlined shapes, and appendages that have developed into fins, flippers and flukes. Their bodies have a layer of blubber which gives them buoyancy and acts as insulation.

Sensing: Their sense of hearing has become highly specialized for use in the water, where sound travels almost 5 times faster than in the air. With their sense of touch, they can detect movements and changes of water pressure, which may be important indicators of food or danger.

ADAPTATIONS OF FISH AND AQUATIC INVERTEBRATES

Where marine mammals have had to re-adapt to a water environment, fish and aquatic invertebrates have evolved directly in the water. Most have gills instead of lungs and can take oxygen directly from the water. Since their body temperatures are the same as the surrounding water ("cold-blooded" animals as compared to "warm-blooded" mammals), they do not require special adaptations to regulate their internal temperatures.

In the endless food cycle of the sea, in order to obtain food and avoid being eaten, these aquatic animals have also had to evolve many special physical adaptations of color, body form and sensory organs.

SOCIAL ADAPTATIONS

Not only have the marine mammals, fish and invertebrates evolved special physical adaptations in order to survive, but also special social adaptations—ways of associating with their own kind, or with others different from themselves, for obtaining food, protection and insuring reproduction.

Teacher's Information

This transparency may be used with the Spirit Duplicating Master copy on **Comparative Swimming Methods in Four Mammals** to illustrate the increasing degree of aquatic specialization from the land dwelling human to the sea lion, which is adapted to both land and sea, to the seal, which spends some time on land, but is more adapted to the water, and finally to the dolphin, which is a mammal fully adapted to living in the water.

In particular you may want to discuss the advantages of some of these adaptations. For example:

Why is it an advantage for marine mammals not to breathe through their mouths? Why would this be important while feeding?

Why would it be an advantage for them to naturally hold their breath and consciously have to open the nostrils or blowhole to breathe? How would this help during long dives?

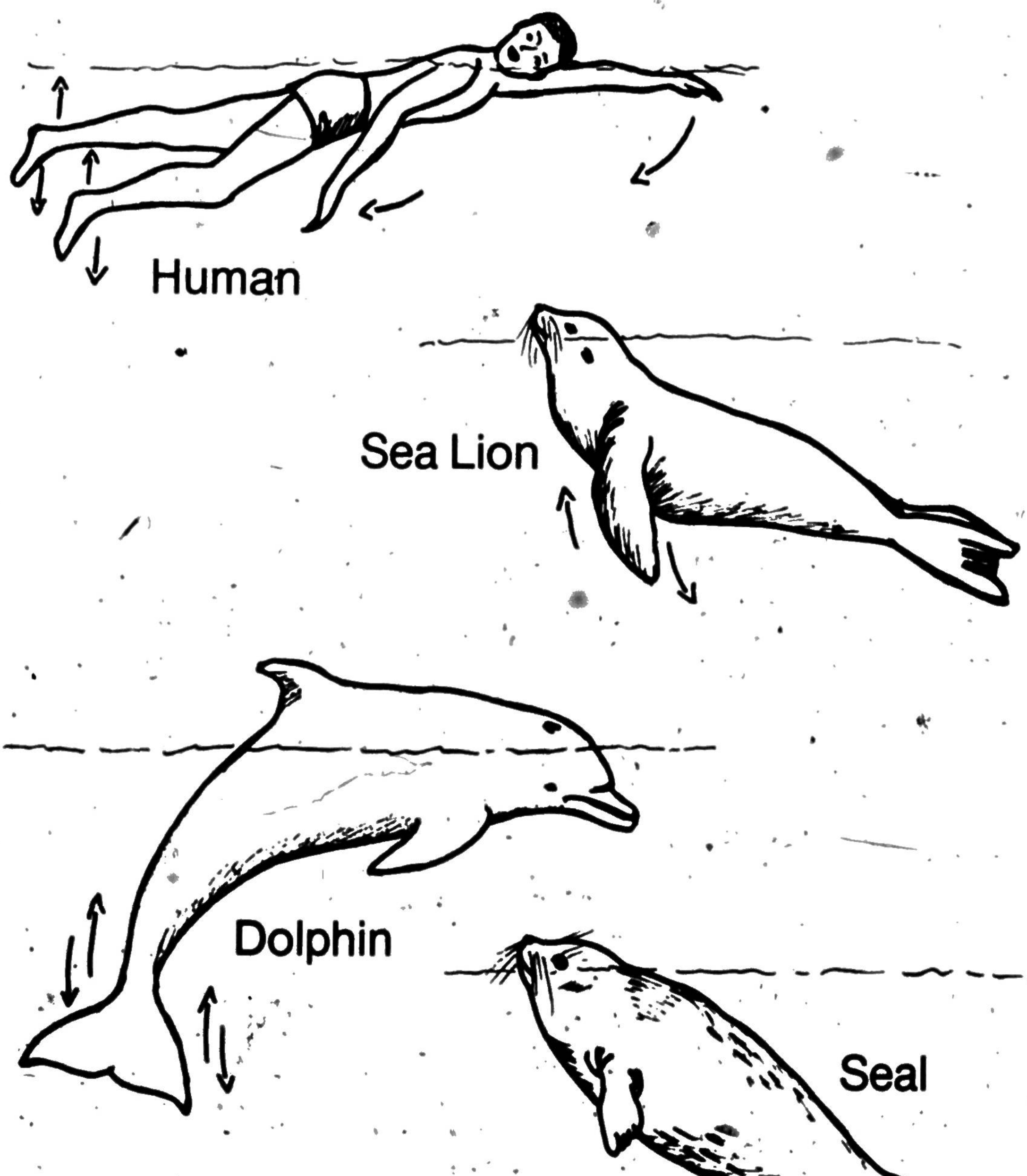
Why is it an advantage to use the tail or hind flippers as the principle means of propulsion? Which is more efficient pushing or pulling?

FURTHER RESEARCH

To encourage further reading about these marine mammals a bibliography of suggested additional reading has been included in this packet. Students might also be encouraged to bring in articles from newspapers or such magazines as: National Geographic, Nature, Oceans, Ranger Rick, and the National and International Wildlife Association Magazines, to share with the class.

CREATIVE WRITING

After doing further reading on these animals the students might try to write their own story about a day in the life of one of these animals—either an animal they have seen at Sea World such as the sea lion, harbor or elephant seal, dolphin or killer whale; or one of the other related marine mammals which particularly interests them such as the grey or humpback whales, walrus, sea otters, Weddell or leopard seals, etc.



Transparency 1

Teacher's Information

Whales and dolphins, like marlin, tuna and sharks live in the sea and are fast swimming predators.

Although the first group are marine mammals and the second group are pelagic fishes, they have evolved many similar adaptations; so much so that whales and dolphins are often mistakenly referred to as fish.

This transparency may be used to illustrate discussions on the similarities as well as the important differences between these pelagic fish and mammals.

SIMILARITIES

Shape: have streamlined, cylindrical "torpedo-shaped" bodies for fast swimming.

Locomotion: have large, wide tail fins or flukes used for rapid propulsion.

Color: are darker on top (dorsal surface) and lighter on the bottom (ventral surface) which makes them difficult to see from above (against the dark bottom) and from below (against the lighter surface).

Feeding: have large mouths with sharp teeth for biting and tearing, but not for chewing. Their diet consists of live crustaceans, fish and in some cases marine mammals and birds.

DIFFERENCES

Locomotion: *Fish* use their body and tail in a side to side motion. These *marine-mammals* use their tails only, in an up and down motion.

Breathing: *Fish* have gills which absorb oxygen directly from the water. *Mammals* have lungs and must breathe air.

Reproduction: Most *Pelagic fish* lay eggs and the young must fend for themselves after hatching. *Marine mammals* give birth to live young which they nurse and care for until old enough to obtain food for themselves.

Temperature control: *Fish* have a body temperature that is the same as the surrounding water (they are "cold-blooded"); no temperature controls necessary. *Mammals* have a body temperature that must remain relatively constant (they are "warm-blooded"). They have a layer of blubber for insulation plus a complex heat exchanging vascular system in their tail and flippers.

Transparency 2

Teacher's Information

This transparency may be used to review information concerning the adaptations of fish and invertebrates to their particular econiches in an aquatic environment.

Fish that live in the shallow world of sunlight and shadows of coral reefs, plants and rocks are adapted in different ways than the fast swimming open ocean predators. Bottom dwelling fish and invertebrates are generally slow moving, so have evolved special adaptations to survive. To eat and keep from being eaten in their world, how have these marine animals become adapted for the following:

Locomotion: shape of body, use of fins or legs, etc.?

Protection: coloration, hard shells, sharp or poisonous spines, etc.?

Food getting: small pincher-shaped mouths, tentacles, claws, etc.?

ART EXPRESSION

Make a wall mural ranging from a coral reef to a coastal tidepool with the background executed in finger paints, or poster paints. Have students draw and cut out various marine animals to be placed in their appropriate econiches. Include as many kinds of animals as they can remember from their visit to Sea World, such as —

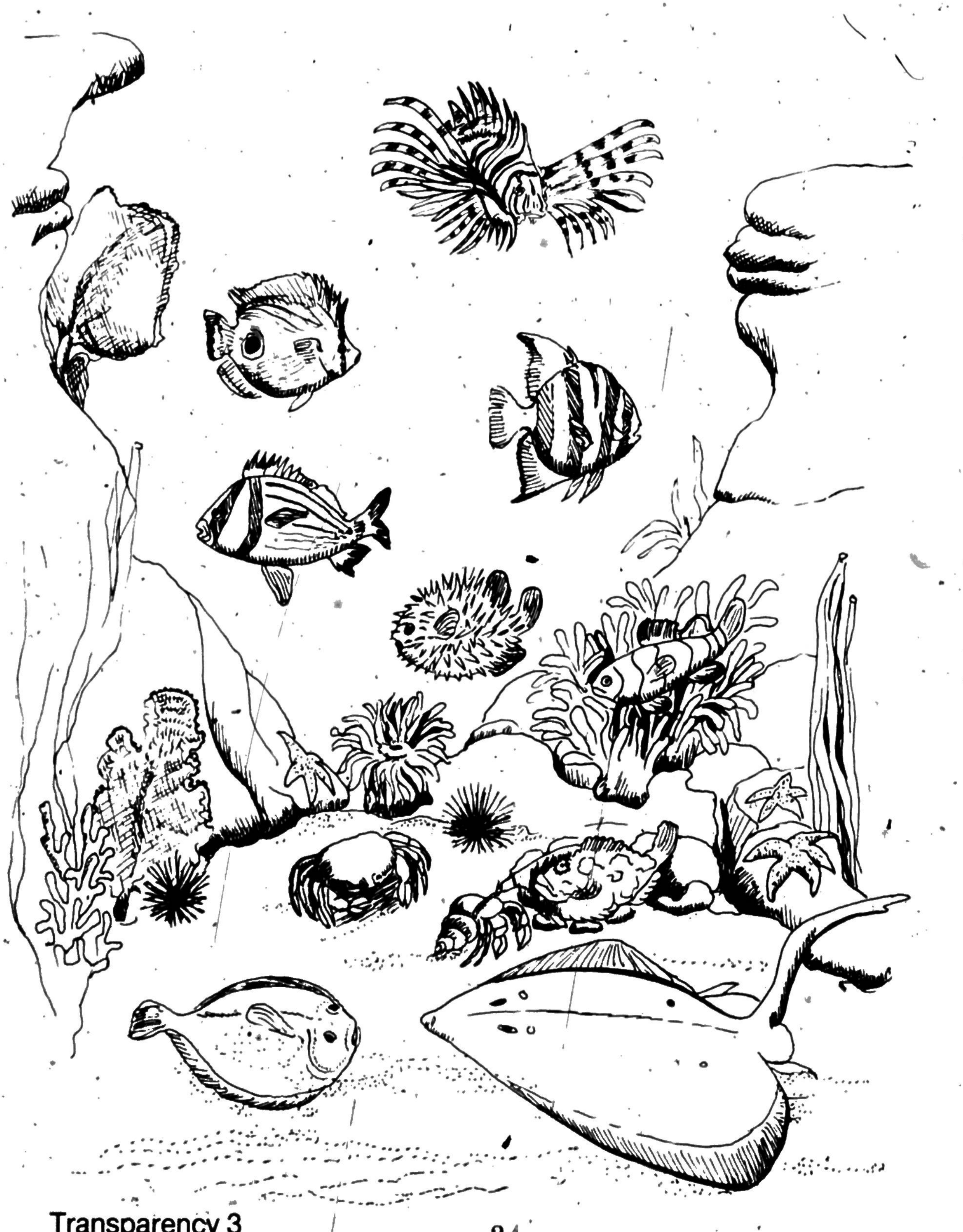
Coral Reef	In or Near Rocks	Sandy Bottom	Tide Pool
Angelfish	Crab	Crab	Limpet
Butterflyfish	Eeel	Starfishes	Chiton
Porkfish	Lobster	Ray	Crab
Porcupine fish	Octopus	Flatfish	Starfishes
Triggerfish	Rockfish	Molluscs	Anemone
Lionfish	Stonefish	Guitarfish	Sea cucumber
Anemone	Starfishes	Sand dollar	Sea hare
etc.	etc.	etc.	etc.

CREATIVE WRITING

Have students choose a marine fish or invertebrate to write about in the first person. For example—"A day in the life of a starfish." Story should include how the animal moves about, finds food (what kind of food and how he catches it), how it keeps from being eaten (hides, swims away, camouflage, sharp spines, etc.) and keeps healthy (visit to cleaner fish).

DRAMATIC EXPRESSION

The children might develop and act out the dialog for a T.V. or radio interview in which marine animals are interviewed to come and live in a Sea World Aquarium or Tide Pool. One child could play the part of the interviewer—a Sea World marine life talent scout, (they might choose a familiar personality to mimic or that *famous* talent scout "Charlie the Tuna.") The other children would choose a fish or invertebrate they would like to represent and tell the interviewer why they are so special and why they are good examples of special adaptations in marine animals.



Transparency 3

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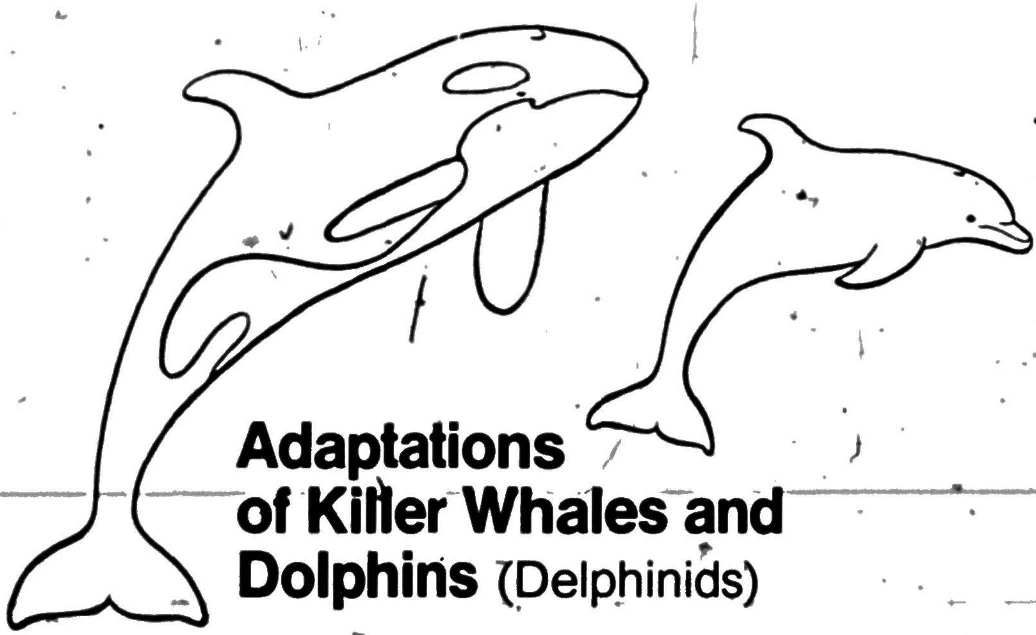


Adaptations of Killer Whales and Dolphins (Delphinids)

Dolphins and killer whales are warm blooded mammals, which breathe air and nurse their young, but whose bodies have become adapted for living entirely in the water.

STRONG GRACEFUL SWIMMERS

With smooth, streamlined *bodies*, the delphinids can move quickly and gracefully through the water, propelled by the powerful up and down strokes of their *tail flukes*. The tail flukes do not contain the bones of the foot (their ancestors lost these millions of years ago), but are a specially broadened and flattened tail adapted for swimming. The up and down motion of a dolphin or whale's tail differs from the side to side movement of a fish's tail. This enables them to swim fast, and helps them surface to breathe while swimming.

HANDS HAVE BECOME FLIPPERS

The *pectoral flippers* on the sides of a dolphin and whale contain bones similar to your hands, but are covered to form a solid flipper, more useful in swimming. They use these for steering and as brakes in quick stops and fast turns. A *dorsal fin* on the back gives stability (keeps them from rolling).

SPECIAL COLOR AND TEMPERATURE ADAPTATIONS

Like other pelagic animals (animals that live in the open seas), dolphins and whales are lighter in color on their under sides. This lighter color makes it difficult to see them from below against the lighter surface. They are darker in color on their upper sides, which makes them more difficult to see from above against the darker water.

Killer Whale and Dolphin Adaptations (cont.)

Unlike fish, whose body temperature is the same as the surrounding water (they are cold blooded), whales and dolphins are warm blooded animals and their bodies must be insulated from the colder water temperatures. Therefore, the bodies of marine mammals are insulated with a thick layer of blubber which has the added advantage of helping them to float.

BREATHE THROUGH HOLE ON TOP OF HEAD

Dolphins and whales do not breathe through their mouths. Their *mouths* are for eating and are equipped with sharp cone shaped teeth for catching and holding fish (or other marine animals) which are usually swallowed whole.

Dolphins and whales breathe through a *blowhole* located on the top of their heads. This allows them to breathe when they are swimming near the surface without lifting their heads out of the water, as you must in order to breathe. When swimming or diving underwater, the blowhole remains closed. They hold their breath naturally and must consciously open the blowhole to breathe. This is a special adaptation shared by marine mammals.

USE SONAR TO "SEE" UNDERWATER

Dolphins and whales have small eyes with curved lenses for seeing underwater, but for swimming or diving in dark waters at night or in murky waters of inland waterways and bays, they rely more on their sonar to find their way around. "Whistling" and "clicking" sounds are sent out by the dolphins and whales. These bounce off objects, and the returning sounds (echos) inform them what objects are near them and what they are like—their size, shape, texture, thickness, etc.

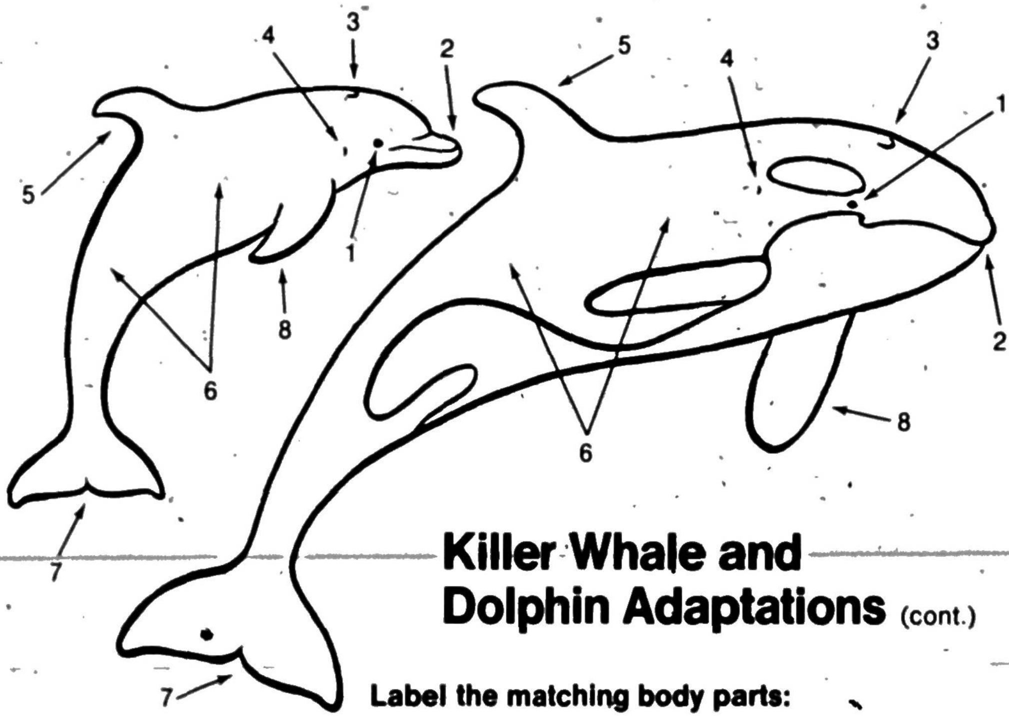
This echo-locating system of marine mammals is now being researched by scientists who hope to find ways for man to move, work and even live underwater more easily and safely.

WHEN YOU VISIT SEA WORLD

Look for the blowhole on the dolphin and the killer whale.
When is it open? When is it closed? How often do they breathe?

Listen to the sounds the dolphin and killer whale make.
How many different sounds can you hear? What do they sound like? When do they make them? How do they make them?

Watch these animals swim.
Why are they able to swim so fast? How does their shape effect their swimming speed?



Killer Whale and Dolphin Adaptations (cont.)

Label the matching body parts:

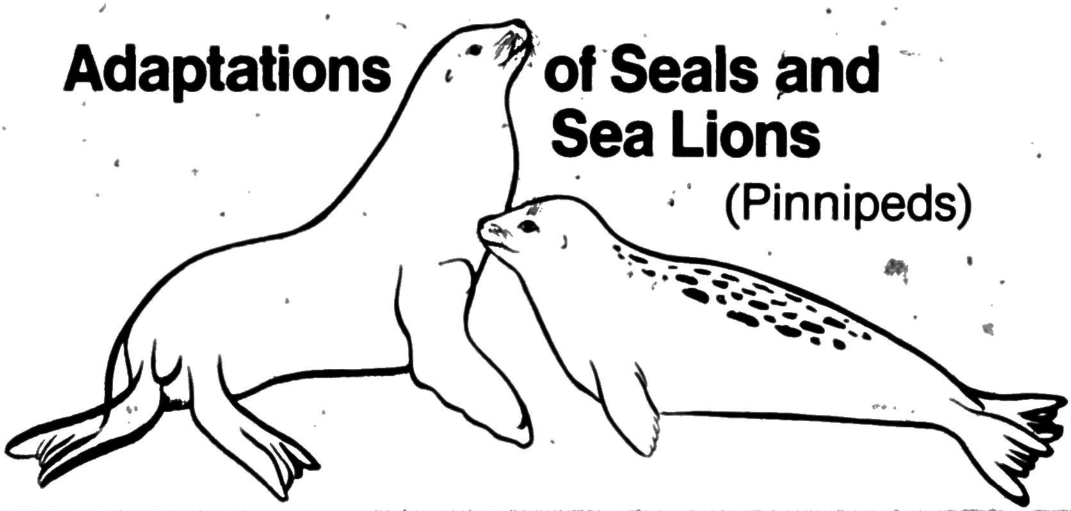
1.______________________ 2.______________________
3.______________________ 4.______________________
5.______________________ 6.______________________
7.______________________ 8.______________________

Fill in with the correct number:

1. Equipped with sharp teeth for catching and holding food ______.
2. Streamlined shape adapted for fast swimming to catch food and escape from danger ______.
3. Used in powerful up and down strokes for fast swimming to catch food and escape from danger ______.
4. Used for steering, braking and turning ______.
5. Gives stability in swimming by keeping animal from rolling ______.
6. Darker on top, lighter on bottom for protective coloration ______.
7. Insulated with thick layer of blubber ______.
8. Remains closed underwater; located on top of head for breathing while swimming ______.
9. Makes sounds with it for communication and echo locating ______.
10. Used for hearing ______.

Adaptations of Seals and Sea Lions

(Pinnipeds)



Seals and sea lions, like other marine mammals are warm blooded, air breathing animals, which nurse their young and have become physically adapted to successfully live in the water. However, like their cousins the walrus, they have retained many of the physical features of their land dwelling ancestors. These serve them well when they return to the land to rest, and to give birth to their pups.

HAVE FLIPPERS FOR LOCOMOTION

The sea lion's large and powerful *front flippers* have retained the bones of the forearm and hand. These flippers are used in an up and down flying motion to propel the animal through the water. Seals use their smaller front flippers to help steer, and fold them next to their streamlined bodies for gliding.

Unlike dolphins and whales, seals and sea lions have retained the leg and foot bones of their land dwelling ancestors in their *hind flippers*. Sea lions are able to bend these flippers under them and use them for walking on land. In the water, they use them for steering.

How they use their flippers for locomotion is one way to distinguish seals from sea lions. Seals cannot bend their hind flippers under their bodies. On the land they must "hump" along, undulating their bodies like caterpillars as they push with their front flippers. In the water, seals use their hind flippers for propulsion, sculling them back and forth to thrust their streamlined *bodies* rapidly through the water.

A NOSE THAT CLOSES UNDERWATER

The *nose* of a seal or sea lion is on the front of the snout, like a land mammal's, and not on top of the head like the blowhole of a whale or dolphin. However, like the blowhole, the nostrils of the seal and sea lion remain closed (they hold their breath naturally) and must be consciously opened to breathe. This is an adaptation particular to marine mammals, and is just the opposite of land mammals, which breathe naturally and must consciously hold their breath.

Seal and Sea Lion Adaptations (cont.)

SENSES THAT OPERATE UNDERWATER AND IN THE AIR

Pinnipeds have large brown *eyes* with thick curved lenses, which make them near sighted on land, but enable them to see very well underwater. They have pupils which are adapted to open very wide to let in the diminishing light when diving. They are equipped with a set of eyelids which protect their eyes when on land, and a set of clear membrane eyelids which cover the eye when underwater.

Seals and sea lions have highly sensitive hearing and are thought to use echo-locating sonar to detect underwater objects, and determine their size and shape. Seals have only *ear holes* on the sides of their heads, which add to their streamlining. Sea lions have small *ear flaps* like land mammals.

Extremely important for locating food underwater are the *whiskers* of the seal and sea lion. Equipped with highly sensitive nerves, the whiskers act as antennas and record movement in the surrounding water as well as temperature and pressure changes. On the land, by pushing their whiskers forward, seals and sea lions can touch objects to identify what they are like—much as we use our fingers to tell a slippery grape from a rough piece of bark.

WHEN YOU VISIT SEA WORLD

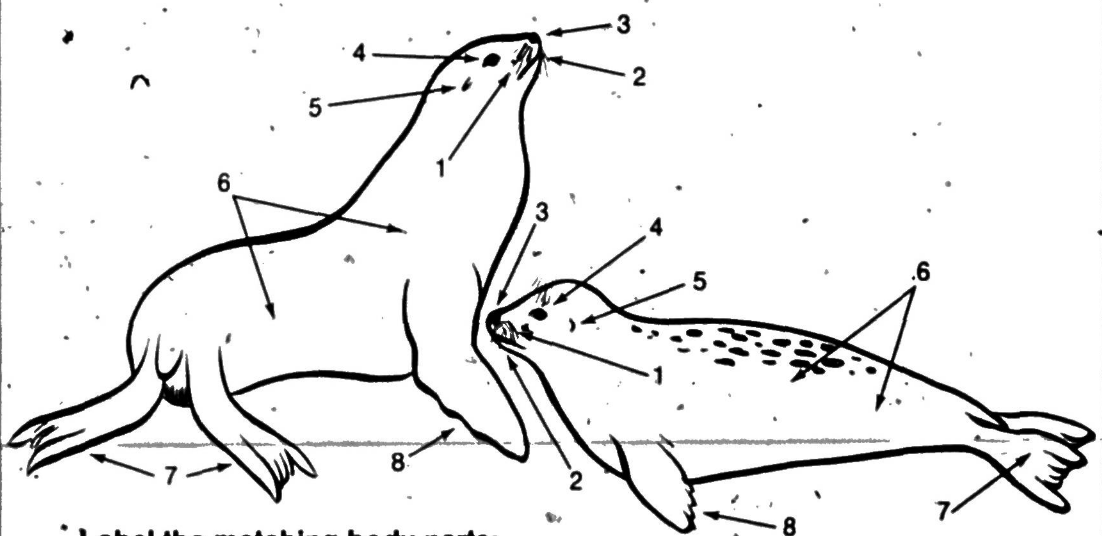
Watch the seals and sea lions swim. Note how extremely streamlined and supple they are in the water.
Can you describe how they differ in the use of their flippers for swimming?

Watch the seals and sea lions move on the land.
How does the seal move? How does the sea lion use its hind flippers to walk?

Watch the sea lions playing together or performing in a show.
How do they use both their front flippers and whiskers as you would use your hands?

Watch seals and sea lions breathe.
When are the nostrils open? How long can they stay underwater?

Seal and Sea Lion Adaptations (cont.)



Label the matching body parts:

1.____________________ 2.____________________

3.____________________ 4.____________________

5.____________________ 6.____________________

7.____________________ 8.____________________

Fill in with the correct number:

1. Used for catching fish, has sharp teeth ________.
2. Streamlined shape adapted for fast swimming to catch food and escape from danger ________.
3. Sea lions use to propel through water ________.
4. Seals use to propel through water ________.
5. Sea lions use to steer in water ________.
6. Seals use to steer in water ________.
7. Sea lions use to walk on land ________ and ________.
8. Seals use to move on land ________ and ________.
9. Adapted for seeing in air and underwater; pupils enlarge for deep dives ________.
10. Sensitive antennaes for feeling ________.
11. A smooth hole on seals, has an external flap on sea lions ________.
12. Remains closed underwater, must be opened to breathe ________.

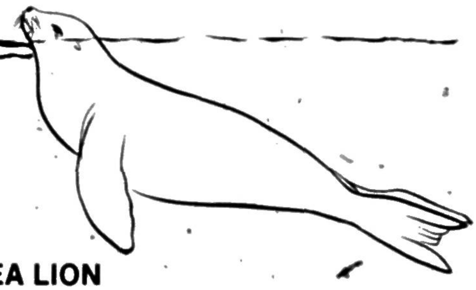
Comparative Swimming Methods in four Mammals

HUMAN

Nose: Must lift up or roll head to side to breathe. Can breathe through mouth or nose. Nostrils are open. Must consciously hold breath underwater.

Arms: Used in pulling motion to move body forward. Must cup hands and hold fingers together.

Legs: Used in up and down motion to move body forward.



SEA LION

Nose: Lifts head and consciously opens nostrils to breathe. Nostrils are closed under water.

Arms: Powerful pectoral flippers used in up and down "flying" motion to move through water.

Legs: Hind flippers are used for steering.

SEAL

Nose: Lifts head and must open nostrils to breathe. Nostrils are closed underwater.

Arms: Small front flippers usually held against side when swimming or used to help steer.

Legs: Large hind flippers are sculled in a side to side motion to move through the water.

DOLPHIN

Nose: Blowhole on top of head so does not have to lift head to breathe. Blowhole must be opened to breathe. Is closed underwater.

Arms: Pectoral flippers used for stability, steering and brakes.

Legs: NONE. Has powerful tail flukes used in an up and down motion to move through the water.

The Six Senses of Fish

Aquatic animals have senses adapted for seeing, hearing, feeling, tasting and smelling in the water, as well as the remarkable lateral line of fishes.

SEEING

Fish have no necks so they cannot turn their heads. Their large round eyes protrude from the sides of their heads giving them a wider field of vision. Have you ever seen a picture taken with a wide angle "fish eye" camera lens? If so you know how much more can be seen at one time than with a common flat camera lens (which is much like your eye). The no neck problem has been solved by crustaceans (lobster, crabs and shrimp) by having their eyes on moveable stalks.

HEARING

Man has called the oceans the "silent sea," because his ears are not adapted to hearing very well in the water. The sea is anything but silent. Sound travels very well in water (almost 5 times faster than in air) and marine animals have many ways of making sounds. Most marine animals have highly sensitive hearing. Man has had to construct hydrophones and sonar receivers to hear as well. Some fish, like the electric eel, use electrical impulses (much like sonar) to locate their food.

FEELING, TOUCHING AND TASTING

Fish have a unique device called a lateral line. This is a row of sensory nerves along each side of their bodies which are sensitive to movement and pressure changes in the water around them. Sightless fish that live in dark underground caves depend on these lateral lines to find food and to navigate.

Many bottom dwellers which have hard shells, protective spines or tentacles have no need for eyes, but use their sense of touch to find food. The tentacles of anemones and the tube feet of starfish and sea urchins are used to sense food.

The catfish which feeds on the bottom has eyes to watch for predators, but feels for his food with his whisker-like chin barbs that are sensitive to touch, and are also covered with taste buds.

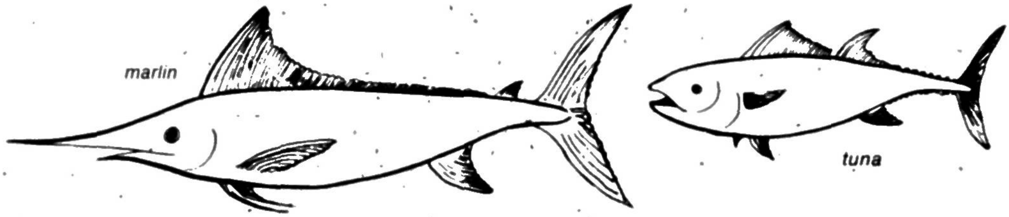
SMELLING

Many predators, like sharks and eels, use their sense of smell to locate food. Salmon are thought to be able to find their way across hundreds of miles of open ocean to their home streams by means of this sense.

WHEN YOU VISIT SEA WORLD—Can you find the lateral line on a park fish? Observe how the electric eel uses its hearing to find food. Watch how the anemone responds with its tentacles to edible and inedible objects.

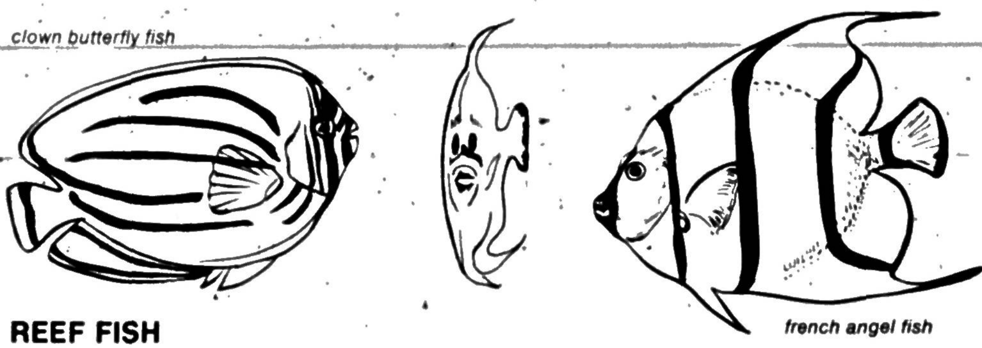
Adaptations for Locomotion

Aquatic animals have evolved distinctive shapes and swimming appendages for efficient locomotion in their environments.



PELAGIC FISH

Streamlined "torpedo-shaped" bodies with wide spread "V" or sickle shaped tails, and narrow streamlined fins are adaptations of the fast swimming fish of the open oceans.



REEF FISH

Fish which must be able to maneuver between the coral heads, rocks and plants of their homes usually have bodies flattened from side to side (laterally compressed), with short fan-shaped tails and fins for abrupt, stop and start, darting movements.

BOTTOM DWELLERS

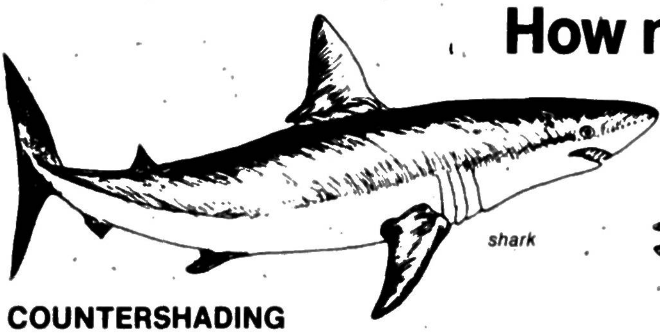
For swimming, undulating or crawling along the bottom, these aquatic animals usually have bodies flattened from top to bottom (dorsal-ventrally depressed). These flat shapes are particularly helpful to animals living in tide pools. Why?

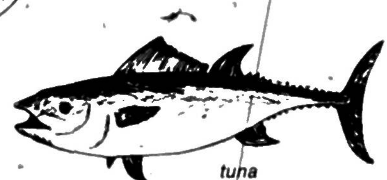
WHEN YOU VISIT SEA WORLD—Can you determine where the fish live by their shapes? How do reef fish use their fins to hover in one spot? Look at the flat fish. It started life as a compressed fish swimming upright, but now lives on the bottom. How has it adapted?

Protective Color and Shape Adaptations

To avoid being seen is an important part of survival for many aquatic animals.

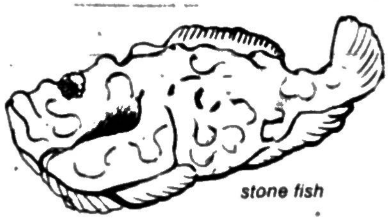
How not to be seen

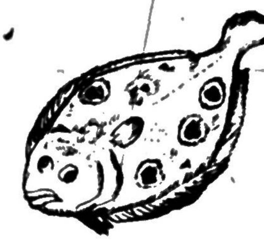




COUNTERSHADING

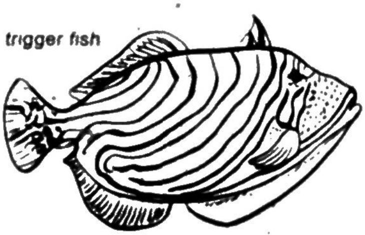
Pelagic fish which live in the open ocean are darker on the top (making them difficult to see from above against the darker water), and are lighter on the bottom (making them difficult to see from below against the lighter surface).

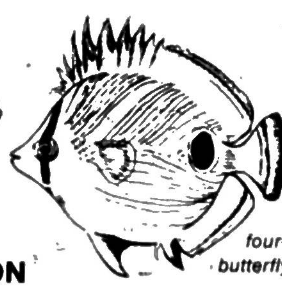


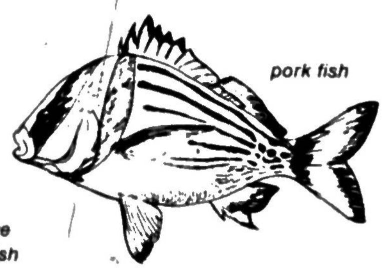


CAMOUFLAGE

Many marine animals are adapted to blend with their surroundings, both in shape and color, and some can even change their color, like the octopus and the flat fish.





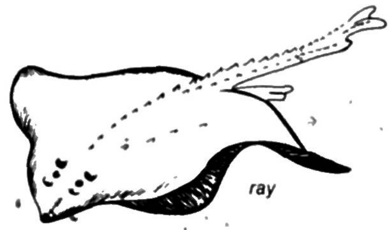


DISRUPTIVE COLORATION

Many fish that live in the changing lights and shadows of the shallow waters of reefs have lines or spots which disguise their body shapes and hide the distinctive round shape of their vulnerable eyes. Some even have false eyespots on the rear portions of their bodies to fool predators into thinking they are coming when they are really going.

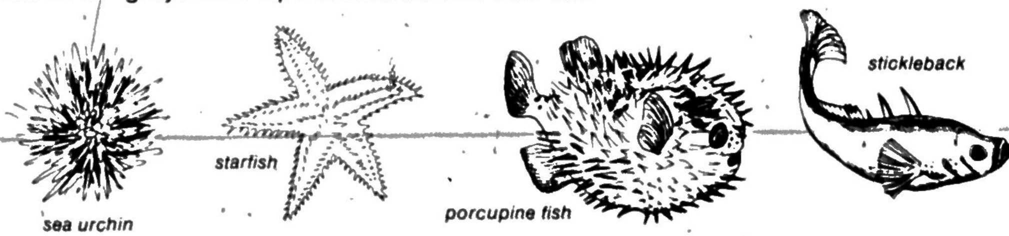
WHEN YOU VISIT SEA WORLD—Look for false eye spots on fish. How many stone fish can you find? Some fish like the Garabaldi are brightly colored with no disruptive markings. They do not try to camouflage themselves. Can you find out why?

Helpful Appendages

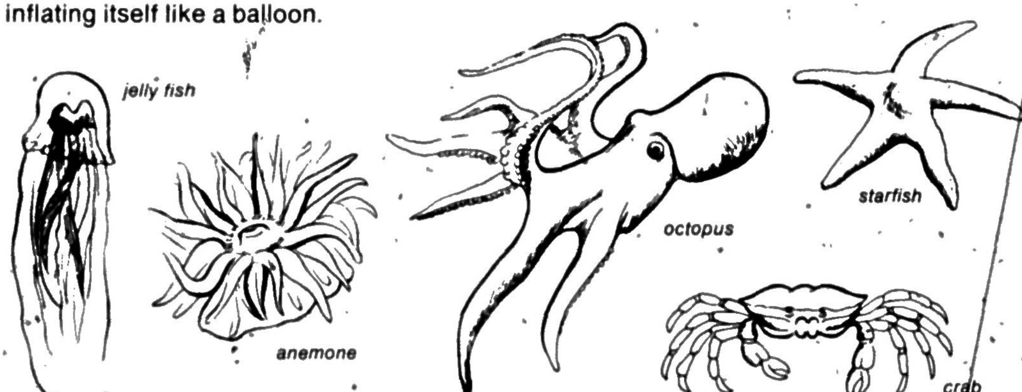


SPINES FOR PROTECTION

Many fish, which are not fast swimmers, have sharp or poisonous spines for protection. The lion fish, scorpion fish and stone fish have venomous dorsal spines along their backs. Stingrays have a poisonous dart on their tail.



Some sea urchins and starfish have their upper surfaces protected by sharp spines. The stickleback and triggerfish have dorsal spines they can erect and lock in place to keep from being swallowed. The porcupine fish is also covered with spines which it erects by inflating itself like a balloon.



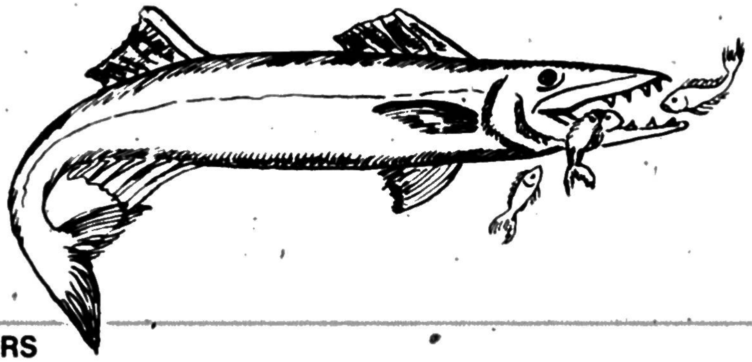
ARMS AND TENTACLES FOR CATCHING AND HOLDING

Some sea animals, like starfish and octopus have arms equipped with suction tubes or discs for catching and tenaciously holding their food. Some lobsters, crabs and shrimp have pinching claws on the ends of their appendages. Jelly fish and sea anemones have tentacles equipped with stinging cells to catch their food.

WHEN YOU VISIT SEA WORLD—Which are the three most poisonous fish? How would a starfish use its arms to open a tightly closed clam shell?

Helpful Partnerships

Besides being physically adapted to survive in their environments, marine animals have also evolved some unique social adaptations to improve their chances of survival. Schooling fish join others of their own kind for protection and to find food; but some animals have adapted some rather strange but beneficial partnerships with other kinds of animals. These relationships are called symbiosis.



CLEANERS

A very important type of relationship in the reef world exists between the brightly colored cleaner fish and cleaner shrimp and the larger predator fish. Instead of trying to conceal themselves, these animals advertise that they are around, for they have a service to offer. They keep other fish clean and healthy by removing bits of dead or infected skin as well as skin parasites and fungus. In return they obtain food and immunity from being eaten.

HERMIT CRABS

The hermit crab does not have a hard shell of his own but borrows the empty, discarded shells of others. Sea anemones sometimes grow on these shells providing camouflage for the crab's home, and in turn are carried about by the crab to new feeding areas.

ANEMONE FISH

The brightly colored anemone fish enjoy a safe home for themselves and their young amongst the stinging tentacles of the sea anemone, to which they are immune. In return, their bright colors help lure other fish for the anemone to eat.