THE DALLAS WORLD AQUARIUM

Living Seas:

A Resource for Teachers

Fish are typically cold-blooded (ectothermic) aquatic vertebrates with gills and fins. The body of a fish is covered with skin that is usually scaly (or has bony plates), has color pigments and may contain slime-producing glands. Some can breathe air and move on land. They are found in both saltwater and freshwater, from the deepest parts of the oceans to mountaintop streams.

Fish are believed to be the oldest, simplest, and most plentiful (both in individuals and species) of all animals. About half of all species of vertebrates are fish (estimated to be 25,000) which outnumber the other four combined classes of terrestrial vertebrates (amphibians, birds, mammals, and reptiles). Fish are divided into three major groups: cartilaginous fish, bony fish, and fish without jaws.

The jawless fish group is made up of hagfish and lampreys. The backbone of this group is a rod-like structure made of gristle. In general, jawless fish prefer cool, temperate waters. Lampreys and hagfish are eel-like animals with skin containing many mucus glands, making them extremely messy to keep in aquariums.

Lampreys use their round, suctioning mouth to attach themselves to other fish to feed on their blood and muscles. Hagfish use their suctioning horseshoe-shaped mouth to feed on dead or dying sea life and trapped prey unable to escape.

Cartilaginous fish have backbones made of pliable tissue that is softer than bone. The ears and nose of humans are made of this gristle-like cartilage. This group includes chimaeras, sharks, and rays. The chimaeras are a primitive group of fish found in deep, cold salt water and most often feed on echinoderms, crustaceans, and mollusks.

Sharks are perhaps the most familiar of all sea animals. The typical graceful, hydrodynamic shark has a pointed nose, two dorsal fins, and a sickle-shaped tail. Their teeth are highly developed, usually in four to six rows with only the first two rows being used. Replacement teeth, in the back rows, move forward as new teeth are needed. Other sharks, such as the nurse shark, shed their teeth and grow new sets every eight days.

Sharks feed primarily on fish, some scavenge on whatever is available, and others feed on mollusks and crustaceans. The largest shark, the whale shark, feeds on tiny forms of plankton. The whale shark (also the largest fish) is between 45-60 feet (13.7-18.2 m) long. The smallest adult shark, *Squaliolus laticaudas*, is only 8-10 inches (20.3-25.4 cm) in length. Most sharks live in salt water; however, a few species inhabit freshwater lakes and rivers. They can be found in all oceans except the Antarctic and live in all depths, however, most sharks live near coastal areas.

Sharks

Brown (or sandbar) sharks *(Carcharhinus plumbeus)* have a slate gray to brown upper body; lower surface is a paler shade of the same color or white. They have stout bodies and short, rounded snouts.

The first dorsal fin is very tall (up to 18 percent of the shark's total length), is triangular, and has a concave rear edge. The second dorsal fin and anal fins are about the same height. The tips and rear edges of the fins are darker than the rest of the body. The pectoral fins are large and broad. The upper teeth have broadly serrated cusps (grinding surface of a tooth) with finely serrated edges. The average length of adult females is between seven or eight feet (2.1-2.4 m); males average six feet (1.8 m).

Brown sharks consume fresh fish (eels, barracuda, mackerel, shad, grouper, flounder, skates, stingrays, squid, shrimp, mollusks, blue crabs, and smaller sharks). They have few predators other than humans. Shark pups are often preyed upon by other sharks.

Brown sharks are found in all the world's tropical waters (inshore and pelagic), between the surface and a depth of approximately 920 feet (280 m). They reach maturity between 3-13 years; life spans are estimated to seldom exceed 21 years. Reproduction is viviparous, once every two years 8-10 live young are born, after a 12-month gestation period.

Overfishing is a concern, particularly since they reproduce only once in two years. They are an important commercial shark species, harvested for their meat, hides, fins, and livers (which contain vitamin-rich oil).

Black-nosed sharks *(Carcharhinus acronotus)* are small, slender sharks with a moderately long and rounded snout. The first dorsal and pectoral fins are small. They are gray or green/gray, sometimes yellow/gray or brown above with a dusky or black spot on the underside of the snout tip. The distinctive black spot on the underside of the snout tip distinguishes it from other gray sharks.

The bonnethead shark *(Sphyrna tiburo)* is one of the smaller species of hammerhead sharks. The snout is shaped like a shovel and is broadly rounded. They are gray brown above and lighter on the underside. Bonneteads reach an average size of 36-48 inches (91 - 122 cm), with a maximum length of approximately 59 inches (150 cm), with females reaching greater lengths than males.

The bonnethead is an active tropical shark that swims in small groups of up to 15 individuals, but sometimes migrating schools of hundreds have been reported. It uses a special body fluid (called cerebrospinal fluid) to let others know it is in the area. It is a timid shark.

Bonnethead sharks feed primarily on crustaceans, consisting mostly of blue crabs, but also shrimp, mollusks, and small fishes. The bonnethead is viviparous, reaching sexual maturity at about 30 inches (76 cm). Bonnetheads are the only known sharks to exhibit sexual dimorphism (male and female adult bonnetheads look different from each other).

They are found in the Western Atlantic (Rhode Island and North Carolina to the Caribbean and southern Brazil) and in the Eastern Pacific (southern California to Ecuador). This species is abundant within inshore, coastal, continental, and insular shelf areas within its range and commonly found in estuaries, shallow bays and channels, mud and sand flats, and reef habitats.

Rays

Also included in the cartilaginous group are rays, sometimes referred to as “flat sharks”. Rays lie on the bottom on their bellies. The gill slit openings are on the underside of their body, making it difficult to take in clean water. Instead, the circular openings behind each eye (called spiracles) allow clean water to flow into the gill chamber and be pumped out through the gill slits.

Most rays remain near the bottom, feeding on shellfish, worms, or other bottom-dwellers. They grind their food with flat teeth. Stingrays, eagle rays, butterfly rays, torpedo rays, and manta rays are some of the more common animals included in this group. The large manta ray can grow to be 20-25 feet (6-7.6 m) wide between fin tips.

South American freshwater stingrays (family Potamotrygonidae) belong to the only group of elasmobranchs completely restricted to freshwater habitats. Freshwater stingray species have been regularly captured for the pet trade and used as a subsistence food source.

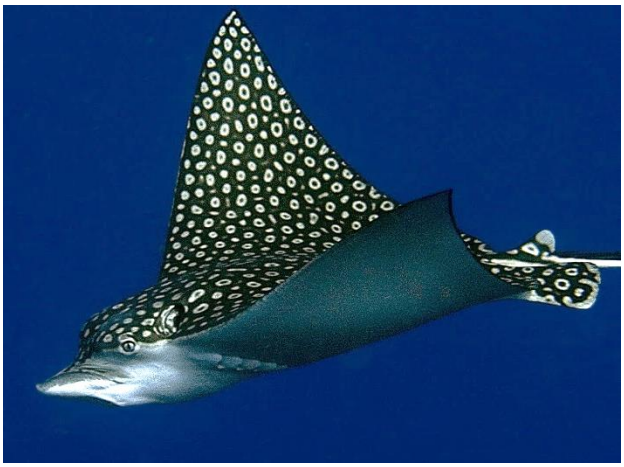
Freshwater stingrays *(Potamotrygon spp.)* live in the shallows of South American rivers. They spend most of the day resting along the bottom. Their body is a large, round disk marked with circular lines or spots. The slender tail is armed with a serrated, stinging spine that produces venom that is absorbed into the victim's wound. The body of an average adult freshwater stingray is 12 inches (30 cm) in length with a tail that can reach eight inches (20 cm).

The bigtooth river stingray *(Potamotrygon henlei)* is likely the most common species of freshwater rays in the pet trade due to their beauty. They average 12-14 inches (30-36 cm) in diameter.

The polka dot stingray *(Potamotrygon leopoldi)* is considered the most beautiful and hardiest among all rays. They grow to 24 inches (60 cm) in diameter.

The ocellate river stingray *(Potamotrygon motoro)* is a medium- to large-sized stingray, commonly 24 inches (61 cm) in diameter at maturity.

The cow-nosed ray *(Rhinoptera bonasus)* can grow quite large; adult males average about 35 inches (90 cm) in width and weigh about 26 pounds (12 kg) while adult females are slightly larger at 28 inches (71 cm) in width and an average weight of 34 pounds (15 kg). The distribution of the cownose ray includes the eastern Atlantic Ocean; also located in the western Atlantic from southern New England to northern Florida (US) and throughout the Gulf of Mexico, migrating to Trinidad, Venezuela, and Brazil. This pelagic species is also sometimes found in inshore waters. For the most part, this gregarious species is known for its migrations to different parts of the ocean. The environments in which they are found include brackish and marine habitats. They are found at depths up to 72 feet (22 m).



The spotted eagle ray *(Aetobatus narinari)* can be identified by its numerous white ringed spots on its blue dorsal surface, white ventral surface, long, whip-like tail and distinctive head shape. It feeds mainly on bivalves but also eats shrimp, crabs, octopus and worms, whelks, and small fish.

Spotted eagle rays grow to a maximum wingspan of ten feet (3 m) and weigh up to 500 pounds (227 kg). The tail is long in relation to other rays. The total length of a mature ray can reach 16 feet (5 m). It can have two to six venomous spines on the tail.

The spotted eagle ray is oviviparous (eggs hatch internally and feed off a yolk sac prior to birth). It is commonly found in shallow inshore waters such as bays and coral reefs but may cross oceanic basins. It is widespread in tropical and warm temperate waters.

In the western Atlantic Ocean, it is found in waters off North Carolina and Florida (U.S.), Gulf of Mexico, Caribbean, and Bermuda south to Brazil. This ray can be found from Mauritania to Angola in the eastern Atlantic Ocean. In the Indo-West Pacific, it is found in the Red Sea and from South Africa to Hawaii, including north to Japan and south to Australia. The spotted eagle ray also resides in the waters of the eastern Pacific Ocean from the Gulf of California south to Peru, including the Galapagos Islands (Ecuador).

The sawfish *(Pristis microdon)* has a heavy body and a long "saw" that is broad at the base and tapers, with 14 to 22 very large teeth on each side.

The most noticeable feature of the sawfish is its saw-like snout. It is covered with motion- and electro-sensitive pores that allow sawfish to detect movements (even heartbeats) of buried prey in the ocean floor. It is also used as a digging tool to dig up buried crustaceans. When suitable prey swims by, the normally lethargic sawfish will spring from the bottom and slash at it furiously with its snout. This generally stuns or injures the prey sufficiently for the sawfish to devour it without much effort.

Sawfish are green, gray, or golden-brown above and cream below. The body and head of a sawfish is flat as they spend most of their time lying on the bottom. Like rays, the sawfish's mouth and nares are located on its underside. Sawfish are nocturnal, usually sleeping during the day and hunting at night.

Females give live birth to pups (ovoviviparous) and reproduce in freshwater. The gestation period is approximately five months, with a litter size of up to 12 young. The young are born with flexible snouts in which the teeth are covered with a sheath of skin to avoid injury to the mother.

Sawfish live in shallow, muddy water and can be found in both fresh and salt water. They likely spend their first three to four years in freshwater where they grow to about half their adult size of 13 feet (or 4 m). The *Pristis microdon* is found in northern Australia, Indonesia and Papua New Guinea, Irian Jaya, India and possibly has a worldwide distribution. All Sawfish are critically endangered.

All fish not included in the jawless and cartilaginous groups are bony fish with skeletons at least partly composed of real bone. The ocean sunfish is perhaps the biggest bony fish. It has an extremely large head, may grow up to 10-11 feet (3-3.3 m) in length and weigh more than one ton (907 kg). The oarfish is the longest bony fish, averaging 25 feet (7.6 m) in length but often grow to over 50 feet (15.2 m).

Humans have always had an interest in fish. They provide food (and sport) for people all over the world, have commercial value and are often kept as pets.

USEFUL VOCABULARY

aquatic	living in or near the water
barbels	fleshy, thread-like appendages growing from the mouth or snout of a fish
brackish	slightly salty, such as the water found in river estuaries
carrion	the decaying flesh of dead animals
cartilage	flexible connective tissue
cold-blooded	having a body whose temperature varies with that of the environment
concave	curves inward
cusp	a cone-shaped protrusion on a tooth
dorsal	relating to the top side (or back)
ectothermic	cold-blooded
estuary	tidal mouth of a river
freshwater	not of the sea (as opposed to saltwater)
gestation period	the period of time spent in the womb
gregarious	living in colonies or flocks
gristle	cartilage
lethargic	lacking energy
nocturnal	awake at night
oviparous	young produced by eggs that hatch after being laid (birds)
oviviparous	animals that produce eggs but retain them inside the body until hatching occurs (offspring are born “live”)
pectoral	relating to the chest
pelagic	relating to open oceans or seas rather than waters near land or inland waters
pliable	easily bent; flexible
scavenge	search for and collect from discarded waste; search for carrion as food
serrated	having a jagged edge like the teeth of a saw
sexual dimorphism	difference in form between male and female members of the same species
slime	moist, soft, and slippery substance
temperate	a region or climate with mild temperatures
terrestrial	relating to dry land; the earth
tropical	a region or climate that is very hot and humid
viviparous	giving birth to young which have developed inside the mother
wingspan	distance from tip to tip (across the wings of a bird or the body of a ray)

FISH SHAPES - Fins Are In!

If you have ever wandered along the beach, you know that it is more difficult to walk in water than out of water. Seawater is 800 times denser than air, therefore, it is harder to move in water. The streamlined shapes of most fish allow them to move through water with minimal effort. Shapes are closely related to feeding needs and habits of fish. Shapes are important adaptations for fish.

If you looked at a torpedo-shaped fish face-to-face, you would find it shaped like a submarine. This streamlined (or fusiform) shape offers the least resistance when swimming through water. Tuna, sharks, and barracuda are all in this category. These fish usually have powerful tails that give them the necessary speed to catch prey or to escape from predators. Sharks and barracudas are streamlined, and even though somewhat more laterally compressed, most wrasses and triggerfish can generally be described as fusiform.

Fish that are flattened from side-to-side (compressiform) appear tall and thin when viewed from the front, making them difficult to see. This shape is common in fish that live in and near coral reefs. They can make sharp turns and fit in narrow crevices when hiding from predators or hunting for food. Angelfish, butterflyfish, and tangs fit into this category.

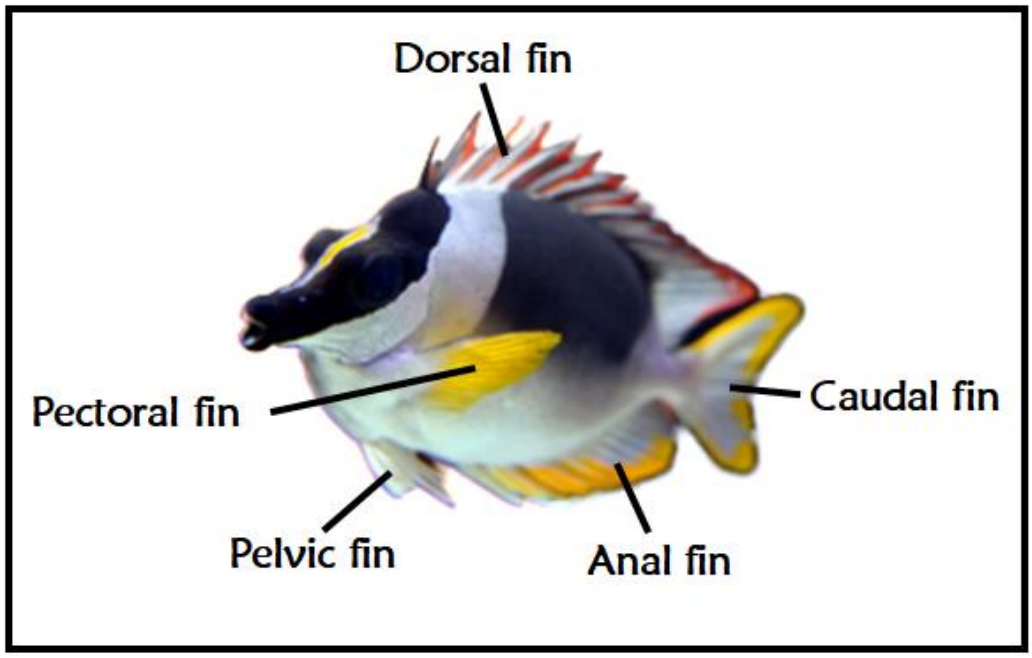
Fish that are flattened from top to bottom (depressiform) tend to use camouflage rather than speed for both hiding and hunting. Some fish in this category can change colors and some hide in sand on the bottom. Rays fit into this category.

Snake-like or elongated (anguilliform) fish are mostly hunters that can slip in and out of small areas and swiftly grab their prey. Eels fit into this category.

Many fish do not fit into any of these categories, including the vertical seadragons and seahorses, the spherical shaped puffer fish, the triangular shaped cowfish, trunkfish, and others.

Fins allow fish to move about and take care of themselves. They are made of either soft and flexible rays or stiff and spiny rays. Most fish have two types of fins - paired fins on their sides and unpaired fins along the midline of their body.

There are two kinds of paired fins - the pectoral fins and the pelvic fins. The pectoral fins of fish correspond to the arms or forearms of land vertebrates. Pectoral fins are at the front of the body behind the gill openings. These fins are important in moving, slowing, stopping, steering, and reversing.



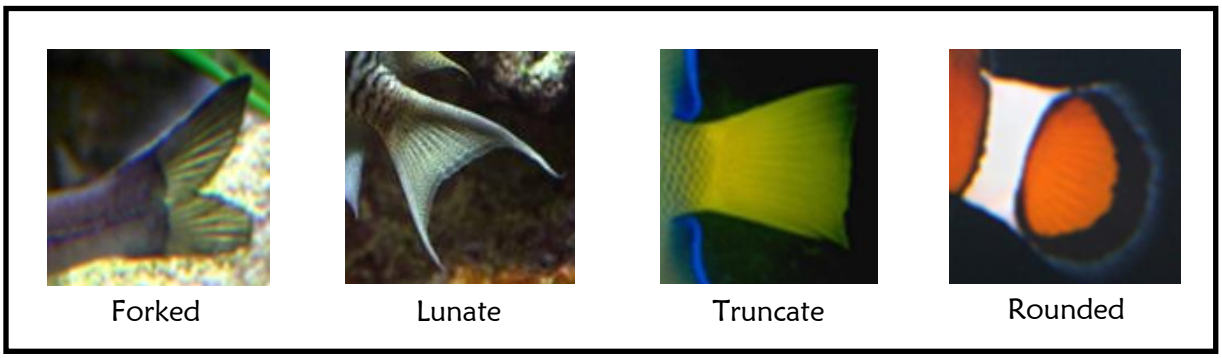
The pelvic fins (also called ventral fins) are comparable to the hind limbs or legs of land vertebrates. Pelvic fins are generally smaller, more restricted in use, and vary more in location than the pectoral fins. Pelvic fins are often located below and behind the pectorals, however, there are many exceptions. Pelvic fins are located below the pectorals on largemouth bass, in front of the pectorals on cod and in the middle of the belly on salmon. The pelvic fins function chiefly for stabilizing and maneuvering.

The unpaired fins, also called median or vertical fins, are located along the centerline at the top, bottom, and end of the body. The dorsal (top) fin is made up of one, two or three parts, with each part being directly behind the other part. The dorsal fin is usually used for stabilization, like a keel on a sailboat. The anal (bottom) fin is on the belly behind the anus or vent. It is made up of one or two parts.

Combined with muscle movements of the body, the caudal (tail) fin propels fish through water. The caudal fin provides for stabilization, acts as a rudder for steering, and creates forward propulsion. Different tail shapes serve different functions.

Most tails are either even (homocercal) or uneven (heterocercal) in shape. Tails that have upper and lower parts that are alike are homocercal (or symmetrical), and those with different shaped upper and lower parts (lobes) are heterocercal (or asymmetrical). In both types, the lower lobe is usually more flexible than the upper part. Sunfish and eels are examples of fish with tails that do not fit the homocercal or heterocercal categories.

A few types of fish caudal fins:

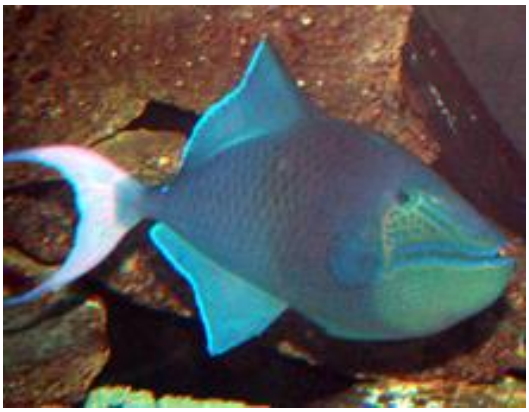


Here are some examples of unique fish fin modifications/adaptations:

- The stiff caudal fin of the snake eel is used for burrowing in reverse.

- Gobies, generally poor swimmers, have fused pelvic fins to form an adhesive sucker that may be used to attach themselves to rocks.

- Remoras have transformed the dorsal fin into an adhesive disk that allows them to attach themselves to large, fast swimming fish and go along for the ride.



- Triggerfish can erect the first ray of the dorsal fin and lock it into place. The erect fin cannot be lowered until released by a mechanism by the base of the second ray. This fin makes it difficult for a predator to swallow the fish and allows the triggerfish to hide and anchor itself in rock crevices or coral formations.

- Many species of fish have poisonous spines in various fins, such as the dorsal fins of the stonefish and scorpionfish, the dorsal, anal, and pectoral fins of the lionfish, and the caudal fin of the stingray.

- Perhaps the most unusual fin modification is that in the first or second dorsal spines of the anglerfish. These spines resemble fishing rods with tentacle-like “worms” dangling in front of the large mouth as the anglerfish "fishes" for its prey.

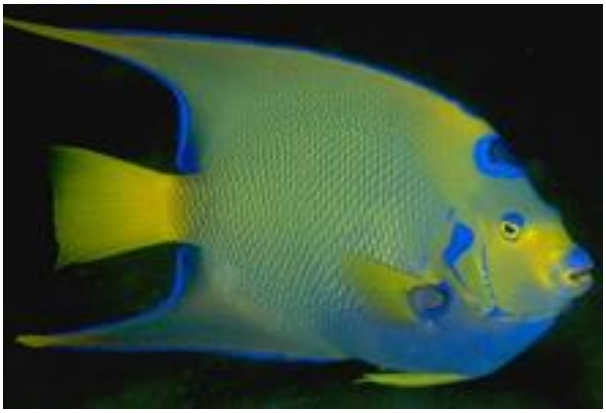
Besides swimming, other forms of locomotion occur by unusual uses or changes in fins. Here are some examples:

- Tarpon and sailfish can leap or jump several feet out of the water by rapidly swimming upward and using strong flips of their tail to clear the surface of the water.

- Flying fish reach high underwater speeds by keeping their fins close to their body. As the flying fish nears and emerges the water surface, the pelvic and pectoral fins spread outward, allowing the fish to sail over the surface of the water. The lower lobe of the caudal fin trails along in the water, moving rapidly from side to side, helping the fish to move at speeds near 35 miles (56 km) per hour. The movement of the caudal fin causes the large, long pectoral fins to appear to be moving like the wings of a bird. However, the fish is sailing, not flying.

- Gurnards use their pectoral fins to "walk" along the ocean floor. The lower rays of the pectoral fin are separated and used to move themselves along, much like the movement of a spider. Batfish, tripod fish and mudskippers are other "walkers" that move much in the same manner.

Fish fins are commonly used for stabilizing, steering, maneuvering, propelling, reversing, and braking. However, with modifications, they also help in such activities as leaping, flying, digging, walking, fishing, and “hitchhiking”.



Fish are unquestionably the masters of the aquatic environment to which they have adapted - from the streamlined and graceful to the alien-like creatures at the bottom of the oceans. The density of the water also allows bodies (or objects) with a large surface-to-volume ratio to float. This, along with lighter materials such as oil or gas in the body, give buoyancy to the fish allowing them to swim with less amounts of energy.

Light absorption is quite fast even in seemingly clear transparent water. Green plants usually live in water not more than 164 feet (50 m) deep. All colors of the spectrum are contained in sunlight, but not all colors penetrate the same. Red is absorbed in the upper 49-52 feet (15-16 m) of water, yellow and green reach to about 60-70 feet (18- 21 m) and blue reaches approximately 300-330 feet (91-100 m). In murky or cloudy water, plants may grow only near the surface of the water due to the reduced light penetration. The densest water, which sinks to the bottom, is usually cold. This contrasts with the warm and clear surface water. Unless moved by energy such as storms or winds, the surface water normally stays where it is and floats on the denser water. Many fish that live at depths where no sunlight can reach, are often dark in color and may be luminous.

Organisms that live in water are under both the pressure of the air above the water and the pressure of the water above them (which is much heavier than air). The pressure increases greatly with depth. Gases are compressed as the pressure increases, limiting the depth range of many organisms.

Less than 1% of the earth's water is freshwater (ponds, swamps, lakes, streams, and rivers) but more than 40% of all known fish species live in freshwater. This is probably because freshwater has such variation in temperature, depth, current, dissolved substances (nutrients and oxygen), and movement. An additional 2% of the world's fresh water is in ice caps at the North and South Poles. The remaining 97% of the earth's water is saltwater.

Saltwater, also called sea water, makes up all the oceans and seas in our world. There is enough salt in the oceans to cover all the land on earth with a layer of salt more than 500 feet deep (152 m). Rain washes salt from the soil and eventually carries the salt to the sea. The amount of salt in sea water is called salinity. The mean ocean salinity is about 35 parts per thousand (roughly 1.3 ounces or 37 gr of salt per quart of water). Some tropical areas such as the Red Sea have a salinity near 40 parts per thousand.

Oceans also have depth, size, diverse bottoms, motion, temperature, and salinity. The division of fish into fresh and marine groups is not that simple; some fish can cross into saltwater; some fish regularly migrate between fresh and salt water and some such as certain sea bass and anchovies can breed and live in either type of water.

Oceans are the main regulators of our climate. They are unevenly spread over the earth, with more water found in the southern hemisphere. These huge bodies of water absorb heat or energy from the sun during the day and in the summer. They slowly release the heat or energy at night and in the winter. Oceans act like a large thermostat with control over the change of seasons. Dramatic effects of the earth's surface can occur from small changes in ocean temperature, depth, and/or currents. It takes five times as much heat to change water temperature as land temperature, therefore, water temperature does not fluctuate as much.

Temperature differences between sea and land cause winds. Wind creates waves and currents on the surface of the water. Currents are large amounts of water that move in a certain direction. Most ocean currents always move in the same direction, usually clockwise in the northern hemisphere and counterclockwise in the southern hemisphere. In the Indian Ocean, currents driven by the monsoon winds change direction twice each year.

Ocean currents can move in both horizontal and vertical directions. Besides currents created by surface winds, deep currents under the surface usually result from the density of adjacent water. Water density increases with rises in salinity, but water density decreases as temperatures drop.

Besides ocean movements by waves and currents, the gravitational pull between the moon, sun and the earth cause tides that can move the whole ocean. There are more than one million miles of shoreline around the land masses on earth. The coastlines around the oceans are not only moving but are also perpetually changing. Sandy beaches, rocky formations, tide pools, lagoons, marshes, swamps, mud flats, deltas, estuaries, and reefs can be found along the coastlines.

The land that extends into the water and goes to a depth of approximately 650 feet (198 m) below the surface (sea level) is called the continental shelf. Most marine life can be found on the continental shelf areas. Below the continental shelf are continental slopes, mountain ranges, volcanoes, trenches, and abyssal plains.

Water is what makes our planet different from other planets. Heat from the sun shining on the ocean water causes the water to rise into the air as invisible vapor. After cooling, clouds form and rain, sleet, hail, or snow fall back to earth to be carried by streams or rivers back to the sea where the water cycle is repeated. Approximately 80% of ocean pollution occurs while the water is on land. The other 20% occurs at sea.

USEFUL VOCABULARY

anguilliform	snake like, elongated
asymmetrical	not alike on both sides from a center line
compressed	pressed together
compressiform	flattened from side-to-side
crescent-shaped	shaped like a moon in the first or last quarter
crevice	a crack
dense	closely compacted together
depressiform	flattened from top-to-bottom
emarginate	notched at the tip
fins	appendages attached to a fish: anal - bottom fin, caudal - tail fin, dorsal - top fin, pectoral - paired fins (like arms or forearms), pelvic - paired ventral fins (like hind legs or limbs), ventral - paired pelvic fins, vertical - unpaired fins along the centerline at the top, bottom, and end of the body
fused	joined together
fusiform	streamlined, torpedo-shaped
gills	the respiratory organs of fish
heterocercal	asymmetrical, uneven
homocercal	symmetrical, even
keel	structure on the bottom of a boat that helps provide stability
lateral	pertaining to the side
locomotion	act of moving
lunate	crescent-shaped
maneuver	move
median	midpoint
modification	the act of changing
predator	preys on other animals
prey	an animal that is hunted
propel	to cause movement
propulsion	the act of propelling, moving forward
rays	bony or cartilaginous rods in fins
resistance	opposition
rudder	vertical blade on vessel used when changing directions
spherical	round (in three dimensions)
stabilize	to keep steady
streamlined	a surface that offers the least resistance to water

symmetrical	alike on both sides from a center line
triangular	three-sided
veer	to turn or change course

FISH COLORS — Not Just for Looks

In addition to the unique traits previously mentioned, fish are also among the most colorful inhabitants on earth. Hundreds of patterns in varying tints and shades can be arranged in lines, stripes, bars, spots, blotches, or patches. These colors may be beautiful but are adaptations that allow a fish to hide from predators, advertise reproductive status, and mimic other animals or plants for some benefit.

Colors differ depending on the appearance of the environment, mood, age, or stage in life. These changes may occur almost instantly or over time.

There are three basic categories of fish coloration:

- Colors that stay for a lifetime.
  The upper dark and lower light coloring of some sharks and rays is evident from birth. The lifetime colors of the wobbegong shark and the stonefish blend with their surroundings.

- Colors that change during the lifespan.
  The juvenile bluehead wrasse is yellow and black striped. Upon reaching adulthood, its back and head turn blue. The Atlantic blue tang is yellow as a juvenile but turns blue in adulthood (with only the tail remaining yellow).

- Colors that can change every day.
  Some animals change to suit darkness or light. For example, the fusilier fish turns dark blue and red to match the background as it becomes dark. As it becomes lighter, the fusilier starts turning pale, always blending in with its surroundings. Bottom-dwelling flatfish (like the flounder) can change colors to blend in with any substrate on the sea floor. Cuttlefish become multi-colored to attract a mate.

The retaining and dispersing of colors seem to be controlled by hormones, nerves, or a combination of both. Quick color changes are controlled by nerve impulses. Slower changes are through hormonal changes in the endocrine system. Colors and patterns help fish survive in their respective habitats whether in open water, near a coastline, in or near a coral reef, near the surface of the water, or on the ocean floor.

Marine colors are largely created by:

- Pigment
  This pigment is contained in cells called chromatophores found mainly in the skin. Cells carrying more than one pigment are called compound chromatophores. Pigments gathered in the center of the cell usually appear as a pale color. Pigment dispersed throughout the cell gives off a more intense color. Different hues are made by combinations of different colored chromatophores overlapping each other or by compound chromatophores.

- Mirror cells (iridocytes)
  These cells contain a substance that reflects color and light from the surrounding environment. These structural colors are generally the iridescent silvery blues and greens, and the pearly white colors found in animals that live in the open ocean.

Fish living near the surface may have silvery or shiny scales that make them appear to be sunlight reflecting off the water. Brown colors blend in with muddy, murky water. Olive green or near black resembles the ocean bottom. Many open ocean animals have light bellies and dark backs. When viewed from above, dark backs seem to blend into the darkness of the deep ocean. When viewed from below, light bellies blend into the brightness of the sunny surface waters. This countershading is seen on some sharks and rays.

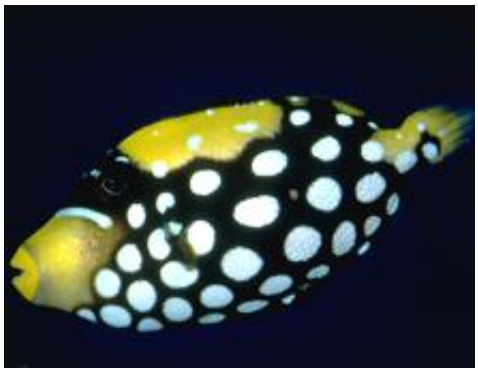
Colors are used by some marine animals for advertising. Cleaner wrasses that perform a "cleaning service" by removing parasites from other fish, are recognized (and not harmed) due to their bright identifying colors. The bright colors of many fish, such as the royal grammas, damsels, and harlequin tusk fish, are their territorial warnings to "do not disturb." Multiple bright colors are used by cuttlefish to announce they are seeking a mate. Gaudy colors representing "danger" are frequent in fish with spines and/or poison, such as the lionfish.

Colored spots, stripes, and markings break up the normal outline or body shape of animals and help them blend into their background. This kind of color camouflage, known as disruptive coloration, is common in coral reef fish such as the threadfin snapper.

Many animals use camouflage or cryptic coloration to match their backgrounds. This type of color change can be found in seahorses, flounders, and groupers. Other fish use color as part of their impersonation of an object, plant, or animal. For example, the stonefish resembles a stone, the wobbegong shark looks like a rugged, brown substrate, and the weedy and leafy seadragons resemble seaweed found in their habitats. This is a form of camouflage and is sometimes referred to as mimicry or false advertising.

A perfect example of false advertising is the sabre tooth blenny. The coloring of the blenny is like that of the cleaner fish. However, it does not provide a cleaning service but grabs and eats pieces of fins and skin from unsuspecting fish. Fish soon learn to notice the somewhat darker color of the false cleaner and avoid it.

It has been noted by scientists that predators often attack vulnerable areas (such as eyes) of marine animals. If one or both eyes are damaged, the chance of getting away or surviving is slim. Many fish have colored areas or markings that help hide or deflect from the vulnerable part. These are known as deflective markings. Some fish such as the fox face and masked bannerfish have patches or stripes of black over their eyes, thus making their eyes almost invisible.



Some animals, such as the ear spot angelfish or copperband butterflyfish, have “directive markings” (colored areas or spots that direct attention to a less vulnerable area, such as the tail). The assasi triggerfish have dark lines or markings on their face, making their mouth look much bigger and more dangerous.

Whether coloration is used to advertise, warn, hunt, hide, trick or mimic, marine life fills the one-color blue sea with breathtaking variety.

USEFUL VOCABULARY

camouflage	to hide by blending into the surroundings
chromatophores	cells containing pigment
compounded	made up of two or more parts
countershading	protective coloration, lighter on the bottom and darker on top
cryptic coloration	camouflage by means of altering the color of the skin
deflective marking	colored area that hides vulnerable body parts
directive marking	colored area that directs attention to a less vulnerable area of the body
disruptive coloration	colors or markings that conceal the body outline to better blend into the background
environment	surroundings or external conditions
gaudy	brightly and vibrantly colored
intense	very strong
iridocytes	mirror cells
juvenile	young animal
mimicry	the imitation of another animal, plant, or substrate
mirror cells	structures that reflect colors and light from the surrounding environment
murky	water that is difficult to see through, not clear
parasite	an animal or plant that lives on or in a “host” organism, providing no benefit (or harming) the host
pigment	a substance that provides color
territorial	associated with a particular area
tint	hue
vulnerable	susceptible to harm

What's for Lunch?

Sunlight is the source of all energy on earth, both on land and in water. Approximately 60% of the sunlight is absorbed within a few feet of the water's surface and no more than 1% reaches 300 feet (91 m) below the surface.

Photosynthesis is the process by which plants capture the sun's energy and convert it into food. Algae has been found in very deep water where there is little or no possibility of photosynthesis occurring, and understanding this is the goal of much scientific research.

Oceanic plants are mostly algae, however, there are a few true marine plants or sea grasses that cover some of the shallow areas. There are four major groups of algae: euglanoids, golden-brown algae/diatoms, fire algae, green algae, red algae, brown algae, and green-yellow algae. Marine algae are categorized as either "micro" or "macro". Macro algae are multi-celled, large complex growths that are usually found attached to solid substrate in shallow areas. Examples of macro algae are the green caulerpa algae or the brown giant kelp. Micro algae include single-celled algae, chains of a few cells, or tiny phytoplanktons. Plant productivity depends on factors such as:

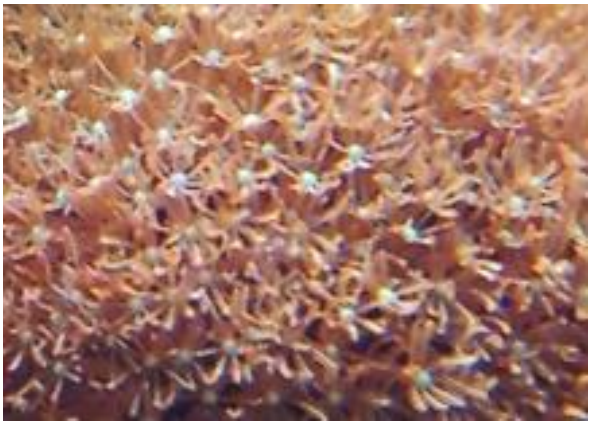
- Light intensity
- Temperature
- Number of grazing animals in the area
- New and recycled nutrients found near surface (upwelling occurs when deep, nutrient-rich water is returned to the surface)
- Seasons (long daylight hours in the polar spring and summer are conducive to active phytoplankton growth)
- Human activity in the area

Plankton comprises microscopic plants (phytoplankton) and animals (zooplankton) that drift in the ocean. The term originated from the Greek "planktos" (wanderer). These floating organisms are not powerful swimmers; therefore, their travels primarily occur by drifting in water movements from tides, currents, and waves, often moving up and down in the water column rather than horizontal journeys of any distance.

Plankton makes up more than 90% of the total productivity of the oceans. Most marine zooplanktons are small; however, they are varied in shape and composition of materials. Some are gelatinous like jellyfish, some have shells, and some are small crustaceans, such as krill.

Many zooplankton aid their buoyancy and movement by contracting and expanding their body, or by waving cilia or tentacles. Zooplanktons are divided into two groups: those who spend their entire life as plankton, and those who start out as planktonic larval forms but become other adult marine species living on the seabed.

FOOD CHAINS



Food chains occur when organisms are interrelated (or "linked") in their feeding habits. Put simply, the larger animals feed on smaller animals that have eaten plants. The crown-of-thorns starfish, with its insatiable appetite for coral polyps, does much damage to coral reefs. Triton snails have a similar liking for crown-of-thorn starfish in their diet. However, because their beautiful shell is collected for commercial use, the scarcity of the triton snail upsets the balance of nature and allows for undue devastation of coral reef habitats.

Overlapping and interconnecting food chains make up a food web, usually illustrated as a pyramid. Marine plants (primary producers) are eaten by herbivorous marine animals. Herbivores, also known as primary consumers, then become food for larger secondary consumers. Carnivores, or secondary consumers, are marine animals that eat other marine animals. Organisms that eat both plants and animals are omnivores. Animals that prefer to eat organic waste such as dead cells and fecal matter are called detritivores (detritus feeders).

All life flourishes on energy. In the marine ecosystem, the flow of energy begins at the base of the pyramid with sunlight which is converted by photosynthetic plants into energy or living tissue. In addition to the carbohydrates made by harvesting the sun's energy, plants also need essential nutrients such as nitrates and phosphates to build the necessary proteins for growth. Organic waste that is produced by dead plants, animals, and fecal matter may be used as food by detritivores before being broken down into inorganic waste, to be used by plants once again.

When one organism is eaten by another, its energy is transferred from one level to another level. In addition to the energy used for growth, an enormous amount is needed for reproduction, movement, and maintenance. The greatest amount of energy and largest number of organisms are the producers that make up the base of the pyramid. Only 10% of the volume or "flesh" at each level will become part of the volume or "flesh" of each directly above level. This indicates that 90% of the energy will be used or "burned up" to maintain life. This percentage level and process continues through the consumer levels.

Ten thousand pounds (4,536 kg) of phytoplankton are needed to produce 1,000 pounds (454 kg) of zooplankton, to produce 100 pounds (45 kg) of fish to transfer into 10 pounds (4.5 kg) of seal, and finally become 1 pound (0.45 kg) of killer whale at the top of the food pyramid. If a killer whale weighs 12,000 pounds (5,443 kg), how many pounds of phytoplankton were required to reach this volume?

The nutrient-rich polar and coastal regions have fewer species, therefore, simpler food webs. The tropical open ocean areas with fewer nutrients include the complex food webs. Animals that live in a specific area of the ocean are those that have adapted to that environment, found adequate food, and have not been eaten.

USEFUL VOCABULARY

absorb	draw up, like a sponge
algae	aquatic plants
bacteria	microscopic organisms that cause fermentation or decaying
buoyancy	the power to float or rise in a liquid
carnivores	organisms that feed on animals
cilia	short hair-like projections that move and propel an organism
consumer	one who uses, devours, or destroys
crustaceans	a group of marine animals with hard shells (for example: lobsters, shrimp, crabs)
detritivores	animals that eat organic waste
ecosystem	all living things and physical components in a given area
food chain	a series of animals and plants interrelated in their feeding habits
food web	interconnecting food chains
herbivores	plant eaters
kelp	giant aquatic plant
krill	large planktonic crustaceans
larval	immature forms of plants and animals, embryonic state
macro	large
micro	small, miniscule
microscopic	invisible to the naked eye
omnivorous	feeding on both animals and plants
photosynthesis	process by which green plants use energy from the sun to produce food
producers	plants that use the sun's energy to produce food to be eaten by consumers
species	a group with distinct, common characteristics
upwelling	cold waters rising from the bottom up into warmer waters
zooplankton	tiny, drifting microscopic animals

Friend or Foe?

Marine animals spend most of their time either hunting or being hunted. Whether on land or in water, all organisms must compete for survival. Unlikely associations between animals have developed for various reasons, including food, shelter, protection, and transportation. This close association of two dissimilar organisms is called symbiosis. Each organism may be referred to as a symbiont (or participant). Symbiosis refers to a relationship that is beneficial to at least one symbiont.

Coral polyps are hosts to microscopic algae called zooxanthellae. These tiny algae live safely in the sunlit cells of the polyps. Zooxanthellae provide the host with the organic carbon products of photosynthesis, sometimes providing up to 90% of their host's energy needs for metabolism, growth, and reproduction. In return, they receive nutrients, carbon dioxide, and an elevated position with access to sunshine.

Growing in the lush mantles of the giant clams are large concentrations of zooxanthellae. The giant clam provides a safe sunlit place for the algae, where it grows and multiplies while producing nutrients for the clam. The plants absorb some of the giant clam's waste products. It is believed that the clam eventually feeds on some or all the algae.

An interesting symbiotic relationship occurs with anemones and clownfish. The tentacles of the anemones are armed with stinging nematocysts. Clownfish seem to produce an unusually thick mucus that allows them to enter the anemones without being stung. Some believe the clownfish coat their bodies with the chemical mucus produced by the anemones so the anemone will not recognize the clownfish as an intruder.

Experiments have shown that clownfish wiped clean of this mucus are then eaten by their hosts. Clownfish benefit by having a safe hiding space in the anemone. The anemone benefits by eating scraps of food left over by the clownfish, and benefits when the clownfish lures other fish to the hungry anemone.

Clownfish are immune only to their host anemones and no others. The anemone will eat other clownfish. Some fish live with only one species of anemones, yet others seem to show no preference and can live in several species.

Fish often live in the anemones as juveniles and move to the corals as adults. Adult fish lay eggs at the base of the anemone and then rub the anemone. This causes the anemone to extend the armed tentacles and form a protective canopy for the eggs. In the Caribbean, a similar relationship exists between various species of shrimp and anemones.

The Mediterranean hermit crab is a favorite appetizer of octopods. Because octopods are extremely sensitive to the stinging tentacles of anemones, the crab attaches an anemone to its shell. In return, the anemone is more mobile, thus increasing the chance of food. The Hermit crab taps with its legs and claws to signal that "taxi service" is available. The anemone then releases its grip on the substrate and moves aboard the crab. When the shell becomes too small for the crab, both anemone and crab move to a larger shell.

The boxer crab carries a stinging anemone on each claw like a "boxing glove" to shove in the face of would-be predators. Crabs from the family Dromiidae hide from predators by attaching pieces of sponge to their shells. This added mobility gives the sponge a wider selection of food that is filtered from the water.

Small Nomeus gronovii fish can be found living in and among the dangerous Portuguese man-of-war. Various small fish have been found living among the needles of certain sea urchins. A small goby often guards a shrimp as he removes sand and stones from their shared burrow. Both retreat to the burrow after the goby alerts the poor-sighted shrimp that danger is near. Various sponges, because of their enormous size, are home to many marine species who benefit from the passing of volumes of food-bearing water.

Cleaning is an important form of symbiosis that removes parasites, bacteria, or old and infected tissues. One symbiont gets food, the other gets rid of harmful parasites and fungus. Cleaners may include gobies, angelfish, butterflyfish, wrasses, shrimp, and crabs. Often the cleaning occurs only at the juvenile stage and stops when adulthood is reached.

Cleaners have special colors or patterns and display signals indicating "open for business" at their cleaning stations. Customers, including large carnivores, recognize their service-providers, and are very cooperative. They wait in line for their turn, remaining still, opening mouths and gill covers.

There are more than 47 identified species of cleaner fish, shrimp, and crabs. Shrimp also “advertise” for customers by dancing and waving their antennae. Some species of blennies mimic the cleaners and sneak bits of skin from the unsuspecting customers.

Commonly seen attached to sharks and rays are hitchhiking remoras. An oval suction disc made from a modified dorsal fin on top of the head allows them to adhere for as long as they like. Remoras detach by merely swimming forward. It is reported that fishermen use remoras for bait, knowing they will attach to a larger animal, and once attached, both fish are brought in for the catch. Pilotfish swim very close to sharks, rays, whales, and turtles to reduce their swimming efforts and possibly feed on left over scraps.

Fish frequently host internal parasites such as protozoans, worms, flukes, etc. Lamprey eels attach themselves to fish to feed on their muscles and blood. Hagfish usually feed on dead sea life but will also attach to trapped or injured prey.

Symbiosis is commonly divided into three main categories. Mutualism is the relationship in which both symbionts benefit. Commensalism is the relationship in which only one organism benefits and the other participant is unaffected. The third relationship is parasitism in which one participant benefits and the other is harmed.

It may be difficult to place associations in one category. For example, the relationship between clams and zooxanthellae is mutualistic unless the clam needs the algae for food, then it becomes parasitic. Regardless of specific category, coral reefs rely on the many unique associations for survival and regardless of eventual outcome, for a while all are better off together than apart.

USEFUL VOCABULARY

adhere	to stick or cling
adoption	the act of accepting or taking in
advertise	to call attention to
association	the act of combining, uniting, sharing
beneficial	helpful
burrow	hole or tunnel
commensalism	the relationship in which only one organism benefits and the other is unaffected
dissimilar	unlike, different
fungus	plants without chlorophyll that live on living or dead organic matter
immune	protected from
intruder	one who is unwelcome or unwanted
lure	entice, attract, tempt
mantle	soft tissue that covers the body of mollusks
mobile	capable of moving
mucus	a sticky secretion of the lubricating membrane that lines the internal surfaces of an organ
mutualism	a relationship in which both participants benefit
nematocyst	an organ consisting of a tiny capsule containing venom and a stinging thread that can be ejected for protection and capturing prey
octopods	eight-armed cephalopods (such as the octopus)
organic	derived from living organisms
parasitism	relationship in which one participant benefits and the other is harmed
predator	one that preys on other animals
substrate	material on which an organism lives
symbiont	participant in an association
symbiosis	the association (or living together) of two dissimilar organisms
tentacles	slender, flexible appendages used by animals for feeling, grasping, stinging, etc.
zooxanthellae	single-celled plants (inside the tissue of coral, anemones, clams, and various other invertebrates) that photosynthesize, providing oxygen and some carbohydrates to their host in return for respiration)

Romance in the Reef

The reproductive habits, processes, behaviors, and strategies of fish are as interesting and varied as their colors, shapes, and sizes, and have allowed them to successfully propagate under many conditions.

Aquatic animals, both vertebrate and invertebrate, are extremely capable of reproducing. They are also very exact in determining the best place and time in each environment for the survival of their eggs and offspring. Cues that it is time to reproduce are probably received from the environment, including factors such as temperature, salinity, solar and/or lunar light, water flow, etc.

Sexual reproduction occurs with the uniting of female cells (eggs) and male cells (sperms). Non-sexual or asexual reproduction, not requiring the union of female and male cells, can happen with a single parent. Most animals function as either male or female, but some species are hermaphrodites, meaning they can produce both male and female sex cells at some point in their development.

Animals that are first male are protandrous (such as clownfish) and animals that are first female are protogynous (such as wrasses). Sex reversals are usually accompanied by changes in color and/or size. These animals are classified as consecutive hermaphrodites. Simultaneous hermaphrodites are those animals who have both mature male and female reproductive cells at the same time. Marine species such as the belted sandfish have reproduced in captivity by self-fertilization.

Some fish lay thousands and even millions of eggs each year. It is estimated that in some species, as few as one egg in ten thousand survive long enough to reproduce. Like baby animals on land, marine babies begin when eggs from the female unite with sperm from the male. This union of reproductive cells is called fertilization.

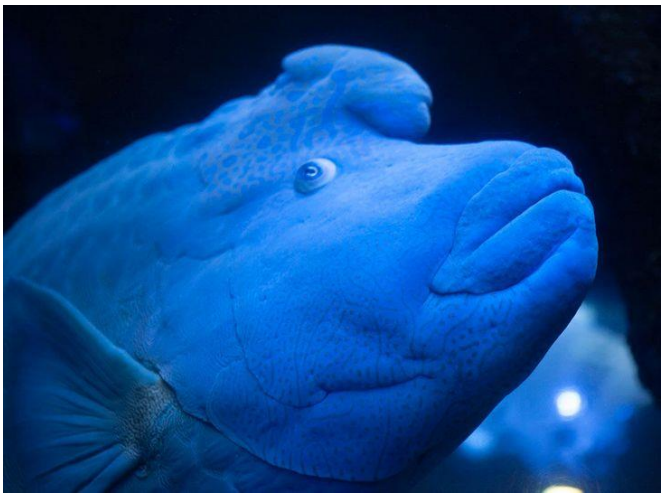
The release of these cells into the water is called spawning. Unlike on land where animals must meet to mate, eggs and sperm may be brought together by water movement. This mass spawning or broadcasting does not require pairing of the fish. However, not all fish are so uninvolved in romance and parenthood. Many males and females form pairs. Fish such as salmon will travel long distances (migrate) to lay their eggs. Some fish perform mating displays or courtship rituals (wrasses).

Often one or both members of the pair prepare sites or nests. This preparation may range from merely cleaning or fanning a spot to building elaborate nests. These nests may be guarded by one or both parents.

Tube-snout fish, found in the North Pacific, deposit eggs in the gill slit areas of sea squirts, leaving their eggs in the care of other animals. Some pairing fish are brooders who incubate eggs in their mouth like the jawfish or in pouches like the seahorses and seadragons.

Fish eggs can be found in all shapes, sizes, and locations. Eggs heavier than water may be attached to the bottom by hooks, tendrils, or other devices. Eggs may attach to each other, attach to vegetation, drift, float freely, move with fast flowing water, lodge in crevices, be buried, etc.

Fish can be divided into egg-layers (oviparous) and live-bearers (ovoviviparous and viviparous). Most fish are oviparous. This means they lay eggs that contain enough nourishment for the development of an embryo. The main requirements for hatching are temperature, salinity, and safety from predators.



In ovoviviparous (also known as oviviparous) fish, the fertilized egg stays inside the mother in a sac that serves as an incubator. Viviparous fish nourish developing embryos in several ways but usually involve a placenta-like yolk sac connected to the embryo by an umbilical-like cord. This provides nutrients from the mother to the embryo.

All three major types of reproduction can be found in sharks. The egg-laying or oviparous Port Jackson shark secretes a shell or case around the egg. The cork-screw shaped egg is then left on the sea floor where the female shark wedges it between rocks to hatch.

Live-bearing ovoviviparous sharks develop their young internally but are not connected to the mother. The yolk sac in the egg provides the needed nourishment and the mother merely provides protection. It is believed that embryos of the great white and grey nurse sharks receive additional nourishment by eating their brothers and sisters. This intra-uterine cannibalism continues until only one embryo remains inside the mother to be born. The hammerhead shark is a viviparous, live-bearing animal.

Asexual reproduction is common among marine invertebrates; however, sexual reproduction does occur by both brooding and broadcasting. In brooders, eggs stay in the abdominal cavity where they are fertilized by sperm carried by currents. After hatching into larvae, they are released through the polyps' mouth. Broadcasters release their reproductive cells synchronously into the water where the male and female cells unite, and embryos develop. Synchronization of spawning is vital to reproductive success because tides quickly move the cells.

Sexual reproduction allows for the dispersal of new animals farther from "home" and for better genetic variability. However, it is the least common method of coral reproduction. Greater numbers can be produced more quickly by asexual methods. One coral polyp can duplicate itself over and over, with each new polyp doing the same. This type of asexual reproduction is known as budding.

Fragmentation arises when a piece or fragment of coral continues to grow after breaking off a larger coral head. Sometimes a weak spot develops in the skeleton of the coral head (fission) and several colonies may develop out of this fission. The weak spot may develop from excess weight of the colony, causing the tissue to tear and polyp balls or colonies to appear. A single polyp may develop and when it becomes too heavy, drops off and continues to grow. Environmental stress resulting from water temperature, amount of oxygen, and pollution may cause polyps to fall off to escape the stress and thus survive.

Regeneration is one method of asexual reproduction found among many species of invertebrates. A sea star can be cut in half and two sea stars will develop. Sea cucumbers and certain sea anemones can pull themselves in

half (binary fission). The pedal disc of the sea anemone moves in opposite directions at the same time until it splits in half. Each part then becomes a new anemone, which can then divide into four, etc.

A whole group of animals that look alike and start from a single individual with exact genetic makeup is known as a clone. Sponges reproduce by releasing eggs and sperm, but they can also regenerate completely new animals from broken pieces.

Segmented sea worms often have sex cells in each segment. At certain times each year, the sex cells are released, fertilization occurs, and larvae are formed. Sea worms often die after releasing their sex cells.

Palolo worms from the South Pacific only have sex cells in their rear segments. These segments change color and size before breaking off and floating to the surface where the sex cells are released. All this happens on the same night in the full moon of October and November. Natives of the surrounding islands consider these segments to be a real delicacy and await their arrival in boats carrying dip nets.

The bottom-dwelling Bermuda fire worm comes to the surface during mating season. The female fire worm gives off a green luminous glow that attracts the males who arrive emitting a flashing light.

Certain species of octopus, perform a mating ritual during which the male changes colors. The male uses one of his arms to place a packet of sperm in the mantle cavity of the female. The fertilized eggs are then released in clusters through a funnel. The eggs are then guarded for several weeks by the female who keeps them oxygenated and clean.

The above-mentioned sexual and asexual methods of marine animal reproduction are only a few of the many varied and interesting reproductive strategies. These tactics must include the necessary care for and quantity of eggs, which are laid at a time when ample food and space will ensure success, thus guaranteeing the survival of all existing marine animals.

USEFUL VOCABULARY

asexual	reproduction in which new individuals are produced from a single parent
binary fission	asexual reproduction by splitting in half to form two new bodies
brooders	incubators of eggs
budding	a type of asexual reproduction by which a separate new individual is produced from a bud or small outgrowth
cannibalism	eating the flesh of one's own kind
clone	a series of identical cells or individuals that develop from a single cell or individual
consecutive hermaphrodite	an animal that has sex reversals, male to female or female to male
cue	give information, prompt
dispersal	the act of spreading or separating something
fertilization	the union of reproductive cells
fission	a type of asexual reproduction where one individual splits into two individuals
fragmentation	separating something into finer or smaller parts
hermaphrodite	an animal that can produce both male and female sex cells at some point in their development
migrate	travel from one place to another
oviparous	egg-laying; egg contains nourishment for the development of an embryo
ovoviviparous	producing living young from eggs that stay inside the mother in a sac that serves as an incubator (also known as oviviparous)
propagate	multiply sexually or asexually; pass on
protandrous	animals that are first male before becoming female at some point in their development
protogynous	animals that are first female before becoming male at some point in their development
regeneration	the ability of an organism to grow a body part that has been lost
reproduction	the process of generating offspring
salinity	amount of salt in a body of water
segments	one of several similar pieces or parts
simultaneous hermaphrodite	animal who has both mature male and female reproductive cells at the same time
spawning	releasing of reproductive cells into the water
strategies	an elaborate and systematic plan of action
synchronization	occurring at the same time
viviparous	produce live young