Present

A Quick Course in Ichthyology

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Contents

Question- What is a fish?

List all the defining features of fish.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. Fish are fun!

Are any of these defining features representatives of fish and only fish? Can you think of any other animals that have these features, or can you think of some fish that don't? Worldwide, there are over 22,000 species of fish, comprising more than 50% of all vertebrate species. The origin of fishes dates back to over 480 million years. Fish evolved in fresh water; the chondrichthyes moved to the sea early in evolution, while the bony fishes went through most of their evolution in fresh water and spread to the seas at a much later period. Fish are the dominant free swimming animals of the seas. The structure of a fish body is designed for ease of movement. This ability to move about easily, without relying on water currents to carry them about, has enabled fishes to exploit most parts of the world's oceans, and this is reflected in an extraordinary variety of sizes and shapes. Fish are found in both fresh and salt water worldwide, and are a very important food source for many nations.

FISH: Any of a large group of cold-blooded, finned aquatic vertebrates. Fish are generally scaled and respire by passing water over gills.Modern fish are divided into three classes.

I. AGNATHA, primitive jawless fish.Lampreys and Hagfish

II. CHONDRICHTHYES, the jawed fish with cartilaginous skeletons. Sharks, Rays, Rat-Fishes

III. OSTEICHTHYES, fish with bony skeletons.Lungfish, Trout, Bass, Salmon, Perch, Parrot Fish

Fish come in all shapes and sizes, some are free swimming, while others rest on the bottom of the sea, some are herbivores and others are carnivores, and some lay eggs while others give live birth and parental care to their young.

FISH: the members of a single species
FISHES: more than one species of fish

FISHES- class Agnatha

Fish of the class agnatha ("no jaw") are the most "primitive" of the fishes; they lack a jaw and a bony skeleton. The hagfish and the lamprey are the only living representatives of this once large class. As they lack true bones, these fish are very flexible, the hagfish can actually tie itself in a knot to rid itself of a noxious slime it can produce to deter predators. They have a smooth, scale less skin and are soft to the touch. In place of the jaws is an oral sucker in the center of which is the mouth cavity. Many of the agnathas are highly predatory, attaching to other fish by their sucker like mouths, and rasping through the skin into the viscera of their hosts. The juvenile lamprey feeds by sucking up mud containing micro-organisms and organic debris - as did the primitive agnatha. Agnathas are found in both fresh and salt water and some are anadromous [living in both fresh and salt water at different times in its life cycle]. The hagfish has no eyes, while the lamprey has well-developed eyes.

Characteristics- agnatha

- Primitive
- No jaws
- Cartilaginous skeleton
- Scaleless skin
- Oral sucker in place of jaws
- Predators and filter feeders
- anticoagulating saliva
- fresh and salt water
- some anadromous

FISH- class Chondrichthyes

Members of the class Chondrichthyes ("cartilage-fish") include the sharks, skates, rays, and ratfish. These fish have a cartilaginous skeleton, but their ancestors were bony animals. These were the first fish to exhibit paired fins. Chondrichthyes lack swim bladders, have spiral valve intestines, exhibit internal

Characteristics- Chondrichthyes

- Cartilaginous skeleton
- Skin covered with denticles, not scales
- Five to seven gill slits per side

fertilization, and posses 5-7 gill arches (most have 5). They have cartilaginous upper and loosely attached lower jaws with a significant array of teeth. Their skin is covered with teethlike denticles which gives it the texture and abrasive quality of sandpaper.

- No swim bladder
- Internal fertilization
- Spiral valve intestines
- Five to seven gill arches
- Cartilaginous jaws, loosely attached lower jaws

Shark Attack

Sharks bring out some of man's greatest primordial fears. To be attacked by a shark is many people's greatest fear of the water, especially after watching the movie JAWS. The motif of being eaten alive by a brainless killing machine has been a major Hollywood success, much to the sharks disfavor. While there have been some documented and highly publicized cases of people being attacked and even eaten by sharks, most sharks do not deserve the title MAN-HUNTERS.

In fact, most sharks are entirely incapable of this feat. The largest fish of all, the Whale Shark, which can reach sizes of up to 59 feet and weigh 88,000 lb., is a very calm and approachable plankton feeder. There are many species of sharks which can inflict severe bodily injury and require the utmost of respect. The most feared of all, the Great White Shark, has been responsible for most of the fatal shark attacks off the California and Australian coastlines. While the Great White gets all the notoriety, pound for pound, the Bull Shark is probably the most ferocious. The Great White generally attacks a person because it has confused it with its favorite food, the seals and sea lions, but the Bull Shark will attack a person just because they are there. Even with these dangerous animals roaming the ocean, your chances of getting attacked by a shark are very remote.

Worldwide, there are only about three hundred documented shark attacks a year. The chances are much higher that you will be hit by a drunk driver while driving to the beach then they are that you will even encounter a dangerous shark when you get there. There are some activities that will greatly increase your chance of a shark attack, such as carrying speared fish with you while diving or collecting abalone in turbid waters. Statistics of 1,652 shark attacks show that males are much more likely to be attacked than females (10 to 1 ratio), this is probably because males are much more active in the water, surfing and going to deeper depths where sharks are more common.

The presence of large numbers of fish, or fish behaving in an unusual manner, has been reported preceding many attacks. In 40 percent of the reported shark attacks, people were pole-fishing or spear-fishing in the area of an attack. A comparison of the number of people swimming to those fishing and spear-fishing seems to show that these two pastimes have by far the highest risk of inducing an attack. While swimming, the chance of drowning is more than 1,000 times greater than that of dying from a shark attack.

Most shark attacks occur in shallow water, where most bathers are, and in 94 percent of the cases the attack was by an individual shark acting alone. About 10 percent of reported shark attacks are on divers; since the number of divers in the water at one time must be much smaller than 10 percent of beach bathers, the odds of being attacked must be significantly greater for divers.

Close passes were seldom made before the attack, and in the majority of the cases there was only one strike. Few attacks involved more than one bite. This indicates that in many cases the attacking shark mistook the victim for a more usual kind of food and did not attack any further when the error was discovered. It is fortunate that sharks, in most cases, do not consider humans to be suitable food. This information also refutes the long-standing notion that fresh human blood is a powerful attractant that excites sharks into a feeding frenzy. If this were so, the presence of blood would certainly have induced that attacking shark to strike the victim repeatedly. Most wounds occur on the appendages- the hands, arms, legs, and feet. Lacerations of varying severity are the most common types of injury. About 25 percent of attacks kill the victim. The most usual cause of death is shock, combined with a severe loss of blood.

REDUCING THE RISK

Swimmers and divers can reduce the chance of being attacked by following a few simple rules: Never swim in areas where sharks are known to be common. Never enter the water where people are fishing, either from the beach or from inshore boats. If there are a number of people in the water, do not separate yourself from them. There is safety in numbers. Avoid swimming near deep channels, or where shallow water suddenly becomes deeper. Do not swim alone, or at dusk or after dark, when sharks are feeding actively and are likely to be closer to the shore. Do not enter the water, or if in the water leave immediately, if large numbers of fish are seen, or if fish seem to be acting strangely. Be alert for unusual movements in the water. Do not wear a watch or other jewelry that shines and reflects light. Do not enter the water with an open wound, and women should not swim during their menstrual periods.

FISHES- Chondrichthyes, Sharks

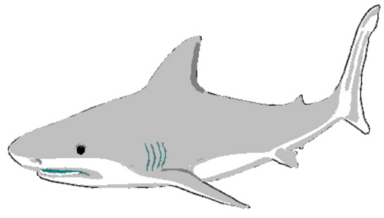
Sharks are animals that are superbly adapted to their environment. Almost all are carnivores or scavengers, although the species that live close to the sea floor feed mostly on invertebrates. Most possess a keen sense of smell, a large brain, good eyesight, and highly specialized mouth and teeth. Their bodies are usually heavier than water, and they do not have an air filled swim bladder for buoyancy like most bony fishes. All sharks have an asymmetric tail fin, with the upper lobe being larger than the lower one. This feature, together with flattened pectoral fins, and an oil-filled liver compensates for the lack of a swim bladder. There are 344 known species of sharks living in all parts of the oceans, from shallow to deep water and from the tropics to the polar regions. A few even venture into fresh water and have been found in rivers and lakes. Contrary to popular belief, most sharks are harmless to humans. Sharks are classified into eight orders:

1. Sawsharks (Pristophoriformes), one family, five sp.Live on the bottom in warm temperate or tropical seas. Easily recognized because of tube, blade like snouts. Bear live young.

2. Dogfish Sharks (Squaliformes), three families, 73 sp. Bottom dwelling deep water sharks, distributed worldwide. Bear live young and eat bony fishes, crustaceans, squid and other sharks. Harmless to humans.

3. Angel Sharks (Squatiniformes), one family, 13 sp. Flattened, bottom dwelling sharks. Found on continental shelves and upper slopes of cold temperate and tropical seas. Have very sharp, awl-like teeth that are used to impale small fish and crustaceans.

4. Bullhead Sharks (Heterodontiformes), one family, 8 sp. Live on rocky reefs where there are plenty of cracks and crevices. Found in Pacific and Indian Ocean. Eat invertebrates.



5. Gilled Sharks (Hexanchiformes), two families, five sp. Deep-water, bottom-dwelling sharks. Worldwide distribution. Only shark with six or seven gill slits. Bear live young and eat bony fish, crustaceans, and other sharks.

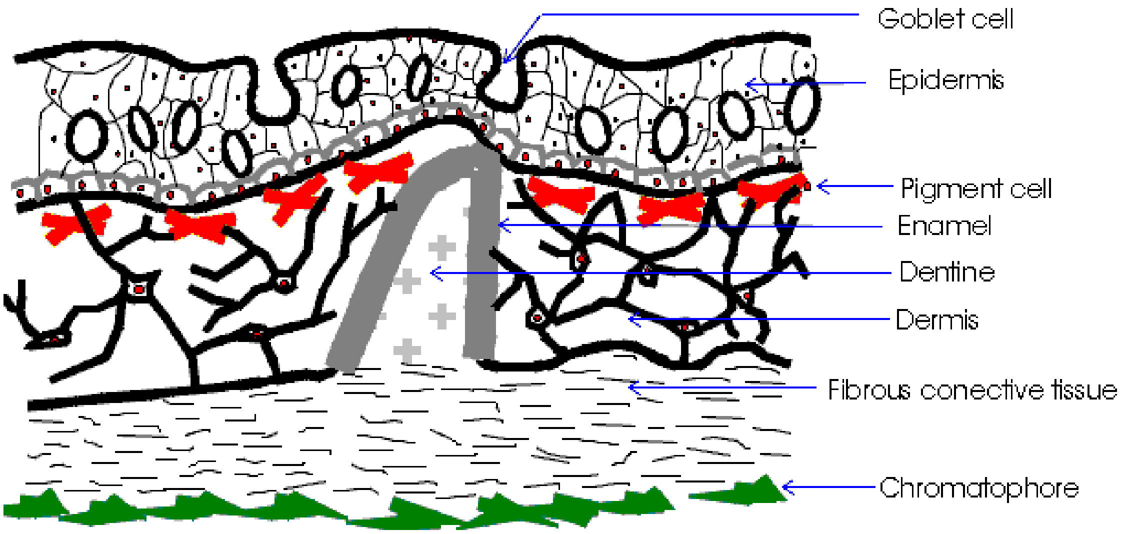
6. Mackerel Sharks (Lamniformes), seven families, 16 sp. Small, highly diverse order. Found in tropical to cold temperate or even Arctic waters. Oceanic and coastal. Most very large, eat bony fish, other sharks, squid, and marine mammals. Includes the Mako and Great White and the plankton eating Megamouth and Basking Sharks.

7. Carpet Sharks (Otectolobiformes) seven families, 31 sp. Warm tropical to temperate waters. All members except whale shark live on bottom. Flattened. Most eat small fishes and invertebrates. Whale shark is plankton feeder. Some bear live young and others lay eggs.

8. Ground Sharks (Carcharhiniformes) 8 families, 193 sp. Largest order of sharks. Worldwide distribution, temperate and tropical waters. Most live near coast, although some found in deeper waters. Eat bony fishes, other sharks, squid, and small invertebrates. Includes the dangerous Tiger shark.

Shark Anatomy

Sharks have numerous structural and physiological features that make them unique among the fishes. They have a simple cartilaginous skeleton with no ribs, and a cartilaginous jaw, backbone, and cranium.



Thick skin supports the flimsy skeleton. The skin is elastic and aids in movement; when the tail is arched, it pulls on the skin, which pulls back like a rubber band. The jaws are not connected to the skull and become unhinged, protruding forward from the skull allowing for a wider gape when feeding. The teeth are ossified with minerals known as 'apatite'. They form a conveyer belt with as many as eight teeth in a row. When a shark looses a tooth, another one just pops up. Sharks go through up to 2,400 teeth a year.

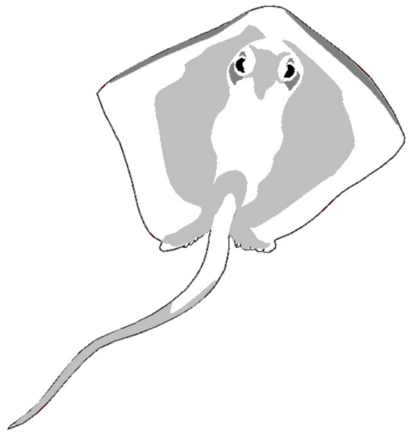
Sharks have placoid scales which are fixed, slightly ossified and layered. They are smooth to the touch in one direction and extremely course in another. Just rubbing a shark the wrong way can inflict serious wounds.

All sharks, rays, and skates are carnivores. They have normal sensory modalities, a small brain (most of which is dedicated to the olfactory lobes giving them an acute sense of smell) and well developed eyes with color vision and adaptation to low light levels.

Some sharks lay eggs (all skates and ratfish do), but most are ovoviviparous (all rays are). The young develop with their yolk sacks within the mother, but without a placenta or umbilical cord. Some sharks (the Great

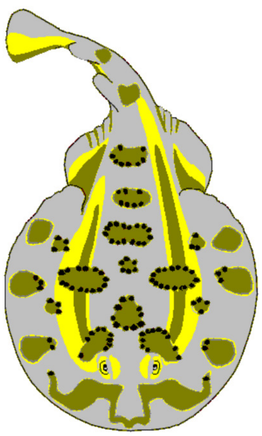
White) are oviphagous; the young eat the other developing young and embryos inside their mother and only the fiercest is born! A few sharks (hammerheads and reef sharks) are viviparous; like mammals, the young are nourished with a placenta within the mother. The gestation period is around 22 months and 2-80 pups are born per litter. Because most sharks are ovoviviparous or viviparous, they do not produce mass numbers of young like other fish do. They are slow to develop and for this reason shark population numbers have been decreasing rapidly due to the recent popularity of shark fin soup. Fishermen are taking many more sharks than the maximum sustainable yield will allow. Some sharks will soon be endangered species. Rays

Rays in general are physiologically exactly like sharks except the rays pectoral fins are fussed to their heads. Their gills are ventrally located. They swim with their ventral fins, like wings. Their eyes are dorsally [top] located and have spericules behind them. The spericules are used to breathe in with.



Rays are modified as bottom feeders, feeding on invertebrates found in the sand. Sometimes you can watch a ray making quite a ruckus on the sand bottom in search of the invertebrates.

Manta rays are planktivores and cruise the open water filter feeding out small animals. Mantas are the largest of the rays.



Electric rays swim with their caudal fin and use their modified pectoral fins to electrically shock and stun their prey.

Sawfish look like sharks but have true fused pectoral fins and gills on the ventral surface.

Stingrays have a toxin filled spine at the base of their tail. Stingrays are not the mean creatures roaming the waters to hurt swimmers, as many people believe them to be. Stingrays are actually very approachable and can be hand fed and petted, just don't step on them!

FISHES- the BONY FISH, OSTIEICTHYES

The bony fish comprise the largest section of the vertebrates, with over 20,000 species worldwide. They are called bony fish because their skeletons are calcified, making them much harder than the cartilage bones of the chondrichthyes. The bony fishes have great maneuverability and speed, highly specialized mouths equipped with protrusible jaws, and a swim bladder to control buoyancy.

The bony fish have evolved to be of almost every imaginable shape and size, and exploit most marine and freshwater habitats on earth. Many of them have complex, recently evolved physiologies, organs, and behaviors for dealing with their environment in a sophisticated manner.

Eels -Anguilliformes 597 spp

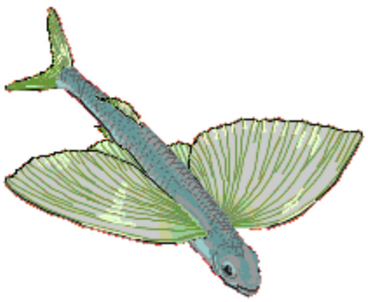
Deep Sea Fish -Stomiiformes 250 spp

Tarpon -Elopiformes 11spp

Gobies -Gobiesociformes 114 spp

Salmon -salmoniformes 350 spp

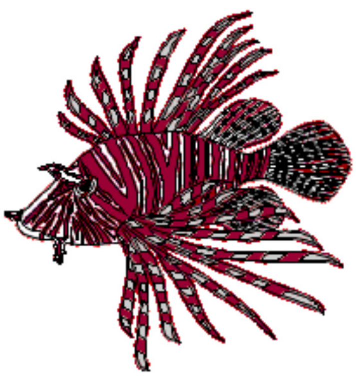
Trumpetfish -Syngnathiformes 257 spp



Flyingfishes -Cyprinodontiformes 845 spp

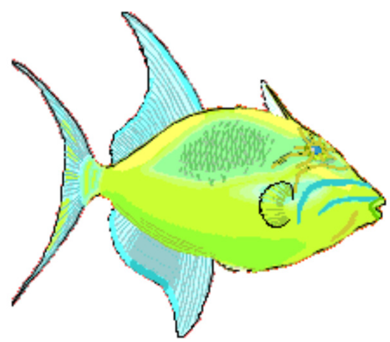
Silversides -Atheriniformes 235 spp

Squirrelfishes -Beryciformes 164 spp



Scorpionfishes -Scopaeniformes 1160 spp

Flatfish -Pleuronectiformes 538 spp



Triggerfish -Tetraodontiformes 329 spp

Perch Like -Perciformes 7791 spp,
largest order

FISH SEX- how fish reproduce

Fish have come up with three modes of reproduction depending on the method they care for their eggs.

Modes of Reproduction

- Ovopartity-- Lay undeveloped eggs, External fertilization (90% of bony fish), Internal fertilization (some sharks and rays)
- Ovoviviparity- Internal development- without direct maternal nourishment- Advanced at birth (most sharks + rays)-Larval birth (some scorpeaniforms- rockfish)
- Viviparity- Internal development- direct nourishment from mother-Fully advanced at birth (some sharks, surf perches)

In fishes, oviparity is most common; the eggs are inexpensive to produce, and as eggs are in the water, they do not dry out (oxygen, nutrients are not scarce). The adult can produce many offspring, which they broadcast into the plankton column. When the offspring settle out of the plankton, they may be in totally new environments, allowing for a great area in which the young may survive. This mode also comes with its disadvantages; when born, the fish must first go through a larval stage for growth before they transform into the adult stage. In this larval stage, they must fend for themselves in obtaining food and avoiding predation. They may not find a suitable environment when they settle out of the plankton column. The survival of individual eggs is very low, so millions of eggs must be produced in order for the parent to successfully produce offspring. The other modes have their advantages, the eggs are much less prone to predation when carried within the mother, and the young are born fully advanced and ready to deal with the environment as miniature adults. These advantages come with a price-tag also; the adult must supply nutrients to its offspring and can only produce a few eggs at a time. The young are limited to the environment that their parents were in, and if this environment is deteriorating, they are stuck with it.

Parental care: In fishes, parental care is very rare as most fish are broadcast spawners, but there are a few instances of parental care. Male gobies guard the eggs in a nest until they are born. The male yellowhead jawfish actually guards the eggs by holding them in his mouth! Weird Fish Sex!

Some fish are very kinky creatures by human standards, displaying behavior that would probably get a human incarcerated for a long time.

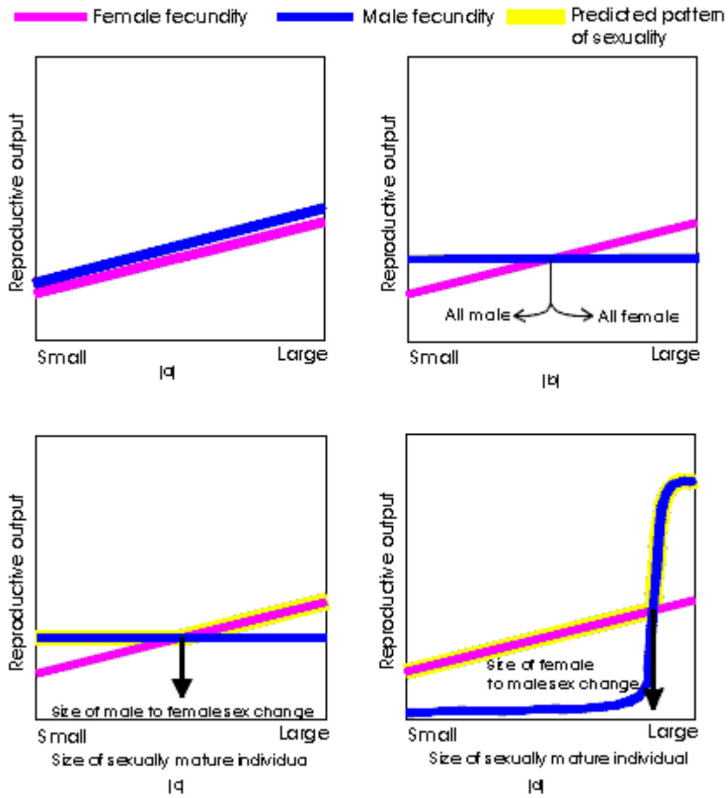
Hermaphroditic Fish

- Hermaphroditism: Some fish individuals are both males and females, either simultaneously or sequentially. There is no genetic or physical reason why hermaphroditism should not be present. About 21 families of fish are hermaphrodites.
- Simultaneous hermaphrodite: There are some instances where being a member of both sexes could have its advantages. Imagine all the dates that you could have! In the deep sea, the low light levels and limited food supply make for a very low population density; meaning that potential mates are few and far between. Members of the fish family Salmoniformes (eg salmon) and Serranidae (hamlets) are simultaneous hermaphrodites; they can spawn with any individual encountered.
- Sequential hermaphrodite: Very strange life histories develop in species whose individuals may change sex at some time in their life. They may change from being males to females (protandry) or females to males (protogyny).

An example of protandry is found in the anemonefishes. The fishes live with anemones in a symbiotic relationship; the anemone provide the fish with shelter and protection from predation, and the fish supply the anemone with food. Groups of fishes will live with one anemone, and will not switch anemones. Only the two largest will mate; the largest female and the second largest, the male. With the female being the largest, she can produce the most eggs. When the female dies, the largest male will change sexes and become the female. The rest of the fish are immature males.

A classic example of protogyny is found in the wrasses and parrotfishes. The males in these species form harems, with one large male sequestering and defending a group of smaller females. The male enjoys spectacular reproductive success, as it has many females to mate with. The females also enjoy a limited reproductive success, producing as many eggs as they can, all fertilized by the one male. The male has the advantage over the females; it has many females producing eggs for him to fertilize, whereas the females only have themselves. It is great to be the king!

Size advantage hypothesis of sex determination and sexual patterns in organisms with labile sexuality such as teleosts. Pink line, female fecundity; blue line, male fecundity; yellow line, predicted pattern of sexuality. (a) Gonochorism (separate sexes) in iteroparous (multiple breeding season) species where males compete directly to fertilize eggs; (b) gonochorism in semelparous (single breeding season) species where sex determination complements size at reproduction; (c) protandrous sequential hermaphroditism in iteroparous species with random mating; (d) protogynous sequential hermaphroditism in iteroparous species with female choice for larger dominant males. (Copyright 1997, Odyssey Expeditions, modified in part from R.R. Warner, 1984, American Scientist).



The weird sex stuff comes in when we analyze what the reproductive success of a smaller male may be. As only the largest male, the 'SuperMale' gets to mate with the females, a smaller male would enjoy zero reproductive success. There is no advantage to being a small male, and this is where the hermaphrodism comes in. If all the smaller fish were females, they could all enjoy a limited reproductive success while they are growing. If the male dies, the one that has grown to be the largest female will change sexes and become the male, in turn enjoying a much greater reproductive success than if she did not switch. So there are no small males and everything is all said and done, but wait! Evolution has a keen ability in finding weaknesses in any system, and it has done so with the parrotfish. In nature, we do find smaller male parrotfish, why should this be so? It has to do with the kind of thing that if a parrotfish was a human, could get the parrotfish into a great deal of trouble. The 'supermale' has to run around all of the time keeping track of and protecting all of his females as well capturing and eating food himself, so he does not necessarily have time to pay close attention to the details. When parrotfish mate, they form a spawning aggregation where the supermale will release his sperm into the water and the many females release their eggs. The sperm and egg find each other in the water column and fertilization takes place, and this is where the weakness of the system lays. Along comes the smaller male, who has evolved to look just like a female. Most of the time the smaller male will make itself completely inconspicuous by behaving just like the females, but during the spawning aggregations, he will be releasing sperm instead of eggs. The supermale will probably not even know that he has been conned. Everything gets really mixed up as males are changing into females changing into males. FISH- Schooling Behavior

FISH SCHOOLING

Everyone has heard of a school of fish, an aggregation of fish hanging out together; but why, they are obviously not learning reading, writing, and arithmetic. Schools of fish may be either polarized (with all the fish facing the same direction) or non polarized (all going every which way)

There are some factors that can make it advantageous to hang out with other fish.

Antipredator: by hanging out with other fish, each individual fish may gain an advantage in not being eaten by other fish.

A. **Confusion effect.** A large school of fish may be able to confuse a potential predator into thinking that the school is actually a much larger organism.

B. **Dilution affect.** If a fish hangs out with a lot of other fish and a predator does come around, the predator must usually select one prey item. With so many choices, the chances are that it will not be you. This is known as the 'selfish herd'.

C. **Predator detection.** A bunch of fish has many times the eyes and other senses than a solitary fish; so a school of fish may be better at detecting predators. But a school may also attract predators due to its large size.

Spawning Aggregation: Many fish species form schools only when it comes time to mate. They will form a huge school and release their eggs and sperm in mass quantities. Releasing a massive onslaught of fertilized eggs in the water may be advantages over a solitary egg, because a massive onslaught may be enough to overwhelm the egg predators. The predators will eat as many as they can, but some eggs will inevitably survive.

Enhanced Foraging: A school of fish may have better abilities to acquire food. With many more eyes to detect food, many more meals may be found; but there would also be many more mouths to feed. By working as a team, the school may be able to take larger food items than any one individual could manage to capture.

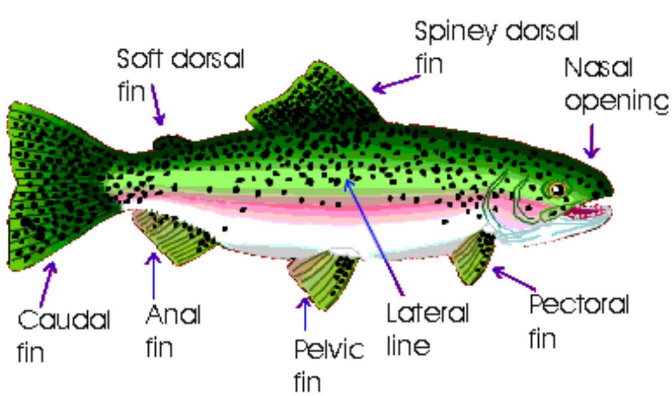
Migration: The migration abilities of fish in schools may possibly be enhanced due to better navigation, etc. Hydrodynamic efficiency: Due to the complex hydrodynamic properties of water (properties the fish probably discovered only by accident), a fish may gain a swimming advantage by being in a school. The slipstream from the fish ahead of it may make it easier to pass through the water. Good for all the fish except for the ones in front.

FISH- how fish swim

The density of water makes it very difficult to move in, but fish can move very smoothly and quickly.

A swimming fish is relying on its skeleton for framework, its muscles for power, and its fins for thrust and direction.

The skeleton of a fish is the most complex in all vertebrates. The skull acts as a fulcrum, the relatively stable part of the fish. The vertebral column acts as levers that operate for the movement of the fish.



The muscles provide the power for swimming and constitute up to 80% of the fish itself. The muscles are arranged in multiple directions (myomeres) that allow the fish to move in any direction. A sinusoidal wave passes down from the head to the tail. The fins provide a platform to exert the thrust from the muscles onto the water.

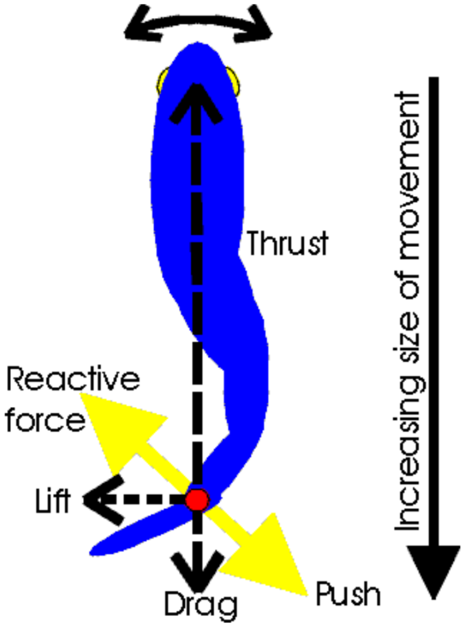


Diagram of forces when a fish swims.

Thrust- force in animal's direction

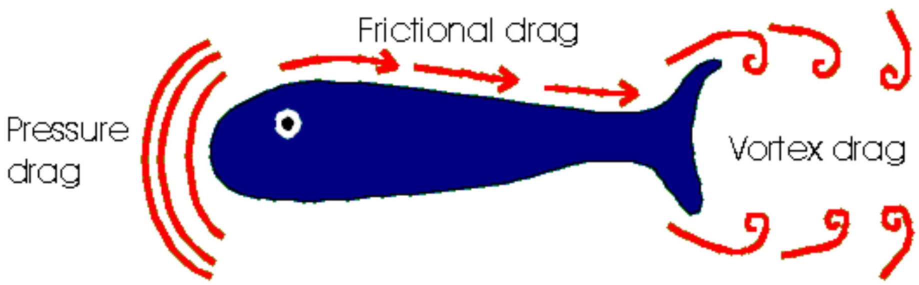
Lift- force opposite in right angles to the thrust

Drag- force opposite the direction of movement

** All lift forces cancel out over one complete tail stroke.

Drag

Drag is minimized by the streamlined shape of the fish and a special slime fishes excrete from their skin that minimizes frictional drag and maintains laminar (smooth) flow of water past the fish.



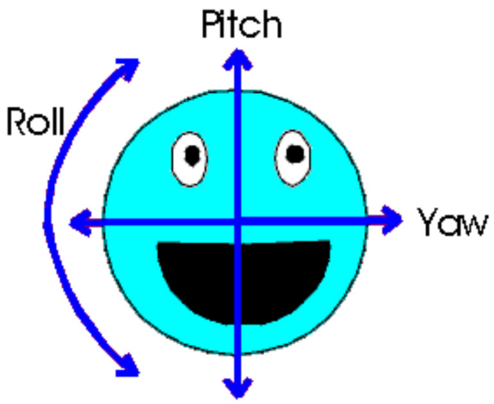
When Thrust > Drag, we have swimming!

Two swimming types in fishes

Defined by their method of living, and reflected in their physiology.

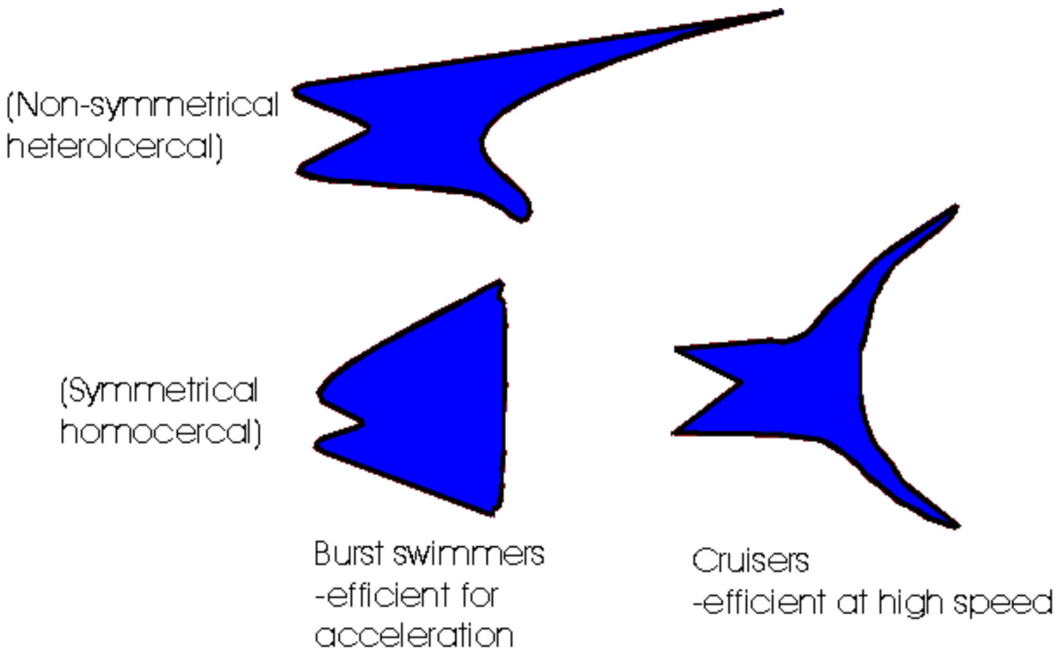
- **Cruisers:** These are the fish that swim almost continuously in search for food, such as the tuna. Red Muscle- richly vascularized (blood-carrying capacity), rich in myoglobin (oxygen holder and transferor into the muscles active sites) * able to sustain continuous aerobic movement.
- **Burst Swimmers:** These fish usually stay relatively in the same place such as most reef fish.

Fins- fins give a fish control over its movements by directing thrust, supplying lift and even acting as brakes. A fish must control its pitch, yaw, and roll.



- Caudal fin-- provides thrust, and control the fishes direction
- Pectorals-- act mostly as rudders and hydroplanes to control yaw and pitch. Also act as very important brakes by causing drag.
- Pelvic fins-- mostly controls pitch
- Dorsal/anal-- control roll

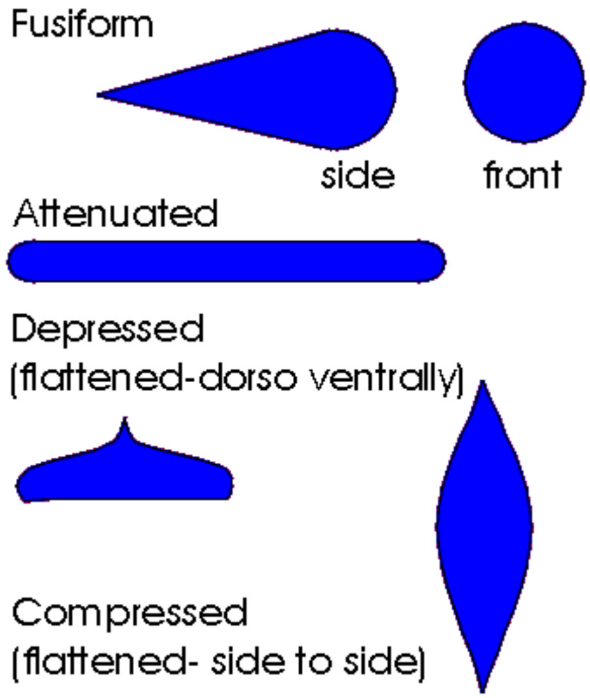
Caudal Fins



VARIATIONS IN BODY FORM

Fish shape has a great bearing on ability to move through the water.

- A tuna fish which has a fusiform similar to a torpedo can cruise through the water at very high speeds.
- The attenuated shape of the eel allows it to wiggle into small crevices where it hunts prey.
- The depressed shape of the angler fish is advantageous for its "sit and wait" strategy of hunting.
- The compressed shape found on many reef fishes such as the butter fish gives the fish great agility for movement around the reef and can support sudden bursts of acceleration.



Fish Thermal Strategies

In general, fishes are cold blooded. They derive their body heat from their environment and conform to its temperature. As water has a high heat capacity, it is able to easily suck any excess heat out of a fish and into the environment.

- Ectothermic: fish derive their heat from the environment
- Poikilothermic: fish conform to the heat in the environment

Some large, fast-swimming fish are not ectothermic. The tunas and mackerel sharks can actually have core body temperatures ten to twenty degrees Celsius higher that the surrounding water. They are endothermic and derive their body heat from their metabolism, but they are still ploikiothermic; their body temperature may be higher than the surrounding water, but they still conform to the temperature of the water, just 10-20 degrees above it.

They maintain a higher body temperature through the use of a specialized counter-current heat exchanger called a reta mirabile. These are dense capillary beds within the swimming muscle that run next to the veins leaving the muscles. Blood passes through the veins and arteries in a counter current (opposite) direction. The heat produced from the muscle contraction flows from the exiting veins into the incoming arteries and is recycled.

Why should they bother having an elevated body temperature? To increase the speed of the fish. The higher the body temperature, the greater the muscular power. Thirty degrees Celsius is the optimum temperature for muscular speed. With increased speed, the tuna can capture the slower, cold blooded fish it prey upon. Tuna have been clocked at record speed of 50-70 mph!

Swim Bladders

Bony fish have swim bladders to help them maintain buoyancy in the water. The swim bladder is a sac inside the abdomen that contains gas. This sac may be open or closed to the gut. If you have ever caught a fish and wondered why its eyes are bulging out of its head, it is because the air in the swim bladder has expanded and is pushing against the back of the eye. Oxygen is the largest percentage of gas in the bladder; nitrogen and carbon dioxide also fill in passively.

Physoclistous- swim bladder is closed to the gut. The gas gets in through a special gas gland in the front of the swim bladder. Gas leaves the bladder through an oval body in the back of the swim bladder. The system works in a pretty miraculous way. Oval body, filled by venous blood -gasses leave here

Gas gland, fed by arterial blood -gasses enter here

inside the spots= giant secretory cells- secrete lactate -in capillary clusters rete mirabile

Increased lactate levels from the giant secretory cells lower the surrounding pH, causing the blood hemoglobin to dump off its oxygen. The oxygen diffuses back into the incoming capillary, increasing the partial pressure of oxygen in the incoming capillary. This continues until the partial pressure of the oxygen in the capillary is higher than that of the swim bladder (which has a high concentration of oxygen). This complex system is necessary because the concentration of oxygen is higher in the swim bladder than it is in the blood, so simple diffusion would tend to pull the oxygen out of the bladder instead of pushing it in. If the fish wants more buoyancy, it must tell its secretory cells to release more lactate. Since oxygen diffuses easily with oxygen-poor venous blood, the gas can be forced out.

*Fish that migrate vertically tend to have high oxygen levels in their bladders because it fills in faster and leaves faster.

*Fish that maintain a stable depth tend to have more nitrogen because it is inert, enters slowly, and exits slowly.

Fishes- How Fish Breathe

How in the heck can a fish, which is underwater, breath if there is no air? When we go under water, we have to bring air with us to survive. Whales and dolphins have lungs that store air from the surface. Fish don't have lungs, and they rarely ever venture into the air, so how do they survive. We all know it has something to do with gills, but what exactly.

The water surrounding a fish contains a small percentage of dissolved oxygen. In the surface waters there can be about 5 ml. of oxygen per liter of water. This is much less than the 210 ml. of oxygen per liter of air that we breath, so the fish must use a special system for concentrating the oxygen in the water to meet their physiological needs. Here it comes again, a counter current exchange system, similar to the one we found in the fish's swim bladder and in the tuna's muscles.

The circulation of blood in fish is simple. The heart only has two chambers, in contrast to our heart which has four. This is because the fish heart only pumps blood in one direction. The blood enters the heart through a vein and exits through a vein on its way to the gills. In the gills, the blood picks up oxygen from the surrounding water and leaves the gills in arteries, which go to the body. The oxygen is used in the body and goes back to the heart. A very simple closed-circle circulatory system.

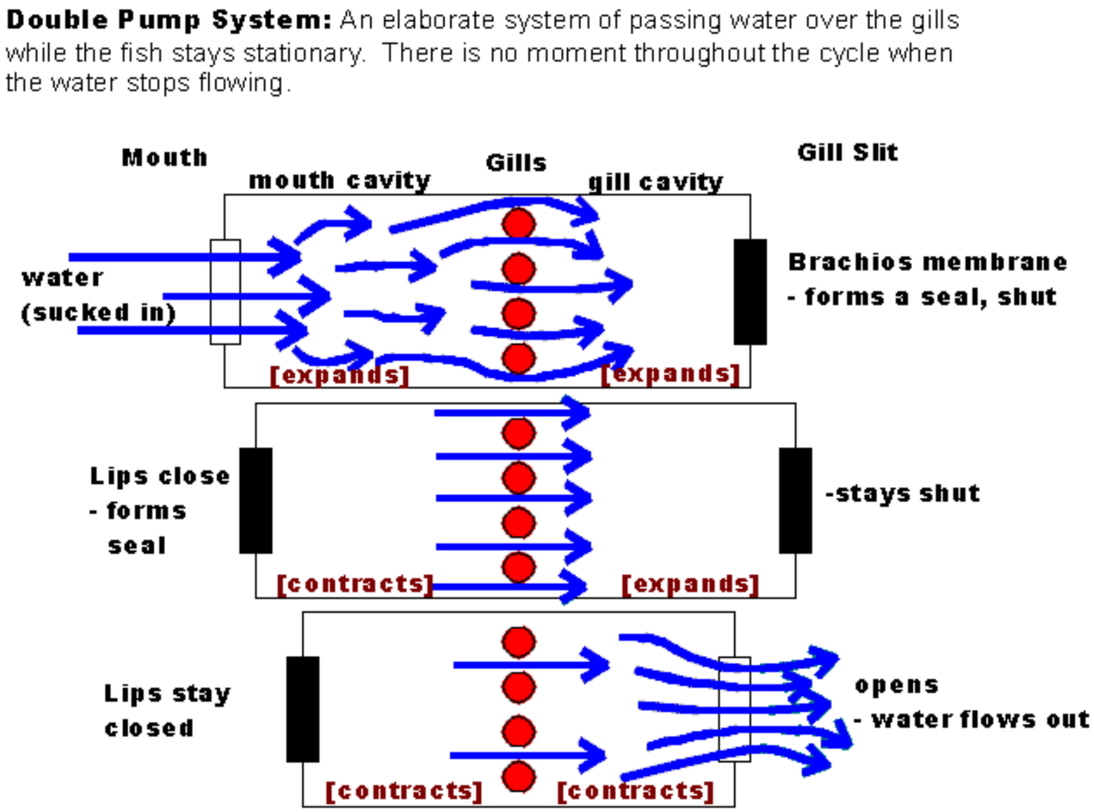
The gills: the gills are composed of a gill arch (which gives the gill rigid support), gill filaments (always paired), and secondary lamellae, (where gas exchange takes place).

Blood Flow, Counter Current Exchanger

- The blood flows thorough the gill filaments and secondary lamellae in the opposite direction from the water passing the gills. This is very important for getting all of the available oxygen out of the water and into the blood.
- If the blood flowed in the same direction as the water passing it, then the blood would only be able to get half of the available oxygen from the water. The blood and water would reach an equilibrium in oxygen content and diffusion would no longer take place.
- By having the blood flow in the opposite direction, the gradient is always such that the water has more available oxygen than the blood, and oxygen diffusion continues to take place after the blood has acquired more than 50% of the water's oxygen content. The countercurrent exchange system gives fish an 80-90% efficiency in acquiring oxygen.
- When fish are taken out of the water, they suffocate. This is not because they cannot breathe the oxygen available in the air, but because their gill arches collapse and there is not enough surface area for diffusion to take place. There are actually some fish that can survive out of the water, such as the walking catfish (which have modified lamellae allowing them to breathe air.
- It is possible for a fish to suffocate in the water. This could happen when the oxygen in the water has been used up by another biotic source such as bacteria decomposing a red tide.

How do fish ventilate their gills? Fish must pass new water over their gills continuously to keep a supply of oxygenated water available for diffusion. Fishes use two different methods for keeping a continuous supply of new water available, one is very simple and the other complex.

--Ram Ventilation: Swim through the water and open your mouth. Very simple, but the fish must swim continuously in order to breathe, not so simple.



Fishes- How Do Fish Sense

Successful survival in any environment depends upon an organism's ability to acquire information from its environment through its senses. Fish have many of the same senses that we have, they can see, smell, touch, feel, and taste, and they have developed some senses that we don't have, such as electroreception. Fish can sense light, chemicals, vibrations and electricity.

Light: photoreception [Vision]. Fish have a very keen sense of vision, which helps them to find food, shelter, mates, and avoid predators. Fish vision is on par with our own vision; many can see in color, and some can see in extremely dim light.

Fish eyes are different from our own. Their lenses are perfectly spherical, which enables them to see underwater because it has a higher refractive index to help them focus. They focus by moving the lens in and out instead of stretching it like we do. They cannot dilate or contract their pupils because the lens bulges through the iris. As the depth at which fish are found increases, the resident fish's eye sizes increase in order to gather the dimmer light. This process continues until the end of the photic zone, where eye size drops off as their is no light to see with. Nocturnal fish tend to have larger eyes then diurnal fish. Just look at a squirrelfish, and you will see this to be so. Some fish have a special eye structure known as the Tapetum lucidum, which amplifies the incoming light. It is a layer of guanine crystals which glow at night. Photons which pass the retina get bounced back to be detected again. If the photons are still not absorbed, they are reflected back out of the eye. On a night dive, you may see these reflections as you shine your light around!

Chemicals: chemoreception [Smell and Taste]. Chemoreception is very well developed in the fishes, especially the sharks and eels which rely upon this to detect their prey. Fish have two nostrils on each side of their head, and there is no connection between the nostrils and the throat. The olfactory rosette is the organ that detects the chemicals. The size of the rosette is proportional to the fish's ability to smell. Some fish (such as sharks, rays, eels, and salmon) can detect chemical levels as low as 1 part per billion.

Fish also have the ability to taste. They have taste buds on their lips, tongue, and all over their mouths. Some fish, such as the goatfish or catfish, have barbels, which are whiskers that have taste structures. Goatfish can be seen digging through the sand with their barbels looking for invertebrate worms to eat and can taste them before they even reach their mouths.

Vibrations: mechanoreception [Hearing and touch]. Have you ever seen a fish's ear. Probably not, but they do have them, located within their bodies as well as a lateral line system that actually lets them feel their surroundings.

Fish do not have external ears, but sound vibrations readily transmit from the water through the fish's body to its internal ears. The ears are divided into two sections, an upper section (pars superior) and a lower section (utriculus) The pars superior is divided into three semicircular canals and give the fish its sense of balance. It is fluid-filled with sensory hairs. The sensory hairs detect the rotational acceleration of the fluid. The canals are arranged so that one gives yaw, another pitch, and the last- roll. The utriculus gives the fish its ability to hear. It has two large otoliths which vibrate with the sound and stimulate surrounding hair cells.

Fish posses another sense of mechanoreception that is kind of like a cross between hearing and touch. The organ responsible for this is the neuromast, a cluster of hair cells which have their hairs linked in a glob of jelly known as 'cupala'. All fish posses free neuromasts, which come in contact directly with the water. Most fish have a series of neuromasts not in direct contact with the water. These are arranged linearly and form the fishes lateral lines. A free neuromast gives the fish directional input.

A lateral line receives signals stimulated in a sequence, and gives the fish much more information (feeling the other fish around it for polarized schooling, and short-range prey detection 'the sense of distant touch').

Electricity: electroreception. Sharks and rays posses special organs for detecting electrical potential [voltage]. A set of pits comprise the electroreceptive system called the ampullae of Lorenzini. These are canals in the skin filled with a gelatin-like material that also contain sensory cells. Movements or disturbances near the shark change the voltage drop along the canals, which allows the shark to sense other organisms nearby. These sensors are so sensitive that if there were not any other distortions a shark could detect the heartbeat of a fish 500 miles away! They can detect muscular contractions of struggling prey and even the earth's magnetic field (which sharks use for navigation).