Fish Resource Guide

What is a Fish?

At first, this might seem like an easy question to answer, but, it is difficult to define what a fish is because there are so many things that we call fish in the world! There are more than 27,900 species of fishes alive today. Fishes are found in marine or freshwaters, in environments as hot as 104°F/40°C to as cold as 28°F/-2°C, and can range in size from 8 mm to 12 m in length. What characteristics unite such a diverse group of animals? Well, what we can say is that:

All Fishes

- Are ***craniates*,** or animals with a brain surrounded and protected by a braincase and a distinct head region with a pair of eyes, teeth, and other sensory organs
- Are ***vertebrates*** with vertebrae surrounding and protecting the spinal cord (except hagfish)

Most Fishes

- Are ***aquatic organisms***, or animals that live in water
- Respire or breathe primarily with ***gills*** rather than lungs
- Have appendages, or limbs we call ***fins that help the fish move through the water***
- Are "***cold blooded***" (ectothermic), or unable to regulate their own internal body temperatures like humans do. Their body temperatures change based on the temperature of the environment they are in.
- Are covered with ***scales*** to protect their bodies

WARNING!!! There are exceptions to this definition.

- The mudskipper can live outside of water.
- Fishes like lungfishes, some catfishes, and gars do not rely only on gills to respire; they have lungs or other breathing structures. This is not surprising because these animals can sometimes live in oxygen poor waters where using gills alone may not be enough to survive.
- Some fishes, like tunas, are essentially warm blooded because of specialized features of their muscles and circulatory system.
- Though most fishes have scales covering their entire body, some only have scales in certain areas, and some lack scales altogether (but their skin is still pretty tough!).

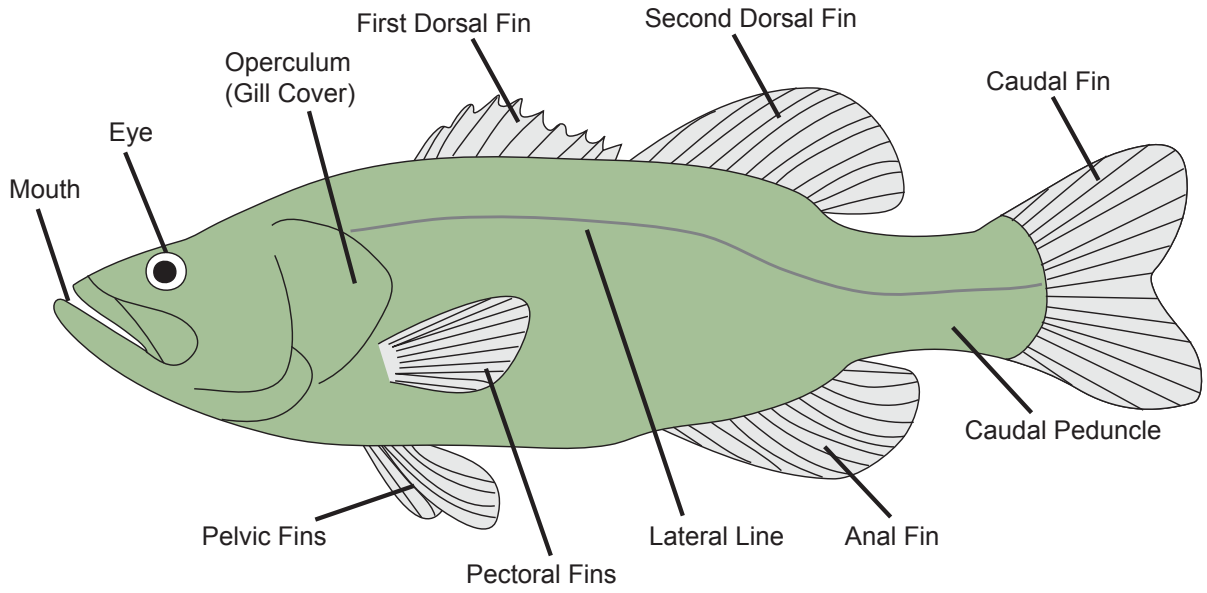
These exceptions, and many others, are ***adaptations*** some fishes have to their environments.

This said, when scientists use the word "fish", they are not using it in the taxonomic sense. It is not a species, genus, family, or any name used in official scientific classification. Instead, the term fish is a convenient term used to refer to diverse aquatic organisms, such as lampreys, sharks, coelacanths, and ray-finned fishes. Therefore, it is important to keep in mind that these common features or characteristics do not necessarily reflect a shared phylogenetic or

evolutionary history among all organisms we might collectively refer to as 'fish'—more on these below in the **Evolutionary Classification: Fishes** section!

A few exceptions aside, a fish has the following basic body plan of: skull, with braincase, jaws, suspensorium, opercular series, gill arches, **vertebrae**, and **fins.** Below are two illustrations showing common external and internal features of bony fishes**.**

External Anatomy



Anal Fin – helps stabilize fish during swimming

Caudal Fin – tail fin used for propulsion

Caudal Peduncle – narrow part of the fish where the tail attaches

Dorsal Fin – protects fish against rolling and helps them stop and turn quickly

Eye – for sight; some fishes that live in the deep sea or caves have degenerate eyes, or eyes that do not aid them visually

Lateral Line – sense organ that helps fish detect vibrations in the water

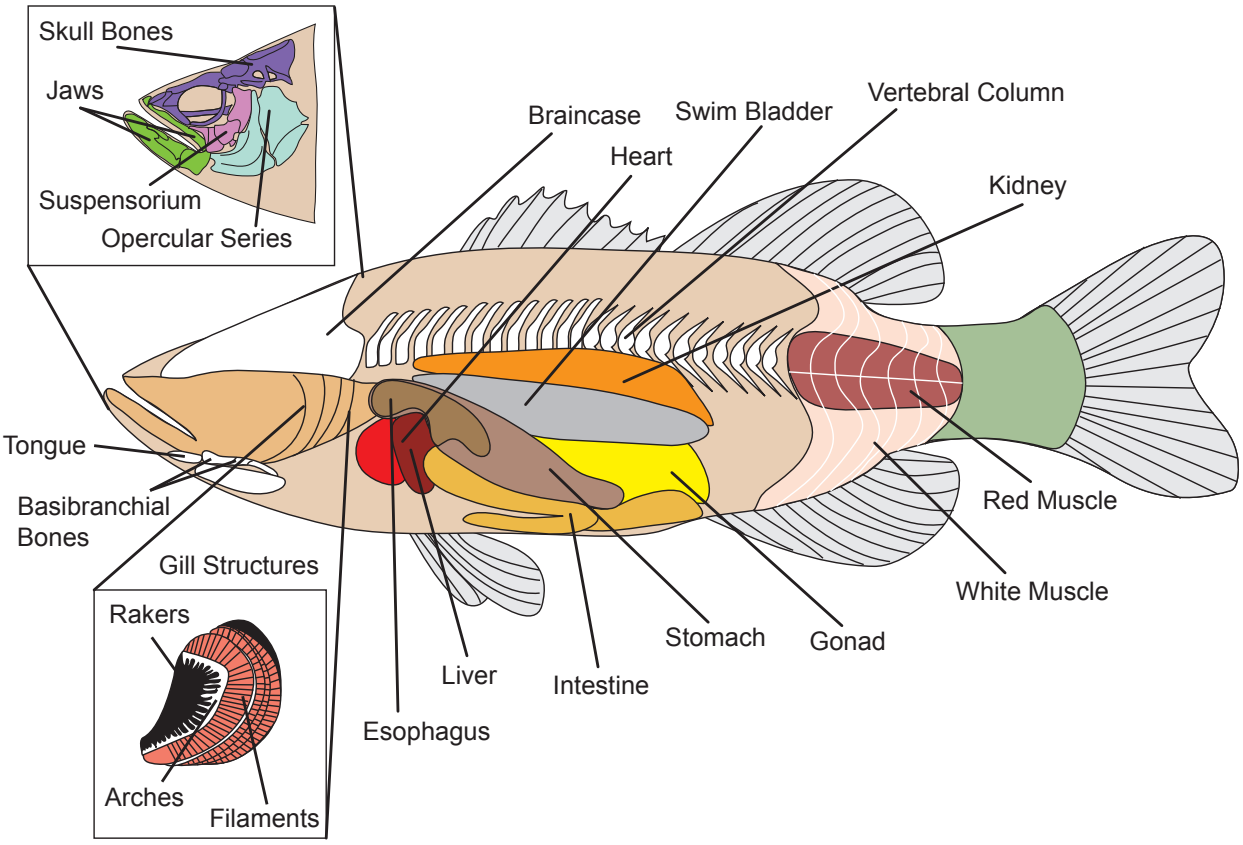
Mouth – for ingesting food; food goes from the mouth into the esophagus before entering the stomach and intestines

Opercular series – a flap formed of several bones that cover the gills and assists in jaw opening in bony fishes; operculum is the most dorsal

Pectoral Fins – depending on the type of fish, they can be used for swimming and maneuvering, to create a lifting force, "walking," or lifting or gliding out of the water

Pelvic Fins – help fish move up and down, turn sharply, and stop quickly

Internal Anatomy (skull bones and jaw structures inset)



Suspensorium – a series of cartilage and bone that suspends the lower jaw from the skull

Basibranchial bones – cartilaginous bones at the floor of the mouth behind the tongue and before the gills; often covered in teeth

Braincase – protects the brain

Esophagus – where food passes between the mouth and stomach

Gill Structures – gill rakers are used for filter feeding tiny prey, crushing hard shell prey, and grasping and passing prey items into the esophagus; gill filaments provide surface area for gas exchange, such as oxygen; gill arches are bony or cartilaginous structures that support the other

gill structures, including pharyngeal toothplates that are used in various ways in feeding and processing food items

Gonad – reproductive organs; testes in males, ovaries in females

Heart – circulates blood through the body

Intestine – absorbs nutrients from consumed food after it has gone through the stomach

Jaws – bony structures for catching and consuming food

Kidney – filters waste materials from the blood and regulates water and salt concentrations

Liver – helps fish digest food by secreting enzymes that break down fats; also stores fats and carbohydrates and helps destroy old blood cells

Red Muscle – aerobic muscle tissue with many capillaries and high myoglobin content; strong, continuous swimmers have proportionally more red muscle than weak, more sedentary swimmers (appears white or cream colored when preserved)

Stomach – breaks down food

Swim bladder – a gas-filled organ that help fish maintain neutral buoyancy in the water and is specialized in some for sound reception and transmission

Tongue – cartilaginous or bony structure on the floor of the mouth located in front of the basibranchial bones; also know as basihyal

Vertebral column – comprises many individual vertebrae that protect the spinal cord and serve as anchors for body musculature used in swimming

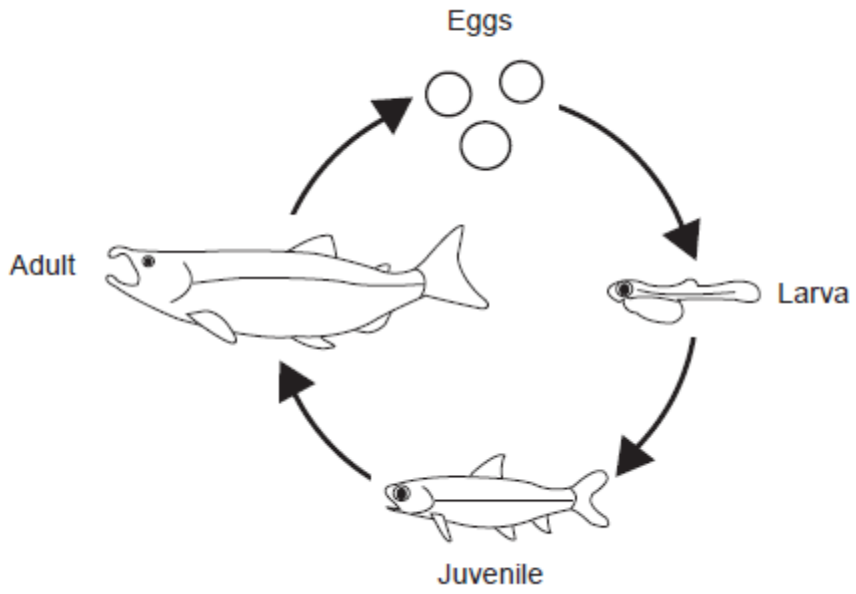
White muscle– anaerobic muscle tissue that lacks myoglobin and has few capillaries (appears brown or red when preserved)

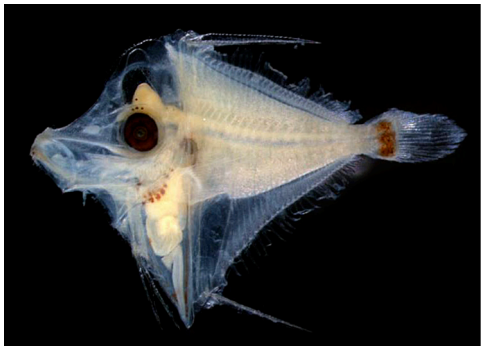
Fun Fish Factoid—Ever notice how people use the words fish and fishes? What's the difference? It's a little more complicated than singular and plural. Scientists use the word "fish" to refer to animals of the same species, regardless of whether there is one individual or 20 individuals. The word "fishes" is used to refer to a grouping of more than one species. For instance, the scientific name (genus and species) of yellowfin tuna, a fish you may have eaten, is *Thunnus albacares*. If you have one yellowfin tuna, you would refer to it with the word "fish." If you have 20 yellowfin tuna, all of the species *Thunnus albacares*, you would also refer to them collectively with the word "fish." If you had a yellowfin tuna, a salmon, and a trout, you would refer to this group with the word "fishes" because they are all different species.

Fish Reproduction and Life Cycle

A common fish life cycle includes a ***fertilized egg***, a ***larva***, a ***juvenile***, and an ***adult*** (see diagram below). In fish with this life cycle, a larva hatches from an egg, and looks drastically different from its eventual adult form. Larvae metamorphose, or change, into juveniles, that look more like a miniature adult. Usually, this transition from a larval to juvenile form is associated with a *change in habitat*—e.g. larvae are often found high in the water column; whereas juveniles and adults may be found in deeper waters, tide pools, rocky shores or coral reefs. The transition to an adult form occurs with reproductive maturity; to be considered an adult, the fish must be reproductively mature.

Example Fish Life Cycle



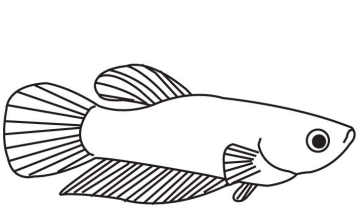


Naso (unicorn fish) – Larva

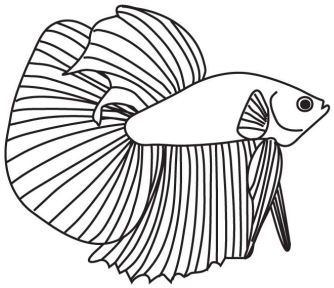
Naso (unicorn fish) – Adult

In addition, many fish display *sexual dimorphism*— e.g. males and females differ significantly in size, shape, and other features.

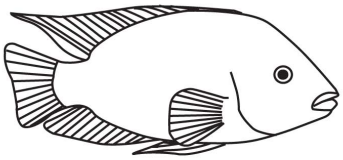
Examples of Sexual Dimorphism in Fishes



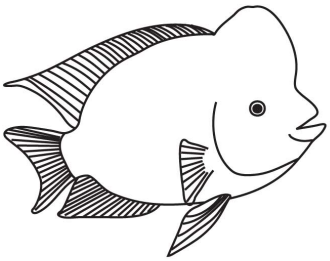
Female Betta



Male Betta



Female Cichlid



Male Cichlid

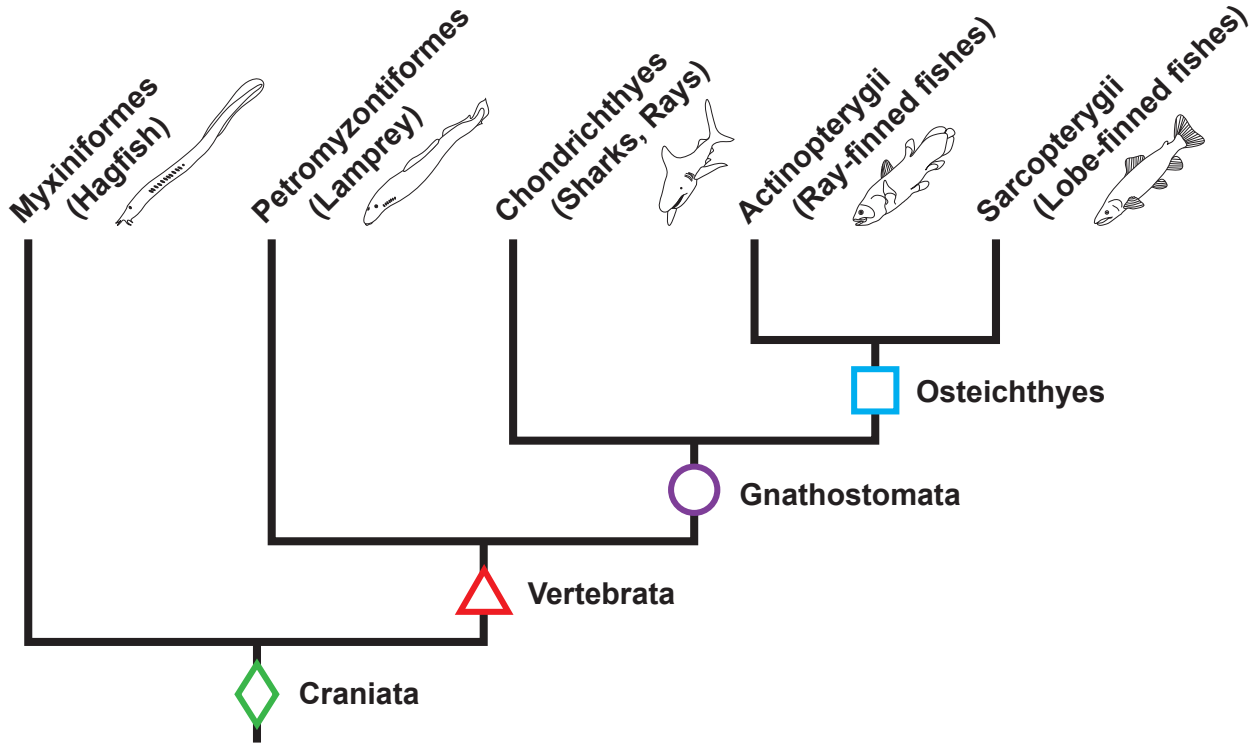
Evolutionary classification: fishes

We have explored the idea of what fishes are and have seen that a clear and consistent definition is challenging. In addition, many of the more familiar ways of thinking about and grouping fishes together are based on overall similarity rather than synapomorphies—shared characters as a result of common ancestry.

It is important to remember that it is derived or 'changed' characters shared by a subset of taxa (synapomorphies) that are useful for determining evolutionary relationships and grouping organisms into clades; whereas, characters that are shared by all taxa (symplesimorphies) are not helpful for determining phylogeny. For example in the tree below, a character shared by ray and lobe-finned fishes only would be a derived character of Osteichthyes and helpful for grouping them together as a clade within Craniates, but this same character would be unchanged for looking at the relationships of species within ray-finned fishes.

We can understand how different types of fishes are related and how different features evolve by generating phylogenetic trees. These are hypotheses of the relationships among fish groups that can be used to look for different patterns.

Below is an evolutionary or phylogenetic classification of what are commonly considered major types or groups of fish based on such shared characters, followed by a brief description and example traits.



Craniata

Fishes and tetrapods (four limbed vertebrates, including you) are craniates. That means that they have a “skull” protecting the brain.

Shared Characters—Craniates:

- braincase surrounding brain
- gills
- distinct head region
- differentiated digestive organs
- heart
- hemoglobin
- complex sensory organs
- complex endocrine system
- brain with three distinct portions
- cranial nerves
- neural crest cells

Vertebrata

All fishes other than hagfishes (Myxiniformes on the tree) are craniates with cartilaginous or bony arches protecting the spinal cord, i.e., vertebrates. All vertebrates that do not have ‘legs’ are referred to collectively as fishes (note: legs can be secondarily lost as is the case with snakes). However, there is no natural group of fishes because some fishes are actually more closely related to tetrapods than to other fishes.

Shared Characters—Vertebrates:

- backbone composed of vertebrae—bony or cartilaginous elements that surround the notochord and spinal cord
- radial fin muscles that control the movement of fins/limbs
- at least two vertical semicircular ducts—ducts in the inner ear that detect certain types of movement

Gnathostomata

Gnathostome means “with jaws”. There are two main groups of jawed fishes based on the type of skeletons the fishes have. Fishes with skeletons of cartilage rather than bone such as sharks, rays, skates and chimaeras are known as cartilaginous fishes (Chondrichthyans); fishes with bony skeletons are bony fishes.

Shared Characters—Gnathostomes:

- upper and lower jaws
- paired fins
- paired nostrils

- five gill slits
- series of gill arches
- three semicircular canal ducts in the inner ear

Osteichthyes (Bony Fishes)

Osteichthyans fishes have skeletons of bone and cartilage.

Shared Characters—Osteichthyans:

- well ossified bony skeletons (most)
- a pair of lungs or a swim bladder (evolved from lungs); some lungs secondarily lost
- bony fin rays (lepidotrichia)

There are two main groups of bony fishes: sarcopterygians or lobe-finned fishes, and actinopterygians or ray-finned fishes.

Sarcopterygii includes lungfishes and coelocanths, as well as tetrapods (four limbed vertebrates – amphibians, reptiles, birds, mammals). Shared characters of sarcopterygians include having a single bone at the base of their paired fins/limbs that articulates with the rest of the body (e.g. think of your humerus and femur).

Actinopterygii includes all other bony fishes alive today such as tuna, trout, salmon, any fish you might have in your aquarium (e.g. goldfish, catfish, clownfish, angelfish). Shared characters for ray-finned fishes include having a single dorsal fin along their back, and paired fins composed of several long flexible rays connected by webbing (hence the name ray-finned fishes).

Studying Fishes

People who study fishes are called ichthyologists. There are many different types of questions being investigated by teams of ichthyologists from around the world such as:

- What types of fishes exist and where do they live?
- How are different types of fishes related?
- How did fishes evolve?
- What role do fishes play in different ecosystems?
- How can we sustain healthy populations of fishes for human consumption?
- And many, many, more!

There are many different tools and techniques that researchers investigating questions about fishes rely on to generate and test their hypotheses. For example, some questions require that fishes be observed in their natural habitat while others rely on collecting specimens to study their physical features, or morphology. These specimens are housed in museums. Ichthyologists also use molecular technology to extract and analyze the DNA or RNA to study fishes.

Sources used (and/or further information see)

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