The great ecological diversity of fishes is reflected in the astonishing variety of body shapes and means of locomotion they possess. Indeed, much can be learned about the ecology of a fish simply by examining its anatomical features or by watching it move through the water. Equally important to students of ichthyology is that these features also form the basis for most schemes of classification and identification.

**Module 2: Ichthyology**

**Section 2: Fishes Structure and Movement**

**Sunshine State Standards**


**Objectives**

- Understand the different body shapes of fishes
- Understand how fish moves
- Learn to identify fish behavior through body shape
**Vocabulary**

**Fin** - is a surface used to produce lift and thrust or to steer while traveling in water, air, or other fluid media. The first use of the word was for the limbs of fish, but has been extended to include other animal limbs and man-made devices.

**Fish** - is any aquatic vertebrate animal that is covered with scales, and equipped with two sets of paired fins and several unpaired fins. Most fish are "cold-blooded", or ectothermic, allowing their body temperatures to vary as ambient temperatures change.

**Pelagic zone** - Any water in the sea that is not close to the bottom or near to the shore is in the pelagic zone.

**Scales** - is a small rigid plate that grows out of an animal's skin to provide protection.

**Background**

Although life in water puts many severe constraints on the "design" of fish, the thousands of species living in a wide variety of habitats means that these constraints are pushed to their limits. This results in many unlikely forms, such as seahorses and lump-fishes. Understanding the significance of the peculiar external anatomy of such forms requires study on case-by-case basis. On the other hand, species that are more recognizably fish-like can usually be placed in some sort of functional category through an examination of body shape, scales, fins, mouth, gill openings, sense organs, and miscellaneous structures.
Fish are somewhat torpedo shaped. Having a shape like this makes it easier to glide through the water. This is called a **fusiform** body shape. The body is compressed at the sides and tapers more at the tail than at the head. Each fish has a set of vertebrae and segmented muscles that repeat from head to tail. This group of bones and muscles help the fish to propel itself from side to side as it swims through the water.

A fish has a number of **fins**. A fin is a membrane supported by rays or spines that function in swimming or orientation in the water. One or more dorsal fins may be located along the center of the back. A caudal fin lies at the end of the tail and is the primary organ for generating thrust to move through the water. One or more anal fins are situated on the **ventral** midline near the caudal fin. There are two pairs of **lateral** fins on fish. The first lateral fin is the **pectoral fin**. It is usually found on the body behind the gills. The second lateral fin, the **pelvic fins**, is found on the belly behind the head, and before the **anal fins**.

There is great diversity in the size, shape and details of fishes. Some fish are stringlike, like the eel, or globe-shaped like the puffer or greatly flattened, like the flounder. Some fish lack eyes, and others lack some of the features by which fish are recognized, including gills, fins, and scales. Their appearance is greatly influenced by their environment.

### Body Shape

The body form of a fish can give a quick assessment of the fish’s way of life. In the diagram on the following pages, the different body shapes, and forms are described. Different shapes allow some fish to be fast or slow, bottom dwellers or live in the **pelagic zone**, and others to survive the extremes of the ocean.

<table>
<thead>
<tr>
<th>Cross Section Body Type</th>
<th>Type</th>
<th>Example</th>
<th>Fish</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fusiform</td>
<td><img src="image" alt="Fusiform Example" /></td>
<td>Tuna, Salmon</td>
<td>Fast swimming, ultra streamlined, open water fishes.</td>
</tr>
<tr>
<td></td>
<td>Compressiform</td>
<td><img src="image" alt="Compressiform Example" /></td>
<td>Angelfish, Filefish</td>
<td>Not constantly moving, require bursts of speed, large eyes</td>
</tr>
<tr>
<td>Image</td>
<td>Description</td>
<td>Image</td>
<td>Scientific Name</td>
<td>Additional Details</td>
</tr>
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<td>--------</td>
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</tr>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>Depressiform</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Skates, Rays Angel Shark Flounder</td>
<td>Flight-like swimming, may live near or on the bottom.</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>leptoccephalii</td>
<td><img src="image4.png" alt="Image" /></td>
<td>larval eels, plankton</td>
<td>Weak swimmer, ribbonlike, continuous body</td>
</tr>
<tr>
<td><img src="image5.png" alt="Image" /></td>
<td>eel-like (anguilliform)</td>
<td><img src="image6.png" alt="Image" /></td>
<td>American Eel</td>
<td>Adults live in freshwater, spawn at sea, lack pelvic fins, scaleless</td>
</tr>
<tr>
<td><img src="image7.png" alt="Image" /></td>
<td>thread-like (filiform)</td>
<td><img src="image8.png" alt="Image" /></td>
<td>Snipe Eel</td>
<td>Long, thin body, moves like a wavy ribbon</td>
</tr>
<tr>
<td><img src="image9.png" alt="Image" /></td>
<td>ribbon-like (taeniform)</td>
<td><img src="image10.png" alt="Image" /></td>
<td>Prickleback Gunnels</td>
<td>Small, elongate, brightly colored, dorsal fin composed of spines</td>
</tr>
<tr>
<td><img src="image11.png" alt="Image" /></td>
<td>arrow-like (sagittiform)</td>
<td><img src="image12.png" alt="Image" /></td>
<td>Pikes Gars Needlefish</td>
<td>Arrow-like body shape, elongated fragile beak, surface dwellers</td>
</tr>
<tr>
<td><img src="image13.png" alt="Image" /></td>
<td>combination of shapes (globiform)</td>
<td><img src="image14.png" alt="Image" /></td>
<td>Lumpsucker Frogfish</td>
<td>Smooth or warty skin, tadpole shaped body, deep water dwellers, pelvic fins united to form sucker</td>
</tr>
</tbody>
</table>
| ![Image](image15.png) | combination of shapes | ![Image](image16.png) | Boxfish Cowfish Puffers | Body covered with bony armor, small mouth, slow-
Another way to classify body types is by their function. In this system:

Most fishes fall into one of six broad categories based on body configuration: rover-predator, lie-in-wait predator, surface-oriented fish, bottom fish, deep-bodied fish and eel-like fish.

1. **Rover predators** (fish that more or less constantly swim about searching for prey) include fusiform body types, as well as salmon, trout, and bass; they have pointed heads, terminal mouths, narrowed caudal peduncles, and forked tails.
2. **Lie-in-wait predators** (predators that catch their prey by ambush) include sagittiform body types; they have dorsal and anal fins placed well back on the body, a streamlined form, flattened heads, and large, well-toothed mouths.

3. **Surface-oriented fishes** are often small, with mouths that are directed upwards toward the surface of the water. These fishes often swim just below the surface, and eat food that is floating on the surface or flying above it. Topminnows, killifish, freshwater hatchetfish, halfbeaks, and flying fish are examples of surface-oriented fishes.

4. **Deep-bodied fish** include all the compressiform types, and are found widely in places where the ability to make tight, close turns is of value, such as rock reefs, coral reefs, thickly vegetated areas, and schools.

5. **Eel-like fish** include taeniform, anguilliform, and filiform shapes all in one category.
6. **Bottom fish** is a very broad category that includes **bottom rovers** like catfishes, suckers, and sturgeons, **bottom clingers** like sculpins, **bottom hiders** like darters and blennies, and **depressiform** body types, like flatfish.

- **Bottom rovers** they have rover predator like body, except that the head tends to be flattened, the back humped and the pectoral fins enlarged.

- **Bottom clingers** are mainly small fish with flattened heads, large pectoral fins, and structures that allow them to adhere to the bottom.
• **Bottom hiders** they are similar to many bottom clingers but they lack the clinging devices and ten dot have more elongated bodies and smaller heads. They live in rocks or in crevices on the bottom of still water.

• **Flatfish** have the most extreme morphologies. Are essentially deep-bodied fish that live with one side on the bottom. In these fish the eye on the downward side migrates during development to the upward side and the mouth often assumes a peculiar twist to enable bottom feeding.

**Fish Scales**

Fish need scales to protect their bodies. The bodies of most fish are covered with overlapping rows of scales. In a number of species, the scales have developed into bony plates. In some species, such as the eel, the scales are minute. In others, such as the catfish, they are almost absent.

Fishes are sometimes classified according to the shape and characteristics of their scales. In the following chart, scale type, shapes and characteristics are listed. A thin layer of skin, the **epidermis**, covers the scales. This layer contains the pigment cells that give the fish its color and cells that secrete a slippery mucous layer that covers the entire body. This mucous layer protects the fish from harmful bacteria and toxins that may be present in it’s watery habitat. Mucous also helps to protect fish when humans handle them!
<table>
<thead>
<tr>
<th>Ganoid</th>
<th>Placoid</th>
<th>Cycloid</th>
<th>Ctenoid</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Ganoid Scale" /></td>
<td><img src="image2.png" alt="Placoid Scale" /></td>
<td><img src="image3.png" alt="Cycloid Scale" /></td>
<td><img src="image4.png" alt="Ctenoid Scale" /></td>
</tr>
</tbody>
</table>

This "primitive" kind of scale is an evolutionary reminder of the time when fishes used armor plating to protect themselves. Ganoid scales are hard and smooth, and may take the form of only a few scales (or scutes, as in the sturgeon and stickleback), partial plating, or overall body plating. **Sturgeons, gars, and sticklebacks** have ganoid scales (or scutes).

Sharks have placoid (PLAK-oyd) scales: tiny, tooth-like structures that are partially embedded in the skin. These tiny, pointed scales, made of the same materials as their (and our) teeth, make their skin feel like sandpaper.

Many fishes with which we are most familiar have cycloid scales, which are the thin, round, almost transparent scales that we find when we are cleaning **trout, salmon, or herring**. **Minnows** also have cycloid scales. These scales are mostly buried in the epidermis, allowing only the small posterior margin to show.

Highly evolved fishes often have ctenoid (TEEN-oyd) scales, which are much like cycloid scales except that they have tiny, comb-like projections (ctenii) on their posterior edges (the edges that show, and are not buried in skin). The colors of brightly colored fishes also show on these posterior edges.

## Fins

Before we start talking about fins, let us be clear about where they are. The diagram of the strange, non-existent fish below will help you follow the discussion of fin types.
Spines

Spines are a late development in fishes, and many fish have them. Spines may be found almost anywhere on the body, and are used primarily for defense. Spines may have painful poisons in them, such as those of the catfish, or simply be annoying because they are sharp and serrated. Some fishes have developed large spines that merely make it difficult for other fishes to get their mouths around them, or impale the unfortunate diner. The most common locations for spines are the first part of the dorsal fin (or in fishes with two dorsal fins, the *first dorsal fin*), and the first part of the pectoral fins. Spines may be counted and their location noted, and this often helps us tell one species from another. Spines may also be cut and their rings counted to provide the fish's age, much like a forester would age a tree trunk.

Pectoral fins

Pectoral fins may be horizontal and down low, like in a salmon, trout, shark, or sturgeon, and used mainly for gliding. Over the course of millennia they have moved upwards on the body of many fishes. Most reef and schooling fishes have their pectoral fins up high and oriented vertically, as in the above diagram. These are often are used for swimming, holding position, and changing directions quickly. Some fishes have further specialized their pectoral fins; the sculpin uses its broad, spiny pectoral fins to help it hold itself to the bottom against strong currents. Flying fishes have lengthened their pectoral fins to allow them to glide. Some fishes use only their pectoral fins to swim, sculling them through the water like oars.

Pelvic fin location

Pelvic fins are usual *abdominal*, meaning that they are attached midway down the belly. Salmon and trout have pelvic fins at this location. When the pelvic fins are below the pectoral fins, such as can be seen in the diagram of the non-existent fish above, they are termed *thoracic*. When a *thoracic* pelvic fin is attached under the gills, it may also be called *jugular*, and if under the chin or eye, *mental*.

Caudal fin shape

A. B. C. D.

A. The *homocercal* (homo-SUR-kul) tail is a modern development. It is symmetrical. It includes truncate, square, slightly forked, and deeply forked types. It is by far the most common caudal fin shape, shared by most fishes.
B. The *heterocercal* tail is an ancient form, possessed by only a few primitive fishes, such as sharks, sturgeon, and paddlefish. It was a necessary tail shape when fishes had no swim bladders and were heavy in the front; if the fish tried to use a symmetrical tail, it would have plunged toward the bottom. Instead, it developed a tail with a deliberately downward-driving design and supplemented it with horizontal, plane-like pectoral fins that transformed that downward force into a horizontal, forward-driving force. Genius!

C. This tail has a non-differentiated caudal fin. This may be found on eels of all sorts, as well as lampreys.

D. The *lunate* tail is a tail that the tuna and mackerel have refined to an engineer's delight. This tail provides powerful forward force, with very little turbulence.

As you might expect, this short list only grazes the very surface of the subject of fin shapes and types, and how they may be used to distinguish one fish from another! Not only fin shapes and types may be used, but also the number and length of rays, the number and length of spines, and the spatial relationship of one fin to another.

**Mouth Types**

Many fishes are identified by looking at or into the mouth. The number of mouth-types exhibited by different species is nothing short of astonishing. Three lakes in Africa contained about 900 species of cichlids, nearly all differentiated mainly by the way their mouths are shaped. (This number is rapidly dwindling, by the way, as the cichlids in these lakes are driven to extinction). Cichlid mouths in Lakes Victoria, Malawi, and Tanganyika are variously adapted to eat other cichlids' eggs, scales pulled from fishes' living bodies, algae from rocks, tiny invertebrates, and many other forms of food. The arrowana of South America has a mouth adapted for spitting water with precision at insects perched on overhead branches. Parrotfish mouths have evolved to look and act like beaks, which they use to grind at coral, making the sand that surrounds coral reefs. Seahorses and pipefish have tubular mouths for sucking in small prey in narrow places like a vacuum cleaner.

Besides mouths, fish also use part of their gills for eating: the gill rakers protrude into the mouth cavity. They can be toothy, small and nubby, or long and comb-like. Long, comb-like gill rakers are useful for filter-feeders, which feed by swimming along with their mouths open, filtering small organisms from the water. Paddlefish, anchovies, and menhaden are good examples of filter-feeders. Toothy gill rakers, on the other hand, can help hold onto unwilling prey.

Fish may have no teeth or different kinds of teeth, as well as teeth in different places in their mouths. Fishes may have jaw teeth, or no jaw teeth. A cutthroat trout may be differentiated from a rainbow trout by the presence of basibranchial teeth, which are just behind the base of the tongue. Loaches and minnows, which have no jaw teeth and look like they are pouting, have plenty of pharyngeal, or throat, teeth for grinding up
their food. Fishes may also have teeth on the roofs of their mouths (vomer and palatine teeth).

The positioning of the mouth is important. Most fish-eating fishes have terminal (at the absolute front of the fish's head) mouths. Suckers and other bottom-feeders have subterminal mouths (below the absolute front tip of the head). Surface-feeders have upturned, or supraterminal, mouths.

Possibly the most prominent difference that can be seen is between gape-and-suck feeders and hit-and-run feeders, both of which can be seen in predatory fish. Hit-and-run feeding was an ancient development for fishes. These fishes, like salmon, trout, gar, and barracuda, have large, hinged jaws, most often with some quite sharp teeth. They lunge at their prey, snap their mouths closed around it, and hold onto it with those sharp teeth. This is a classic sort of predation, and works quite well, but modern fishes have improved upon it. Gape-and-suck feeders have developed protrusible mouths; that is, their mouths open much, much wider, and much, much faster, than you could ever have thought possible from the size of their mouths at rest. This is due to a special arrangement of the bones that make up their mouths. These fishes, like bass, sunfish, and rockfish, actually create a kind of vacuum when they open their mouths, sucking water--along with prey--right into their mouths. The advantage of this is that the fish does not have to move quiet so fast or snap so accurately to catch its prey. Some fishes, like scorpionfishes and anglerfishes, do not have to move at all. They merely lurk in their hiding place until a likely fish drifts by, then open their giant mouths and suck them in.

Locomotion: Fish Movement

Fishes may move in ways that we don't usually think they can, like certain fishes that can fly, glide, hop, or walk using their pectoral fins. And of course, some fishes dig down into the substrate, or bottom. But even when they are swimming, fishes exhibit a remarkable variety of ways of moving.

Most fishes swim by pushing their bodies against the water sideways--first to one side, and then to the other. The reason for this is the way their bodies' muscles are built, limiting them to lateral movements.
The main muscles in the body of a fish are arranged along the sides of the trunk and the tail. The larger muscles run along the back at either side of the spinal cord, and the smaller ones are located below it. Each muscle group is composed of a series of interlocking segments. In ordinary swimming, the muscles alternate contraction from either side. This contraction moves from the front of the fish to the back. This gives the **caudal fin** a wavelike motion. A few types of fishes, such as the eel, swim by a slithering, **serpentine** (snake-like) motion of their bodies. Certain others, among them the trunkfish, propel themselves by the action of their fins without great body motion.

<table>
<thead>
<tr>
<th>Anguilliform</th>
<th>Subcarangiform</th>
<th>Carangiform</th>
<th>Thunniform</th>
<th>Ostraciiform</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ang-WIL-i-form)</td>
<td>(SUB-ca-RANJ-i-form)</td>
<td>(ca-RANJ-i-form)</td>
<td>(TOO-ni-form)</td>
<td>(oh-STRAY-kee-i-form)</td>
</tr>
</tbody>
</table>

The way most eels and many other fishes, such as brotula, gunnels, oarfish, and nurse sharks move. In addition, the sea snakes of Australia’s seas swim this way. In streams, **eels** and **lampreys** use anguilliform movement. The fish moves the entire body against the water in a snake-like fashion. This method of swimming is surprisingly efficient. Electric eels do not swim.

This movement category includes **salmon**, **trout**, **catfish**, **minnows**, and cod. These fishes undulate most of their bodies, but leave their heads fairly still and concentrate most of the movement in the last two-thirds of their bodies.

These fishes include **jacks**, **snappers**, and are very swimmers. In streams, **crappie sunfish** use carangiform movement. The forward parts of their bodies are not capable of undulation. They throw their bodies into a shallow wave that increases in amplitude as it moves backward toward the tail, which snaps like a whip. As you can see, this leaves the head almost still. The **caudal**

This term is sometimes used to describe the extremely fast and efficient movements of fishes like tuna, billfish, and lamnid sharks. These fishes have very narrow caudal peduncles and large caudal fins that are **lunate** (look like the sliver of a waxing moon). Their tails are reinforced by keels, for strength and stability. This

Many fishes are hampered by a boxy or globular shape. Trunkfishes, cowfishes, and boxfishes have too much armoring to be able to flex their bodies. These fishes scull their tails like oars.
this way, but instead hold their bodies very still and undulate only their fins to swim. This is because of the electrical fields that they generate.

**peduncles** (the part of the tail just before the caudal fin) are narrow and the tails are often forked, leading to more efficient movement. This movement type can also be seen in whales and **dolphins** (mammals), and was used by the extinct **ichthyosaurs** (reptiles).

There are still more ways for a fish to swim: rays use the **rajiform** mode, knifefish and some eels use the **gymnotiform** mode, triggerfish use the **balistiform** mode, and so on and so on!
Air bladder

Most fishes (but not all) have air bladders, which we will call gas bladders here. The primary function of the gas bladder is to allow the fish to achieve neutral buoyancy; that is, to keep from sinking. To achieve neutral buoyancy—that is, to be able to stay at any depth it wants—a fish has to be able to take gas into the bladder and let gas out of it, just like you might blow up a balloon or let it deflate.

There are two major different types of gas bladder in fishes: physostomous, in "primitive," and physoclistous, in "derived" fishes.

Fish with physostomous air bladders take gas into their bladders using their mouths: they rise to the surface and swallow air. To let out air, they just burp it out. Examples of this kind of fish are catfish, trout and salmon, sturgeon, minnows, suckers, and eels.

Physoclistous gas bladders, however, do not open to the mouth, so the fish has to let gas in and out of the bladder using a very complex little patch of blood vessels that absorb or let go of gases from the blood. Fishes with these bladders include bass, perch, mosquitofish, and sunfish.

Since physoclistous fishes cannot just burp the gas out of their bladders, they cannot change depths quickly. This is why many fishes, when taken quickly from deep habitats to the surface, will eventually die: they cannot deflate their bladders quickly enough. A good example of this is the rockfish. Many rockfish are caught by nets but fishermen do not want them because of young age, small size, or because they were not looking for rockfish: these fish, even when released, will likely die. (This is unfortunate, because
rockfish are long-lived fish, often living to 80 years or more. Because they live a long time, they do not reproduce in large numbers like other fish. Therefore, once you have killed the small population of rockfish in one area, it may be gone forever).

There are other ways for fishes to store gases, and fishes use their gas bladders for other things besides buoyancy, such as respiration, hearing (all minnows), and sound production. Deepsea fishes often store fat in their gas bladders rather than gases. One, the Coelacanth, stores fat in *lungs*--for the purpose of buoyancy.
**ACTIVITY: INTERVIEW WITH A FISH**

**DURATION:** 30 minutes

**OBJECTIVES**

- Students will generalize that fish have a variety of sizes, colors and forms.
- Students will also grasp that fish characteristics are relative to their environment.

**MATERIALS**

- Internet access
- Fish books
- Fish pictures
- Notebook
- Pencil

**BACKGROUND**

The ocean is a vast realm of knowledge and diversity. When people think of the ocean, they think of huge whales, playful dolphins, schools of fish, and beautiful coral reefs. Often, people fail to realize how different each organism really is. The main purpose of this activity is for students to establish an understanding of fish adaptations and the purposes for the differences in each. Stress to the students that they should try to see the world through the animals’ eyes, not give them human characteristics.

**PROCEDURE**

1. **OPTIONAL EXPERIENCE:** Invite a local newspaper reporter to talk with your students. Ask him or her to describe what a reporter does, and especially to talk about the techniques of interviewing and writing used.

2. Have the students brainstorm, research, or search on the internet for lists and descriptions of different fish species from different aquatic and marine locations.

3. Work with the students to establish a research, interview and reporting format for their use as reporters. Follow the example below:

**RESEARCH**

Each team of students should:

- Decide which fish to interview
- Write a list of questions to ask
**INTERVIEW:**
- Each team of reporters has now selected an animal.
- The team will first need to gather information about the animal through observation and consulting resource materials.
- One student asks questions while the other student assumes the role of the fish and responds to the questions.
- Questions might include
  - Fin shape
  - Size and length
  - Mouth location and appearance
  - Coloration and appearance
- Have the students change roles.
- Use care: Remind the students not to project human attributes to the animal. Stress to the students that they should try to see the world through the eyes of the fish.

**FINAL REPORT**

Each team of students should use its notes and information that they have gathered as the background for writing up the interview with the chosen fish. The write up should be in the form of an informative newspaper article. The article should talk about the fish differs from other fish, its adaptations, its appearance, what it eats and where it lives. The article should convey that the students understand why fish are found in varieties of shapes, sizes and forms.
ACTIVITY: FISH ANATOMY LESSON PLAN

DURATION: 30 minutes

OBJECTIVES

Students will learn the following:

1. Internal anatomy of the fish
2. Vocabulary for anatomical parts
3. Anatomical functions and forms
4. Differences in fish morphology as relates to behavior

MATERIALS

For this lesson you will need:

- Biology books on fish and/or human anatomy and behavior
- Pictures of different types of fish
- Computer with Internet access
- Materials to build the dissection model
- Drawing paper and pencils for sketching new fish

PROCEDURES

1. Introduction: Talk about how form affects function in living creatures. Long torpedo shaped fish swim quickly. Short round fish swim slowly. Fish with long toothed jaws like a dog feed on different prey than those with big sucker-like lips on the bottom of their heads. Talk about how biology of creatures varies giving some creatures survival advantages in one place while limiting their survival capacity in others. Ex. Fish are cold-blooded and can live at the bottom of lakes where the water is cold and freezes but they die if exposed to water temperatures that are too warm. Fish take up dissolved oxygen across the gill membranes without drowning. Some swim quickly, others bury themselves in the silt. Some fish like trout and salmon can exploit different habitats in the same stream to minimize competition when they are have otherwise very similar needs.

2. Background: Early colonial explorers noted the types of fish in New England. Study of the biology and management of fish in the Connecticut River did not get going until the 1860s when alarming declines in the fisheries alerted basin residents to a problem. To this day, there are many areas of fish biology that are unexplained – ex. How do salmon find their home streams? How can a three-foot long salmon leap an 11 feet high waterfalls? What is limiting salmon survival in the ocean? Understanding the answer to questions like these requires an understanding of fish biology and the environment.
ADAPTATIONS

This lesson can be conducted without building the model for dissection by using one-dimensional drawings from the Internet.

Real fish obtained from biological supply companies can be dissected.

Fish behavior can be observed in an aquarium or in the stream.

DISCUSSION QUESTIONS

1. What are some examples of salmon anatomy that are the same as human anatomy? How about examples where the organs are not the same? Why are there differences?
2. Give an example of fish that are very different but live in the same environment.
3. Give an example of fish that are very similar in the same environment. How does at least one of these fish find a differing niche?
4. What are the advantages of being different or being the same?

EXTENSIONS

External Anatomy
Create a dissection demonstration that keys on external anatomy, fins etc. How does external anatomy vary among fish and why are there these differences? Students can create fish that have novel external anatomy by mixing and matching fins, body shape, etc. Ask them how and where their newly invented fish would thrive most successfully? They should be able to explain why?

Evolution
Study the shapes and behaviors of prehistoric fish and other animals. Discuss how changes over time have benefited or better adapted these animals or else lead to extinction. Discuss any physical abnormalities observed among hatched fry. How could these changes potentially help the fry? How could they benefit those who have not changed? Why do fish have varying life cycles?

Systems
Have students delve further into fish biology by looking at systems – nervous system, endocrine system, etc. How do these systems work during salmon smoltification, or when a salmon is exposed to contamination like copper or estrogen hormones? What does this suggest about threats to fish populations and the environment?

Fish Health
Understanding the anatomy of a healthy fish helps in diagnosing disease in others of the same species. have students identify types of fish diseases and how they are transmitted. Are fish diseases dangerous to human health?
Human vs. Fish Anatomy

Compare fish and human anatomy and life cycles. Discuss the differences and the advantages and disadvantages of both.
ACTIVITY: FISH HEADS

DURATION: 30-45 minutes

MATERIALS

1. Fish head handout or dried fish heads
2. Pencil

PROCEDURES

Introduction

1. Ask how many children have pets. How many have dogs? Ask what breeds their dogs are. How are breeds different and how are they the same? Discuss how animals such as dogs can be similar but have features that make them different. Talk about small dogs that are adapted to chasing game down holes, or webbed-toe breeds adapted to water rescue. Then ask the question, "Why are animals different?"
2. Today, we are going to look at different types of fish heads and discuss why they are different and how they came to be this way.

Activity

1. Give students handout. Review the vocabulary terms habitat, niche and adaptation. Ask: what is in an aquatic environment? How might these environmental factors vary from one lake to another. Are they different in lakes and rivers? What about in the ocean?
2. Have students examine pictures of fish heads on handout or actual fish heads.
3. Ask the question, "How are these fish heads different?" What features do they have which vary and which are the same? Look at the shapes of their heads, the size and shape of their mouths and teeth, and the location of their eyes.
4. What might these similarities and differences tell you about where the fish lives, what kind of food it eats, and where it is in the food chain?
FISH HEAD HANDOUT
**ACTIVITY: FLATFISH IN MOTION**

**DURATION:** 1 hour

**OBJECTIVES**
- Students will learn about the life cycle of flatfish. Students will discover how flatfish develop differently from other fish. Students will use vocabulary terms related to fish biology. Students will be able to convey what they have learned through a follow-up art/writing activity.

**MATERIALS**
- Flatfish Information Sheet (below)
- Chart Paper
- Markers or crayons
- Drawing Paper
- Small plastic fish (crumpled up paper will also work.)

**ANTICIPATORY SET (LEAD-IN)**
(Teacher will read and become familiar with flatfish information sheet.) Make a chart of what the children know about fish. (Children can either write on the chart or dictate to the teacher depending on level of proficiency.)

Introduce the term flatfish. Explain that flatfish hatch from eggs looking like every other fish - with one eye on each side of their head, but as they grow, their eyes migrate (move) to one side of their head. Some flatfish have both eyes on the left side (left-eyed) and some have both eyes on the right side (right-eyed)!

Discuss why they might be flat and where they might live in the water. Discuss what they eat.

**PROCEDURES**
(Make sure there is enough floor space for children to lie down during the activity.)

Step 1. "Now, we are going to pretend to be flatfish. Let’s start out as eggs." Children curl into a little ball.

Step 2. "We are growing into larvae now - that means we are becoming flatfish children. Swim around the ocean." Children stand up and swim like fish around the room.

Step 3. "Now we are growing up more. Put your eyes on one side of your head! No, you can’t really do that, can you? But you can pretend by turning your head to one side.
Now make yourself flat on the bottom of the ocean." Children slowly turn their heads and then lay down flat on the floor.

Step 4. "Now try to swim like a flatfish. Do this by just moving your body." Let them do this for a little while.

Step 5. "Flatfish lie on the bottom and their color changes to match the background. Can anyone tell me how this helps them hide? Why do they want to hide?" Discuss predator/prey relationship and camouflage. "Who in our class is the most hidden right now? Can you tell me why?"

Step 6. Throw the plastic fish (or pieces of crumpled up paper) onto the floor and let the fish "feed." "I am putting some crabs, shrimp and smaller fish into the ocean. Now you have to swim around and collect your food."

**PLAN FOR INDEPENDENT PRACTICE**

Students can use what they learned to extend the activity to playtime (outside or inside).

**CLOSURE**

As a group, look at the chart that was made before the activity. Is there anything that the students can add that they learned during the activity?
Flatfishes are easy to identify. In an adult flatfish, both eyes are on the dark (pigmented) side of the body, while the other side is eyeless and white. Flatfishes lie on the bottom with the dark side up and the pale side down. Flatfishes can change color to camouflage themselves to match the bottom. Their shape and color makes it easy for them to lie on the bottom and hide from both predators and prey. Most flatfishes swim close to the bottom by undulating their bodies. They have long dorsal and anal fins to help them move along the bottom.

Flatfishes do not start out life flat. The larvae look like most other fish. They are the same color on both sides, and have one eye on each side of the head. As the flatfishes grow, their color and pigmentation patterns change and one eye migrates across the top of their heads to end up on the same side as the other eye.

Some flatfishes are left-eyed and some are right-eyed. This means, some flatfishes have both eyes on the left side (left-eyed) and some have both eyes on the right side (right-eyed)! Left-eyed flatfish rest on their right side and right-eyed flatfish rest on their left side.

Many flatfishes are found on muddy bottoms in shallow waters. Some flatfishes migrate in the winter to deeper waters. Most feed on worms, crustaceans and other small bottom invertebrates.

There are more that 500 species of flatfishes, in 6 or 7 families. Flatfishes include flounder, sole, turbot, halibut, sand dab, plaice and tonguefish. The flatfishes included in this unit are from the families Bothidae and Cynoglossidae. Both of these families are left-eyed flatfishes.
ACTIVITY: CONDIMENT DIVER: THE WORLD'S SIMPLEST CARTESIAN DIVER

This activity uses a condiment packet to teach students how fish use their swim bladders to rise and descend in the water. The students will also learn about density, buoyancy, and sinking and floating.

DURATION: 1 hour

OBJECTIVES

- Students should be able to explain why some objects sink and some objects float.
- Students should be able to explain what density is and how it affects objects and other substances.
- Students should be able to explain why the condiment packet floats and what causes it to sink, and then relate this information to how fish, and submarines rise and descend in the water.
- Students should be able to form a hypothesis
- Students should be able to collect and analyze data
- Students should be able to communicate data by using a data collection sheet
- Students should be able to draw a conclusion based on the data collected

MATERIALS

- Several squeeze condiment packets (soy sauce, ketchup, mustard, etc.) Many fast food restaurants, such as McDonald's, Arby's, and Burger King, will donate the condiments. * Not all condiments behave the same; therefore it is recommended that they be tested beforehand. Have twice the number of condiment packets that you think you will need.
- Clear plastic bottle with tight-fitting lid (1-liter is easier to use for small hands than 2-liter); Wide-mouth bottles are easier to use than regular water bottles in case it is necessary to remove the packet from the bottle.
- *Optional: a pair of tweezers to help retrieve the condiment packets from the bottle of water - when the condiment packet needs to be exchanged.
- Bucket or large container to empty the bottles of water - when the condiment packet needs to be exchanged.
- Bowl of water for testing packets. The teacher may want to put "catch pans" or trays under students' bottles in case of splashes or spills.
- Water to fill the plastic bottles: Gallon milk jugs work well
- Paper towels
- Worksheet
- Eggs
- Salt
PROCEDURES

1. Place a fresh egg in a clear glass of water. It should sink to the bottom. Ask the students how they can get the egg to float without touching the egg. (Gradually add salt. As more salt is added, the egg will begin to float. You can get the egg to remain in the center of the glass before it floats to the top. Sink and float at the same time - neutral buoyancy. By continuing to add salt, the density of the water is increasing. The egg will eventually float on top of the water.)

2. The density of a fresh egg is greater than that of an older egg because it loses water through the tiny pores in the shell. (So, don't eat an egg that floats in fresh water. It's spoiled.) If you save an egg for several days past the expiration date, you will be able to demonstrate this to the students. Keep checking the egg at home to make sure it is ready to float in time for your demonstration. Place a fresh egg in water - it goes to the bottom and lies on its side; 3-4 days old - stays on the bottom at a 45 degree angle; 10-12 days old - stays on the bottom, but stands straight up; If it floats to the top - it is bad and should not be opened in the house because it will smell.

3. Show a picture of a submarine or fish and ask the students what they know about its motion, what makes it possible for each to rise and sink in the water. The swim bladder is filled with gasses which are produced in its blood. When the swim bladder is inflated with these gasses, it increases the fishes' volume decreasing its density, which keeps it from sinking.

Assessment

Before proceeding, by your questions and their responses, make sure the students' understand what density is and how it affects objects. Explain how a fish is able to rise and sink in water
Explain how a submarine is able to dive and float in water
Explain how to check if an egg, past its expiration date, is still safe to eat

Exploration

Before beginning this activity, review safety procedures with students; make sure that students know they are not to taste/eat anything in the science lab.

1. Today we will make a condiment diver. Find out if your condiment packet is a good candidate for a Cartesian diver by dropping the packet in a bowl of water. (See "Content Knowledge" for an explanation of what a Cartesian diver is and how it is made.) The best ones just barely float. *Even though the packets just barely float, some of them still will not sink in the bottle when the bottle is squeezed.
2. Fill the clear plastic bottle with water leaving a small amount of air space. Push the unopened packet into the bottle.

Screw the cap on tight.

3. Squeeze the bottle to make the packet sink, and release to make it rise. *If the diver does not sink, use another packet. This is where a wide mouth opening is to your advantage since it makes it easier to remove the packet from the bottle. A pair of tweezers also works to help remove the packet from the bottle, but be careful not to puncture the packet.

**Assessment**

Monitor the students’ work to make sure they are following the correct procedures, making observations, and recording data accurately. Redirect their attention to the task, as needed.
Make sure that students are employing safe practices as they conduct the experiment. Check to see that each member of the group is participating.

Answer students’ questions regarding procedures.
1. Name the brands and the contents of the condiment packets that floated.
2. Name the brands and the contents of the condiment packets that did not float.
3. Name the brands and the contents of the condiment packets that worked as Cartesian divers.
4. Are there any similarities with the condiment packets that worked as Cartesian divers.
5. Is there anything inside the packets besides the condiment? (Air)

Explanation

Students report their findings.
1. What property are we talking about when we are talking about objects floating? (Density which is a comparison between the mass of an object and its volume. Mass is how much stuff is in an object. Volume is how much space an object occupies. Density = mass/volume; Also Buoyant force: Water and air pressure increase the deeper you go. Think of a "Cheer-leader pyramid" - Who has more pressure on them, the person at the top or the cheerleaders on the bottom? (bottom since they have the rest of the cheerleaders on top of them) Since there is more pressure at the bottom of an object in water than at the top, there is an upward force on the object. This force is buoyant force. If an object in water weighs more than the buoyant force, it will sink. If an object in water weighs the same as the buoyant force, it will float. The steel that is used to build a ship is much heavier and denser than water. So why does it float? The secret is its shape. It is built with a hollow shape which increases it's volume (how much space it takes up), which in turn reduces its density. Therefore it floats.)

2. Why do you think the condiment packet floats? (The density of the packet is less than the density of the water.)

3. What happens to the pressure on the inside of the bottle when you squeeze the bottle? (It increases)

4. When the bottle is squeezed what changes, to the condiment packet, are taking place? (The air in the packet is compressed which changes the volume, which in turn changes the density.)

5. What is affecting the buoyancy of the condiment packet? (Density of the packet/ air inside the packet.)
Most students are familiar with air being in flotation devices for swimming. Relate this same principle to the condiment packets, which also contain some air.

Assessment

Listen to students' accounts of their findings to judge if their reports are supported by the findings that you observed as experiments were being conducted. Ascertain students' knowledge of density and buoyancy by asking questions. See above #

1. Have students create a concept map for buoyant force and density. Include information that shows objects that float on the surface of water, objects that float between the surface and the bottom, and objects that sink to the bottom.

2. Name three things that can be done to change the density of an object. (Change its shape, change its mass or change its volume.)

Elaboration

- Take a 6 square inch piece of foil. Press it into the shape of a boat. Place it gently in a container of water. Record your observations. (It floats)
- Roll the foil boat into a ball. Place the foil ball gently into the container of water. Record your observations. (It sinks)
- What did you change that made the piece of foil sink? (Changed the shape, which decreased the volume, which increased the density, causing it to sink)

Assessment

Ask questions to ascertain students' understanding of density and buoyancy. Give students 2-3 minutes to complete a brief written summary of the experience. The prompt will be: Imagine that your friend tells you that all heavy objects sink in water. Explain why you agree or disagree with his statement.

2. Make a poster that explains how a life jacket helps a person float. (Most are made of porous material filled with air. The life jacket increases the person's volume which decreases his/her density, therefore the person floats.)

Content Knowledge

- The original Cartesian Diver is made with a pipette and a hex nut that can fit snugly onto the stem of the pipette.
1. Cut off almost all of the stem (leave about 15mm). Place the hex nut snugly onto the remaining part of the stem.

![Figure 1—Cutting the pipette](image)

2. Fill the pipette about 1/2-way with water. Place the pipette with the nut into a bottle of water. Screw the lid on tightly, squeeze the bottle.

![Diagram of bottle and pipette](image)

The pipette sinks to the bottom of the bottle when it is squeezed, and rises when you release the squeeze. If it doesn't work, adjust the amount of water in the pipette, by adding or subtracting water in the pipette.

- Whether an object sinks or floats is dependant on whether the object's density is greater or less than the liquid it is in.
- Since density is a comparison between the mass of the object to the volume of the object, if you add to the mass without changing its volume, the density will increase. If you keep the mass the same, but decrease the volume, the density will decrease. Since gas/air can be compressed, when you apply pressure to the bottle, you also apply pressure to the air in the packet which in turn will decrease the volume of the packet, making the packet less dense.
Density = mass /volume. A pan balance is the instrument used to find the mass of an object.

- Most of the sauces in the condiment packets are denser than water which should make the packets sink, but there is also some air in the packets. It is the air that helps the packets float. When you squeeze the bottle, you put pressure on the bottle, which increases the pressure on the water, which in turn increases pressure on the packet causing the air to compress. This compression makes the packet smaller, which causes the packet to sink/dive. When you release the pressure on the bottle, the packet returns to the original volume, causing it to rise.

- Submarines use the same principle to float and dive.
- Scuba divers add weights/mass to keep from floating.
- If the density of an object is less than the density of water, it will float. If the density of an object is greater than the density of water, it will sink.

Safety

Remind students to use materials for the intended purpose; no horseplay in the lab; do not eat or taste anything in the science lab. Be careful about spills; report any spills to the teacher.

Applications

Fish use swim bladders to rise and descend in the water. Submarines use the same principle to rise and descend in the water. Scuba divers use the principle of buoyancy and density to float and sink in the water. Safety devices for swimming and boating such as life preservers, life raft, "air wings" for the upper arms of young children that cannot swim, etc.
Student Cartesian Diver Worksheet

Cartesian Diver with Condiment Packet Name ______________________

Part 1

1. Name the brands and the contents of the condiment packets that floated.

2. Name the brands and the contents of the condiment packets that did not float.

3. Name the brands and the contents of the condiment packets that worked as Cartesian divers.

4. How do you explain what you observed?

5. What do the packets, that float, have in common?

6. What do the packets, that sink, have in common?

7. Is there anything inside the packets besides the condiment?

8. Explain why objects float.

9. Why do you think the condiment packet floats?

10. What happens to the pressure on the inside of the bottle when you squeeze the bottle?

11. When the bottle is squeezed what changes, to the condiment packet, are taking place?

Part 2

12. What is affecting the buoyancy of the condiment packet?

13. How might fish use this technique to become more or less buoyant?

14. How might a submarine use this technique to become more or less buoyant?

15. What can a scuba diver do to keep from floating back to the surface of the water?
RESOURCES

http://chamisa.freeshell.org/fish.htm#mouth


http://www.lessonplanspage.com/SciencePEArtLAMDFlatfishMovementActivityK2.htm

http://www.spice.centers.ufl.edu/Floating%20Fishes/Floating%20Fishes%20Summary.doc

http://www.agpa.uakron.edu/p16/lesson.php?id=condiment&pg=abstract


http://en.wikipedia.org/wiki/Fish

http://australianmuseum.net.au/fish-scales

http://www.stream.fs.fed.us/fishxing/help/9_Fish_Performance/Fish_Movement.htm

http://en.wikipedia.org/wiki/Fish_locomotion

http://jeb.biologists.org/cgi/reprint/13/1/63.pdf

http://www.iowas.co.uk/fish%20anatomy.html

http://badmanstropicalfish.com/anatomy.html