DESIGNER FISH

Introduction

As you've learned in Science class, many animals have adapted to better fit their environment. Fish are no different. The wide varieties of fish all have special adaptations that help them in various ways. As we examine fish, we immediately notice that coloration plays a very important role, but have you ever looked closely at the other parts of a fish? What about the patterns, spots. or lines? Have you ever looked at the mouth of the fish, the eyes, the fins & tail? All of these traits / structures have enabled each species of fish to better survive in its environment. Each is a valuable adaptation that has benefited the fish.

This booklet is designed to have you gain a better understanding of fish and their characteristics. It is filled with information and activities for you to complete as part of the *Trout in the Classroom* program in a cross-curricular approach with Art & Science. Nature itself contains patterns and rhythm which create expressions and can show students how to express themselves, work cooperatively, and gain respect and understanding.. Although our collaboration with Nature is often ephemeral, things that only last a short while, it can be utilized to help teach artistic and scientific concepts in many ways.

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Science Activities

Fish Heads, Fish heads,…

Design a fish

Life Patterns (Science meets Art)

When studying the world of nature, art and science are two sides of the same coin. In the scientific world of observation & discovery many art terms and concepts are used. The world of art consists of designs categorized into two broad areas: elements and principles. These also are used in the scientific discipline of describing the natural world.

The elements of design are as follows:

Color (hue, intensity, value)	Line
Shape / form	Space
Texture	

The elements of design are the "tools" of art, and the markings / features of the world of nature, such as fish, for example.

The principles of design are as follows:

Balance	Variety	Harmony
Emphasis	Proportion	Movement
Rhythm	Unity	

The principles of design are "how the tools (elements) are used" in art, and how they are organized or observed in the world of nature, such as fish, for example.

The world of life is an expressive world of discovery which can be analyzed, synthesized and evaluated with great depth when art & science combine in the life long journey of learning

Coloration

Nature is full of color. Color provides a number of strategies which includes hiding from predators and prey, attracting mates and even acting as a warning to other animals. One thought must always be kept in mind. The colors that we see are not the same colors that other animals may see. The *coloration* of fish is one of the widest and most varied adaptations among fish. Coloration may vary slightly even among members of the same species or population. There are no distinct rules for the colors and patterns found on fish but, there are a few general guidelines.

Clean clear water has a blue appearance because blue light waves are bent by the water molecules. This is the same reason why the sky appears to be blue! Blue and Cyan colors can also penetrate deeper in water than other colors of light. The red and orange color light waves can only reach down to about 45 feet deep while the blues can reach as deep as 120 feet. This is the main reason why the most common color found on fish would be some shade of blue. Especially for those that live in very deep water. Fish that are found in more shallow water (where the red and orange light waves can reach) tend to have a greater range of colors in red and orange. Most fish have scales that are transparent so … the colors we see are created by the skin color shining through.

Generally speaking, male fish are more colorful than female fish. This happens because of the male fish wanting to attract females during their spawning time. It is thought that female fish find the more colorful male fish to be stronger or more fit therefore giving their offspring a better chance for survival.

Fish are generally colored darker on the top and lighter on the bottom. This strategy is called counter-shading. This helps to camouflage the fish from predators who may hunt from the surface. Dark colors on top help the fish to blend in with the bottom. While light belly colors help the fish blend into the bright sky color which camouflages the fish from bottom predators. Darker

colored fish tend to be found in deeper water while lighter colored fish tend to be found in more shallow waters.

Camouflage

As we learned about natural selection and adaptations, you can see how important camouflage can be to an organism. *Camouflage* is a way to hide familiar shapes / colors / and patterns to help better blend into the surroundings. Camouflage is a form of adaptation. This benefits an organism by allowing it to hide from predators / prey, stalk prey, and protect the young. As a general rule, environments with the greater diversity offer greater types of camouflage. Some fish go thorough seasonal color changes to remain better camouflaged.

The best camouflage would be for an organism to be completely transparent. Of course this would be next to impossible. The next best strategy would be reflecting light .

"Mirror" Camouflage is one type of camouflage that can often be found on fish that live in open water. In open water, there tend to be very few objects or structure for fish to blend in with. One of the best strategies would be for the fish body to reflect sunlight like a mirror. This will then reflect direct sunlight as well as other light from the surroundings allowing the fish to better blend in. Studies have found that this strategy works well in certain conditions (high noon – direct sunlight, lighter colors) but not well in other conditions.

Some fish have eyes adapted to sense polarized light (light that is traveling along only one plane instead of two.)

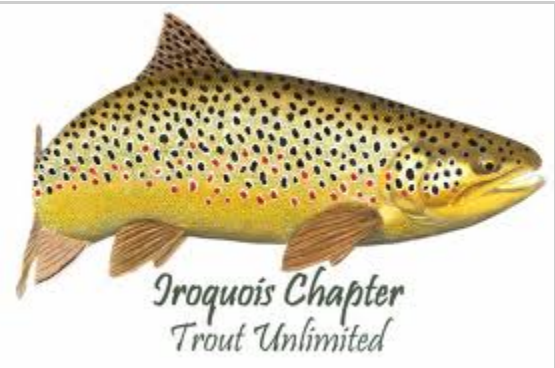
Mimicry

Mimicry is a strategy used by some species which takes advantage of pretending to be something else. This is done by adaptations in color, patterns and camouflage. If one particular organism can have a colors or patterns that resemble that of a species that is poisonous then they too would not fall prey to a

potential predator. Pretending to be someone else can certainly have advantages.

Spots

Spots help to break up the silhouette (outline) of a fish. This helps the fish to hide. Spots may be large or small, dark or light and may even vary in color. Fish may even have a single large spot mimicking an eye to confuse predators as to which end of the fish is the front. Usually, if a fish has a darker color background, lighter colored spots will be seen. Likewise, a fish with a lighter colored background will have dark spots to accompany it. Some of the most beautiful spots on a fish can be found on the Brook trout. The spots are red with a light blue halo. The pictures below show dark spots on a light background, light spots on a darker background and an image of the spots found on a Brook trout.



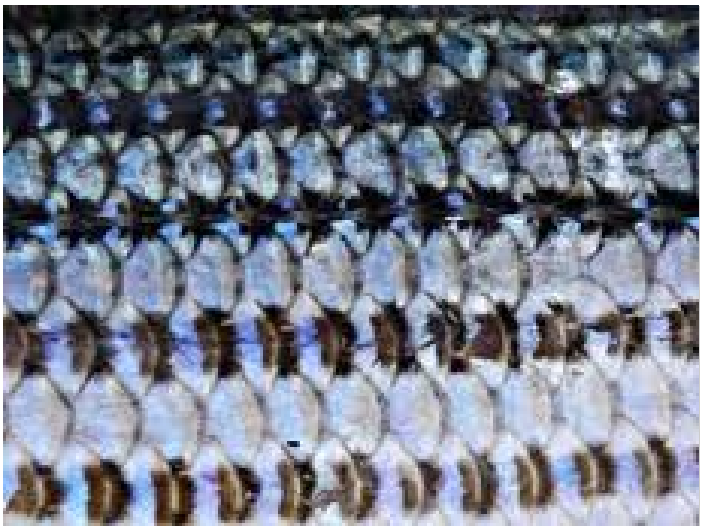
Dark spots – light background

Light spots – dark background

red spots – blue halos

Stripes

Anglers often us the stripes on fish to help identify them, but there is a more important role for the stripes on a fish. Stripes also help to camouflage the fish. Fish that have vertical (up and down) stripes help them blend in with close surroundings like branches and weeds. These vertical stripes would stick out in open waters where there is little structure. Fish that live in more open waters will generally have horizontal (side to side) stripes. These horizontal stripes help the fish to blend in with the horizontal lines created by the bottom and surface. Horizontal stripes also help to confuse predators. Fish with horizontal stripes often school together. The pictures on the left show the stripes found on a striped bass (rock fish). The picture on the right shows several striped bass. You may notice that it is more difficult to pick out an individual fish because of the horizontal stripes.



Rhythm & Pattern

What is *rhythm*? Rhythm is created by patterns. Rhythm is repeating an element to make a work of art seem active or to suggest vibration. As a pattern repeats

itself it may be slightly altered. These changes may be a change is the tone (A pattern becoming stronger or more prevalent.) or stress (A pattern becoming more or less organized or visible.) They may even be created by balance and steadiness of the pattern.

As we can see when we observe the many patterns on fish, they can create a certain rhythm. Sometimes this can occur among an individual fish or within a school of fish.

Variety

Combining one or more elements such as lines and color to create interest by adding slight changes.

Harmony

Blending the elements in a pleasing way. It's as if they fit well together.

Emphasis

Emphasis can be achieved with any of the elements to make an element in a work stand out.

Proportion

How the parts of a work relate to each other and to the whole.

Movement

Movement leads your eye through the composition. The movement can be static or very dynamic.

Texture

Texture can be described as how "smooth" or "harsh" something may be. Texture can be applied to colors, patterns, and even music. Texture can create a sense of

Balance

Imagine a vertical line dividing an object or organism in half. If each side of the object is a mirror image, then it is said to be *symmetrical* (Formal). Symmetry creates patterns in nature. The body structure of most multicellular organisms has some type of symmetry.

Examples of this can be seen in many fruits. IF you were to cut an apple in half to separate the top and bottom you would notice that there are five distinct sections. This would be an example of symmetry that is fivefold (pentamireism.)

Some of the more common forms of symmetry are listed below:

Bilateral Symmetry - This describes objects or organisms which can be divided into two sides from top to bottom. Each side would mirror the other. The letters "H" , "T", and "O" could be considered bilaterally symmetrical.

Radial Symmetry – This is used to describe an object or organism which is structured around a central point like the spokes of a wheel or the individual pieces of a pie.

Spherical Symmetry – This is used to describe an object or organism that could be cut into two identical halves in any direction provided the cut goes through the center point.

Asymmetry (Informal)– We describe objects or organisms that have an irregular shape by calling them asymmetrical. These would be objects that lack symmetry. Very few organisms have true asymmetry.

Unity

Considering all of the previously mentioned elements of art and nature, you can easily see how they can be arranged in countless combinations, as they are in nature, to give the appearance of fish *unity*. When we speak of unity we are considering how the elements are organized to create a feeling of completeness.

What would your fish look like?

In Science class we discussed adaptations. You learned that adaptations are inherited traits that enable organisms to survive and reproduce more successfully in their environment. Trout are no different. The many different trout and their many different appearances are one example of various adaptations. Coloration and patterns are two traits we will be examining.

Look at the various pictures of trout on the cabinet doors, the Smartboard, or even the fish in our tank. Examine the elements and principles of design we find in the wild, especially colors and patterns.

1. What characteristics seem to be common among all the appearances?

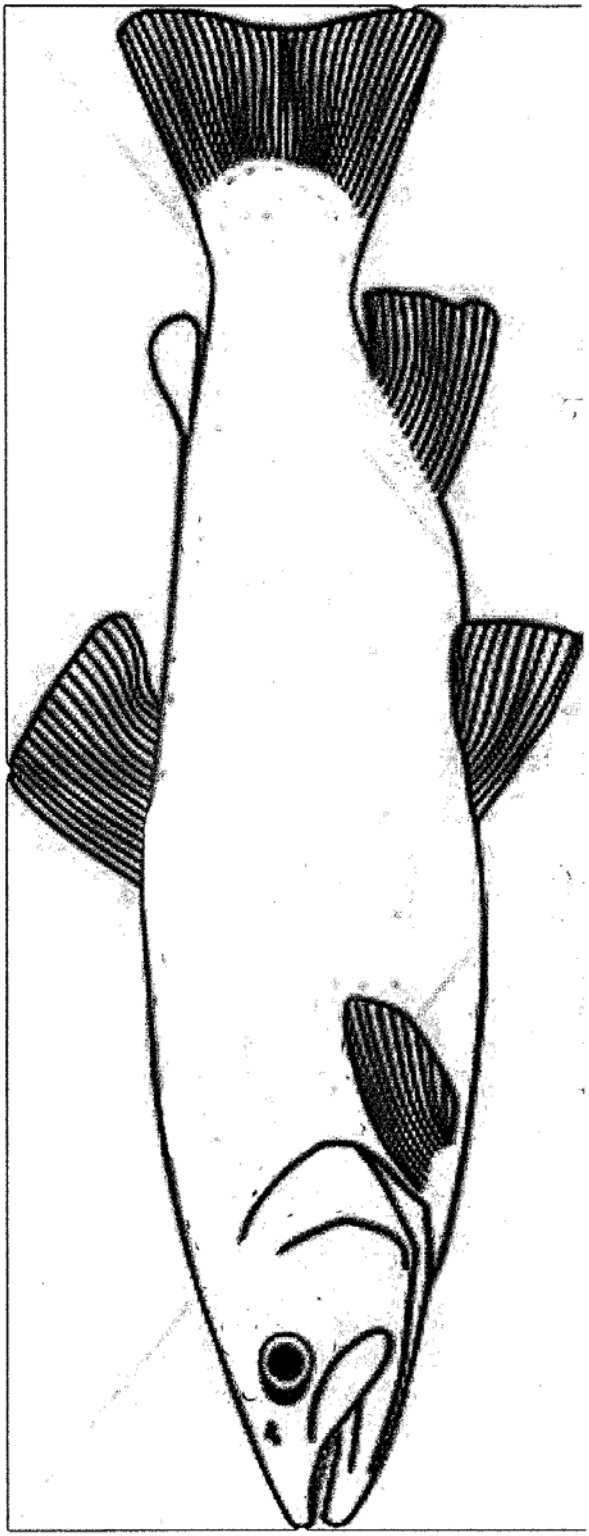
2. How would the coloration of the fish help it survive in the wild?

3. How would the patterns on the fish help it survive?

4. Are there any fish that have patterns / coloration that may be a detriment?

5. What reasons may exist other than camouflage for fish to have colors / patterns?

6. If you were to design the colors of a fish, what would it look like? Color the fish on the next page with the pattern/colors to show off your design.



Drawing on Nature

1. Locate an animal. Watch that animal closely. Examine its color, form and body shape as it may be outlined against the sky.
2. Close your eyes and try to imagine the animal in your mind. Visualize the color and shape.
3. Now, try to draw just the body shape of the animal. Draw the outline of the animal as you visualized it. If the animal is still there, it may help to look at the animal and not the the paper you are drawing on.
4. After completing the outline, which may be the hardest part, begin drawing more of the animals body parts. You may make minor adjustments to the outline of the body shape.
5. Fill in more details about the animal. Look for patterns, shapes etc
6. You may keep your drawings black & white or you may use colored pencils, crayons or chalk to fill in the color.

Now that you have finished drawing your animal, close your eyes again and visualize you animal. Pay attention to the shapes, spots or lines that may have created patterns. Think about the patterns you have seen. Did the pattern(s) create a rhythm? What did the rhythm feel like? Give a written description of the rhythm you observed.

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Adaptations & Variations (Science)

Body Shape & Form

The fish that can be found in Pennsylvania usually fall into one of three categories: Depressed, Compressed, and Attenuated.

A. Depressed

Fish which have a *depressed* shape appear to have been pushed down and squeezed from the top. A good example of this would be a catfish. Look closely at a catfish. You will notice that the front of the fish appears to be flattened as if it were squeezed form the top and bottom.

B. **Compressed**

Fish that have a *compressed* body shape appear as though they were squeezed from each side. This results in a fish that is narrow and not very wide. Bass and Sunfish are excellent examples of fish with a compressed body shape.

C. Attenuated

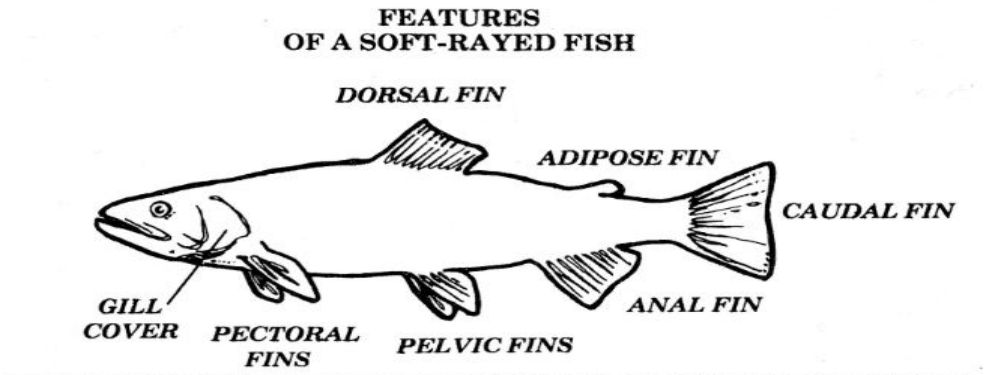
Some fish do not look as though they have been squeezed from neither top to bottom or from each side. These fish usually appear as if someone stretched them out from the front and back causing the fish to look elongated. The American Eel is an example of an *attenuated* fish body.

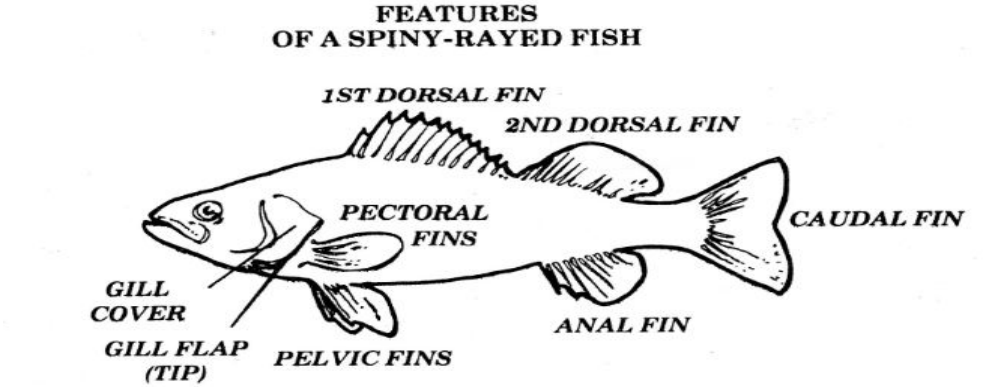
Fins & Tails

Fins and tails allow fish to swim and move about in the water. Fins and tails vary greatly from species to species. Some have very large ornate fins and tails while others have very small and seemingly insignificant fins. Fins can even offer protection from predators. However, some species may have only a few fins in certain locations on the fish body while other species have many fins placed in other positions on the fish body. Some fins and tails may be decorated with spots, patterns, and colors while others may have plain looking fins.

A. Fins

The main purpose of fins is to allow the fish to swim straight or to maintain stability in moving water. Therefore, the basic fins are usually present in all species. These fins are: the dorsal fins, pectoral fins, pelvic fins, and the caudal fin (which is the tail). We will discuss the caudal fin in the "Tail" section. Below is a drawing of a 'basic' fish with all the fins labeled. Remember that certain species may not have all the fins shown in the drawings.



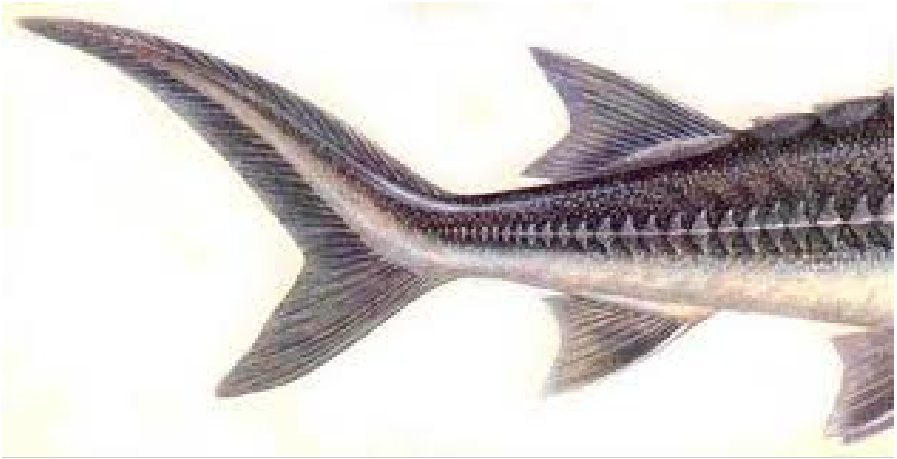


B. Tail Shape

The main purpose of the tail (caudal fin) is for propulsion. With a quick back and forth motion, a fish can quickly propel itself through the water. Tails can come in three different types: square shaped, forked tail, and a single lobed tail. The tail of most trout species is square. As seen in the pictures below, the tail has a general square shape to it. The tail of a juvenile channel catfish is deeply forked. You can see the V shape that is created in the middle of the tail. The sturgeon has a single lobed tail. The single lobed tail (heterocercal) is thought to have evolved very long ago and can be found in very old species like the sturgeon and paddle fish.

Forked tail – Juvenile Channel Catfish

Square Tail – Brook trout



Lobed tail (heterocercal) – sturgeon

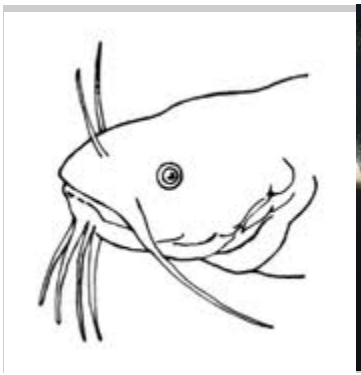
C. Spines or No Spines

When examining the fins of a fish, you will find that some fish have spines in their fins while others do not. Members of the perch and sunfish families all have spiny rays in their fins. Members of the catfish family even have a sharp pointed bone located in their pectoral fins. These sharp rays or bones provide protection from predators. Often anglers will quickly grab one of these species and get stuck by the sharp rays or bones. You can see the spines in the dorsal fins of a bass in the picture below.

Many other species lack these sharp spines or bones. These species are called soft-rayed fish. Trout and Muskellunge are examples of soft-rayed fish.

D. Mouth Shape

Fish have a wide variety of mouth and head shapes. The shape of the head & mouth are usually matched to the main food of the fish species. The shapes can range from long narrow and pointed which are suited for catching and holding prey to short small and located along the underside of the head which is designed for foraging along the bottom for dead or decaying matter. Along with the shape of the head, a species may have evolved barbels. Barbels are the whisker-like appendages commonly found on members of the catfish family. Barbels act as small feeler like appendages used to sense food on or under the bottom. You can see some of the more common types of mouth shapes on the pictures for the "Fish Heads, Fish Heads…" activity.



Catfish barbels Strugeon barbels

E. Taste & Smell

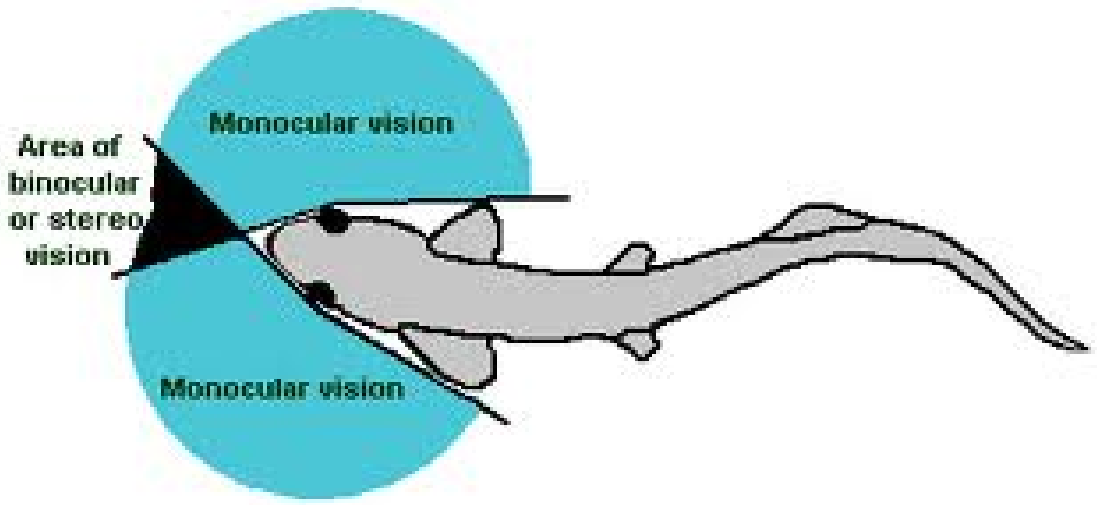
The senses of smell and taste are important to us but, we could live without them if necessary. Fish have these same senses however; they play a much more important role.

When we smell and odor we are sensing certain chemicals mixing into the air. When we taste something we are sensing chemicals that are mixing in with

our saliva. Therefore taste and smell are very closely linked to each other. Smell is used for gathering information at long ranges while taste is used for gathering information at close range.

A fish is basically immersed in the same medium. Therefore their senses of smell and taste are even more closely linked. Despite not having a nose, fish still have olfactory organs (olfactory is the sense of smell.) These organs are called *nares*. They are located in front of the eyes but behind the mouth of the fish. The nare allows water to pass through an opening and then exit. Within this organ a group of nerves that are connected to the brain are located at the bottom of the nare.

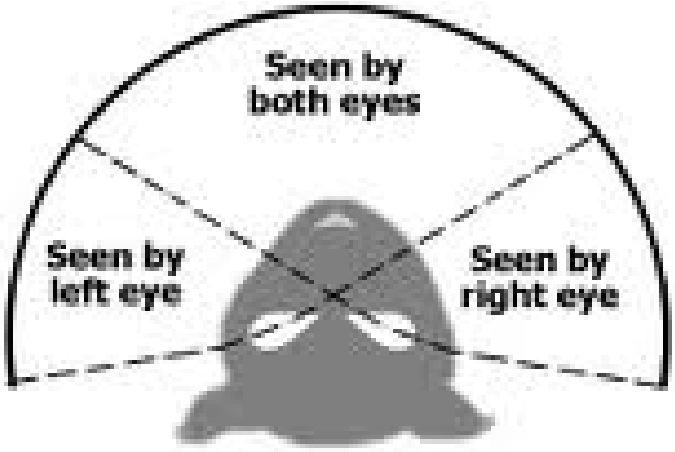
Fish also have taste buds as we do. They are far more numerous than ours and can even be found outside the mouth of a fish. Some of these same taste buds are located on the lips of a fish and those that have barbels have those covered in taste buds. Because water is much more dense than air, a fishes sense of smell and taste are far more acute than ours. It is thought that a fish can smell an odor as low as one in a trillion and can taste something as far away as 15 feet.



F. Eyes

Fish see in much the same way we do. The structure of their eye is similar to a camera without the ability to close. The eye of a fish has no eye lid or the ability to open or close as the iris of our eye does. It does however have a lens which focuses the light that is captured.

The eyes of a fish are located along the side of their head. This allows the fish to see nearly all around themselves. There are usually three small blind spots located directly in front of their nose, behind their back and directly beneath their body. Binocular vision is what we experience. Binocular vision allows an organism to perceive depth. Two requirements are necessary for binocular vision: pair of eyes and overlapping fields of vision. Fish do have binocular vision

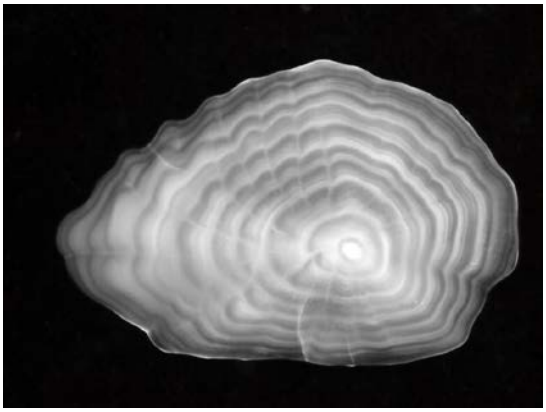


however this depth perception only occurs in front and above the fish's head. The rest of their field of view is what is referred to as monocular vision. We can experience this by covering one eye with our hand. You will notice that vision seems to be equal but the ability to perceive depth is much more difficult.

Can fish see color? This is a difficult question to answer. We know that located in the back of the eye there are two cell types that are sensitive to light rods & cones. Rods are sensitive to black and white colors along with movement but, cones are sensitive to color light waves. A human eye has three types of cone cells which are sensitive to yellow, green or blue light waves. These same three cone cells are found in the eyes of a fish.

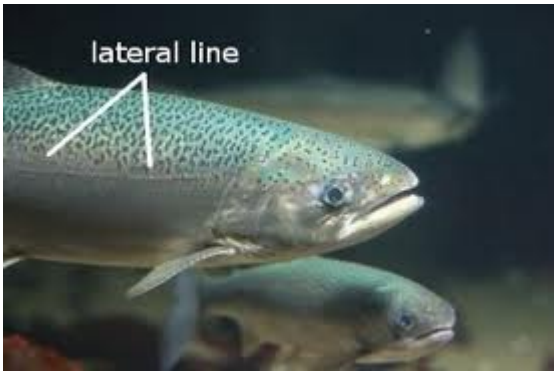
Some research suggests that two of the sets of cones see light waves similar to our eyes (like orange and greens) but because blue light gets scattered by the water molecules scientists think that the third type of cones has adapted to be sensitive to ultraviolet light rather than blue wave lengths. Studies have shown that fish living in relatively shallow water seem to be more sensitive to orange and green colors when compared with fish that live in much deeper water. This seems to make sense as we consider our earlier discussion about colored light waves and the depth of water they can penetrate.

G. Hearing & Sound



Unlike you and I, fish have more than just one organ that allows them to hear. The sense of hearing sound is basically the ability to sense vibrations. We have ears which vibrate (ear drum) as we detect vibrations traveling throughout the air. We call these vibrations sound. Despite not having ears, fish too can detect sound vibrations by a structure located on both sides of the brain. This structure is a rudimentary (basic) inner ear similar to ours. The structure is called an *otolith* which is a boney structure that is surrounded by a fluid filled sac that is lined with hairs. As vibrations move the otolith and it touches the hairs they send messages that are interpreted by the brain as sounds.

An additional structure fish have that we do not is called the *lateral line*. This is a line that runs down the length of the body on each side. The lateral line is a string of openings or pores that go through the scales and into the body. At the bottom of each pore tiny hairs can be found. These hairs allow the fish to sense vibrations in the water.

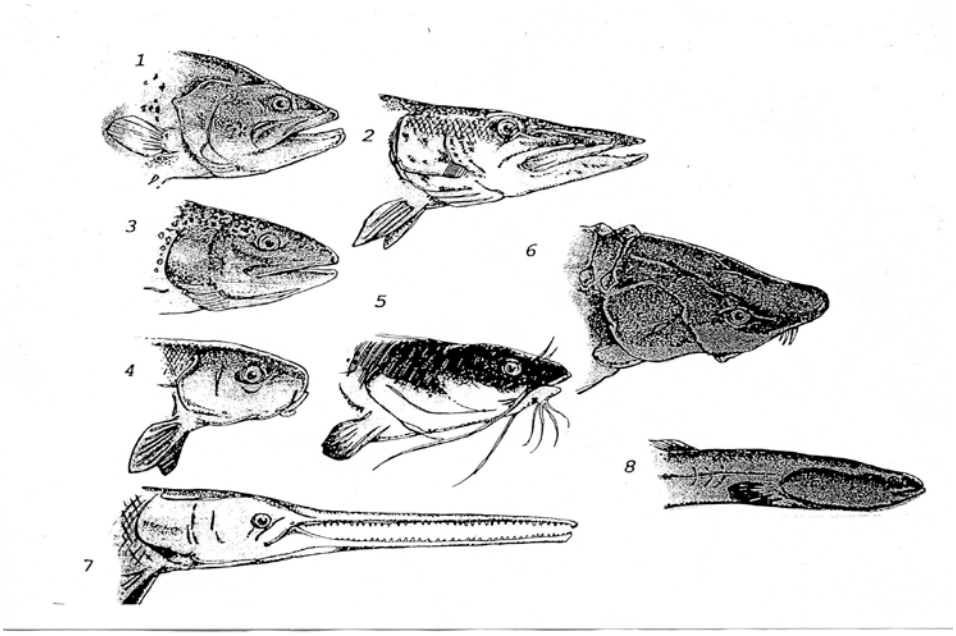


Both of these structures working together allow a fish to detect vibrations from any direction.

Fish Heads, Fish Heads…

Below are drawings of the faces of eight different fish types. Notice that each has a different type of mouth shape adapted to the type(s) of foods each fish prefers. Look at each of the mouth shapes and how each has adapted. Infer what type of food each fish may like based on the adaptations of the mouth. Describe what environment the fish would live in based on the foods it might eat.

Fish #	Food they prefer	Environment fish may live in
1		
2		
3		
4		
5		
6		
7		
8		



Design a Fish

Fish are products of many adaptations over many years. These adaptations give the fish a better chance of surviving and reproducing. As the environment changes, new adaptations arise and are passed along from generation to generation.

In this activity you will design a fish. You will make choices for certain structures of your fish. Keep in mind that these structures would take a long time to evolve.

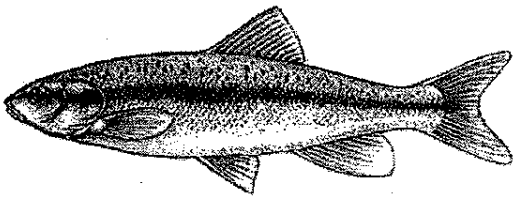
1. You will get into groups of three to four students.
2. Each group will be given an "adaptation" card from each category (coloration , mouth, body shape, and reproduction)
3. Each group will be responsible for designing (drawing) a fish with all four of the characteristics found on their cards.
4. Each group will name their fish and then draw the environment in which their fish lives. The environment should accurately illustrate how their fish is well adapted to that type of environment.

Below is a listing of adaptations and how the benefit.

Adaptation	**Benefit**	**Example**
Mouth		
Sucker shaped mouth	feed of samll plants & animals	sucker, carp
elongated upper jaw	feed on prey below	sturgeon
elongated lower jaw	feed on prey above	trouot
duckbill jaws	grasp prey	musky, pike
extremely large jaws	surround prey	largemouth bass
Body Shape		
topedo shape	fast moving	trout, salmon
Flat-bellied	bottom feeder	catfish, sucker, sculpin
vertical disk	feeds above or below	bluegill, sunfishes
humped back	satble in fast moving water	chubs, coho salmon
snake-like	streamlined for long distances	American eel
Coloration		
light colored belly	difficult from seeing below	minnows, perch
dark upperside	difficult to see from above	bluegill, catfish
vertical stripes	can hide in vegetation	musky, bluegill, perch, bass
horizontal stripes	camouflage in open water	striped bass
mottled color	can hide in rocks	trout, rock bass, crappie
Reproduction		
eggs on bottom	hidden from predators	trout, salmon, minnows
eggs on bottom in nest	protected by adults	sunfish, bluegills
eggs in burrow nests	protected by adults	catfish
floating eggs	dispersed in high numbers	striped bass, shad

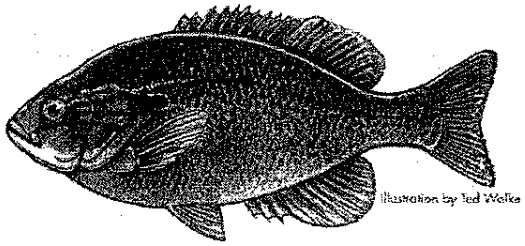
Coloration--Light-colored belly

blacknose dace



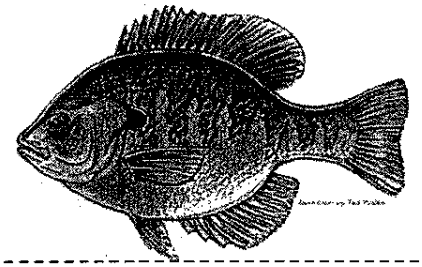
Reproduction--Eggs deposited in bottom nests

redbreast sunfish



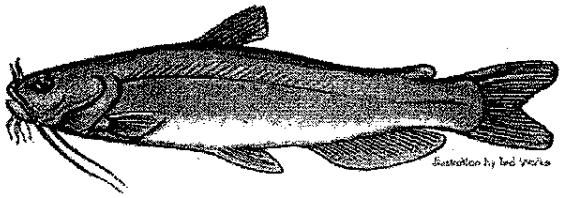
Coloration--Dark upper side

bluegill



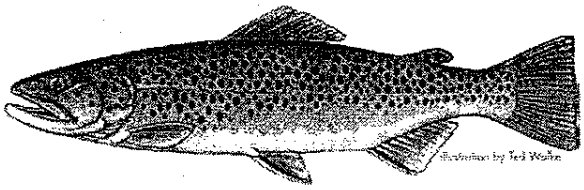
Reproduction--Eggs deposited in burrow nests

white catfish



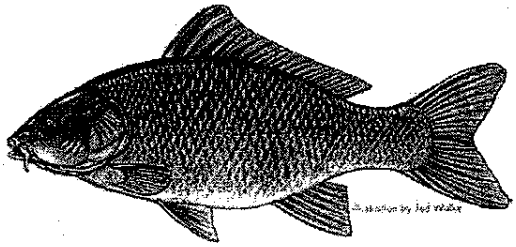
Coloration—Mottled

brown trout



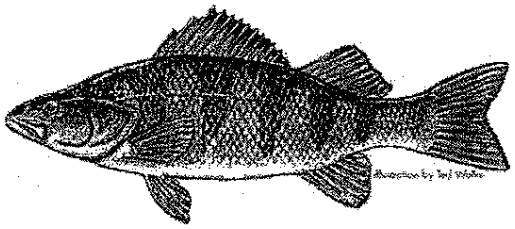
Reproduction--Eggs deposited on plants

common carp



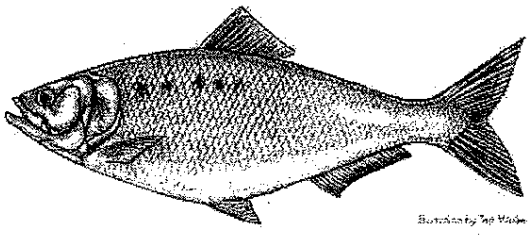
Coloration--Vertical stripes

yellow perch



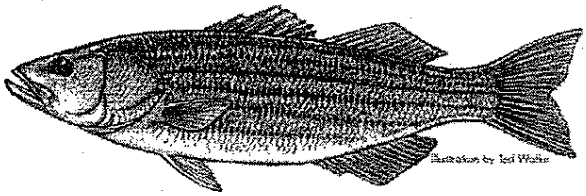
Reproduction--Free floating eggs

American shad



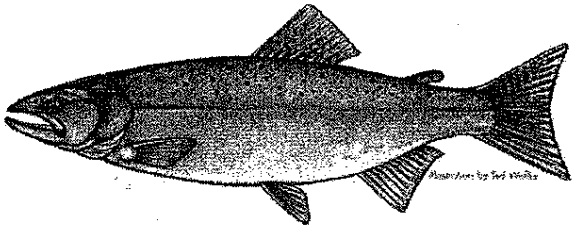
Coloration--Horizontal stripes

striped bass



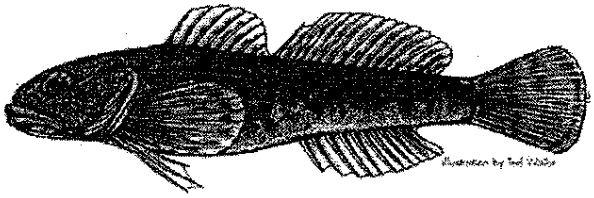
Reproduction--Eggs deposited on the bottom

coho salmon



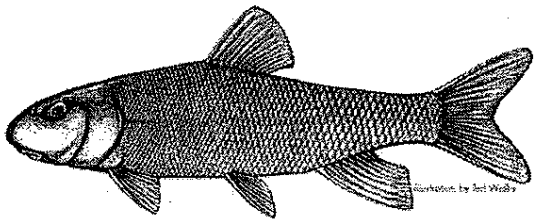
Body Shape--Flat-bellied

slimy sculpin



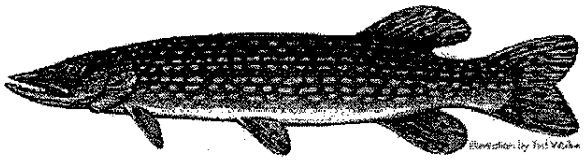
Mouth/Feeding--Sucker-shaped

white sucker



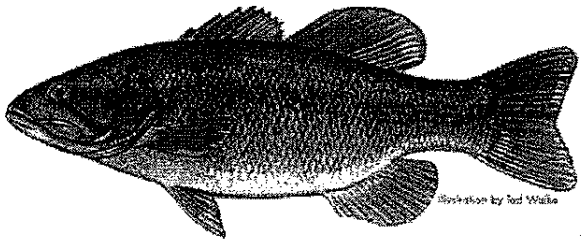
Body Shape--Torpedo-shaped

Northern pike



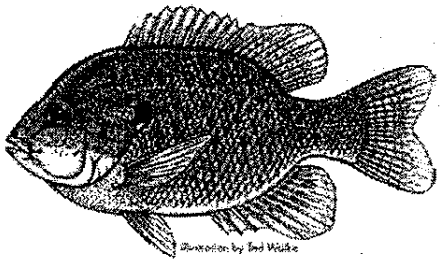
Mouth/Feeding--Extremely large

largemouth bass



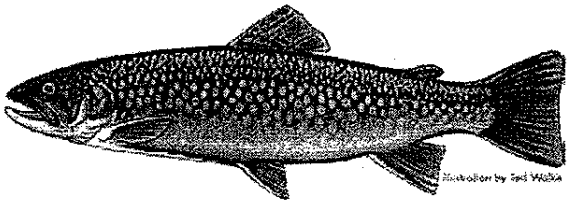
Body Shape--Vertical disk

pumpkinseed



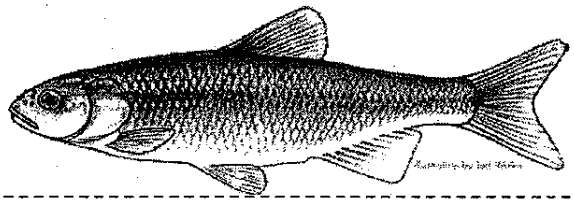
Mouth/Feeding--Elongated lower jaw

brook trout



Body Shape--Humped back

creek chub

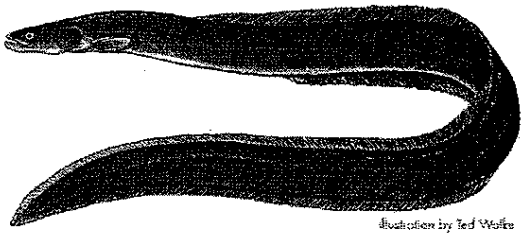


Mouth/Feeding--Elongated upper jaw

shortnose sturgeon

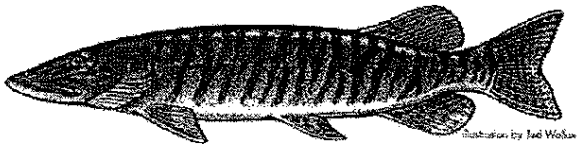
Body Shape--Snake-like

American eel



Mouth/Feeding--Duckbill jaw

tiger muskellunge



Trout Body Crossword

Across

2 the fin that gives the trout a 'push' and acts as a rudder

4 a hard plate covering the gills

7 this fin is used as a brake and helps with up and down movement

10 the opening through which eggs or sperm (milt) pass during spawning

12 these organs have triangle-shaped pupils

13 one of the fins used for swimming and stabilization

14 this organ works the same way our lungs do

Down

1 the hooked part of the lower jaw

3 this "fatty" fin does not have rays

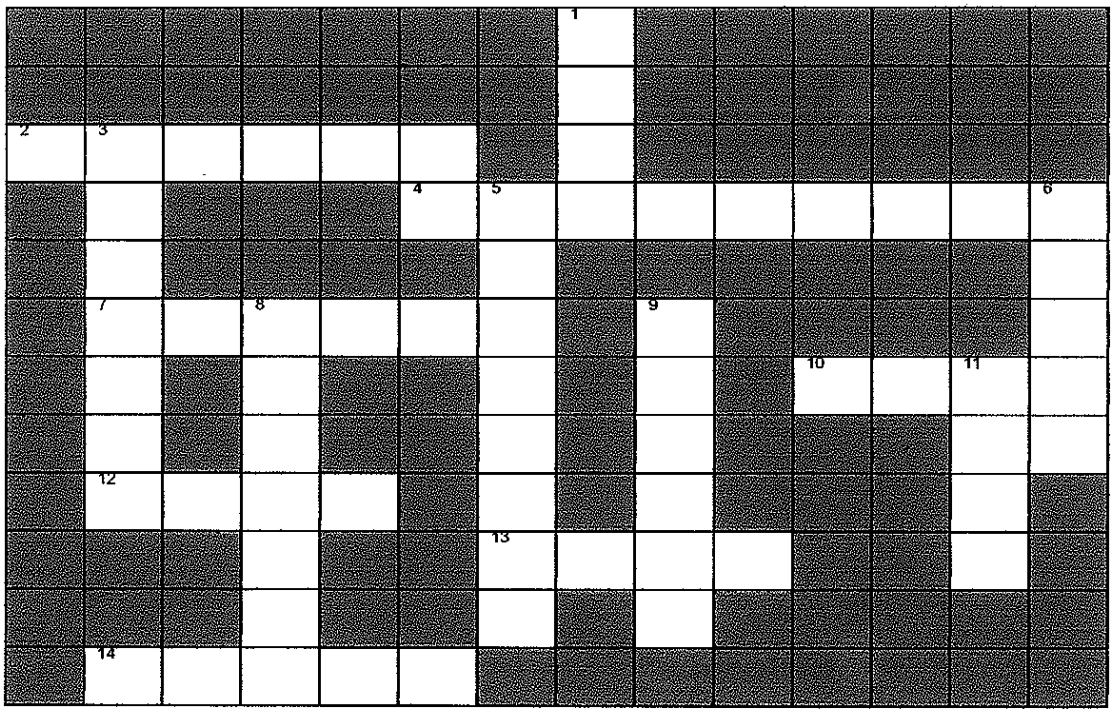
5 fins below the gills

6 the trout use this body part to suck up food

8 this line is a sense organ running from the operculum to the tail

9 one of the fins used for swimming and stabilization

11 this organ helps the trout detect odors



Surreal Fish

The term *surreal* is an adjective used to describe anything that is beyond real or unreal. The word can be divided into two parts: the prefix "sur" – which means above, outside or beyond; and the root word "real" – meaning true, not imaginary, or occurring in fact.

In this activity you will be given the opportunity to express you artistic ability by creating a fish that is surreal. Your focus should be on the structures and design of the fish (shape, appendages, color, and pattern.) Consider how the fish you design may interact with things in its environment such as predators, obtaining food, reproduction, etc.

Examine the photos of existing fish that could be considered surreal. Despite having very unusual adaptations, these fish are real. Consider what advantages their unusual adaptations may give them.

Genetically Engineered Fish

Name_____

Part A: Obtain two coins from the front table. One coin will represent the mother while the other coin will represent the father. As you can see in the chart the parents are heterozygous for each and every trait. Flip the coin for each parent for each trait. If the coin lands 'heads' up this will represent the first (dominant) allele while 'tails' up will represent the second (recessive) allele. Record your results by circling the letter in the chart. When finished, record the genotype in the next column and the phenotype in the last column.

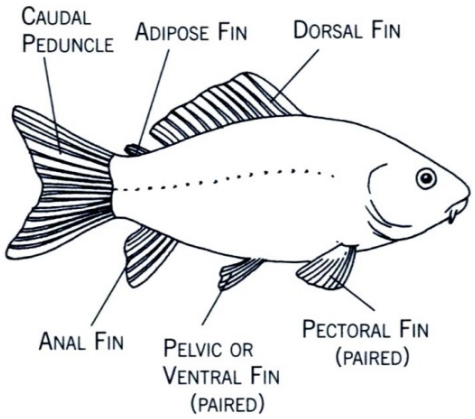
Trait	Mother	Father	Genotype	Phenotype
Mouth location	F f	F f		
Caudal Fin	T t	T t		
Pectoral Fin	P p	P p		
Pelvic Fin	V v	V v		
Adipose fin	A a	A a		
Barbels	B b	B b		
Eye Size	E e	E e		
Body color	C c	C c		
Lateral Line	L l	L l		
Spots	Y y	Y y		
Stripes	S s	S s		
Teeth	Z z	Z z		

Gender: Because gender is determined only by the father of the fish you will only need to flip the coin once to see what allele the father will contribute.

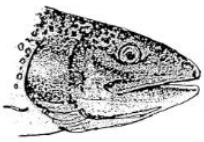
	Mother	Father	Genotype	Phenotype
Gender	X X	X Y	X _____	

Part B: You will now use the chart above and the trait sheet to sketch your fish.

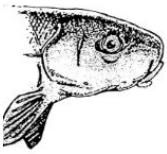
FISH TRAITS



Mouth



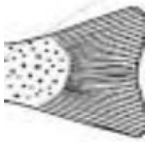
Front (F)



Underside (f)

Tail

Forked (T)



Squared (t)

Pelvic fin

Present (V)

Absent (v)

Pectoral Fins

Present (P)

Absent (p)

Barbels

Present (B)

Absent (b)

Adipose Fins

Present (A)

Absent (a)

Lateral Line

Present (L)

Absent (l)

Eyes

Large (E)

Small (e)

Spots

Absent (Y)

Present (y)

Stripes

Absent (S)

Present (s)

Teeth

Present (Z)

Absent (z)

Body Color

Blue (C)

Orange (c)