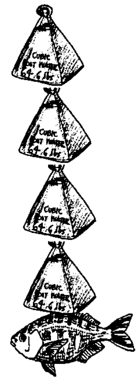
The Pressure's On!

Key Concepts

1. Deep sea animals live under conditions of extreme pressure due to the force of the water column above them.

2. Deep sea fish have unusual adaptations for finding prey in the deep sea.



Background

Structure and function in deep ocean fish is influenced by pressure. As recently as the middle of the last century scientists thought that no life would be found in the great depths of the ocean. They believed that high water pressures and lack of light would create an environment that could not support life. We now know that there is quite an assortment of marine animals that can live deep beneath the surface. Deep sea animals have developed many ways to help them deal with pressure.

Materials

For each student:

- one copy of "The Pressure's On" student pages

Teaching Hints

"The Pressure's On" looks at pressure, a physical factor that greatly affects marine organisms living in the ocean depths.

Duplicate the activity pages. One set is recommended per student. This activity is best accomplished on an individual basis with group or class discussion as a follow-up. A period for discussion and review of the correct answers should be planned for the end of the exercise.

The concepts of pressure and surface area will likely be unfamiliar to many of your students. The English system of units has been used in parts of this activity since it is likely to still be more familiar to your students. Metric equivalents are included where helpful.

Key Words

adaptation - hereditary characteristic of an organism in a population that improves its chances for survival

atmosphere - a measure of pressure equal to the weight of the Earth's atmosphere at sea level, about equal to 14.6 pounds per square inch

bioluminescence - the production of light by living organisms

lateral line system - a series of sensory structures along the head and sides of fishes which detect water currents and pressure changes and vibrations

pressure - exertion of force upon a surface of an object or organism

surface area - area of outer face of an object or organism

volume - the amount of space, measured in cubic units, that an object or substance occupies

Answer Key

1. The force on a fish with one square foot of surface area at a depth of 36,200 feet would be:

$$\frac{64.6 \text{ pounds}}{\text{cubic foot}} \times 36{,}200 \text{ feet} = 2{,}338{,}520 \text{ pounds per square foot!}$$

2. The force on each square inch of a fish at 36,200 feet would be

$$\frac{2{,}338{,}520 \text{ pounds per square foot}}{144 \text{ square inches per square foot}} = 16{,}239 \text{ pounds per square inch.}$$

3. Mr. Shood B. Flat is subjected to a total force of 37,843.2 pounds.

(i.e. 2592 sq. inches x 14.6 pounds/sq. inch)

4. The pressure exerted by the water on one square foot of surface area was equal to:

$$\frac{64.6 \text{ pounds}}{\text{cubic foot}} \times 3{,}000 \text{ feet} = 193{,}800 \text{ pounds per square foot}$$

5. The surface area of the circular window was:

$$A = \pi r^2 = 3.14 \times \left(\frac{1.5 \text{ feet diameter}}{2}\right)^2 = 1.77 \text{ square feet.}$$

6. To find the force per bolt we first need to calculate the total force on the window:

$$\frac{64.6 \text{ pounds}}{\text{cubic foot}} \times 1.77 \text{ square feet} \times 3{,}000 \text{ feet} = 343{,}026 \text{ pounds}$$

The force per bolt would equal:

$$\frac{343{,}026 \text{ pounds}}{10 \text{ bolts}} = 34{,}302.6 \text{ pounds}$$

The purpose behind these mathematical manipulations is to impress the student with the tremendous forces involved with ocean depths.

7. There are several kinds of experiments that your students may suggest to test the hypothesis that gulper fish move up into the lighted ocean zones. Some are practical, some are not. Some possible suggestions: Mark fish (either with dye or radioactive tracers) and follow their movements by radio or visually; put the fish in a pressurized aquarium and watch its behavior; fish for gulpers in the lighted ocean zones, etc. Originality here should be rewarded with a kind word and not with criticism about impracticality.

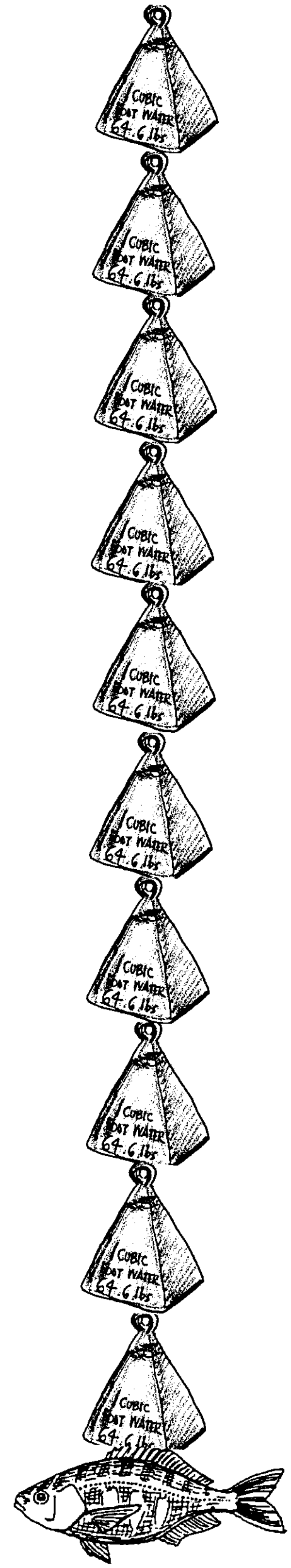
8. Answers will vary.

9. The observation suggests that gulpers may use their tails to hold their prey, or perhaps even to catch it.

10. This question calls for speculation. Bioluminescence is an interesting phenomena. It is suggested that it may help in the location of mates, in species recognition, or perhaps in communication. Other theories are also possible.

11. Since the outside pressure on the cells decreases as the fish swims upward, the fish needs to compensate by decreasing the intracellular pressure at the same rate. Fish can withstand small changes in depth with no compensation. Large changes in depth, however, require some adjustments.

The Pressure’s On!



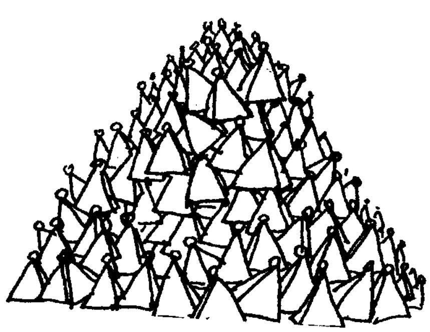
The ocean is deep. If we shaved off all of the continents and filled the trenches in the oceans with the earth from the continents, the entire globe would be covered with water about 2 miles in depth. The average ocean depth i s 12,566 feet (about 3800 meters). The greatest ocean depth is 36,200 feet (over 11,000 meters) over six miles deep! What effect does this great depth of water have on things living in the ocean? The answer depends upon where in the ocean the living thing lives. A fish or a plant near the surface feels little effect from the great depths. It really matters little if there is six feet or six thousand feet **beneath** a swimming fish. An animal living at 10,000 feet depth, however, is greatly influenced by the depth of the water **over** it. Let’s see how.

Water weights 64.6 pounds per cubic foot. A fish doesn’t have to swim very far down in the ocean to have a great deal of weight pressing down on it. If the fish has a **surface area** of one square foot, at a depth of 10 feet the water would be exerting a **pressure** of 646 pounds per cubic foot.

Pressure is the force distributed over the surface of the fish.

1. How much pressure would be exerted on a fish with one square foot of surface area at the greatest ocean depth?

2. How much pressure would be exerted on each square inch of a fish at the deepest part of the ocean? (Hint: How many square inches in one square foot?)

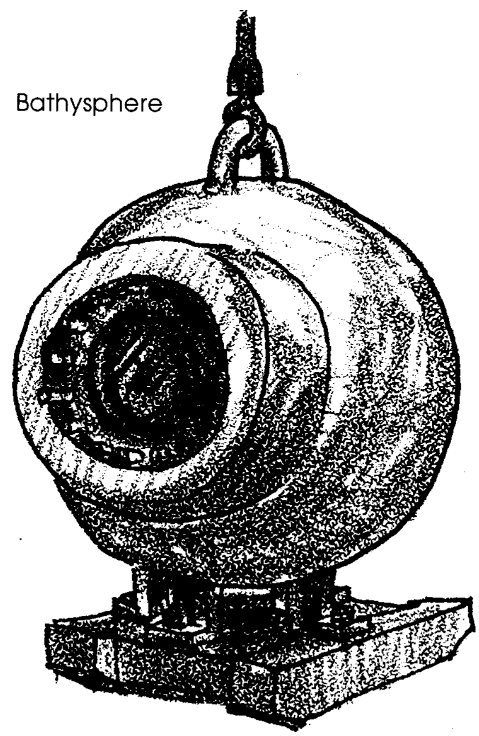


We often speak of pressure in terms of **atmospheres**. One atmosphere is equal to the weight of the earth's atmosphere at sea level, about 14.6 pounds per square inch. If you are at sea level, each square inch of your surface is subjected to a force of 14.6 pounds.

3. Mr. Shood B. Flat is six feet tall. He has 2592 square inches of skin surface. What is the total force Mr. Flat is subjected to at sea level?

The pressure increases about one atmosphere for every 10 meters of water depth. At a depth of 5,000 meters, the pressure will be approximately 500 atmospheres or 500 times greater than the pressure Mr. Flat has to deal with. That's a lot of pressure. Let's see just how much.

Dr. William Beebe was a pioneer in deep sea exploration. With support from the National Geographic Society and the New York Zoological Society, Beebe constructed the **bathysphere** (bathy = deep). In this steel sphere he would be lowered to depths of over 2,500 feet. The thick walled sphere was designed to withstand the great pressures of the ocean deep. The sphere had two thick quartz windows for viewing. On one expedition, Beebe and crew added a third quartz window in the field, sure that their work was as precise as that of the factory.



To test the new window, the bathysphere, unoccupied, was lowered to 3,000 feet. When the great steel ball was hauled up, Beebe wrote:

". . it was apparent that something was very wrong, and as the bathysphere swung clear, I saw a needle of water shooting across the face of the port window.

"Weighing much more than she should have, she came over the side and was lowered to the deck. Looking through one of the good windows I could see that she was almost full of water. There were curious ripples on the top of the water, and I knew that the space above was filled with air, but such air as no human being could tolerate for a moment. Unceasingly the thin stream of water and air drove obliquely across the outer face of the quartz. I began to unscrew the giant wingbolt in the center of the door and after the first few turns, a strange high singing came forth, then a fine mist, steam-like in consistency, shot out, a needle of steam, then another and another. This warned me what I should have sensed when I looked through the window, that the contents of the bathysphere were under terrific pressure. I cleared the deck in front of the door of everyone, staff and crew. One motion picture camera was placed on the upper deck and a second one close to, but well to one side of the bathysphere. Carefully, little by little, two of us turned the brass handles, soaked with the spray, and I listened as the high, musical tone of impatient confined elements gradually descended the scale, a quarter tone or less at each slight turn. Realizing what might happen, we leaned back as far as possible from the line of fire.

"Suddenly, without the slightest warning, the bolt was torn from our hands, and the mass of heavy metal shot across the deck like a shell from a gun. The trajectory was almost straight, and the brass bolt hurtled into the steel winch thirty feet across the deck and sheared a half inch notch gouged out by the harder metal. This was followed by a solid cylinder of water, which slackened after a while to a cataract, pouring out of the hole in the door, some air mingled with the water looking like hot steam, instead of compressed air shooting through ice-cold water. If I had been in the way. I would have been decapitated."

Pressures are great, indeed!

* From *Half Mile Down*, by William Beebe. Published by Duell Sloan. Pearce (New York) in 1951.

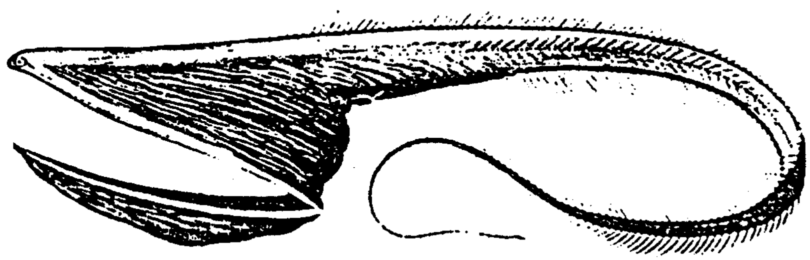
4. What was the pressure exerted on the window per square foot of surface area?

5. The circular window was 1.5 feet in diameter. What was the surface area? (Remember that the area of a circle - pi r^2 and that pi = 3.14)

6. The window was fastened with 10 one inch bolts. If we assume all bolts held evenly, how much force was distributed to each of the bolts?

Surely nothing could live under these great pressures. Or could it?

In the 1800's scientists hypothesized that life could not exist in the great depths of the ocean. In 1872, *H.M.S. Challenger* sailed from England on a four year investigation of the world's oceans. The *Challenger* expedition was charged to look for creatures at great depths in the ocean. What might these creatures look like? Would they be flat from the pressure? Tall and thin to avoid the pressure? Spherical to withstand the pressure? Much to everyone's surprise, the *Challenger* found there were fish of all shapes and styles. Let's see what kinds of deep sea fish the drag nets brought up from the bottom.



Gulper, or pelican eel (Eurypharynx pelecanoides).

A tiny eye is set over a gigantic mouth in this pelican eel or gulper. The gulpers are usually found below 6,500 feet in depth. The large mouth is perched below a brain barely a quarter of an inch long! What evolutionary forces have helped shape this strange fish? First, we must look at the environment in which the gulper lives. Six thousand feet is well below the depth of the sunlit layer of the ocean. The gulper's world is perpetually dark and cold. The number of organisms living in this world is small. Since there is no light, there is almost no plant life. Getting food is a major problem for the inhabitants of this region.

7. Notice that the gulper has eyes. The eyes are sensitive to light, a fact that makes scientists wonder if these fish do occasionally move up into the lighted zones of the ocean. Describe an experiment to test the hypothesis that gulper fish move up into the lighted ocean zones.

The gulpers are well designed to obtain the food they require. While most dwellers of the deep sea are small, some of the gulpers reach several feet in length. Most of the length, however, is made up by the tail. The body is but a few inches long, and most of the body is comprised of the mouth.

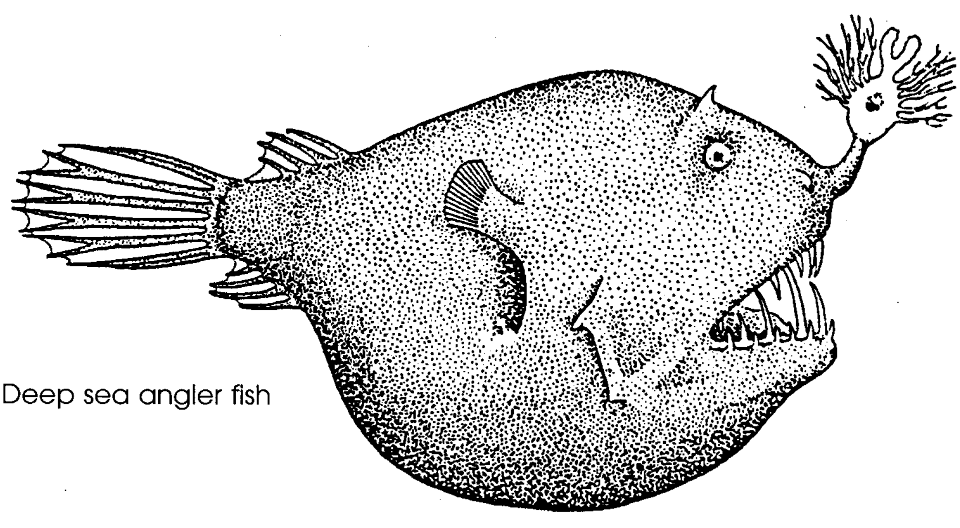
8. Look at the body of the gulper. How do you suppose it obtains food?

No one has ever seen a gulper feed so your hypothesis about feeding might be as good as those of the scientists. We do, however, know a few things. The gulper's mouth is a large, roomy bag. There are a lot of teeth but the soft muscles and thin bones do not seem well adapted to a vicious hunter. The muscles for swallowing are weak. At the end of a whip-like tail there is a reddish light. Like many fish the gulper has a **lateral line system**, a series of organs located along each side. What do these things suggest?

Here is what some scientists think: The gulper, swimming slowly or standing nearly still, slowly sweeps its lighted tail back and forth in the darkness of the ocean deep. What is this moving light? Other fish come to investigate. The gulper can't see these other fish because of the darkness, but it can sense them with its lateral line. The curious prey moves closer. Suddenly, the gulper opens its mouth and gulps the curious fish. The curved teeth grasp the prey and the gulper draws itself over the fish, much like a snake feeding. Using these techniques gulpers can swallow fish larger than themselves.

9. One gulper, caught in a deep sea trawl, had its tail tightly coiled around a small animal in the net. How else does this suggest that the gulper uses its tail?

Other deep ocean fish are just as bizarre. The deep sea angler fish lives below 11,500 feet in the Pacific and Atlantic Oceans.

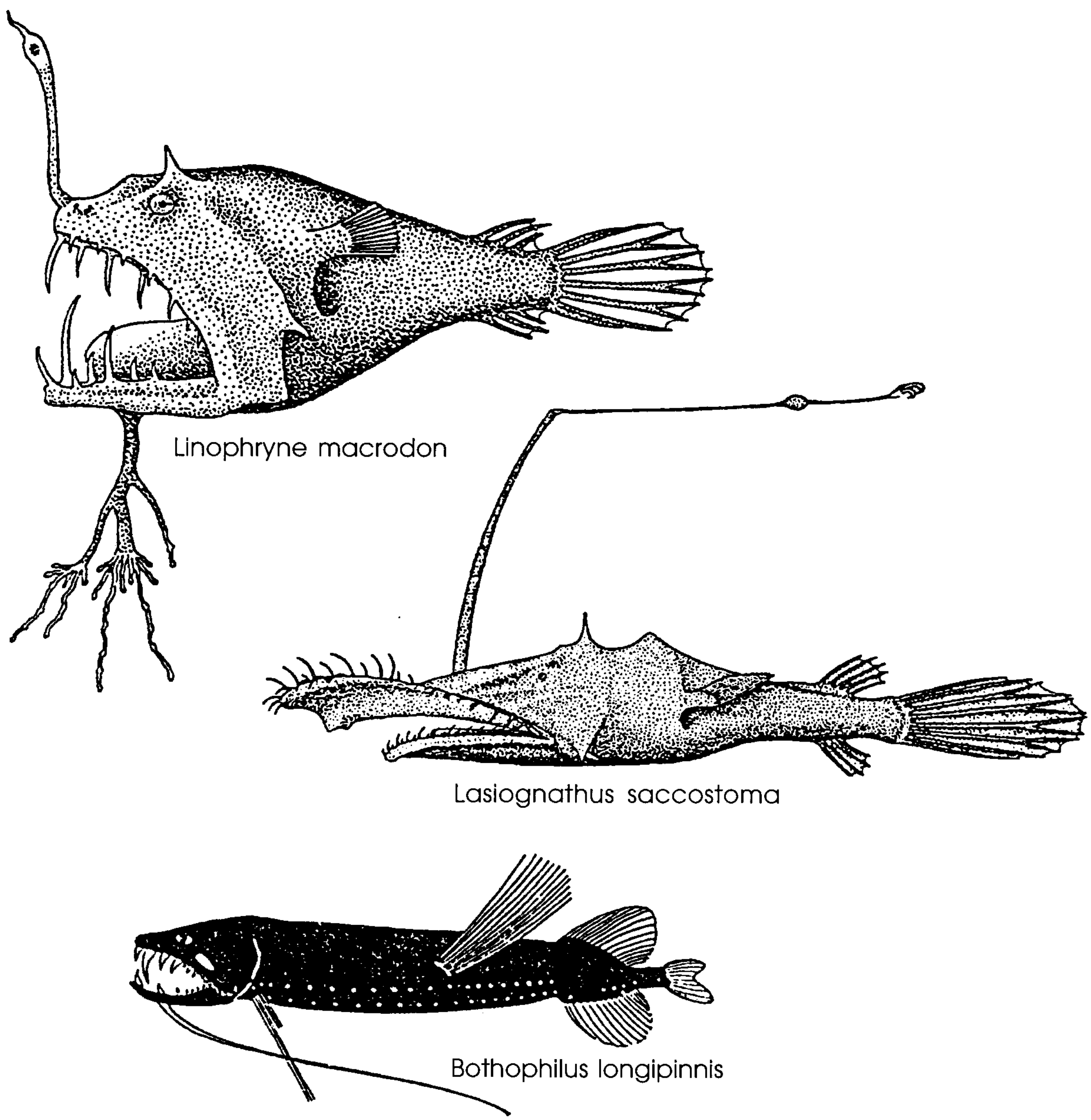


Deep sea angler fish

While this fish looks quite a bit different than the gulper, it shares some things in common. The darkness requires the deep sea angler to use its lateral line system to help detect possible food. The strange structure on the front of the fish glows in the darkness of the depths. The angler wiggles this lure. Again, curious, fish move in to observe. The angler fish moves the "bait" closer to its mouth, the fish follows. Now the mouth yawns open and the fish is pulled into the mouth by the strong suction produced. The teeth fold down and hold the victim. Other sets of teeth move the victim toward the stomach. The huge stomach is able to expand to contain animals almost as big as the angler itself.

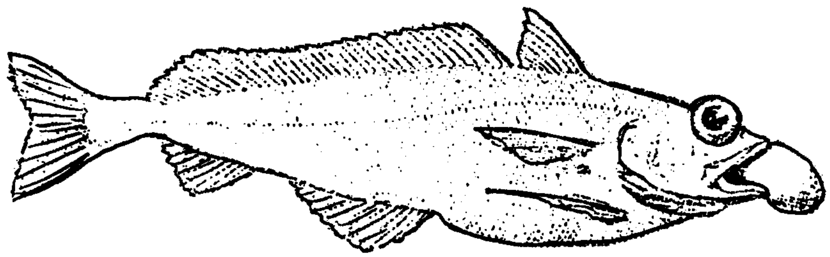
10. Deep sea animals use **bioluminescence**, the ability to produce light, to attract food. What else might they use this light for?

Other anglers have more interesting rod and lure arrangements.



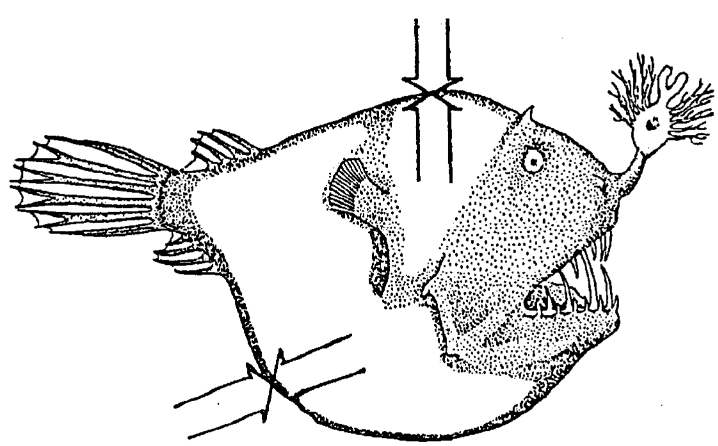
Other fish found in the depths also have special adaptations. Some deep sea dwellers have rows of lights along the side. The variety within the fishes is great. Evidently these fish can handle the ocean pressure without adopting special shapes. If the answer isn't in the shape, how do these fish withstand the pressure?

Look at the next picture. This fish has just reached the surface after being dragged up some 3,000 feet from the deep ocean.



What is protruding from the mouth? Many fish have an air bladder, a bag full of air that helps them float at different depths. In this picture, the air bladder has been forced out of the mouth. Can this observation give us a clue about how fish withstand the pressures of the deep ocean?

As the fish was brought up, the pressure on the outside of the air bladder **decreased**. The air inside the air bladder, however, was still at the pressure found at 3000 feet. Because **pressure** and **volume** of a gas are related, the air expanded inside the bladder as the pressure outside of the bladder decreased. If you increase the pressure, you decrease the volume. (Think about squeezing a balloon full of air.) If you decrease the pressure, you increase the volume. (Think about releasing the balloon.) Decreasing pressure and increasing volume caused the air bladder to expand. How does this help us? The fish was obviously adjusted to the pressure at 3,000 feet. Just as the pressure on the outside of the air bladder at that depth was equal to the pressure on the inside of the air bladder, the pressure on the inside of each cell pressing outward was equal to the pressure of the water on the outside of the cells. The fluids in the cells cause an equal but opposite pressure. The fish can be any shape.



11. Some deep ocean fish swim upward. To keep the same shape, what must happen to the pressure pushing outward in each cell as a fish swims upward?

So, how do creatures living in the great depths of the ocean withstand the pressure? They create an equal but opposite pressure within themselves to maintain their shape. Very clever.

Life in the deep ocean is very interesting. Creatures living in the deep oceans face lots of problems. They have evolved many unique ways to deal with these problems.

To learn more read: *Abyss* by C.P. Idyll, published by Thomas Y. Crowell, New York (1964).