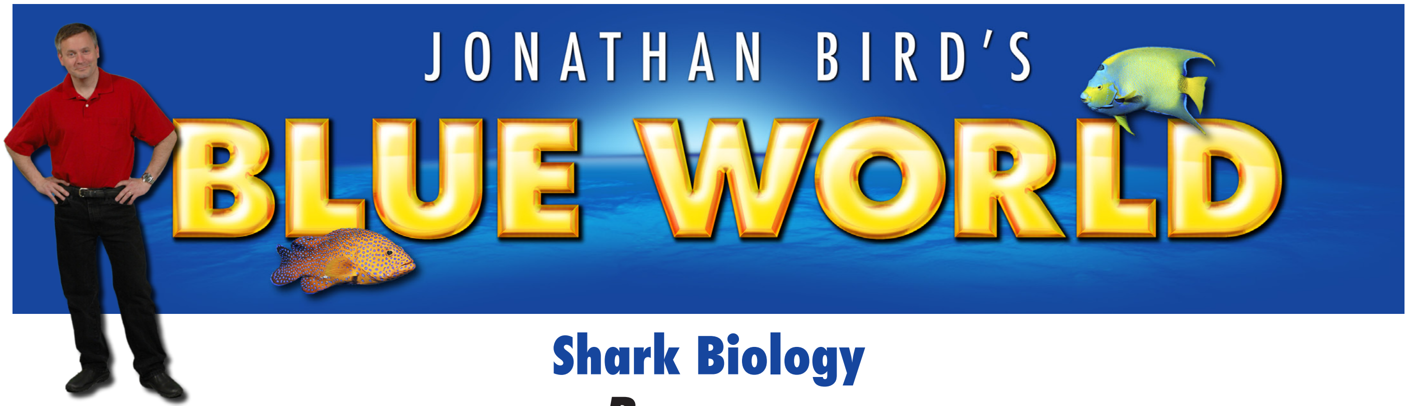

Shark Biology
Buoyancy

by Bill Andrake

Science Lesson: Buoyancy - Based on Webisode 45 - Shark Biology
Grade Level: 6-8
Time: Four (45-50 minute) class periods

Introduction

Jonathan narrates an educational segment about the biology of sharks. They represent a very diverse group of animals from the plankton grazing Whale and Basking sharks to some of the most formidable of predators in the sea, Great White and Tiger sharks. They are evolutionarily advanced animals and are incredibly well adapted for their place in ocean ecosystems.

In this video, differences between sharks and their bony cousins are highlighted and celebrated. One such difference is in each group's ability to control their vertical position in the water. Bony fish have a swim bladder that they can inflate and deflate to control their buoyancy. Sharks on the other hand must swim and control their depth with their fins. It's like the bony fish are hot air balloons with a propulsion system and sharks are airplanes, moving forward to stay aloft. So how does buoyancy work? Why can bony fish control buoyancy and why do sharks lack this ability? This lesson looks at the science behind the principle of buoyancy.

Science Standards

National Science Education Standards

Physical Science:
- Motions and Forces

Life Science:
- Diversity and adaptations of organisms

Ocean Literacy Principles
- *Principle #5:* The ocean supports a great diversity of life and ecosystems.

Objectives

- To understand buoyancy; why things float or sink.
- For students to learn how fish are able to control buoyancy.
- To learn how sharks have evolved alternative strategies for controlling their depth in the sea.

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Science Activity: Understanding Buoyant Force

Helpful Vocabulary

Density: The amount of material (**mass**) in a given space (**volume**). It is calculated by dividing a material's **mass** by its **volume**. (Density = mass ÷ volume)
Units are typically expressed in grams per milliliter (g/ml).

*** Important Fact: The density of water is about 1 gram per milliter.*

Displacement: When an object pushes a material out of the way. An object displaces its volume when submerged in a fluid.

Fluid: A liquid or gas. A fluid has no definite shape... it flows. Air and water are fluids.

Force: A push or pull

Mass: A measure of the amount of matter. The basic unit of mass in the metric system is the gram. Mass is measured using an object's weight on a balance.

Volume: The amount of space occupied by a quantity of material or object.
The basic unit of volume in the metric system is the liter (l). Smaller volumes are measured in milliliters (ml) 1 ml = 0.001 liters, also known as 1 cubic centimeter (cc).

Weight: The force of gravity on an object

Introduction:

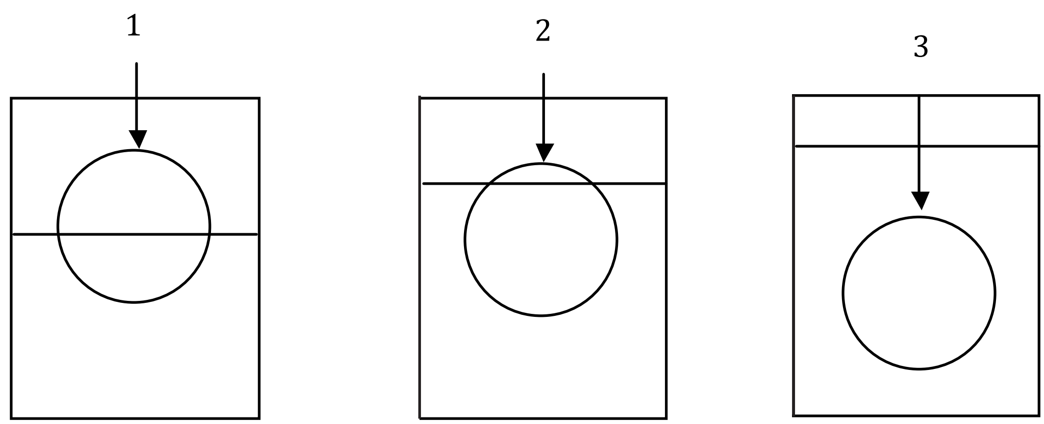
When an object is at rest on a table, the table pushes up on the object with a force equal to the downward force of gravity on the object. **When the same object is in a fluid, the fluid pushes up on the object with a force called buoyancy.**

Materials:
- Inflated ball, such as a basketball
- 5 gallon bucket of water

Activity: Understanding Buoyant Force

Procedure:

1. Place an inflated ball into a 5 gallon bucket filled about two-thirds with water.
2. Slowly push the ball down into the water. *It might take two hands*. Notice that there is an upward force of the water against the ball.
3. Keep pushing the ball SLOWLY deeper into the water. The upward force increases as more of the ball is pushed below the surface of the water. *It's important to note that the water level in the bucket is rising… is there a relationship?*



4. Keep pushing SLOWLY. Once the ball is **totally submerged** the upward force pushing back does not increase and remains constant, no matter how much deeper you push the ball into the water.

Important..the water level has basically stopped rising once the ball has been totally submerged.

Discussion:

This upward force that the water exerts on the basketball is called **buoyancy or buoyant force.**

But where does this force come from?

It was important to see that as the ball was pushed further into the water the **buoyant force** increased. At the same time more water was being displaced by the ball. Once the ball was completely submerged and no more water was being displaced, the buoyant force stayed the same.

Conclusion: Buoyant force is due to the displacement of the water.

Simply put… if you push water out of the way… it pushes back. This push back is the **buoyant force**.

But why does water push back when it has been displaced ?

If you let go of the ball submerged in the water, the ball goes back to the surface quickly. At the same time the water level in the bucket returns to back to its original level. Gravity pulled the water back into its original position. Thus, when you push a ball into the water, the water pushes back with its weight.

Conclusion: Buoyant force is the weight of displaced water.

The principle of buoyancy was discovered by the Greek scientist Archimedes around 250 B.C.

Activity: Understanding Buoyant Force (cont'd)

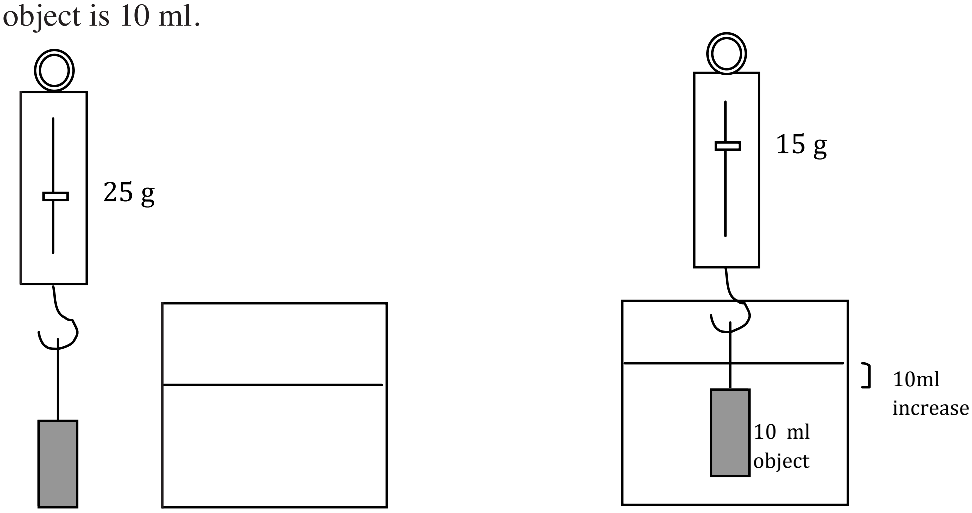
Follow up:

If the buoyant force on the object is equal to the weight of the fluid the object displaces…

The weight that an object loses when placed in a liquid is equal to the weight of the liquid that the object displaces.

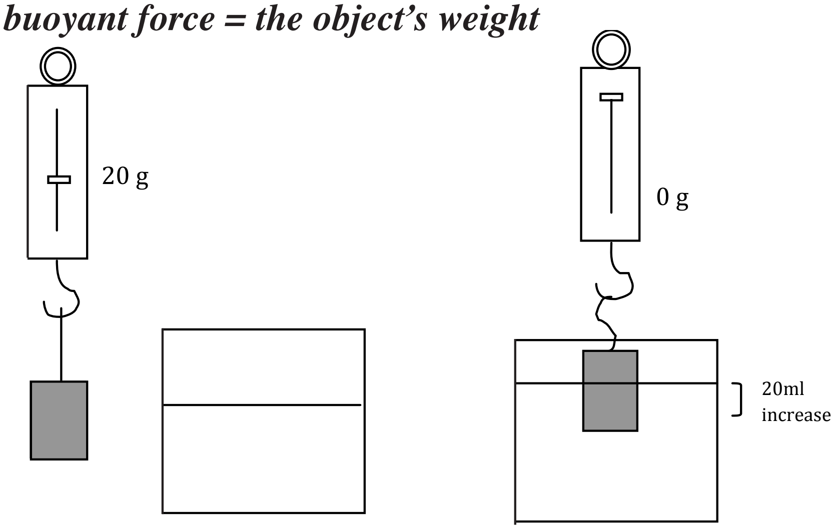
For convenience, let's use gram force for the measurement of weight.

- For example, a 25 gram weight is placed in water. When in water the object weighs 15 grams *(it lost 10 g of weight)*.
- Water must be pushing back with a force of 10 grams; the buoyant force = 10 grams.
- Since water has a density of 1g per ml, then the **volume** of the displaced water must be 10 ml, thus the volume of the object is 10 ml.



When an object floats: the buoyant force = the object's weight

This means that the **weight of the water displaced** must equal the weight of the object. If an object weighs 20 g and floats in water, it must displace 20 g of water... or a volume of 20ml.



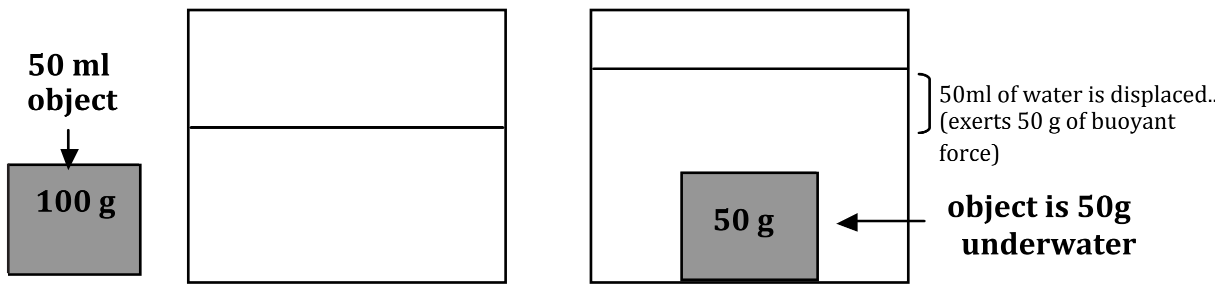
Activity: Understanding Buoyant Force (cont'd)

If an object sinks: the weight of the object is greater than the buoyant force.

This means that the weight of the object is greater than the **weight of the displaced liquid.**

- Let's say we have a 50 ml object that weighs 100 g and sinks to the bottom.
- It can only displace 50 ml of water, which is 50 grams of water.
- Water can only exert a **buoyant force** of 50 grams on this object.
- Thus the object sinks, but it lost 50 g of weight when submerged.

This last example shows why something more dense than the fluid that it is in will sink in that fluid. This object would have had a density of 2 grams per ml whereas water is 1g/ml.



Buoyancy Activity: Floating a Submerged Weight

In this activity you will calculate the amount of buoyant force needed to lift a sunken weight in an aquarium off the bottom. Then you will put together a float arrangement that can exert that amount of buoyant force. Attach the float to your sunken weight to see if it brings your weight off of the bottom.

Materials:

- For floats:
  - Small empty plastic bottles
  - Small pieces of styrofoam, corks, etc.
  - Wire hooks (bent paper clips) for attaching to the sunken weight
- Graduated cylinders, beakers of water, and droppers.
- Teriyaki sticks / skewers for pushing floats into graduated cylinders of water.
- Gram scale or balance. 500 g and 1000 g spring scales.
- At least ten gallon aquarium or 5 gallon bucket filled with water. With an a aquarium you can see the lift of the weight off the bottom; better visual learning.
- Weights. 250 – 1000 grams. (could be anything from lab weights to rocks with a way to hook a float on to it, such as being wrapped with string.

Buoyancy Activity: Floating a Submerged Weight (cont'd)

Procedure:

Step 1: How to Calculate the Maximum Buoyant Force of a Float.

Buoyant force is the weight of displaced water.

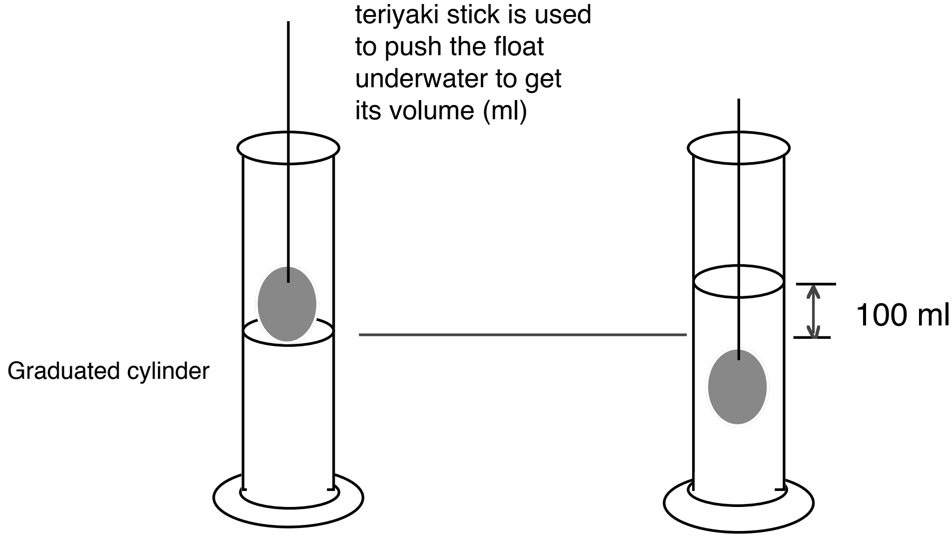
Floats work by **displacing a lot of water without adding much mass or weight**. So they expand volume without adding much mass... *thus floats decrease the **density** of the object to which they are attached.*

Think of a life preserver… it increases volume without adding much mass to a person. Thus they displace more water and increase buoyant force without really increasing their weight.

To determine the maximum buoyant force that a float can exert on a weight underwater you need to know two measurements.

1. You need to know the amount of water a float can displace which means that you need to know the volume of the float.
2. You have to take into consideration the weight or mass of the float. This will take away from the maximum buoyant force that a float can have.

So: **Buoyant force = the weight of displaced water minus the weight of the float**

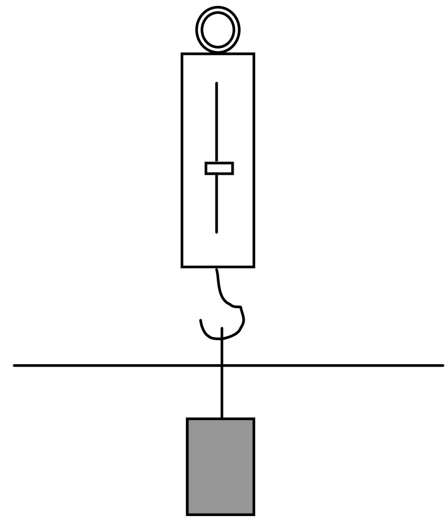


For example:

- A float displaces 100 ml of water... so the weight of the displaced water is 100 grams.
- The mass of this float out of water is 10 grams weighed on a scale.

Buoyant Force = weight of displaced water - weight of the float
Buoyant Force = 100 grams - 10 grams
Buoyant Force of the Float = **90 grams... which means that it is capable of lifting an object that weighs 90 grams underwater**

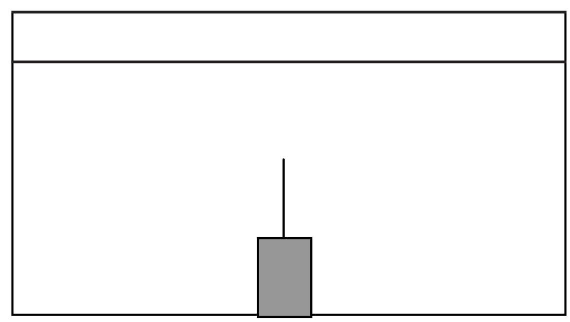
Buoyancy Activity: Floating a Submerged Weight (cont'd)



Step 2: The weight to be raised.

- Select a weight for this experiment.
- Hang the weight from a spring scale and lower it totally underwater.
- Measure the weight in grams of its weight **underwater** and record it on the next page in the data section.

- Next, lower the weight to the bottom of an aquarium or a tall bucket.



We will now try to raise the weight off the bottom using an assortment of floats made from small empty plastic bottles, small pieces of styrofoam, corks, etc. Each float will have a wire hook (such as large bent paper clip) for attaching to the sunken weight.

Step 3: Buoyant Force of Floats.

As explained earlier…

To determine the buoyant force of a float push it with a stick into a graduated cylinder with water and measure the amount of water it displaces. *Since water is 1gram for every ml of water... the number of ml displaced water is also the grams of displaced water.*

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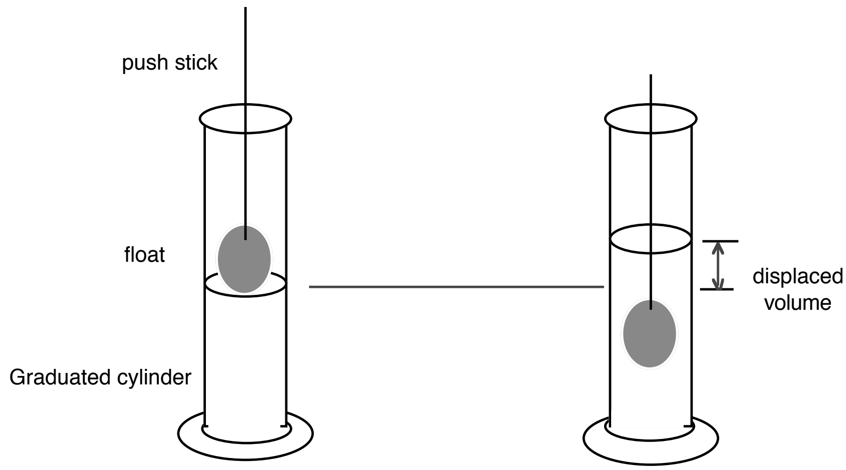
Buoyancy Activity: Floating a Submerged Weight (cont'd)



- Next, **you must** get the weight or mass of the float (with its hook) on a balance or scale and subtract that from the weight of the water displaced by the float.

So....

Maximum Buoyant force of a float = Weight of displaced water - Weight of the float

Record this information in the data table for each float.

DATA TABLE

Weight underwater of the sunken object on the bottom of the aquarium? ________ g

Buoyant Force of Floats that You're Testing

Float	Volume of Displaced water (ml)	Weight of Displaced water (g)	Mass of the Float (g)	Buoyant Force of the float (g)

Buoyancy Activity: Floating a Submerged Weight (cont'd)

Step 4: Raising the weight off of the bottom.

What is the weight underwater of the sunken object on the bottom of the aquarium? __________ g

How much buoyant force would be needed to lift the weight off the bottom of the aquarium? __________ g

From your data on the floats you have, describe the number and type of floats that you could attach to the sunken object to lift it off the bottom of an aquarium.

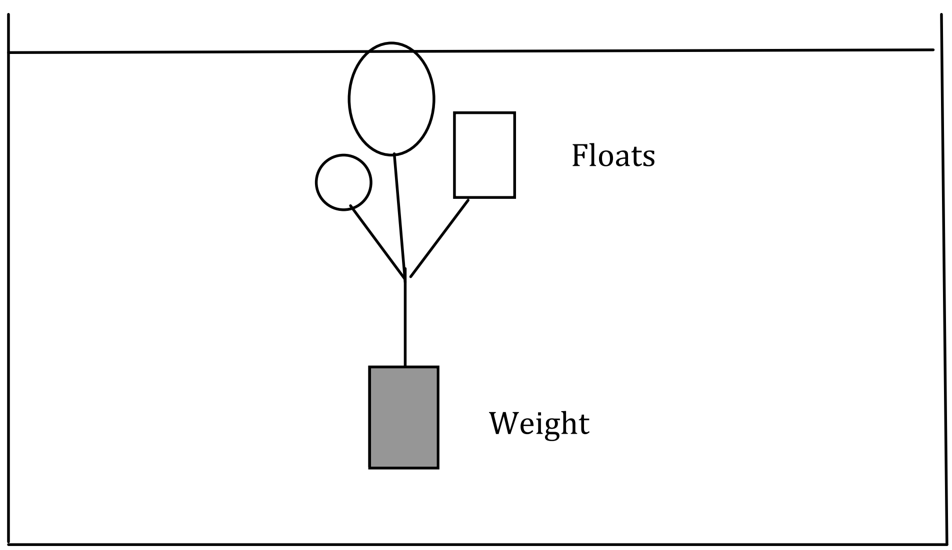
____

____

____

____

Hook your floats on to your weight and see if you are correct.



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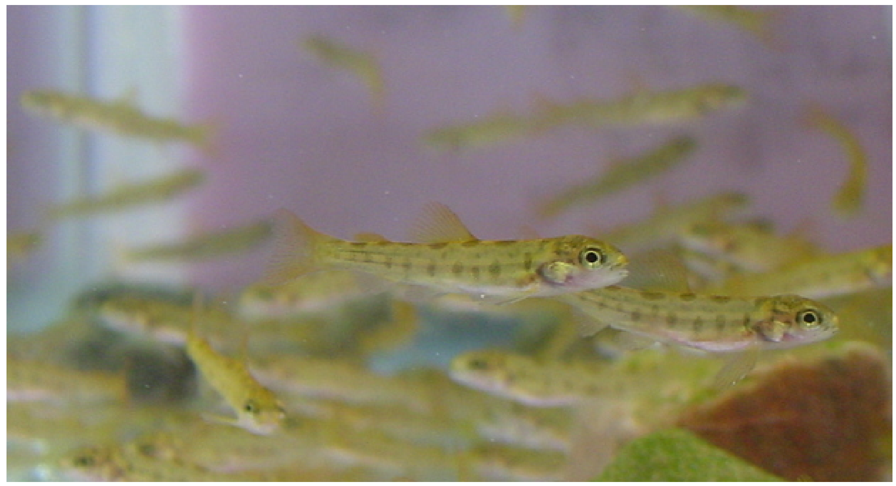
Buoyancy Activity: Neutral Buoyancy Challenge

When a fish hovers motionless in the water, it is not sinking or floating. It is **neutrally buoyant.** For this to happen, the amount of buoyant force must be exactly equal to the underwater weight of the fish.

Bony fish control their buoyancy by increasing or decreasing the amount of water that they displace. This is done by inflating or deflating their swim bladder by exchanging gas with their bloodstream. It's a very sophisticated system and one that is not present in sharks.



Atlantic salmon fry, photo by Bill Andrake

Since the gas molecules are "undissolved" from the bloodstream to inflate the bladder the volume of the bladder and the fish increase without adding any mass to the animal. Thus the fish displaces more water, increasing its buoyancy. The opposite effect happens to reduce their buoyancy and drop to a lower depth. Gases from the bladder are reabsorbed by the blood, lowering the volume of the swim bladder. The fish displaces less water and buoyant force is reduced.

We can repeat the previous activity, but to incorporate the challenge of getting a weight neutrally buoyant. Basically the lift from a float(s) must be exactly equal to the underwater weight of a sunken object.

Getting Neutral Buoyancy *(same materials and procedure as previous activity)*

1) Underwater weight of sunken object with spring scale: ____________ g

2) The buoyant force needed to be exerted by float(s) for neutral buoyancy = ____________ g*

3) Prepare a float or floats to hook on to your sunken object whose weight of:

displaced water - weight of the float(s) = buoyant force that you need (p. 9).

Total Buoyant Force of the Floats : __________ ***g*** **-** _________ ***g*** **=** __________ ***g ****

weight of displaced water	***weight of floats***	***buoyant force of floats***

It isn't easy, but if you're successful the floats and sunken object will be suspended in the water; not sinking or floating.

NEUTRALLY BUOYANT!