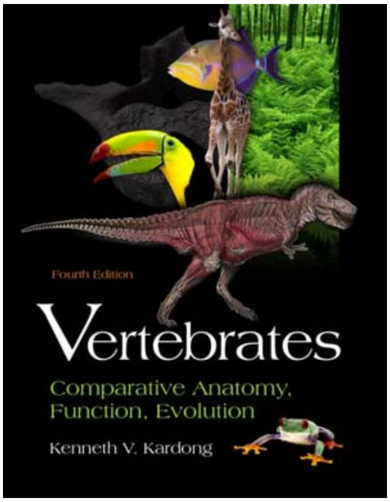


Buoyancy and Air Bladders:

Passing gas

Follow up in Textbook: pp. 421-423

A. Objective:

Explain how fish swim bladders produce neutral buoyancy. Explain how changes in atmospheric pressure influence buoyancy.

B. Textbook Reference:

No textbooks are to be used during this exercise. Work in seminar teams, but each member is responsible to answer the question in the space provided BEFORE running the experiment.

C. Introduction:

Buoyancy describes the tendency of a submerged object in a fluid to sink or to rise. Long ago, Archimedes (287-212 B.C.E.) figured out that buoyancy was related to the volume an object displaces compared to its own weight. If the density of the submerged object is less than water, then buoyancy will be a positive upward force. If its density is greater than water, the buoyancy is negative, and it is forced downward. Since density is related to volume, any change in volume will affect the tendency of the object to rise or sink.

Many bony fish possess a flexible gas bladder (swim bladder) that can be filled with various gases. As the fish dives deeper, pressure increases, compressing the air, reducing volume, and thereby effectively making the overall fish denser. The negative buoyancy now pushes the fish down, and it starts to sink. Such fish can add more gas into the gas bladder to increase its volume and return it overall to neutral buoyancy.

D. Preparation & Procedures:

Exercise 1: Cartesian Diver

The Cartesian diver is an experiment named after René Descartes (1596-1650), a French scientist and philosopher who used the diver to demonstrate the laws of buoyancy, or the tendency of an object to float or sink in a fluid. At pressures likely experienced even in deep oceans, water is essentially incompressible and does not significantly change its volume with changes in pressure. However, air is quite compressible such that as pressure on an enclosed chamber of air changes, so does its volume.

Materials - Obtain the following materials from your instructor.

-- 1 clear, plastic, 1 liter bottle with screw cap
-- 2-3 sealed packets of soy sauce, ketchup, or other condiment

Procedure

1. Place one sealed packet into the bottle and fill the bottle with water.
2. Check to see if the packet barely floats. If it sinks, set that packet aside and try another.
3. Once you find a packet that floats, screw the cap firmly onto the bottle.
4. Squeeze the bottle to see if you can get the packet to sink.
5. If the packet doesn't sink, keep trying other packets until you find one that floats until the sealed bottle is squeezed.

Explain why some of the packets sink when pressure is applied.

Explain why some of the packets didn't ever float.

Explain why some of the packets floated and didn't sink when the bottle was squeezed.

Explain how this same process might affect a diving fish that has an air bladder.

Exercise 2: Goldfish and its swim bladder

The goldfish has a swim bladder it can fill by gulping air at the surface or empty by belching air from the swim bladder via a pneumatic duct connected to the esophagus or to the pharynx.

Place a live goldfish into a large (5 gallons or more), clear, plastic container containing water suitable for the fish (fresh tap water is usually toxic to fish). Allow the fish to adjust to its environment for several minutes.

Prediction: What do you think will immediately happen if we press firmly on the plastic container? Record your hypothesis below.

Now try the experiment. Press firmly on the plastic container and watch what happens to the goldfish. Record your observations below.

Why do you think this happened?

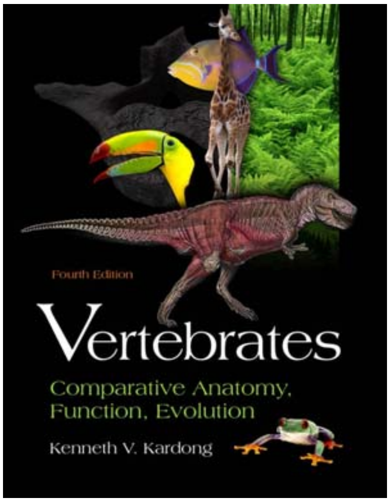
Prediction: What would happen if we removed some of the air from the container? Record your hypothesis below.

Now try the experiment. With your instructor's assistance, gently remove some of the air from the container. Record your observations below.

Why do you think this happened?

E. Synthesis:

Explain why neutral buoyancy is an adaptive advantage for a fish?



Instructor's Guide

Buoyancy and Air Bladders: Passing gas

Follow up in Textbook: pp. 421-423

A. Background

Vertebrates in water tend to be denser than water and so tend to sink. Sharks lack swim bladders. The hydrodynamic shape of their bodies, especially their anterior ends, and the upward forces produced by a sweeping heterocercal tail produce lift while they swim. If they stop swimming, they sink.

Many teleost fishes possess a swim bladder, a fluid filled sac within their bodies. Fishes living near the surface may gulp air and swallow it through a connecting pneumatic duct into the swim bladder. To empty air, the fish belches air from the swim bladder out the mouth. Such swim bladders, connected by a pneumatic tube, are physostomous. In the physoclistous swim bladder the connecting pneumatic tube is absent, and gas is added or subtracted directly across the walls of the bladder by associated specializations of the circulatory system.

A fish changing depth in the water column experiences different pressures which act to compress (deep) or expand (surface) the volume of air held in its swim bladder. Normally, a fish adjusts to its descent or ascent by adding or removing gas from its swim bladder. The problem of adjusting buoyancy can be illustrated with a small goldfish, which is exposed to a sudden change in pressure.

B. Materials Preparation and Facilitating Tips

Cartesian Diver Materials

- Clear 1 liter bottles (The bottles must be clear to allow students to monitor the buoyancy of the packets.)
- A source of water

- A collection of neutrally buoyant packages of condiments (soy sauce is typically stored in clear plastic packets, which helps students to appreciate the enclosed air. Packets of mustard, ketchup, or other sauces also may work well). You may wish to have your students sort through the packets until they find ones that are neutrally buoyant or which barely float. Be sure to have enough packets available to meet your needs. Managers of major restaurant chains will likely be willing donors if they understand that the packets will be used in education.

Note: The altitude and temperature of your laboratory will also influence the ability of the packets to float, because both factors will affect the size of the air pocket within the packet. This might serve as an additional challenge to your class.

Goldfish

Don't use just any fish as some lack a pneumatic tube and hence do not adjust quickly. Salmon, carp (including goldfish), and eels have pneumatic ducts.

Plastic containers

- Large 10 gallon carboys work well if available. Smaller 5 gallon carboys might also be adequate. The goal is to have a large, clear, flexible container.
- Fill the containers about half full way using water suitable for a goldfish.
- Prior to the lab, have this conditioned water with the enclosed goldfish already in the container.
- Be sure to use containers with screw caps that will form a tight seal.

Aspiration device

If air is aspirated, then the carboy should be solid walled (not flexible plastic). The final step in the goldfish experiment requires that air be removed from the container enough to lower internal air pressure. A hose sealed to the container and a vacuum pump or other aspirator will need to be established prior to the start of the lab.

Aspirate the air above the water slightly. This changes the pressure on the fish and a natural rise in the water column by the fish. The gas in the swim bladder expands imparting positive (upward) force and the fish abruptly rises before adjusting itself. A fish that has adjusted (e.g. belch out extra gas) will sink when atmospheric pressure is restored, again until it readjusts.

Credits: Steven Vogel for the goldfish experiment.