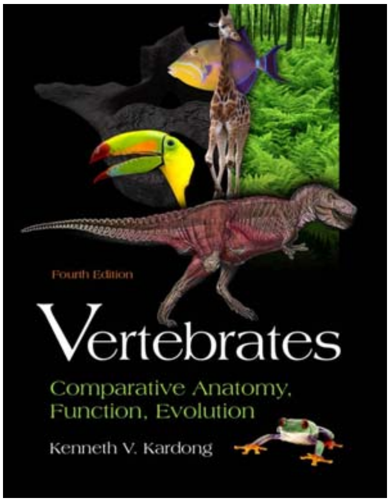


Buoyancy and Swim bladders:

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.

<u>Materials</u> - Obtain the following materials from your instructor.

- 1 clear, plastic, 1 liter bottle with screw cap
- “diver” and “sinker”

<u>Procedure</u>

1. Place the “diver” in the bottle so it just barely floats at the surface; the “sinker” so it just barely rests on the bottom of the plastic bottle.
2. Adjust volume of water for each to achieve this positioning.
3. Screw the cap firmly onto the bottle.
4. Squeeze the bottle to see if what happens to the “diver”.

If the “diver” doesn't sink, keep adding water until you get it to sink when the sealed bottle is squeezed.

Explain why the “diver” sinks when pressure is applied.

Explain how this same process might affect a diving fish that has a swim 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, glass carboy containing water suitable for the fish (chlorine in 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 aspirate air above the water of the carboy? Record your hypothesis below.

Now try the experiment. With your instructor's assistance, gently aspirate air and watch what happens to the goldfish. Record your observations below.

Why do you think this happened?

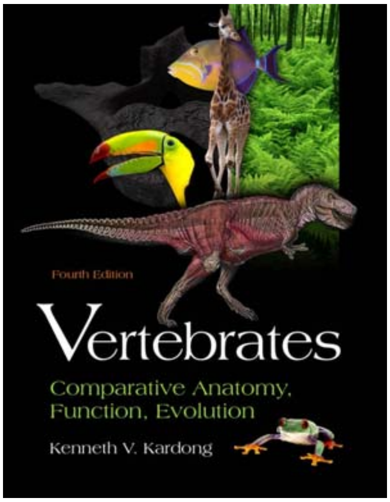
Prediction:
What would happen if now we return air that was aspirated? Record your hypothesis below.

Now try the experiment. With your instructor's assistance, gently allow ambient air to return to 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 Swim bladders: Passing gas

Follow up in Textbook: pp. 421-423

A. Objective:

To understand the physical principles upon which fish swim bladders operate.

B. Textbook Reference:

Chapter 11.

C. Introduction:

Vertebrates in water overall 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.

D. Approach

Cartesian diver. The setup illustrates the basic principle of buoyancy and how a change in pressure results in a drop in volume of the diver causing it to sink.

Goldfish. Place a small gold fish in a large, clear carboy (10 gallons or more) and allow it to adjust. Aspirated the air above the water slightly. This changes the pressure on the fish as well and simulates a natural rise in the water column by the fish. The gas 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.

Technical Background

Cartesian Diver. The Cartesian Diver is currently available as an inexpensive kit through Edmund Scientific under the trademark name, HOOK. It is the creation of Bob Becker, a science teacher in Kirkwood, Missouri, and is distributed by Steve Spangler Science. Assembly is simple and quick guided by an included instruction book.

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.

Credits: Steven Vogel for the goldfish experiment.