Respiration, Pressure Of Gases And The Biomechanics Of Breathing

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Grade Level:

High School

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Purpose:
Students will investigate the mechanics of breathing and quantify the relationships involved. This activity is appropriate for high school students in a biology or physiology class.

Objectives:
Students will be able to:

- understand how changes in the volume of the thoracic cavity and lungs cause inspiration and expiration.
- quantify the relationship between the volume of the lungs and pressure using Boyle's law.
- calculate partial pressures of gases using Dalton's law.
- use a model of the respiratory system to design an experiment to quantify the relationship between volume and pressure.
- apply the concepts learned in the lab to a nonhuman species.
- correctly interpret graphs of given data.
- explore scientific research in real life by communicating and/or visiting with research scientists in the field of respiratory physiology.

Materials (Students should work in groups of two or three):

- lung demonstration kit (one per class)
- syringe lung model with manometer (one per group)
- calculators (one per student)
- ring stands (one per group)
- video tape of bird flight in slow motion (one per class)
- handouts on Dalton's law with practice problems (one per student)
- computer with modem and electronic mail capability (optional)

Preparation and Procedure:
As a means of experiencing real science relevant to this activity, students should interact with scientists who are studying respiratory physiology. This can be done in a variety of ways, either by a visit to a local laboratory (such as at a university), a classroom visit by the scientists, or via electronic mail to the scientists in which data can be downloaded for analysis. For example, my class is in contact with Drs. Delbert Kilgore and Dona Boggs at the University of Montana in Missoula, Montana who are currently studying respiratory physiology in magpies and pigeons. Contact scientists in your area well in advance to make arrangements for student interaction with them.

Another integral part of the activity is the hands-on use of a lung model with attached manometer. This apparatus can be used to delineate the relationship between pressure and volume. A suggested design that is both inexpensive and easy to construct using 60 cc syringes and balloons can be found in the article "Model Demonstrating Respiratory Mechanics for High School Students" (Chan et al., 1996 - see References and Resources).

A short video showing bird flight in slow motion is critical to the section of the activity in which the mechanics concepts are applied to birds. This type of video should be readily available in wildlife or other scientific films (see References and Resources).

A suggested procedure for running the activity is given below. If followed as described, this is a two to three hour activity.

Procedure:

1. Brainstorm with the whole class: Facilitate a discussion with the whole class on the mechanics of inspiration and expiration. Have everyone feel their thorax as they breath. If necessary, use the lung demonstrator as an additional cue. Otherwise, use it to confirm the class's conclusions.
2. Discussion of diffusion and partial pressures of gases: Students in high school may or may not be familiar with the concept of diffusion. Open a vial of perfume or other aromatic liquid in one corner of the room (or peel an orange) and ask students why they can smell the perfume on the other side of the room. Ask students to raise their hands when they first smell the perfume. This can help them visualize that the perfume is diffusing outward from the bottle. Encourage the formation of hypotheses concerning diffusion. If desired, question #2 on the student handout can be the basis of student-designed, inquiry-based experiments. In particular, emphasize the concept of movement between areas of differing concentrations until equilibrium is reached. Next, ask students about the concentration of various gases in the atmosphere. Tie this concept to the idea of partial pressures and diffusion. Distribute the worksheet on partial pressures of gases and demonstrate how to do the calculations using Dalton's Law. Students then should do some problems on their own or in pairs. Circulate throughout the room to assess proficiency. To apply the concept, ask students to work in groups to form hypotheses about how partial pressures create such effects as hypoxia at high altitudes and the "bends" in scuba divers. Ask a representative from each group to present their hypotheses to the class. Facilitate a discussion on everyone's ideas until the class reaches correct conclusions on what causes these two effects.
3. Experimental design: Tell students that one of the factors affecting respiration is the pressure of gases within and outside of the lungs. Tell them that they will be designing an experiment to quantify the relationship. Demonstrate the syringe lung model with attached manometer, explaining how the manometer measures pressure. Ask each group to write up a procedure and data table that will quantify the volume/pressure relationship using the lung model. Circulate through the room asking leading questions, if necessary, and evaluating each group's progress. Remind students that their procedure must be okayed by you before they can proceed with implementation of the experiment and data collection.
4. Implementation of the experiment: Student groups should run their experiments and collect their data. Have them graph their data on a large graph that is posted on the board.
5. Quantifying the Boyle's Law relationship: As a whole class, examine the various lines of data on the graph. Discuss the idea of an inverse relationship. Ask student

groups to develop an equation that expresses the relationship between volume and pressure. Again circulate throughout the room, cueing as necessary and assessing the participation of group members and their progress. Finally, ask groups to volunteer to share their equations with the class.

6. <u>Applying the concept to another species:</u> Show the videotape of slow motion bird flight. Ask student groups to submit an hypothesis about how the mechanics of wingbeats might facilitate or inhibit respiration in birds, especially integrating the concepts just discovered concerning volume and pressure.
7. <u>Interacting with respiratory physiologists:</u> Confirm or disprove the students' hypotheses about wingbeats and respiration by having them interact with scientists in the field of respiratory physiology. This can be done via electronic mail communication with scientists, by a classroom visit by a scientist, or by taking students to visit a local physiology laboratory. Students should examine actual data collected by the scientists, illustrating the effects of wingbeats on respiration. If done via e-mail, students should download the data and interpret it, describing their findings in a short report which they then submit to their teacher.

Safety:
Safety precautions will vary as students' experimental designs vary. Be sure to approve experimental designs before students conduct their experiments.

Questions to Ask:
See student handout for questions.

Suggestions for Assessment:
Assessment should be multifaceted, including observation of and feedback from students as the teacher visits each group throughout the activity. Also, it could include evaluation of the written procedure, data table, hypotheses, and data interpretation report that each group was asked to write.

Where To Go From Here:
This activity can provide a entry point into further studies on both the respiratory and cardiovascular systems, including comparative anatomy and physiology of humans and other animals.

References and Resources:

1. Chan, V., J. Pisegna, R. Rosian, and S.E. Dicarlo Model demonstrating respiratory mechanics for high school students. *Advances in Physiology Education* 15: S1-S18, 1996.
2. *Go Geese* (video) is the award-winning documentary video about retraining Canada geese to migrate. It has excellent footage of geese in flight and can be used in discussions of ecology and animal behavior, as well. It is available from Environmental Studies, Airlie Center, 6809 Airlie Road, Warrenton, VA 22186, (540) 341-3239. Similar footage can be found in the popular film, *Fly Away Home*, available at most video stores.

Dalton's Law, Diffusion, and the Partial Pressure of Gases

1. Define diffusion:

2. How does the concentration of a substance affect the rate of its diffusion?

Earth's atmosphere is made up of a mixture gases and its pressure varies with one's position on Earth. For example, at sea level Earth's atmosphere exerts a pressure of 1 atmosphere, which is equivalent to 760 mm of mercury. Generally, as elevation increases, pressure decreases.

The total pressure of the atmosphere or any mixture of gases is the sum of the pressures of each of the gases in the mixture. In turn, the pressure of each gas in the mixture is proportional to its relative concentration. The pressure of each gas in a mixture is referred to as the *partial pressure* of that gas. Look at the table below, which lists the relative concentrations of gases in dry air:
Oxygen - 21%
Nitrogen - 77%
Argon - 1%
Carbon dioxide - 0.03%
Other gases - 0.97%

The partial pressure of a gas can be calculated by multiplying the relative concentration of a gas to the total pressure of the gas. For example, if the relative concentration of oxygen is 21% and the total atmospheric pressure is 760 mm, then the partial pressure of oxygen is
.21 x 760 mm = 159 mm

Using the information in the box above, solve the following practice calculations and questions.
1) If the total atmospheric pressure of dry air is 760 mm, what is the partial pressure of nitrogen?

2) If the total atmospheric pressure of dry air is 698 mm, what is the partial pressure of oxygen?

3) If the total atmospheric pressure of air is 720 mm and the sum of the partial pressures of nitrogen, oxygen, argon and carbon dioxide is 712, what is the sum of the partial pressures of the other gases?

4) As partial pressure of a gas increases, what happens to its diffusion rate?

5) How is the partial pressure of oxygen related to the rate of respiration?

6) Why is it generally harder to breathe at high altitudes as compared to low altitudes?