Overview:

The respiratory system transports gases to and from the circulatory system. In this lesson students will measure their lung volume and examine how the alveoli in the lungs act to increase the surface area of the lungs.

Objectives:

The student will:

- measure the tidal volume and vital capacity of their lungs;
- make a bar graph comparing tidal volume and vital capacity;
- calculate the surface area of human lungs; and
- describe how the structure of the lungs function to increase surface area for gas exchange.

Targeted Alaska Grade Level Expectations:

Science

[10-11] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[10] SC2.1 The student demonstrates an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms by describing the structure-function relationship (ie joints, lungs).

[11] SC2.1 The student demonstrates an understanding of the structure, function, behavior, development, life cycles, and diversity of living organisms by describing the structure-function relationship.

Vocabulary:

tidal volume – the volume of gas inhaled or exhaled in each respiratory cycle
vital capacity – the volume of gas that can be forced out from the lungs at the end of maximum inhalation
alveoli – a small cell containing air in the lungs

Whole Picture:

Lungs are located in the thorax, bounded by the rib cage and diaphragm. During inhalation the muscles of the diaphragm contract causing it to flatten. At the same time muscles of the abdomen relax and the intercostals muscles contract causing the ribs to move up and outward. As the chest enlarges, air is pulled into the lungs by the lower air pressure. During expiration the opposite occurs.

Air enters through the mouth and nose. It moves into the pharynx, then to the trachea. The trachea branches into two bronchi, leading to each lung. These, in turn, branch into smaller and smaller tubes called bronchioles. Eventually the bronchioles end at small air sacs called alveoli. Capillaries surround the alveoli where gases are exchanged by diffusion. Oxygen moves into the bloodstream and carbon dioxide is released so it can be exhaled.

The rate of breathing is not controlled by the amount of oxygen we need. Instead, it is controlled by the amount of carbon dioxide in the bloodstream. As cells use oxygen through aerobic respiration they release CO2 into the bloodstream. The increase in CO2 stimulates nerves to increase the rate of respiration. When the CO2 level returns to normal, so does the rate or breathing.

Materials:

- Balloons (large and small, round)
- String (50 cm)
- Ruler (30 cm)
- Calculator (four function)

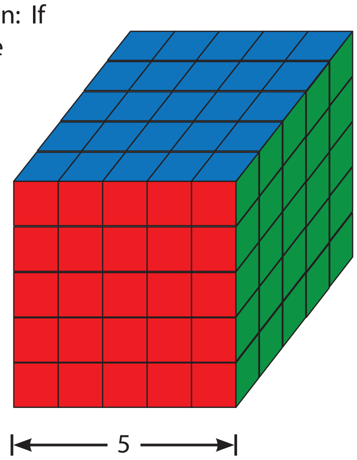
- Grapes (or bag of marbles)
- Sugar cubes (125)
- Clear container (six liters or larger)
- MULTIMEDIA: "How we breathe" (http://www.nhlbi.nih.gov/health/dci/Diseases/hlw/hlw_when.html)
- STUDENT LAB: "Breathe Deep"
- STUDENT WORKSHEET: "Breathe Deep"

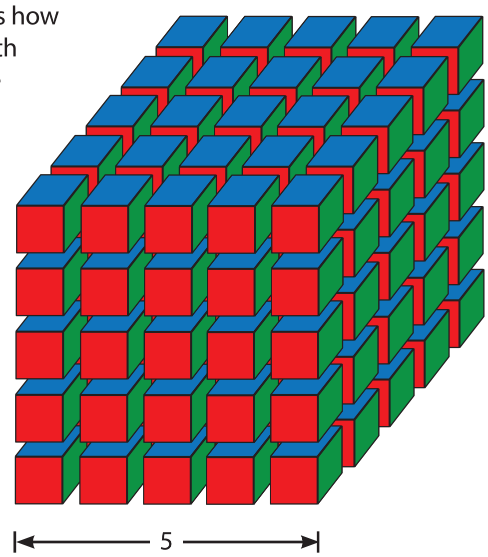
Activity Preparation:

1. Set out materials for the lab activity. .

Activity Procedure:

1. Ask students if they think a taller person would have a greater lung volume than a shorter person and their reasons why. Ask if they think an athletic student would have a greater lung capacity than a non-athletic student and their reasons why, or how the lung volume of a person who plays a wind instrument would compare to a person who does not. Ask student how they could find their lung volume.
2 Before beginning the lab activity review with students the mechanism of breathing and the interactions of the diaphragm, abdomen and ribs. Show multimedia "How we breathe" for an overview of respiration.
3. Explain that the total volume of the lungs is approximately 5 to 6 liters. Show students a clear container filled with 5 to 6 liters of water. The volume of air in a normal breath is called the tidal volume. The maximum amount a person can inhale and exhale is the vital capacity. In the activity students will find the approximate volume of their tidal volume, and vital capacity.
4. Divide students into lab groups and go over the procedure with them before starting the lab activity.
5. After the activity discuss with students their findings. Compare lung capacities of taller students to shorter ones, those that play wind instruments to those that don't, etc.
6. In the lab activity a balloon is used to find lung volumes. Ask students if an inflated balloon is a good example of a lung? Have any students looked closely at the lungs of animals such as moose and caribou? Ask how they are similar and how are they different from a balloon.
7. Explain to students that lungs consist of extremely small air sacs, called alveoli. Ask what they think the advantage of having a large number of small sacs instead of a one large air sac would be?
8. Show students a bunch of grapes in a bag, or a bag of marbles. Ask what is greater, the surface area of the bag or the combined surface area of all the grapes (marbles), or would the surface areas be equal.
9. Show students a 5 x 5 x 5 cube made of sugar cubes. Ask students how they could find the surface area of the whole cube to compare with the surface area of all 125 cubes. Have a student demonstrate the solution on the board. Solution: If each cube were 1 cm on a side then the surface area would be 6 x 1 cm^2 = 6 cm^2 for each cube. In a 5 x 5 x 5 cube there would be a total of 125 cubes, so 6 cm^2 x 125 = 750 cm^2. The surface area of a cube 5cm on a side would be 5 cm x 5 cm x 6=150 cm^2. Point out to students that this is area, so the units are squared (cm^2). If volume were calculated it would be cubed (cm^3).





10. Make the connection with students that alveoli greatly increase the surface area of the lung. Ask students if they think the surface area of the classroom floor is greater, the same as, or less than the surface area of their lungs. Hand out the Student Worksheet and have them complete it, or go over the calculations with them.
11. Have students, or a student, find the length and width of the classroom floor. Use those values to find the area in m^2. Area = length x width.
12. Tell students that the average lung has approximately 300,000,000 alveoli and each one has a diameter of .2 mm. Ask how they would use that information to find the surface of a lung.
13. Using 300,000,000 alveoli with an average diameter of .2 mm find the surface area of the lungs.

    Solution.

    First find the surface area of one alveoli: The formula for the surface area of a sphere is $4\pi r^2$

    $$SA = 4 \times 3.14 \times .1 \text{ mm} \times .1 \text{ mm}$$

    $$SA = 0.12566370614 \text{ mm}^2$$

    $$\text{rounded} \quad SA = .1257 \text{ mm}^2$$

    Next, find the total surface area per lung

    $$SA = 300{,}000{,}000 \times .1257 \text{ mm}^2$$

    $$SA = 37{,}710{,}000 \text{ mm}^2$$

    Convert mm^2 to m^2

    $$37{,}710{,}000 \text{ mm}^2 = 37.71 \text{ m}^2$$

    Since there are two lungs $37.71 \text{ m}^2 \times 2 = 75.42 \text{ m}^2$

14. Compare the area of the classroom floor to the surface area of human lungs.
15. Have a student take a deep breath and blow up a balloon. As was done in the lab activity, find the circumference of the balloon. Use the formula for finding the surface area of a sphere ($SA=4\pi r^2$) to find the surface area of the balloon and compare it to the surface area of one lung.
16. Discuss with students why it is important to have a large surface area in the lungs.

Extension Idea:

Have students research respiratory diseases such as asthma, brochitis, COPD, emphysema, lung cancer, pneumonia and pulmonary edema.

Answers:

STUDENT LAB: "Breathe Deep"

1. Answers will vary. Normally it is around .5 L.
2. Answers will vary. Normally it is around 4.5 L.
3. The graph should accurately show the comparison.
4. Answers will vary. It should be around 20 x .5 L, or 10 L.
5. The vital capacity measured what a person is capable of exhaling, not total volume. It will be less than the total volume of the lungs. It is impossible to exhale 100% of the air in the lungs. In order to exhale all of the air in the lungs the alveoli would need to completely collapse. There will always be some residual volume of air in the lungs.

STUDENT WORKSHEET: "Breathe Deep"

1. Answers will vary.
2. First find the surface area of one alveoli:

   SA = 4 x 3.14 x .1 mm x .1 mm

   SA = 0.12566370614 mm^2

   SA = .1257 mm^2 (rounded)

   Next, find the total surface area per lung:

   SA = 300,000,000 x .1257 mm^2

   SA = 37,710,000 mm^2

   Convert mm^2 to m^2

   37,710,000 mm^2 = 37.71 m^2

   Since there are two lungs 37.71 m^2 x 2 = 75.42 m^2
3. Answers will vary.
4. The alveoli are small air sacs. By having a large number of smaller air sacs instead of one large air sac the surface area of the lung is increased. The increased surface area allows a greater area for gas exchange to occur.
5. The surface area would be decreased.
6. The villi in the intestine and the nephrons in the kidneys are structures that increase surface area.

NAME: ______________________________

BREATHE DEEP

Testable Question:

How much larger is the vital capacity of lungs compared to the tidal volume?

Hypothesis:

Investigation:

Materials:

- Large and small ound balloons
- String
- Ruler
- Calculator

Procedure:

1. Gather materials. Inflate and deflate a small balloon a few times to stretch it out.
2. Breathe normally and exhale in to the balloon. Pinch the balloon off and have your lab partner wrap a string around the balloon at the widest point. Remove the string, measure the length with a ruler and record the circumference on Data Table #1.
3. Repeat Step 2, two more times and record the data on Data table #1.
4. Inflate and deflate a larger balloon to stretch it out.
5. Take a deep breath and exhale in to the balloon. As before, pinch off the balloon, measure and record the circumference on Data Table #2.
6. Repeat Step 5, two more times and record the data.

Data:

1. Record the Circumference of the balloon after each trial.
2. Calculate the Radius using the formula $r = C/(2\pi)$
3. Calculate the Approximate Volume using the formula for a sphere, $V = 4/3\pi r^3$.. Since the balloon is not a perfect sphere the volume is an approximation.
4. Find the average for Tidal Volume and for Vital Capacity.

Data Table #1 (normal breath)

Tidal Volume	Circumference (cm)	Radius (cm)	Approximate Volume (cm^3)
Trial 1			
Trial 2			
Trial 3			
		Average	

Data Table #2 (deep breath)

Tidal Volume	Circumference (cm)	Radius (cm)	Approximate Volume (cm^3)
Trial 1			
Trial 2			
Trial 3			
		Average	

1. How many cm^3 greater is the vital capacity of your lungs than the tidal volume?

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2. How many times larger is the vital capacity of your lungs compared to the tidal volume?

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3. Draw a bar graph comparing the tidal volume to vital capacity.

4. If you inhale and exhale 20 cycles per minute how many cm^3 of air are you exchanging?

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5. The volume of human lungs is generally described as 5 – 6 liters. How does your vital capacity compare to that value? Explain why you think it is, or is not, possible to exhale completely so there is no air remaining in your lungs?

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NAME: ______________________________ **STUDENT WORKSHEET**

BREATHE DEEP

Question: How does the surface area of the human lung compare to the area of the classroom floor?

1. Find the area of the classroom floor in meters. Area = length x width. Show your work.

2. Each human lung has approximately 300,000,000 alveoli. Each alveoli has a diameter of about .2 mm. Using the formula for finding the surface of a sphere ($SA = 4\pi r^2$) find the surface area of human lungs. Show your work.

3. Which has the greatest surface area, the classroom floor, or human lungs? ______________________________

4. Describe how the structure of the alveoli allows lungs to have a large surface and why it is important to have a large surface area.

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5. What would happen if a disease caused a breakdown of the alveoli, so instead of having a large number of small alveoli, there were fewer alveoli that had a greater diameter?

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6. List at least one other structure in humans that has a shape that serves to increase surface area.

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