The Young Scientist Program - Teaching Kits
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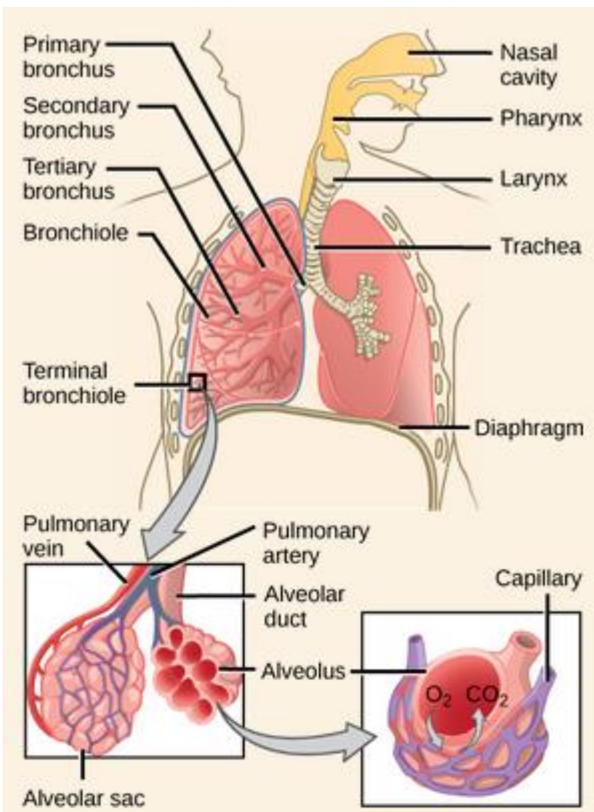
Washington University School of Medicine
Funding provided by The Leon Lowenstein Foundation

Anatomy of Breathing
Student Handout

Background

Breathing is one of the most important processes that the body uses to stay alive. Breathing allows us to take in oxygen, which is a gas that the body needs to stay alive, and get rid of carbon dioxide, which is the exhaust that the body produces. This is called **gas exchange**, because you are exchanging one gas (carbon dioxide) for another (oxygen). Oxygen and carbon dioxide are carried in the blood as it circulates around the body. Blood going away from the lungs is high in oxygen and low in carbon dioxide; blood going towards the lungs is low in oxygen and high in carbon dioxide.

The **lungs** are the gas-exchange organs of the body. You have two lungs, one on the right and one on the left. The lungs function like balloons: they inflate and deflate each time you breathe. The lungs are also very big! Feel your ribcage in the front, side, and back of your body: the lungs extend from the very top to almost the bottom of the ribcage in all three directions, in a space called the **thoracic**, or chest, cavity.



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Drawing gas into the lungs and removing unwanted gases from the lungs is called breathing. The process of breathing is split into two parts: inhalation and exhalation. **Inhalation** involves drawing in air—which is composed of 20% oxygen—from the environment. **Exhalation** expels carbon dioxide from the lungs to the environment.

Inhalation and exhalation both depend on creating a difference in pressure between the chest cavity and the outside environment. Whenever there are two regions of gas at different pressures, the gas will flow from the region of higher pressure to the region of lower pressure; in other words, air flows in and out of the lungs down its **pressure gradient**. Vacuum cleaners work

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on the exact same principle—the inside is at low pressure, so air flows into the vacuum cleaner and carries dirt along with it.

How does the body create a pressure gradient between the thoracic (chest) cavity and the outside? Take a deep breath in and see what happens to your own thorax, or chest. You will notice that your shoulders rise and your torso (especially your belly) expands outward. Each of those movements is controlled by a separate set of muscles, but there is one muscle in particular that does the vast majority of the work: the **diaphragm.** It's not a muscle that you can see, because the diaphragm sits directly beneath the lungs and is shaped like an upside-down bowl when it is relaxed. When you breathe in, the diaphragm contracts, just like any other muscle in the body. Contracting causes the diaphragm to flatten out, which increases the volume of the thoracic cavity above it and decreases the volume of the abdominal cavity below. (This is why your belly pushes out when you breathe in—your abdominal organs have nowhere else to go but out when your diaphragm pushes down on them!) When the volume of the thoracic cavity increases, its pressure decreases in a relationship known as **Boyle's Law**. When the diaphragm relaxes, the volume of the chest cavity decreases, the pressure inside increases and air is pushed out of the lungs. The equation for Boyle's Law is:

Pressure x Volume = a Constant value (if the temperature and the amount of substance do <u>not</u> change)

As the pressure inside decreases, air from the outside rushes into the nose and mouth. It flows down the **trachea**, also known as the windpipe, which branches into tubes called **bronchi** and then into **bronchioles**. At each splitting, the tubes get smaller, like the branches of a big tree, until finally they branch into microscopic sacs called **alveoli**. Alveoli are extremely thin walled, and serve to greatly increase the surface area of the lung. In fact, if you stretched all the alveoli out, a set of lungs could cover a tennis court! Gas in the alveoli can be directly exchanged with gas in the tiny blood vessels (capillaries) that run alongside the alveoli.

A **concentration gradient** works on the exact same principle as a pressure gradient—gases go from high concentration to low concentration. Carbon dioxide is at a high concentration in the bloodstream as it approaches the lungs. The carbon dioxide then moves into the alveoli because the concentration of carbon dioxide is low in the alveoli. Oxygen is at a high concentration in the alveoli due to you breathing in. The oxygen moves into the bloodstream, because the concentration of oxygen in your blood is low when it flows past your lungs. Your blood then carries the oxygen all through your body, so your body can use it.

Lots of interconnected parts need to work together for this process to occur. Lung diseases can occur when these parts are not working as they should. The airways can get inflamed, which reduces the available space for air to flow through. Asthma is a good example of this, as is COPD, a disease that many smokers get. Another type of lung disease occurs when parts of the lung become scarred, such as from breathing in asbestos. These diseases make it hard for the oxygen and carbon dioxide to move between the alveoli and your blood, so the rest of your body can not work as it should.

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Materials
- One plastic bottle
- Two balloons
- One rubber band
- Scissors
- Many red and blue pieces of paper
- Straw

Safety
Use the scissors carefully! Depending on the age of the students, it may be best for the teacher to do any cutting necessary.

In the second activity, be sure to leave enough space to move around that the students will not trip or fall over. Be wary of sharp corners.

In the third activity, be cautious with students with known respiratory issues. Students with asthma should have their inhalers nearby. Again, leave enough space that students will not injure themselves.

Protocol
Experiment 1: Diaphragm
<u>Materials:</u>
One plastic bottle
Two balloons
One rubber band
Scissors

The diaphragm is the most important muscle involved in breathing. When it moves down, the pressure inside the chest cavity decreases and air flows in, filling up the lungs. When it moves up, the pressure goes back up again and the lungs deflate. This is called following a <u>pressure gradient</u>. Air always moves from a region of higher pressure to a region of lower pressure—it moves DOWN the pressure gradient.

<u>Experimental Procedure and Discussion Questions</u>
1. Cut off the bottom of the plastic bottle. **Make sure the students are careful! If they are young, it may be best to cut the bottles before class.**
2. Carefully insert a balloon through the neck of the bottle, closed end first.
3. Wrap the open end of the balloon over the neck of the bottle.
4. Cut the neck off the other balloon.
5. Unfold and flatten out the balloon.
6. Pull the balloon across the open cut end of the plastic bottle.
7. Hold this in place with the rubber band.
8. Pull down on the flat balloon. What happens to the balloon inside the bottle?
9. Once you've properly examined this, poke a hole in the side of the bottle. Now try to inflate the balloon inside again. What happens?

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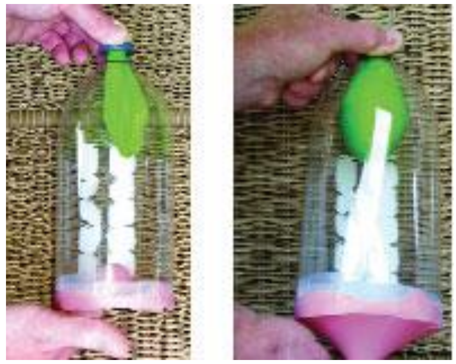
Finished product



Functioning diaphragm

This is how the diaphragm draws air into the lungs!

Q: 1. What do the bottle, the balloon inside, and the balloon outside represent?

2. What happened to the VOLUME (the amount of space) inside the bottle when you pulled down on the balloon? What did this do to the PRESSURE inside the bottle?

3. What happened to the balloon inside the bottle? Why?

4. What do you have to do to make air leave the lung? Did you have to do any work to make this happen?

5. What happened when you poked a hole in the bottle, and why? Can this happen in the human body?

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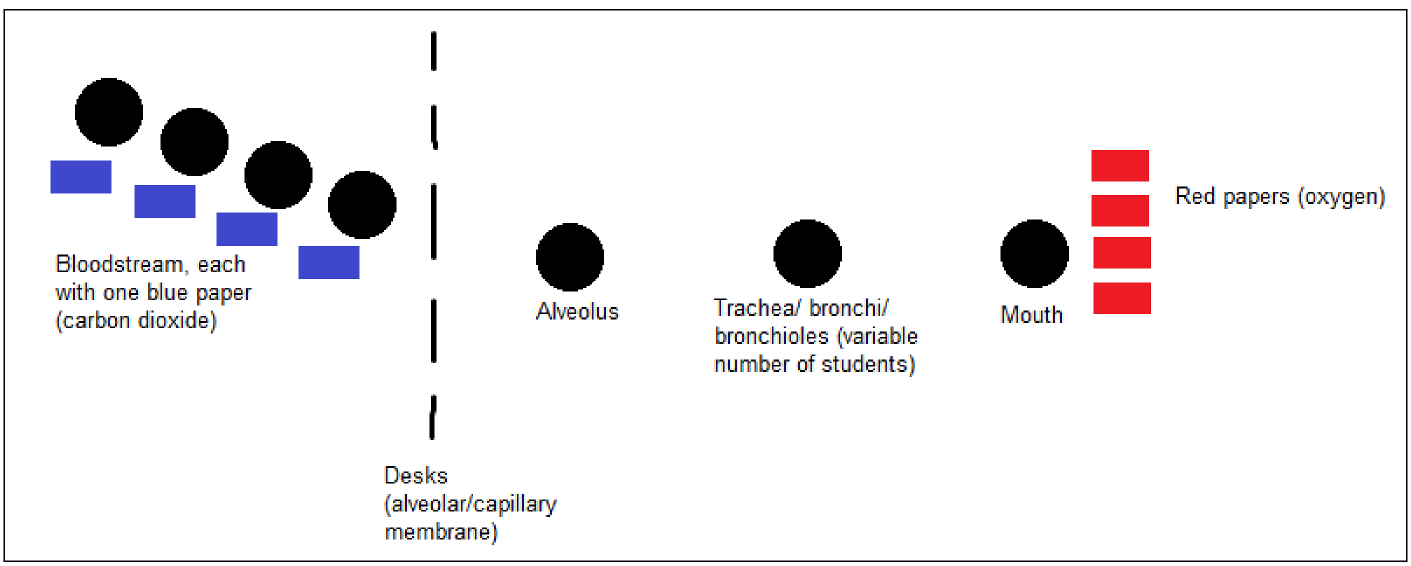
Experiment 2: Gas exchange
Materials
Red and blue pieces of paper
Desks arranged down the center of the room with empty space on either side

Experimental Procedure and Discussion Questions
1. Arrange the room so that there are two empty spaces with a divider down the middle (such as a row of desks).
2. Get two groups of student volunteers. One group will be the respiratory tract/lung and the other will be the bloodstream.
3. Begin by saying "breathe." The student who represents the mouth should take several red papers (representing oxygen) and pass them down the trachea, bronchi, and bronchioles to the last student, who is the alveolus.
4. Each student in the bloodstream should be carrying a blue paper to represent carbon dioxide, and should walk in a line past the alveolus.
5. When a student carrying a blue paper reaches the alveolus, s/he should give the blue paper to the alveolus and accept a red paper. This represents carbon dioxide diffusing into the lung due to the concentration gradient, and oxygen diffusing into the bloodstream due to the concentration gradient.
6. To continue the demonstration, the bloodstream should loop around. At the far end of the loop, the red paper should be exchanged again for a blue one. This represents dropping off oxygen at the muscles and organs and picking up the carbon dioxide waste product.
7. With the next breath, the blue papers in the alveoli should be passed up to the mouth and removed from the "body," and more oxygen should be drawn into the lungs.



Starting setup

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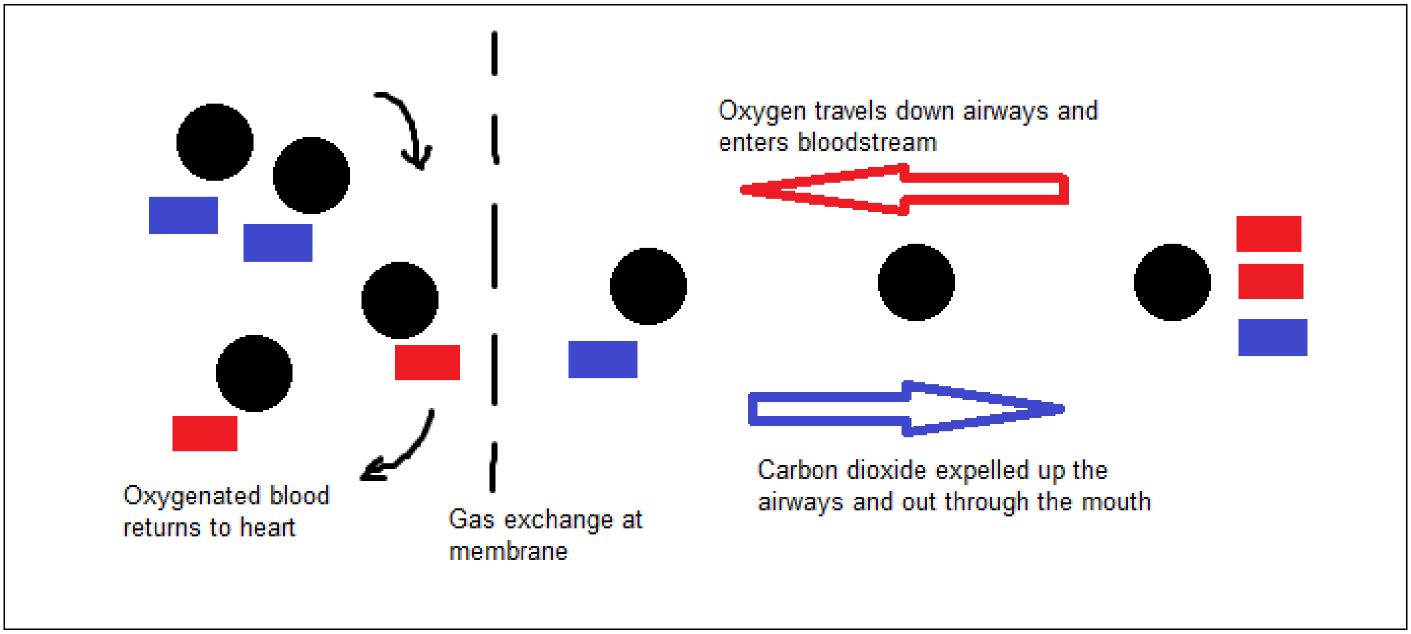

Progression of blood/gases

Q: 1. What are the vessels that air flows down before it gets to the alveolus (plural alveoli) at the end?

2. How does oxygen leave the alveolus and enter the bloodstream, and how does carbon dioxide leave the bloodstream and enter the alveolus?

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Experiment 3: Obstructive Lung Disease

Materials
Straw

Experimental Procedure and Discussion Questions

1. Clear some space in the room.
2. Pair up with a partner.
3. Count the number of breaths your partner takes in 30 seconds. Have them do the same to you.
4. Do 15 jumping jacks.
5. Again, count the number of breaths your partner takes.
6. Put a straw in your mouth. With one hand, pinch your nose so you can only breathe through the straw.
7. Do 15 jumping jacks, keeping your nose pinched.
8. Count your partner's breaths one last time. How did the breathing rate change?

Q: 1. Why does your breathing rate go up when you exercise?

2. How is breathing through a straw different from normal breathing?

3. Why does exercising while breathing through a straw change the breathing rate compared to the breathing rate after normal exercise?