Funding provided by The Leon Lowenstein Foundation

Anatomy of Breathing
Teacher Handout

Module Overview
This module covers the anatomical basis of breathing through a set of fun simulations. Students will model the major physical mechanism of inhalation and exhalation, demonstrate the pathway taken by air from the nose to the alveoli, which is where gas exchange takes place, and learn how and why gas exchange occurs in the alveoli and the consequences of damage to the lungs.

Curriculum Links
Missouri Science Standards

3.1.A Organisms have basic needs for survival
3.2.C Complex multicellular organisms have systems that interact to carry out life processes through physical and chemical means
3.2.F.a Explain the significance of the selectively permeable membrane to the transport of molecules
3.2.F.b. Predict the movement of molecules across a selectively permeable membrane (i.e., diffusion, osmosis, active transport) needed for a cell to maintain homeostasis given concentration gradients and different sizes of molecules
3.2.G Life processes can be disrupted by disease (intrinsic failures of the organ systems or by infection due to other organisms)

Goals
1. Learn how the diaphragm changes intrathoracic pressure, the pressure in your chest, to allow air to flow in and out.
2. Learn how gas exchange occurs at the alveoli.
3. Learn how disease processes can prevent the lungs from functioning at full capacity.

Timing
This module takes 30-45 minutes to complete

Kit Materials
Included by the Young Scientist Program (for a class of about 30 students)
- Balloons (24)
- Rubber bands (12)
- Red and blue papers (15 each)
- Straws (36)

Supplied by the Teacher
- Scissors
- Plastic bottles (1 per group of students), please ask students to bring from home

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Lesson Design Tool

Course: Teacher:
Week of: Grade Level:

CONTENT AREA:	**DIFFERENTIATED INSTRUCTION/CROSS CONTENT INTEGRATION**
Goals: Big Idea/Concept	*HOW will you teach the content? (groups, strategies, accommodations, variation, etc.)*
Learn about the lungs and how breathing works; learn how gas exchange occurs; learn how diseases can change the breathing process	Short lecture with pictures and videos about lung anatomy Hands-on demonstration of diaphragm function Group activity about gas exchange and obstructive lung disease
Grade Level Expectation/Objective: *(WHAT are you going to teach?)*	
Basic anatomy of the lungs; how the diaphragm changes intrathoracic pressure to draw in air; how and why gas exchange occurs	
Essential Question(s)/DOK: *Higher Order Questions (scaffolded questions to get to Big Idea)*	
Why does your breathing rate go up when you exercise? How is breathing through a straw different from normal breathing? Why does exercising while breathing through a straw change the breathing rate compared to the breathing rate after normal exercise?	
Assessment/Performance Task: *How will students SHOW what they have learned?*	**Teacher Reflections/Student Work Analysis**
Discussion questions included	

Vocabulary	**Vocabulary Strategies**	**Reteaching Strategies**
alveoli, Boyle's Law bronchi, bronchioles, carbon dioxide, concentration gradient, diaphragm, exhalation, gas exchange, inhalation, lungs, oxygen, pressure gradient, thorax, trachea		
Technology/Manipulatives		
Diaphragm demonstration using balloons and plastic bottle		

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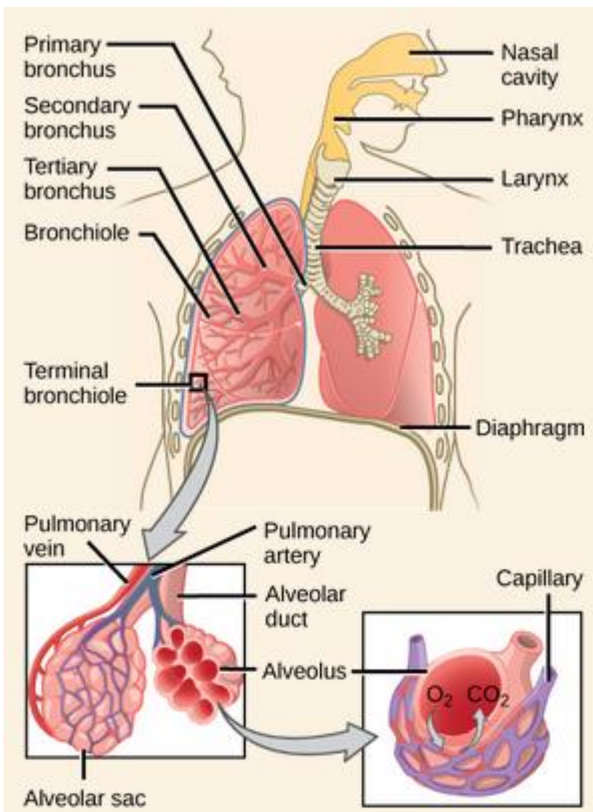
Background

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.



http://cnx.org/content/m44792/latest/?collection=col11592/latest

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.

References and Further Information

- Khan Academy video on lungs and the pulmonary system: http://www.youtube.com/watch?v=SPGRkexI_cs
- Another Khan Academy video (esp. 2:50 onwards): http://www.youtube.com/watch?v=qGiPZf7njqY
- Overview of lung anatomy: http://en.wikipedia.org/wiki/Lung#Anatomy

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- For a lesson plan on diffusion, see the YSP Diffusion kit
- Asthma and airways: http://www.nhlbi.nih.gov/health/health-topics/topics/asthma/

Helpful Tips

It will help if you include a short lecture on the basics of lung anatomy and function before attempting these activities. Using some of the videos linked above or displaying pictures will be helpful as well.

Be careful when doing some of the activities. The first activity requires the use of scissors, and the second and third activities require the students to move around quite a bit.

Materials

For every group of 3-4:
- One plastic bottle
- Two balloons
- One rubber band
- Scissors

Individual:
- Straw

Larger groups (whole class or groups of approximately 10 students, per the teacher's discretion)
- Red and blue pieces of paper, divided among the students according to their "role" (see protocol for experiment 2)

Safety

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

The balloons included are latex. Please be wary of latex allergies and do not allow students with allergies to handle the balloons directly.

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>.

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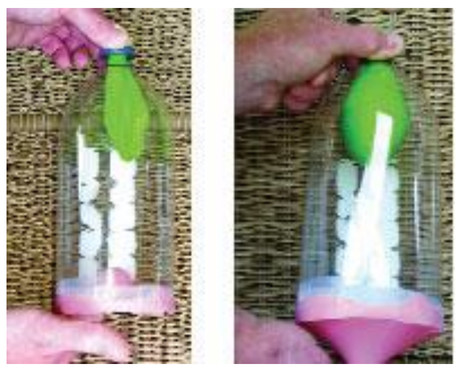
Air always moves from a region of higher pressure to a region of lower pressure—it moves DOWN the pressure gradient.

Experimental Procedure and Discussion Questions

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?


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?

Chest, lung, and diaphragm, respectively.

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?

Volume increased, and pressure decreased. This is called Boyle's law.

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

It filled up with air. The pressure inside the bottle is less than the pressure outside the bottle, so air rushed in through the opening and into the balloon. This is exactly how our lungs fill up with air.

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

To make air leave the lung, you just had to let go of the diaphragm. This does not require any work, although pulling air in did require the work of pulling down on the diaphragm. This is how breathing works, too—you have to actively contract your diaphragm to pull it down, but you relax it to push it back up.

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

This one is tough to understand. When the bottle is broken, there is an additional way

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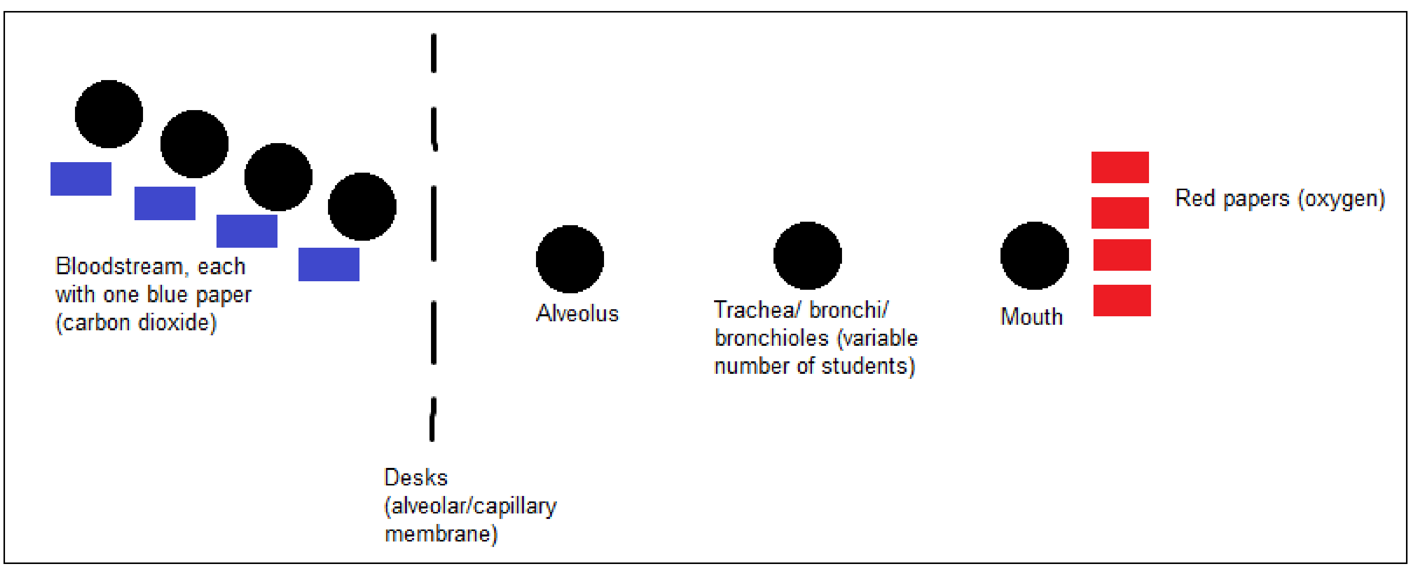
for pressure inside the bottle to equalize with pressure outside the bottle. Therefore, there is now no pressure gradient for air to move down, so the balloon inside does not inflate. Although our ribcage normally protects our lungs, this absolutely can happen in real people. It is called a pneumothorax or collapsed lung, and a bad accident or a stab wound can cause it. It is very dangerous and must be dealt with quickly.

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.



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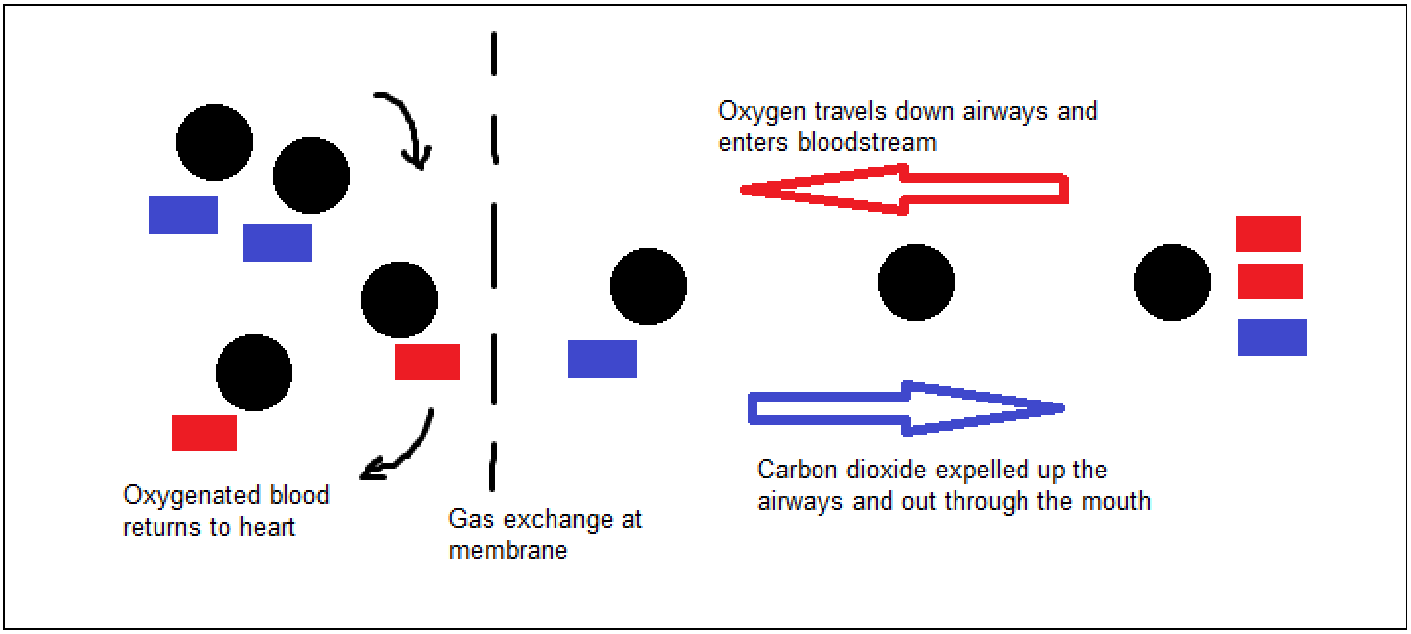
Starting setup



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?

From the nose and mouth (oropharynx) air goes down the trachea, bronchi, and bronchioles before ending up in the alveoli, which are tiny thin-walled sacs.

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

Gases move across the membranes of the capillaries (blood vessels) and the membrane of the alveolus by simple diffusion. Both carbon dioxide and oxygen move down their respective concentration gradient—from the side where there is more to the side where there is less of the respective gas.

3. How does blood get from the body to the lungs and back again?

This one is tough. The heart pumps oxygenated blood to the body and deoxygenated blood to the lungs. The left side of the heart accepts oxygenated blood from the lungs and sends it out to the body. The right side of the heart accepts deoxygenated blood from the body and sends it out to the lungs.

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

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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?

When you exercise, your body uses up more oxygen and produces more carbon dioxide. You need to get rid of that carbon dioxide and replace it with oxygen more quickly, so you breathe faster.

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

There is less room for air to move through the straw, so it is harder to push air in and out of the lungs. This is the same thing that happens to people who have obstructive lung diseases like asthma or COPD. The air passages (bronchi and bronchioles) become inflamed and constricted, so that air cannot move through them properly anymore. Breathing through a straw feels a lot like having an asthma attack.

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

Since you cannot get the amount of air flow you need in each breath, you have to compensate by breathing faster.