

**Educator's Guide and Script For**  
*Human Body: The Respiratory System*

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## **INTRODUCTION**

The goal of this program is to present an upper level high school or introductory pre-med or pre-nursing school overview of the anatomy and physiology of the respiratory system. Using the latest in 3-D graphics, medical imaging and for the first time detailed cadaver dissection, this program is designed to maximize student learning. *Human Body: The Respiratory System* opens with a brief examination of how breathing works in humans. Then, the program looks at the anatomy of the respiratory system beginning with the air passageway and the respiratory structures. Next, the way oxygen and carbon dioxide are exchanged in the lungs is examined. The program ends with a look at the simple process of exhalation and respiratory diseases, such as bronchitis.

## **ADVANCED VOCABULARY DEFINITIONS**

- **Acute bronchitis:** An inflammation of the large bronchi (medium-sized airways) in the lungs that is usually caused by viruses or bacteria
- **Alveoli:** Tiny, thin walled air sacs in the lungs where oxygen and carbon dioxide exchange places
- **Bronchitis:** An inflammation of the membranes lining the bronchial tubes
- **Bronchus:** Either of the two main branches of the trachea, through which air passes to and from the lungs
- **Capillary beds:** Blood vessels which enable the exchange of water and chemicals between the blood and the tissues
- **Cardiovascular system:** The heart and the whole of the circulatory system, which is divided into the systemic (arteries and veins of the body) and pulmonary (arteries and veins of the lungs)
- **Chest cavity:** The cavity enclosed by the ribs between the diaphragm and the neck and containing the lungs and heart
- **Diaphragm:** A sheet of muscle extending across the bottom of the rib cage, it separates the thoracic cavity from the abdominal cavity and performs an important function in respiration

- **Endoscope:** A long slender medical instrument for examining the interior of a bodily organ or performing minor surgery
- **Epiglottis:** A flap of cartilage that covers the windpipe while swallowing
- **Flu:** An acute viral infection of the respiratory tract caused by one of three strains of influenza virus
- **Heimlich maneuver:** An emergency procedure to help someone who is choking because food is lodged in the trachea
- **Intercostal muscles:** Several groups of muscles that run between the ribs, and help form and move the chest wall
- **Larynx:** Also known as the voice box, the larynx is a cylindrical grouping of cartilage, muscles, and soft tissue which contains the vocal cords
- **Lung cancer:** Lung cancer is a disease of uncontrolled cell growth in tissues of the lung
- **Lung capacity:** The amount of air the lungs hold
- **Pharynx:** The area of the throat containing openings to both the trachea and the esophagus
- **Pneumonia:** A disease that causes inflammation of the lungs and the buildup of fluid in the lungs. Symptoms include fever, chills, cough, and difficulty breathing
- **Primary bronchus:** The split in the trachea that sends air into the left and right lungs
- **Pulmonary artery:** The artery that carries venous blood, rich in carbon dioxide and poor in oxygen, from the heart to the lungs
- **Pulmonary circuit:** The portion of the cardiovascular system which carries oxygen-depleted blood away from the heart, to the lungs
- **Smoker's lung:** Lungs diseased with emphysema, lung cancer, and chronic bronchitis.
- **Total lung capacity:** The total amount of air in the lungs when a person has breathed in as far as possible
- **Trachea:** Also known as the wind-pipe, it is the upper portion of the airways. It divides into two branches, the left and right main stem bronchus. Each main stem bronchus is the main airway to a lung
- **Vocal chords:** Two folds of tissue located in the larynx that vibrate when air passes over them, producing the sound waves associated with talking and singing
- **Windpipe:** Also known as the trachea, it is the upper portion of the airways. It divides into two branches, the left and right main stem bronchus. Each main stem bronchus is the main airway to a lung

## **SCRIPT**

### **HUMAN BODY: THE RESPIRATORY SYSTEM**

The miracle of all miracles on this planet is the human body. Now see it in a way never revealed before.

Oxygen. It's critical for the human body. Indeed for all animal life. Our respiratory system takes the oxygen found in the air we live in, takes the oxygen and transfers it to the bloodstream. Then, in an interesting twist of body brilliance, the oxygen is used to power the muscles that produce breathing, breathing that brings the oxygen into the body. Join me, Dr. Mark Reisman, as I take you on a journey through the respiratory system and the mechanism of breathing.

#### **Breathing**

When a diver enters the water, the oxygen that was once so readily available is suddenly cut off. The diver is holding her breath, and if she's good at it, she can hold it for several minutes. But the record is over ten minutes. Or she can snorkel, extending an air tube out of the water through which she can breathe. Interestingly, the snorkeler's breathing tube is only effective near the surface. Extend it down 10 feet and the water pressure will be too great for the diver's breathing mechanism to overcome.

Breathing. A breathing mechanism that on the outside looks like this. I take a deep breath. My chest expands. Then I let the breath out. And my chest contracts. In its simplest form, breathing is the moving of air in and out of the lungs.

It is much like the device that an old-time blacksmith used for stoking his fire. In order to increase the heat for melting metal, he would set up a simple device called a bellows. As he opens the bellows, air rushes in, just like when I inhaled. When he closes the bellows, air is forced out, just like when I exhaled.

Breathing occurs automatically. Just try and hold your breath. As we all know, we cannot kill ourselves by holding our breath. In humans, the breathing cycle repeats itself about 16 times a minute or 23,000 times a day, each time taking in about a half liter of air. That's about the volume of a typical plastic soda bottle, and is called the tidal volume.

But we can consciously impact our breathing - slow it down, speed it up, take deeper breaths.

And elite athletes like Nate know that while there is no way to increase the size of their lungs, there are many ways to increase the amount of air taken in by their lungs, and to increase the efficiency with which their lungs capture oxygen. Here at the Boulder Center for Sports Medicine, Nate's vital lung capacity is being measured by a spirometer, which measures the maximum amount of air Nate can take in.

### **Test Supervisor speaks**

Nice one; a little more. It's already higher than your previous. Looking good, looking good. And big breath in. Nice OK, relax. Based on the screen here, for the total amount of air he can exhale, as well as - that's the top number - as well as how fast he can get that out. In terms of how many liters of air he can get out in the first second. So as you can see his best effort was 3.67 liters in the first second, and 3.97 for the total exhalation, which is about 93% of the total.

After exercise, Nate's lungs can take in almost 10 times the volume compared to when he was at rest. Now the combination of vital lung capacity and the amount of air remaining in the lungs after a complete exhalation is what doctors call the total lung capacity... Total lung capacity varies according to weight, sex, age, and exercise - exercise that strengthens the muscles surrounding the rib cage - muscles that are used in taking a deep breath. Nate's goal is to increase the total lung capacity by 10%. However, total lung capacity can be reduced by a lack of exercise. Muscles get stiff, causing inhalation to become difficult, less elastic, and weak muscles leave stale air in the tissues of the lungs and prevents fresh oxygen from reaching the blood stream, as does smoking. Smoking can produce diseased lungs that look like this. Whether healthy or diseased, the expanding and constriction of lungs makes use of a well-known principle of physics. The simplicity is almost miraculous.

It's a law of physics that says: gases, such as air, always move from regions of higher pressure to ones of lower air pressure. Watch. I squeeze this plastic bottle. Tighten the cap. Look. The reason the bottle cannot return to its original shape is the air pressure outside of the bottle is greater than the air pressure inside the bottle. Loosen the cap and the air rushes in. Just as air rushes into your lungs, through your nose and mouth when the muscles around your lungs expand the chest cavity. It's brilliantly simple. Then during exhalation, the same muscles relax, expand into the chest cavity and force the air out through your nose and mouth. Let's look at how these muscles work in more detail.

So how does the body expand the chest cavity, reducing the air pressure inside? Reduced air pressure that is immediately equalized by sucking in outside air?

The process involves two sets of muscles. The first is called the diaphragm, a dome shaped muscle that separates the chest cavity from the abdominal cavity. When it contracts, it flattens and lowers, thus creating additional space in the chest cavity. In the same way, the powerful muscles that lie between the ribs contract and pull the rib cage up and out. It's what you see when somebody takes a deep breath. Together the diaphragm and the rib muscles increase the volume of the chest cavity so that air flows naturally into the mouth and nose. Exhalation is produced when those same two sets of muscles relax, now diminishing the volume of the chest cavity. When this happens, air is forced out, once again through the nose and mouth. Then the process repeats itself. It is a process that is controlled by a region of the brain called the breathing center. And when activity increases, a second-level of control is activated by the buildup of CO<sub>2</sub> which triggers accelerated breathing and deeper breaths.

## **Air Passageway**

Breaths always start at the mouth or nose. When air enters through the nose, it passes through the nasal cavity where it meets up with air that enters through the mouth. Of course, food also enters through the mouth. Food needs to go in one direction down the esophagus, and air, which is now in the pharynx, needs to move on down to the lungs. Food cannot go down to the lungs and air cannot go down to the stomach. How does the body keep this straight? By a most ingenious flexible flap called the epiglottis. A simple flap, seen here, that makes sure air goes one way and food another.

One of the most extraordinary structures in the whole human body is the epiglottis, a cartilage flap that tilts over the entrance to the larynx - the route to the lungs -- when you swallow. Try swallowing and breathing at the same time. Impossible, right? But we all know sometimes water goes down the wrong way into the windpipe. Sometimes even food, food that gets stuck in the windpipe and the person cannot breathe. Many lives have been saved by a procedure called the Heimlich Maneuver. I'll demonstrate. Sometimes a person can scream help. But often you'll get the universal I'm choking sign. When you see that, you grab the person from just below the rib cage or the xiphoid process and give them a big push up, and often the food would be ejected forward.

So oxygen-rich air has now made it past the epiglottis and into the larynx, also called the voice box because this hollow, rigid structure contains the vocal cords. These two folds of tissue vibrate when we talk or hum. Past the vocal cords air enters the trachea, the windpipe. Entering the chest cavity the trachea divides into two large branches, which feed into each of the lungs. Inside the lungs these tubes continue to branch extensively into ever smaller tubes. Keeping the whole air passageway network open is the job of some important reflexes.

## **Respiratory Structures**

These are two air passageway reflexes we are all familiar with - coughing and sneezing. They both blow out crud that's been building up - mucus, dust, irritants. Sneezing expels the stuff in the upper part of the airway, the nasal passages. Coughing expels stuff from further down, stuff from the pharynx, larynx and trachea. Have you noticed that before you sneeze or cough you are forced to take a deep breath, filling the chest cavity with air, air that can be expelled with great force out of your nose and mouth. And along the way, rattling your vocal cords, producing the characteristic sneezing and coughing sounds. So, next let's take a look at these air structures in a unique way.

Using an endoscope we will travel through the air passageway. First, as air enters the nose, hair filters out large particles of dust and debris. Next is the nasal cavity. The sticky mucous membrane traps more dust and bacteria. Here is the pharynx, the short tube which passes both food and air to the epiglottis - the middle structure seen here which acts like a switch, sending food down the esophagus and air down the larynx. The larynx is another short tube clearly showing the V-shaped vocal cords. Next, the air

passes down the trachea to the primary bronchus, the split that sends air into the left and right lungs. From there, each bronchus divides and divides, getting ever smaller in diameter.

## **Gas Exchange**

Here we are, deep inside the lungs. This is where the pulmonary and respiratory systems meet up, where two great branching systems meet up and gases are exchanged. Carbon dioxide and oxygen are exchanged. For the respiratory system this is simply called the “gas exchange.”

Air is made up of mostly nitrogen and oxygen - 78% nitrogen and 21% oxygen. Oxygen is generated in the atmosphere by photosynthesis. A process plants and algae use to convert sunlight, carbon dioxide and water into plant tissue. It is a process that has a by-product: oxygen

Unlike plants, which can survive for a considerable time without light, water, or carbon dioxide, animals are in need of a constant supply of oxygen in order to break down sugars at the cellular level. Sugars that ultimately supply life-sustaining energy for the whole body. Deprived of fresh oxygen for only a few minutes, humans quickly lose consciousness, and then die.

For us, food and water, which we also have to take in from the environment, can be stored for later use, but our body has no means or mechanism for storing oxygen. So fresh oxygen must be supplied to the body 24/7.

It does this in a very ingenious way. First let's look at the pulmonary circuit of the cardiovascular system. It takes the de-oxygenated, carbon dioxide rich blood returning from the body's trillions of cells, and through the pumping of the heart, pushes this blood through the pulmonary artery into the lungs. Inside the lungs a network of ever branching and ever smaller arteries terminate at one of the 150 million alveoli a typical human lung contains. Alveoli are tiny air sacs, air sacs that are arranged in clumps, like grapes on a vine. Here the arteries form capillary beds, which surround the alveoli.

Now let's return to the air as it enters the lungs. It enters through the two short tubes, the left and right bronchi. In the lungs the bronchi branch into smaller and smaller tubes until at last they cannot get any smaller. These last sets of tubes are called bronchioles. So now, when air moves into the alveoli, it meets up with the capillary beds. This is where the remarkable gas exchange, vital to our existence, takes place. Here, oxygen and carbon dioxide are literally exchanged from one system to the other

Oxygen from the inhaled air passes through the super thin walls of the alveoli. Then right through the equally thin walls of the capillaries. Once there, the oxygen is picked up by the hemoglobin in the red blood cells and begins a journey back out of the lungs through a network of veins, finally exiting the lungs through the left and right pulmonary veins that arrive back at the heart. From here the oxygen rich blood is distributed

throughout the body by its many arteries.

Back at the alveoli and capillary beds, carbon dioxide diffuses out of the blood plasma in the capillaries - the yellowish liquid that contains many dissolved chemicals - and diffuses into the empty airspace of the tiny alveoli. The body is now ready for exhalation.

### **Exhalation**

Remember, exhalation occurs when the muscles involved in enlarging the chest cavity, intercostal-muscles and diaphragm, relax and expand, shrinking the chest cavity space. When this happens, air flows out of the nose and mouth. On a cold day you can see your breath. That's because the warm air your body expels during exhalation contains water that condenses when it hits the cold outside air. Where is this water coming from?

When the oxygen delivered to the cells meets up with their stores of sugar, a chemical process takes place. That process produces, CO<sub>2</sub>, energy and water. Typically a quart of water is exhaled daily by each of us.

There's something else that happens during exhalation. Something we all take for granted - talking. Have you ever thought about just how amazing it is that we can effortlessly and precisely produce all the sounds that come out of our mouths. That's the job of the vocal cords, vocal cords vibrating in thousands of nuanced ways.

Here we can see the vocal cords found in the larynx. Paired vocal cords displayed in a V-shaped pattern, a V-shaped gap that occurs during normal breathing. Vocal sounds are produced when the cords are closed by muscle action and then air is passed through them, air that causes them to vibrate. Just as when you tighten your lips and force air through. You can feel the vibration and hear the sounds made.

### **Two Forest Rangers speak**

Am I understanding correctly that some of the condors roosted in the high peaks last night?

They did, at least two of them.

Speaking. There is nothing like it in the animal kingdom. It is one of the greatest miracles of the human body, in that it provides us with the ability to effortlessly communicate with each other, communicate our feelings and thoughts.

### **Respiratory Disease**

Remember that coughing and sneezing reflex we looked at earlier? Most the time they are indications of some upper or lower respiratory disorder or disease.

### **Dr. Reisman speaks with a patient**

Your lungs sound perfectly clear, and by your symptoms it sounds like you have probably the beginning or the mid portion of a flu. And those usually go away by themselves in a couple of days.

Flus are most typically caused by viruses and they usually get better after a few days of symptoms similar to what our patient has. More serious types of problems can be a bacterial infection, which may cause pneumonia. And by the fact that she answered those questions that she's not bringing up any sputum or is not bringing up any greenish material from her nose, generally indicates that it's probably not a bacterial infection. So by virtue of that, we'll just tell her to get a lot of rest and some fluids and we expect her to get better in the next couple of days.

There are other diseases that affect the capacity of the lungs to deliver vital oxygen to the body. Acute bronchitis is an infection and inflammation of the larger tubes in the lungs. Asthma, which tends to affect the many smaller tubes in the lungs, is caused by allergens, infection, and irritants, small foreign substances contained in the air or sometimes found in food. Largely caused by smoking, lung cancer is the most common cancer worldwide. Tanned lungs is one of the visible signs of a "smoker's lung" brought about by inhaling one of the over a thousand carcinogens found in cigarette smoke.

### **Conclusion**

The human body has evolved so that the two most vital organs sit right next to each other. The heart and lungs are contained in the protective casing of the chest cavity, the bony rib cage of the skeletal system. While the heart is the most powerful muscle, the lungs, remarkably, have no muscles of their own. Instead they rely on the action of the rib cage muscles and the diaphragm, which can receive both voluntary and involuntary signals from the central nervous system. Indeed, the human cardiovascular, nervous and respiratory systems are molded into one beautifully functioning homeostatic mechanism, a homeostatic mechanism that allows an athlete, or you, to move effortlessly from rest to intense activity and maintain that activity over a long period of time. Perhaps the most advanced body system in the animal kingdom.

The respiratory system is truly the breath of life. A system constantly exchanging chemicals from outside the human body. And it is the most delicate of all the body systems. A system under constant attack from harmful chemicals, microbes and irritants, yet performing its vital function for many years in spite of many self-induced hazardous behaviors, such as smoking and living in polluted air. I'm Dr. Mark Reisman and thanks for watching *Miracle of the Human Body*.

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