

# Young Scientist Program: Anatomy Teaching Team



## **Module 1: Basic Anatomy of the Respiratory System “What happens when we breathe?”**

### **A.) Introduction**

Everyone knows that breathing is essential to life. Every person on the planet has air going into and out of their bodies multiple times per minute, and remarkably this process keeps us all alive. Yet why do we need to breathe? Where does the air go once it enters into our bodies? and How is our body designed to allow for the controlled exchange of gas/air with the environment? This lesson will answer these questions as well as look at the structure of the most important organs in the respiratory system: the lungs.

### **B.) Why do we need to breathe?**

Everyone knows that almost all animals breathe in some form or another. Humans do it, dogs do it, fish do it, and even some single celled organisms do it (sort of). In all of these cases each organism uses breathing as a way to obtain oxygen from the environment (be it air, water, etc.) and remove waste gases (ex: CO<sub>2</sub>) from their own systems. *Why is this so process so important?* Well, all cells, including those in our body, run on energy. [Energy in cells is mainly stored in the chemical bonds in small molecules known as ATP, adenosine triphosphate.] Cells need this energy to reproduce, grow, repair their membrane, activate various processes, and synthesize protein. Cells can produce this required energy by breaking down large macromolecules such as sugars (glucose), which come from the food that we eat. [Similar to the way that wood is used to generate heat in a furnace.] Specifically, the chemical bonds within these molecules are broken, releasing energy which is then harnessed and converted into chemical energy that can be utilized by the cell. Yet, over millions of year cells have figured out a really efficient way of obtaining the greatest amount of energy from each sugar molecule utilized. This method utilizes a biochemical pathway known as the electron transport chain (ETC). [The ETC generally utilizes small parts (electrons) of the sugar molecules to create a large ionic gradient across the membrane within the mitochondria, which can then be utilized to synthesize ATP (much like how a hydroelectric dam works).] Yet, a cell can only use the ETC if oxygen is present in the cell, as oxygen serves as a “sink” to absorb and remove all the used up byproducts (electrons) of the process. In order for cells to carry out all the functions required for survival cells must produce lots of energy, and therefore must use the ETC. Energy production using the ETC in the presence of oxygen is termed “aerobic respiration,” while energy production in the absence of oxygen

is termed “anaerobic respiration.” Some cells can survive without oxygen, yet these cells are generally very simple and are not found within the body.

*So, overall, we need to breathe to obtain oxygen. Oxygen allows our cells to make more energy, which in turn allows them to carry out all their functions, survive, and allow the organism to survive.*

Furthermore, breathing also allows organisms to get rid of waste gasses that accumulate within their systems. For example, carbon dioxide is a byproduct of the breakdown of the sugar molecules that occurs inside cells during energy production. If the carbon dioxide is not removed from the cells the delicate chemical balance (pH, chemical reactions, etc.) inside the cell can be upset and the cell will not be able to function normally. Therefore, these waste gasses must be removed to allow normal cell function and survival, and therefore survival of the organism.

*Therefore, we also need to breathe to remove waste gasses from our system. Eliminating these waste gasses into the air allows our cells to function normally and survive, allowing our bodies to function properly.*

### Questions to ask:

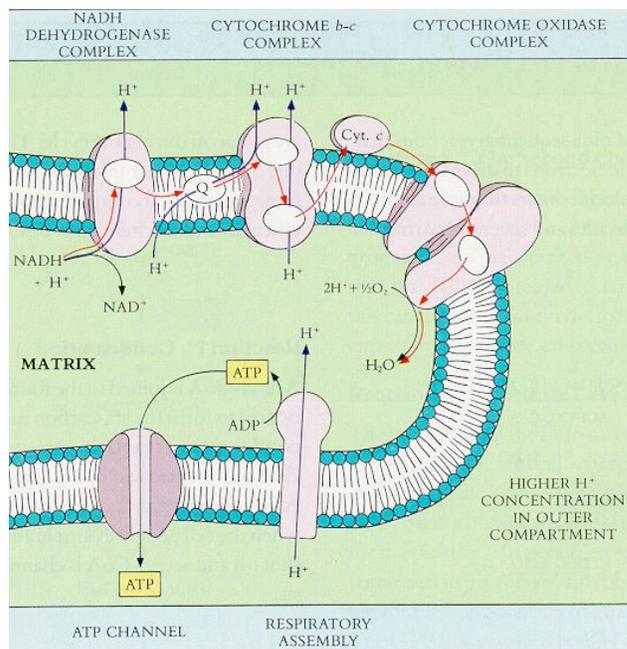
Why do we need to breathe?

What gasses do we exchange with the air during breathing?

What does oxygen do inside the cell?

### In Depth Topics:

Krebs Cycle, ATP / Energy in Chemical Bonds, Electron Transport Chain, Aerobic/Anaerobic Respiration



### C.) Where does the air go inside our bodies?

We all know that when we breathe air enters and exits through our mouth or our nose. But where does it go from there? Air entering into our noses passes through a series of hairs in our nose (which filter out particles in the air) before entering into a large space known as the **nasal cavity**, which is divided into two parts by the **nasal septum**. Inside the nasal cavity are many openings to the sinuses and ducts, which explains why mucus collects inside your nose when you are sick, as well as three **nasal concha** which help to warm the air as it passes through the cavity (these look like fins, similar to those on a radiator grill). Next the air passes into the **nasopharynx**, which is a small passage that leads down into the back of the mouth to the **oropharynx**. Here the air that enters the nose meets up with air entering the mouth. This explains why when you close your mouth, or nose, you can still breathe through the other. They are all connected! The air then continues down into the **laryngopharynx** by passing around the **epiglottis**. The epiglottis is very important because it prevents food from entering into your respiratory system (specifically the larynx/trachea) and prevents you from choking. The epiglottis acts much like a flap valve (similar to the one used in toilets) which, upon swallowing, covers up the entrance to the larynx, forcing food to go down the esophagus, which is located just next to the opening to the trachea.

Air passing around the epiglottis then passes the vocal cord and into the **trachea**. The trachea is a semi-rigid, branching “pipe” that directs the air into the lungs. It contains small rings of cartilage that help to keep the “pipe” open, even deep inside the body. (Similar to dryer tubing.) As the air continues down the trachea it is eventually forced down one of two smaller “pipes” known as the **left/right main bronchi**. The splitting of the trachea into these two bronchi gives the trachea a “Y” shape. The air moving down each of these two bronchi will ultimately go to the left and right lung. Next, the air in each main bronchus is split up again into smaller “pipes” known as **lobar bronchi**. These smaller and smaller “pipes” help to spread the air around to different regions of the lungs, where gas exchange can occur.

#### Questions to ask:

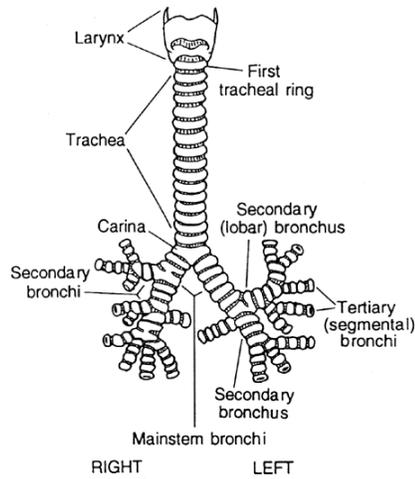
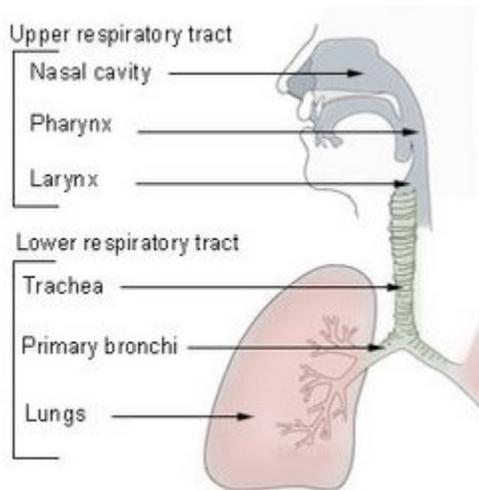
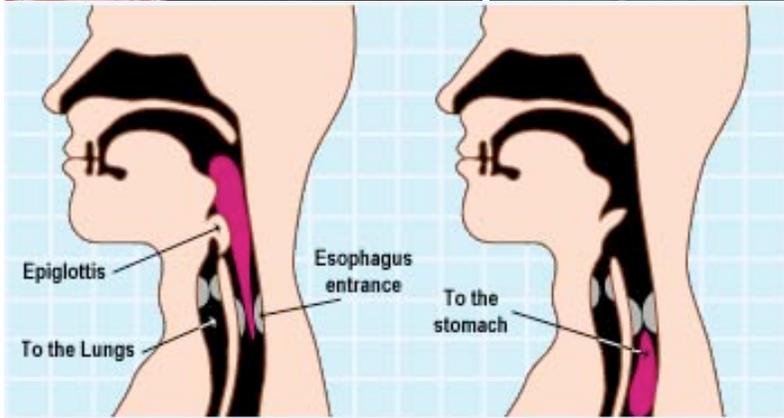
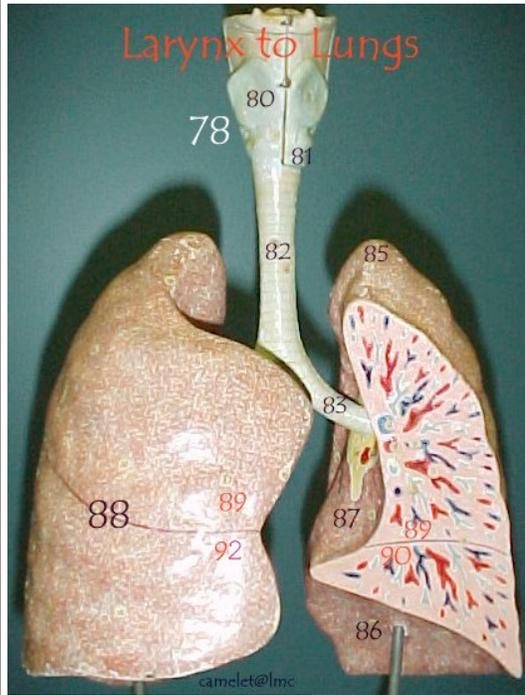
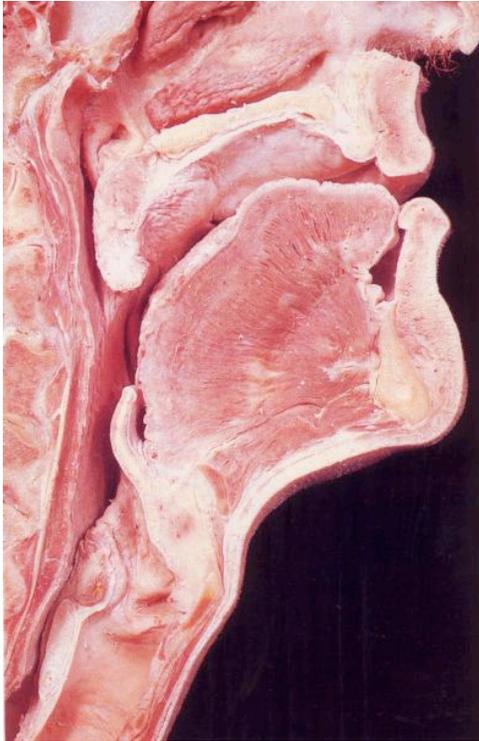
Where does air enter into our body?

What else enters into our mouth?

How could the body separate the food from the air?

#### In Depth Topics:

Protective Mechanisms of the Upper Airways, Swallowing Reflexes



A

## D.) Lung Function

So we now know how air gets to the lungs, but what happens inside of the lungs? As we said before, air comes into the lungs through a series of branching “pipes” known as the trachea and the bronchi. Inside the lungs these pipes continue to branch into smaller and smaller pipes, known as **segmental bronchi**, **bronchioles**, **terminal bronchioles**, and **respiratory bronchioles**. Again, these many branches help to spread the air around the large volume of the lungs. Eventually, all of the very small “pipes” lead to bundles of very very small “sacs” known as **alveoli**. (You can think of each alveoli as a small balloon that is filled with air.) [Overall, you can think of the tissue inside the lungs looking a lot like a piece of broccoli, with lots of small rods (the stems) branching out and eventually ending in lots of very small balls (the buds at the crown of the broccoli).]

So what happens in the alveoli? Well, as we said before, the most important function of the lungs is gas exchange. The alveoli are the main site where this gas exchange occurs. But how do gasses get from the air into our bodies? Well, each alveoli is surrounded by a very small “net” of blood vessels known as capillaries. [These capillaries are so small that only one red blood cell can fit through them at a time.] The blood coming into this network of capillaries is “old, used up blood,” meaning it has very low levels of oxygen in it and very high levels of waste gasses such as carbon dioxide. [This blood is pumped to the lungs through the right side of the heart via the **pulmonary arteries**.] This “used” blood then practically “covers” the surface of the alveoli, providing a large surface area, or region of contact, with the air inside the alveoli, which has high levels of oxygen and low levels of carbon dioxide. Due to the difference in concentrations of oxygen and carbon dioxide between the blood and the air inside the alveoli, oxygen will diffuse into the blood and carbon dioxide will diffuse into the air inside the alveoli. [This process will continue until equilibrium is reached, or the concentration of each gas in the air and blood is equivalent.] Effectively, this process will increase the amount of oxygen in the blood, decrease the amount of carbon dioxide in the blood, decrease the amount of oxygen in the air in the alveoli, and increase the amount of carbon dioxide in the air in the alveoli. Through this gas exchange the blood surrounding the alveoli has been “renewed” (re-oxygenated) and can now be sent back to the left side of the heart, via the **pulmonary veins**, to be distributed throughout the body. The air inside the alveoli, on the other hand, has been “used up” and is now of no use to the body (the body cannot get anything else out of it) and therefore gets rid of this air through exhalation, which moves the air from the lungs back out the nose/mouth in the reverse order that it came in.

*So, overall, the lungs contain many small “pipes” which distributes air to small sacs, called alveoli. These small sacs provide a large region of contact between air and blood, which allows for gas exchange between the environment and our body. This process is important for keeping the delicate chemical balance in our bodies, and for oxygenating the blood that is passed throughout our body.*

So why is the lung organized like this? It's all about **surface area**! The only way to get a lot of oxygen into the blood and a lot of carbon dioxide out of the blood is to provide a lot of contact area between the air/blood. [Since you can't change the concentration of oxygen or carbon dioxide in the air or in your blood, well at least not normally!] The "architecture" of the lungs, with millions of these tiny air sacs, allow for a maximum amount of air/blood contact for a given volume of tissue. In this way the lungs are really the "optimal solution" to this gas exchange problem. Actually, if you calculate out the total surface area of all of our alveoli it would be nearly the same as the surface area of a tennis court!

**Questions to ask:**

What is the main function of the lungs?

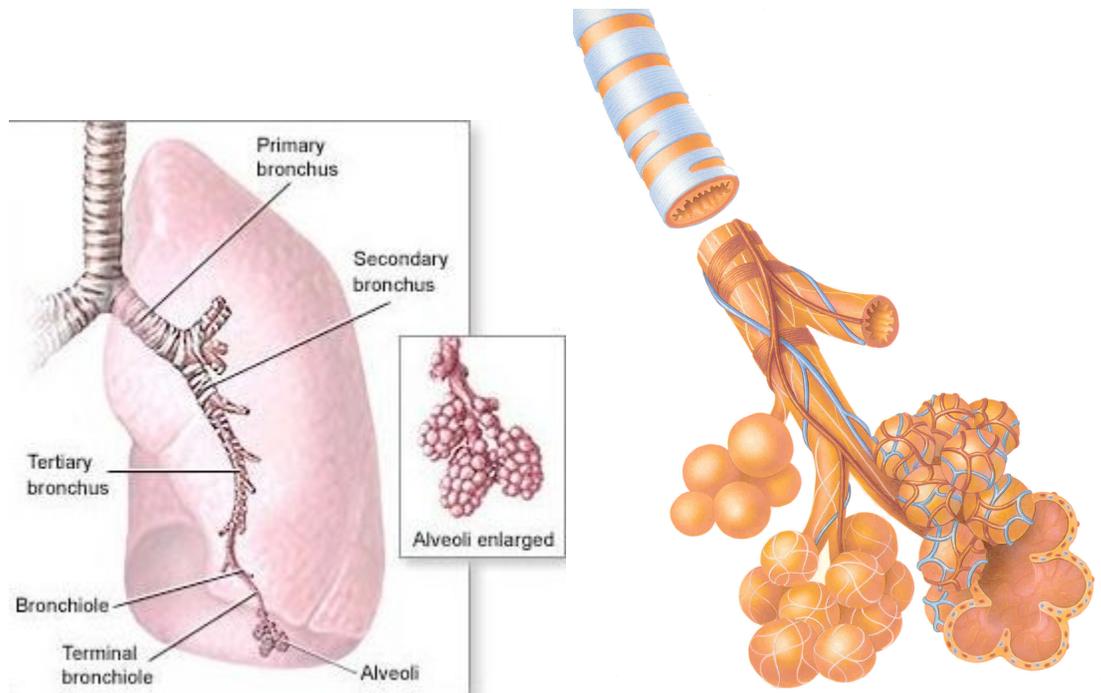
Why does the blood coming into the lungs have low amounts of oxygen?

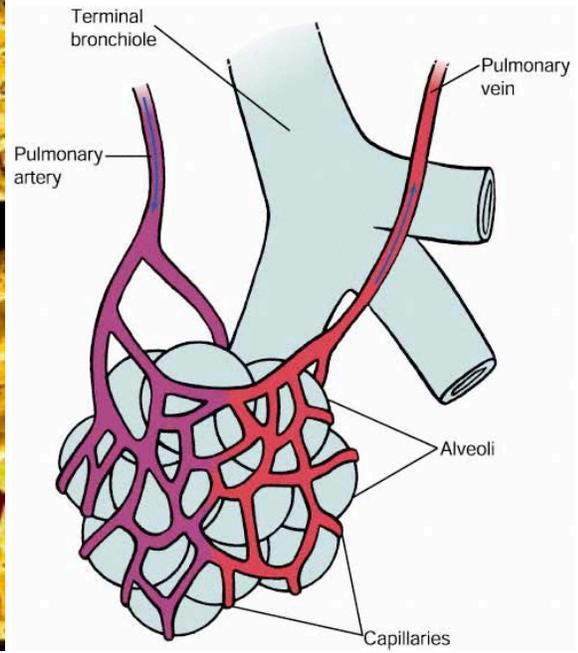
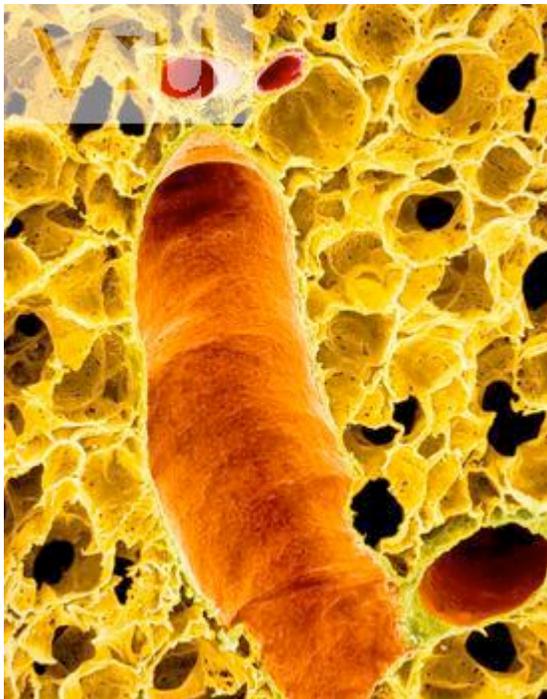
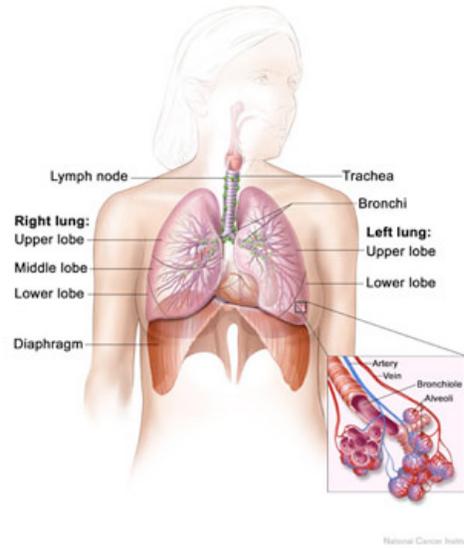
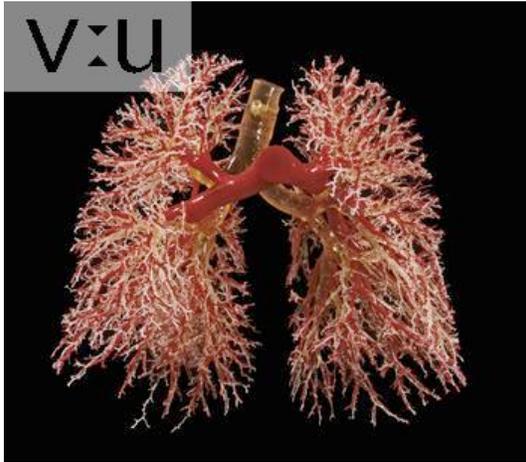
How does blood get into/out of the lung?

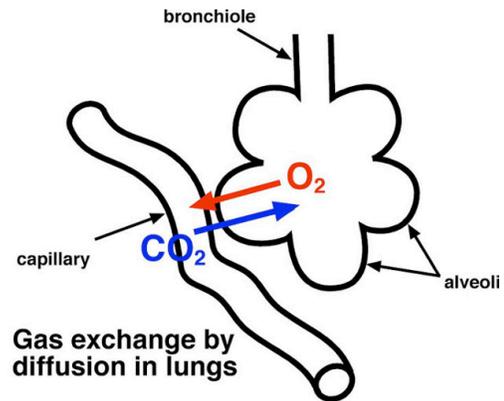
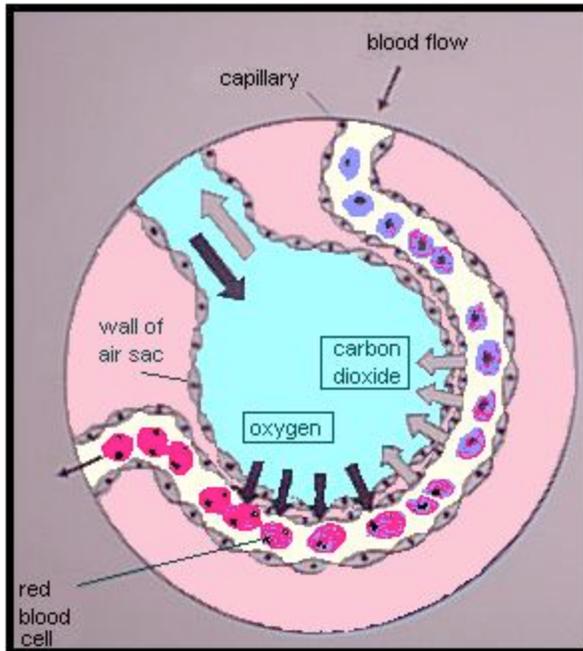
**In Depth Topics:**

Hemoglobin, How  $O_2/CO_2$  is Carried in the Blood, Surface Area/Diffusion

[Fick's Law]







## E.) Lung Structure / Anatomy

So now that we know what goes on inside the lungs let's take a look at what an actual lung looks like. Everyone has two lungs in their body, a left and a right lung, and both lungs are located in the upper part of the chest (thorax). The lungs normally sit within the rib cage, and are bounded by the diaphragm (inferior) and the mediastinum (proximally). [Demonstrate position/orientation of lungs in the chest.]

*The first thing you generally notice about the lungs is their color and texture.* Normally the lungs are a pinkish/grayish color, depending on the age of the specimen and the length/type of preservative used. Lungs from a middle aged person, such as these, will almost always have some black/gray spots on the outside even if the person was not a smoker! This is due to the fact that we all live in a fairly industrial setting, and we are all normally exposed to particulates in the air such as dust, pollution, etc. As we inhale this "pollutants" into our lungs particles will get caught/deposited at various points along the "pipes" leading into and out of our lungs. Since the cells in our lungs do not like to be dirty/contaminated, specialized cells will breakdown and "engulf" the particles in order to prevent them from harming other cells. The immune cells carrying these particles will then cluster together in lymph nodes or other places to "get out of the way." The content of these cells, the collected debris, is what causes these collections of immune cells to appear black/gray. Another thing that you might notice about these lungs is the texture. Normally, in the human body, lungs are very light and airy, almost like a very delicate sponge. This is due to the fact that, as we mentioned before, the lungs are full of very small sacs of air called alveoli. These lungs are much harder than normal. This is due to the fact that they have been preserved for a very long time and have been handled a lot, causing the "sponge-like" tissue to compress into a more dense structure. With that in mind, normal lungs inside the body are actually a good deal larger than this.

The next thing that you may notice is that the lungs are divided up into smaller “pieces.” Each lung is actually made up of a few **lobes**, which are smaller independent parts of the lungs. Each lobe will have its own specific “air supply”, coming from one dedicated **bronchus**, as well as its own specific blood supply. You can tell whether a lung is from the right or left side of the body by the number of lobes. The right lung will have three lobes (**superior, middle, inferior lobe**), while the left lung will only have two lobes (**superior, inferior lobe**). Why does the left lung only have two lobes? Well, the heart actually occupies the space of the third lobe of the left lung. This is why the left lung is smaller than the right lung. Each lobe can also be broken down into even smaller parts called **segments**, which all function independently, but we will not be able to see these in these lungs.

The other part of the lung that you may be able to find is the **hilum**. The hilum is the point where all of the air and blood go into and out of the lung. This is also the only point where the lung is attached to the rest of the body. This makes the lung very flexible and mobile inside the chest cavity. You will recognize the hilum as a small “bundle” of “holes” coming out of the medial portion of the lungs. Every lung will appear to have a different number of “hole” or “tubes” at the hilum, due to the fact that the number will change depending on exactly where the hilum was severed when the lungs were removed from the cadaver, but in general each hilum has three different types of “tubes” running through it. First, each hilum will have one or more **bronchi**. These are the large “pipes” carrying air from the trachea into/out of the lung. These are easy to distinguish because they will have a rigid ring of cartilage around them, which is used to prop the bronchus open. Next, each hilum will have one or more **pulmonary arteries**. These blood vessels carry deoxygenated blood from the right side of the heart (right ventricle) and the pulmonary trunk to the lungs to get oxygenated. [Explain why its an artery even though it carries deoxygenated blood.] Blood inside these arteries will be split up into smaller and smaller arteries until it is passed over the surface of the alveoli, where it will exchange its gasses with the air in the alveoli. Finally, each hilum will have one or more **pulmonary veins**. These blood vessels carry oxygenated blood, collected from the capillaries surrounding the alveoli, back to the left side of the heart (left atrium) to be pumped out to the rest of the body via the left ventricle. In general, the pulmonary arteries and veins are very similar in appearance and are hard to tell apart. One way you might be able to tell the difference between the pulmonary veins and arteries is through their orientation in the hilum in reference to the bronchi. In the left lung the pulmonary artery is the most superior vessels in the hilum (superior to the bronchus), while in the right lung the pulmonary artery is the most anterior vessels in the hilum (anterior to the bronchus). [Remember RALS, right anterior, left superior]

### Questions to ask:

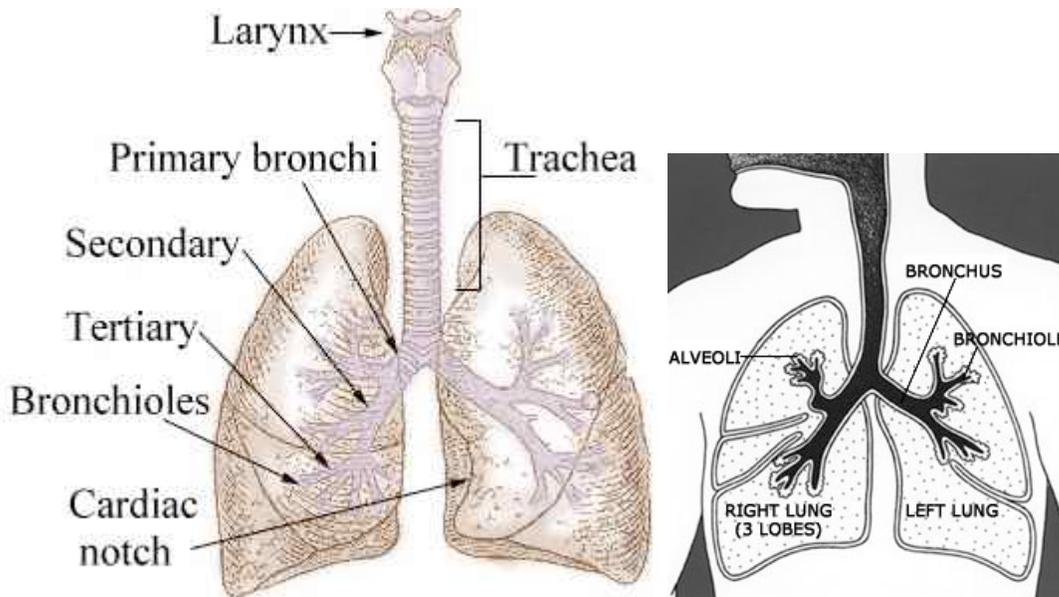
Why are the lungs different sizes?

Why would they contain different number of lobes?

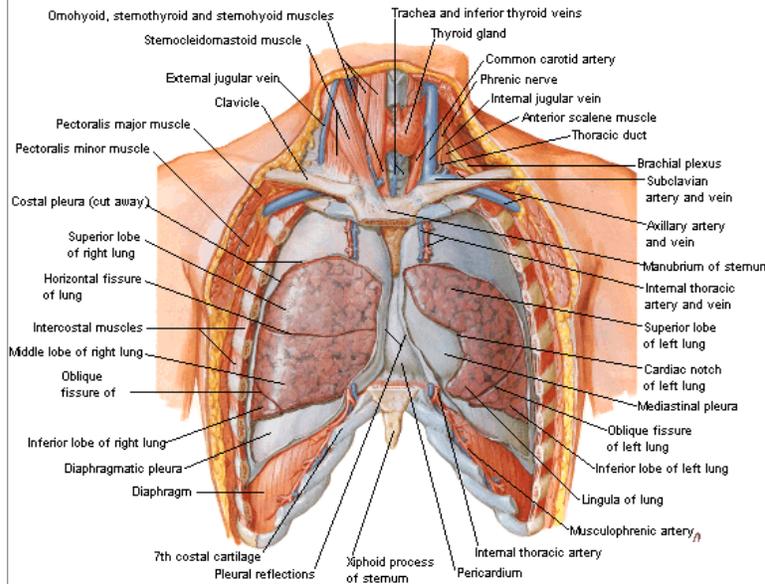
What goes in and out of the lungs?

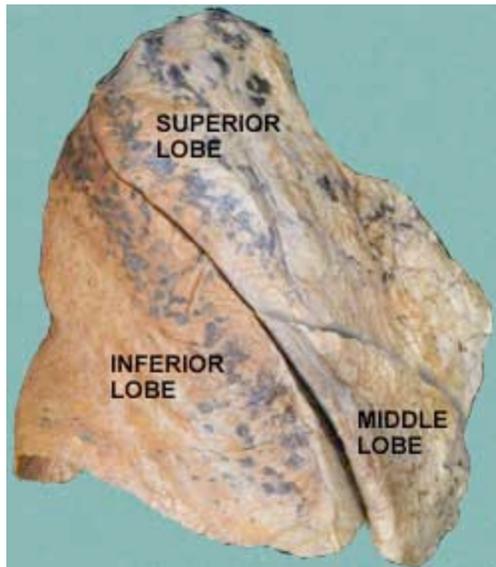
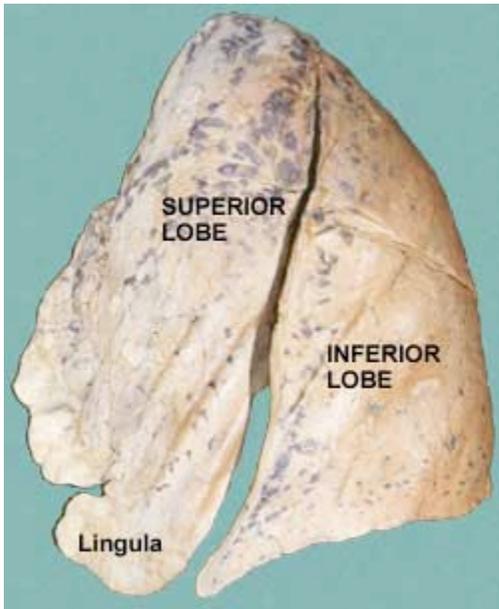
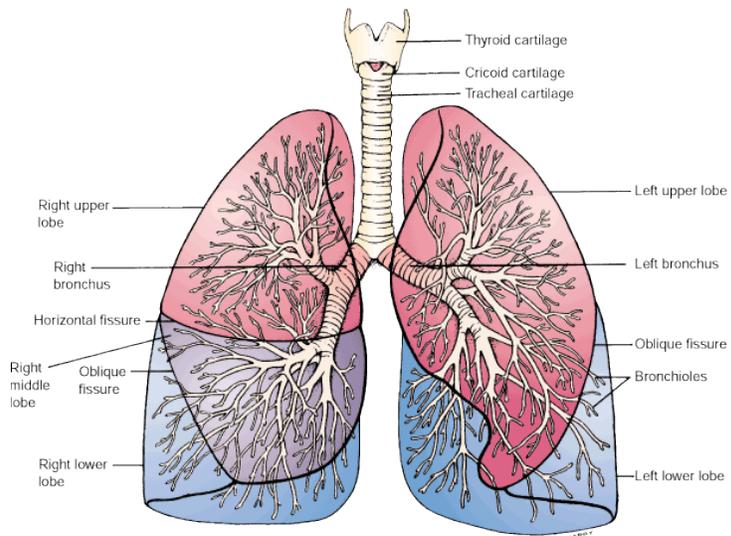
**In Depth Topics:**

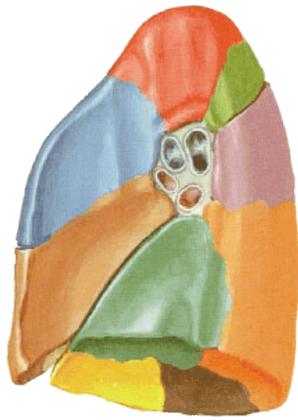
Circulation of Blood in the Heart/Body, Explanation of Inspiration/Expiration  
 Motions in the Chest, Lobar Pneumonia



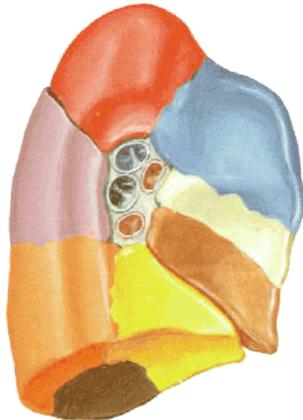
**Lungs in Situ  
 Anterior View**







Right lung



Left lung

**Right**

**Left**

