Young Scientist Program: Anatomy Teaching Team

Washington University in St. Louis
School of Medicine

Module 3:
Basic Lung Radiology + Auscultation
"How can we tell what is happening in the lungs?"

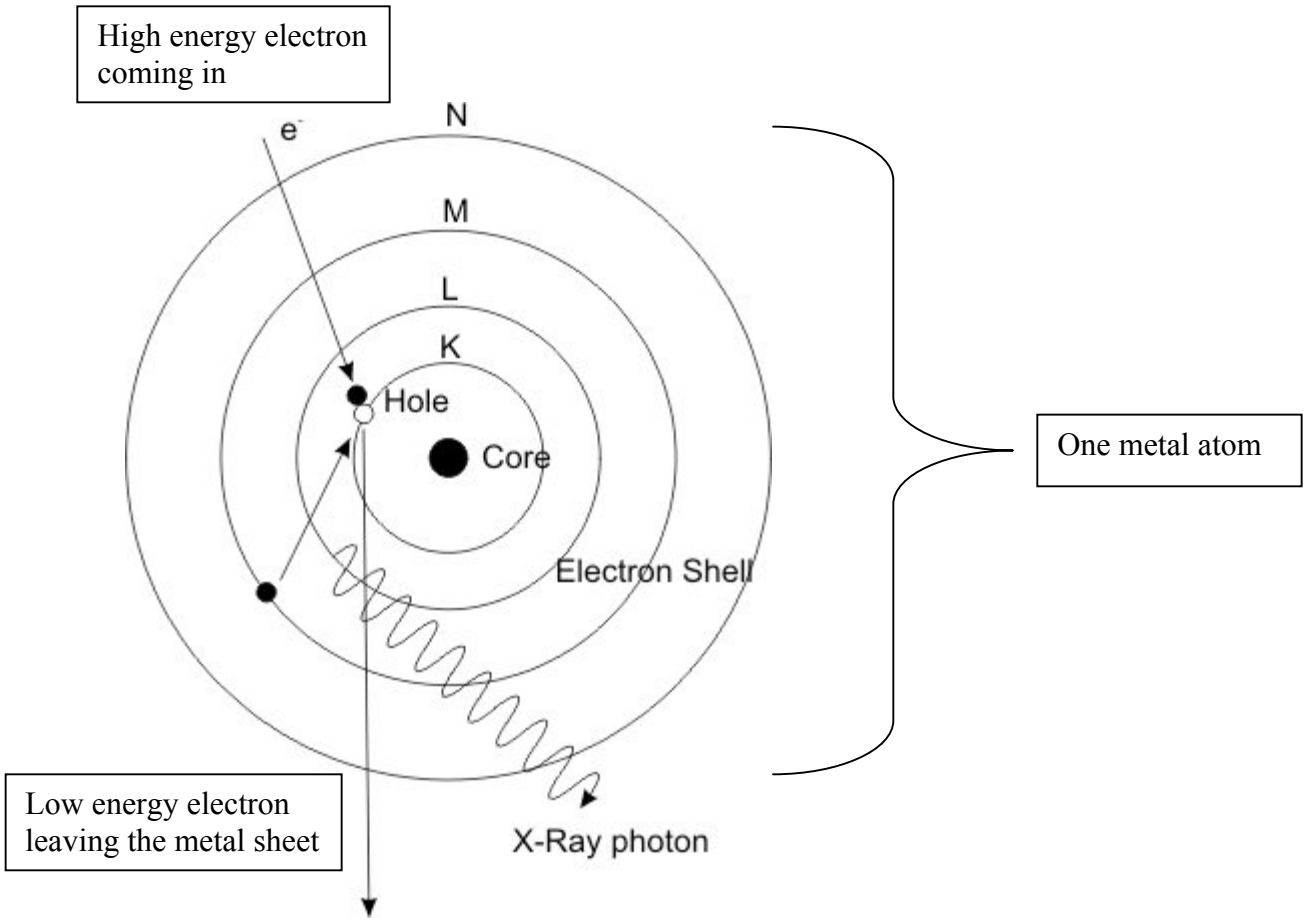
A.) Introduction

When people get sick or have various health related problems it is the doctor's job to figure out what is causing the person's illness or health condition. In many cases this diagnosis of the problem can be determined by recording the patient's symptoms, talking to patients about how they feel, physically examining the patient, taking/analyzing various tissue or blood samples, etc. While these are all powerful tools the doctor can use to figure out what is wrong in certain cases, other more complex cases, especially involving the internal organs and anatomical structures, cannot be determined using these tools along. In many cases a doctor could really use a way to see inside a patient's body. This would allow them to figure out what is going on structurally, without actually surgically opening the patient up. Luckily there are many different types of technology that allow doctors to do just that. The study and application of these technologies is called "radiology." The use of these technologies are extremely important in the field of medicine and almost all doctors use them in their practice. Here we will talk about some of the basic type of imaging techniques used by doctors, and how they work to help doctors look into the body.

B.) X- rays

1.) What are x-rays?

X-rays are a type of "electromagnetic radiation," which are waves (or particles) of energy that fly through space, similar to light or radio waves (but with a shorter wavelength and higher frequency and therefore more energy). X-rays are formed from the transition or collision of electrons, small negative particles that orbit the nucleus of atoms. *(Optional)* [Specifically, medical x-rays are generated by shooting electrons at a sheet of metal. These fast (high energy) electrons collide with the slow moving (low energy) electrons around the metal atoms, kicking them out of their orbit around the atomic nucleus. In order to fill the empty electron spot a higher energy electron must "convert" to the lower energy state of the empty spot. This "conversion" therefore releases a certain amount of energy in the form of an x-ray, which shoots off away from the metal plate. These x-rays are then guided and focused towards the target.]



2.) How to medical x-rays "see" into the body?

In order to understand how x-rays work lets compare x-rays to light. X-rays and light are very similar in some ways, as both are types of electromagnetic radiation. They can both penetrate through certain materials (like light passes through glass) and can be blocked by certain materials (like light is blocked by a window shade). Yet x-rays and light are also very different, specifically in the types of materials that they can and cannot go through. X-rays have a smaller wavelength and higher energy and can therefore pass through more dense materials than light can.

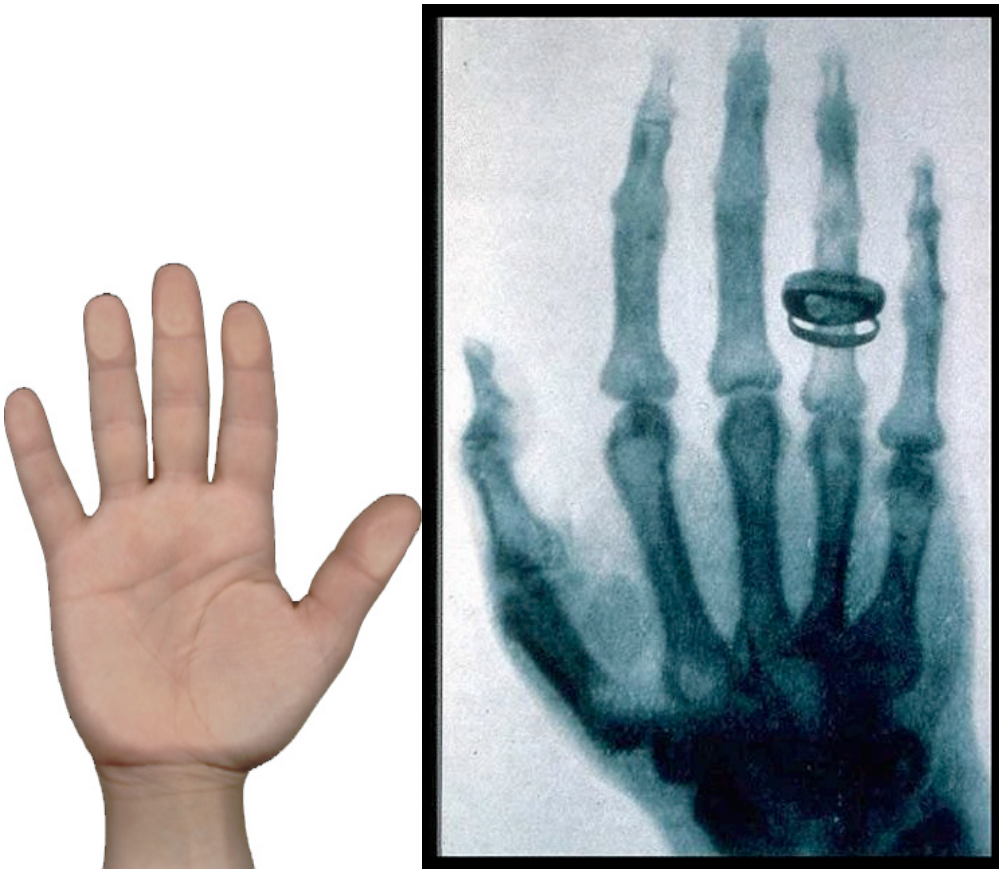
[Think of x-rays as "smaller" particles than light. For example, if light particles were the size of marbles, x-rays might be the size of BB's.]

So x-rays can pass through tissues such as fat and skin, (lower density materials) just like light passes through glass, while light cannot pass through fat and skin (as you can see by making a shadow with your hand).

[To continue the analogy, you can think of different materials a different type of sieves. More dense materials would be sieves with smaller holes, while less dense materials would be sieves with larger holes. Therefore, if you took a more dense material, like skin, it may have "holes" in it that are a little bigger that the x-ray

particles (BB's) and a little smaller than the light particles (marbles). Therefore if you put both marbles and BB's into this sieve (just like shining both light and x-rays onto the skin) only the BB's (x-rays) will pass through.]

Just like a window shade can block light, there are some materials that can block x-rays. These are generally very dense materials such as bone or metal.



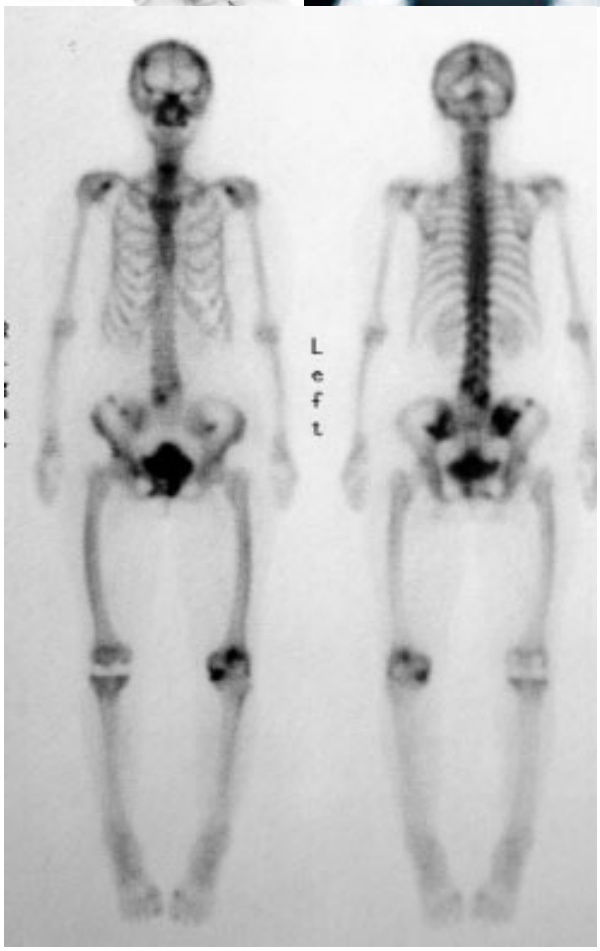
Therefore, if you "shine" x –rays onto the hand the x-rays will pass through the skin very easily, but will be blocked by bones and metal (as you can see by the dark parts of the x-ray above).

3.) So we know that x-rays pass through the body, now how do you get an image or picture with them?

Getting an x-ray "image", or a "radiograph," is a lot like taking a normal photograph (which uses light) just using x-rays instead of light and special film sensitive to x-rays. So, in order to take an x-ray picture of a person you first put the x-ray source (think of it as a big flashlight that gives off x-rays) on one side of the person and you place the x-ray film on the other side of the person away from the x-ray source. Next you turn the x-ray source on for just a second. During this time x-rays go from the source and pass into the body. Some x-rays make it all the way through the body (those that go through only skin, fat, or air), other x-

rays are blocked by dense materials such as bone and do not make it through. X-rays that get through the body hit the film and cause a small chemical reaction in the film, turning the film from white to black. The more x-rays that hit the film in a specific location make the film more and more black. Therefore, parts of the body that let lots of x-rays through will be very black on the "picture" while the parts of the body that do not let any x-rays through will be very white on the picture. So, in a way taking an x-ray is a lot like recording a special type of shadow of what is inside the body. This picture can then be used to figure out what is going on or what is causing problems inside the body.

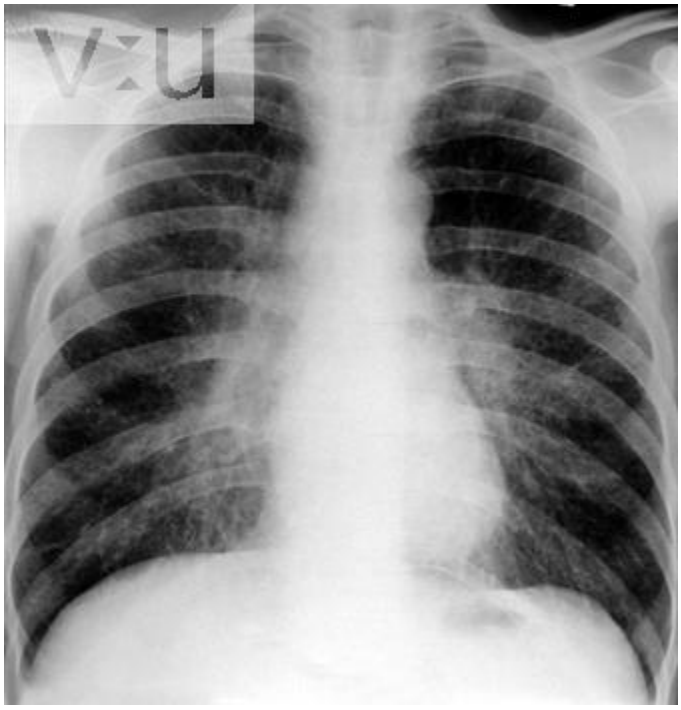
[Simple x-ray examples: head, hand, chest]



4.) The 3D to 2D problem

Just like normal photographs, x-rays are only flat images (two dimensional). Yet the "shadow" picture that is formed on the x-ray film is actually due to the x-rays passing through different tissues/organs/etc (a three dimensional structure) as they make their way from the x-ray source to the x-ray film. Therefore, the "picture" that results from taking an x-ray is actually an overlapped image of the shadow formed from structures that are closer to the x-ray source and those that are farther away from the x-ray source.

The best example of this concept is looking at a chest x-ray. In out chest we have multiple sets of bones called ribs and curve around a form our "rib cage." When we look at a chest x-ray we can see the outline of the rib-cage easily in the picture, but when we look inside the rib cage we just see a whole bunch of criss-crossing lines.



These lines are actually just individual shadows of the ribs overlapping on the image (or superimposing on each other). Since the ribs are actually slightly tilted forward they will all overlap each other a bit in the front to back (anterior to posterior) direction. Therefore, their shadows overlap on the film causing this funny criss-crossing appearance.

In Depth Topics: How CT Scans Work, How MRI Works, How US Works

5.) What else we can see in a chest x-ray

Looking at a chest x-ray can tell you a lot about what is happening to some of the most important organs of the body, namely the lungs and the heart. In this x-ray we can identify the ribs, the clavicles, the spinal cord, the heart, the aorta, the diaphragm, and the airways in the lungs.

[Point out basic anatomical structures on the x-ray.]

So based on what we talked about before why do you think the heart is so white? How is the heart different from the lungs?

C.) Using X-Rays to Look at Normal Lungs

As we just mentioned the lungs appear very dark on x-rays due to the fact that they are filled mainly with air and have a very low density. This allows us to not only see a good outline of where the lungs are, but also to see structures inside and around the lungs as well. When looking at a chest x-ray, the first aspect of the lungs that you can see is their *size* and *shape*. Look for the two almost pyramidal black areas on the x-ray, these are the lungs. From this x-ray we can determine how big the lungs are (how much volume they take up), whether the lungs are the same size, and where they are located in the chest (high, low). We can also look at the overall shape of the lungs. Normally the lungs should have an almost pyramidal shape with a rounded top that extends above the clavicles and a generally flat base that curves down at the outside (lateral) edges. The shape of this lung "field" is mainly determined by the structures that surround/border the lungs. The top and peripheral borders of the lung "field" is formed by the **rib cage**. The medial border of the lung "field" is formed by the **mediastinum**, a pouch that contains the heart, esophagus, trachea, and major blood vessels. Finally, the lower border of the lung "field" is formed by the **diaphragm**. As we mentioned before the diaphragm is shaped a lot like an open parachute (curved in a dome shape), and therefore the small triangular corner regions of the lung "fields" represent the part of the lungs that fits into the angle between the curved diaphragm and the rib cage (known as the **costodiaphragmatic recess**). [This part of the lung "field" is especially important as it is the lowest point in the lungs, and is therefore the first place that fluid will collect.] So, overall, by looking at the shape of the lungs, and comparing it to a normal picture, we can tell what is going on with all of the structures around the lung.

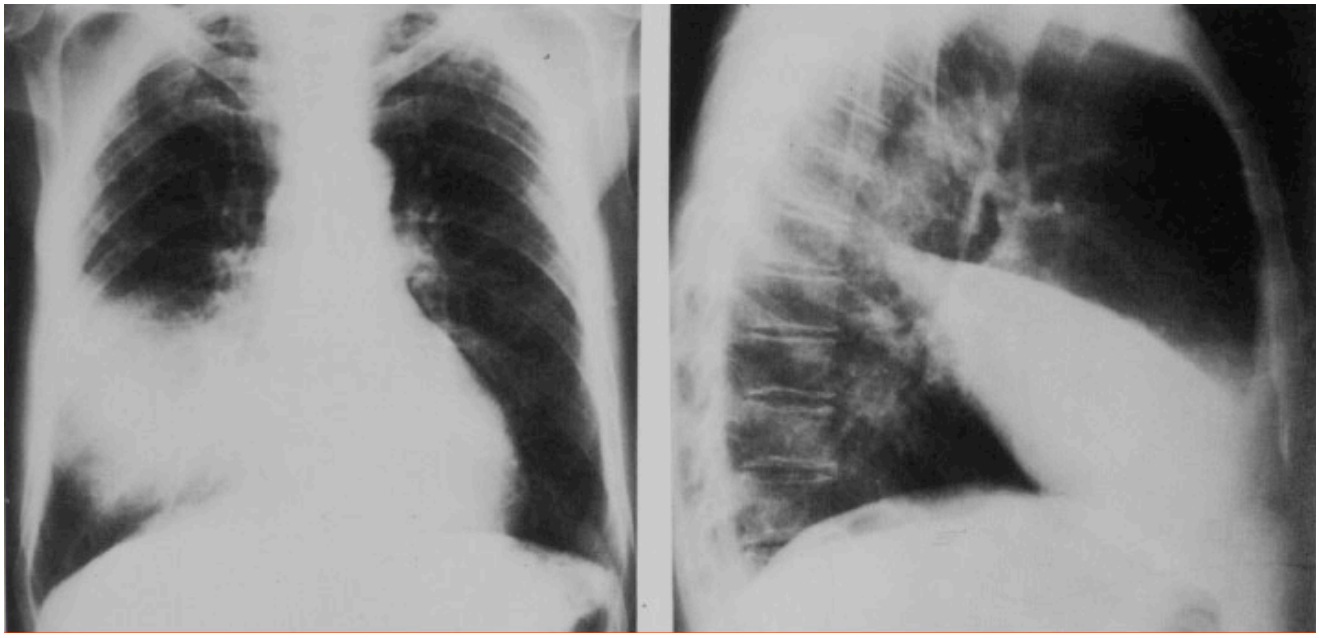
Next, we can look at the *color or shade* of the lungs. Even though x-rays are only black and white we can see difference in the "color" of different parts of the lungs. [Remember the "color" of the lungs represents the density of the tissue the x-rays are passing through. Darker grays and blacks represent less dense material like air, and lighter grays and whites will represent more dense materials like tissue, fluid, or bone.] Normally the lungs are completely filled with air and contain very small amounts of tissue. Therefore a normal lung "field" or "picture" should show all of the regions of the lung are being very black or dark gray. By comparing the color of different parts of the lungs we can see if the lungs are completely "uniform" and filled with air, or if some parts are different than others and are filled with other materials (such as fluid or tissue). So, overall, looking at the color of the lungs can tell us what substance/material is inside them.

Finally, we can look at specific *structures* inside the lungs. [This only works for really good x-rays that focus on the correct density window.] Again, we know that the lungs should be all black or gray. But if you look closely you may be able to see small light gray lines inside the lung "fields". These lines are actually the **bronchi/bronchioles** inside the lungs (they are especially prominent near the **hilum**). If dye (contrast agent) is injected into the blood stream you may also be able to see the blood vessels in the lungs/chest. By looking at these "lines" we can determine the size, shape, and overall appearance of some of the structure inside the lungs.

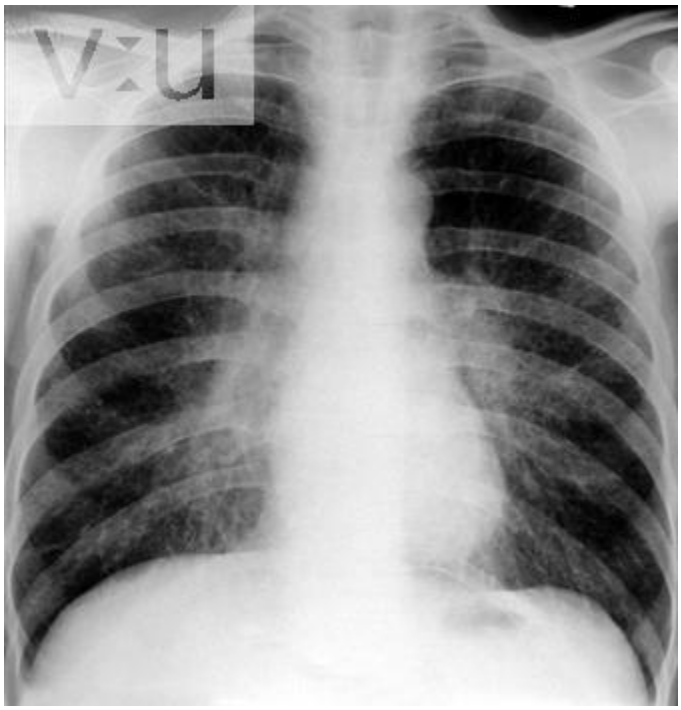
D.) Using X-Rays to Diagnose Lung Problems

So now that we know what a normal chest x-ray looks like, and know what the normal lung "field" should look like, we can diagnose various problems with the lungs. By comparing other x-rays to the "control" we should be able to figure out what "looks different" and then figure out what is happening in the patient's body.

Example #1: [Lobar Pneumonia]

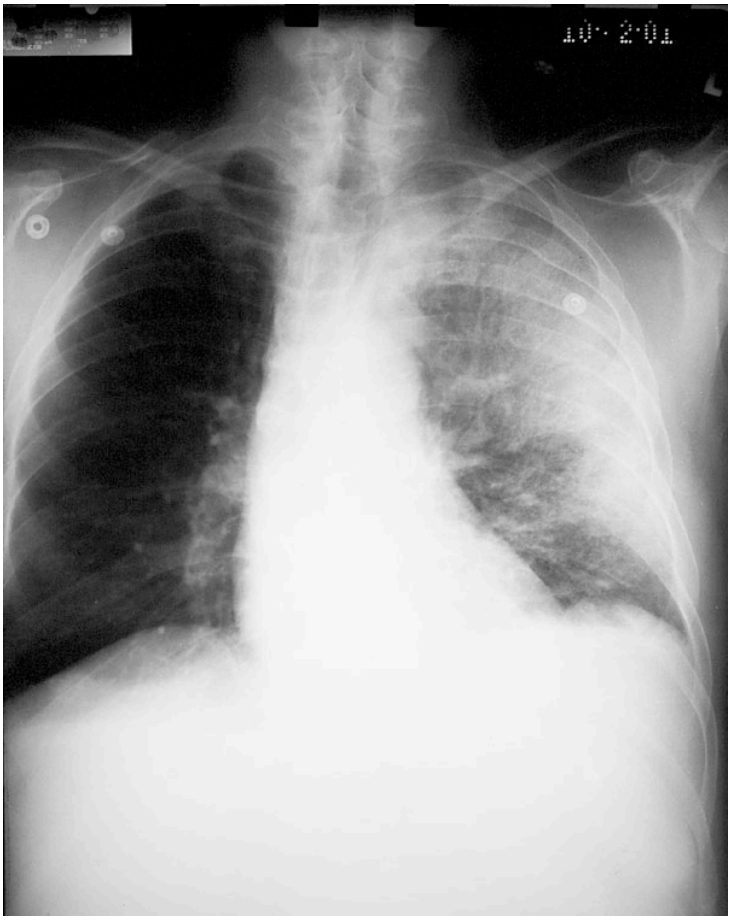


Versus



So, let's look at the two images using the characteristics that we just talked about: size of the lungs, shape of the lungs, color of the lungs, and structures inside the lungs. The big difference should be seen in the color of the lungs. Specifically, there is a big large white blob inside the right lung in our patient. So what could be inside this person's lung that would be white? Fluid, pus? What else is unique about this blob? Is it very spread out and "blended in" to the surrounding, or does it have very sharp borders? If you remember what we talk about in one of the other module you may recognize that this blob is the exact shape of one of the lobes (the middle lobe) of the right lung. This really gives this diagnosis away, and if we know the patient's symptoms (fever, trouble breathing, coughing, etc.) we could definitely say that this person has what is called "**lobar pneumonia**." Lobar pneumonia is when bacteria (typically *Streptococcus pneumoniae* , *Haemophilus influenzae* , or *Moraxella catarrhalis*, or also S. Aureus, Pseudomonas, etc.) get inside your lungs and cause a large infection that damages your lung tissue and attracts a lot of immune cells to the area. This forms lots of pus or fluid which then fills up the entire lobe of the lung, being that the lobe is a separate/independent unit of the lung. To treat this you would need to give the patient antibiotics to kill the type of bacteria that is causing the infection.

Even worse case of pneumonia:



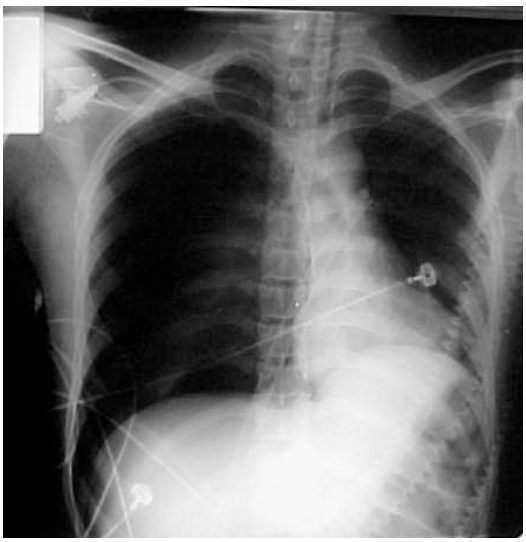
Anterior View

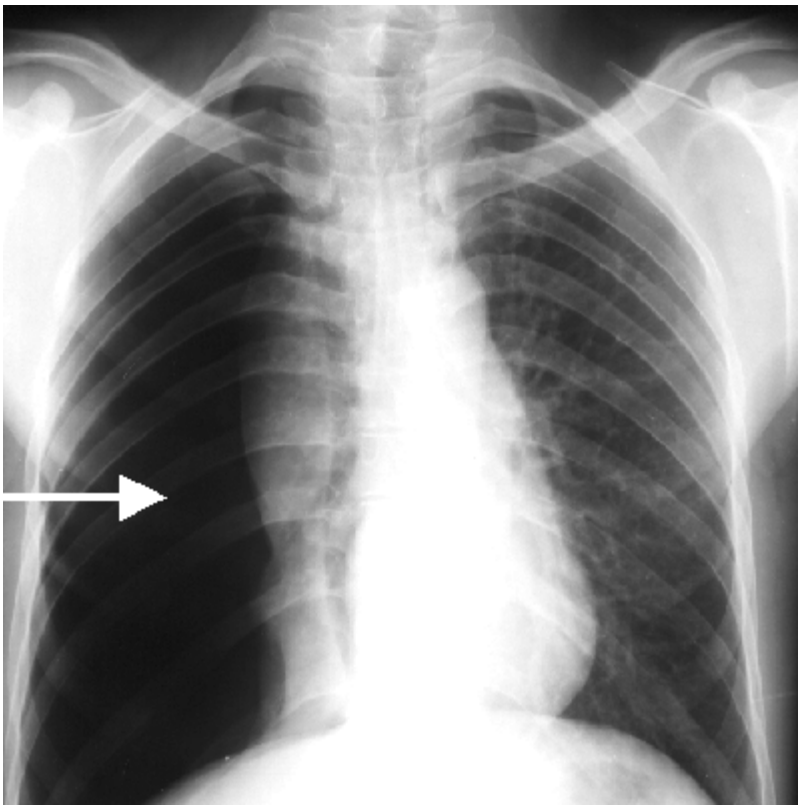
Lateral Views

Right lung Left lung Right lung Left lung

Example #2: [Collapsed Lung + Tension Pneumothorax]

or





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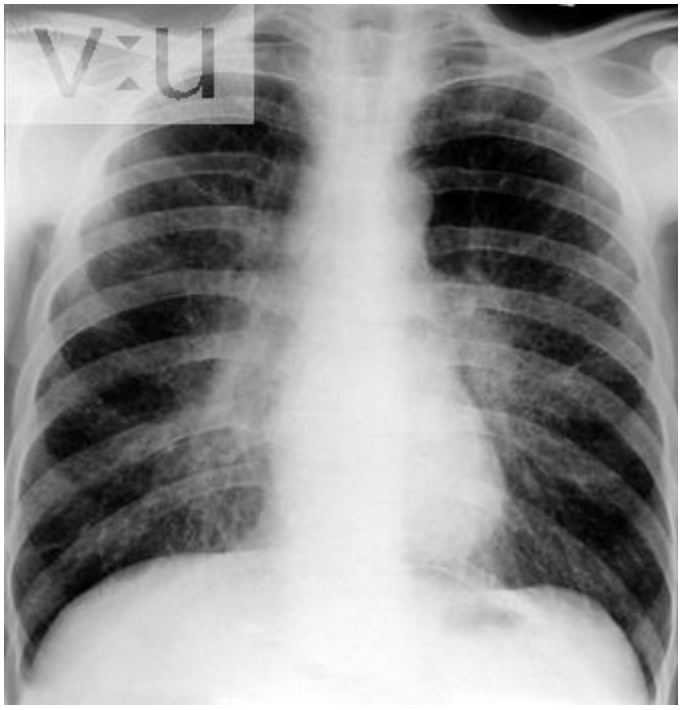
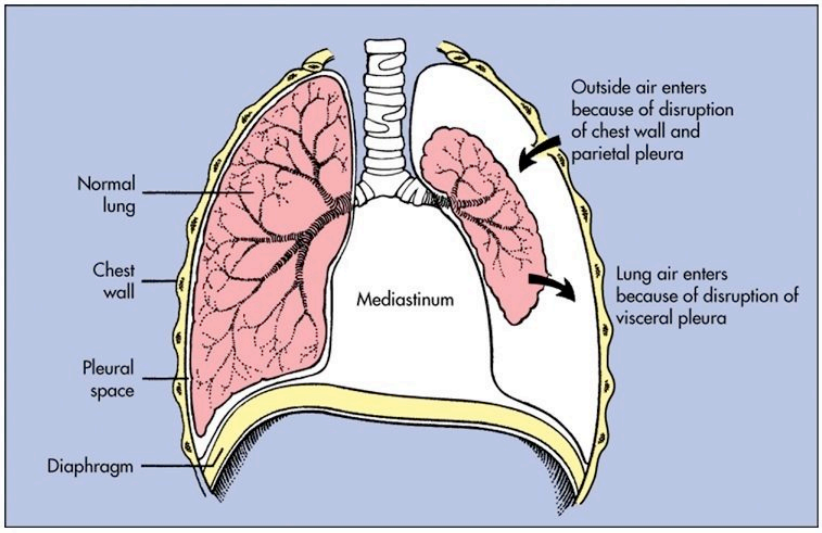
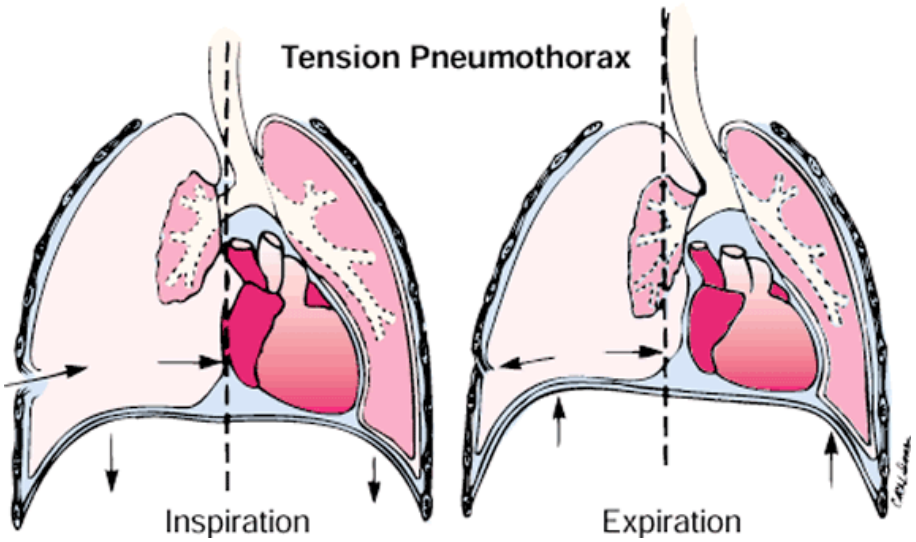


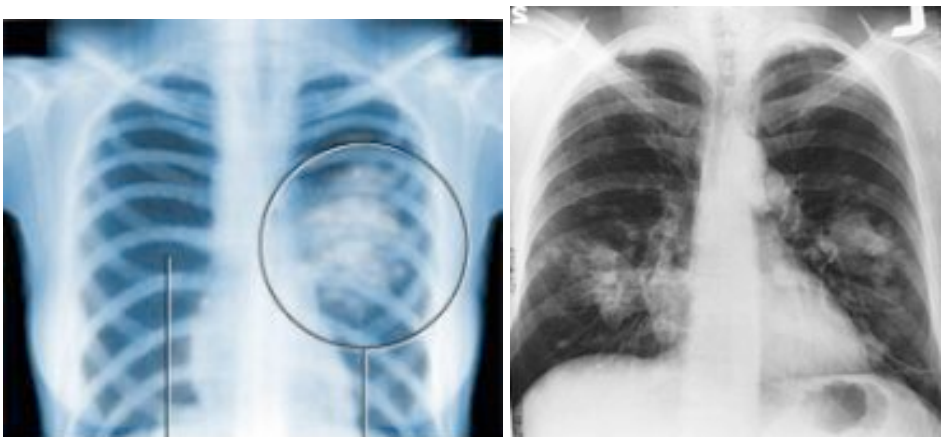
So, let's look at the two images using the characteristics that we just talked about: size of the lungs, shape of the lungs, color of the lungs, and structures inside the lungs.

The big difference should be seen in comparing the shape, size, and color of the two lungs. In these x-rays we notice that one of the lung "fields" appears larger than the other, and that this bottom border of this lung "field" (represented by the diaphragm) is lower than that of the other lung. We can also see that the larger lung "field" appears to be a bit darker (more black) than the smaller lung "field," suggesting that there is less tissue in it that normal. Also we can see that the heart (and the mediastinum) has shifted compared to its central position in the normal x-ray. So what would cause all of these things to happen? The best clue is what would cause the one, larger lung "field" to become darker? What has a lower density that the lung tissue which is mostly air? Pure air! So how would air get outside the lung, or in between the lung and the rib cage? One way would be a **collapsed lung**, where the lung develops a leak, or "pops", and then deflates inside the chest. Another way would be a stab wound, or trauma, to the chest which causes a puncture in the tissue of the rib cage. In this case the air coming into the chest cavity will have a higher pressure than that inside the lung which causes the lung to collapse, or deflate, inside the chest. In a very special instance the wound in the chest may form a sort of "one way valve" that only opens while the patient is breathing in. In this case air continuously enters the chest cavity through the wound, but does not have a chance to leave. Therefore, the pressure inside that half of the chest cavity builds and builds, forcing the diaphragm down on that side and pushing the mediastinum and the heart towards the opposite side of the chest. This condition is called a "**tension pneumothorax**." The only way to relieve this problem is to stick a tube into the pressurized chest cavity and release the air that has accumulated (along with repairing the wound in the chest wall).





Example #3: [Lung Masses - Lung Cancer]



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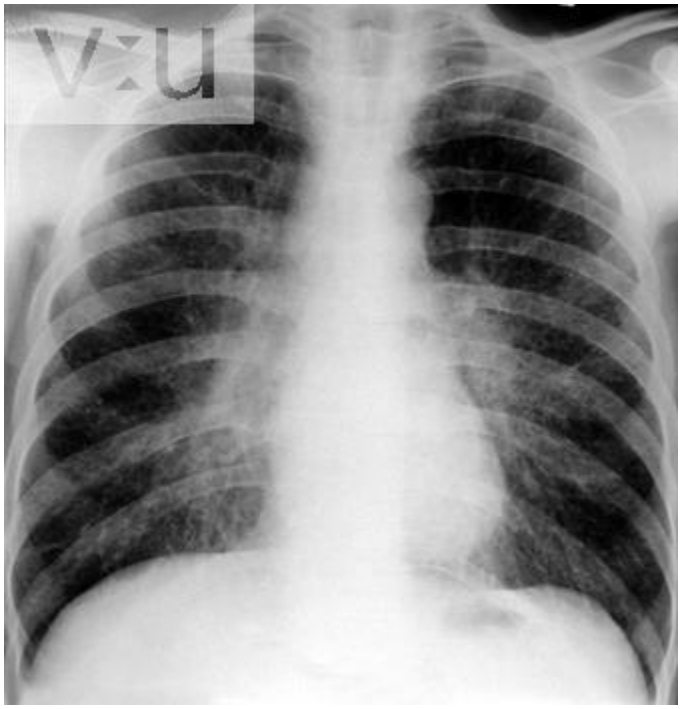
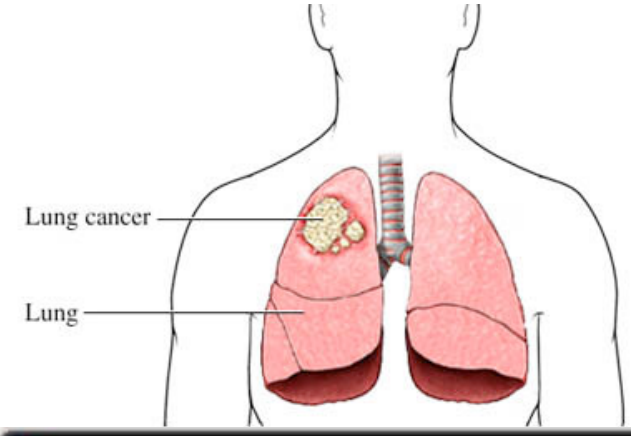
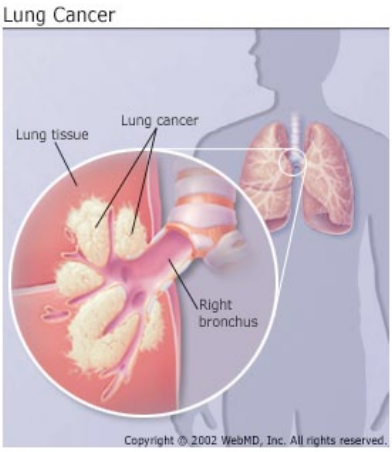
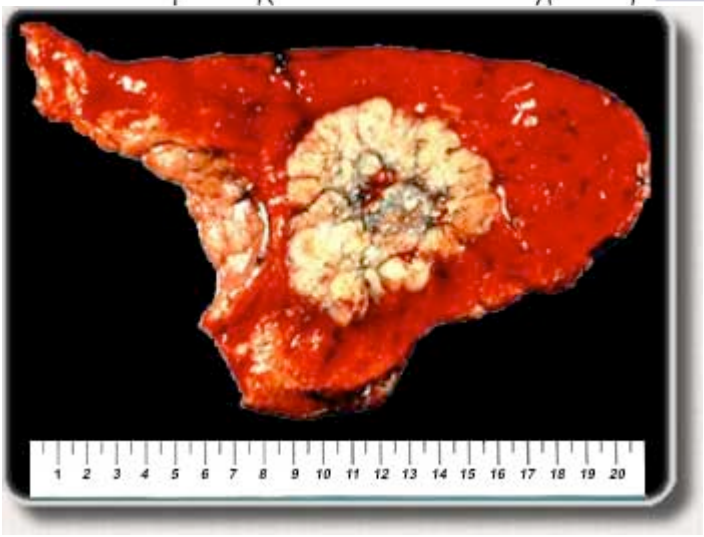


So, let's look at the two images using the characteristics that we just talked about: size of the lungs, shape of the lungs, color of the lungs, and structures inside the lungs. The big difference should be seen in comparing the color of the two lungs. Specifically, some of the lungs show abnormal, white blobs in the middle of them. These are about the same color as the "white blob" in the pneumonia case but it looks different. What is different about these white blobs? They had irregular borders, they are not "well defined" and do not have a "sharp border," and they do not take up one whole lung lobe. Since these blobs are white what does that tell us about them? They are probably more dense than air and are probably tissue, or possibly fluid/pus. If we knew that this person was a long time smoker we might easily be able to diagnose them. What do you think they might have? Lung cancer! All of these white blobs are growths called "tumors" which are mainly groups of cancerous cells that are growing in a big clump in a way that they aren't supposed to! There are many way that cancerous cells can be formed, but one of the most common ways is through the inhalation of cigarette/tobacco smoke. These tumors eventually grow bigger and bigger and take up space in the lung that is needed for gas exchange. In the end this make it harder and harder for the patient to breathe, and may eventually lead to death. Cancerous masses such as these may also generate "metastatic" cells which can spread throughout the body and cause tumors in other organs/sites as well. Some lung cancer can be treated with radiation therapy, chemotherapy, or surgery, but when the tumor are very large and invasive (or have metastasized) there is little that can be done. This brings up one point about cancer diagnosis. Generally you want to find these kinds of tumors early on, when they are small, because they are generally easier to treat. But as you can see in this x-rays it is very hard to determine what small dots on the x-rays are, and is therefore hard to diagnose cancer in this way. This is why many researchers are trying to develop new

way to detect lung cancer/tumors when they have just begun to grow. This will help doctors diagnose cancer earlier and be able to cure more patients!

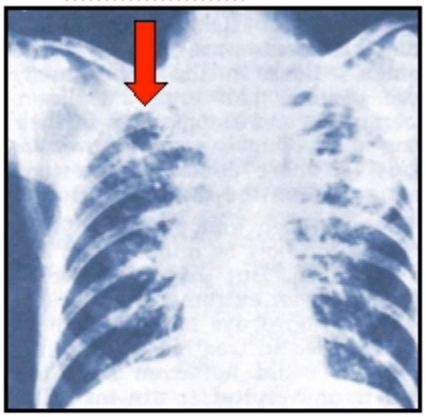




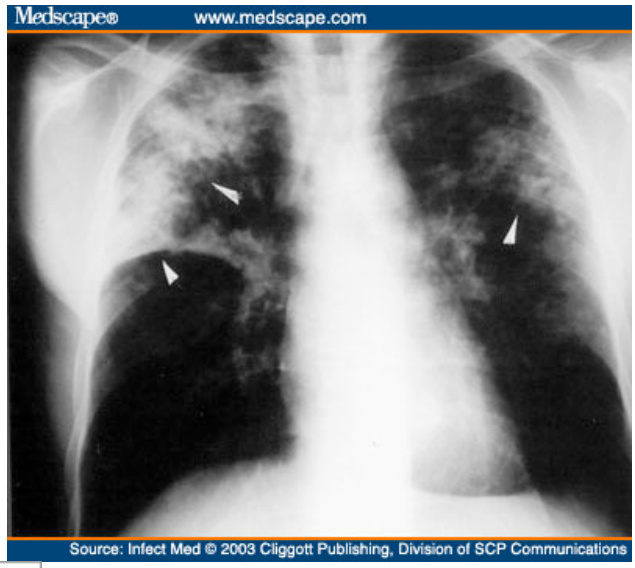


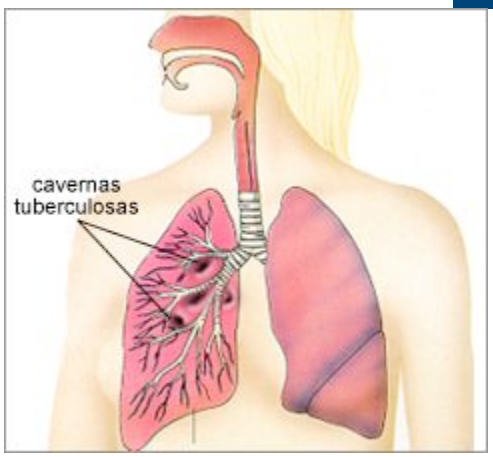
Bonus Example #4: [Tuberculosis]

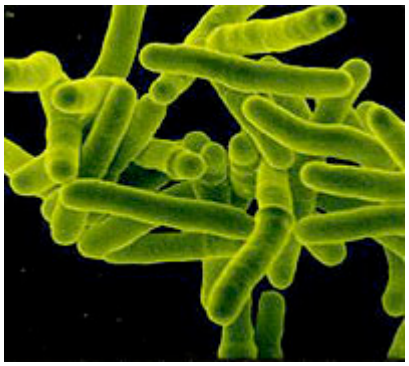
Cavitation

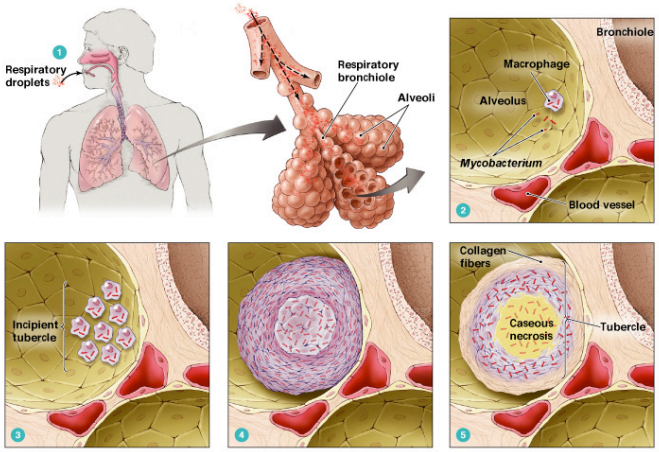


Pulmonary Tuberculosis with cavitary lesions visible on CXR









(a) Primary tuberculosis infection

E.) Auscultation of Lung/Breathing Sounds

Another way to determine what is going on in the lungs is to listen to the lungs with a stethoscope. Particularly, the sounds of air going into/out of different parts of the lungs can tell a doctor a lot about what is happening in the lung. A doctor will generally listen to 6 to 8 different parts of the lungs on both the front and the back of the patient in order to hear air moving in different parts of the lung. Also, a doctor may listen in more of the middle of the chest to hear the **bronchial sounds** (air moving through the larger diameter bronchi and trachea), these sounds are generally higher pitched and "tubular" (more "wooshing"), or may listen to the outer portions of the chest to hear the **vesicular sounds** (air moving through the smaller bronchioles/alveoli), these sounds are more like a "rustling" noise. Also, doctors may listen for special or abnormal sounds such as **crackles/rales** (indicating fluid in the lungs), or **wheezes** (indicating constricted bronchioles, generally associated with asthma).

[Listen to each other and try to determine the difference between bronchial/vesicular sounds.]

[Listen to examples of sounds on boom box, including that of crackles and wheezes.]