>> Steve Langjahr: November 7th. The day before the election. 2016. This is our second side, second lecture, devoted to the respiratory system. We said we'd arbitrarily divide the system into upper and lower segments. So you recall we took you through the upper respiratory system which includes the nasal cavity, the pharynx, the larynx, the trachea, and we left you off I believe at the branches of the trachea which you remember are called bronchi. So that's where we'll pick up the story. By definition, the lower portions of the respiratory system are confined to, that means found in, the thoracic cavity. And the essential anatomy here are the bronchioles, and the bronchial anatomy which begin, of course, where the trachea leaves off. So here's a schematic view of the lungs and the associated airways. So branching from the trachea, recall there are two, these are called main stem, also called primary bronchi. The one on the left is called the left primary bronchus. The one on the right, right primary bronchus. We did make a notation about the length. Which of these two is slightly longer? Actually, the left. And the reason for that is the left lung is more off center than the right lung. And what places the left lung off center is of course what? The heart. So the left primary bronchus is slightly longer, slightly smaller in diameter, as it turns out, than the right primary bronchus. Branching off of the primary bronchi are those that are called secondary. They're also known as lobar because there's one for each of the primary lobes associated with each lung. I think it's fairly common knowledge that you have how many lungs? Two. But actually you could argue that you have five. That is, you have, it turns out, three on the left, and two on the right. By that I mean lobes. Each of these lobes is served by their own airway, by their own pulmonary, and – pulmonary artery and vein. And so, with that said, can you live with one lung? Yes. Can you live with just the lobe of one lung? The answer is yes too. So that might not be perfectly clear now, but actually you have five lobes, and we'll get to that fact again in a moment. Secondary bronchi give rise to tertiary bronchi. The word tertiary means third or three. And these are obviously smaller and more numerous than the primary bronchi. And their numbers are variable so we won't give you a particular number for them. They are, however, pretty much constructed the same as the more proximal airways. And let's remember. What is the predominant histology which we find throughout the upper respiratory system? Simple, ciliated, columnar, epithelium, which was also punctuated with cells called goblet cells. Remember goblet cells making the mucus? And it turns out that mucus and cilia are working cooperatively not just to trap debris, but to move that debris back up so that it can be swallowed or spat out or whatever. So the tertiary bronchi are also made of what? Ciliated, columnar epithelium. In other words, a mucus membrane. And as we move in to the tertiary bronchi, the cartilage which was so dominant and so visible in the trachea and the earlier airways becomes more sparse. So there are fewer and fewer cartilaginous discs at this location. We use the word disc because they are just little pieces of cartilage as opposed to being C shaped or otherwise more ring-like. So in short the cartilage is getting less and less prominent as we move in to these tinier airways. Replacing the cartilage, and serving a similar function, is smooth muscle which appears for the first time in

the tertiary bronchi. And, after all, what's smooth muscle capable of? What is smooth muscle expected to do? Contract. And so the tertiary bronchi are the first airways which have the ability to contract or relax. Therefore changing or affecting the flow of air beyond this point. How are they able to do that? Because they have what? Smooth muscle. The earlier airways are pretty much devoid of smooth muscle. Once we get past the tertiary bronchi, we're now in airways that are very tiny. And so we don't use the word bronchus or even bronchi. Instead the word is bronchioles. And that's not entirely a new word because what was the word we gave to tiny arteries? Arterioles. So these are not bronchi. These are bronchioles. Smaller in diameter, naturally, than the terminal bronchi are. And, not surprisingly, the cartilage is pretty much replaced at this point. That is there's no hyaline cartilage at all. It's entirely replaced by smooth muscle. This fact is not entirely brand new to you because I bet you're aware of the most common respiratory ailment that's related to anatomical issues. Starts with an A. Asthma. And asthmatics have issues with their bronchioles. That is they tend to be at times what? Constricted. And that minimizes or interferes with air movement. So it's the contraction of this bronchial smooth muscle which brings about an asthmatic attack, an acute asthmatic attack. And speaking a little bit in the physiological realm, how do asthmatics deal with that, that crisis, that asthmatic episode? Don't they inhale a little vapor and perhaps you know that's epinephrine vapor which has the ability to do what to that smooth muscle? It relaxes and dilates these airways. You bet. Those are called rescue inhalers because basically they allow relaxation of this bronchial smooth muscle. Also at this location the cilia are pretty much eliminated as well. And so the simple ciliated columnar epithelium is replaced by just simple cuboidal epithelium. And that might seem odd or may be a bit surprising. What was the function of the cilia? What was the function of the goblet cells? Goblet cells made mucus. The cilia move that material along. It turns out these airways are so tiny that mucus would be, well, more harm than good because the mucus would tend to clog up these airways. So thankfully there is no mucus at this level. Instead the epithelium is simple cuboidal epithelium. After the terminal bronchioles, we come in to what are called respiratory bronchioles. These are very tiny in diameter, less than a millimeter, only 0.4 millimeters in diameter. And if that's hard to visualize, imagine an ordinary pin, P-I-N, a pin. A pin is a millimeter. So this is what? This is only 4/10 of a millimeter. So a very tiny airway indeed. And they're made of? Simple cuboidal epithelium. How many cells thick, then? One. And these are the airways which convey air to, that is in and out of, the final – the final recipients of environmental air. Namely the alveoli. The word alveoli, is that plural or singular? Plural. What would the singular version be? Alveolus. And Alveolus is only 0.25 millimeters in diameter, but more interesting than that is their wall thickness. Alveoli are made of not cuboidal, but what? Simple squamous epithelium. The wall thickness here – You don't need to memorize this, but it's incredible. The wall thickness is only half of a micron. Now a micron is a millionth of a meter, but even that doesn't really get the point across. So here's an interesting fact. If you take a piece of salami – You with me? And you cut a half inch slice. You got that? And then you make 2,000 slices out of that. That's the thickness of a what? An alveolus. My point is these are thin. Right? To say they're paper thin is a huge exaggeration because paper's not that thin. Alveoli are thin for what reason? What is the alleged, maybe obvious function, of an alveolus? What's going on here is? Gas exchange. Getting oxygen. Getting rid of carbon dioxide. So these containers, these air sacs, are thin by virtue of being only one cell thick. And a simple squamous cell at that. So naturally these alveoli are surrounded by the capillaries of the pulmonary system, and with that said, what are capillaries made of? Blood capillaries also are made of simple squamous epithelium. So if you're an oxygen molecule, how many cells do you have to go through as you leave the alveoli and enter the blood itself? Just two. And so it's a very short journey, a very simple process of gas exchange. And not only gasses such as oxygen and carbon dioxide, but also nutrients are exchanged. I mean doesn't the blood contain glucose and other nutrients that actually provide support that is metabolic support for the alveoli themselves? And the answer is yes. So here, as you can see, is an anatomy – an anatomical drawing of the bronchial tree which starts out with the primary bronchi which become then secondary, which then become tertiary. Notice that the cartilaginous pieces are becoming more fragmented, more disc-like. And then as we branch from tertiary we get in to the terminal bronchioles. The word terminal means at the end or almost at the end. And off of those are the tinier so-called what? Respiratory bronchioles which then are like stems of a grape or a cluster of grades because the alveoli represent little grape-like clusters. That is, tiny air sacs, air sacs that are only 0.25 millimeters in diameter. And, as a matter of anatomical fact, you have about 150 million alveoli in each of the two lungs. And so you have plenty of alveoli. More than enough to get the job done. And didn't we already say that? Can you live with one lung? Yeah. You can. So this surface area that we're speaking of is more than enough. It's overkill, really. But certainly important in periods of exertion. That is, exercise and so forth. Here's an actual histological photograph of lung tissue, and so BR probably an abbreviation for bronchi, whether they're tertiary or otherwise, we don't know. PA stands for? Pulmonary artery which incidentally is blue here for good reason. What kind of blood do you find in pulmonary arteries or arterioles? Deoxygenated. PV stands for pulmonary veins. By now the blood has been oxygenated. But right down here at the tiniest levels are these air sacs which aren't necessarily identified there, but here in a higher magnification we can see them. AL. That stands for? Alveoli. 150 million of those. Here's a colorized view of a few alveoli. The histology is what? What are the cells that make up a single alveolus? Simple squamous – Simple squamous epithelium. This is an interesting photo. It seems to be the same as the one that was just up there, but actually this is not the alveolus. This is the capillary network around the alveolus. And so this picture sort of combines those two ideas. This is a single alveolus. How many do you have in each of your two lungs? 150 what? Million. And these are made of what cells? What cells make up each and every alveolus? Simple squamous epithelium. Up here is CA. CA stands for? Capillary. And what's this cell which you can see, and is labeled here for you as ER? That must be a? Erythrocyte. So if this point of light represents oxygen, how many cells does this oxygen molecule have to cross as it leaves the alveolus and finds its way in to the capillary? Just two. A simple squamous epithelial cell of the alveolus. And then another simple squamous epithelial cell of the capillary. What are these cells down here? They're labeled AP. That stands for alveolar phagocytes. These are also known affectionately as dust cells because that's their diet. They consume what? Dust. Does dust make it down here? Yeah. It does, because every breath that you take contains particles that are otherwise known as dust. Some people have this interesting habit. They take leaves and they put in cylinders of paper. Then they set that on fire, and then they take a huge drag of that. I'm not quite – I don't understand that, but does that bring a lot of pollutants down to this level? And does that do damage, recognizable damage, over time? Yeah. And so a lot of people say, "Well, you know, I've been smoking all my life. It doesn't do me any good to quit now." Does it? The answer is yes, it does. Because what cells do you have here? Alveolar what? And will they clean up your lungs, given time? Yeah. Given three or four years, your lungs will be pink again instead of black again. Now don't get me wrong. It doesn't mean that damage hasn't been done. But is there good reason, always a good reason, to stop smoking regardless of how long you've been doing that? Of course. Thanks to what? Thanks to what cells down here? The alveolar phagocytes. These are lungs photographed in gross anatomy. And we've already mentioned, and described, basic pulmonary anatomy. So, with that said, we see there are two lobes here, and on this side we see one, two, three. So what's what? The lungs, as you know, are protected and surrounded by the pleura. The right lung has three major lobes. What are we going to call these? Let's call this the superior lobe. Let's call this one down here the inferior lobe. And let's call this one the middle. And over on the left side let's call this the superior lobe, and let's call this the inferior lobe. So that goes to what I said earlier. You could say you have two lungs, but you could also argue you have how many? Five. Two on the left. Three on the right. These have their own blood supply. They have their own air supply. And so surgically, can a surgeon remove let's say the right superior lobe, and not interfere with any of the other lobes whatsoever? The answer is yes. And why might that be necessary? Well, certainly tumors or other issues might demand that that be done as a surgical procedure. This is the natural appearance of lungs in an adult, although they can vary quite a bit in color. This I hope is the color of your lungs. This is the color of a city dweller in say, I don't know, Beijing, China or something. And here is a smoker. Okay. We're getting there. And here's a smoker coal miner combination which is the worst case scenario. I don't get this. These people spend all their day underground inhaling coal dust, and then they come out after a shift and light up a cigarette, adding insult to injury. But yeah. This is not an exaggeration. That's the way lungs actually look in that situation. Left lung, then, has two major lobes. Right lung has three. And in case you aren't connecting, what are the lungs actually made of? Well, here's a pair of lungs from a pig. And I'm going to pass it around, and they're a little bit shop worn. But this is not plastic, although many people when they handle it they think, “Oh. Well, this is Styrofoam.” Well, no. It’s not Styrofoam. These are actual lungs from a pig that have been ripped out of them after they’ve been killed for other reasons, and then they’ve just been hung on a clothesline to dry. And so these are actual lungs. If you were to hold on to these and jump in to a pool, what would happen? You would float. Because what is most of this? Most of this is air. Air sacs called what? Alveoli. So we cut out a piece there just to have you see the internal anatomy. And over here on this document camera we’ll switch to that image now. We have an interesting comparison. We have lung tissue right next to bread. Yep. This is bread. This is lung tissue. And you might say, “Well, they’re not related.” Well, of course they’re not. But what is bread? It’s very porous, and what makes it so is the yeast. You know about making bread and how it rises due to the gasses produced by yeast. So what is most bread? It’s not actually carbohydrate. Most of bread is air. I guess I’m trying to make that point. So I brought in a loaf of bread. Got this fresh today. It’s Sara Lee. And why is it so light? Well, because most of this is what? Air. So I love doing this. So I’m going to sacrifice this loaf of bread. You see how natural and wonderful it is? So okay. Now most of what was there was what? Air. All right. So point being most of what we have in lung is not tissue. Most of what makes the lungs the size they are is the air. And this might have occurred to you because you might recall the rat work. Remember when you dissected the rat? And you opened up the thoracic cavity. You found the heart right away, but the lungs were kind of pathetic because they were all deflated. And you might have taken that little air bulb and you might have inflated them back, and you were impressed about how big they really are once they’re filled with what? Once they’re filled with air. So the anatomy of the lungs, interesting, but most of the volume of lung is actually just air. So let’s go on to the next issue which has to do with how air actually moves or otherwise enters and leaves the lungs, which is strictly a function of the chest. And not really a function of the lungs themselves. Breathing mechanics. Two phases, of course. The inhalation is called inspiration. And the opposite is? Expiration. Here’s a profile or side view of the rib cage. And before we get further, we need to see that below here, marked with two labels, are the relative positions of what muscle? What muscle seals and defines the lower boundary of the thorax? Diaphragm. And, incidentally, what kind of muscle is the diaphragm? Is it skeletal, cardiac or smooth? Skeletal. So that muscle assumes or can essentially be seen in two profiles or locations. This is the relaxed position. This is the contracted. So relaxed. Contracted. In short, when it contracts, the muscle flattens out. When it relaxes, it becomes concave like that from the underside. Inspiration then involves or at least begins with the contraction, the lowering of the diaphragm. And what nerve does that? What nerve stimulates the diaphragm, after all? Phrenic nerve. And so the result is that the diaphragm moves from this position which is labeled relaxed to this position which is the contracted position. It’s as if this floor were to drop five feet. What would that do to the volume of this room if the floor were to fall five feet down? The volume would be increased. So the contraction of the diaphragm brings about expansion of the chest which then lowers the air pressure in the chest, and that then causes the lungs to inflate, thereby lowering their pressure. Thereby bringing air in. That is, air moving from a high pressure outside to a low pressure inside. There are muscles that are involved in a supportive or synergistic role. Not with the kind of breathing you're doing now. The breathing you're doing now is almost entirely the result of what muscle? Diaphragm. But can you inhale more than you're doing right now? Let's all do it. Take a deep breath. And you'll notice your shoulders going up. And you'll notice the sternocleidomastoids are getting real tight. Right? What's the point? The muscles that raise your clavicle, including the sternocleidomastoid, help to further expand, that is further enlarge, the thorax. Therefore further lower air pressure in the chest. And so synergistic muscles to the diaphragm include the sternocleidomastoid, even the clavotrapezius, but also these that are new to you, the external intercostals. Intercostals are the muscles that are found between the ribs. Hence the name intercostal. Costal means ribbed. And these are sloped or angled diagonally so that the net effect of these is to raise the ribs. And when the ribs are raised, you can feel that when you inhale. That further expands the chest. Notice the diaphragm contracts, but notice the sternum seen here protruding out, and that's especially true when the intercostals, which ones, external intercostals, contract. Your book, and certainly YouTube, can show you all sorts of animations. Here from the side is the diaphragm. This is in the relaxed position. Excuse me. This is the relaxed position. This is the contracted position. In other words, when the muscle contracts, it flattens, and moves downward. This enlarges the chest. That air pressure drop causes the lungs to expand. And, as a result, air moves in. I know this is physiology, but I want to make it clear because there's a common misconception that air goes in to the lungs and they expand. That's false. What happens first? The lungs expand as the diaphragm contracts, and then air is drawn in. So air doesn't move in to fill the lungs. The lungs expand, and air moves in as it always does from a high pressure outside to a low pressure inside. That can be dramatized, illustrated, with a simple model that you'll have a chance to play with in lab. Clearly those balloons must represent what? Lung. And this down here represents the? And here's the? Chest wall, which is air tight. So here's the diaphragm in the relaxed position. And the lungs are relatively empty. But when the diaphragm contracts, which way does it go? And what does that do to the air pressure in the chest? Lowers it. What happens to the lungs? They? Get big. And thus they suck air, and then the opposite occurs when the diaphragm relaxes. So the lungs are operated not by any muscles on themselves, but rather the movement of this muscle. What is it? Clearly the diaphragm does most of the work, then, in normal breathing. And to repeat, what's the nerve that makes that action possible? Phrenic nerve. Good. So of course at times we inhale things that find their way in to the trachea. And you're aware of this procedure. You know it by name. Where someone comes up from behind and takes – and brings their hands together and creates a concentrated area where they what? They push in and what? Up. The name of that method? The name of that procedure? Heimlich maneuver. Which is designed to push the diaphragm even higher, which raises pressure and hopefully blows out whatever might be obstructing the upper airways. Looks like a set of ribs, right? And so these muscles that you can see running diagonally on the outside from rib to rib, those must be the external intercostals. Deep to those, and running in opposite or perpendicular orientation, are the internal intercostals which are involved not with inspiration, but as we'll see, they're involved with expiration. Expiration, though, basically is the reverse of inspiration. So the diaphragm doesn't contract. It simply what? Relaxes. That tends to shrink or reduce the volume of the chest. That raises intrathoracic pressure which causes the lungs to collapse a bit. Not entirely. And that smaller volume of lung will raise the pressure therein. That pushes air out. And the sum total of that is simply called expiration. Are there muscles that can assist this at times? Right now you're using just the what? Just the diaphragm. But can you exhale more than that if you had to? What if there was a birthday candle there you had to blow out? You would find yourself bending over and squeezing. And the muscles you're using are synergistic for forceful expiration. These include the internal intercostals. And, surprisingly, the abdominal muscles which you would think have nothing to do with breathing, but the abdominal muscles when they contract compress the abdomen, and therefore they force the liver which way? If we have abdominal muscles contracting, the only way the liver can go is up. And when the liver goes up, what muscle gets higher up in to the chest as a result? Diaphragm. So, believe it or not, it's the abdominal muscles that can actually assist not in inhalation, but assist in what? Exhalation, also known as expiration. And these are involved not in routine breathing, but in forceful exhalation that you might do from time to time. All right. So there's a guy enjoying some burning leaves. Okay. We'll move on. Speaking of respiratory disorders, that's where we have arrived now. Because certainly this system is constantly assaulted. Assaulted by voluntary or involuntary lifestyles. And so let's talk about some of the afflictions that can affect this system. And all of them, and I do mean all of them, will produce this symptom which is called what? Hypoxia. Literally two words put together, hypo oxia means just that. Low oxygen. And so hypoxia is the consequence, the impact, that any and all respiratory disorders have because they compromise gas exchange, and therefore lead to lower levels of oxygen in the blood and/or the tissues. So for no good reason we divided these disorders into three groups that you see on your page. The first group are those things that impair or affect the alveoli. The lungs themselves. And in this category we have a recognizable champion of death, namely what? Pneumonia. Pneumonia is an infection, of course, which doesn't occur overnight. It's usually a progressive worsening of upper respiratory infections. So, with that said, how do respiratory infections start? What is the location which is impacted first? The nose. Then it goes to the? Pharynx. Then it goes to the larynx. Then it goes to the trachea. Then it goes in to the bronchi. Do all of these have corresponding names? Yeah. Rhinitis. Pharyngitis. Laryngitis. Bronchitis. Do these progress in that order? A nasal infection becomes a throat infection which becomes a laryngeal infection which becomes a bronchiole infection. Eventually, finally, if it's not arrested or corrected, you're going to end up with pneumonia. Which is an infection of the alveoli. And there we have a problem because the infection creates a lot of WBC infiltration. What's that? Which causes a lot of fluid to accumulate. And now your alveoli which are supposed to contain what – Alveoli are supposed to contain A-I-R. Right? Now they contain something other than air. And is this going to enhance air or gas exchange or interfere with it? So pneumonia interferes with gas exchange because fluid is blocking the path and making the movement of these gasses more difficult. In effect, you've heard it said that people who have pneumonia are drowning in their own secretions because it is like drowning. And, in fact, drowning is the same thing, at least in one way. Because when you drown, what have you inhaled? And now water is in the alveoli instead of air. So pneumonia and drowning have something in common, although pneumonia is an infection. Drowning, of course, is a tragic accident. Apart from pneumonia, which incidentally can be treated, you know, by what? How do we treat any respiratory infection? Antibiotics. But the second condition here is called emphysema which is not an infection per se because it's not caused by a microbe as such. Emphysema is described and defined as consolidation of alveoli with lost elasticity of the alveoli. In other words, the alveoli are not as capable of expanding and contracting. They lost what? So this makes it harder for air to come in. It makes it equally hard for air to go out. And, as if that weren't bad enough, the alveoli are consolidated. What's that mean, to consolidate? To consolidate a business would be you have two businesses and you what? You consolidate them in to one. So very simply this is how alveoli might look. How many alveoli? One. Two. Three. Four. Once that happens, once consolidation occurs, you now have one big what? And you might say, "What difference does it make? Four small ones. One big one. Well, it makes a big difference. Which has more surface area? So the loss of surface area leads to this H word. What is the symptom? The symptom that eventually occurs is hypoxia. How do you get emphysema? Do this a lot, and you'll get it sooner. Will we all have emphysema to one degree sooner or later? The answer is yes. It's age related, but it's also aggravated by cigarette smoking. And so what is the cause of death? There it is right there. Hypoxia. What do people with emphysema resort to? There is no cure. There's no way to reverse or treat emphysema, but how are they able to survive at all? Oxygen. You've seen people with green tanks, you know, going around Disneyland or whatever, and they have a nasal cannula, and they are of course inhaling what? Oxygen. Emphysema is a killer, but it's a slow and rather insidious condition, one that gets worse, worse, worse with time. And what is the cause or at least the aggravating factor is smoking. Most people fear or at least associate smoking mostly with what? It's the C word. I must have – Somebody said it. Right? Cancer. Yeah. But yet much more prevalent in smokers is not cancer, but the E word here. What? Emphysema. And you say,"Well, at least they're alive." It's a pretty miserable life, I'll tell you that. And certainly nothing you'd want to deliberately opt for. Next, tuberculosis which perhaps you don't hear much about. Although you're all tested for, even inoculated against, tuberculosis. It's a bacterial infection. It used to cause massive numbers of deaths in the earlier part of the twentieth century. Today, not so much because we have effective what? We have effective inoculations against it. And we also have of course antibiotics to treat it. But by definition it's another bacterial infection that causes fibrosis, that is thickening of alveoli, and therefore reducing what process? What process occurs across alveoli? Gas exchange and diffusion. Still, in this category we have what's called RDS, respiratory distress syndrome. You're going to see in lab an interesting video. This condition is a condition of premature infants, of premature infants. What system do you think is one of the last systems for a fetus to develop or bring to maturity? The respiratory system. So a baby who's born premature has an okay circulatory system, an okay nervous system, an okay digestive system, but not an okay what? And therefore they simply can't exchange gas. So they're going to be suffering from hypoxia. The reason for this is they have a low level of a compound in the alveoli called surfactant which lines the alveoli and prevents the alveoli from collapsing with each breath. And this makes taking a new breath very difficult, especially for a premature infant who has a very weak chest wall, a very floppy rib cage. And therefore they just can't move air, and if they can't move air, then obviously they're going to suffer from hypoxia. Today we treat this because there are artificial surfactants that you can give to these infants which prevent the collapse of their lungs, and therefore maintain them for a longer period of time so that they can survive and grow. That is their respiratory system can mature to the point that it will function. Second category impairment of other respiratory structures. Other than what? What have we been dealing with up to now? Alveoli. Are there other respiratory structures that can be involved in respiratory distress? The answer is yes. And one we mentioned earlier is asthma which is not so much a problem with the alveoli. It's due to constriction of the airways. Which airways? Not the bronchi. Not the trachea. But the bronchioles. The ones with smooth muscle. This makes it hard to get air in, hard to get air out, and therefore culminates in? Hypoxia. How do you treat this? Well, it is fundamentally an allergic reaction. So in some sense there's no way to treat that directly, although there are agents which are anti-inflammatory such as antihistamines, and many other products on the market which block the inflammatory response. But at least in the short term what's needed is a way to dilate these airways. And what is the smooth – Oh. There I gave it away. What is the muscle which has to be dilated? Smooth muscle. Then there's a condition called pleuritis which is also known as pleurisy. This has nothing to do with the lungs directly, but remember the lungs are surrounded by that cirrus membrane called a pleural sac. If that becomes enflamed, then it becomes dry and sticky, and therefore the whole function of the pleura is lost. What is the function of any cirrus membrane? To reduce friction. So inflammation and infection of the pleura essentially destroys that function. As a result, it's very painful to breathe. And when it's painful to breathe, guess what? You're not going to be breathing as well or as completely as you normally do. So this also leads to the H word. What's the H word? Hypoxia. Next a condition called pneumothorax which can be caused by trauma or by rupture of the lungs internally. The word pneumothorax literally means air within the chest. So here's our model again. What's this? That's the thoracic space. Down here's the diaphragm. What if a hole is created in the chest wall?

What would cause such a hole? Well, a gunshot wound would do it. A knife wound would do it. And so now air is free to do what? Free to do this. Go in and out of that hole. The diaphragm will still work, and air pressure will change, but air won't go through the airways. It will take the easier route. It will go in and out of what? Does ventilating your chest amount to much? Is that what we want to do? No. We want to get air in and out of the lungs. Will air move in and out of the chest? You bet it will. Does that do you any good? No. The lungs in the meantime are collapsed, and therefore they're not moving any air. Therefore what condition develops rather quickly? Hypoxia. In other words, a pneumothorax will cause bilateral or unilateral collapse of the lungs. And this is often the cause of death, never mind bleeding, but the cause of death in a gunshot wound to the chest or anything that violates that space. Then the third category to round it off are those things that actually impair pulmonary circulation. In other words, these are things that don't involve the respiratory system at all, but yet impact it. And the biggest culprit here is a condition called pulmonary edema which is actually the result of a failed or weak – What is it here? Weak left ventricle. So you have to follow me here. The left ventricle is weak. Got that? So it's not pumping blood out. But, after all, where does the left ventricle get its blood? From the left atrium. So if the left ventricle is weak, it's not putting blood out, and therefore it's still filled with what? That makes it hard for blood to move from the left atrium to the left ventricle. And now blood coming back from the lungs can't come back to the lungs. I should say blood coming back from the lungs can't reach the heart because the heart is already filled with what? So the pressure builds up, and backs up to the capillary level, and now the blood capillaries, the pulmonary capillaries, start to leak fluid. And that fluid fills what spaces? What are the air spaces that are ultimately now going to fill up with water? That's the alveoli. What's that called when the alveoli fill up with water? It's called pulmonary edema. Does that interfere with gas exchange? Yes. Is that the fault of the lungs? No. What's at fault here is actually the heart. This is also known as CHF. Some of you know that stands for congestive heart failure. And the heart side which is involved is the left ventricle. So with the left ventricle weakening, blood can't move from the left ventricle. Therefore blood can't move from the atria. Therefore pulmonary circulation is stagnated, fluid builds up in the lungs, and that leads to poor gas exchange. What's the net effect? Net effect is the H word there. It's what? Hypoxia. So all of these can lead to low tissue oxygen, some as a result of failures of the circulatory system, some involving changes to the lungs themselves, or the associated structures, muscles, diaphragm, and so forth. Have a good afternoon. We have some bread up here if anybody's hungry.