Human Physiology
Prof. Nishikant Subedar
IISER-Pune

Lecture – 36
Physiology and Introduction of Respiration - Part 2

Just to illustrate a point that there is negative pressure outside. How do you prove it? The answer to that question - author tells us is that as long as our glottis is open - it closes, it closes only when we eat. Otherwise we are just breathing normally. At that time the air pressure in even in the alveoli is almost same as that of the outside. Means - you are sitting and suddenly you decide that for 10 seconds I am not going to breathe ok.

At that moment the air pressure in the alveolus and the air pressure outside is same ok. And let us call it 0. What atmosphere let us forget about the atmosphere pressure outside inside so it is 0. Are you ok so far? Alright.

Now the pressures we are talking about are generally so low that I will not use the mercury manometer because mercury has a lot of inertia. I will use a water manometer. Are you ok so far? Hello. I can use a water why cannot I use water manometer? So if you introduce a water manometer which goes right into the bronchi ok and then you fill in water and this is open to the atmosphere. Do you find any difference in the water level in the right and left arm? No.

No what does it mean? Same. That the pressure in the bronchi and pressure outside is same, therefore we call it at 0 ok. Now what we will do is you will now use another manometer - water manometer and this manometer is introduced not in the bronchi but in the pleural space. Pleural space means what? In the space that is in the thoracic cavity but outside the lungs. We will call it as what? Plural cavity.

And there you what do you find? There you find that the this the water in this arm has gone up as compared to that which means what? There is a lower pressure in the thoracic cavity. Are you with me? And that lower pressure is about as compared to outside ok is about in terms of water column ok it is about minus 6 minus 7 minus 5 or 6 minus 7 centimeters of water centimetres of what? Centimetres of water. Centimetres of water right. What will happen if the pressure ok let us presume it is let us presume this is this is 7 centimetres of water. What will happen if by mistake it drops to from minus 7 minus 6 minus 5 minus 4? If it drops to minus 4 and below lungs will simply collapse.

Lungs will simply collapse which means for the lungs to remain open you have to continuously make sure that the outside pressure is negative. Hello are you with me? It has to be negative you have to make sure that the lungs are pulled from outside by applying the negative pressure. So that the air can so that the lungs will open otherwise the alveoli which is like this will just collapse ok. So let us look at the image on the previous slide and I am going to couple it with this image. We are trying to look at the volume change in the your in your lungs ok.

And we find that every time we take in the air which is you have just started taking in the air and then you take in the air and fill up your lungs. And now your lungs are full and in regular normal breathing. Look at the graph and tell me how many ml of air you have taken in? Half litre - 500 ml how much is it? 500 ml. It is 500 ml. So, under normal breathing under resting conditions for an individual 70 kg ok how much air is being taken in and taken out and taken in how much? 500 ml. 500 ml ok.

We just take an average about 500 ml is good enough ok. Now how why this is 500 ml is a question and for doing that we have this image which we call as we try to find out what is trans pulmonary pressure. What is this trans-pulmonary pressure? Let us see - to begin with let us see what is this alveolar pressure. Alveolar pressure is the pressure of air pressure when we stop breathing it is almost same as outside. But when you start breathing in - for the air to pass in there must be negative pressure generated in the alveoli ok.

And that negative pressure that is being generated is from - if this is 0 it goes to about 1 it goes to about what? 1 centimetre. It is about what? 1 centimetre of what - water column? Water column. 1 centimetre of water column.

So when the pressure air pressure in the alveoli goes from 0 to minus 1 my both the lungs put together are capable of inspiring how much of air? Remember this equation ok. How much? 500 ml. So it has and when I when I expire when I expire it goes from it from 0 it goes to plus 1 when it goes to plus 1 then the positive pressure is generated in the alveoli and then I am able to expel how much of air? 500 ml. 500 ml so 500 ml so minus 1 take in 500 ml plus 1 give out 500 ml under normal under normal breathing circumstances.

Now when alveolar pressure - I mean they are they are not muscular organ ok. So they depend on what? They depend on the pressure generated by the diaphragm and generated by your thoracic cavity and your sternum. You see that is your main respiratory apparatus, ok. Where does the power come from? The power comes from diaphragm. So now we are measuring if we if we keep on measuring this pressure we find that to begin with it is about 5 here, about minus 5. Now your information has come from phrenic nerve - as a result of that the diaphragm has started contracting as a result of that the negative pressure is being generated in the thoracic cavity and as a result of that the negative pressure goes almost to 7.

Where does it go? 7.5. So, from 5 we have gone where? Minus 7.5. Where in the thoracic in the in the outside the lungs talking of outside the lungs ok.

That translates into this because outside it goes from 5 to 7.5 therefore, in the alveoli it is it goes from 0 to minus 1 are you ok so far? And that translates into inspiration of how much volume of air? 500. Translates to 500 and then exactly opposite happens - and then because this happens, ok. And we will call this difference as the trans pulmonary pressure from here to here we will call it as what? Transpulmonary. And the transpulmonary pressure is in a continuous rhythm ok and it is it is because of the trans pulmonary pressure that we are able to take in air and then when it decreases we are able to expel the air from our respiratory system.

Now let us let us forget about the lungs and instead of lungs I am going to take a balloon. Are you with me? I am going to take what - a balloon, but I am going to subject it to this phenomenon. For all practical purposes let us presume that it is very much like lungs which means what? When the outside pressure goes from here to here - there is a balloon where do I put it? I put it in a bottle and then seal it at the top, but it is connected by a tube ok. So the air can enter only by a tube and in the bottle I can reduce the pressure ok and if I reduce the pressure by so much, are you with me? This is outside pressure - outside the balloon are you done? And this is inside the alveoli inside the balloon and when the inside balloon pressure goes from 0 to minus 1 then in my balloon how much of air should enter? 500 ml. 500 ml are you with me? Are you with me? 500 ml are you done everybody so far? Now what I will do is now I will remove that balloon - listen to this I remove that balloon- and replace it with another balloon, but this balloon has thicker walls hello what did I do? What did I do? Replace it with what? Thicker walled baloon. Thicker wall and I repeat the experiment what response will I get? Will I get 500 ml so far? I will not get it will depend on the thickness of the balloon - if it is slightly thick I will get 400 ml, if it is thicker 300 ml if it is it depend on thickness. So, what am I talking about there is a direct correlation between how much of fall in pressure is there and depending on that how much air is getting into your into your lungs. And that depends on what? That depends on the elasticity of the lungs, which I can translate into the thickness of the wall of the balloon are you ok so far? This phenomenon we will call as the compliance of the lungs what do you call it as? Compliance of the lungs.

Compliance of the lungs. So - you are a smoker or you have had a lung disease and as a result of that the tissue becomes fibrosed - the tissue responds whenever the tissue responds it becomes fibrous - it loses elasticity and as a result your lungs are not as compliant which means what? The pressure change is there but in response to that pressure change you are not getting 500 ml of air, are you with me? Everybody ok. So, the whole apparatus is so designed that if I apply so much pressure, so much air should come in but if your apparatus is not efficient enough, it is not compliant enough, then you would not be able to get so much of what? So much of air and then then everything consequential to that will follow, ok. So, has everybody understood the phenomena of compliance? Remember we also talked about compliance when? When. When. Very good very good very good.

So, we are actually talking about compliance because this gives you - this is a normal lung ok. and this is the lung of a patient. You know what happens when the lungs are infected, badly infected, the alveolar walls collapse, ok. So, as if 4 alveoli put together and as a result of a disease, the alveolar wall has collapsed and now 4 alveoli have more or less joined into one. So, total surface area is reduced or increased? Reduced. Reduced which means efficiency of your lungs has gone down.

A low lung compliance would mean that the lungs would need a greater than average change in the intrapleural pressure to change the volume of the lungs. We just want to find out how much we talked about - 500 ml ok, but when you are normally breathing ok, you stop breathing ok or you exhale air and stop breathing is your system free from air? No some residual volume is already there, ok. So, just to give you a rough idea as to what are the different volumes which are there in your respiratory system - this is a very simple instrument which we call as spirometer. What do you call it call it as? Spirometer. Spirometer has a mouthpiece you put it your mouth and keep on breathing gently and then it is connected - there is a cylinder - there is a big cylinder - there is a water - there is another inverted cylinder - the inverted cylinder will have inertia of its own. You counter it with the help of this weight here. So, this cylinder has no weight because you have countered it. Are you with me? And then you blow in and blow out and then you connect it to a kymograph.

So, that you are recording. So, it goes up, it goes up goes down - in breathing in and breathing out. Now we will do this recording and we come across some very interesting observations. If you are weighing 70 kg ok you are taking 500 ml in and out to begin with - you are here. What do you mean by you are here? There is already about 2300 ml of air in your system. how much is there? 2300 ml. It is there when you are breathing normally you are going from 2300 to 2800. Are you with me 500, 2300 to 2800 and 2800, 2300, 2800, 2300. Are you with me? We will call this as tidal breathing. This is a tide like - comes and goes come with every 500 ml air right. So, we will call this as what tidal volume what do you call it as? Tidal volume.

Now what I will do is I will ask you to use extra strength, ok. And try to take in as much air as you can deep breathe, deepest possible breathe. In that particular case you will find that you are going from 2300 you are almost going to almost 5500, 5600 ml deep breathe you have taken ok. What do we call it as? We call it as the inspiratory reserve volume we will call it this. Now I will do opposite. I will ask you to blow out as much as air you can and then you will go here.But even if you go deep here your system still has about how much of air? 1200 ml of air. So, 1200 ml of air is always going to be there and you cannot get rid of it. It is always going to be there, ok. After exhaling maximum amount and depending on that we have different words inspiratory capacity, vital capacity you can read about but this gives you a general ideas to what limits are. Now we are going to this interesting - just look at this.

Now we are ready to take the first breath are you with me? We will call it as breath number 1 or breath number 0, whatever. Now whatever air you have taken - normal breathing normal breathing when you say normal breathing, ok you have taken in air. So, what is the volume of air that is in your system now? 2800 ml. 2800 ml you have taken in ok 2800 ml. Now what I will do is - every molecule of air nitrogen oxygen whatever - I am going to put a red dot on it in imagination I can do that red dot that is all. That is all I have done I am not going to put anymore.

Now you breathe out and you breathe in - now this is second breath. Now if that was the first this is the second one and I try to look at it as to how many of those red dotted molecules are still there are they there? First breath are they there and then look at the second breath are they there? Some of them are there, ok. Those of which were taken in that first one and then go to the third and go to the fourth and go to the eighth and go to the twelfth and go to the sixteenth. What is the message author is trying to give us here? That we do not replace all the molecules. You may have to take 20 25 breaths for all of them to to go, ok. Can anybody guess as to what might be the nature's purpose or rationale in giving this kind of a system when actually we want fresh air, ok. But this is not fresh air, ok. You know the stale air is going to remain in your system for quite some time. And are you replacing that? Yes. You are but you are very gradually replacing the air, ok. I will give you the reasons. One of the reasons is that the lung want that every molecule of air that is in every alveolus should have exactly the body temperature as your. If you were to replace - supposing you have 100 molecules being replaced by fresh 100 molecules that have the temperature of 30 degree Celsius - where as a temperature in your alveoli is 37 degrees, are you with me? No no you cannot subject the cell type one of your alveolus to that. You want to make sure that humidity stays, ok. Because if humidity does not stay then the dry air will dry out and evaporate the water in your lungs, ok. For this reason you want to keep a very constant atmosphere at the level of alveolus, therefore, the nature has taken this phenomenon in which you do not replace all the molecules in one go ok. So, there is a new there and there is an old part, but the old part so, gradually, ok. This tells us about the importance of the slow replacement of the air, ok.

I will discuss this slide. If you look very carefully see the slide. You see two types of arrows can you see them what type of arrows are there? Those are straight arrows those are curved arrows ok. You will find that the curved arrows are there mostly in the alveoli - the message here is - the straight arrow indicates the flow of air, ok, but the flow of air will rub on a surface ok, but when it comes to alveoli the system does not want the air to rub finally. It has to diffuse, are you with me? So, those curved arrows indicate that the atmosphere in the alveolus is absolutely free of turbulence, are you with me? there is no turbulence, ok. There is a gentle diffusion without any turbulence. The gases are being exchanged means that some of the old molecules will be taken and some of the new molecules should be brought in, are you with me? But they are being brought in by what process at the level of alveolus by diffusion. Are they being brought into the alveolus by way of flow of air or air current no no. So, for an alveolus, there is no flow of air, ok. Just there is just constant and steady atmosphere with a same amount of oxygen and same amount of carbon dioxide in the alveolus always and it is our duty to have an elaborate system to make sure that that homeostasis is maintained. .