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Physiology sheet

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Overview of respiratory System

Terminology: Pulmonary ventilation, external respiration, Internal respiration, and cellular respiration.

Main function of respiratory: to gain the sufficient amount of O_2 and lose the sufficient amount of CO_2; to maintain normal body functions. If there is no sufficient O_2 amount, the body will no longer function normally

Pulmonary (refers to respiratory system, specifically the lungs) ventilation (it means gas exchange)

- **Air moves in and out of lungs**

- **Continuous replacement of gases in alveoli (air sacs) air moves in and out of lungs, this process is called pulmonary ventilation. Then O_2 goes from alveoli to blood, while CO_2 goes from blood stream to alveoli, this process is external respiration. Then, O_2 goes from capillaries to tissues; CO_2 comes back from tissues to capillaries, this process is called Internal respiration. Because it occurs between blood and tissues.**

External respiration It occurs between the lungs and capillaries. After the internal respiration, the O_2 goes to the cells (specifically the mitochondria organelle, which is responsible for cellular respiration.)

- **Gas exchange between blood and air at alveoli**
- **O_2 (oxygen) in air diffuses into blood**
- **CO_2 (carbon dioxide) in blood diffuses into alveoli**
- **The main goal of inhalation (شهيق) and exhalation(زفير) to transport oxygen to mitochondria; to gain enough ATP (Adenosine triphosphate), which supplies energy.**

Internal respiration Gas exchange in capillaries between blood and tissue cells

- **O_2 in blood diffuses into tissues**
- **CO_2 waste in tissues diffuses into blood**

Cellular respiration It occurs in mitochondria

- **Oxygen (O_2) is used by the cells**
- **O_2 needed in conversion of glucose to cellular energy (ATP)**
- **Carbon dioxide (CO_2) is produced as a waste product**
- **The body's cells die if either the respiratory or cardiovascular system fails**

Overview of respiratory system

Respiratory zone

Site of gas exchange

Composed of

- **Respiratory bronchioles**
- **Alveolar ducts**
- **Alveolar sacs**

It consists of alveoli; and responsible for Oxygen-CO_2 exchange. O_2 exits from alveoli to blood; CO_2 exists from blood to alveoli. (main function)

Conducting zone

Respiratory passages that carry air to the site of

gas exchange

Filters,

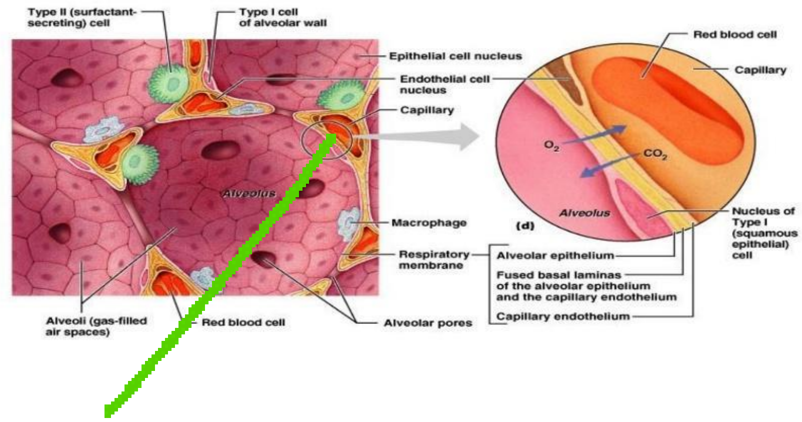
humidifies

It begins from nose to terminal bronchioles

What if conducting zone is malfunctioning, would it have effect on CO_2 and O_2 percentage in blood? No direct effect on gases percentage, maybe after a very long time, in contrast to respiratory zone

It is made from the fusion of the epithelium of alveolus and the epithelium of capillaries. By this thin layer, CO_2 goes to alveolus and O_2 to capillaries

Type II cell's function is producing enough surfactant



very thin layer cannot be seen under the microscope; however, only under Electron Microscope.

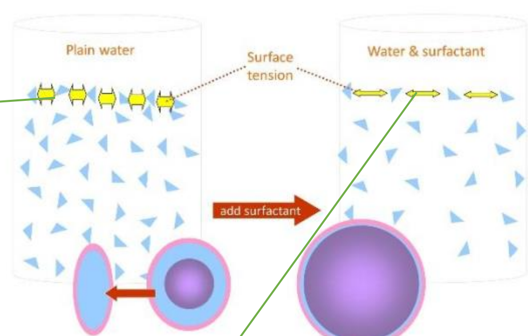
air-blood barrier (the respiratory membrane)

It is where gas exchange occurs Oxygen diffuses from air in alveolus (singular of alveoli) to blood in capillary.

Carbon dioxide diffuses from the blood in the capillary into the air in the alveolus

Space between water molecules is very close; therefore, surface tension is strong and bonding forces are, too.

Surface tension is what makes water droplets pour.



Adding surfactant here moves water molecules farther; therefore, reducing surface tension. As a result of which making the droplets larger

How does soap clean our hands while washing? Because soap is a surfactant.

Why is surfactant important inside the lungs? Consider blowing in a balloon, this process is smooth and easy if you're not compressing on the surface of the balloon. When you breathe in (inhale) to blow in the alveoli, there must be no resistance acting on the surface of alveoli other than the inhaled air. Therefore, the surface tension must be low.

Pneumonia, for example, if it makes obstacles around the membrane of alveoli increases surface tension, hence, the mechanism of inhalation would be harder.

For the average-sized alveolus with a radius of about 100 micrometers and lined with normal

surfactant, this calculates to be about 4 centimeters of water pressure (3 mm Hg).

- **If the alveoli were lined with pure water without any surfactant, the pressure would calculate to be about 18 centimeters of water pressure, 4.5 times as great.**
- **Thus, one sees how important surfactant is in reducing alveolar surface tension and therefore also reducing the effort required by the respiratory muscles to expand the lungs.**

If there were no surfactant in the lungs, breathing in and out would be very hard, and no sufficient amount of oxygen is taken

This mathematical equation is called Laplace law. It's essential for the lectures of CVS(cardiovascular system)

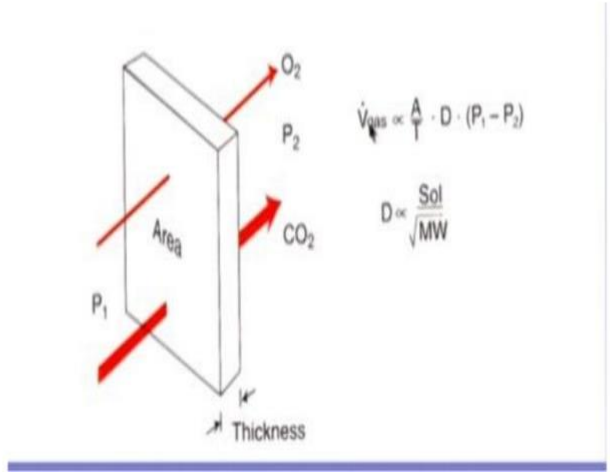
$$\text{Pressure} = \frac{2 \times \text{Surface tension}}{\text{Radius of alveolus}}$$

It indicates that when surface tension increases, radius decreases. And when surface tension decreases, radius increases. Therefore it is called indirectly proportional equation.

Surfactant’s main goal is to increase the radius of the alveolus (expanding the alveolus), increasing air amount and alveolus volume; decreasing surface tension.

With surfactant, the pressure inside alveolus is 4 centimeters; without surfactant, the pressure is 18 centimeters.

When there are premature infants (babies who are at early childbirth) (less than 7 months). Along time ago, a premature baby’s fate was death. Now, premature infants can live with surfactant shots. Premature infants have no mature lungs, and therefore alveoli are not able to produce enough surfactant



Fick’s law of diffusion through a tissue sheet

- if you have a tissue sheet like a postage stamp then the volume of gas which moves a cross the sheet is proportional to the area of the sheet and proportional to the constant which is called the diffusion constant and the difference of partial pressure between one side of the sheet and the other
- Inversely proportional to the thickness of sheet
- So we need thin sheet as possible and large area as possible

The blood gas barrier is phenomenally thin and the area is about 50 to 100 square meters enormous area that is generated by 500 million alveoli and in each walls of the alveoli you get these capillaries with their blood gas barrier

Properties of gas barrier: rapid diffusion. As the difference of concentration between both sides is high, the diffusion is easier. As the area is wider, the diffusion is easier. Inverse relationship is with thickness. As the thickness of the barrier is higher, the diffusion is less.

As we have said earlier, the blood-gas barrier is very thin and cannot be seen under light microscope, because it is less than 1 micron.

Each lung has more than 500 million alveoli, with a very enormous area (50 to 100 square meters)

Given the large area, as much oxygen as possible can be diffuse to the blood capillaries. And as much CO2 as possible can go out of lungs.

Arterial blood gas

- An Arterial Blood Gas (ABG) lab test measures dissolved gases in, and other properties (pH, etc..) of, arterial blood.
- ABGs are most often used with patients in critical care settings.
- *In less critical settings, pulse oximetry is often used as it is less invasive, faster, and cheaper.*

According to Henderson-Hasselbalch equation, when concentration of protons increases, pH value decreases. It is called acidosis

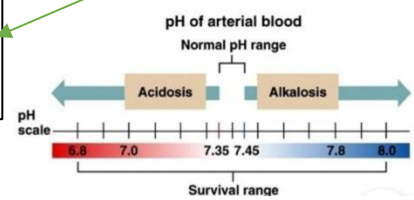
If, however, proton concentration decreases, pH value increases. It is called alkalosis

Blood pH is measured by arterial blood gas (ABG), taking a very small amount of blood from radial vein. It gives the results: Blood pH, CO2, and bicarbonate ion amount

Homeostasis of pH is tightly controlled 7.4 is roughly the normal blood pH value (between 7.35 to 7.45)

- < 6.8 or > 8.0 death occurs
- Acidosis (acidemia) below 7.35
- Alkalosis (alkalemia) above 7.45

Milliequivalents per liter = it describes how many ions in one liter



Any imbalance in blood pH will disrupt pH balance, and therefore, imbalance in homeostasis inside the blood ; it also affects protein function (denaturation of protein, like functions of enzymes, pumps, and protein channels.) That's why pH balance is crucial for homeostasis. If pH disrupts, respiratory system, buffering system and urinary system maintain the condition.

First system to maintain is buffering system, because it is very fast. It includes hemoglobin protein, bicarbonate acid (which maintains 50% of buffering. Phosphate, ammonia (in urinary system)

Acid base homeostasis

- The body is very sensitive to pH level
- Outside the acceptable range of pH, proteins are denatured and digested, enzymes lose their ability to function
- Therefore, the body's pH is tightly regulated
- The respiratory system -The renal system - Buffering Agents

$$CO_2 + H_2O \overset{\text{Carbonic Anhydrase}}{\longleftrightarrow} H_2CO_3 \longleftrightarrow H^+ + HCO3^-$$

Le Châtelier's Principle

Its principle is that CO_2 bind with H_2O under control of a specific enzyme (carbonic anhydrase) in every cell type in your body. Secreted by type II cell (the same cell that secretes surfactant) Its reverse equation

CO_2 binding with water makes H_2CO_3 (bicarbonate acid) when it dissociate, it gives proton+HCO_3^- (bicarbonate ion)

Suppose there's increase in concentration of CO_2, the equation will go from left to right .

Ultimately, a lot of CO_2 makes protons (decrease in pH), resulting acidosis .

If, however,CO_2 decreases, the equation will proceed from right to left. Therefore, proton concentration will decrease (increase in pH), resulting alkalosis.

Buffer, chemically, is a weak acid with weak base, can take excessive protons (decreasing acidity, increasing pH.) If chemical buffering system (bicarbonate acid) fails, respiratory system is involved.

After respiratory system, urinary system involves in (a very slow mechanism, but most powerful.)

Metabolic or renal compensation

Respiratory Acidosis

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO3^-$$

Increasing in proton, so CO_2 is already increased (the reason of respiratory acidosis). Why CO_2 increases? Smoking is one reason.

CO_2 increases = protons increase (pH value decreases)

Decreasing breathing rate is also another reason. This condition is called hypercapnia.

Here, urinary system takes protons from the blood. (Secretion)

Respiratory Alkalosis

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

Decreasing of CO2 will decrease proton concentration in blood; pH value increases. This condition occurs when the patient develops hypocapnia (increasing in breathing rate and decreasing CO2)

To reach equilibrium, renal compensation system is involved to maintain pH blood level. Metabolic acidosis and Metabolic alkalosis are maintained by respiratory system; if respiratory system fails, urinary system works. Urinary system adds protons to the blood (reabsorption)

The relationship between proton and HCO3- is Inversely rational. In acidosis, protons increase, HCO3- decreases. In alkalosis, protons decrease, HCO3- increases. Urinary system works on that.

The Renal System

- **Changes the retention and secretion balance of bicarbonate and hydrogen ions .**
- **If the renal tubular cells retained more bicarb and secreted more H+, then there would be an increase of the blood PH (alkalotic) .**
- **If the renal tubular cells secreted bicarb and retained H+, then there would be a decrease of the blood PH (acidic) .**
- **"Metabolic compensation", slower (12-24 hours)**

عن أبي الدرداء، قال صلى الله عليه وسلم: من سلَكَ طريقًا يلتَمِسُ فيهِ علمًا ، سَهَّلَ اللَّهُ لَهُ طريقًا إلى الجنَّةِ ، وإنَّ الملائِكَةَ لتَضعُ أجنحتَها لطالِبِ العلمِ رضًا بما يصنعُ وإنَّ العالم ليستغفِرُ لَهُ مَن في السَّمواتِ ومن في الأرضِ ، حتَّى الحيتانِ في الماءِ ، وفضلَ العالِمِ على العابِدِ كفَضلِ القمرِ على سائرِ الكواكبِ ، وإنَّ العُلَماءَ ورثةُ الأنبياءِ إنَّ الأنبياءَ لم يورِّثوا دينارًا ولا درهمًا إنَّما ورَّثوا العلمَ فمَن أخذَهُ أخذَ بحظٍّ وافرٍ