Abbreviated Respiratory Physiology.

Physics related to the mechanism of breathing.

Understanding the physics of ventilation/respiration.

Boyles Law: the pressure of a given quantity of gas is inversely proportional to its volume.

Charles Law: the volume of a given quantity of gas is directly proportional to its temperature.

Dalton's Law: The total pressure of a gas mixture is equal to the sum of the partial pressures of its individual gasses.

Henry's Law: at the air-water interface, the amount of gas that dissolves in water is determined by its solubility in water and its partial pressure in the air.

Law of Leplace: the force drawing an alveolus in on itself (tendency to collapse) is directly proportional to the surface tension and inversely proportional to the radius of the alveolus.

Intrapleural Pressure - is always about 4 mm Hg less than the pressure in the alveoli. This difference is due to three main factors:

> 1) lungs have elastic recoil and therefore have the tendency to assume the smallest possible shape.
>
> 2) surface tension of the alveolar fluid causes alveoli to assume the smallest possible size.
>
> 3) the above forces are opposed by the elasticity of the thoracic wall.

Oxygen Transport.

> Oxygen is transported in the blood bound to the heme portion of the hemoglobin molecules found in the red blood cells.

Binding characteristics of hemoglobin.

> Hemoglobin will bind four oxygen molecules. Binding of the first molecule causes a conformational change which enhances the binding of the next molecule, and then the next, and finally the last. A hemoglobin with four oxygen molecules bound is referred to as "saturated." Any hemoglobin with less than four oxygen molecules bound is considered to be "partially saturated."

The release of oxygen molecules into the tissues, known as oxygen unloading is facilitated in just the opposite manner.

Hemoglobin saturation - An increase in temperature, **P**CO_2, H^+ of the blood, and BPG (2,3-bisphosphoglycerate) all decrease the affinity of hemoglobin for O_2.

All of these factors are increased in the peripheral tissues.

Just the opposite is true for a decrease in these factors, as is normally seen in the lungs.

CO_2 Transport.

CO_2 is transported in the blood by three different mechanisms.

1) Dissolved in plasma (7 - 10%).

2) Bound to the globin portion of the hemoglobin molecule (20-30%).

3) As bicarbonate ion (HCO_3^-) in plasma (60 - 70%).

Carbonic Acid - Bicarbonate Buffer System.

$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ \; HCO_3^-$.

H_2CO_3 (carbonic acid).

HCO_3^- (bicarbonate ion).

Note that an increase in any of these components will push the reaction in the opposite direction.

Some common terms that apply to respiratory physiology:

Acidosis: A condition in which the pH of the blood is below 7.35.

Alkalosis: A condition in which the pH of the blood is higher than 7.45.

Compensation: the physiological response to an acid/base imbalance that acts to normalize the pH of arterial blood.

Complete compensation: results if the arterial pH is brought to within normal limits.

Partial compensation: arterial pH is only partially corrected, but does not fall within the normal range.

If a person has an altered blood pH due to metabolic causes, hyper/hypoventilation may bring the pH back into the normal range. This would be known as respiratory compensation.

If a person has an altered blood pH due to respiratory causes, then they must use renal compensation to try to return to normal limits. Renal compensation works by changing the secretion of H^+ and reabsorption of HCO3- by the kidneys.

The partial pressure of carbon dioxide is the single most important indicator of respiratory function.

When respiratory function is normal **P**CO_2 ranges from 35 - 45 mm Hg.

Respiratory acidosis and alkalosis are both disorders resulting form changes in the partial pressure of CO_2 (**P**CO_2).

Values of **P**CO_2 above 45 mm Hg indicate respiratory acidosis.

Values of **P**CO_2 below 35 mm Hg indicate respiratory alkalosis.

Respiratory acidosis, is defined as an abnormally high **P**CO_2 in arterial blood. Inadequate exhalation of CO_2 causes the blood pH to drop. Respiratory acidosis can result from slow breathing or hampered gas exchange, such as is seen in pneumonia, cystic fibrosis, and emphysema. In these conditions, CO_2 accumulates in the blood. This causes a falling blood pH and rising **P**CO_2. The kidneys may provide renal compensation by increasing the excretion of $H^{+,}$ and the reabsorption of HCO_3^-.

The goal in treating respiratory acidosis is to increase the blow off (exhalation) of CO_2.

Respiratory alkalosis, is defined as an abnormally low **P**CO_2 in the arterial blood. The cause of this condition is hyperventilation and CO_2 is eliminated from the body faster than it is produced. Hyperventilation may be caused by several factors, such as oxygen deficiency due to high altitude, stroke, or sever anxiety. Renal compensation may bring the blood pH into the normal range if the kidneys are able to decrease the excretion of H^+ and reabsorption of HCO_3^-.

Note that, unlike respiratory acidosis, respiratory alkalosis this is rarely caused by pathology.

Metabolic acidosis/alkalosis results from changes in HCO_3^- concentrations in the blood.

The normal range for HCO_3^- is 22 – 26 mEq/liter.

Metabolic acidosis is defined as the arterial blood HCO_3^- level dropping below 22 mEq/liter. This could result from actual loss of HCO_3^- as may be seen with severe diarrhea or renal disease, or an accumulation of an acid other than HCO_3^-, or failure of the kidneys to excrete H^+. If this problem is not too severe, we can use respiratory compensation (through hyperventilation) to bring the blood pH back into the normal range.

Metabolic alkalosis is defined as an arterial blood HCO_3^- level above 26 mEq/liter. A loss of acid, or excessive intake of alkaline drugs, can cause the blood pH to rise above 7.45. The most frequent cause of metabolic alkalosis is excessive vomiting, which results in a substantial loss of HCl. Hypoventilation may provide respiratory compensation.

There are basically 4 steps in diagnosing acid/base imbalances:

1) determine whether the pH is high (alkalosis) or low (acidosis).
2) determine which value (**P**CO_2 or HCO_3^-) is out of range.
3) If the cause is a change in **P**CO_2 the problem is respiratory. If the cause is HCO_3^-, the problem is metabolic.
4) NOW, look at the value that doesn't correspond with the observed pH change. If it is within its normal range, there is no compensation occurring. If it is outside its normal range compensation is occurring, and partially correct the problem.

Other Clinically related respiratory conditions.

Ondines Curse: In this condition a person has to actually think about breathing. They must remember to breath. If they fall asleep, they will die if they are not hooked up to a respirator that will do the breathing for them.

Cystic fibrosis: is a hereditary disease. Cells make chloride pumps and normally put these pumps in the plasma membrane. In cystic fibrosis the cells make the chloride pumps but fail to put them into their plasma membrane. This leads to an inadequate saline layer on the surface of the cell, causing cellular mucus to be dehydrated or overly sticky. Cystic fibrosis is commonly known as a respiratory problem because the mucus clogs the cilia of the bronchial tree, and respiratory tract becomes congested and often infected. This may lead to pulmonary collapse. Less commonly known problem in cystic fibrosis is that mucus plugs the ducts of the pancreas, thus preventing secretion of digestive enzymes into the duodenum, thus digestion and nutrition are inadequate.