Abbreviated Respiratory Physiology

Physics related to the mechanism of breathing:

**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 (oxygen unloading) is facilitated in just the opposite manner.

**Hemoglobin saturation** - An increase in temperature, $\text{PCO}_2$, $\text{H}^+$ of the blood, and BPG (2,3-bisphosphoglycerate) all decrease the affinity of hemoglobin for $\text{O}_2$.

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.
CO₂ Transport

CO₂ 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 (HCO₃⁻) in plasma (60 - 70%)

Carbonic Acid - Bicarbonate Buffer System

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ \text{HCO}_3^- \\
\text{H}_2\text{CO}_3 \text{ (carbonic acid)} \\
\text{HCO}_3^- \text{ (bicarbonate ion)}
\]

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**: 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 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 PCO₂ ranges from 35 - 45 mm Hg.

Respiratory acidosis and alkalosis are both disorders resulting form changes in the partial pressure of CO₂ (PCO₂)

Values of PCO₂ above 45 mm Hg indicate respiratory acidosis

Values of PCO₂ below 35 mm Hg indicate respiratory alkalosis

Respiratory acidosis is defined as an abnormally high PCO₂ in arterial blood. Inadequate exhalation of CO₂ causes the blood pH to drop. Respiratory acidosis can result from slow breathing or hampered gas exchange (pneumonia, cystic fibrosis, emphysema). Here CO₂ accumulates in the blood. This causes a falling blood pH and rising PCO₂. The kidneys may provide renal compensation by increasing the excretion of H⁺ and the reabsorption of HCO₃⁻.

The goal in treating respiratory acidosis is to increase the blow off (exhalation) of CO₂.

Respiratory alkalosis is defined as an abnormally low PCO₂ in the arterial blood. The cause of this condition is hyperventilation and CO₂ 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 HCO₃⁻.

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

Metabolic acidosis/alkalosis results from changes in HCO₃⁻ concentrations in the blood.

The normal range for HCO₃⁻ is 22 – 26 mEq/liter.

Metabolic acidosis is defined as the arterial blood HCO₃⁻ level dropping below 22 mEq/liter. This could result from actual loss of HCO₃⁻ as may be seen with severe diarrhea or renal disease, or an accumulation of an acid other than HCO₃⁻, 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 HCO₃⁻ 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 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<sub>CO₂</sub> or HCO₃⁻) is out of range
3. If the cause is a change in P<sub>CO₂</sub> the problem is respiratory. If the cause is HCO₃⁻, 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.