Respiration: Exchange of gases

* Movement via:

Gas Movements:

• Dependent on:

• Atmospheric Air: “sea” of gases

  Oxygen (O₂) : ~ 21% (20.9%)
  Nitrogen (N₂) : ~79% (78.6%)
  Carbon Dioxide (CO₂) : <.04% (0.038%)

• Gas Pressure: DALTON’S LAW:

  * Total Pressure of a gas mixture = Equal to:

    ⇔ Each gas exerts a:

  * Gas Pressure: Proportional to its:

    Partial pressure: *Indirect method of measuring:

Atmospheric Pressure = 760 mmHg (sea level)

1. O₂: 21% of atmospheric Air
   ⇔ 0.21 (760 mm Hg) =

2. N₂: 79% of atmospheric Air
   ⇔ 0.79 (760 mm Hg) =

3. CO₂: < 0.04% of atmospheric Air
   ⇔ 0.0004 (760 mm Hg) =

\[
P_{\text{dry air}} = P_{O_2} + P_{N_2} + P_{CO_2}
\]

= 

= 

RESPIRATORY SYSTEM:

Respiration: *Gas Exchange* via

✓ Alteration in gas:

✓ Alterations in gas:

Blood Gas Concentration:
• Gases win blood after exchange with alveoli

1. **Arterial Blood**: PO₂ & PCO₂ diffuse quickly toward equilibrium with:

   \[ \text{PO}_2 = \]  

   \[ \text{PCO}_2 = \]

\[ \text{PO}_2 = 100 \text{ mmHg} \quad \text{PCO}_2 = 40 \text{ mmHg} \]

2. **VENOUS BLOOD**: Deoxygenated blood

   • PO₂ & PCO₂ after exchange with:

     ✓ O₂ Delivered to cells:

     ✓ CO₂ Produced by cells:

   \[ \text{PO}_2 = \]  

   \[ \text{PCO}_2 = \]

   • Gas exchange in LUNGS

     ✓ Venous blood delivered to alveoli:

     \[ \text{PO}_2 = 40 \text{ mmHg} \Rightarrow \text{PO}_2 = \]  

     \[ \text{PCO}_2 = 46 \text{ mmHg} \Rightarrow \text{PCO}_2 = \]

**RESPIRATORY GAS DIFFUSION:**

• Gas Diffusion directly dependant on gas:

   \[ \text{Gas must be dissolved BEFORE it can} \]

\[ \Rightarrow \]
Diffusion of Gas into Liquid (Plasma)

HENRY’S LAW: Solubility of Gas

• Gas dissolved in a liquid is dependent on:

1. Gas Solubility: Gas Constant
   ✓ Oxygen:
   ✓ Carbon Dioxide:

2. Temperature: Body Constant
   ✓ Temperature & dissolution:
   \[ \text{Temperature} = \text{gas dissolved} \]

3. Partial Pressure: Body Variable
   ✓ Pressure & dissolution
   \[ \text{Pressure} = \text{gas dissolved} \]
   \[ \text{Carbonated soda} = \]

*PLASMA dissolved gas concentration dependant on:

EXAMPLES:
1. Alveolar Air / Capillary Blood (37°C)
   Capillary PO\(_2\) =
   Dissolved O\(_2\) = 0.3 ml of O\(_2\)/100 ml

2. Partial Pressure INCREASED by 2x
   Capillary PO\(_2\) =
   Dissolved O\(_2\) = ml O\(_2\)/100 ml

\[ \Rightarrow \text{Dissolved gas concentration is directly related to:} \]

Clinical Significance of PO\(_2\)

1. PO\(_2\) ONLY indicates concentration of:
   • Whole Blood O\(_2\) =
   \[ \Rightarrow \text{Plasma: mls O}\(_2\)/100 ml blood} \]
   \[ \Rightarrow \text{RBC’s: mls O}\(_2\)/100 ml blood} \]
   • Because O\(_2\) is NOT very soluble MOST O\(_2\) is:

2. PO\(_2\) can ONLY measure:
   ✓ Can NOT measure O\(_2\) bound to:
Can NOT provide accurate measurements of:

\[ \text{Total Blood } O_2 = \]

**Clinical Significance of PO\(_2\)**

Assessment of:

• **Normal lung function:**
  
  \[ \text{Diffusion results in almost Equilibration} \]

  \[ \star \text{ Arterial } PO_2 \sim 5\text{mmHg less than} \]

  \[ \star \text{ Arterial } PO_2 = \]

  \[ \text{Alveolar } PO_2 = \]

• **Abnormal lung function:** Compromised

  \[ \text{Do NOT diffusion until} \]

  \[ \star \text{ Difference between Arterial } PO_2 \& \text{ Alveolar } PO_2. \]

  \[ \star \text{ Indicates:} \]

**TOTAL BLOOD OXYGEN:**

Determined by:

1. **PO\(_2\)**: Determines:
2. **RBCs**: Determines:
3. **Hemoglobin Concentration**: Determines:

\[ \star \text{ Arterial } PO_2 (100\text{mmHg}) \text{ produces Hemoglobin saturation of:} \]

\[ \star \text{ Total Blood } O_2 \text{ content} = \quad \text{ml } O_2/100 \text{ ml} \]

• 19.7 ml O\(_2\) carried in RBCs
• 0.3 ml O\(_2\) dissolved in plasma

How is increased oxygen concentration used clinically?

**Increased Oxygen Concentration: Oxygen Therapy**

• **Mechanism:** INCREASE inspired:

  \[ \Rightarrow \text{ Increases:} \]

  \[ \text{ie: } Double \text{ inspired air } PO_2. \text{ } Double \text{ dissolved plasma } O_2. \]

  \[ \Rightarrow 0.3 \text{ mlsO}_2 \rightarrow 0.6 \text{ mlsO}_2 \]

  \[ \checkmark \text{ Does NOT significantly increase} \]

  \[ \Rightarrow \text{ BUT DOES increase :} \]

  \[ \Rightarrow \text{ Increases } O_2 : \]

  ★★ MORE O\(_2\) available to ★★
✓ Used to treat:
- Poor wound healing
- Hypoxia
- Necrosis
- Burns
- Crush injuries
- etc.

Altitude affects on PO$_2$

\[ \text{↑ Altitude} = \text{Total pressure} \]
\[ \text{Total pressure} = \text{Partial Pressure} \]
\[ \text{Partial pressure} = \text{O}_2 \text{ dissolved} \]
\[ \text{O}_2 \text{ dissolved} = \text{O}_2 \text{ to Tissue} \]

<table>
<thead>
<tr>
<th>Altitude (Feet Above Sea Level)</th>
<th>Atmospheric Pressure (mmHg)</th>
<th>PO$_2$ in Air (mmHg)</th>
<th>PO$_2$ in Alveoli (mmHg)</th>
<th>PO$_2$ in Arterial Blood (mmHg)</th>
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Study Questions:

1. Air is a mixture of gases. What are the three primary gases which comprise our surrounding air? What are their relative concentrations (Expressed in %)?
2. Define partial pressure. What does Dalton’s Law say about partial pressure?
3. What are the approximate partial pressures of the three main gases at sea level?
4. What occurs across the alveolar epithelium to the gases? After exchange has taken place what is the partial pressure of oxygen and carbon dioxide with arterial blood? Why do the partial pressures not change in the arterial blood? Why do the partial pressure of oxygen and carbon dioxide change in the capillaries of the tissues?
5. What are the partial pressures of oxygen and carbon dioxide in the venous system?
6. What drives the diffusion of gases?
7. According to Henry’s Law what three things can determine the solubility of a gas? Which gas is naturally more soluble – oxygen or carbon dioxide? How do temperature and pressure affect solubility?
8. If homeostasis is being maintained, what is the only factor varies, thus affecting gas solubility?
9. Explain why when you open a can of carbonated soda it bubbles.
10. Plasma dissolved gas concentration is directly dependant on which changing variable?
11. What happens to the amount of dissolved oxygen when the partial pressure increases?
12. What is the total concentration of oxygen carried in the blood? Oxygen is carried in what two places (forms) in the blood?
13. If only 0.3 ml / 100 ml of oxygen is carried dissolved in the blood where is the remaining oxygen? Does this indicate how important red blood cells are to the oxygen carrying capacity of the blood!!!
14. What is the clinical significance of knowing the blood pO$_2$? Is plasma pO$_2$ a good indicator of total blood volume?
15. Does increasing the inhaled oxygen concentration significantly increase total blood Oxygen? What does increased inhaled oxygen increase? Hoe is this used clinically as oxygen therapy?
16. What happens to the amount of available oxygen at increased altitudes? Often times individuals living at high altitudes can have increased hematocrits. Why might this occur?
17. SCUBA divers experience very high pressure when diving. One problem with diving is what is called nitrogen narcosis. This results from increases dissolved nitrogen. Nitrogen normally has such a low solubility it does not dissolve in plasma at atmospheric pressures. Explain why diving would increase the solubility of nitrogen.
18. Another problem with SCUBA diving is the bends. This results from when a diver ascends too quickly from a dive. Gases dissolved in the blood start forming bubbles in the vessels (especially in the joints). Explain why the gases would be coming out of solution and into their gaseous form?