Respiration: Exchange of gases

* Movement via Diffusion

Gas Movements:
- Dependent on Pressure Gradients
- Atmospheric Air: "sea" of gases

\[
\begin{align*}
\text{Oxygen (O}_2\text{)} &: \sim 21\% \ (20.9\%) \\
\text{Nitrogen (N}_2\text{)} &: \sim 79\% \ (78.6\%) \\
\text{Carbon Dioxide (CO}_2\text{)} &: \sim 0.04\% \ (0.038\%)
\end{align*}
\]

* Gas Pressure: **DALTON’S LAW.**

* Total Pressure of a gas mixture

= Equal to Sum of individual gas pressures

Each gas exerts a Partial Pressure
Gas Pressure:
Proportional to its concentration

Partial Pressure:
Indirect method of measuring concentration

Atmospheric Pressure = 760 mmHg (sea level)
1. **O₂**: 21% of atmospheric Air
   \[ \text{0.21 (760 mm Hg)} = 159 \text{ mmHg} \]

2. **N₂**: 79% of atmospheric Air
   \[ \text{0.79 (760 mm Hg)} = 601 \text{ mmHg} \]

3. **CO₂**: < 0.04% of atmospheric Air
   \[ \text{0.0004 (760 mm Hg)} = 0.3 \text{ mmHg} \]

\[ P_{dry \ air} = P_{O_2} + P_{N_2} + P_{CO_2} \]
\[ = 159 + 601 + 0.3 \]
\[ = \sim 760 \text{ mm Hg} \]

**Respiratory System:**

Respiration: **Gas Exchange via diffusion**

- Alterations in gas concentrations
- Alterations in gas partial pressure

**Blood Gas Composition:**

- **Gases in blood after exchange with alveoli**

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

\[ \text{PO}_2 = 100 \text{ mmHg} \]
\[ \text{PCO}_2 = 40 \text{ mmHg} \]
2. **VENOUS BLOOD**: Deoxygenated blood

- PO\textsubscript{2} & PCO\textsubscript{2} *after exchange with tissues*
  
  - O\textsubscript{2} Delivered to cells: *Decreases*
  - CO\textsubscript{2} Produced by cells: *Increases*

  - Amount exchanged dependant on cellular activity

  *ie. Exercise:*  
  - PO\textsubscript{2} = < 40 mmHg  
  - PCO\textsubscript{2} = >46 mmHg

- Gas exchange in *LUNGS*

  - **Venous blood** delivered to alveoli:  

  - Exchange occurs again:

  - PO\textsubscript{2} = 40 mmHg  
  - PO\textsubscript{2} = 100 mmHg  
  - PCO\textsubscript{2} = 46 mmHg  
  - PCO\textsubscript{2} = 40 mmHg
**RESPIRATORY GAS DIFFUSION:**

- **Gas Diffusion** directly dependent on **gas solubility**
  - Gas must be dissolved BEFORE it can diffuse

**Diffusion of Gas into Liquid (Plasma)**

**HENRY’S LAW:** Solubility of a GAS

**Gas dissolved** in a liquid is dependent on:

1. **Gas Solubility Constant**: Gas [Constant]
   - **Oxygen** NOT very soluble
   - **Carbon Dioxide** very soluble

2. **Temperature**: Body [Constant]
   - Temperature & dissolution inversely related
   - $\uparrow$ Temperature $\Rightarrow$ gas dissolved
3. **Partial Pressure**: Body Variable
   - Pressure & dissolution directly related
     - ↑ Pressure = ↑ gas dissolved

   - **Carbonated soda** = CO\(_2\) dissolved under pressure

*PLASMA dissolved gas concentration dependant on: **Gas partial pressure**

**EXAMPLES:**

1. **Alveolar Air / Capillary Blood** (37°C)
   - Capillary PO\(_2\) = 100 mm Hg
   - Dissolved O\(_2\) = 0.3 ml of O\(_2\)/100 ml
2. **Partial Pressure INCREASED by 2x**
   - Capillary $PO_2 = 200$ mm Hg
   - Dissolved $O_2 = 0.6$ ml $O_2 / 100$ ml
   - Dissolved gas concentration is directly related to Partial Pressure

Clinical Significance of $PO_2$

1. $PO_2$ ONLY indicates concentration of:
   - **Dissolved Gas**

   ![Diagram showing dissolved gas in plasma and RBCs]

   - Whole Blood $O_2 = $ Plasma + RBC’s
     - 20 mls $O_2 / 100$ ml blood
     - **Plasma**: 0.3 mls $O_2 / 100$ ml blood
     - **RBC’s**: 19.7 mls $O_2 / 100$ ml blood

   - Because $O_2$ is NOT very soluble, MOST $O_2$ is carried on RBCs
2. **PO2** can ONLY measure dissolved **O2**

✓ Can NOT measure **O2** to bound **Hemoglobin**
✓ Can NOT provide accurate measurements of **Total Blood O2**

Rightarrow **Total Blood O2 = Bound O2 + Dissolved O2**

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**Clinical Significance of PO2**

✓ Assessment of: **LUNG FUNCTION**

- **Normal lung function:** **Gas Exchange**
  - Diffusion results in almost Equilibration
  - Arterial **PO2~ 5mmHg less** than Alveolar **PO2**
    
    \[
    \text{Arterial PO}_2 = 100 \text{ mmHg} \\
    \text{Alveolar PO}_2 = 105 \text{ mmHg} 
    \]

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<th>Altitude (Feet)</th>
<th>Atmospheric Pressure (mmHg)</th>
<th>PO2 in Arterial (mmHg)</th>
<th>PO2 in Arterial (mmHg)</th>
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- **Abnormal lung function:** **Compromised Gas Exchange**
  - Do NOT diffuse until Equilibration
  - Difference between:
    - Arterial **PO2** & Alveolar **PO2 > 5 mmHg**
    - Indicates: **Inadequate Gas exchange**

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Mucus obstruction, airway edema, bronchospasm, a foreign body, or a tumor.
TOTAL BLOOD OXYGEN:

Determined by:
1. PO₂: Determines dissolved oxygen
2. RBCs: Determines bound oxygen
3. Hemoglobin Concentration: Determines bound oxygen

- Arterial PO₂ (100mmHg) produces Hemoglobin saturation of ~98%
- Total Blood O₂ content = ~20 ml O₂/100 ml
  - 19.7 ml O₂ carried in RBCs
  - 0.3 ml O₂ dissolved in plasma

How is increased oxygen concentration used clinically?
Increased Oxygen Concentration: Oxygen Therapy

- Mechanism: INCREASE inspired Alveolar PO$_2$
  - Increases dissolved plasma O$_2$
    - Double inspired air PO$_2$
    - Double dissolved plasma O$_2$
  - 0.3 mlsO$_2$ → 0.6 mlsO$_2$

Does NOT significantly increase Total O$_2$ ???

- BUT DOES increase DISSOLVED O$_2$
- Increases O$_2$ DIFFUSING to TISSUE

★ ★ MORE O$_2$ available to tissues !!!! ★ ★

- Used to treat:
  - Poor wound healing
  - Hypoxia
  - Burns
  - Crush injuries
  - Necrosis . . . . . . etc.

Altitude affects on PO$_2$

- Altitude
- Total pressure
- Partial pressure
- O$_2$ dissolved
- O$_2$ to Tissue