NOTES: Respiratory System
(CH 13) Part 2 – Control of Breathing / Gas Exchange and Transport
*Normal breathing is rhythmic and involuntary.
Respiratory Center:

- the respiratory center is in the **brain stem** and includes portions of the **PONS** and **MEDULLA OBLONGATA**
FACTORS AFFECTING BREATHING:

1) respiratory center in the brain
2) chemical concentrations (gases, ions, pH, etc.)
3) stretching of lung tissue
4) emotional state
EXAMPLES:

*when chemoreceptors in the walls of certain large arteries detect low O$_2$ levels (or high CO$_2$ levels), breathing rate increases

*fear and pain typically increase the normal breathing pattern
ALVEOLAR GAS EXCHANGES

*Gas exchange between air and blood occurs in the alveoli.

- **ALVEOLI**: tiny air sacs in the lungs clustered at the ends of alveolar ducts
ALVEOLAR GAS EXCHANGES

● Gases (O$_2$ and CO$_2$) diffuse from regions of **HIGH concentration** (and partial pressure) to regions of **LOW concentration** (partial pressure)

● **OXYGEN** diffuses from **alveolar air** into **blood**

● **CARBON DIOXIDE** diffuses from **blood** into **alveolar air**
<table>
<thead>
<tr>
<th>Gas</th>
<th>Partial Pressure in Blood</th>
<th>Action</th>
<th>Partial Pressure in Alveolar Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>45 mm Hg</td>
<td>exit</td>
<td>40 mm Hg</td>
</tr>
<tr>
<td>Oxygen</td>
<td>40 mm Hg</td>
<td>enter blood</td>
<td>104 mm Hg</td>
</tr>
</tbody>
</table>
GAS TRANSPORT IN THE BLOOD / BODY

*Blood transports gases between the lungs and body cells.
OXYGEN TRANSPORT:

- oxygen binds to the protein **hemoglobin** in the blood
  - **heme** = group that surrounds an atom of iron
  - **globin** = protein made up 574 amino acids in 4 polypeptide chains

- the resulting molecule, oxyhemoglobin, is unstable and readily releases oxygen in regions where $P_{O2}$ is low
OXYGEN TRANSPORT:

- $PO_2$ determines the amount of oxygen that hemoglobin binds
  - Greater the $PO_2$, the more oxygen binds
  - Normal arterial $PO_2$ is 95mm Hg which means hemoglobin is totally saturated

- Bond between oxygen and hemoglobin is unstable
  - Once $PO_2$ decreases, oxygen is released and diffuses into nearby cell
OXYGEN TRANSPORT (continued)…

- more oxygen will be released from oxyhemoglobin when:
  - $\text{CO}_2$ levels in the blood increase
  - blood becomes more acidic
  - blood temperature increases
The diagram illustrates the process of carbon dioxide (CO₂) release from muscle cells to the blood in capillaries. The reaction can be represented by the following equations:

1. **Inside the Cell**
   - CO₂ + H₂O → H₂CO₃
   - H₂CO₃ → H⁺ + HCO₃⁻

2. **In Blood (Hemoglobin)**
   - H⁺ + HCO₃⁻ → H₂CO₃
   - H₂CO₃ → H₂O + CO₂

Muscle cells release CO₂, which diffuses into the blood through capillaries. CO₂ combines with water to form carbonic acid (H₂CO₃), which then dissociates into hydrogen ions (H⁺) and bicarbonate ions (HCO₃⁻). In blood, hemoglobin binds with oxygen (O₂), while the released H⁺ ions combine with HCO₃⁻ to form more H₂CO₃, which eventually dissociates into H₂O and CO₂, allowing for the efficient transport of CO₂ back to the lungs for exhalation.
CARBON DIOXIDE TRANSPORT:

• carbon dioxide may be carried in 3 ways:
  1) in solution
     - CO$_2$ dissolves into plasma
     - higher PCO$_2$, CO$_2$ will go into the solution
     - only 7% of CO$_2$ is transported this way
CARBON DIOXIDE TRANSPORT:

2) **bound to hemoglobin** (different spot on molecule than where oxygen binds)
   - $\text{O}_2$ and $\text{CO}_2$ do not bind at same site on hemoglobin
   - $\text{CO}_2$ loosely binds to compound called **carbaminohemoglobin**
     - when $\text{PCO}_2$ is low, $\text{CO}_2$ releases quickly
     - only about **15-25%** of how $\text{CO}_2$ is transported
CARBON DIOXIDE TRANSPORT:

3) as a bicarbonate ion \textit{(HCO}_3^-\textit{)} \ldots \text{ MOST CO}_2 \text{ is in this form!}

\begin{itemize}
\item CO\textsubscript{2} reacts with water to form carbonic acid
\item Reaction occurs slowly in plasma
\item \underline{Carbonic anhydrase} speeds up reaction between CO\textsubscript{2} and water
\end{itemize}
CARBON DIOXIDE TRANSPORT:

- carbon dioxide reacts with water to form carbonic acid:

\[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \]
Aqueous phase of blood cells passing through capillaries in lung

Air space in lung
CARBON DIOXIDE TRANSPORT:

• New hydrogen ions in the systemic capillaries generate deoxyhemoglobin
  – This is a buffer that causes hydrogen ions to bind to it…. Therefore no decrease in blood pH
• Bicarbonate ions diffuse into blood plasma
• Blood passes through capillaries of lungs, CO₂ diffuses into alveoli lowering plasma PCO₂
CARBON DIOXIDE TRANSPORT:

- Lower $\text{PCO}_2$, hydrogen ions and bicarbonate ions in red blood cells bind to form **carbonic acid**
- With **carbonic anhydrase** present, carbonic acid yields a new $\text{CO}_2$ molecule and water molecule
- **Carbaminohemoglobin** releases its $\text{CO}_2$
- $\text{CO}_2$ diffuses out of blood
CARBON DIOXIDE TRANSPORT:

- carbonic acid dissociates to release hydrogen ions and bicarbonate ions:

\[ \text{H}_2\text{CO}_3 \rightarrow \text{H}^+ + \text{HCO}_3^- \]
Aqueous phase of blood cells passing through capillaries in lung

Air space in lung