There are three major contributors to regulating the pH of blood. **Bicarbonate**, **phosphate** and **proteins**

Blood pH Must be Kept Close to 7.4
- Hydrogen ion is extremely reactive and affects many molecules which regulate physiological processes
- Blood pH is set at a slightly alkaline level of 7.4 (pH 7.0 is neutral)
- A change of pH of 0.2 units in either direction is considered serious
- Blood pHs below 6.9 or above 7.9 are usually fatal if they last for more than a short time

### Blood Buffers

The bicarbonate system is the most important and is controlled by the rate of respiration
- Dissolved carbon dioxide in water reacts to form carbonic acid

- The pKa of carbonic acid is 6.35. the pH of blood is 7.4 so the acid is greater than 1 pH away from the pKa and it is primarily dissociated

- Under physiological conditions the equilibrium for the first reaction is far to the left, and the combined pKa for the two reactions is 6.4

CO₂

At first glance this does not look like a good buffer for blood. The buffering capacity is poor. To maintain a pH of 7.4 there would have to be a ratio of 11 to 1 of bicarbonate to carbon dioxide.

\[ \text{pH} = 6.4 + \log \frac{[\text{HCO}_3^-]}{[\text{CO}_2]} \]

Because this is an open system, the CO₂ dissolved and the bicarbonate can rapidly change

Changes resulting in loss of carbonic acid are replaced by CO₂ dissolving - This is an open system

Normal concentration of carbon dioxide is 1.2 mM and bicarbonate is 15 mM

**Acidosis and Alkalosis**

A decrease in arterial carbon dioxide partial pressure causes the bicarbonate/carbon dioxide ratio to exceed 20 and the pH to rise above 7.45 – **Alkalosis**

Increases in partial pressure of CO₂ have the opposite affect and decrease the pH below 7.2 – **Acidosis**
Blood buffering is an “open” buffered system

**Acidosis and Alkalosis**

**Metabolic Conditions** lead to both acid and alkali conditions

- Metabolic acidosis results from an increase in loss of bicarbonate (such as diarrhea) or overproduction of acids (ketosis, anaerobic metabolism)
- Metabolic alkalosis results from Conditions that lead to a reduced amount of fluid in the body, like vomiting or excessive urination due to use of diuretic drugs, or excess bicarbonate ingestion.

**There can also respiratory reasons for either condition:**
- Respiratory acidosis results from hypoventilation which is manifested by the accumulation of CO₂ in the blood and a drop in blood pH.
  - Central Nervous System Depression (Sedatives, CNS disease, Obesity Hypoventilation syndrome)
  - Lung Disease (emphysema, pneumonia)
  - Musculoskeletal disorders (Myasthenia Gravis, Polio)

**There can also respiratory reasons for either condition:**
- Respiratory alkalosis results from hyperventilation which is manifested by excess elimination of CO₂ from the blood and a rise in the blood pH.
  - Catastrophic CNS event (CNS hemorrhage)
  - Drugs (salicylates, progesterone)
  - Pregnancy (especially the 3rd trimester)
  - Decreased lung compliance (interstitial lung disease)
  - Liver cirrhosis
  - Anxiety

### Compensation

<table>
<thead>
<tr>
<th>Disturbance</th>
<th>Response</th>
<th>Expected Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESPIRATORY ACIDOSIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>↑ [HCO₃⁻]</td>
<td>1 mmol/L/10mmHg increase in PaCO₂</td>
</tr>
<tr>
<td>Chronic</td>
<td>↑ [HCO₃⁻]</td>
<td>4 mmol/L/10mmHg increase in PaCO₂</td>
</tr>
<tr>
<td><strong>RESPIRATORY ALKALOSIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>↓ [HCO₃⁻]</td>
<td>2 mmol/L/10mmHg decrease in PaCO₂</td>
</tr>
<tr>
<td>Chronic</td>
<td>↓ [HCO₃⁻]</td>
<td>4 mmol/L/10mmHg decrease in PaCO₂</td>
</tr>
<tr>
<td><strong>METABOLIC ACIDOSIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>↓ PaCO₂</td>
<td>1.2 x the decrease in [HCO₃⁻]</td>
</tr>
</tbody>
</table>
**Adjusting levels - Compensation**

In reality the kidneys regulate the bicarbonate concentration. If there is too little bicarbonate, the kidneys filter and excrete $H^+$, causing a shift in the equilibrium to increase bicarbonate.

- If there is too much bicarbonate, kidneys will excrete it.

The carbon dioxide is replaced by metabolism (Food $\rightarrow$ H$_2$O and CO$_2$)

Changes in breathing can increase or decrease the CO$_2$

- Breathe too fast and what happens. Decrease the breathing rate and alter the pH as well. (think of the last time you got sick and threw up)

The pH problem (either metabolic or resp) cannot be compensated by the same means. i.e. if you have a lung disease you can not compensate by breathing faster – it just isn’t possible.