ACID/BASE DISORDERS

- **Simple acidosis/alkalosis**
  - One primary change occurs – same direction as pH
  - Loss or gain of an acid or a base
  - Compensatory response, when present, is:
    - A secondary change in opposite direction to pH
    - Usually incomplete; **Overcompensation does NOT occur**
    - When pH still too low/high, look for another A/B disorder

<table>
<thead>
<tr>
<th>Simple A/B disorder</th>
<th>pH</th>
<th>[H+]</th>
<th>Primary change</th>
<th>Compensatory response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory acidosis</td>
<td>↓</td>
<td>↑</td>
<td>pCO₂ ↑</td>
<td>[HCO₃] ↑</td>
</tr>
<tr>
<td>Respiratory alkalosis</td>
<td>↑</td>
<td>↓</td>
<td>pCO₂ ↓</td>
<td>[HCO₃] ↓</td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>↑</td>
<td>↓</td>
<td>[HCO₃] ↓</td>
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Although the primary and compensatory responses shift in opposite directions **relative to pH**, the concentration of ions are actually both increasing or decreasing - higher CO₂ is ↑ acid, higher HCO₃ is ↑ base.

*Note: some authors use direction to refer to number values as they go up or down; In these notes, direction of change refers to pH*

- **Mixed** – more than one change, usually 2, but more is possible
  - Metabolic and/or respiratory
  - Interpretation more difficult
  - See **Blood Gas Evaluation** notes

- **Acute vs. Chronic**
  - Compensatory capability differs – greater in chronic diseases
  - Expected compensation can be calculated
  - Compensatory response, when present, is:
    - pH should ↓ or ↑ a specific amount based on change in pCO₂ or HCO₃
    - Varies with species, duration of disease

Pharyngeal/laryngeal edema in a dog caused airway obstruction, hypoventilation and respiratory acidosis
Image courtesy Dr. M. Radlinsky

Hypoventilation secondary to obesity - respiratory acidosis, and hypoxemia;
Image courtesy Dr. C Braun
CAUSES OF ACID/BASE DISORDERS

- **ACIDOSIS** – loss of base or increased acid

- **Respiratory acidosis** – ↑ levels of carbon dioxide
  - Compensation for metabolic alkalosis
  - Hypoventilation – decreased elimination of CO₂
    - Respiratory tract dysfunction
      - Upper airway – obstruction
      - Lower airway – pulmonary or thoracic dz
      - Muscle weakness – ↓ tidal volume
      - Atelectasis – recumbency, obesity
    - Dysfunction of respiratory centers in brain
      - Anesthesia, sedation – resets threshold at higher pCO₂
      - Cerebral disease
  - Increased production of CO₂ - overwhelms ventilation
    - Malignant hyperthermia – abnormal muscle metabolism
    - Heatstroke
    - Lactic acidosis also develops

Dogs pant to stay cool and usually have respiratory alkalosis; but pH is dependent on balance between O₂ demand of exercise & effectiveness of removal;

Athletic dogs may develop hyperthermia and even heat stroke; Metabolic acidosis, and respiratory acidosis can occur.

Images courtesy [Abujoy](https://www.abujoy.com) and [M Kloet](https://www.m Kloet.com)
ACIDOSIS – continued

- **Metabolic acidosis 1** – compensation for respiratory alkalosis
- **Metabolic acidosis 2** due to loss of HCO₃⁻
  - Hyperchloremic normal anion gap acidosis
    - Kidney resorbs Cl w/ Na to restore volume - see ↑Cl
    - ↑Cl balances AG equation - HCO₃⁻, Cl are measured anions
  - Vomiting/reflux of biliary/pancreatic fluids
  - Diarrhea in large animals (E. Coli, Salmonella spp)
  - Esophageal obstruction “choke”- cows, horses
  - Renal loss
    - Tubular acidosis
    - Addison’s disease

- **Metabolic acidosis 3** – due to increased acid – called ‘titration acidosis’
  - High anion gap acidosis, normochloremic
  - Organic acids are buffered by bicarbonate

  **Titration acidosis:**
  **Strong acid dissociates:**
  \[ \text{H}^+\text{UA}^- \rightarrow \text{H}^+ + \text{UA}^- \]
  **Buffered by bicarbonate:**
  \[ \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{↑CO}_2 \]
  \[ \text{CO}_2 \text{ is exhaled} \]
  \[ \text{UA}^- \text{↑s} - \text{AG} \text{↑s, pH drops} \]
  \[ \text{[HCO}_3^-] \text{↓s} - \text{pH drops} \]

- Uremic acids with renal failure
- Ketoadicosis – diabetes, ketosis in cattle/camelids
- Antifreeze poisoning (ethylene glycol)
- Other toxins - salicylates, methanol, metaldehyde, etc.

<table>
<thead>
<tr>
<th>Metabolic acidosis</th>
<th>Likely cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ Anion Gap w/ Normal Cl</td>
<td>↑ UA</td>
</tr>
<tr>
<td>↓ Anion Gap w/ High Cl</td>
<td>Loss of HCO₃⁻</td>
</tr>
</tbody>
</table>

Adapted from chart at Cornell Clin Chem Basics website

Holstein heifer recovered from E. Coli diarrhea with severe metabolic acidosis caused by loss of bicarbonate and severe dehydration

Castrated male cat post urethral obstruction; Uremia caused ‘titration’ metabolic acidosis; resolved with removal of uroliths & diuresis.

Ethylene glycol (antifreeze), and its metabolites are toxic organic acids;

Image courtesy dno1967
ACIDOSIS – continued

- Metabolic acidosis due to increased acid – continued

  - Lactic acid – COMMON – also an organic acid
    - Tissue hypoxia - anaerobic metabolism - ↑ lactate
      - Decreased perfusion of tissues
      - Hypovolemia – dehydration/hemorrhage
      - Hypotension / vasodilation
      - Sepsis, heart failure, shock, cardiac arrest, etc
      - Hypoxemia - Pneumonia, A/W obstruction, etc
      - Increased demand for O₂ - seizures, exercise
      - Severe anemia
    - Rumen acidosis – grain overload
      - ↑ production of L form of lactic acid,
      - Sometimes D-lactate too
      - Often hypovolemic/dehydrated as well
    - Hyperthermia
      - Severe anemia
      - Heat stroke
      - Excessive exercise, especially if unfit – get too hot
        (Labradors that won’t stop)

  - Hyperproteinemia/globulinemia = acids
    - Many proteins are weak acids
      - Presence of histidine in side chains
    - Identified with physiochemical theory of A/B - ↑ A_TOT
    - Plasma cell myeloma, chronic infection, neoplasia, etc.

Race horses develop short term lactic acidosis due to anaerobic metabolism during high speed exercise. Hypercarbia and hypoxemia also occur due to respiratory limitations.

Image courtesy Softeis

Right torsed abomasum;

Begin with metabolic alkalosis, Can develop metabolic (lactic) acidosis with hypovolemia/dehydration

Plasma cell myeloma

Image courtesy Nephron

NOTE! Patients with significant fluid deficits will have some lactic acidosis – Rx with FLUIDS, not HCO₃⁻
ALKALOSIS – increased base or loss of acid

- **Respiratory alkalosis** – ↑ elimination of CO₂ (volatile acid)
  - Compensatory response to metabolic acidosis
    - Often incomplete
    - Limited by hypoxemia
  - Hyperventilation
    - Excitement, anxiety, fear, warm environments, pain
    - Hyperthermia-Fever; Exercise; Heat stroke (milder forms)
    - COMMON in small animals – panting

- **Metabolic alkalosis**
  - Compensatory response for respiratory acidosis
    - Often very good in chronic diseases
  - Loss of H⁺ and Cl⁻
    - Vomiting in SA; gastric reflux in horses
      - HCl production continues, generates NaHCO₃
      - H⁺, Cl⁻ are lost, but HCO₃⁻ retained
    - Upper GI obstruction, especially ruminants (“choke”)
      - Displaced/torsed abomasum – sequestration of H⁺ and Cl⁻
      - Kidney saves HCO₃⁻, Cl⁻ not available to resorb w/ Na
  - Increased excretion or loss of Cl⁻
    - Sweating, exertional rhabdomyolysis
      - Lose lots of Cl⁻; also K, Ca, Na
      - Sweat volume can be profound
    - Diuretic therapy
      - Loop of Henle type - furosemide - lose Na, Cl, K
      - Thiazide type – lose Na, Cl
  - Increased sodium levels - Na levels > Cl⁻
    - Hyperaldosteronism
    - Hyperadrenocorticism

- Hypoproteinemia
  - Many proteins are weak acids. (Histidine-containing side groups)
  - Not apparent with traditional A/B principles
  - Important component of the ‘strong ion’ theory of A/B
  - “Hidden” underlying A/B abnormality
    - Acidosis appears less severe in diseases with protein loss
References: Unless otherwise noted, images are courtesy of Dr. JG Adams

