Cells

Extracellular Fluid
Volume ~ 1/3 body water; Osmol 290 mOsm/Kg H₂O
Na⁺ 142 mM; K⁺ 4 mM; H⁺ 40 nM (pH 7.40)

Intake:
Na⁺ ~ 5-200 mmoles/day
K⁺ ~ 50-300
H₂O ~ 0.5-3 L/day
H⁺ ~ 50-100 mEq/day

Air water ~ 3000 mOsm/Kg H₂O

The task of the kidney in acid-base balance is excretion of the daily acid load

- Oxidation of amino acids, fats and carbohydrates often leads to acid production
- On an average American diet we produce about 1 of H⁺ mEq/kg/day

Buffers

\[ A^- + H^+ \xrightarrow{} HA \]

\[ pH = pK + \log \frac{[HCO_3^-]}{\alpha pCO_2} \]

pK = 6.1 at 37°C and 0.15 M salt
\[ \alpha = 0.03 \]
**Filtered Bicarbonate**

**HCO₃⁻ Reabsorption by H⁺ secretion**

- **Urine**
  - H₂O
  - CO₂ + OH⁻
  - CO₂ + H₂O

**H⁺ Secretion in the Proximal Tubule**

- **BLOOD**
  - Na⁺
  - HCO₃⁻
  - CO₂ + OH⁻
- **URINE**
  - Na⁺
  - H⁺
  - H⁺

- **NHE₃** Na:H Exchanger
- **H⁺ translocating ATPase**
- **NBC** Na:HCO₃ cotransporter

**H⁺ secretion in the Collecting Tubule**

- **Urine**
  - H₂O
  - CO₂ + OH⁻
  - CO₂ + H₂O

- **H⁺ translocating ATPase**
- **AE₁** Cl:HCO₃ exchanger

**HCO₃⁻ reabsorption / H⁺ secretion occurs in the Proximal and Collecting tubules**

- **PCT**
- **DCT**
- **ThAL**
- **CD**

**Proximal Tubule**

- Na-H exchanger 3
- Na-KATPase
- NBC1
The Membrane Potential Generated by Na Absorption Regulates H⁺ and K⁺ Secretion in Collecting Tubules

Regulation of H⁺ Secretion in the Collecting Tubule by Aldosterone

Aldosterone Action in Collecting Duct

CO₂ stimulates Exocytosis of H⁺ATPase Vesicles

pH of Tubular Urine

Collecting Tubule Urine pH
**H⁺ Secretion in the Collecting Tubule**

Rate of H⁺ Secretion

<table>
<thead>
<tr>
<th>Rate of H⁺ Secretion</th>
<th>Urine pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.4</td>
<td>0</td>
</tr>
<tr>
<td>6.4</td>
<td>1</td>
</tr>
<tr>
<td>5.4</td>
<td>2</td>
</tr>
<tr>
<td>4.4</td>
<td>3</td>
</tr>
</tbody>
</table>

Trans-epithelial pH difference, pH units

**Gluconeogenesis**

\[ \text{NH}_3 \xrightarrow{\text{HCO}_3^-} \text{CO}_2 + \text{OH}^- \]

\[ \text{NH}_4^+ \]

- NH₃
- Glutamine ← Glutamate ← α-keto-glutarate ← PEP ← Glucose

**Acid Ingestion increases Ammonia Synthesis and Excretion**

- H⁺ + NH₃
- H₂O
- HCO₃⁻ CO₂ + OH⁻

C.A.II

**Potassium Distribution**

**Intake:**

- Na⁺ = 5-200 mmoles/day
- K⁺ = 50-300 mEq
- H₂O = 0.5-3 L/day
- H⁺ = 50-100 mEq/day

**Air water = 3000 mOsm/Kg H₂O**

**Intracellular**

- [K] = 140 mEq/L
- [Na] = 10 mEq/L

**Extracellular Fluid**

- Volume = 1/3 body water; Osmol 290 mOsm/Kg H₂O
- Na⁺ = 142 mM; K⁺ = 4 mM; H⁺ = 40 nM (pH 7.40)

**Cells**

- K⁺ = 110 mM

**Urine**

- K⁺ = 4 mEq/L
- Na⁺ = 140 mEq/L

- [K] = 4 mEq/L
- [Na] = 10 mEq/L

**Membrane Potential**

**Regulation of H⁺ Transport**

- pCO₂
- Aldosterone
- K⁺: Acid-Base status

- NH₃: pH Gradient

**Intake:**

- Na⁺: 5-200 mmoles/day
- K⁺: 50-300 mEq
- H₂O: 0.5-3 L/day
- H⁺: 50-100 mEq/day

**Air water: 3000 mOsm/Kg H₂O**

**Total Body K⁺: 4400 mEq**

**Extracellular**

- Total Body K⁺: 50 mEq
Disposal of an ingested K Load occurs by re-distribution and by urinary excretion.

Plasma Potassium Concentration

Insulin Increases K+ Uptake by Cells

Renal Potassium Handling

K is Freely Filtered

> 95% of Filtered K is reabsorbed in the Proximal Tubule and Thick Ascending Limb

What appears in the Urine is secreted by the Distal Tubule and Collecting Duct

K Secretion in Collecting Duct

K+ Urinary Excretion and Urine Flow Rate

Concentration Gradient

Trans-epithelial Membrane Potential
Interaction Between Aldosterone and Urine Flow in K⁺ Excretion

High aldosterone

Low aldosterone

Aldosterone
- increases activity of K channel
- increases activity of Na channel
- increases Na,K ATPase

Urine Flow Rate
- brings in low K tubular fluid

Regulation of K Secretion