Acid base the update

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Step1 : Determine primary abnormality

Determine Acidosis versus alkalosis

pH <7.35: Acidosis

pH >7.45: Alkalosis

Determine Metabolic versus Respiratory

Primary Metabolic Disorder

- pH changes in same direction as bicarbonate, pCO2

Metabolic Acidosis

- Serum ph decreased
- Serum bicarbonate and paCO2 decreased

Metabolic Alkalosis

- Serum ph increased
- Serum bicarbonate and paCO2 increased

Primary Respiratory Disorder

- pH changes in opposite direction bicarbonate, pCO2

Respiratory Acidosis

- Serum ph decreased
- Serum bicarbonate and paCO2 increased

Respiratory Alkalosis

- Serum ph increased
- Serum bicarbonate and paCO2 decreased

Step 2: Sharpen the diagnosis

- **Calculate the Anion Gap**
  - Helpful in Metabolic Acidosis
  - Helpful in mixed acid-base disorders
- **Calculate Osmolar Gap**

  Helpful in Metabolic Acidosis
- **Calculate Urinary Anion Gap**
  - Helpful in Non-Anion Gap Metabolic Acidosis
  - Distinguishes renal from extra-renal cause
  - Na+ + K+ − Cl−

- **Decreased Urine Anion Gap <-10**
- **Extrarenal Non-Anion Gap Metabolic Acidosis**
- **Increased Urine Anion Gap >+10**
- **Renal Non-Anion Gap Metabolic Acidosis**

CalculatedOsm = (SerumNa * 2) + (SerumGlucose / 18) + (SerumBUN / 2.8) + (SerumEthanol / 4.6)

OsmolalGap = MeasuredOsm - CalculatedOsm

Step 3: Determine Compensation

Metabolic Acidosis

- $PaCO_2$ decreases 1.2 mmHg per 1 meq/L bicarbonate fall

Metabolic Alkalosis

- $PaCO_2$ increases 6 mmHg per 10 meq/L bicarbonate rise

Acute Respiratory Acidosis

- Bicarbonate increases 1 meq/L per 10 mmHg $PaCO_2$ rise

Chronic Respiratory Acidosis

- Bicarbonate increases 4 meq/L per 10 mmHg $PaCO_2$ rise

Acute Respiratory Alkalosis

- Bicarbonate decreases 2 meq/L per 10 mmHg $PaCO_2$ fall

Chronic Respiratory Alkalosis

- Bicarbonate decreases 4 meq/L per 10 mmHg $PaCO_2$ fall

Step 4: Define Associated Abnormalities

Calculated PaCO2

- Useful in High Anion Gap Metabolic Acidosis
- Defines concurrent respiratory abnormalities

Excess Anion Gap

- EAG > 30 mEq/L: Metabolic Alkalosis present
- EAG < 23 mEq/L: Metabolic Acidosis present

<u>The following features give you an indication that a mixed acid-base disturbance is present:</u>

The expected compensatory response does not occur

1. The **pH is normal but there is an abnormal pCO_2 and/or bicarbonate**. (Remember that compensation rarely results in a normal pH.)
2. **Changes in pCO_2 and bicarbonate occur in opposing directions**. (Remember that with compensation, changes in pCO_2 and bicarbonate parallel each other.)
3. **Change in pH is opposite to that predicted from the pCO_2 and HCO_3.**
4. Compensation exceeds upper or lower limits.

- Change in AG = Measured AG - Normal AG
- Change in bicarbonate = Measured bicarbonate - Normal bicarbonate
- Change in chloride = corrected chloride concentration - Normal chloride

Mixed metabolic disorders

- **Anion Gap and Normal Anion Gap Acidosis**.
- **Anion Gap Acidosis and Metabolic Alkalosis**
- **Normal Anion Gap Acidosis and Metabolic Alkalosis**

Rule of thumb:

- **When the PCO2 is elevated and the [HCO3-] reduced, respiratory acidosis and metabolic acidosis coexist.**
- **When the PCO2 is reduced and the [HCO3-] elevated, respiratory alkalosis and metabolic alkalosis coexist**

ABG Interpretation

Haber RJ. A practical approach to acid-base disorders. *West J Med* 1991; 155:146-51.

RULES OF THUMB:

1. **Look at pH**. Whichever side of 7.4 the pH is on, the process that caused it to shift to that side is the primary abnormality.
2. **Calculate the anion gap**. If AG≥20, there is a primary metabolic acidosis regardless of pH or serum bicarbonate concentration
3. **Calculate the excess anion gap** = total anion gap – 12 + measured bicarb.
   * If sum is > 30, then metabolic alkalosis.
   * If sum is < 23, then nongap metabolic acidosis

* Respiratory compensation occurs almost immediately in response to metab disorders
* Metab compensation occurs over 3-5 days in response to respiratory disorders

Primary Respiratory Alkalosis (eg. 7.50 / 29 / 80 / 22)

Anxiety	Pregnancy
Hypoxia	Sepsis
Lung disease w/ or w/o hypoxia	Hepatic encephalopathy
CNS disease	Mechanical ventilation
Drug use (ASA, catechol, progesterone)	

Primary Respiratory Acidosis

eg. 7.25 / 60 / 80 / 26 = acute b/c no bicarbonate compensation
eg. 7.34 / 60 / 80 / 31 = chronic b/c bicarbonate compensation

CNS depression	Impaired lung motion (PTX)
Neuromuscular disorder	Thoracic cage injury – flail chest
Acute airway obstruction	Ventilator dysfunction
Severe pneumonia or pulm edema	

Primary Metabolic Alkalosis (eg. 7.50 / 48 / 80 / 36)

* If Urine Cl is low: Vomiting, NG suction, diuretic use in past, post-hypercapnia
* If Urine Cl is normal-high: Excess mineralocorticoid activity, current diuretic use, excess alkali administration, refeeding alkalosis

Primary Metabolic Acidosis (7.20 / 21 / 80 / 8)

* Nonanion gap: GI bicarb loss (diarrhea, ureteral diversion), renal bicarb loss (RTA, early renal failure, carbonic anhydrase inhibitors, aldosterone inhibitors), HCl administration, post-hypocapnia
* Anion Gap: MUDPILES

Pearl: If anion gap>20 exists, there is a primary metabolic acidosis.

Pearl: If anion gap exists, calculate the excess anion gap to determine if an underlying metabolic alkalosis or nongap metabolic acidosis exists.

Examples

7.4 / 40 / 80 / 24, Na 145, Cl 100 --> Metab acidosis + metab alkalosis
7.5 / 20 / 80 / 15, Na 145, Cl 100 --> Resp alkalosis+ metab acidosis+ metab alkalosis
7.1 / 50 / 80 / 15, Na 145, Cl 100 --> Resp acidosis+ metab acidosis+ metab alkalosis
7.15 / 15 / 80 / 5, Na 140, Cl 110 --> Metab acidosis gap AND nongap

Arterial Blood Gas Analysis

ABG Parameter			ABG result
pH	>7.45	Alkalaemia	
	7.36-44	Normal	
	<7.35	Acidaemia	
pCO2	>45	High	
	35-45	Normal	
	<35	Low	
HCO3	>26	High	
	24+/- 2	Normal	
	<22	Low	
AG	> 16	High	
	12+/-4	Normal	
	< 8	Low	
Glucose	>10	High	
	< 2	Low	
Gap: Gap	$\frac{\Delta AG}{\Delta HCO_3} = \frac{AG - 12}{24 - HCO_3}$		
Lactate	<1.9	Normal	
	>2.0	High	
pO2	80-100	Normal	
	< 80	Hypoxia	

Calculation and interpretation

pH	pCO2	Interpretation
↓	↓	Metabolic acidosis
↑	↑	Metabolic alkalosis
↑	↓	Respiratory alkalosis
↓	↑	Respiratory acidosis

Corrected standard AG for albumin

$$\frac{Albumin}{4} + 1.5 \times Phosphate$$

Anion Gap calculation

$$\{[Na^+] - [Cl^- + HCO_3]\} = 12 +/- 4$$

Corrected Na+ for AG in hyperglycemia

$$\text{Corrected } Na^+ = Na + \frac{Glucose - 5}{3}$$

Gap: Gap calculation for metabolic acidosis

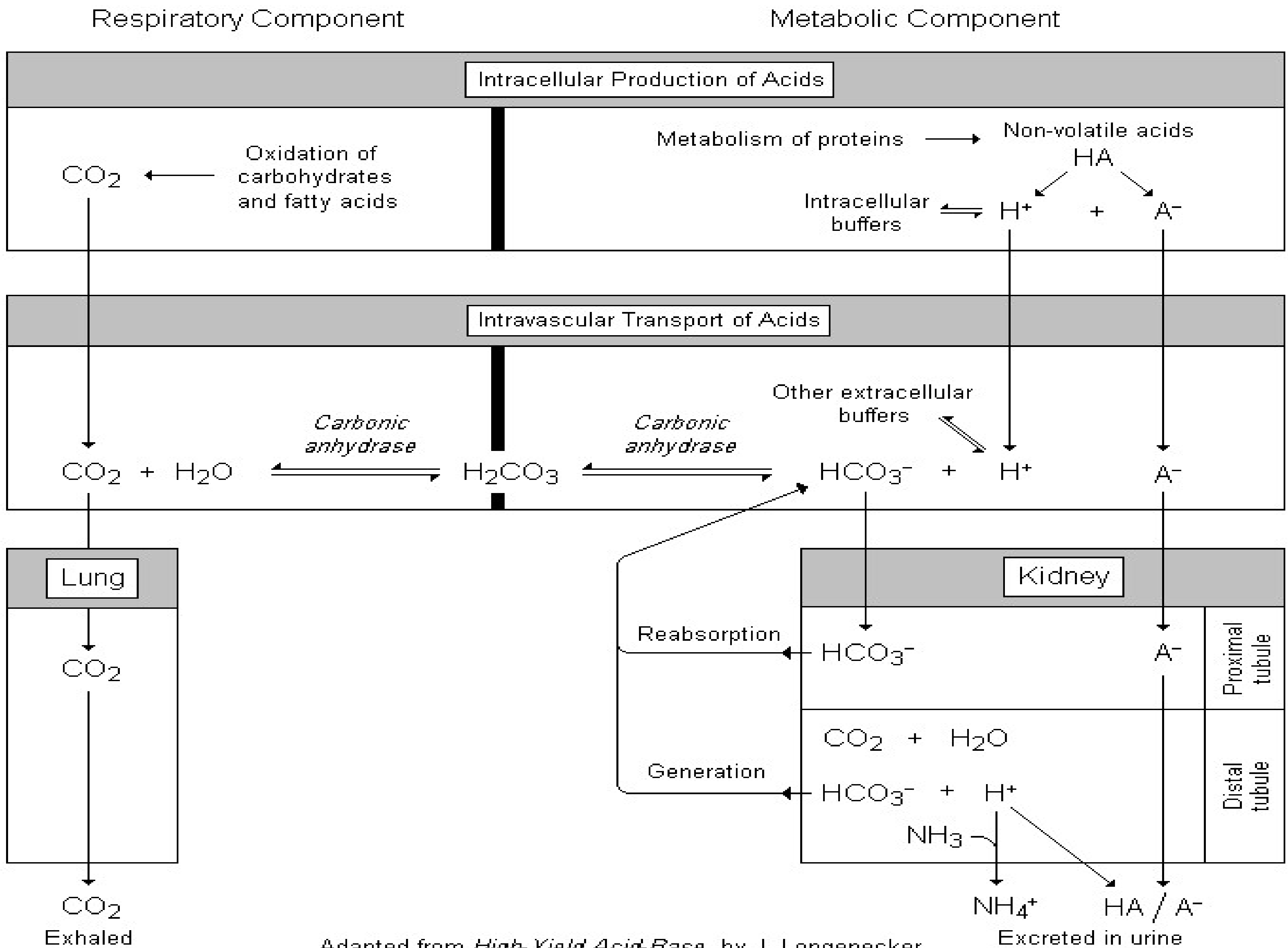
<0.4	Low or Normal AG metabolic acidosis
0.4-0.8	Normal + high AG metabolic acidosis
0.8-2.0	Pure high metabolic acidosis
>2.0	Metabolic acidosis with metabolic alkalosis/respiratory acidosis

PAO2 = [713 x FiO2] – [pCO2 x 1.25]

A-a gradient = PAO2 – PaO2 = $\frac{Age}{4} + 4$

Compensation rules for

	Metabolic acidosis		Metabolic alkalosis	
Expected PCO2	1.5 X [HCO3] + 8 (+/- 2)		0.7 X [HCO3] + 20 (+/- 5)	
	Respiratory acidosis		Respiratory alkalosis	
	Acute	Chronic	Acute	Chronic
Expected HCO3	$24 + \frac{pCO2 - 40}{10} \times 1$	$24 + \frac{pCO2 - 40}{10} \times 4$	$24 - \frac{40 - pCO2}{10} \times 2$	$24 - \frac{40 - pCO2}{10} \times 5$



Adapted from *High-Yield Acid-Base*, by J. Longenecker.

Henderson-Hasselbalch Equation

$$pH = pK_a + \log \frac{[A^-]}{[HA]} \longrightarrow pH = pK_a + \log \frac{[HCO_3^-]}{[H_2CO_3]} \longrightarrow pH = 6.1 + \log \frac{[HCO_3^-]}{(0.03 \times pCO_2)}$$

Henderson-Hasselbalch Equation

- **Normal extracell pH=7.4**
- **Acidosis pH<7.4 (death <6.8)**
- **Alkalosis pH>7.4**

Compensation (continued)

Primary Disorder	Compensatory Mechanism
Metabolic acidosis	Increased ventilation
Metabolic alkalosis	Decreased ventilation
Respiratory acidosis	Increased renal reabsorption of HCO_3^- in the proximal tubule Increased renal excretion of H in the distal tubule
Respiratory alkalosis	Decreased renal reabsorption of HCO_3^- in the proximal tubule Decreased renal excretion of H^+ in the distal tubule

The Four Primary Acid-Base Disturbances

Type of Disturbance	Primary Alteration	Secondary Response	Mechanism of Secondary Response
Metabolic acidosis	Decrease in plasma $[HCO_3^-]$	Decrease in Pa CO_3	Hyperventilation
Metabolic alkalosis	Increase in plasma $[HCO_3^-]$	Increase in $PaCO_3$	Hypoventilation
Respiratory acidosis	Increase in PaCO3	Increase in plasma $[HCO_3^-]$	Acid titration of tissue buffers; transient increase in acid excretion and sustained enhancement of HCO_3^- reabsorption by kidney
Respiratory alkalosis	Decrease in Pa CO_3	Decrease in plasma $[HCO_3^-]$	Alkaline titration of tissue buffers; transient suppression of acid excretion and sustained reduction in bicarbonate reabsorption by kidney

Rules of Thumb for Bedside Interpretation of Acid-Base Disorders

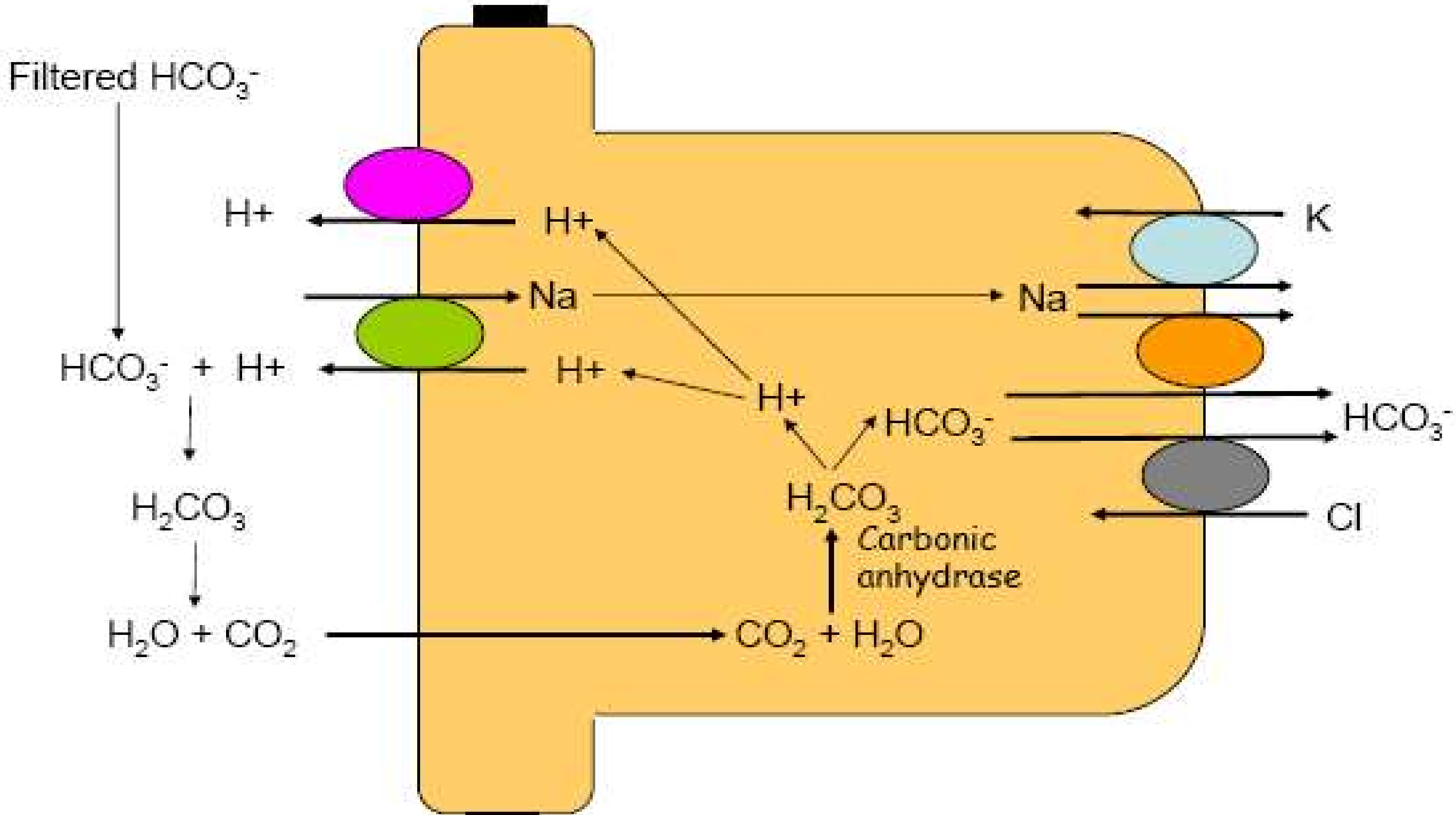
Metabolic acidosis	**$PaCO_2$ should fall by 1.0 to 1.5 X the fall in plasma HCO_3^- concentration**
Metabolic alkalosis	**$PsCO_2$ should rise by 0.25 to 1.0 X the rise in plasma HCO_3^- concentration**
Acute respiratory acidosis	**Plasma HCO_3^- concentration should rise by about 1 mmole per liter for each 10 mm Hg increment in $PaCO_2$ ($\pm$ 3 mmoles per liter).**
Chronic respiratory acidosis	**Plasma HCO_3^- concentration should rise by about 4 mmoles per liter for each 10 mm Hg increment in $PaCO_2$ ($\pm$ 4 mmoles per liter).**
Acute respiratory alkalosis	**Plasma HCO_3^- concentration should fall by about 1 to 3 mmoles per liter for each 10 mm Hg decrement in the $PaCO_2$, usually not to less than 18 mmoles per liter.**
Chronic respiratory alkalosis	**Plasma HCO_3^- concentration should fall by about 2 to 5 mmoles per liter per 10 mm Hg decrement in $PaCO_2$ but usually not to less than 14 mmoles per liter.**

Practical Approach

Most prominent disorder	**Compensation formula**
Metabolic acidosis	$pCO_2 \approx 1.5\ [HCO_3^-] + 8$
Metabolic alkalosis	$pCO_2 \approx 0.9\ [HCO_3^-] + 16$
Respiratory acidosis	For every 10 Δ in pCO_2, pH decreases by: 0.08 (in acute resp. acidoses) 0.03 (in chronic resp. acidoses)
Respiratory alkalosis	For every 10 Δ in pCO_2, pH increases by: 0.08 (in acute resp. alkaloses) 0.03 (in chronic resp. alkaloses)

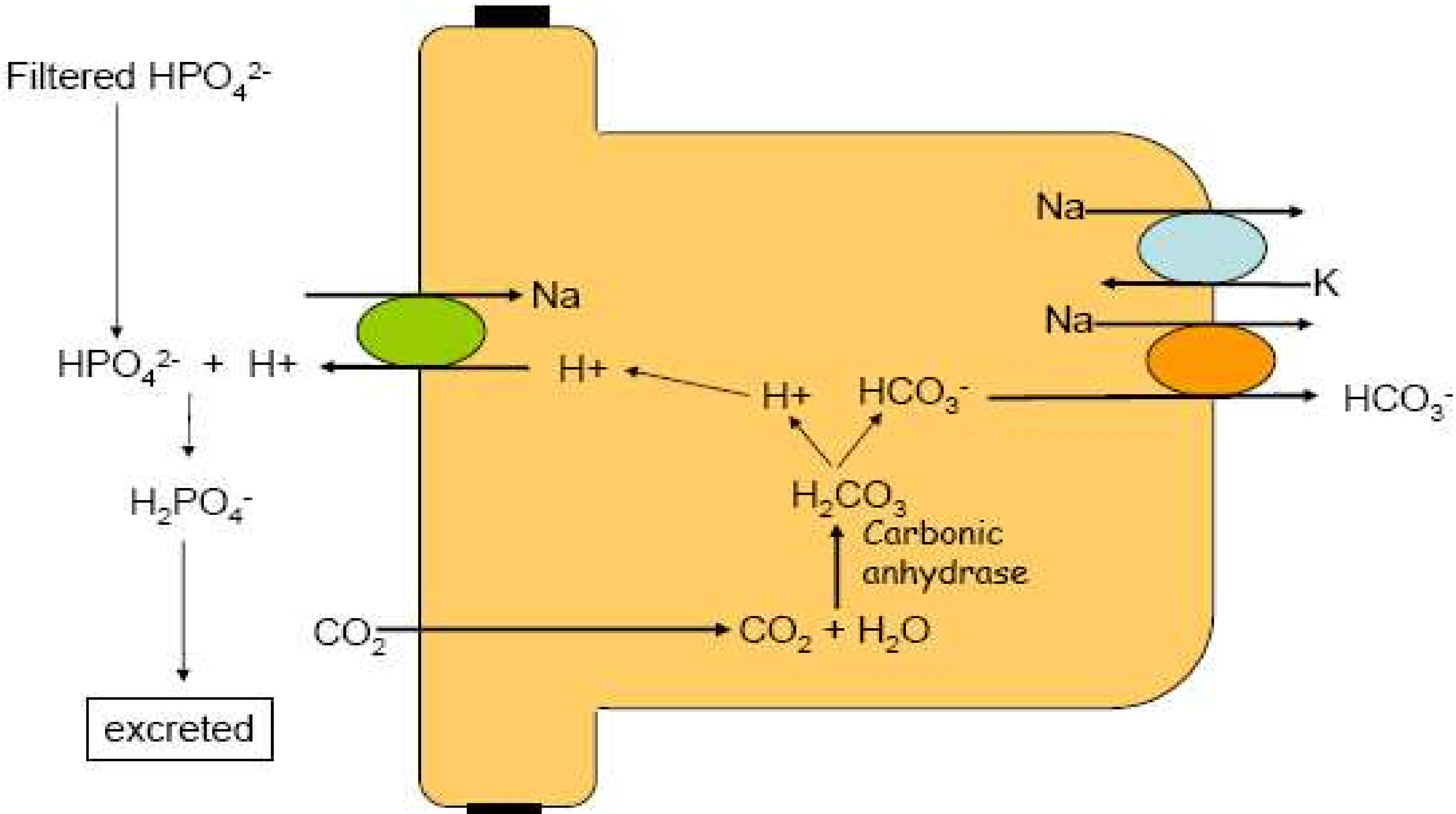
Basic Renal HCO_3^- handling

Almost all the HCO_3^- in the plasma is filtered

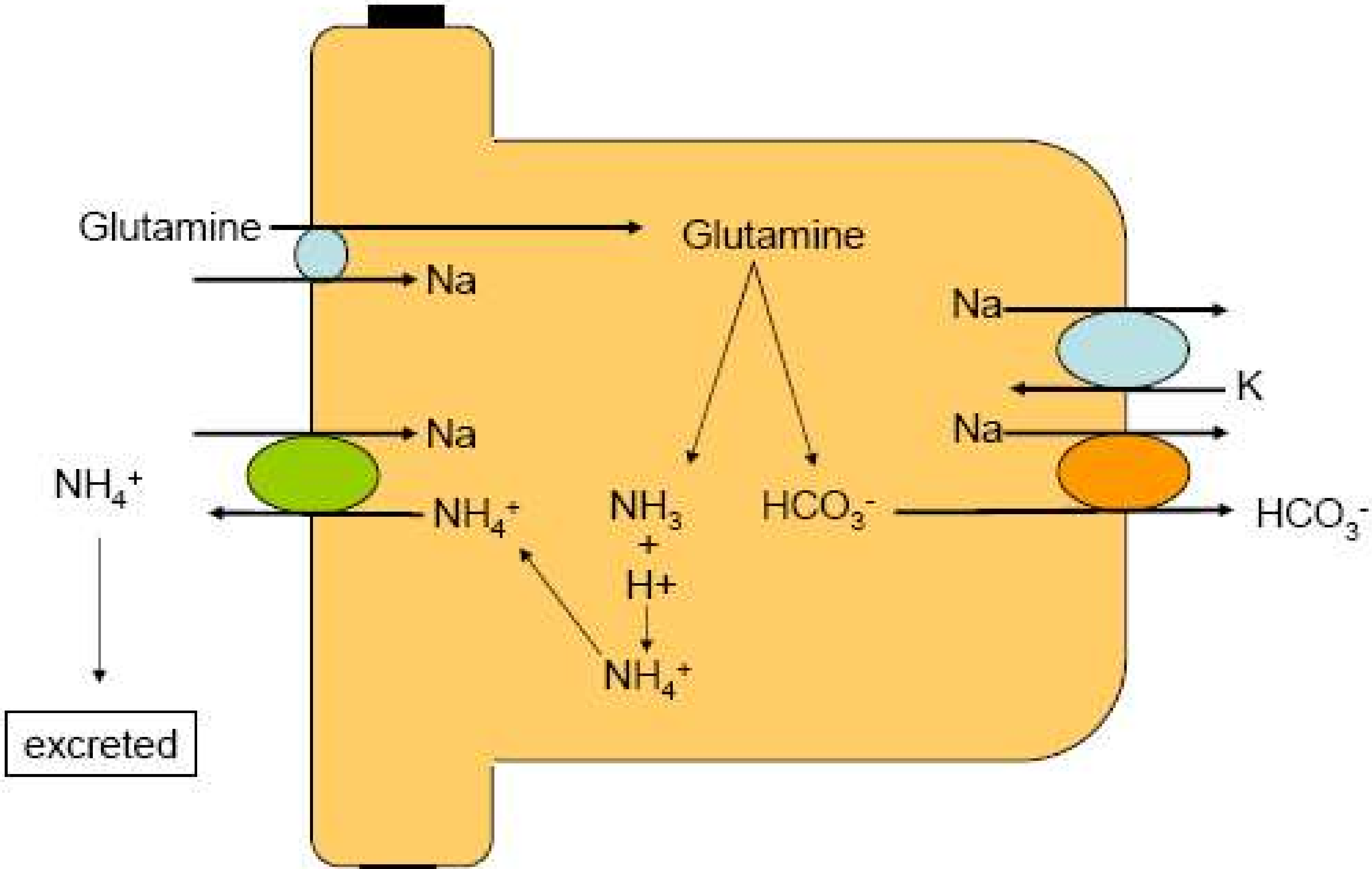


Renal HPO_4^{2-} handling and new HCO_3^-

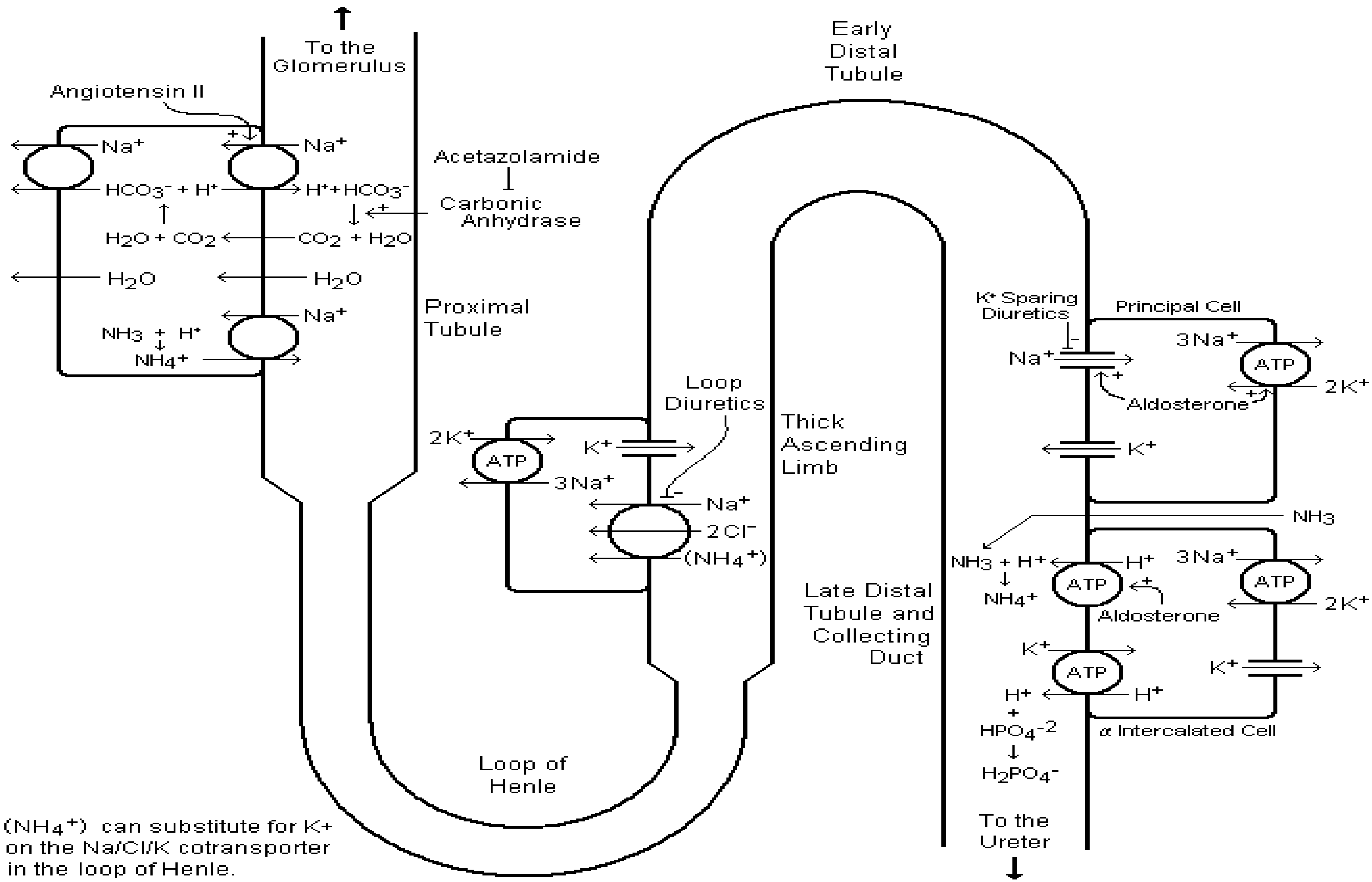
Almost all the HPO_4^{2-} in the plasma is filtered



Renal NH_4^+ handling and new HCO_3^-



Renal Regulation of Acid-Base



Practical Approach

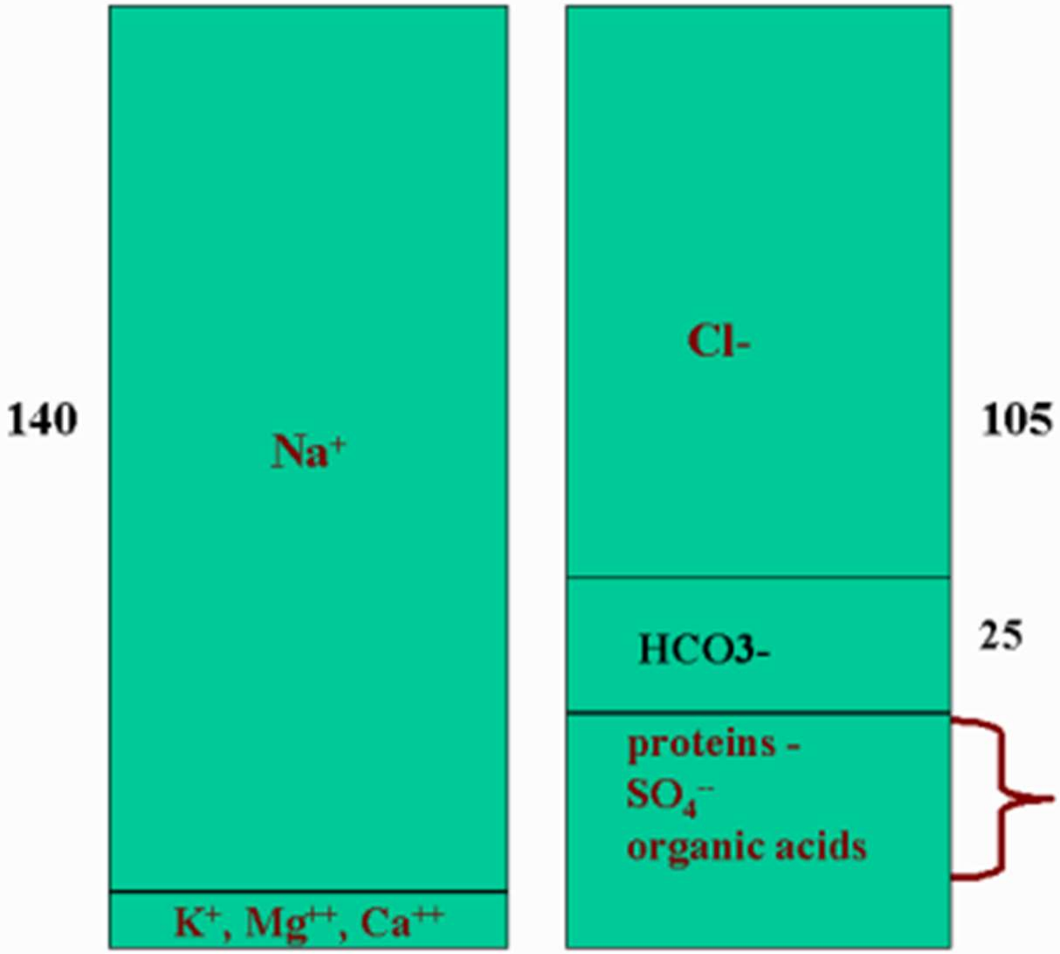
5. Calculate the anion gap

Anion gap $= [Na^+] - ([Cl^-] + [HCO_3^-])$

If the anion gap is elevated, an elevated gap metabolic acidosis is likely present.

Anion Gap (AG)

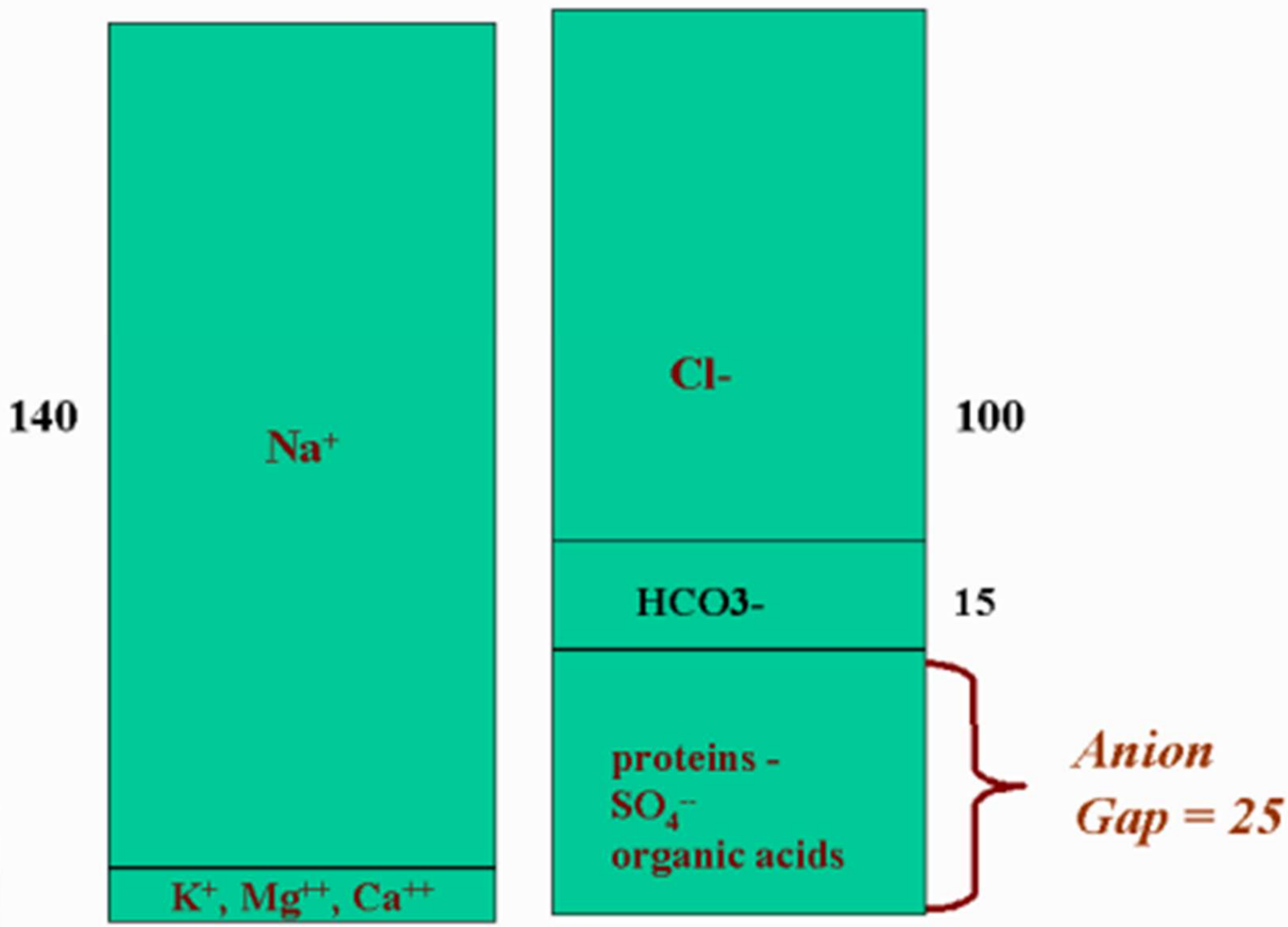
$$AG= (Na^{+}\ \ - (Cl^{-} + HCO_3^{-})$$



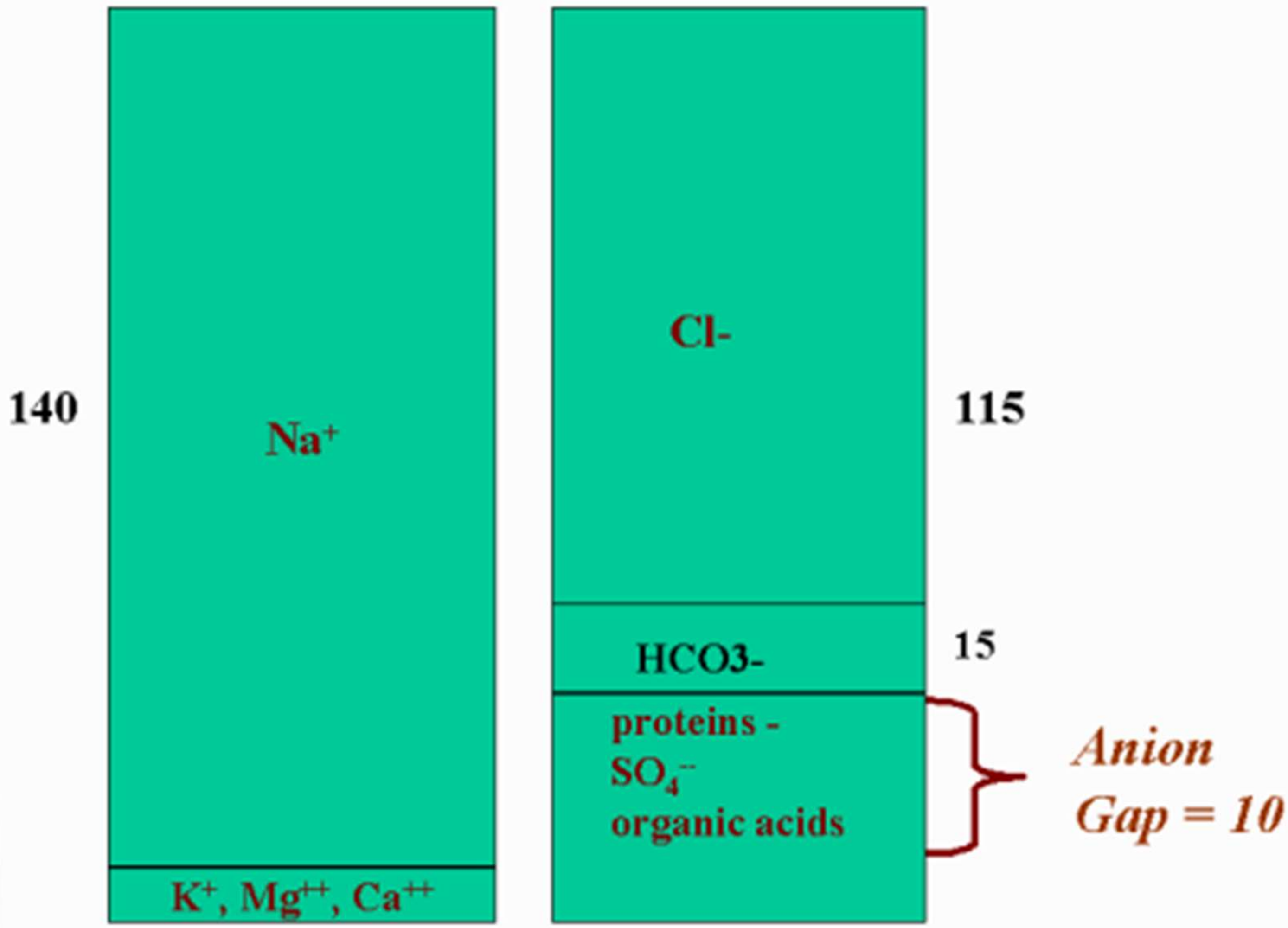
Anion Gap = 10

- Normal AG 10-14
- AG is primarily due to albumin
- Increased AG almost always due to a rise in unmeasured anions

Increased anion gap metabolic acidosis



Normal anion gap metabolic acidosis



Metabolic Acid-Base Disturbance

1. Metabolic Acidosis

A. Causes

- Diarrhea (loss of HCO_3^-)
- Acid ingestion (aspirin – acetylsalicylic acid)
- Kidney failure to secrete H^+

B. Effects

- CNS depression and coma, death

2. Metabolic Alkalosis

A. Causes

- Vomiting (loss of H^+)

B. Effects

- CNS excitability, muscle tetanus, death

Acid-Base balance

- 1. Fluid Buffering systems
- 2. Kidney
- 3. Respiratory

A buffering system

Major physiologically important buffer in blood plasma:

a) Bicarbonate

- consists of a mixture of a weak acid and its base
- **Resists changes in pH when small amounts of H+ or OH- are added**

$$CO_2 + H_2O \overset{\text{Carbonic anhydrase}}{\rightleftharpoons} H_2CO_3 \rightleftharpoons H^+ + HCO3^-$$

Respiratory system **Renal System**

First line of defense against pH shift

- **Chemical buffer system**
  - Bicarbonate buffer system
  - Phosphate buffer system
  - Protein buffer system

Second line of defense against pH shift

- **Physiological buffers**
  - Respiratory mechanism (CO_2 excretion)
  - Renal mechanism (H^+ excretion)

Anion gap Acidosis "MUDPILES"

- M ethanol
- U remia
- D iabetic Ketoacidosis, Ketoacidosis
- P araldehyde
- I ron, Isoniazid (INH)
- L actic Acidosis
- E thanol, Ethylene glycol
- S alicylates

Signs and Symptoms Gap Acidosis

- Drunk off their ____
- Hx of drug use
- Fruity breath
- Kussmaul's breathing
- tinnitus
- hypotension

Laboratory Workup

- Chemistries
  - BUN, Cr, glucose
- Lactate level
- Ketones
- Ethanol level
- Salicylate level
- Osmolal gap
- UA

Osmolar Gap
Normal (< 25mOsm/kg)

- Uremic Acidosis
- Lactic Acidosis
- Ketoacidosis
- Salicylates

Osmolar Gap

Increased (>25mOsm/kg)

- Ethylene Glycol
  - Look for Oxalate crystals in the Urine

- Methanol Intoxication
  - Visual Changes

Treatment

- Treat underlying condition

- Remember:
    - Methanol
    - Ethanol
    - Ethylene Glycol
    - Salicylates
- Can Be Removed via Dialysis

Non gap Acidosis "HARDUPS"

- H yperalimentation
- A cetazolamide, amphotericin
- R TA
- D iarrhea
- U reteral Diversions
- P ancreatic fistula
- S aline resucitation

Non Gap Acidosis
Is There Intestinal Fluid Loss?

IF YES THINK About

- Ileostomy
- Diarrhea
- Enteric Fistula