بسم الله الرحمن الرحيم

Acidosis and Alkalosis (1)

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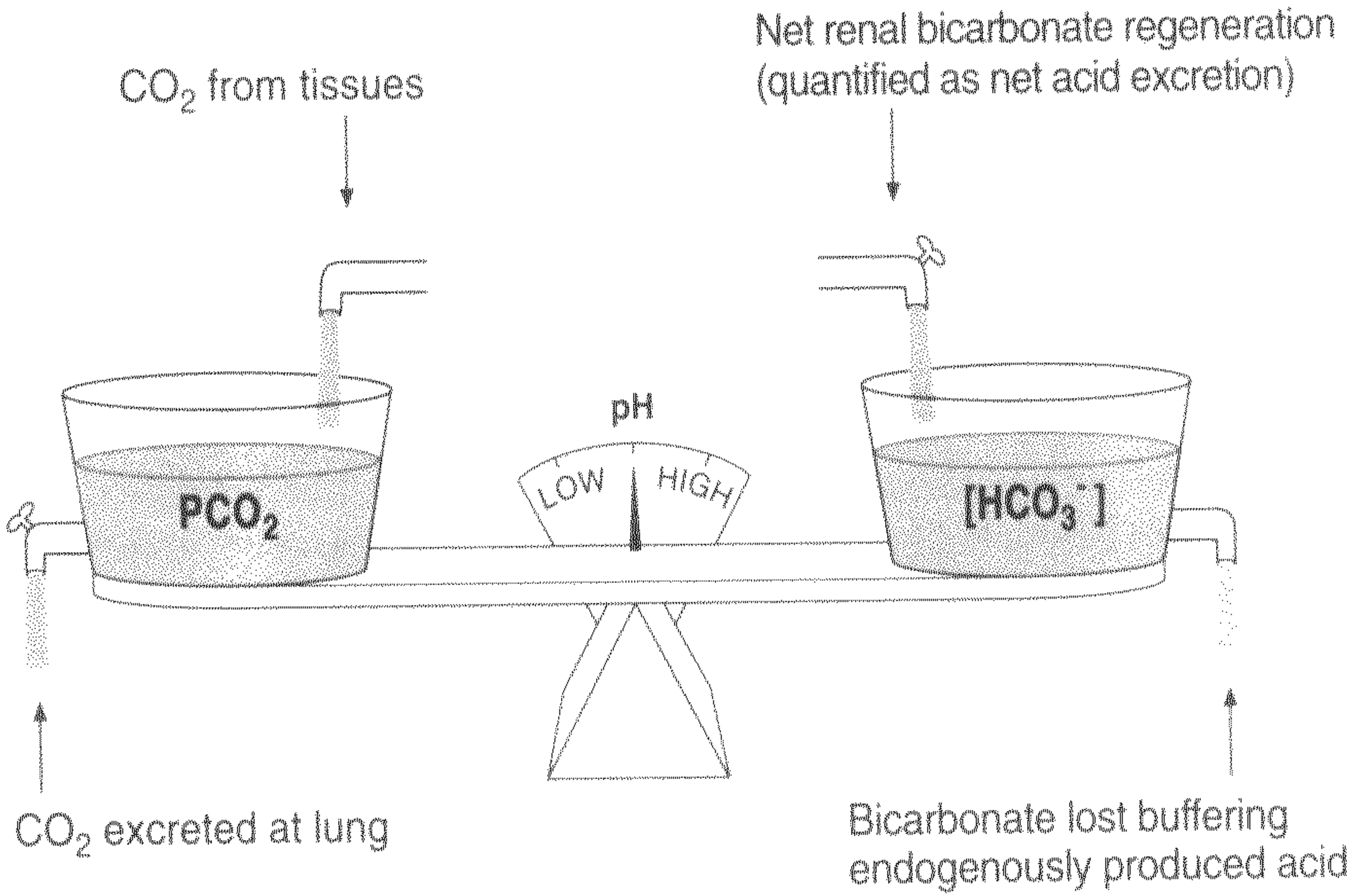
SKUMS

NORMAL ACID-BASE HOMEOSTASIS

- Systemic arterial pH is maintained between 7.35 and 7.45 by extracellular and intracellular chemical buffering together with respiratory and renal regulatory mechanisms.
- The control of arterial CO2 tension (Paco2) by the central nervous system (CNS) and respiratory systems
- and the control of the plasma bicarbonate by the kidneys stabilize the arterial pH by excretion or retention of acid or alkali.

The acid base "balance"



Abelow, Understanding Acid-Base, Williams & Wilkins 1998

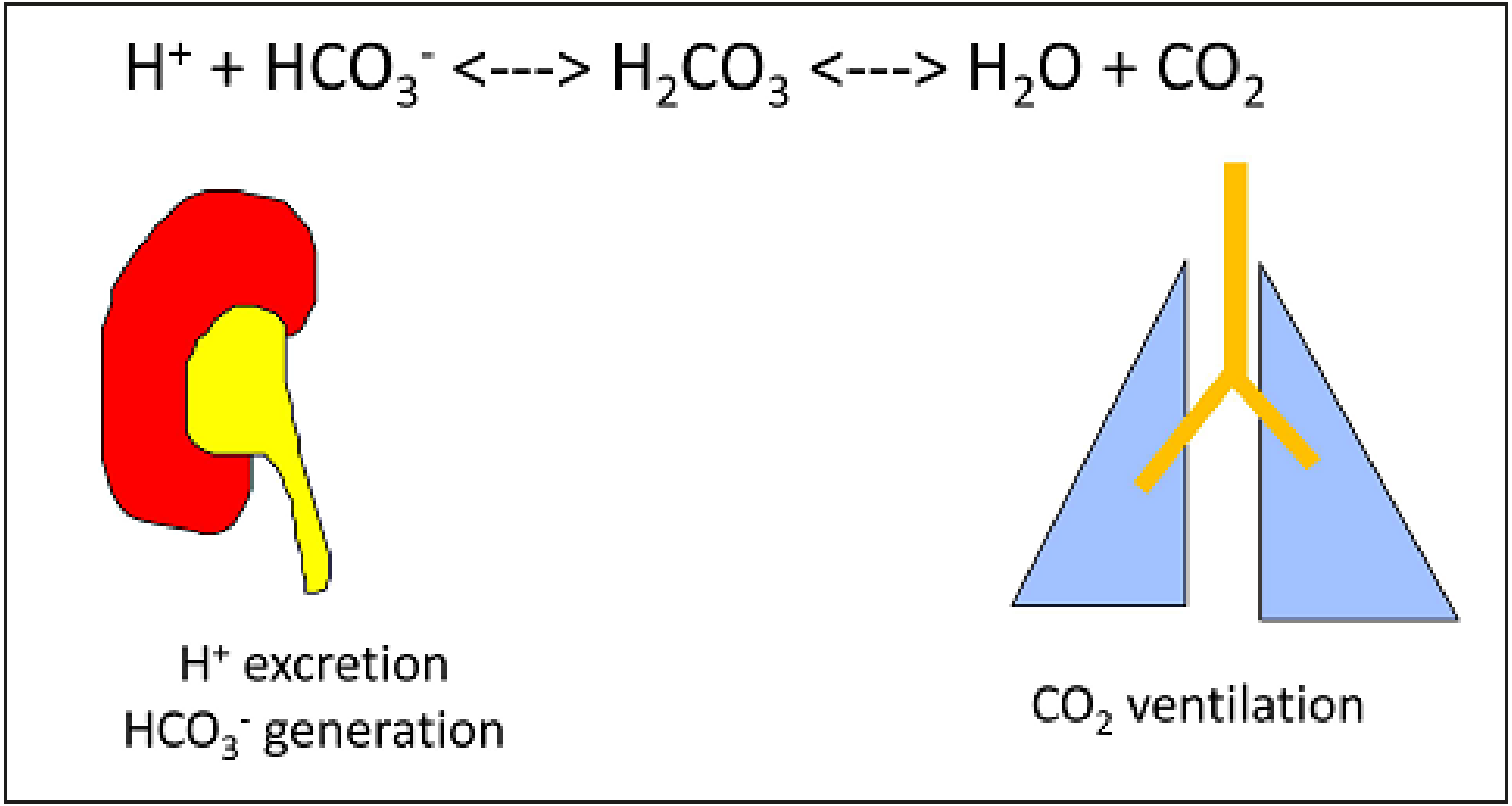


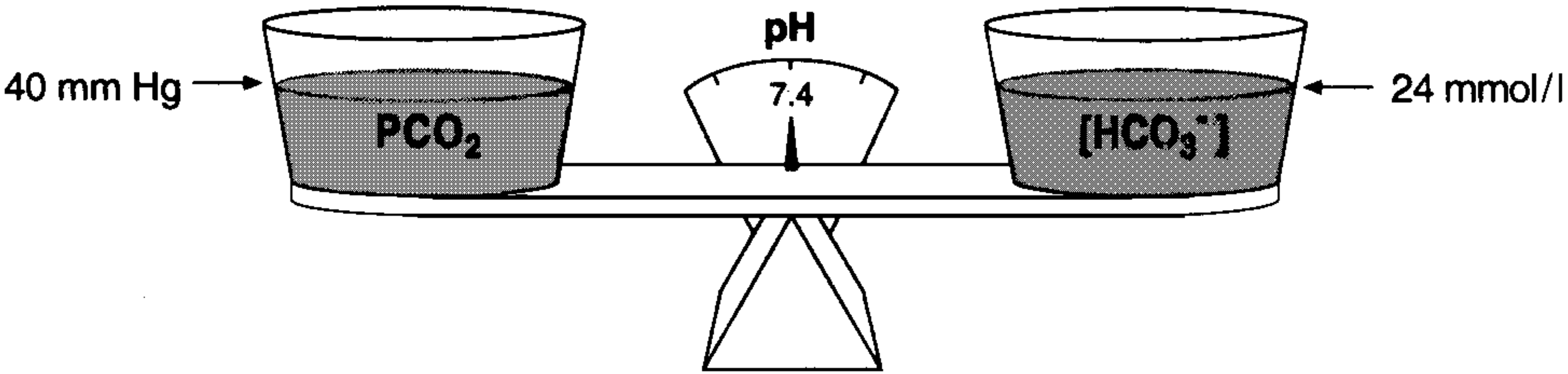
Fig 1. Acid-base balance is maintained by effective renal and respiratory homeostatic mechanisms

- The metabolic and respiratory components that regulate systemic pH are described by the
- Henderson- Hasselbalch equation:

HENDERSON-HASSELBALCH EQUATION

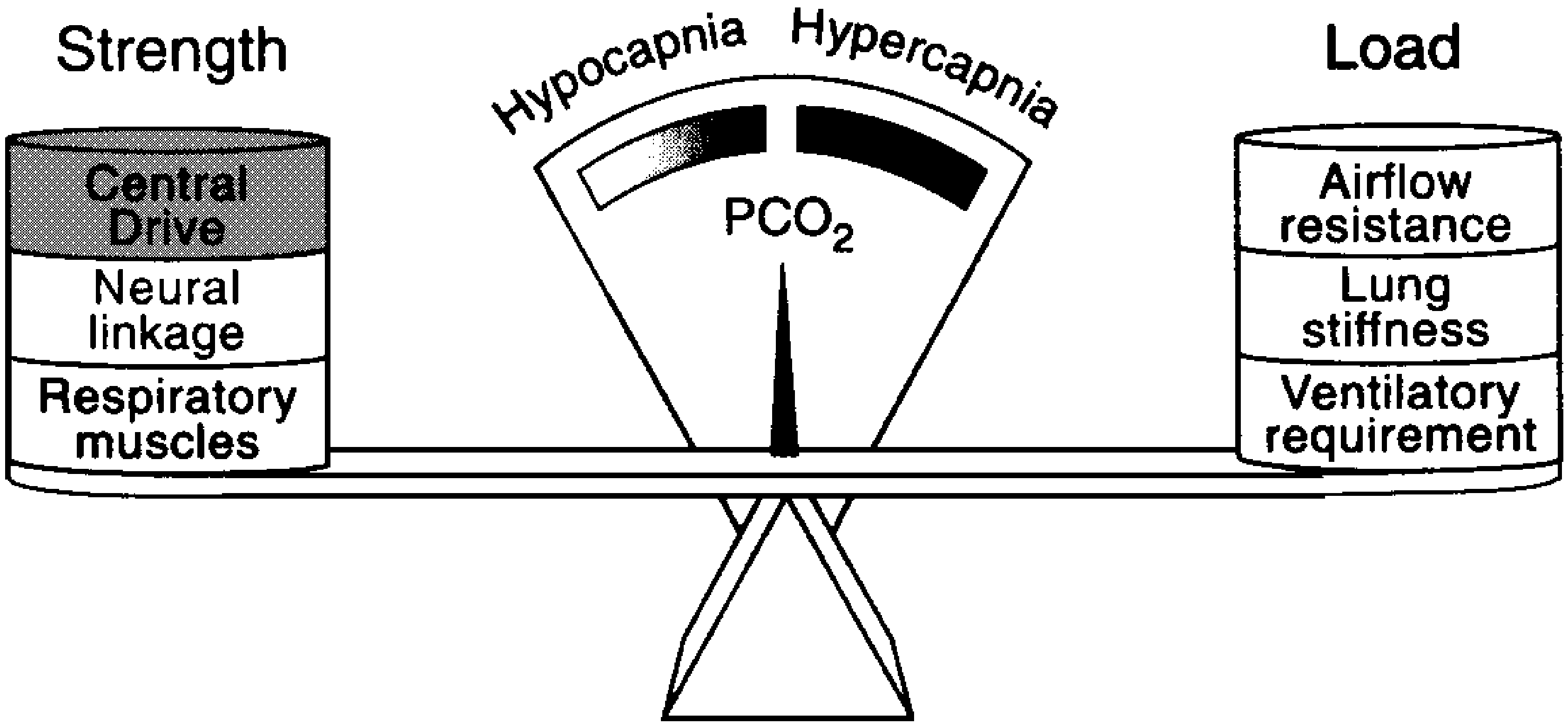
$$pH = pK + \log [HCO_3^-]/0.03PCO_2$$
$$pH = 6.1 + \log 24/(0.03 \times 40)$$
$$pH = 6.1 + \log 24/1.2$$
$$pH = 6.1 + \log 20$$
$$pH = 6.1 + 1.3$$
$$pH = 7.4$$

(Abelow B, 1998 "Understanding Acid-Base")



(Abelow B, 1998 "Understanding Acid-Base")

- Under most circumstances, CO_2 production and excretion are matched, and the usual steady-state $Paco_2$ is maintained at 40 mmHg.
- Underexcretion of CO_2 produces hypercapnia, and overexcretion causes hypocapnia.
- Nevertheless, production and excretion are again matched at a new steady-state $Paco_2$.
- Therefore, the $Paco_2$ is regulated primarily by neural respiratory factors and is not subject to regulation by the rate of CO_2 production.
- Hypercapnia is usually the result of hypoventilation rather than of increased CO_2 production.
- Increases or decreases in $Paco_2$ represent derangements of neural respiratory control or are due to compensatory changes in response to a primary alteration in the plasma [HCO_3^-].



(Abelow B, 1998 "Understanding Acid-Base")

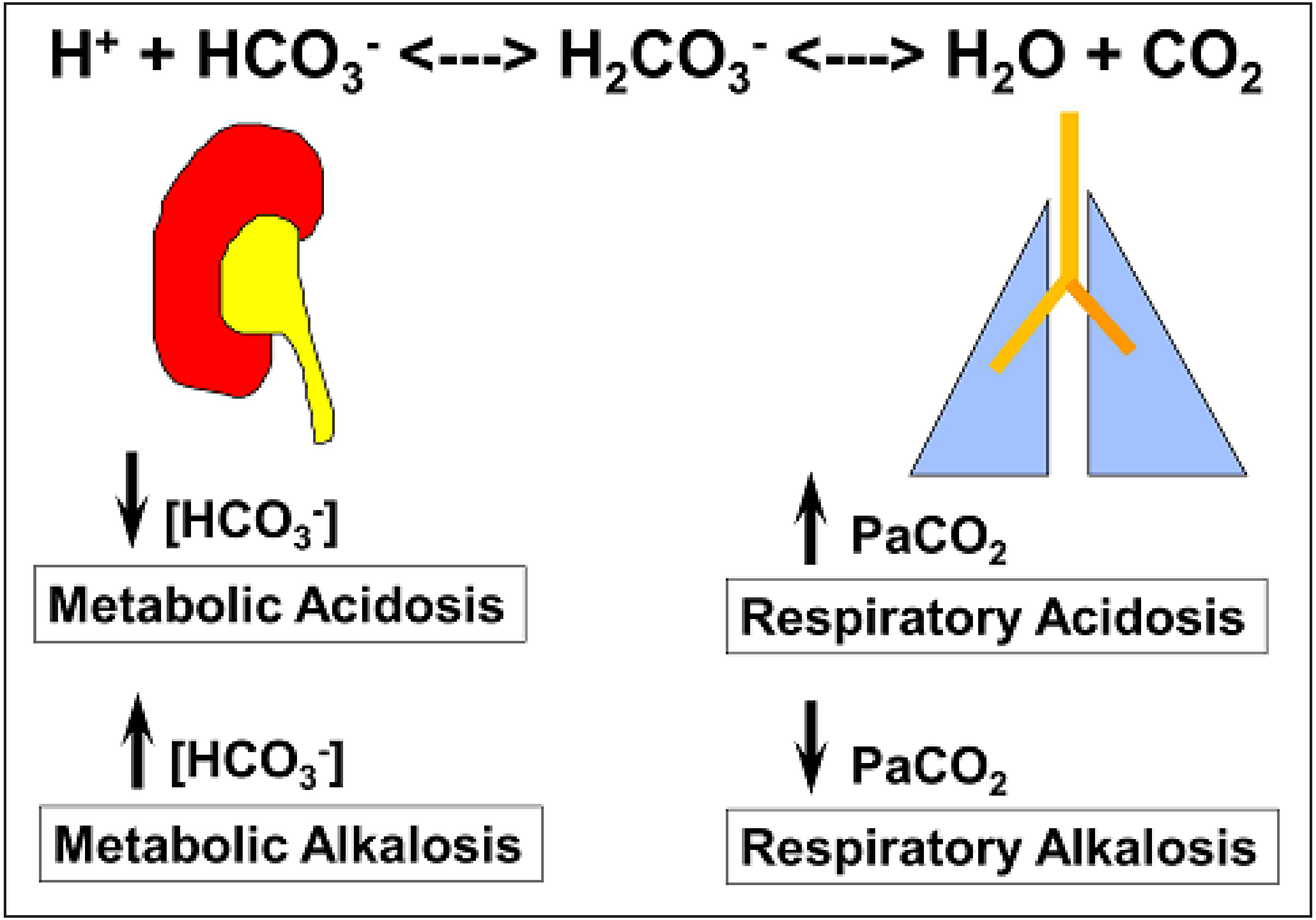
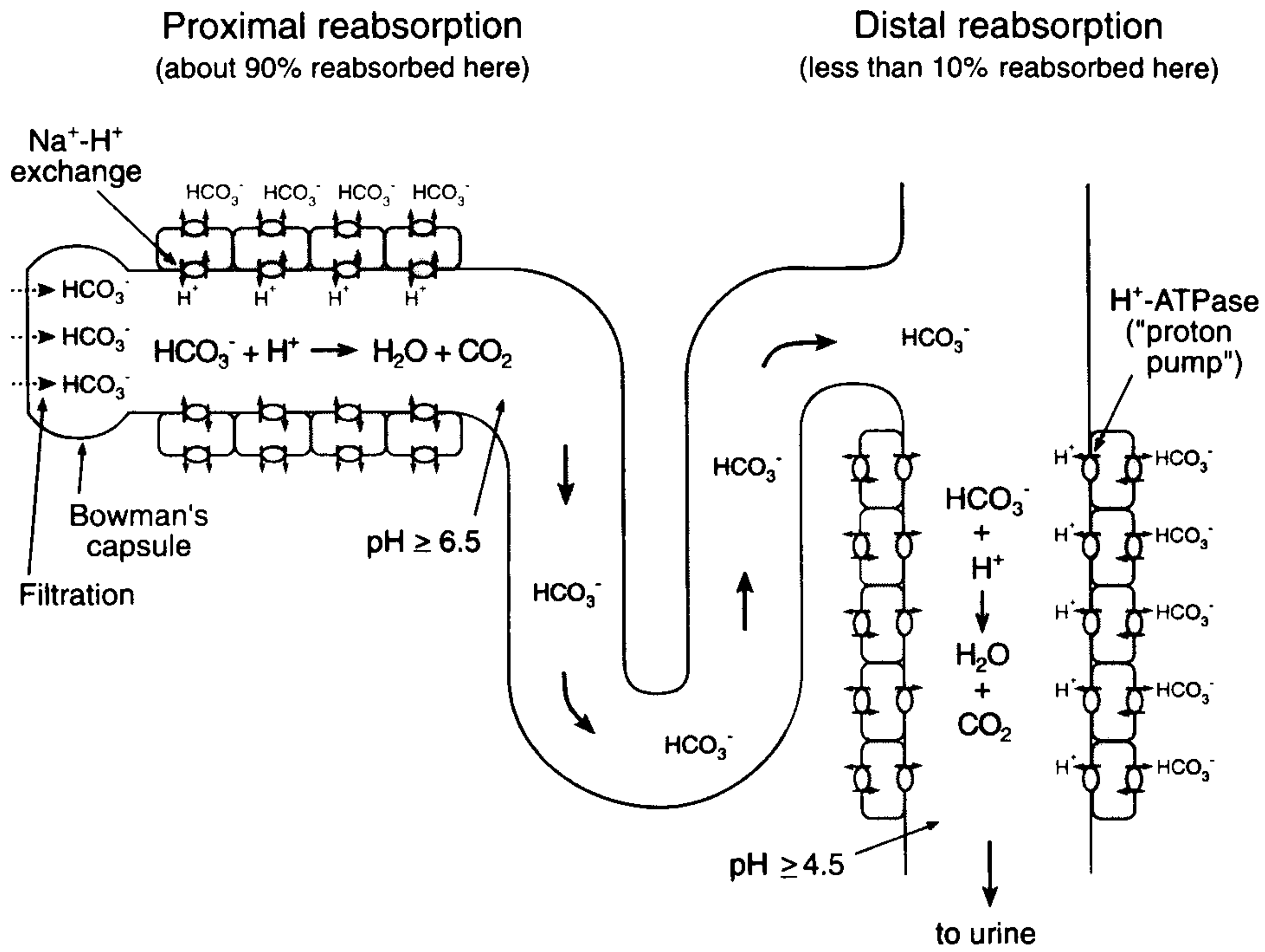


Fig 2. Changes in $PaCO_2$ level and bicarbonate concentration [HCO_3^-] can help identify the nature of the acid-base disorder.

The kidneys regulate plasma [HCO_3^-]

- through three main processes:
  - (1) "reabsorption" of filtered HCO_3^-,
  - (2) formation of titratable acid, and
  - (3) excretion of NH_4^+ in the urine.

Renal bicarbonate reabsorption



Abelow, Understanding Acid-Base, Williams & Wilkins 1998

- The kidney filters 4000 mmol of HCO_3^- per day. To reabsorb the filtered load of HCO_3^-, the renal tubules must therefore secrete 4000 mmol of hydrogen ions.
- Between 80 and 90% of HCO_3^- is reabsorbed in the proximal tubule.
- The distal nephron reabsorbs the remainder and secretes H^+ to defend systemic pH.

- While this quantity of protons, 40–60 mmol/d, is small, it must be secreted to prevent chronic positive H+ balance and metabolic acidosis.
- This quantity of secreted protons is represented in the urine as titratable acid and NH4+.
- Metabolic acidosis in the face of normal renal function increases NH4+ production and excretion.
- NH4+ production and excretion are impaired in
  1. chronic renal failure,
  2. hyperkalemia, and
  3. renal tubular acidosis

DIAGNOSIS OF GENERAL TYPES OF DISTURBANCES

- The most common clinical disturbances are simple acid-base disorders;
- i.e., metabolic acidosis or alkalosis or respiratory acidosis or alkalosis.
- Because compensation is not complete, the pH is abnormal in simple disturbances.
- More complicated clinical situations can give rise to mixed acid-base disturbances.

Simple Acid-Base Disorders

- Primary respiratory disturbances (primary changes in Paco2) invoke compensatory metabolic responses (secondary changes in [HCO_3^-]),
- and primary metabolic disturbances elicit predictable compensatory respiratory responses (secondary changes in Paco2)

- Physiologic compensation can be predicted from the relationships

Primary Acid-Base Disturbances with a Secondary ("Compensatory") Response

- **Metabolic acidosis**
  - pH <7.38 and bicarbonate [HCO3 −] <22 mmol per liter
  - Secondary (respiratory) response:
    - **Paco2 = 1.5 × [HCO3 −] + 8±2 mm Hg†**
    - or [HCO3 −] + 15 mm Hg‡
  - Complete secondary adaptive response within 12–24 hr
  - Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated Paco2 is greater or less than predicted

Primary Acid-Base Disturbances with a Secondary ("Compensatory") Response

- **Metabolic alkalosis**
  - pH >7.42 and [HCO3 −] >26 mmol per liter
  - Secondary (respiratory) response: Paco2 = 0.7 × ([HCO3 −] – 24) + 40±2 mm Hg
  - or **[HCO3 −] + 15 mm Hg**‡
  - or 0.7 × [HCO3 −] + 20 mm Hg§
  - Complete secondary adaptive response within 24–36 hr
  - Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated Paco2 is greater or less than predicted

Primary Acid-Base Disturbances with a Secondary ("Compensatory") Response

- **Respiratory acidosis**
  - pH <7.38 and Paco2 >42 mm Hg
  - Secondary (metabolic) response
    - Acute: $[HCO_3^-]$ is increased by 1 mmol/liter for each Paco2 increase of 10 mm Hg above 40 mm Hg
    - Chronic: generally $[HCO_3^-]$ is increased by 4-5 mmol/liter for each Paco2 increase of 10 mm Hg above 40 mm Hg
  - Complete secondary adaptive response within 2–5 days
  - Superimposed metabolic alkalosis or acidosis may be diagnosed if the calculated $[HCO_3^-]$ is greater or less than predicted

Primary Acid-Base Disturbances with a Secondary (“Compensatory”) Response

- **Respiratory alkalosis**
  - pH >7.42 and Paco2 <38 mm Hg
  - Secondary (metabolic) response
    - Acute: [HCO3 −] is decreased by 2 mmol/liter for each Paco2 decrease of 10 mm Hg below 40 mm Hg
    - Chronic: [HCO3 −] is decreased by 4–5 mmol/liter for each Paco2 decrease of 10 mm Hg below 40 mm Hg
  - Complete secondary adaptive response in 2–5 days
  - Superimposed metabolic alkalosis or acidosis may be diagnosed if the calculated [HCO3 −] is greater or less than predicted

Compensation Example

- Metabolic acidosis due to an increase in endogenous acids (e.g., ketoacidosis) lowers extracellular fluid [HCO_3^-] and decreases extracellular pH.
- This stimulates the medullary chemoreceptors to increase ventilation and to return the ratio of [HCO_3^-] to Pa_{CO_2}, and thus pH, toward, but not to, normal.
- The degree of respiratory compensation expected in a simple form of metabolic acidosis can be predicted from the relationship:
- $Pa_{CO_2} = (1.5 \times [HCO_3^-]) + 8 \pm 2$.
- Thus, a patient with metabolic acidosis and [HCO_3^-] of 12 mmol/L would be expected to have a Pa_{CO_2} between 24 and 28 mmHg.
- Values for Pa_{CO_2} <24 or >28 mmHg define a mixed disturbance (metabolic acidosis and respiratory alkalosis or metabolic alkalosis and respiratory acidosis, respectively).

TABLE 51-1 Prediction of Compensatory Responses to Simple Acid-Base Disturbances and Pattern of Changes

DISORDER	PREDICTION OF COMPENSATION	RANGE OF VALUES		
		pH	HCO_3^-	Pa_{CO_2}
Metabolic acidosis	$Pa_{CO_2} = (1.5 \times HCO_3^-) + 8 \pm 2$ *or* Pa_{CO_2} will ↓ 1.25 mmHg per mmol/L ↓ in $[HCO_3^-]$ *or* $Pa_{CO_2} = [HCO_3^-] + 15$	Low	Low	Low
Metabolic alkalosis	Pa_{CO_2} will ↑ 0.75 mmHg per mmol/L ↑ in $[HCO_3^-]$ *or* Pa_{CO_2} will ↑ 6 mmHg per 10 mmol/L ↑ in $[HCO_3^-]$ *or* $Pa_{CO_2} = [HCO_3^-] + 15$	High	High	High
Respiratory alkalosis		High	Low	Low
Acute	$[HCO_3^-]$ will ↓ 0.2 mmol/L per mmHg ↓ in Pa_{CO_2}			
Chronic	$[HCO_3^-]$ will ↓ 0.4 mmol/L per mmHg ↓ in Pa_{CO_2}			
Respiratory acidosis		Low	High	High
Acute	$[HCO_3^-]$ will ↑ 0.1 mmol/L per mmHg ↑ in Pa_{CO_2}			
Chronic	$[HCO_3^-]$ will ↑ 0.4 mmol/L per mmHg ↑ in Pa_{CO_2}			