Acid Base Terminology

Acid

Donates a hydrogen ion (H^+)

Base

Accepts a hydrogen ion (H^+)

pH

Negative logarithm of the hydrogen ion concentration

Arterial Blood Gas

Used to assess acid base status and alveolar oxygenation

Mixed Venous Blood Gas

Sampled from a Pulmonary Artery Catheter
Used to assess tissue oxygenation

Normal Arterial Blood Gas Values*

pH:	7.35 - 7.45
$PaCO_2$	35 - 45 mm Hg
HCO_3^-	22 - 26 meq/l
Base Excess	-2 to +2
PaO_2	80 - 100 mm Hg
SaO_2	95% or greater

*At sea level, pH = 7.4, temperature =37.0^0 C, & $PaCO_2$ 40 mm Hg

Acidemia vs Alkalemia

Acidemia: pH< 7.35

Accumulate too much acid or lose too much base

pH<6.8 incompatible with life

Alkalemia: pH > 7.45

Accumulate too much base or lose too much acid

pH > 7.8 incompatible with life

Carbonic Acid:

$$H^+ + HCO_3^- \leftrightarrow H_2C0_3 \leftrightarrow H_20 + CO_2$$
$$\Uparrow \text{ carbonic anhydrase}$$

Protein:

Hemoglobin - Binds to CO_2 and H^+ forming HHb and $Hb \cdot CO_2$

Phosphate:

$$HPO_4^{-2} + H^+ \rightarrow H_2PO_4^-$$

Effects of Changes in Ventilation

Hypoventilation → ↑ CO_2 Retention → Acidemia

Hyperventilation → ↓ CO_2 Retention → Alkalemia

Influence of Non-Respiratory Acid Base Disturbances on the Respiratory System

Non-respiratory Acidosis → Increased Ventilation

Non-respiratory Alkalosis →Decreased Ventilation

Metabolic Causes of Acidosis:

Will see: ↓ HCO_3^- or ↑ H^+

To compensate or correct

Kidneys Increase Excretion of H^+ and Retention of HCO_3^-

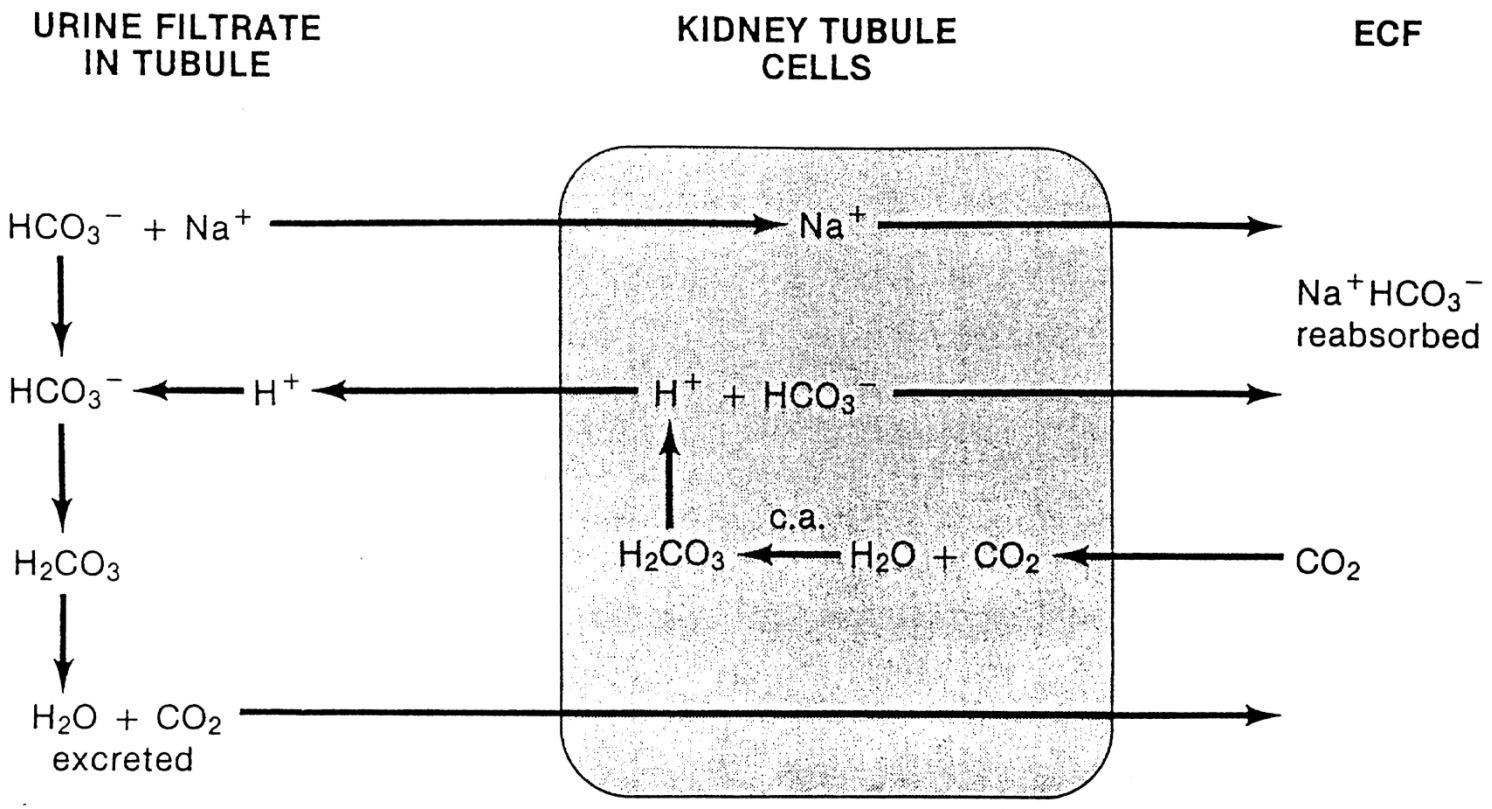
Metabolic Causes of Alkalosis:

Will see ↑ HCO_3^- or ↓ H^+

To compensate or correct

Kidneys Increase Excretion of HCO_3^- and Retention of H^+

Tubular Control of H^+ by the Bicarbonate-Carbonic Acid System



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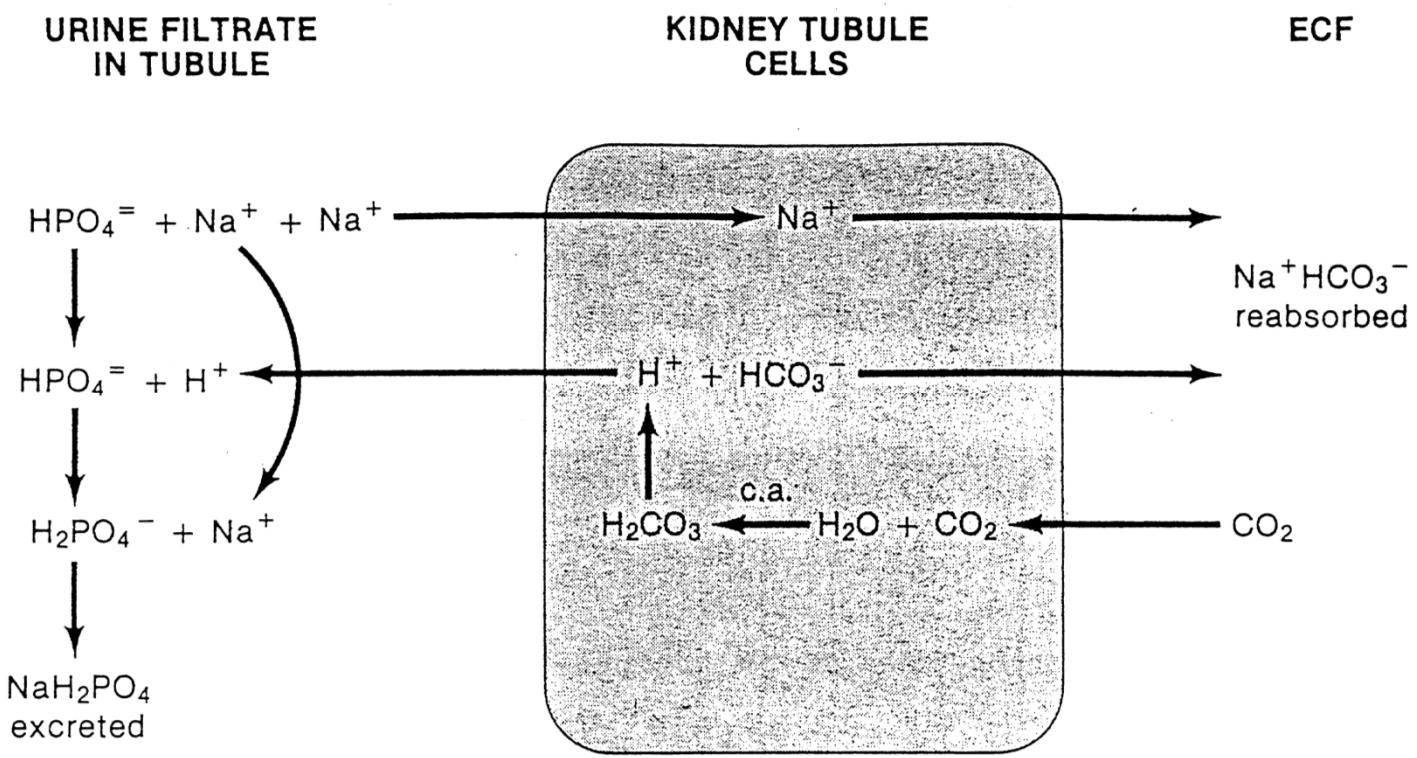
Tubular Control of H^+ by Phosphate



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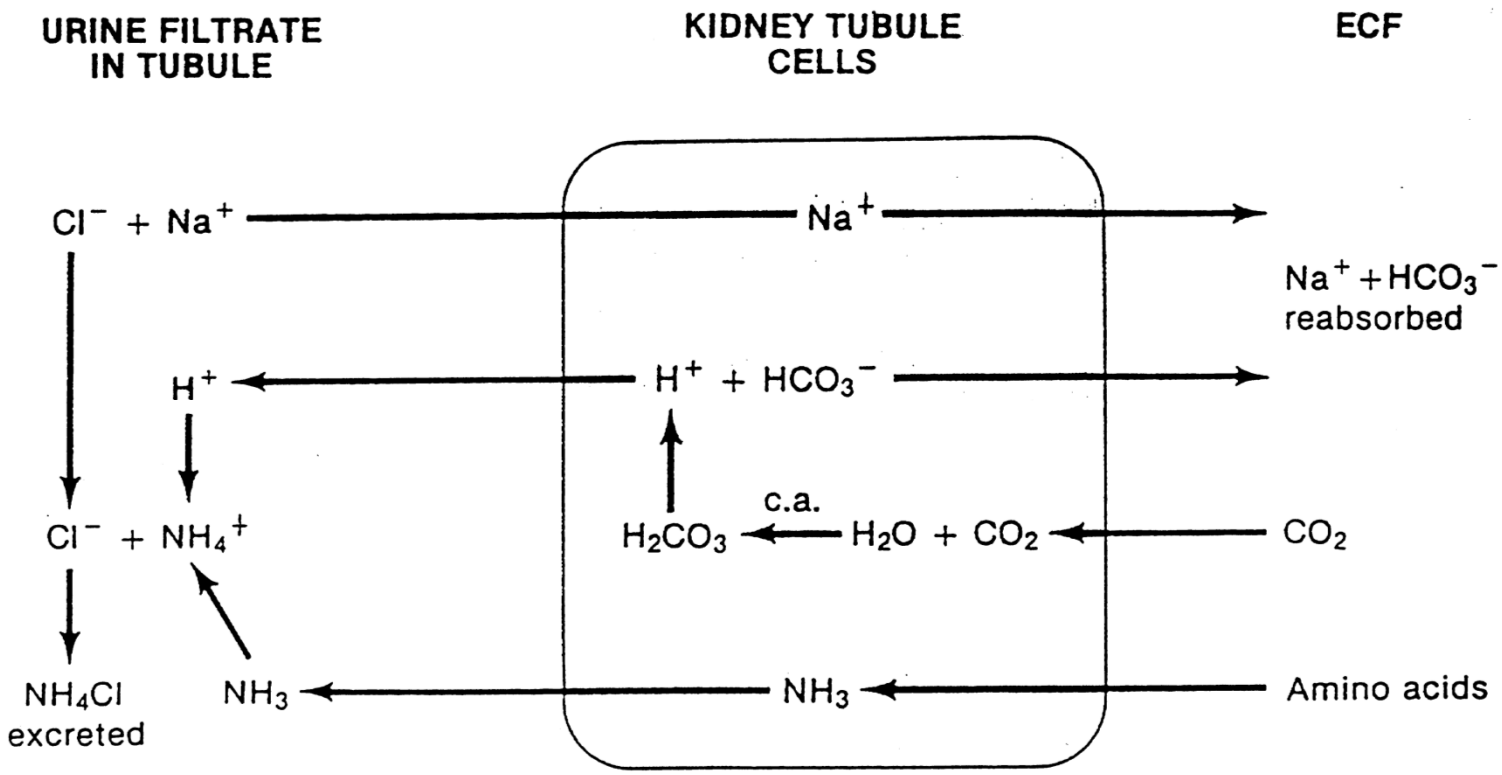
Tubular Control of H^+ by Ammonia



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Correction vs Compensation

Correction:

- Primary disorder is repaired - all acid base parameters return to normal

Compensation:

- Primary disorder continues, opposite system begins to adjust
- Attempts to restore ratio of 1 part acid to 20 parts base
- Can be partial or complete compensation

Steps to Acid Base Interpretation

1. **Analyze each acid base parameter.**

   pH: **Low, Normal or High?**

   $PaCO_2$ **Low, Normal or High?**

   HCO_3^- **Low, Normal or High?**

2. **Match acid base disturbance with parameter causing disturbance**

   pH ↓ and $PaCO_2$ ↑ = Respiratory Acidosis

   pH ↑ and $PaCO_2$ ↓ = Respiratory Alkalosis

   pH ↓ and HCO_3^- ↓ = Metabolic Acidosis

   pH ↑ and HCO_3^- ↑ = Metabolic Alkalosis

Practice Acid Base Interpretation

pH	$PaCO_2$	HCO_3^-	Interpretation
7.31	48	24	_____
7.47	45	33	_____
7.20	36	14	_____
7.50	29	22	_____
7.23	59	22	_____
7.50	38	30	_____
7.40	41	25.5	_____
7.49	44	33.8	_____

3. Look for Compensation

All variables are abnormal

Either the $PaCO_2$ or the HCO_3^- abnormality would cause the acid base change.

The opposite system has changed in a manner that would have caused the opposite pH change.

Example: **pH < 7.37**
$PaCO_2$ ↓
HCO_3^- ↓
Disturbance: Metabolic Acidosis with Respiratory Compensation

Example: **pH > 7.42**
$PaCO_2$ ↑
HCO_3^- ↑
Disturbance: Metabolic Alkalosis with Respiratory Compensation

Practice Acid Base Interpretation (Compensation)

pH	$PaCO_2$	HCO_3^-	Interpretation
7.36	56	31.4	_____
7.43	32	21	_____
7.46	29	18.1	_____
7.34	70	42	_____
7.47	49	33.1	_____
7.42	31	20	_____

4. Look for Combined Disorders

All acid Base parameters are abnormal

Both the $PaCO_2$ and HCO_3^- would have caused the pH to change in the manner that occurred

Examples:

pH	$PaCO_2$	HCO_3^-	Interpretation
7.09	50	15	_____
7.54	33	27.8	_____

Respiratory Acidosis

Blood Gas Values:
pH < 7.35
$PaCO_2$ > 45 mm Hg,
HCO_3^- normal or elevated

Causes: (Alveolar Hypoventilation)

a. Depression of the respiratory center
b. Respiratory muscle paralysis
c. Chest wall disorders
d. Disorders of the lung parenchyma
e. Alteration in the function of the abdominal system

Signs and symptoms:

a. CNS depression
b. Muscle twitching which can progress to convulsions
c. Arrhythmias, tachycardia, diaphoresis
d. Palpitations
e. Flushed skin
f. Electrolyte abnormalities

Compensation:

Increased H^+ secretion and increased HCO_3^- reabsorption

Treatment:

Increase / Improve ventilation

Respiratory Alkalosis

Blood Gas Values:

pH > 7.45

$PaCO_2$ < 35 mm Hg

HCO_3^- normal or decreased

Causes:

(Alveolar Hyperventilation)

a. Psychogenic

b. CNS stimulation

c. Hypermetabolic states

Signs and Symptoms:

a. Headache

b. Vertigo

c. Paresthesias, carpal pedal spasm and tetany

d. Tinnutis

e. Electrolyte abnormalities

Compensation:

Decrease H^+ secretion and increased HCO_3^- excretion

Treatment:

Slow the hyperventilation

Metabolic Acidosis

Blood Gas Values

pH < 7.35
$PaCO_2$ normal (rarely) or decreased
$HCO3^-$ < 22 meq/l.

Causes: (Increase in H^+ or an excess loss of HCO_3^-)

a. Overproduction of organic acids
b. Impaired renal excretion of acid
c. Abnormal loss of HCO_3
d. Ingestion of acid

Signs and Symptoms:

Central nervous system depression
Cardiac Arrhythmias
Electrolyte abnormalities
Flushed skin
Nausea

Compensation:

Lungs increase ventilatory effort

Treatment:

Cause specific
Assess hemodynamic and respiratory status
Careful administration of $NaHCO_3$

Anion Gap

Definition:
Unmeasured anions in the serum

Calculated Value:
$(Na^+ + K^+) - (HCO_3^- - Cl^-)$

Normal Value: 12 ± 2

Acidosis with Increased Anion Gap:
Accumulation of anions other than Cl^-

Acidosis with Normal Anion Gap:
Renal Reabsorption of Cl^- due to the loss of HCO_3^-

Metabolic Alkalosis

Blood Gas Values

pH > 7.45
$PaCO_2$ normal (rarely) or increased
HCO_3^- > 26 meq/l

Causes: (A loss of hydrogen ions or an increase in HCO_3^-)

a. Large losses of gastric contents
b. Loss of potassium chloride
c. Ingestion of large amounts of bicarbonate
d. Prolonged use of diuretics

Signs and Symptoms:

a. Diaphoresis
b. Nausea and vomiting
c. Increased neuromuscular excitability
d. Shallow breathing
e. EKG changes
f. Confusion, lethargy to coma
g. Electrolyte abnormalities

Compensation:

Decrease in respiratory rate and depth of ventilation to retain CO_2

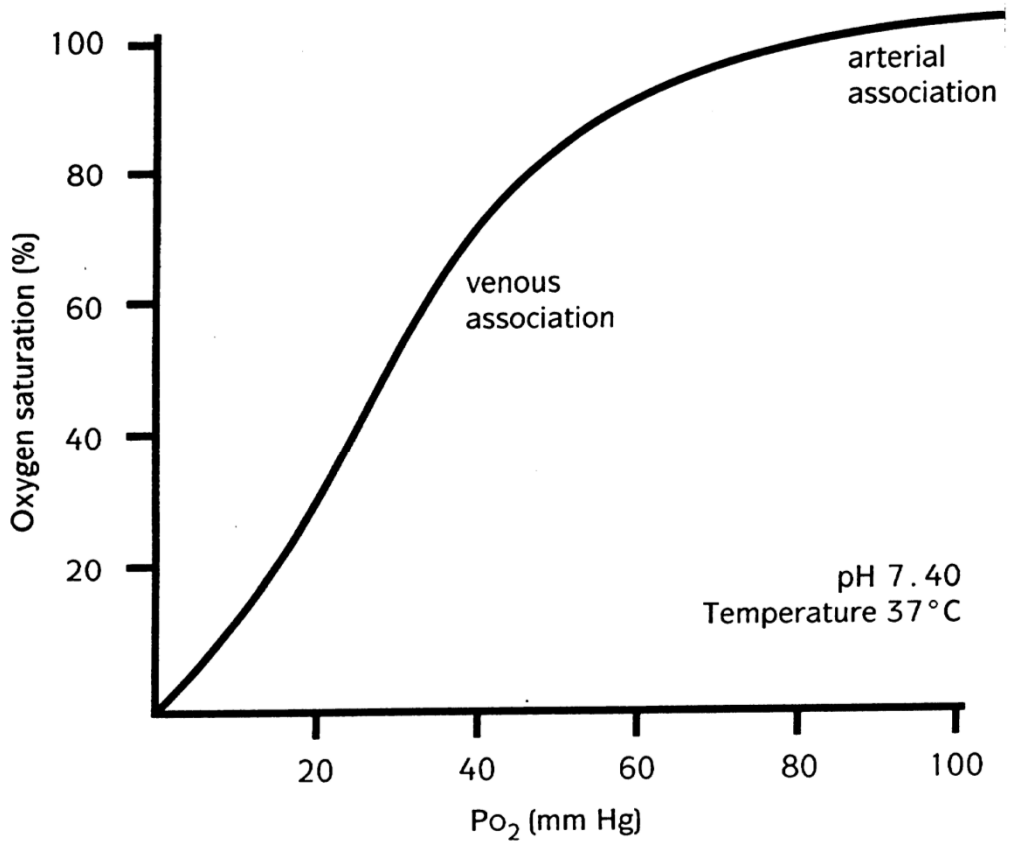
Treatment:

Underlying cause must be corrected

Arterial and Mixed Venous Gases

	Arterial	Mixed Venous
pH:	7.35 - 7.45	7.33 - 7.43
PCO_2 (mm Hg)	35 - 45	41 - 51
HCO_3^- (meq/l)	22 - 26	24 - 28
Base Excess	-2 to +2	0 to +4
PO_2 (mm Hg)	80 - 100	35 - 49
O_2 Saturation (%)	$\geq$ 95%	70 - 75

Oxyhemoglobin Dissociation Curve



Normal curve with oxygen transfer sites

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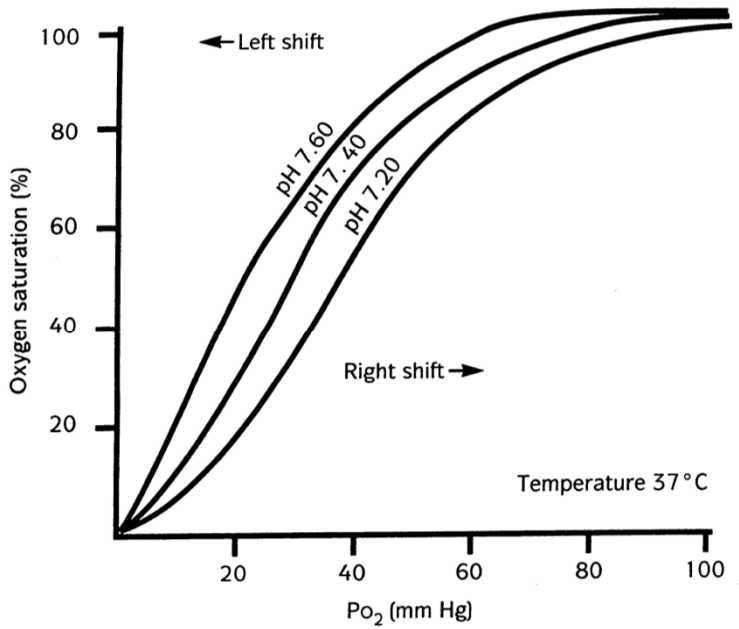
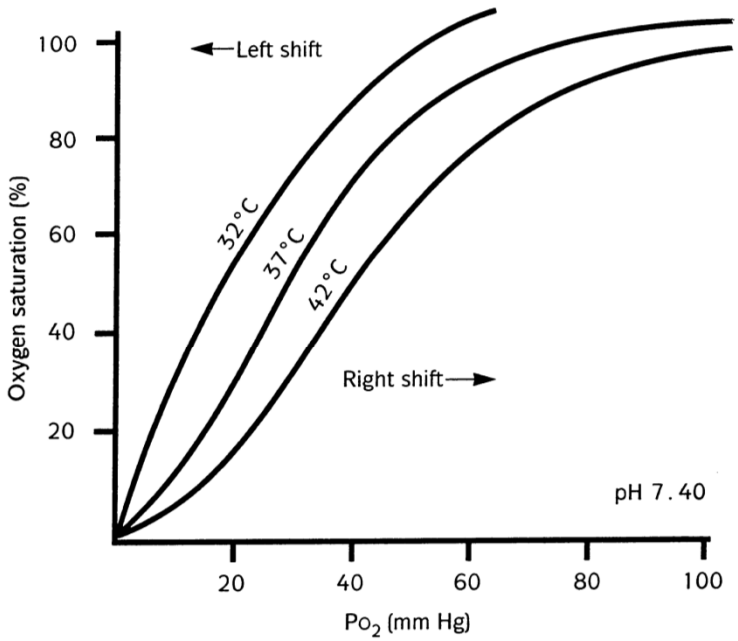
Oxyhemoglobin Dissociation Curve: Causes of Shifts



Curve shifts: pH



Curve shifts: temperature

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Factors Leading to Tissue Hypoxia

Low cardiac output

Decreased oxygen carrying capacity

Non-functional hemoglobin

Right to left cardiac shunt

Impaired respiration

Body's Compensation for Tissue Hypoxia

Tachycardia

Tachypnea

Erythrocytosis

Further desaturation of hemoglobin