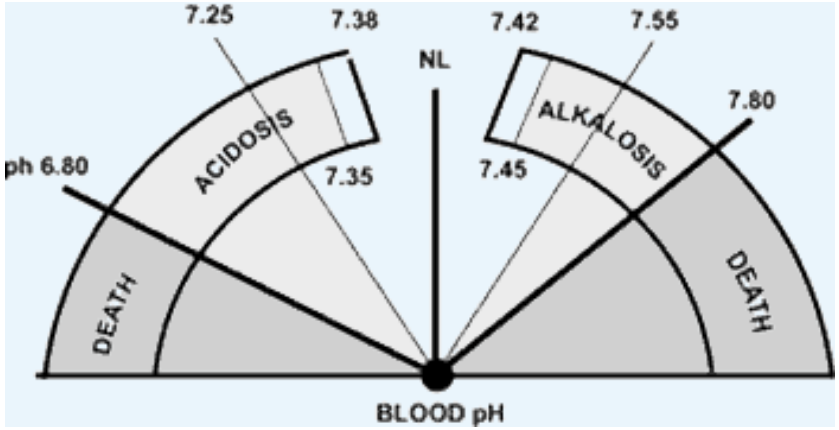
Acidosis and alkalosis



- Normal pH of body fluids
  - Arterial blood is 7.4
  - Venous blood and interstitial fluid is 7.35
  - Intracellular fluid is 7.0
- Alkalosis or alkalemia – arterial blood pH rises above 7.45

  Neurons become more excitable, seizures may result
- Acidosis or acidemia – arterial blood pH drops below 7.35

  Neuron activity slows
  Lower level of consciousness
  coma

What to learn?

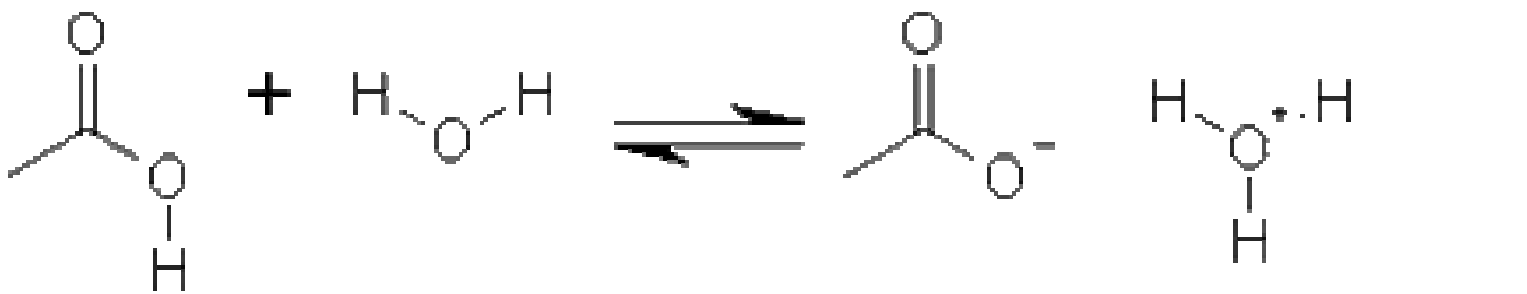
What is acid & base?
How body pH is controlled?
What is acidosis & alkalosis?
What causes acidosis & alkalosis?
The importance of body's pH balance
http://biomedx.com/microscopes/rrintro/rr4.html
How to measure body pH?

Webpage: Vince Austin, Kentucky Univ.
http://faculty.deanza.edu/cuffjudy/stories/storyReader$48

Acid-base balance

Acids: Electrolytes that ionize and release hydrogen ions
Bases: Electrolytes that combine with hydrogen ions

$HA \leftrightarrow H^+ + A^-$



Regulation of H^+ concentration

- Concentration of hydrogen ions is regulated sequentially by:
  - Chemical buffer systems – act within seconds
  - The respiratory center in the brain stem – acts within 1-3 min
  - Renal mechanisms – require hours to days to effect pH changes

Sources of hydrogen ions

anaerobic and aerobic respiration of glucose
incomplete oxidation of fatty acids
oxidation of sulfur-containing amino acids
hydrolysis of phosphoproteins and nucleic acids

pH effects in cellular & molecular level

Chemical solubility
Enzyme activity
Protein denaturation
Cell growth
Organ dysfunction

Chemical Buffer Systems

- One or two molecules that act to resist pH changes when strong acid or base is added
- Three major chemical buffer systems
  - Bicarbonate buffer system
  - Phosphate buffer system
  - Protein buffer system
- Any drifts in pH are resisted by the entire chemical buffering system

Bicarbonate buffer system

Present in intra- and extracellular fluid

Bicarbonate ion acts as weak base, carbonic acid acts as a weak acid

Bicarbonate ions combine with excess hydrogen ions to form carbonic acid

Carbonic acid dissociates to release bicarbonate ions and hydrogen ions

Phosphate buffer system

Important in intracellular fluid and urine pH regulation

Consists of two phosphate ions

Monohydrogen phosphate ions act as a weak base and combine with hydrogen ions to form dihydrogen phosphate

Dihydrogen phosphate dissociates to release hydrogen ions

Protein buffer system

Consists of Plasma Proteins (albumin, hemoglobin)

Remember proteins are just chains of AA

The exposed amine group of the AA (NH_2) accepts H^+ ions when conditions are acidic

The exposed carboxyl group of AA can release H^+ ions when conditions are basic

Proteins can act as Acids or Bases

Respiratory Buffer Systems

- The respiratory system regulation of acid-base balance is a physiological buffering system
- There is a reversible equilibrium between:
  - Dissolved carbon dioxide and water
  - Carbonic acid and the hydrogen and bicarbonate ions

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

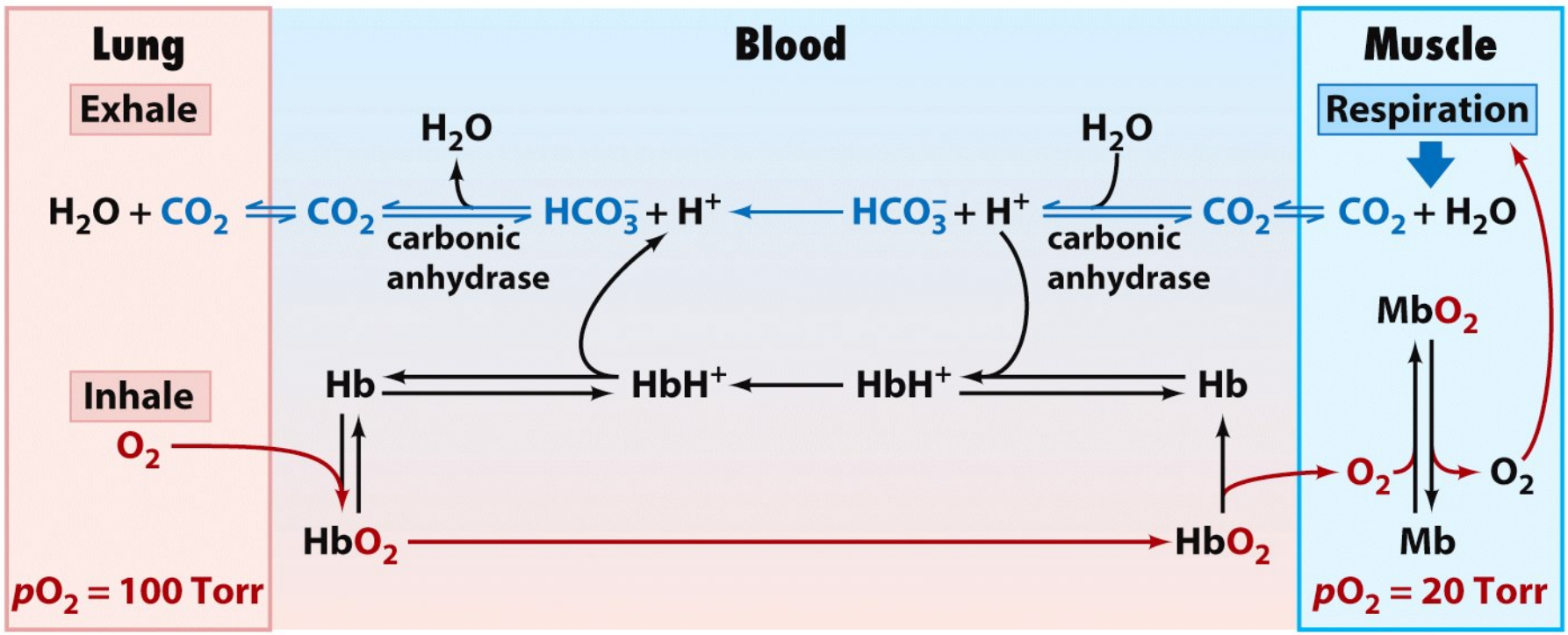
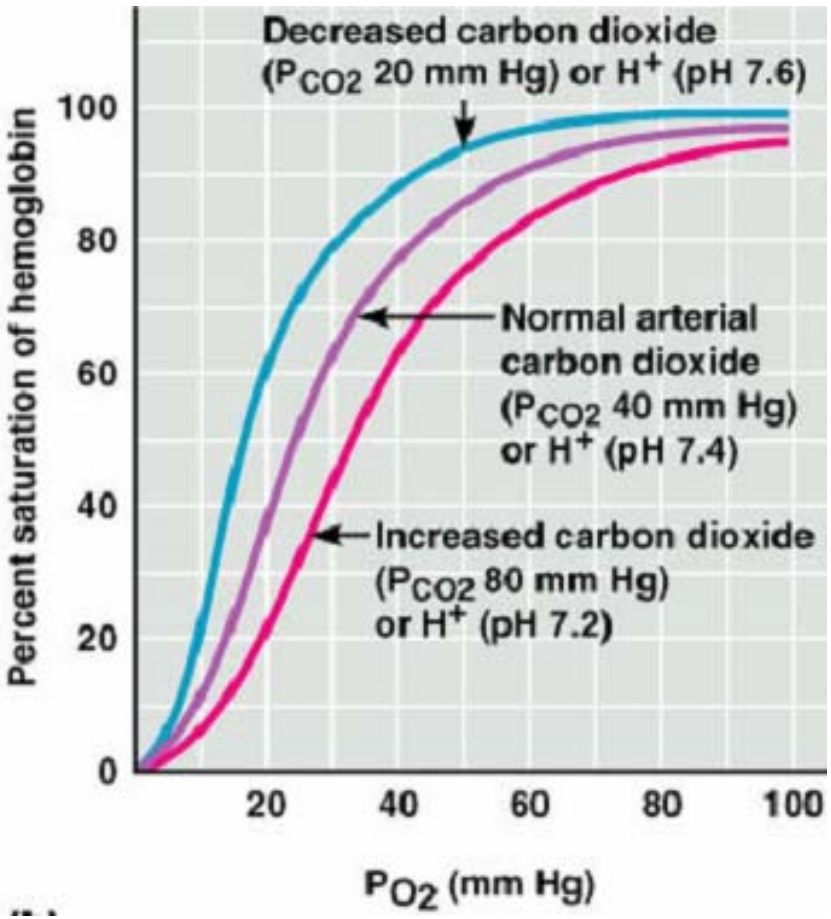
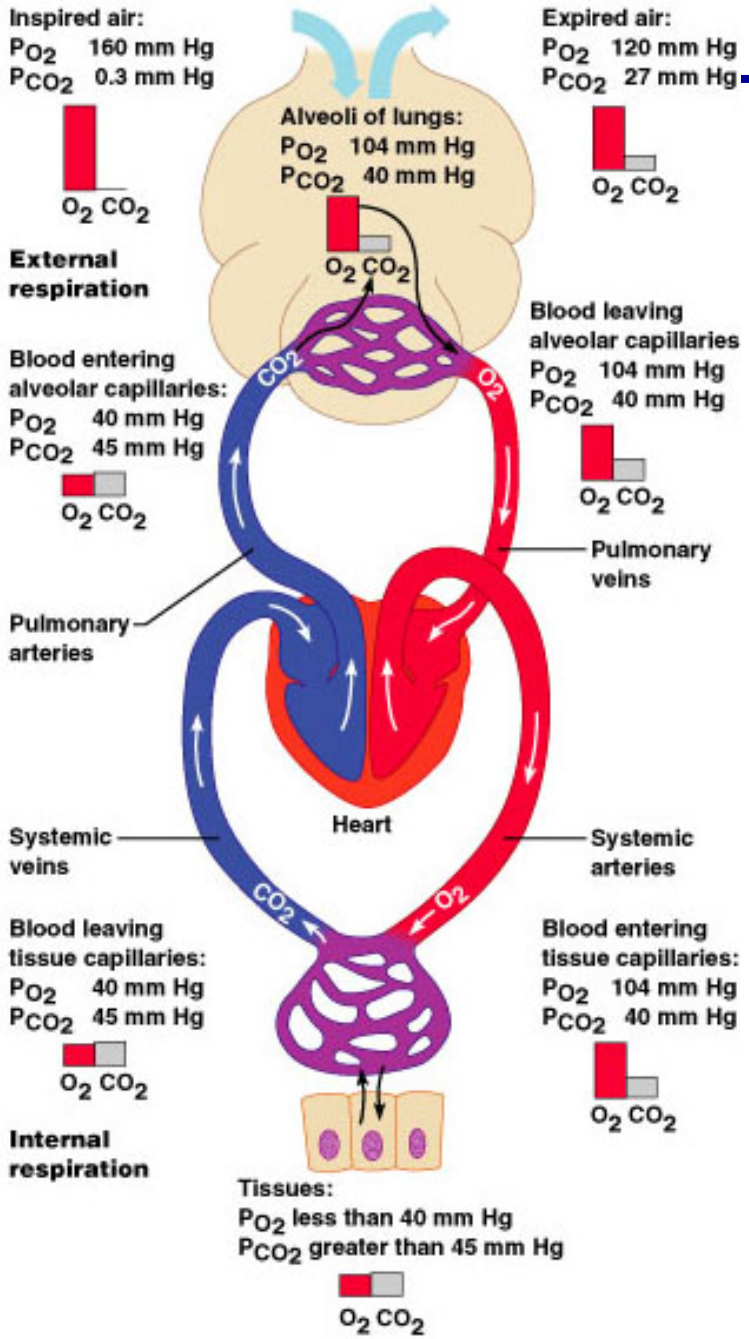


Figure 7-13 Fundamentals of Biochemistry, 2/e

CO_2 transport





Physiological Buffer Systems

- When hypercapnia or rising plasma H^+ occurs:
  - Deeper and more rapid breathing expels more carbon dioxide
  - Hydrogen ion concentration is reduced
- Alkalosis causes slower, more shallow breathing, causing H^+ to increase
- Respiratory system impairment causes acid-base imbalance (respiratory acidosis or respiratory alkalosis)

Renal Mechanisms of Acid-Base Balance

- Chemical buffers can tie up excess acids or bases, but they cannot eliminate them from the body
- The lungs can eliminate carbonic acid by eliminating carbon dioxide
- Only the kidneys can rid the body of metabolic acids (phosphoric, uric, and lactic acids and ketones) and prevent metabolic acidosis
- The ultimate acid-base regulatory organs are the kidneys

Renal Mechanisms of Acid-Base Balance

- The most important renal mechanisms for regulating acid-base balance are:
  - Conserving (reabsorbing) or generating new bicarbonate ions: decreases acidity of ECF
  - Excreting bicarbonate ions: increases acidity of ECF
  - Excreting excess H+

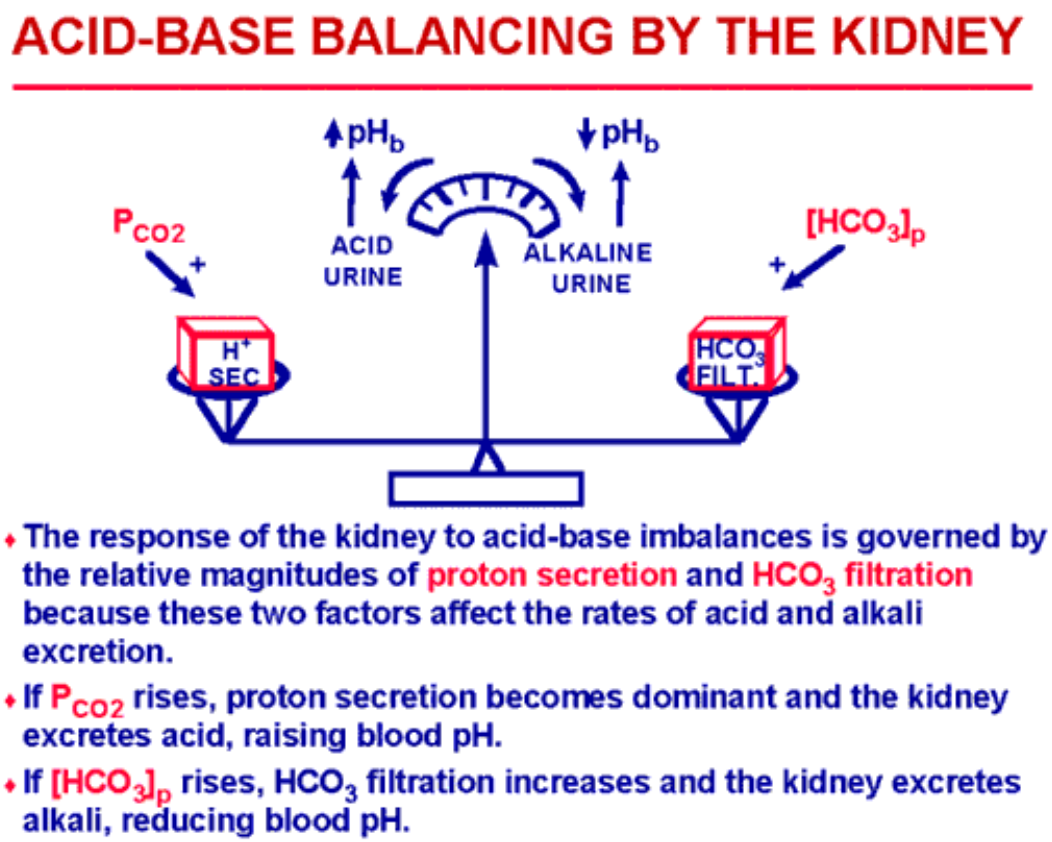
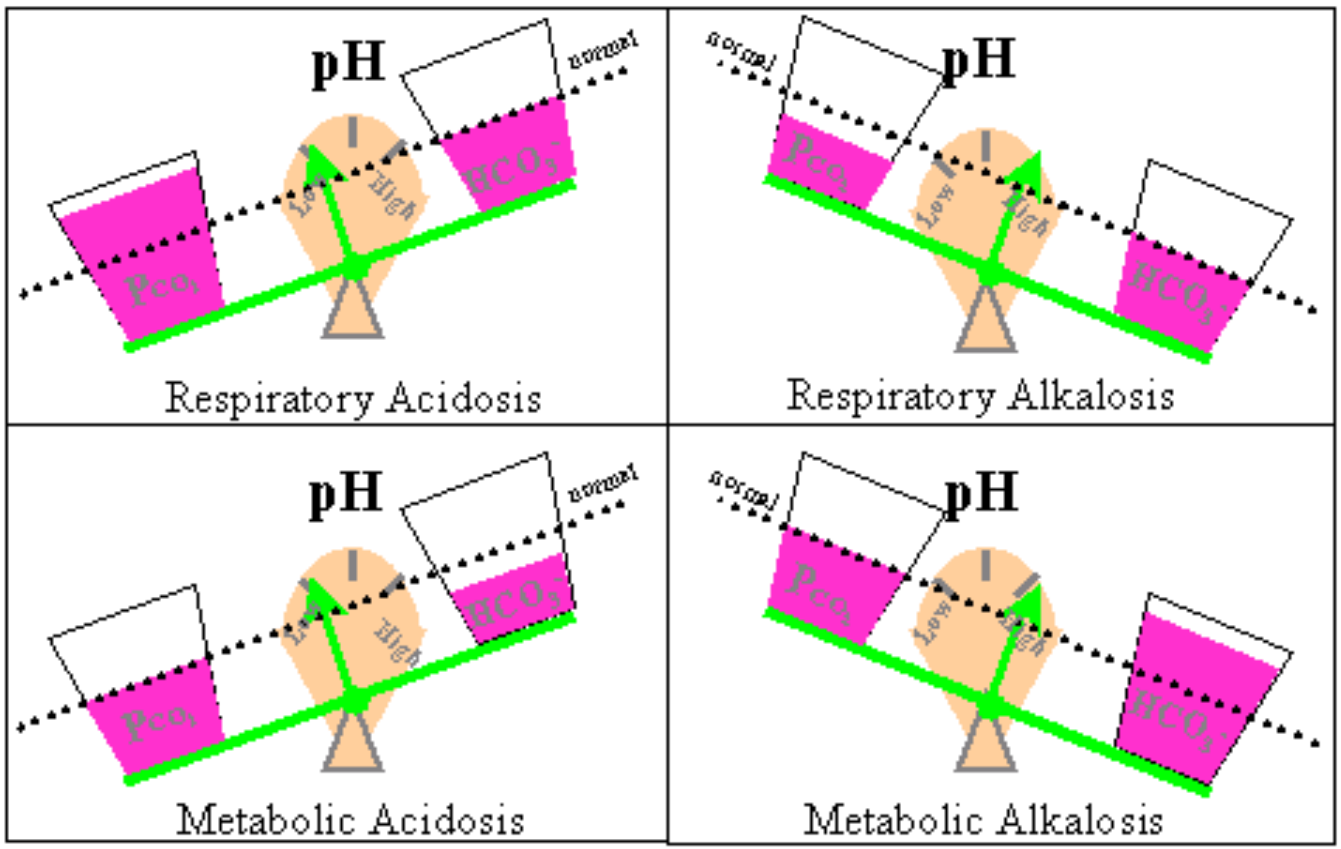


Figure 6: Primary Acid-Base Disturbances



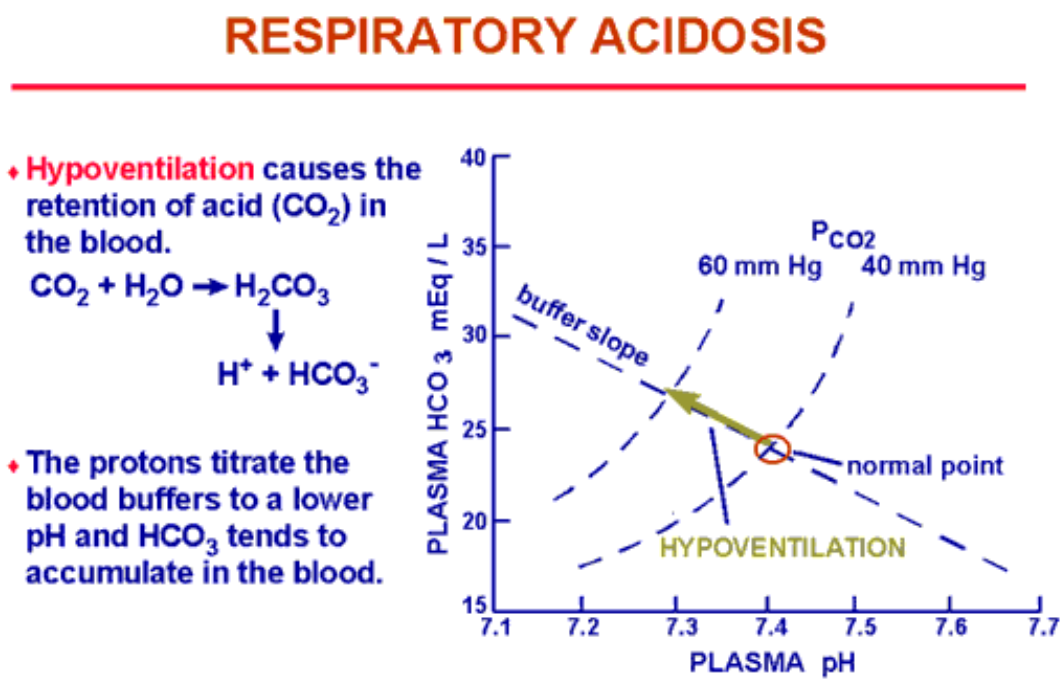
http://romerosnap1.phol.cwru.edu/AcidBase-SOMy1.htm

Respiratory Acidosis and Alkalosis

- Result from failure of the respiratory system to balance pH
- P_{CO2} is the single most important indicator of respiratory inadequacy
- P_{CO2} levels
  - Normal P_{CO2} fluctuates between 35 and 45 mm Hg
  - Values above 45 mm Hg signal respiratory acidosis
  - Values below 35 mm Hg indicate respiratory alkalosis

Respiratory Acidosis

- Respiratory acidosis is the most common cause of acid-base imbalance
  - Occurs when a person breathes shallowly, or gas exchange is hampered by diseases such as pneumonia, cystic fibrosis, or emphysema



Respiratory alkalosis

A common result of hyperventilation

Excessive loss of CO_2 & subsequent loss of carbonic acid

Caused by hyperventillation: too much CO_2 lost ($\downarrow$carbonic acid and H^+ ions)

Anxiety, high altitudes (low O_2 levels), musicians,

Symptoms: lightheadedness, agitation, dizziness,

Metabolic Acidosis

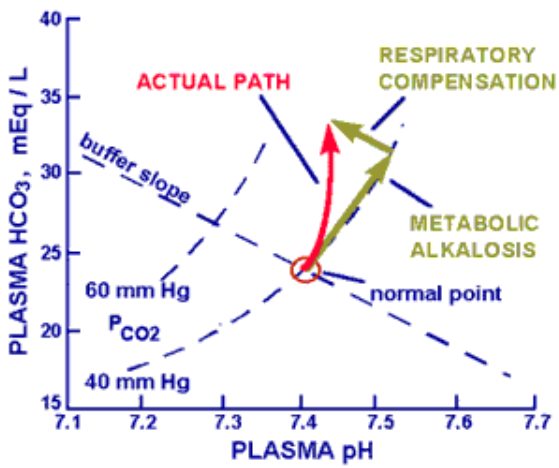
- All pH imbalances except those caused by abnormal blood carbon dioxide levels
- Metabolic acidosis is the second most common cause of acid-base imbalance
  - Typical causes are ingestion of too much alcohol and excessive loss of bicarbonate ions
  - Other causes include accumulation of lactic acid, shock, ketosis in diabetic crisis, starvation, vomiting, and kidney failure

Metabolic Alkalosis

- Rising blood pH and bicarbonate levels indicate metabolic alkalosis
- Typical causes are:
  - Vomiting of the acid contents of the stomach
  - Intake of excess base (e.g., from antacids)
  - Constipation, in which excessive bicarbonate is reabsorbed

METABOLIC ALKALOSIS

- The addition of alkali to the blood or the loss of acid causes the blood pH and $[HCO_3]_p$ to rise.
- The respiratory response to the high pH is hypoventilation. The rise in CO_2 titrates the blood buffers toa lower pH and a further small increase in $[HCO_3]_p$.



Respiratory and Renal Compensations

- Acid-base imbalance due to inadequacy of a one system is compensated for by the other system
  - The respiratory system will attempt to correct metabolic acid-base imbalances
  - The kidneys will work to correct imbalances caused by respiratory disease

Respiratory Compensation

- In metabolic acidosis:

  The rate and depth of breathing are elevated

  Blood pH is below 7.35 and bicarbonate level is low

  As carbon dioxide is eliminated by the respiratory system, P_{CO2} falls below normal

- In respiratory acidosis, the respiratory rate is often depressed and is the immediate cause of the acidosis

- In metabolic alkalosis:

  Compensation exhibits slow, shallow breathing, allowing carbon dioxide to accumulate in the blood

- Correction is revealed by:

  High pH (over 7.45) and elevated bicarbonate ion levels

  Rising P_{CO2}

Renal Compensation

- To correct respiratory acid-base imbalance, renal mechanisms are stepped up
- Acidosis has high P_{CO2} and high bicarbonate levels
  - The high P_{CO2} is the cause of acidosis
  - The high bicarbonate levels indicate the kidneys are retaining bicarbonate
- Alkalosis has Low P_{CO2} and high pH
  - The kidneys eliminate bicarbonate from the body by failing to reclaim it or by actively secreting it

Clinical Applications

- Homeostatic mechanisms slow down with age
- Elders may be unresponsive to thirst clues and are at risk of dehydration
- The very young and the very old are the most frequent victims of fluid, acid-base, and electrolyte imbalances

Problems with Fluid, Electrolyte, and Acid-Base Balance

- Occur in the young, reflecting:
  - Low residual lung volume
  - High rate of fluid intake and output
  - High metabolic rate yielding more metabolic wastes
  - High rate of insensible water loss
  - Inefficiency of kidneys in infants