BIOS 2015 ... CHAPTER 2- Fluid, Electrolyte, and Acid-Base Imbalances

Page	Note

Note: Key to meeting the objectives in this chapter is to learn the metabolic processes in a way that allows you to derive answers when given data. Similar to multiplication, you can only memorize a handful of products like 2 x 2 = 4 and 9 x 9 = 81. Memorization does not help when you get 2134 x 5623. You have to know how to multiply. Likewise in this chapter you need to understand what hydrostatic pressure and osmotic pressure are and what the lungs and kidneys do to alter the pH of the blood in order to know what happens when there is a change in a compartment.

About 60% of an adult's body weight is water.

Distribution of water in the body: two main compartments

1. Intracelluar fluid
2. Extracellular fluid
   - Intravascular fluid (the fluid within blood vessels)
   - Interstitial fluid (the fluid between cells in a space referred to as "the interstitium")

Balance of water in the compartments essential for homeostasis

- assume ions A and B are similar and can substitute for each other.
- one compartment has A at 100 mEq/L and another compatment has B at 5 mEq/L
- now 2 mEq of A move into the compartment with B
- both compartments are 1 liter so now:
  A has 98 mEq and B has 2 + 5 mEq
  A has only decreased by 2% but B has increased by 40%

So, a small change in the compartment with A produced a big change in the compartment with B.

This is why homeostasis is so important.

In the model human fluid distribution would be as follows:

Intracellular 28 L
Extracellular 15 L
- plasma 4.5 L
- interstitial 10.5 L

The above shows that about 2/3 of the fluid is intracellular and 1/3 is extracellular.

This distribution highlights how the intracellular compartment can be a considerable reservoir for some ions and this reservoir can affect the interstitium that can then effect what is in the circulation.

A typical day of fluid intake and loss is as follows:

In:		Out:	
Liquid	1200 ml	Urine	1400 ml
Solid Food	1000 ml	Feces	200 ml
Cell		Lungs*	400 ml
metabolism	300 ml	Skin*	500 ml

* Lungs and Skin are "Insensible fluid loss"

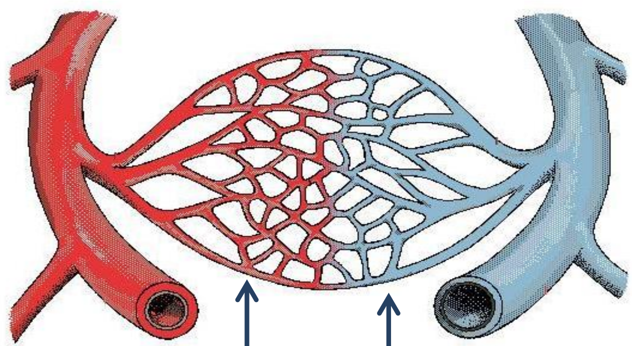
NOTE - how much can be lost in lungs (being breathed out as vapor) and skin (by sweat) as "Insensible loss" (loss that you do not notice).

HYDROSTATIC AND OSMOTIC PRESSURE - The basics:

Hydrostatic pressure is like water pressure, it **pushes**. Like a hose under pressure, if you poke a hole in it water squirts out. **Hydrostatic pressure pushes fluid** from areas of high hydrostaic pressure to areas of low hydrostatic pressure. **[high to low]**

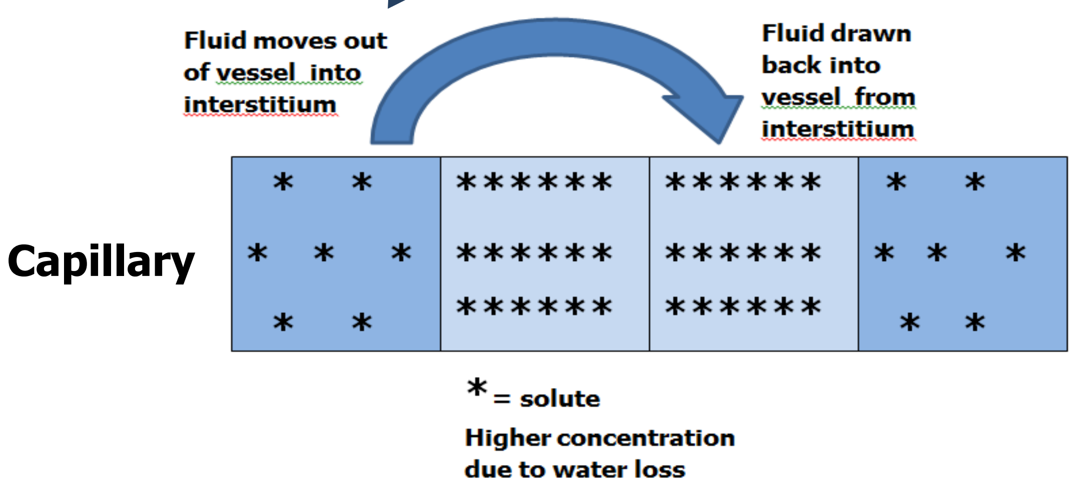
Osmotic pressure is driven by solute concentration. Solutes are solids like proteins and salts (ions). Water moves from regions of low solute concentration to regions of high solute concentration in order to dilute the solute. High osmotic pressure means high solute concentration that pulls fluid to the area of high osmotic pressure. **Osmotic pressure pulls fluid** from areas of low osmotic pressure to areas of high osmotic pressure**. [low to high]**

Understand these basic concepts so that you can figure out any one of the combinations in a biologic system works. Note that hydrostatic and osmotic operate in an inverse fashion. High hydrostatic pushes fluid away, high osmotic pulls fluid in.



Arteriolar end of capillary bed:
- hydrostatic pressure moves fluid out of the vessels into the interstitium

Venous end of capillary bed:
- because fluid was lost on the arteriolar side, solute concentration is higher. This produces osmotic pressure that pulls the fluid back into the circulation



The above picture is all blue to highlight the water movement; the picture above it uses red and blue to highlight the oxygen content of the two halves

EDEMA: excess fluid collecting in the interstitium

Causes of edema:

1. high blood pressure leads to high hydrostatic pressure that drives fluid out of the vasculature into the interstitium.
2. low serum protein leads to low osmotic pressure and the interstitium with higher osmotic pressure draws the fluid into the interstitium.
3. lymphatic blockage - fluid can not be drained from interstitium
4. inflammation can cause localized edema from increased capillary permeability, fluid leaks out as well as protein, then more fluid follows the protein.

Severe edema can limit range of motion as well as compromise circulation.

Pitting Edema (if you push on the edematous tissue it leaves a pit)

Dehydration - loss of body fluid

- see dry mucous membeanes and loss of skin turgor (lift skin and it does not bounce back).
- causes include poor fluid intake and excess fluid loss, usually from vomiting and/or diarrhea.

How you lose the fluid is important. In the next section on acid-base balance, you will see that vomiting (losing acid) produces alkalosis (high blood pH). In contrast, diarrhea (losing base) produces acidosis (low blood pH).

pH reflects the hydrogen ion (H^+) concentrationin the blood.

pH = - log [H^+ concentrationin] , this means that a higher H^+ concentrationin (more acidic) gives a lower pH ; conversely a lower H^+ concentrationin (more alkaline or basic) gives a higher pH.

pH of 7 = neutral

pH less than 7 = acid

pH greater than 7 = base or alkaline

The blood must stay in a narrow pH range of 7.35 to 7.45

- when you move toward lower than normal pH you are said to be acidotic or have acidosis.
- when you move toward igher than normal pH you are said to be alkalotic or have alkalosis.

Acidois and Alkalosis can come from either lung function (Respiratory Acidosis, Respiratory Alkalosis) or from a body function (Metabolic Acidosis, Metabolic Alkalosis).

To understand this we must look at how the body processes acid.

ACID PROCESSING

Under normal conditions, acid in the blood comes from cellular metabolism (a byproduct or waste product)

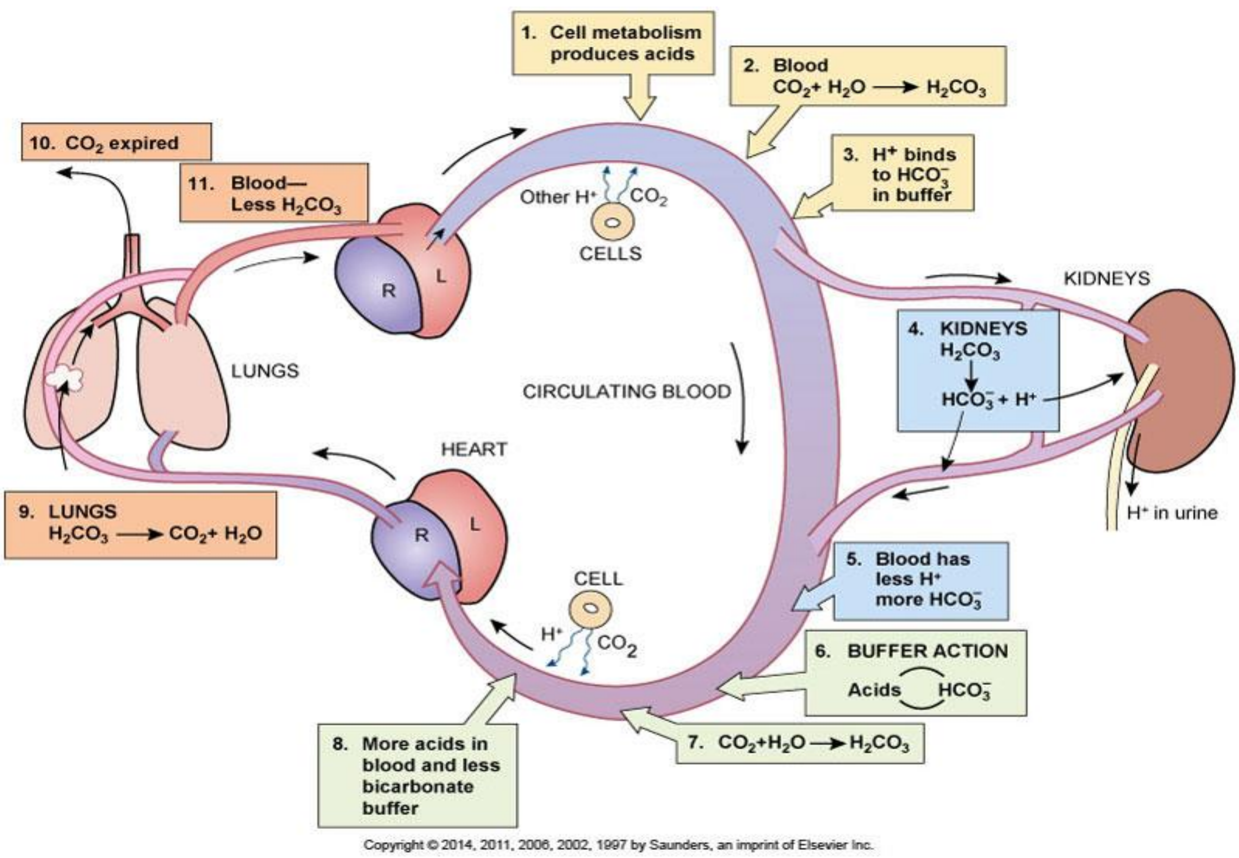
The form of the acid is "Carbonic Acid" H_2CO_3 and it forms a buffer pair with "Bicarbonate" HCO_3^-

The carbonic acid can be processed in one of two compartments:

1. Lungs - in the lungs H_2CO_3 breaks into CO_2 and H_2O (carbon dioxide and water). The carbon dioxide is a gas and is expelled in exhalation. Fast breathing (hyperventilataion) drives off carbon dioxide and produces respiratory alkalosis. Shallow breathing limits the carbon dioxide loss and produces respiratory acidosis.

2. Kidneys - in the kidneys, the H_2CO_3 breaks into H+ and HCO_3^- (hydrogen ions and bicarbonate). If he blood is acidotic, the hydrogen ions will go into the urine (lowering its pH) and the bicarbonate will be resorbed and put into the blood to neutralize the acid. The converse happens in alkalosis where hydrogen ions would be retained and bicarbonate lost (raising the pH of the urine).

Understand these processes well and you can figure out what is going on in a sick patient.



Compensation: When one system tries to balance the other.

Respiratory Acidosis lead the kidneys to dump hydorgen ions and retain bicarbonate.

Respiraory Alkalosis leads the kidneys to dump bicarbonate and retain hydrogen ions.

Metabolic Acidosis causes fast breathing to blow off carbon dioxide.

Metabolic Alkalois casues shallow breathing to retain carbon dioxide.

These four statements should make sense if you understand how the system works.

Causes of Respiratory Acidosis:

Acute problems

Pneumonia, airway obstruction, chest injuries

Drugs that depress the respiratory control center

Chronic respiratory acidosis

Common with chronic obstructive pulmonary disease

Causes of Respiratory Alkalosis:

Hyperventilation: Caused by anxiety, high fever, overdose of aspirin

Head injuries

Brainstem tumor

Causes of Metabolic Acidosis:

Excessive loss of bicarbonate ions to buffer hydrogen (HCO3- levels decrease in blood)

- Diarrhea—loss of bicarbonate from intestines

Renal disease or failure

- Decreased excretion of acids
- Decreased production of bicarbonate ions

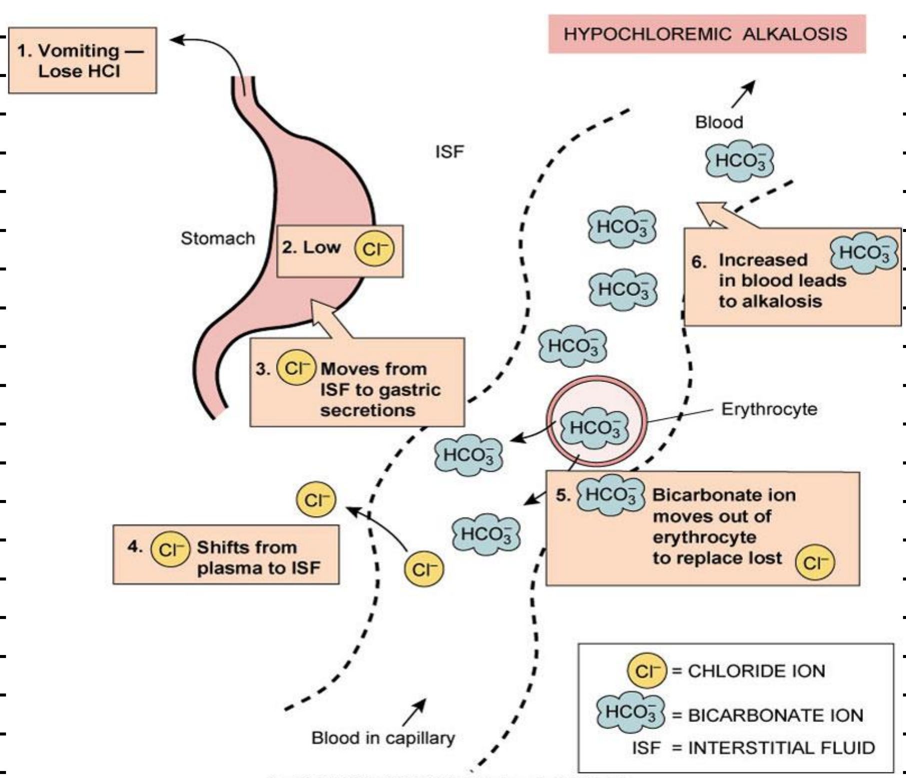
Metabolic imbalance

- Lactic acidosis from anaerobic metabolism.
  Hypoxia, hypoperfusion
  Sepsis
  Shock
  Inborn errors in metabolism.

Causes of Metabolic Alkalosis:

Increase in serum bicarbonate ion

- Loss of hydrochloric acid from stomach (chloride lost from stomach compensated by chloride in blood, compensated by bicarbonate from red blood cells - SEE Diagram below)
- Hypokalemia (potassium going into cells, opposite of acidosis with potassium coming ot of cells).
- Excessive ingestion of antacids (bicarbonate).



ELECTROLYTES - IONS

Ions exist in all of the fluid compartments - extracellular and intracellular.
They are partitioned differently:

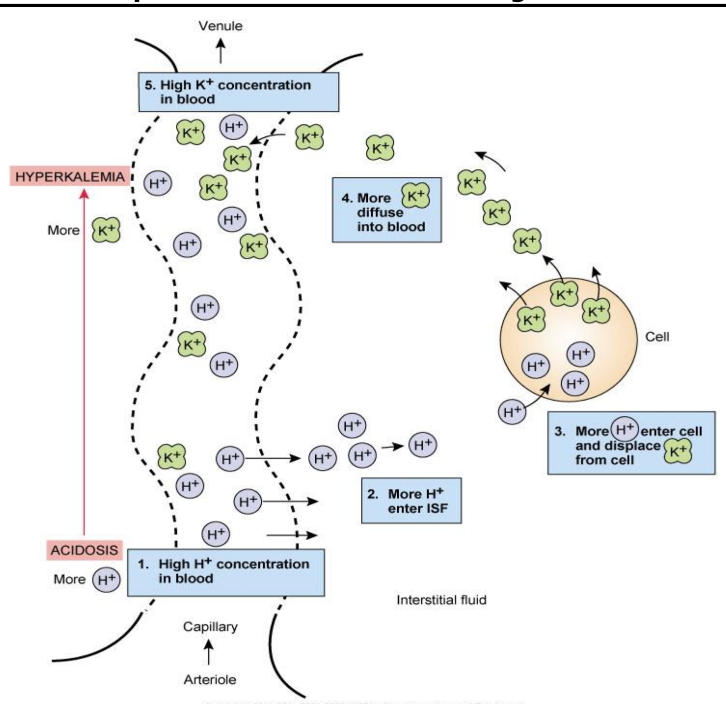
Distribution of Major Electrolytes (mEq/L)

Ion	Intracellular	Blood
Sodium (Na^+)	10	142
Potassium (K^+)	160	4
Calcium (Ca^{++})	variable	5
Magnesium (Mg^{++})	35	3
Bicarbonate (HCO3-)	8	27
Chloride (Cl-)	2	103
Phosphate (HPO4-)	140	2

Positive = cations Negative = anions

Sodium (hyper, hyponatremia):
primary cation in blood and extracellular fluid
90% of solute in extracellular fluid (affecting osmotic pressure).
Lost in sweat, vomiting and diarrhea.
Affected by water consumption and kidney function

Potassium (hyper, hypokalemia):
primary cation in intracellular fluid
blood levels have profound effect on heart
abnormal potassium levels cause changes in cardiac conduction and are life-threatening!



Relationship of Hydrogen and Potassium Ions:

Acidosis (low blood pH) is characterized by increased hydrogen ions (H^+) in the blood.

H^+ moves to interstitium then into cells pushing potassium (K^+) out.

K^+ gets back into blood stream producing increased blood K^+

	Review of calcium (hyper, hypocalcemia): Stored in bone Balance controlled by hormones: - **parathyroid hormone (PTH) raises calcium in blood** - **calcitonin lowers calcium in blood (tones the bones).** - Vitamin D promotes calcium absorption from intestine Ingested or synthesized in skin in the presence of ultraviolet rays Activated in kidneys
	Functions of Calcium: Provides structural strength for bones and teeth Maintenance of the stability of nerve membranes **Required for muscle contractions (heart and skeletal muscle).** Necessary for many metabolic processes and enzyme reactions Essential for blood clotting
	Magnesium Intracellular ion Hyper, Hypomagnesemia **Phosphate** Bone and tooth mineralization Phosphate buffer system—acid-base balance Reciprocal relationship with serum calcium Hyper, Hypophosphatemia **Chloride** Major extracellular anion Chloride levels related to sodium levels Can shift in response to acid-base imbalances. Hyper, Hypochloremia
	Cl- and HCO3- are most important for acid-base balance in body