**Acid-Base Balance**

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**Introduction**

* Acid-base balance is one of the most important of the body’s homeostatic mechanisms
* Acid-base balance refers to regulation of hydrogen ion (H+) concentration in body fluids
* Precise regulation of pH at the cellular level is necessary for survival
* Slight pH changes have dramatic effects on cellular metabolism

**Mechanisms That Control pH of Body Fluids**

* Review of pH concept
	+ pH indicates degree of acidity or alkalinity of a solution - range is from 0 - 14
	+ If [H+] is high, solution is acidic; pH < 7
	+ If [H+] is low, solution is basic or alkaline ; pH > 7
	+ Acidosis describes arterial blood pH of less than 7.35
	+ Alkalosis describes arterial blood pH greater than 7.45

**Small changes in pH can produce major disturbances**

* Most enzymes function only with narrow pH ranges
* Acid-base balance can also affect electrolytes (Na+, K+, Cl-)
* Can also affect hormones

**The body produces more acids than bases**

* Acids take in with foods
* Acids produced by metabolism of lipids and proteins
* Cellular metabolism produces CO2
	+ CO2  + H20 ↔ H2CO3 ↔ H+ + HCO3

**Mechanisms That Control pH of Body Fluids**

* Types of pH control mechanisms
* Chemical: rapid-action buffers
	+ Bicarbonate buffer system
	+ Phosphate buffer system
	+ Protein buffer system
* Physiological: delayed-action buffers
	+ Respiratory response
	+ Renal response
* Summary of pH control mechanisms
	+ Buffers
	+ Respiration
	+ Kidney excretion of acids and bases

**Buffer Mechanisms for Controlling pH of Body Fluids**

* Buffers
	+ Substances that prevent a marked change in pH of a solution when an acid or base is added to it
	+ Buffer pairs present in body fluids: mainly carbonic acid, proteins, hemoglobin, acid phosphate, and sodium and potassium salts of these weak acids
* Buffer systems
	+ Take up H+ or release H+ as conditions change
		- Buffer pairs – weak acid and a base
		- Exchange a strong acid or base for a weak one
		- Results in a much smaller pH change
	+ Types of buffer systems
		- Bicarbonate buffers
			* Sodium Bicarbonate (NaHCO3) and carbonic acid (H2CO3)
			* Maintain a 20:1 ratio : HCO3- : H2CO3
			* HCl + NaHCO3 ↔ H2CO3  + NaCl
			* NaOH + H2CO3  ↔ NaHCO3 + H2O
		- Phosphate buffers
			* Major intracellular buffer
			* H+ + HPO42- ↔ H2PO4-
			* OH- + H2PO4- ↔ H2O + H2PO42-
		- Protein Buffers
			* Includes hemoglobin, work in blood and ISF
			* Carboxyl group gives up H+
			* Amino Group accepts H+
			* Side chains that can buffer H+ are present on 27 amino acids.

**Respiratory mechanisms**

* Respiratory mechanism – limited to adjustments of CO2.
	+ With every exhalation CO2 and H2O leaves the body
	+ Hypoventilation causes respiratory acidosis, and hyperventilation cause respiratory alkalosis
	+ Respiratory control centers “sense” and regulate RR and depth
	+ Changes in respiratory rate and depth also can partially correct metabolic disturbances
* Respiratory Mechanisms of pH Control
	+ Explanation of respiratory mechanisms
		- Amount of blood carbon dioxide (CO2) directly relates to the amount of carbonic acid and therefore to the concentration of H+
		- With increased respirations, less CO2 remains in blood, hence less carbonic acid and fewer H+; with decreased respirations, more CO2 remains in blood, hence more carbonic acid and more H+
	+ Respirations adjustment to counter pH imbalance of arterial blood
* Principles that relate respirations to pH value
	+ Prolonged hyperventilation, by decreasing blood H+ excessively, may produce alkalosis
	+ Alkalosis causes hypoventilation, which tends to correct alkalosis by increasing blood CO2 and therefore blood H2CO3 and H+
	+ Prolonged hypoventilation, by eliminating too little CO2, causes an increase in blood H2CO3 and consequently in blood H+, thereby possibly producing acidosis

**Kidney Excretion**

* Urinary mechanism - greatest capacity to adjust pH changes
* Slow to begin but long-lasting
	+ The kidneys are the most effective regulators of blood pH
	+ Eliminates much larger amounts of acid than the lungs, and if necessary can excrete excess base which the lungs cannot do
	+ Renal Failure – acid base control fails

**Urinary Mechanisms That Control pH**

* General principles concerning urinary mechanisms
	+ Play vital role in acid-base balance because kidneys can eliminate more H+ from the body while reabsorbing more base when pH lowers
* Mechanisms that control urine pH
	+ Secretion of H+ into urine: when blood CO2, H2CO3, and H+ increase above normal
	+ Secretion of NH3: when blood H+ concentration increases, distal tubules secrete more NH3

**Rates of correction**

* Buffers function almost instantaneously
* Respiratory mechanisms take several minutes to hours
* Renal mechanisms may take several hours to days
* Evaluation of the role of buffers in pH control: cannot maintain normal pH without adequate functioning of the respiratory and urinary pH control mechanisms



**Acid Base Disturbances**

* Metabolic Acidosis – to little bicarbonate
	+ Acidosis – may be related to kidney disease, uncontrolled diabetes mellitus, excessive diarrhea, vomiting or use of diuretics.
		- Increased H+ stimulate respiratory centers and RR increases
		- Effects/symptoms of acidosis – depresses CNS, confusion, coma, and perhaps death
* Metabolic Ketoacidosis
	+ Occurs in diabetic patients ( and those on the Atkin’s diet) when fats and proteins are used for energy instead of glucose
	+ The use of fats without some glucose is inefficient and ketones accumulate in the blood making it acid
* Metabolic Alkalosis - to much bicarbonate
	+ Alkalosis – rare but can occur with ingestion of too many antacids, vomiting of stomach contents only
		- Effects/symptoms – affects the PNS, irritability, muscle spasms, convulsions

**Respiratory Disturbances**

* Acidosis – to much carbonic acid
	+ Seen in pneumonia and emphysema which retains CO2 in blood
	+ Also seen in drug abuse and decreased breathing
* Alkalosis – to little carbonic acid
	+ Seen in hyperventilation

**Language of Medicine – Ch. 30**

* Bicarbonate loading
* Emesis
* Hyperkalemia
* Lactic acidosis
* Metabolic acidosis
* Metabolic alkalosis
* Pernicious vomiting
* Respiratory acidosis
* Respiratory alkalosis

