Ch. 26: Fluid, Electrolyte, Acid-Base Balance

- Maintenance of homeostatic balance of bodily fluids
- Fluid compartments in body:
  - Intracellular fluid compartment – in the cells
  - Extracellular fluid compartment – internal milieu surrounding each body cell
    - Plasma & Interstitial fluid, lymph, CSF, etc.
- Body fluids contain electrolyte (carry charge) & nonelectrolyte (no charge) solutes

Solutes in Intra- & Extracellular Fluids

- All dissolved solutes contribute to osmotic activity
  - Water moves down its concentration gradient to area of greater osmolality
- Electrolytes have greater osmotic power
  - Dissociation
- Extracellular (plasma & interstitial): HI Na^+ & Cl^-
- Intracellular: HI K^+ & phosphate

Fluid Movement

- Alteration of solute concentration between 2 compartments leads to net water flow
  - Size, charge, pumps
- Exchange btwn plasma & interstitial fluid
  - Capillary beds: leaky
  - If not imm. resorbed by blood, lymphatic fluid
- Exchange btwn interstitial & intracellular fluid
  - Ions move selectively through plasma membranes
  - Most substances move unidirectionally; water moves freely
  - **Plasma** links the internal + external environments

Water Balance

- Proper hydration: water intake = water output
- Rise in plasma osmolality (solute conc.):
  - Triggers thirst – drinking
  - Stimulates ADH release – kidneys produce concentrated urine
- Drop in plasma osmolality – inhibits thirst, ADH
- Thirst mechanism: hypothalamus
  - Drop in plasma volume *or* rise in plasma concentration stimulate drinking

Water Balance, cont'd.

- Regulation of water output
  - Obligatory water loss – minimum 500 ml urine/day to carry away wastes; losses through skin/lungs
  - Concentration & volume of urine rely on intake/diet/sweat
  - Na^+ balance
  - ADH inhibited within ~30 min after hydration – kidneys begin to eliminate excess water

Water balance disorders

- Dehydration (negative fluid balance)
  - Hemorrhage, burns, vomiting, diarrhea, sweating, water deprivation, endocrine disturbance
  - Confusion; hypovolemic shock
- Hypotonic hydration (overhydration)
  - Hyponatremia
  - Cells swell; nausea, cramping, cerebral edema, confusion, convulsions, coma
- Edema (swelling; interstitial fluid)
  - Causes: increased BP; inflammation

Electrolyte balance

- Especially *salt balance* in body
  - Provide minerals + control fluid movement
- IN – diet, metabolic activity; OUT – sweat, feces, urine
- Sodium balance
  - $NaCl + NaHCO_3$ – 90-95% of all ECF solutes
  - Na^+ exerts strong osmotic pressure
  - Controls water distribution in body – "water follows salt"
  - Factors controlling balance: movement between ECF & ICF; hormonal controls; acid-base balance

Regulation of Sodium Balance

- Most Na^+ in filtrate reabsorbed to blood
  - (~90% without influence)
- Balance influenced by:
  - Aldosterone, ADH, neural controls, ANP
- Aldosterone (adrenal cortex hormone)
  - Causes remaining sodium to be resorbed (also promotes water retention)
  - Renin-angiotensin system triggers release

Regulation of Sodium Balance, cont'd.

- ADH (antidiuretic hormone; posterior pituitary)

- Controls water reabsorption in collecting ducts
  - Low ADH: dilute urine, reduction of blood volume
  - Hi ADH: high resorption, small volume concentrated urine
- Hypothalamus (osmoreceptors) control ADH level

- Neural control (sympathetic ANS)
  - Baroreceptors in heart, vessels
  - Rise in pressure > vasodilation of kidney afferent arterioles (rise in GFR > rise in Na/water output)

Regulation of Sodium Balance, cont'd.

- ANP (atrial natriuretic peptide; heart)
  - Reduces BP, blood volume
  - Inhibits: vasoconstriction, sodium retention, water retention (diuretic, natriuretic)
  - Suppresses release of ADH, renin, aldosterone
- Other hormones
  - Estrogen: enhances Na^+ reabsorption
  - Glucocorticoids: raise BP, promote edema

Regulation of Potassium Balance

- Main intracellular cation – balance important
  - Too little: disruption of skeletal/cardiac muscle function
  - Too much: reduced excitability of neurons, muscle
- Sensitive to pH shifts (a balancing cation)
  - pH shifts thus alter excitable cells' activity
- Balance maintained in kidney
  - ~85% already reabsorbed from filtrate
  - Collecting ducts secrete extra K^+ into urine

Calcium Balance

- Calcium-phosphate salts: bone rigidity
- Ionic Ca^{++} in ECF: clotting, membrane transport, muscle contraction
- Hyper/hypo-calcemia: neuromuscular inhibition, arrhythmia
- Normally ~98% resorbed to blood
- Balance closely regulated by 2 hormones
  - PTH: (parathyroid glands) promotes Ca^{++} increase
    - Bones, small intestine, kidneys
  - Calcitonin: (thyroid) stimulates Ca^{++} deposit to bone

Magnesium Balance

- Activates coenzymes in glucose & protein metabolism
- Cardiac function & neuromuscular activity

- Too much: impairment of nervous, respiratory function
- Too little: increased neuromuscular excitability (tremors, convulsions)

- Divided between skeleton & ICF
- Majority resorbed to blood

Acid-Base Balance

- pH critical to biochemical reactions, protein stability
  - ICF ~7.0, ECF ~7.3-7.4
- Alkalosis – blood pH >7.45
- Acidosis [physiological] – blood pH <7.35
- Regulation of blood proton (H^+) concentration:
  - Chemical buffer systems
  - Brain stem respiratory center
  - Renal mechanisms

Chemical Buffering

- Strong vs. weak acids & bases
- Chemical acid-base buffers – systems to resist changes in pH
  - Bind to H^+ when pH drops; release H^+ when pH rises
  - Bicarbonate, phosphate, protein

Chemical Buffering Systems

- Bicarbonate buffer system
  - Carbonic acid (H_2CO_3) <> Sodium bicarbonate ($NaHCO_3$)
  - Buffers intracellular & *extracellular* fluid
  - More of the weak acid when conditions acidic
    - Can resist dropping pH until all bicarbonate (alkaline reserve) used up
  - More of the weak base when conditions alkaline
    - Carbonic acid supply ever-abundant (from CO_2)

Chemical Buffering Systems, cont'd.

- Phosphate buffer system
  - Important for buffering *within* cells
  - Same as bicarbonate but with phosphate salts
- Protein buffer system
  - In plasma & within cells – most powerful, widespread buffer system
  - Acid (carboxyl) groups release H^+ when pH rises
  - Basic (amino) groups bind to H^+ when pH drops

Physiological Buffer Systems

- Respiratory system (ventilation) regulation
  - Increase in CO_2 concentration activates chemoreceptors in medulla > Increased respiratory rate & depth
    - Plasma pH drop: same effect (via chemoreceptors)

- Rise in blood pH > respiratory center depressed
- Renal mechanisms
  - Slower/more permanent changes (*eliminates* acids/bases from body)
  - Reabsorption or excretion of bicarbonate ions

Ch. 27 – The Reproductive System

- Gonads (primary sexual organs)
  - Male – testes; Female – ovaries
  - Produce gametes (sex cells) & sex hormones
  - All other structures: accessory reproductive organs
- Role of the male:
  - Make & deliver male gametes (sperm)
- Role of the female:
  - Produce female gametes (eggs)
  - Protect embryo between fertilization and birth

Male Reproductive Anatomy

- Scrotum: contains **testes** - lower temperature
  - Seminiferous tubules – sperm production site
  - Interstitial cells – androgen (testosterone) production
  - Spermatic cord
- Penis – sperm delivery
- Duct system – epididymis, vas deferens, urethra
- Accessory glands – seminal vesicles, prostate gland, bulbourethral gland