22. ENDOCRINE CONTROL of GROWTH & METABOLISM (& Ch. 7):
(Diurnal rhythms, stress, cytoplasmic receptors) – peaks late AM, low early AM. Carrier protein in plasma = Corticosteroid Binding Globulin / TBG (Diurnal rhythms, stress, cytoplasmic receptors) – peaks late AM, low early AM. Carrier protein in plasma = Corticosteroid Binding Globulin / TBG

STRESS hormone: essential, protective against hypoglycemia, permissive on glucagon and catecholamines. Anti-HypOglycemia: ↑glucoseogenesis in liver, ↑catab of musc prot, ↑lipolysis, ↓immune, ↓ILGFs, in body, brain – mood/memory. Hypercortisolism (Cushing’s syndrome): primary (ad cort secondary), (pit tumor/ACTH), latrirogenic (medicinal)—muscle & fat tissue breakdown, fat trunk and face, hyperglycemia, mood swing. Hypocortisolism (Addison’s) = autoimmune destr’n, excess androgen/ masculinization.

THYROID: C cells → Calcitonin. Follicle cells → TH’s (Thyroglobulin into colloidal glycoproteins (storage) → iodinated = T4 → secreted (plasma with TBG) → deiodinase in target cells to T3 (active thyroxine/TH); nuclear receptor). Heat, cold tolerance, mood. Thermogenic, ↑↑metabolism (O2 consum’n; mitoch transport), permissive on GH. Myelination, synaptogenesis. HyperTH = warm, sweaty, prot loss/weakness, excitable reflexes, ↑THR & SV (CO; ↑AdrR upreg’n). HypoTH = slow metab, cold↓, ↓prot syn, accum’s polysacc/glucoprot → Myxedema, slow child growth, slow reflexes/fatigue, bradycardia. TSH ↑↑ Goiter (or by autoimmune TSI’s / Graves, or ↓Iodine).


19. KIDNEY/RENAL Physiology: salt/water or fluid/electrolyte balance. Regulate: ECF volume, Osm (290mOsm, blood). Ion Balance (Na+, K+, Ca++), pH (H+, -HCO3, NH4+), metabolic wastes excretion (urea, creatinin, uric acid, urobilinogen); foreign compounds: (saccharin, benzoate), hormone production (erythropoietin, rennin, vitD3 conversion). Function @ 25% (huge reserve capacity!). Kidney: nephrons in (Cortex, Medulla, Renal pelvis, ureter, bladder, urethra). NEPHRON: glomerus/ Bowman’s Capsule (renal corpuscle) → proximal tubule → Descending loop of Henle → Ascending loop of henle → Distal tubule → collecting tubules & common collecting ducts. Peritubular capillaries, vasa recta. Afferent/efferent arterioles bound glomerulus on each side (Portal System!!). Distal tubule twists back between afferent & efferent arterioles = Juxtaglomerular Apparatus. 180L/day filtered, but only 1.5L/day is excreted. Filtration (capsule; 300 mOsm plasma & filtrate), Reabsorption (bulk in prox tub; solute in Henle loop = 100 mOsm; distal & collecting), Secretion (selective via memb prots; distal & collecting). Urine Excretion: 1.5L/day, 50-1200 mOsm.

FILTRATION: glomerular capillaries = fenestrated – fluids/ions pass, cells/prots held in. Filtr. Reg’n: Podocytes and Mesangual cells (cytokines/immune) regulate capillary filtration area. Basal lamina barrier, Bowman’s capsule epithelium. Hydrostatic pressure > colloid osmotic pressure → Filtration!! (GFR = 125mL/min = 180L/day (plasma volume = only ~3L). ↑BP → ↑PH → ↑GFR. Afferent vasoconstr’n → ↓GFR; Efferent VC’n → ↑GFR. Autoregulation: ↑BP → myogenic vasoc (starch-sens. Channels open); Tubulogluemal Feedback → re: high fluid flow, Macula Densa cells in distal tubule secrete paracines → paracrine VC’n of afferent arteriole (JuxtaGlomerular Apparatus). Low BP & flow: JG cells secrete Renin → Aldosterone, Angiotensin (see Ch. 20; restore ↑BP & maintain BV). Hormones: ANG-II VC’n, Prostaglandin VD’n; also act on podocytes & mesangial cells. Autonomic NS: Sympathetic NE → αR → afferent & efferent VC’n! ↓↓BP → symp. adaptive conserv’n of BV.

REABSORPTION: ↑↑ of the filtered 180L/day. Rapid cleaning of toxins/wastes, regulation of ions and water. Reabsorption = active transport (water follows ion gradients, if permeable). Na+ actively reabsorbed Na/K ATPase; glucose, AAs, ions cotransported (2ª active) with Na+. Urea is passively concentrated in the ECF of the kidney; urea gradient created when water and salts exit proximal tubule and urea left behind → moves down gradient out of lumen into renal ECF. Small proteins and hormones may be filtered, by reabsorbed by transcytosis. Saturation of transport in renal reabsorption = all protein carriers loaded, so all excess cannot be reabsorbed, remains in lumen, and is excreted in uring. Concentration of transported substrate at saturation = Tm = transport maximum. Plasma concentration at which Tm is reached, and a substance (eg: glucose in diabetes mellitus) first appears in the urine – Renal Threshold.

SECRETION: selectively enhances excretion of compounds (eg: H+, K+). Eg: Probenecid competes with transporter → ↓Penicillin secr’n. EXCRETION: Glucose, amino acids, useful metabolites reabsorbed, not excreted. Organic wastes concentrated, ions and water variable. Clearance = (=inulin, creatinin) = of solute is # ml urine free of solute/time. For substance freely filtered, but neither secreted nor reabsorbed, Clearance = GFR. Clearance = Urine excretion rate (mg/min)/plasma concentration (mg/ml plasma). Determines renal handling of a solute.

MICTURITION: Bladder-urethra sphinctor, internal sphincter = smooth muscle of bladder, external sphincter = skeletal muscle (somatic control; CNS tonic contraction). Micturition/urinary reflex: Spinal reflex: bladder fills, smooth muscle stretches → parasympathetic → ↑sm musc contr’n (pushes open internal sphincter); ↓motor neurons to external sphincter → urination! Inhibit reflex by learned input from brain stem & cerebral cortex to override micturition reflex.
20. **FLUID & ELECTROLYTE Balance**: 2L/day food and drink, w/ 6-15 g NaCl/day. K+, H+, Ca++, HCO3-, PO42-. Thirst, Salt appetite (cravings). EF: osmolarity affects cell volume → cell shape → cell function! INTEGRATION: respiratory, cardiovascular, renal, and behavioral responses to regulate fluid/ion balances.

**Baroreceptors**: Carotid, Aortic, Atrial → reg BV & BP (ΔCO, Δthirst, Δkidney concentration/excretion of H2O & salts). *Water = 50-60% of total body wt (42L/70 kg man).*

- 23/2 H2O in cells (28L), 3L/plasma, 11L in interstitial fluid. Daily input → 22L. H2O + respiration produces 0.3L H2O/day → 2.5L/day daily intake of H2O. Daily intake = Daily Excretion. Output = 2.5L/day = skin, urine, feces = 0.9+1.5+0.1L/day. Kidneys conserve water, but cannot replace lost. Removal of excess water in diuretic urine = **Diuresis**. Blood = 300 mOsm, concentrated urine = 1200 mOsm. Water and Na+ reabsorption controlled in Distal Nephron. Concentration of urine: **Diuresis**.

**Potassium Balance**: K+ mostly in ICF (98%). Hypokalemia → (hyperpolarized) muscle weakness, Hyperkalemia → more, then less excitability, arrhythmias. ↑K+ → Aldosterone → K+ excretion & [↑Na+] reabsorption. **Acidosis** → hypokalemia, since H+ antagonized with K+ to remove acid.


**Avoidance of heat**: INTEGRATED control if VOL and OSM: Crisis: dehydration or hemorrhage. OSM and ECF Volume are independently regulated. Respond to TVol/TOsm, TVol alone, TVol/TOsm, TVol alone, Osm alone, Osm alone, or (rare) Osm alone.

**DEHYDRATION** (↓BV, ↑Osm!!) (Renal and CardioVasc responses: Conflicting aldosterone signals, regulation rule = *Rule of 280 mOsm.*)


**RENAL Compensation**: Acidosis: Kidneys Reabsorb HCO3-, Excrete H+ (as H+ or NH4+). Alkalosis: Kidneys reabsorb H+, Excrete HCO3-. Apical Na+/K+ Antipporter, Basolateral Na+/HCO3- Symport, H+/K+ ATPase secretes H+, reabsors K+ (possib Hyperkalemia). Na/NH4+ Antiport moves H+ to lumen. Proximal Tubule = most bicarbonate reabsorption (as CO2 or glutamine/alpha-ketoglutarate intermediate into cell). Distal Nephron:

- **Intercalated Cells (I Cells)**: *Type A (acidosis)*: secretes H+ (Apical H+/K+ ATPase antipporter & H+ ATPase to lumen), reabsorbs bicarbonate (Basolateral HCO3-/Cl- Antipporter). *Type B (base; alkalosis)*: secretes HCO3- (Apical HCO3-/Cl- Antipporter), reabsorbs H+ (Basolateral H+/K+ ATPase antipporter & H+ ATPase to ECF). Renal compensation if Resp fails (eg: Resp acidosis from COPD). Metabolic Acidosis: diarheea loses HCO3- from small intestine (exocrine pancreas). Alkalosis: resp = hyperventilation/anxiety, metabolic = excess vomiting → depressed ventilation.

**GI/Urinary Reflexes**: Deglutition, Defecation, Emesis, Micturition

**Spinal Reflexes**: micturition/urination, defecation.

**Medullary Reflexes**: Blood pressure (carotid/aorta), vomiting/emesis, Respiration (carotid/aorta – glomus cells), Cephalic digestive reflexes, Deglutition.
Possible Short Essay Topics (be prepared to give thorough EXPLANATIONS and to DRAW diagrams as well! ** Focus questions = in BOLD!):

Ch. 23 (& 7):

1. Diagram and give a specific example of short-loop and long-loop negative feedback in endocrine regulation. Describe the differences in levels of each hormone in the pathway in response to a Primary hypersecretion defect, and to both types of Secondary hypersecretion defects (hypothalamic and pituitary).

2. Outline the effects and possible causes and treatments for hypercortisolism and hypocortisolism. Outline the complete pathway of Cortisol secretion and control.

3. Outline the effects and possible causes and treatments for hyper- and hyposecretion of Growth Hormone (Somatotropin). Outline the complete pathway of Growth Hormone secretion and control.

4. Outline the effects and possible causes and treatments for hypothyroidism and hyperthyroidism. How/where is TH (thyroxine) produced, transported, and activated (which form is most active)?

5. Compare and contrast the effects of ParaThyroid Hormone (PTH), Calcitriol (vit D3) and Calcitonin on calcium metabolism, phosphate metabolism, and bone growth. What other hormones are involved in bone growth, what bone cells are affected, and how does each type affect bone structure and growth?

Ch. 19 & 20:

6. Outline/diagram the flow of filtrated fluid from the bloodstream through the nephron and into the urine.

7. Describe the regulation of filtration in the nephron (renal corpuscle) in response to blood pressure, nervous input, hormones, and Tubuloglomerular Feedback. (Be sure to compare activity at the afferent and efferent arterioles.)

8. Outline and diagram the effects of Vasopressin (ADH) on the nephron, and how it promotes water conservation in the kidneys. Be sure to EXPLAIN the cellular mechanisms of action.

9. Diagram and Explain the mechanism for urine concentration in the Loops of Henle and the Vasa Recta (peritubular capillaries) of the kidney. (How can urine concentration exceed the original filtered plasma concentrations? -- 2 mechanisms.)

10. Compare & Contrast the activation pathways and the effects of the Renin-Angiotensin-Aldosterone System (RAAS) and ANP/BNP on sodium and water homeostasis.
   a. (be sure to describe the activities/functions of EACH major molecular/cellular member of the RAAS pathway).

11. Compare the buffer, renal, cell polarity, and respiratory compensations for alkalosis and acidosis. Diagram the cells in the area of the Nephron where these occur.

Reminder: For compare/contrast questions, try making a TABLE with all important categories for comparison.

- **Passive Transport**: simple diffusion (diffusion rate: size, charge, temperature, strength of gradient, membrane surface area & thickness), facilitated diffusion, concentration gradients, Equilibrium;
- **Active Transport**: (Primary) use ATP, against concentration gradient. Protein-Ligand interactions (eg: Membrane carriers, receptor proteins, & enzymes) → exhibit Specificity, Competition, & Saturation. Na+/K+ Pump (ATPase), Na+-Glucose Symporter.

- Bulk Vesicular Transport: **Endocytosis** (phagocytosis, receptor-mediated, coated pits - clathrin), Exocytosis.
- **Transporting Epithelia**: apical/mucosal membrane, basolateral membrane, polarized cells, absorption (lumen to ECF), secretion (ECF to lumen), Chemical & Electrical Disequilibrium – sodium, potassium, chloride, bicarbonate, calcium = potential energy stores!.


8. **Neurotransmitters (NTs)**: Acetylcholine (cholinergic); Amines – dopamine/ norepinephrine/ epinephrine (adrenergic); Amino Acids – glutamate, aspartate, GABA, Glycine.

- **Receptors**: Cholinergic – nicotinic (direct, fast), muscarinic (indirect, slow); Adrenergic (indirect, slow) – α, β1, β2; NT termination: degradation, active removal, recycling to vesicles. Neural INTEGRATION: Divergence, Convergence -- Summation (Spatial, Temporal). Presynaptic Modulation, Postsynaptic Modulation.

9. **MUSCLES**: Striated Muscle – skeletal (somatic motor neuron control), (autonomic control) cardiac; Smooth Muscle. Origin & insertion, tendons attach. Flexible joints,


- **Fast Twitch Glycolytic fibers** (white muscle; widest), Oxidative fibers – Fast twitch, Slow twitch (red muscle; thinner, more capillaries, myoglobin, & mitochondria). Optimum Filament length. Contraction strength: summation of contraction to Tetanus, recruitment of more motor units.

- **MECHANICS of MOVEMENT**: Isotonic Contractions (concentric/shortening actions, eccentric/lengthening actions), elastic connective tissues and cytoskeletal proteins aid in relaxation/lengthening. Bones =levers, joint = fulcrum.

10. **CARDIOVASCULAR PHYSIOLOGY**: Heart (LR atria, LR ventricles), Blood Vessels (arteries – to body, veins – to heart), valves. Deoxygenated blood = veins/right heart; oxygenated blood = arteries/left heart. Pulmonary artery (deox. To lungs); Pulmonary vein (ox. To left heart). [Veins to atrium to ventricle to pulmonary artery to lungs to pulmonary vein to aorta to carotid artery] → body/head → veins/valves ....R heart......] Capillaries, systemic circulation.

- Blood Pressure gradient (∆P) decreases; length, smaller radius, viscosity (higher resistance: $R \propto \frac{L}{r^4}$). Hydrostatic/Hydraulic Pressure. Flow Rate = Vol blood passing/time (how much flow). Flow Velocity = Flow rate/C.S. area = distance a fixed volume of blood will travel in a given period of time (how fast flow). Semilunar valves: lead to pulmonary artery or aorta; AV valves: bicuspid (mitral) between L atr/ventr, tricuspid between R atr/ventr. Myocardium = cardiac muscle (major mass of heart). Fed by coronary arteries and veins. One-Way Flow: $\Delta P$, valves (heart, veins), Left ventricular and arterial pressures (contraction, constriction). Autorythmic Muscle cells = pacemakers. Cardiac Muscle = striated, intercalated disks, gap junctions, desmosomes, large T-tubules, EC & SR Ca++ influx, mitochondria. Ca++-induced Ca++ release: VG channels (RyR) activated in SR re: EC Ca++ depol’n. Cyto Ca++ and Na+ removed by Ca/ATPase, Na/Ca Antiporter, and Na/K ATPase. Graded Contractions $\propto$ Ca++/troponin complexes $\propto$
15. **BLOOD FLOW & CONTROL of BP:**


**BLOOD PRESSURE**: driver = **ventricular contraction** and arteriolar **elastic recoil** (pulsatile flow in arteries). **Pulse pressure** = systolic P – diastolic P. Venous return: valves, skel muscle pump, respiratory pump, vein constr’n. **Mean Arterial Pressure (MAP)** = diastolic P + 1/3 pulse pressure (sP-dP). Korotkoff sounds = systolic → diastolic pressures. **MAP/BP ↔ CO x arteriolar R**

↑periph R, ↑BVol → ↑BP; fluid loss must be replaced from outside. Arteries: 11% total BV, Veins: 89% total circulating BV. **MAParteriolar resistance**: reflex & local controls – sympathetic reflexes (eg: temp), local control for metabolic needs, hormones – kidney salt/water, arteriolar vasoreg’n precap sphincters.

**Myogenic Autoregulation** by vascular sm muc (↑BP, ↓ arteriole D) – stretch opens Ca++ channels, ↑Ca++/CaM.

Local control of arteriolar resistance: Paracines - low O2, high CO2, high NO, H+ → signals for ↑ metabolism → vasodilation → ↑BF to area. **Vasoconstrictors**: NE (α), Serotonin, VasoPressin, AngTIll. **Vasodilators**: NO, bradykinin, Adenosine, Histamine, EPI (β2 = vasc in Heart, liver, skel muc). ACh/NO, VIP, ANP. Deliver metabolites, remove wastes (Hyperemia). Paracines/Vasoresponse affect **BLOOD DISTRIBUTION**: exercise brings muscle BF from 20→85% CO. 2/3 Resting CO → GI, liver, muscles, kidneys. Distribution regulated by arteriolar vasoregulation & precapillary sphincters. **Capillary Exchange**; blood-brain tight junctions in endothelium; Continuous Capillary, Fenestrated Capillary, Sinusoids. **Capillaries**: ↑ C.S. area → ↑ Flow Rate ↑ Effient exchange!! Arteriolar side: ↑Hydrostatic P > P (colloid osmotic pressure) = Net FILTRATION, Venous side: P < P = Net ABSORPTION. Lose 3L fluid/day by filtration; reabsorbed by lymph. Colloidal proteins (eg: albumin; plasma proteins from liver) maintain abs’n pressure (P).

**Blood Pressure Regulation**: CNS Medulla Oblongata Cardiovascular Control Center (CCC). **Baroreceptor Reflex**: sensory neurons (stretch receptors) in walls of Aorta and Carotid Artery. **↑BP** → baroreceptors → CCC → ↑Parasymp (↑ACH/muscarinic & ↑NE/α) hyperpolarize β1 in ventr and SA node → ↓HR and Force → ↓CO & ↓Symp (↑NE/α → arterioles vasodilate by ↓R periph) → ↓BP!! Coronary Artery Disease – atherosclerosis: fatty streaks (LDL > HDL), bulging plaques (stable → vulnerable) → platelet clotting → ischemia (loss of blood flow) → heart attack / myocardial infarction (death of heart muscle).

17. **MECHANICS OF BREATHING:**

**Functions**: Gas exchange between blood and atmosphere, pH Homeostasis, Protection from Pathogens and Irritants, Vocalization.

**Central Theme**: **Gases move from areas of higher partial pressures, to areas of lower partial pressures**. The gas laws drive respiratory function. Anatomy: Upper Resp: pharynx, larynx, trachea; Lower Resp: Bronchi, Bronchioles, Alveoli. Mucosal epithelium/alveoli supported by elastin for passiver recoil during exhalation. **Respiratory power**:

**Inhalation** = Diaphragm, External Intercostals, Sternum/costomastoids, Scaleseness (contraction expands thoracic cavity to ↑Vol & ↓ Pressure) → air moves in; **Exhalation** = passive recoil at rest; active exhalation = abdominal muscles and internal intercostals → create positive pressure to force air out. **Alveoli**, small sacs, surrounded by capillary beds (cover 80-90% of alveolar surface) → maximizes surface area for gas exchange (single layer of epithelium adjacent to single layer of capillary endothelium). Two pleura/pleural sacs (membranes) surround the lungs, holding lungs to walls of ribcage/thorax with thin layer of pleural fluid (creates vacuum and adheresiveness due to water’s cohesiveness to itself in the thin layer). Bronchioles are small collapsible passageways to the alveoli, surrounded by smooth muscle to control **Alveolar Ventilation**, by **Bronchonstriction**. Total crosssectional area of lungs increases as airways branch down to alveoli → creates a decreasing pressure gradient from Atmosphere → trachea → bronchi → bronchioles → alveoli to keep fresh air passively moving inward while the chest cavity is expanded. Type II alveolar cells secrete surfactant (lipoprotein detergent, dipalmitoylphosphatidylcholine) to interfere with water’s cohesive H-bonding, and prevent alveoli from collapsing on themselves (absent in premature infants) → ↑↑Surfactant in smaller alveoli. P ATM = 760 mm Hg (ATM: P 02 = 160 mm; P CO2 = 0.22 mm in dry air).

**Ventilation**: Upper airways are conducting passageways to the alveoli, warm air to body temp (protects alveoli), add water vapor to 100% to keep alveoli hydrated, and filter-out microbes, dust, and pollutants. Trachea/Bronchi = Ciliated Epithelium, Goblet Cells = mucus layer (ciliary/mucus escalator), immunoglobulins (antibodies, IgA), secretion of watery layer keeps cilia motile under mucus. Flow ∝ ΔP/R. **Inhalation**: external intercostals & scaleseness pull ribs upward and out (“open the umbrella”), diaphragm drops pleural cavity down to lower abdomen (TV → ↓P = vacuum gradient for inward airflow). Normal Resting Ventilation Rate (VR) = 12-20 breaths/min; ActiveExpiration occurs (abdom muscles, external intercostals) >30-40 bpm.

**MATCHING ALVEOLAR VENTILATION & PERFUSION:**

- CO 2 = bronchoactive; O 2 = vasoactive!!
- High O 2 vasodilates; Low O 2 vasoconstricts (pulmonary)
- NOTE: O 2 has opposite effects on Peripheral blood vessels!!
- High CO 2 bronchodilates; Low CO 2 bronchoconstricts.
18. **GAS EXCHANGE and TRANSPORT:**

Gas Exchange driven by Fick’s Law of Diffusion. Factors in lung: concentration gradient (partial pressure gradient), surface area, membrane thickness, diffusion distance (varied by ECF). **Concentration gradient** is by far the most important: $P_{O_2 \text{ alveoli}} (100\text{mm}) \rightarrow P_{O_2 \text{ blood}} (40\text{mm})$; $P_{CO_2 \text{ blood}} (46) \rightarrow P_{CO_2 \text{ alveoli}} (40)$. Partial pressure influences solubility, but $O_2$ (nonpolar gas) is much less soluble (1/20th) than $CO_2$ (polar). Alveolar exchange (gradient!) is greatly influenced by Hypoxia and by Hypercapnia. Hypoxia types: Hypoxic (low arterial $P_{O_2}$), Anemic (low Hb-O2), Ischemic (low tissue flow; heart failure, shock, thrombosis), Histotoxic (poisoned cells, cyanide, azide). Hypoventilation: increased airway resistance (asthma – bronchoconstriction), decreased lung compliance & scarring (fibrosis), increased diffusion distance ($\uparrow$ECF vol; edema).

**GAS TRANSPORT in BLOOD:** **OXYGEN** = low solubility, so 98% transported bound to Hemoglobin (4 subunits: adult = $2\alpha, 2\beta$; fetal = $2\alpha, 2\gamma$). 200ml $O_2/L$ blood (only 3ml w/out Hb). $O_2$ carrying capacity of blood depends on RBC count (hematocrit) and # Hb molecules/RBC. Heme group (non-protein) contains Fe, which binds $O_2$. $Hb + O_2 \Leftrightarrow Hb-O_2$, determined by $P_{O_2}$. Metabolism maintains low $O_2$ in cells, to keep a large $O_2$ gradient from blood to tissue. Hb binds $O_2$ so fast that it’s 98% (@ 100mm) saturated after passing alveoli. Drops to 75% when releases $O_2$ to match resting tissue, or ~35% in hard-working tissues. Steep slope in binding curve between resting metabolic $P_{O_2}$ (40mm) and exercising muscle $P_{O_2}$ (20mm) to allow quick release of $O_2$ to hypoxic tissues. Still, huge reserve capacity of $Hb-O_2$ in resting tissues (75% left!!!). Hb-$O_2$ binding reduced to release $O_2$ by metabolic signals of high activity: $\downarrow$pH, $\uparrow$CO$_2$, $\uparrow$DPG, $\uparrow$Temp $\rightarrow$ all shift binding curve to the right, so that $O_2$ is more easily released to tissues at lower partial pressures.

$CO_2$ is transported 7% dissolved in plasma, 25% bound to Hb, and 70% as Bicarbonate ion ($HCO_3^-$). Bicarbonate is produced in Red Blood Cells by Carbonic Anhydrase. $HCO_3^-$ leaves RBC’s by antiport with Cl-, known as the Chloride Shift. $HCO_3^-$ also functions as a pH buffer in plasma and tissues. Extra H+ produced by carbonic anhydrase (from $CO_2$ and $H_2O$) combines with Hb, or is removed by renal or respiratory compensation. Hyperventilation removes $CO_2$, and raises ECF/plasma pH.

**REGULATION of VENTILATION:** Breathing = unconscious and rhythmic, controlled by skeletal muscles and somatic neurons. Somatic neurons are controlled by a CNS network in the brain stem (medulla and pons), called the Central Pattern Generator. Autorhythmic neurons (with unstable membrane potentials, $V_m$) create rhythmic cycles of breathing, but are controlled by receptors (central and peripheral) for $CO_2$, $O_2$ and H+ ($CO_2/H_+ \text{ signals dominate!!}$).
Possible Short Essay Topics (be prepared to draw diagrams as well!  ** Focus questions = in BOLD!):

** Ch. 8: **
1. Diagram and describe the initiation and conduction of a nervous signal from the “receiving region” of a neuron to a post-synaptic membrane. What is the difference between graded, threshold, and action potentials? Where does each occur? What ions, proteins, and glial cells can be involved?
2. Diagram a typical Action Potential chart, and describe what is happening to ions and channels during the rising, peak, declining, and undershoot phases. Label on the chart, and describe what is happening to ions and channels during the absolute and relative refractory periods.
3. Using diagrams, compare and contrast the anatomy of Sympathetic and Parasympathetic autonomic pathways of the peripheral nervous system. What characteristics are shared? Where do ganglia occur, and what neurotransmitters and receptors are present at the ganglionic and postganglionic synapses?

** Integrative Question:** Compare and contrast the anatomies, neurotransmitters, receptors, and effects/functions of the somatic, sympathetic, and parasympathetic NERVOUS systems. How does each affect the heart, peripheral circulation, nephron/renal circulation, GI tract, endocrine pancreas, and the smooth (bronchiole, arteriole) and skeletal muscles of the respiratory system? 

(Suggestion: make a TABLE)

** Ch. 12: **
5. Diagram and describe 6 main steps in the Sliding Filament Theory of muscle sarcomere contraction, including all of the subcellular structures and molecules involved. EXPLAIN how excitation is coupled to contraction. (eg: Actin, myosin, Ca++, tropomyosin, troponin, nebulin, titin, t-tubules, sarcoplasmic reticulum)
6. Compare and contrast the organization and contractile function of skeletal, cardiac, and smooth muscle cells. What controls the force of contraction in each type of muscle at both the cellular/molecular levels, and the organ levels? (hint: processes stimulated by Ca++, neurotransmitters sensed)

** Integrative Question:** Describe at least FIVE processes in neurons, myocytes (muscle cells skeletal, smooth, & cardiac), and secretory endocrine glands in which Calcium Ions (Ca++) function as important intracellular secondary messengers. Diagram how calcium exerts its effect on cells in each of these cases (what cells and molecules does Ca++ act upon, and what is the result?).

** Ch. 14 - 15: **
8. Describe in detail 5 factors regulating Blood Pressure (MAP). Describe specific examples of homeostatic responses to changing conditions in the body/bloodstream.
9. Comparing responses to low blood pressure and to high blood pressure, explain how the Baroreceptor Reflex regulates Blood Pressure. What paracrine (neurotransmitter & metabolite), endocrine, chemical receptors, and nervous pathways are involved?
10. Describe the major pacemakers of the heart, and diagram and explain how they spontaneously generate action potentials at the molecular and cellular levels. How is this affected by different autonomic inputs? Diagram the path of heart AP conduction, and relate this to the functional sequence of contraction in the four chambers.
11. Explain and diagram how hydrostatic (hydraulic) Pressure and colloidal osmotic pressure vary along a capillary vessel, and how these regulate capillary filtration and absorption.
   • (Be sure to indicate the direction of flow, and general names of incoming and outgoing vessels)

** Ch. 17 - 18: **
12. Compare and contrast how oxygen and carbon dioxide are transported in the bloodstream, and the properties of each molecule that determine its necessary mode of transport. How do the properties of these molecules and their transporters determine where and how each gas enters or leaves the blood?
13. Describe how ventilation is regulated by six different neural (sensory and autorhythmic), chemical, and higher brain (conscious/emotional) inputs. Explain the responses to and the results of each of these regulatory signals.
14. Outline the physical and chemical factors controlling gas exchange between the alveoli and pulmonary capillaries. Diagram and describe the local signals and responses that help match ventilation and perfusion.
15. Using diagrams of Hb saturation graphs, describe how at least 5 different physical, chemical, and developmental factors influence where in the body Hemoglobin binds or releases O2.

** Integrative Question:** In every body system that we have examined, we have seen the crucial role played by gradients to supply the energy and driving force for the proper function of each system. Compare and contrast the type (chemical, electrochemical, pH, gas pressure, liquid pressure), the source of the stored energy, and final function of the gradients found in neurons, muscles, respiration, circulation, and renal filtration & reabsorption.

** Suggestion for simplicity:** For all “Compare” and/or “Contrast” questions, make a table with each system or factor to compare in the top of each column, and label the far left column (each row) with the title of each characteristic being compared.