Lecture Study Guide for Midterm

Chapter 1
1. Understand the scientific method and clinical trials
2. Define and understand homeostasis
   a. Sensor
   b. Integration Center
   c. Effector
   d. Set-point
3. Know the difference and understand negative and positive feedback
4. Understand tissues – four categories and subcategories
   a. Epithelium, Muscle, Connective and nervous
   b. Stem Cells: definition, types, what go on to generate
5. Compartments: intracellular and extracellular

Chapter 2
1. Understand the basic properties of an atom
   a. Proton, Neutrons, electrons
   b. Atomic number
   c. Atomic mass (N+P)
   d. Valence electrons: electron in outer shell
   e. Isotope: atom with different number of neutrons
2. Understand the basic principles of forming molecular bonds
   a. Covalent bonds
      i. Non-polar – O₂, H₂
      ii. Polar - H₂O
   b. Ionic (valence electrons not shared but transferred)– NaCl
   c. Hydrogen Bond
3. pH: log scale that measures the inverse of H⁺ concentration
4. Organic molecules: carbon-based molecules
   a. Carbohydrates: mono- and di-saccharides
   b. Lipids (fats) – ketones, phospholipids, steroids, prostaglandins
   c. Proteins
   d. Deoxyribonucleic (DNA) – double stranded helix, complementary pairs (A-T; G-C)
   e. Ribonucleic Acid (RNA) – Single stranded, A-U; G-C

Chapter 3
1. Understand cell membrane
   a. Structure – double phospholipids with proteins, glycoproteins, and glycolipids
   b. Functions
   c. Modifications – Cilia, Flagellum, and Microvilli
2. Major cell parts
   a. Cytoplasm/cytoskeleton
   b. Organelles
3. Phagocytosis, Endocytosis, and Exocytosis
4. Replication
   a. S – phase of interphase
   b. histones
5. Understand mRNA, rRNA, and tRNA
6. Transcription: DNA to pre-mRNA to mRNA (modifications)
7. mRNA to protein
8. Understand meiosis and mitosis and the differences
9. Cell Cycle: G1, S, G2, M
10. Telomeres – repetitive nucleotides at the end of chromosomes; key in aging
11. Apoptosis: programmed cell death
12. Epigenetics – study of genetic modification

Chapter 4
1. Understand what enzymes are and how they function
   a. Proteins that catalyze a reaction by lowering activation energy
   b. Work unidirectional or bidirectional
   c. Lock and Key
2. Regulations of Enzyme activity
   a. Temperature, pH, amount of substrate
   b. Cofactors
   c. Coenzymes
3. Oxidation vs. Reduction
   a. Oxidized state vs reduced state
   b. Oxidizing reagent vs reducing reagents

Chapter 5
1. Endergonic vs Exergonic reactions
2. First and Second Laws of Thermodynamics
3. Cell respiration and metabolism (anabolic and catabolic reactions)
   a. Glycolysis
      i. Net gain: 2 ATP
      ii. Glucose locked in the cell
      iii. Generates 2 pyruvate (pyruvic acid)
   b. Anaerobic respiration
      i. Lack of oxygen
      ii. Form lactic acid (utilizing NADH)
   c. Aerobic respiration
      i. Oxygen present
      ii. Forms Acetyl CoA (utilizing Coenzyme A, generating NADH)
      iii. Acetyl CoA – entry point to many pathways
         1. Can form citric acid (For Kreb cycle and produce CO2), fatty acids (lipogenesis), ketone bodies, and cholesterol (go on to make steroids and bile acids)
         2. Lipolysis can breakdown fatty acid and beta-oxidation to Acetyl CoA
   iv. Kreb cycle
      1. Occurs in the mitochondria
      2. Starts with Acetyl-CoA which combines with molecules of the Kerb cycle (that are recycled
      3. End results per molecule of acetyl-CoA (1 GTP, 3 NADH, 1 FADH2, and 2 CO2) or glucose (2X)
   v. Electron Transport Chain
      1. NADH and FADH2 from Kerb Cycle are oxidized in the inner mitrochondrial membranes (cristae) in a process called oxidative phosphorylation
      2. Final acceptor of the electrons is oxygen
      3. Theoretically yields 30-32 ATP
   c. Know the Cori Cycle (pathways and locations, purpose)
   d. Glycogenesis vs Glycogenolysis
   e. Transamination Reactions and Deamination (generates and purpose)
Chapter 6

1. Intracellular: 2/3 of body water
2. Extracellular: 1/3 of body water - 1/5 is plasma, 4/5 is interstitial (between cells)

3. Cell Transport
   a. Passive Transport: The net movement of molecules and ions across a semi-permeable membrane from high to low concentrations
   b. Includes: simple diffusion and carrier-mediated facilitated diffusion
   c. Diffusion – the net movement of a solute in a solution from low entropy to high entropy. In biological systems, it is often the movement from high concentration to low concentration across a semi-permeable membrane
   d. Facilitated diffusion – down a concentration gradient (from high to low concentration) with the use of a carrier molecule (usually a protein)
   e. Active Transport – the movement of molecules against a concentration gradient (From low to high concentration) This requires energy (ATP)
   f. Examples of Active Transport:
      i. Ca$^{2+}$ pump – calcium concentration is higher outside the cell than inside. It will flow into the cell by diffusion, but must be pumped out of the cell via a carrier protein and the use of ATP
      ii. Na-K ATP pump – three Na$^+$ pumped out of the cell for 2K$^+$ into the cell. Requires ATP. This creates a charge difference across the cell membrane with the inside of the cell being negatively charged (also because negatively charged proteins) and the outside of the cell being positively charged.

4. Cotransport: an ion moving down its concentration gradient can carry a molecule against its concentration gradient. This eventually will cost the cell energy.

5. Exocytosis and Endocytosis

6. Osmosis: The net movement of water across a selective semi-permeable membrane. In the cell membrane there are proteins channels called aquaporins (water pores) that aid this movement.

7. Osmotic pressure: the force required to stop osmosis. The greater the solute concentration, the greater the pressure. In physiology, the term "colloidal pressure" is often used interchangeably.

8. Molality: 1 mole of solute + 1 liter of water

9. Osmolality: total molality – Ex. 1 mole of glucose in 1 liter of water is 1 osm, and 1 mole of glucose + 1 mole of fructose is 2 osm, 2 moles of glucose is 2 osm;
   a. Blood plasma osmolality = ~290 mOsm

    a. Isotonic: no net movement of water
    b. Hypertonic: higher amount of osmotically active solute that will draw water out of the cell and cause the cells to shrivel and crenate
    c. Hypotonic: lower amount of osmotically active solute that will draw water to enter the cell and cause the cells to swell and burst

11. Membrane Potential: The difference in charge across a semi-permeable membrane. Dependent on ions such as K$^+$, Na$^+$, Ca$^{2+}$, Cl$^-$, but the cell is most permeable to K$^+$, thus K$^+$ has the greatest single effect on the resting membrane potential.
    a. Hypokalemia – low blood plasma K$^+$ levels
    b. Hyperkalemia – high blood plasma K$^+$ levels

12. Cell Signaling: cells releasing chemicals into the extracellular environment
    a. Paracrine: cells secreting messengers within an organ
    b. Synaptic: neurons secreting chemicals across a synapse
    c. Endocrine: cells secreting hormones to a different target organ

13. G-proteins: common regulatory proteins (consist of Alpha, and beta and gamma subunits) in the cell membrane that utilizes GTP
Chapter 7

1. Central nervous system: Brain and spinal cord, white matter is neuronal tracts and gray matter is cell bodies (described as nuclei and occasionally as ganglia)
   a. Neurons (sensory-afferent, motor-efferent, interneurons), astrocytes, oligodendroglia, microglia, ependymal, choroid plexus

2. Peripheral nervous system:
   a. Neurons (sensory, motor, mixed) Schwann Cells (neurolemmocytes), cell bodies in ganglia outside the CNS
   b. Types of neurons: pseudounipolar (sensory in the PNS), biopolar, multipolar (motor)
   c. Myelinated versus unmyelinated (fast vs. slower)

3. Blood Brain Barrier: formed as a result of tight junctions of brain capillaries (endothelial cells) and astrocytes’ foot processes. Most drugs (except alcohol) including antibodies cannot pass the BBB

4. Blood-CSF Barrier: Choroid plexus epithelial cells with tight junctions but brain capillaries lack the junctions

5. Action Potential: neuron with a resting membrane potential (-70mV) which occurs because of the Na+ gradient secondary to the Na-K ATPase pump
   a. Stimulates causes a change in the resting membrane potential. When it reaches threshold (-55mV), an action potential occurs. This is an all or none response.
   b. Phases
      i. Depolarization: stimulus applies, threshold is reached and Na+ channels open. Na+ flows from high to low into the axon. Membrane potential becomes positive to about +30mV
      ii. Hyperpolarization: Na+ channels become inactive, K+ channels open and K+ flows from high to low outside the axon.
   c. Absolute refractory period: Depolarization + repolarization
   d. Relative refractory period: hypopolarization
   e. Amplitude of the AP does not change (all or none response), but frequency can change and therefore interpretation of the stimulus.
   g. Synapse: Terminal bouton, synaptic cleft, presynaptic axon, postsynaptic axon, synaptic vesicles, neurotransmitter.
   h. When an action potential reaches the terminal bouton, the AP changes from an electric to chemical impulse.
      i. Axon potential reaches the terminal axon.
      ii. Ca2+ flows into the cell via Ca channels.
      iii. Ca2+ binds to a protein-sensor.
      iv. Ca2+-protein complex binds to neurotransmitter
      v. Neurotransmitter is released via exocytosis
      vi. Neurotransmitter binds to receptors on post-synaptic axon
      vii. Influx of Na+ occurs causing an Excitatory Post Synaptic Potential (EPSP)
      viii. These cause opening of K+ channels at the axon hillock
      ix. An action potential is created
      x. Neurotransmitter is broken down via enzymes or reabsorbed by the presynaptic membrane (axon) and re-packed into vesicles
   i. Alternatively, the neurotransmitter could be inhibitory. This will cause an influx of Cl at the post-synaptic axon which in turn will hyperpolarize the membrane thus making it difficult to obtain an AP.

6. Excitatory Neurotransmitters:
   a. CNS: acetylcholine, serotonin, glutamic and aspartic acid, dopamine, endorphins
   b. PNS: acetylcholine, epinephrine, norepinephrine
7. Inhibitory Neurotransmitters: Glycine, gamma-aminobutyric acid (GABA)

Chapter 8
1. CNS: Brain – cerebrum, diencephalon (“epithalamus,” thalamus, hypothalamus, pituitary gland), brainstem (midbrain, pons, medulla oblongata), cerebellum (hindbrain)
2. Embryological Development: prosencephalon (telencephalon and diencephalon), mesencephalon (midbrain), rhombencephalon (metencephalon- pons and cerebellum, myelencephalon- medulla oblongata)
3. Laterization: left - mathematical and analytical; right – creative/spatial
4. Lobes:
   a. frontal – motor and personality
   b. Parietal – sensory
   c. Occipital – vision
   d. Temporal – auditory
   e. Insula – memory
5. Speech – Broca’s area (motor speech), Wernicke’s area (receptive speech) arcuate fasciculus (connection)
6. Visual Pathways – optic nerves, optic chiasm, optic tracts, lateral geniculates (of the thalamus), occipital lobe
7. Limbic System – cingulate gyrus, amygdala, hippocampus, septal nuclei
8. Basal Nuclei (ganglia) – caudate, globus pallidu, patamen
9. Thalamus – sensory relay station (except smell)
10. Hypothalumus – main part of the brain responsible for homeostasis, body temperature, hunger, thirst (osmoreceptors), wakefulness, pituitary gland function
11. Circadian Rhythm – retina-suprachiamatic nucleus (of the hypothalamus) to pineal gland. Light inhibits formation of melatonin (hormone made by the pineal gland, which helps control your sleep and wake cycles)
12. Brainstem:
   a. Midbrain – motor pathways (cerebral peduncles), sensory pathways, corpora quadrigemina (superior for visual, inferior for hearing)
   b. Pons – motor and sensory pathways, lower cranial nerves, apneustic and pneumotaxic breathing centers
   c. Medulla oblongata – crossing of sensory and motor pathways, vital centers of breathing and vasomotor
13. Reticular activating system (RAS) - Complex network of nuclei and nerve fibers within medulla, pons, midbrain, thalamus and hypothalamus that control non-specific arousal to incoming sensory information.
14. Cerebellum – coordination and balance
15. Ventricles – four total: 2 lateral ventricles (in each hemisphere), 3rd ventricle, and 4th ventricle; choroid plexus – produce CSF, ependymal – control flow of CSF with cilia
17. Pyramidal vs extrapyramidal pathways
18. Reflex arc – Figure 8.28

Chapter 9
1. Autonomic Nervous System – neural control of involuntary effectors
2. Preganglionic vs. Postganglionic neurons
3. See Table 9.1
4. Sympathetic division
a. Preganglionic neurons come from the thoracic and lumbar regions of the spinal cord, these are called the thoracolumbar division.
b. Preganglionic neurons synapse in sympathetic ganglia that run parallel to the spinal cord, these are called the paravertebral ganglia.
c. Divergence vs Convergence
d. Mass activation: Divergence and convergence cause the SNS to be activated as a unit.
e. Postganglionic neurons are unmyelinated to the effector organ.
f. Collateral Ganglia - Many of the sympathetic neurons that exit the spinal cord below the diaphragm do not synapse in the sympathetic chain of ganglia.
g. Adrenal Gland - The adrenal medulla secretes epinephrine and norepinephrine when stimulated by the sympathetic nervous system as a part of mass activation.

5. Parasympathetic Division
a. Preganglionic neurons come from the brain or sacral region of the spinal cord, called the craniosacral division.


7. Adrenergic and Cholinergic Synaptic Transmission
a. ACh is NT for all preganglionic fibers of both sympathetic and parasympathetic nervous systems called cholinergic.
b. Axons of postganglionic neurons have numerous varicosities along the axon that contain NT. Varicosities - Axons of postganglionic neurons have various swellings called varicosities that release neurotransmitter along the length of the axon.
c. Catecholamines – family of neurotransmitter of adrenergic
   i. Norepinephrine most postganglionic sympathetic nerve fibers.
   ii. Epinephrine, released by the adrenal medulla is synthesized from the same precursor as NE.
d. Comparison of Nicotinic & Muscarinic ACh Receptors
    e. Other Autonomic NTs
       i. Certain nonadrenergic, noncholinergic postganglionic autonomic axons produce their effects through other NTs.
          1. ATP.
          2. vasoactive intestinal peptide (VIP).
          3. nitric oxide (NO).

8. Organs With Dual Innervation
a. Complementary - Sympathetic and parasympathetic stimulation produces similar effects.
b. Cooperative - Sympathetic and parasympathetic stimulation produce different effects that work together to produce desired effect.
c. Most of the time these systems are antagonists (Actions counteract each other):
   i. Heart rate – sym increases, para decreases
   ii. Digestive functions – sym decreases, para increases
   iii. Pupil diameter – sym dilates, para constricts

9. Organs Without Dual Innervation
a. Adrenal medulla, arrector pili muscles in the skin, sweat glands in the skin and most blood vessels.
b. Nonshivering thermogenesis – sympathoadrenal system is required for proper thermoregulatory responses to heat
   i. Examples – hot room, decrease in sympathetic stimulation produces dilation of the blood vessels in the skin, which increases cutaneous blood flow and provides better heart radiation or during exercise, sympathetic activity increases, causing the constriction of the blood vessels in the skins and stimulation of sweat glands.
Chapter 10

1. Sensory Receptors: chemoreceptors (olfactory, taste), photoreceptors (rods and cones), thermoreceptors, mechanoreceptors (touch, pressure), nociceptors (pain)
2. Receptors transduce (change) at stimulus into nerve impulse
3. Sensory adaption: phasic receptors – fire quickly and adapt quickly (odor, touch, temperature), tonic receptors maintain a relatively constant firing rate and are slow to adapt (pain receptors)
4. Two point discrimination – touching in two separate receptive fields, the parts of the body that require fine touch will have more receptive fields present
5. Lateral Inhibition – sharpens the impulse in the center of the receptive field
6. Taste – 5 types of chemoreceptors in the taste bud: salt ($\text{Na}^+$) and sour ($\text{H}^+$) – depolarization, sweet and bitter (G-proteins – secondary messenger)
7. Smell– olfactory epithelium – olfactory tract which travels to the frontal and temporal lobes, including the limbic system
8. Vestibular apparatus:
   a. semicircular canals sense rotational acceleration (posterior, anterior and lateral canals) via sensory hair cells embedded in a gelatinous membrane called the cupula
   b. utricle – senses horizontal rotation – via hair cells are embedded in a gelatinous membrane called otolithic membrane
   c. Saccule – senses vertical movement
9. Hearing: conductive hearing – outer and middle ear; neural signal interpretation: inner ear
   a. Cochlea: hair cells of the basilar membrane,
   b. Sound waves travel along the basilar membrane moving hair cells – higher frequency is closer to the oval window
   c. Vestibulocochlear nerve – to brainstem where it travels on both sides, then to the thalamus, then to the superior temporal gyrus
10. Vision – Light rays are refracted by the cornea and lens. The lens inverts the image on the retina. The outer portion of the retina contains rods (black and white and night vision) and cones (color – blue, red, and green receptors and visual acuity at the fovea centralis)
   a. Refraction and refraction index
   b. Field of Vision
   c. Myopia – Light rays fall short of the retina (nearsightedness); eyeball too long; concave lenses are used that allow the light to diverge
   d. Hyperopia – light rays fall behind the retina (farsightedness); eyeball too short. Light rays need more refraction to fall on the retina, thus convex lenses are used
   e. Astigmatism – is a defect in the shape of the cornea (or lens) causing asymmetry in the refracting of light rays. Uneven lens corrects.
11. Visual Pathway – optic nerve, optic chiasm, optic tract, lateral geniculate (thalamus), some fibers to the superior colliculus (for papillary response and accommodation) in the midbrain, or optic radiation (through superior temporal and parietal lobes) to occipital lobe