Organ System Physiology

The remainder of the biology material focuses on the physiology of the various organ systems of the body. The MCAT tests these heavily, so this should be a point of emphasis in your studies. We begin our physiology review with five systems that have been MCAT favorites in recent years: the excretory, respiratory, cardiovascular, nervous, and endocrine systems. In the aggregate, there have consistently been more MCAT questions asked on these topics and slightly fewer on the systems we will cover in the Biology 3 lesson. Remember, however, that *any* combination of topics could show up on your particular form of the exam!

The Excretory System (The Kidneys)

- Functions: Excrete liquid and solute waste (e.g., excess water, excess salts, nitrogenous wastes, etc.); maintain pH, osmolarity and blood pressure.

- ***Anatomy of the Kidney:***
  - *Q1. Draw a kidney and label the following: nephron, cortex, medulla, renal pelvis, and ureter.*
  - *Q2. Draw a nephron and label the following: glomerulus, Bowman's capsule, proximal convoluted tubule, descending loop of Henle, ascending loop of Henle, juxtaglomerular apparatus, distal convoluted tubule, and collecting duct.*
  - *Q3. Describe the function of each of the items labeled on your diagram, focusing on the role each component plays in the concentration of the filtrate, exchange of ions, etc.*
  - *Q4. Describe the interplay between: the juxtaglomerular apparatus, the renin-angiotensin pathway, aldosterone, and the distal convoluted tubules of the kidney.*

> ***IMPORTANT NOTE***
>
> It is easy to confuse the ureters and the urethra. The ureters carry urine from the renal pelvis portion of the kidneys to the bladder. The urethra carries urine from the bladder to the external urinary orifice. You have two ureters, but only have one urethra.

- ***Hormonal Regulation of Kidney Function:***
  - ***Aldosterone*** acts on the distal tubule causing an increase in sodium uptake. Aldosterone also causes reabsorption of Na^+ out of the collecting duct via the insertion of Na^+ channels, K^+ channels, and Na^+/K^+ ATPases in the cells that line the collecting duct. This increases the osmolarity of the cells lining the distal tubule, causing water to flow out of the filtrate and into the cells. ***The net effect = water retention and increased blood pressure.***
  - ***ADH*** acts on the collecting duct, making it permeable to water. In the absence of ADH the collecting duct is impermeable to water. Because the collecting duct passes through the highly-concentrated medulla, as soon as the membrane becomes permeable there is a large net flow of water out of the filtrate, concentrating the urine. ***The net effect = water retention and increased blood pressure.***

The Respiratory System

- Function: Primary function is gas exchange. Inhalation and expiration are necessary functions to deliver air to the alveoli where gas exchange can occur. Oxygen diffuses down its concentration gradient into the blood, and carbon dioxide diffuses down its concentration gradient out of the blood and back into the lungs.

- Inhalation/Exhalation:
  - Path of Air = Mouth/nose → pharynx → larynx → trachea → bronchi → bronchioles → alveoli.
  - *Q5. Provide a conceptual definition for the following terms: tidal volume, reserve volume, residual volume, and vital capacity.*
  - *Q6. Laryngitis is the loss of one's normal voice due to inflammation of the vocal chords. A common home remedy suggests that drinking honey soothes and hydrates the vocal chords, speeding recovery. Does the anatomy of the respiratory system support or refute this proposed remedy?*
  - The Diaphragm: Be careful, students frequently get the following confused:
    1) ***The diaphragm moves down when it is flexed and moves up when it is relaxed.*** When relaxed it has an upward-oriented convex shape. When flexed it is almost flat.
    2) ***The diaphragm moves down during inhalation and up during exhalation.***

- Gas Exchange:
  - Hemoglobin = quaternary protein made of four protein chains, two alpha and two beta. Each protein has an Fe-containing "heme" group at its center. Each heme can hold one O_2 molecule.
    - *Q7. How many oxygen atoms are carried on one molecule of Hb at 100% saturation?*
  - Oxygen Dissociation Curves: A graph of % Hemoglobin Saturation vs. pO_2
    - *Q8. Draw a hemoglobin binding curve. Show the shape of the curve for both O_2 binding and CO binding. Demonstrate the effect of $[CO_2]$, $[H^+]$, [BPG], and temperature on the O_2 binding curve.*
  - How CO_2 is carried in the blood: You must know and understand the following equation:
    - $\boldsymbol{CO_2 + H_2O \rightarrow HCO_3^- + H^+}$
    - *Q9. The equation above is actually the net reaction for the sum of two related reactions that occur as CO_2 dissolves in the blood. Demonstrate how these two reactions combine to form the above reaction.*

IMPORTANT NOTE

Blood gases and blood pH are very frequent MCAT topics. Questions usually ask you to predict changes to blood pH based on a wide variety of scenarios or changes, such as: increased partial pressure of CO_2 in the lungs, changes to the $[CO_2]$ in the blood, hyperventilation, difficulty exhaling, blockage of a pulmonary vein or artery, and so on. For example, "If the pulmonary artery became blocked, what would be the immediate short-term effects on blood pH?"

The Cardiovascular System

- Function: Deliver oxygen and nutrients to the cells and tissues of the body; pick up CO_2 and waste products and deliver them to the lungs and kidneys.

- The Heart:
  - *Q10. Draw a heart and correctly label the following: superior and inferior vena cava, right atrium, left atrium, pulmonary artery, pulmonary veins, left atrium, left ventricle and aorta.*
  - **Systemic Circulation**: Blood flows from the left ventricle, through the arteries, arterioles, capillaries, venules, veins, vena cava and back to the right atrium.
  - **Pulmonary Circulation**: Blood flows from the right ventricle through the pulmonary arteries to the lungs and back through the pulmonary veins to the left atrium.
    - ***Arteries leave the heart and veins return to the heart.*** The naming of blood vessels is NOT based on whether they carry oxygenated or de-oxygenated blood. Rather, it is based on the direction of flow: either toward or away from the heart.
    - *Q11. Name at least one artery and one vein that carry oxygenated blood. Name at least one artery and one vein that carry deoxygenated blood.*
  - Electrical System of the Heart:
    - *Q12. Draw and describe the following on a diagram of the heart: sinoatrial node, atrioventricular node, bundle of His, and Purkinje fibers.*
    - ***Sympathetic NS activity increases heart rate and blood pressure.***
    - ***Parasympathetic NS activity decreases heart rate and blood pressure.***

- Blood Vessels:
  - Arteries → Arterioles → Capillaries → Venules → Veins
    - Arteries: muscular, thick-walled vessels that push blood through via rhythmic contraction.
    - Veins: thin-walled vessels with little to no musculature that rely on a valve system to move blood back toward the heart.
  - *Q13. Describe how the interplay of hydrostatic and osmotic pressure accounts for the flow of fluid into and out of the capillary beds.*
  - *Q14. Draw a graph for each of the following: a) cross-sectional area vs. blood vessel type (aorta/arteries/arterioles/capillaries/venules/veins/vena cava), b) velocity vs. blood vessel type, c) blood pressure vs. blood vessel type (Hint: Q = AV).*

- Blood:
  - Functions: Transport nutrients, gases, waste products and hormones to and from cells; regulate the extracellular environment; help maintain homeostasis; repair injuries; protect the body from foreign bodies (i.e., antigens).
  - Contents: White Blood Cells (a.k.a. WBCs or leukocytes), Red Blood Cells (a.k.a. RBCs or erythrocytes), antibodies (a.k.a. immunoglobulins), clotting factors (e.g., fibrinogen), transport proteins (e.g., albumin) and platelets. *Q15. Blood is an example of which tissue type?*
    - ***Erythrocytes:*** Sacks of hemoglobin; immature RBCs start out with a nucleus and organelles, but ***mature RBCs have no organelles***.
      - *Q16. Do erythrocytes undergo mitosis? Y / N*

- ***Leukocytes:*** Do not contain hemoglobin. These are normal cells, with all their organelles, that are involved in the immune system (we'll discuss WBCs in more detail in an upcoming section on the Immune System).
  - Granulocytes: neutrophils, eosinophils, and basophils. ***These cells live for hours to days.***
  - Agranulocytes: monocytes (become macrophages) and lymphocytes. ***These cells live for months to years.***
- Platelets: Tiny membrane-bound drops of cytoplasm. They are sticky when exposed to injured epithelium and non-sticky to healthy epithelium. If they encounter injured epithelium, they release chemicals that activate other platelets and clotting factors. Platelets are derived from megakaryocytes, a type of blood cell that remains in the bone marrow. Mature megakaryocytes produce small fragments, which they release into the circulating blood. These cellular fragments are platelets.
- All blood cells develop from stem cells (undifferentiated cells) in the bone marrow; a process called ***hematopoiesis***.

➢ Blood Typing:

- Four phenotypes: A, B, AB, and O
  - *Q17. Blood type is an example of what kind of genetic inheritance pattern?*
- The letters A and B indicate the **antigens** that ***are*** present on that individual's blood cell membranes:
  - A = A antigens only
  - B = B antigens only
  - AB = Both A and B antigens
  - O = Neither A or B antigens

IMPORTANT NOTE

To avoid mistakes on blood-typing questions, ***always focus on the recipient.*** If a person's immune system sees any protein it does not have on its own blood cell membranes, it will attack it and coagulation/rejection will result. Thus, a patient with type A blood is fine with A antigens on donated blood cells, but will attack B antigens, whether from an AB, or a B donor. Type O blood can be donated to anyone because it has no A or B antigens. A person with blood type AB can receive from anyone because no donor will have any antigens this person's immune system hasn't seen previously.

The Lymphatic System

➢ Function: Gather excess interstitial fluid and return it to the blood; remove from the interstitial spaces proteins and other molecules too big to be taken up by the capillaries; monitor the blood and lymph for infection.

- Lymph Nodes: Lymph nodes are filled with lymphocytes. These immune system cells monitor the blood for foreign antigens and fight infections (We'll cover this topic more when we cover the "Immune System" in the Biology 3 Lesson).
- Lymphatic Vessels: Lymphatic vessels, also known as lymphangions, are a lot like veins in that many of them (but not all) contain one-way valves. Backward flow is restricted when single cells overlap slightly, creating a trap door that allows fluid in, but not back out. The entire lymph system eventually drains into two main vessels, the right lymphatic duct and the thoracic duct, which both dump back into the blood stream by merging with large veins in the lower portion of the neck.

Sample MCAT Question

1) Hardening of the arteries (arteriosclerosis) is often accompanied by hypertension, primarily because:

A) smooth muscle lining the arteries is weakened and cannot contract.
B) there is less force against the artery wall in a rigid vessel than in a flexible vessel.
C) hardened arteries are narrowed, increasing vascular resistance.
D) new vascular pathways generate to bypass the blockage, increasing the length of the conduit through which the blood must pass.

Solution: Answer A is false because this would increase the diameter of the vessel and decrease blood pressure. Answer B would also decrease blood pressure per the equation P = F/A. Answer D describes a process that does not occur in the human body. Answer C is therefore correct. Blood pressure is primarily a function of cardiac output and vascular resistance.

The Nervous System

- Definition: The nervous system includes the brain, spinal cord, peripheral nerves, neural support cells (astrocytes, Schwann cells, ependymal cells, etc.) and sensory organs such as the eyes and ears.

- The Neuron: A neuron is a specialized cell that can carry an electrochemical signal (i.e. action potential).
  - Remember that neurons:
    1) Are frozen in G_0 phase (unable to divide)
    2) Depend *entirely* on glucose for energy
    3) Don't require insulin for glucose uptake
    4) Have very low glycogen & oxygen storage capability and thus require high perfusion (blood flow)
  - *Q18. Draw a neuron and label the following: dendrites, cell body, nucleus, axon hillock, terminal button, synapse, Schwann cells, myelin sheath, and nodes of Ranvier.*
  - *Q19. Describe the function and significance of each item labeled in your diagram.*

- ***Creation and Propagation of the Action Potential:* A Very Important Topic!**
  - Action Potential: A disturbance (i.e., a dramatic change) in the resting electrical potential (i.e., voltage) across the membrane of a nerve cell. Once an action potential is created, it will propagate along the cell membrane to neighboring portions of the neurons. As it does, the areas where it originally started gradually return to the normal resting potential (see below).
  - Resting Potential: ***-70 mV***. The voltage across the membrane when an action potential is NOT present (e.g., one has not yet occurred, or it has already passed). Know the exact value: -70 mV. This is the only exact value that is used consistently in most textbooks. The other values given below vary from source to source and you only need to know their sign and *approximate* value.
  - Sodium/Potassium Pump: An ATP pump that actively transports 3 Na^+ ions *out* of the cell and 2 K^+ ions *into* the cell per cycle. The net effect is more positive charge outside the cell and a progressively more negative charge inside the cell.
  - Voltage-Gated Sodium Channels: Integral proteins that change shape ("open") in response to a disturbance in the resting potential (i.e., voltage) across the membrane. In their "open" state, they allow the rapid flow of sodium back into the cell.

- Depolarization: The opening of the voltage-gated sodium channels causes a sudden spike in the membrane potential, from -70 mV to somewhere around ***+40 mV***. This process is referred to as "depolarization."
- Threshold Potential: This is the minimum stimulus that must be exerted upon the membrane to initiate the full action potential. It is usually reported as somewhere around ***-55 mV***. If a stimulus depolarizes the membrane above this threshold, the entire action potential will follow. If not, the membrane potential will return to -70 mV.
- Voltage-Gated Potassium Channels: These are also integral proteins that respond to a change in the membrane potential. However, their threshold for responding is much higher than that for the voltage-gated sodium channels. As a result, they only react following the very large change in membrane potential caused by depolarization. ***Just before maximum depolarization is reached, the Na^+ channels begin to close and the K^+ channels begin to open.***

IMPORTANT NOTE

A stimulus (i.e., the action potential) starts at the dendrites and passes through the cell body to the axon hillock. The axon hillock then generates a new stimulus only if the initial stimulus is above a certain threshold. Thus, the action potential that arrives at the terminal button is NOT the same stimulus that began at the dendrites; it is a new, regenerated stimulus. Also remember, impulses can only flow down the axon in one direction: cell body to synapse.

- Repolarization: Because there are more potassium ions inside the cell (due to the Na^+/K^+ pump), opening of the potassium channels causes K^+ ions to flow out of the cell. This results in a sudden decrease in the membrane potential from +40mV back down to ***-70 mV***, and is referred to as "repolarization."
- Hyperpolarization: The potassium channels are somewhat slow to close as the membrane potential approaches -70 mV. Thus, the membrane potential actually dips to around ***-90 mV*** before gradually returning to the resting potential.
  - *Q20. Provide a definition for the "absolute refractory period" and the "relative refractory period." Why does it take a stronger stimulus than normal to cause an action potential during the relative refractory period?*
  - *Q21. Graph and label the entire action potential as Voltage vs. Time. Include resting potential, threshold stimulus, absolute refractory period, relative refractory period, depolarization, repolarization and hyperpolarization. Also label on the graph the approximate point at which each channel type opens and closes.*

➢ ***The Synapse:*** There are two kinds of synapses: electrical and chemical. Transmission across the synapse is by far the slowest part of signal transmission.

- Electrical Synapses: Gap junctions between cells that allow electrical signals to pass very quickly from cell to cell. In humans they are found only in specific locations: the retina, smooth muscle, cardiac muscle, and the CNS.
- Chemical Synapses: This is the traditional synapse you probably think of when you hear the word. It is the small gap between the terminal button and either 1) the dendrite of a subsequent neuron, or 2) the membrane of a muscle or other effector.
  - *Q22. Describe the process by which the signal is transmitted from the terminal button, across the synaptic cleft, to the subsequent neuron or effector. Define and explain the function of: presynaptic membrane, Ca^{2+} ions, calcium channels, neurotransmitter, neurotransmitter bundles, exocytosis, postsynaptic membrane, and protein receptors.*

- ***Stopping the Signal:*** The post-synaptic membrane will be continuously stimulated as long as neurotransmitter is present. Specialized enzymes in the synaptic cleft must break down the neurotransmitter to interrupt its action. The most common one is acetylcholinesterase. ***The MCAT loves to ask about acetylcholinesterase.*** They often ask about acetylcholinesterase activators or inhibitors. ***Agonist*** is another term for an activator and ***antagonist*** is another term for an inhibitor.
  - *Q23. Name several possible effects caused by a drug that acts as an acetylcholinesterase antagonist at the neuromuscular junction. How would the effects differ if the drug were an acetylcholinesterase agonist?*

➢ Neural Support Cells:

- These cells are not neurons that conduct electrical potentials, but cells in the nervous system that provide support to neurons. Schwann cells (oligodendrocytes in the CNS), cells lining the cerebrospinal fluid cavities (ependymal cells) and structural support cells (astrocytes) are a few prominent examples.

➢ Neuron Types:

- ***Sensory (Afferent) Neurons:*** Receive sensory signals from sensory cells.
- ***Motor (Efferent) Neurons:*** Carry signals to a muscle or gland to respond to the stimulus.
- ***Interneurons:*** Connect afferent and efferent neurons. They also transfer and process signals. The brain and 90% of all other neurons are interneurons.

➢ Nervous System Organization: The nervous system is divided into the CNS and PNS.

- **CNS**: The brain and spinal cord; interneurons only. No subdivisions.
- **PNS**: All neurons outside of the CNS; both sensory and motor neurons. Contains "somatic" and "autonomic" subdivisions.
  - **Somatic**: Voluntary; innervates skeletal muscle; contains both sensory and motor subdivisions.
  - **Autonomic**: Involuntary; innervates cardiac muscle, smooth muscle, and glands; contains both sensory and motor subdivisions.
    - **Sensory**: The sensory subdivision of the autonomic nervous system is not well developed, explaining why visceral pain is often referred (i.e., felt at a location other than the actual source) and poorly localized.
    - **Motor**: The motor subdivision of the autonomic nervous system contains the "sympathetic" and "parasympathetic" divisions with which you are likely familiar.
      - **Sympathetic:** "Fight or Flight." Cell bodies located far from the effectors. Neurotransmitters: acetylcholine at the ganglia, norepinephrine at the effector.
      - **Parasympathetic: "**Rest and Digest." Cell bodies located very close to, or inside, the effector. Neurotransmitters: acetylcholine *only*, at both the ganglia and the effector.
      - A common misconception is that the sympathetic stimulates and the parasympathetic inhibits. This is false. They both stimulate and inhibit, depending on the situation. Always rely on "Fight or Flight" and "Rest and Digest" to predict what they will do.
- *Q24. Describe the effect of 1) parasympathetic stimulation and 2) sympathetic stimulation, on each of the following: pupil constriction, heart rate, blood pressure, blood flow to skeletal muscle, blood flow to the digestive organs, blood flow to the brain, and blood flow to the skin.*
- *Q25. Draw a flow chart (i.e., algorithm) demonstrating the hierarchical organization of the human nervous system. At a minimum, include all of the bolded terms from the previous section*

Sample MCAT Questions

2) If a concentrated saline solution were to be injected at the proximal end of one of the collecting ducts of the kidney, what changes would be expected to urinary output and blood pressure, respectively?

A) Urinary output would increase and blood pressure would decrease
B) Both urinary output and blood pressure would decrease
C) Both urinary output and blood pressure would increase
D) Urinary output would increase, but blood pressure would remain constant

Solution: Without the presence of the hormone ADH, the collecting ducts of the kidney remain impermeable to water and thus no changes in urinary output or water retention could occur. However, considering the injection itself would join with the urine, it is logical to say that urinary output would increase slightly. Answer D is correct.

3) All of the following changes to the physiology of the cell membrane of a neuron would decrease the sensitivity of that neuron to the propagation of a new action potential, EXCEPT:

A) a complete inhibition of ATP production and availability in the cell
B) administration of a drug that upregulates the function of the sodium-potassium pump
C) increased selective permeability of the neuronal membrane to sodium ions
D) increased rate of diffusion of potassium ions relative to sodium ions

Solution: If there were no ATP at all, the sodium-potassium pump would stop functioning and all ions would equilibrate. Upregulation of that same pump would make the cytosol more negative than resting membrane potential and a larger stimulus would be required. Similarly, increased diffusion of potassium would also make the cytosol more negative. Increased permeability to sodium, however, would cause sodium to flow into the cell, moving resting potential closer to the threshold. It would then be easier to propagate a new stimulus. Answer C is therefore correct.

The Endocrine System

- Description: The endocrine system includes the "endocrine glands" and the fluids and ducts into which they are released. ***Exocrine glands release enzymes or other liquids into the external environment*** (which includes the digestive tract and epithelial-lined orifices; substances released include sweat, oil, mucus, digestive enzymes, etc.); whereas ***endocrine glands release hormones into the internal fluids of the body*** (e.g., blood, lymph, etc.).

- Endocrine Hormones:
  - You need to know each hormone, its function, whether it is a peptide, steroid, or tyrosine derivative, the organ that secretes it, and where that endocrine organ is located in the body.
  - PEPTIDES: (water-soluble)
    - ***Anterior Pituitary:*** **FSH, LH, ACTH, hGH, TSH and Prolactin**
    - ***Posterior Pituitary:*** **ADH and Oxytocin**
      - The hormones released from the pituitary gland are directly regulated by hormones secreted by the hypothalamus. These hormones follow a familiar naming pattern, which includes the name or class of the pituitary hormone it stimulates, plus the term "releasing," as in *Gonadotropin-Releasing Hormone* (GnRH) or *Growth Hormone-Releasing Hormone* (GHRH).
    - ***Parathyroid:*** **PTH** (Parathyroid Hormone)
    - ***Pancreas:*** **Glucagon & Insulin** (also releases several digestive enzymes, but this is an exocrine function, not an endocrine function)
    - ***Thyroid:*** **Calcitonin**
    - ***Embryo/Placenta:*** **hCG** (Human Chorionic Gonadotropin)
  - STEROIDS: (lipid-soluble; ***all steroids are cholesterol derivatives***)
    - Adrenal Cortex: **Cortisol & Aldosterone**
    - Gonads: **Estrogen, Progesterone & Testosterone**
  - TYROSINES: (T_3/T_4 = lipid-soluble; Epinephrine/Norepinephrine = water-soluble)
    - Thyroid: **T_3** (Triiodothyronine) & **T_4** (Thyroxine)
    - Adrenal Medulla: **Epinephrine & Norepinephrine**

- Hormone Transport and Action at the Effector:
  - Transport: *Lipid-soluble hormones* require a protein carrier or a micelle/vesicle. *Peptide hormones* are water soluble and dissolve in the blood readily.
  - Target: *Lipid-soluble hormones* act almost exclusively by binding to a receptor on or inside the nucleus and influencing transcription; *peptide hormones*, by contrast, act at a variety of cell locations.
  - Membrane Permeability: *Lipid-soluble hormones* diffuse easily through the lipid center of the membrane and thus do NOT require a cell membrane receptor. They still require a receptor eventually, wherever they act inside the cell. *Peptide hormones* are hydrophilic and cannot dissolve through the membrane, thus they require a membrane receptor.

- Second Messenger Systems:
  - You must know what a second messenger system is and how it works. It usually occurs via a cascade. In a cascade, one hormone activates another hormone, enzyme, or other signaling molecule. The signal recipient then activates another member of the cascade, with the size of the reaction and the number of molecules involved increasing with each step.
    - Review: During the Biology 1 lesson we discussed the function of G-proteins. G-proteins are a prime example of a second messenger system. As a review from Biology 1 (and a good test of whether or not you are truly mastering and retaining the content as required) attempt to answer the following question asked of you previously in Biology 1. Attempt to do so from memory, without consulting the internet, the study links, or any other resources:
      - *Q26. Give a generalized description of a G-protein cascade. Include terms such as G-protein-coupled receptor (GPCR), alpha/beta/gamma subunits, GDP, GTP, adenylyl cyclase, cAMP, and Protein Kinase A (Hint: Many enzymes are activated by phosphorylation).*

- Predicting Hormone Levels: ***This is a very frequent MCAT question!***
  - ***Remember: Hormones always act to return the system to homeostatic, or "normal," conditions. They never cause a drift away from normal.***
  - *Q27. Recalling that glucagon stimulates the release of glucose into the bloodstream and insulin stimulates the uptake and storage of glucose, answer the following:*
    - *Patient A has high blood glucose levels. Which hormone is likely to be found in highest concentration in her blood?*
    - *Patient B has low blood glucose levels. Which hormone is likely to be in highest concentration in his blood?*
  - *Q28. Recalling that parathyroid hormone causes the breakdown (a.k.a., resorption) of bone and a concomitant release of calcium into the blood; and that calcitonin causes the buildup of bone matrix with a concomitant decrease in blood calcium, answer the following:*
    - *Patient A has ingested a large dose of a calcium supplement. Which hormone will be found in highest concentration in her blood?*
    - *Patient B suffers from calcinuria, a condition marked by low blood calcium. Which hormone will be found in highest concentration in his blood?*

The Hormone Chart

- Meet Your New Friend: At the end of this lesson, you will find a color-coded chart highlighting every major hormone you must know for the MCAT—including its class and function, the gland that secretes it, and the location of that gland in the body. Make "The Hormone Chart" your new best friend. You will need to know and understand everything in the chart at a deep, conceptual level. To practice, make copies of the blank chart provided below, then attempt to fill in the blanks from memory.
  - Study Hints:
    1) Don't just memorize hormones individually. Memorize them by type, function, permeability, and by the gland that secretes them. After you have memorized the entire chart, try to obtain a more conceptual understanding of each hormone in terms of how it acts, how it could be either inhibited or upregulated, and what physiological effects might result from either action. Notice that every gland (with one exception) secretes only one kind of hormone (steroid, peptide, or tyrosine derivative), but any given kind of hormone could come from various glands.
    2) The notable exception mentioned in #1 above is the thyroid. ***It secretes both a tyrosine derivative and a peptide hormone.***
    3) Be able to answer the following questions (and others like them) without referencing the chart:
       - Name all of the glands that secrete peptide hormones.
       - Name all of the glands that secrete steroid hormones.
       - Name all of the glands that secrete tyrosine derivatives.
       - Hormone X is water-soluble. What glands could have secreted it?
       - Hormone X is lipid-soluble. What glands could have secreted it?
       - Hormone X is secreted by the pituitary. What is its solubility?
       - Hormone X is secreted by the gonads. What is its solubility?
       - T/F? The adrenal gland secretes only lipid-soluble hormones.
       - T/F? Steroid hormones are always lipid-soluble.
       - T/F? Hormones derived from tyrosine are always lipid-soluble.

Sample MCAT Question

4) Polycystic Ovary Syndrome causes the formation of fluid-filled cysts on the ovaries. A researcher has discovered that female lab animals administered high doses of "male hormones," called androgens, exhibit almost identical symptoms. The researcher hopes to develop a drug that associates with the androgens in a woman's body and prevents them from binding to their receptors. To be effective, it is important that the drug:

A) be lipid-soluble.
B) be water-soluble.
C) have a short half-life under physiological conditions.
D) bind reversibly to its target.

Solution: The androgen targeted is most likely testosterone, a male steroid hormone that is lipid soluble. Because testosterone is lipid-soluble and the researcher wants the drug to associate with it, the drug should most likely also be lipid-soluble. This makes Answer A the best choice. Answer B is false because testosterone is not water-soluble. Answers C and D may or may not be desirable in a drug design. Reversible binding and a short half-life could limit the drug's usefulness.

Hormone	Location	Class	Function
ACTH	anterior pituitary	peptide/water-soluble	stimulates the adrenal cortex to release stress hormones called "glucocorticoids"
LH	anterior pituitary	peptide/water-soluble	surge in LH causes ovulation; stimulates the secretion of the sex hormones estrogen and testosterone
FSH	anterior pituitary	peptide/water-soluble	stimulates growth of the follicle during menstrual cycle and production of sperm
TSH	anterior pituitary	peptide/water-soluble	stimulates release of T3/T4 from the thyroid
hGH	anterior pituitary	peptide/water-soluble	stimulates growth throughout the body
Prolactin	anterior pituitary	peptide/water-soluble	stimulates milk production in the breasts
ADH	posterior pituitary	peptide/water-soluble	causes the collecting duct of the kidney to become highly permeable to water, concentrating the urine
Oxytocin	posterior pituitary	peptide/water-soluble	stimulates contractions during childbirth and milk secretion during nursing
Parathyroid Hormone	parathyroid	peptide/water-soluble	increases blood calcium by stimulating proliferation of osteoclasts, uptake of Ca^{2+} in the gut, and reabsorption of Ca^{2+} in the kidney
Insulin	pancreas	peptide/water-soluble	stimulates uptake and storage of glucose from the blood
Glucagon	pancreas	peptide/water-soluble	stimulates gluconeogenesis and release of glucose into the blood
Calcitonin	thyroid	peptide/water-soluble	decreases blood calcium by inhibiting osteoclasts
hCG	egg/ placenta	peptide/water-soluble	prevents degeneration of the corpus luteum, maintaining pregnancy
Aldosterone	adrenal cortex	steroid/lipid-soluble	increases Na^+ reabsorption and K^+ secretion at the distal convoluted tubule and the collecting duct; net increase in salts in the plasma, increasing osmotic potential and subsequently blood pressure
Cortisol	adrenal cortex	steroid/lipid-soluble	a stress hormone; increases gluconeogenesis in the liver and thus blood glucose levels; stimulates fat breakdown
Testosterone	gonads (testes)	steroid/lipid-soluble	stimulates development of secondary sex characteristics and closing of epiphyseal plates
Estrogen	gonads (ovaries)	steroid/lipid-soluble	stimulates female sex organs; causes LH surge in menstruation
Progesterone	gonads (ovaries)	steroid/lipid-soluble	stimulates growth and maintenance of uterus during pregnancy
T3 & T4	thyroid	tyrosine derivative/**lipid-soluble**	increases basal metabolic rate, effecting metabolism
Epinephrine & Norepinephrine	adrenal medulla	tyrosine derivative/ ***water-soluble***	cause responses almost identical to a sympathetic nervous system response (fight or flight)

Hormone	Location	Class	Function