Human Physiology
Study Questions-3

Physics of flow:

1. Explain why we need a circulatory system. (Notes from early lectures may help you answer this question.)

2. How is moving a fluid different than moving a solid?

3. Explain how the combination pipes and chamber & valve pumps can be used to move fluids in a specific direction. How many chamber-and-valve pumps does your circulatory system have? Explain.

4. Use your understanding of the no-slip condition to give an intuitive explanation of why pipe diameter makes such a large difference in flow rate (increasing with the 4th power).

5. How does hematocrit influence blood flow rate?

6. Why is it important that blood flows through your capillaries at a slower rate than it moves through your aorta? How is this slower capillary flow achieved?

Maintaining blood flow through capillary beds:

1. Explain this statement: Maintaining flow through capillary beds is the focus of circulation. What role does the maintenance of arterial blood pressure play in maintaining flow through capillary beds?

2. Explain how the arrangement of elastin and collagen in arteries helps maintain arterial blood pressure and prevents aneurysms from forming.

3. At what two points in a circulatory system is arterial blood pressure controlled?

4. Explain the statement: Maintaining arterial blood pressure simply involves keeping arterial input and arterial output equal. Use this understanding to go through the various options of maintaining arterial blood pressure in a two or more “capillary bed problem”.

5. List some ways that smooth muscle is different than skeletal muscle? similar to skeletal muscle?

6. What is the developmental origin of sympathetic ganglia? How does the location of sympathetic ganglia fit with the notion that changes in the level of sympathetic stimulation is largely about controlling circulation? What is sympathetic tone? What is the logic of sympathetic tone?

7. Where is the vasomotor system located? Within the vasomotor system, what role does the rostral ventrolateral medulla play? does the caudal ventrolateral medulla play? The descending tract that originates in the rostral ventrolateral medulla forms synapses with what types of neurons within the spinal cord?

8. Increasing the rate of sympathetic activity has what effect on: (1) the release of acetylcholine from preganglionic neurons? (2) the release of norepinephrine from postganglionic neurons? (3) the release of epinephrine from the adrenal medulla? the activity of β₁ receptors in the heart? the activity of α receptors on smooth muscle wrapped around arterioles? the activity of β₂ receptors on smooth muscle?

9. Name a few locations where smooth muscle has β₂ receptors? Why does it make sense that they are located there? There may be β₂ receptors on the smooth muscle wrapped around the arterioles prior to capillary beds that supply some skeletal muscles in the body. But if so, it would seem that either their effect or their distribution would need to be somewhat limited. Explain!

10. The contraction and dilation of smooth muscles surrounding arterioles is largely controlled locally. Explain how this works, and why it makes sense.
11. Where are baroreceptors located? Why is this a good vantage point? What region of the central nervous system do the sensory neurons (that detect the stretch associated with increasing pressure) innervate? Why does this make sense? Generate a scenario where the baroreceptors play an important role in maintaining arterial pressure. Make sure that you can explain all the basic features of the generated response.

12. Why does both increasing and decreasing blood volume pose problems for the maintenance of arterial blood pressure? What are some of the ways that the body attempts to deal with each of these problems?

13. Explain the role that higher brain areas, vasomotor center, increasing sympathetic activity, and local control play in maintaining arterial blood pressure as you take off running. Make sure you have explained how blood flow increases to the skeletal muscles involve in running and decreases to other parts of the body, such as the gut. Furthermore, discuss all the paths by which cardiac output is increased, blood flow through coronary arteries is increased, sweating is increased, and adequate blood flow to the brain is maintained.

14. Explain why arterial blood pressure increases more during the exertion of individual muscles than during whole body exertion. Increasing arterial blood pressure during exercise involves health risks. Provide a biological reason as to why we are set up to take such risks?

**Hearts:**

1. Suppose your heart was located underneath your belly button. First, explain why this change in heart location would necessitate a change in arterial blood pressure. Next, estimate the magnitude of the needed change.

2. Explain how a S-A node rhythmically initiates action potentials. Explain how an action potential originating at the S-A node can spread across the entire atrial part of a heart. Ventricular cardiac fibers commonly start contracting around 0.13 seconds later than the atrial cardiac fibers. How does this delay occur, and why is it important?

3. The action potentials that spread across interconnected cardiac muscle cells are in some ways different than the action potentials that spread across skeletal muscle fibers. What are some of the basic differences? Why are these differences important?

4. Compare and contrast cardiac muscles and skeletal muscles. Be sure to include the difference in the nature of each muscle types action potentials, and the biological significance of this difference.

5. Explain the mechanism by which a heart contracts more forcefully as venous return increases. (Note: It is known as the Frank-Starling mechanism.)

6. Explain how sympathetic stimulation is thought to increase cardiac output. Next explain how parasympathetic stimulation is thought to decrease cardiac output.

**Microcirculation and the lymphatic system:**

1. By what means do fluids (water and smaller solutes) typically flow from capillaries to interstitial spaces? How does albumin (and other plasma proteins) help fluids from interstitial spaces flow back into the capillaries?

2. Under what conditions will some of the fluids that leave the capillaries at the arteriole end fail to reenter the capillaries at the venule end? How does the slow leakage of albumin (and other plasma proteins) out of the capillaries enhance these conditions? How does your body content with these two problems (i.e., fluids that fail to reenter capillaries and the slow leakage of albumin molecules)?

3. Explain this statement: The development of the cellular component of blood goes on throughout a person’s life. Explain one way a body makes a counter-acting response to tissue hypoxia.
4. Why is it important that the circulatory system is self-sealing? Explain how vasoconstriction, platelet aggregation, and the coagulation cascade are all involved in temporarily plugging a hole in a blood vessel. Identify some of the co-acting aspects of this chain of events. Why are these co-acting components both important and dangerous? Speculate as to why the coagulation cascade is so complex.

5. Discuss some of the ways that the platelet aggregation and clot formation is prevented from spreading beyond the site of damage, or occurring in inappropriate places.

**Maintaining oxygen and carbon dioxide balance:**

1. Distinguish between maintaining an input-output balance in a scarce resource and an excess resource. Be sure to consider both the supply-side and demand-side of the issue.

2. Use the perspective established in the above question to discuss, in general, maintaining an oxygen and carbon dioxide balance.

3. Explain this statement: Regardless how it happens, breathing has to do with changing the size of the pleural cavity. How are the properties of lung tissue, specifically elastance and compliance involved in ventilation (both inspiration and expiration)?

4. Explain how a (relatively) negative pressure in each pleural cavity develops. How is negative pressure involved in keeping lungs from collapsing?

5. Why it is more difficult to maintain oxygen balance when breathing through a five-foot long snorkel than a foot long snorkel? through a foot long snorkel than no snorkel at all?

6. How would the absence of surfactants make ventilation more difficult? Explain your answer.

7. Discuss how each of the following proteins make it possible for blood to absorb more O₂ and/or CO₂: hemoglobin, carbonic anhydrase, the permease involved in the antiport of Cl⁻ and bicarbonate.

8. Discuss the similarities and the differences between how oxygen and carbon dioxide are transported in the circulatory system.

9. Be able to interpret an oxygen dissociation curve. Under what conditions do oxygen dissociation curves shift to the right? How does this type of shift facilitate oxygen transport to tissues?

10. What factors can lead to constriction of bronchioles? What factor leads to the dilation of bronchioles? Why does constriction/dilation in the presence of these factors make sense?

11. Discuss breathing in terms of being controlled by a central pattern generator. Where in the nervous system is this CPG seemingly generated? What muscles are involved in inspiration and expiration during quiet breathing?

12. What factors modulate ventilation rate? Where are monitors to these factors located? Explain why the chemosensitive area is affected more by blood levels of carbon dioxide than by hydrogen ions, even though the actual sensor responds to hydrogen ion levels.

13. Use your understanding of the oxygen dissociation curve to make sense the oxygen levels (measured in terms of mm Hg) that start having a pronounced effect on ventilation rate.

**The kidney’s role in maintaining osmotic, volume, and blood pressure balance:**

1. What is the general function of kidneys? Explain, in general terms, how the kidney works.

2. Why are plasma proteins not normally found in urine?
3. Basically, what happens in the proximal convoluted tubule portion of a nephron?

4. Complete this statement: Any molecule dissolved in blood plasma will be removed from the body in the urine unless...

5. Explain how kidney output could continue to match fluctuating levels of salt and water input in the absence of a renin-angiotensin system. What are the problems associated this method of outputs matching inputs? Use understanding of these problems to explain why a person with a poorly functioning renin-angiotensin system needs to carefully regulate their salt intake.

6. Where is the sensor in the renin-angiotensin system located? Explain what conditions trigger an increase in the release of renin, and then go through the steps by which additional renin lead to additional angiotensin II.

7. In what ways does increasing levels of angiotensin II effect the kidney, and how does this help an organism deal with fluctuating levels of input.

8. In addition to altering the kidney, what are some other effects that angiotensin II has on the body?

9. By the time filtrate (within a nephron) passes through the early distal tubule, it is osmotically dilute (less than 300 mOsm).
   a. How did it become osmotically dilute?
   b. Complete this statement: This dilute filtrate will remain dilute as it passes to the bladder, and then out of the body if...
   c. When would the production of dilute urine be biologically important?
   d. What CNS created sensation should not accompany the production of dilute urine?

10. Explain why a nephron lacking a loop of Henle could help restore osmotic balance to an organism with low blood osmolarity (too much water in the mix), but could not help restore osmotic balance to an organism whose blood’s osmolarity is too high (too little water in the mix).

11. Two different counter-current multipliers work to increase, above normal, interstitial fluid osmolarity within the inner region of a kidney (the medulla).
   a. Explain how each of these work?
   b. Explain the biological importance of generating this high osmotic area.
   c. What hormone must be present for an organism to take advantage of this high osmotic area?
   d. Why are individuals with low protein diets unable to concentrate their urine to the same degree as individuals with high protein diets?

12. Where in the body is the sensor that monitors blood osmolarity?

13. A human and an Australian hopping mouse are both on board a ship that shipwrecks on a small tropical island. The island has plenty of nutritious food but no freshwater. The human dies within a few days, while the hopping mouse keeps on hopping. Why was the mouse, but not the human, able to survive?

**pH and potassium balance:**

1. Explain this statement: While carbon dioxide is a by-product of metabolism, it seems incorrect to call it a waste product.

2. By what means do we increase bicarbonate levels in blood plasma? Why is this increase in bicarbonate biologically important?

3. Explain the connection between excessive levels of cell breakdown, aldosterone, and prevention of irregular heart beats.