**Biology 212: Anatomy and Physiology II**

**Lab #8: ANATOMY OF THE URINARY SYSTEM**

 **and CHARACTERISTICS OF URINE**

References: Saladin, KS: Anatomy and Physiology, The Unity of Form and Function 7th ed. (2015)

**Be sure you have read and understand Chapter 23 before beginning this lab.**

***With COVID we are not allowed to have open lab or in-house lab activities. When the lab manual says to look at a slide, you will need to find an image online. The best I can do is put this up and suggest that when you see microscope items (histology) you simply try a google search. For example, you will need to type in the word “kidney-nephron-human” and click “images”, this should get you to quite a few images of what this looks like. Some of the content of this lab should be a review from what you learned in Bio 211, this will also be good content for a Bio 212 lab exam. There is an assignment at the end, copy past this into a separate file and submit your answers (Microsoft word, or pdf, or what ever you like) to my D2L Dropbox, but do not send the entire lab packet….just the answers to the questions at the end (this way the files will not fill too much space in D2L). If you answer things correctly and do the work, you will get the full credit for this lab, please commit to being complete however, there is not going back to revise your work on these questions.***

**INTRODUCTION:**

The urinary system (i.e., renal system) is responsible for maintaining the homeostatic composition of the blood. It regulates the concentrations of nutrients, waste products, electrolytes, hormones, drugs, and literally hundreds of other types of molecules. The kidneys accomplish this task by filtering large amounts of both water and the solutes from the blood to form a filtrate (up to 180 L of filtrate per day), then reabsorbing the things the body needs to retain. The filtrate can be further modified to remove potentially harmful nitrogenous wastes (urea, uric acid, creatinine) from the blood through a process called secretion. Indeed the urine is the only way creatinine can to be cleared from the blood. Recall that creatinine is the waste product from creatine phosphate metabolism in skeletal muscle. Levels of creatinine are used for evaluation of the presence of kidney disease severity).The fluid that remains becomes urine (1-2 Liters/day) and consisting of excess water and solutes that were not reabsorbed from the filtrate. This fluid passes out of the kidneys into the ureters, which transport it to the bladder where it is stored until it can be voided through the urethra. We will examine these organs at both the histologic and gross anatomy levels, correlating structures with their functions.

**LEARNING OBJECTIVES:**

At the end of this exercise, students should be able to:

1. Identify all of the organs of the human urinary system and their functions
2. Identify the regions of the kidney and their functional relationships
3. Describe the flow of blood through the kidney and relate this to elements of urine formation
4. Identify the parts of a nephron and their functions
5. Describe the histology of the human kidney and urinary bladder
6. Describe the normal and abnormal characteristics and constituents of human urine

**GROSS ANATOMY OF THE HUMAN URINARY SYSTEM**

**Exercise 1:** Using Figures 23.1, 27.10, and 28.1 in your Saladin text, identify the right and left kidneys, renal arteries and renal veins, ureters, urinary bladder, and urethra. Since the male and female urethras are different, be sure you examine models with both male and female genitalia.

The **kidneys** are located on either side of the vertebral column in the abdomen. Notice that they are posterior to all of the other abdominal organs, just anterior to the lower two ribs and the muscles forming the posterior wall of the abdomen. Although not shown on these models, the kidneys are retroperitoneal - that is, they are located posterior to the parietal peritoneum which lines the abdominal cavity. The kidneys are situated just inferior to the liver, and the right kidney is slightly more inferior compared to the left kidney because of the larger mass of the liver on the right side. The anterior and posterior surfaces and the lateral edge of each kidney are convex while its medial surface is slightly concave.

The large left and right **renal arteries** branch off the abdominal aorta carrying oxygenated blood to each kidney. **Renal veins** return deoxygenated blood that has been modified/cleared of nitrogenous and other wastes to the inferior vena cava. These vessels enter the kidney together at its medial border, the **hilum**. Compare the size of these vessels to the size of other branches of the abdominal aorta - they are relatively large, indicating that the kidneys receive a large amount of blood. In fact, about 25% of the total cardiac output goes through capillaries in the kidney - probably the highest blood flow based on size of any organs in the body. It is this blood that will be filtered and then modified to form urine.

A **ureter** exits the hilum of each kidney and runs inferiorly toward the bladder. This muscular tube is also retroperitoneal (even though the peritoneum is not shown on the torso models), lateral to the bodies of the vertebrae and then anterior to the sacrum of the pelvis and its overlying muscles. It enters the bladder through that organ’s posterior surface, near its lateral and superior surfaces.

The **urinary bladder** lies deep in the pelvis, posterior to the pubic bone. It is spherical in shape and flattened on its superior surface. The ureters enter the posterior surface on either side. In women, the uterus is tipped posteriorly over the superior surface of the bladder. In men, the intestine lies along its superior surface. The **urethra** exits the bladder inferiorly, carrying urine to the **external urethral orifice**. In women, the urethra is immediately anterior to the vagina and is relatively short, passing inferiorly to end between the minor labia. The urethra is longer in men, initially directed inferiorly but then turning anteriorly to enter the penis. Just inferior to the bladder it is surrounded by the *prostate*, and within the penis it is surrounded by one of the erectile bodies called the *corpus spongiosum*.

***Question for discussion:***

 *Urine is not pulled through your ureters by gravity: it moves from your kidneys to your bladder just fine*

 *even if you are standing on your head. Explain to other members of your lab group why this is true.*

**Exercise 2:** On Figure 23.4 of your Saladin text, identify the following regions of a kidney:

* The **capsule** is a layer of dense irregular connective tissue which surrounds the entire organ;
* The **cortex** forms the outer part of the kidney, just deep to the capsule.
* The **medulla** is a broad region deep to the cortex. It consists of approximately a dozen cone-shaped **renal pyramids** (all of them will not show, of course: some are above or below the level of section in this diagram) separated by **renal columns**.
* The **pelvis** is deepest region of the kidney, near the hilum on its medial surface. This is a hollow space in which urine gathers before it enters the ureter. Large extensions of the pelvis facing toward the medulla are called **major calyces** (singular = **calyx**), which branch to form smaller **minor calyces**. Notice that the tip of each cone-shaped renal pyramid extends into a minor calyx.

**Exercise 3:** *IF AVAILABLE*-Identify each of the regions listed in bold in Exercise 2 on the large model of the kidney and on the fresh sheep or pig kidneys in the sink. Please wear gloves when examining the fresh or preserved specimens.

**Exercise 4:** Get a preserved sheep kidney from the bucket near the sinks, wearing gloves as you handle it. Identify the structures listed above in Exercise 2. Return the kidney to the bucket.

**Exercise 5:** On Figures 23.5 and 23.6 of your text, identify the following blood vessels within the kidney and trace the pattern of blood flow. (Remember: the function of arteries is to deliver blood to capillaries, where the exchange of molecules can occur into and/or out of the blood, then the function of veins is to gather this blood and carry it out of the organ and back to the heart. Unlike flow through most organs, the blood flows through two sets of capillaries between the arteries and the veins.)

A **renal artery** divides into **segmental arteries** and then **interlobar arteries** running through the renal columns of the medulla toward the cortex. At the boundary between the medulla and cortex the vessels curve to run parallel to this boundary as the **arcuate arteries**. **Cortical radiate arteries**, more commonly called i**nterlobular arteries,** branch off and extend into the cortex, giving off **afferent arterioles** that carry blood into the **capillaries** forming the **glomeruli**. An **efferent arteriole** then carries blood out of each glomerulus and delivers it into another set of capillaries surrounding the tubules of the nephrons. These are called the **peritubular capillaries** in the cortex of the kidney and the **vasa recta** in the medulla of the kidney**.** From these, blood gathers into veins which follow the same pathways (in reverse, of course) as the arteries: **interlobular** or **cortical radiate veins**, then **arcuate veins,** then **interlobar veins**, then **lobar veins**, then the **renal vein** leading out of the kidney.

Blood in the afferent arterioles feed the capillary beds inside the Bowman’s Capsule where filtration occurs. Afterwards the blood enters the efferent arterioles before it is delivered to the peritubular capillaries in the renal vortex or the vasa recta that surround the loops and collecting ducts located mostly in the medulla. Blood passing through this second capillary bed picks up reabsorbed fluids and solutes to permit recycling of these “desirable” materials back to the body. ***This is organized as a Portal System***, and is similar to what we observed in the hypothalamus and anterior pituitary.

**Exercise 6:** On the model of the kidney, identify each of the vessels listed bold letters in Exercise 5 above. You will have to use all three “levels” of magnification shown on this model: a) the gross model; b) the model of one nephron; and c) the model of one glomerulus with its afferent and efferent arterioles. Be sure you can trace the flow of blood through these vessels, from the aorta to the inferior vena cava.

**Exercise 7:** Close your book. In the space below, sketch the structure of one kidney showing the following structures: (You are wasting your time if you try to get a pretty, accurate drawing. Instead, this drawing it is to see how well your brain understands the structure of the kidney. Therefore, do not simply copy a figure from your book. Draw it from memory, using your text as a reference when necessary.)

 **capsule major and minor calyces,**

 **cortex renal artery and vein**

 **medulla interlobar arteries and veins**

 **pyramids arcuate arteries and veins**

 **columns interlobular arteries and veins.**

 **pelvis proximal ureter**

 **hilus Vasa Recta**

 **Afferent arteriole Peritubular Capillaries**

 **Efferent arteriole**

Now, from memory (refer back to earlier pages of this handout or the book only as a very last resort) explain to other members of your lab group the vessels of the kidney through which blood follows from the time it leaves the aorta until it enters the inferior vena cava. Be sure you identify these vessels in the proper order. If other members of your lab group are not explaining this correctly, be sure to help guide them through the pathway so that they understand. You will only hurt them if you let them give a poor explanation. If you had to refer to the book to do this exercise, repeat the sequence of vessels again. Do not give up until every single person in the lab group can do this from memory.

**MICROSCOPIC ANATOMY OF THE URINARY SYSTEM**

Each kidney contains over a million **nephrons**, which are the anatomical structures responsible for removing materials from the blood to form urine. As shown in Figures 23.6 of your Saladin textbook, each nephron consists of two parts: a **glomerulus** (i.e., a capillary network) where this filtration occurs and a **renal tubule** in which the composition of this filtrate is modified to form the urine. The proximal end of each renal tubule, called the **glomerular (Bowman’s) capsule**, is enlarged and surrounds the glomerulus. The glomerulus and glomerular capsule together are often called a **renal corpuscle.**

The rest of the renal tubule has four primary regions, called the **proximal convoluted tubule**, the **loop of Henle (**called **“nephron loops”** in your Saladin text), the **distal convoluted tubule**, and the **collecting duct**. Actually, each collecting duct is shared by many nephrons. The glomeruli (that’s plural of *glomerulus*), the proximal convoluted tubules, and the distal convoluted tubules of all nephrons are always located in the cortex of the kidney. The loops of Henle (nephron loops) dip down into the renal pyramids in the medulla and then back up into the cortex. The collecting ducts gather the urine from the distal convoluted tubules in the cortex and pass through the medulla to empty it into the minor calyces of the pelvis of the kidney.

The entire renal tubule is surrounded by an extensive network of **peritubular capillaries** in the cortex and down in the medulla of the kidney. The protion that is in the medulla is called the **Vasa Recta**.

Notice from Figure 23.6 in your text that some nephrons lie more superficially in the cortex, with short loops of Henle that barely dip into the medulla. These are called **cortical nephrons** and are less concerned with concentrating the urine. Other nephrons are situated more deeply in the cortex and have long loops of Henle (nephron loops) that dip deeply into the medulla. These are called **juxtamedullary nephrons**.

**Exercise 8:** Examine a model of a nephron - this will be part of the model that shows the gross structure of the kidney. Identify the following:

**Collecting duct**

 **Distal convoluted tubule** (not very

 “convoluted” on the model, unfortunately)

 **Glomerular capsule**

 **Glomerulus**

 **Loop of Henle / Nephron loop**

 **Proximal convoluted tubule**

 **Renal tubule**

Although they are not well shown, try to visualize where the peritubular capillaries and vasa recta would be.

On the third part of the model, showing one renal corpuscle, identify the **glomerulus** and parietal wall of the **glomerular capsule**. Notice that blood enters the glomerulus through one vessel, called the **afferent arteriole,** and leaves through a second vessel called the **efferent arteriole**, although you will not be held responsible for differentiating between these two. Observe how the space of the glomerular capsule is continuous with the proximal part of what must be a **proximal convoluted tubule**.

**Exercise 9:** Draw the structure of one nephron and label all of its parts. Here again, the purpose is not to get a pretty drawing, but rather it is to see how well your brain understands the structure of a nephron. Do not copy a figure from your book. Draw it from memory, using your text as a reference when necessary.

From your reading, you should be able to correlate the structure of the nephron with its function:

 a) The plasma of your blood consists of water with hundreds of other types of molecules dissolved in it.

 b) Water and other molecules filter out of the capillaries of the glomerulus into the glomerular capsule;

 c) This filtrate then passes through the various parts of the renal tubule, which allows many molecules (including most of the water) to be reabsorbed from the urine back into the blood of the peritubular capillaries and vasa recta. Thus, these molecules are still in the blood when it later leaves the kidney;

 d) Certain types of molecules, such as ammonia, which were not filtered out of the blood in the

 capillaries of the glomerulus are actively secreted from the tubules into the forming urine in order to eliminate them from the body.

 e) Although more than 180 liters of liquid per day is actually filtered out of the blood from the glomeruli into the glomerular capsule, you only eliminate one or two liters of urine each day. This is because 99% or more of the filtrate is reabsorbed back into the blood as it passes through the renal tubule.

***Questions for discussion:***

 *What would happen to you if your glomeruli lost their ability to filter water and other molecules*

 *out of your blood?*

 *What would happen to you if your nephrons lost their ability to reabsorb almost all of the liquid*

 *which is filtered out of the blood in the glomerulus?*

**HISTOLOGY OF THE URINARY SYSTEM**

**Exercise 10:** Examine Slide #16 with your naked eye. This is a coronal section of the kidney from a mouse, but it has exactly the same structure as the human kidney (Figure 23.4). You should be able to identify the **hilus, cortex, medulla,** and **pelvis** under this minimal magnification.

Now examine this slide in the usual way, starting at 40x magnification and then 100x. Move the slide so you can see the **cortex** and identify a **glomerulus**, which appears as a ball of tightly packed material (these are actually capillaries, of course) surrounded by a thin space (the **glomerular capsule**). Examine a glomerulus at 400x magnification (Figure 23.7). You can now see the nuclei of the capillary cells and of the simple squamous epithelial cells which line the glomerular capsule.

Still at 400x, move the slide slightly and examine the cortex immediately surrounding the glomerulus. It is composed of thousands of **proximal convoluted tubules** and **distal convoluted tubules**, although you will not be held responsible for differentiating these from each other on this slide. Since these are “convoluted” or coiled up, they will be cut in many different orientations on your slide. Don’t be surprised if you see an arteriole, venule, or larger blood vessel as well as many capillaries.

Return to low magnification and move your slide so you see the **medulla** of the kidney. This is also composed of thousands of microscopic tubules, but the characteristic feature is that adjacent tubules are all running in the same direction rather than being “convoluted” as they were in the cortex. Scan around the medulla under low power. In some regions these tubules will be cut longitudinally; in other regions obliquely; in other regions in cross-section. These are a mixture of **collecting ducts** and the **ascending and descending limbs of the loops of Henle**, plus many blood vessels.

Move even deeper in the kidney and you will observe large, empty-appearing regions near the **hilum** of the kidney. These are parts of the **pelvis**, including **major and minor calyces**. Under high power magnification notice that these spaces are lined by **transitional epithelium.**

***Questions for discussion:***

 *What type of epithelium forms the proximal and distal convoluted tubules in the cortex of the kidney?*

 *Which blood vessels would you expect to see in the cortex of the kidney?*

 *Which blood vessels would you expect to see in the medulla of the kidney?*

**Exercise 11:** Slide 18 is a slide of part of the urinary bladder - obviously, the entire organ would be too large to fit on one slide. Examine this under low power and then high power. Identify the transitional epithelium which lines it lumen - this is in the relaxed (cuboidal) state, and the entire epithelium is in fact wrinkled or folded into **rugae** to reduce the size of the organ. Deep to the epithelium, identify the thick layer of smooth muscle which form its muscularis layer - this if often called the **detrusor muscle**. Your slide will probably not show the adventitia of this organ.

**Exercise 12:** A molecule called *creatinine* is a cellular waste product which is normally produced by muscle cells and must be transported through the blood to the kidney for disposal in the urine. From memory (don‘t refer back to earlier pages of this handout or the book unless you absolutely have to!) explain to other members of your lab group the pathway that a molecule of creatinine (or, of course, a molecule of any other waste product) would follow from the time it is filtered out of the blood until it exits your urethra with the urine. Identify, in order, every part of the nephron, every part of the kidney, and all other organs that it will pass through. If other members of your lab group are not explaining this correctly, be sure to help them understand. You are only hurting them by letting them give a poor explanation. Do not give up until every single person in the lab group can do this from memory.

**NAME:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(type or write in the blank)**

**URINARY SYSTEM LABORATORY REVIEW Questions: 10 points**

**CUT-PASTE this assignment into a separate Microsoft Word file and write or type the answers in that document. Submit the document to D2L when you are finished.**

1) Write a minimum of 15-25 words to describe each of the following items:

a) Identify all of the organs of the human urinary system and their functions

b) Identify the regions of the kidney and their functional relationships

c) Describe the flow of blood through the kidney and relate this to elements of urine formation

d) Identify the parts of a nephron and their functions

e) Describe the histology of the human kidney and urinary bladder

f) Describe the normal and abnormal characteristics and constituents of human urine

2) Compare and contrast these three terms with a minimum of 15-25 words:

 Renal Blood Flow- Glomerular Filtration Rate- Urine Formation Rate

3) For an otherwise healthy young person describe the predicted color, osmolarity, and volume of urine that would be expected under these three conditions. Also discuss how the hormones Aldosterone, Antidiuretic Hormone and Angiotensin are involved in the physiological response. Write a minimum of 15-25 words to describe each condition:

 a) Their condition an hour after they drank a liter of water-

 b) Their condition hour after having mowed the yard on a hot sunny day without drinking any water-

4) How is creatinine clinically used as an indicator of glomerular filtration and kidney function?