Chapter 25 The Urinary System Reading Guide
Honors Human Anatomy and Physiology

Each day your kidneys filter over 50 gallons of blood returning necessary components while removing toxins, metabolic wastes (especially those that contain nitrogen), and excess ions. Urine is the product and it is transported, stored, and eventually eliminated from the body. The kidney and liver play a role as the master chemists of your body. This unit, like the other units you have covered this year, tells a great story but it complicated. Pay attention in class and ask questions. The urinary system has a lot of anatomy (kidney anatomy as well as the plumbing) and physiology (blood flow and urine formation).

This unit will be broken into two sections:
- Urinary System Anatomy: 25.1, 25.9

Sections I Urinary System Anatomy
Introduction (pp. 961-962)
- Check out the micrograph of the network of capillaries found in one glomerulus on p. 961. Millions of glomeruli are found in the kidney where components are removed from the blood and enter the kidney plumping (a process called filtration).
- Know the 7 major functions of the urinary system/kidney.
- Know the basic roles of the two ureters, the urinary bladder, and the urethra.
- Memorize the anatomy on Figure 25.1.

25.1 Kidney Location and Anatomy
- Do you know where the kidneys are located? (retroperitoneal, superior lumbar region)
- Why is the right kidney lower than the left kidney?
- What is the renal hilum and the renal sinus and what is found there?
- What organ sits on the superior aspect of the kidney (hint: releases epinephrine, norepinephrine, aldosterone, and cortisol).
- Know the role of the renal fascia, perirenal fat (adipose) capsule, and the fibrous capsule.
- What causes renal ptosis and why can it be fatal if hydronephrosis occurs?

Internal Gross Anatomy (before you can learn the physiology you must know the anatomy of a kidney).
- In class you will diagram the anatomy of the kidney. Know these structures!
  - What are the three distinct regions of the kidney?
  - Where are the medullary pyramids located? What are their position (apex, base)?
  - What separates the pyramids?
  - The renal pelvis collects all the urine and conducts it to the ureter. The major and minor calyces are extensions or branches of the renal pelvis that collect urine at the apex of each pyramidal and funnel the urine to the renal pelvis.
  - The Pyelitis and Pyelonephritis (kidney infections) are most commonly caused by fecal bacteria working their way up the urinary system and to the kidney. After defecating, always wipe away from the opening of the urethra and never towards it. These infections are much more common in females (less distance for the bacteria to travel). UTI (Urinary tract infections) and bladder infections may also be caused by this.

Blood Supply: Follow the blood through the kidney from the aorta to the inferior vena cava
- Descending Aorta
- Renal Artery
- 5 Segmental Arteries (located in the pelvis)
- Interlobar Arteries (located in the renal columns)
- Arcuate Arteries (located along the base of each pyramid)
- Cortical Radiate Arteries (located at the cortex (outer edge) of the kidney, these arteries enter the Bowman’s capsule where the glomerulus, the capillaries that the blood is filtered in the nephron, is located).
  - Nephron blood supply will be addressed later (afferent arteriole, glomerulus, efferent arteriole, peritubular capillaries).

Now the blood has been filtered and needs to be returned to the aorta)
- Cortical Radiate Veins (exit the Bowman’s capsule of the nephron along the kidney cortex)
- Arcuate Veins (located along the base of each pyramid)
- Interlobar Veins (located in the renal columns)
- Renal Vein
- Inferior Vena Cava

*note: there are no segmental veins.

**25.9 Ureters, Urinary Bladder, and Urethra**

**Ureters**
- What organs do the ureters connect?
- As the pressure in the bladder increases, what happens to the distal part of the ureter? Why is this beneficial?
- Know the 3 layers of the ureter.
- How does peristalsis play a role in the ureters?
- What is shock wave lithotripsy and how is it used for people suffering from kidney stones?

**Urinary Bladder**
- Where is the male prostate gland in relation to the urinary bladder?
- What is the trigone and what form it?
- How many layers are there in the urinary bladder? What are they?
- How do rugae play a role in the urinary bladder?

**Urethra:**
- Where is the urethra located?
- How many sphincter muscles does the urethra have? Describe them.
- How is the urethra different in females and males?
- How can sexual intercourse contribute to UTI (urinary tract infections) especially in women?
- What is Micturition?
Section II: Nephron and Urine Formation

25.2 The Anatomy of the Nephron (the part of the kidney that is the master chemist)
In class you will diagram a nephron and learn about urine formation. Pay attention. This part has a lot of steps and can be difficult to understand on your own. Check out Mr. B’s website for a link to urine formation after you have completed the reading.

Renal Corpuscle
- From the Cortical Radiate Artery, the blood enters the Glomerular Capsule (Bowman’s Capsule) and become the afferent arterioles that lead to the glomerulus.
- The Renal Corpuscle: The Bowman’s Capsule and the Glomerulus
- The capillaries of the Glomerulus form a ball (remember the micrograph photo from pg. 961?) that are fenestrated (perforated with microscopic holes). This is where the filtrate is formed as just about everything is removed from the blood and it enters the nephron tubules (see the section on urine formation).
- You do not need to know the Glomerular Capsule section.
- The Efferent Arteriole exits the Bowman’s Capsule and becomes the Peritubular Capillary. This will be discussed in the urine formation section.

Renal Tubule and Collecting Duct (This section gives an overview of the anatomy that will be used in the urine formation section).
- What are the three main parts of the Renal Tubule found in the Nephron?
- The Proximal Convoluted Tubule exits the Bowman’s Capsule and the Distal Convoluted Tubule is at the opposite end (where the duct empties into a collection duct).
- PCT: just understand that it has a lot of surface area to allow for reabsorption (placing things back into the blood from the filtrate). Do not worry about the type of cells.
- Nephron Loop: Know the descending and ascending limbs. Do not worry about the type of cells. This is one area where urine get concentrated.
- DCT: Do not worry about the cell type. This is where Secretion (selectively removing things from the blood to the filtrate) happens.
- Collecting Duct: This is where the urine gets concentrated if you are dehydrated, where the body’s Na⁺ balance is achieved, and where pH of the blood is controlled.

Classes Of Nephrons
- Cortical Nephrons:
  - The most common type found in the kidney
  - Found entirely in the cortex except for a small section of their nephron loop that dips slightly into the medullary pyramid section
- Juxtamедullary Nephrons:
  - Found at the cortex-medullary junction
  - Have long nephron loops in the pyramids that work to concentrate urine

Nephron Capillary Beds
- Know the blood vessels of the glomerulus (afferent and efferent arterioles)
- Most capillaries are drained by low pressure veinules. Not the glomerulus. It is drained by the efferent arteriole that can contract its lumen and build up pressure. This pressure is what causes filtration to happen in the glomerulus.
- Peritubular Capillaries: cling to the PCT to absorb things from the filtrate that the body needs and clings to the DCT to secrete things (toxins, nitrogenous wastes) to the filtrate if not needed.
- **Vasa Recta:** Found in juxtamedullary nephrons, this capillary clings to the nephron loop as it descends and ascends. It is responsible for delivering oxygen and nutrients to this part of the kidney as well as playing a vital role in forming concentrated urine (see urine formation section).

At this point, you should be able to diagram the areas of a nephron (Corpuscle, PCT, Nephron Loop, DCT, Collecting Duct) and blood vessels (afferent arteriole, glomerulus, afferent arteriole, peritubular capillary, vasa recta).

**Juxtaglomerular Complex:**
- The only thing you need to know about this is that it is the site where the afferent arteriole (the blood vessel entering the glomerulus) comes in contact with the ascending nephron loop. This is not seen in the simplified diagram you Mr. B draws in class. His diagram helps you understand the pathway. Look at Figure 25.10 for the more complicated and accurate anatomy found in your nephron.
- This junction monitors the amount of NaCl in the blood. If the level of NaCl is too high in the filtrate within the ascending limb, cells will release vasoconstrictors that will constrict the afferent arteriole lumen. This will cause the blood flow in the glomerulus to slow down and thus allow more time for NaCl to be reabsorbed into the blood in the vasa recta or peritubular capillaries.

25.3 Urine Formation Basic Overview: Filtration, Absorption and Secretion

**Glomerular Filtration:**
- Dump everything that is in the blood, except for the cells and proteins, into the nephron creating a filtrate.

**Tubular Reabsorption:**
- Selectively move substances (water, glucose, amino acids, salt, and others) that the body needs back into the blood from the filtrate.

**Tubular Secretion:**
- Selectively move toxins, nitrogenous wastes, and other things out of the blood and into the filtrate to eventually form urine.

25.4 Urine Formation Step 1: Making the Filtrate or “Dumping into a Waste Container”

This section goes into a lot of detail. Use this reading guide to help you identify what you need to know.

- **Filtration** is a type of passive transport where solutes move through a membrane from areas of high hydrostatic fluid pressure to areas of low hydrostatic fluid pressure.
- The glomerulus with its fenestrated membrane works as a *mechanical filter*. As the high pressure blood travels through the glomerulus, almost everything except cells and large proteins are passively moved from the blood and into the nephron tubule.
- What easily gets filtered out of the blood: water, glucose, amino acids, nitrogenous wastes (urea and uric acid).
- Some water is left in the blood as the proteins create a hypotonic environment. Water will diffuse in an attempt to equilibrate the solutions. This creates some osmotic pressure.
- If blood cells are proteins occur in the urine, this system is failing.
- Do not concern yourself with knowing the pressures other than what what described above.

**Glomerular Filtration Rate**
- The following will, influence the rate of filtration:
Regulation of Glomerular Filtration

- **Intrinsic (within the organ) Autoregulation**
  - The kidney has the ability to monitor and adjust the pressure to maintain a fairly steady glomerular filtration rate without involving the nervous system.
  - The smooth muscle of the afferent arteriole responds to being stretched (by high blood pressure in the arteriole) by constricting or relaxing when less pressure is in the arteriole. This keeps the pressure in the glomerulus steady even though the cardiovascular blood pressure changes all the time.
  - The other control mechanism was already mentioned. It is the juxtaglomerular complex (see previous page) where the amount of NaCl in the filtrate is monitored. If the level of NaCl is too high, vasoconstrictor are released and the afferent arteriole constricts. This will slow the blood flow and allow more time for the NaCl to be removed from the filtrate in the nephron loop.

- **Extrinsic (outside the organ) Control**
  - If a person has a major drop in blood pressure the sympathetic nervous system (fight or flight) will kick in and epinephrine and norepinephrine will be released. These hormones constrict the blood vessels of the body in an attempt to rise overall blood pressure. The afferent arteriole in the glomerulus also constricts, slowing the flow of blood in the kidney and potentially damaging the kidney. This is a mechanism to save the body at the expense of the kidney.
  - Aldosterone. Stay tuned. This will be discussed in the next section (reabsorption).

25.5 Urine Formation Step 2: Reabsorption

- **Reabsorption** is the process of selectively returning some substances that were filtered out of the blood (forming the filtrate in the nephron) and moving them back into the blood (to the peritubular capillary).
- Reabsorption happens mainly in the **proximal convoluted tubule (PCT)** where ions, nutrients (glucose, amino acids, vitamins), bicarbonate ions, water, lipids and urea move back into the blood from the filtrate.
- Your textbook also includes the nephron loop (loop of Henle) and the collecting duct as areas of reabsorption. Mr. B will address this as “how to adjust the concentration of urine.” Stay tuned.
- Skip the section on pp. 978-979 regarding the reabsorption of sodium.
Reabsorption Capabilities of the Renal Tubules and Collecting Ducts (p. 979-980)

- **The PTC**
  - How much glucose and amino acids is reabsorbed back into the blood in the PTC?
  - How much Na ion and water is reabsorbed back to the blood in the PTC?

“How to Adjust the Concentration of Urine Part 1”

- **The Nephron Loop (Loop of Henle)** - *this section is not directly in the reading. For some reason the author puts the info under the collecting duct section. This is a summary of what takes place in the descending nephron loop.*
  - The nephron loop is one place the filtrate concentration is adjusted. If you are dehydrated, your kidney will release a hormone called Renin. Renin tells the adrenal gland to release the hormone Aldosterone.
  - When released, Aldosterone, causes the descending limb of the nephron loop to actively transport salt and Na⁺ out of the filtrate into the interstitial fluid of the kidney. **Water follows salt.** Water leaving the filtrate will make the urine more concentrated and this water can then enter the bloodstream and increase overall blood pressure or hydrate cells.

25.6 Urine Formation Step 3: Secretion

- **Secretion** is the process of selectively transporting any remaining toxins, wastes, or substances in overabundance out of the blood and into the filtrate (urine).
- The main location of secretion is in the Distal Convoluted Tubule (DCT).
- The main things secreted are:
  - Drugs
  - Nitrogenous Wastes (Ammonia, Urea, Uric Acid)
  - Excess Ions (especially K⁺ ions.)
  - H⁺ ions and/or HCO₃⁻ (bicarbonate ions). This adjusts the pH of the blood keeping it at 7.35.
  - Creatinine for muscle metabolism

“How to Adjust the Concentration of Urine Part 2” : The Collecting Duct and ADH (p.980)

- The last chance move move water out of the urine and back to a dehydrated body happens in the collecting duct.
- The posterior pituitary gland will release Antidiuretic Hormone (ADH) if you are dehydrated.
- ADH causes more aquaporins to accumulate on the walls of the collecting duct. Thus, water can move out of the urine and into the interstitial fluid of the kidney where it can be reabsorbed back to the blood.

You may skip Section 25.7.

You may skip Section 25.8 Except for the passage about Urine on p. 987.

- Be familiar with the component of urine.
- Why is concentrated urine yellow?