Slide 2

The kidney has a number of functions.

First is the excretion of toxic metabolic waste through urine production. The kidneys filter blood plasma and as a result of filtering blood, the kidneys help eliminate toxic materials, drugs, and hormones from the body.

A number of the kidney's functions correspond with the elimination or conservation of H2O. Blood volume and concentration is regulated by the amount of water that is pulled out and/or put back into blood. Blood pressure is influenced by the quantity or volume of blood regulated by the movement of water. The movement of electrolytes, such as sodium ions, influences how much water is excreted or put back into the blood.

Blood pH is regulated via the removal of wastes such as metabolic wastes and nitrogenous wastes like urea.

Slide 3

The kidney is a retroperitoneal, paired organ. Meaning that it is posterior to the peritoneum and there are 2. The Gross Anatomy of the kidney is composed of a few structures.

1. The Fibrous Capsule covers the outside of the kidney. It is made of fat and fibers.

2. The renal cortex is the outer, functional layer of the internal structure. It contains nephrons, units that filter blood. The cortex also has extensions that goes further into kidney called the renal columns.

3. The inner, functional layer of the kidney is called the renal medulla. The Medulla is composed of 6-10 Renal Pyramids.

4. At the tip of each pyramid there is a small funnel like structure called a Minor Calyx.

5. When 2 or more Minor Calyces merge, they form a Major Calyx.

6. When 2 or more Major Calyces merge they form the Renal Pelvis.

7. The Renal Pelvis is an enlarged chamber that leads to the Ureter, which carries urine out of the kidney to the bladder.

8. The Renal Hilum is a concave space, or opening, that allows the ureters, renal vein and artery to enter and leave the kidney. Each kidney has a renal artery that brings blood to the organ and a renal vein that leaves the kidney and returns blood to the inferior vena cava.

Slide 4

The functional unit of the kidney is called the nephron. There are 1.2 million nephrons per kidney. Each nephron contains a renal corpuscle and renal tubules.

The renal corpuscle begins the nephron and is located in the renal cortex. It has the glomerulus which is a network of fenestrated capillaries that filters blood plasma. The fenestrated capillary wall means that it has small holes that allow substances to pass. The afferent arterioles are the blood vessels that come into the corpuscle and the efferent arterioles leave the glomerulus. The glomerular capsule is a double

layered, bowl shaped capsule that encloses the glomerulus and wraps around the capillaries. It receives the material that is filtered by the glomerulus which is referred to as filtrate.

Slide 5

After the renal corpuscle, the nephron is also composed of a series of tubules, or ducts. The ducts are process filtrate further into urine. They are located in both the cortex and medulla. The Proximal Convoluted Tubule (PCT) arises out of the glomerulus and looks like one big twisted, curvy tube. It is made of simple cuboidal epithelium and has microvilli. Most of the reabsorption during urine production occurs here. The next segment is called the nephron loop. The nephron loop starts when the tube straightens out and is U shaped in structure. There are two limbs on the nephron loop. The descending limb dips down and goes into the renal medulla. After the u turn and the tube returns back towards the cortex it is referred to as the Ascending limb. The nephron loop can also be broken into thick and thin segments. The thick segment, constitutes the majority of the ascending and descending limbs, is made of simple cuboidal. The thin segment is made of simple squamous and found at the u turn of the loop. The difference in cell types found in the limbs is a result of their function. The cuboidal cells in the thick segment participate heavily in active transport and need a lot of mitochondria to produce ATP. The squamous cells in the thin segment are not as metabolically active, but they allow for movement of water. They are highly permeable to water. Once the tube has returned to the cortex, it becomes twisted again (although less twisted than the PTC) and is called the Distal Convoluted Tubule (DCT). The DCT is made of cuboidal epithelium and has little to no microvilli. This is also the end of the nephron.

The tubules are covered by a network of blood vessels called the peritubular capillaries. They arise from the efferent arterioles and play an active role in the formation of urine.

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All nephrons dump into a collecting duct. The DCT of several nephrons empty into a duct. The collecting ducts ultimately lead to a minor calyx.

Slide 6

The formation of urine is a four step process. It begins by making filtrate in the glomerulus.

Glomerular filtrate is the fluid that has been filtered from the blood plasma in the glomerulus and throughout the nephron.

Fluid passes from glomerulus (ie capillaries) into the glomerular capsule via a filtration membrane.

The Filtration membrane is made of 1. fenestrated endothelium of the capillary, 2. a shared basement membrane, 3. and filtrations slits formed by the podocytes (cells) in the capsule wall.

The fenestrated endothelium is honeycombed shaped with large filtration pores, like a colander.

Particles are pushed out by an increase in blood pressure. The increase in blood pressure is due to dramatic decrease in vessel size of the afferent arteriole. The restriction of size causes pressure to build up and moves particles through the filtration membrane. This is similar to putting your thumb over the end of a garden hose to spray water. At this stage, the things that get filtered out are water,

electrolytes, glucose, fatty acids, amino acids, nitrogenous wastes, and vitamins. Blood cells and plasma proteins do not normally pass through the filtration membrane.

Glomerular Filtration Rate is the amount of filtrate formed in 1 minute by both kidneys. Healthcare providers can use the glomerular filtration rate to help determine if the kidneys are working properly. Approximately 99% of this filtrate is reabsorbed back into the blood as we will see in the following steps. Therefore, we only end up with 1-2 liters of urine per day.

Slide 7

These are microscopic photos of the glomerulus.

Slide 8

The fenestrated endothelium of the capillary on the left, the shared, thin basement membrane in the middle, and then the slotted epithelial wall formed by podocytes of the glomerular capsule. Notice in the diagram the substances that are allowed to pass through and those that are not and remain in the blood.

Slide 9

After the fluid leaves the glomerulus and enters the tubules, it is still considered filtrate and not yet urine.

Tubular Reabsorption in the PCT. The PCT reabsorbs most of the glomerular filtrate back into the peritubular capillaries.

This process utilizes both passive and active processes.

- Sodium is key to the movement of everything else, it sets up the concentration gradients.
- Chlorine tends to follow Na+ because it is negative and is attracted to the positively charged sodium.
- Normally, all glucose is reabsorbed here.
- Nitrogenous Wastes are partially reabsorbed, but a significant portion remain in the filtrate
- Most of the water is reabsorbed here as well and follows sodium through osmosis

The nephron loop reabsorbs some water and sodium and aids the collecting duct in conserving water.

The DCT also absorbs small amounts of water.

Tubular Secretion extracts chemicals from blood then and secretes them into the renal tubules. This is an insurance policy of sorts, anything toxic that didn't make the 1st filtration process (or anything that was too big to pass through the filtration membrane) can be removed through tubular secretion. This process occurs throughout the tubules. For example, hydrogen ions are removed to help maintain pH control. Additionally nitrogenous wastes, potassium and some drugs can also be removed.

Water conservation is the final step in urine formation and occurs primarily in the collecting duct. Multiple nephrons empty into the collecting duct. Once the filtrate has entered the collecting duct, it is

considered urine. As the collecting duct passes through the renal medulla, water is reabsorbed to further concentrate the urine up to 4 times its original concentration.

Slide 11

Urine leaves the kidneys by way of the ureters. The walls of the tubes are made of three layers.

1. The Mucosa is the inner layer. It is made of transitional epithelium (recall back to histology and that transitional epithelium is really good at stretching, which is essential in the urinary system to accommodate the fluctuations in urine output) that begins at minor calyces and extends through the bladder.

2. The middle layer is a muscle layer referred to as the muscularis. There are actually 2 layers of smooth muscle within the muscularis, and as the tube nears the urinary bladder, it becomes 3. The muscularis works in peristaltic wave to move urine, almost like a milking action.

3. The Adventitia is the outer layer. It is made of connective tissue that binds to the surrounding tissues.

As mentioned, the ureters function to transports urine from the kidney to the bladder. A valve formed from a flap of mucosa is found at the opening into the bladder which keeps urine from back flowing into the ureters.

Slide 12

The urinary bladder is a large muscular sac. Like the ureters, it has three layers.

1. The Mucosa continues into the urinary bladder and is still made of transitional epithelium. There are also rugae that allows the bladder to stretch, similar to that found in the stomach.

2. The muscle layer is referred to as the detrusor muscle and is composed of 3 layers of smooth muscle.

3. There are two different segments of connective tissue that covers the urinary bladder. Adventitia covers the majority of the bladder and parietal peritoneum is found on the superior/curved portion of the bladder.

Internally, there is a region called the Trigone. It is triangular in shaped and is formed by the entrance of both ureters and the exit to the urethra. This is a common site for UTIs (urinary track infections).

The urinary bladder functions as a place to store urine until it can be eliminated from the body. The elimination of urine is called the Micturition Reflex (urination reflex).

Slide 13

The steps of the Micturition reflex (urination reflex) are simplified in the diagram.

1. Filling of the bladder excites stretch receptors which sends a message to the spinal cord.

2. The spinal cord responds and sends out a signal via parasympathetic nerve fibers.

3. The signal excites the detrusor muscles to contract.

4. The signal also stimulates the internal urethral sphincter to relax.

At this point one of two paths can be followed. The pons regulates voluntary control of the elimination of urine. It will give the go ahead signal or not.

If timely, the pons stops regulating signals which allows the external urethral sphincter to relax and urine to leave the body. If it is not timely, the external sphincter will not relax. When toddlers are potty training, this is the reflex control that they are developing.

Of course, there are situations when it may be necessary for the body to eliminate urine and it will override the voluntary control.

Slide 14

As you may have surmised from the previous slide, the urethra is a tube that conveys urine from the urinary bladder out of the body. There are two sphincters, the external and internal, that allow for control of the passage of urine. The external urethra orifice is the opening to the external environment. The external opening is slightly different in females and males, which we'll see when we do the reproductive unit. In females, the external urethral orifice is found between the vaginal opening and the clitoris. Also, in males, the urethra is used in both the urinary and reproductive systems. In females, at least in human females, this tube is used solely by the urinary system.