URINARY SYSTEM

The urinary system is composed of many parts, this includes two kidneys, the ureters, the urinary bladder, the urethra and two urinary sphincters. It has many functions that include ion and electrolyte balance in the blood, monitor fluid volume and blood pressure, excretion of waste products, gluconeogenesis, vitamin D activation, and pH balance in the blood. The function of the kidneys is dependent on its anatomy.

Looking at the kidney first you can see that it is surrounded by a capsule called the renal capsule which is composed of loose irregular connective tissue. When dissecting, one may notice that the kidneys are behind the peritoneum, which is the membrane that lines most of the abdominal cavity. This means that the kidneys are a relatively fixed structure. If one were to take the kidney and cut it coronally, we could see two distinct regions, the outer most layer called the cortex and inner layer called the Medulla.

The Renal medulla is made up of triangles, called pyramids and the space between the triangles called columns. It is important to note that the Renal pyramids have higher sodium concentration than the rest of the kidneys and that it is in a gradient with the highest concentration being at the apex of the pyramid.

There are then tubes leaving the kidney which contact the apex of the renal pyramids called the minor calyxes. These minor calyxes come together to form major calyxes which come together to form the renal pelvis. The renal pelvis leaves the kidney and becomes renal ureters which will drain into the urinary bladder. The urinary bladder then has a small tube called the urethra which leaves the body.

1. What is the name of the capsule around the kidney and what tissue type is it?

2. What part of the kidney has a higher sodium concentration?

3. On the cross section of the kidney label the following:
   - A. Renal cortex
   - B. Renal Medulla
     - i. Medullary columns,
     - ii. Medullary pyramids.
   - C. Minor calyxes
   - D. Major calyxes
   - E. Renal pelvis
   - F. Ureter

For the kidneys to function in the formation of urine and excretion of metabolic waste, it must have a large blood supply. This means that the Renal artery that leaves the abdominal aorta must be large. As soon as the renal artery enters the kidney it branches into the Segmental arteries. Then, before entering the medullary columns the segmental arteries branch into the lobar arteries which branch again as they reach the cortex to form interlobar arteries then anastomose around the base of the medullary pyramids to for an arch called the arcuate arteries. The arcuate arteries have radiations called the interlobular arteries which will form arterioles. The concomitant veins will have the same names as the arteries until they reach the inferior vena cava.

4. Draw and label the renal artery and vein, segmental artery, lobar arteries, interlobar arteries, arcuate arteries, and the interlobular arteries.

Many tissues make up the renal system. If we look at the kidney itself, we can find that most of it is made up of simple cuboidal epithelium. When we look at the lumen of the calyx, pelvis, ureters, bladder, and urethra, we find a new specialized tissue called transitional epithelium. Transitional epithelium has many cell shapes as it is under the stress of stretching and contracting.

5. Look at a slide of the kidney and draw what you see. Identify the basement membrane, and cells as well as the tissue type.

6. Draw what is seen in a slide of the ureter or urinary bladder lumen. Label the cell and tissue type.

With the tissues and gross structures of the renal system understood, the functional unit, called the nephron can be explored. Nephrons are collections of cells which begin at the specialized renal arterioles. The first part is called the Afferent arterioles which indicates that the blood is going to an organ (in this case the nephron.) Prior to the tubules, there is a thickening of smooth muscle which controls the flow of blood.

Upon entering the first part of the nephron, the afferent arteriole becomes a modified capillary bed named the Glomerulus. This glomerulus has a second arteriole that leaves the nephron called the Efferent Arteriole (Efferent means going out of) which also has a thickened smooth muscle valve to control flow out of the nephron. As it is a modified capillary bed, the Glomerulus is made up of simple squamous endothelium which is used to filter the blood into the nephron.

The blood must pass first through the fenestrations within the endothelium, then through the basement membrane which contains negatively charged heparin then through another layer of cells called the podocytes. In short, to enter the nephron's lumen, blood must go through three levels of filtration. That first area of the nephron is called the Bowman's space where the podocytes are part of the Bowman's capsule. The filtrate will only allow small molecules such as amino acids, sugar, water and positively charged electrolytes and is referred to as ultrafiltrate.

7. Draw a picture of the three layers of filtration to enter Bowman's Space, label the endothelium basement membrane, and podocytes.

Once ultrafiltrate enters the Bowman's Space, it is technically outside of the body. Anything in the Bowman's space must now be reabsorbed or secreted depending on if there is a need for some of the things in the ultrafiltrate. From the Bowman's space, the ultrafiltrate enters the Proximal Convoluted Tubules which can reabsorb 2/3 of all the ultrafiltrate. This is the only place where glucose can be reabsorbed. The Proximal convoluted tubule enters a hairpin loop called the Loop of Henle (or Loop of the Nephron.)

The two sides of the Loop of Henle have different functions. The descending limb, which is the first section, allows for the reabsorption of Sodium though special channel proteins. The Ascending limb of the Loop of Henle allows for the reabsorption of water. Once we get to the end of the Loop of Henle, we have concentrated the Urea by removing the water and salt.

The Ascending limb of the Loop of Henle is attached to the Distal Convoluted Tubule. The Distal Convoluted Tubule can reabsorb either Sodium or Potassium. As water tends to follow sodium, this means that reabsorption of Sodium will cause an increase in fluid retention and blood pressure. The reabsorption of Sodium is under the control of a hormone called Aldosterone.

On the end of the Distal Convoluted Tubule, is the Collecting ducts which can reabsorb everything passively when Anti Diuretic Hormone (ADH) acts on it causing the formation of aquaporins. This is usually increased during dehydration. Whatever is not reabsorbed is then eliminated as urine.

8. Draw the nephron labeling the glomerulus, proximal convoluted tubule, loop of Henle, distal convoluted tubule, and collecting ducts.

9. What is the difference between medullary and cortical nephrons?

The blood supply around the nephron does continue past the efferent arteriole where it forms peritubular capillaries. These capillaries can pick up what has been reabsorbed by the nephron to return it to the body. The Peritubular capillaries come together to form interlobular veins and continue to come together until they form the renal veins which enter the Inferior Vena Cava.

When we look at the nephron within a kidney, we see that some structures are found in similar areas. First, we must understand that there are two classifications of nephrons, the medullary and the cortical nephrons. The largest difference is where these nephrons are located.

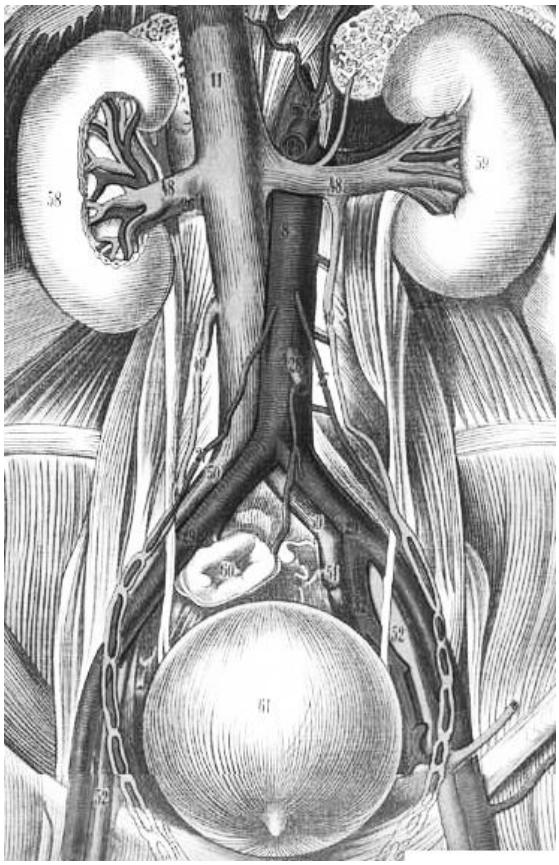
The cortical nephrons begin with the glomerulus, Bowman's capsule, and Distal convoluted tubules within the cortex and the Loop of Henle and Collecting Ducts within the Medullary Pyramids. The Medullary nephrons have their glomerulus, Bowman's capsule, and Distal convoluted tubules within the Medullary columns and the Loop of Henle and Collecting Ducts within the Medullary Pyramids. As the Pyramids have the highest Sodium concentration of the kidney, it aids in the passive reabsorption.

While the nephron is described in a linear fashion, its convoluted tubules allow it to fold upon itself. This allows the Distal Convoluted Tubules to fold over and meet the afferent and efferent arterioles near the glomerulus to form a specialized structure called the Juxtaglomerulus apparatus. The Afferent and efferent arterioles contact the distal convoluted tubules in an area of specialized cells collectively called the Macula Densa. When there is high levels of sodium in the tubules, the Macula densa cells will trigger the contraction of the smooth muscle of the afferent arterioles Reducing blood flow to the glomerulus thus decreasing Glomerulus filtration rate.

The Juxtaglomerulus apparatus also has cells specialized in the efferent arterioles which release Renin when blood pressure is low to cause the release of aldosterone which increases sodium reabsorption. The reabsorption of sodium will usually cause the reabsorption of water.

10. Draw the section of the nephron with a juxta-glomerulus Apparatus and label the afferent arteriole, the efferent arteriole, the glomerulus, the distal convoluted tubule, the distal convoluted tubule, and macula densa cells and the juxtaglomerulus apparatus.

Once fluid leave the nephron, it enters the lesser calyx, which will drain into the greater calyxes until it reaches the renal pelvis. This fluid will then enter the ureters which lead into the urinary bladder. At the bladder, urine is held in place via two urinary sphincters, called the internal and external urinary sphincters. When the sphincters are relaxed, the urine will flow into the Urethra which exits the body completely. Unlike the kidneys, which are retroperitoneal, the ureters, bladder, and urethra are within the peritoneum.



11. On the picture provided label the following:
    a. Kidney
    b. Renal artery
    c. Renal vein
    d. Renal pelvis
    e. Ureter
    f. Bladder

12. What two sphincters hold urine from leaking out of the urinary bladder?

13. What is the tube which connects the urinary bladder to the end of the urinary tract?

14. Which urinary system organ is retroperitoneal?

Within the lumen of the urinary tract, we find a special type of tissue called transitional epithelium. This layer is called the mucosa layer. This tissue needs to be able to stretch then return to its normal state, so the cells tend to be in a state of transition thus the cells cannot be seen as either flat, cube-like or columnar but are a varied pattern of cells. This tissue layer is usually over a connective tissue layer called the submucosa. The Submucosa is then followed by a layer of smooth muscle (called the Detrusor muscle) which is the tunica muscularis which is followed by the tunica adventitia. You might note that this is a similar arrangement as found it the GI tract.

15. Draw what is seen in a slide of a ureter, label the lumen, adventitia, muscularis, and mucosa layers. What tissue lines the lumen?

16. Draw a picture of the wall of the bladder labeling the tissues. What is the detrusor muscle?

Clinical:

An interesting clinical note is that as the kidneys are near the bottom of the ribs, when an infection occurs (Called Pyelonephritis) many will feel pain in the upper back. Therefore, many clinicians use Lloyd's sign to confirm a kidney infection. This test is done by going to back near the 12^{th} rib and placing a hand over that area. The other hand is used to strike the first hand and if patient complains of pain, then there is a high likelihood of a kidney infection though you will want to check the skin first to make sure not abrasions or rashes are present.

Clinical:

The Kidneys can be damaged due to trauma to the back so in contact sports such as boxing, punching the posterior area of the back is illegal. This type of trauma can lead to tearing the blood vessel so when intentional it is taken extremely seriously.

Embryology of the renal system:

The embryology of the renal system can explain certain congenital conditions as well as provide support for evolution. First, a set of kidneys are formed called the pronephrons which go through Apoptosis but before that form the pronephric (primary excretory) duct which attaches to the cloaca. Week five the mesonephros develops using the Primary excretory duct as an exit. It functions until it goes through begins to apoptosis as the third set of

kidneys start to function. The primary duct continues as both the primary excretory duct where the metanephros develop and as the Mesonephric duct superior to it. In week five an out pouch called the Ureteric bud develops off the primary excretory duct. It will form the renal pelvis, the calices, and collecting ducts. The surrounding mesoderm begins to form nephrons (kidney cells). With the metanephric kidney formed it ascends to the abdomen. With the metanephron formed, the Cloaca divided into the urogenital sinus and the rectum.

Genital development begins from the medial portion of the intermediate mesoderm.

At Week 5 gonadal ridges form in the dorsal abdominal wall next to the mesonephros. Then some cells from the yolk sac seed the gonadal ridges to become the Primordial germ cells. At the end of week 5 the paramesonephric (Mullerian) ducts develop lateral to the mesonephric (Wolffian) ducts. Male differentiation begins on week 7 based on the presence of a protein called SRY. If the SRY protein is present, then the testes cords develop (these will become the Seminiferous tubules) and fuse with the Wolffian ducts. The Wolffian ducts will become the epididymis, ductus deferens, and ejaculatory ducts. As this occurs, the Mullerian ducts will go through apoptosis.

Prior to differentiation of external genitalia both male and female will form identical structure. These include the genital tubercle, the urethral folds, and the labioscrotal swelling. Male external genitalia differentiation begins on week 8 male. Genital tubercle enlarges forming the glans penis. The Urethral folds fuse forming the penile urethra and the labioscrotal move inferiorly to form the scrotum.

The internal gonads descend until they reach the floor of the pelvic region and wait until month 7. In the seventh month, a fibrous cord called the gubernaculum that attaches to the bottom of the scrotum and bottom of the testes shortens, pulling some of the peritoneum and the testes with it. This process is called the vaginal process. At the end the Inguinal canal closes and the vaginalis process is cut off from the peritoneum and surrounds the testes. This is now the Tunica Vaginalis

If the SRY protein is not present, then the fetus will develop female genitalia. This means that the wolffian ducts will go through apoptosis and he Mullerian ducts will develop into the fimbriae, ampule, fallopian tubes, and fuse to make the uterus. The Mullerian ducts will also form the internal vagina. On week 8, the genital tubercle will become the glans clitoris, the urogenital folds will become the labii minora and the labioscrotal swelling will become the labii majora.

17. What would occur if a genetic male has a damaged region of the Y chromosome leading to an inhibition of the formation of the SRY protein?