

I. Urinary System

A. Functions

1. Excretes metabolic waste into the urine.
2. Regulates blood volume and pressure.
3. Maintains pH.
4. Excretes hormones into the urine.

B. Anatomy of the kidney

1. Location

- a. The kidneys are located on the posterior body wall behind the parietal peritoneum (**retroperitoneal**) at the T12-L3 level.

2. External anatomy

- a. The kidneys are covered in three capsules.
 - i. The **true (renal) capsule** covers, but does not adhere to, the outer surface of the kidney.
 - (a) Provides a barrier against infection and trauma.
 - ii. The middle **adipose capsule** is a layer of adipose tissue to cushion the kidney.
 - iii. The outer **renal fascia** of dense irregular connective tissue helps to anchor the kidneys to the posterior body wall.

3. Internal anatomy

- a. The kidneys are divided into an inner region known as the **medulla** and an outer region known as the **cortex**.
 - i. The filtration of the blood will occur at **glomeruli** within the cortex.
 - ii. The medulla is divided into cone shaped **renal (medullary) pyramids**.
 - (a) The renal pyramids contain **loops of Henle** and **collecting ducts** that carry urine away from the nephrons.
 - (b) There will be a high concentration of salt within the medulla.
- b. Urine will flow from the renal pyramids into **minor calyces**.
- c. The minor calyces will join into **major calyces**.
- d. The major calyces join into the **renal pelvis** that connects to the **ureter** carrying urine away from the kidney towards the bladder.

4. Renal blood supply

- a. Blood flows into the kidneys through the renal arteries which divide into the segmental arteries-> interlobar arteries-> arcuate arteries-> interlobular arteries-> afferent arterioles-> glomerulus-> efferent arterioles-> peritubular capillaries-> interlobular veins-> arcuate veins-> interlobar veins-> into the renal vein which drains into the inferior vena cava.

C. Anatomy of the nephron

1. These are the functional units of the kidney where the blood is filtered and urine is formed.
2. Consists of:
 - a. The **renal corpuscle** is composed of two parts.
 - i. The **glomerulus** is a ball of fenestrated capillaries where filtration of the blood occurs.
 - ii. The **Bowman's capsule** is a double-layered structure that surrounds the glomerulus.
 - (a) The parietal layer consists of simple squamous epithelial cells.

- (b) The visceral layer consists of cells called **podocytes** that cover the surface of the glomerulus and form a filtration membrane.
 - (c) The cavity between the two layers of the Bowman's capsule collects **filtrate** from the glomerulus.
 - b. The **proximal convoluted tubule** carries filtrate away from the Bowman's capsule.
 - c. The filtrate then enters the **Loop of Henle** which dips down into the medulla of the kidney.
 - d. The **distal convoluted tubule** carries the filtrate away from the Loop of Henle and drains into a **collecting duct**.
- D. Physiology of urine formation
 1. Consists of three processes occurring at the nephron.
 2. **Glomerular filtration** is the first step and consists of blood fluid and solutes being pushed out of the glomerulus by blood pressure, and into the space of the Bowman's capsule forming filtrate.
 - a. Filtration occurs because the blood (hydrostatic) pressure within the glomerulus exceeds the blood osmotic pressure and the capsular hydrostatic pressure which counteract filtration.
 - b. The differences between these pressures produce a **net filtration pressure** that normally forces the fluid out of the glomerulus and into the Bowman's capsule.
 - i. Changes in blood hydrostatic pressure or blood osmotic pressure, such as with dehydration, can influence the net filtration pressure and therefore the amount of urine produced.
 - c. Blood cells and proteins are too large to normally pass through the filtration membrane.
 - d. Factors that control glomerular filtration include:
 - i. Altering the diameter of the afferent arteriole.
 - (a) Constriction of the afferent arteriole allows less blood flow into the glomerulus decreasing the net filtration pressure, causing less filtrate to be made.
 - (b) Dilation of the afferent arteriole allows more blood flow into the glomerulus increasing the net filtration pressure, causing more filtrate to be made.
 - ii. Sympathetic stimulation
 - (a) Sympathetic neurons supply the small renal arteries and the afferent arterioles.
 - (b) Increased sympathetic stimulation to the arteries causes vasoconstriction allowing less blood flow into the glomerulus, decreasing net filtration pressure and urine output.
 - iii. **Atrial natriuretic peptide (ANP)**
 - (a) Produced by the walls of the heart in response to increased stretch caused by high blood volume.
 - (b) Causes arteries in the kidneys to relax increasing blood hydrostatic pressure in the glomerulus and net filtration pressure.
 - (c) Increases the rate of filtrate formation and urine output, lowering the blood volume.

3. **Tubular reabsorption** is the second step of urine formation and consists of removing molecules from the filtrate and returning them back to circulation.
 - a. 80% of reabsorption occurs within the proximal convoluted tubule.
 - i. Glucose, amino acids, vitamins and positive ions are actively transported from the tubule and into the peritubular capillaries to reenter circulation.
 - ii. Negative ions follow the positive ions due to electrochemical attraction.
 - iii. Water leaves by osmosis as a result of the other nutrients leaving the tubules.
 - b. The descending portion of the Loop of Henle continues to reabsorb water.
 - i. The ascending portion of the Loop of Henle is **always** impermeable to water.
 - c. The distal convoluted tubule and collecting ducts can reabsorb water in the presence of **Antidiuretic Hormone**.
 4. **Tubular secretion** is the final step of urine formation and consists of secreting substances from the blood of the peritubular capillaries into the nephron so they will be eliminated with the urine.
 - a. Within the proximal convoluted tubule the active secretion of ammonia, urea, hydrogen ions and drugs such as penicillin occurs.
 - b. Within the distal convoluted tubule and collecting duct the passive secretion of hydrogen and potassium ions occurs.
- E. Hormones controlling tubular reabsorption and secretion.
1. **Antidiuretic hormone (ADH)** is secreted from the **posterior pituitary gland** in response to low water (dehydration) being detected by the hypothalamus.
 - a. ADH targets the distal convoluted tubule and collecting ducts causing them to produce water channels which are inserted into the tubules and ducts making them more permeable to water.
 - b. More water is reabsorbed from the filtrate into the peritubular capillaries which reduces the rate of dehydration and produces scant volumes of concentrated urine.
 - c. In addition to its effects at the kidneys, ADH also constricts blood vessels supplying salivary and sweat glands causing thirst and less water loss from the body by sweat.
 2. **Aldosterone** is secreted from the cortex of the **adrenal gland** in response to high blood potassium levels and low blood sodium levels.
 - a. May also be stimulated by low blood volume at the kidneys causing the kidney to release **renin**, which results in a blood protein being converted into **Angiotensin II** stimulating the release of aldosterone.
 - b. Aldosterone increases the reabsorption of sodium ions from the urine into the blood and increases the secretion of potassium ions from the blood into the urine, bringing levels of potassium and sodium ions back to homeostatic levels.
- F. Abnormal urine constituents.
1. **Glucosuria** is when glucose appears in the urine.
 - a. Is a sign of diabetes mellitus.
 2. **Ketonuria** is when ketone bodies appear in the urine.
 - a. Ketone bodies are produced as a by-product of the excessive breakdown of fats.
 - b. Is a sign of diabetes mellitus, starvation or extreme dieting.
 3. **Albuminuria** is when the blood protein albumin appears in the urine.
 - a. Often due to inflammation of the kidney (glomerulonephritis), high blood pressure or acidosis causing dilation of the glomeruli.
 4. **Hematuria** is when blood appears in the urine.

- a. Due to kidney trauma, infection or kidney stones.
- 5. **Pyuria** is the presence of white blood cells in the urine.
 - a. Is a sign of infection in the kidneys or other urinary organs.
- G. Organs that transport, store and eliminate urine.
 - 1. The **ureters** transport urine from the kidney to the urinary bladder.
 - a. Have an outer fibrous layer that helps anchor the ureters in place.
 - b. The middle layer of the ureters consists of two layers of smooth muscle (circular and longitudinal) which create peristaltic waves.
 - c. The ureters are lined with a mucous membrane with **transitional epithelium** on the free surface.
 - 2. The **urinary bladder** is a storage area for urine.
 - a. The superior surface is covered by the parietal peritoneum.
 - b. The bulk of the wall of the bladder is composed of three layers of smooth muscle known as **detrusor muscle**.
 - c. The bladder is lined with a mucous membrane with transitional epithelium on the free surface.
 - i. When the bladder is empty the mucosal layer is folded into wrinkles known as **rugae**.
 - ii. The rugae allow the mucous membrane to stretch as the bladder fills.
 - d. **Cystitis** is an infection of the bladder.
 - i. More common in women than men because of the short urethra.
 - ii. Most often caused by self-contamination of bacteria found within the digestive tract.
 - iii. Prevention includes good hygiene, cotton underwear, no chemical or sprays, drinking plenty of fluids.
 - iv. Treated with sulfa drugs and antibiotics.
 - 3. The **urethra** carries urine away from the bladder and eliminates it from the body.
 - a. The female urethra is 1.5 inches long while the male urethra is 8 inches long and has an additional function of carrying spermatozoa.
 - b. Has an **internal smooth muscle sphincter** under autonomic control and an **external skeletal muscle sphincter** under voluntary control.
- H. The **micturation reflex**.
 - 1. A parasympathetic reflex responsible for the voiding of urine from the body.
 - 2. Initiated by stretch in the urinary bladder.
 - 3. Results in contraction of the detrusor muscle of the bladder wall and relaxation of the internal smooth muscle sphincter.
 - 4. Voluntary relaxation of the external skeletal muscle sphincter allows urination to take place.
- I. The kidneys and pH balance.
 - 1. Normally, arterial blood pH is 7.41 and venous blood pH is 7.36.
 - 2. The human body can survive a pH range of 7.0-7.8.
 - 3. The kidneys are the most powerful means of eliminating pH balances, but it is also the slowest requiring several hours to a day.
 - 4. The primary way in which the kidneys help in maintaining pH balance is by the secretion of hydrogen ions.

- a. If the body is too acidic the kidneys secrete more hydrogen ions into the urine helping to bring pH back to normal.
 - b. If the body is too basic (alkaline) the kidneys secrete less hydrogen ions into the urine helping to bring pH back to normal.
5. If the arterial blood pH drops below 7.35 it is referred to as **acidosis**.
- a. The consequences of acidosis include:
 - i. Increased respiratory rate
 - ii. Increased heart rate and blood pressure
 - iii. Depression of the central nervous system.
 - b. If the pH drops below 7.0 the individual becomes disoriented, comatose and dies.
6. If the arterial blood pH rises above 7.45 it is referred to as **alkalosis**.
- a. The main consequences of alkalosis include:
 - i. Decreased respiratory rate
 - ii. Decreased heart rate and blood pressure.
 - iii. Overexcitability of the central nervous system.
 - b. Can result in nervousness, muscle spasms and convulsions.