Filtration, Reabsorption and Secretion

1. **How is the blood filtered by the kidneys?**

   - Blood enters the kidney through the renal artery, which narrows into interlobular arteries that travel through the kidneys to feed the renal pyramids.
   - These arteries narrow into arcuate arteries which lead toward the individual nephrons.
   - The arcuate arteries narrow into afferent arterioles that lead into the glomerulus.
1. Distal Convoluted Tubule
2. Afferent arteriole
3. Glomerulus
4. Bowman’s Capsule
5. Proximal Convoluted Tubule
6. Efferent Arteriole
7. Collecting Duct
8. Nephron Loop
9. Peritubular capillary
**Filtration**

- Blood enters into the glomerulus under pressure.
  - The afferent arteriole (into the glomerulus) is larger than the efferent arteriole (exiting the glomerulus).

- Capillaries in the glomerulus have large pores which allow most solutes to be easily filtered.
  - The pores (fenestrations) of the glomerular capillaries are 100-400 times more permeable to water, dissolved solutes and plasma than the capillaries of skeletal muscles.

- The glomerular (Bowman’s) capsule has filtration slits to allow the filtrate from the glomerular capillaries to pass through into the tubules.

- Water and dissolved solutes (glucose, urea, salts, uric acid etc.) pass from the blood plasma through the pores in the capillary walls, through the filtration slits in the Bowman’s capsule and then into the nephron tubule.

- Red and white blood cells, platelets and proteins are too large to be filtered and remain in the capillaries.
Rates of Filtration

• The glomerular filtration rate (GFR) is the volume of filtrate produced per minute by both kidneys; it ranges from 115 to 125 ml per minute, which is equivalent to 7.5 L per hour and 180 L per day!

• Since the total blood volume averages about 5-8 L, the total blood volume is filtered into the urinary tubules every 40 minutes.

• The GFR can be regulated by constriction or dilation of the afferent arterioles.

• Most of the filtered water must be returned immediately to the circulatory system or a person would literally urinate to death within minutes.

• Approximately 20% of the blood is filtered each minute, while the other 80% services the rest of the body.
2. What wastes are removed during filtration?

• **Urea** – waste product from metabolism of protein. Ammonia created during the metabolism of protein is converted to urea by the liver.

• **Uric Acid** – from breakdown of purines, found in foods such as beef, pork, poultry, fish and seafood, asparagus, cauliflower, spinach, mushrooms, green peas, lentils, dried peas, beans, oatmeal, wheat bran and wheat germ.

• Some electrolytes.

• Waste products from phagocytosis by white blood cells.
3. How do the kidneys ensure the non-harmful substances are not permanently removed? (Glucose, water, salt etc.)

Reabsorption

1) Proximal Convoluted Tubule

- All glucose, amino acids and 85% of mineral ions are immediately reabsorbed by active transport through the proximal convoluted tubule and into the peritubular capillaries.
- 80% of water is immediately reabsorbed by osmosis.
- Some urea is reabsorbed (it can easily pass through the cell membranes.
- Small proteins are reabsorbed through pinocytosis. They are broken down into amino acids, which can then diffuse into the blood.
2) Loop of Henle

• The Loop of Henle makes the tissue fluid outside of it hypertonic (more concentrated) than the filtrate inside. Called a “salt bath”.
• Purpose of salt bath is to reabsorb water.
• Creates salt bath by actively pumping sodium and chloride ions out of the tubule and into the tissue fluid.

How does this occur?
Descending Limb of Loop of Henle

• Impermeable to ions, but allows water to diffuse via osmosis.
• Filtrate becomes more concentrated as it descends.

Ascending Limb of Loop of Henle

• Contains a sodium and chloride pump to actively transport ions out of the tubule.
• Tubule is impermeable to water, so it cannot follow via osmosis. Osmosis occurs in the descending limb.
• Greatest concentration of filtrate and tissue fluid is at the bottom of the loop. (3 times more concentrated than seawater).
4. **How do the kidneys maintain homeostasis of pH, water volume in blood plasma and salt balance?**

**Distal Convoluted Tubule (Secretion and Homeostasis)**

In the distal convoluted tubule, substances are Actively transported from the blood to the filtrate. (called “secretion”). This is controlled by hormones.
1. **Acid/Base (pH) Balance**

- Hydrogen ions are actively transported from blood to filtrate.
- Removing $\text{H}^+$ reduces the acidity of the blood. Not removing $\text{H}^+$ ions increases pH of blood.
- Bicarbonate (a base) is usually entirely reabsorbed in the proximal convoluted tubule.
2. **Salt Balance**

- Control of plasma Na$^+$ is important to regulate blood volume and pressure.
- Control of K$^+$ is important to maintain proper function of cardiac and skeletal muscles.
- Approximately 90% of filtered Na$^+$ and K$^+$ is reabsorbed in the proximal convoluted tubule.
- Final concentration of Na$^+$ and K$^+$ in the urine is determined in the distal convoluted tubule.
- The hormone “**aldosterone**” secreted by the adrenal gland controls reabsorption and excretion of Na$^+$ and K$^+$.
**Na⁺**

**No aldosterone present**

• 80% of Na⁺ is automatically reabsorbed in distal convoluted tubule (which is 8% of amount filtered).
• Therefore, 2% of Na⁺ is excreted from the body in the complete absence of aldosterone. This amounts to 30g of Na⁺ excreted in urine per day.

**Max aldosterone present**

• 100% of Na⁺ is reabsorbed which is zero grams per day.
K⁺

No aldosterone present
• 90% of K⁺ is reabsorbed in the proximal convoluted tubule.
• If no aldosterone is present, 100% of what is left is reabsorbed in the distal convoluted tubule, meaning zero grams of K⁺ is excreted in the urine.

Max aldosterone present
• Presence of aldosterone stimulates secretion of K⁺ into distal convoluted tubule.
• At max aldosterone, 50 times more K⁺ is excreted than when no aldosterone is present.
Summary

Aldosterone promotes Na\(^+\) retention and K\(^+\) loss from the blood by stimulating reabsorption of Na\(^+\) and secretion of K\(^+\).
3. Water Balance

Controlled by presence of **anti-diuretic hormone** around the **collecting duct** of the nephron.

- The interstitial fluid surrounding the walls of the collecting duct is very hypertonic (concentrated) to the fluid inside the collecting duct.
- This will cause water to passively diffuse out of the collecting duct via osmosis because the walls of the collecting ducts are **permeable to water but not to salt** so water can diffuse out, but salt cannot diffuse in. (Remember the collecting ducts are very close to the salt bath for the loop of Henle.)
• The water that leaves the collecting duct immediately enters the peritubular capillaries, so it does not dilute the interstitial fluid.

• The water channels in the collecting ducts are proteins that can be controlled by ADH.

• ADH is produced by neurons in the hypothalamus and is secreted from the posterior pituitary.

• The secretion of ADH is stimulated by when osmoreceptors in the hypothalamus respond to an increase in blood osmotic pressure.
• When the concentration of ADH is increased, the collecting ducts become more permeable to water and more water is reabsorbed. (NOT EXCRETED)

• When the concentration of ADH is decreased, the collecting ducts become less permeable to water and less water is reabsorbed. A larger volume of more dilute urine is excreted.
Anti-Diuretic Hormone – can also be called...

Water-Retaining Hormone
or
Urine-Decreasing Hormone
5. Where does the filtrate go from the collecting duct?

The collecting ducts converge into the minor calyces which then converge into the major calyces. The major calyces empty into the ureter, which drains into the bladder.

When the bladder is full, sensors sense the stretching and signal the brain to urinate.