In this chapter, you will learn:
• Each kidney receives blood that is processed to form urine, which drains through a ureter and into the urinary bladder for excretion.
• Each kidney contains over one million nephrons that process blood to form urine.
• The functional unit of the kidney is the nephron.
• Each nephron filters blood, reabsorbs substances such as sodium and glucose for reuse in the body, and secretes excess or toxic substances such as urea to produce urine.

• Antidiuretic hormone (ADH) regulates the amount of water reabsorbed in the distal tubule.
• Aldosterone regulates the amount of salt that is reabsorbed or secreted.
• The acid-base balance of the blood is adjusted by the secretion of hydrogen ions and reabsorption of bicarbonate ions.
• Various technologies are used to solve problems involving dysfunctions and disorders of the excretory system.
9.1 The Structures and Function of the Excretory System

In this section, you will:

• Identify the main structures and functions of the human excretory system
• Explain the function of the nephron
• Dissect a mammalian kidney and observe its structure

Crash Course

• Excretory System

Excretory System

• Regulates body fluid volume
• Removes waste / Returns substances to body systems
• Wastes
  – Carbon dioxide
  – Water
  – Sodium/Chlorine
  – Hydrogen

Excretion

• Process of separating wastes from body fluids
• Eliminating waste
  – Respiratory- Expels carbon dioxide
  – Skin- excretes salts, water, perspiration
  – Notes- elimination of food- feces- not excretion
  • Not suspended in solution
The Kidneys

- Regulate the body's composition of bodily fluids
- Removal of wastes — Na, Cl, carbon dioxide, water, ammonia, hydrogen etc...
- Some wastes have a higher priority to be removed, like nitrogenous wastes
- Can you identify some other metabolic wastes produced by the body that are removed?

Organs of the Excretory System

Kidneys

The view in (A) includes some blood vessels to reinforce the connection between the circulatory and excretory systems. The views in (B) and (C) do not include blood vessels, and identify the three regions of the kidney: renal cortex, renal medulla, and renal pelvis. The view in (C) introduces the functional unit of the kidney: the nephron.
Functional Regions of the Nephron

1. Filter: The filtration structure at the top of each nephron is a cap-like formation called the **Bowman's capsule**.
   1. Within each capsule, a **renal artery** enters and splits into a fine network of capillaries called a **glomerulus**.
   2. The walls of the glomerulus act as a filtration device. They are impermeable to proteins, other large molecules, and red blood cells, so these remain within the blood. Water, small molecules, ions, and urea—the main waste products of metabolism—pass through the walls and proceed further into the nephron.
   3. The filtered fluid that proceeds from the glomerulus into the Bowman's capsule of the nephron is referred to as **filtrate**.

Functional Regions of the Nephron

1. Tubule: The Bowman's capsule is connected to a small, long, narrow tubule that is twisted back on itself to form a loop.
   1. This long, hairpin loop is a reabsorption device. The tubule has three sections: the **proximal tubule**, the **loop of Henle**, and the **distal tubule**.
   2. Like the small intestine, this tubule absorbs substances that are useful to the body, such as glucose and a variety of ions, from the filtrate passing through it.
   3. Unlike the small intestine, this tubule also secretes substances into the tissues surrounding it.

Functional Regions of the Nephron

1. Duct: The tubule empties into a larger pipe-like channel called a **collecting duct**.
   1. The collecting duct functions as a water-conservation device, reclaiming water from the filtrate passing through it so that very little precious water is lost from the body.
   2. The filtrate that remains in the collecting duct is a suspension of water and various solutes and particles. It is now called urine.
   3. Its composition is distinctly different from the fluid that entered the Bowman's capsule. The solutes and water reclaimed during reabsorption are returned to the body via the **renal veins**.

Crash Course

- **Part 1 - Urinary System**
9.2 Urine Formation in the Nephron

In this section, you will:

- **Explain** the function of the nephron in maintaining the composition of blood plasma
- **Describe** the function of the kidney in excreting metabolic wastes and expelling them into the environment

Steps in urine formation

- **Filtration** - water and small molecules removed from blood
- **Reabsorption** - water and essential molecules returned to blood
- **Secretion** - wastes and excess salts added from body fluids to filtrate (urine)
1. filtration

- blood pressure forces small molecules from the glomerulus to the capsule

Filtrates: glucose, amino acids, uric acid, urea

2. Tubular Reabsorption

- return of filtrates from blood at the proximal tubule through diffusion and active transport.

3. Tubular Secretion

- movement of molecules from blood into the distal convoluted tubule

Molecules: drugs and toxins
Reabsorption of water

- return of $\text{H}_2\text{O}$ via osmosis along the loop of Henle and collecting duct

Urine Formation

Reabsorption in the Loop of Henle

- Active transport of sodium ions
- Passive transport of other ions occurs in the thick segment of the ascending limb of the loop of Henle. There is no reabsorption of water in this part of the nephron.

Parts of the Nephron and Their Functions

- **Glomerulus**: Filtration
  - Glomerular blood pressure forces some of the water and dissolved substances from the blood plasma through the pores of the glomerular walls

- **Bowman's capsule**: Receives filtrate from glomerulus

- **Proximal tubule**: Reabsorption
  - Active reabsorption of all nutrients, including glucose and amino acids
  - Active reabsorption of positively charged ions such as sodium, potassium, calcium
  - Passive reabsorption of water by osmosis
  - Passive reabsorption of negatively charged ions such as chloride and bicarbonate by electrical attraction to positively charged ions

- **Secretion**
  - Active secretion of hydrogen ions

- **Descending loop of Henle**: Reabsorption
  - Passive reabsorption of water by osmosis

- **Ascending loop of Henle**: Reabsorption
  - Active reabsorption of sodium ions
  - Passive reabsorption of chloride and potassium ions

- **Distal tube**: Reabsorption
  - Active reabsorption of sodium ions
  - Passive reabsorption of negatively charged ions such as chloride and bicarbonate
  - Passive secretion of hydrogen ions

- **Collecting tube**: Reabsorption
  - Passive reabsorption of water by osmosis

9.3 Excretory System Health
In this section, you will:
- **Describe** how the kidneys contribute to homeostasis with respect to water and ions
- **Perform** a urinalysis using simulated urine samples
- **Relate** the design of dialysis technologies to the design of the kidney

The release of ADH controls the amount of water reabsorbed or excreted in urine.

**Kidney Stones**
Hemodialysis & Peritoneal Dialysis

- Hemodialysis is a process that uses a man-made membrane (dialyzer) to: Remove wastes, such as urea, from the blood. Restore the proper balance of electrolytes in the blood. Eliminate extra fluid from the body.
- Peritoneal dialysis (PD) is a treatment for patients with severe chronic kidney disease.
  - Peritoneal dialysis: A dialysis technique that uses the patient's own body tissues inside the abdominal cavity as a filter.

Urinary Tract Infection (UTI)

- Infection involving the kidneys, ureters, bladder, or urethra. These are the structures that urine passes through before being eliminated from the body.

Chapter 9 Review

- Draw a diagram or flowchart to show how the excretory system works.
- What wastes are produced by the human body?
- Describe the functions of each major structure in the excretory system.
- How does the excretory system interact with blood and circulation?
- Why do wastes need to be eliminated from the body?
Chapter 9 Summary

- The metabolic activities of cells, including energy release, maintenance, and repair, produce substances that change the balance of the volume of water and the concentration and composition of dissolved substances in the body's fluids. The excretory system removes these materials to maintain the optimal volume of water and composition of body fluids, dispose of wastes, and recycle the non-waste substances. The substances in question include carbon dioxide; water; ions of sodium (Na\(^{+}\)), chloride (Cl\(^{-}\)), and hydrogen (H\(^{+}\)); and other compounds resulting from the breakdown of proteins and nucleic acids. The excretory system also plays a key role in maintaining the acid-base balance (pH) in the blood.

- The organs of the excretory system are the kidneys, the ureters, the urinary bladder, and the urethra. The kidneys contain millions of tiny nephrons that each contain a filter, a tube, and a duct. The nephrons filter out waste and reabsorb substances such as sodium and water for reuse by the body's systems. The resulting filtrate, known as urine, is sent through the ureters to the urinary bladder for temporary storage until it is eliminated from the body through the urethra.

- Disorders of the excretory system include urinary tract infections, kidney stones, and renal insufficiency. Renal insufficiency may require dialysis or a kidney transplant in order to ensure that wastes are secreted rather than building up to toxic levels in the body.