

Chapter 9

Excretion and the Interaction of Systems



Goals for This Chapter

- 1. Identify the main structures and functions of the human excretory system**
- 2. Explain the function of the nephron**
- 3. Describe the function of the kidney in excreting wastes and expelling them into the environment**
- 4. Describe how the kidneys maintain homeostasis with respect to water and ions**
- 5. Relate the design of dialysis technologies to the design of the kidney**

The Importance of Kidneys

- **Our body's cells break down complex compounds into simpler ones**
- **Many of the simple compounds can be toxic**
- **The liver removes an amine group from proteins, forming ammonia**
- **The liver then combines this ammonia with carbon dioxide to form urea**
- **The kidneys then filter out the urea and uric acid from the blood**

Excretion of Wastes

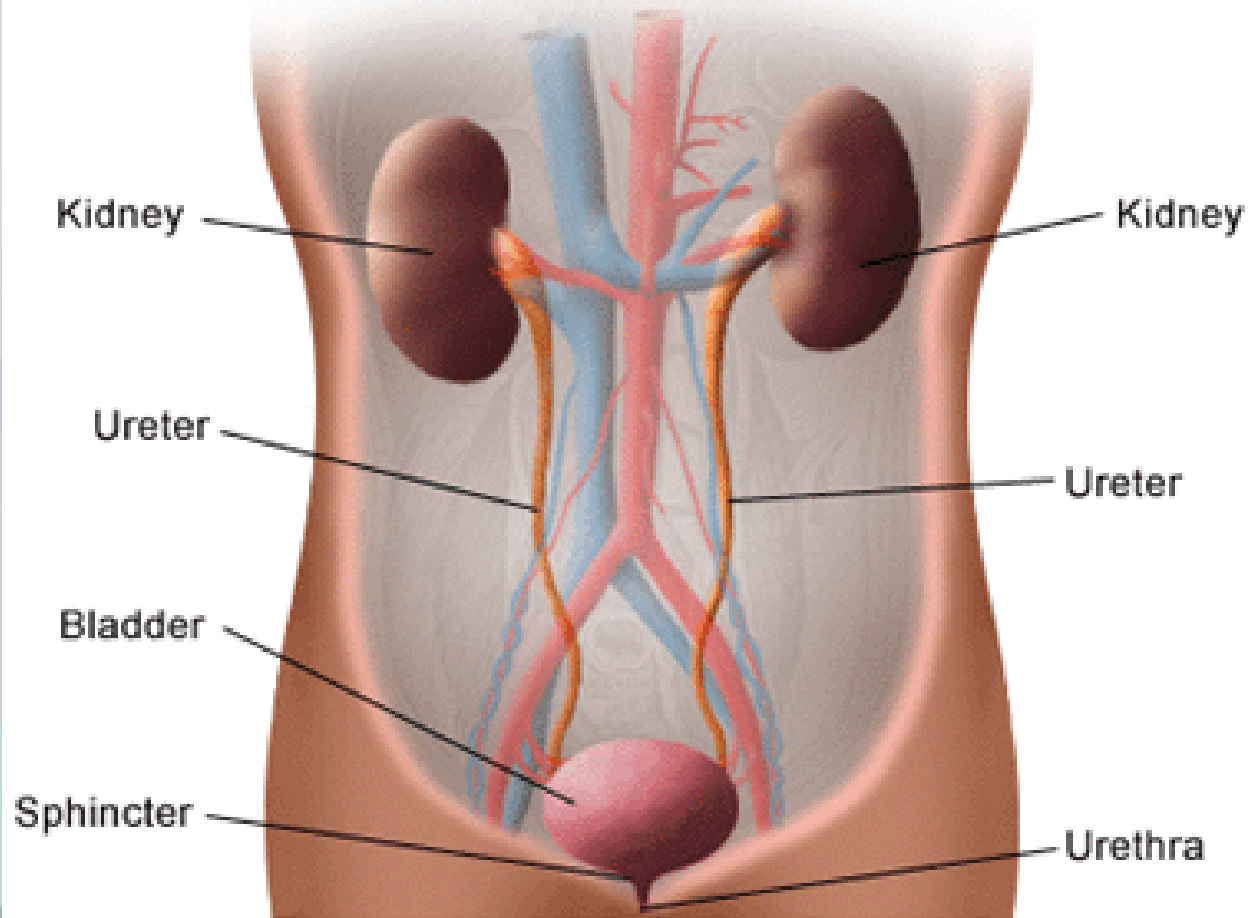
- **Excretion is the process of separating wastes from the body fluids and eliminating them**
- **The respiratory system and the skin are both involved in excretion**
- **However, the elimination of solid food residue (feces) is not considered to be excretion**

The Urinary System

- **Renal arteries branch from the aorta and enter the kidneys**
- **Waste is filtered from the blood in the kidneys and sent to the bladder via ureters**
- **The urinary sphincter at the base of the bladder releases urine into the urethra, where it leaves the body**

The Urinary System

Front View of Urinary Tract



Bladder Volume

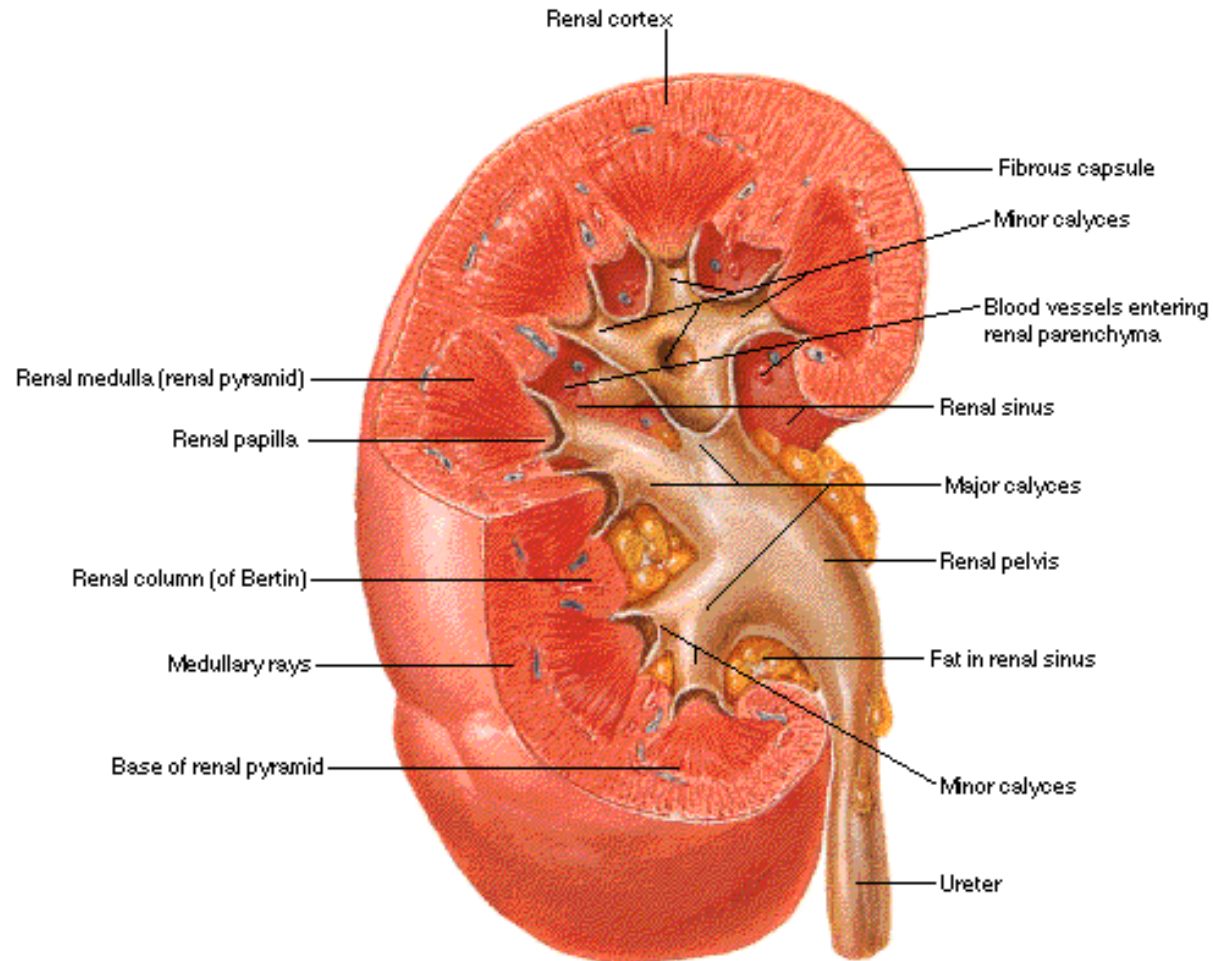
- **At a urine volume of 200 mL, the bladder stretches and sends a message to the brain indicating that it needs to be emptied**
- **At 400 mL, a more urgent message is produced**
- **At a volume of 600 mL, the voluntary control of the bladder is lost, and it empties itself**

The Kidney

- The kidney has three different structures
- An outer layer, the **cortex**, encircles the kidney
- The inner layer, the medulla, is found beneath the cortex
- The **pelvis** is a hollow chamber which joins the kidney with the ureter

Kidney Cross Section

Right Kidney Sectioned in Several Planes

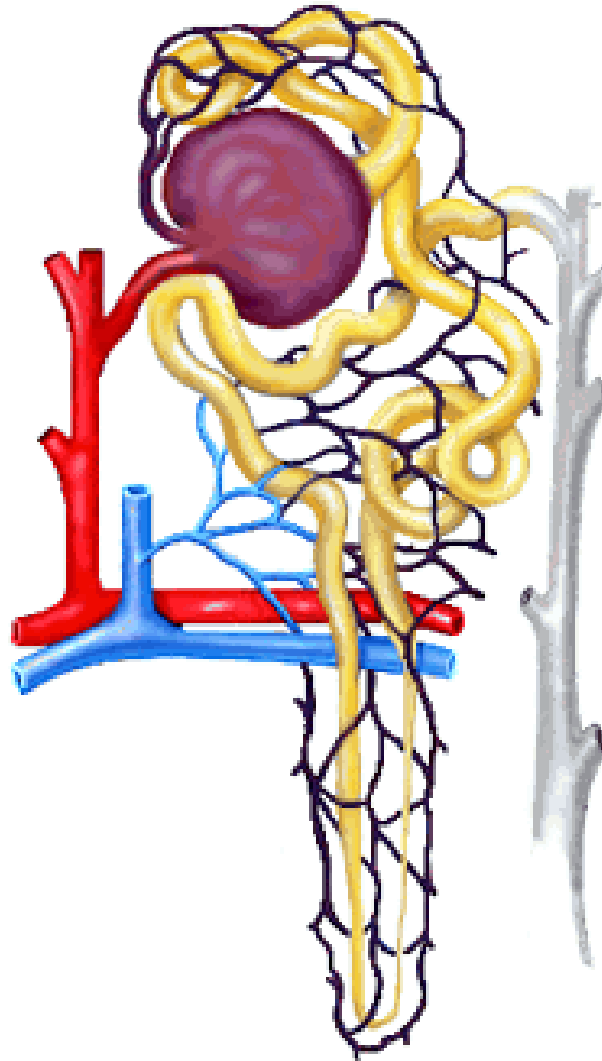


Nephrons

- The **nephrons** are the functional units of the kidney
- Tiny **afferent arterioles** supply the nephrons with blood
- These arterioles branch into a capillary bed known as the **glomerulus**
- Blood leaves the glomerulus by the **efferent arteriole**

- The glomerulus is surrounded by a funnel-like structure known as **Bowman's capsule**
- Fluids to be processed into urine enter Bowman's capsule from the blood (major site of filtration)
- The capsule tapers to a thin tubule called the **proximal tubule**
- Urine travels through the *loop of Henle* (ascending limb is impermeable to water) and into the **distal tubule** (which have lots of mitochondria) and into the **collecting ducts**

The Nephron



Formation of Urine

- **Formation of urine involves three functions:**
 - 1. Filtration**
 - 2. Reabsorption**
 - 3. Secretion**

1. Filtration

- **Blood moves into the glomerulus, which acts as a high-pressure filter**
- **Dissolved solutes pass through the walls of the glomerulus into Bowman's capsule, creating a filtrate similar to blood plasma**
- **Plasma proteins, platelets and erythrocytes do not pass into Bowman's capsule because they are too large to pass through the membrane**

2. Reabsorption

- **About 120 mL of fluid per minute is filtered into the nephron**
- **Reabsorption is required otherwise you would need to continually consume fluids to maintain homeostasis**
- **Out of the 120 mL, 119 mL are reabsorbed**
- **This is accomplished by active and passive transport**

- **Carrier molecules carry Na^+ ions out of the nephron into the blood, which are followed by Cl^- and HCO_3^- ions**
- **The concentrated solutes in the blood create an osmotic pressure that pushes water back into the blood**
- **Glucose and amino acids are also reabsorbed by the blood by attaching themselves to carrier molecules**
- **This also increases osmotic pressure into the blood**

3. Secretion

- **Secretion is the movement of wastes from the blood into the nephron**
- **Nitrogen wastes, histamine, excess hydrogen ions, and mineral levels are balanced through secretion**
- **Secretion involves active transport, but molecules are shuttled from the blood into the nephron**

Water Balance

- **Increased water intake is adjusted for by increasing urine output**
- **The kidneys rely on the nervous and endocrine systems to help maintain a balance of water**

Regulating ADH

- **ADH (antidiuretic hormone)** regulates the osmotic pressure in the kidneys to increase water absorption
- If ADH is released, more concentrated urine is produced
- ADH is released from the hypothalamus as the water from the hypothalamus cells leaves and they shrink (due to increased solute levels in the blood)
- The shrinking of hypothalamus cells also creates a sensation of thirst

- **As you take in water, the solute levels in the blood drop**
- **This reduces the osmotic pressure, allowing fluids to move from the blood into the hypothalamus, releasing less ADH and causing less water to be reabsorbed by the nephrons**

ADH and the Nephron

- **85% of the water filtered into the nephron is reabsorbed in the proximal tubule**
- **ADH makes the upper part of the distal tubule and collecting duct permeable to water**
- **This allows NaCl in the intercellular spaces to create an osmotic pressure that draws water from the tubule back into the blood**

Kidneys and Blood Pressure

- Kidneys regulate blood pressure by regulating blood volume
- **Aldosterone** acts on nephrons to increase Na^+ reabsorption
- If there is a decrease in blood pressure, aldosterone is produced, which increases Na^+ absorption and therefore brings more water into the blood, increasing its volume (and therefore, pressure)

Kidneys and Blood pH

- The blood pH is maintained by acid-base buffer systems
- The most important acid-base buffer system is the following equation:



pH decreases

pH increases

- **The kidneys help to maintain this balance by balancing H^+ and HCO_3^-**
- **If the blood is too acidic, H^+ is excreted and HCO_3^- is reabsorbed and returned to the blood**

The Balance of the Excretory System

- **Often the balance of materials in our urine depends on a number of factors**
- **However, diet, physical activity, stress and fatigue can affect the levels of materials in urine**
- **These many factors must be taken into account by healthcare professionals when they analyze urine to look for indicators of diseases such as diabetes**

Diabetes Mellitus

- **Diabetes mellitus is caused by inadequate levels of insulin**
- **Without insulin, blood sugar levels rise**
- **The excess sugars remain in the nephron, creating osmotic pressure that opposes the osmotic pressure created by other solutes**
- **As a result, diabetes mellitus sufferers produce excess urine which contains high amounts of sugar**

Diabetes Insipidus

- **This occurs when ADH-producing cells of the hypothalamus are destroyed**
- **This causes a dramatic increase in urine output (up to 20 L of urine per day!)**
- **People with this disease must drink huge volumes of water to maintain fluid balance**

Bright's Disease (Nephritis)

- **This collection of diseases is characterized by inflammation of the nephrons**
- **Proteins and other large molecules enter the nephron via damaged blood vessels**
- **These molecules cannot be reabsorbed, creating an osmotic pressure that pulls water into the nephron, increasing urine production**

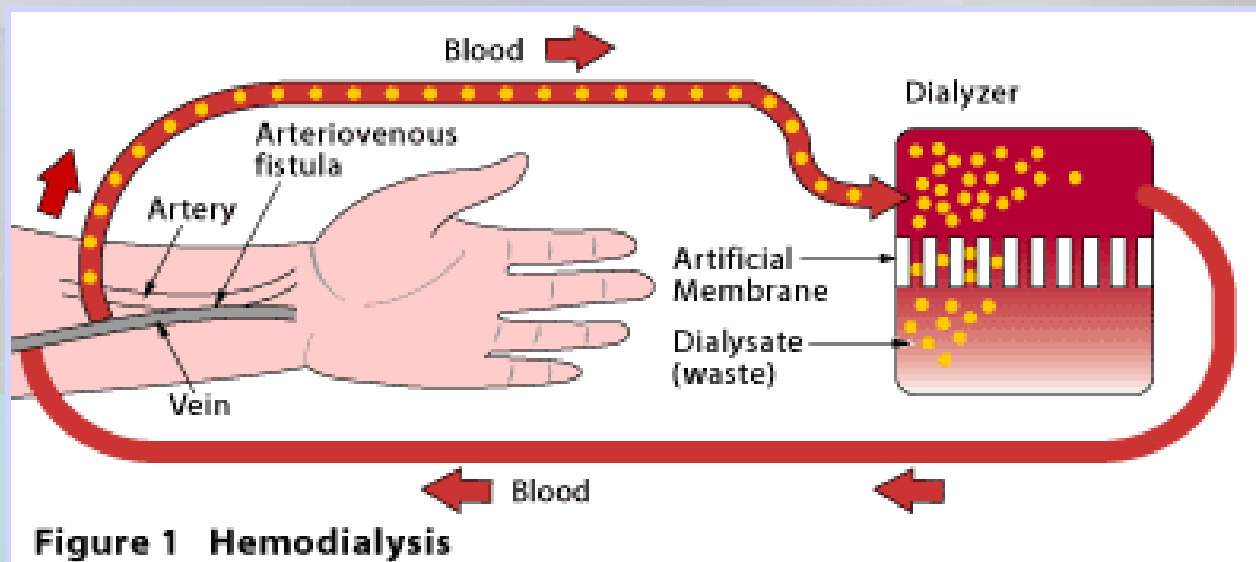
Dialysis

- **If a kidney loses its function, then the patient may be in danger of dying from uric acid poisoning**
- **One solution for this condition is to perform dialysis**
- **During dialysis treatment, a person's blood is filtered using a machine**

Dialysis Machines (Hemodialysis)

- **A dialysis machine consists of a long tube made from a semipermeable membrane immersed in a solution**
- **This solution contains the same ingredients as clean blood plasma**
- **The patient's blood (known as dialysate) is passed through this tube and the wastes diffuse into the surrounding solution**

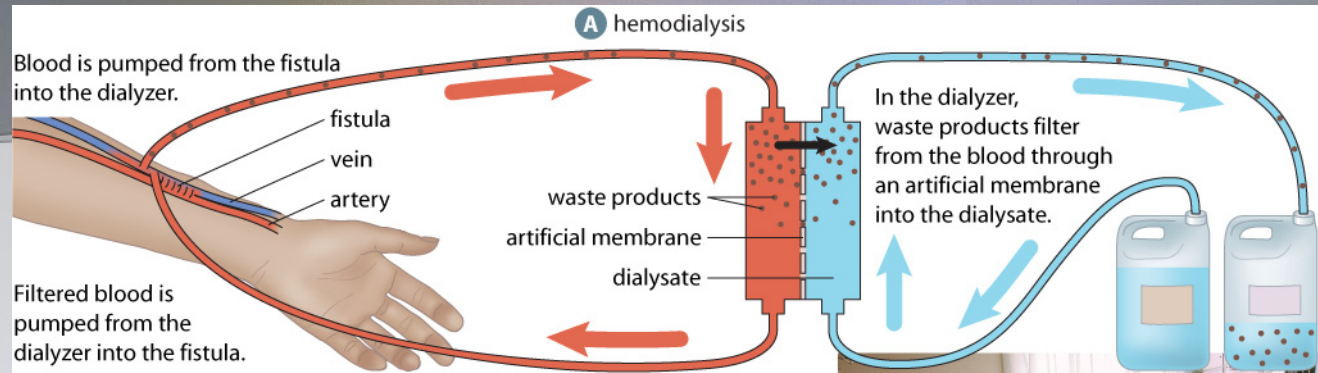
- Dialysis treatments take between 5 and 8 hours, and may be repeated up to three times a week
- As well, patients must have a strictly regulated diet to prevent excess levels of toxins to build up in their systems



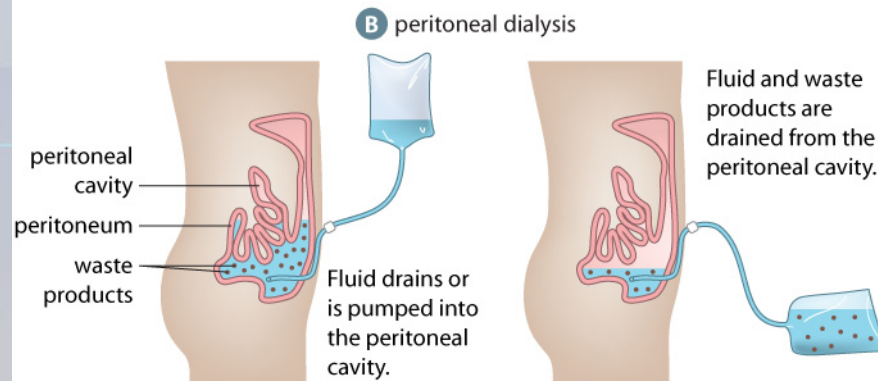
Peritoneal Dialysis

- **Peritoneal dialysis uses the lining of the intestines (the peritoneum) as the dialysis membrane**
- **The dialysate is introduced into the abdominal cavity, where the large surface area and the rich supply of capillaries slowly filter the blood**

Hemodialysis vs. Peritoneal Dialysis



A In hemodialysis, blood is pumped from an artery to a dialysis machine and returned to the body by way of a vein. (The artery and vein are surgically joined, forming what is called a fistula, to enable easier long-term access to the person's blood.) Each hemodialysis treatment takes three to five hours and is performed three or four times a week. A person must remain seated or lying down during the procedure.



B In peritoneal dialysis, a catheter (flexible tube) is surgically inserted into the abdominal cavity and dialysate may be delivered, removed, and replaced. Because dialysate is always present, the blood is continuously filtered. The full name for this type of dialysis is continual peritoneal dialysis, or CPD. There are several types of CPD. In continuous

ambulatory peritoneal dialysis (CAPD), the procedure can be done at home, work, or school—any place that is clean and convenient. Usually, three to five exchanges of fresh dialysate for used dialysate are needed each day. In automated peritoneal dialysis (APD), a machine performs the exchange, which often is done at night for a period of up to 12 hours.



Figure 9.10
Hemodialysis (A) and peritoneal dialysis (B)

Kidney Transplants

- **One permanent solution to dialysis is to replace the damaged kidney with a fully functional one**
- **Kidney transplants often involve a close family member donating one of their healthy kidneys to the patient**
- **As a result, both the donor and recipient will have one fully functional kidney**

- **However, because both the donor and recipient only have one kidney, they should closely monitor their diet in the future**
- **Kidneys can also be obtained from cadavers as long as the organ donation card had been filled out**



The Kidney-Coronary Connection

- **Kidneys can fail due to high blood pressure**
- **If the blood vessels in the kidneys are damaged due to high blood pressure, they lose their ability to filter wastes effectively**
- **Unfortunately, the symptoms of high blood pressure and kidney impairment do not appear until the damage has already been done**

Kidney Stones

- **Kidney stones are collections of mineral salts from the blood**
- **These sharp stones become lodged in the pelvis or the ureter, causing severe pain**
- **Ultrasound can be used to break up these stones so that they will be passed in the urine (previously, only surgery could remove the kidney stones)**



Well Mr. Osborne, it may not be kidney stones after all.

