

Chapter 17 - Urinary System

17.1 Introduction (Fig. 17.1)

- A. The urinary system consists of two kidneys that filter the blood, two ureters, a urinary bladder, and a urethra to convey waste substances to the outside.

17.2 Kidneys (Fig. 17.2)

- A. The kidney is a reddish brown, bean-shaped organ 12 centimeters long; it is enclosed in a tough, fibrous capsule.
- B. Location of the Kidneys
 - 1. The kidneys are positioned retroperitoneally on either side of the vertebral column between the twelfth thoracic and third lumbar vertebrae, with the left kidney slightly higher than the right.
- C. Kidney Structure (Figs. 17.1-17.2)
 - 1. A medial depression in the kidney leads to a hollow renal sinus into which blood vessels, nerves, lymphatic vessels, and the ureter enter.
 - 2. Inside the renal sinus lies a renal pelvis that is subdivided into major and minor calyces; small renal papillae project into each minor calyx.
 - 3. Two distinct regions are found within the kidney: a renal medulla and a renal cortex.
 - a. The renal medulla houses tubes leading to the papillae.
 - b. The renal cortex contains the nephrons, the functional units of the kidney.
- D. Kidney Functions
 - 1. The kidneys function to regulate the volume, composition, and pH of body fluids and remove metabolic wastes from the blood in the process.
 - 2. The kidneys also help control the rate of red blood cell formation by secreting erythropoietin, and regulate blood pressure by secreting renin.
- E. Renal Blood Vessels (Figs. 17.1,17.3-17.4)
 - 1. The abdominal aorta gives rise to renal arteries leading to the kidneys.
 - 2. As renal arteries pass into the kidneys, they branch into successively smaller arteries: interlobar arteries, arcuate arteries, interlobular arteries, and afferent arterioles leading to the nephrons.
 - 3. Venous blood is returned through a series of vessels that generally correspond to the arterial pathways.
- F. Nephrons (Table 17.3)
 - 1. Nephron Structure (Figs. 17.2,17.5-17.7)
 - a. A kidney contains approximately one million nephrons, each of which consists of a renal corpuscle and a renal tubule.
 - b. The renal corpuscle is the filtering portion of the nephron; it is made up of a ball of capillaries called the glomerulus and a glomerular capsule that receives the filtrate.
 - c. The renal tubule leads away from the glomerular capsule and first becomes a highly coiled proximal convoluted tubule, then leads to the nephron loop, and finally to the distal convoluted tubule.
 - d. Several distal convoluted tubules join to become a collecting duct.
 - 2. Blood Supply of a Nephron (Fig. 17.4, 17.6)
 - a. The glomerulus receives blood from a fairly large afferent arteriole and passes it to a smaller efferent arteriole.
 - b. The efferent arteriole gives rise to the peritubular capillary system, which surrounds the renal tubule.
 - 3. Juxtaglomerular Apparatus (Fig. 17.7)
 - a. At the point of contact between the afferent and efferent arterioles and the distal convoluted tubule, the epithelial cells of the distal tubule form the

- macula densa.
- b. Near the macula densa on the afferent arteriole are smooth muscle cells called juxtaglomerular cells.
- c. The macula densa together with the juxtaglomerular cells make up the juxtaglomerular apparatus.

17.3 Urine Formation

- A. Urine formation involves glomerular filtration, tubular reabsorption, and tubular secretion.
- B. Glomerular Filtration (Fig. 17.8; Table 17.1)
 - 1. Urine formation begins when the fluid portion of the blood is filtered by the glomerulus and enters the glomerular capsule as glomerular filtrate.
- C. Filtration Pressure (Fig. 7.10)
 - 1. The main force responsible for moving substances by filtration through the glomerular capillary wall is the hydrostatic pressure of the blood inside.
 - 2. Due to plasma proteins, osmotic pressure of the blood resists filtration, as does hydrostatic pressure inside the glomerular capsule.
- D. Filtration Rate
 - 1. The factors that affect the filtration rate are filtration pressure, glomerular plasma osmotic pressure, and hydrostatic pressure in the glomerular capsule.
 - 2. When the afferent arteriole constricts in response to sympathetic stimulation, filtration pressure, and thus filtration rate, declines.
 - 3. When the efferent arteriole constricts, filtration pressure increases, increasing the rate of filtration.
 - 4. When osmotic pressure of the glomerular plasma is high, filtration rate decreases.
 - 5. When hydrostatic pressure inside the glomerular capsule is high, filtration rate declines.
 - 6. On the average, filtration rate is 125 milliliters per minute or 180 liters in 24 hours, most of which is reabsorbed further down the nephron.
- E. Regulation of Filtration Rate (Figs. 17.7, 17.11)
 - 1. Glomerular filtration rate is relatively constant, although sympathetic impulses may decrease the rate of filtration.
 - 2. Another control over filtration rate is the renin-angiotensin system, which regulates sodium excretion.
 - a. When the sodium chloride concentration in the tubular fluid decreases, the macula densa senses these changes and causes the juxtaglomerular cells to secrete renin.
 - b. Secretion of renin triggers a series of reactions leading to the production of angiotensin II, which acts as a vasoconstrictor; this may, in turn, affect filtration rate.
 - c. Presence of angiotensin II also increases the secretion of aldosterone, which stimulates reabsorption of sodium.
 - d. The heart can also increase filtration rate when blood volume is high.
- F. Tubular Reabsorption (Fig. 17.12)
 - 1. Changes in the fluid composition from the time glomerular filtrate is formed to when urine arrives at the collecting duct are largely the result of tubular reabsorption of selected substances.
 - 2. Most of the reabsorption occurs in the proximal convoluted tubule, where cells possess microvilli with carrier proteins.
 - 3. Carrier proteins have a limited transport capacity, so excessive amounts of a substance will be excreted into the urine.
 - 4. Glucose and amino acids are reabsorbed by active transport, water by osmosis, and proteins by pinocytosis.

- G. Sodium and Water Reabsorption (Fig. 17.13)
 - 1. Sodium ions are reabsorbed by active transport, and negatively charged ions follow passively.
 - 2. As sodium is reabsorbed, water follows by osmosis.
- H.. Tubular Secretion (Fig. 17.12, 17.14)
 - 1. Tubular secretion transports certain substances from the plasma into the renal tubule.
 - 2. Active transport mechanisms move excess hydrogen ions into the renal tubule along with various organic compounds.
 - 3. Potassium ions are secreted both actively and passively into the distal convoluted tubule and the collecting duct.
- I. Regulation of Urine Concentration and Volume (Table 17.2)
 - 1. Most of the sodium ions are reabsorbed before the urine is excreted, and sodium is concentrated in the renal medulla by the countercurrent mechanism.
 - 2. Normally the distal convoluted tubule and collecting duct are impermeable to water unless the hormone ADH is present.
- J. Urea and Uric Acid Excretion (Table 7.3)
 - 1. Urea is a by-product of amino acid metabolism; uric acid is a by-product of nucleic acid metabolism.
 - 2. Urea is passively reabsorbed by diffusion but about 50% of urea is excreted in the urine.
 - 3. Most uric acid is reabsorbed by active transport and a small amount is secreted into the renal tubule.
- K.. Urine Composition (Table 17.1)
 - 1. Urine composition varies from time to time and reflects the amounts of water and solutes that the kidneys eliminate to maintain homeostasis.
 - 2. Urine is 95% water, and also contains urea, uric acid, a trace of amino acids, and electrolytes.

17.4 Urine Elimination (Figs. 17.1-17.2)

- A. After forming in the nephrons, urine passes from the collecting ducts to the renal papillae, then to the minor and major calyces, and out the renal pelvis to the ureters, urinary bladder, and finally to the urethra, which conveys urine to the outside.
- B. Ureters (Fig. 17.15)
 - 1. The ureters are muscular tubes extending from the kidneys to the base of the urinary bladder.
 - 2. The wall of the ureter is composed of three layers: mucous coat, muscular coat, and outer fibrous coat.
 - 3. Muscular peristaltic waves convey urine to the urinary bladder where it passes through a flaplike valve in the mucous membrane of the urinary bladder.
- C. Urinary Bladder (Figs. 17.1, 17.16)
 - 1. The urinary bladder is a hollow, distensible, muscular organ lying in the pelvic cavity.
 - 2. The internal floor of the bladder includes the trigone, which is composed of the openings of the two ureters and the urethra.
 - 3. The wall of the urinary bladder is made up of four coats: inner mucous coat, submucous coat, muscular coat made up of detrusor muscle, and outer serous coat.
 - a. The portion of the detrusor muscle that surrounds the neck of the bladder forms an internal sphincter muscle.
- D. Micturition
 - 1. Urine leaves the bladder by the micturation reflex.
 - 2. The detrusor muscle contracts and the external urethral sphincter (in the urogenital

- diaphragm) must also relax.
 - 3. Stretching of the urinary bladder triggers the micturation reflex center located in the sacral portion of the spinal cord.
 - 4. Return parasympathetic impulses cause the detrusor muscle to contract in waves, and an urge to urinate is sensed.
 - 5. When these contractions become strong enough, the internal urethral sphincter is forced open.
 - 6. The external urethral sphincter is composed of skeletal muscle and is under conscious control.
- E. Urethra (Fig. 17.17)
- 1. The urethra is a tube that conveys urine from the urinary bladder to the outside.
 - 2. It is a muscular tube with urethral glands that secrete mucus into the urethral canal.