25: The Urinary System

***I. Kidney Anatomy (pp. 961–969; Figs. 25.1–25.8)***

A. Location and External Anatomy (pp. 961–962; Figs. 25.1–25.2)

1. The kidneys are bean-shaped organs that lie retroperitoneal in the superior lumbar region.

2. The medial surface is concave and has a renal hilus that leads into a renal sinus, where the blood vessels, nerves, and lymphatics lie.

3. The kidneys are surrounded by an outer renal fascia that anchors the kidney and adrenal gland to surrounding structures, a perirenal fat pad that surrounds and cushions the kidney, and a fibrous capsule that prevents surrounding infections from reaching the kidney.

B. Internal Anatomy (pp. 962–963; Fig. 25.3)

1. There are three distinct regions of the kidney: the cortex, the medulla, and the renal pelvis.

2. Major and minor calyces collect urine and empty it into the renal pelvis.

C. Blood and Nerve Supply (pp. 963–964; Fig. 25.4)

1. Blood supply into and out of the kidneys progresses to the cortex through renal arteries to segmental, lobar, interlobar, arcuate, and cortical radiate arteries, and back to renal veins from cortical radiate, arcuate, and interlobar veins.

2. The renal plexus regulates renal blood flow by adjusting the diameter of renal arterioles and influencing the urine-forming role of the nephrons.

D. Nephrons are the structural and functional units of the kidneys that carry out processes that form urine (pp. 964–969; Figs. 25.4–25.8).

1. Each nephron consists of a renal corpuscle composed of a tuft of capillaries (the glomerulus) surrounded by a glomerular capsule (Bowman’s capsule).

2. The renal tubule begins at the glomerular capsule as the proximal convoluted tubule, continues through a hairpin loop, the loop of Henle, and turns into a distal convoluted tubule before emptying into a collecting duct.

3. The collecting ducts collect filtrate from many nephrons, and extend through the renal pyramid to the renal papilla, where they empty into a minor calyx.

4. There are two types of nephrons: 85% are cortical nephrons, which are located almost entirely within the cortex; 15% are juxtamedullary nephrons, located near the cortex-medulla junction.

***II. Kidney Physiology: Mechanisms of Urine Formation (pp. 969–984; Figs. 25.9–25.18; Table 25.1)***

A. Step 1: Glomerular Filtration (pp. 969–974; Figs. 25.9–25.12)

B. Step 2: Tubular Reabsorption (pp. 974–978; Figs. 25.13–25.14, 25.18; Table 25.1)

C. Step 3: Tubular Secretion (p. 978)

***III. Urine (pp. 984–985; Table 25.2)***

A. Physical Characteristics (pp. 984–985)

1. Freshly voided urine is clear and pale to deep yellow due to urochrome, a pigment resulting from the destruction of hemoglobin.

2. Fresh urine is slightly aromatic, but develops an ammonia odor if allowed to stand, due to bacterial metabolism of urea.

3. Urine is usually slightly acidic (around pH 6) but can vary from about 4.5–8.0 in response to changes in metabolism or diet.

4. Urine has a higher specific gravity than water, due to the presence of solutes.

B. Chemical Composition (p. 985; Table 25.2)

1. Urine volume is about 95% water and 5% solutes, the largest solute fraction devoted to the nitrogenous wastes urea, creatinine, and uric acid.

***IV. Ureters (pp. 985–986; Figs. 25.19–25.20)***

A. Ureters are tubes that actively convey urine from the kidneys to the bladder (pp. 985–986; Fig. 25.19).

B. The walls of the ureters consist of an inner mucosa continuous with the kidney pelvis and the bladder, a double-layered muscularis, and a connective tissue adventitia covering the external surface (p. 986; Fig. 25.20).

***V. Urinary Bladder (pp. 986–987; Fig. 25.21)***

A. The urinary bladder is a muscular sac that expands as urine is produced by the kidneys to allow storage of urine until voiding is convenient (p. 986; Fig. 25.21).

B. The wall of the bladder has three layers: an outer adventitia, a middle layer of detrusor muscle, and an inner mucosa that is highly folded to allow distention of the bladder without a large increase in internal pressure (pp. 986–987).

***VI. Urethra (pp. 987–988; Fig. 25.21)***

A. The urethra is a muscular tube that drains urine from the body; it is 3–4 cm long in females, but closer to 20 cm in males (p. 987; Fig. 25.21).

B. There are two sphincter muscles associated with the urethra: the internal urethral sphincter, which is involuntary and formed from detrusor muscle; and the external urethral sphincter, which is voluntary and formed by the skeletal muscle at the urogenital diaphragm (p. 987; Fig. 25.21).

C. The external urethral orifice lies between the clitoris and vaginal opening in females, or occurs at the tip of the penis in males (p. 987; Fig. 25.21).

***VII.   Micturition (p. 988; Fig. 25.22)***

A. Micturition, or urination, is the act of emptying the bladder (p. 988; Fig. 25.22).

1. As urine accumulates, distention of the bladder activates stretch receptors, which trigger spinal reflexes, resulting in storage of urine.

2. Voluntary initiation of voiding reflexes results in activation of the micturition center of the pons, which signals parasympathetic motor neurons that stimulate contraction of the detrusor muscle and relaxation of the urinary sphincters.

***VIII. Developmental Aspects of the Urinary System (pp. 988–991)***

A. In the developing fetus, the mesoderm-derived urogenital ridges give rise to three sets of kidneys: the pronephros, mesonephros, and metanephros (pp. 988–989).

1. The pronephros forms and degenerates during the fourth through sixth weeks, but the pronephric duct persists, and connects later-developing kidneys to the cloaca.

2. The mesonephros develops from the pronephric duct, which then is named the mesonephric duct, and persists until development of the metanephros.

3. The metanephros develops at about five weeks, and forms ureteric buds that give rise to the ureters, renal pelvis, calyces, and collecting ducts.

4. The cloaca subdivides to form the future rectum, anal canal, and the urogenital sinus, which gives rise to the bladder and urethra.

B. Newborns void most frequently, because the bladder is small and the kidneys cannot concentrate urine until two months of age (p. 990).

C. From two months of age until adolescence, urine output increases until the adult output volume is achieved (p. 990).

D. Voluntary control of the urinary sphincters depends on nervous system development, and complete control of the bladder even during the night does not usually occur before 4 years of age (p. 991).

E. In old age, kidney function declines due to shrinking of the kidney as nephrons decrease in size and number; the bladder also shrinks and loses tone, resulting in frequent urination (p. 991).