

The Urinary System

Urinary System Organs

- Kidneys are major excretory organs
- Urinary bladder is the temporary storage reservoir for urine
- Ureters transport urine from the kidneys to the bladder
- Urethra transports urine out of the body

Kidney Functions

- Removal of toxins, metabolic wastes, and excess ions from the blood
- Regulation of blood volume, chemical composition, and pH

Kidney Functions

- Gluconeogenesis during prolonged fasting
- Endocrine functions
 - Renin: regulation of blood pressure and kidney function
 - Erythropoietin: regulation of RBC production
- Activation of vitamin D

Kidney Anatomy

- Retroperitoneal, in the superior lumbar region
- Right kidney is lower than the left
- Convex lateral surface, concave medial surface
- Renal hilum leads to the renal sinus
- Ureters, renal blood vessels, lymphatics, and nerves enter and exit at the hilum

Kidney Anatomy

- Layers of supportive tissue
 1. Renal fascia
 - The anchoring outer layer of dense fibrous connective tissue
 2. Perirenal fat capsule
 - A fatty cushion
 3. Fibrous capsule
 - Prevents spread of infection to kidney

Internal Anatomy

- Renal cortex
 - A granular superficial region

- Renal medulla
 - The cone-shaped medullary (renal) pyramids separated by renal columns
- Lobe
 - A medullary pyramid and its surrounding cortical tissue

Internal Anatomy

- Papilla
 - Tip of pyramid; releases urine into minor calyx
- Renal pelvis
 - The funnel-shaped tube within the renal sinus

Internal Anatomy

- Major calyces
 - The branching channels of the renal pelvis that
 - Collect urine from minor calyces
 - Empty urine into the pelvis
- Urine flows from the pelvis to ureter

Blood and Nerve Supply

- Renal arteries deliver $\sim \frac{1}{4}$ (1200 ml) of cardiac output to the kidneys each minute
- Arterial flow into and venous flow out of the kidneys follow similar paths
- Nerve supply is via sympathetic fibers from the renal plexus

Nephrons

- Structural and functional units that form urine
- ~ 1 million per kidney
- Two main parts
 1. Glomerulus: a tuft of capillaries
 2. Renal tubule: begins as cup-shaped glomerular (Bowman's) capsule surrounding the glomerulus

Nephrons

- Renal corpuscle
 - Glomerulus + its glomerular capsule
- Fenestrated glomerular endothelium
 - Allows filtrate to pass from plasma into the glomerular capsule

Renal Tubule

- Glomerular capsule
- Parietal layer: simple squamous epithelium
- Visceral layer: branching epithelial podocytes
 - Extensions terminate in foot processes that cling to basement membrane
 - Filtration slits allow filtrate to pass into the capsular space

Renal Tubule

- Proximal convoluted tubule (PCT)
 - Cuboidal cells with dense microvilli and large mitochondria
 - Functions in reabsorption and secretion
 - Confined to the cortex

Renal Tubule

- Loop of Henle with descending and ascending limbs
 - Thin segment usually in descending limb
 - Simple squamous epithelium
 - Freely permeable to water
 - Thick segment of ascending limb
 - Cuboidal to columnar cells

Renal Tubule

- Distal convoluted tubule (DCT)
 - Cuboidal cells with very few microvilli
 - Function more in secretion than reabsorption
 - Confined to the cortex

Collecting Ducts

- Receive filtrate from many nephrons
- Fuse together to deliver urine through papillae into minor calyces

Collecting Ducts

- Cell types
 - Intercalated cells
 - Cuboidal cells with microvilli
 - Function in maintaining the acid-base balance of the body

Collecting Ducts

- Principal cells
 - Cuboidal cells without microvilli

- Help maintain the body's water and salt balance

Nephrons

- Cortical nephrons—85% of nephrons; almost entirely in the cortex
- Juxtamedullary nephrons
 - Long loops of Henle deeply invade the medulla
 - Extensive thin segments
 - Important in the production of concentrated urine

Nephron Capillary Beds

1. Glomerulus

- Afferent arteriole → glomerulus → efferent arteriole
- Specialized for filtration
- Blood pressure is high because
 - Afferent arterioles are smaller in diameter than efferent arterioles
 - Arterioles are high-resistance vessels

Nephron Capillary Beds

2. Peritubular capillaries

- Low-pressure, porous capillaries adapted for absorption
- Arise from efferent arterioles
- Cling to adjacent renal tubules in cortex
- Empty into venules

Nephron Capillary Beds

3. Vasa recta

- Long vessels parallel to long loops of Henle
- Arise from efferent arterioles of juxtamedullary nephrons
- Function information of concentrated urine

Vascular Resistance in Microcirculation

- High resistance in afferent and efferent arterioles
 - Causes blood pressure to decline from ~95 mm Hg to ~8 mm Hg in kidneys

Vascular Resistance in Microcirculation

- Resistance in afferent arterioles
 - Protects glomeruli from fluctuations in systemic blood pressure
- Resistance in efferent arterioles
 - Reinforces high glomerular pressure

- Reduces hydrostatic pressure in peritubular capillaries

Juxtaglomerular Apparatus (JGA)

- One per nephron
- Important in regulation of filtrate formation and blood pressure
- Involves modified portions of the
 - Distal portion of the ascending limb of the loop of Henle
 - Afferent (sometimes efferent) arteriole

Juxtaglomerular Apparatus (JGA)

- Granular cells (juxtaglomerular, or JG cells)
 - Enlarged, smooth muscle cells of arteriole
 - Secretory granules contain renin
 - Act as mechanoreceptors that sense blood pressure

Juxtaglomerular Apparatus (JGA)

- Macula densa
 - Tall, closely packed cells of the ascending limb
 - Act as chemoreceptors that sense NaCl content of filtrate
- Extraglomerular mesangial cells
 - Interconnected with gap junctions
 - May pass signals between macula densa and granular cells

Filtration Membrane

- Porous membrane between the blood and the capsular space
- Consists of
 1. Fenestrated endothelium of the glomerular capillaries
 2. Visceral membrane of the glomerular capsule (podocytes with foot processes and filtration slits)
 3. Gel-like basement membrane (fused basal laminae of the two other layers)

Filtration Membrane

- Allows passage of water and solutes smaller than most plasma proteins
 - Fenestrations prevent filtration of blood cells
 - Negatively charged basement membrane repels large anions such as plasma proteins
 - Slit diaphragms also help to repel macromolecules

Filtration Membrane

- Glomerular mesangial cells
 - Engulf and degrade macromolecules
 - Can contract to change the total surface area available for filtration