The Urinary System

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Objectives:

General objectives:
- to identify the kidney’s structures, function and location
- to analyze the relationship between microscopic structure and function

Specific objectives:

To describe and analyze the structure and function of the glomerulus as a whole
To describe and analyze the structure and function of the glomerular filtration barrier
To identify elements of the nephron and the collecting system
To contrast and compare the structure and function of different segments of the nephron
To identify the elements of the juxtaglomerular apparatus and define their relationship to each other
To identify the general structural features of the ureters, the urinary bladder and the urethra
To contrast and compare the male versus the female urethra
Urinary System Organs:  
Kidneys

- Filter 200 liters of blood daily, allowing toxins, metabolic wastes, and excess ions to leave the body in urine
- Regulate volume and chemical makeup of the blood
- Maintain the proper balance between water and salts, and acids and bases
- Produce Renin to help regulate blood pressure and erythropoietin to stimulate red blood cell production
- Activate vitamin D and produce glucose during prolonged fasting
Other Urinary System Organs

- **Urinary bladder** – provides a temporary storage reservoir for urine
- **Paired ureters** – transports urine from the kidneys to the bladder
- **Urethra** – transports urine from the bladder out of the body
Location and External Anatomy

- The bean-shaped kidneys lie in a retroperitoneal position in the superior lumbar region and extend from the twelfth thoracic to the third lumbar vertebrae.
- The right kidney is lower than the left because it is crowded by the liver.
- The lateral surface is convex and the medial surface is concave, with a vertical cleft called the renal hilus leading to the renal sinus.
  - Structures that enter and exit at the hilus
    - Ureters, renal blood vessels, lymphatics, and nerves.
Location and External Anatomy

- Body wall
- Renal capsule
- Adipose capsule
- Renal artery
- Renal vein
- Peritoneum
- Peritoneal cavity
- Posterior renal fascia
- Anterior renal fascia
- Body of vertebra L2
- Kidney
- Aorta
- Inferior vena cava
Kidney: Associated Structures

- The functionally unrelated adrenal gland sits on top of each kidney

- Three supportive tissues surround the kidney
  - Renal capsule – adheres to the kidney surface and prevents infections in surrounding regions from spreading to the kidneys
  - Adipose capsule – cushions the kidney and helps attach it to the body wall
  - Renal fascia – dense fibrous connective tissue that anchors the kidney
A frontal section shows three distinct regions

- **Cortex** – the light colored, granular superficial region
- **Medulla** – exhibits cone-shaped medullary (renal) pyramids
  - Pyramids are made up of parallel bundles of urine-collecting tubules
  - Renal columns are inward extensions of cortical tissue that separate the pyramids
  - The medullary pyramid and its surrounding capsule constitutes a lobe
- **Renal pelvis** – flat, funnel-shaped tube lateral to the hilus within the renal sinus
Internal Anatomy

- Major calyces – large branches of the renal pelvis
  - Collect urine draining from papillae
  - Empty urine into the pelvis
- Urine flows through the pelvis and ureters to the bladder
Internal Anatomy

- Interlobular vein
- Interlobular artery
- Arcuate vein
- Arcuate artery
- Interlobar vein
- Interlobar artery
- Lobar artery
- Segmental artery
- Renal artery
- Renal vein
- Renal pelvis
- Major calyx
- Ureter
- Papilla of pyramid
- Cortex
- Minor calyx
- Medullary (renal) pyramid
- Renal capsule

(b)
The Functional unit of the Kidneys

“Nephron”

- Nephrons are the blood-processing units that form urine, consisting of:
  - **Renal corpuscle** – the glomerulus and its Bowman’s capsule
  - **Glomerulus** – a tuft of capillaries associated with a renal tubule
  - **Glomerular (Bowman’s) capsule** – blind, cup-shaped end of a renal tubule that completely surrounds the glomerulus
  - **Glomerular endothelium** – fenestrated epithelium that allows solute-rich, virtually protein-free filtrate to pass from the blood into the glomerular capsule
The Nephron

Glomerulus

Bowman’s capsule
Capillary Beds of the Nephron

Every nephron has two capillary beds
- Glomerulus
  - Fed by an afferent arteriole
  - Drained by an efferent arteriole
- Peritubular capillaries
  - Arise from efferent arterioles
Capillary Beds
Juxtaglomerular Apparatus (JGA)

- Macula densa
  - Tall, closely packed distal tubule cells
  - Lie adjacent to JG cells
  - Function as chemoreceptors or osmoreceptors

- Where the distal tubule lies against the afferent (sometimes efferent) arteriole
- Arteriole walls have juxtaglomerular (JG) cells
  - Enlarged, smooth muscle cells
  - Have secretory granules containing renin
  - Act as mechanoreceptors
Juxtaglomerular Apparatus (JGA)
Anatomy of the Glomerular Capsule

- The external parietal layer is a structural layer
- The visceral layer consists of modified, branching, epithelial podocytes
- Extensions of the octopus-like podocytes terminate in foot processes
- Filtration slits – openings between the foot processes that allow filtrate to pass into the capsular space
Filtration Membrane

Filter that lies between the blood and the interior of the glomerular capsule

It is composed of three layers

- Fenestrated endothelium of the glomerular capillaries
- Visceral membrane of the glomerular capsule (podocytes)
- Basement membrane composed of fused basal laminas of the other layers
Renal tubule

- Proximal convoluted tubule (PCT) – composed of cuboidal cells with numerous microvilli and mitochondria
- Loop of Henle – a hairpin-shaped loop of the renal tubule
  - Proximal part is similar to the proximal convoluted tubule
  - Proximal part is followed by the thin segment (simple squamous cells) and the thick segment (cuboidal to columnar cells)
- Distal convoluted tubule (DCT) – cuboidal cells without microvilli that function more in secretion than reabsorption
Renal tubule

- Parietal layer of glomerular capsule
- Distal convoluted tubule
- Visceral layer of glomerular capsule
- Fenestrated endothelium of the glomerulus
- Proximal convoluted tubule
- Blood vessels
- Cortex
- Medulla
- Loop of Henle
  - Ascending limb
  - Descending limb
- Collecting duct
  - Thick segment
  - Thin segment
- Microvilli
- Mitochondria
- Highly infolded plasma membrane
- Proximal convoluted tubule cells
- Distal convoluted tubule cells
- Loop of Henle (thin-segment) cells
- Collecting duct cells
Ureters

- Slender tubes that convey urine from the kidneys to the bladder
- Ureters enter the base of the bladder through the posterior wall
  - This closes their distal ends as bladder pressure increases and prevents backflow of urine into the ureters
- Ureters have a trilayered wall
  - Transitional epithelial mucosa
  - Smooth muscle mucosa
  - Fibrous connective tissue adventitia
- Ureters actively propel urine to the bladder via response to smooth muscle stretch
Urinary Bladder

- Smooth, collapsible, muscular sac that temporarily stores urine
- It lies retroperitoneally on the pelvic floor posterior to the pubic symphysis
  - Males – prostate gland surrounds the neck inferiorly
  - Females – anterior to the vagina and uterus
- Trigone – triangular area outlined by the openings for the ureters and the urethra
  - Clinically important because infections tend to persist in this region
Urinary Bladder

- Ureter
- Parietal peritoneum
- Detrusor muscle
- Ureteric openings
- Trigone
- Bladder neck
- Internal urethral sphincter
- Prostate gland
- Prostatic urethra
- Membranous urethra
- External urethral sphincter
- Urogenital diaphragm
- Bulbourethral gland and duct
- Crus of penis
- Bulb of penis
- Spongy (penile) urethra
- Erectile tissue of penis
- External urethral orifice
- (a)
- (b)
Urinary Bladder

- The bladder wall has three layers
  - Transitional epithelial mucosa
  - A thick muscular layer
  - A fibrous adventitia

- The bladder is distensible and collapses when empty

- As urine accumulates, the bladder expands without significant rise in internal pressure
Urethra

Muscular tube that:
- Drains urine from the bladder
- Conveys it out of the body

Sphincters keep the urethra closed when urine is not being passed
- Internal urethral sphincter – involuntary sphincter at the bladder-urethra junction
- External urethral sphincter – voluntary sphincter surrounding the urethra as it passes through the urogenital diaphragm
- Levator ani muscle – voluntary urethral sphincter
The female urethra is tightly bound to the anterior vaginal wall.

Its external opening lies anterior to the vaginal opening and posterior to the clitoris.

The male urethra has three named regions:

- **Prostatic urethra** – runs within the prostate gland.
- **Membranous urethra** – runs through the urogenital diaphragm.
- **Spongy (penile) urethra** – passes through the penis and opens via the external urethral orifice.