Chapter 26 Adapted form Tortora 10th ed.

LECTURE OUTLINE

A. Introduction (p. 808)
   1. The major function of the urinary system is to help maintain homeostasis by controlling the composition, volume, and pressure of blood, and removing wastes from the blood; it does so by removing and restoring selected amounts of water and solutes.
   2. The urinary system consists of:
      i. two kidneys which perform the above functions and consequently produce urine
      ii. two ureters which drain urine from the kidneys and transport it to...
      iii. one urinary bladder which stores urine until it is ready to be expelled
      iv. one urethra which transports urine from the urinary bladder to the exterior; in males, the urethra also transports semen
   3. The kidneys perform several specific functions:
      i. regulation of blood volume and composition
      ii. regulation of blood pressure by secreting renin
      iii. contribution to metabolism by:
           a. performing gluconeogenesis
           b. secreting erythropoietin
           c. participating in synthesis of the active form of vitamin D
   4. Nephrology is the medical specialty that deals with the anatomy, physiology, and pathology of the kidney; urology is the branch of medicine that deals with the male and female urinary systems and the male reproductive system.

B. Anatomy and Histology of the Kidneys (p. 810)
   1. The paired reddish kidneys are retroperitoneal organs attached to the posterior abdominal wall just above waist level
      i. they are positioned between the levels of the last thoracic and the third lumbar vertebrae
      ii. they are partially protected by the eleventh and twelfth pairs of ribs
      iii. the right kidney is slightly lower than the left because of the presence of the liver on the right side
   2. External Anatomy:
      i. near the center of the kidney’s concave medial border is a depression called the renal hilus through which travel:
         a. ureter
         b. blood vessels and lymphatic vessels
         c. nerves
         - the hilus is the entrance to a cavity in the kidney called the renal sinus
      ii. the kidney is surrounded by three layers of tissue:
         a. inner renal capsule
         b. intermediate adipose capsule
         c. outer renal fascia
   3. Internal Anatomy:
      i. the kidney’s functional tissue, called the parenchyma, has:
         a. outer layer called the renal cortex
         b. inner region called the renal medulla
ii. the medulla contains 8-18 cone-shaped renal pyramids whose apexes are called renal papillae

iii. the renal cortex is divided into:
   a. outer cortical zone
   b. inner juxtamedullary zone
   - renal columns are portions of the cortex that extend between renal pyramids; a renal lobe consists of a renal pyramid, its overlying area of renal cortex, and half of each adjacent renal column

iv. within the parenchyma are the functional units of the kidney called nephrons which produce urine; urine from the nephrons drains into papillary ducts and onwards into minor calyces which merge to form major calyces that deliver the urine into a large cavity called the renal pelvis (the renal pelvis is located within the renal sinus); urine then exits the kidney by flowing into a ureter

4. Blood and Nerve Supply:
   i. blood flows through kidneys via the following sequence of blood vessels:
      a. right and left renal arteries
      b. segmental arteries
      c. interlobar arteries
      d. arcuate arteries
      e. interlobular arteries
      f. afferent arterioles
      g. glomeruli (singular is glomerulus)
      h. efferent arterioles
      i. peritubular capillaries which enmesh the proximal and distal convoluted tubules
         - efferent arterioles of juxtamedullary nephrons also give rise to vasa recta which dip down alongside the loop of Henle into the medulla
      j. peritubular venules
      k. interlobular veins
      l. arcuate veins
      m. interlobar veins
      n. right and left renal veins (each exits at the renal hilus)
   ii. the nerve supply to the kidneys is primarily vasomotor and derives from the celiac ganglion and renal plexus of the sympathetic division of the ANS

5. Nephron: (p. 814)
   i. each kidney’s parenchyma contains about one million nephrons; the nephron is the functional unit of the kidney which filters blood, returns useful substances to blood, and removes unwanted substances from the blood, thereby producing urine
   ii. the nephron consists of two portions:
      a. renal corpuscle, where plasma is filtered
      b. renal tubule, into which the filtered fluid passes
   iii. the renal corpuscle has two components:
      a. network of capillaries called the glomerulus
         - receives blood from an afferent arteriole
         - blood drains into an efferent arteriole
      b. surrounding the glomerulus is a double-walled epithelial cup called the glomerular (Bowman’s) capsule
   iv. as blood flows through the glomerulus, a filtrate of the blood plasma enters the capsular space
   v. the filtered fluid then flows into the renal tubule, which consists of three segments:
a. proximal convoluted tubule (PCT)

b. loop of Henle (neuron loop)
   - it loops into the renal medulla
   - it consists of a descending limb and an ascending limb

c. distal convoluted tubule (DCT)

vi. the distal convoluted tubules of several nephrons empty into a single collecting duct

vii. collecting ducts merge to form papillary ducts which drain into a minor calyx

viii. there are two types of nephrons:
   a. cortical nephron (80-85% of all nephrons)
      - usually has its glomerulus in the outer part of the cortex and its short loop of Henle penetrates only into the outer region of the medulla
   b. juxtamedullary nephron (15 to 20% of all nephrons)
      - usually has its glomerulus deep in the cortex and its long loop of Henle penetrates deeply into the medulla
      - the ascending limb consists of a thin ascending limb followed by a thick ascending limb
      - permits excretion of very dilute to very concentrated urine

ix. histology:
   a. the glomerular (Bowman’s) capsule consists of an inner visceral layer and an outer parietal layer that have a space between them called the capsular (Bowman’s) space into which enters the fluid filtered from the glomerular capillaries
   b. the visceral layer consists of modified simple squamous epithelial cells called podocytes whose footlike projections (pedicels) wrap around the single layer of endothelial cells of the glomerular capillaries and form the inner wall of the capsule
   c. the parietal layer consists of simple squamous epithelial cells that form the outer wall of the capsule
   d. the renal tubule consists of a single layer of epithelial cells surrounded by a basement membrane; as summarized in Table 26.1, each segment of the renal tubule has a particular type of simple epithelium
   e. the final portion of the ascending limb of the loop of Henle makes contact with the afferent arteriole serving the renal corpuscle; the tubule cells here are columnar and crowded together, and thus are known as the macula densa
   f. alongside the macula densa, the wall of the afferent arteriole (and sometimes the efferent arteriole) contains modified smooth muscle fibers called juxtaglomerular (JG) cells; together with the macula densa, they constitute the juxtaglomerular apparatus (JGA)
   g. the distal convoluted tubule and the collecting ducts have two types of epithelial cells:
      1. most are principal cells, which have receptors for and thus are regulated by antidiuretic hormone (ADH) and aldosterone
      2. some are intercalated cells, which can secrete hydrogen ions and thus play a role in homeostasis of blood pH
C. Functions of Nephrons (p. 819)
   1. Urine formation involves three major processes:
      i. glomerular filtration
         a. blood flowing through a glomerulus is filtered by the filtration membrane
            or endothelial-capsular membrane resulting in formation of a glomerular filtrate which contains all blood components except:
            1. formed elements
            2. most plasma proteins
         b. the filtration membrane consists of:
            1. glomerular endothelial cells with fenestrations and mesangial cells
            2. basal lamina
            3. podocytes with pedicels and filtration slits and associated slit membrane
      ii. tubular reabsorption
         a. as the filtrate flows through a renal tubule about 99% of it is reabsorbed into blood in the peritubular capillaries or vasa recta
         b. the substances reabsorbed include glucose, amino acids, urea, various ions, and most of the water along with most small proteins and peptides that passed through the filter
         c. therefore, tubular reabsorption returns needed substances to the blood
      iii. tubular secretion
         a. substances are transported from the blood in peritubular capillaries into the filtrate flowing through the renal tubule
         b. the substances secreted include hydrogen ions, other excess ions, creatine and other wastes, and certain drugs
         c. therefore, tubular secretion helps control blood pH and helps eliminate unwanted substances from the body

D. Ureters (p. 822)
   1. From the renal pelvis, urine drains into a ureter which exits the kidney at the renal hilus.
   2. The ureters are retroperitoneal and enter the urinary bladder medially from the posterior aspect.
   3. There is no anatomical valve but there is a functional valve at the opening of each ureter into the urinary bladder: Each ureter passes obliquely through the wall of the urinary bladder to create an effective physiological valve which prevents backflow of urine since filling of the urinary bladder with urine compresses the oblique openings into the ureters.
   4. The wall of each ureter consists of three layers:
      i. inner mucosa with transitional epithelium lying over lamina propria
      ii. intermediate muscularis consists of:
         a. inner longitudinal layer of smooth muscle tissue
         b. outer circular layer of smooth muscle tissue
         c. extra outer longitudinal layer in the distal third of the ureter - the muscularis is responsible for peristalsis
      iii. outer adventitia which has extensions that anchor the ureters in place.
   5. The function of the ureters is to transport urine into the urinary bladder; transport is accomplished by:
      i. peristaltic waves
      ii. hydrostatic pressure
      iii. gravity
   6. The ureters receive blood from the renal, testicular or ovarian, common iliac, and inferior vesical arteries; blood drains into the corresponding veins.
7. The ureters are innervated by the renal plexuses, which are supplied by sympathetic and parasympathetic fibers from the lesser and lowest splanchnic nerves.

E. Urinary Bladder (p. 822)
1. The urinary bladder is a hollow muscular organ located retroperitoneally in the pelvic cavity posterior to the pubic symphysis
   i. in males, it is directly anterior to the rectum
   ii. in females, it is anterior to the vagina and inferior to the uterus and it usually has a smaller capacity
2. The shape of the urinary bladder ranges from collapsed to spherical to pear-shaped, depending on the volume of urine it contains.
3. The floor of the urinary bladder has a small triangular area called the trigone
   i. the two posterior corners contain the two ureteral openings
   ii. the anterior corner contains the internal urethral orifice
   iii. because its mucosa is firmly bound to the muscularis, the trigone has a smooth appearance
4. The wall of the urinary bladder consists of three layers:
   i. inner mucosa with transitional epithelium lying over lamina propria
      a. except in the trigone, rugae are also present
      b. these features permit the urinary bladder to continually inflate and deflate
   ii. intermediate detrusor muscle (the muscularis) which consists of three layers of smooth muscle tissue:
      a. inner longitudinal layer
      b. middle circular layer
      c. outer longitudinal layer
      - around the opening to the urethra, the circular fibers form an internal urethral sphincter
      - below the internal sphincter is the external urethral sphincter, which is composed of skeletal muscle and is a modification of the urogenital diaphragm muscle
   iii. outer adventitia with serosa on the superior surface of the bladder
5. Urine is expelled by micturition (urination or voiding)
   i. accumulation of urine in the urinary bladder stimulates stretch receptors which initiate nerve impulses delivered to the spinal cord’s micturition center which in turn initiates a parasympathetic spinal micturition reflex; the latter involves contraction of the detrusor muscle and relaxation of the internal urethral sphincter accompanied by relaxation of the external urethral sphincter
   ii. the cerebral cortex may voluntarily initiate or delay micturition for a limited period of time
6. The urinary bladder receives blood from the superior, middle, and inferior vesical arteries; blood drains into the internal iliac veins.
7. The nerves of the urinary bladder are derived partly from the hypogastric sympathetic plexus and partly from the second and third sacral nerves.

F. Urethra (p. 824)
1. The urethra is a tube leading from the floor of the urinary bladder to the exterior
   i. in females:
      a. it lies directly posterior to the pubic symphysis and is embedded in the anterior wall of the vagina
      b. it is about 6 mm wide and 4 cm long
      c. it leads to the external urethral orifice which is located between the clitoris and vaginal opening
   ii. in males:
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Biology 218_Lecture Outline_26 Urinary System

1. a. It is about 15–20 cm long
   b. It consists of the **prostatic urethra**, the **membranous urethra**, and the **spongy urethra** (which passes through the body of the penis)

2. The wall of the female urethra consists of two layers:
   i. deep **mucosa** consisting of **epithelium** and **lamina propria**
   ii. superficial **muscularis** that is continuous with that of the urinary bladder and consists of circularly arranged smooth muscle fibers

3. The wall of the male urethra consists of two layers:
   i. deep **mucosa** consisting of **epithelium** and **lamina propria**
   ii. superficial **muscularis**

4. There are several openings in the wall of the male urethra:
   i. the prostatic urethra contains openings of the ducts from the **prostate gland**, the two **seminal vesicles and ductus (vas) deferens**
   ii. the spongy urethra contains openings of the ducts from the **bulbourethral (Cowper's) glands**
   iii. throughout the urethra, but especially in the spongy urethra, there are openings for the **urethral (Littre) glands** which discharge mucus for lubrication during sexual arousal and ejaculation

5. Thus the urethra is a passageway for expelling urine from the body and, in males, the urethra is also a passageway for discharging semen from the body. **Table 26.2** lists the physical characteristics of normal urine and **Table 26.3** lists abnormal constituents in urine.

G. Developmental Anatomy of the Urinary System (p. 826)

1. In successive time periods during development, the **intermediate mesoderm** differentiates into three pairs of kidneys in the following chronological order:
   i. **pronephros**
      a. associated with its formation is the **pronephric duct** which empties into the **cloaca**
      b. the pronephros degenerates but the pronephric ducts remain
   ii. **mesonephros** replaces the pronephros
      a. the retained pronephric duct develops into the **mesonephric duct**
      b. the mesonephros degenerates
   iii. **metanephros**
      a. it develops from the **ureteric bud**, an outgrowth of the mesonephric duct near the cloaca, and metanephric mesoderm
      b. the ureteric bud forms the **collecting ducts, calyces, renal pelvis, and ureter**
      c. the **nephrons** develop from the **metanephric mesoderm** around each ureteric bud

2. The cloaca divides into:
   i. **urogenital sinus** which develops into the **urinary bladder**
   ii. **rectum**

3. In the female, the **urethra** develops from lengthening of the short duct that extends from the urinary bladder to the urogenital sinus; in the male, the urethra is longer and more complicated but it is also derived from the urogenital sinus.
H. Aging and the Urinary System (p. 828)
   1. With aging, the kidneys decrease in size and become less effective at cleansing blood.
   2. Urinary system disorders associated with aging include:
      i. acute and chronic kidney inflammation
      ii. renal calculi
      iii. susceptibility to dehydration
      iv. urinary tract infections
      v. polyuria
      vi. nocturia
      vii. increased frequency of urination
      viii. dysuria
      ix. urinary retention
      x. incontinence
      xi. hematuria

I. Key Medical Terms Associated with the Urinary System (p. 831)
   1. Students should familiarize themselves with the glossary of key medical terms.