- [ ] I. Unit 15: The Urinary System
  - [ ] A. Functions of the Urinary System
    - [ ] 1. Elimination of waste products
      - [ ] a) Nitrogenous wastes
      - [ ] b) Toxins
      - [ ] c) Drugs
    - [ ] 2. Regulate aspects of homeostasis
      - [ ] a) Water balance
      - [ ] b) Electrolytes
      - [ ] c) Acid-base balance in the blood
      - [ ] d) Blood pressure
      - [ ] e) Red blood cell production
      - [ ] f) Activation of vitamin D
  - [ ] B. Organs of the Urinary System
    - [ ] 1. Kidneys
      - [ ] a) Location of the Kidneys
        - [ ] (1) Against the dorsal body wall
        - [ ] (2) At the level of the T12 to L3 vertebrae
        - [ ] (3) The right kidney is slightly lower than the left (due to position of
      - [ ] b) Kidney Features
        - [ ] (1) Renal hilum (sometimes called hilus)
          - [ ] (a) A medial indentation where several structures enter or exit the kidney (ureters, renal blood vessels, and nerves)
        - [ ] (2) An adrenal gland sits atop each kidney
      - [ ] c) Coverings of the Kidneys
        - [ ] (1) Fibrous capsule
          - [ ] (a) Surrounds each kidney
        - [ ] (2) Perirenal fat capsule
          - [ ] (a) Surrounds the kidney and cushions against blows
        - [ ] (3) Renal fascia

- [ ] (a) Outermost capsule that helps hold the kidney in place against the muscles of the trunk wall
- [ ] d) Regions of the Kidney
  - [ ] (1) Renal cortex - outer region
  - [ ] (2) Renal medulla - inside the cortex
  - [ ] (3) Renal pelvis - inner collecting tube
- [ ] e) Kidney Structures
  - [ ] (1) Renal or medullary pyramids - triangular regions of tissue in the medulla
  - [ ] (2) Renal columns - extensions of cortex-like material inward that separate the pyramids
  - [ ] (3) Calyces - cup-shaped structures that funnel urine towards the
- [ ] f) Blood Supply
  - [ ] (1) One-quarter of the total blood supply of the body passes through the kidneys each minute
  - [ ] (2) Renal artery provides each kidney with arterial blood supply
    - [ ] (a) Renal artery divides into segmental arteries ➙ interlobar arteries ➙ arcuate arteries ➙ cortical radiate arteries
  - [ ] (3) Venous blood flow
    - [ ] (a) Cortical radiate veins ➙ arcuate veins ➙ interlobar veins ➙
    - [ ] (b) There are no segmental veins
- [ ] g) Nephron Anatomy and Physiology
  - [ ] (1) The structural and functional units of the kidneys
  - [ ] (2) Responsible for forming urine
  - [ ] (3) Main structures of the nephrons
    - [ ] (a) Glomerulus
    - [ ] (b) Renal tubule
- [ ] h) Nephrons
  - [ ] (1) Nephron Anatomy
    - [ ] (a) Glomerulus
      - [ ] (i) Knot of capillaries
      - [ ] (ii) Capillaries are covered with podocytes from the renal tubule

- [ ] (iii) Glomerulus sits within a glomerular (Bowman's) capsule (the first part of the renal tubule)
- [ ] (b) Renal tubule extends from glomerular capsule and ends at the collecting duct
  - [ ] (i) Glomerular (Bowman's) capsule
  - [ ] (ii) Proximal convoluted tubule (PCT)
  - [ ] (iii) Loop of Henle
  - [ ] (iv) Distal convoluted tubule (DCT)
- [ ] (c) Nephrons are associated with two capillary beds
  - [ ] (i) Glomerulus
  - [ ] (ii) Peritubular capillary bed
- [ ] (d) Glomerulus
  - [ ] (i) Fed and drained by arterioles
    - [ ] (a) Afferent arteriole - arises from a cortical radiate artery and feeds the glomerulus
    - [ ] (b) Efferent arteriole - receives blood that has passed through the glomerulus
  - [ ] (ii) Specialized for filtration
  - [ ] (iii) High pressure forces fluid and solutes out of blood and into the glomerular capsule
- [ ] (e) Peritubular Capillary Beds
  - [ ] (i) Arise from efferent arteriole of the glomerulus
  - [ ] (ii) Normal, low pressure capillaries
  - [ ] (iii) Adapted for absorption instead of filtration
  - [ ] (iv) Cling close to the renal tubule to reabsorb (reclaim) some substances from collecting tubes

- [ ] (2) Types of Nephrons
  - [ ] (a) Cortical nephrons
    - [ ] (i) Located entirely in the cortex
    - [ ] (ii) Includes most nephrons
  - [ ] (b) Juxtamedullary nephrons

- [ ] (i) Found at the boundary of the cortex and medulla
- [ ] i) Collecting Duct
  - [ ] (1) Receives urine from many nephrons
  - [ ] (2) Run through the medullary pyramids
  - [ ] (3) Deliver urine into the calyces and renal pelvis
- [ ] 2. Ureters
  - [ ] a) Ureters
    - [ ] (1) Slender tubes attaching the kidney to the bladder
      - [ ] (a) Continuous with the renal pelvis
      - [ ] (b) Enter the posterior aspect of the bladder
    - [ ] (2) Runs behind the peritoneum
    - [ ] (3) Peristalsis aids gravity in urine transport
- [ ] 3. Urinary bladder
  - [ ] a) Urinary Bladder
    - [ ] (1) Smooth, collapsible, muscular sac
    - [ ] (2) Temporarily stores urine
    - [ ] (3) Trigone - triangular region of the bladder base
      - [ ] (a) Three openings
        - [ ] (i) Two from the ureters
        - [ ] (ii) One to the urethra
    - [ ] (4) In males, the prostate gland surrounds the neck of the bladder
    - [ ] (5) Urinary Bladder Wall
      - [ ] (a) Three layers of smooth muscle collectively called the
      - [ ] (b) Mucosa made of transitional epithelium
      - [ ] (c) Walls are thick and folded in an empty bladder
      - [ ] (d) Bladder can expand significantly without increasing
    - [ ] (6) Urinary Bladder Capacity
      - [ ] (a) A moderately full bladder is about 5 inches long and holds about 500 mL of urine
      - [ ] (b) Capable of holding twice that amount of urine

- 4. Urethra
  - a) Urethra
    - (1) Thin-walled tube that carries urine from the bladder to the outside of the body by peristalsis
    - (2) Release of urine is controlled by two sphincters
      - (a) Internal urethral sphincter
        - (i) Involuntary and made of smooth muscle
      - (b) External urethral sphincter
        - (i) Voluntary and made of skeletal muscle
    - (3) Urethra Gender Differences
      - (a) Length
        - (i) Females is 3–4 cm (1 inch)
        - (ii) Males is 20 cm (8 inches)
      - (b) Location
        - (i) Females - along wall of the vagina
        - (ii) Males - through the prostate and penis
      - (c) Function
        - (i) Females - only carries urine
        - (ii) Males - carries urine and is a passageway for sperm cells
    - (4) Micturition (Voiding)
      - (a) Both sphincter muscles must open to allow voiding
      - (b) The internal urethral sphincter is relaxed after stretching of
      - (c) Pelvic splanchnic nerves initiate bladder to go into reflex
      - (d) Urine is forced past the internal urethra sphincter and the person feels the urge to void
      - (e) The external urethral sphincter must be voluntarily relaxed to void
- C. Urine Formation
  - 1. Glomerular filtration
    - a) Glomerular Filtration
      - (1) Nonselective passive process

- (2) Water and solutes smaller than proteins are forced through
- (3) Proteins and blood cells are normally too large to pass through the filtration membrane
- (4) Filtrate is collected in the glomerular capsule and leaves via the renal tubule

2. Tubular reabsorption
   - a) Tubular Reabsorption
     - (1) The peritubular capillaries reabsorb useful substances
       - (a) Water
       - (b) Glucose
       - (c) Amino acids
       - (d) Ions
     - (2) Some reabsorption is passive, most is active
     - (3) Most reabsorption occurs in the proximal convoluted tubule
     - (4) Materials not reabsorbed
       - (a) Nitrogenous waste products
         - (i) Urea - protein breakdown
         - (ii) Uric acid - nucleic acid breakdown
         - (iii) Creatinine - associated with creatine metabolism in muscles
3. Tubular secretion
   - a) Some materials move from the peritubular capillaries into the renal tubules
     - (1) Hydrogen and potassium ions
     - (2) Creatinine
   - b) Process is important for getting rid of substances not already in the filtrate
   - c) Materials left in the renal tubule move toward the ureter
4. Characteristics of Urine
   - a) In 24 hours, about 1.0 to 1.8 liters of urine are produced
   - b) Urine and filtrate are different
     - (1) Filtrate contains everything that blood plasma does (except proteins)
     - (2) Urine is what remains after the filtrate has lost most of its water, nutrients, and necessary ions

- [ ] (2) Urine is what remains after the filtrate has lost most of its water, nutrients, and necessary ions
- [ ] (3) Urine contains nitrogenous wastes and substances that are not needed

- [ ] c) Yellow color due to the pigment urochrome (from the destruction of hemoglobin) and solutes
- [ ] d) Sterile
- [ ] e) Slightly aromatic
- [ ] f) Normal pH of around 6
- [ ] g) Specific gravity of 1.001 to 1.035
- [ ] h) Solutes normally found in urine
  - [ ] (1) Sodium and potassium ions
  - [ ] (2) Urea, uric acid, creatinine
  - [ ] (3) Ammonia
  - [ ] (4) Bicarbonate ions
- [ ] i) Solutes NOT normally found in urine
  - [ ] (1) Glucose
  - [ ] (2) Blood proteins
  - [ ] (3) Red blood cells
  - [ ] (4) Hemoglobin
  - [ ] (5) White blood cells (pus)
  - [ ] (6) Bile

- [ ] D. Fluid, Electrolyte, and Acid-Base Balance
  - [ ] 1. Blood composition depends on three factors
    - [ ] a) Diet
    - [ ] b) Cellular metabolism
    - [ ] c) Urine output
  - [ ] 2. Kidneys have four roles in maintaining blood composition
    - [ ] a) Excretion of nitrogen-containing wastes (previously discussed)
    - [ ] b) Maintaining water balance of the blood
    - [ ] c) Maintaining electrolyte balance of the blood

- [ ] d) Ensuring proper blood pH
- [ ] 3. Maintaining Water Balance
  - [ ] a) Normal amount of water in the human body
    - [ ] (1) Young adult females = 50%
    - [ ] (2) Young adult males = 60%
    - [ ] (3) Babies = 75%
    - [ ] (4) The elderly = 45%
  - [ ] b) Water is necessary for many body functions, and levels must be maintained
- [ ] 4. Distribution of Body Fluid
  - [ ] a) Intracellular fluid (ICF)
    - [ ] (1) Fluid inside cells
    - [ ] (2) About two-thirds of body fluid
  - [ ] b) Extracellular fluid (ECF)
    - [ ] (1) Fluids outside cells that includes
      - [ ] (a) Interstitial fluid
      - [ ] (b) Blood plasma
- [ ] 5. The Link Between Water and Salt
  - [ ] a) Solutes in the body include electrolytes like sodium, potassium, and calcium ions
  - [ ] b) Changes in electrolyte balance causes water to move from one compartment to another
    - [ ] (1) Alters blood volume and blood pressure
    - [ ] (2) Can impair the activity of cells
- [ ] 6. Maintaining Water Balance
  - [ ] a) Water intake must equal water output
  - [ ] b) Sources for water intake
    - [ ] (1) Ingested foods and fluids
    - [ ] (2) Water produced from metabolic processes
  - [ ] c) Thirst mechanism is the driving force for water intake
  - [ ] d) Sources for water output

- (1) Vaporization out of the lungs
- (2) Lost in perspiration
- (3) Leaves the body in the feces
- (4) Urine production

- e) Dilute urine is produced if water intake is excessive
- f) Less urine (concentrated) is produced if large amounts of water are lost
- g) Proper concentrations of various electrolytes must be present

- 7. Regulation of Water and Electrolyte Reabsorption
  - a) Osmoreceptors
    - (1) Cells in the hypothalamus
    - (2) React to changes in blood composition by becoming more active
  - b) Regulation occurs primarily by hormones
    - (1) Antidiuretic hormone (ADH)
      - (a) Prevents excessive water loss in urine
      - (b) Causes the kidney's collecting ducts to reabsorb more water
      - (c) Diabetes insipidus
        - (i) Occurs when ADH is not released
        - (ii) Leads to huge outputs of dilute urine
    - (2) Aldosterone
      - (a) Regulates sodium ion content of ECF
      - (b) Sodium is the electrolyte most responsible for osmotic water flows
      - (c) Aldosterone promotes reabsorption of sodium ions
      - (d) Remember, water follows salt!
    - (3) Renin-angiotension mechanism
      - (a) Mediated by the juxtaglomerular (JG) apparatus of the renal tubules
      - (b) When cells of the JG apparatus are stimulated by low blood pressure, the enzyme renin is released into blood
      - (c) Renin produces angiotension II
      - (d) Angiotension causes vasconstriction and aldosterone release
      - (e) Result is increase in blood volume and blood pressure

- 8. Maintaining Acid-Base Balance in Blood
  - a) Blood pH must remain between 7.35 and 7.45 to maintain homeostasis
    - (1) Alkalosis - pH above 7.45
    - (2) Acidosis - pH below 7.35
  - b) Physiological acidosis - pH between 7.35 and 7.0
    - (1) Most ions originate as by-products of cellular metabolism
  - c) Acids produced by the body
    - (1) Phosphoric acid, lactic acid, fatty acids
    - (2) Carbon dioxide forms carbonic acid
    - (3) Ammonia
  - d) Most acid-base balance is maintained by the kidneys
  - e) Other acid-base controlling systems
    - (1) Blood buffers
    - (2) Respiration
  - f) Blood Buffers
    - (1) Acids are proton (H+) donors
      - (a) Strong acids dissociate completely and liberate all of their H+
      - (b) Weak acids, such as carbonic acid, dissociate only partially
    - (2) Bases are proton (H+) acceptors
      - (a) Strong bases dissociate easily in water and tie up H+
      - (b) Weak bases, such as bicarbonate ion and ammonia, are slower to accept H+
    - (3) Dissociation of Strong and Weak Acids
    - (4) Molecules react to prevent dramatic changes in hydrogen ion (H+) concentrations
      - (a) Bind to H+ when pH drops
      - (b) Release H+ when pH rises
    - (5) Three major chemical buffer systems
      - (a) Bicarbonate buffer system

- (i) Mixture of carbonic acid (H_2CO_3) and sodium bicarbonate ($NaHCO_3$)
  - (a) Carbonic acid is a weak acid that does not dissociate much in neutral or acid solutions
  - (b) Bicarbonate ions (HCO_3^-) react with strong acids to change them to weak acids
- (ii) Carbonic acid dissociates in the presence of a strong base to form a weak base and water
- (b) Phosphate buffer system
- (c) Protein buffer system

9. Respiratory System Controls of Acid-Base Balance
   - a) Carbon dioxide in the blood is converted to bicarbonate ion and transported in the plasma
   - b) Increases in hydrogen ion concentration produces more carbonic acid
   - c) Excess hydrogen ion can be blown off with the release of carbon dioxide from the lungs
   - d) Respiratory rate can rise and fall depending on changing blood pH

10. Renal Mechanisms of Acid-Base Balance
   - a) Excrete bicarbonate ions if needed
   - b) Conserve (reabsorb) or generate new bicarbonate ions if needed
   - c) When blood pH rises
     - (1) Bicarbonate ions are excreted
     - (2) Hydrogen ions are retained by kidney tubules
   - d) When blood pH falls
     - (1) Bicarbonate ions are reabsorbed
     - (2) Hydrogen ions are secreted
   - e) Urine pH varies from 4.5 to 8.0

E. Developmental Aspects of the Urinary System
   1. Functional kidneys are developed by the third month
   2. Urinary system of a newborn
      - a) Bladder is small

- b) Urine cannot be concentrated for first 2 months
- c) Void 5 to 40 times per day
- d) Control of the voluntary urethral sphincter does not start until age
- e) Complete nighttime control may not occur until the child is 4 years old
- f) Urinary infections are the only common problems before old age
  - (1) Escherichia coli (E. coli), a type of bacteria, accounts for 80% of UTI (urinary tract infections)

3. Aging and the Urinary System

- a) There is a progressive decline in urinary function
- b) The bladder shrinks and loses bladder tone with aging
- c) Associated problems with aging
  - (1) Urgency - feeling that it is necessary to void
  - (2) Frequency - frequent voiding of small amounts of urine
  - (3) Nocturia - need to get up during the night to urinate
  - (4) Incontinence - loss of control
  - (5) Urinary retention - common in males, often the result of hypertrophy of the prostate gland