Lecture Outline: The Urinary System

I. The **Urinary System**: Overview

A. Purpose and Components

1. Last of 11 organ systems to cover, very important
2. Macroscopically simple, physiologically complex
3. Main structures: **two kidneys**, **two ureters**, **urinary bladder**

B. Key Functions

1. Ureters: tubes carrying urine from kidneys to bladder
2. Urinary bladder: allows **urine storage** until convenient for voiding
3. Urine production is continuous; bladder fills gradually
4. **Urination** (or **Micturition**): intermittent voiding/emptying of bladder

C. Location of Kidneys

1. Located in the **abdominal pelvic cavity**
2. **Retroperitoneal**: behind or posterior to the peritoneum

II. Macroscopic Anatomy of the Kidney

A. External Features

1. Peritoneum: serous membrane in abdominal cavity; kidneys are behind it
2. Parietal peritoneum covers anterior surface of kidneys
3. Kidneys embedded in the back wall
4. Right kidney slightly **inferior** to left due to **liver displacement**
5. Lower ribs partially protect kidneys
6. **Bean-shaped** with a depression for plumbing attachment
7. **Hilum**: region where major plumbing (ureter, blood vessels) attaches

B. Internal Structure

1. **Renal Cortex**: superficial, lighter reddish-pink, just deep to fibrous capsule

2. **Renal Medulla**: deeper, contains **renal pyramids**
    a. **Renal pyramids**: triangular-shaped, several in each kidney
    b. **Calices** (singular: calyx): goblet/funnel-shaped structures
        (1) (1) **Minor calyx**: collects urine from one renal pyramid
        (2) (2) **Major calyx**: two or more minor calyces converge
    e. **Renal pelvis**: larger, bowl-shaped structure, combination of major calyces
3. Urine Pathway: Pyramids → Minor calyces → Major calyces → Renal pelvis

III. Blood Supply to the Kidney

A. Arterial Flow

1. **Renal artery**: brings large amount of blood to each kidney, branches off abdominal aorta
2. Branches of Renal Artery (from largest to smallest)
    a. **Segmental arteries** (supply kidney segments)
    b. **Interlobar arteries** (between pyramids, through medulla toward cortex)
    c. **Arcuate arteries** (arc over superficial part of pyramids)
    d. **Cortical radiate arteries** (radiate in renal cortex)

B. Venous Return (reverse of arterial flow)

1. **Cortical radiate veins**
2. **Arcuate veins**
3. **Interlobar veins**
4. **Renal vein**: takes blood away from kidney, empties into inferior vena cava

IV. The **Nephron**: Functional Unit

A. Quantity and Categories

1. Each kidney contains between **1 and 1.5 million nephrons**
2. Total: **2 to 3 million nephrons** in a normal human
3. Two categories:

a. **Cortical nephrons**: situated entirely in the cortex

b. **Juxtamedullary nephrons**: partially in cortex, part extends into medulla; important for producing **highly concentrated urine**

B. Main Parts of a Nephron

1. **Renal Corpuscle**: combination of glomerulus and surrounding capsule

a. **Glomerulus**: ball-like **capillary bed**; receives blood from afferent arteriole

b. **Bowman's capsule** (also Renal or Nephric capsule): sac-like structure surrounding glomerulus; collects filtered fluid

(1) (1) **Capsular space**: space inside Bowman's capsule, immediately surrounds glomerulus

2. **Renal Tubule**: the rest of the nephron, fluid flows through it

a. **Proximal convoluted tubule** (PCT): first in line, convoluted/twisted

b. **Nephron loop** (or **Loop of Henle**): extends into medulla (especially in juxtamedullary nephrons)

(1) (1) Descending limb: allows water to leave filtrate, concentrating it

(2) (2) Ascending limb: allows salt to leave filtrate (active and passive transport), maintaining medullary gradient; water does not leave

e. **Distal convoluted tubule** (DCT): convoluted/twisted, empties into collecting duct

C. **Collecting Ducts**

1. Collect output from several nephrons

2. Eventually empty into a minor calyx

V. Major **Renal Processes** (Kidney Functions)

A. **Filtration** (**Glomerular filtration**)

1. Occurs **only at the glomerulus** (in the renal corpuscle)

2. Driven by **blood pressure** (hydrostatic pressure)

3. Glomerular capillaries are especially leaky; surrounded by **podocytes** with **filtration slits**

4. Removes anything **small enough** from blood, regardless of whether it's desired
5. Fluid formed is called **filtrate** (not yet urine)

B. **Reabsorption**

1. Occurs along the **renal tubule**
2. Brings necessary substances (e.g., water, glucose, amino acids) **back into the bloodstream** from the filtrate

C. **Secretion**

1. Occurs along the **renal tubule**
2. Moves substances (e.g., larger wastes, drugs, poisons) **from the bloodstream into the filtrate** that were not removed by filtration

D. **Urine Formation**

1. Final fluid is properly called **urine** only after all three processes are complete, typically some distance down the collecting duct
2. Once formed, **urine composition does not change**; water cannot be reclaimed from the bladder

VI. Urinary Bladder and **Micturition**

A. Anatomy of the Bladder Interior

1. **Trigone**: triangular region formed by three openings
2. **Ureteral orifices**: two entry points from the ureters (posterior surface)
3. **Internal urethral orifice**: one exit point to the urethra

B. **Urethra**: tube emptying the urinary bladder for micturition

1. **Female Urethra**: dedicated tube for urine
2. **Male Urethra**: **double duty** for both urine (micturition) and semen (ejaculation)
    a. Membranous urethra passes through the urogenital diaphragm (floor of pelvic cavity)

C. Bladder Distension and Epithelium

1. Bladder is small and flat when empty, can become highly **distended/ stretched**
2. Lined by **transitional epithelium**: special multi-layered epithelium

a. Unstretched: columnar cells

b. Stretched: cells become squamous to accommodate stretching without damage

VII. Body Water and Fluid Balance

A. Total Body Water Compartments (average adult: 40 liters)

1. **Intracellular Fluid (ICF)**: fluid **inside cells** (~25 liters, 40% of total body weight)
2. **Extracellular Fluid (ECF)**: fluid **outside cells**
   a. **Interstitial fluid**: fluid **between cells** in tissues (not blood)
   b. **Plasma**: extracellular matrix of blood, contained within **blood vessels**

B. Intercompartmental Exchange and Organ Systems

1. Fluid compartments are always communicating and exchanging materials
2. Examples of exchange with organ systems:
   a. **Respiratory system (lungs)**: exchanges O2/CO2 between air, blood, interstitial fluid, and intracellular fluid
   b. **Digestive system**: exchanges nutrients, water, and ions with blood, then to interstitial and intracellular fluid
   c. **Urinary system**: **Urine is filtered blood**; formed by filtration, reabsorption, and secretion

C. **Nitrogenous Waste**

1. Comes from breaking down **proteins** (amino acids contain nitrogen)
2. Ammonia: toxic product; liver converts it to less toxic **urea**
3. **Kidneys excrete urea** as part of urine

VIII. Water Balance: Intake and Output

A. Daily Water Intake (adds water to body)

1. **Metabolism**: ~10% (water produced as a byproduct of catabolizing fuels)
2. **Food**: ~30% (water in watery foods)
3. **Beverages**: major source, most highly variable intake

B. Daily Water Output (removes water from body)

1. **Feces**: ~4% (large intestine reabsorbs water)
2. **Sweating**: variable loss
3. **Insensible losses**: continuous, unnoticed water loss
    a. Through **skin** (evaporation)
    b. Through **lungs** (water vapor in breath)
4. **Urine**: most highly variable output

C. Regulation of Urine Production

1. Urine production matches the body's needs
2. **Antidiuretic hormone (ADH)**:
    a. (1) Released when dehydrated
    b. (2) Tells collecting ducts to **open water channels (aquaporins)**
    c. (3) Causes water to leave filtrate and return to body, thus **concentrating urine**
3. **Diuresis**: production of large volume of dilute urine (e.g., when overhydrated, less ADH)
4. **Antidiuresis**: production of small volume of highly concentrated urine (e.g., when dehydrated, more ADH)
5. **Juxtamedullary nephrons** (with long loops of Henle) are important for concentrating urine
6. **Concentration gradient** in kidneys (cortex to medulla) established by loop of Henle allows final adjustment of urine wateriness in collecting ducts
7. **Homeostasis**: total water intake should match total water output

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