THE URINARY SYSTEM

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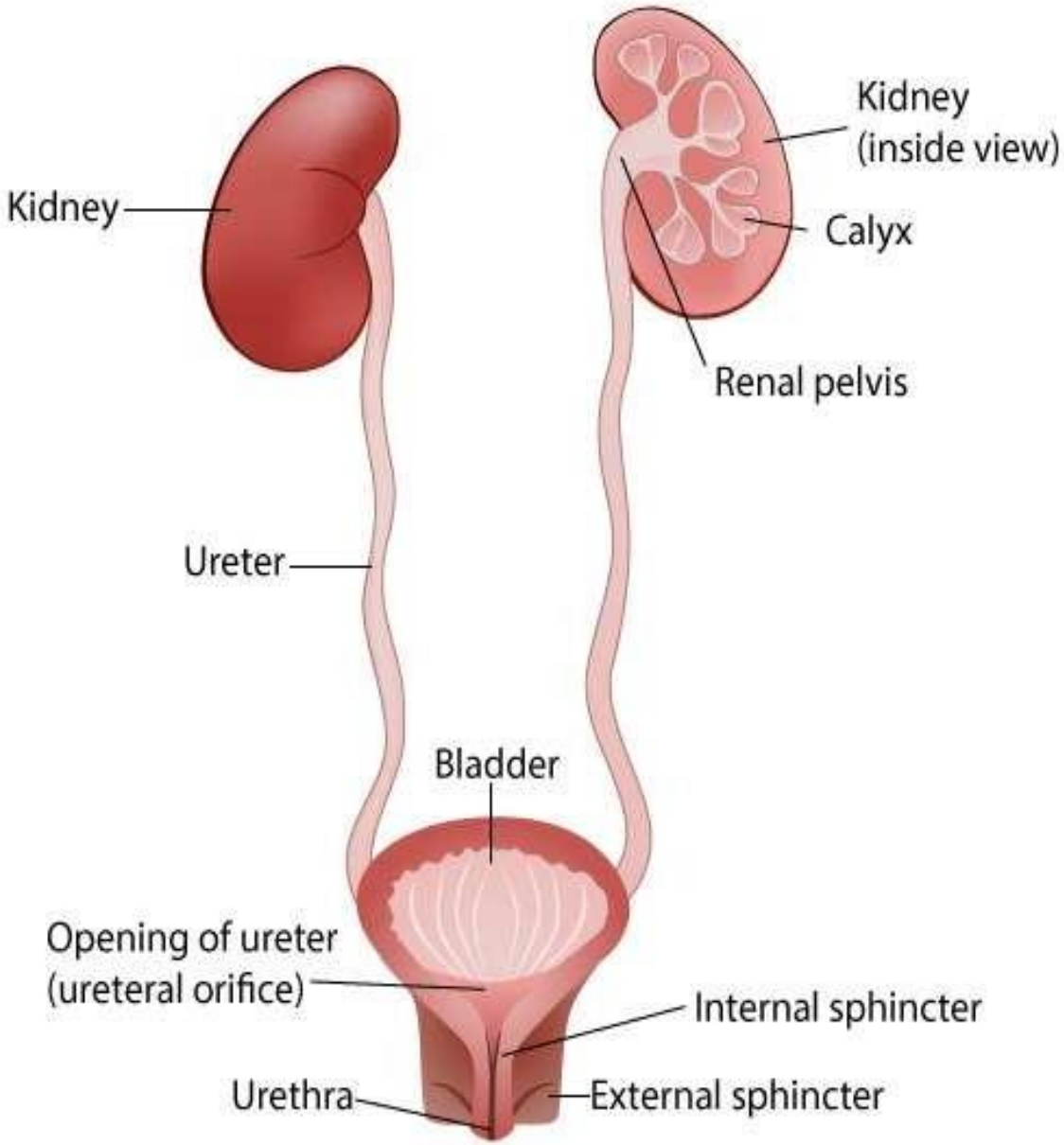
Course contents

- What is urinary system
- Organs of urinary system
- Define kidney
- Structure of kidney
- Function of kidney
- What is nephron and its parts
- Function of nephron
- Mechanism of urine formation
- Descruiption of ureter ,Urinary bladder and urethra

- **WHAT IS URINARY SYSTEM?**
- The **urinary system**, also known as the **renal system** or **urinary tract**, consists of
- The kidneys **(two)**
- Ureters **(two)**
- Bladder **(one)**
- The urethra**(one)**
- The purpose of the urinary system is to eliminate waste from the body, regulate blood volume and blood pressure, control levels of electrolytes and metabolites, and regulate blood pH.
- The urinary tract is the body's drainage system for the eventual removal of urine.


Kidney
Kidney
(inside view)
Calyx
Renal pelvis
Ureter
Bladder
Opening of ureter
(ureteral orifice)
Internal sphincter
Urethra
External sphincter

- **There are several functions of the Urinary System:**
- Removal of waste product from the body **(mainly urea and uric acid)**
- Regulation of electrolyte balance **(e.g. sodium, potassium and calcium)**
- Regulation of acid-base balance
- Controlling blood volume and maintaining blood pressure.

- **THE KIDNEYS**

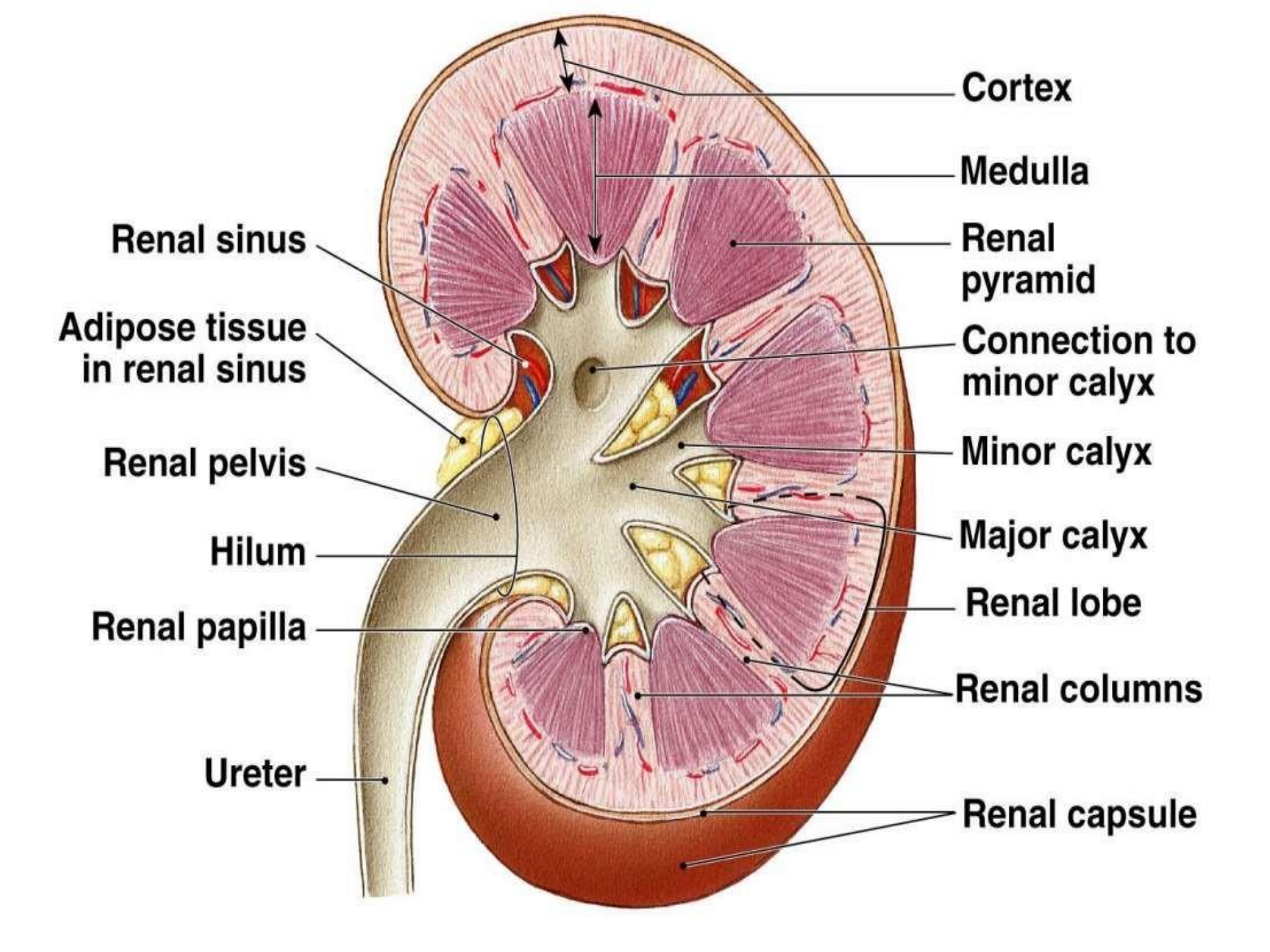
- The **kidneys** are two bean shaped organs found on the left and right sides of the body in vertebrates.
- They are located at the back of the abdominal cavity in the retroperitoneal space.
- The kidneys are located high in the abdominal cavity, one on each side of the spine
- The asymmetry within the abdominal cavity, caused by **the position of the liver**, typically results in the **right kidney being slightly lower and smaller than the left**, and being placed slightly more to the middle than the left kidney.

- **RELATIONSHIP**
- **Right kidney**
- **Anteriorly:**the duodenum,hepatic flexure of the colon & right lobe of the liver.
- **Posteriorly:** Diaphragm,muscles of posterior abdominal wall
- **Superiorly:** the right adrenal gland
- **Left kidney**
- **Anteriorly:**the spleen & splenic vessels,jejunum splenic flexure of the colon,pancreas & stomach.
- **Posteriorly:** Diaphragm,muscles of posterior abdominal wall
- **Superiorly:** the left adrenal gland

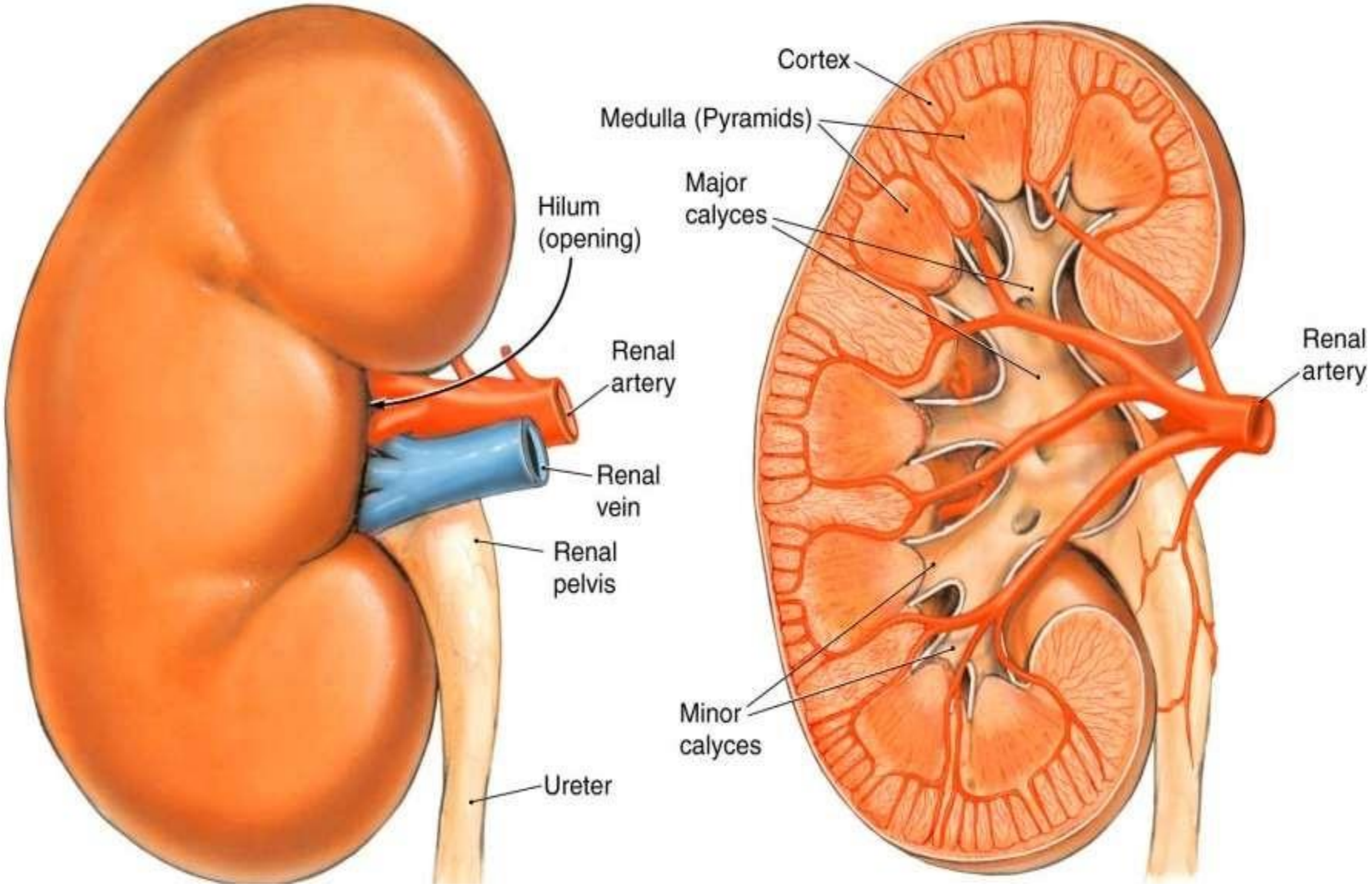
STRUCTURE

- **LENGTH:**11 centimetres or 4.3 inch
- **WIDTH:**5 cm
- **THICK**:2.5 cm
- **WEIGHT:** Male:150 - 170 gram
- Females:130 - 150 gram

- **The left kidney** is approximately at the vertebral level **12th thorasic vertebrae to 3rd lumber vertebrae** and the right is slightly lower.
- The kidney is a bean-shaped structure with a **convex** and a **concave** border
- the kidney is divided into two major structures:
- the outer **renal cortex** and
- the inner **renal medulla**.


Cortex
Medulla
Renal sinus
Renal pyramid
Adipose tissue in renal sinus
Connection to minor calyx
Renal pelvis
Minor calyx
Major calyx
Hilum
Renal lobe
Renal papilla
Renal columns
Ureter
Renal capsule

The Right Kidney

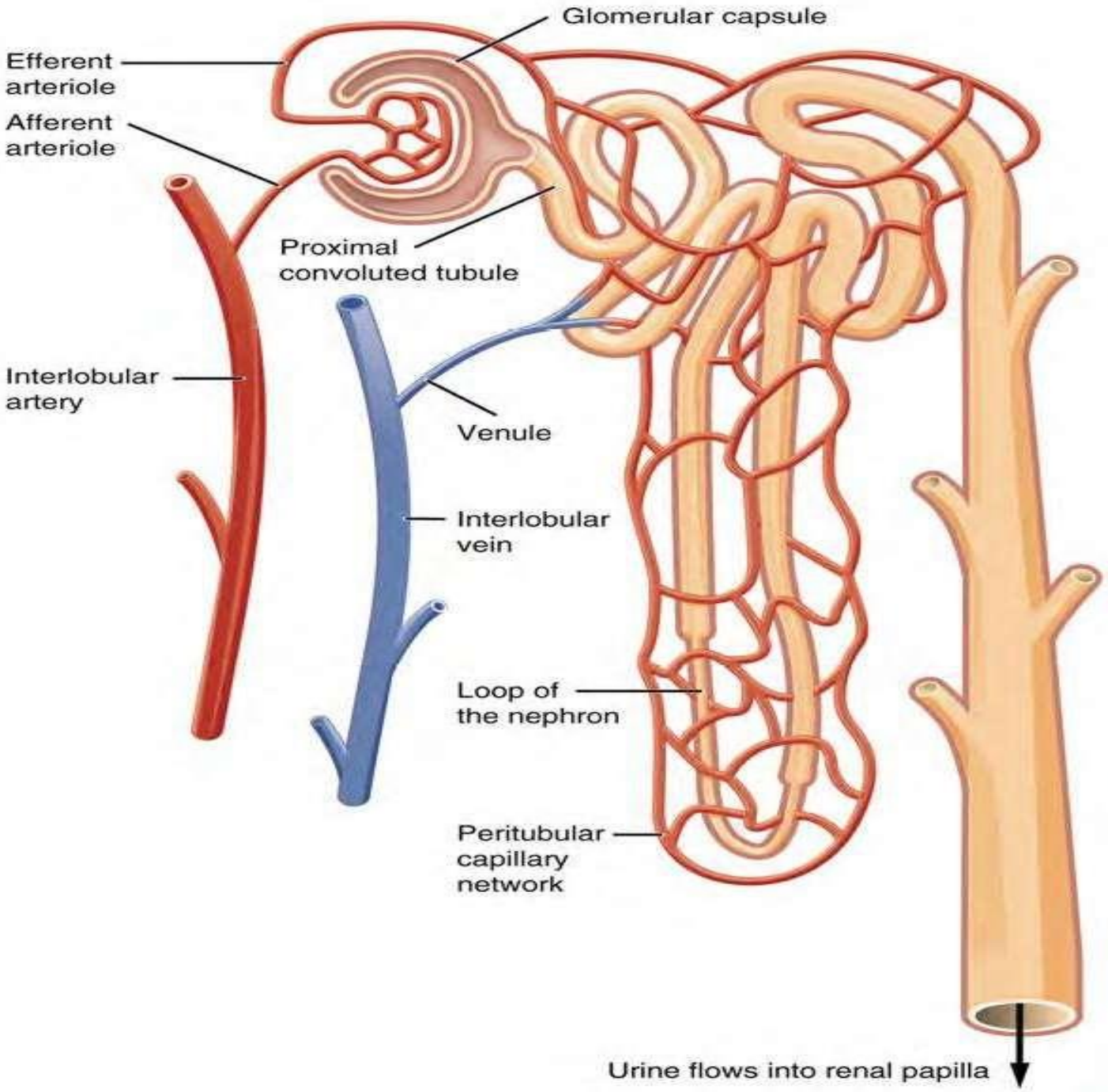


- A recessed area on the concave border is the **renal hilum**, where the renal artery enters the kidney and the renalvein and ureter leave.
- The kidney is surrounded by tough fibrous tissue, the **renal capsule.**
- the kidney is divided into two major structures: the outer **renal cortex** and the inner **renal medulla**.
- these structures take the shape of eight to 18 cone-shaped **renal lobes**, each containing renal cortex surrounding a portion of medulla called a **renal pyramid.**

- Between the renal pyramids are projections of cortex called **renal columns.**
- The **nephron** is **the structural and functional unit** of the kidney,span the cortex and medulla.
- Each adult kidney contains around one million nephrons
- The initial filtering portion of a nephron is the renal corpuscle which is located in the cortex.
- This is followed by a **renal tubule** that passes from the cortex deep into the medullary pyramids.

- Part of the renal cortex, a **medullary ray** is a **collection of renal tubules** that drain into a single **collecting duct**.
- each pyramid empties urine into a **minor calyx**; minor calyces empty into **major calyces**, and major calyces empty into the **renal pelvis.**
- This becomes the ureter.
- At the hilum, the ureter and renal vein exit the kidney and the renal artery enters.
- **THE NEPHRON**
- The **nephron** is the microscopic structural and functional unit of the kidney.
- It is composed of a renal corpuscle and a renal tubule.

- The renal corpuscle consists of a of capillaries called a **glomerulus** and an **Bowman's capsule**.
- A healthy adult has **0.8 to 1.5 million** nephrons in each kidney.
- they cleanse the blood and balance the constituents of the circulation.
- The afferent arterioles form a tuft of high-pressure capillaries about 200 µm in diameter, the **glomerulus.**
- After passing through the renal
- corpuscle, the capillaries form a second arteriole, the **efferent arteriole**


Glomerular capsule
Efferent arteriole
Afferent arteriole
Proximal convoluted tubule
Interlobular artery
Venule
Interlobular vein
Loop of the nephron
Peritubular capillary network
Urine flows into renal papilla

- In a dissected kidney, it is easy to identify the cortex; it appears lighter in color compared to the rest of the kidney.
- All of the renal corpuscles as well as both the **proximal convoluted tubules (PCTs) and distal convoluted tubules are**
- found here. Some nephrons have a short **loop of Henle that does not dip beyond the cortex.**

- **URINE FORMATION**

- Nephrons take a simple filtrate of the blood and modify it into urine. Many changes take place in the different parts of the
- nephron before urine is created for disposal.

- The principle task of the nephron population is to balance the plasma and excrete toxins in the urine.
- They do this by accomplishing three principle functions—
- **Filtration**
- **reabsorption, and**
- **secretion.**
- They also have additional secondary functions that exert control in three areas: blood pressure (via production of renin),
- red blood cell production (via the hormone EPO),
- and calcium absorption (via conversion of calcidiol into calcitriol,the active form of vitamin D).

- **Renal Corpuscle**
- The renal corpuscle consists of a tuft of capillaries called the glomerulus that is largely surrounded by Bowman's (glomerular) capsule.
- The glomerulus is a high-pressure capillary bed between afferent and efferent arterioles.
- As blood passes through the glomerulus, 10 to 20 percent of the plasma filters by Bowman's capsule and funneled to the PCT (**proximal convoluted tubules)**.

- **Proximal Convoluted Tubule (PCT)**
- Filtered fluid collected by Bowman's capsule enters into the PCT.
- It is called convoluted due to its tortuous path. Simple cuboidal cells form this tubule with prominent microvilli on the luminal surface, forming a **brush border.**
- These microvilli create a large surface area to maximize the absorption and secretion of solutes (Na+, Cl–, glucose, etc.), the most essential function of this portion of the nephron.

- **Loop of Henle**
- The descending and ascending portions of the loop of Henle (sometimes referred to as the nephron loop) are, of course, just continuations of the same tubule.
- **The descending loop of Henle** consists of an **initial short, thick portion and long**, whereas **the ascending loop consists of an initial short, thin portion** followed by a long, thick portion.
- The descending thick portion consists of simple **cuboidal epithelium** similar to that of the PCT. The descending and ascending thin portions consists of **simple squamous epithelium**.

- **Distal Convoluted Tubule (DCT)**
- The DCT, like the PCT, is very tortuous and formed by simple cuboidal epithelium, but it is shorter than the PCT.
- These cells are not as active as those in the PCT; thus, there are fewer microvilli on the apical surface.
- However, these cells must also pump ions against their concentration gradient.
- **Collecting Ducts**
- The collecting ducts are continuous with the nephron but not technically part of it.
- In fact, each duct collects filtrate from
- several nephrons for final modification.

- They are lined with simple squamous epithelium with receptors for ADH **antidiuretic hormone** or **Vasopressin**.
- **Glomerular Filtration Rate (GFR)**
- The volume of filtrate formed by both kidneys per minute is termed the **glomerular filtration rate (GFR).**
- The heart pumps about 5 L blood per min under resting conditions.
- Approximately 20 percent or one liter enters the kidneys to be filtered.
- On average, this liter results in the production of about 125 mL/min filtrate produced in **men** (range of 90 to 140 mL/min) and 105 mL/min filtrate produced in **women** (range of 80 to 125 mL/min).

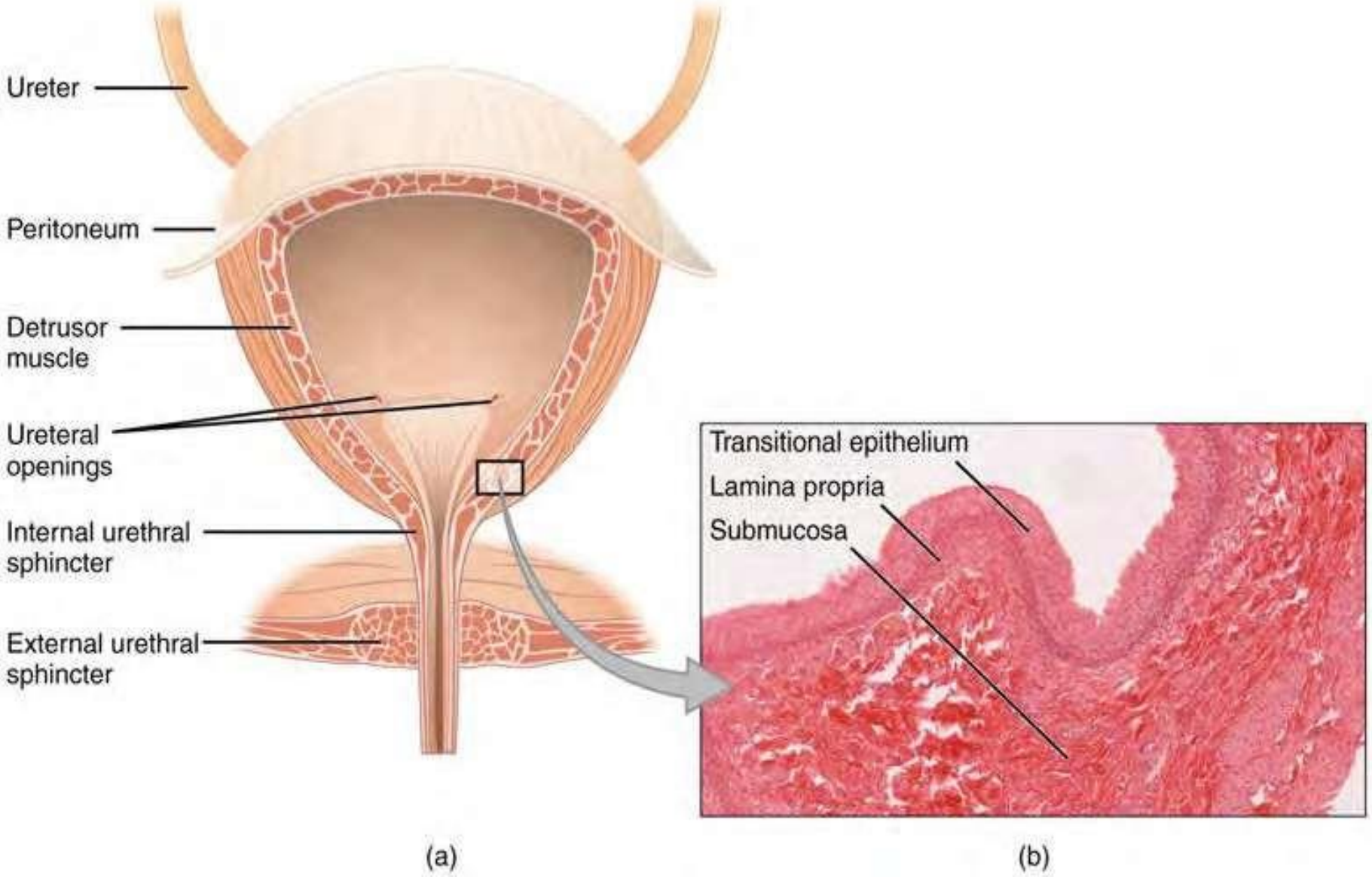
URETERS

- The kidneys and ureters are completely retroperitoneal, and the bladder has a peritoneal covering only over the dome.
- As urine is formed, it drains into the calyces of the kidney, which merge to form the funnel-shaped renal pelvis in the hilum of each kidney.
- The hilum narrows to become the ureter of each kidney.
- As they approach the bladder, they turn medially and pierce the bladder wall obliquely.
- This is important because it creates an one-way valve that allows urine into the bladder but prevents reflux of urine from the bladder back into the ureter.

- The ureters are approximately **30 cm long**.
- The muscular layer of the ureter consists of longitudinal and circular smooth muscles that create the peristaltic contractions to move the urine into the bladder without the aid of gravity.

- **URINARY BLADDER**

- The urinary bladder collects urine from both ureters.
- The bladder lies anterior to the uterus in females,posterior to the pubic bone and anterior to the rectum.
- During late pregnancy, its capacity is reduced due to compression by the enlarging uterus, resulting in increased frequency of urination.
- The bladder is partially **retroperitoneal (outside the peritoneal cavity)**
- Volumes in adults can range from nearly zero to 500–600 mL.


Ureter
Peritoneum
Detrusor muscle
Ureteral openings
Internal urethral sphincter
External urethral sphincter
Transitional epithelium
Lamina propria
Submucosa
(a)
(b)

- The bladder's strength diminishes with age, but voluntary contractions of abdominal skeletal muscles can increase intra-abdominal pressure to promote more forceful bladder emptying.
- Such voluntary contraction is also used in forceful defecation and childbirth.
- **Micturition Reflex**
- Micturition is a less-often used for urination or voiding.
- It results from an interplay of involuntary and voluntary actions by the internal and external urethral sphincters.
- When bladder volume reaches about 150 mL, an urge to void is sensed but is easily overridden.

- As the bladder fills, subsequent urges become harder to ignore.
- Ultimately, voluntary constraint fails with resulting **incontinence,** which will occur as bladder volume approaches 300 to 400 mL.
- The micturition reflex is active in infants but with maturity, children learn to override the reflex by asserting external sphincter control, thereby delaying voiding (potty training).

- **Urethra**

- The urethra transports urine from the bladder to the outside of the body for disposal.
- The urethra is the only urologic organ that shows any significant anatomic difference between males and females

- Voiding is regulated by an involuntary autonomic nervous system-controlled internal urinary sphincter, consisting of smooth muscle and voluntary skeletal muscle that forms the external urinary sphincter below it.
- **Female Urethra :**The external urethral orifice is embedded in the anterior vaginal wall inferior to the clitoris, superior to the vaginal opening and medial to the labia minora.
- Its short length, about **4 cm**, is less of a barrier to fecal bacteria than the longer male urethra and the best explanation for the greater incidence of UTI in women.

Male Urethra

- The male urethra passes through the prostate gland immediately inferior to the bladder before passing below the pubic symphysis. .
- The length of the male urethra varies between men but averages **20 cm** in length

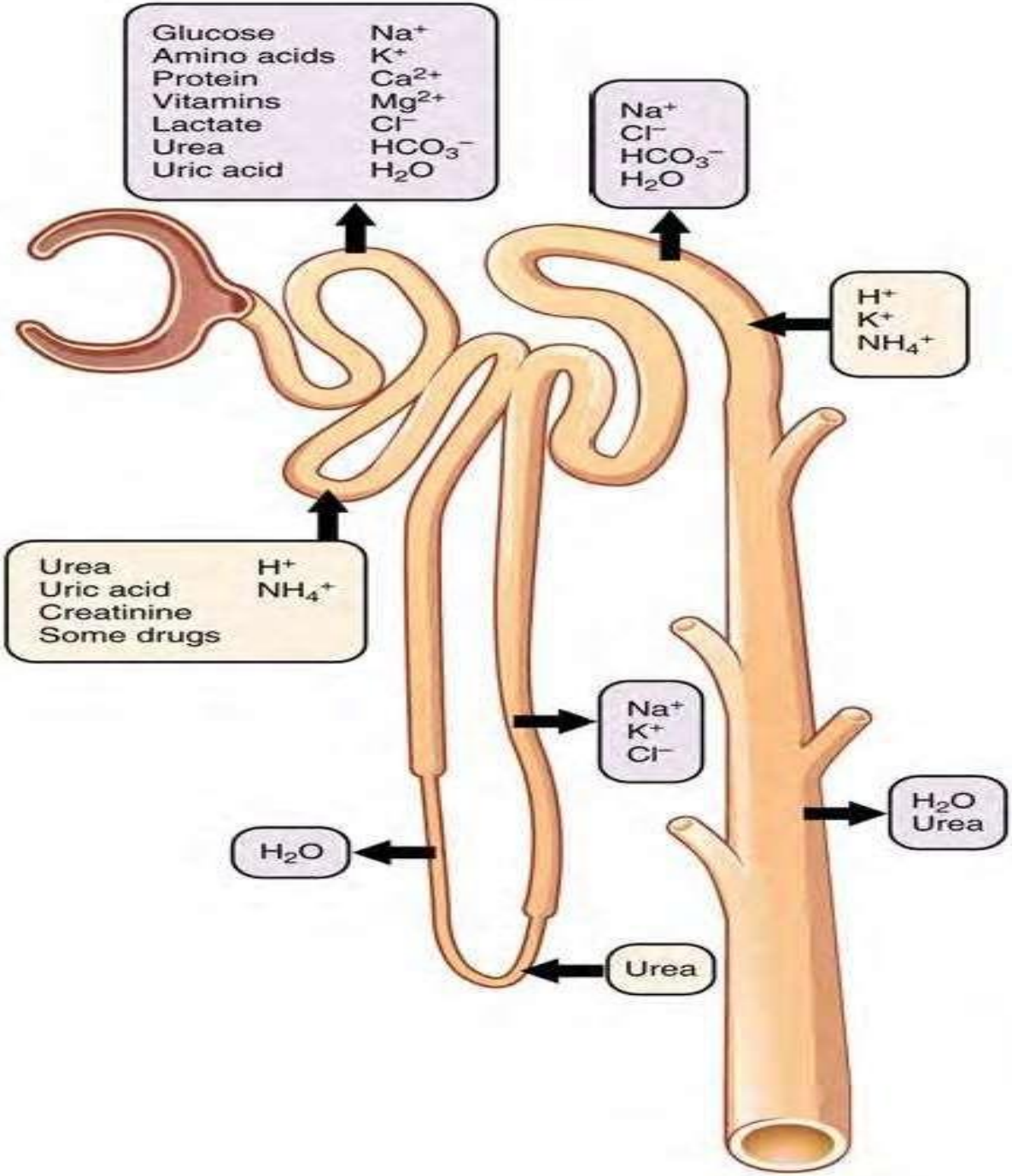
Filtration, Reabsorption, Secretion: The Three Steps of Urine Formation

- The kidneys filter unwanted substances from the blood and produce urine to excrete them.
- There are three main steps of urine formation: glomerular filtration, reabsorption, and secretion.
- These processes ensure that only waste and excess water are removed from the body.
- **1. The Glomerulus Filters Water and Other Substances from the Bloodstream**
- Each kidney contains over 1 million tiny structures called nephrons. Each nephron has a glomerulus, the site of blood filtration.

- The glomerulus is a network of capillaries surrounded by a cuplike structure, the glomerular capsule (or Bowman's capsule). As blood flows through the glomerulus, blood pressure pushes water and solutes from the capillaries into the capsule through a filtration membrane.
- This glomerular filtration begins the urine formation process.

2. The Filtration Membrane Keeps Blood Cells and Large Proteins in the Bloodstream

- Inside the glomerulus, blood pressure pushes fluid from capillaries
  into the glomerular capsule through a specialized layer of cells.
- This layer, the filtration membrane, allows water and small solutes to pass but blocks blood cells and large proteins. Those components remain in the bloodstream.
- The filtrate (the fluid that has passed through the membrane) flows from the glomerular capsule further into the nephron.

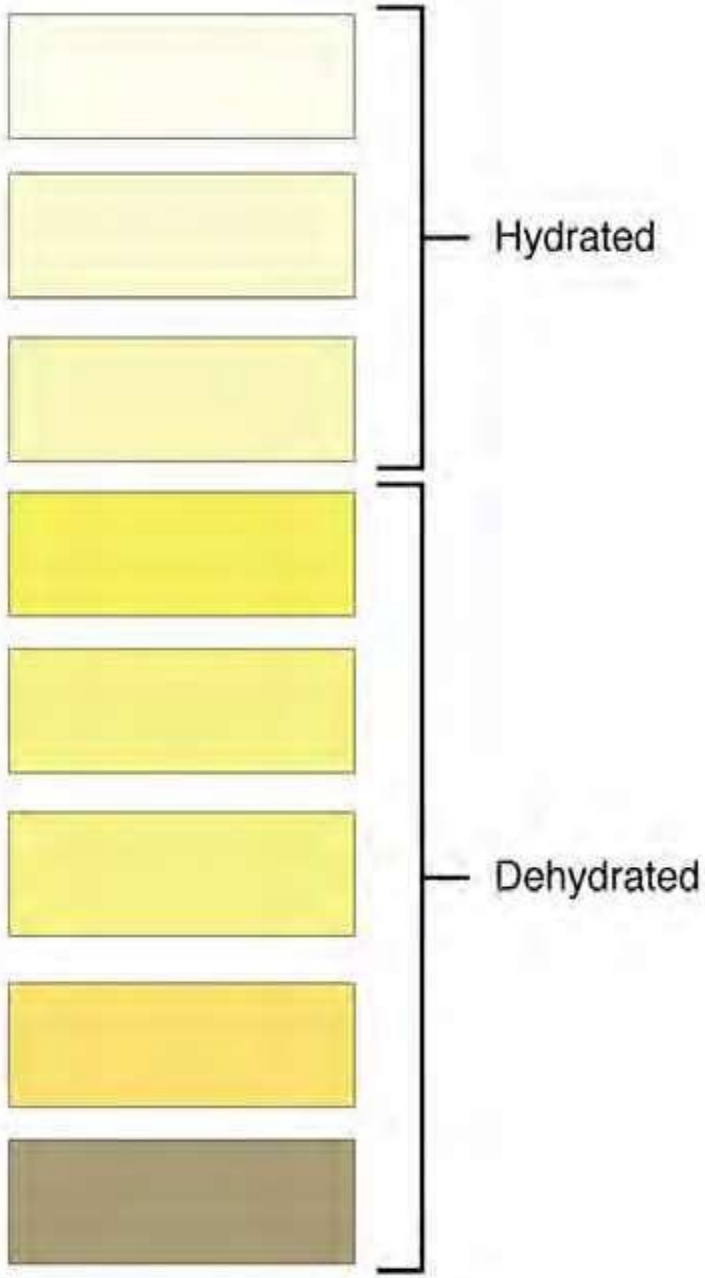

Glucose
Amino acids
Protein
Vitamins
Lactate
Urea
Uric acid
Na^+
K^+
Ca^{2+}
Mg^{2+}
Cl^-
HCO_3^-
H_2O
Na^+
Cl^-
HCO_3^-
H_2O
H^+
K^+
NH_4^+
Urea
Uric acid
Creatinine
Some drugs
H^+
NH_4^+
Na^+
K^+
Cl^-
H_2O
Urea
H_2O
Urea

- **3. Reabsorption Moves Nutrients and Water Back into the Bloodstream**
- The glomerulus filters water and small solutes out of the bloodstream.
- The resulting filtrate contains waste, but also other substances the body needs: essential ions, glucose, amino acids, and smaller proteins. When the filtrate exits the glomerulus, it flows into a duct in the nephron called the renal tubule.
- As it moves, the needed substances and some water are reabsorbed through the tube wall into adjacent capillaries.
- This reabsorption of vital nutrients from the filtrate is the second step in urine creation.

- **4. Waste Ions and Hydrogen Ions Secreted from the Blood Complete the Formation of Urine**
- The filtrate absorbed in the glomerulus flows through the renal tubule, where nutrients and water are reabsorbed into capillaries.
- At the same time, waste ions and hydrogen ions pass from the capillaries into the renal tubule.
- This process is called **secretion**.
- The secreted ions combine with the remaining filtrate and become urine.
- The urine flows out of the nephron tubule into a collecting duct. It passes out of the kidney through the renal pelvis, into the ureter, and down to the bladder.

- **Physical Characteristics of Urine**
- The urinary system's ability to filter the blood resides in about 2 to 3 million tufts of specialized capillaries—the glomeruli—distributed more or less equally between the two kidneys.
- The glomeruli create about 200 liters of this filtrate every day, yet you excrete less than two liters of waste you call urine.
- Some of the characteristics such as color and odor are rough descriptors of your state of hydration.
- For example, if you exercise or work outside, and sweat a great deal, your urine will turn darker and produce a slight odor, even if you drink plenty of water. Athletes are often advised to consume water until their urine is clear.

CHARACTERISTIC	NORMAL VALUES
COLOR	Pale yellow to deep amber
ODOR	Odorless
VOLUME	750–2000 mL/24 hour
PH	4.5–8.0
SPECIFIC GRAVITY	1.003–1.032


Hydrated
Dehydrated

VOLUME CONDITION	VOLUME	CAUSES
NORMAL	**1–2 L/day**	
POLYURIA	**>2.5 L/day**	Diabetes mellitus; diabetes insipidus; excess caffeine or alcohol; kidney disease; certain drugs, such as diuretics; sickle cell anemia; excessive water intake
OLIGURIA	**300–500 mL/day**	Dehydration; blood loss; diarrhea; cardiogenic shock; kidney disease; enlarged prostate
ANURIA	**<50 mL/ day**	Kidney failure; obstruction, such as kidney stone or tumor; enlarged prostate

- Specific gravity is a measure of the quantity of solutes per unit volume of a solution.
- Urine will always have a specific gravity greater than pure water (water = 1.0) due to the presence of solutes.
- **Endocrine Regulation of Kidney Function**
- Several hormones have specific, important roles in regulating kidney function.
- They act to stimulate or inhibit blood flow.
- **Renin–Angiotensin–Aldosterone**
- **Antidiuretic Hormone (ADH)**

- **Regulation of Fluid Volume and Composition**
- The major hormones influencing total body water are ADH, aldosterone.
- Blood volume is important in maintaining sufficient blood pressure.
- **Diuretics and Fluid Volume**
- A diuretic is a compound that increases urine volume.
- **Regulation of Extracellular Na+**
- Sodium has a very strong osmotic effect and attracts water.
- It plays a larger role in the osmolarity of the plasma than any other circulating component of the blood.

- If there is too much Na+ present, either due to poor control or excess dietary consumption, a series of metabolic problems ensue.
- There is an increase in total volume of water, which leads to hypertension (high blood pressure).
- Over a long period, this increases the risk of serious complications such as heart attacks,strokes, and aneurysms.
- It can also contribute to system-wide edema (swelling).
- Mechanisms for regulating Na+ concentration include the renin–angiotensin–aldosterone system and ADH.