ANATOMY & PHYSIOLOGY II

GHC 2013 / NMS 2012 / OHC 3013 / PTAP 1123

CHAPTER 2

URINARY SYSTEM

TOPIC OUTLINES

2.1 Main Organs of Urinary System

2.2 Main Functions of Urinary System

2.3 Structure of the Kidney

2.4 Nephron

2.5 Urine Formation

2.6 Evaluation of Kidney Function

2.7 Ureters

2.8 Urinary Bladder

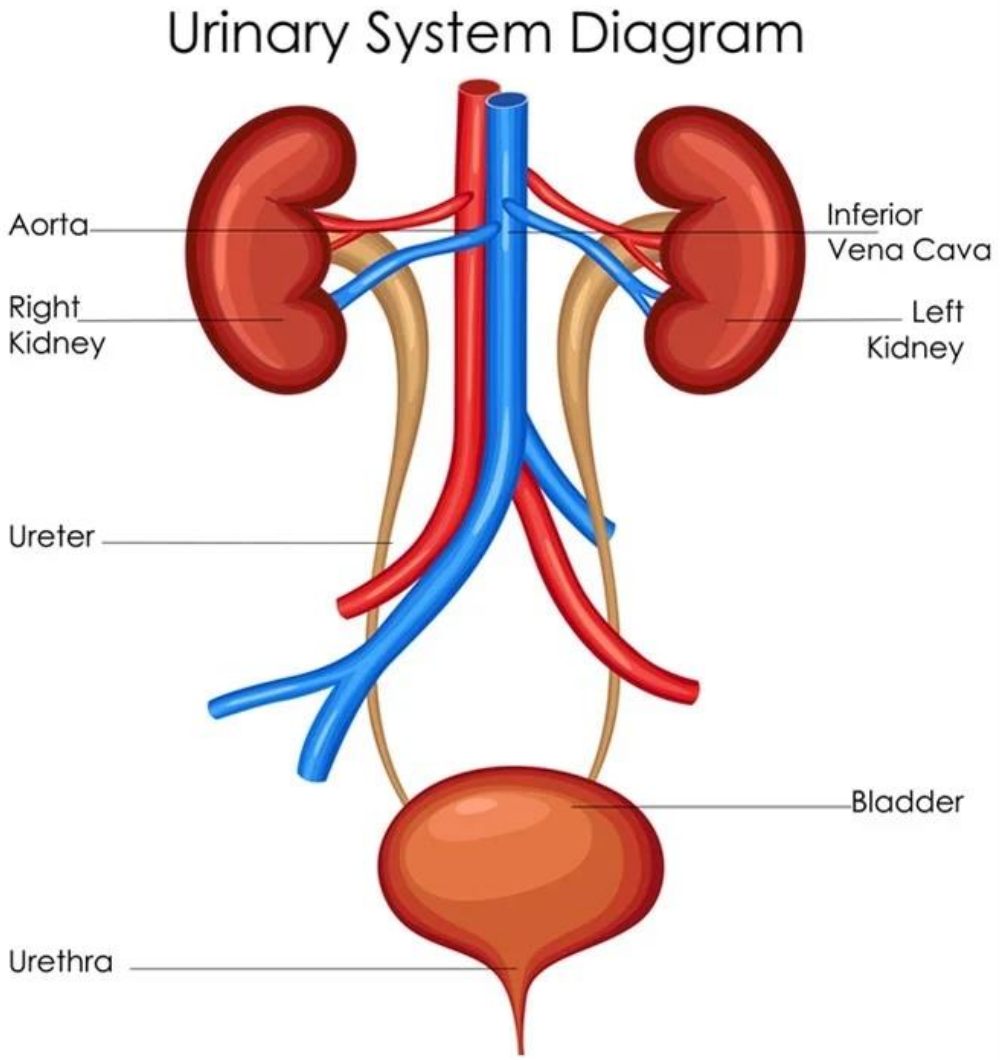
2.9 Urethra

2.10 Micturition

LEARNING OUTCOMES

At the end of this chapter, students should be able to:

- ❑ Describe the main organs and functions of urinary system
- ❑ Explain the basic physiological process of urinary system
- ❑ Explain the process of urine formation

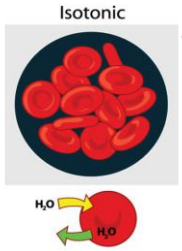


2.1 Main Organs of Urinary System

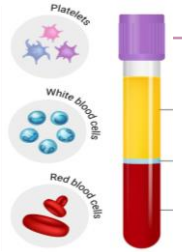
- Kidneys
- Ureters
- Bladder
- Urethra

2.2 Main Functions of Urinary System

Regulate blood ionic (Na^+ , K^+ , Ca^{2+})

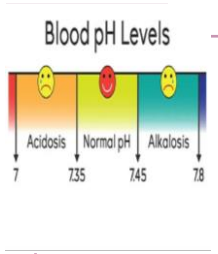


Maintain of blood osmolarity



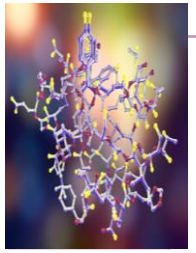
Regulate blood volume

Regulate blood pressure



Regulate blood pH

Regulation of blood glucose level



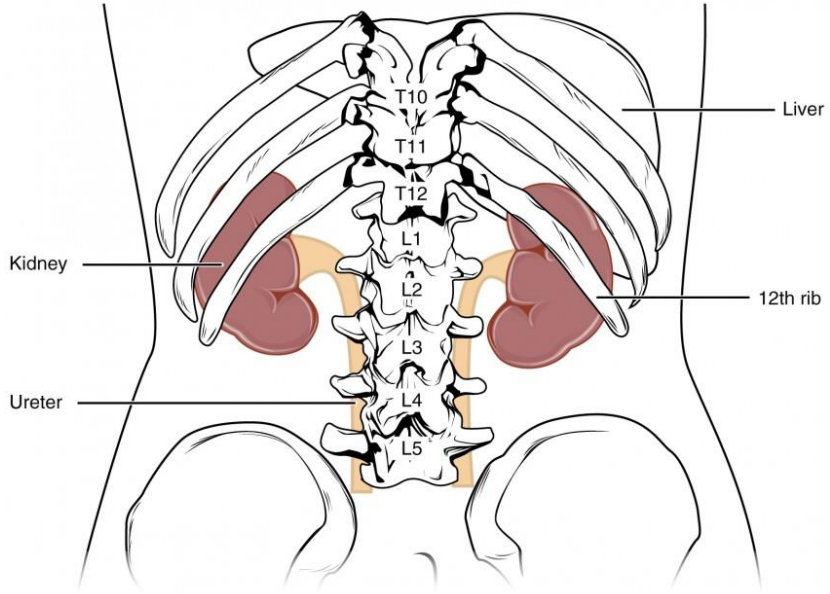
Release hormones - calcitriol & erythropoietin

Excretion of wastes & foreign substances: URINE

2.3 Structure of the Kidney

LOCATION

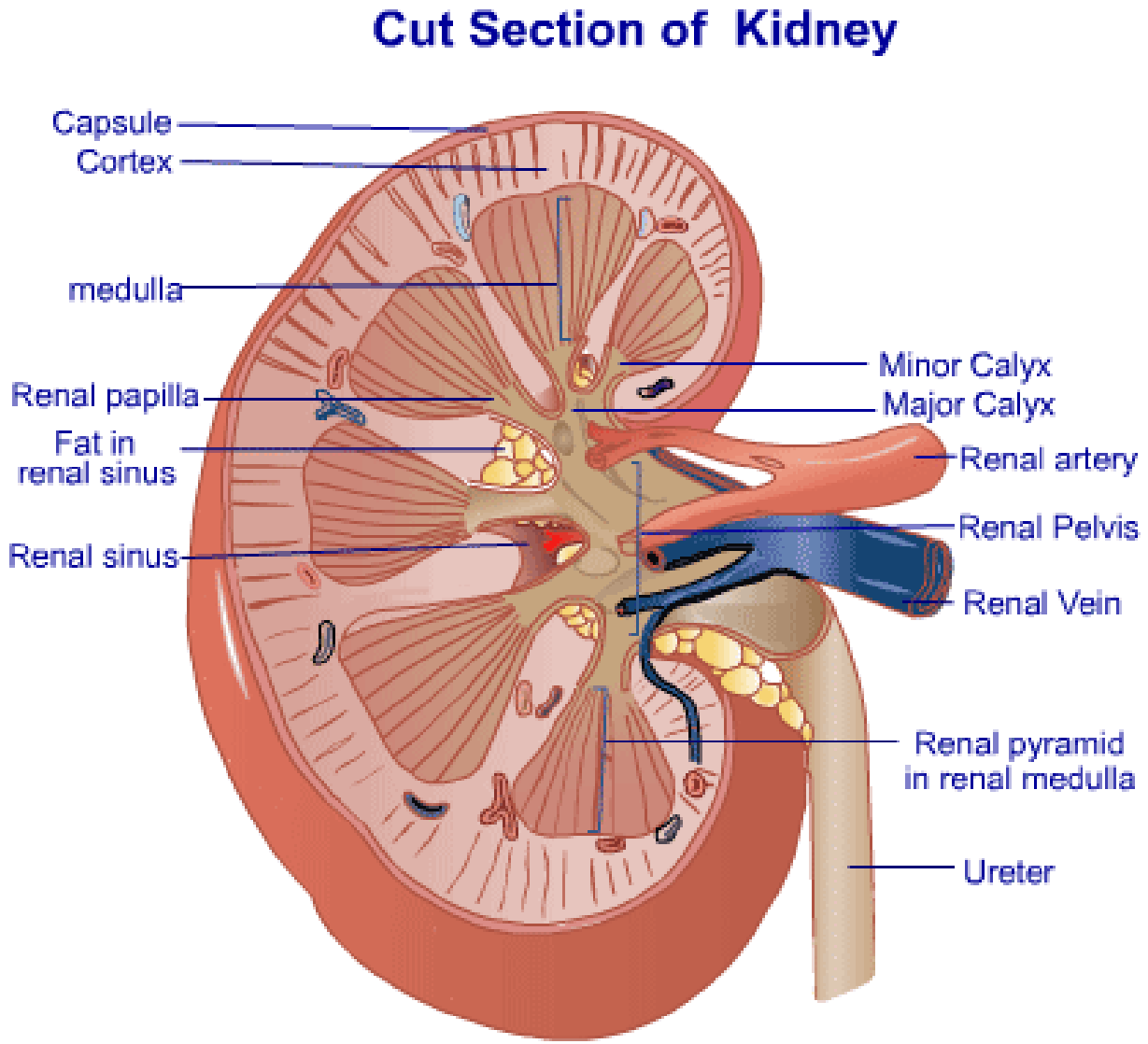
- Bean – shaped organ
- 10cm long, 5cm wide, 2.5cm thick and weight 150gm
- Lie on the posterior abdominal wall, behind peritoneum, below diaphragm and each side of vertebral column
- Extend from the 12th thoracic vertebra (T12) to the 3rd lumbar vertebra (L3)
- **Transpyloric plane**
  - plane where both kidneys, pancreas, upper duodenum & pyloric of gaster is locate
- Right kidney is slightly lower than left kidney due to liver

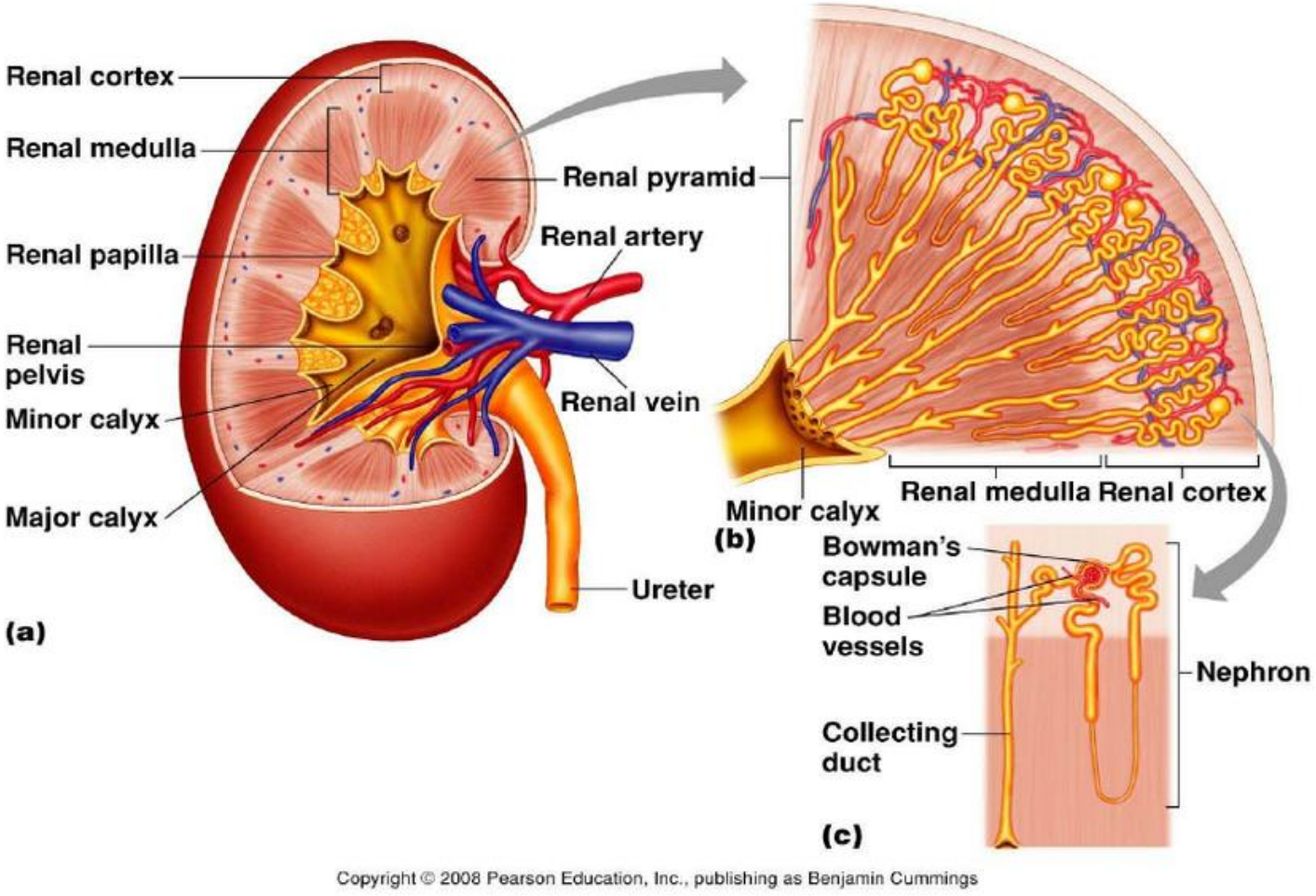


2.3 Structure of the Kidney

- Embedded and held by a protective layer of fat (adipose capsule) around the organ → **fibrous/ RENAL CAPSULE**
- **HILUM** = Border of kidney where ureters, renal artery, renal vein, nerve leaves the kidney
- **RENAL CORTEX** = Reddish brown, superficial, outer layer
- **RENAL MEDULLA** = Deep, consist of 8 – 18 cone shaped **RENAL PYRAMIDS**
- **RENAL PAPILLA** = Apex of the renal pyramids
- **RENAL COLUMN** = Between renal pyramids
- Renal papilla continue to **MINOR CALYX**
- Minor calyx form the **MAJOR CALYX**, and then continue to **RENAL PELVIS** before go out with **URETERS**

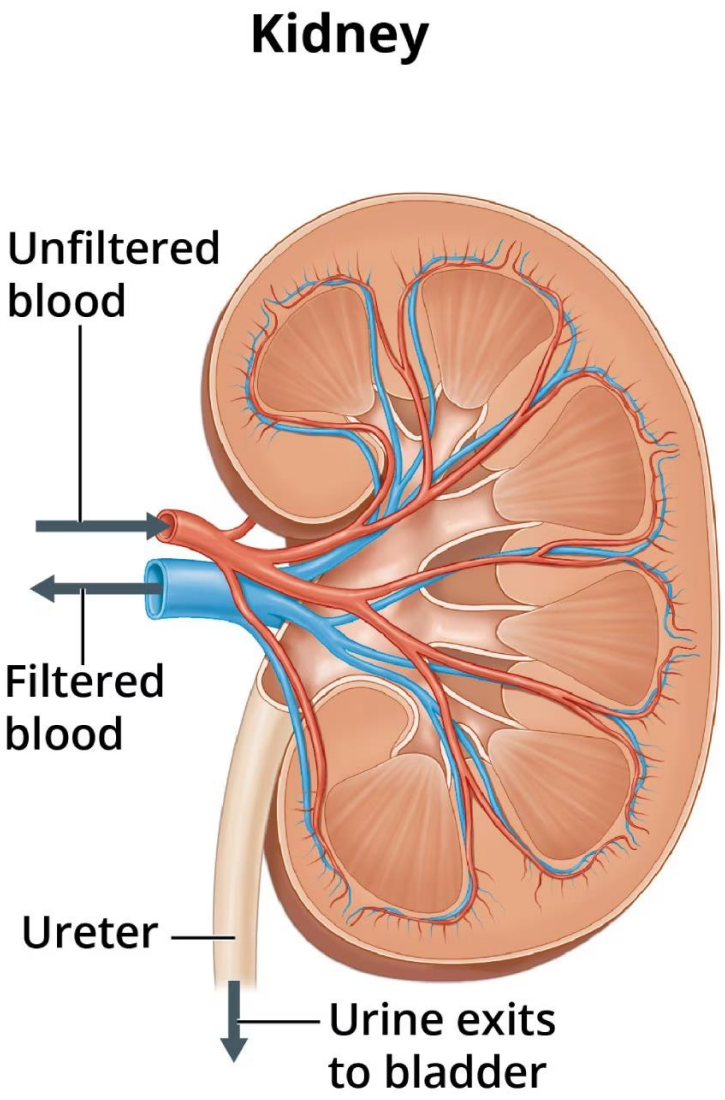
2.3 Structure of the Kidney





2.3 Structure of the Kidney

2.3.1 Associated Blood Vessels

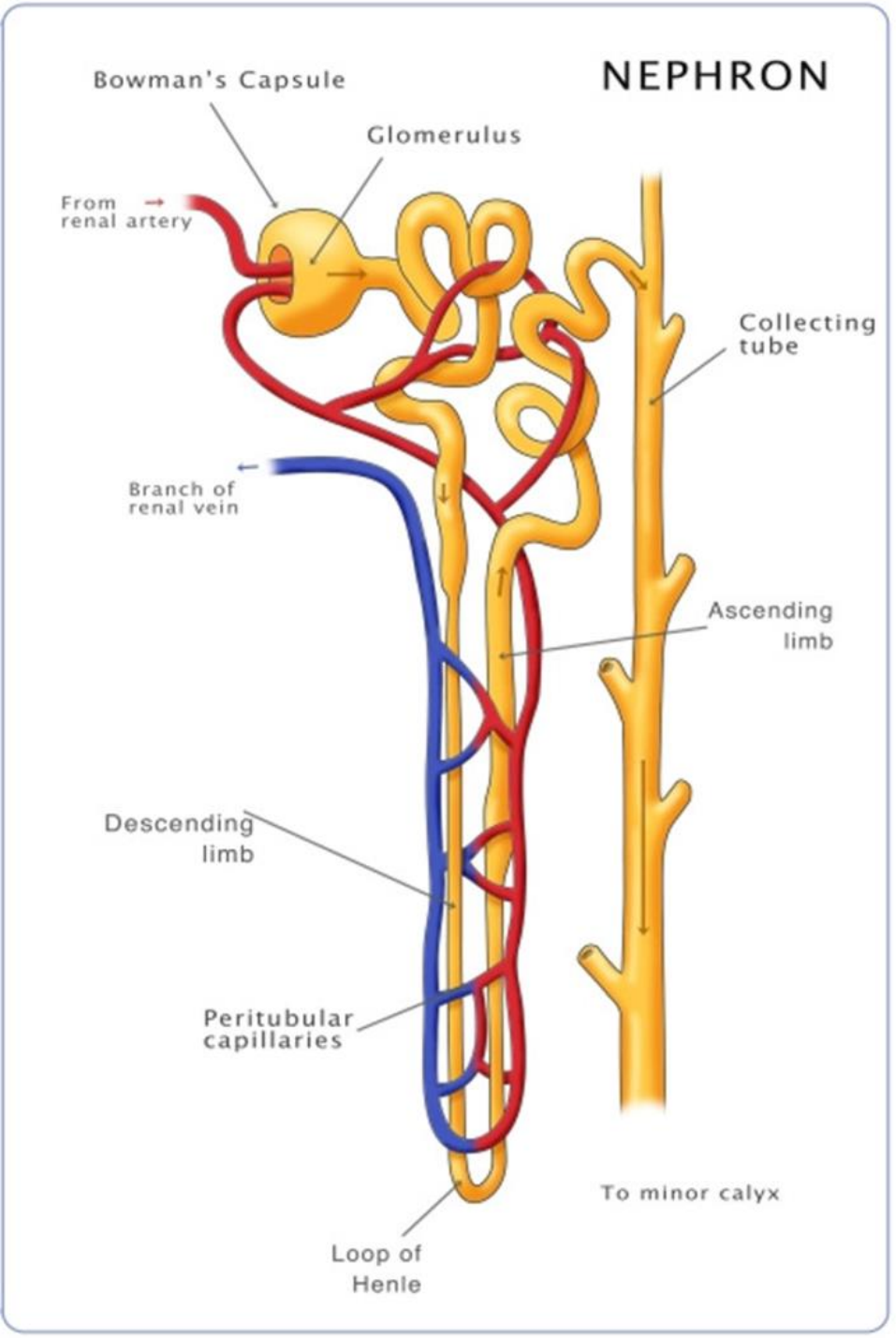


Renal Arteries

- Bring oxygenated blood containing urea, excess water & heat to the kidneys

Renal Veins

- Take away the deoxygenated blood (urea, excess water & heat have been removed) from the kidney



2.4 Nephron

- Functional units of kidney
- Location: Upper portion = renal cortex
  Lower portion = renal medulla
- Main function: Urine formation
- Do THREE (3) basic process:

a. Filtering blood

b. Returning useful substances into blood

c. Removing substances from the blood

2.4 Nephron

About one third of nephrons in a kidney must be functional to ensure survival of the organ

Consists of a specialized tubular structure and closely associated blood vessels

Each kidney contains 1,000,000 nephrons that filter the blood and form urine

About 99% of the initial filtrate from the glomerulus is reabsorbed by the nephron and returned to the blood

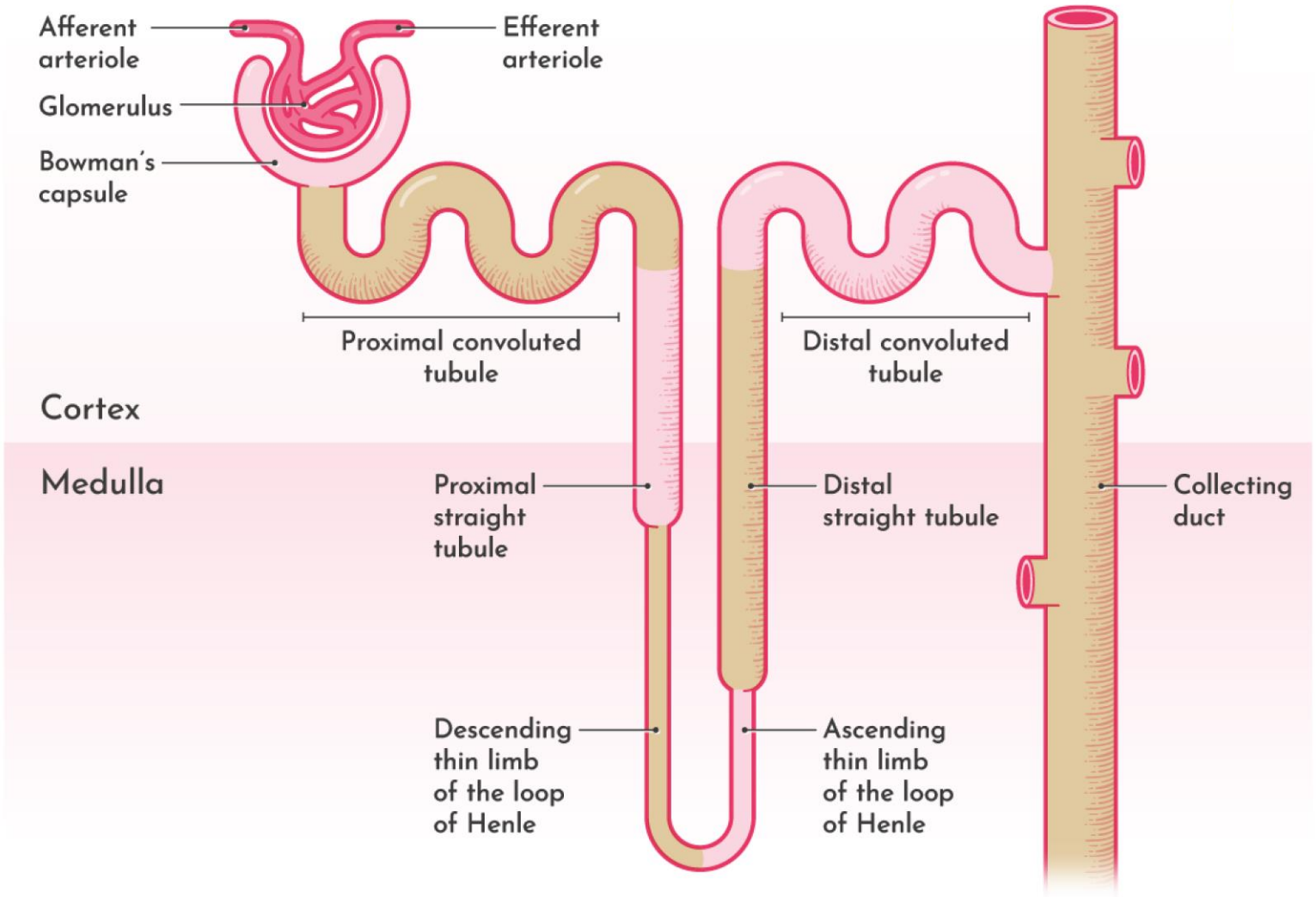
When nephrons are damaged, they are not replaced or regenerated

2.4.1 Component of Nephron

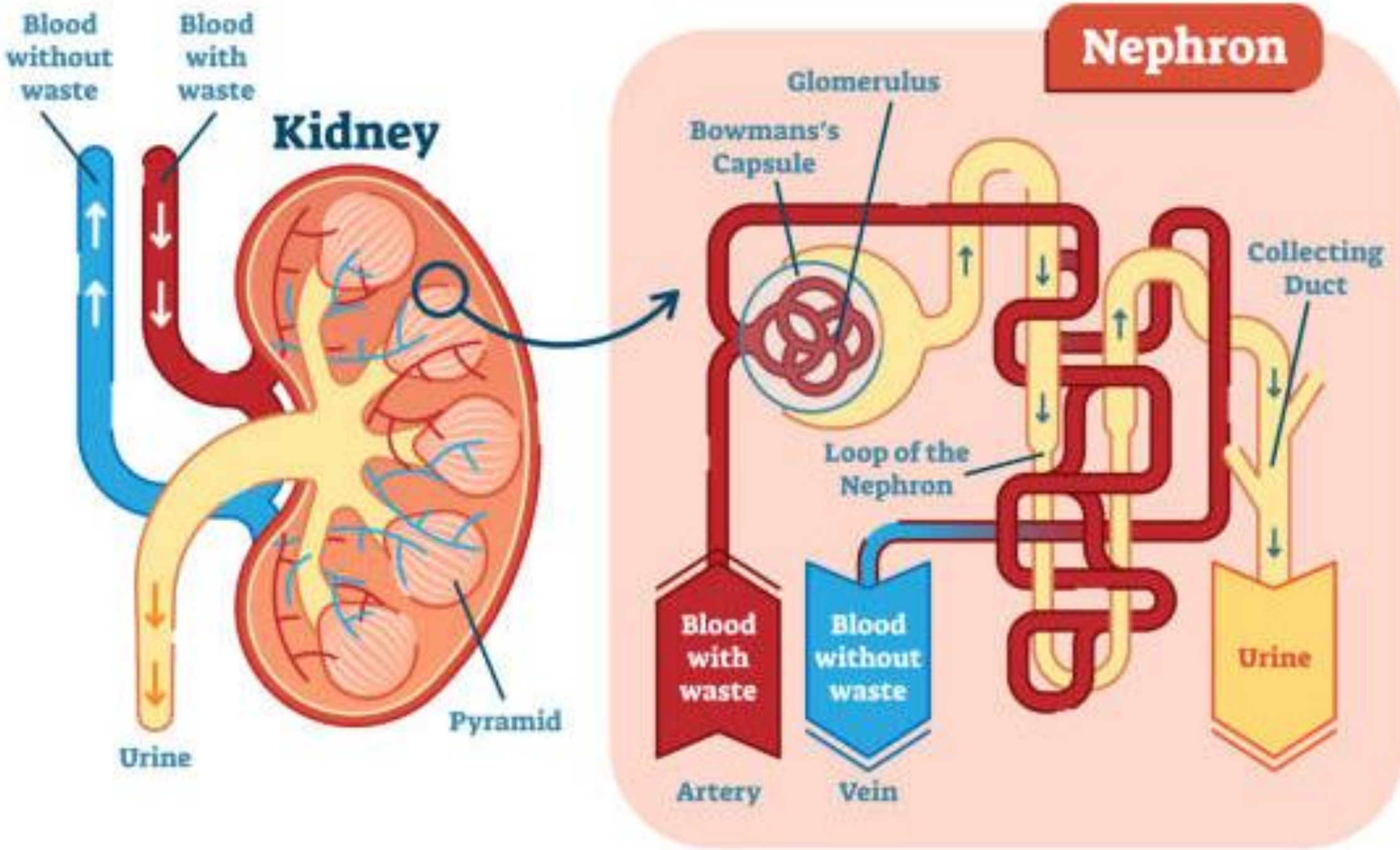
Glomerulus	• Glomerular capsule or Bowmen’s capsule • Beginning of the nephron, located in the cortex
Proximal convoluted tubule	• First twisted region after the Bowman's capsule, located in the cortex
Loop of Henle	• Long, hairpin loop after the proximal tubule, extends from the cortex down into the medulla and back

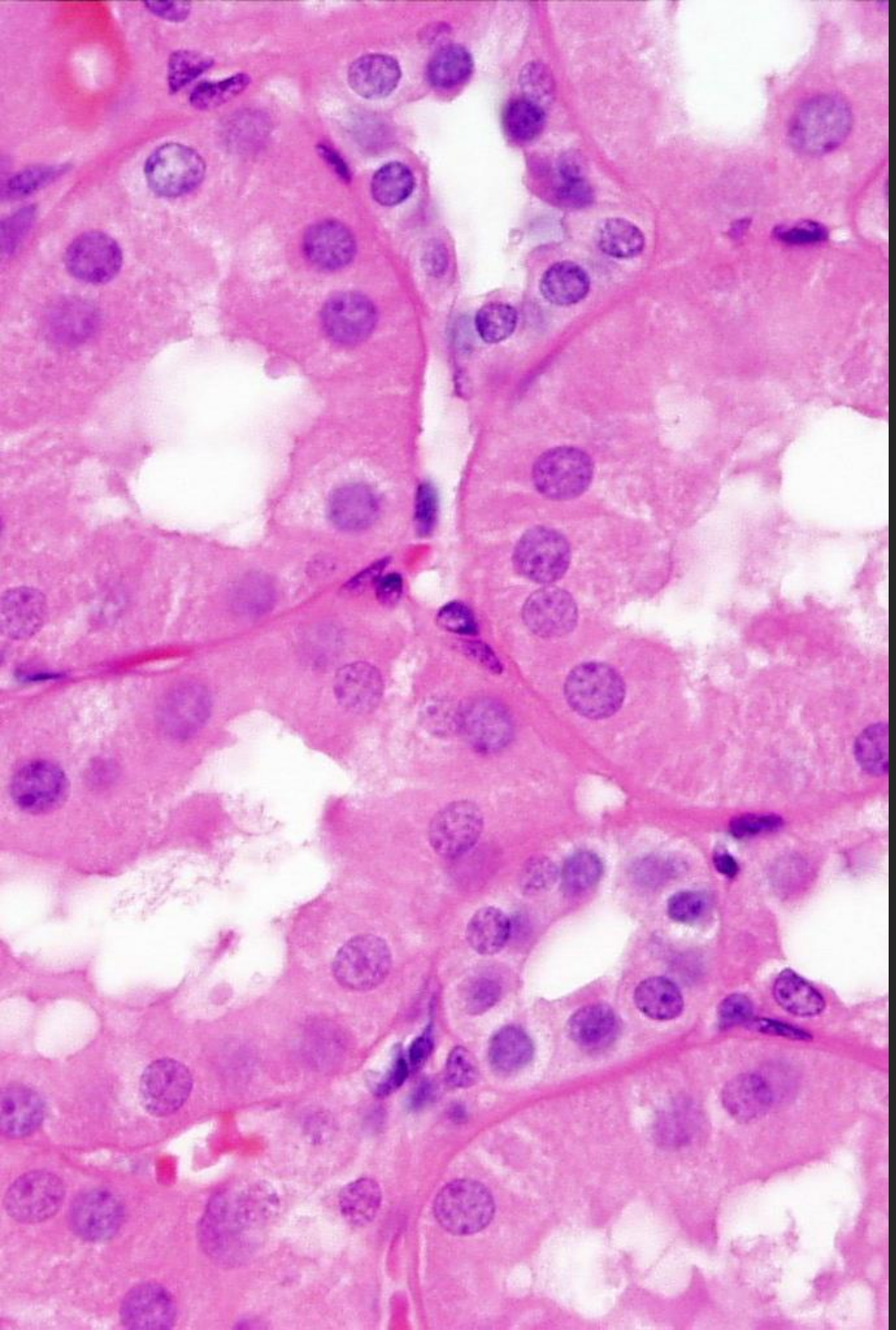
2.4.1 Component of Nephron

Distal convoluted tubule	• Second twisted portion of the nephron after the loop of Henle, located in the cortex
Collecting duct	• Long straight portion after the distal tubule, extends from the cortex down through the medulla



2.4.1 Component of Nephron


Blood without waste
Blood with waste
Kidney
Urine
Pyramid
Nephron
Glomerulus
Bowmans's Capsule
Collecting Duct
Loop of the Nephron
Blood with waste
Blood without waste
Urine
Artery
Vein



2.4.2 Histology of the Nephron

1. Glomerular Capsule

- Simple squamous epithelium (Outer wall)
- Modified simple squamous epithelium called podocytes (Inner wall)

2. Proximal Convoluted Tubule

- Simple cuboidal epithelium cell

3. Loop of Henle

- Mix up epithelium
- Simple squamous epithelium → simple cuboidal epithelium → columnar epithelium

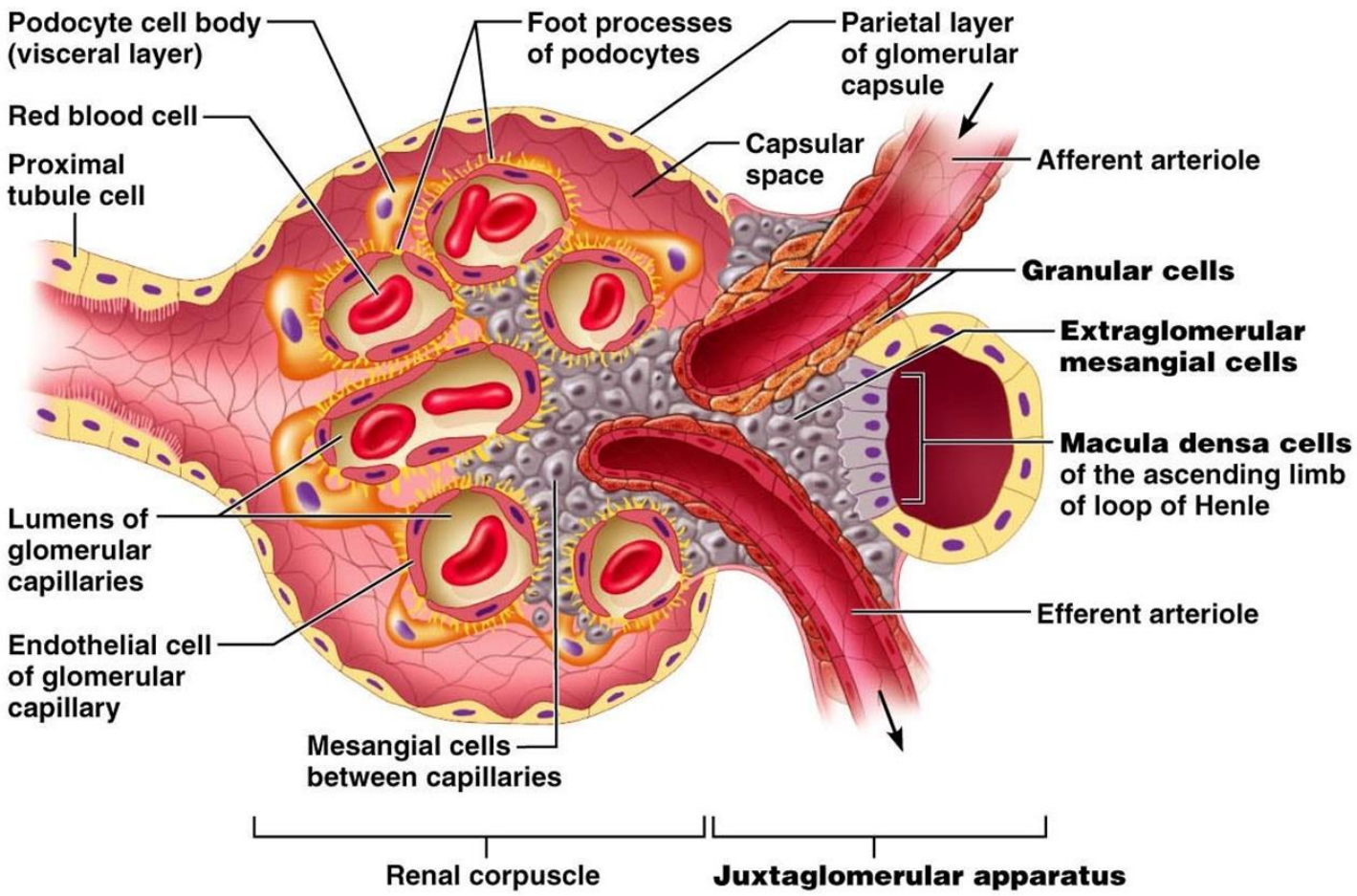
2.4.2 Histology of the Nephron

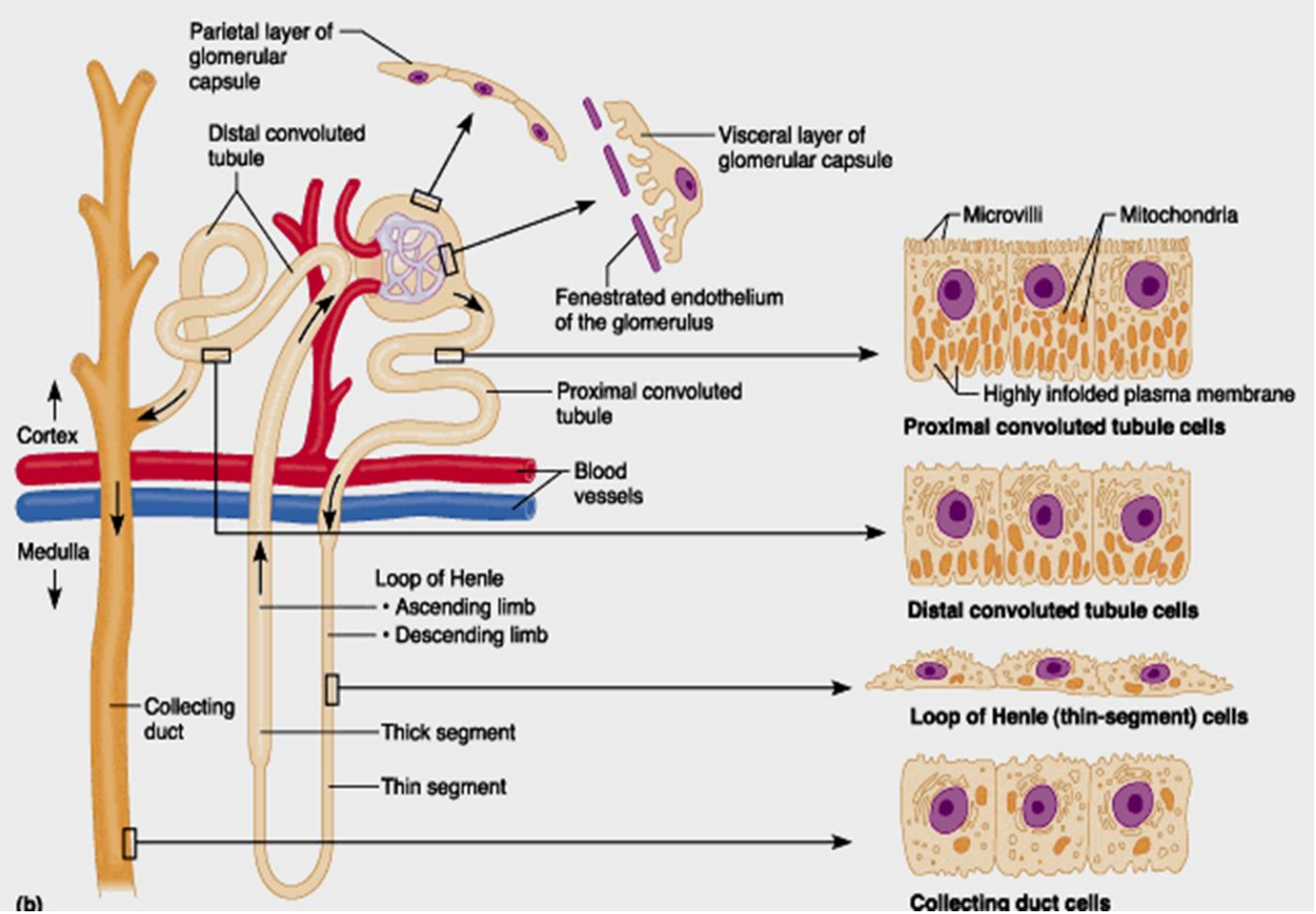
4. Distal Convoluted Tubule

- ❑ Simple cuboidal epithelium

5. Collecting Duct

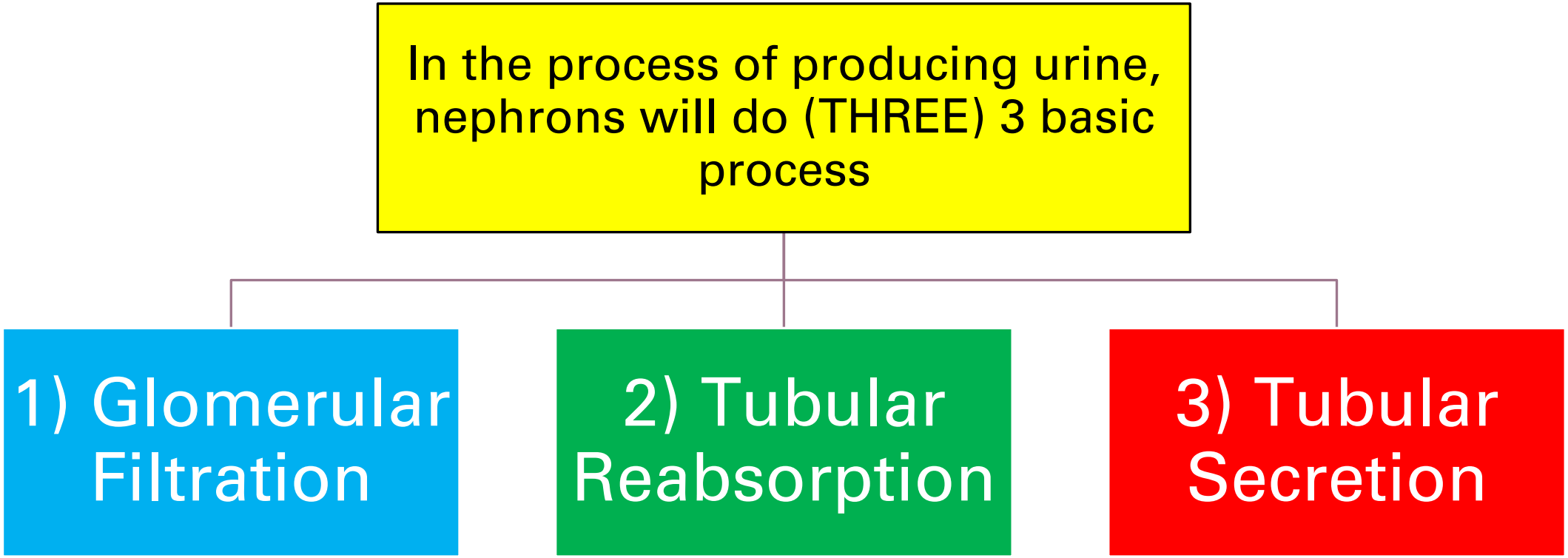
- ❑ Simple cuboidal epithelium
- ❑ Mix up with principal cells & intercalated cells





2.4.2 Histology of the Nephron

2.5 Urine Formation



2.5.1 Glomerular Filtration

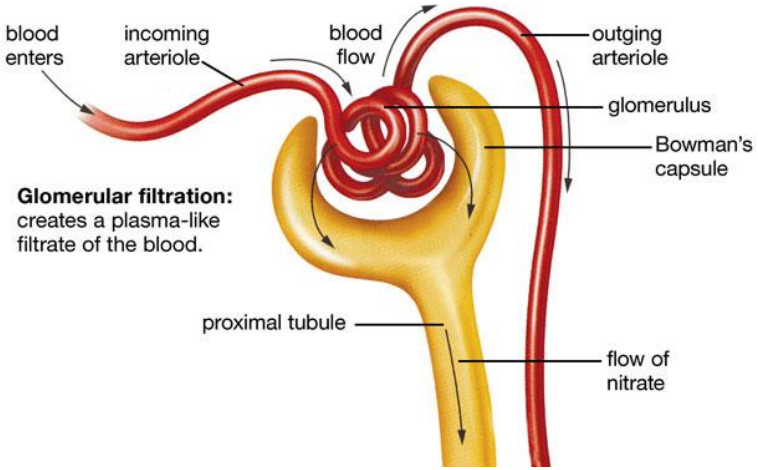
Water & most solutes in blood enter the afferent arteriole pass across the wall of glomerulus to the glomerular capsule before drain into renal tubule

Glomerular filtration occur in = **glomerulus**

Blood from renal artery brings **metabolic waste (urea & excess water)** and **useful substances (glucose & amino acids)** to kidney tubule

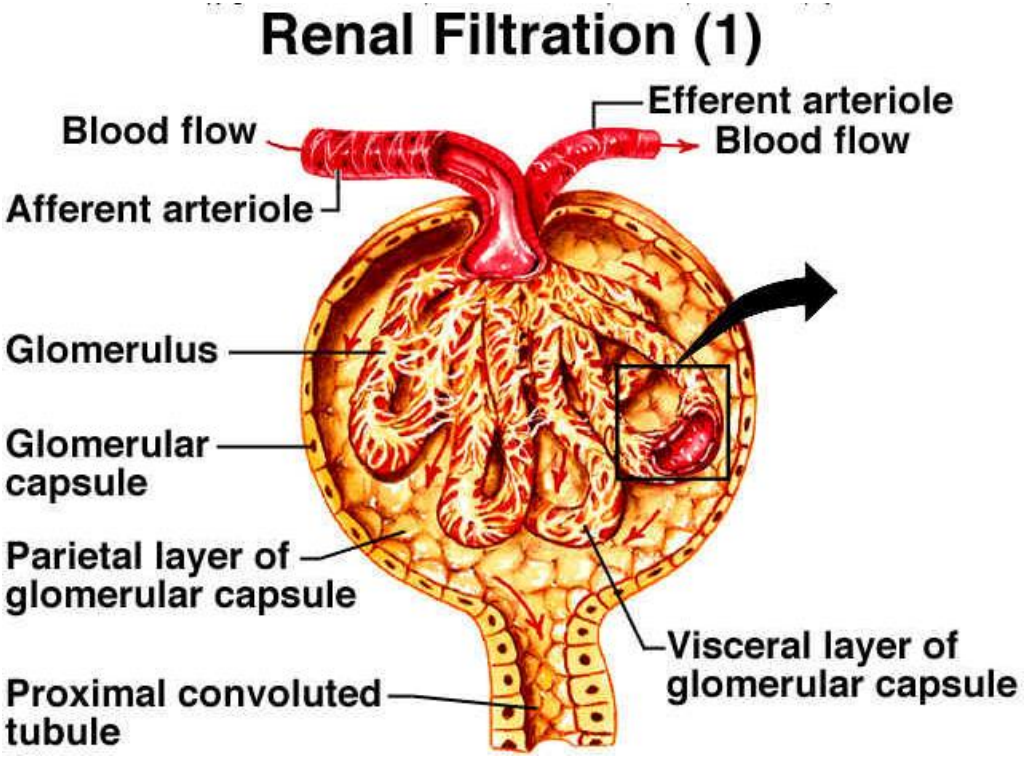
All small molecules (urea, glucose & amino acids) are forced into kidney tubule by blood pressure (**Ultrafiltration**)

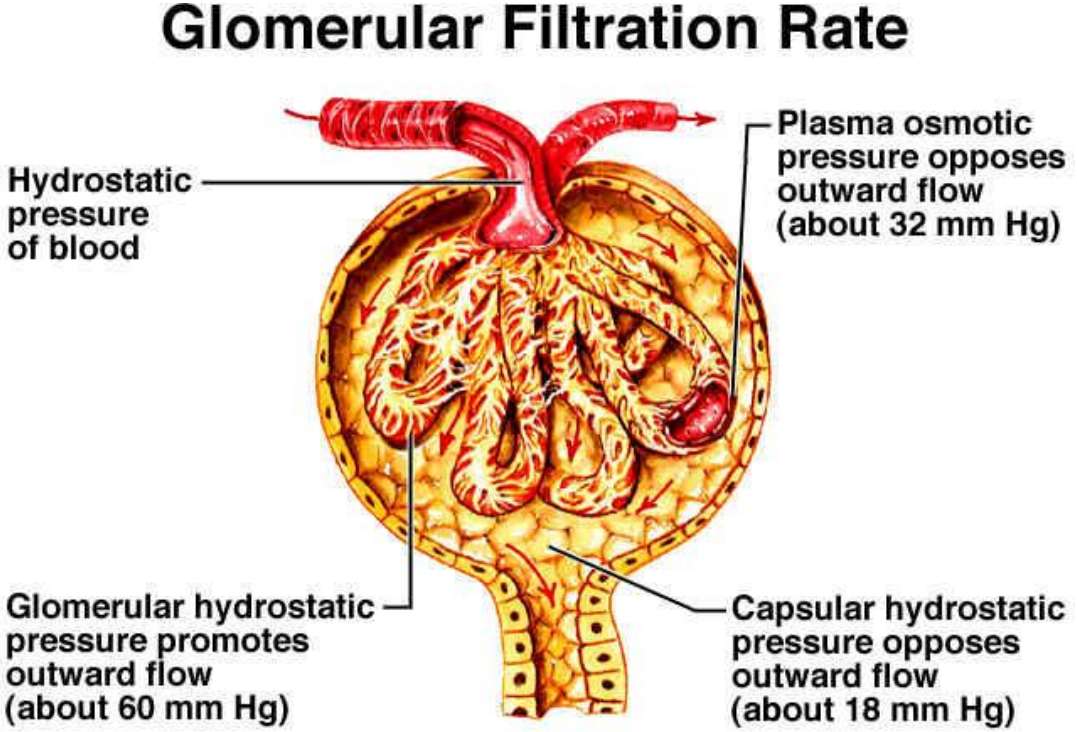
The fluids that can cross & filtered in the capsular space is called **glomerular filtrate**



Glomerular Filtration Rate (GFR)

→ the glomerular filtrate amount in both kidneys for every minutes





2.5.1 Glomerular Filtration

2.5.2 Tubular Reabsorption

Returning most of the filtered water & many of the filtered solutes to the bloodstream

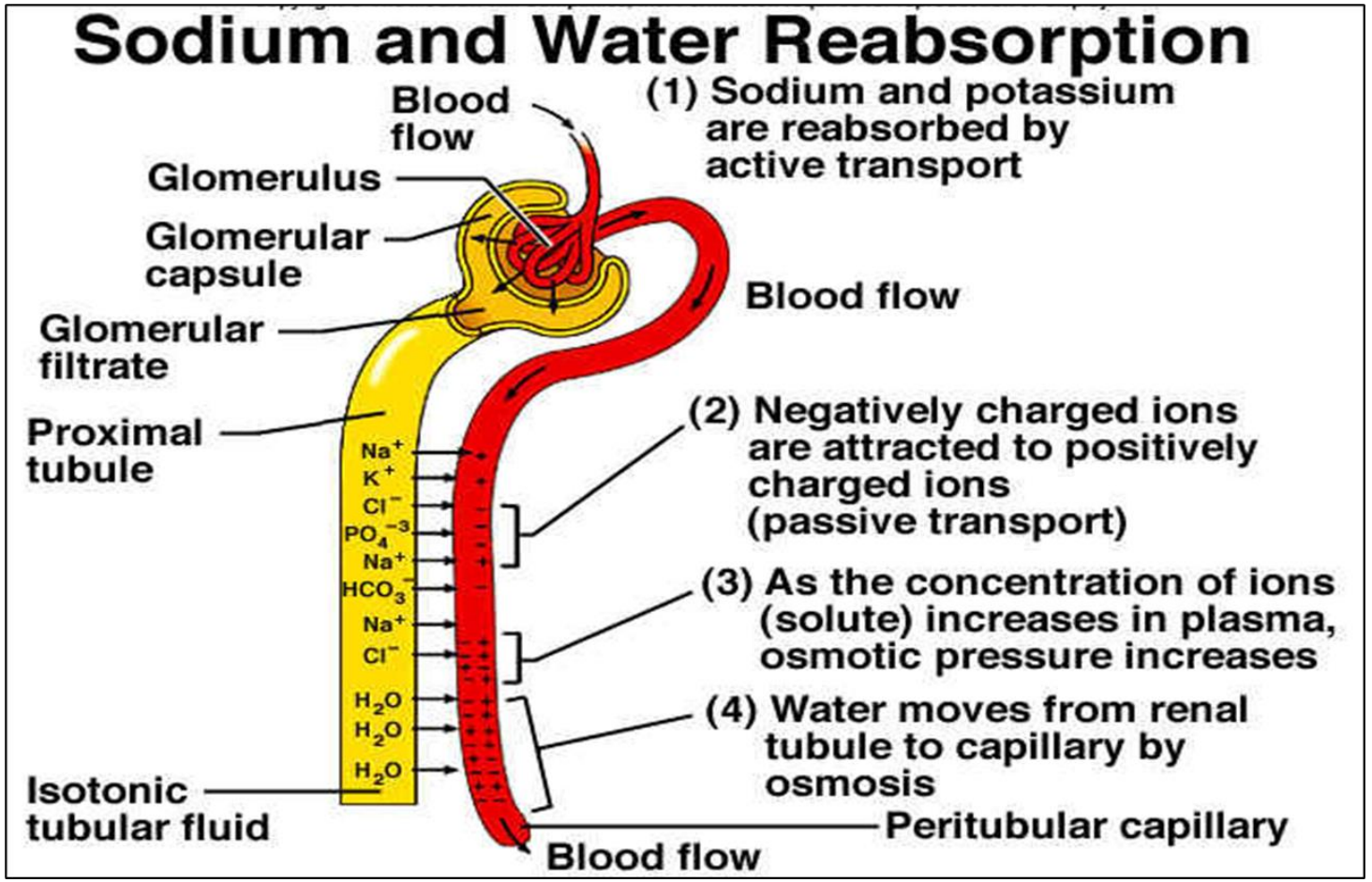
Mostly done by proximal convoluted tubule

Solutes that are reabsorbed:

- glucose, amino acids (useful substances) = by active transport
- water = by osmosis

Excess water, mineral salts & urea continue down to tubule to form urine

#Main hormone regulate reabsorption is ADH (anti-diuretic hormone)



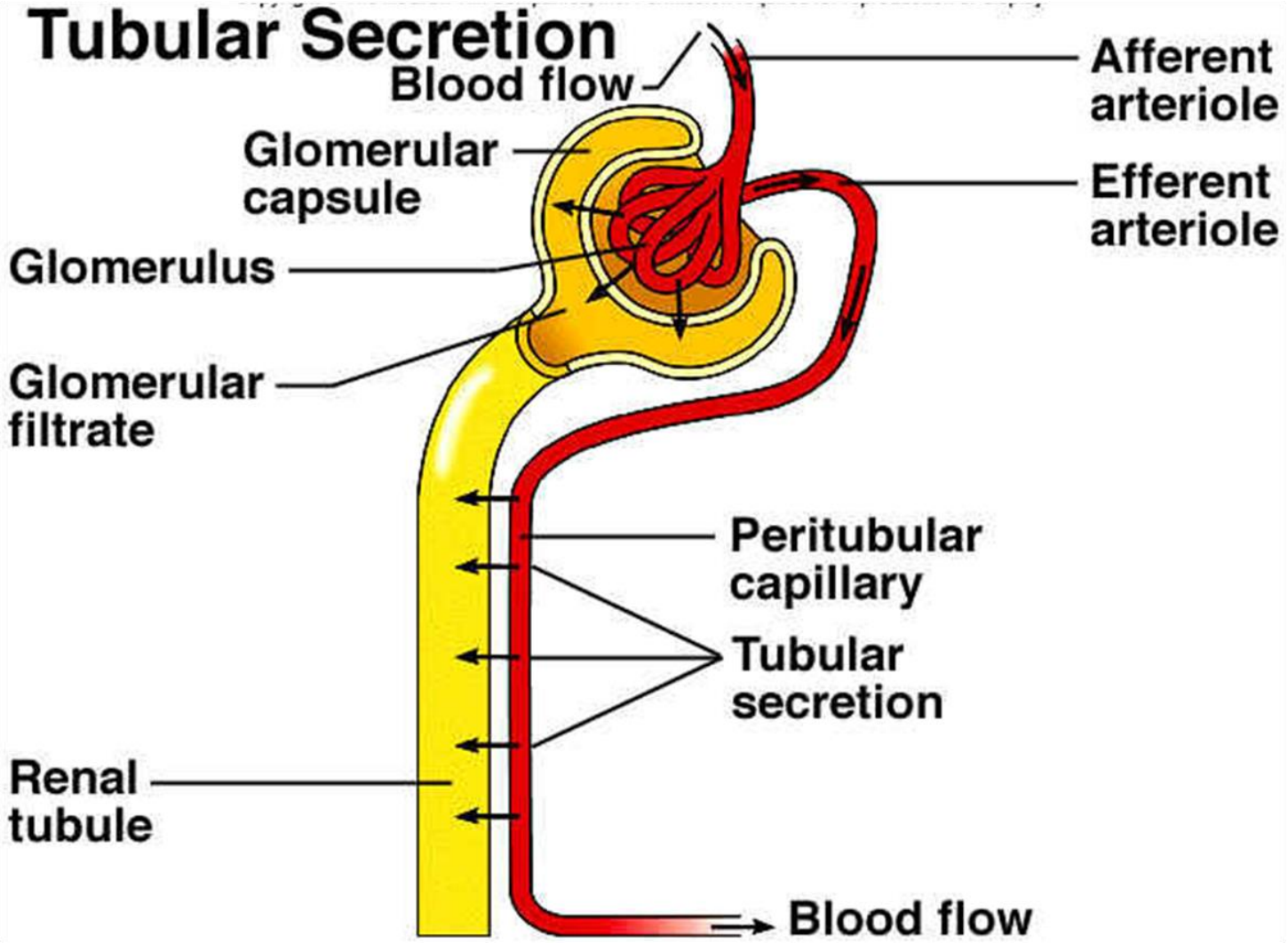
2.5.2 Tubular Reabsorption

2.5.3 Tubular Secretion

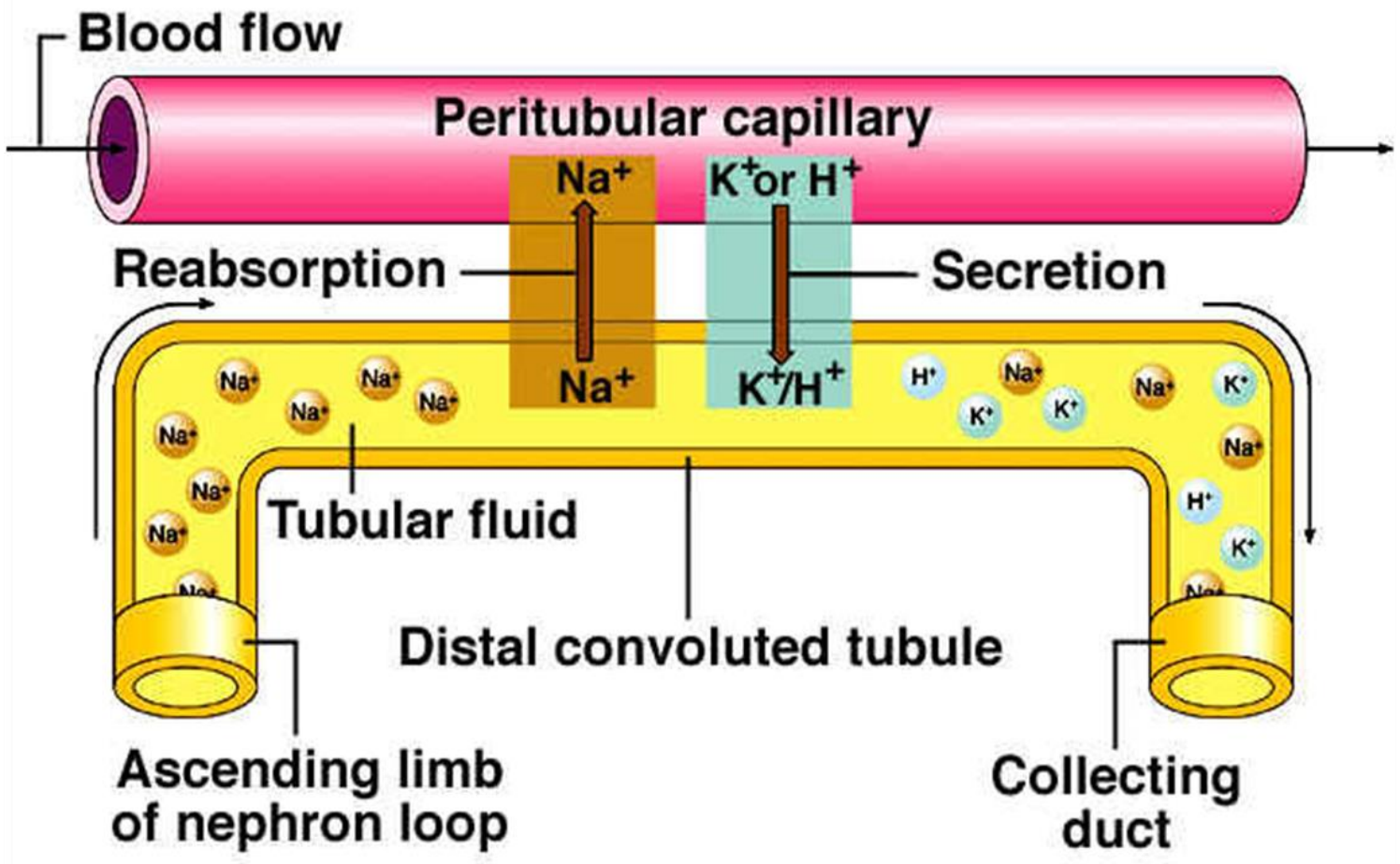
The transfer of materials from the blood into tubules

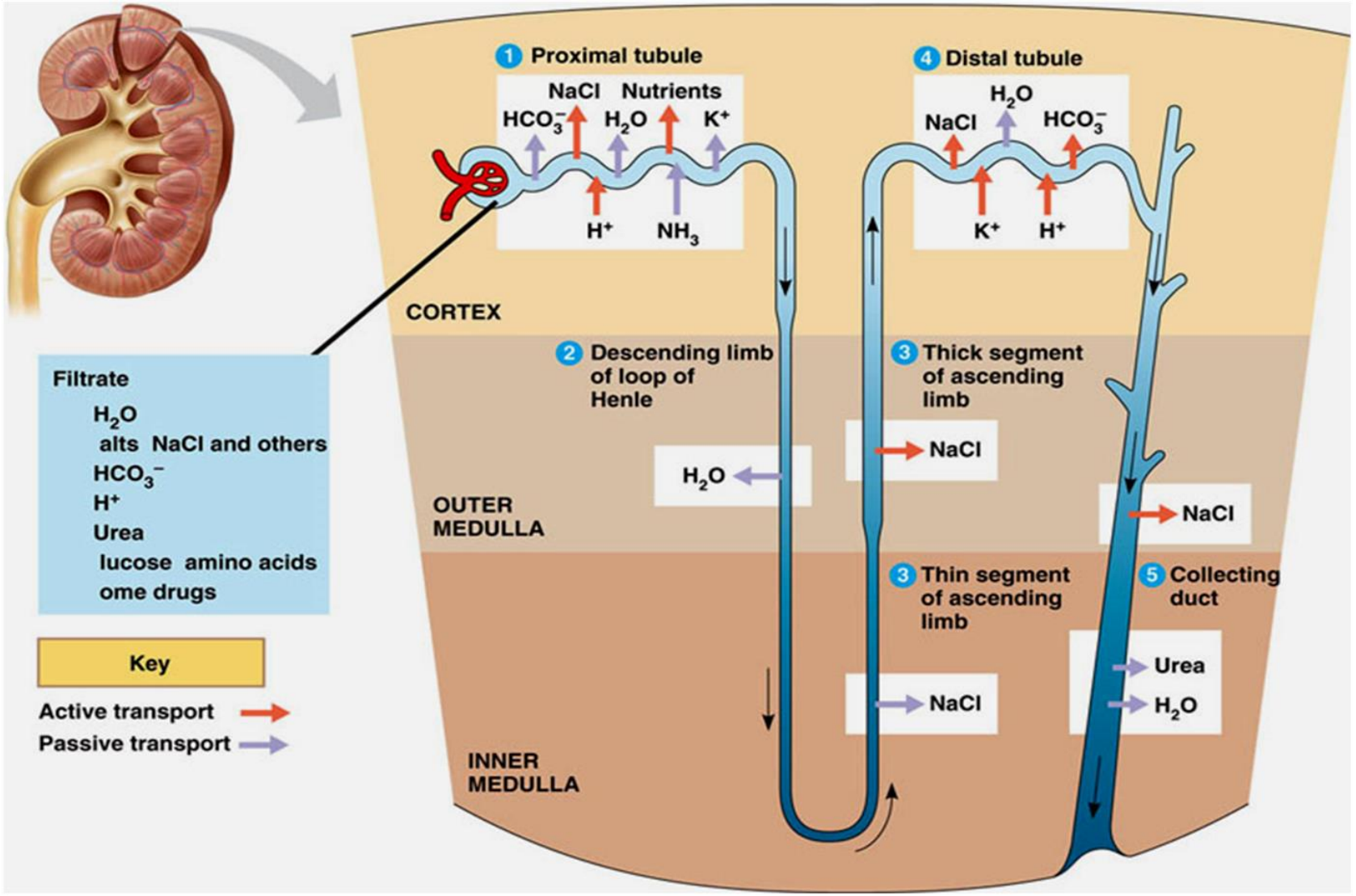
Secreted substances are:

- H^+, creatinine, ammonium (NH_4^+)



Tubular Reabsorption and Secretion




1 Proximal tubule
NaCl
Nutrients
HCO_3^-
H_2O
K^+
H^+
NH_3
4 Distal tubule
H_2O
NaCl
HCO_3^-
K^+
H^+
CORTEX
2 Descending limb of loop of Henle
3 Thick segment of ascending limb
NaCl
H_2O
OUTER MEDULLA
NaCl
3 Thin segment of ascending limb
5 Collecting duct
Urea
H_2O
NaCl
INNER MEDULLA
Filtrate
H_2O
alts NaCl and others
HCO_3^-
H^+
Urea
lucose amino acids
ome drugs
Key
Active transport
Passive transport

Summary

Process	Substances Involved
Glomerular filtration	Water, glucose, amino acids, salts and urea pass through the glomerulus
Tubular reabsorption	Water, glucose, amino acids, vitamins, bicarbonates, calcium, magnesium, sodium and potassium
Tubular secretion	Ammonia, creatine, hydrogen, potassium and some drugs

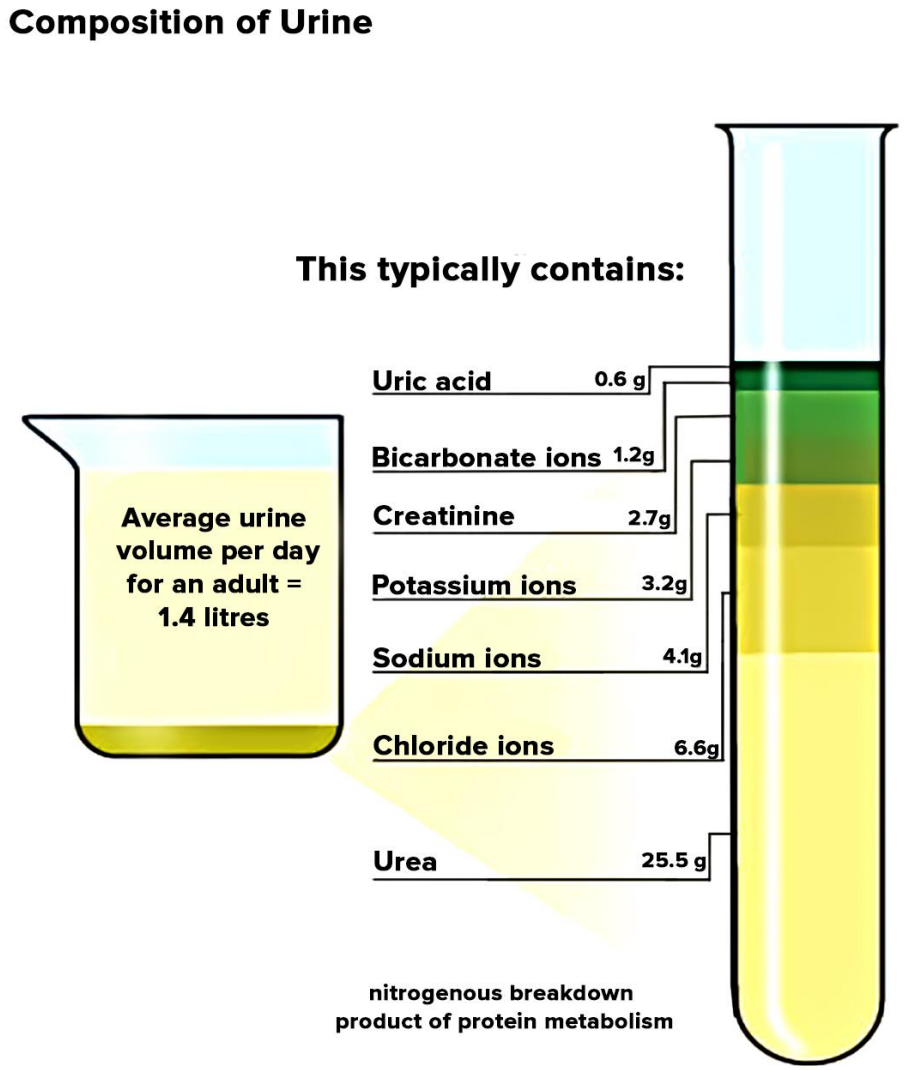
2.5.4 Constituents of Urine

Constituents of Urine

- **Nitrogenous waste products** → urea, uric acid & creatinine
- **Electrolytes** → sodium chloride, sulfate & phosphates
- **Pigment** → from bile compounds, foods & drugs

5% solutes including: urea, sodium, potassium, phosphate and sulfate ions, creatinine, uric acid

95% water



2.5.5 Composition of Urine

95% Water

5% includes:

- - Urea
- - Uric acid
- - Creatinine
- - Ammonia
- - Sodium
- - Potassium
- - Chlorides
- - Phosphates
- - Sulphates
- - Oxalates

2.6 Evaluation of Kidney Function

URINALYSIS

- Analysis of the **volume**, **physical**, **chemical** & **microscopic** properties of urine
- Screening test or to look for signs of infection, kidney or liver disease, diabetes or other health conditions
- 1.5L / day, yellow color (normal)
- Smell = ammonia

2.6 Evaluation of Kidney Function

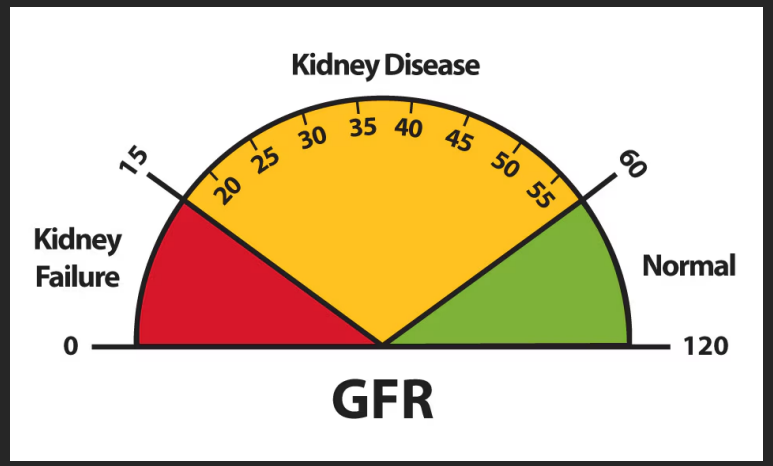
BLOOD TEST

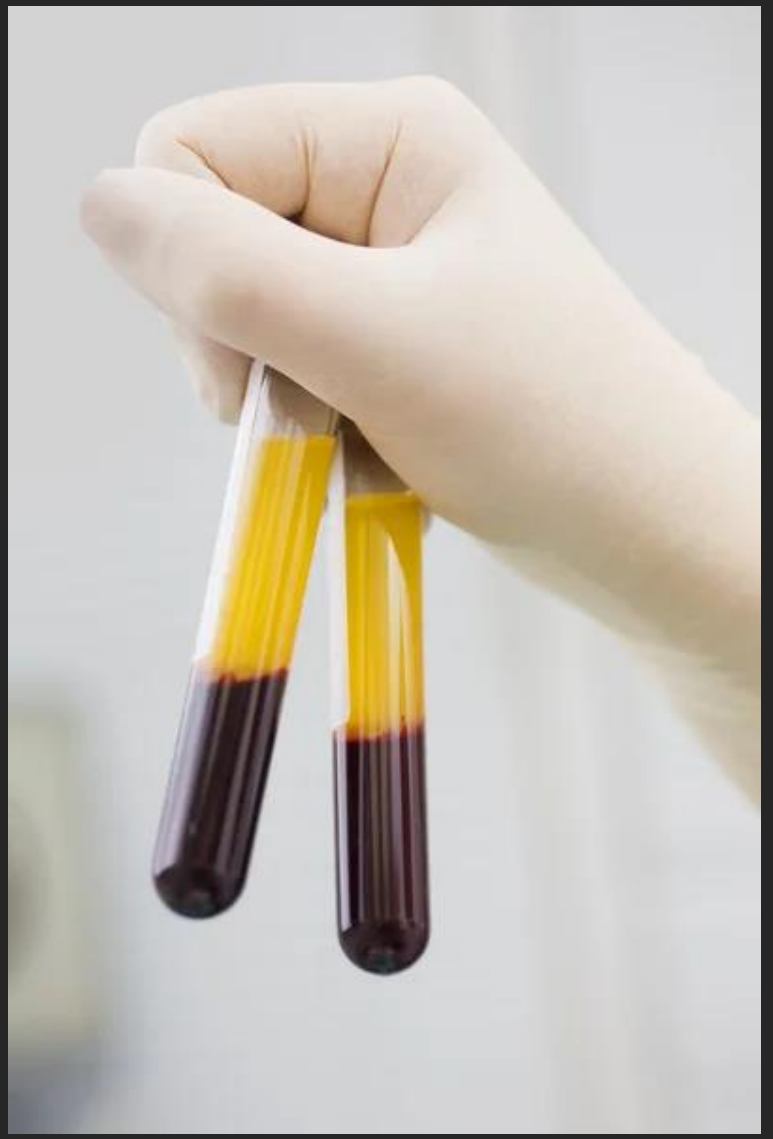
- **Blood urea nitrogen (BUN)**
  - measures the amount of urea nitrogen in blood
  - 2.9 – 9.3 mmol/ L
- **Plasma creatinine**
  - measure of how well kidneys are performing their job of filtering waste from the blood
  - 45 – 105 µmol/ L

2.6 Evaluation of Kidney Function

RENAL PLASMA CLEARANCE

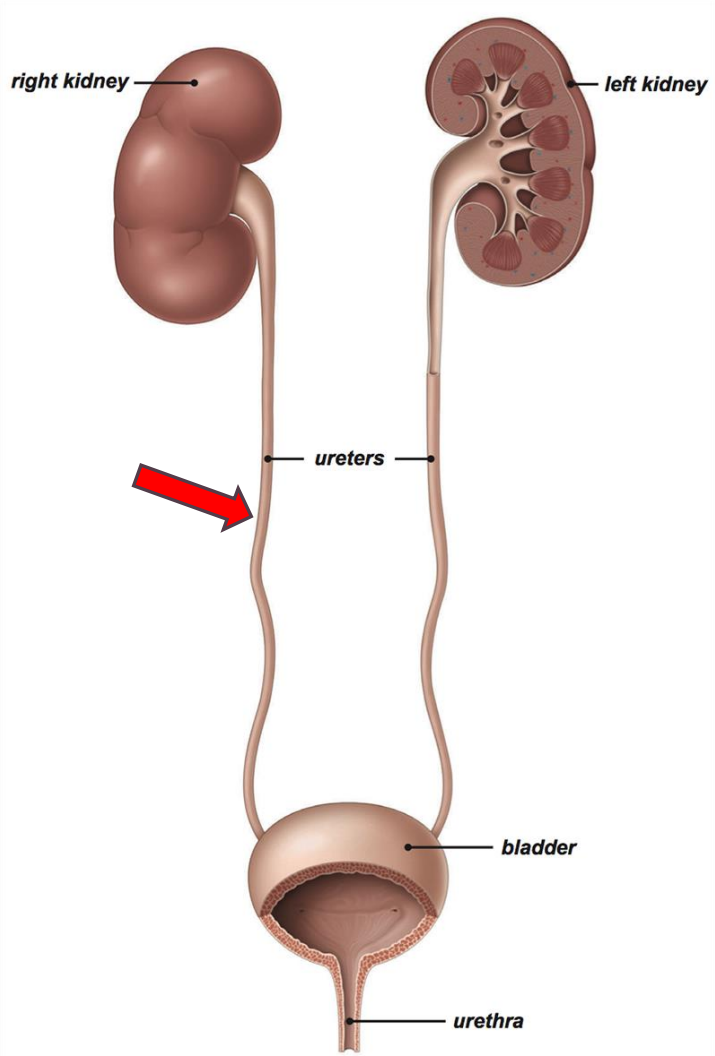
- The volume of plasma containing that amount of the substance that is removed by the kidney in unit time





2.7 Ureters

- Long, narrow tube (1/4 inch (3 mm)) wide and 10 to 12 inch (25 – 30 cm) long
- Thick wall
- Retroperitoneal organ
- At the base of urinary bladder, ureters curve medially & pass posterior urinary bladder
- Main function: **Propel urine from the kidneys into the bladder** by peristalsis contraction of the smooth muscle layer



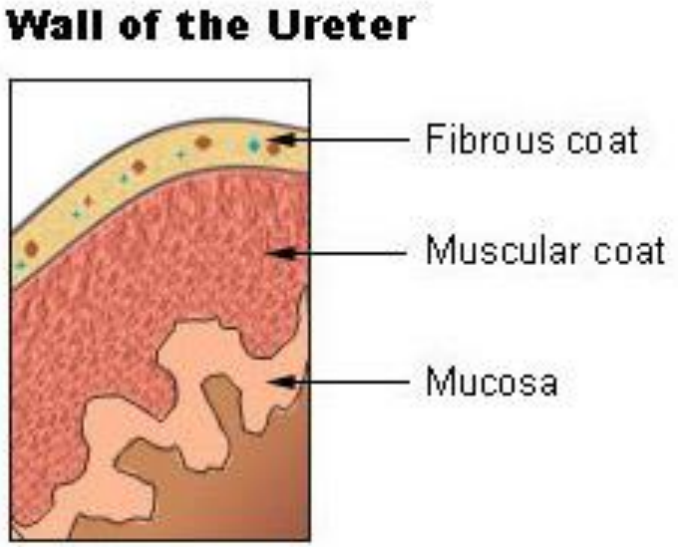
2.7.1 Structure of the Ureters

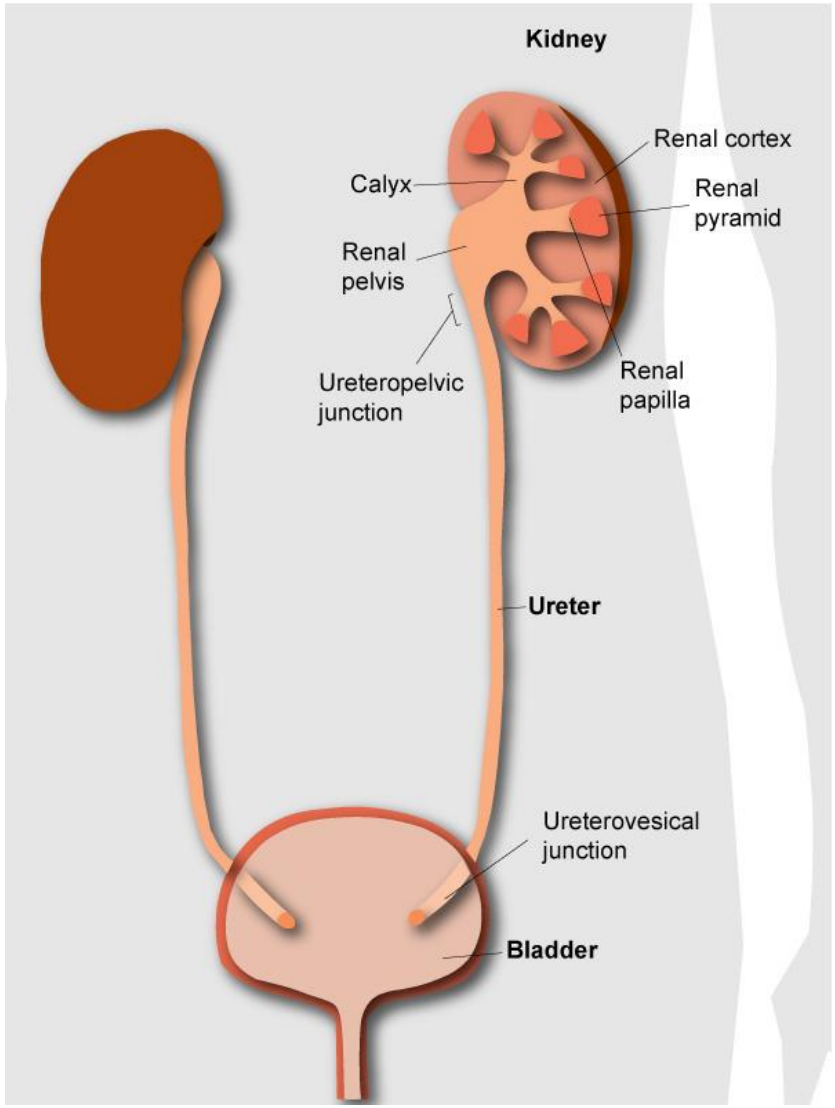
Ureters consist of THREE (3) layers of tissue

Outer
- fibrous tissue (adventitia)

Middle
- muscular layer consisting of interlacing smooth muscle fibres

Inner
- mucosa, composed of transitional epithelium





2.7.1 Structure of the Ureters

Consists of TWO (2) junction:

a) Ureteropelvic Junction

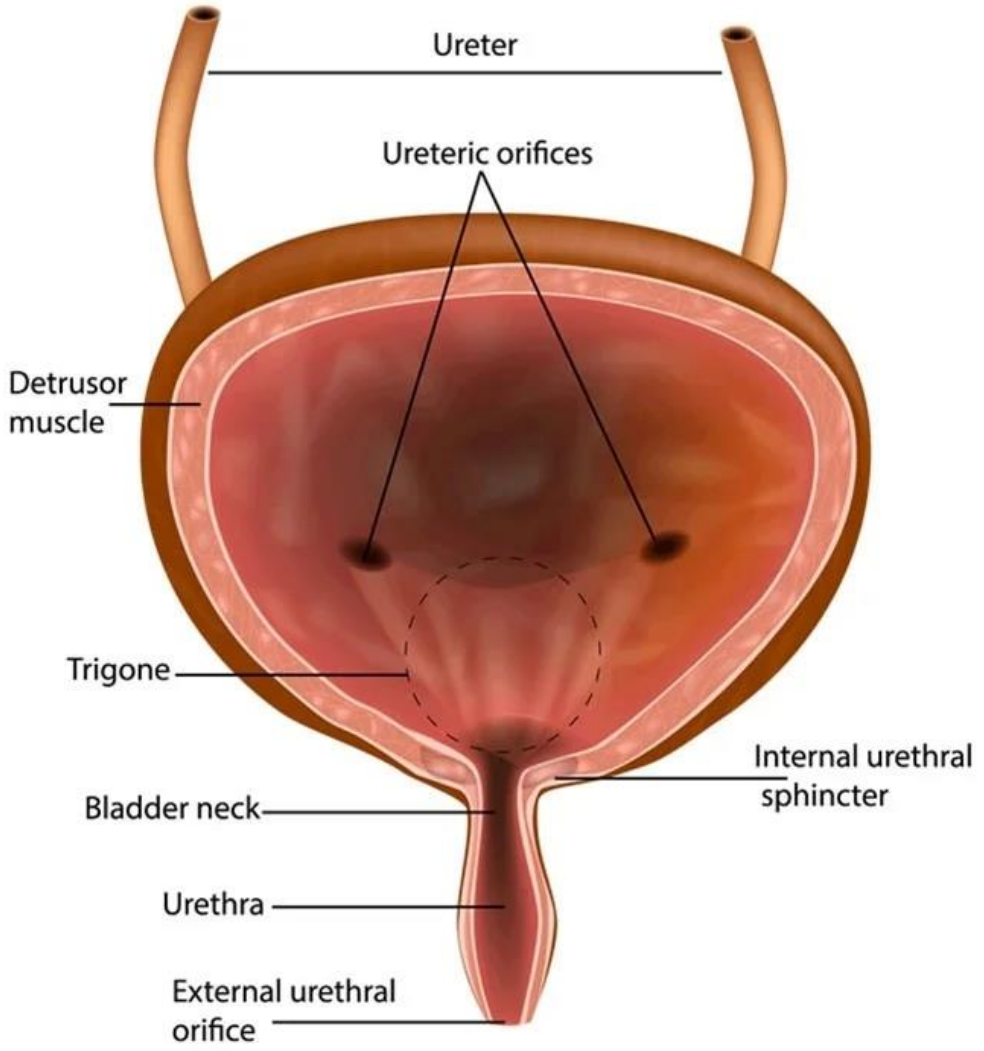
- area where the ureter meets the renal pelvis

b) Ureterovesical Junction

- area where the ureter meets the bladder

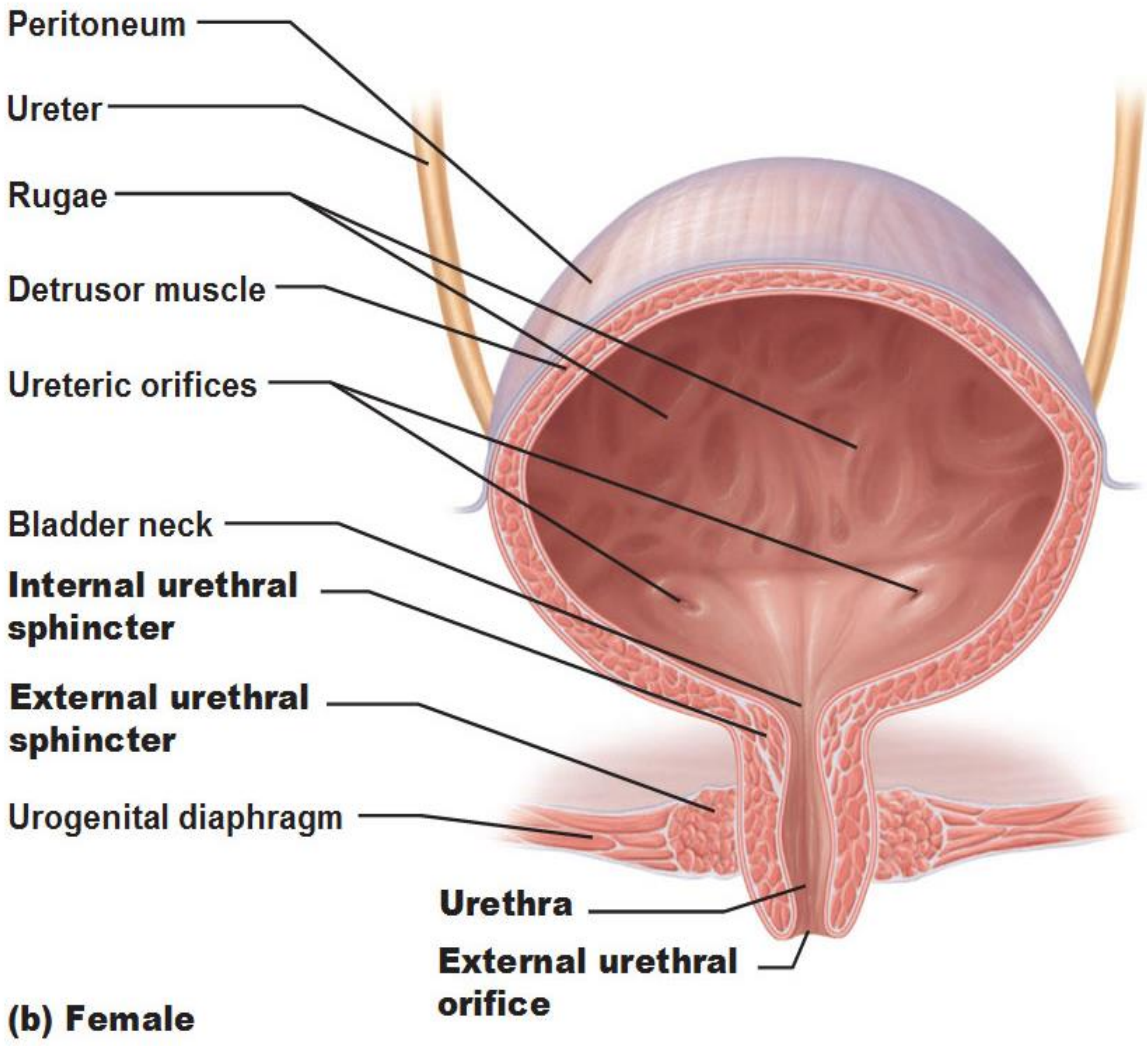
2.8 Urinary Bladder

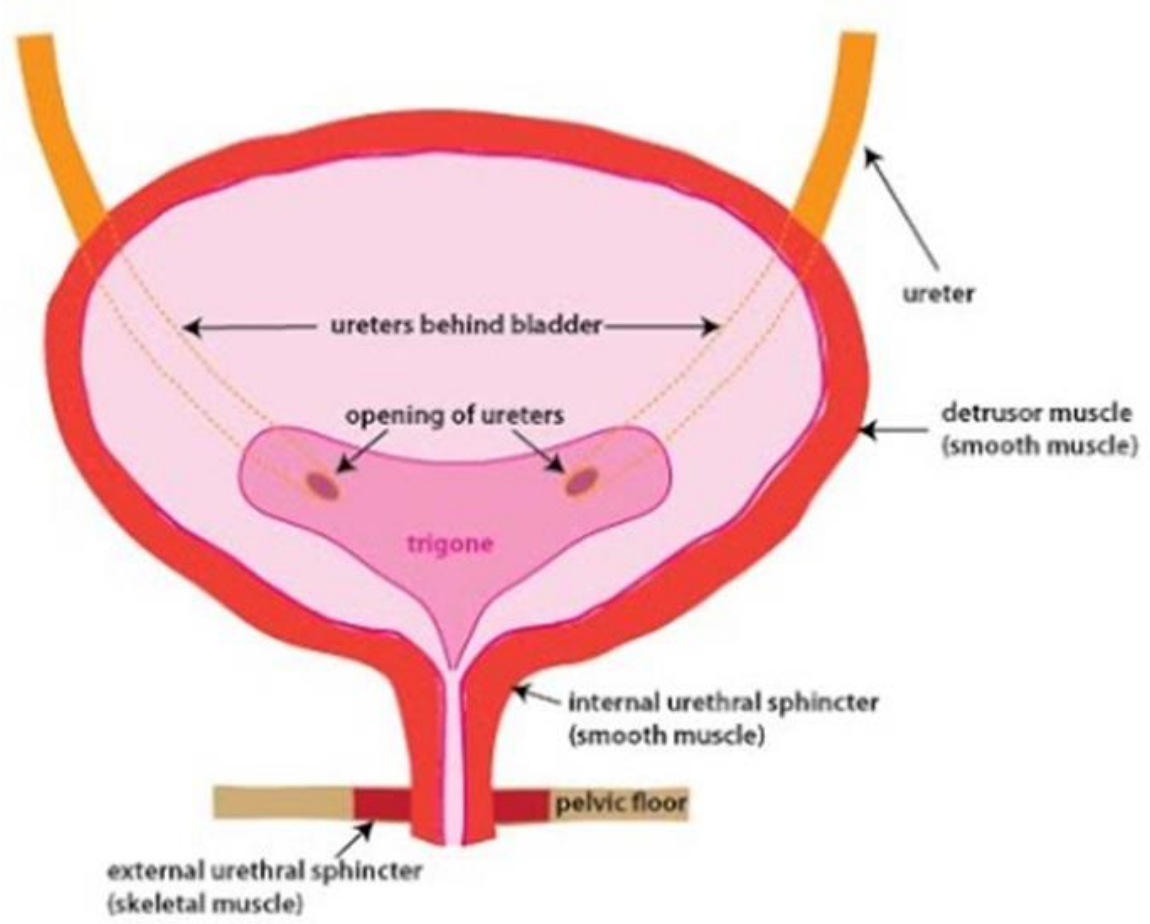
- Simply called bladder
- Hollow, muscular, pear – shaped organ
- Location: pelvic cavity
- Capacity: 500mL of urine
- Main function: **Storage of urine**



2.8.1 Structures of Urinary Bladder

- Floor of the bladder is a small triangular area called = **TRIGONE**
- Three edge of the trigone are:
  - → two ureteral opening
  - → one internal urethral orifice
- Around the opening of the urethra got two circular fibers:
  - → internal urethral sphincter
  - → external urethral sphincter





2.8.1 Structures of Urinary Bladder

The trigone is a triangular – shaped region in floor of bladder

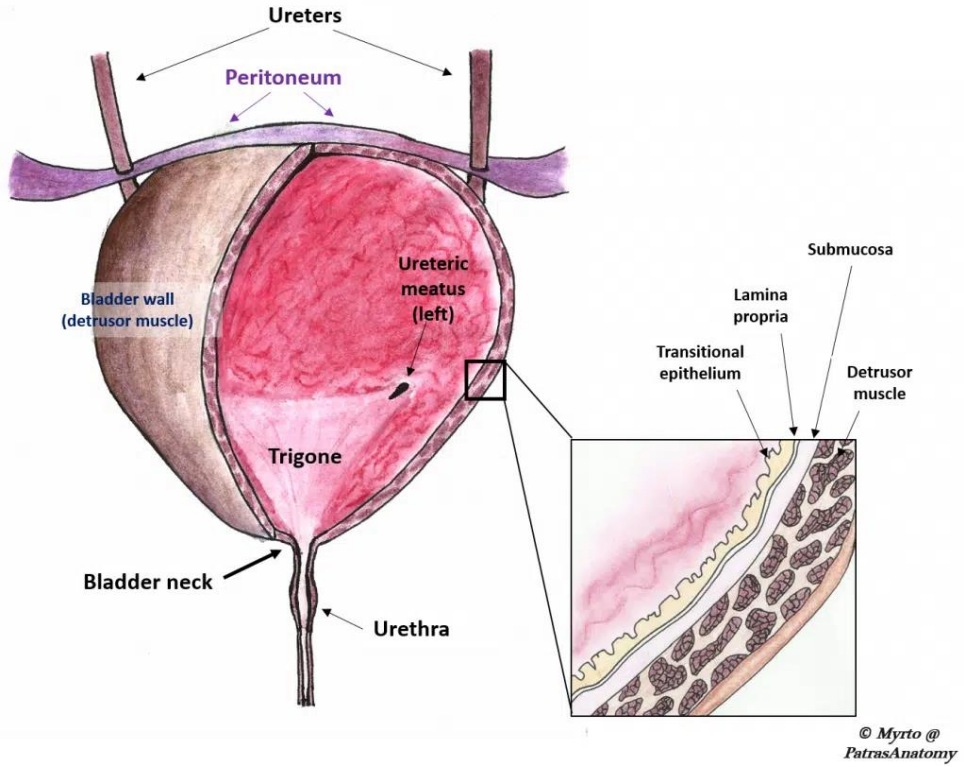
Marked by the openings of the two ureters and urethra

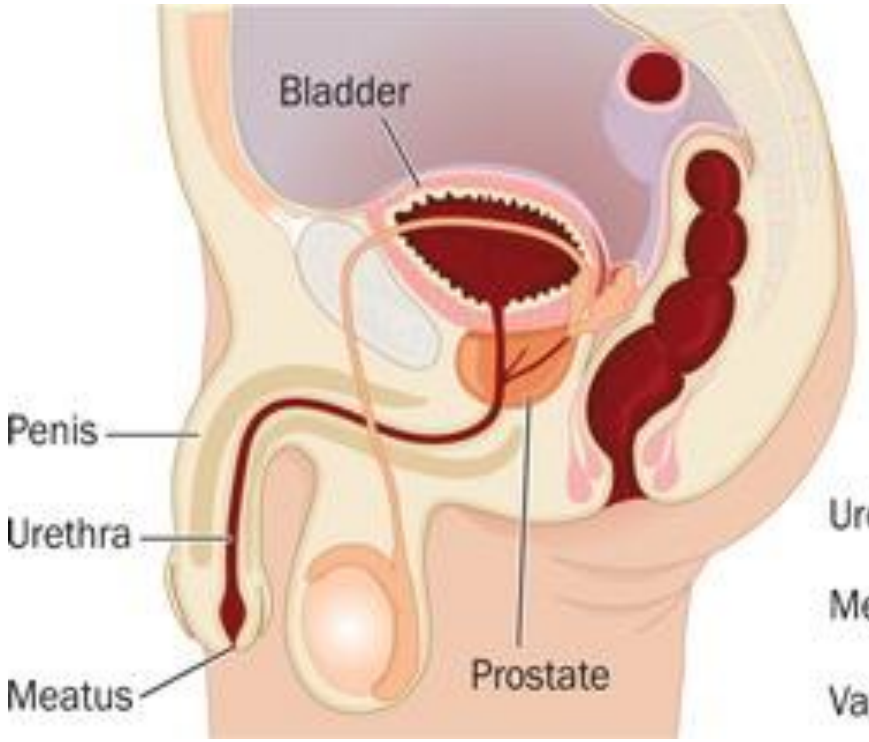
As the bladder fills with urine, it expands upward, leaving the trigone at the base stationary

This prevents stretching of the ureteral openings and possible backflow

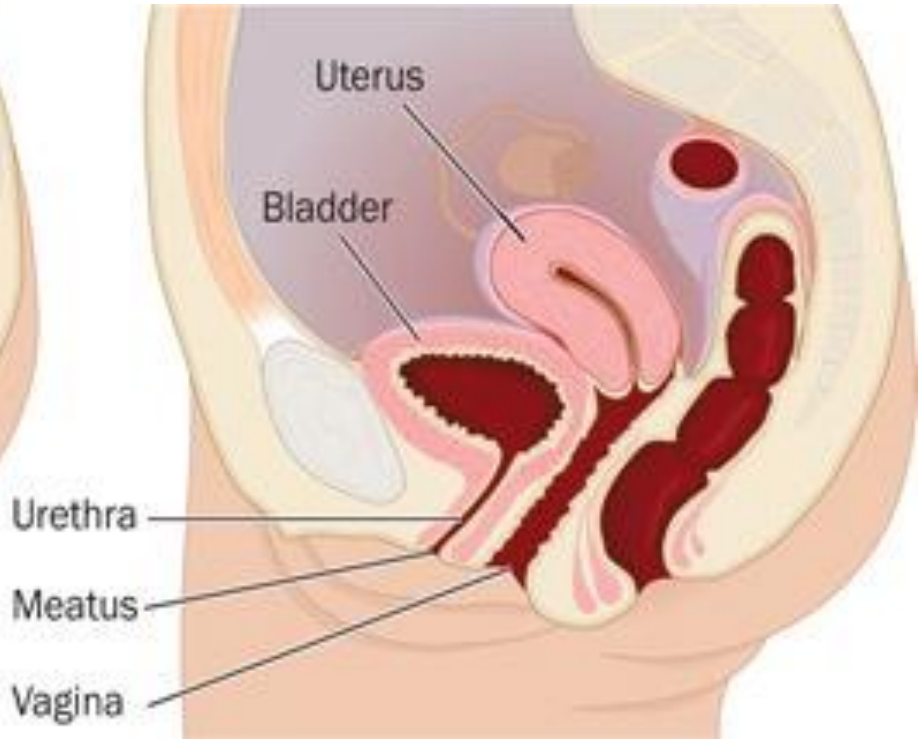
2.8.1 Structures of Urinary Bladder

Bladder wall composed of THREE (3) layers:	outer layer of loose connective tissue containing blood and lymphatic vessels and nerves, covered on the upper surface by the peritoneum
	middle layer of interlacing smooth muscle fibres and elastic tissue called the detrusor muscle
	inner layer of mucosa, composed of transitional epithelium





Male Bladder



Female Bladder

2.8.2 Comparison Between Male & Female Bladder

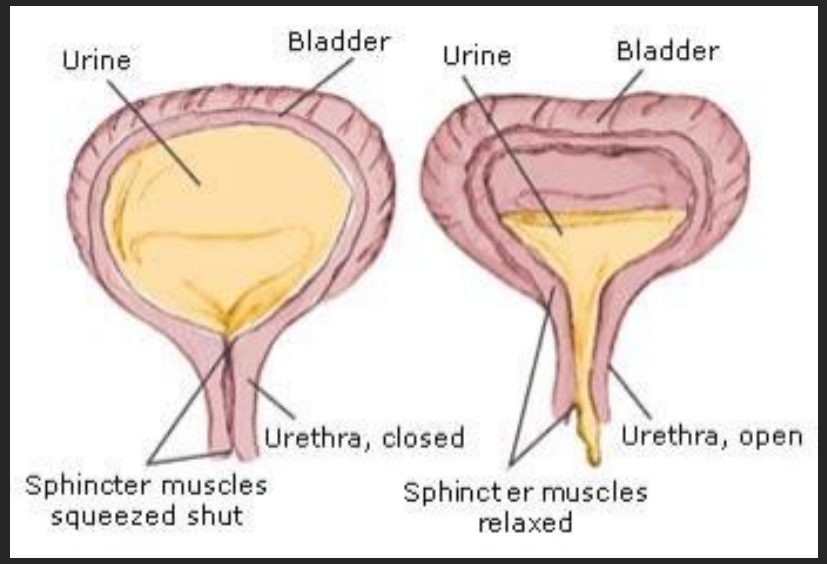
2.9 Urethra

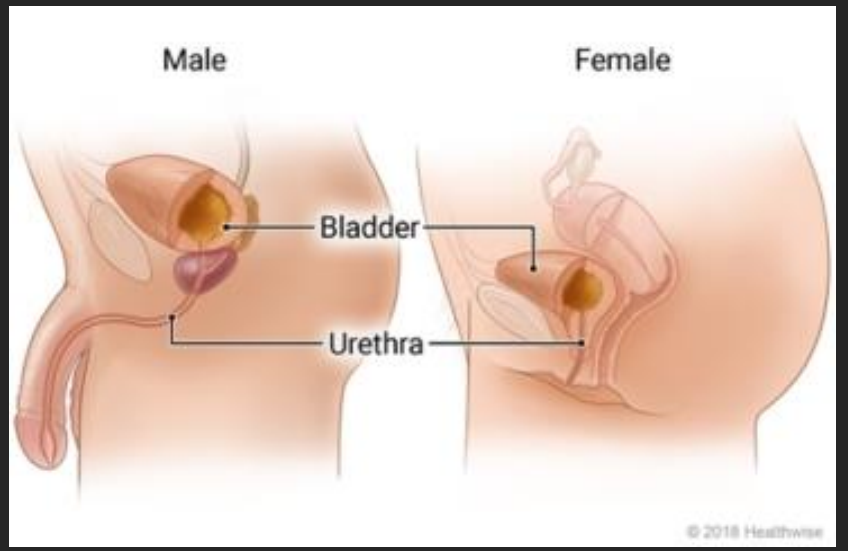
A canal extending from neck of bladder to external urethral orifice

Longer in the male (19 – 20 cm) than in female (4 cm)

External urethral orifice is guarded by the external urethral sphincter (voluntary control)

Main function: **Allows urine to pass outside the body**

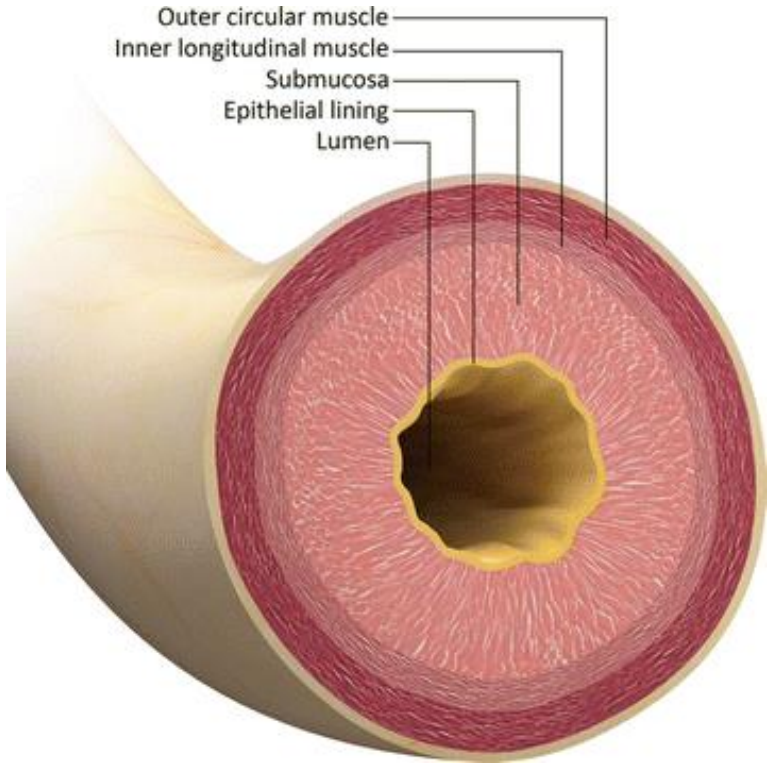




2.9.1 Structures of the Urethra

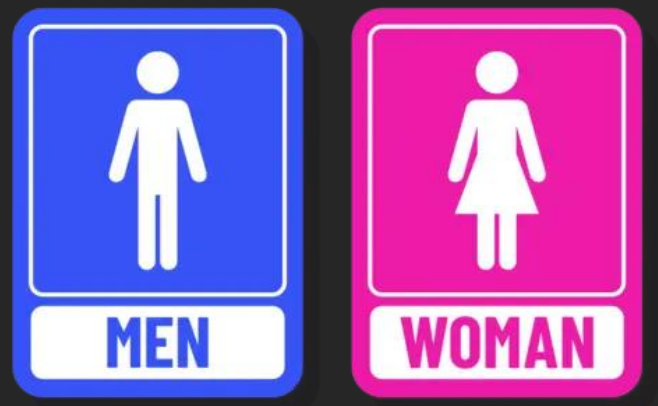
The walls consist of THREE (3) layers of tissue:

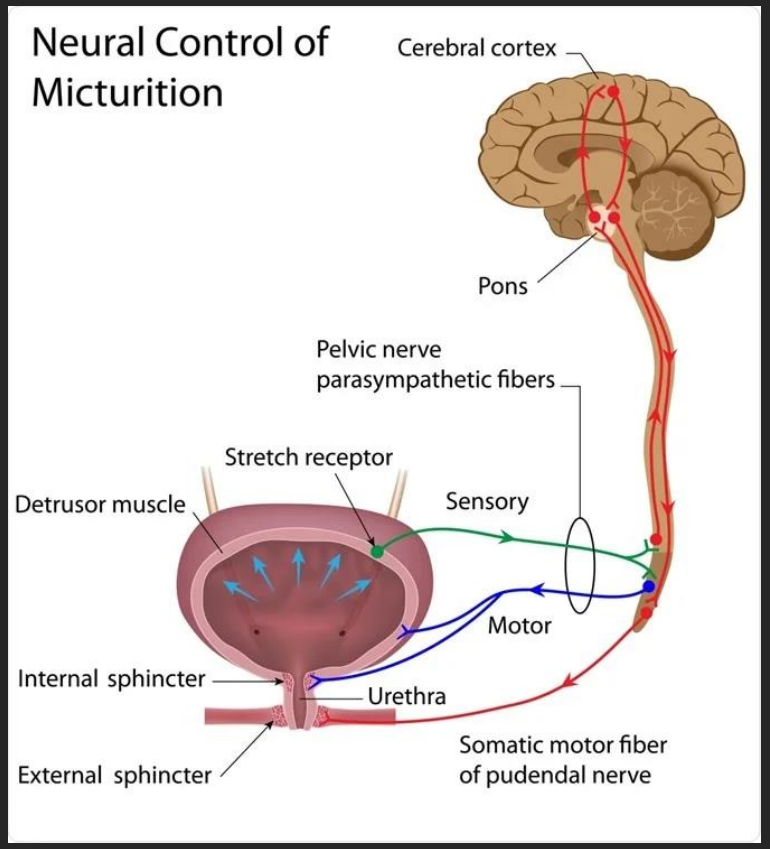
- The **muscle layer** is continuous with that of the bladder. It is mainly elastic tissue and smooth muscle fibres, under autonomic nerve control.
- The **submucosa** is a spongy layer containing blood vessels and nerves.
- The **mucosa** is continuous with that of the bladder in the upper part of the urethra. The lower part consists of stratified squamous epithelium, continuous externally with the skin of vulva.



2.10 Micturition

- Discharge of urine from the urinary bladder
- Also called → urination, pass urine (PU) or voiding
- The process is a combination of involuntary & voluntary muscle contractions





Volume of urine in bladder reaches more than 200 – 400 ml

Stimulation of stretch receptors

Nerve impulse transmit to the spinal cord

Spinal cord propagate impulse to the micturation centre at S_2 & S_3

Trigger the micturition reflex

Contraction of the detrusor muscle

Relaxation of the internal urethral sphincter

Skeletal muscle relax at the external urethral sphincter (voluntary contraction)

Urination takes place

2.10.1 Mechanism of Micturition

REFERENCES

Human Anatomy & Physiology, 11th edition. Marieb E.N & Hoehn K (2018), USA: Benjamin Cummings

Fundamentals of Anatomy & Physiology, 11th edition. Martini FH (2017): Pearson Benjamin Cummings, USA


Thank You