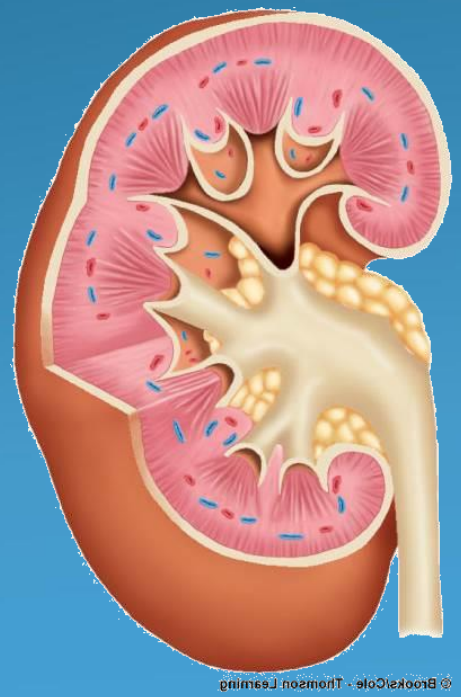
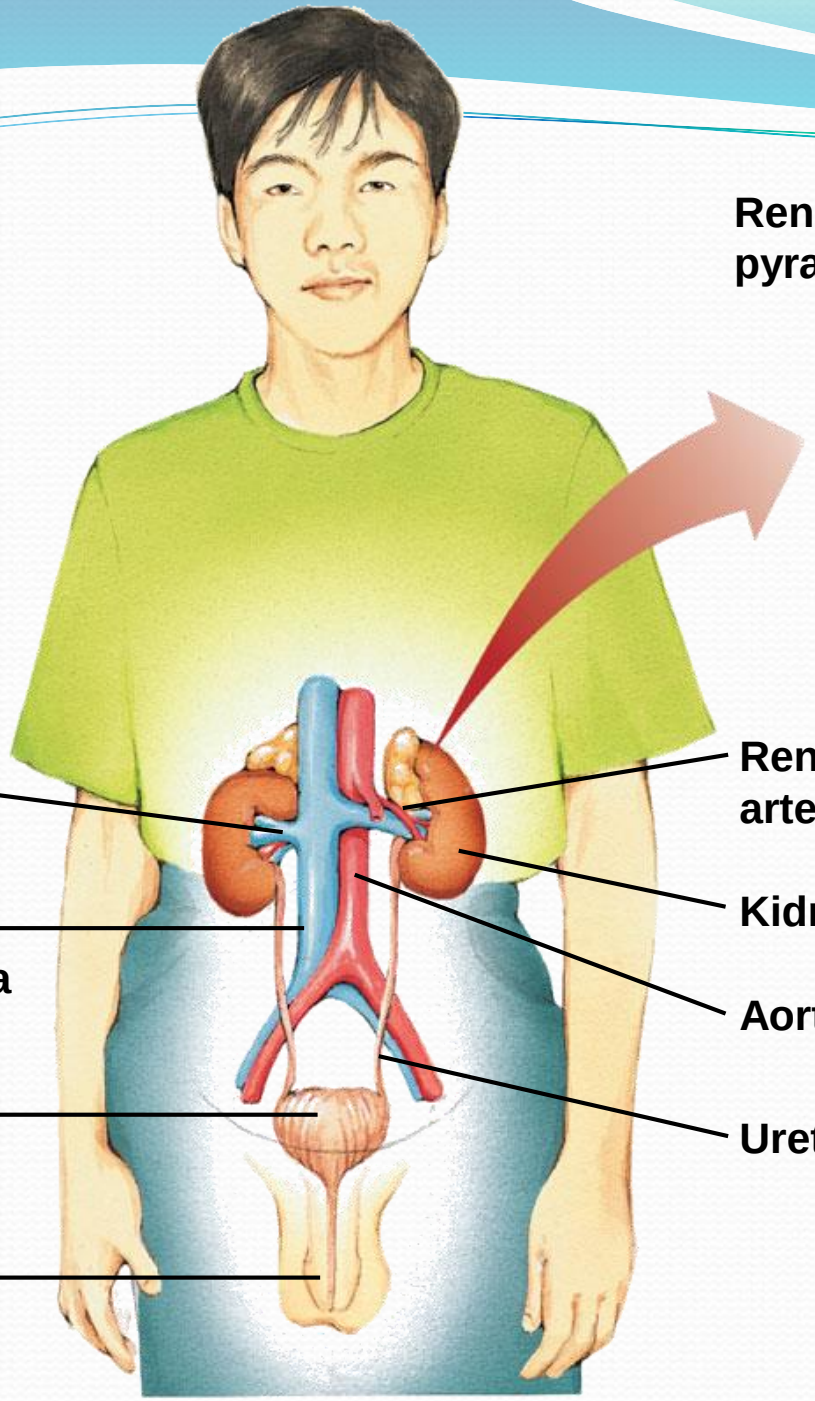
# The Urinary System
# part one




*Dr. A. K.Goudarzi, D.V.M. Ph.D*
*Faculty of Veterinary Medicine*
*Department of Basic Sciences*


Renal vein
Inferior vena cava
Urinary bladder
Urethra
Renal artery
Kidney
Aorta
Ureter
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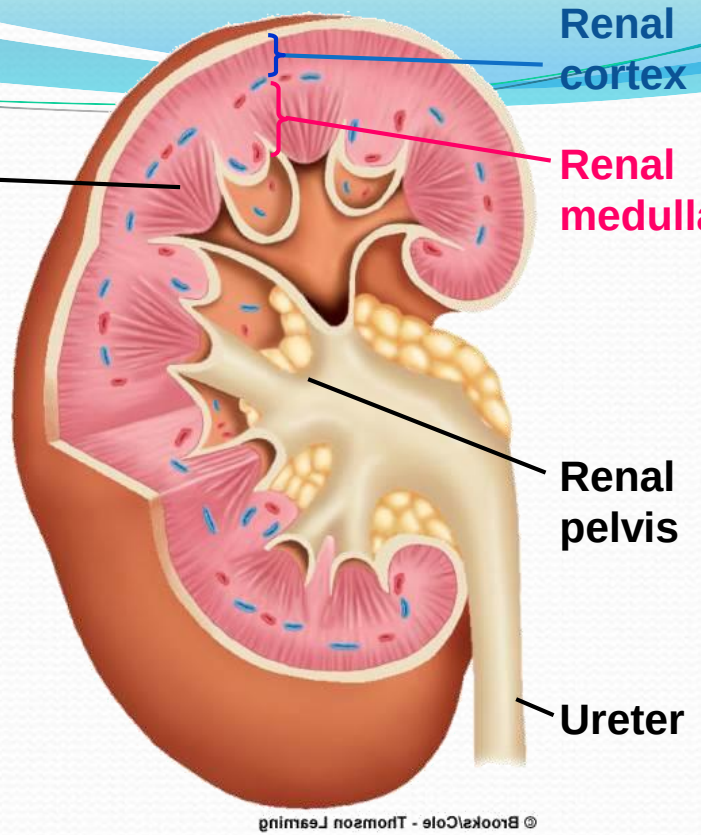
Renal cortex
Renal medulla
Renal pyramid
Renal pelvis
Ureter
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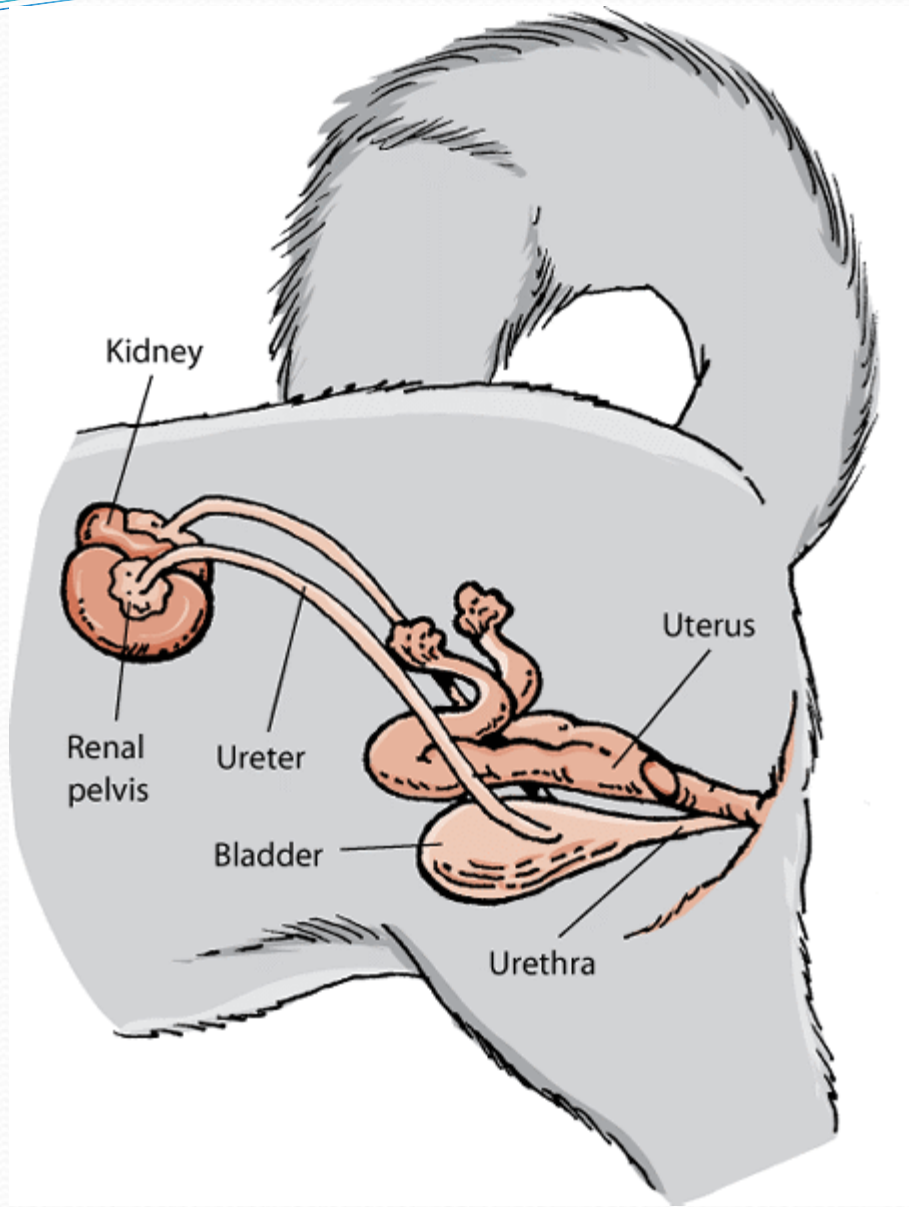
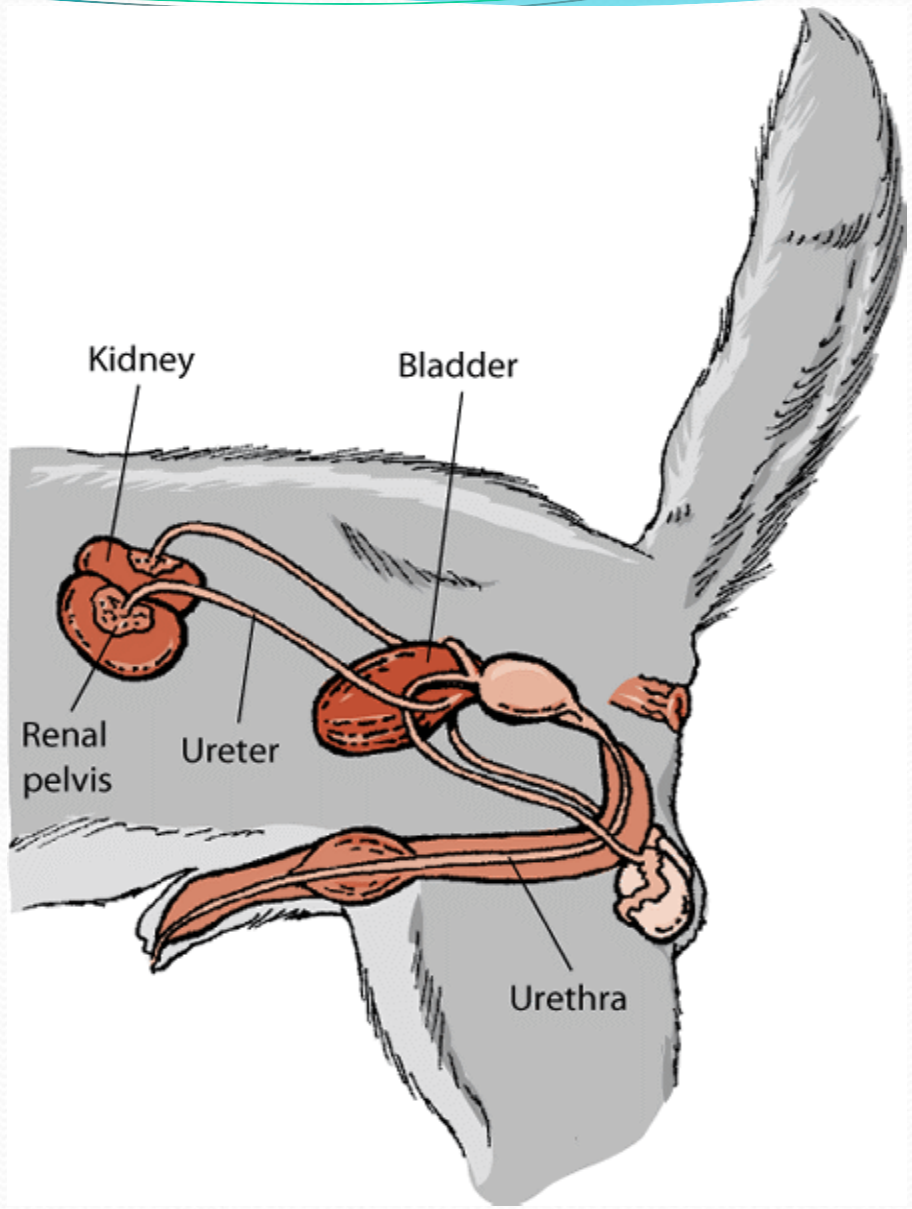
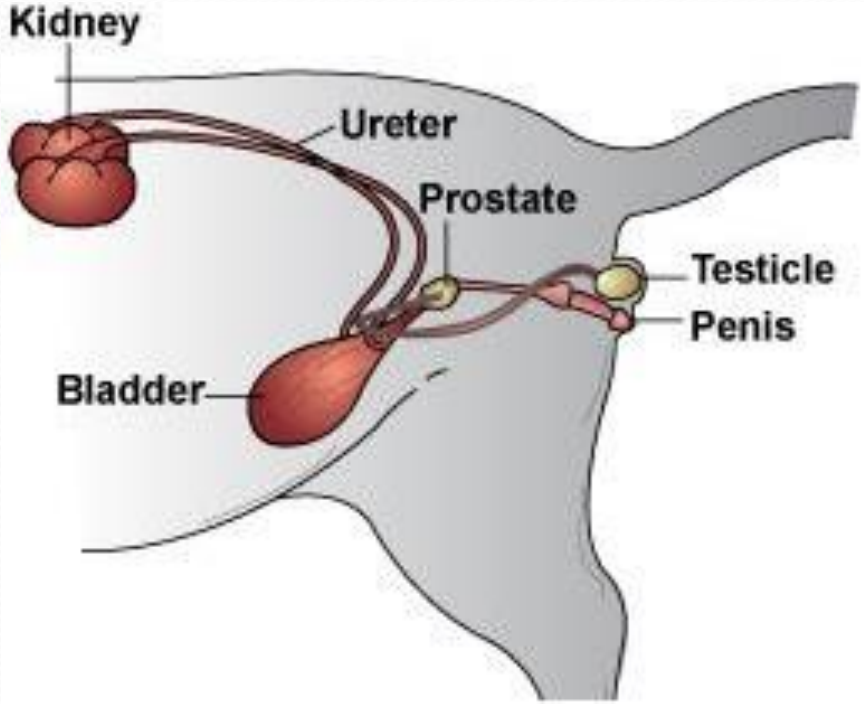
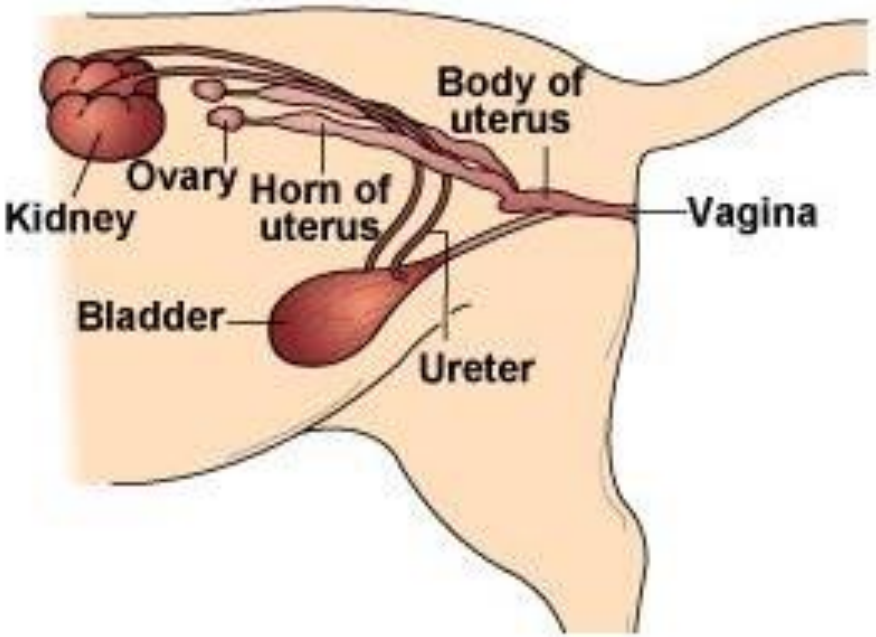

Kidney
Renal pelvis
Ureter
Uterus
Bladder
Urethra

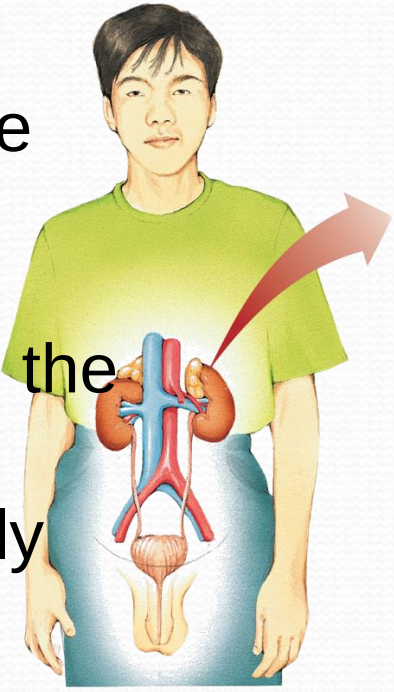

Kidney
Bladder
Renal pelvis
Ureter
Urethra


Kidney
Ureter
Prostate
Testicle
Penis
Bladder


Body of uterus
Ovary
Horn of uterus
Kidney
Vagina
Bladder
Ureter

# Urinary system

- Organ system that produces, stores, and carries urine
- Includes two kidneys, two ureters, the urinary bladder, two sphincter muscles, and the urethra.
- Humans produce about 1.5 liters of urine over 24 hours, although this amount may vary according to the circumstances.
- Increased fluid intake generally increases urine production.
- Increased perspiration and respiration may decrease the amount of fluid excreted through the kidneys.
- Some medications interfere directly or indirectly with urine production, such as diuretics.

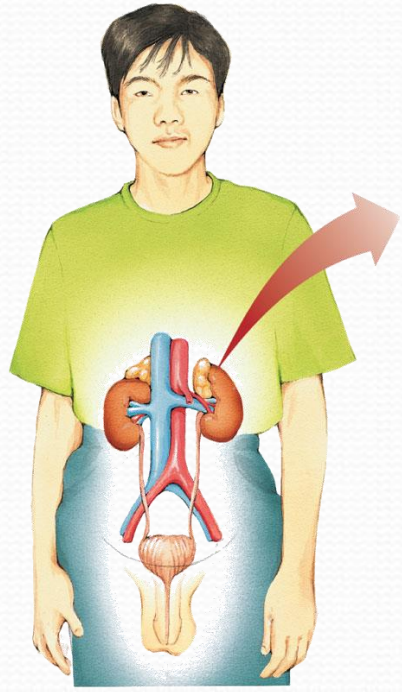


# Function of urinary system

- Excretion
- Keeping homeostasis
- Keeping acid-base balance
- Secretion (rennin, kallikrein, erytropoetin)

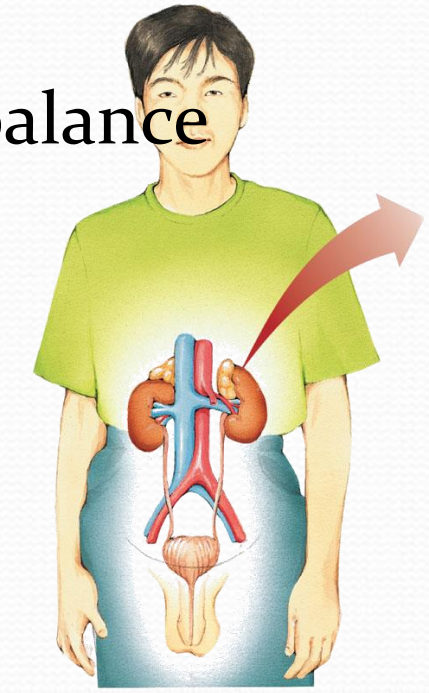
**Excreted products:**

- Product of the metabolism
- Water
- Hormones
- Vitamins
- Toxic substances



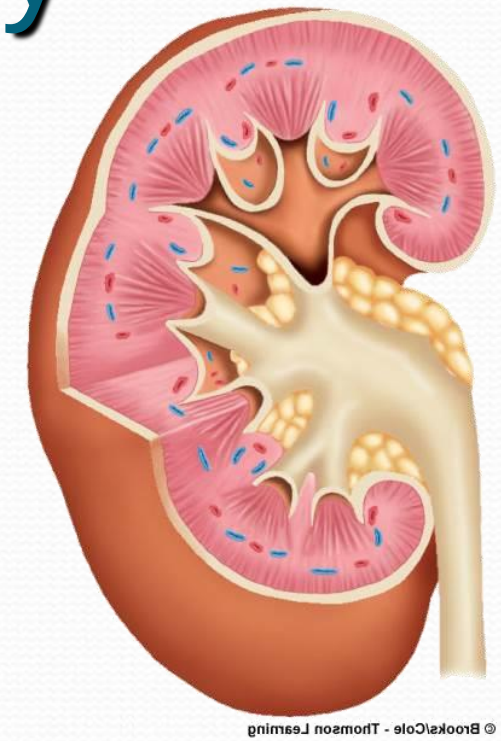
# Function of urinary system

- Other functions :
  - maintaining the proper osmolarity of body fluids
  - maintaining proper plasma volume
  - helping to maintain proper acid-base balance
  - excreting wastes of body metabolism
  - excreting many foreign compounds
  - producing erythropoietin and renin
  - converting vitamin D to an active form

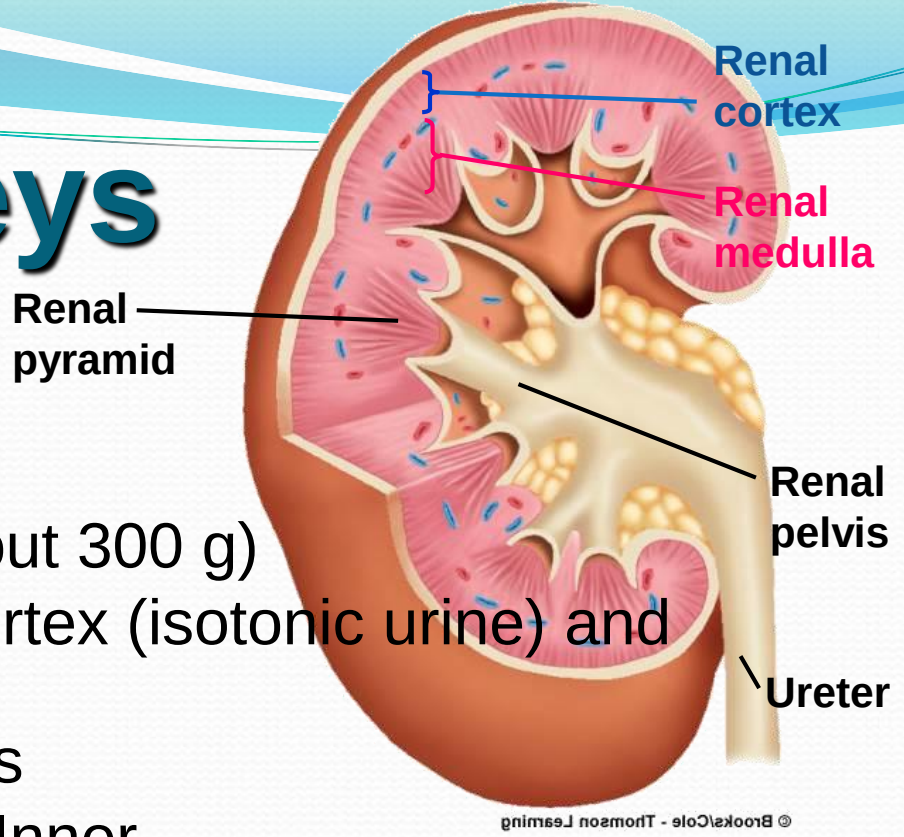


# Function of kidney

- Each kidney is supplied by a renal artery and renal vein. The kidney acts on the blood plasma flowing through it.
- As urine is formed, it drains into the renal pelvis and is channeled into the ureter.
- The urine is stored in the urinary bladder. It is emptied periodically through the urethra.
- The urethra serves the urinary and reproductive tracts in the male.

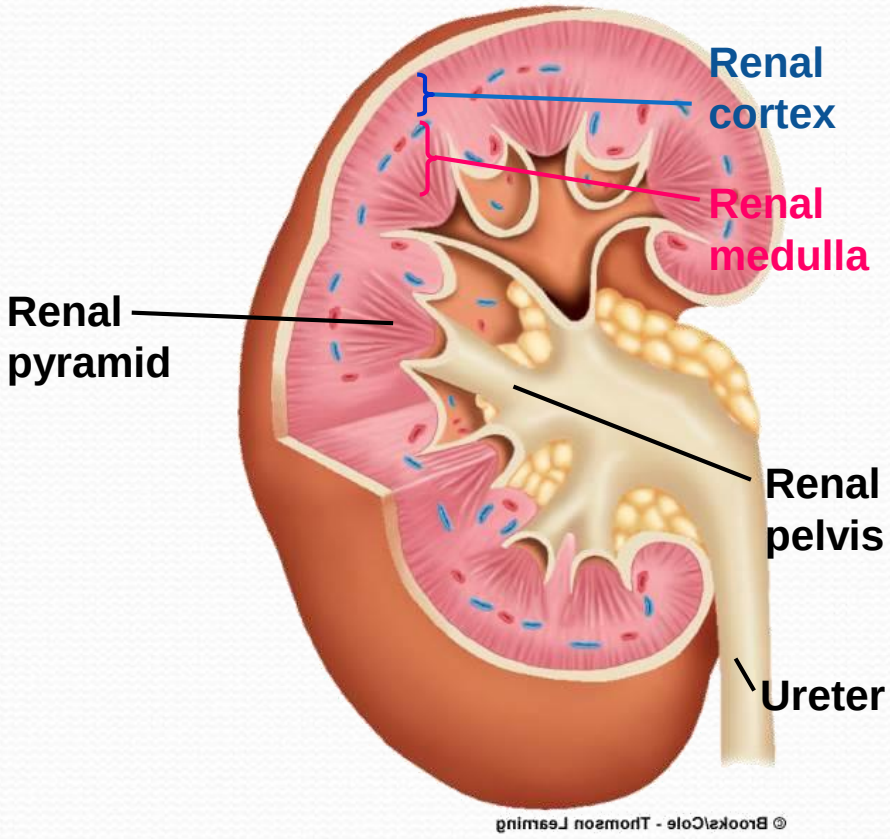


# Kidneys



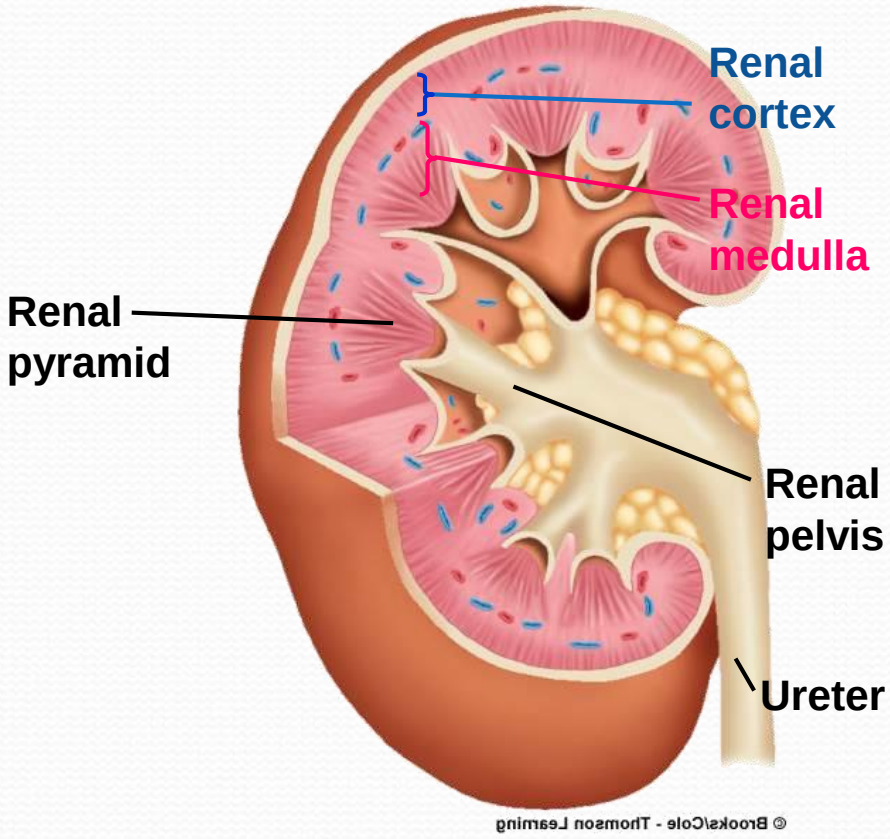

- **Morphology**
  - It is paired organ (weight about 300 g)
  - Compound from two parts cortex (isotonic urine) and medulla (hypertonic urine)
  - Cortex: Glomerular apparatus
  - Medulla: Divided: Outer and Inner
- Consists of about 1 million filtering units termed nephrons (basic structural and functional unit)
- The kidney plays a crucial role in regulating electrolytes in the human blood (e.g. $Na^+$, $K^+$, $Ca^{2+}$).
- It clears urea, a nitrogenous waste product from the metabolism of amino acids.

# Renal pelvis




- The major function of the renal pelvis is to act as a funnel for urine flowing to the ureter.
- The **renal pelvis** represents the funnel-like dilated proximal part of the ureter.
- It is the point of convergence of two or three major calices.
- Each renal papilla is surrounded by a branch of the renal pelvis called a calyx.

# Ureters




- Urine is collected in the renal pelvis (or pyelum), which connects to the ureters, which carry urine to the bladder.
- The ureters are about 200 to 250 mm long.
- Smooth muscular tissue in the walls of the ureters peristaltically force the urine downward.

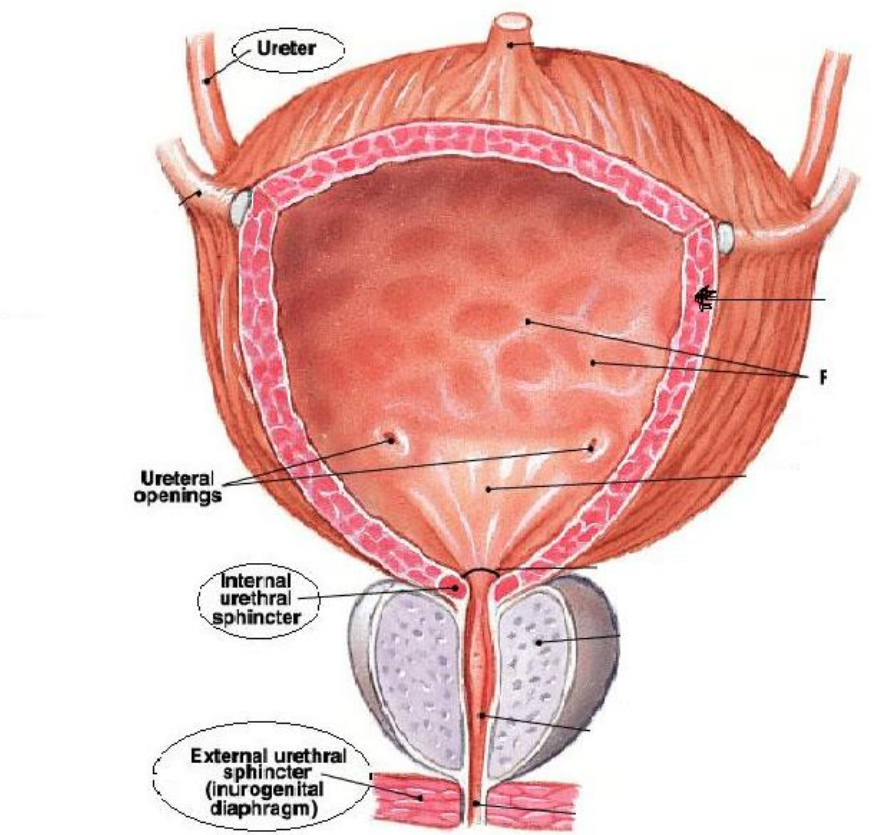
# Ureters

- Urine is not flowing through the ureter, but goes to the bladder as an urinary spindle.
- Starts with the sucking up of the urine during the diastolic phase → closing of collecting ductus → peristaltic movements.
- Small amounts of urine are emptied into the bladder from the ureters about every 10 to 15 seconds.

# Urinary bladder

- The urinary bladder is a hollow muscular organ shaped like a balloon.
- It is located in the pelvic fossa and held in place by ligaments attached to the pelvic bones.
- The bladder stores urine - up to 500 ml of urine comfortably for 2 to 5 hours.
- Sphincters (circular muscles) regulate the flow of urine from the bladder.
  - **Internal urethral sphincter** = in the beginning of urethra smooth muscle – not under our voluntary control
  - **External urethral sphincter** = skeletal muscle – we can control it

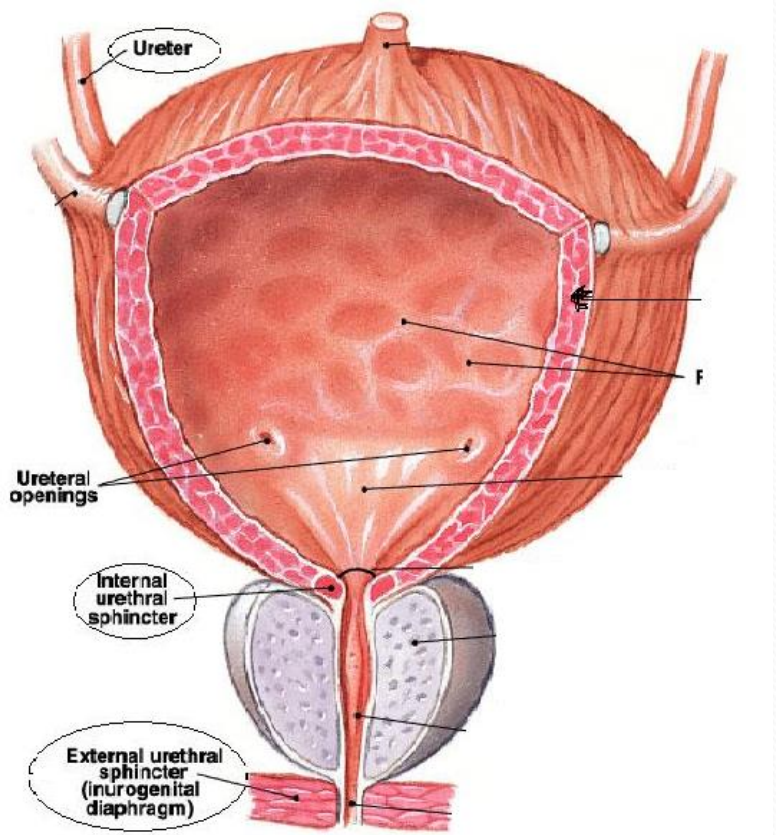
# Urinary Bladder




- 3 layers
  - Outer layer
    - Loose connective tissue
  - Middle layer
    - Smooth muscle and elastic fibres
  - Inner layer
    - Lined with transitional epithelium

# Urinary bladder

- The detrusor muscle is a layer of the urinary bladder wall, made up of smooth muscle fibers arranged in inner and outer longitudinal layers and a middle circular layer.
- Contraction of the detrusor muscle causes the bladder to expel urine through the urethra.
- Problems with this muscle can lead to incontinence.

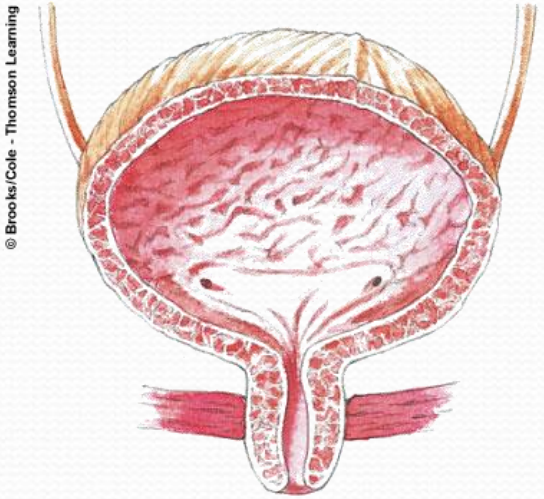


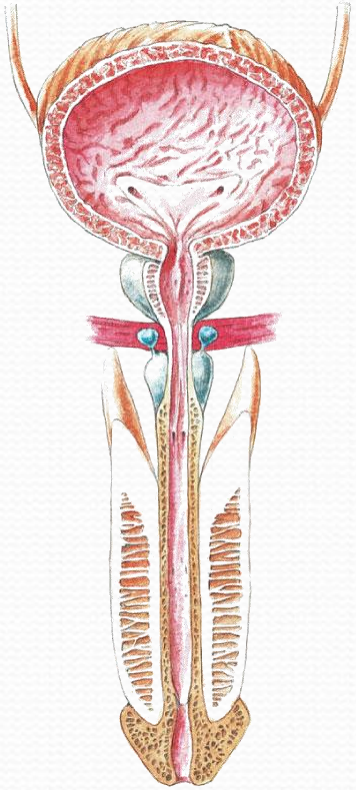
# Urethra

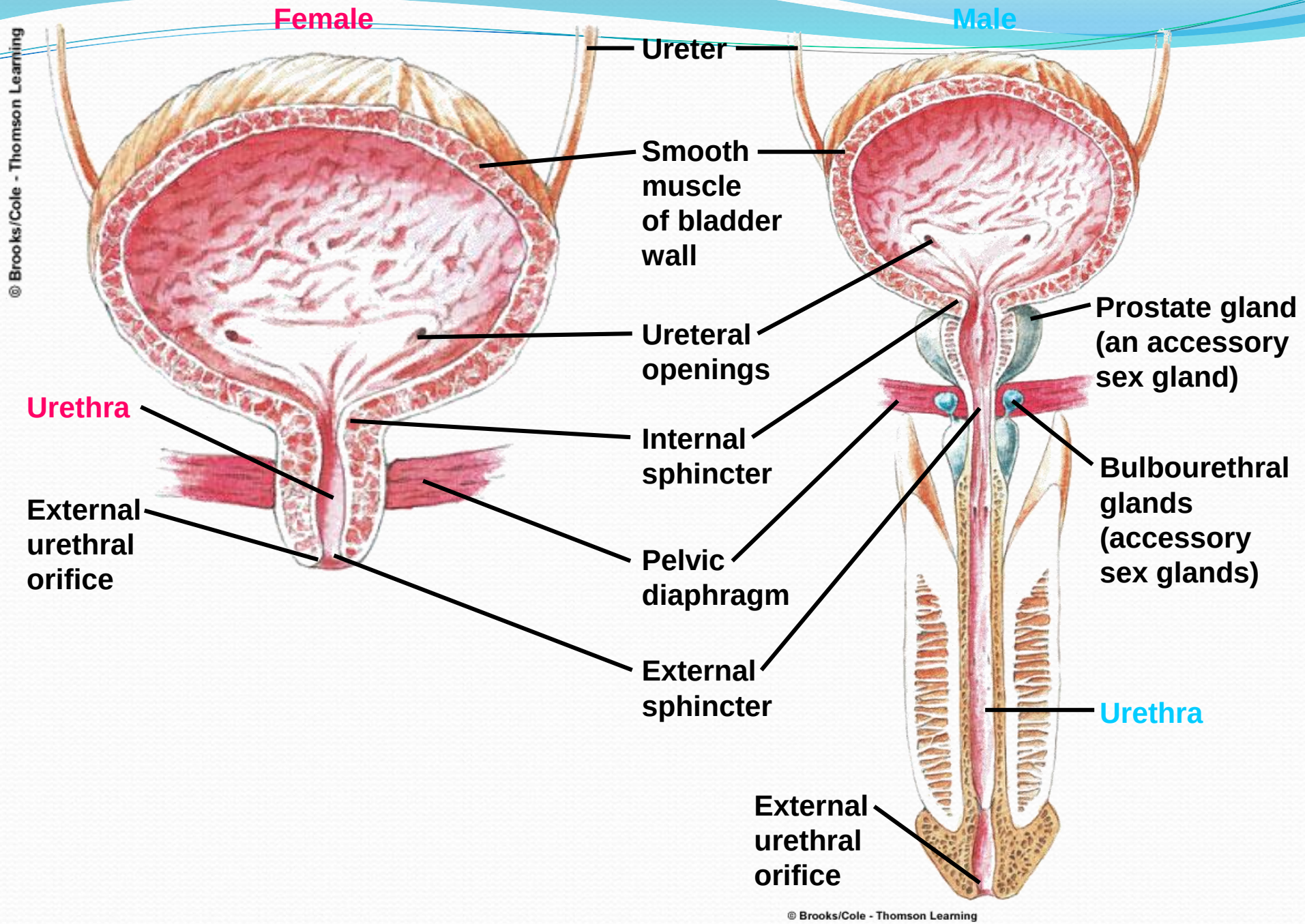
- The urethra has an excretory function in both sexes, to pass urine to the outside, and also a reproductive function in the male, as a passage for sperm.
- The external urethral sphincter is a striated smooth muscle that allows voluntary control over urination.
- **Urethral sphincters**:
  - Internal
  - External
- In males the internal and external urethral sphincters are more powerful, able to retain urine for twice as long as females

# Urethra

- Women: shorter
- Mans: Longer (together with genital efferent system)
  - 4 parts
    - Intramuralis
    - Prostatica
    - Membranacea
    - Spongiosa




Female
Male
Ureter
Smooth muscle of bladder wall
Ureteral openings
Urethra
Internal sphincter
External urethral orifice
Pelvic diaphragm
External sphincter
Prostate gland (an accessory sex gland)
Bulbourethral glands (accessory sex glands)
Urethra
External urethral orifice
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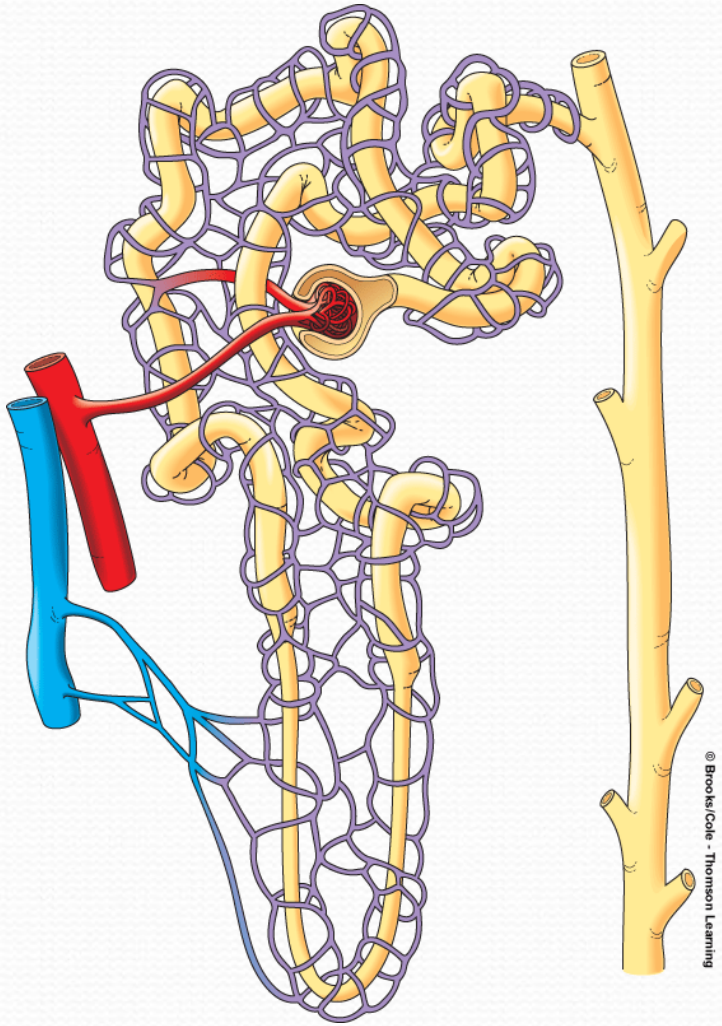
# Urination (micturition)

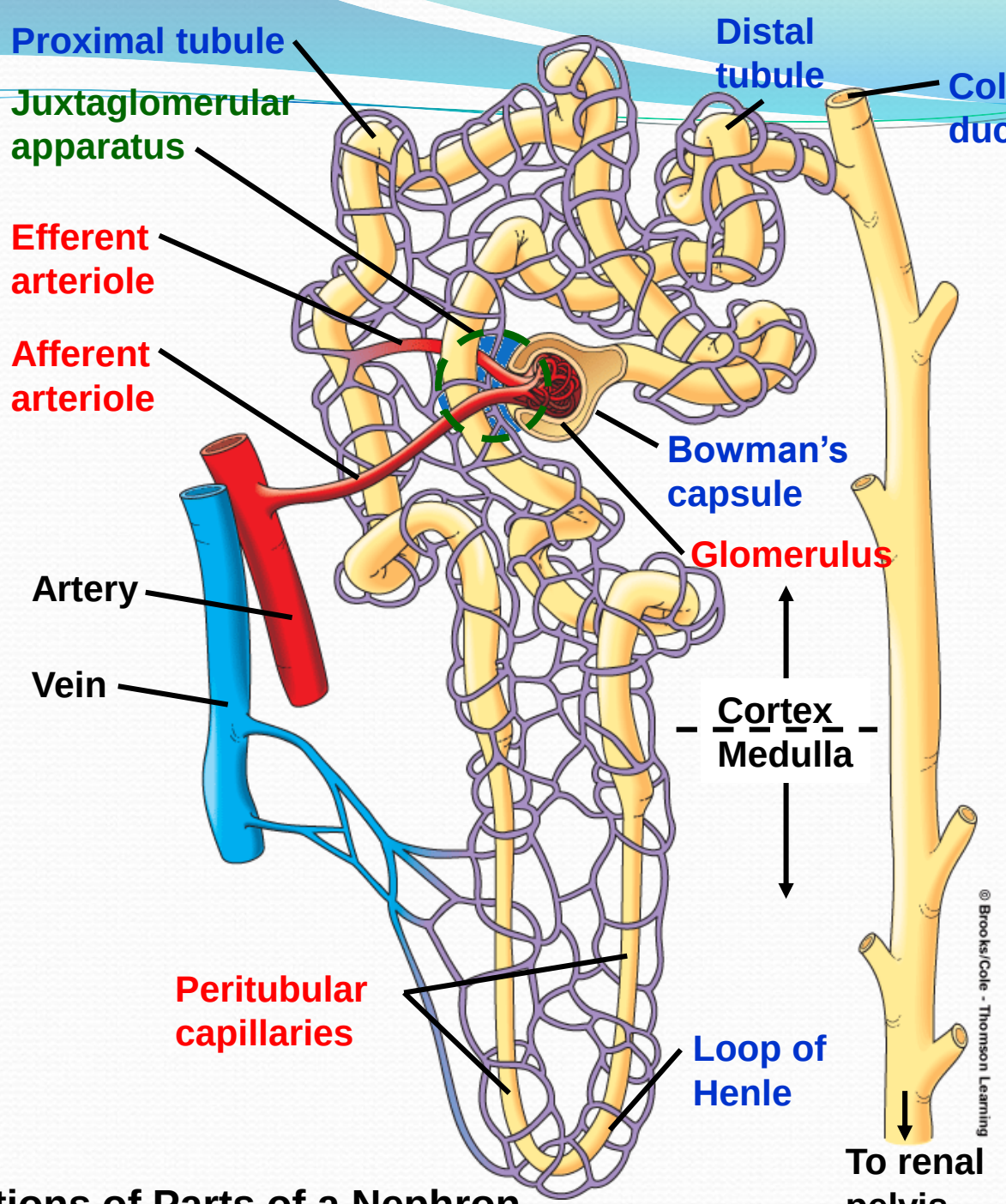
- The process of disposing urine from the urinary bladder through the urethra to the outside of the body.
- The process of urination is usually under voluntary control.
- Urinary incontinence is the inability to control urination, and is more common in women than men.
- Urinary retention refers to the inability to urinate.
- Enuresis nocturna = incontinence during the night (effects of emotions).

# Micturition reflex

- Activated when the urinary bladder wall is stretched; it results in urination.
- This reflex occurs in the spinal cord, specifically in the sacral region that is modified by the higher centers in the brain: the pons and cerebrum.
- The presence of urine in the bladder stimulates the stretch receptors, which produces action potential.
- The action potentials are carried by sensory neurons to the sacral segments of the spinal cord through the pelvic nerves, the parasympathetic fibers carry the action potentials to the urinary bladder in the pelvic nerves.
- The pressure in the urinary bladder increases rapidly once its volume exceeds approximately 400-500 ml.

# Nephron

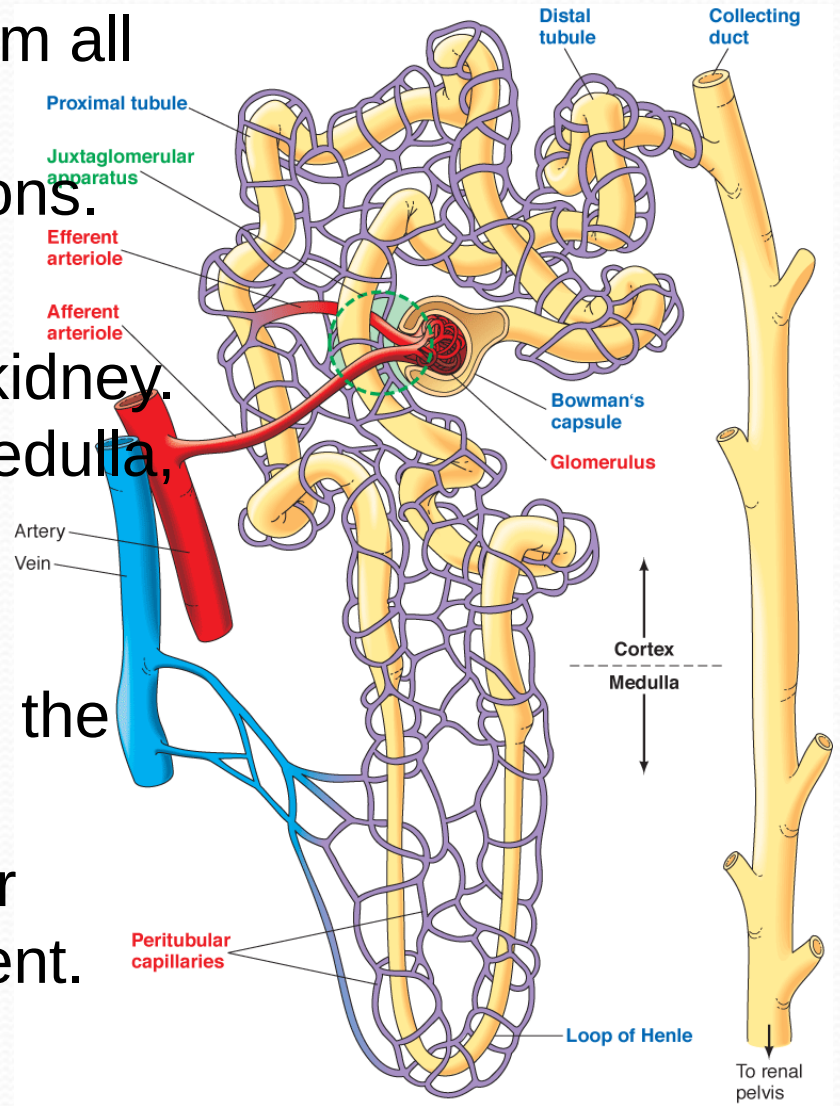





Overview of Functions of Parts of a Nephron

# Nephron

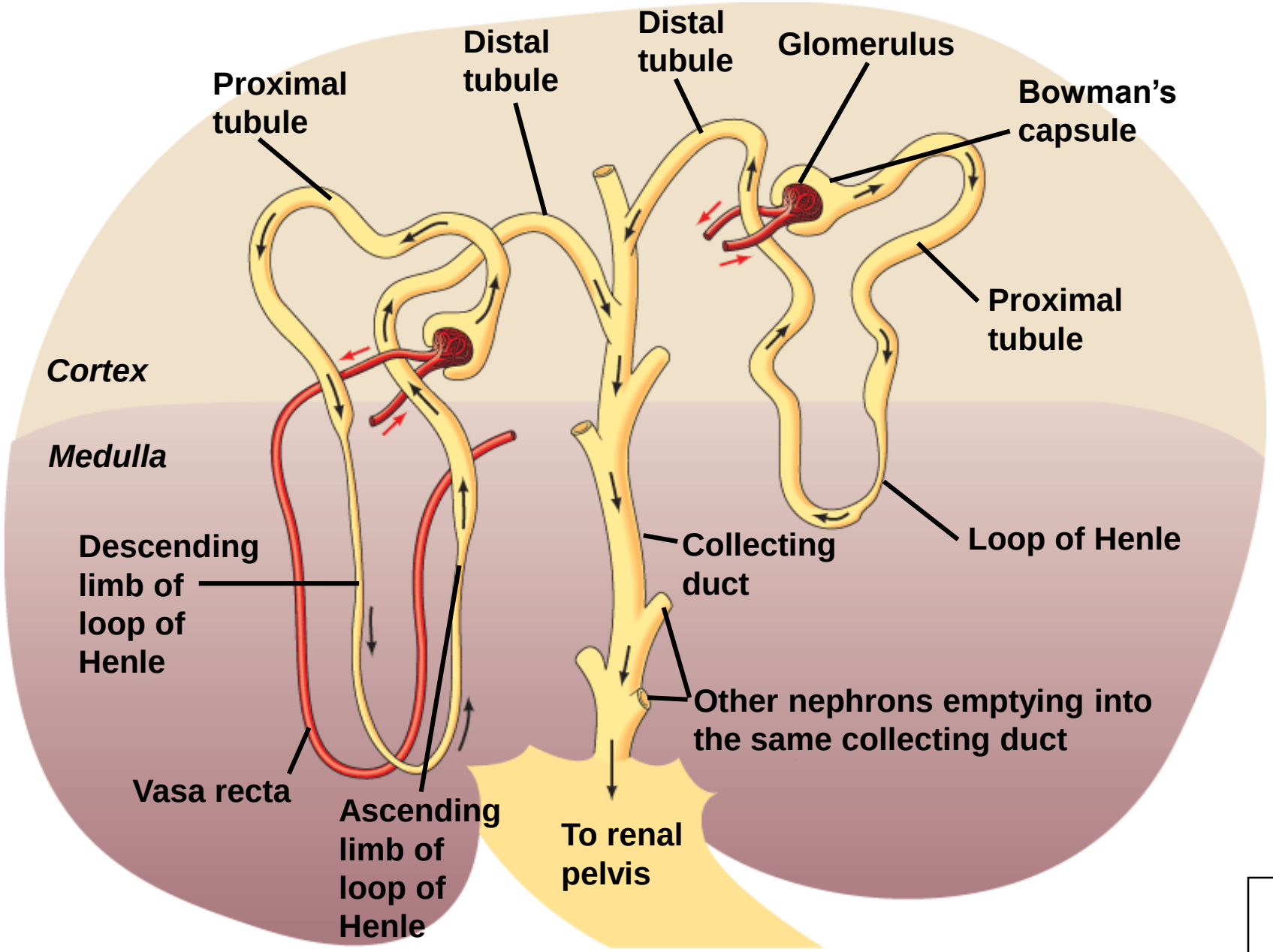
- It is the smallest unit that can perform all of the functions of the kidney. Each kidney has about one million nephrons.
- The cortex is the outer layer of the kidney. The inner layer of the kidney, the medulla, consists of renal pyramids.
- The nephrons are arranged through the cortex and medulla of the kidney.
- Each nephron consists of a vascular component and an tubular component.



Overview of Functions of Parts of a Nephron

# Nephron

- The glomerulus is a ball-like tuft of capillaries. Water and solutes are filtered through the glomerulus as blood passes through it.
- From the renal artery, inflowing blood eventually passes through afferent arterioles. Each afferent arteriole delivers blood to the glomerulus.
- The efferent arteriole transports blood from the glomerulus.
- The efferent arteriole breaks into peritubular capillaries. They surround the tubular part of the nephron. They are involved with tubular changes between this part of the nephron and the blood.
- The peritubular capillaries join into venules which transport blood into the renal vein.

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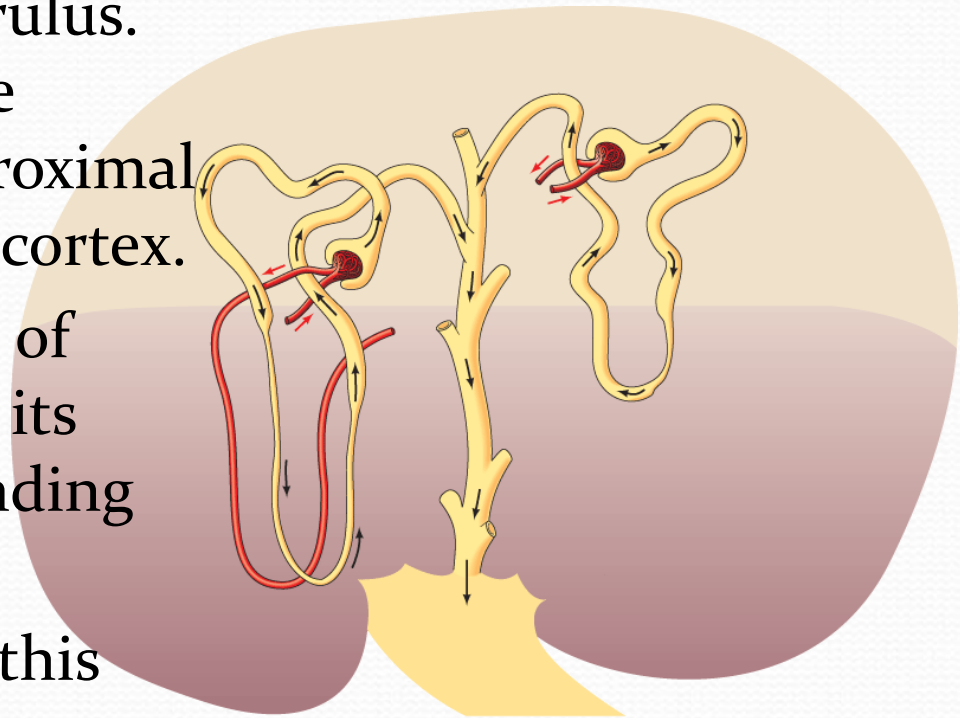
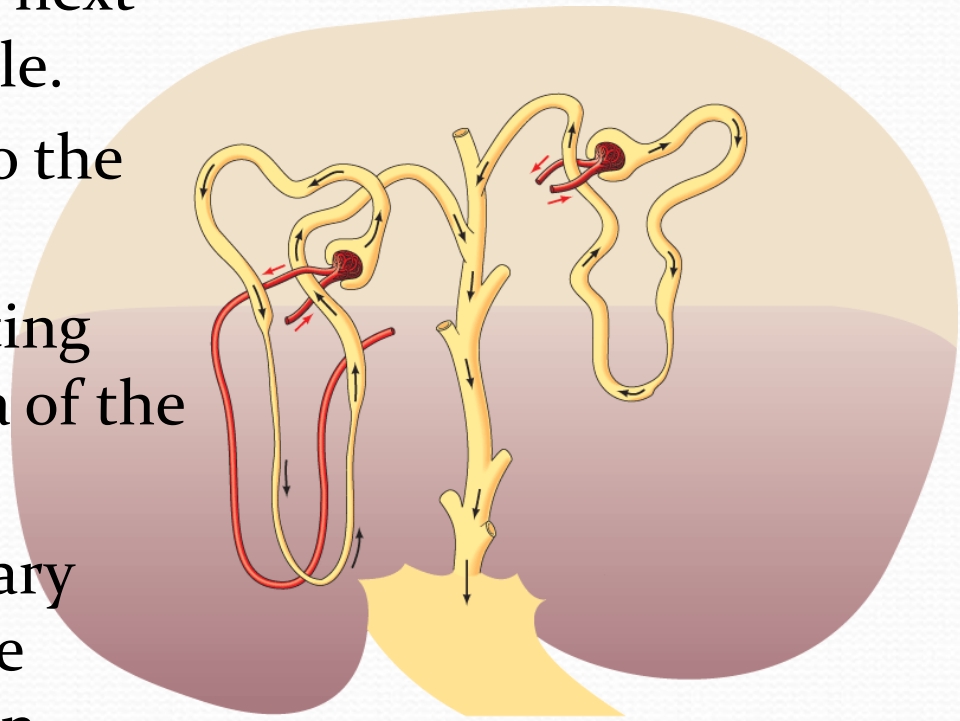
# Nephron – tubular part

- Fluid passes through it.
- It begins with the Bowman's capsule which fits around the glomerulus. Filtered fluid passes from the Bowman's capsule into the proximal tubule. It lies entirely in the cortex.
- The next segment is the loop of Henle. Fluid passes through its descending limb and is ascending limb next.
- Tubular and vascular cells at this point form a juxtaglomerular apparatus.



# Nephron – tubular part

- From the ascending limb, the next tubular part is the distal tubule.
- The distal tubule empties into the collecting duct.
- The loop of Henle and collecting duct are found in the medulla of the kidney.
- The cortical and juxtamedullary nephrons (with vasa recta) are distinguished by their location (cortex or medulla) and length.

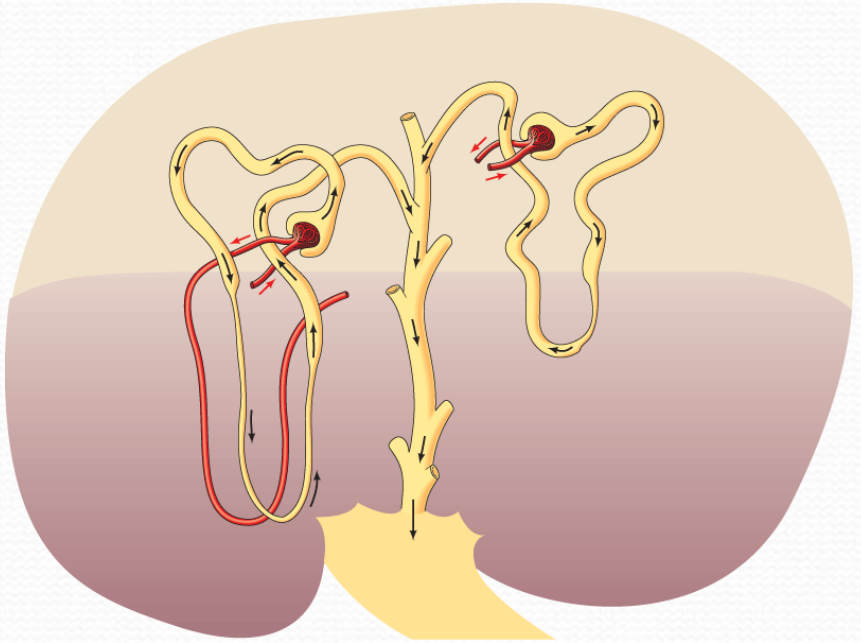


# Nephron

- A nephron (1-1.2 millions) is the basic structural and functional unit of the kidney.
- Its chief function is to regulate water and soluble substances by filtering the blood, reabsorbing what is needed and excreting the rest as urine.
- Each nephron is composed of an initial filtering component (the renal corpuscle) and a tubule specialized for reabsorption and excretion (the renal tubule).
- The renal corpuscle filters out large solutes from the blood, delivering water and small solutes to the renal tubule for modification.

# Nephron

- **Parts:**
  - Glomerular apparatus
  - Proximal tubule
  - Loop of Henle
  - Distal tubule
  - Collecting ducts

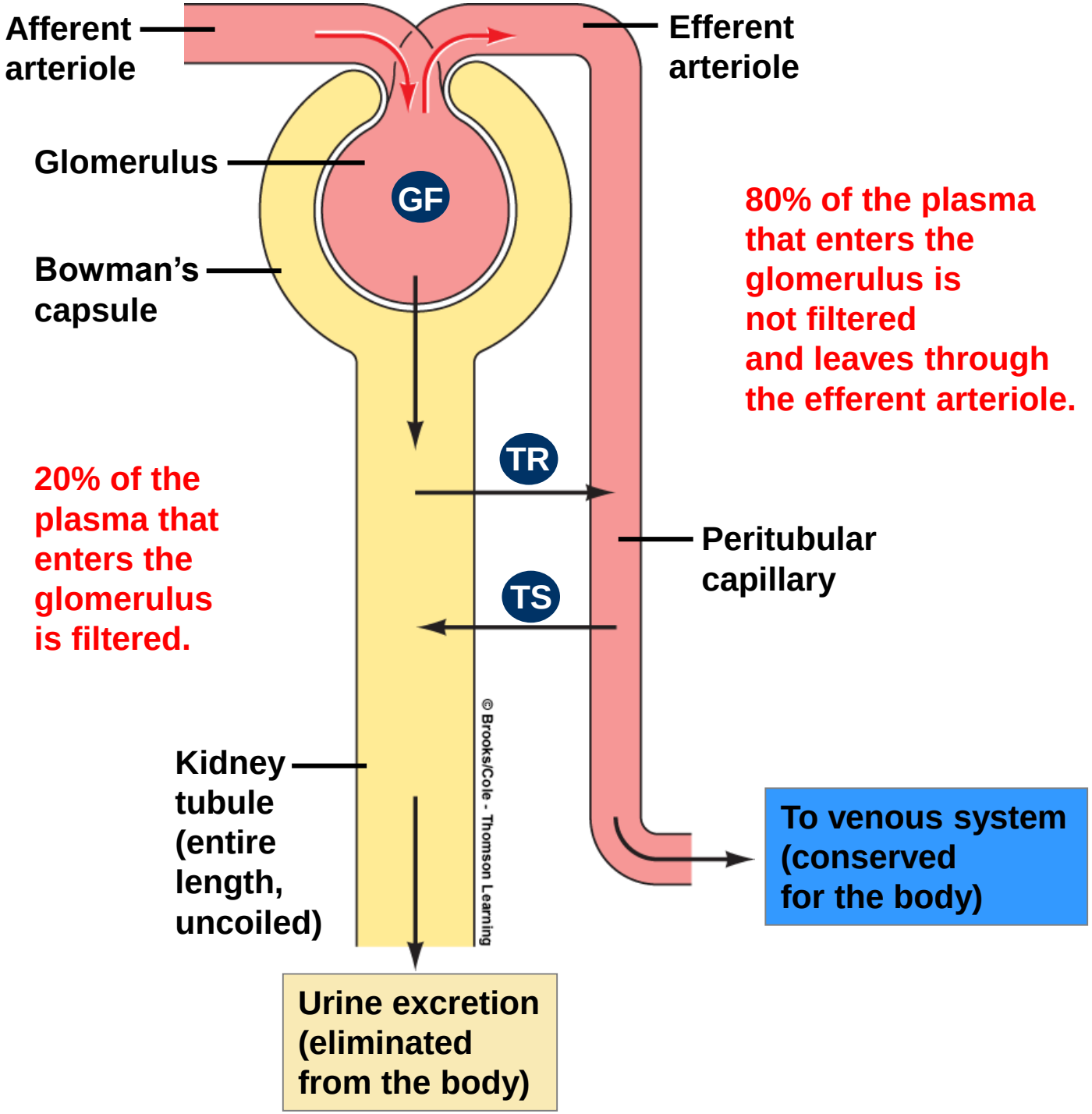



- **Types of nephrons:**
  - **Cortical nephrons** (glomerular apparatus belong the surface and Loop of Henle only to the outer part of the medulla)
  - **Intermedial nephrons** (in the middle)
  - **Juxtamedullary nephrons** (glomerular apparatus deep in cortex near the medulla and Loop of Henle is going deep to the inner part of the medulla)

# Basic Urinary processes

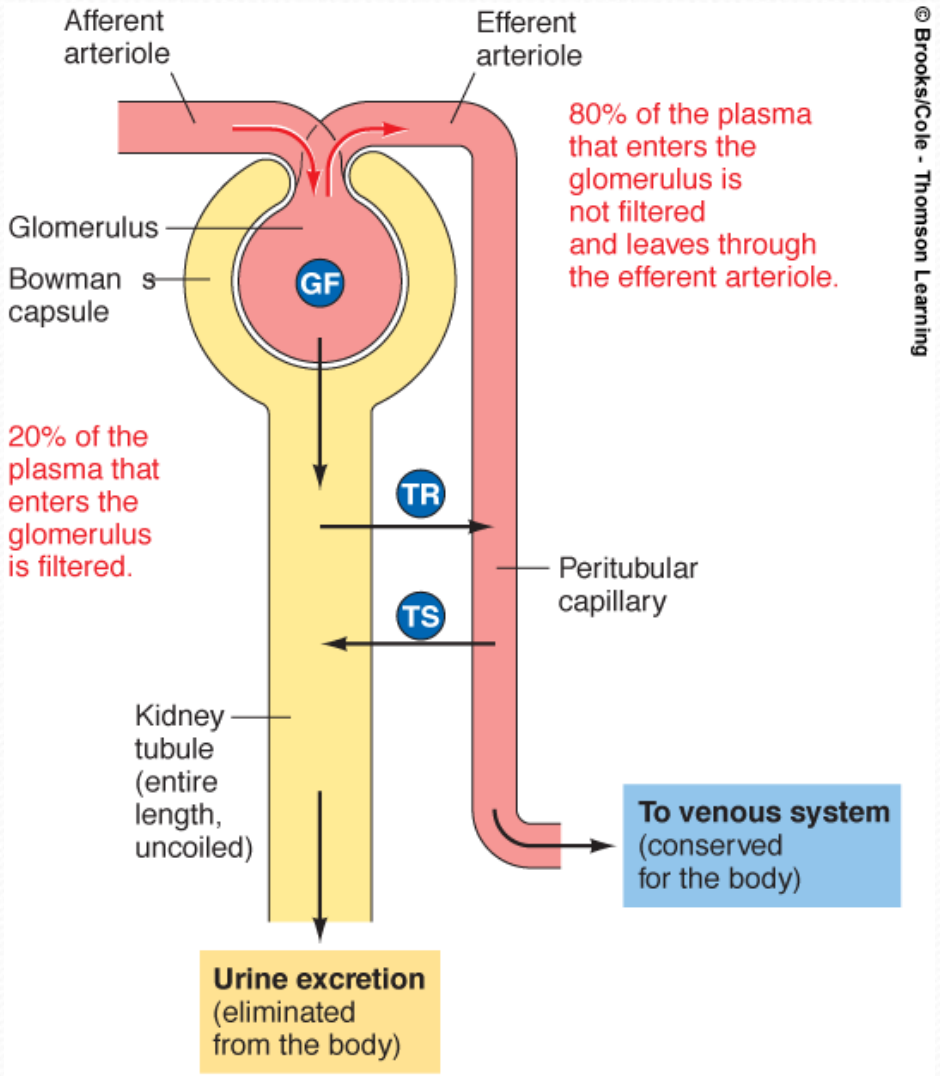
- Glomerular Filtration
- Tubular Reabsorption
- Tubular Secretion

- Glomerular Filtration

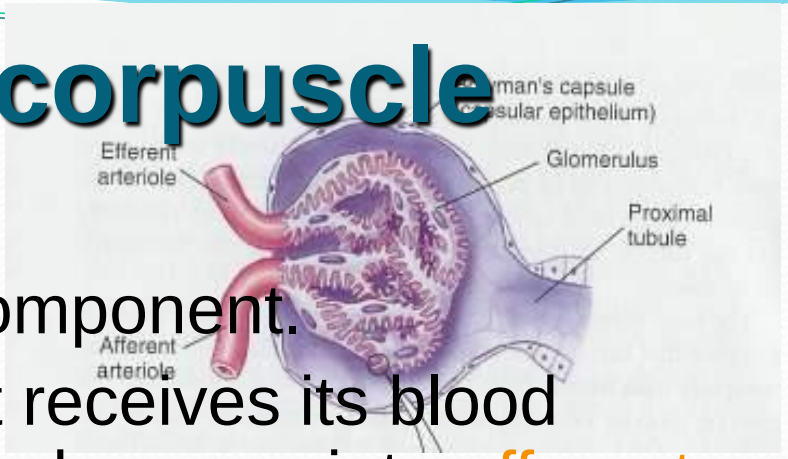

Afferent arteriole
Efferent arteriole
Glomerulus
GF
Bowman's capsule
80% of the plasma that enters the glomerulus is not filtered and leaves through the efferent arteriole.
TR
20% of the plasma that enters the glomerulus is filtered.
Peritubular capillary
TS
Kidney tubule (entire length, uncoiled)
© Brooks/Cole - Thomson Learning
To venous system (conserved for the body)
Urine excretion (eliminated from the body)

# Basic Urinary processes

- Glomerular filtration is the first process. A protein-free plasma is filtered from the glomerulus into the Bowman's capsule. Blood cells are not normally filtered. Normally about 20 % of the plasma is filtered. Glomerular filtrate is produced at the rate of 125 ml per minute (180 liters per day).



# Renal (Malphigian) corpuscle

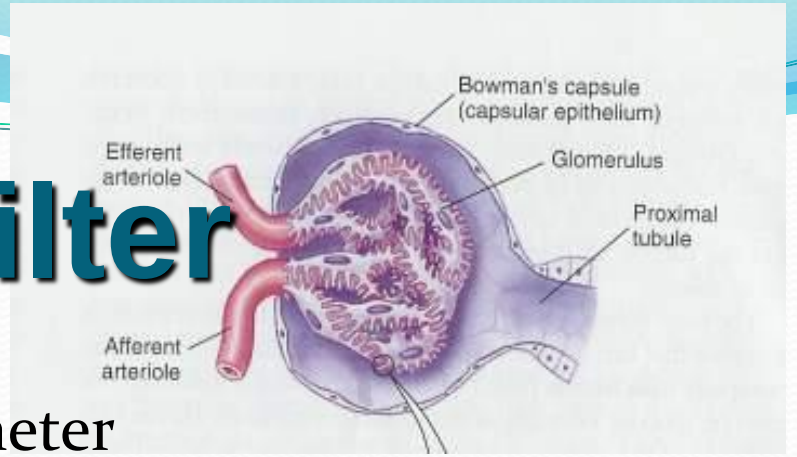



- It is the nephron's initial filtering component.
- Glomerulus - is a capillary tuft that receives its blood supply from an afferent arteriole and passes into efferent arteriole of the renal circulation.
- Efferent arterioles of juxtamedullary nephrons (ie, the 15% of nephrons closest to the medulla) send straight capillary branches that deliver isotonic blood to the renal medulla.
- Along with the loop of Henle, these vasa recta play a crucial role in the establishment of the nephron's countercurrent exchange system.
- Bowman's capsule - surrounds the glomerulus and is composed of visceral (inner) and parietal (outer) layers.

# Glomerulus

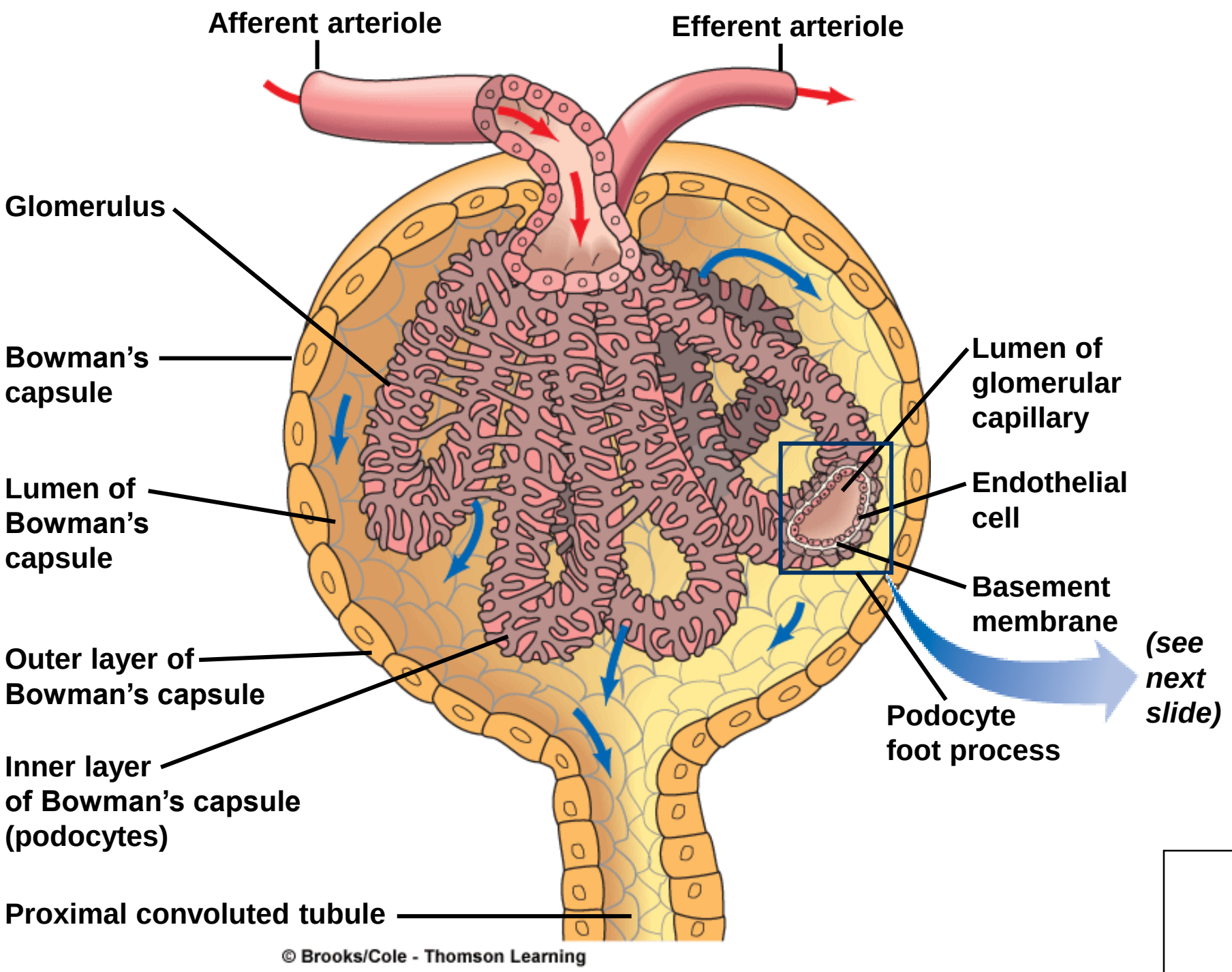

- The glomerulus has several characteristics that deviate from the features of most other capillaries of the body.
  - the endothelial cells of the glomerulus contain numerous pores (fenestrae)
  - glomerular endothelium sits on a very thick basement membrane
  - On the surface of the cells are negatively charged glycosaminoglycans such as heparan sulfate. The negatively-charged basement membrane repels negatively-charged ions from the blood, helping to prevent their passage into Bowman's space.
  - blood is carried out of the glomerulus by an efferent arteriole instead of a venule, as is observed in most other capillary systems.

# Glomerular filter




- The filtration surface is 1.5 square meter
- Amount of the solution, which is filtered in glomerular apparatus is around 180-200 l.
- The rest (97 %) has to be reabsorbed in the tubules back to the body, so the final volume of urine is around (1.5 - 2 l per day).

- **Glomerular filter:**
  - the capillary endothelium
  - basal membrane
  - epithelium of the Bowman's capsule (PODOCYTES)
- **Podocytes:** special cells which have numerous of pseudopodia (pedicles) that interdigitate to form filtration slits along the capillary wall.


Afferent arteriole
Efferent arteriole
Glomerulus
Bowman's capsule
Lumen of Bowman's capsule
Outer layer of Bowman's capsule
Inner layer of Bowman's capsule (podocytes)
Proximal convoluted tubule
Lumen of glomerular capillary
Endothelial cell
Basement membrane
Podocyte foot process
(see next slide)
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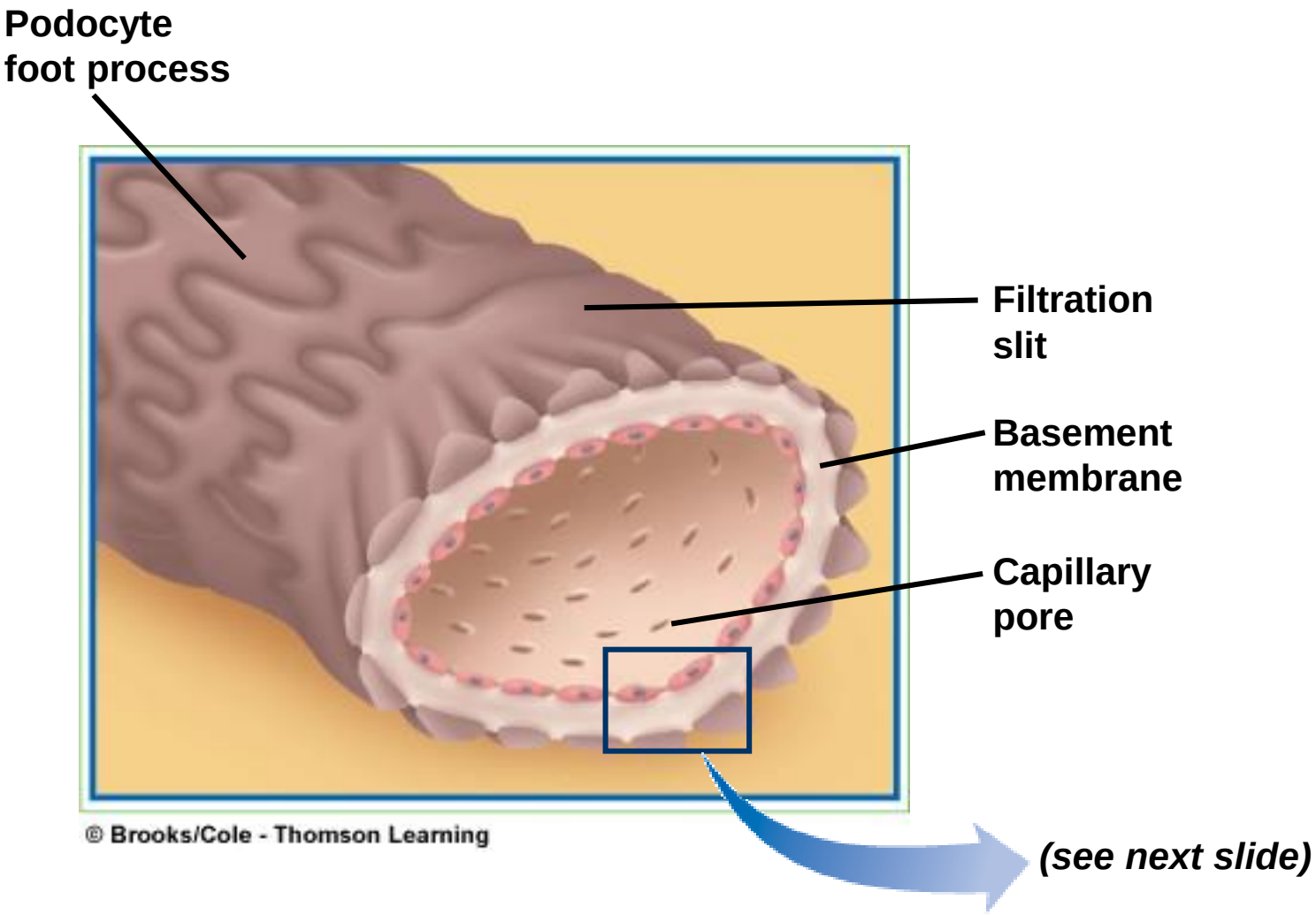
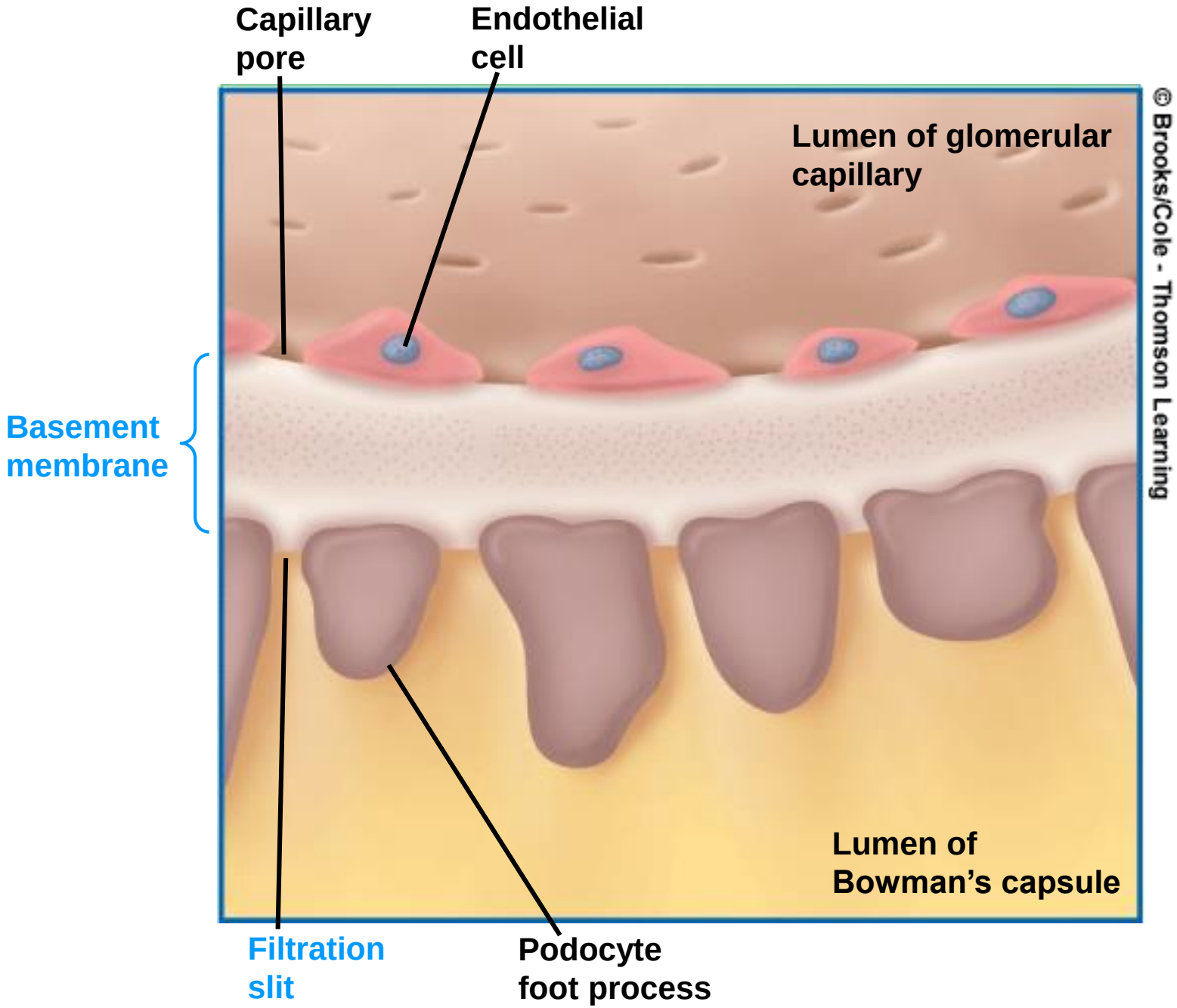
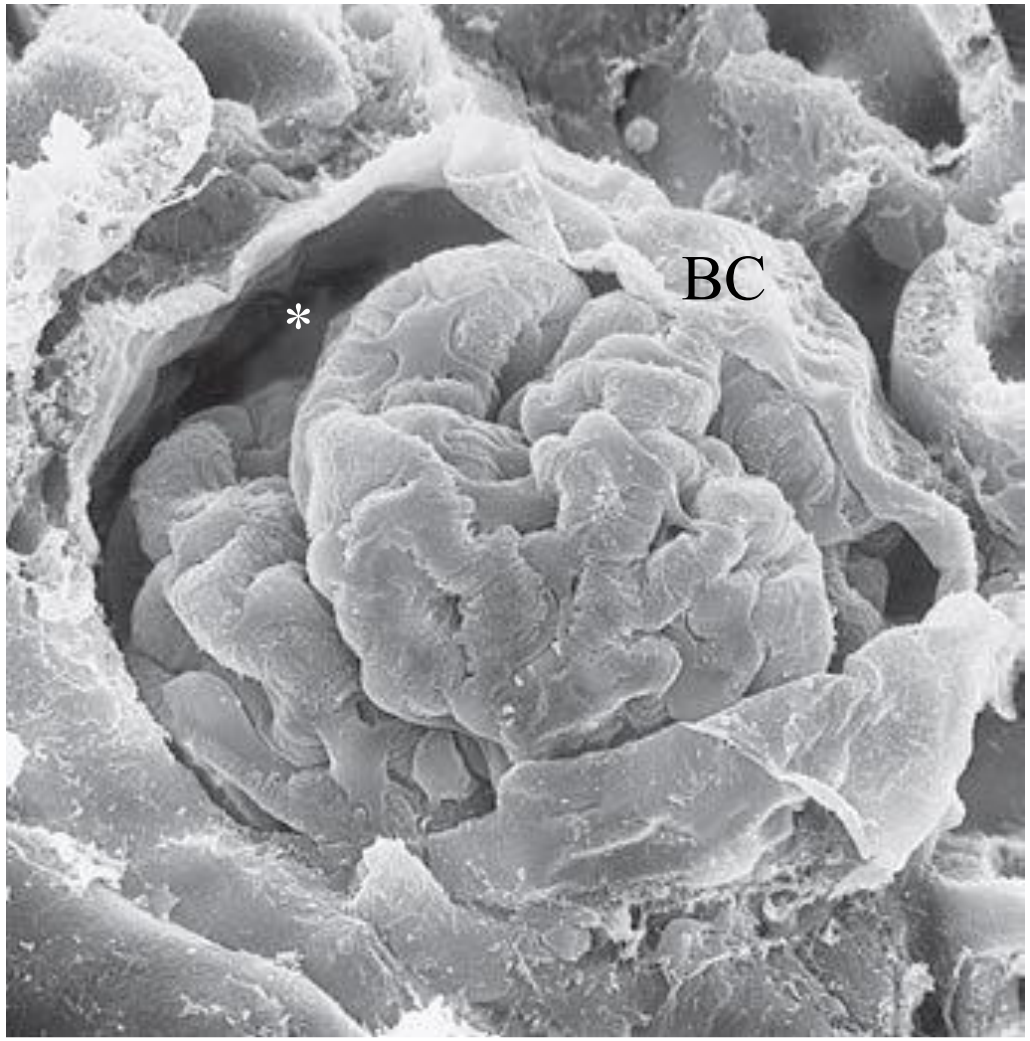

Podocyte
foot process
Filtration
slit
Basement
membrane
Capillary
pore
© Brooks/Cole - Thomson Learning
(see next slide)


Capillary pore
Endothelial cell
Lumen of glomerular capillary
Basement membrane
Lumen of Bowman's capsule
Filtration slit
Podocyte foot process
© Brooks/Cole - Thomson Learning




Scanning electron micrograph of rat glomerulus. The glomerular tuft is a complex network of capillaries that is encased in visceral epithelial cells and Bowman's capsule *(BC).* Between the visceral epithelial cells and BC is Bowman's space *(asterisk),* where the glomerular filtrate is collected and delivered to the proximal tubule.

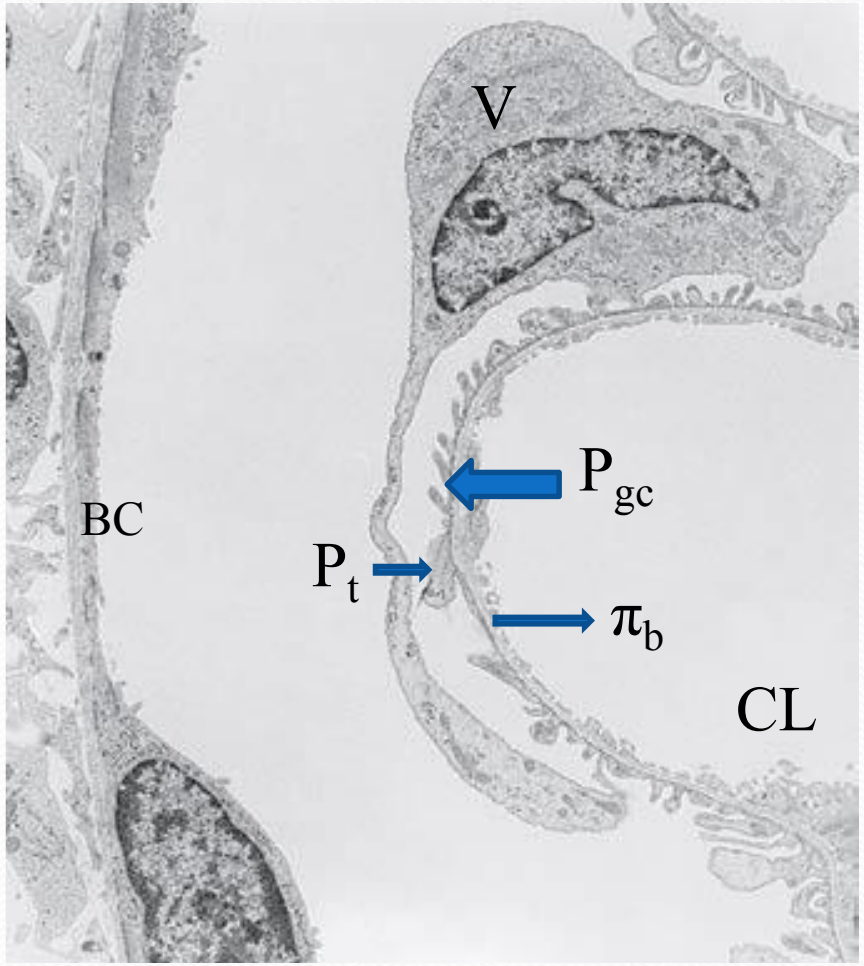
# GLOMERULAR FILTRATION

- **Depends on:**
  - Pressure gradient across the filtration slit (endothelium, basal membrane, epithelium = podocytes)
  - Blood circulation throughout the kidneys
  - Permeability of the filtration barrier
  - Filtration surface
- The solution after filtration is very similar like plasma, but should be **WITHOUT PROTEINS**

# GLOMERULAR FILTRATION

$$P_f = P_{gc} - (\pi_b + P_t)$$

Transmission electron micrograph of rat glomerular capillary and Bowman's capsule *(BC)* illustrating the forces favoring and opposing filtration. The main force favoring filtration is the hydrostatic pressure of the glomerular capillary (*P*gc). The forces opposing filtration are the hydrostatic pressure of Bowman's space (*P*t) and the oncotic pressure of the blood (πb). *CL,* Capillary lumen; *V,* visceral epithelial cell.




$$GFR = P_f \times K_f \ (ml/min/kg)$$

# GLOMERULAR FILTRATION

- $K_f$ : The filtration barrier permeability and its surface area is the ultrafiltration coefficient

- **GFR measurement, Plasma Clearance**
- GFR can be measured by measuring the excretion and plasma level of a substance that freely filtered through the glomeruli and neither secreted nor reabsorbed by the tubules, such as INULIN (polymer of fructose).

$$GFR = C_{inulin} = (U_{inulin} V)/P_{inulin}$$

U = concentration of inulin in urine

V = volume of the urine in one min.

P = concentration of inulin in plasma

# GLOMERULAR FILTRATION

- In clinical situations:

$$C_{creatinine} = U_{creatinine} V/P_{creatinine}$$

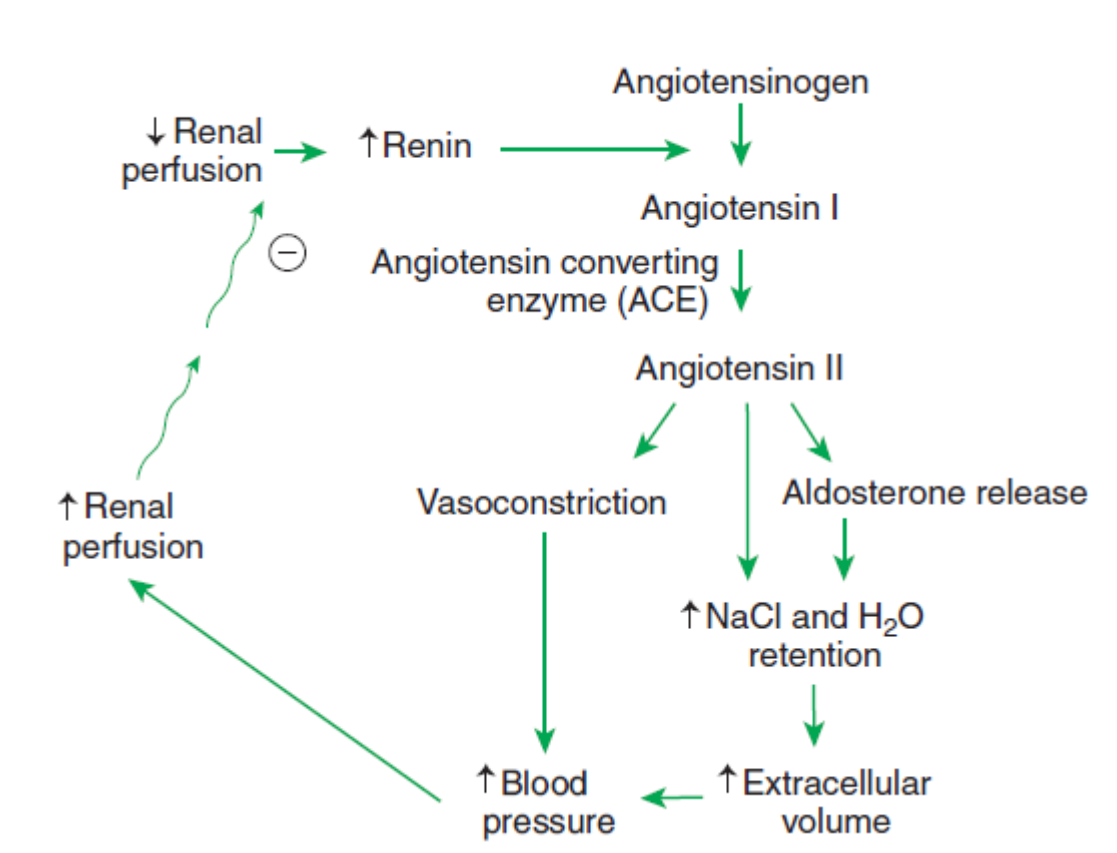
- In clinical practice, the serum creatinine level alone is frequently used to assess renal function. It must be remembered that a very small increase in serum creatinine correlates with a large reduction in glomerular filtration rate and conversely, that a normal serum creatinine does not necessarily reflect normal renal function.

- Normal range of GFR:
  - Dogs: 1.56 to 2.96 mL/min/kg
  - Cats: 3.22 to 6.23 mL/min/kg
  - Human: 125 ml/min (7.5 l/h)

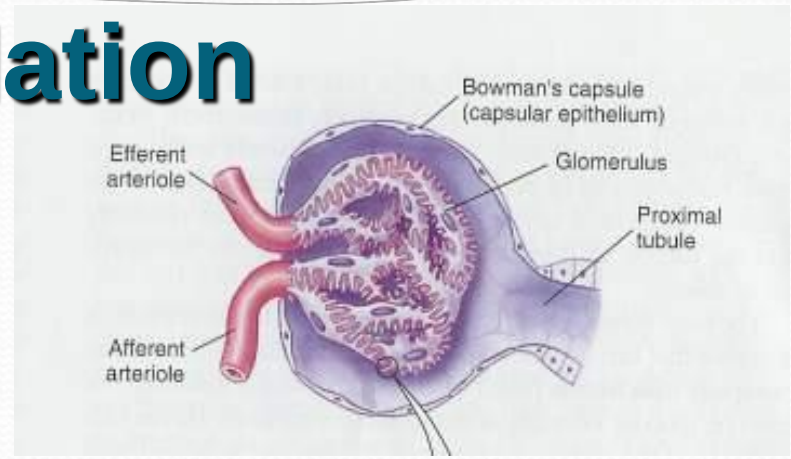
# GFR Regulation

- Systemic Factors:

Renin-Angiotensin-Aldosterone system



# GFR Regulation




- Intrinsic Factors

Myogenic reflex

The myogenic reflex regulates renal blood flow and GFR by almost immediate afferent arteriolar constriction after an increase in arteriolar wall tension, thus increasing resistance to blood flow in response to increased perfusion pressure. Conversely, arteriolar dilation occurs almost immediately after a decrease in arteriolar wall tension, thus reducing resistance to flow when vascular perfusion pressure decreases.

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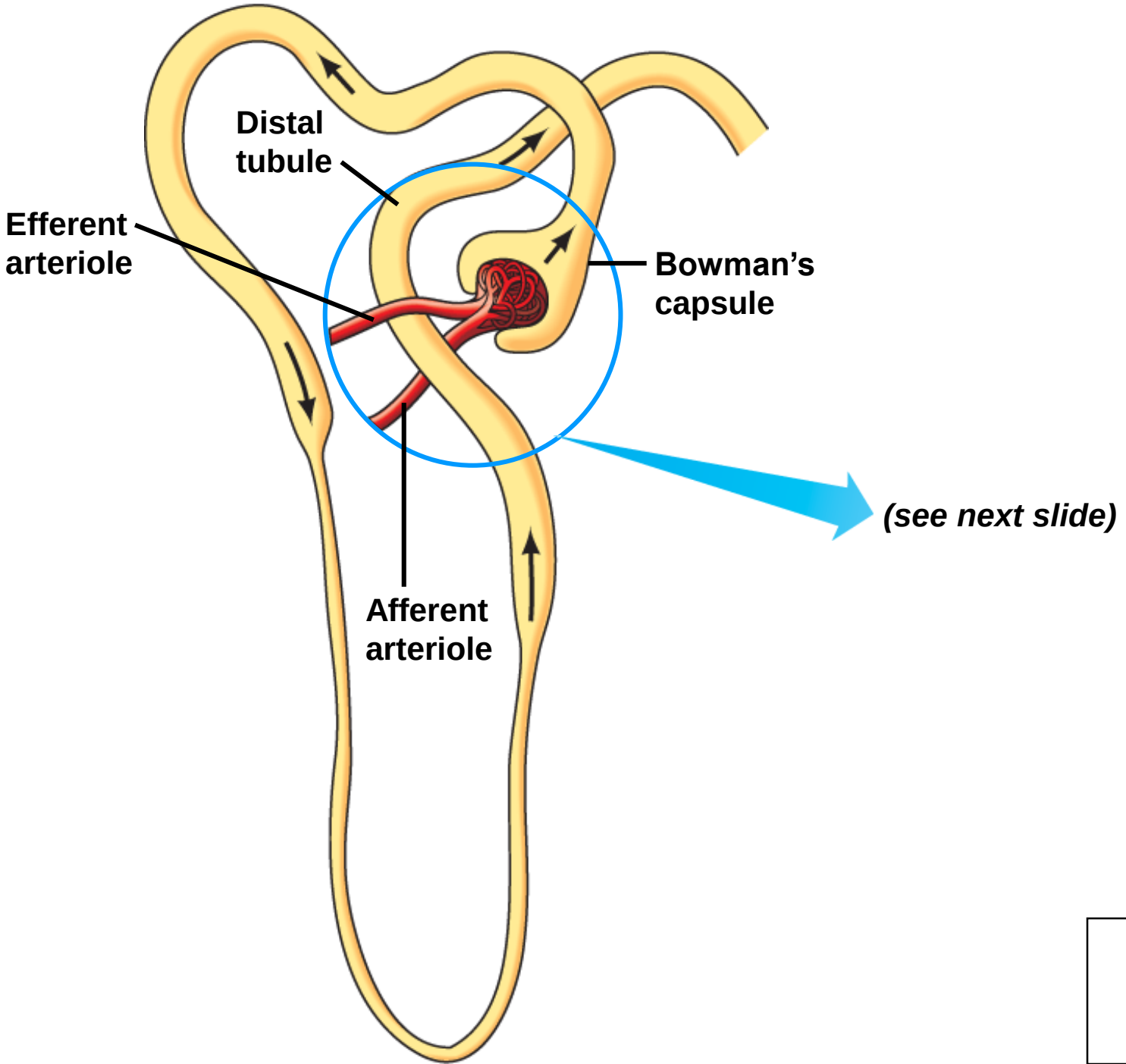

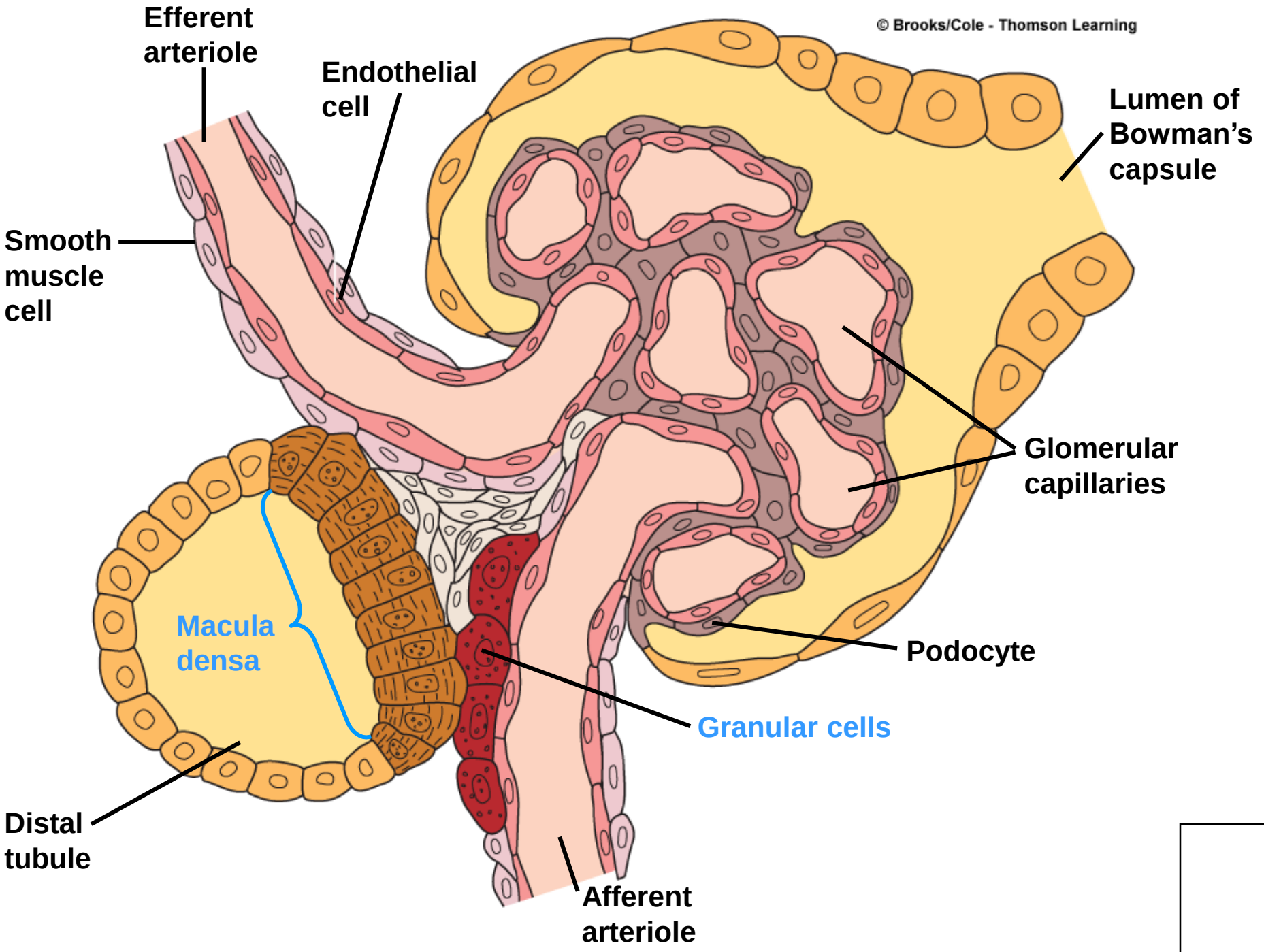
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Efferent arteriole
Endothelial cell
Lumen of Bowman's capsule
Smooth muscle cell
Glomerular capillaries
Macula densa
Podocyte
Granular cells
Distal tubule
Afferent arteriole

# Juxtaglomerular apparatus

- The **juxtaglomerular cells** are cells that synthesize, store, and secrete the enzyme renin.
- Specialized smooth muscle cells in the wall of the afferent arteriole that are in contact with distal tubule.
- Have mechano-receptors for blood pressure
- The **macula densa** is an area of closely packed specialized cells lining the distal convoluted tubule where it lies next to the juxtaglomerular apparatus.
- Cells of **macula densa** are taller and have more prominent nuclei than surrounding cells.
- Sensitive to the concentration of sodium ions in the fluid.

# GFR Regulation

- Intrinsic Factors

## Tubuloglomerular Feedback (TGF)

- Increased GFR increases tubule fluid flow rate;
- increased flow in the thick ascending limb (TAL) increases NaCl delivery to the macula densa (MD);
- increased NaCl uptake at the MD causes basal ATP release;
- ATP release suppresses renin release from juxtaglomerular (JG) cells in the afferent arteriole, causes afferent arteriolar constriction, mesangial cell contraction and thereby decreased Kf.
- The result is decreased single-nephron GFR.