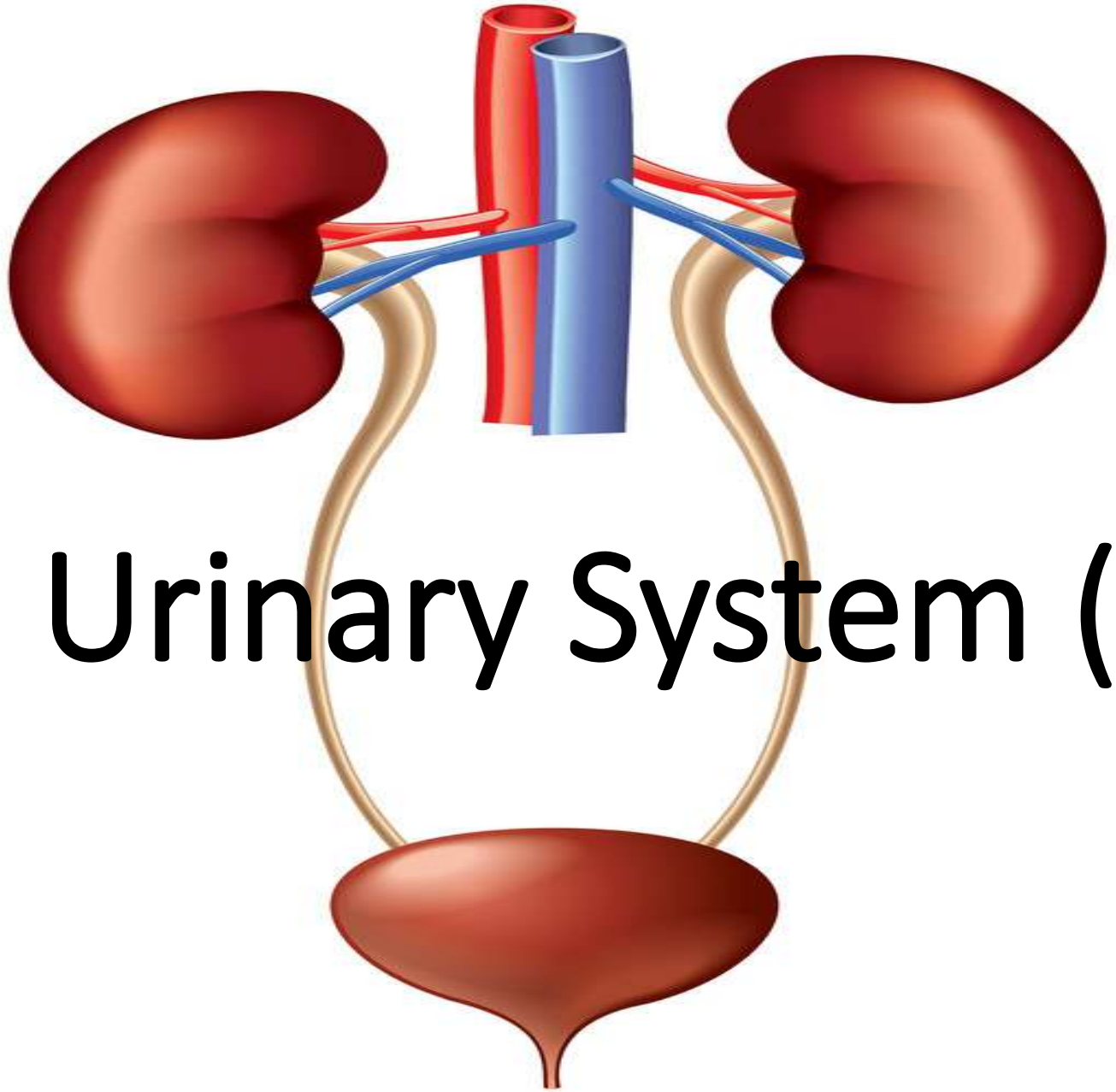
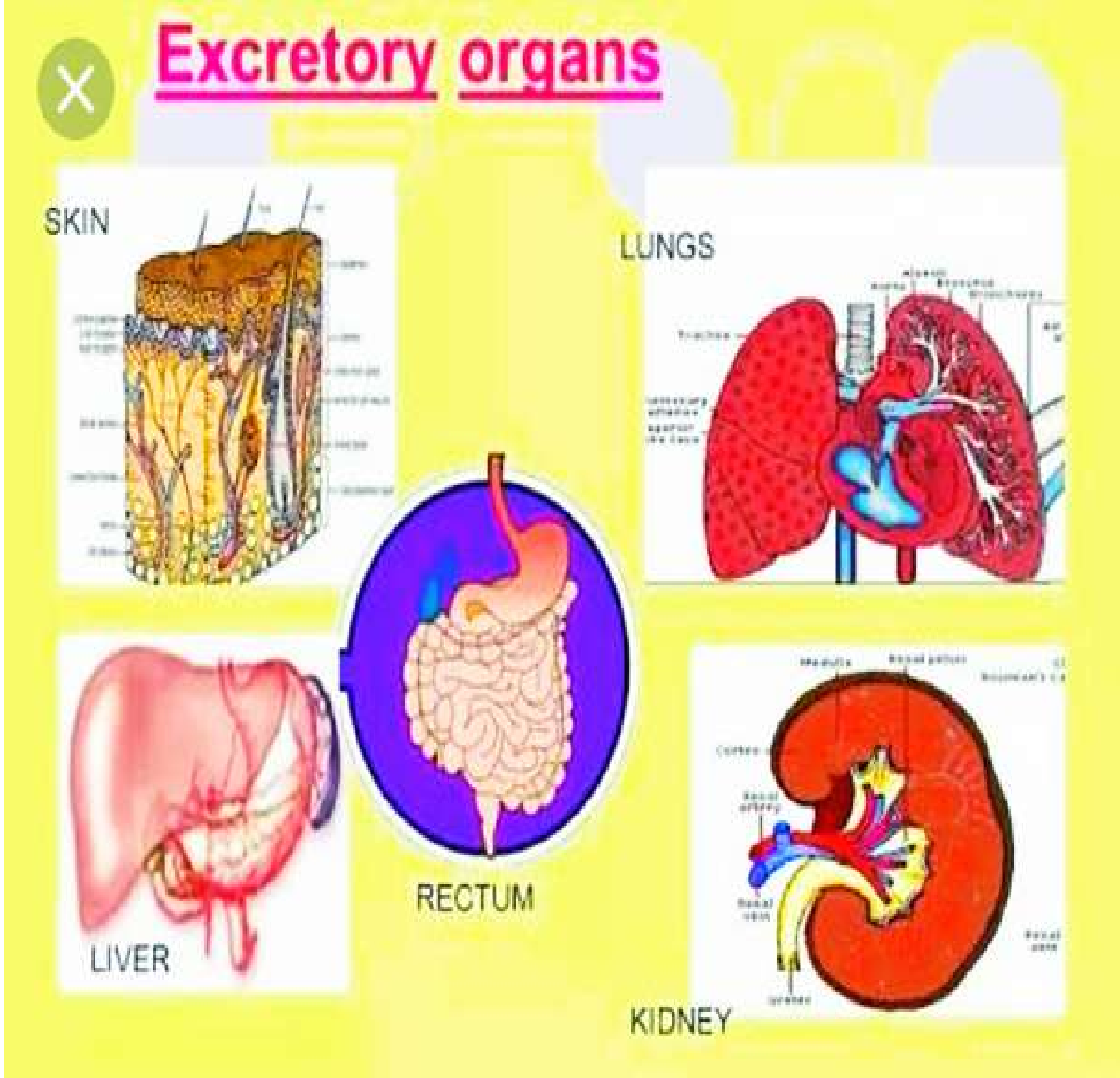
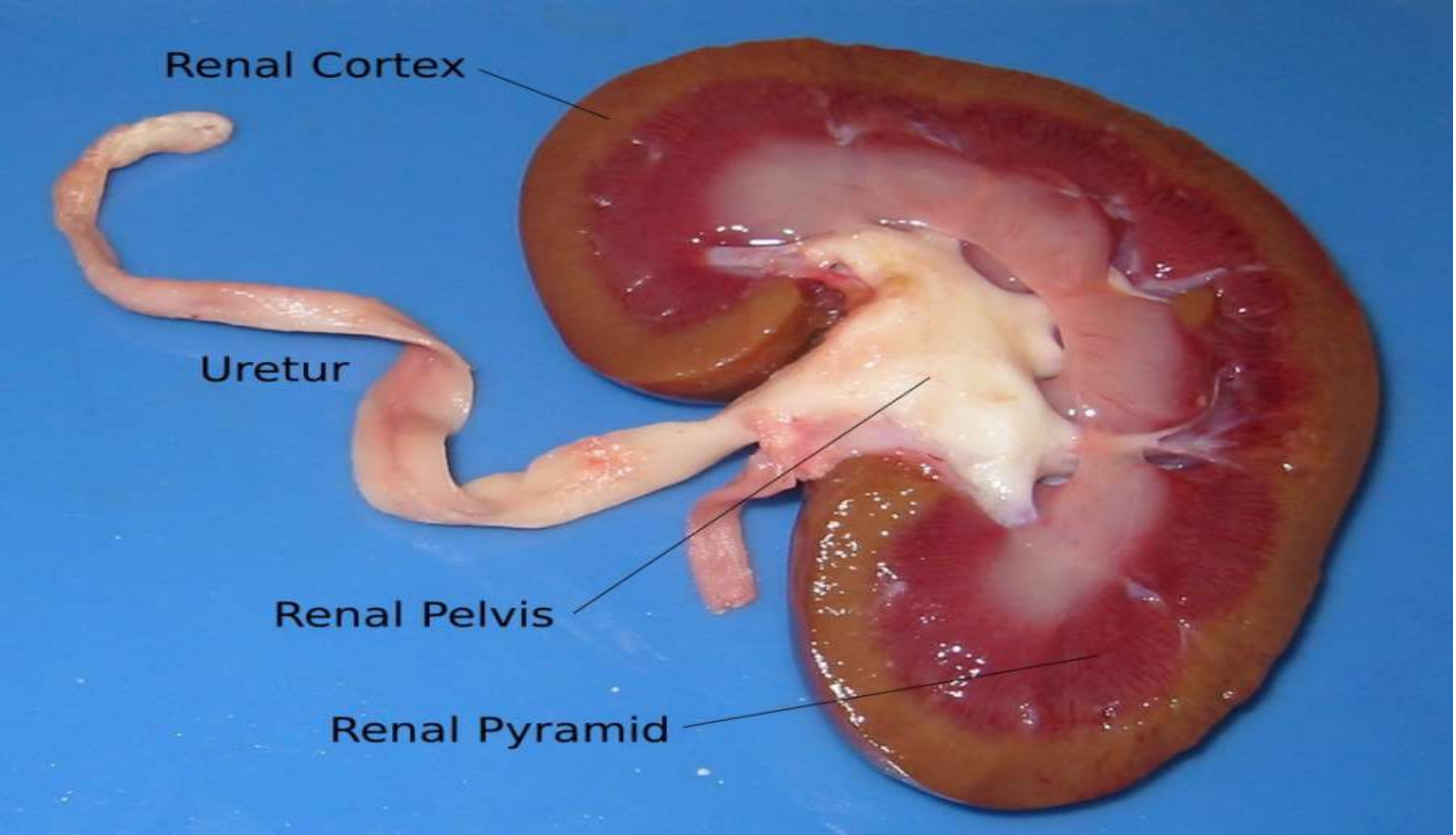


The Urinary System (US)

Parts and Purposes

Excretion – the elimination of toxic and or excess materials from the body. This is accomplished by the kidneys, skin, rectum and lungs. The urinary system performs the excretion of substances from the blood.

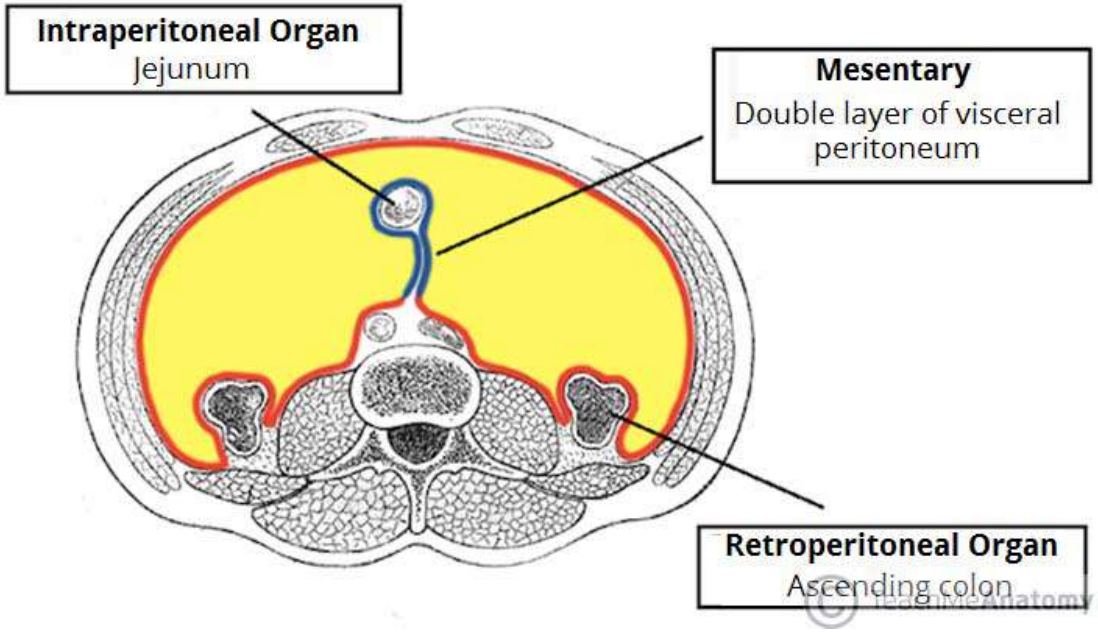


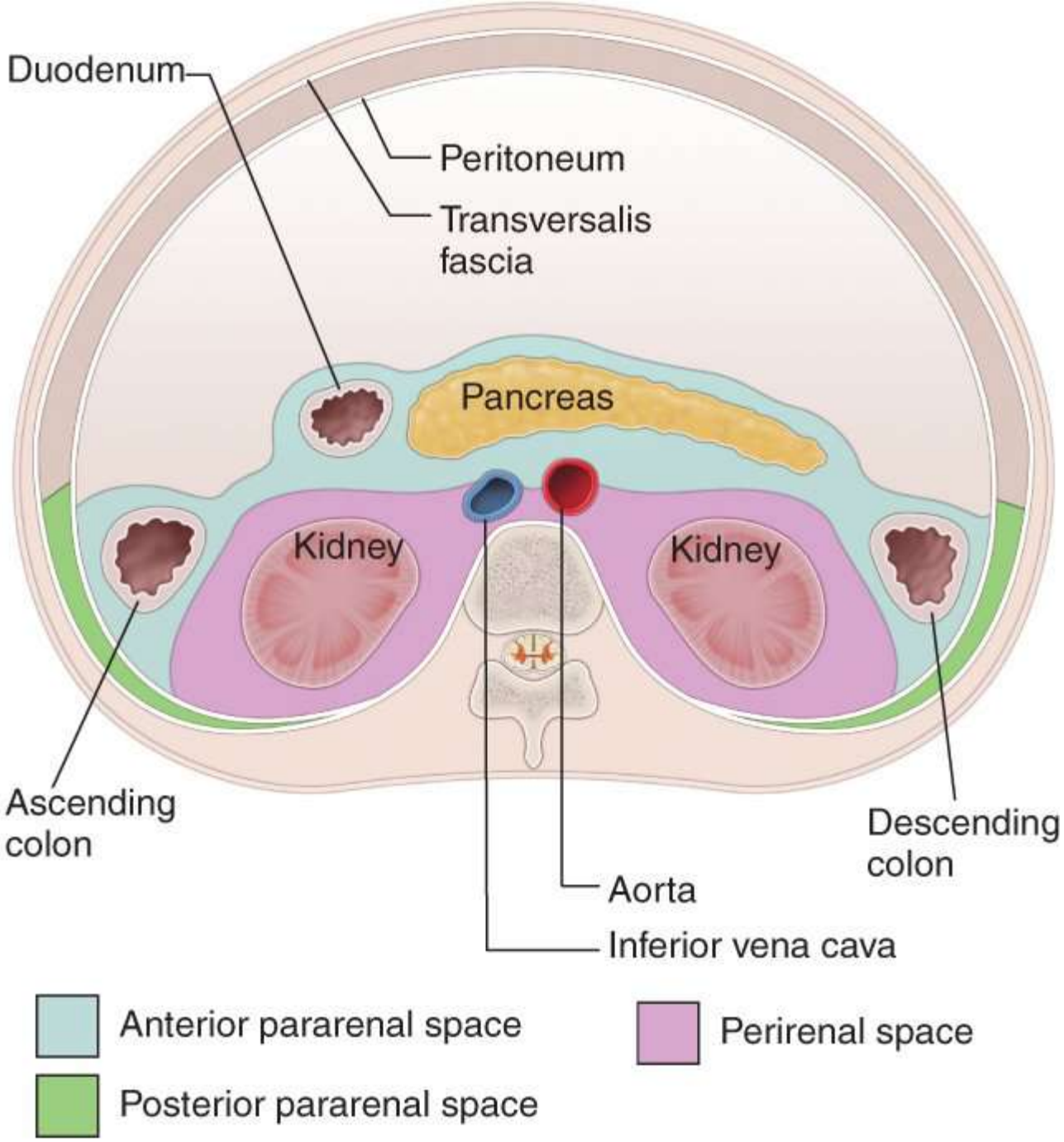

Renal Cortex
Uretur
Renal Pelvis
Renal Pyramid

Kidney Structure

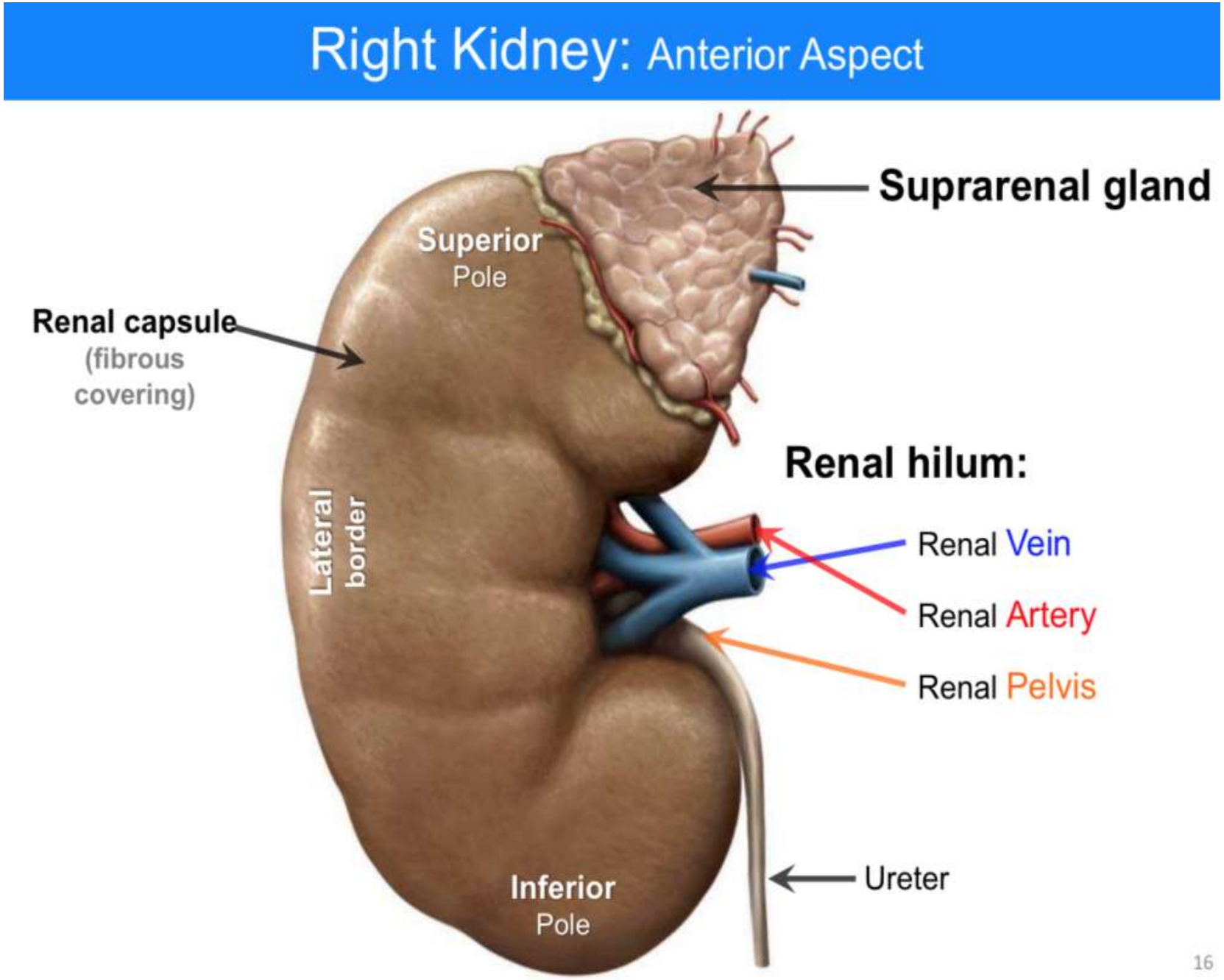
A.External

2. The kidneys are in a position that is called retroperitoneal – outside the peritoneum lining.



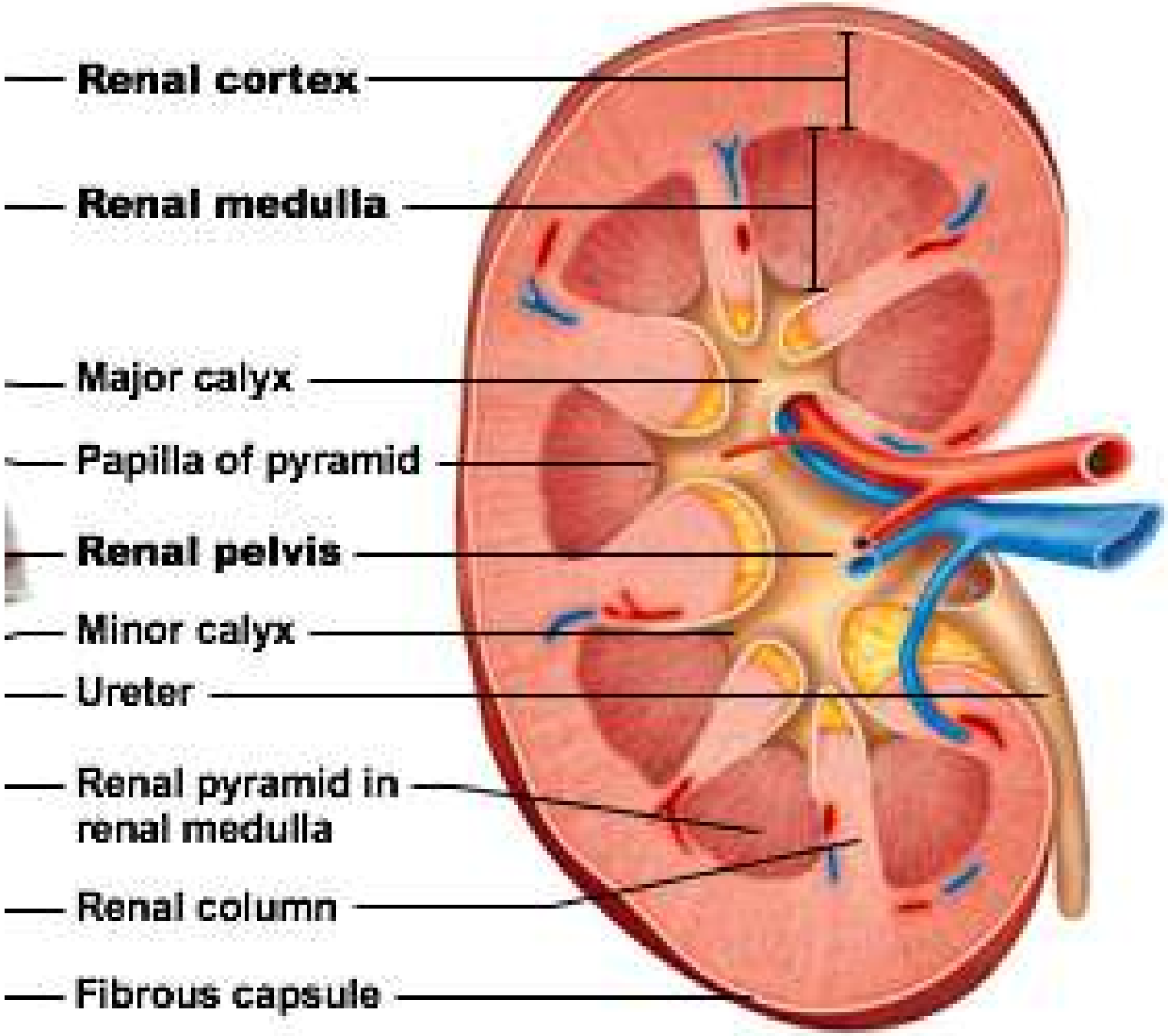


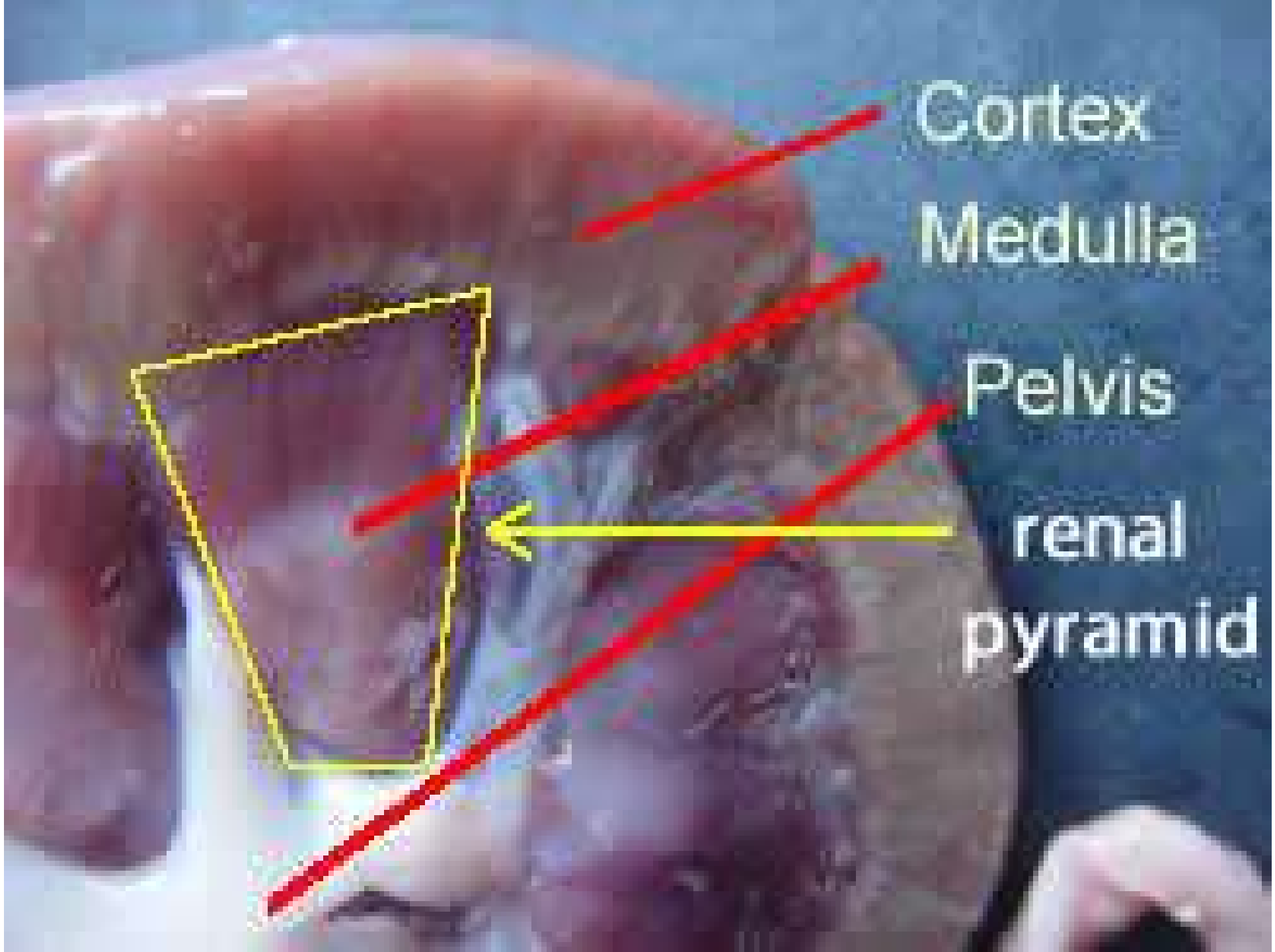
2. They are covered by a tough layer called the renal capsule. The indention in the middle that the renal artery and vein use to enter and leave is called the renal hilus.



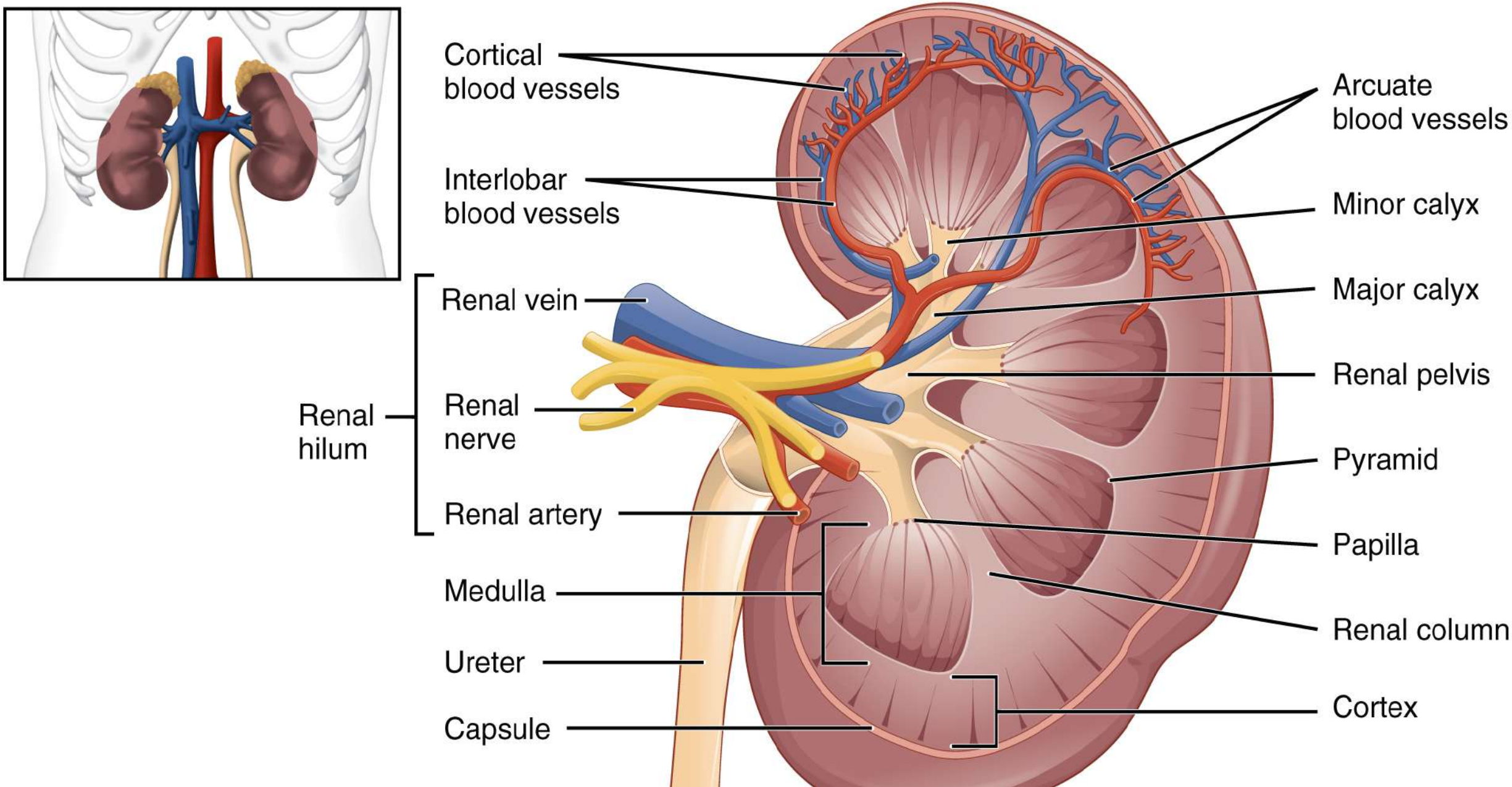
B. Internal

1. The inside can be divided from superficial to deep into the renal cortex, renal medulla and renal pelvis

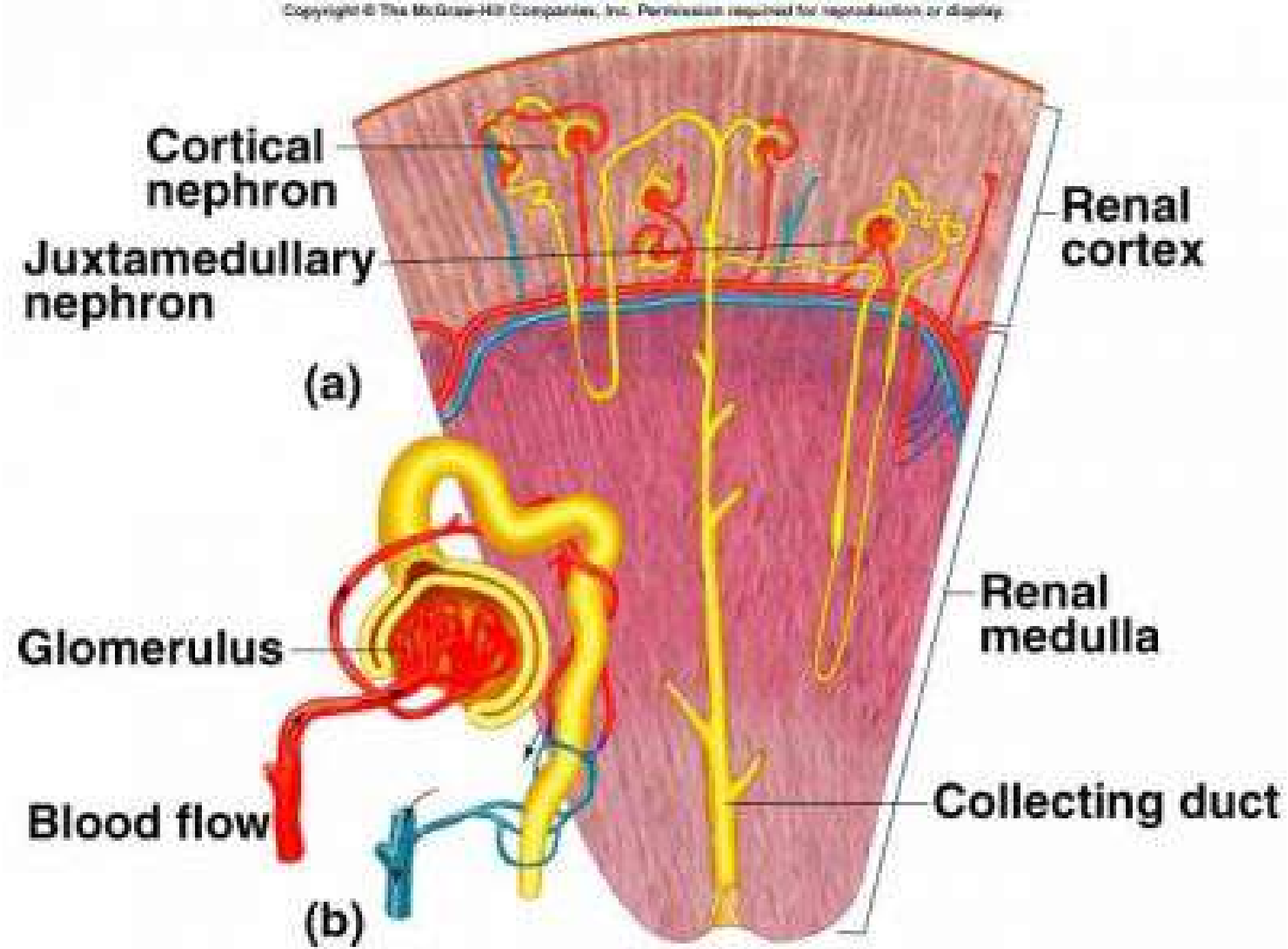


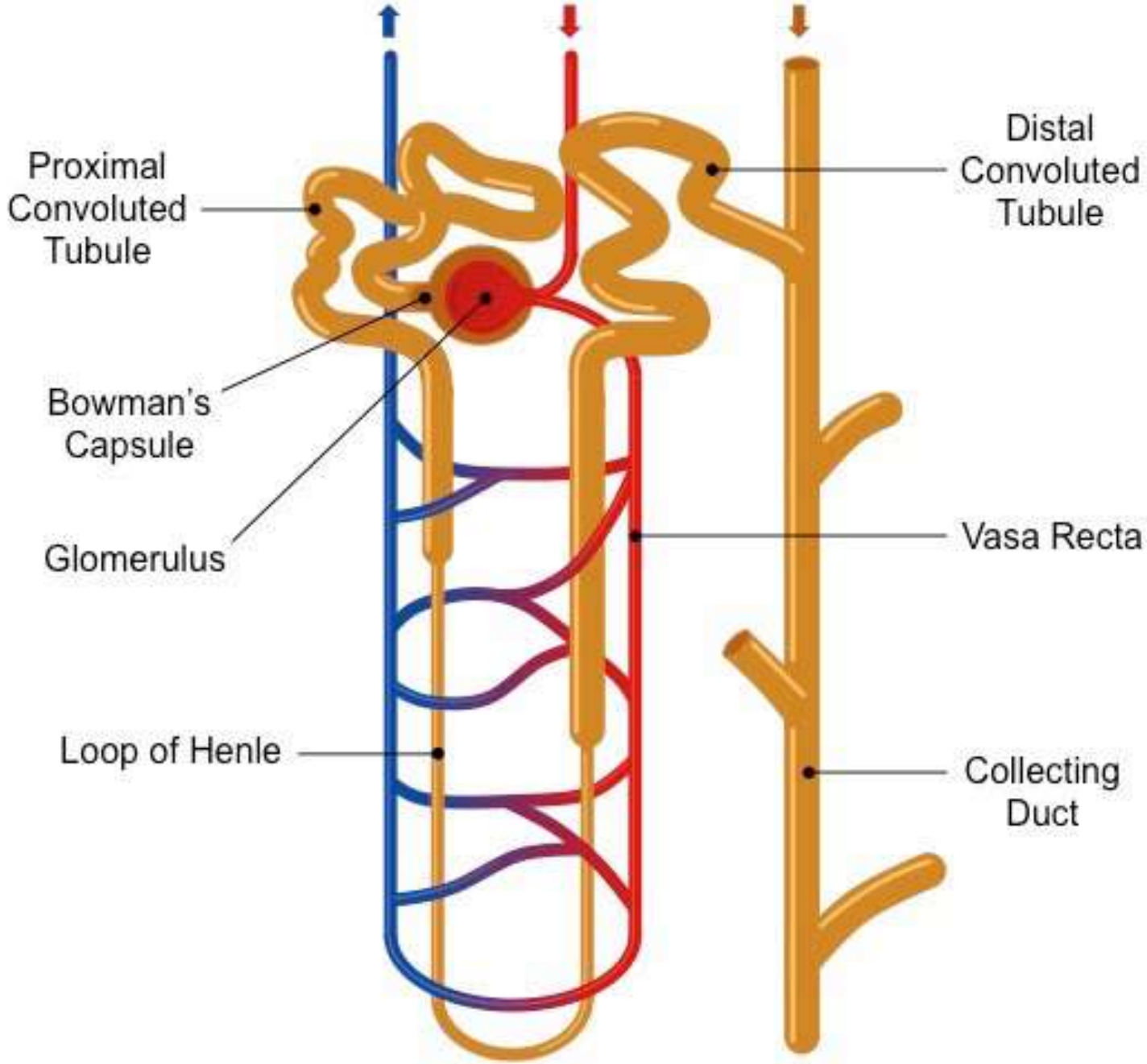

Cortex
Medulla
Pelvis
renal
pyramid

2. The renal medulla can be divided into the renal pyramids and renal columns.



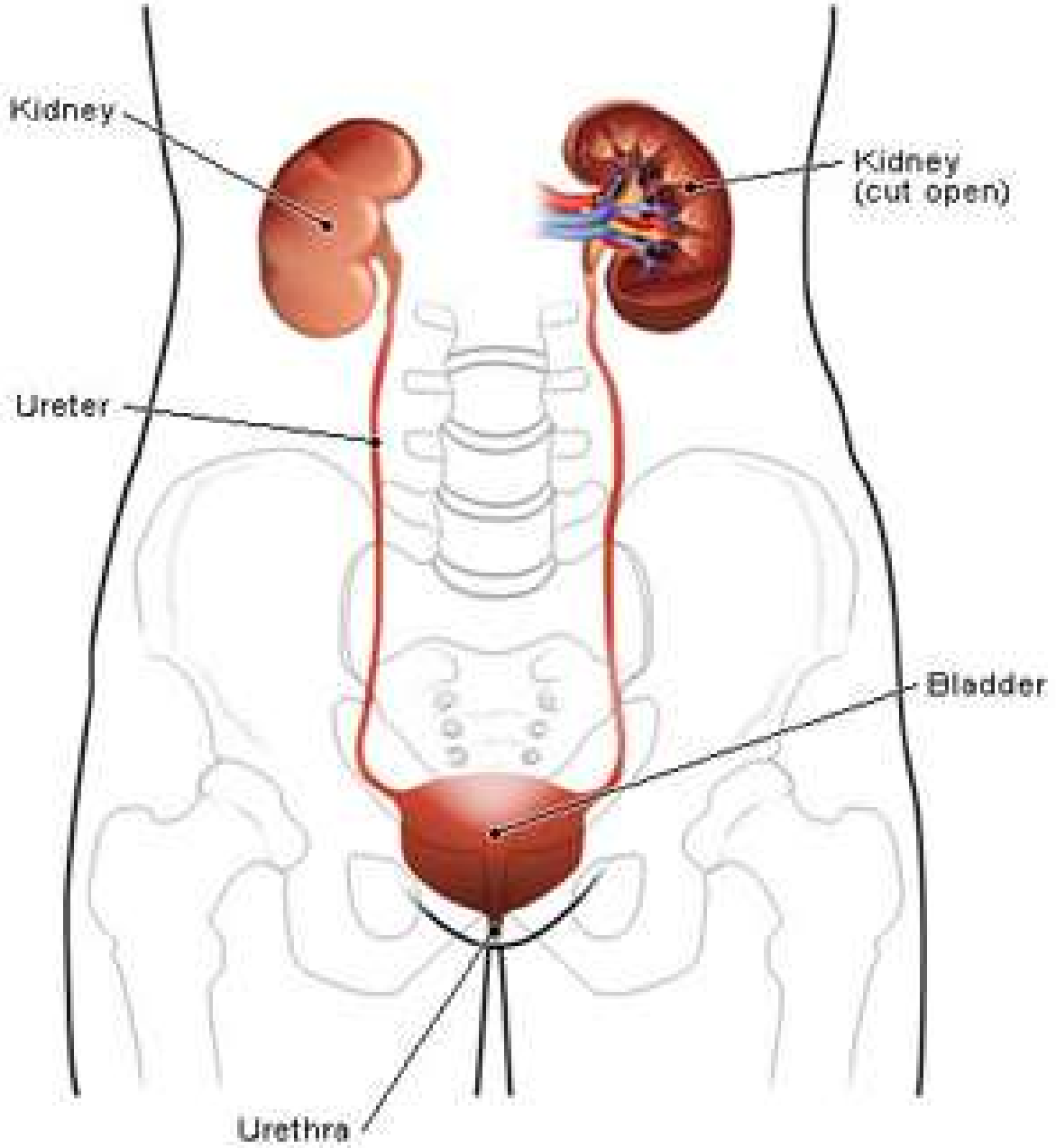
3. The nephron (filtering unit) is positioned in the cortex and medulla




Proximal Convoluted Tubule
Bowman's Capsule
Glomerulus
Loop of Henle
Distal Convoluted Tubule
Vasa Recta
Collecting Duct

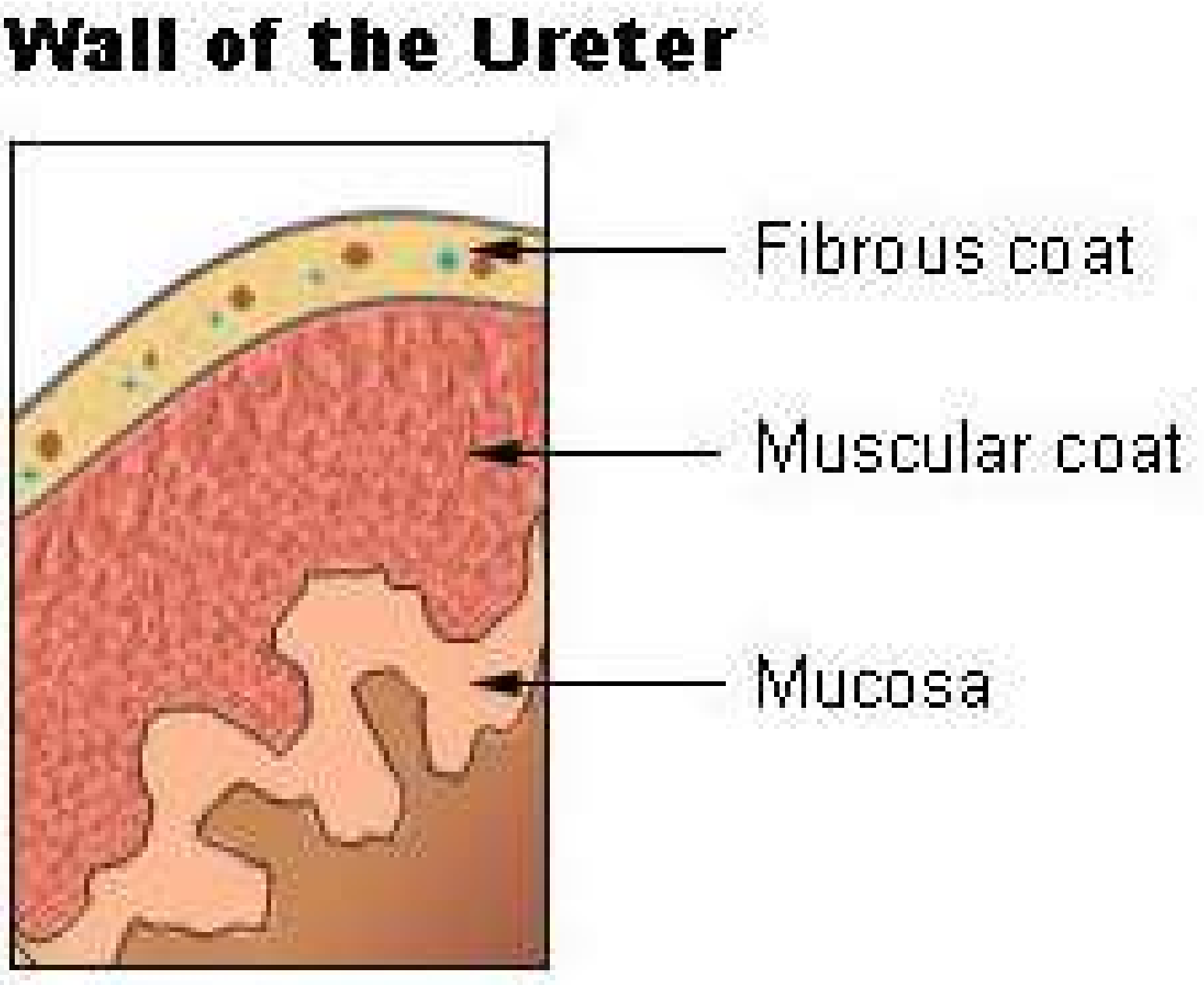
Ureter

1. Connects the kidney to the bladder



Ureter

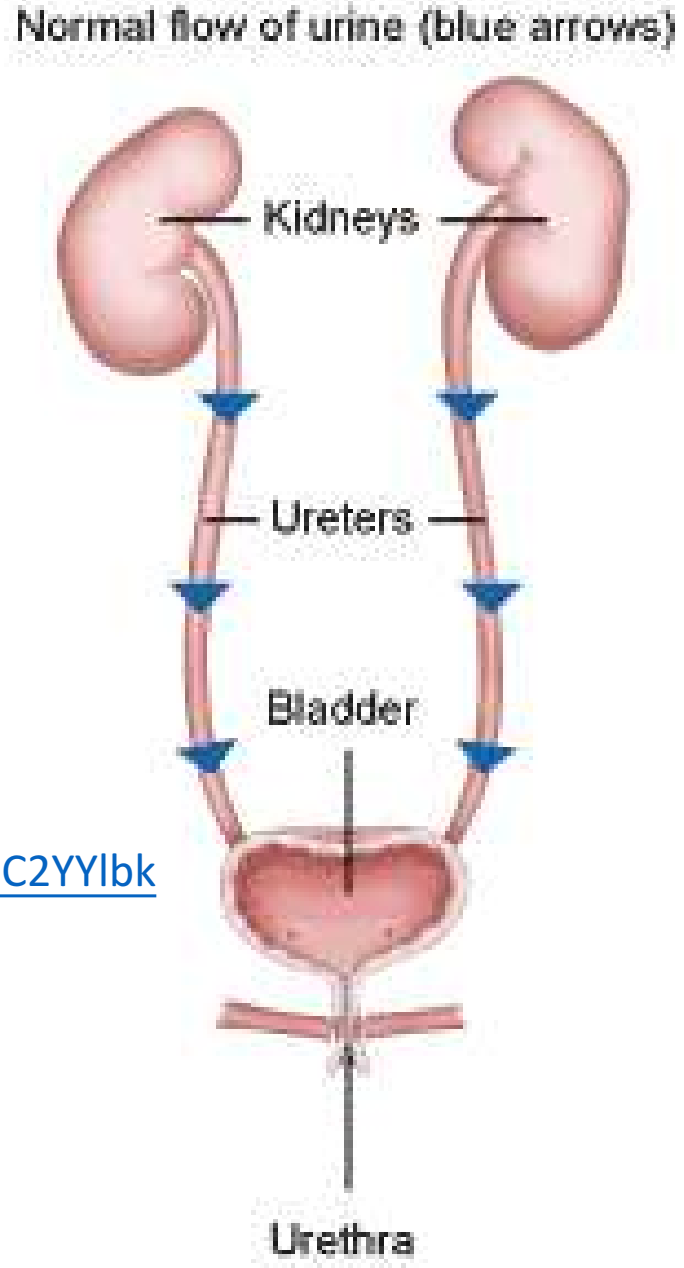
1. *Connects the kidney to the bladder*
2. Made of mucus coat, smooth muscle and connective tissue

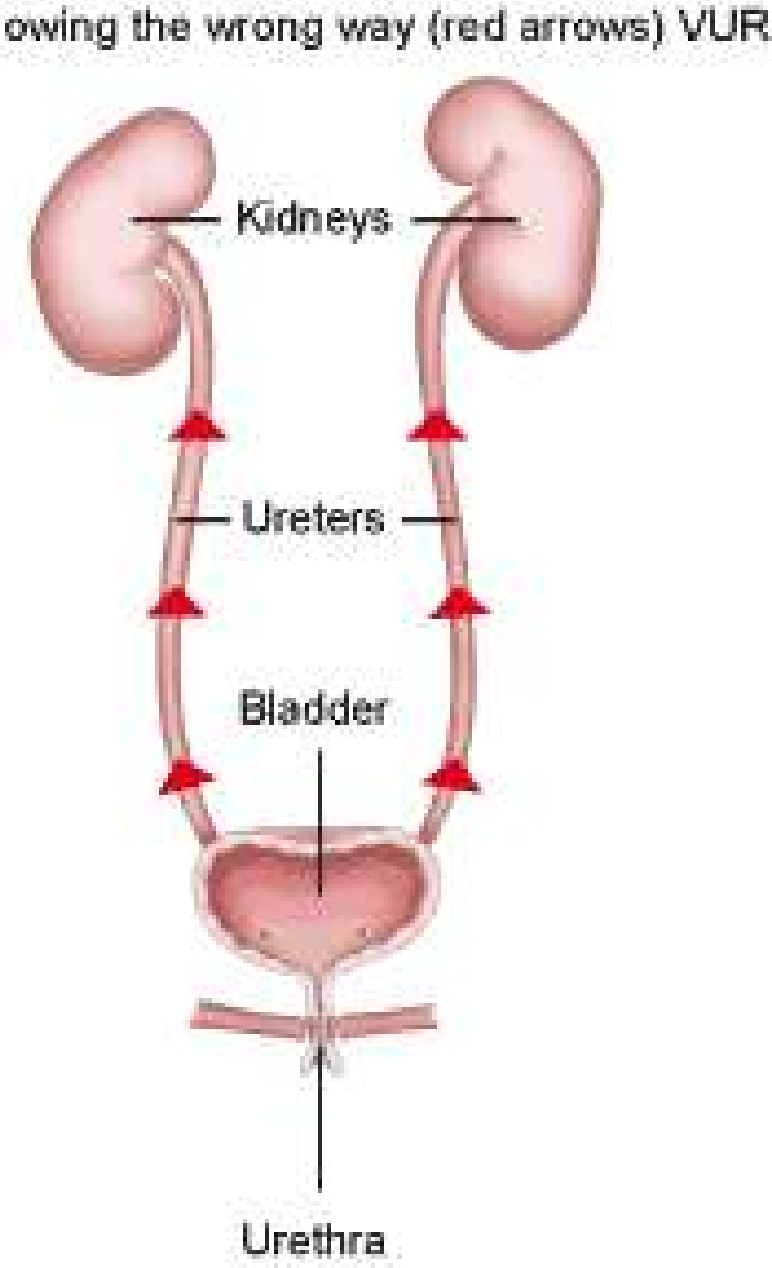


Ureter

1. *Connects the kidney to the bladder*
2. *Made of mucus coat, smooth muscle and connective tissue*
3. Peristaltic waves propel urine

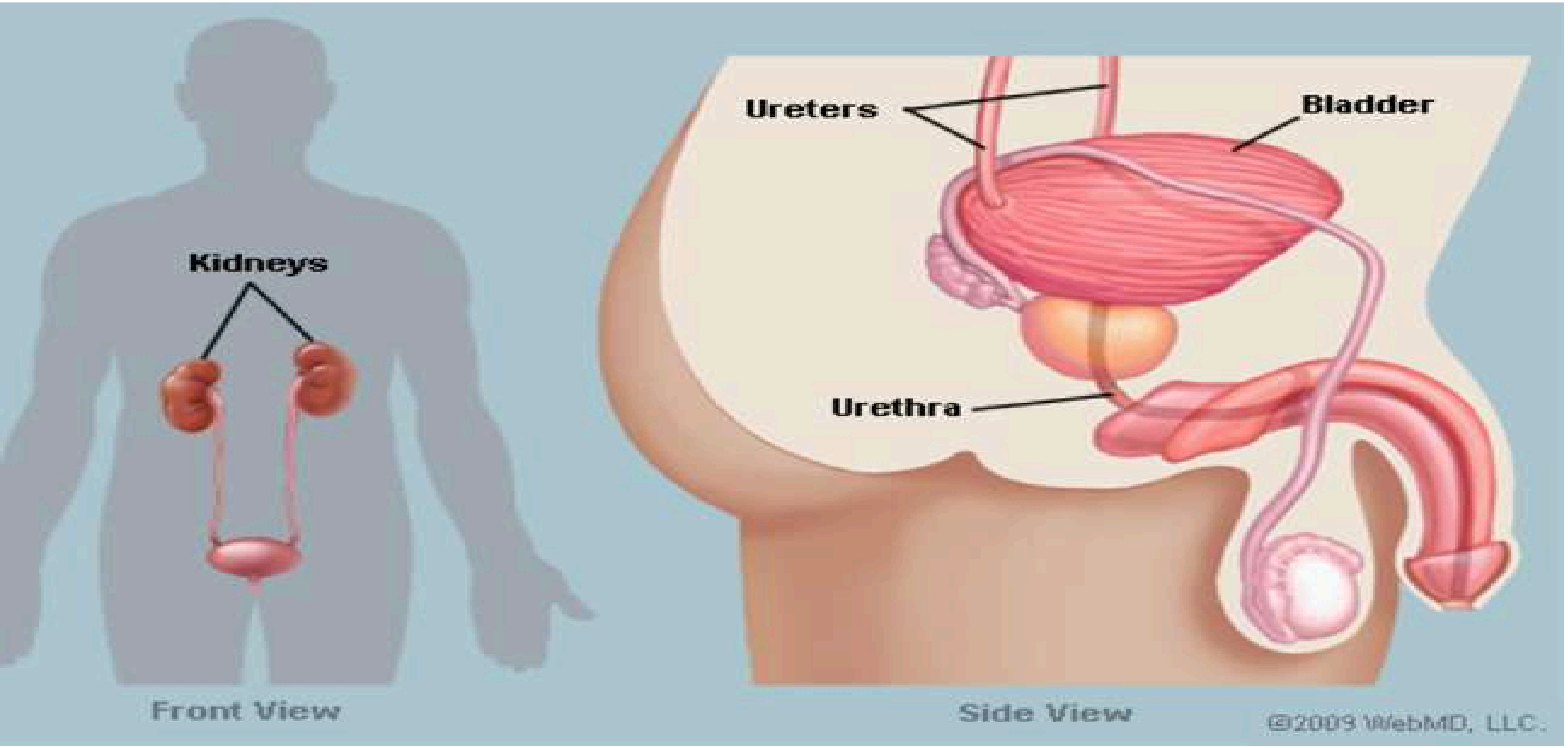
https://www.youtube.com/watch?v=uAy5C2YYlbk

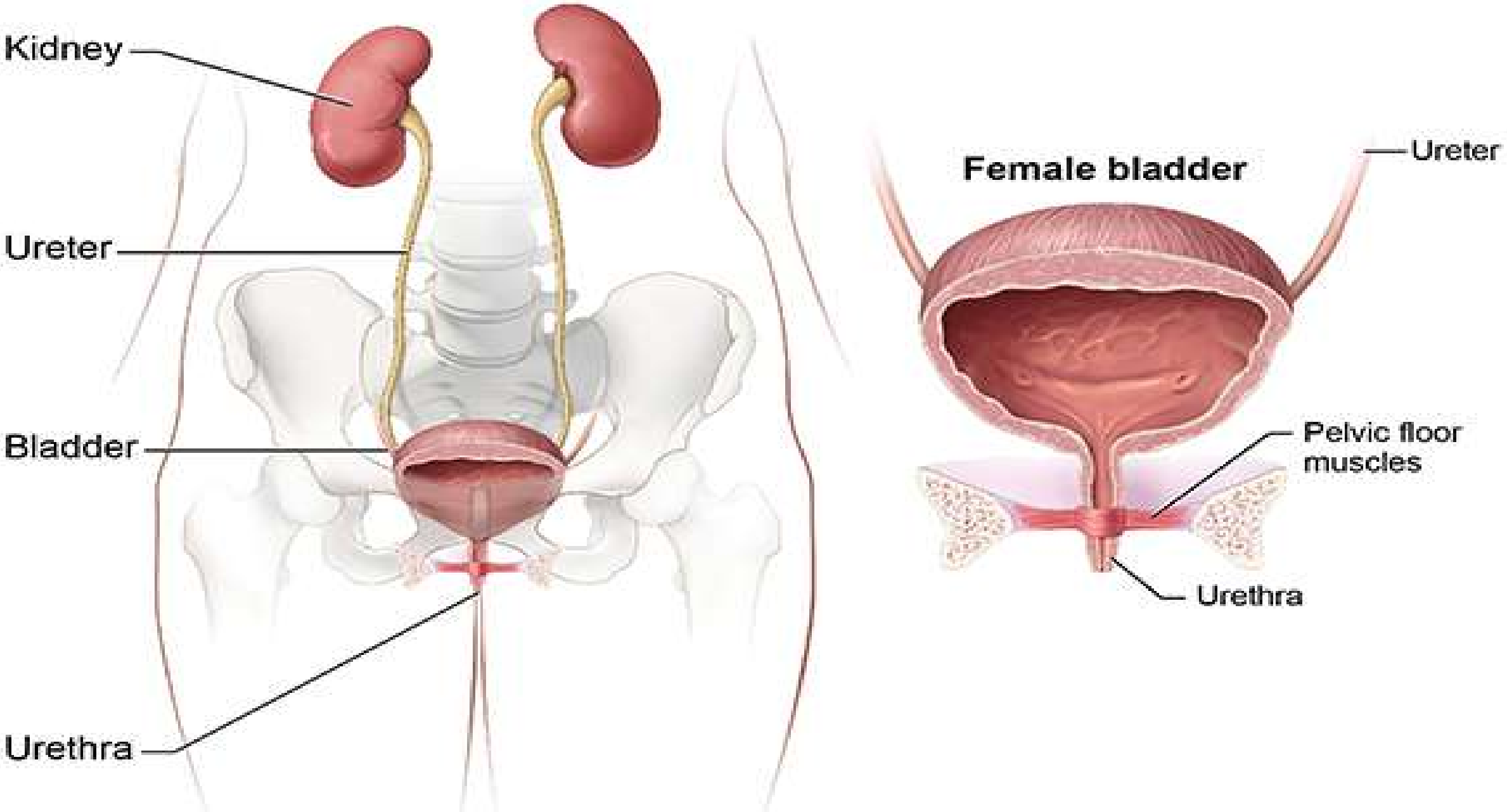


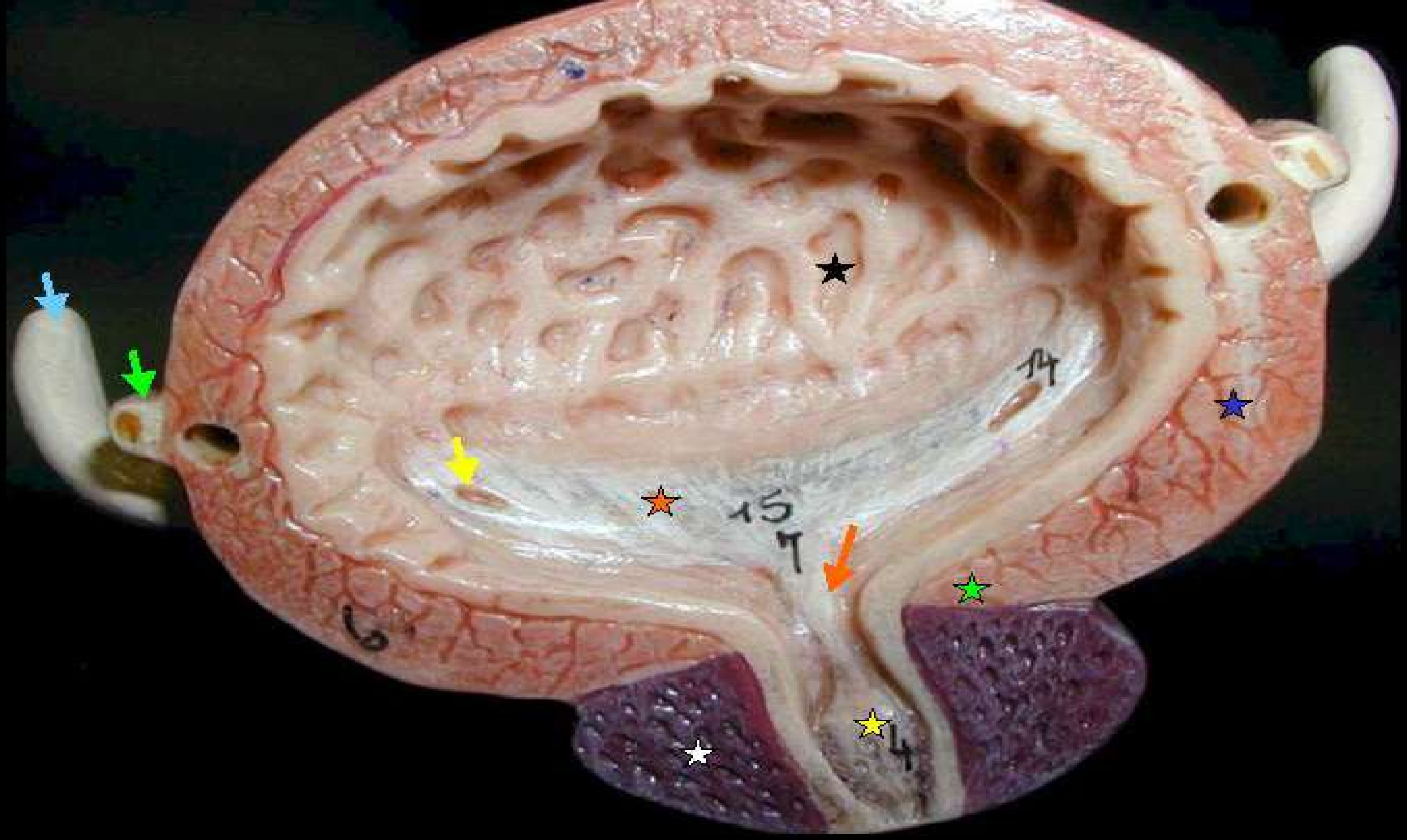


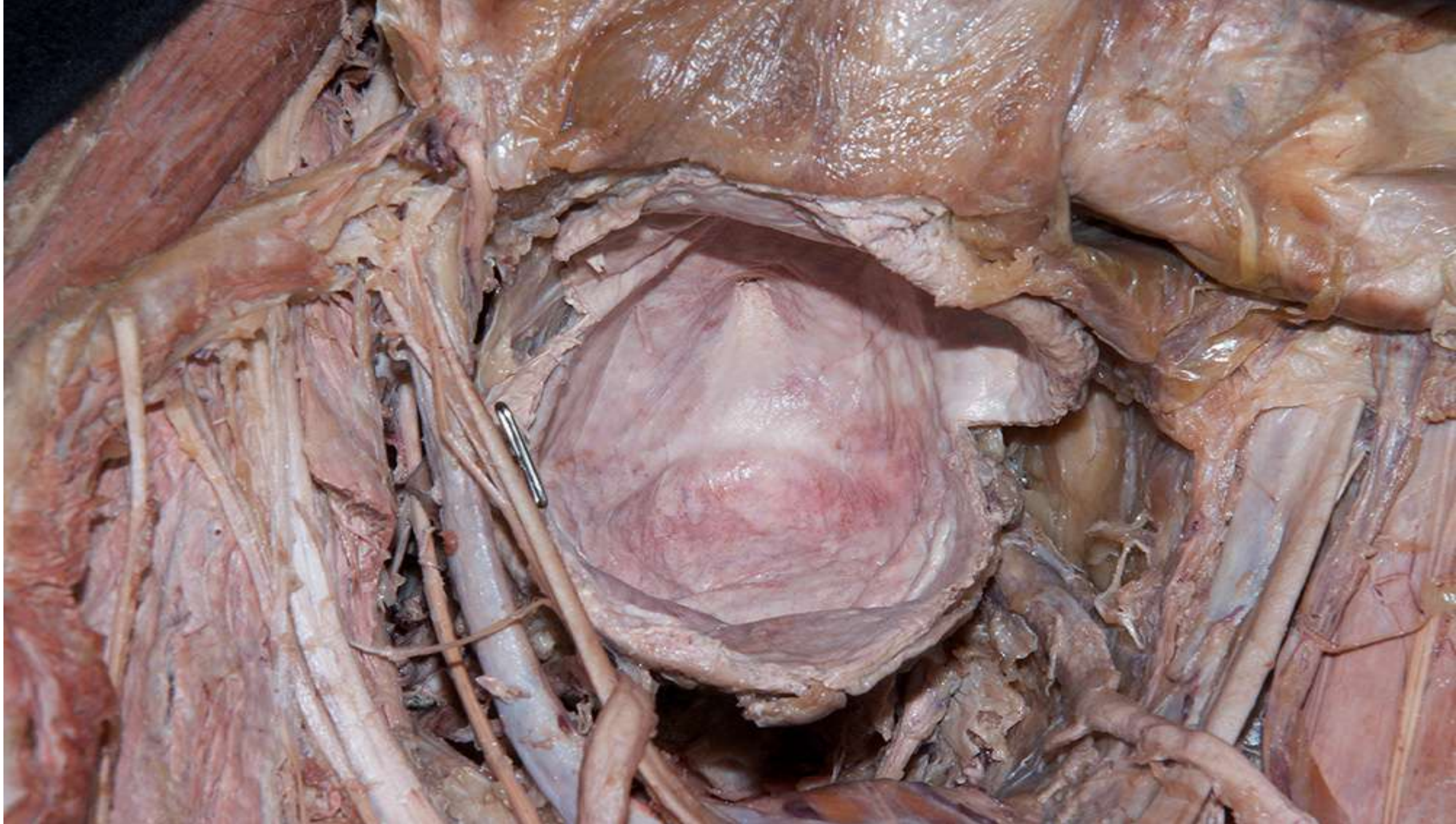
Bladder

1. A hollow distensible storage unit for urine



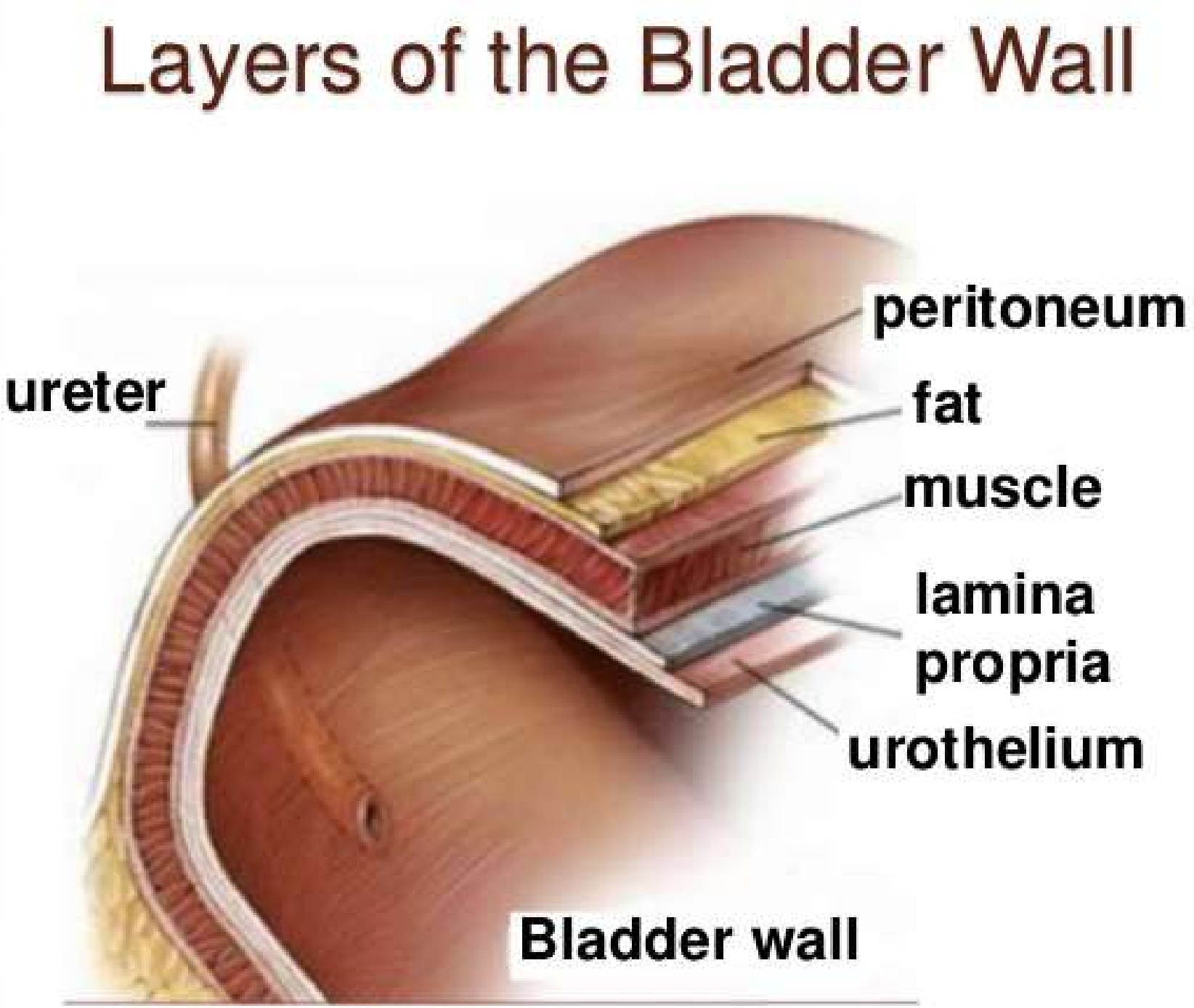

Kidney
Ureter
Bladder
Urethra
Female bladder
Ureter
Pelvic floor muscles
Urethra





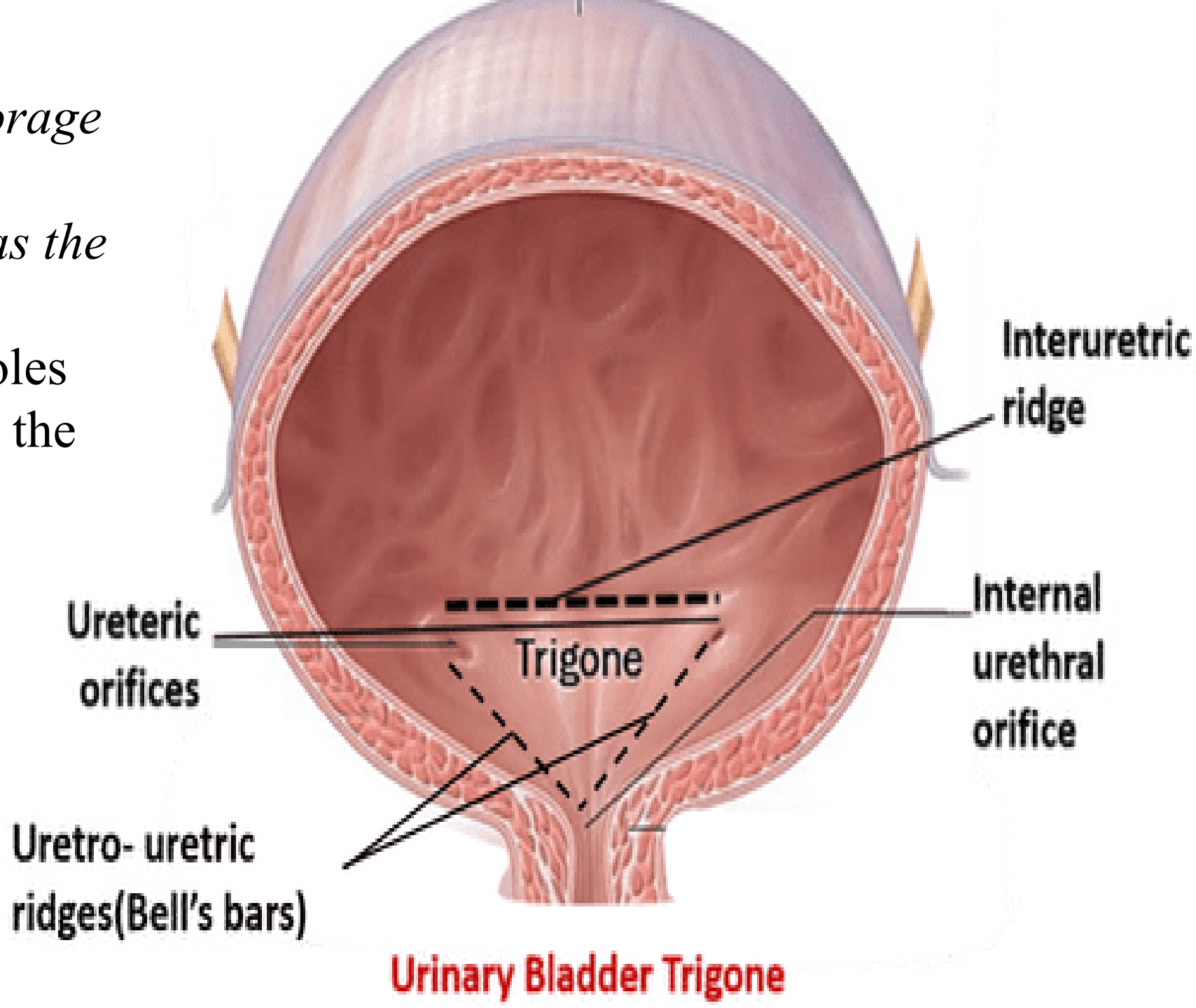
Bladder

1. *A hollow distensible storage unit for urine*
2. Has the same 4 layers as the alimentary canal



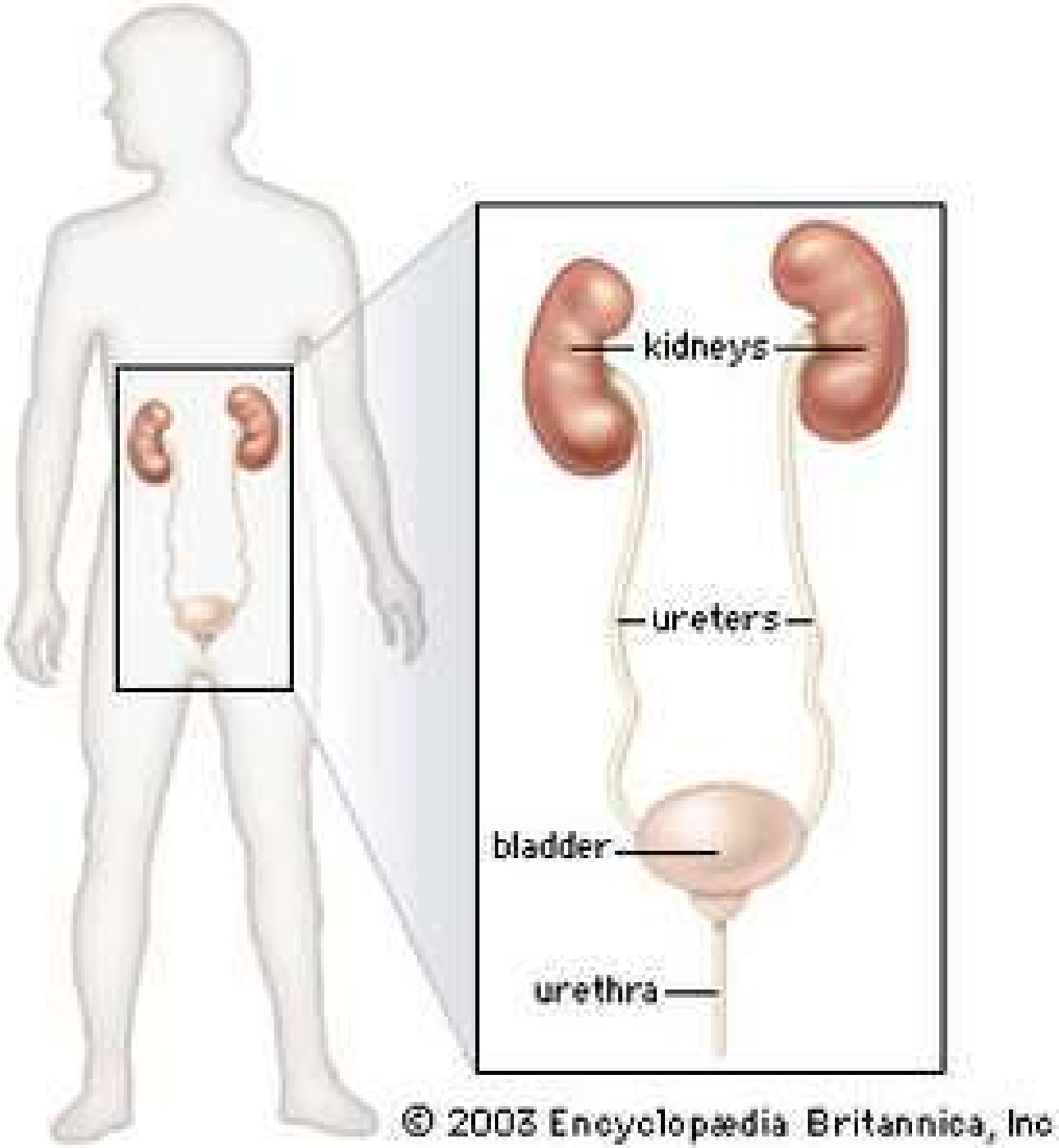
Bladder

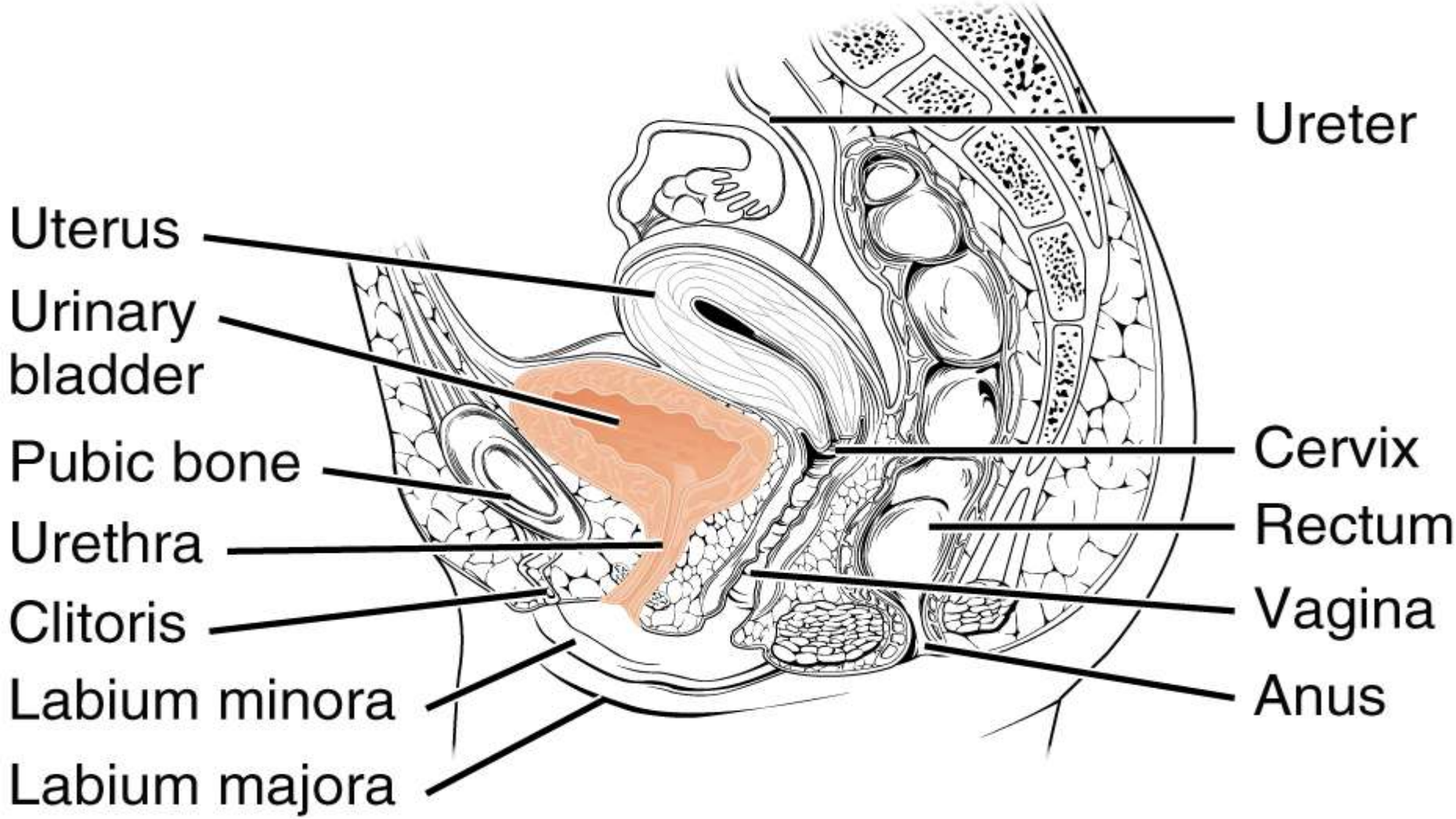
1. *A hollow distensible storage unit for urine*
2. *Has the same 4 layers as the alimentary canal*
3. The trigone are the 3 holes of the bladder. 2 are for the ureters and one for the urethra



Urethra

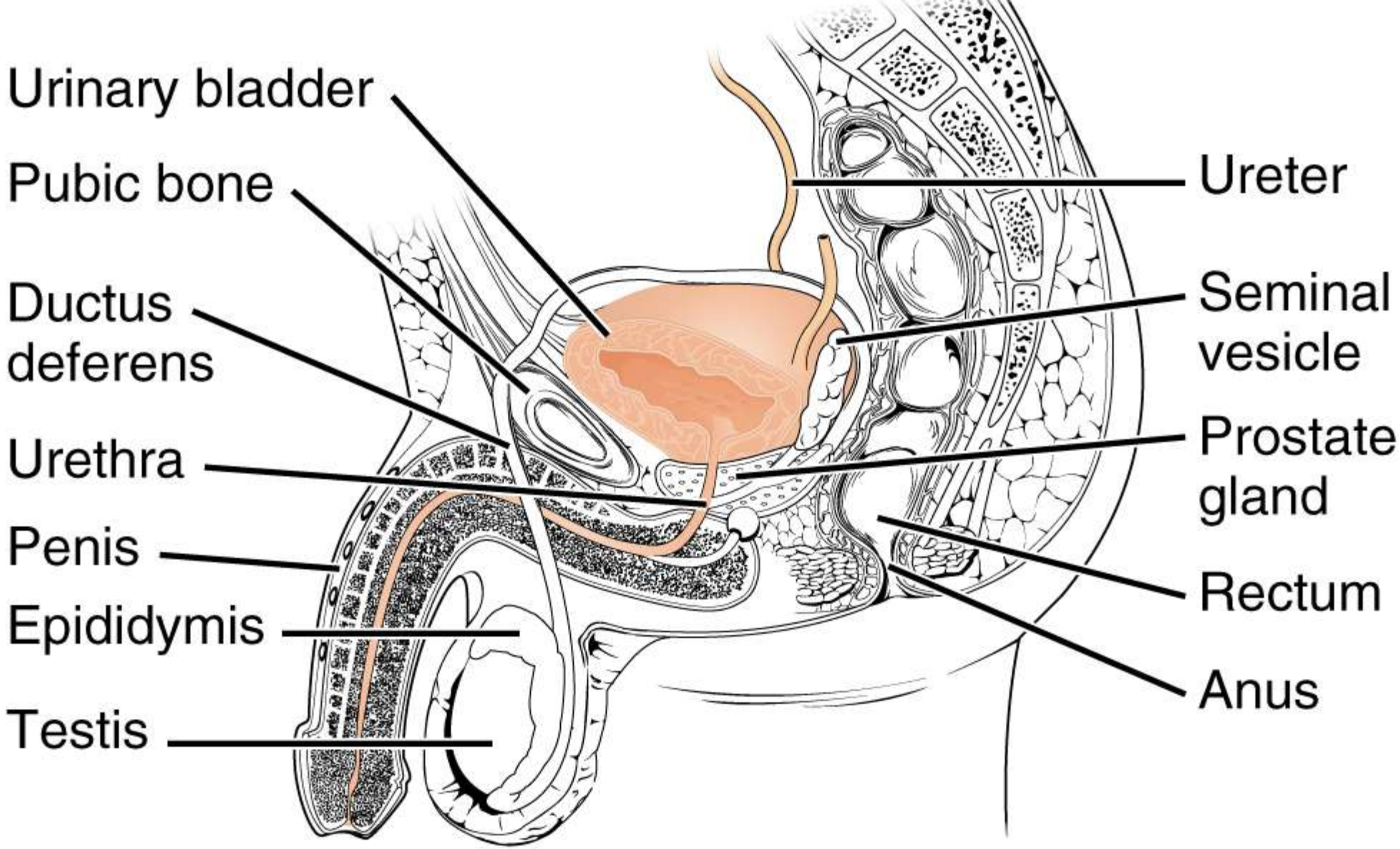
1. Pathway from bladder to outside world
2. The structure is much the same as in the ureter



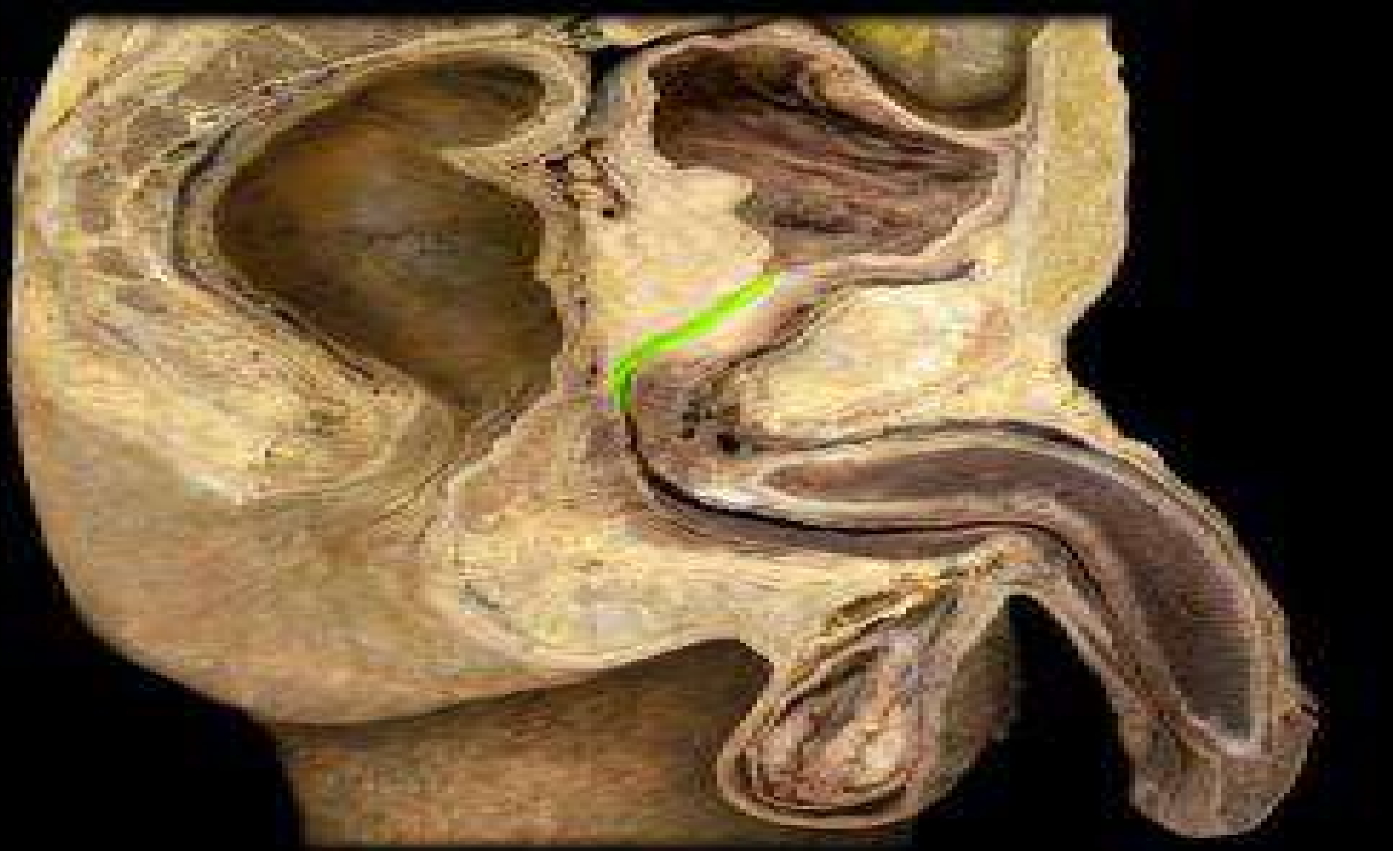

Ureter
Uterus
Urinary bladder
Pubic bone
Urethra
Clitoris
Labium minora
Labium majora
Cervix
Rectum
Vagina
Anus

(a)


Urinary bladder

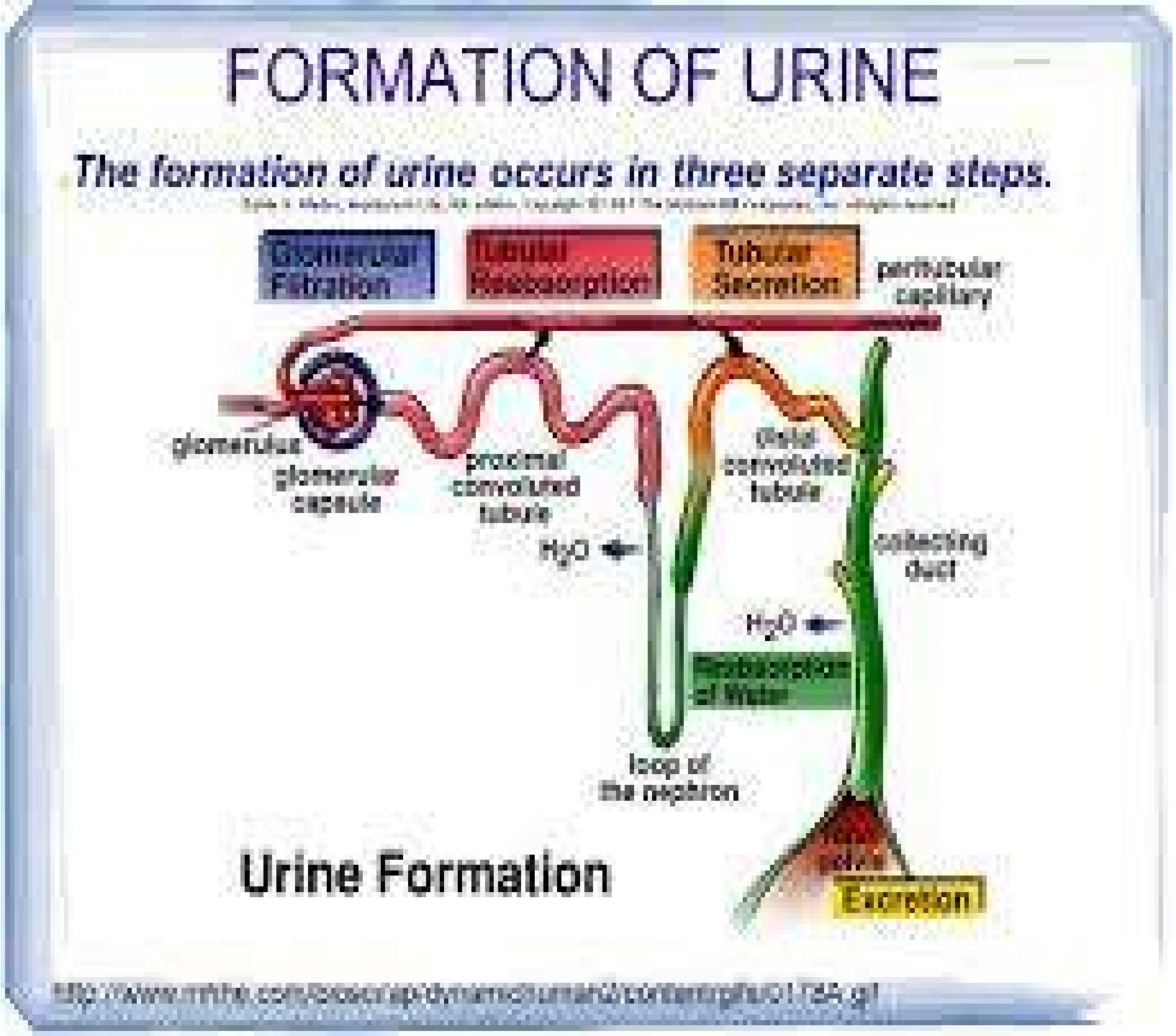

Urinary bladder
Pubic bone
Ductus deferens
Urethra
Penis
Epididymis
Testis
Ureter
Seminal vesicle
Prostate gland
Rectum
Anus

(b)

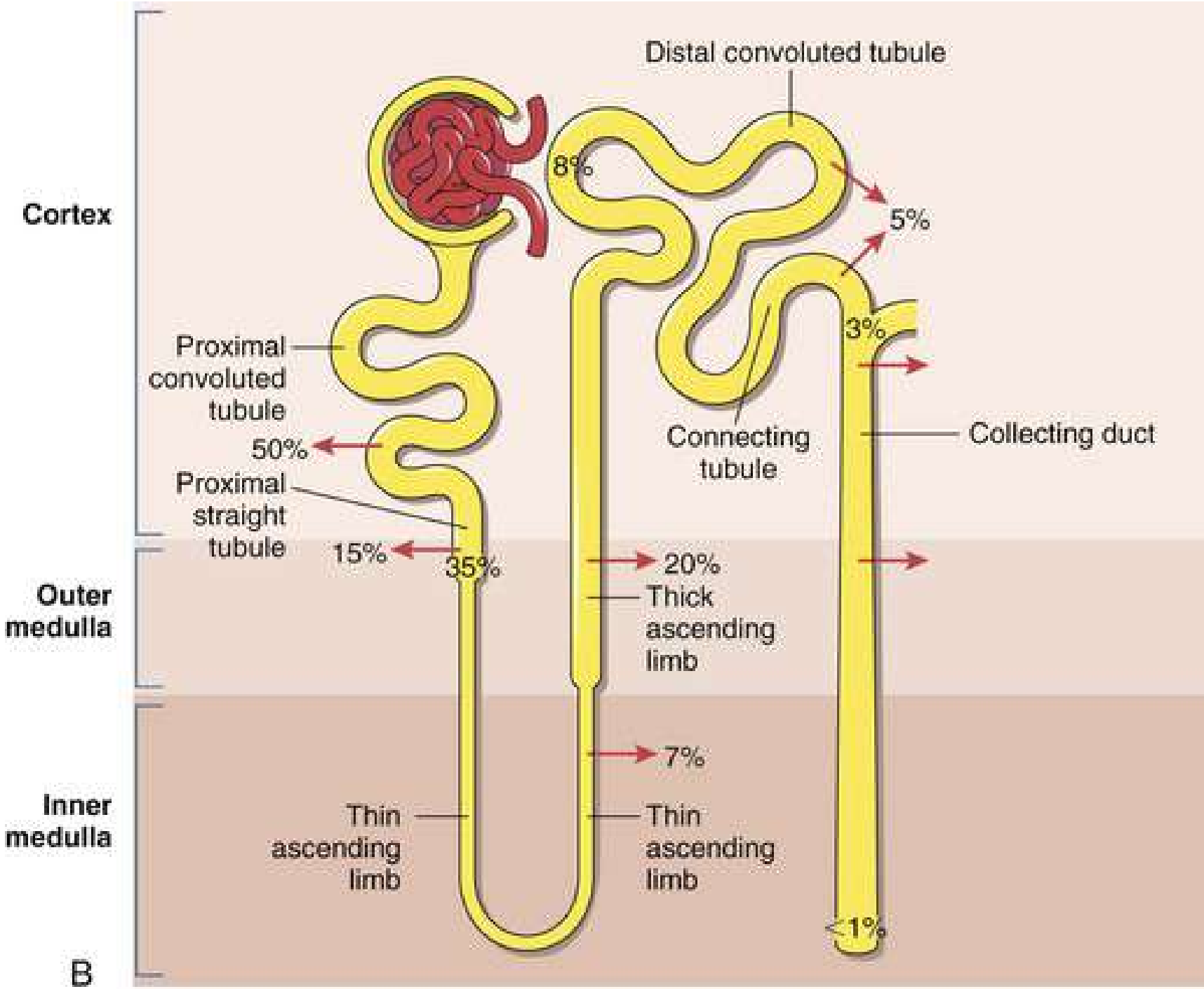


Urine formation

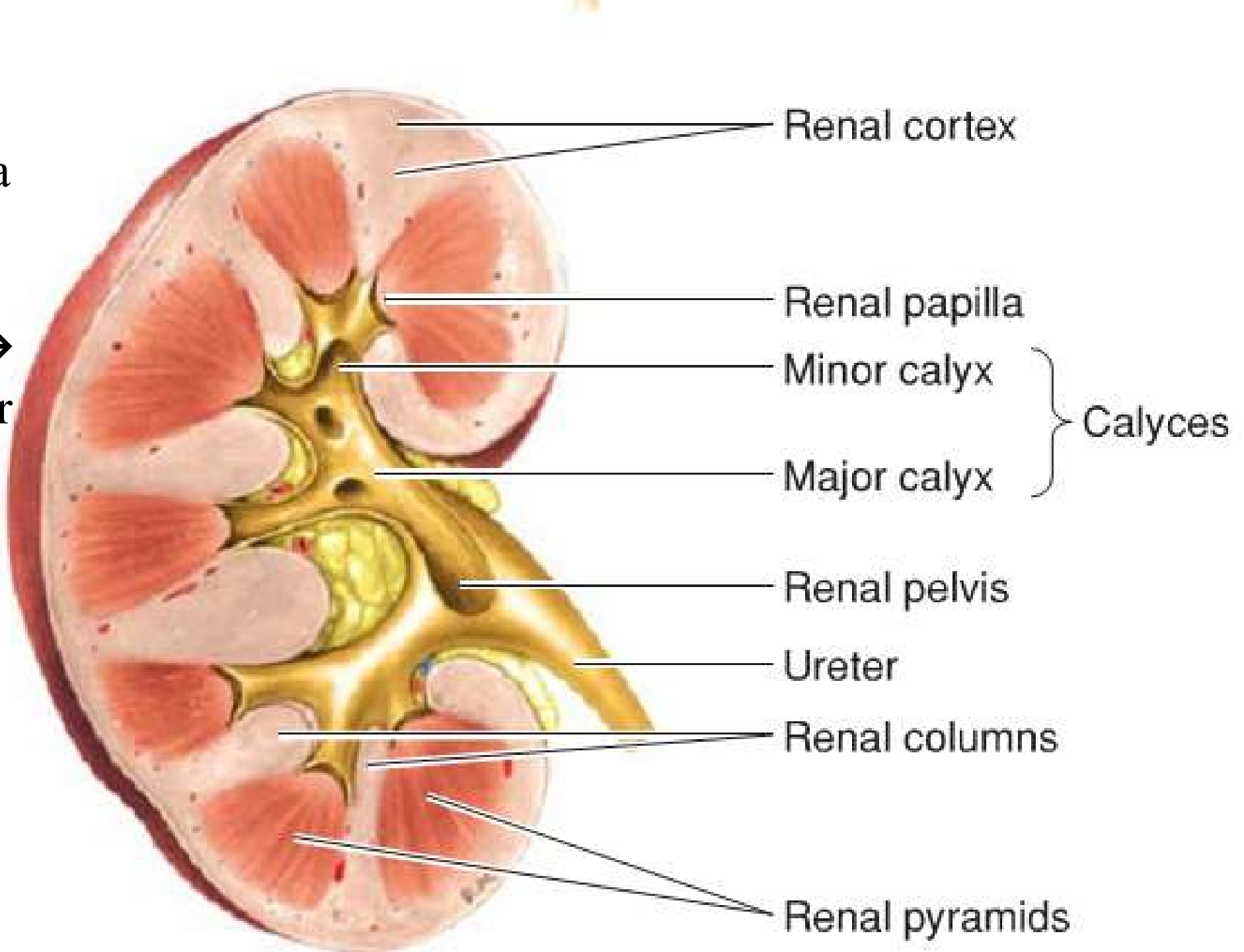
There are 3 processes and 4 pathways involved in urine formation. The nephron is free to manipulate these 2 factors, in any way, to do its job of maintaining the volume, pressure and composition of the blood.



B. Once the nephron forms urine, it will leave the nephron via the collecting duct. Urine will then flow to the renal papilla → minor calyx → major calyx → renal pelvis → ureter → bladder → urethra



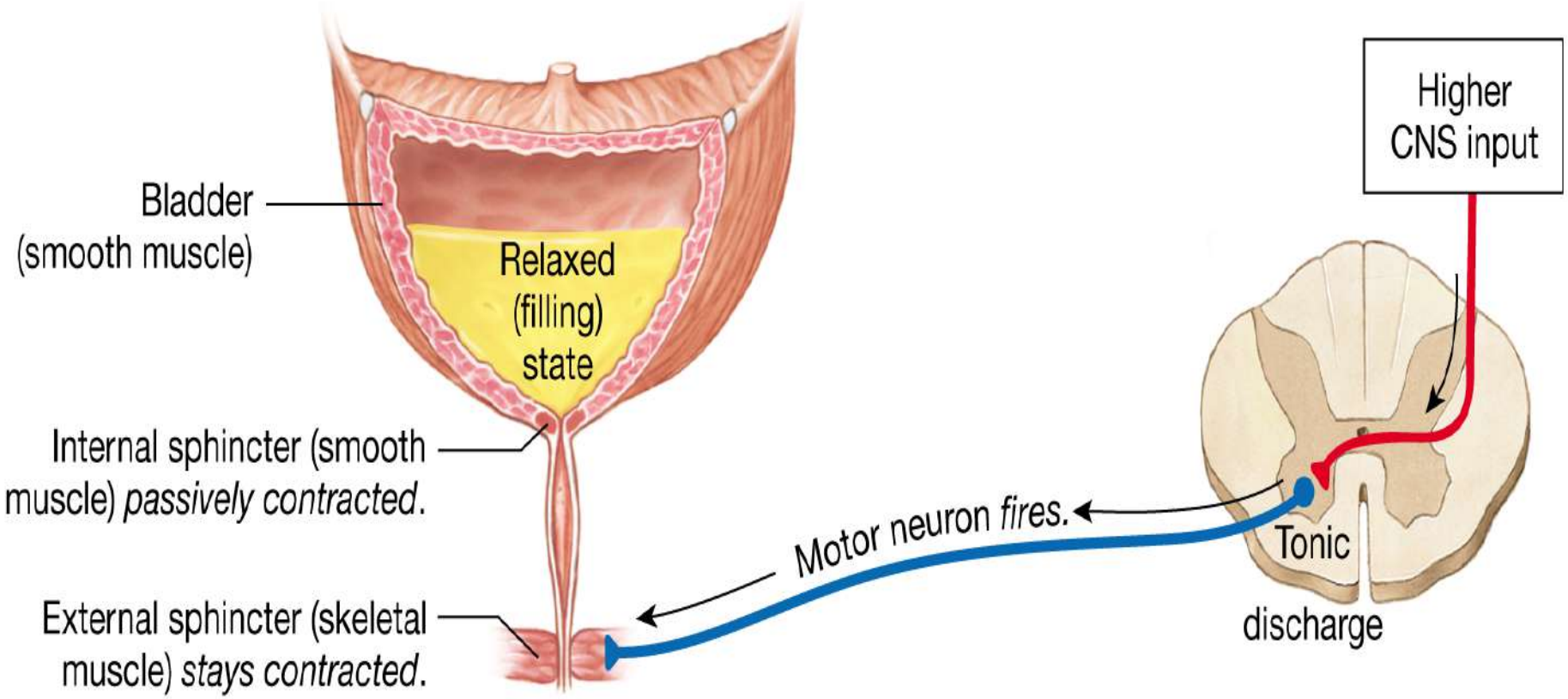
B. Once the nephron forms urine, it will leave the nephron via the collecting duct. Urine will then flow to the renal papilla → minor calyx → major calyx → renal pelvis → ureter → bladder → urethra



C. Micturition is the process of expelling urine from the bladder. The filling of the bladder signal stretch receptors that send messages to the micturition reflex center in the spinal cord. Parasympathetic impulses cause the detrusor muscle to contract the bladder. This occurs at around 150 ml of urine. The external urethral sphincter voluntarily relaxes to let the urine escape.

Micturition is a spinal reflex subject to higher brain control.

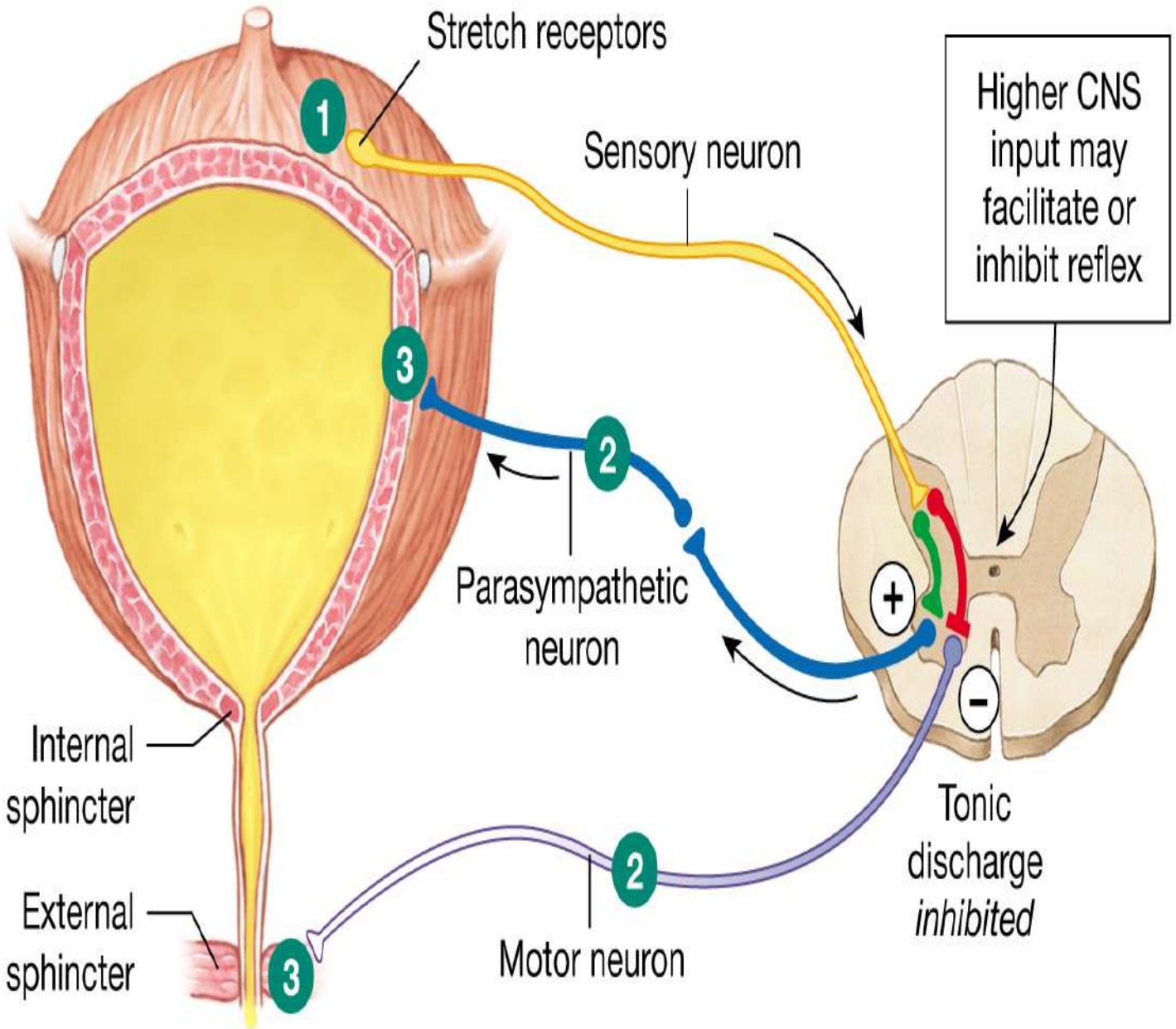
(a) Bladder at Rest



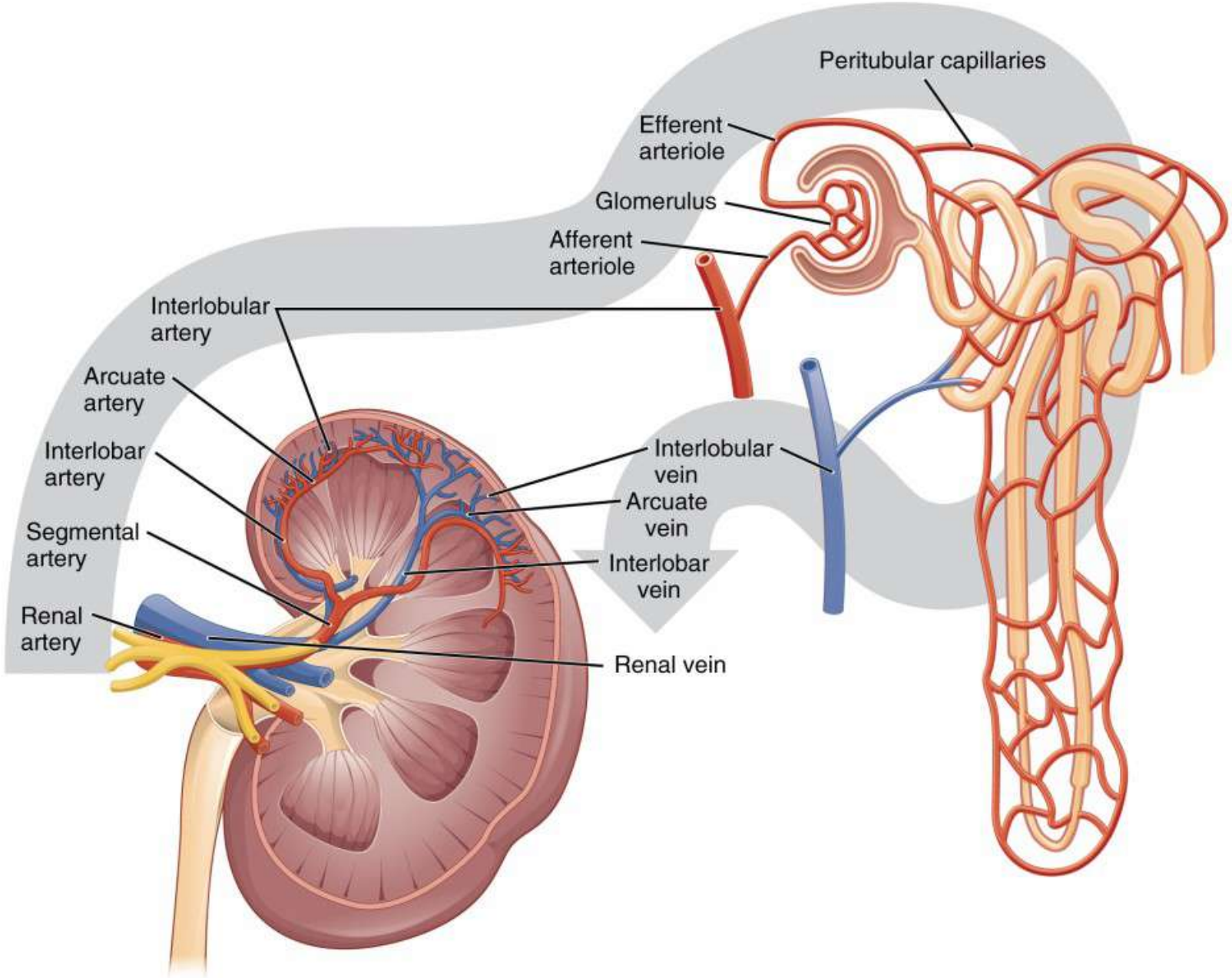
(b) Micturition

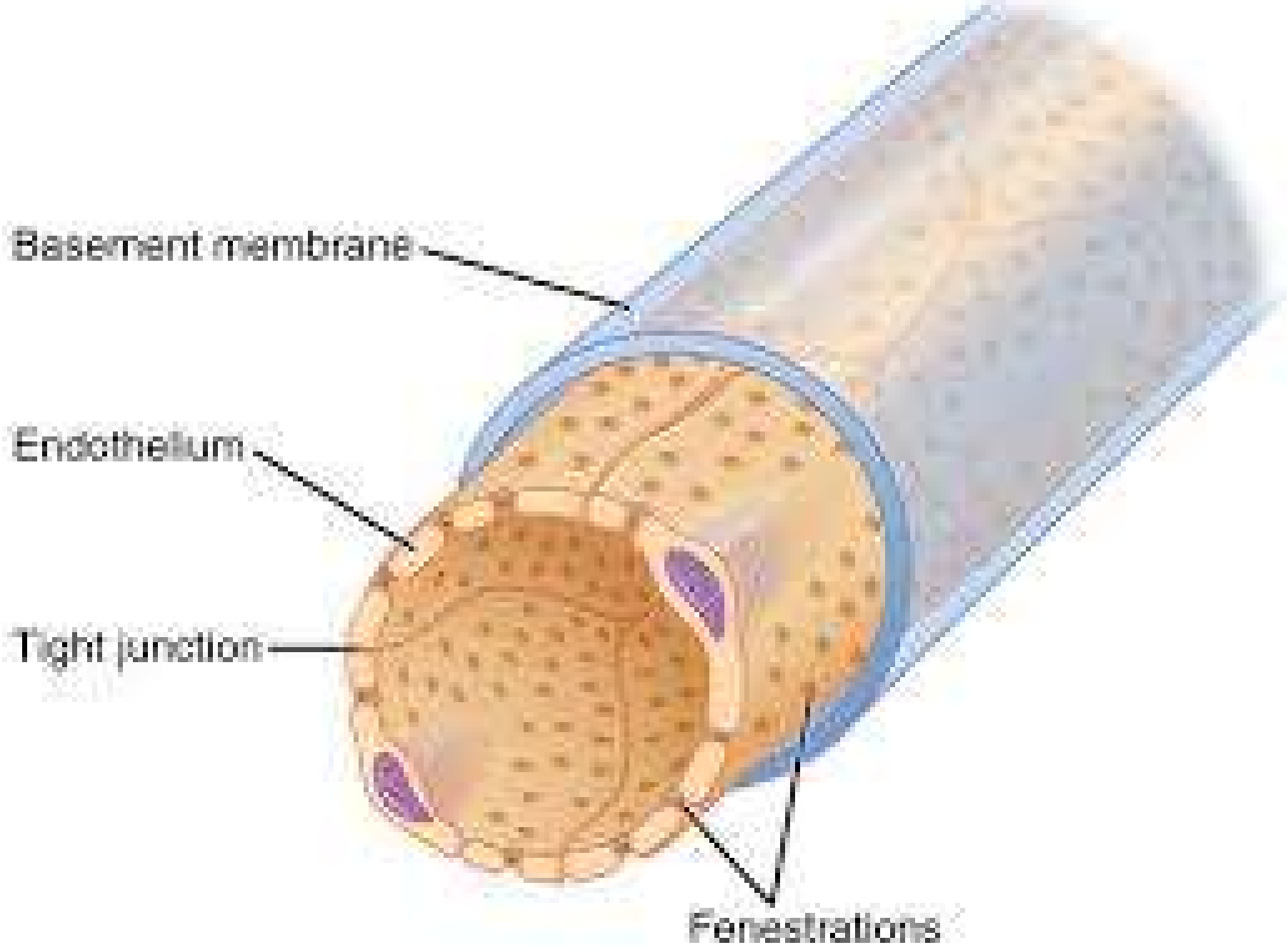
(b) Micturition

1. Stretch receptors fire.
2. Parasympathetic neurons fire. Motor neurons stop firing.
3. Smooth muscle contracts. Internal sphincter is passively pulled open. External sphincter relaxes.

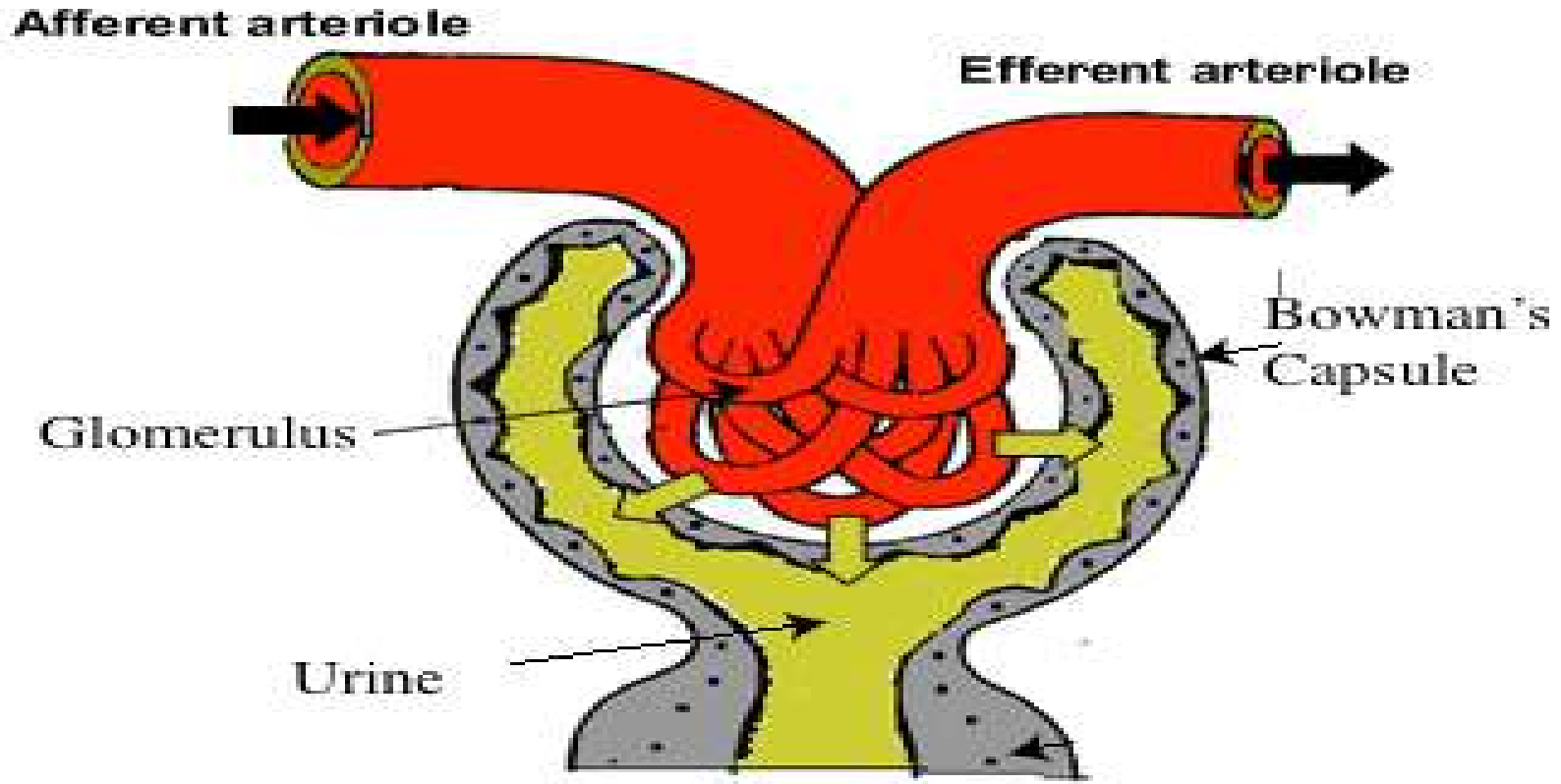


Pathway 1 - **Filtration** – Blood enters the renal artery and flows through the arcuate artery to the afferent arteriole and then the glomerulus. Filtration occurs at the glomerulus when substances are forced through the glomerular walls via fenestrae into the Bowman's capsule of the nephron.

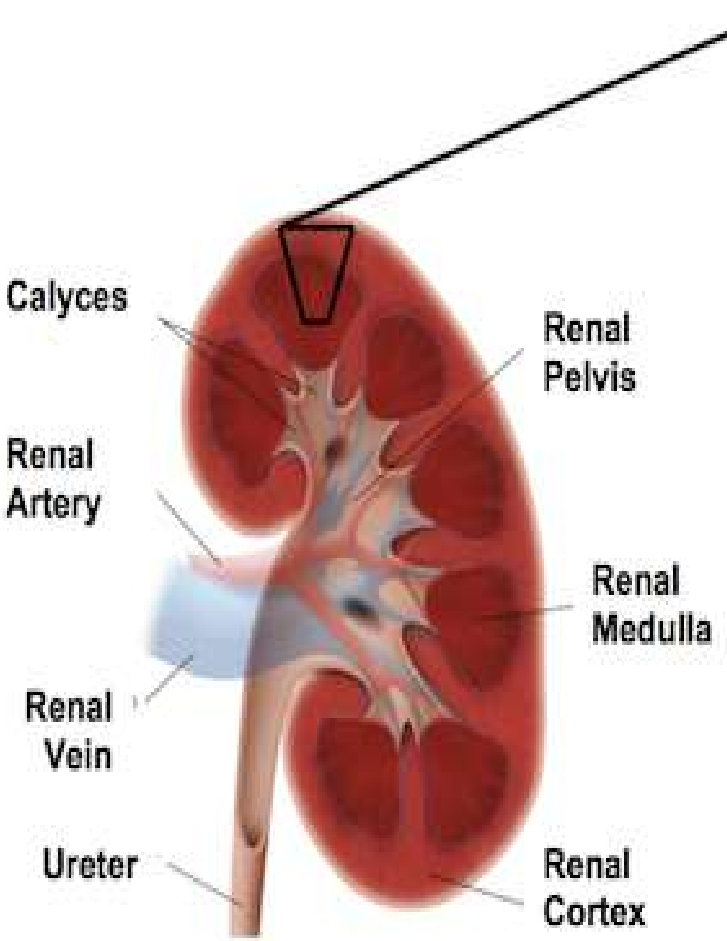


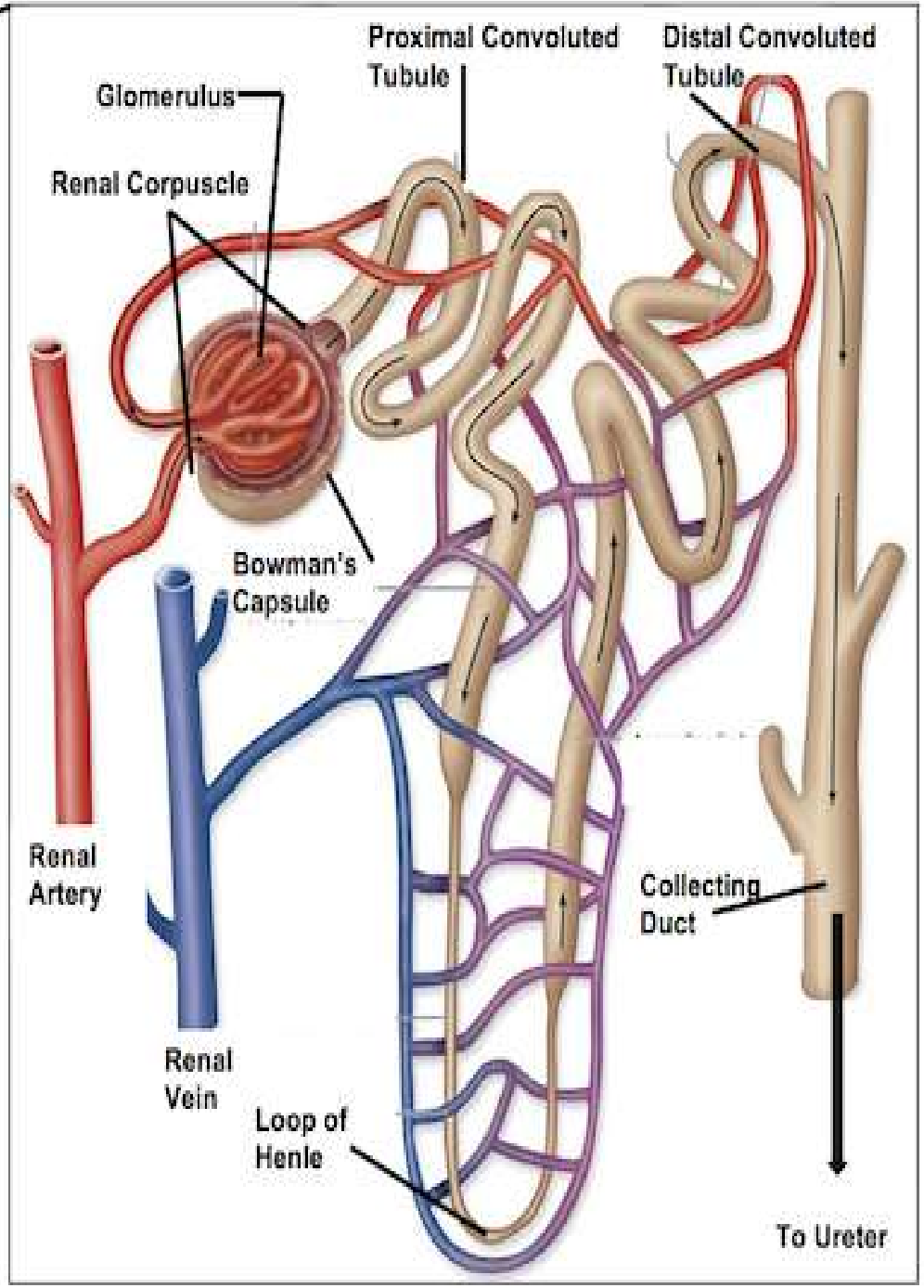

Basement membrane
Endothelium
Tight junction
Fenestrations

.The excessive pressure found in the glomerulus is caused by the fact that the blood vessel that exits the glomerulus, the efferent arteriole, has a smaller diameter than the blood vessel that enters it, afferent arteriole. Substances that can be **filtered** include water, salts, glucose, urea and H^+. **Filtration** is the only process that the nephron cannot change. It is random and the substances that get **filtered** are **filtered** by chance.



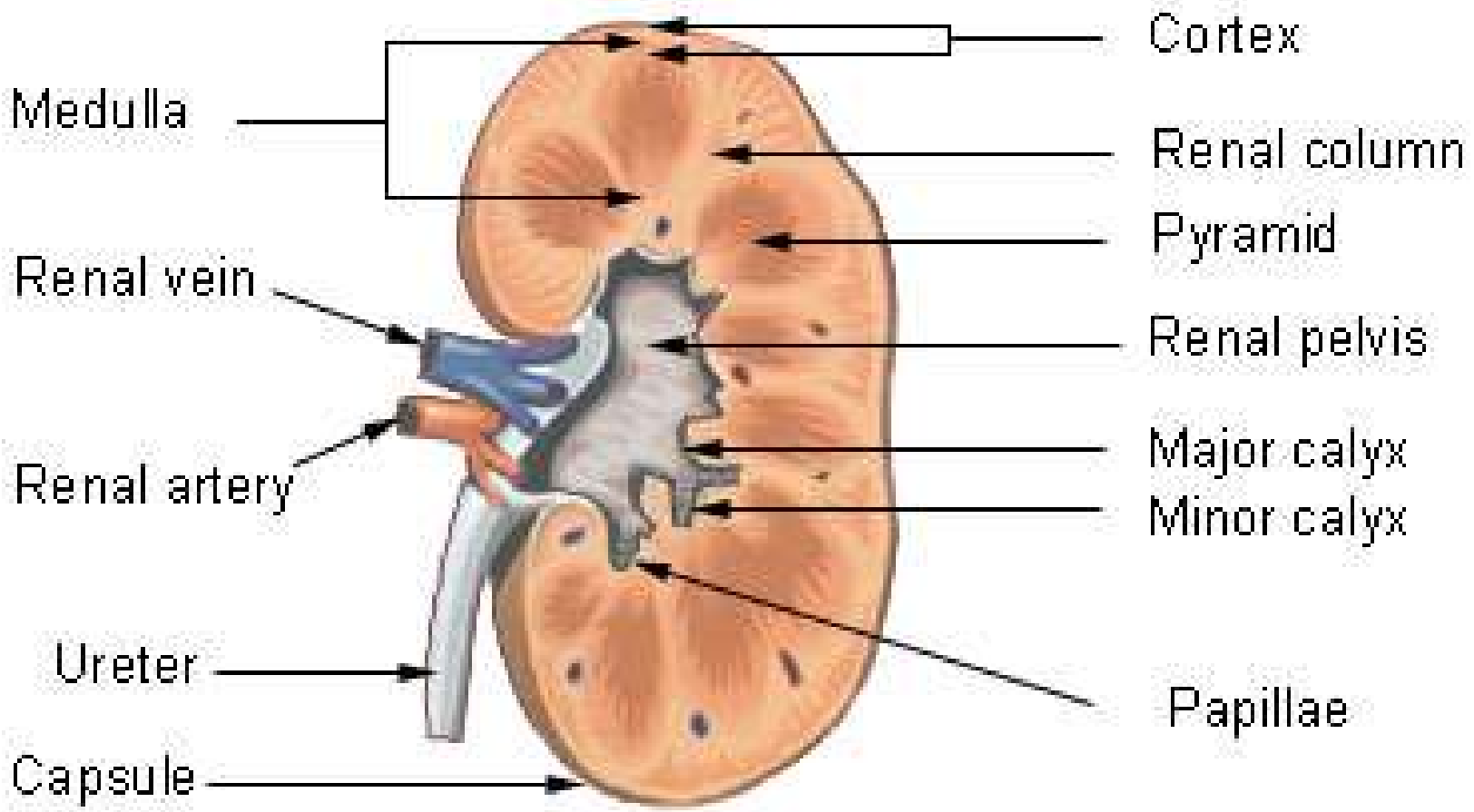
Once in the Bowman's capsule, the **filtrate** passes through the proximal convolute tubule → descending loop of Henle → ascending loop of Henle → distal convoluted tubule → collecting duct. This is the end of the nephron.



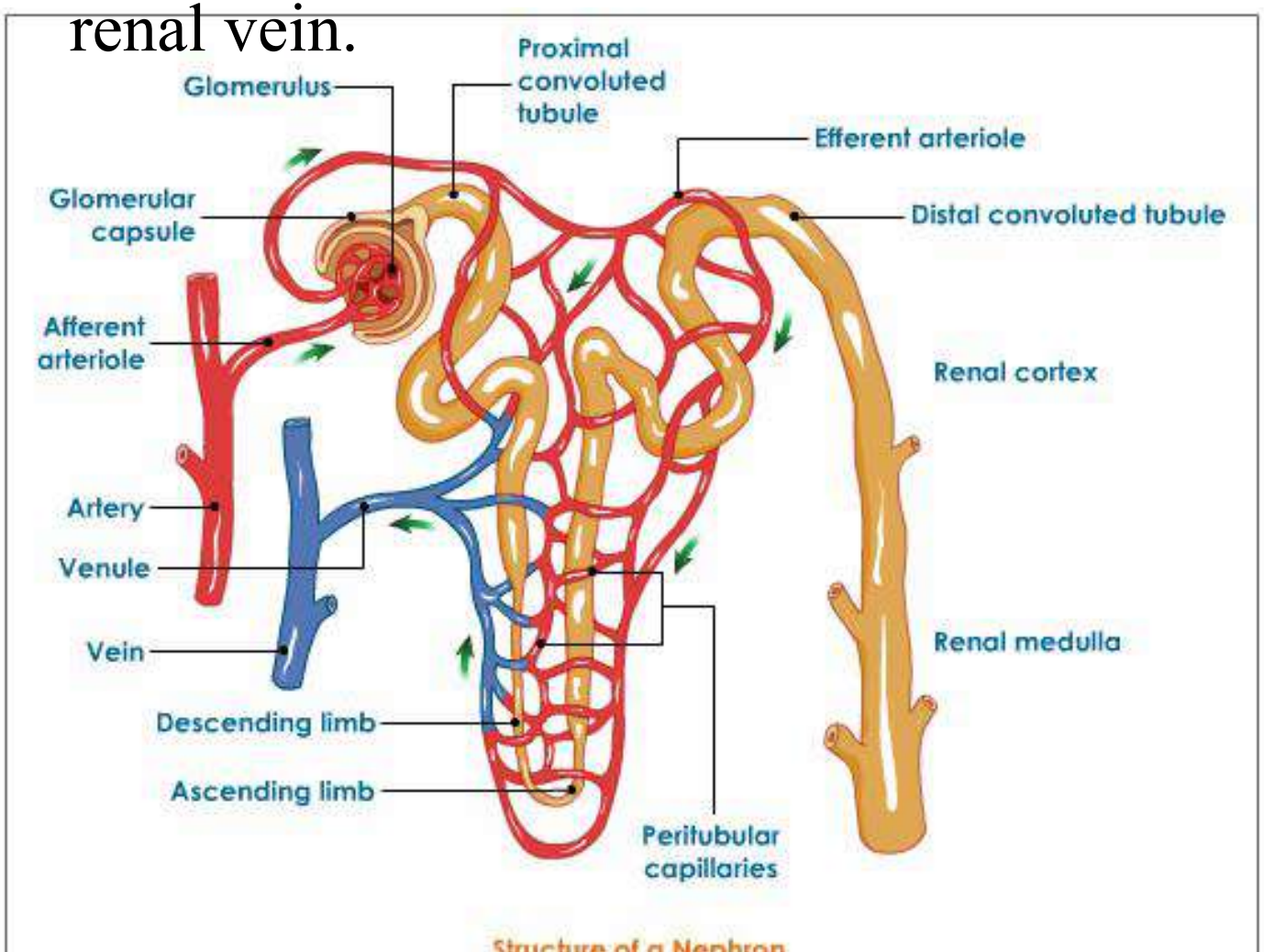


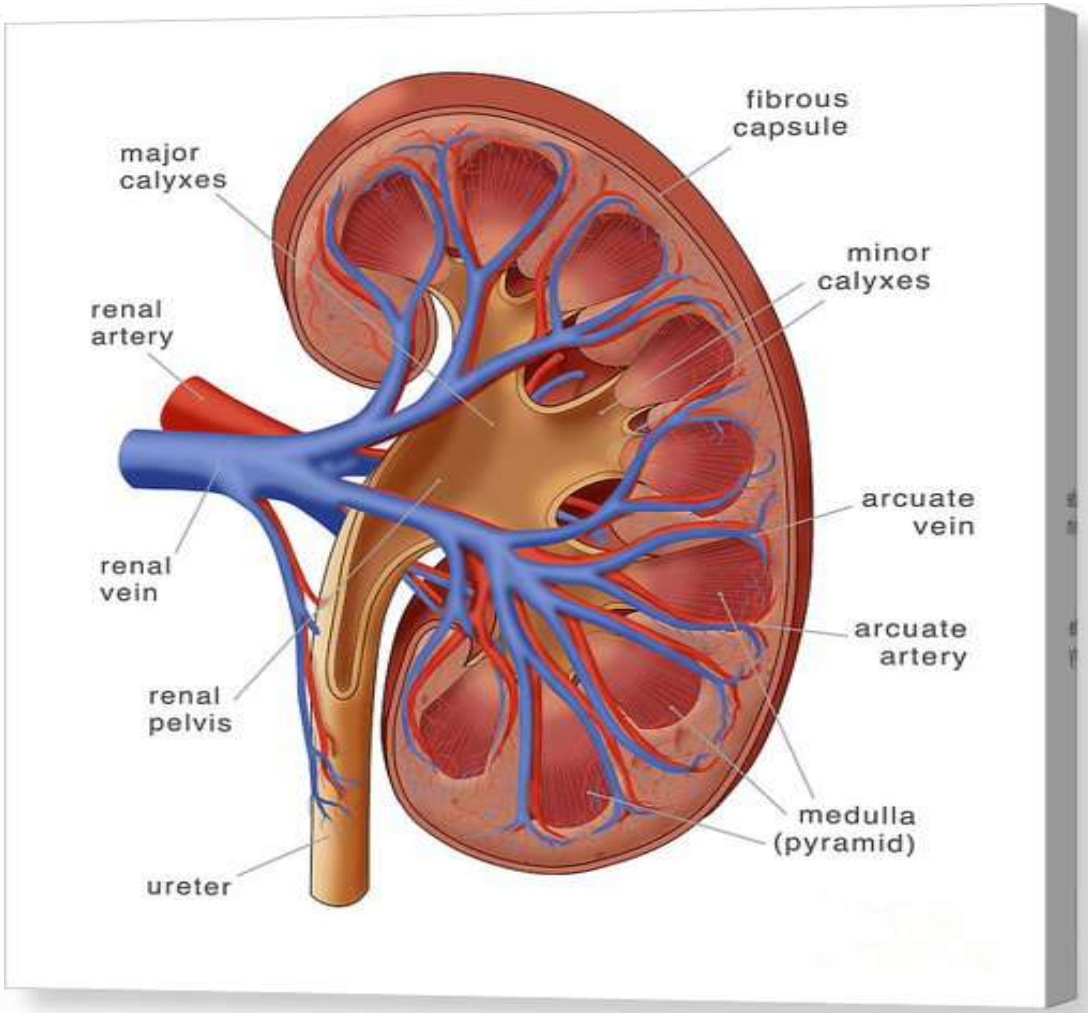
At this point the **filtrate** has become urine. Collecting ducts of several nephrons will drain into a minor calyx → major calyx → renal pelvis → ureter

Frontal section through the Kidney

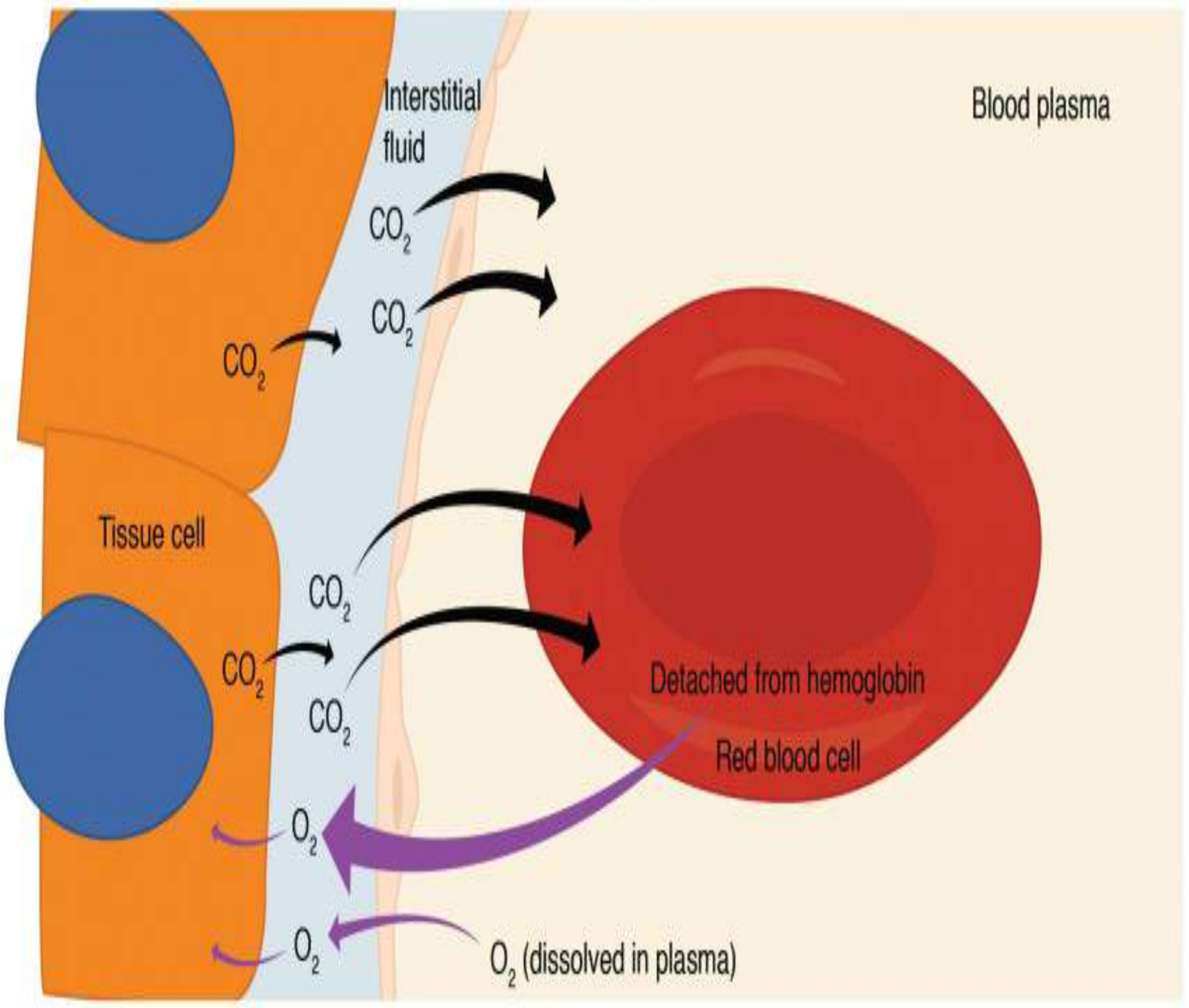


Pathway 2 – No filtration – Blood enters the renal artery and flows through the arcuate artery to the afferent arteriole and then the glomerulus. Substances following this pathway DO NOT get filtered into the nephron. They pass out the glomerulus via the efferent arteriole → peritubular capillaries → arcuate vein → renal vein.

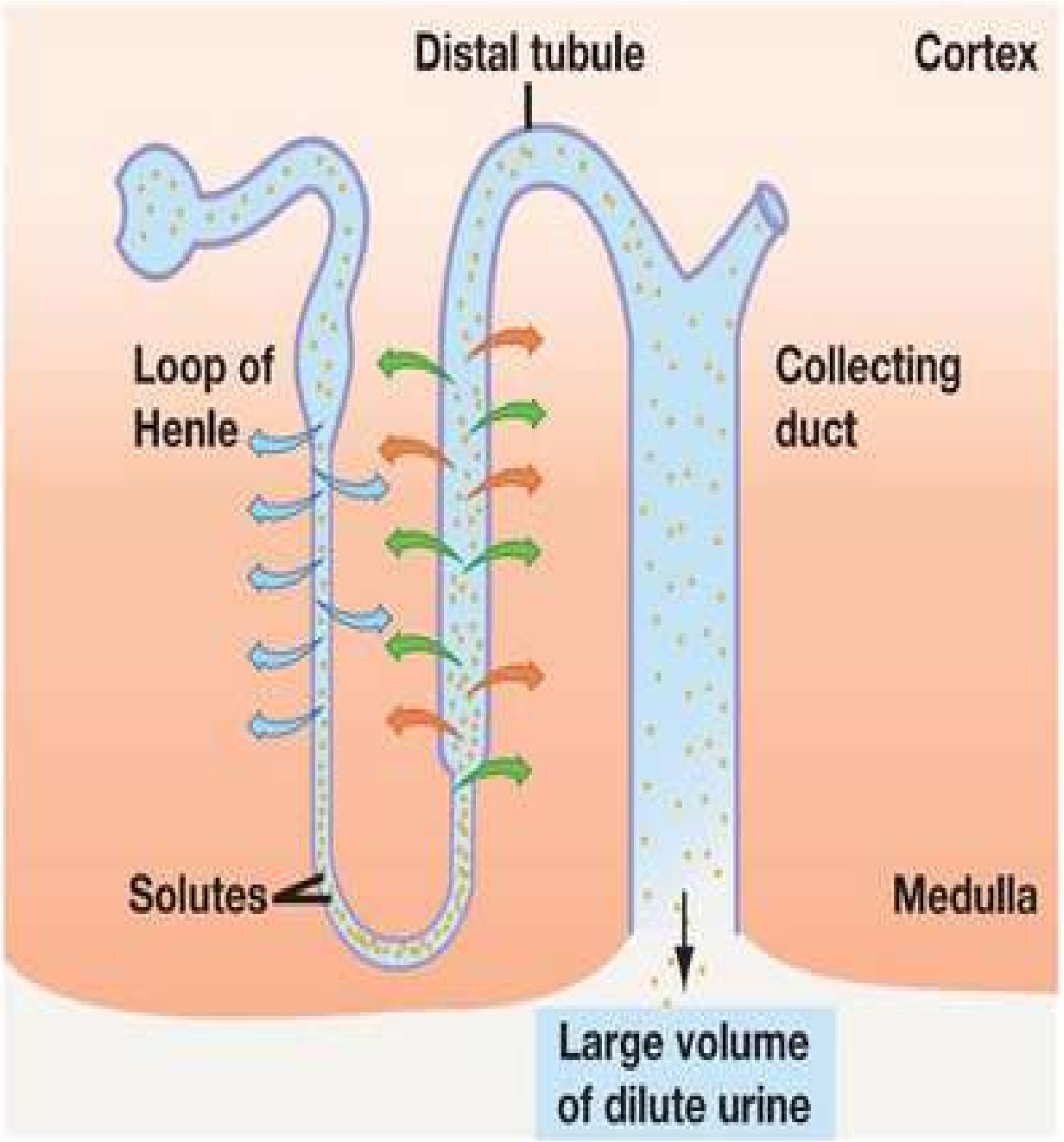




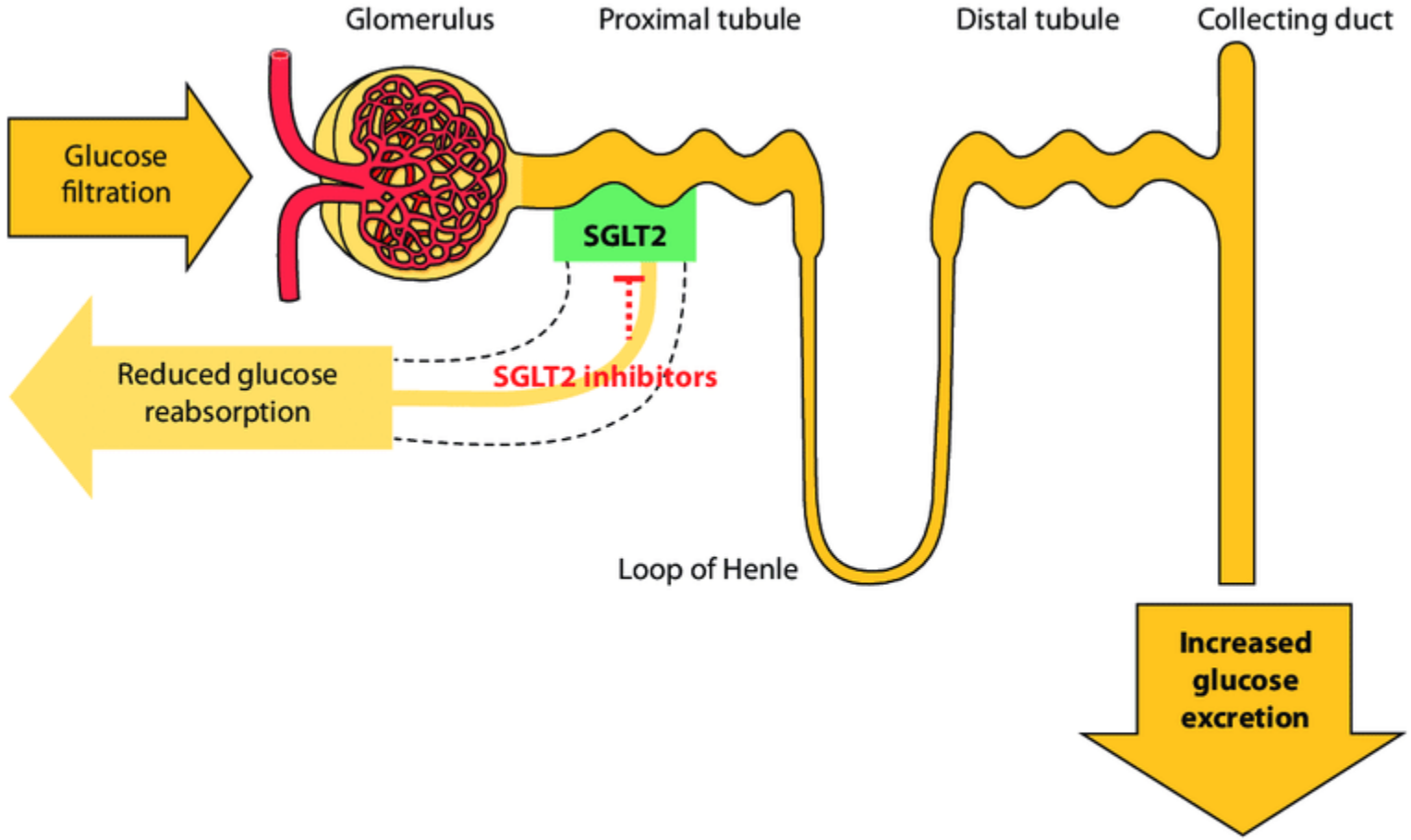
This pathway contains blood that is not cleaned or modified in any way by the nephron. Its purpose is to supply the nephron/kidney cells with oxygen and nutrients, while picking up CO_2 and waste. Normal blood functions. Substances in this pathway include water, salts, glucose, urea, RBC's, proteins/amino acids and H^+.



Pathway 3 – **Reabsorption** - Blood enters the renal artery and flows through the arcuate artery to the afferent arteriole and then the glomerulus. Filtration occurs at the glomerulus when substances are forced through the glomerular walls into the Bowman's capsule of the nephron. Substances that can be filtered include water, salts, glucose, urea and H^+. You filter about 180 liters in 24 hours. Do you urinate out that much? No. Substances that were filtered, but that the body needs back in the blood are pulled back into the peritubular capillaries (blood) through the process of **reabsorption**.



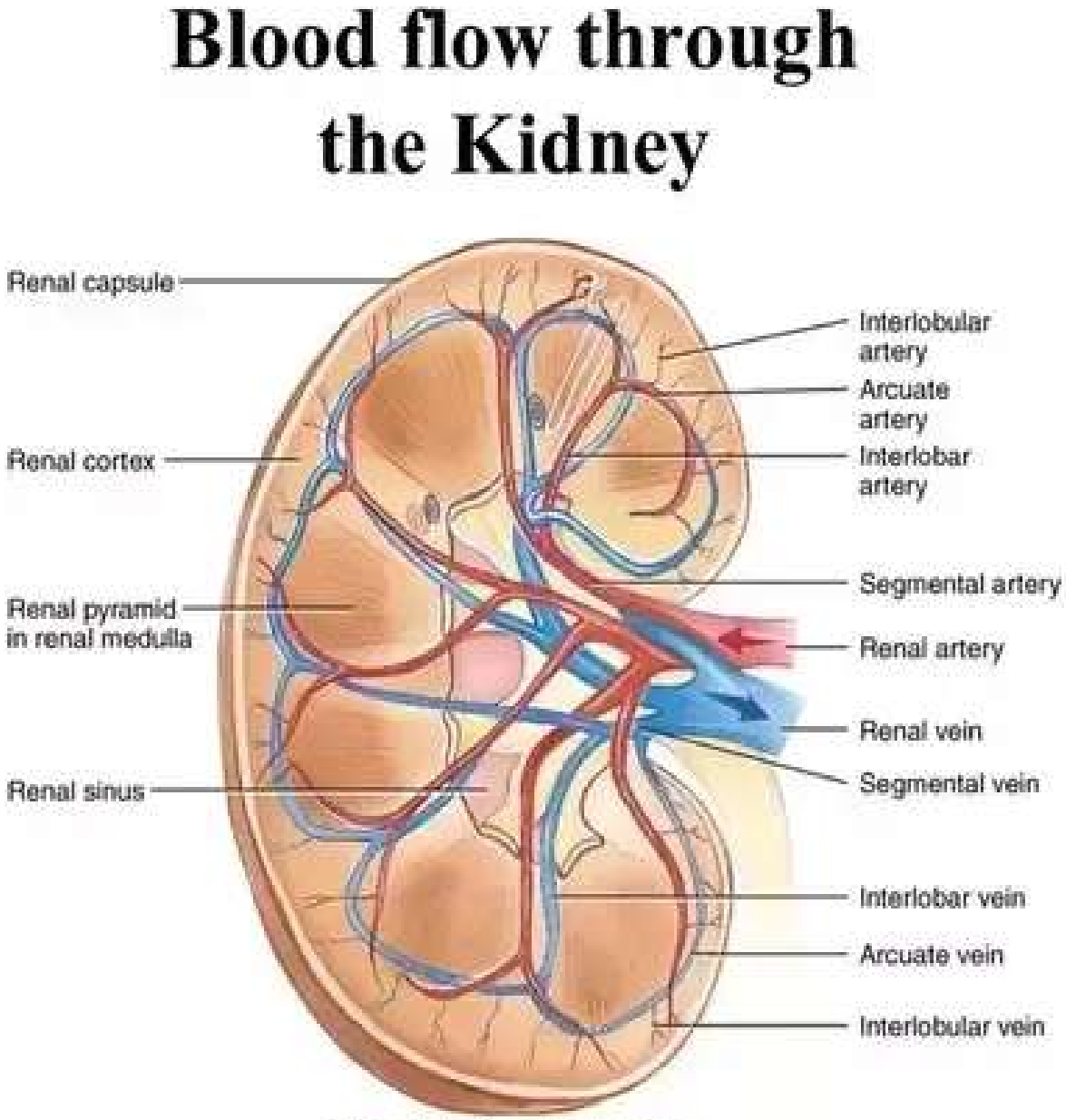
Looking at the list of filtered substances, you can see that glucose is filtered. Glucose is a vital substance to your body. It must be entirely reclaimed by **reabsorption**. Substances that are **reabsorbed** include water, salts, glucose, and urea.



Reproduced with permission from Freeman JS. Review of insulin-dependent and insulin-independent agents for treating patients with type 2 diabetes mellitus and potential role for sodium-glucose co-transporter 2 inhibitors. Postgrad Med 2013;125(3):214–26.
SGLT2, sodium-glucose co-transporter 2

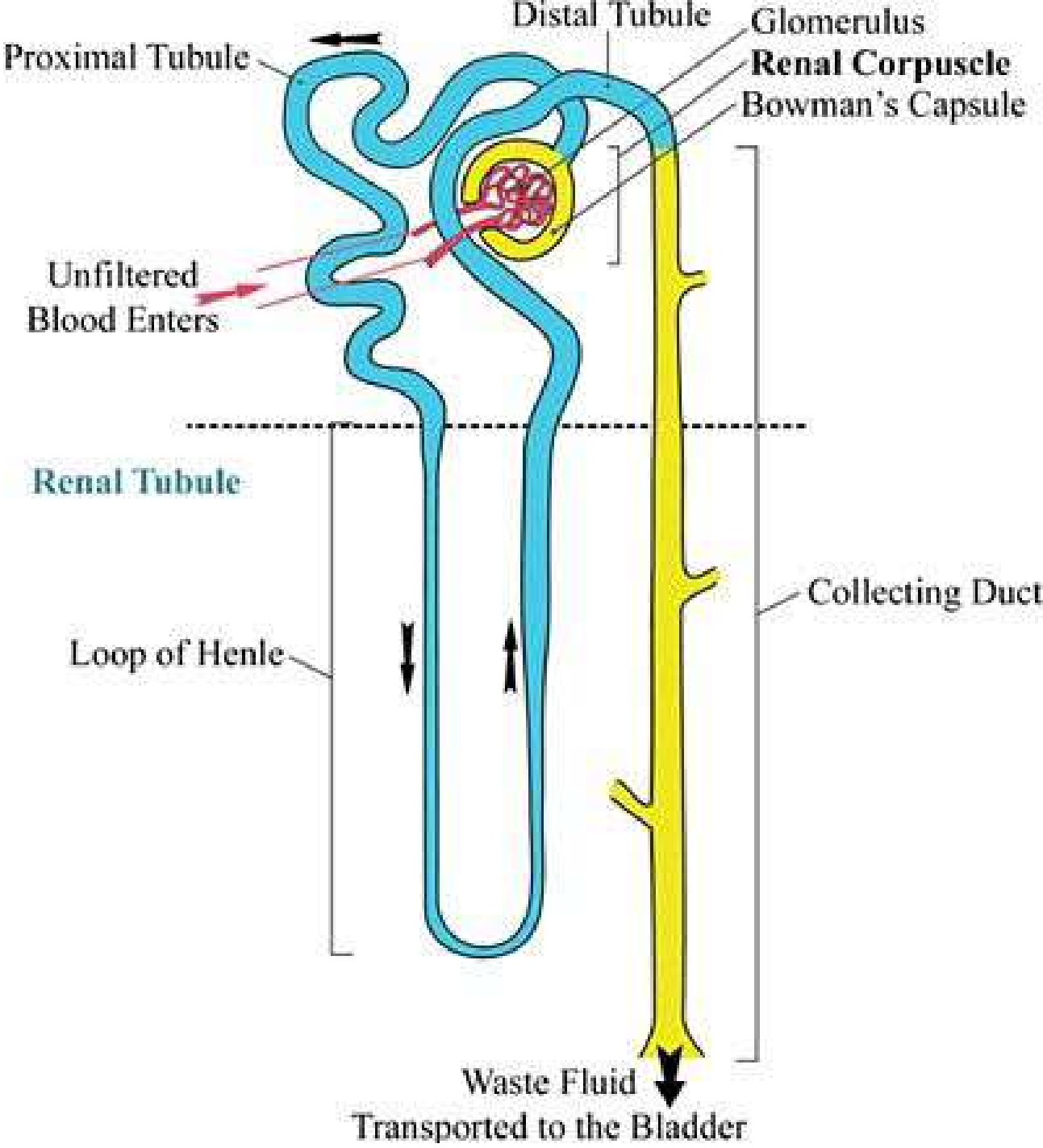
Pathway 4 – **Secretion** - Blood enters the renal artery and flows through the arcuate artery to the afferent arteriole and then the glomerulus. Substances following this pathway DO NOT get filtered into the nephron. They pass out the glomerulus via the efferent arteriole → peritubular capillaries → arcuate vein → renal vein

(b) Path of blood flow



(a) Frontal section of right kidney

Regretfully, there is still an excess amount of urea and H^+ in the blood after their filtration at the glomerulus. So the urea and H^+ that did not get filtered and are still in the blood, get **secreted** out of the peritubular capillaries/blood into the collecting duct of the nephron to join the substances in the urine that had been filtered into urine back at the glomerulus. This is how the nephron gets unwanted substances out of the blood if they did not get filtered out.



Use of the pathways and processes

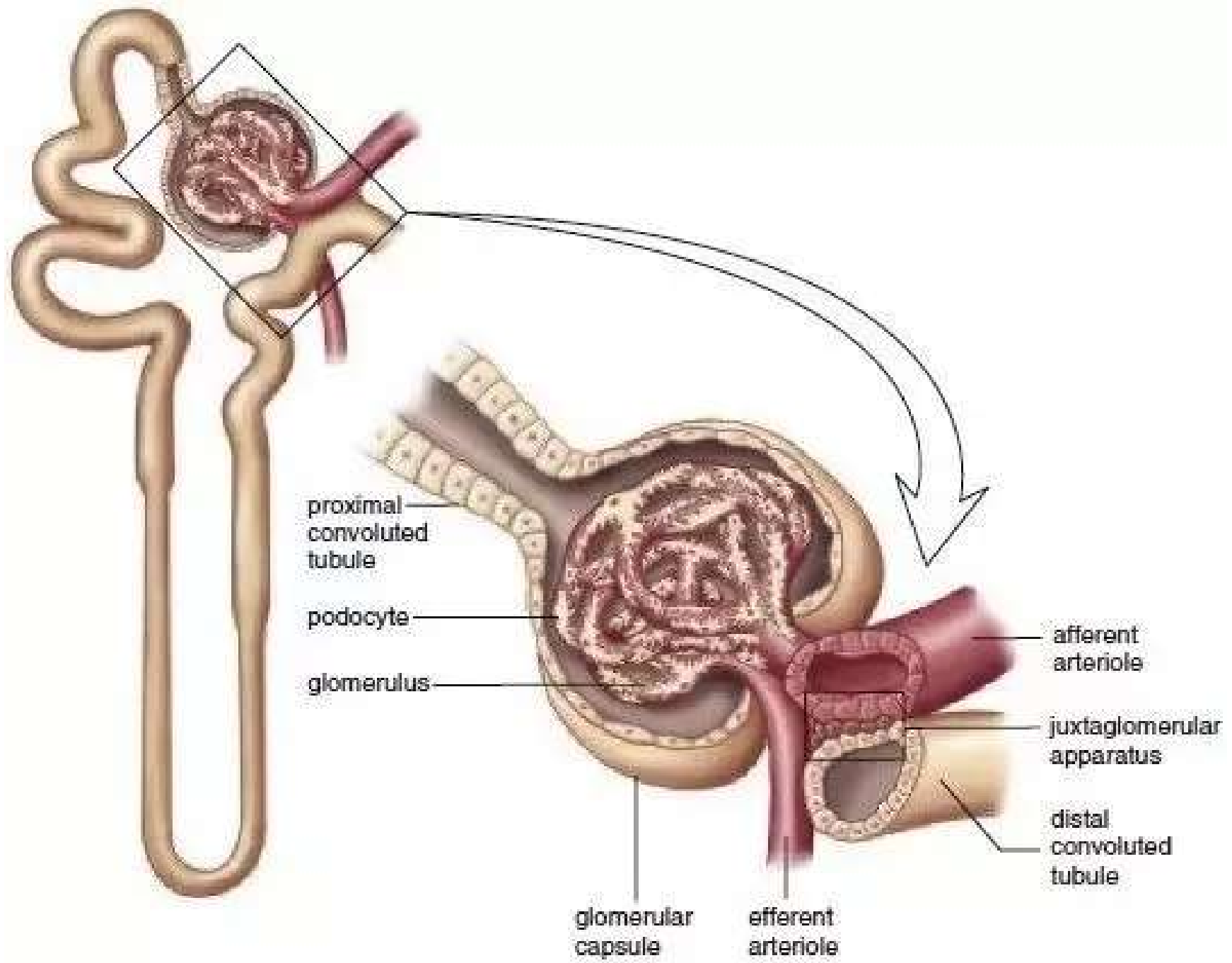
Blood volume

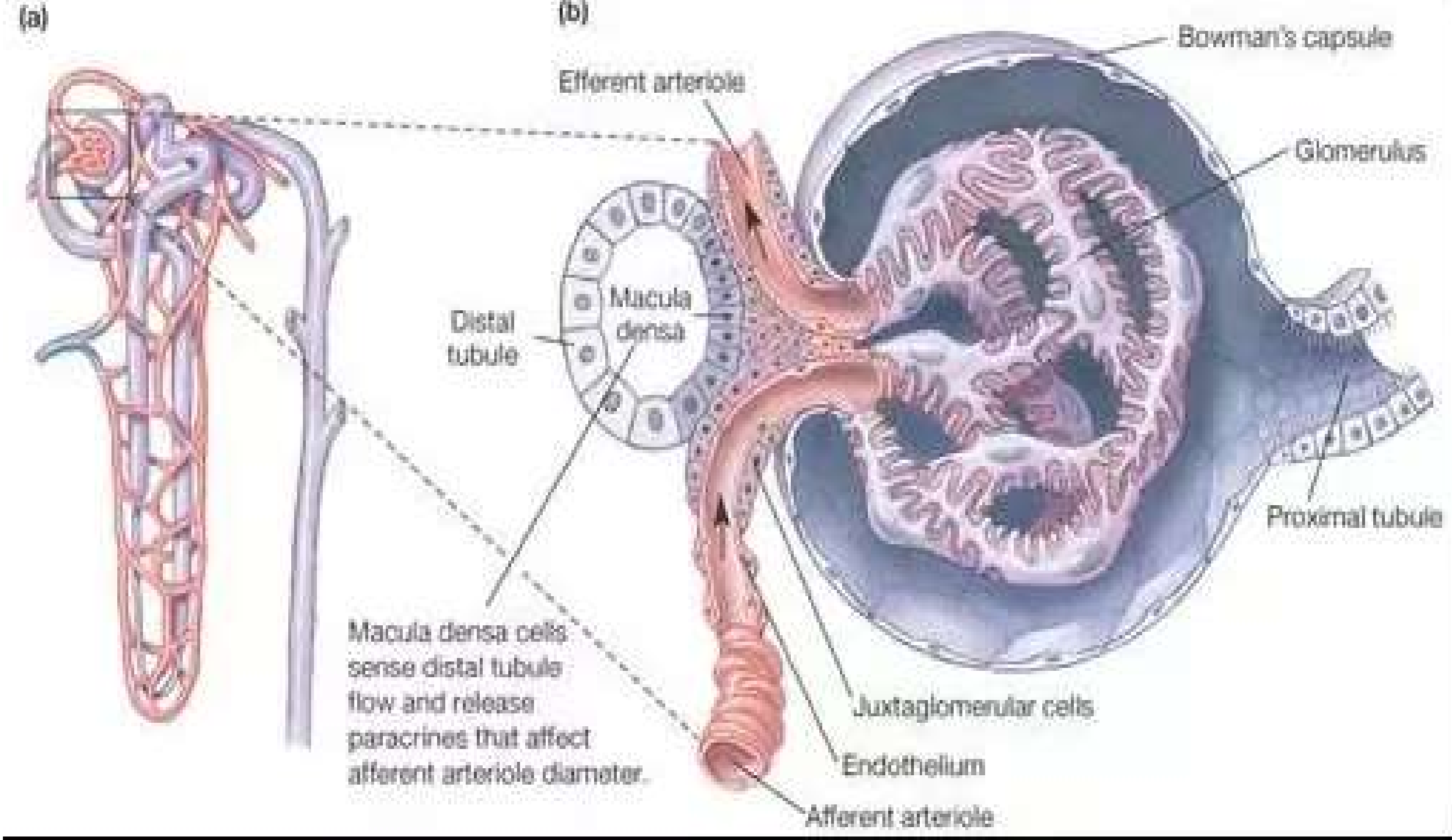
What how does the nephron use these 3 processes and the 4 pathways to do its job? To accomplish the job of maintaining blood volume, the nephron will control water level in the blood. Say that to maintain homeostasis you need 8 water molecules in your blood. 12 water molecules enter the kidney. 6 water molecules would be filtered and 6 water molecules would pass by to remain in the blood. The 6 water molecules in the blood are not enough to maintain homeostasis. So, the nephron will reabsorb 2 more water molecules at the proximal convoluted tubule to bring the blood level up to the desired 8 water molecules. Out of the original 12 water molecules, only 4 water molecules would become urine and the remaining 8 (homeostasis) are in the blood.

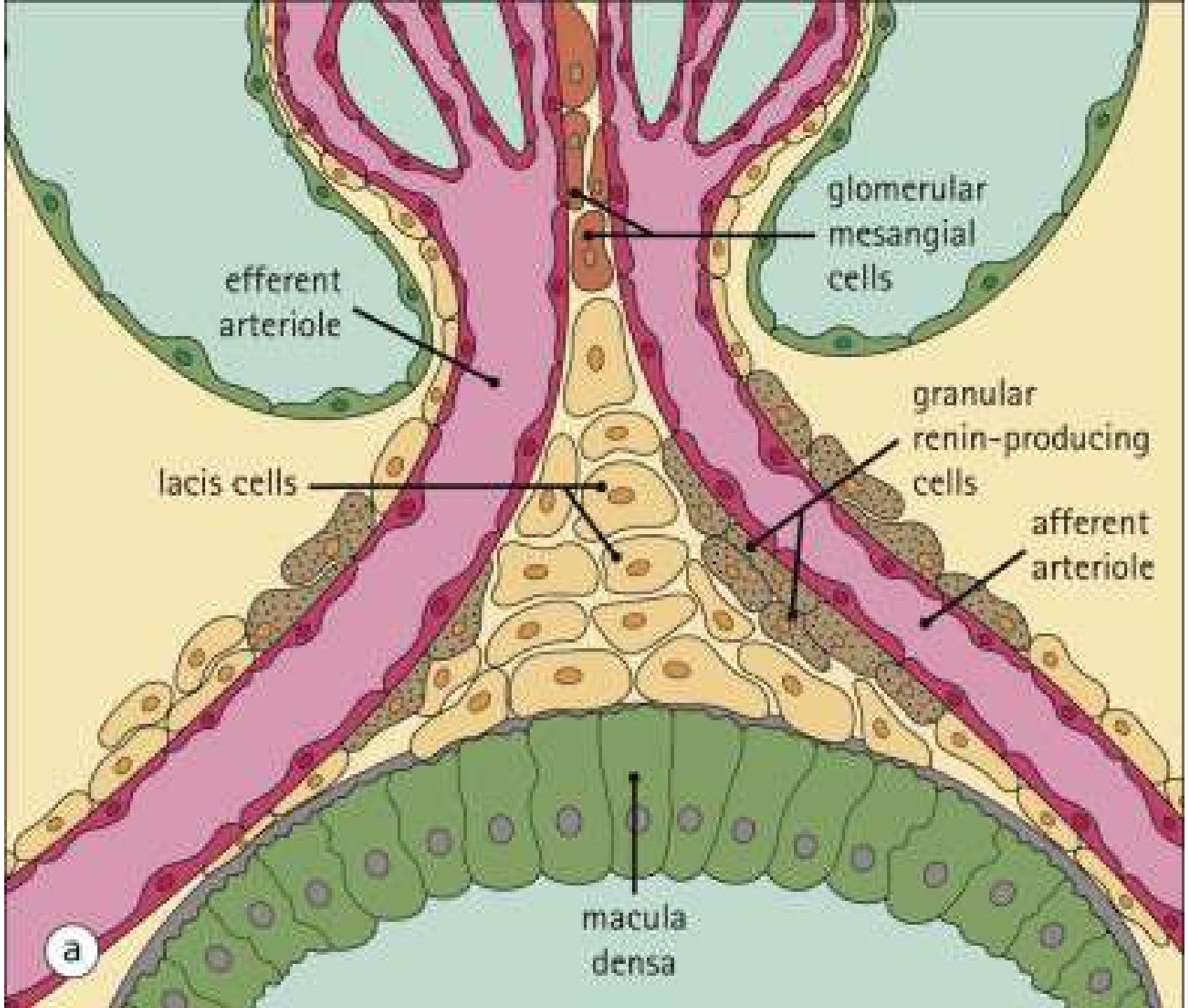
What about if you were drinking more water – like 16 water molecules? 16 water molecules enter the kidney. 8 water molecules would be filtered and 8 water molecules would pass by to remain in the blood. The 8 water molecules in the blood are just enough to maintain homeostasis. So, the nephron will not reabsorb any more water molecules at the proximal convoluted tubule. Out of the original 16 water molecules, 8 water molecules would become urine and the remaining 8 (homeostasis) are in the blood.

What about if you were drinking less water – like 8 water molecules? 8 water molecules enter the kidney. 4 water molecules would be filtered and 4 water molecules would pass by to remain in the blood. The 4 water molecules in the blood are not enough to maintain homeostasis. So, the nephron will want to reabsorb all 4 water molecules in the nephron at the proximal convoluted tubule. But you can't do that. Some water has to remain in the filtrate at all times. At most 3 water molecules can be reabsorbed. That leaves you with only 7 water molecules in the blood. You are now dehydrated. Out of the original 8 water molecules, only 1 water molecules would become urine.

A sensor called the juxtaglomerular apparatus (JGA) monitors the blood pressure of the blood entering the glomerulus. The JGA is composed of some modified cells of the afferent arteriole and the macula densa of the ascending loop of Henle.




(a)
(b)
Bowman's capsule
Efferent arteriole
Glomerulus
Macula densa
Distal tubule
Proximal tubule
Macula densa cells sense distal tubule flow and release paracrines that affect afferent arteriole diameter.
Juxtaglomerular cells
Endothelium
Afferent arteriole


glomerular
mesangial
cells
efferent
arteriole
granular
renin-producing
cells
lacis cells
afferent
arteriole
macula
densa
a

If the blood pressure is too high, the JGA will signal the brain. The brain will signal the nephron to NOT reabsorb water. High blood pressure indicates a high volume of water in the blood and no need to reabsorb water out of the nephron back into the blood.

If the blood pressure is too low, the JGA will signal the brain. The brain will signal the nephron to reabsorb water. Low blood pressure indicates a low volume of water in the blood and a need to reabsorb water out of the nephron back into the blood.

The renin-angiotensin-aldosterone system increases blood volume and pressure

Angiotensin —(**Renin**)→ **Angiotensin I** —(ACE)→ **Angiotensin II**

Triggers release of other hormones

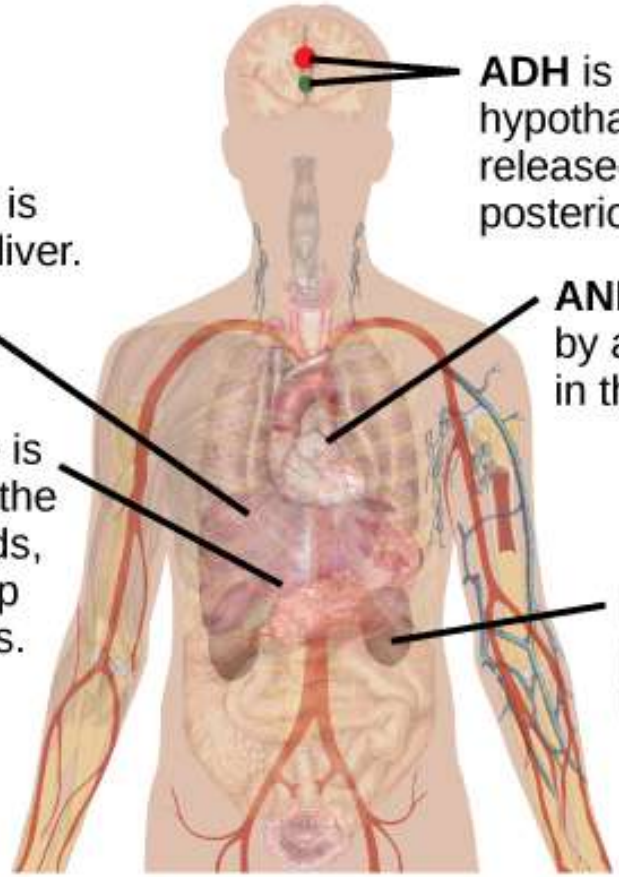
Direct effects:
- Causes arteries to constrict and increases cardiac output resulting in an increase in blood pressure and volume
- Decreases glomerular filtration rate resulting in water retention
- Increases thirst

Aldosterone

Causes nephron distal tubules to reabsorb more Na^+ and water, which increases blood volume

ADH

- Mediates insertion of aquaporins into nephron collecting duct cells; as a result, more water is reabsorbed into the blood
- Increases sodium reabsorption in the medulla of the kidney



ADH is made in the hypothalamus and released by the posterior pituitary.

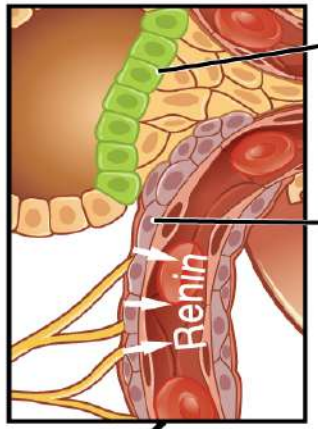
Angiotensin is made by the liver.

ANP is made by atrial cells in the heart.

Aldosterone is produced by the adrenal glands, located on top of the kidneys.

Renin is produced by the kidney.

ANP is a hormone antagonistic to the angiotensin pathway. ANP decreases blood voluume and pressure by:
- Increasing the glomular filtration rate
- Decreasing of reabsorption of Na^+ by nephrons
- Inhibiting the release of renin, aldosterone, and ADH

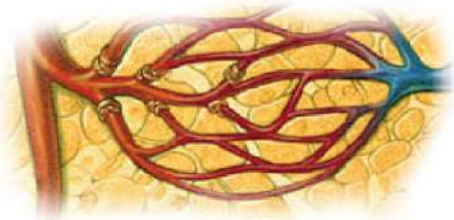


Macula densa senses low fluid flow or low Na^+ concentration

Juxtaglomerular cells secrete renin

Kidney releases enzyme renin into blood

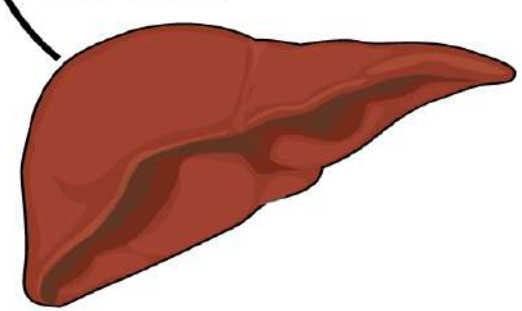
Angiotensin-converting enzyme (ACE) in pulmonary blood



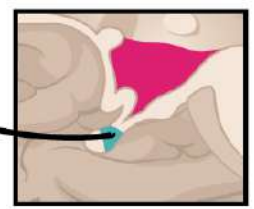
Widespread vasoconstriction

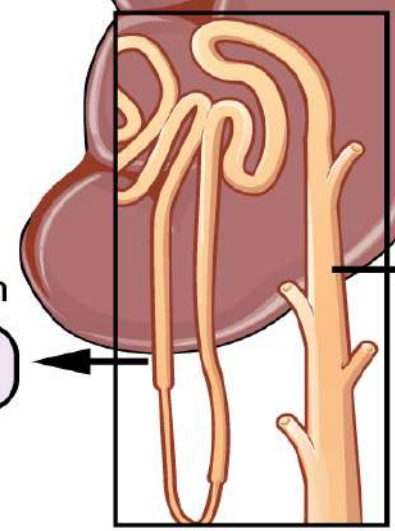
Enzyme reaction → Angiotensin I → Enzyme reaction → Angiotensin II → Stimulates → Adrenal cortex to secrete → Aldosterone

Liver releases angiotensinogen into blood



ADH causes aquaporins to move to the collecting duct plasma membrane, which increases water reabsorption





Na^+

H_2O

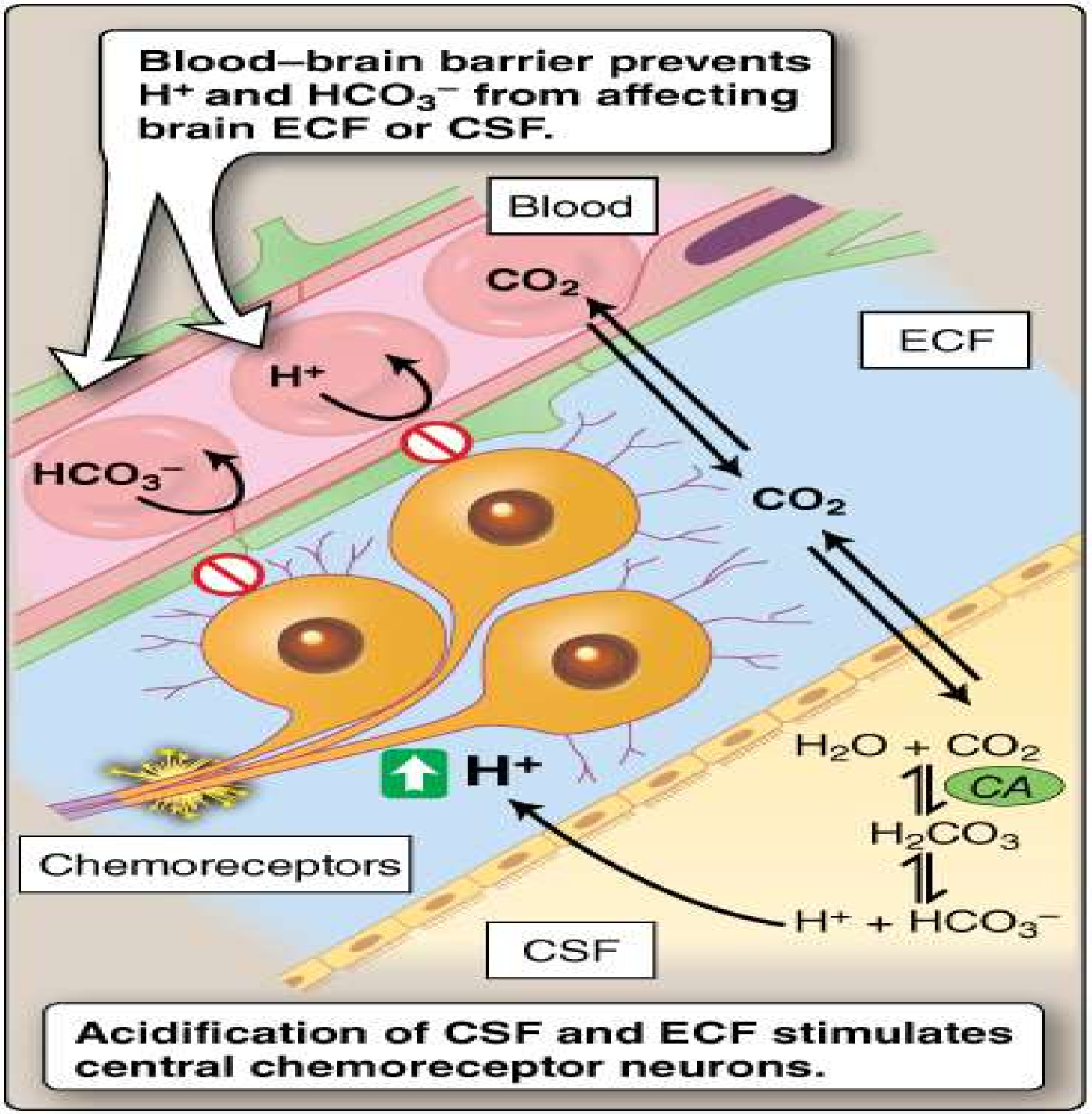
Aldosterone stimulates Na^+ uptake on the apical cell membrane in the distal convoluted tubule and collecting ducts

Blood composition

To accomplish the job of maintaining blood composition, let's pick blood pH as an example. Most of the foods you eat are acidic releasing many H^+ ions into your blood. As an example, to maintain homeostasis, you need 4 H^+ ions in your blood. 12 H^+ ions enter the kidney. 6 H^+ ions would be filtered into urine and 6 H^+ ions would pass by to remain in the blood. The 6 H^+ ions in the blood are too many for homeostasis. The nephron will secrete 2 more H^+ ions out of the blood in the peritubular capillaries into the collecting duct to bring the blood level down to the desired 4 H^+ ions. Out of the original 12 H^+ ions, 8 H^+ ions would become urine and the remaining 4 (homeostasis) are in the blood

What about if you were eating more acidic food and created a blood level of 16 H^+ ions ? Remember to maintain homeostasis, you need 4 H^+ ions in your blood. 16 H^+ ions enter the kidney. 8 H^+ ions would be filtered into urine and 8H^+ ions would pass by to remain in the blood. The 8H^+ ions in the blood are too many for homeostasis. The nephron will secrete 4 more H^+ ions out of the blood in the peritubular capillaries into the collecting duct to bring the blood level down to the desired 4 H^+ ions. Out of the original 16 H^+ ions, 12 H^+ ions would become urine and the remaining 4 (homeostasis) are in the blood

Chemoreceptors in your blood vessels will determine your blood pH and signal the brain. The brain will then signal the nephron as to how many H^+ ions to secrete.



Urine

Characteristics

1. Byproduct of kidney's activities
2. Urinalysis – the testing of a urine sample – see reference sheet for abnormal urine examples

Table. Patient Test Results

Laboratory Test	Patient's Values	Reference Range
Urine dipstick		
Glucose	Negative	Negative
Protein	Negative	Negative
Ketones	Negative	Negative
Specific gravity	1.015	1.005-1.030
pH	7.5	5.0-8.0
Blood	Trace	Negative
Nitrite	Negative	Negative
Leukocytes	Negative	Negative
Clarity	Clear	
Color	Yellow	
Urobilinogen, EU/dL	1	0.2-1.0
Bilirubin	Negative	Negative

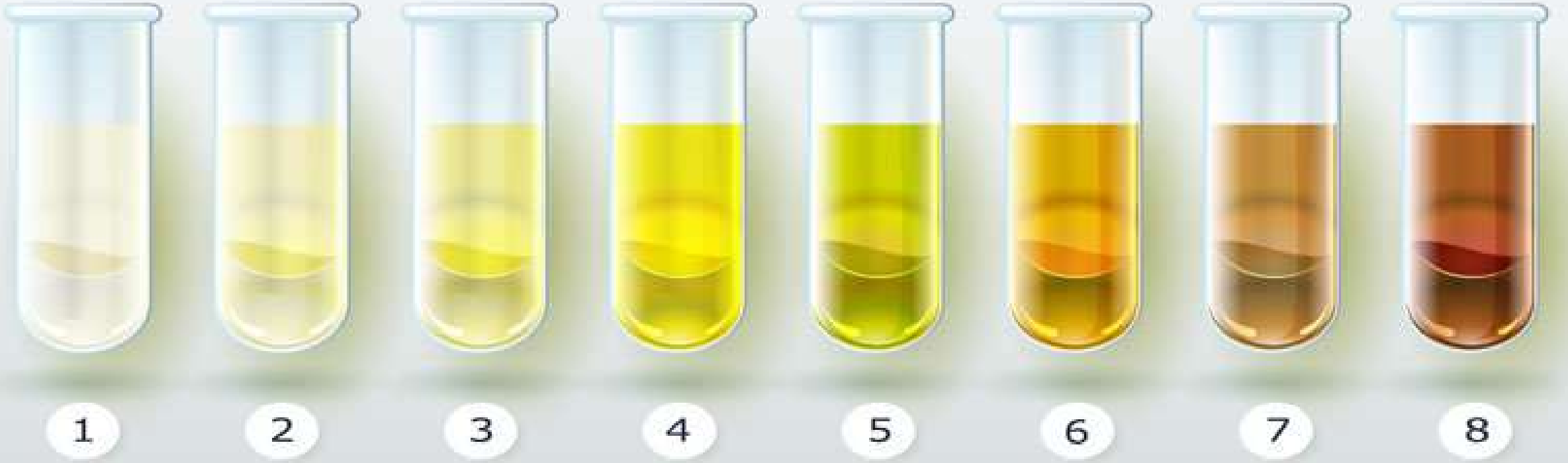
Urine

Characteristics

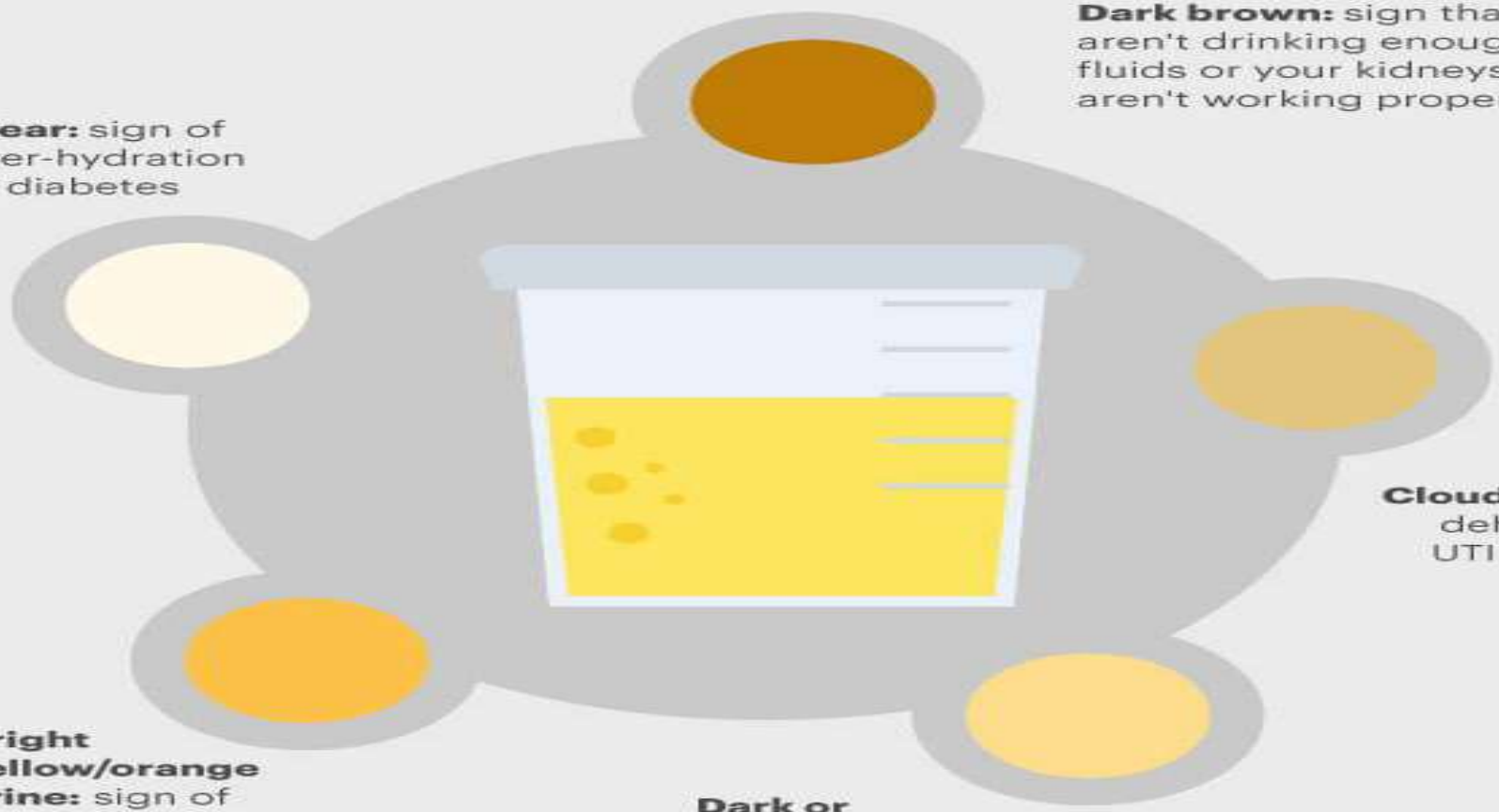
1. Byproduct of kidney's activities
2. Urinalysis – the testing of a urine sample – see reference sheet for abnormal urine examples
3. Daily volume 1500 ml
4. Transparent

URINE COLOR CHART

Urine varies in appearance, depending principally upon your level of hydration.
Normal urine is a transparent solution ranging from colorless to amber but is usually a pale yellow.
Strange colors could be narmless or could indicate serious issues.
Seek medical advice for actual diagnosis of unusual colors.



WHAT THE COLOR OF YOUR URINE MEANS



Clear: sign of over-hydration or diabetes

Dark brown: sign that you aren't drinking enough fluids or your kidneys aren't working properly

Cloudy: sign of dehydration, UTI or kidney stones

Bright yellow/orange urine: sign of dehydration or a problem with your liver or bile duct

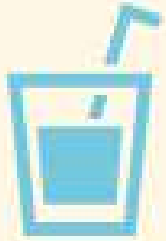
Dark or transparent yellow: normal

Dr. Axe
FOOD IS MEDICINE


Clear Urine
HealthyAndNaturalWorld.com


Cloudy Urine
Image: James Heilman, MD - Wikimedia Commons

8 Reasons for Cloudy Urine

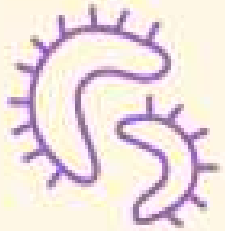


Dehydration

Diabetes

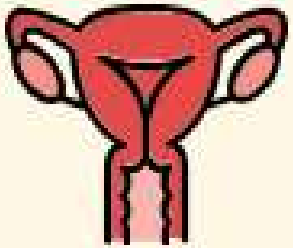
Sexually Transmitted Infections

Kidney Stones



Urinary Tract Infections

Prostatitis



Vaginitis

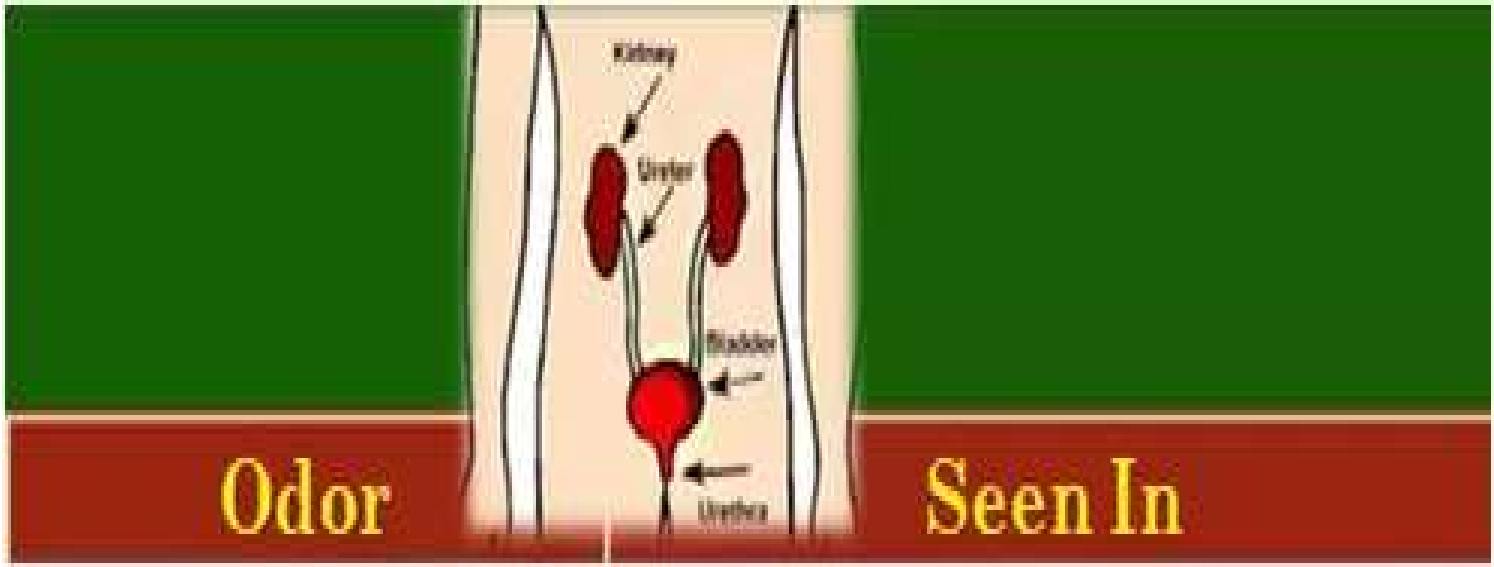
Diet

DrFormulas™
Health starts here.

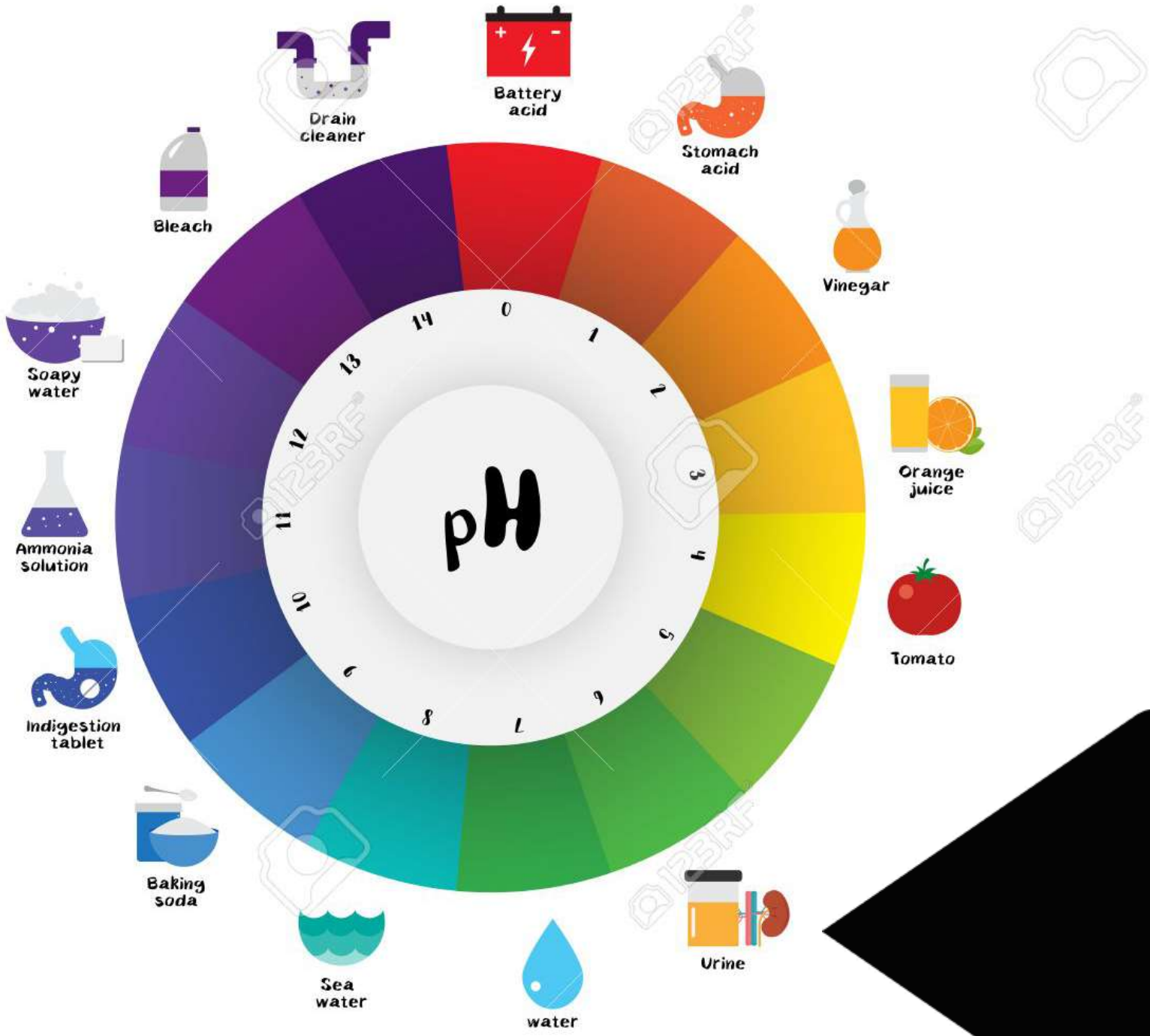
Urine

Characteristics

1. Byproduct of kidney's activities
2. Urinalysis – the testing of a urine sample – see reference sheet for abnormal urine examples
3. Daily volume 1500 ml
4. Transparent
5. Slight odor
6. pH 6.0



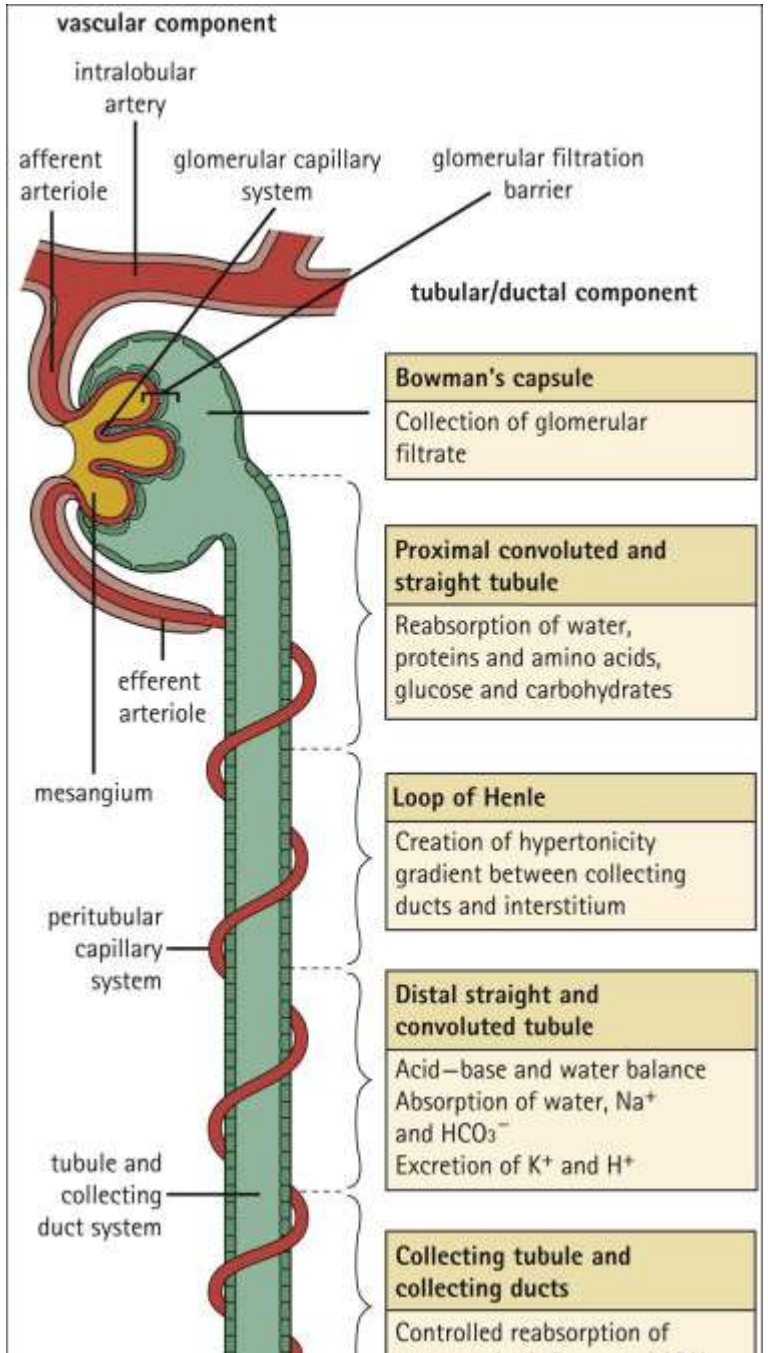
Odor	Seen In
• Fruity smell	• Diabetes mellitus Type 1
• Mousy odor	• Phenylketonuria
• Fishy	• UTI
• Ammonical odor	• UTI caused by *pseudo-monas & proteus*
• Burnt sugar	• Maple syrup urine disease


pH
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Battery acid
Drain cleaner
Stomach acid
Bleach
Vinegar
Soapy water
Orange juice
Ammonia solution
Tomato
Indigestion tablet
Baking soda
Urine
Sea water
water

Urine

Characteristics

1. Byproduct of kidney's activities
2. Urinalysis – the testing of a urine sample – see reference sheet for abnormal urine examples
3. Daily volume 1500 ml
4. Transparent
5. Slight odor
6. pH 6.0
7. 95% water



Bowman's capsule

Collection of glomerular filtrate

Proximal convoluted and straight tubule

Reabsorption of water, proteins and amino acids, glucose and carbohydrates

Loop of Henle

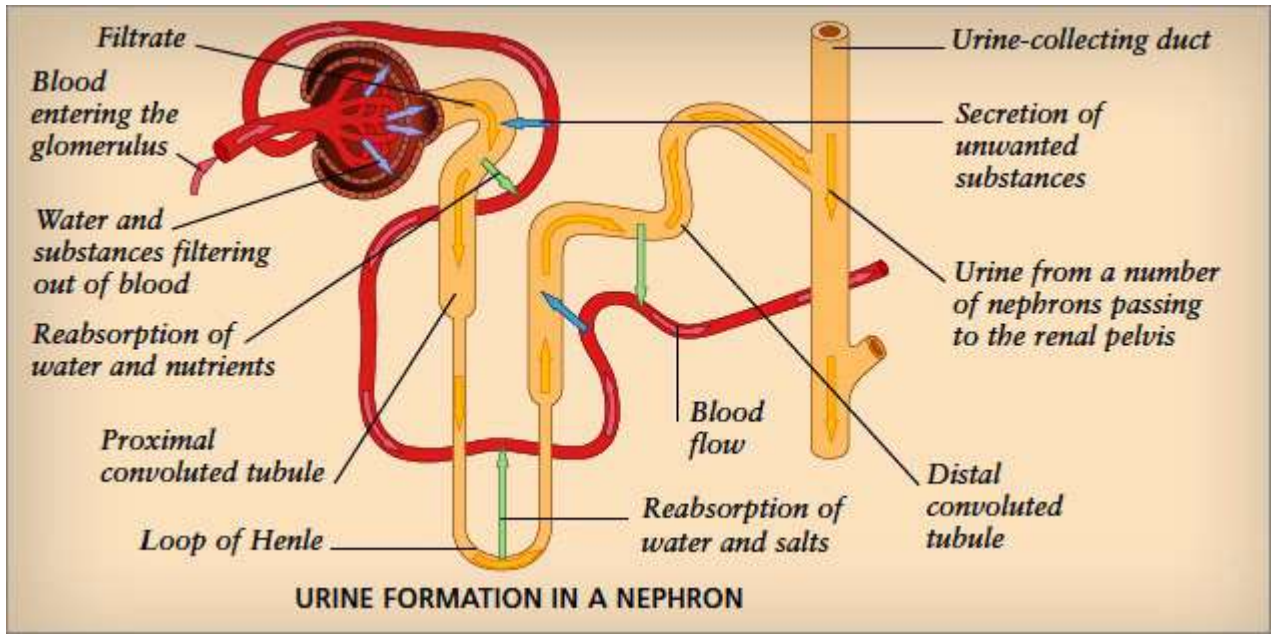
Creation of hypertonicity gradient between collecting ducts and interstitium

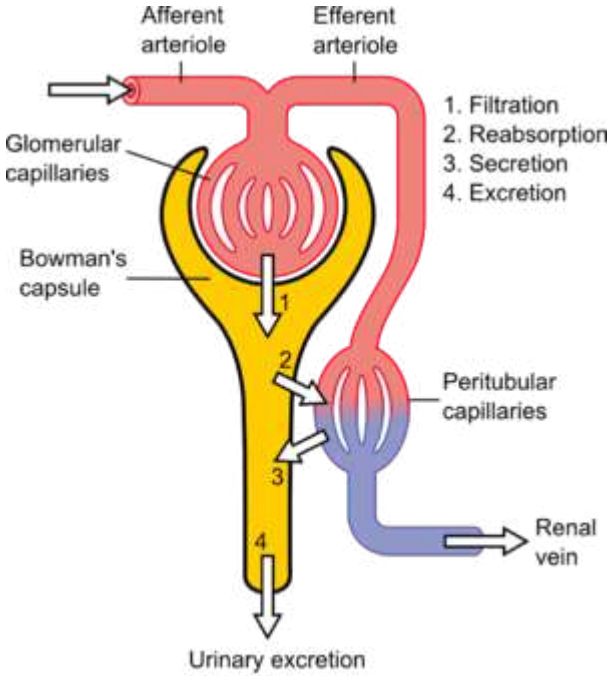
Distal straight and convoluted tubule

Acid–base and water balance
Absorption of water, Na^+ and HCO_3^-
Excretion of K^+ and H^+

Collecting tubule and collecting ducts

Controlled reabsorption of


Filtrate
Blood entering the glomerulus
Water and substances filtering out of blood
Reabsorption of water and nutrients
Proximal convoluted tubule
Loop of Henle
Urine-collecting duct
Secretion of unwanted substances
Urine from a number of nephrons passing to the renal pelvis
Blood flow
Distal convoluted tubule
Reabsorption of water and salts
URINE FORMATION IN A NEPHRON



Excretion = Filtration – Reabsorption + Secretion