Glomerular Filtration &Role of Absorption and Secretion Mechanism In Kidneys

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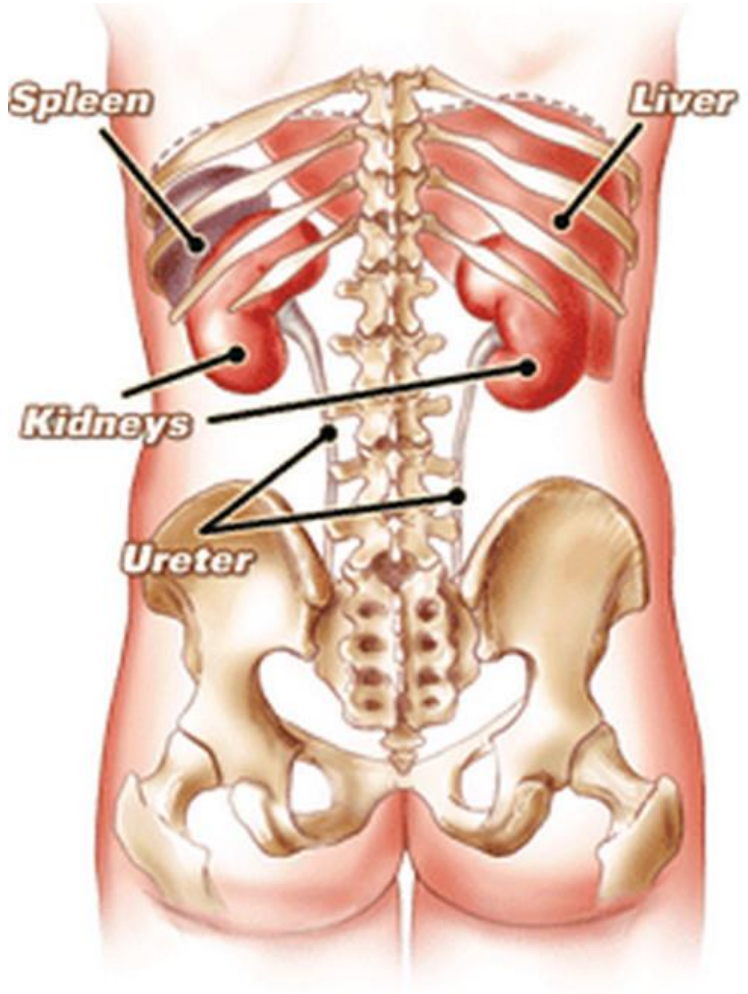
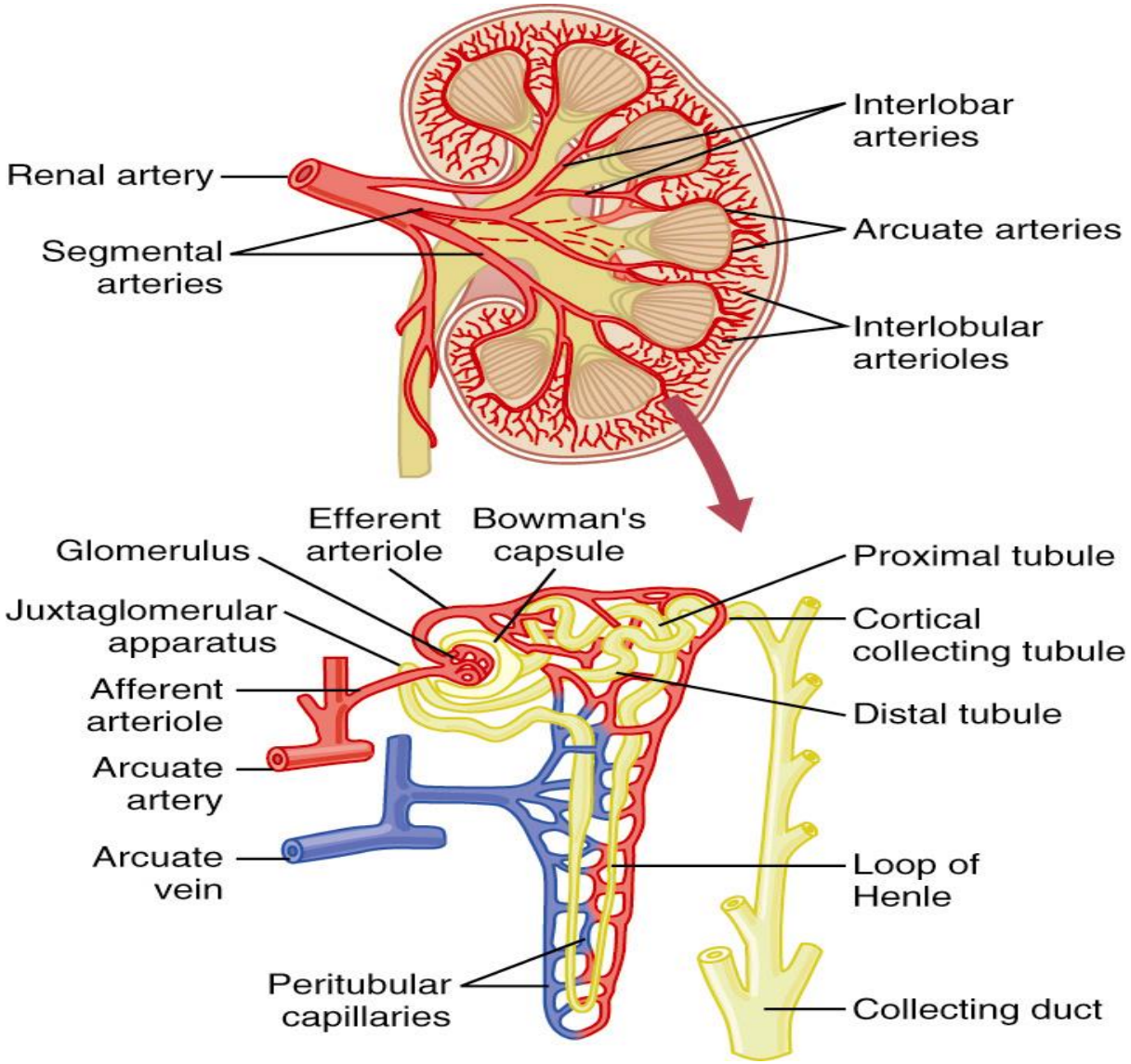
Course: Molecular Physiology

LOCATION OF KIDNEYS

The **kidneys** are bean-shaped organs (about 11 cm x 7cm x 3cm) that are **located** against the back muscles in the upper abdominal area. They sit opposite each other on both the left and right side of the **body** the right **kidney** however, sits a little lower than the left to accommodate the size of the liver.





Nephron: functional unit of the kidney

Figure 26-3;
Guyton and Hall

Nephron Tubular Segments

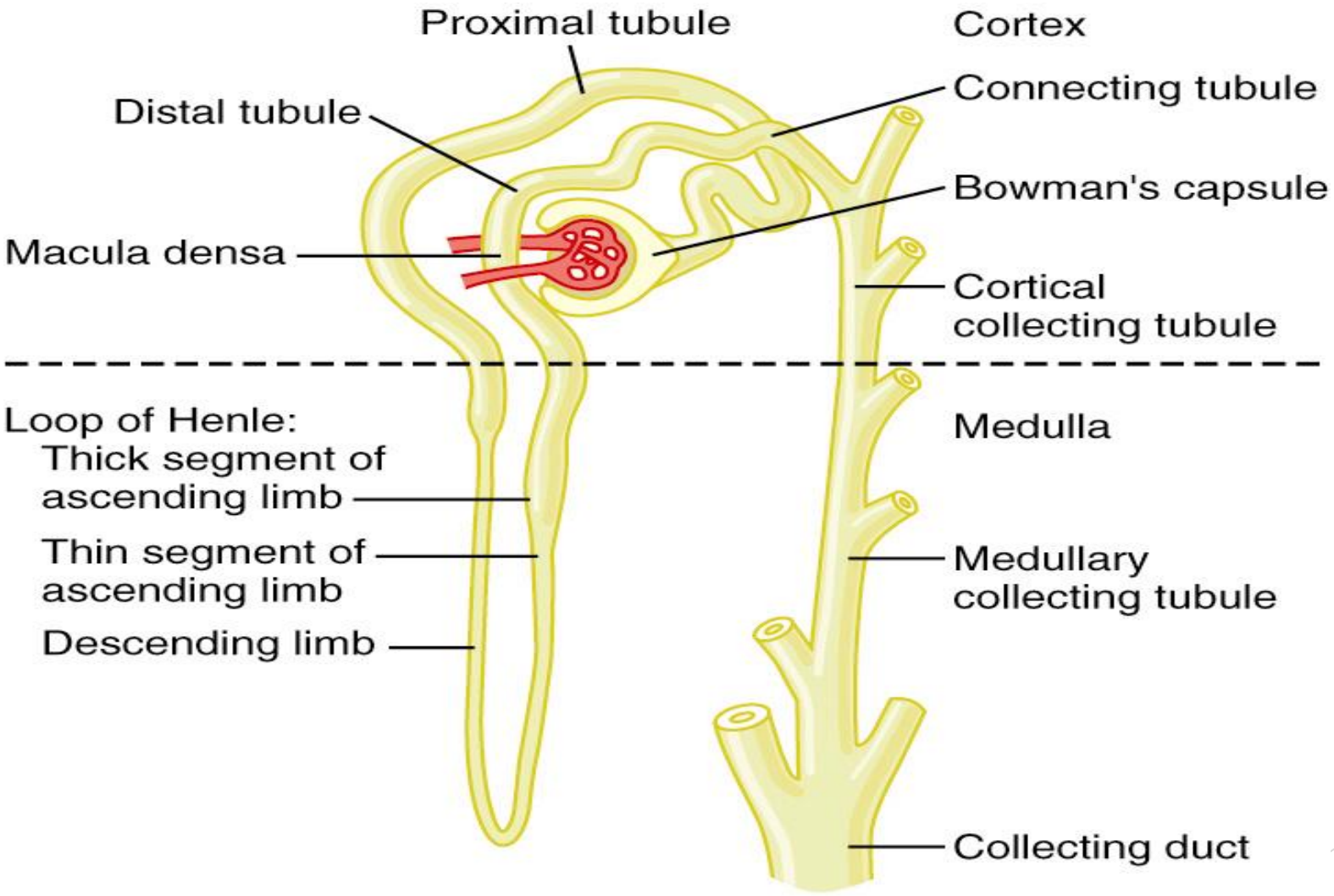
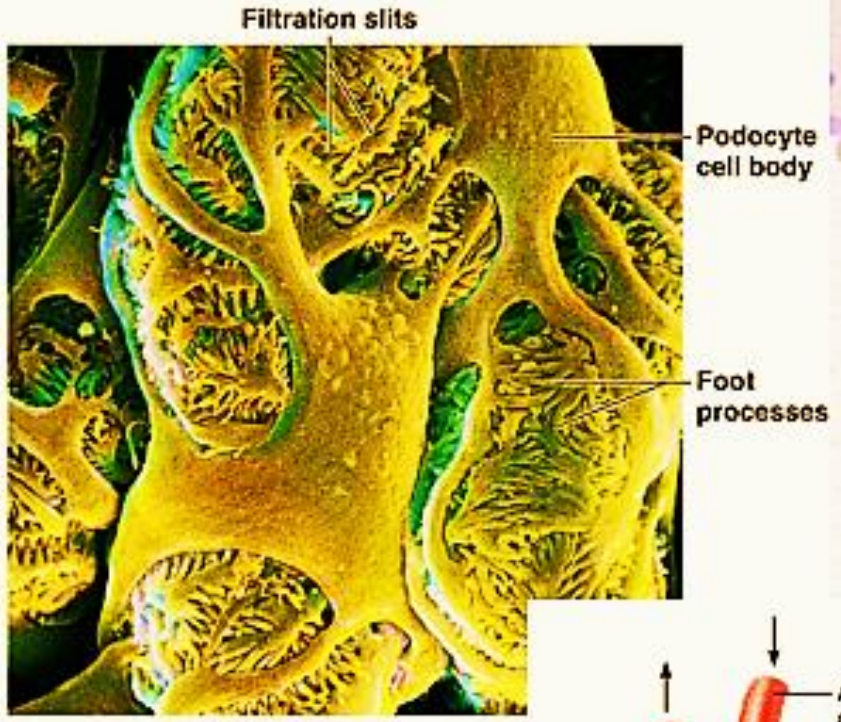
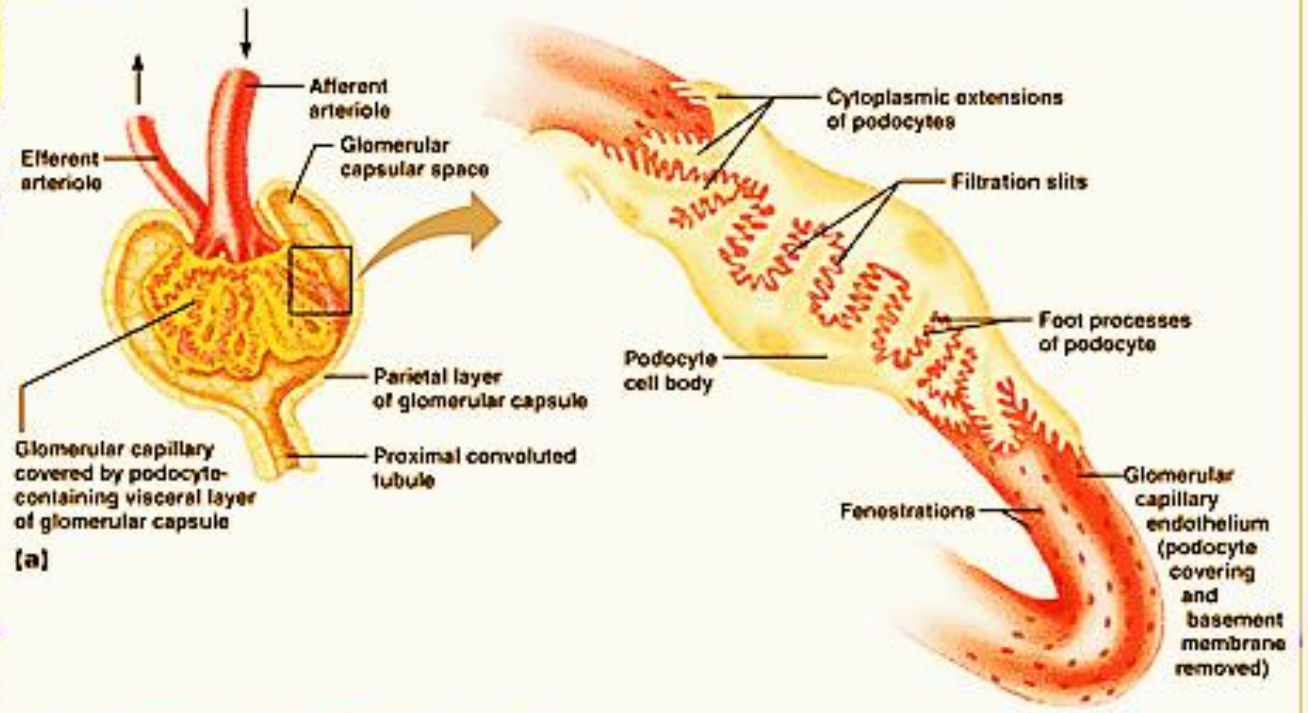


Figure 26-4;
Guyton and Hall

Filtration at Glomerulus

Filtration membrane formed by podocyte cells lets all of plasma components of blood filter out of glomerular capillaries and into proximal convoluted tubule





Structure of the juxtaglomerular apparatus: macula densa

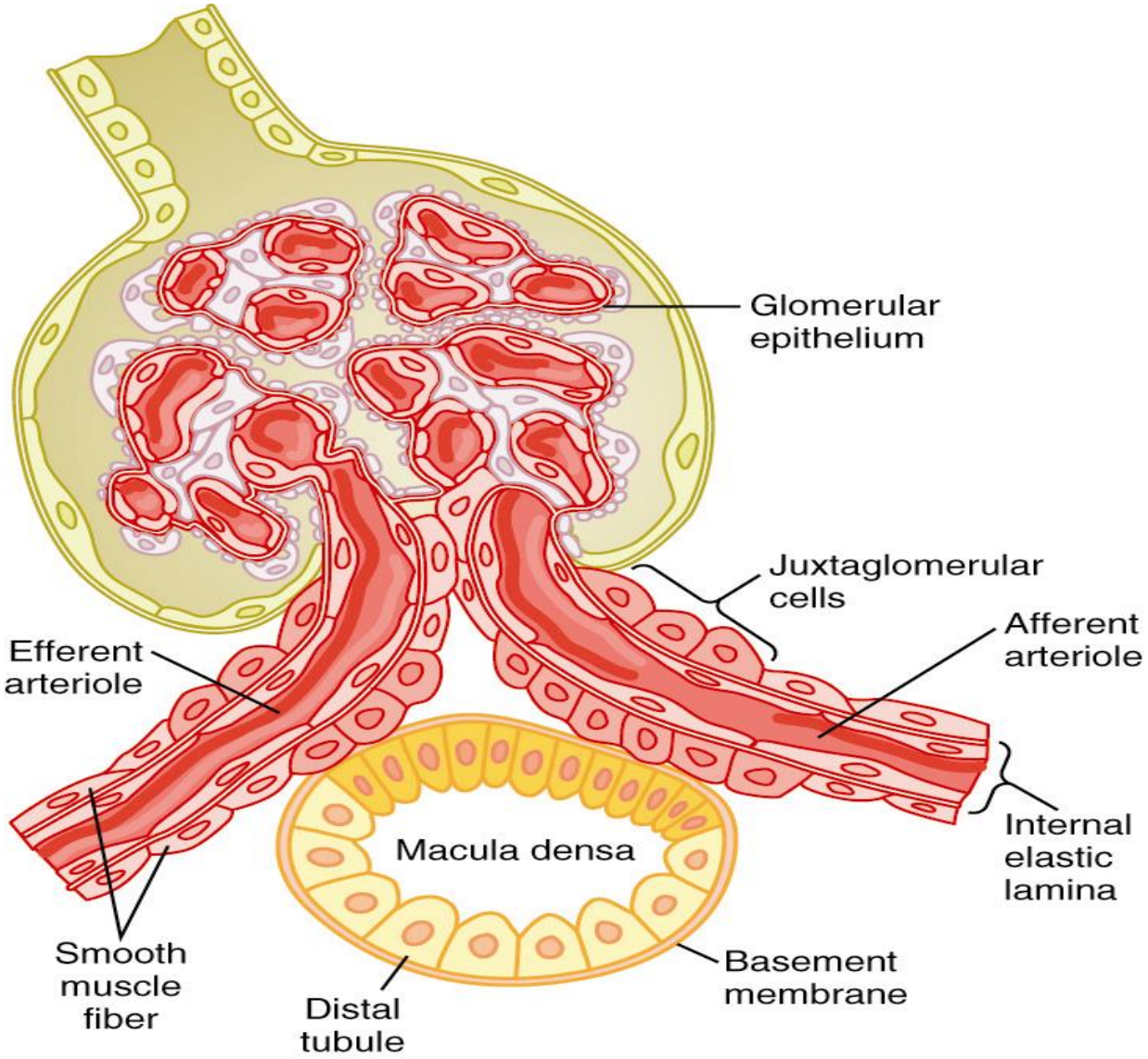


Figure 26-17;
Guyton and Hall

Cortical and Juxtamedullary Nephron Segmen

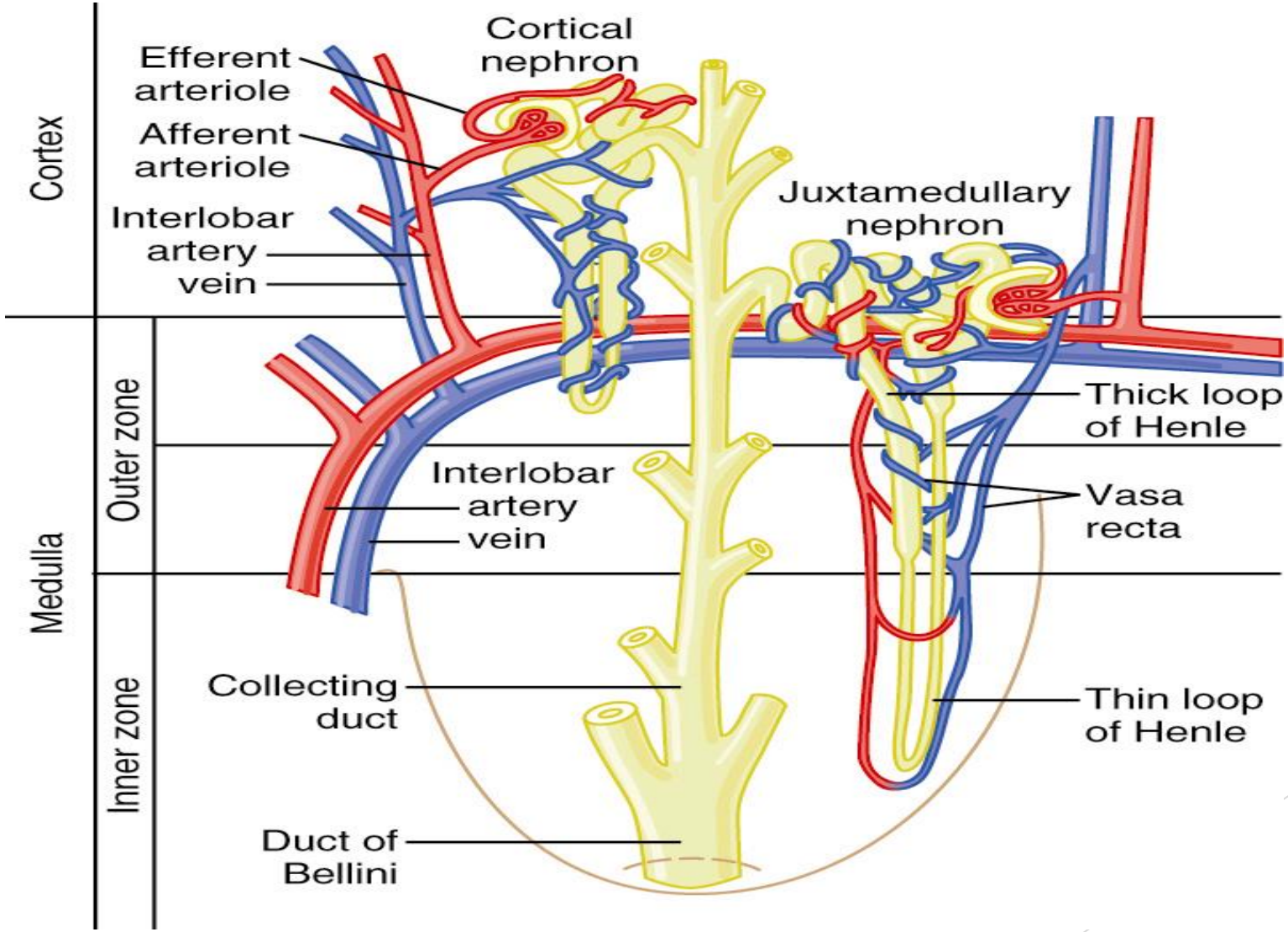
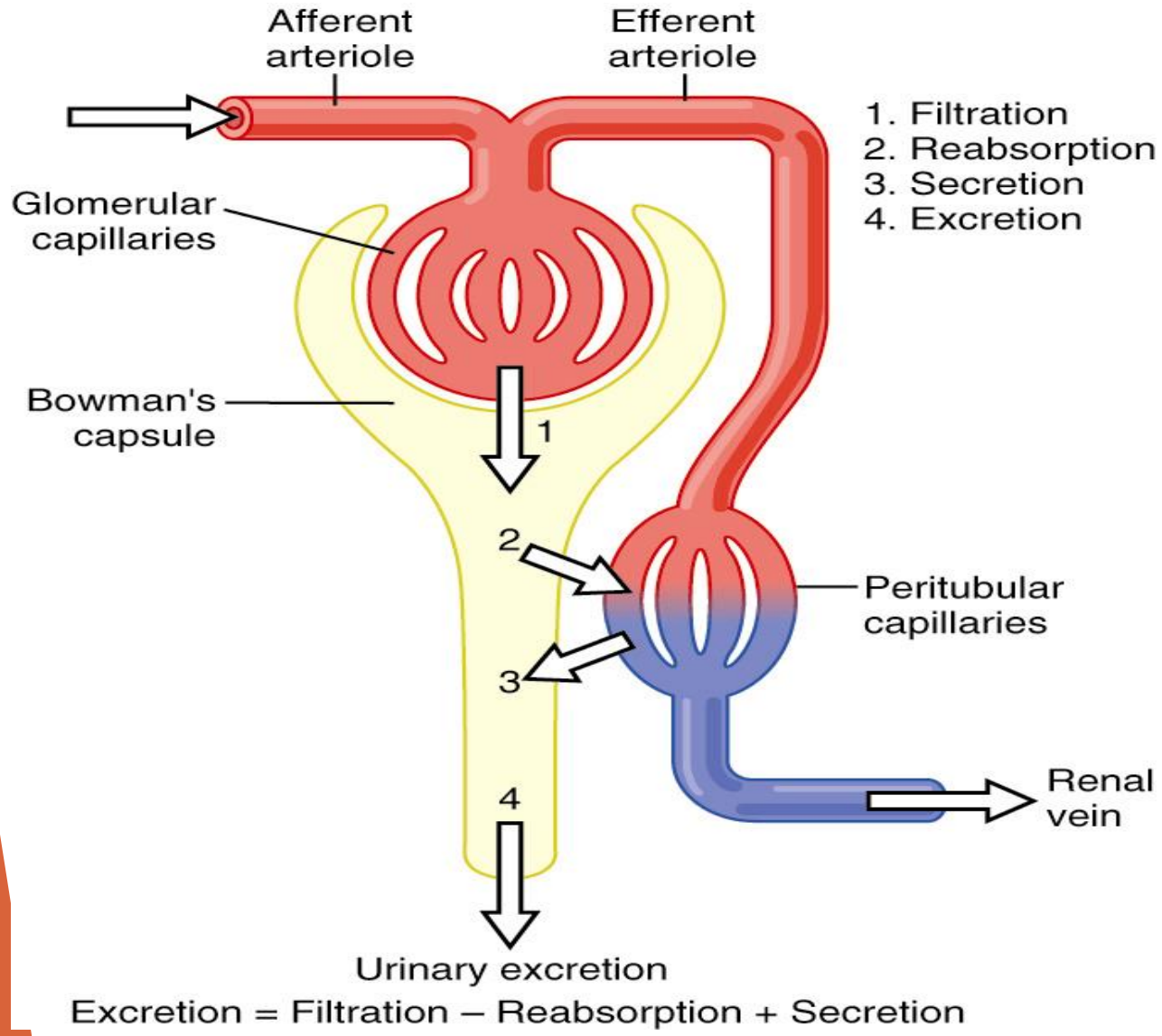


Figure 26-5;
Guyton and Hall



Basic Mechanisms of Urine Formation

Figure 26-8;
Guyton and Hall

Renal Handling of Different Substances

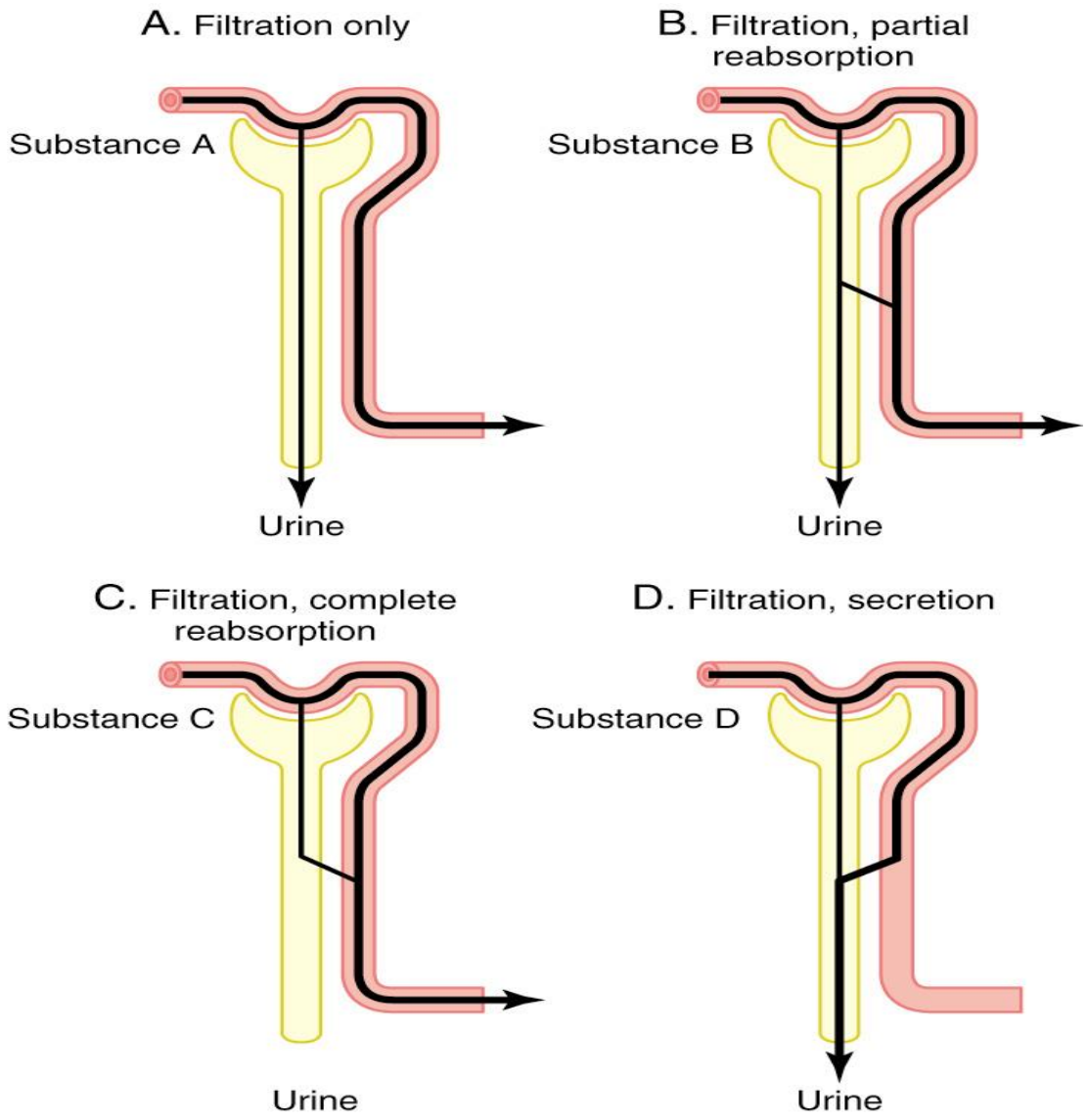
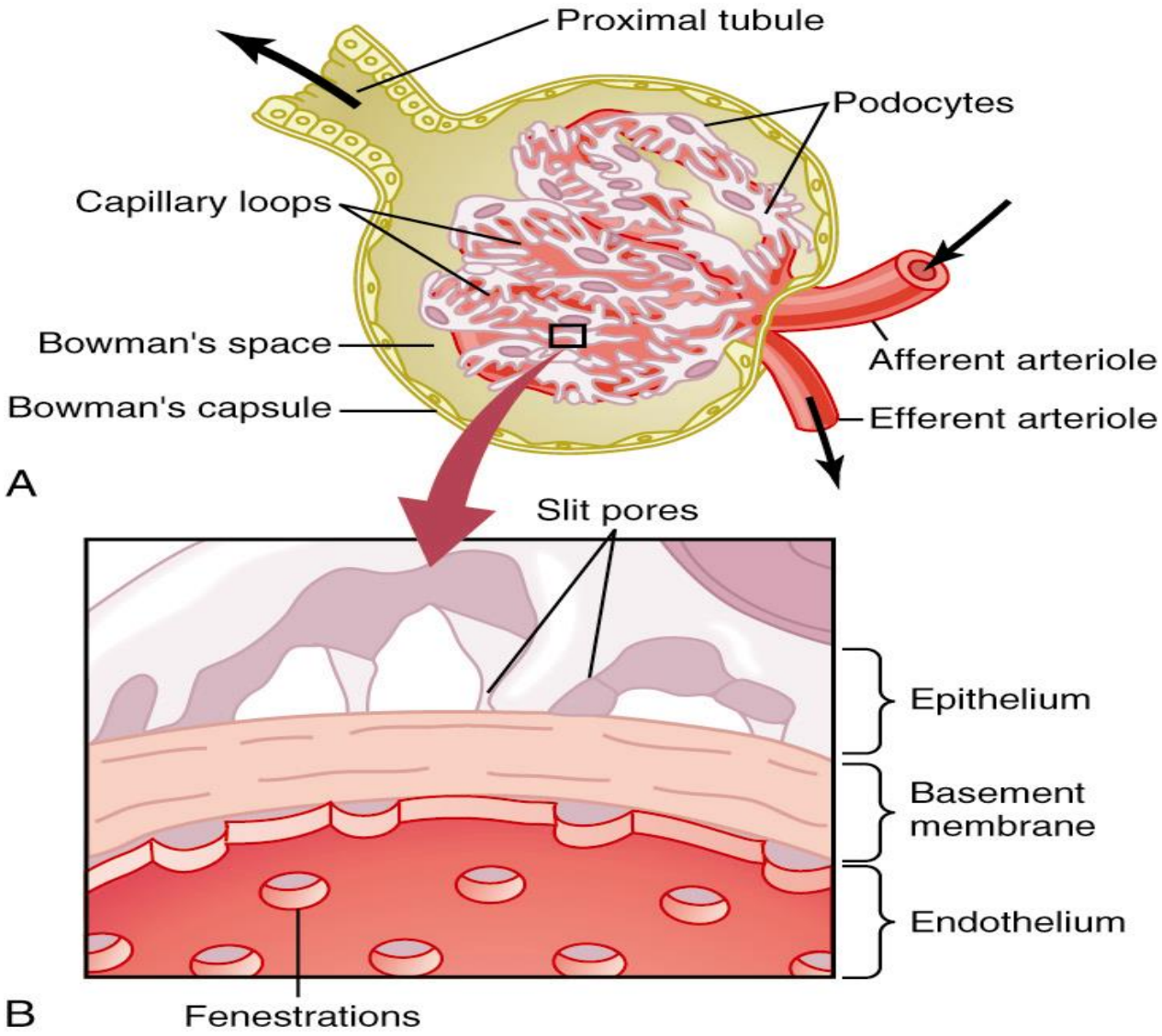


Figure 26-9;
Guyton and Hall



Glomerular Capillary Filtration Barrier

Figure 26-10;
Guyton and Hall

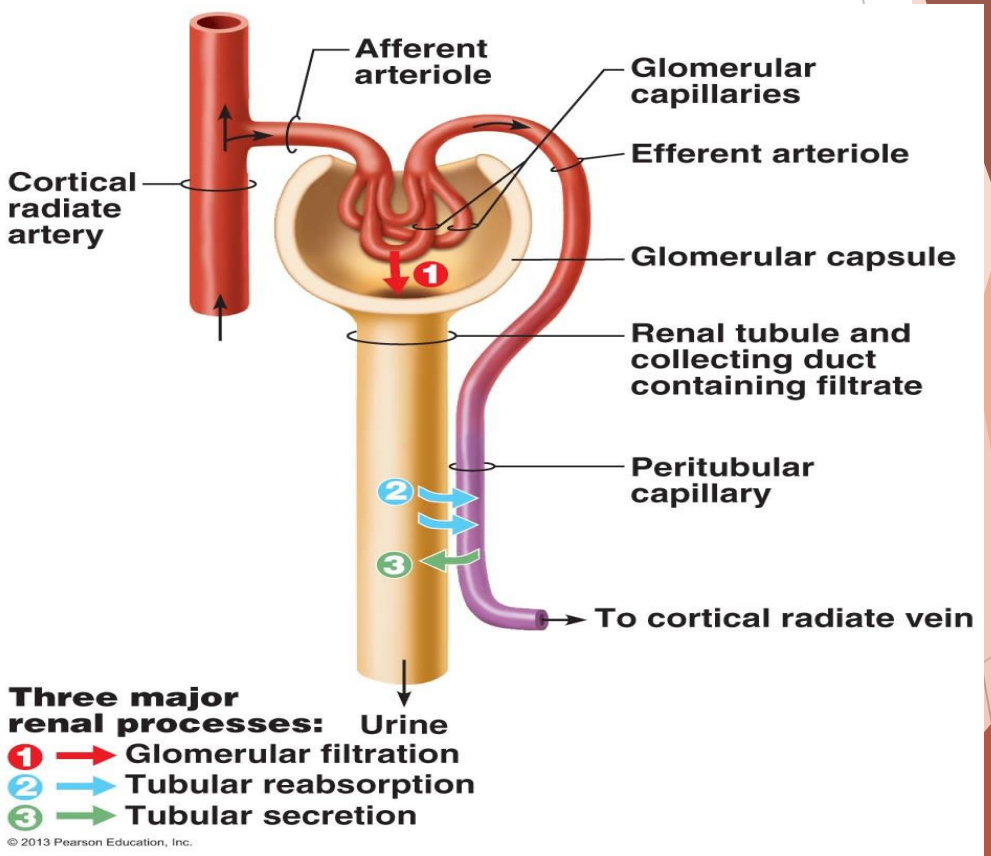
Glomerular Filtration

- Renal process whereby in the blood is filtrated across the capillaries.
- Formation of urine involves three main steps

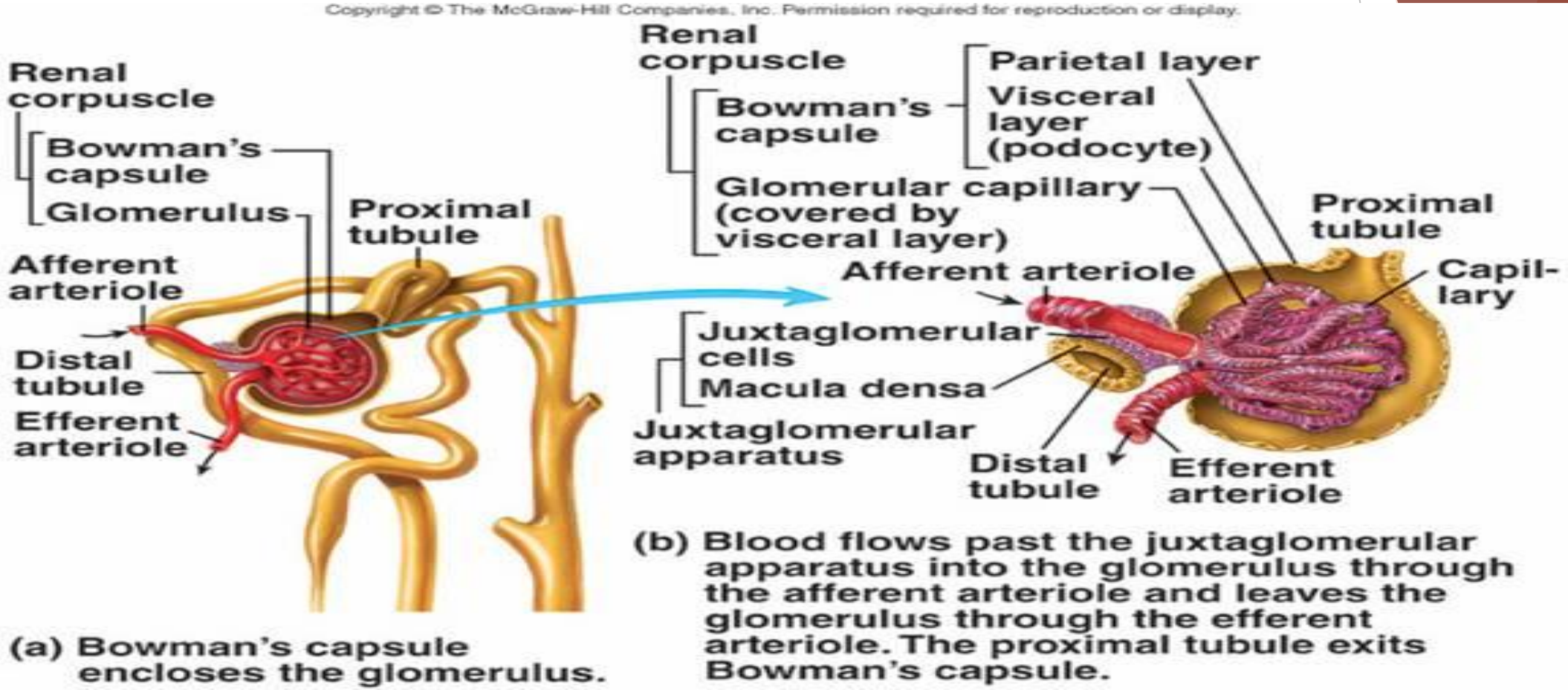
a. Filtration

b. Reabsorption

c. Secretion



Renal Processes



Renal Processes

Filtration

- The formation of urine begins with the process of filtration. Fluid and small solutes are forced under pressure to flow from the glomerulus into the capsular space of the glomerular capsule.
- Blood plasma enters the afferent arteriole and flows into the glomerulus .
- Podocytes which send foot processes over the length of the glomerulus interdigitate with one another forming filtration slits.
- Electrostatic repulsion.

Renal Processes

- Blood in the glomerulus has filterable and non-filterable blood components.
- The glomerular filtrate is not the same consistency as urine, as much of it is reabsorbed into the blood as the filtrate passes through the tubules of the nephron

Regulation of Glomerular Filtration Rate

- Filtration Pressure is the force that drives the fluid and its dissolved substances through the glomerular filter

Net Filtration pressure NPF (or Net Hydrostatic Pressure NHP) is the difference between three pressures:

1. Glomerular (blood) hydrostatic pressure GHP or GBHP
2. Capsular Hydrostatic Pressure (CHP)
3. (Blood) Colloid Osmotic Pressure (BCOP)

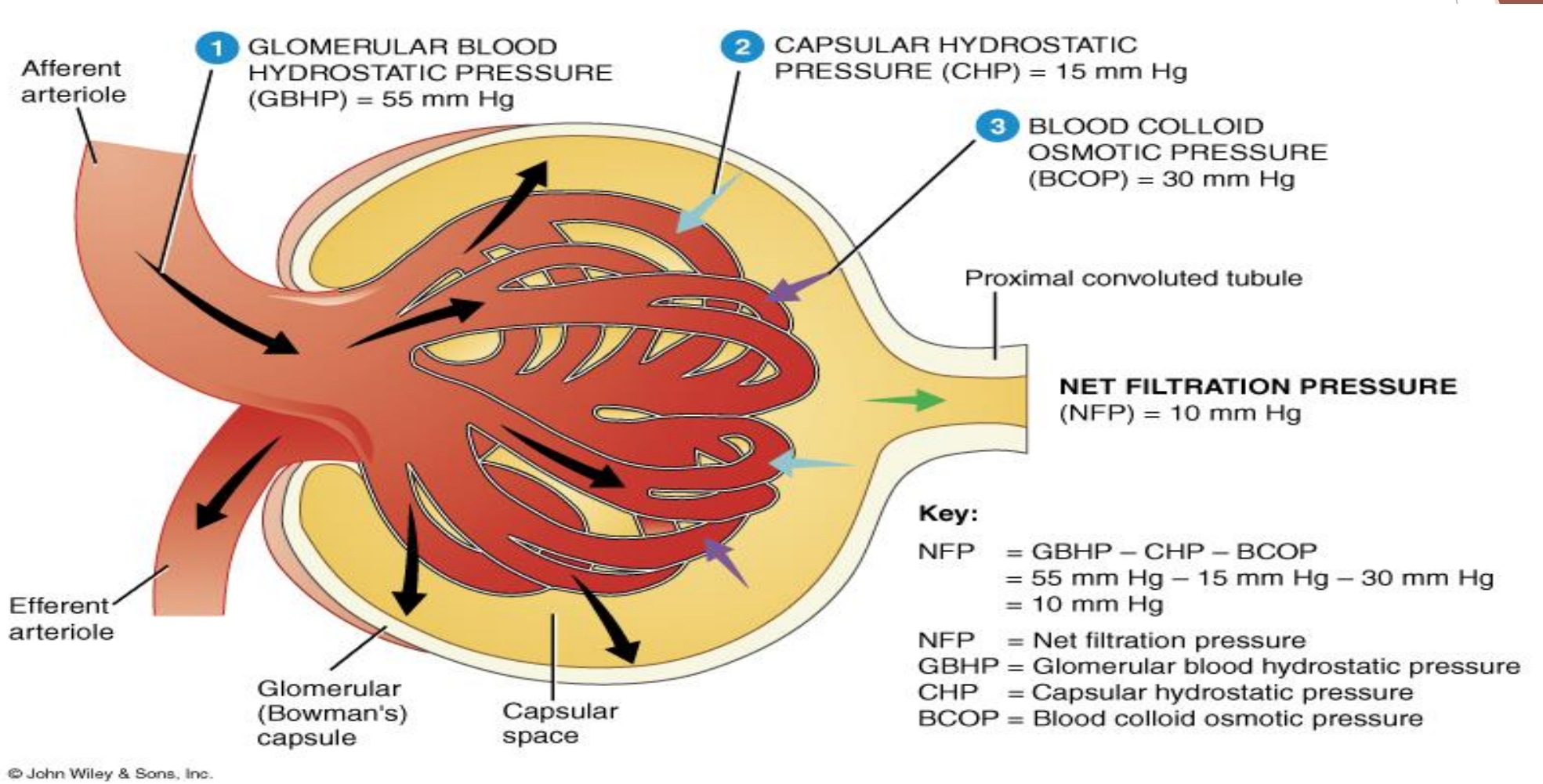
The relationship can be expressed by

$$NFP = GBHP – (CHP + BCOP)$$

Glomerular Filtration Rate: amount of filtrate the kidneys produce each minute. (about 125 ml per minute)

Determined by a creatinine clearance test

Factors affecting filtration rate in the kidney

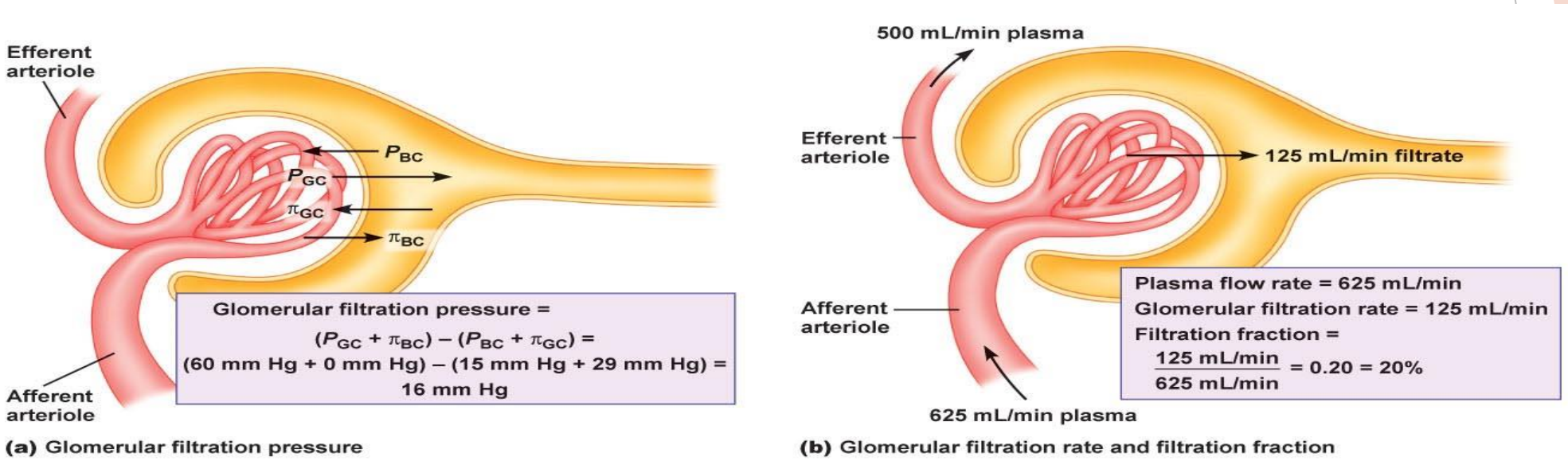


Glomerular Filtration Rate (GFR)

- The total amount of filtrate formed by all the renal corpuscles in both kidneys per minute is called the glomerular filtration rate, or GFR.
- **Starling equation**
- The rate of filtration from the glomerulus to the Bowman's capsule is determined by the Starling equation

$$GFR = K_f[(P_{gc} - P_{bc}) - (\pi_{gc} - \pi_{bc})]$$

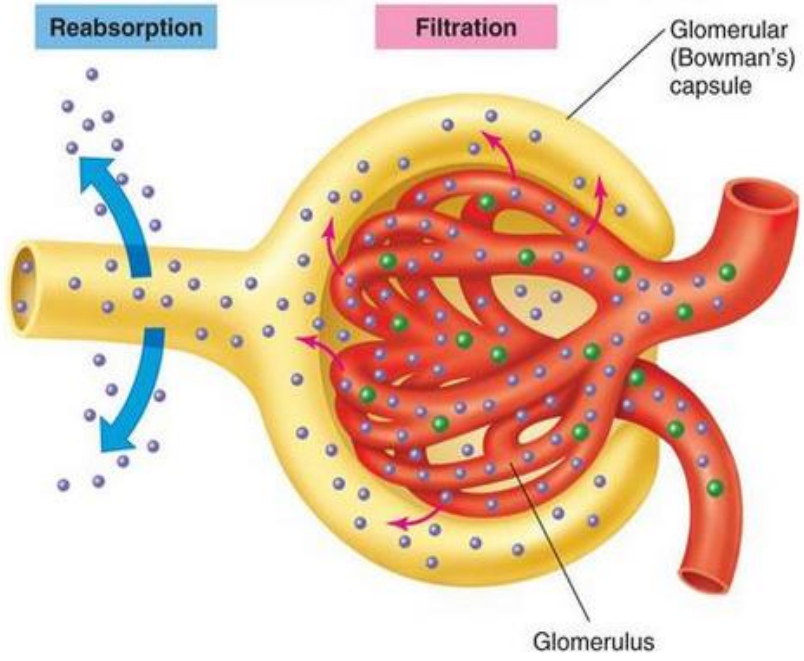
Glomerular Filtration Rate (GFR)

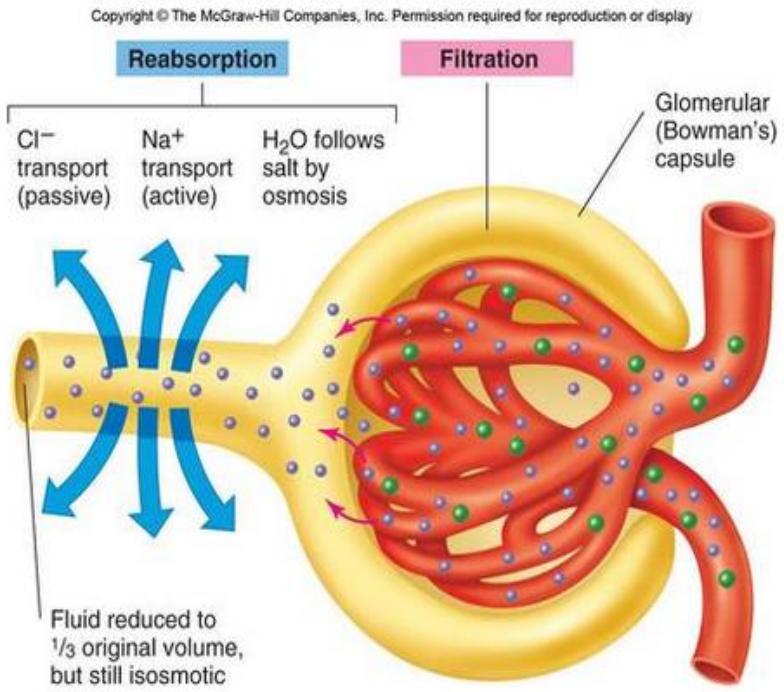


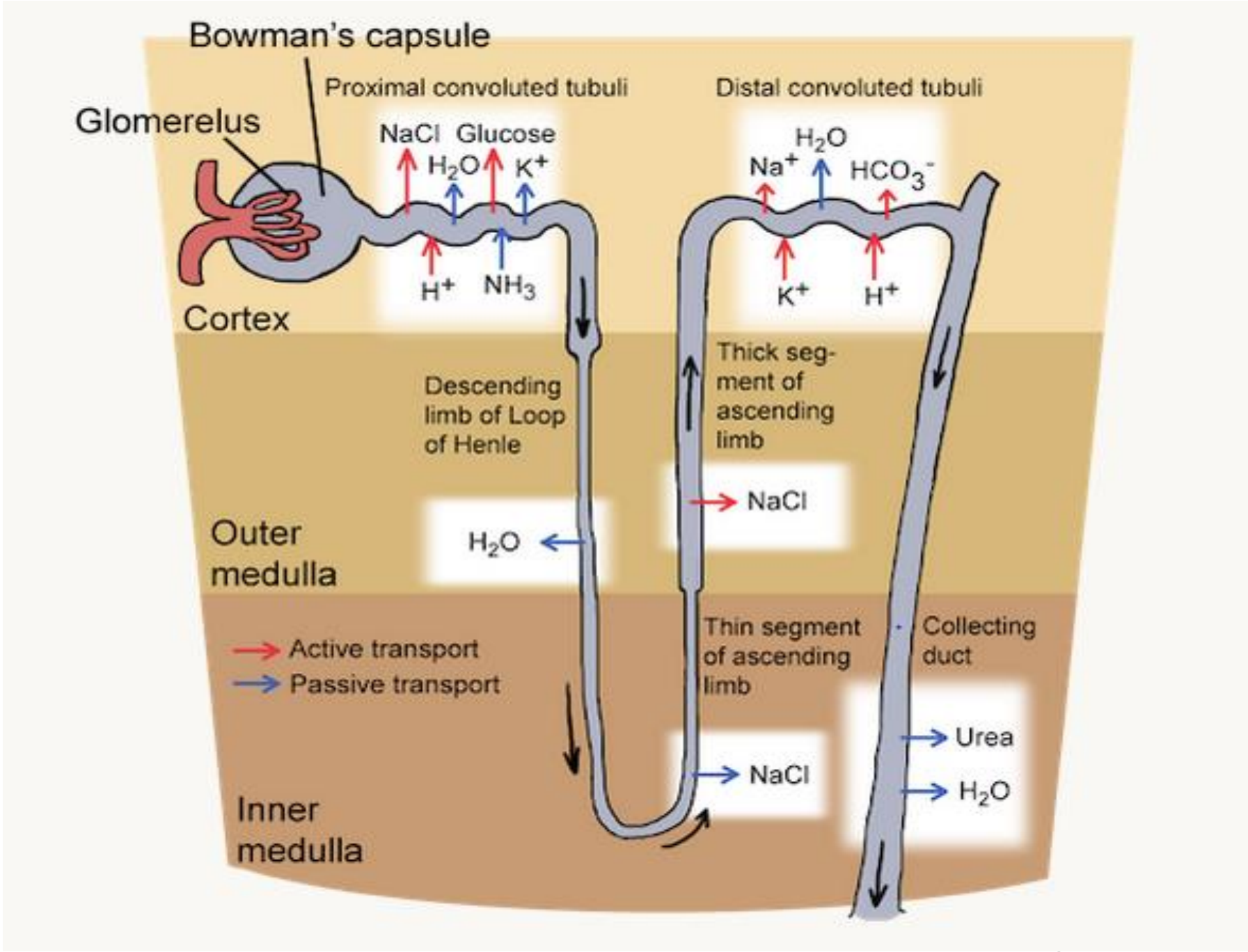
TUBULAR REABSORPTION

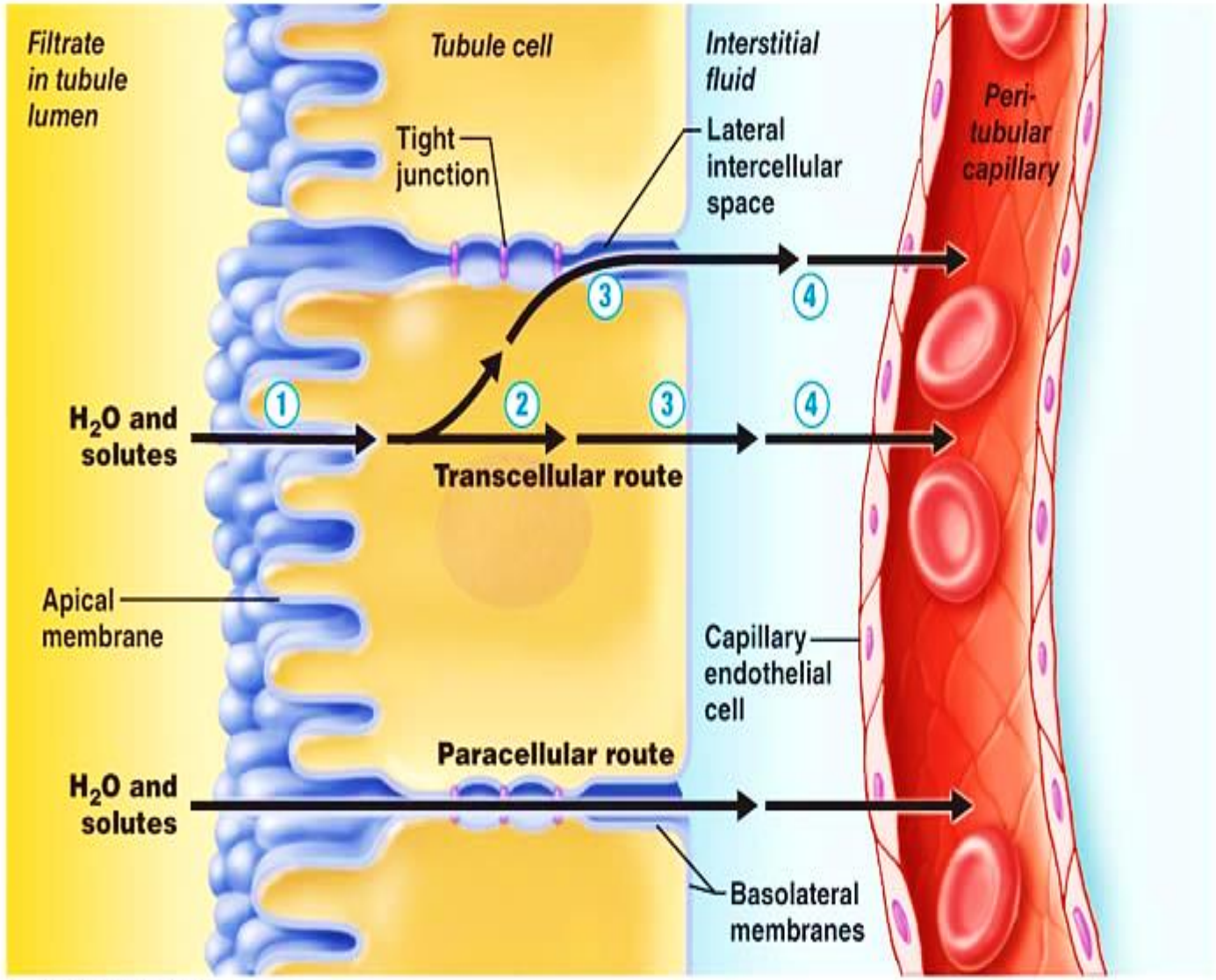
REABSORPTION OF SOLUTES AND WATER

- Kidneys receive about 180 liters of glomular ultrafiltrate every day and only let go 1-2 liters that was received during the whole day.
- 99% of what the kidneys receive are filtered back into to vascular system. The remaining 1% in put into the urine.
- If a lot of water is consumed, the urine is diluted down and the amount increases.






Bowman's capsule
Glomerelus
Proximal convoluted tubuli
Distal convoluted tubuli
NaCl Glucose
H_2O K^+
H^+ NH_3
H_2O
Na^+ HCO_3^-
K^+ H^+
Cortex
Descending limb of Loop of Henle
Thick segment of ascending limb
NaCl
H_2O
Outer medulla
Active transport
Passive transport
Thin segment of ascending limb
Collecting duct
NaCl
Urea
H_2O
Inner medulla

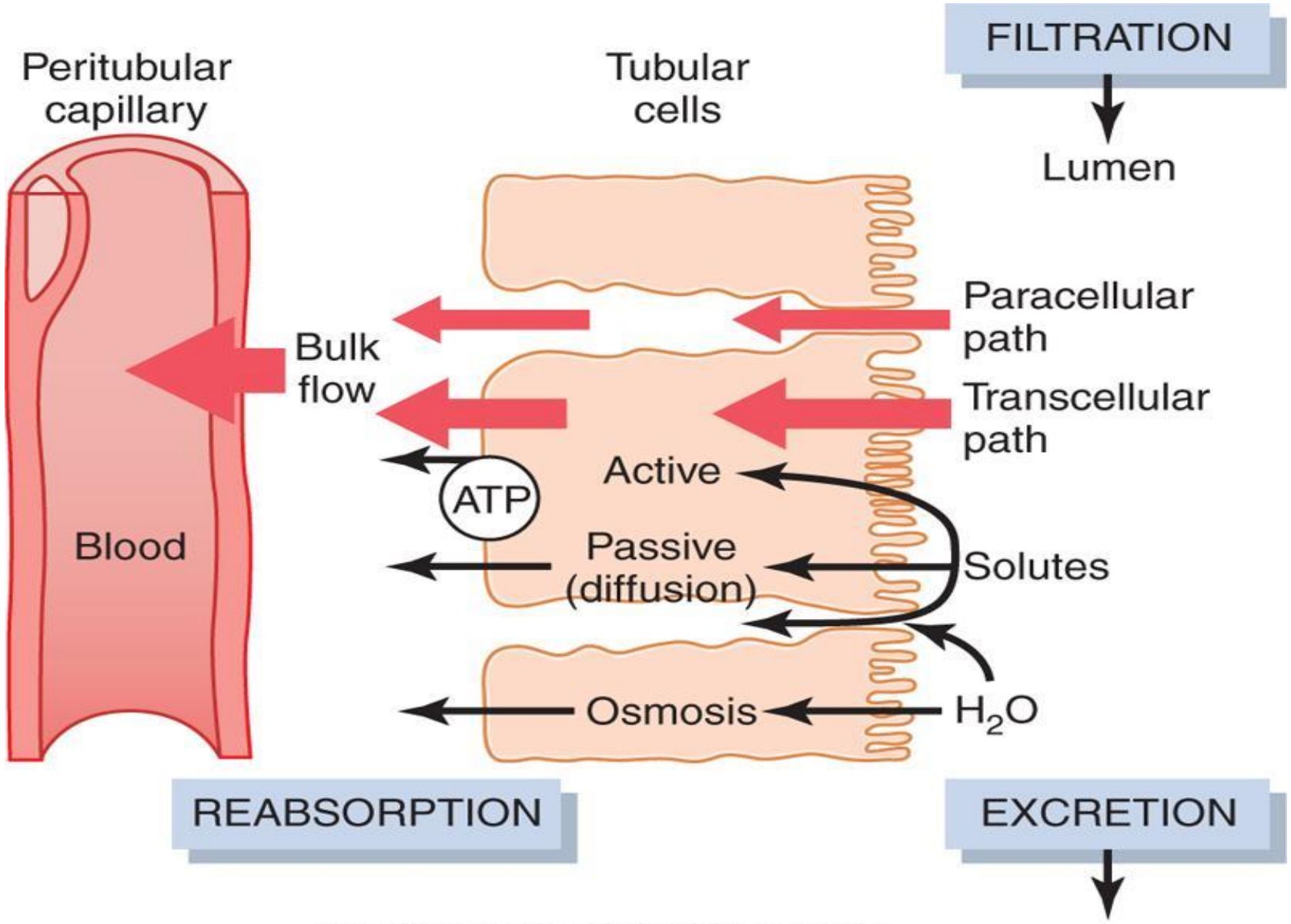


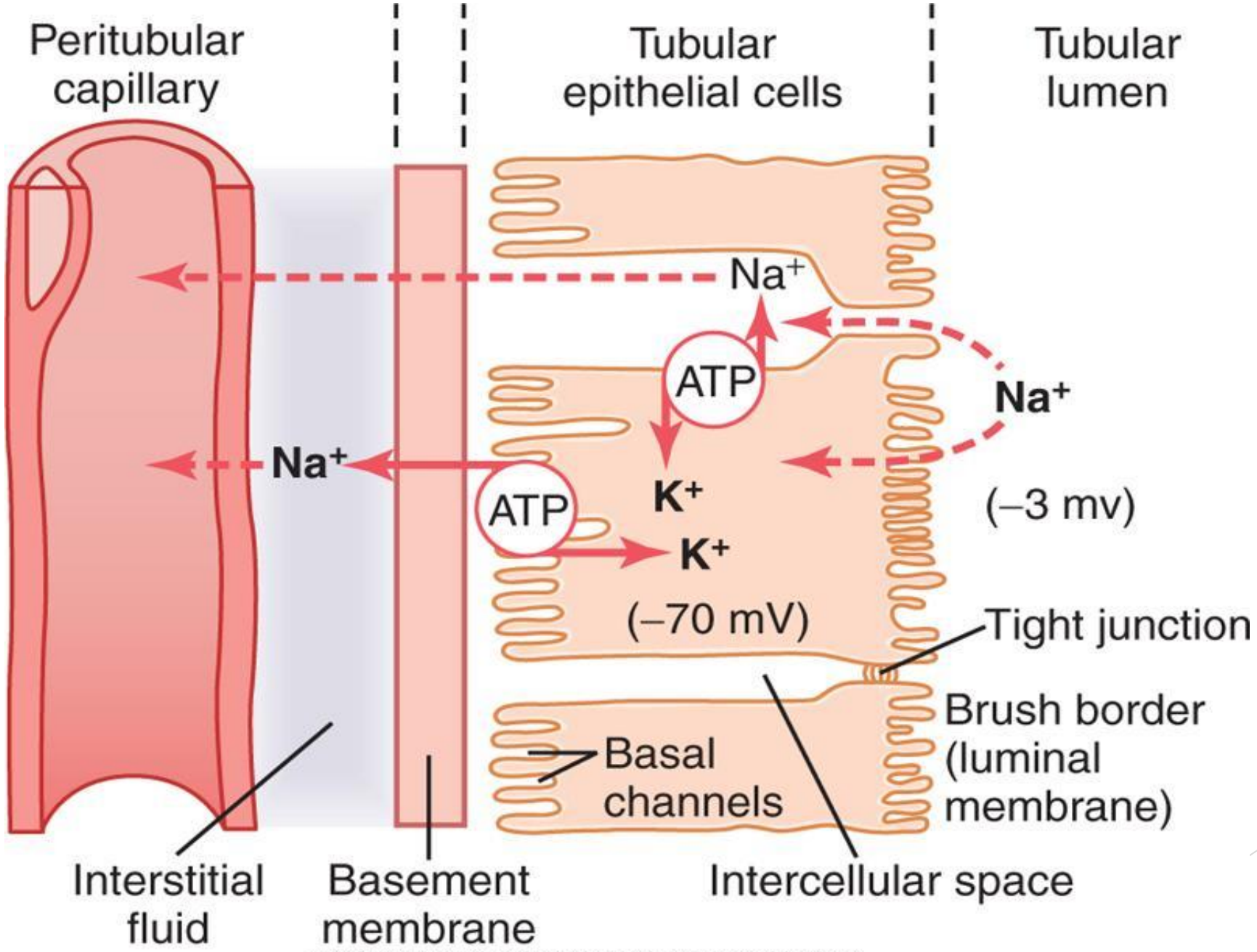
The transcellular route involves:

1. Transport across the apical membrane.
2. Diffusion through the cytosol.
3. Transport across the basolateral membrane. (Often involves the lateral intercellular spaces because membrane transporters transport ions into these spaces.)
4. Movement through the interstitial fluid and into the capillary.

The paracellular route involves:

- Movement through leaky tight junctions, particularly in the PCT.
- Movement through the interstitial fluid and into the capillary.

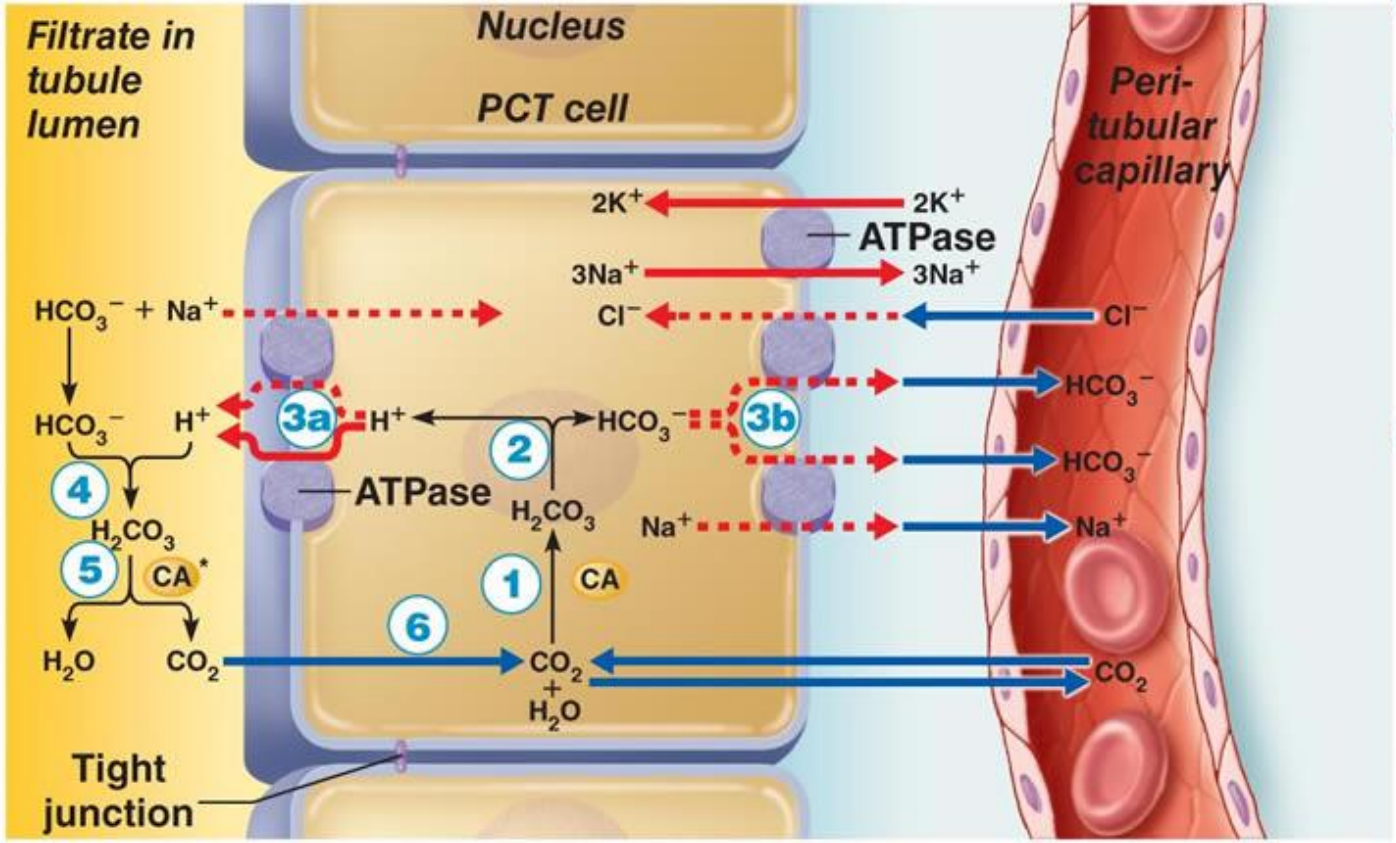




BICARBONATE IONS REABSORPTION AND SECRETION

1 CO_2 combines with water within the tubule cell, forming H_2CO_3.

2 H_2CO_3 is quickly split, forming H^+ and bicarbonate ion (HCO_3^-).



Primary active transport
Secondary active transport
Simple diffusion
Transport protein
CA Carbonic anhydrase

3a H^+ is secreted into the filtrate.

3b For each H^+ secreted, a HCO_3^- enters the peritubular capillary blood either via symport with Na^+ or via antiport with Cl^-.

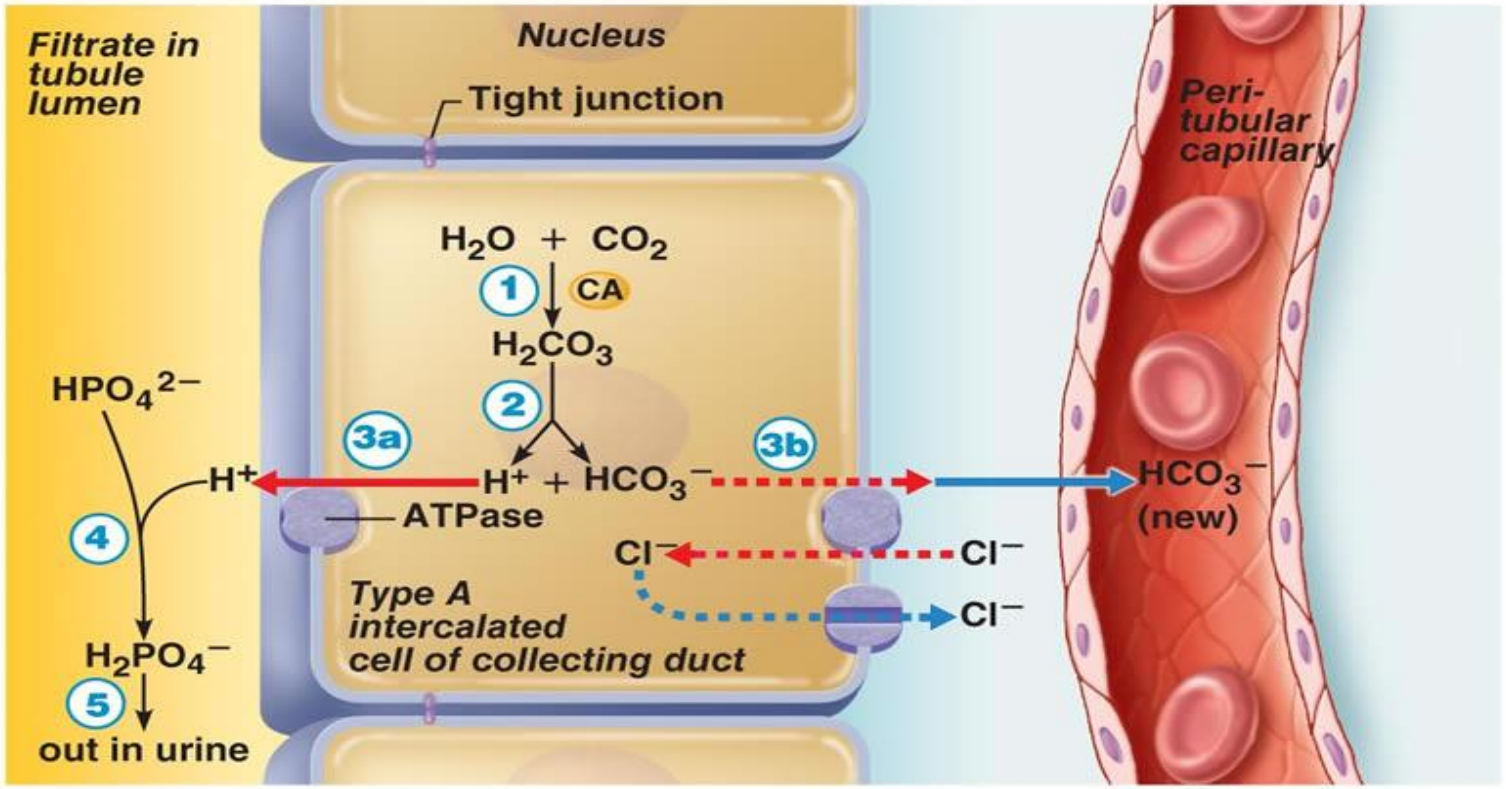
4 Secreted H^+ combines with HCO_3^- in the filtrate, forming carbonic acid (H_2CO_3). HCO_3^- disappears from the filtrate at the same rate that HCO_3^- (formed within the tubule cell) enters the peritubular capillary blood.

5 The H_2CO_3 formed in the filtrate dissociates to release CO_2 and H_2O.

6 CO_2 diffuses into the tubule cell, where it triggers further H^+ secretion.

SYNTHESIS OF NEW BICARBONATE/EXCRETION OF BUFFERED H+

The renal tubules can **synthesize new bicarbonate ions** while excreting more hydrogen ions.



1 CO_2 combines with water within the type A intercalated cell, forming H_2CO_3.

2 H_2CO_3 is quickly split, forming H^+ and bicarbonate ion (HCO_3^-).

3a H^+ is secreted into the filtrate by a H^+ ATPase pump.

3b For each H^+ secreted, a HCO_3^- enters the peritubular capillary blood via an antiport carrier in a HCO_3^--Cl^- exchange process.

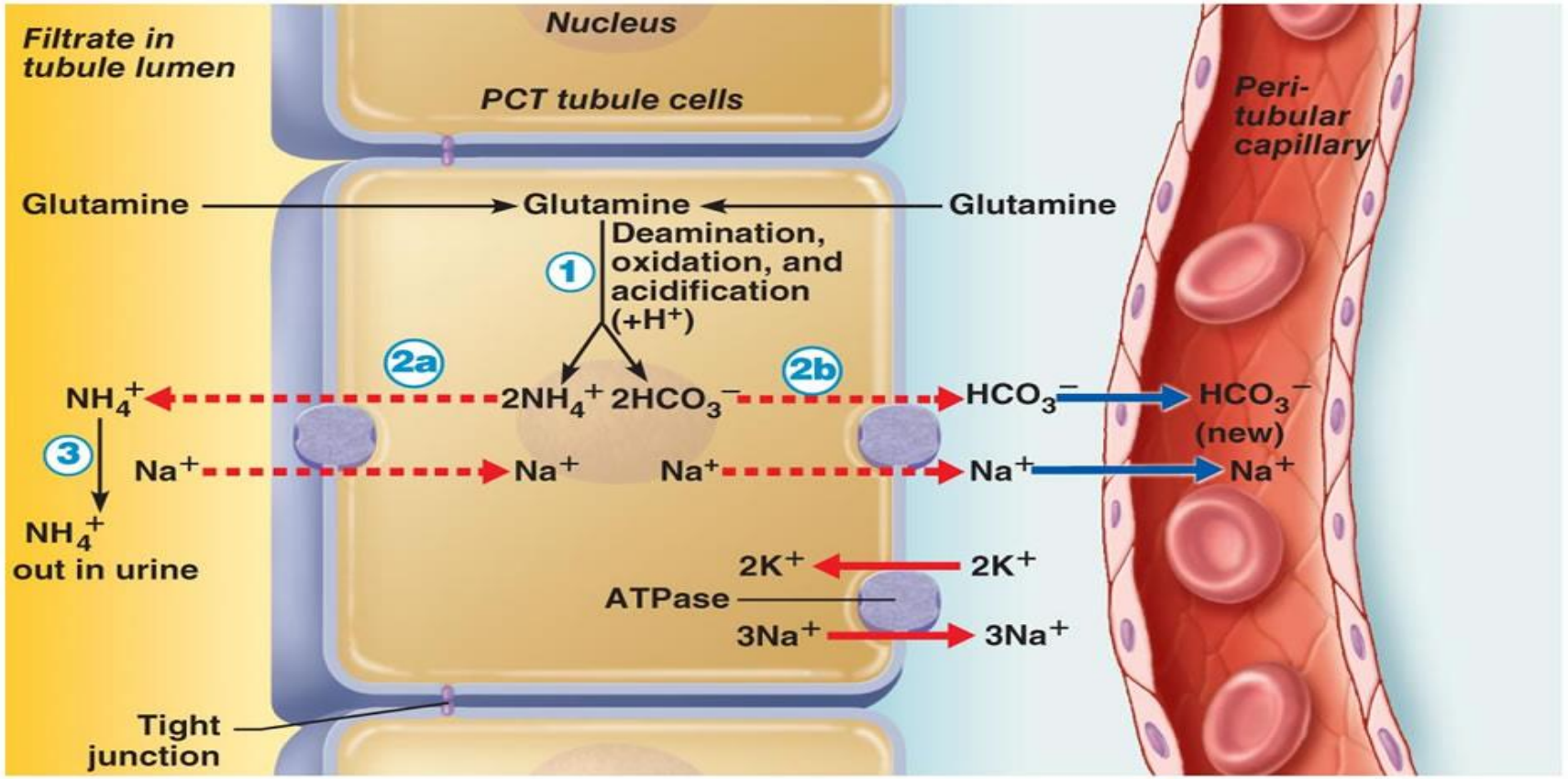
4 Secreted H^+ combines with HPO_4^{2-} in the tubular filtrate, forming $H_2PO_4^-$.

5 The $H_2PO_4^-$ is excreted in the urine.

- Primary active transport
- Secondary active transport
- Simple diffusion
- Facilitated diffusion
- Transport protein
- Ion channel
- CA Carbonic anhydrase

AMMONIUM EXCRETION

Ammonium ions are weak acids that are excreted and lost in urine, replenishing the alkaline reserve of the blood.

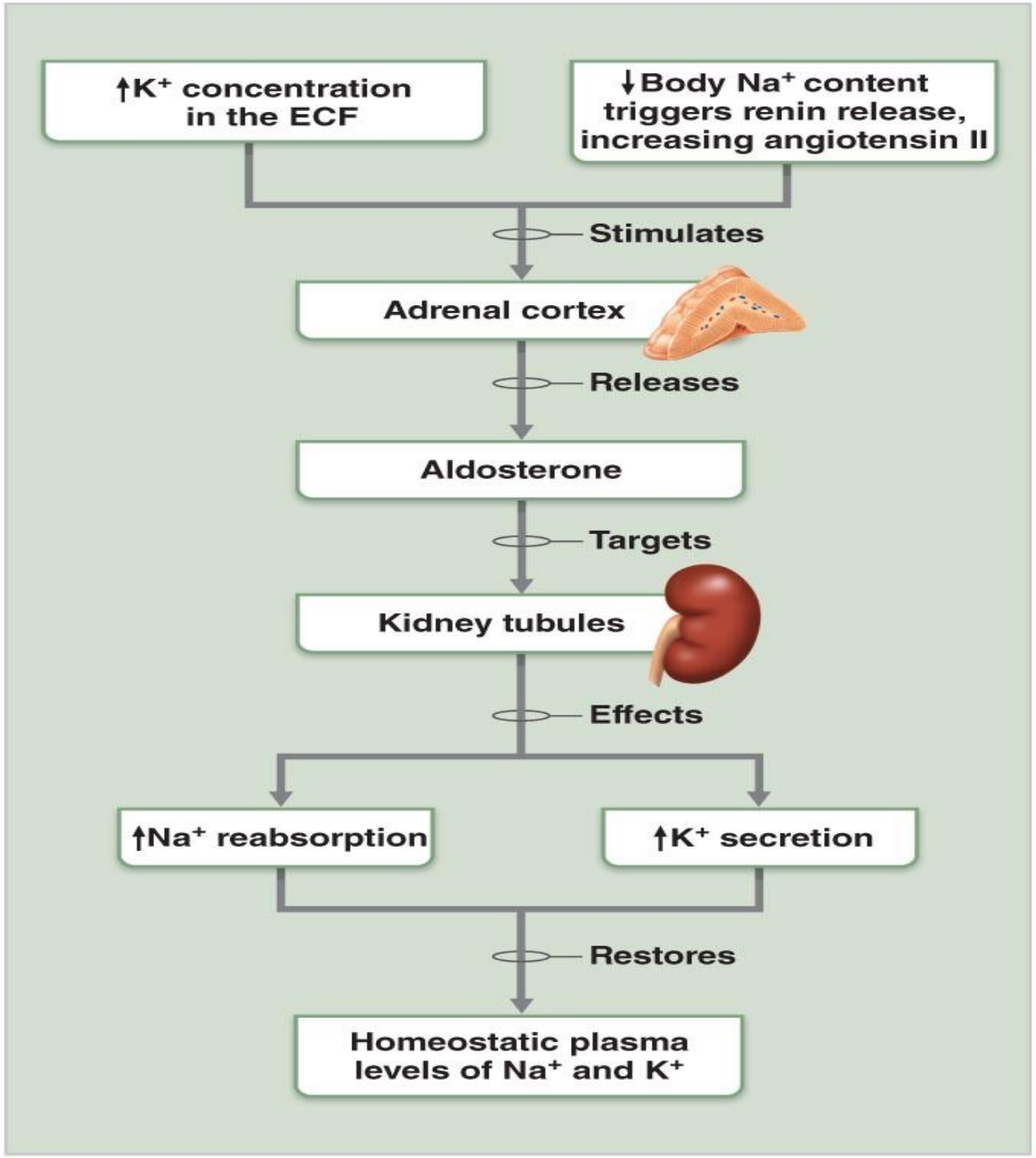


HORMONAL CONTROL OF TUBULAR REABSORPTION

- ALDOSTERONE
- ANGIOTENSIN II
- ANTIDIURETIC HORMONE

ALDOSTERONE

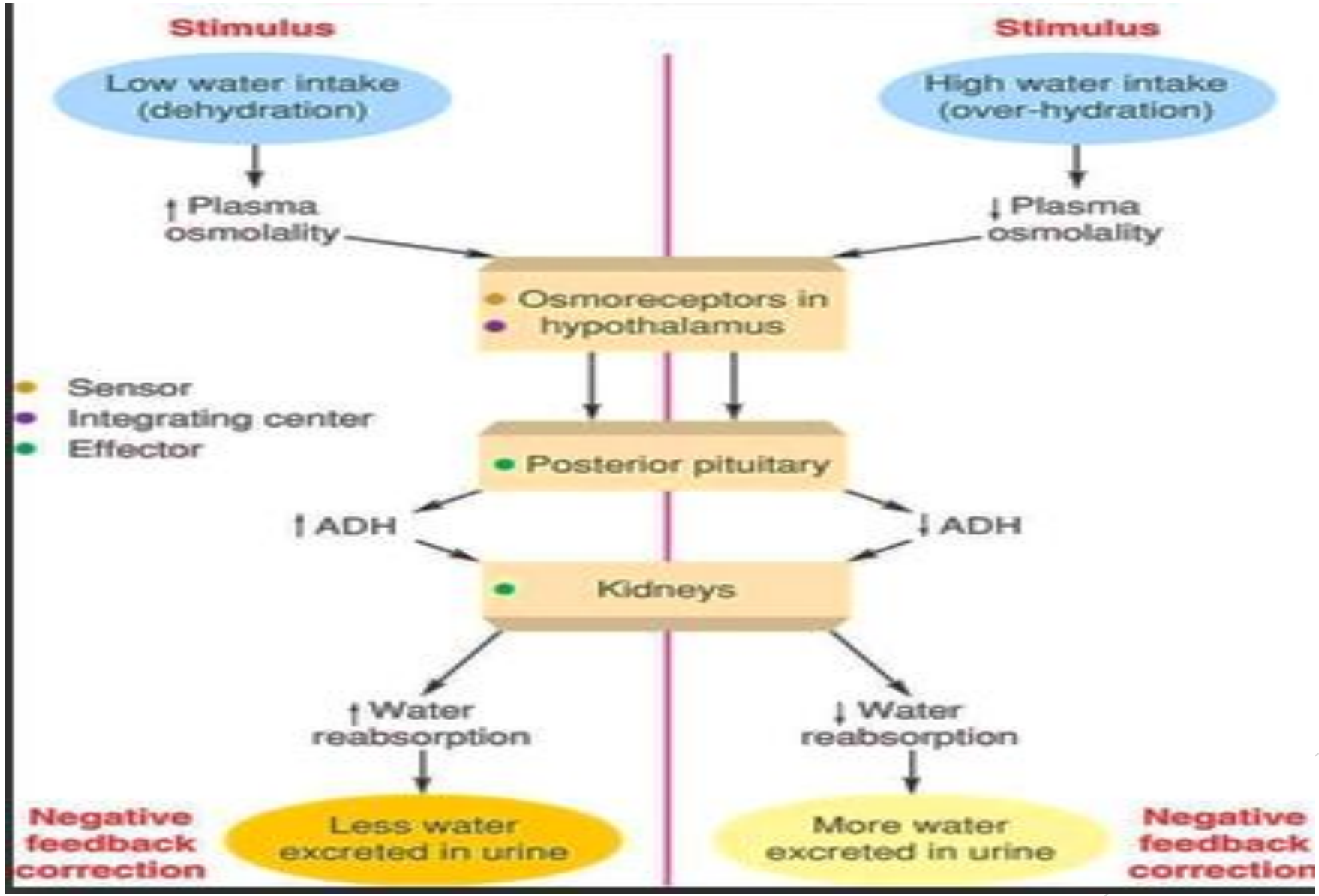
- When aldosterone secretion is high, nearly all the filtered sodium is reabsorbed in the distal convoluted tubule and the collecting duct.
- The most important trigger for the release of aldosterone is the renin-angiotensin mechanism, initiated in response to sympathetic stimulation, decrease in filtrate osmolality, or decreased blood pressure.



ANGIOTENSIN II

- It stimulates aldosterone secretion which then increases sodium reabsorption.
- It constricts the efferent arterioles in two ways:
- Firstly, when it constricts it reduces peritubular capillary hydrostatic pressure which increases net tubular reabsorption.
- Secondly, when constricts it reduces renal blood flow which rises filtration fraction in glomerulus and increases concenteration of protiens and the colloidal osmotic pressure in peritubular capillaries that increases reabsorptive force at the peritubular capillary.
- It stimulates directly in proximal tubules, loop of henle, distal tubules and collecting duct.

ANTIDIURETIC HORMONE:



Urine Formation

- Regulation of Urine Concentration and Volum
  - Most of the sodium ions are reabsorbed before the urine is excreted under the direction of the hormone, aldosterone
  - Normally the distal convoluted tubule and collecting duct are impermeable to water unless the hormone ADH is present.

Urine Formation

- Urea and Uric Acid Excretion
  - Urea is a by-product of amino acid metabolism; uric acid is a by-product of nucleic acid metabolism.
  - Urea is passively reabsorbed by diffusion but about 50% of urea is excreted in the urine.
  - Most uric acid is reabsorbed by active transport and a small amount is secreted into the renal tubule.

Urine Formation

- Tubular Secretion
  - Tubular secretion transports certain substances, including penicillin, histamine, phenobarbital, hydrogen ions and potassium ions, from the plasma into the renal tubule.
  - Active transport mechanisms move excess hydrogen ions into the renal tubule along with various organic compounds.

Urine Formation

- Potassium ions are secreted both actively and passively into the distal convoluted tubule and the collecting duct.

THANK YOU