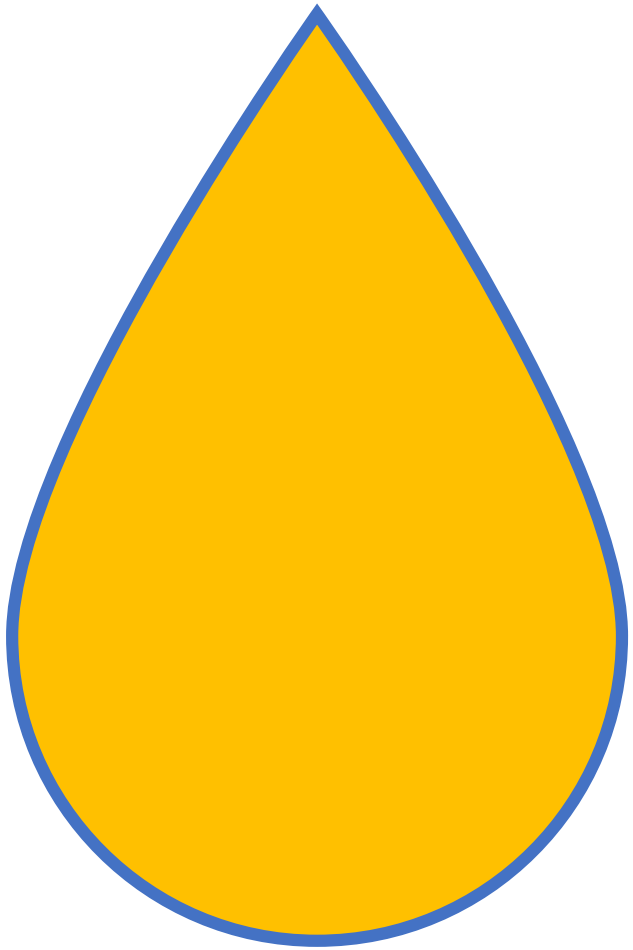
The Urinary System

By Scientist Cindy



What is the Urinary System?

- The **Urinary System** is a group of organs in the body concerned with filtering out excess fluid and other substances from the bloodstream.
  - The substances are filtered out from the body in the form of **urine**.
  - Urine is a liquid produced by the kidneys, collected in the bladder and excreted through the urethra.
  - Urine is used to extract excess minerals or vitamins from the body.

Functions of the Urinary System

Excretion – the process of eliminating waste products

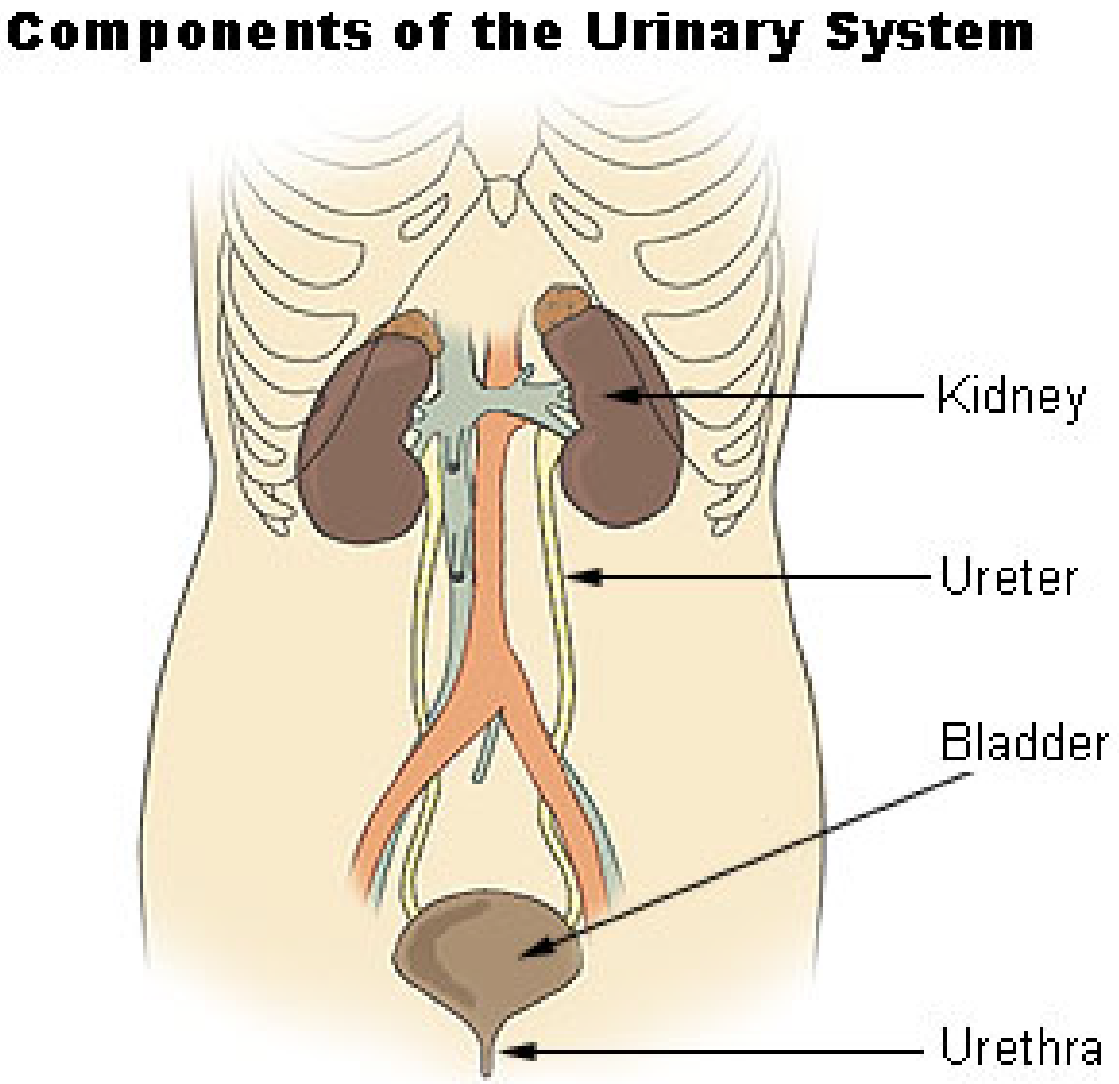
Maintains an appropriate fluid volume – regulating the amount of water that is excreted in the urine.

Regulates the concentrations of various electrolytes in the body fluids

Maintaining normal pH of the blood.

The Urinary organs

- The Urinary organs include
  - the kidneys
  - The ureters
  - The bladder
  - The urethra



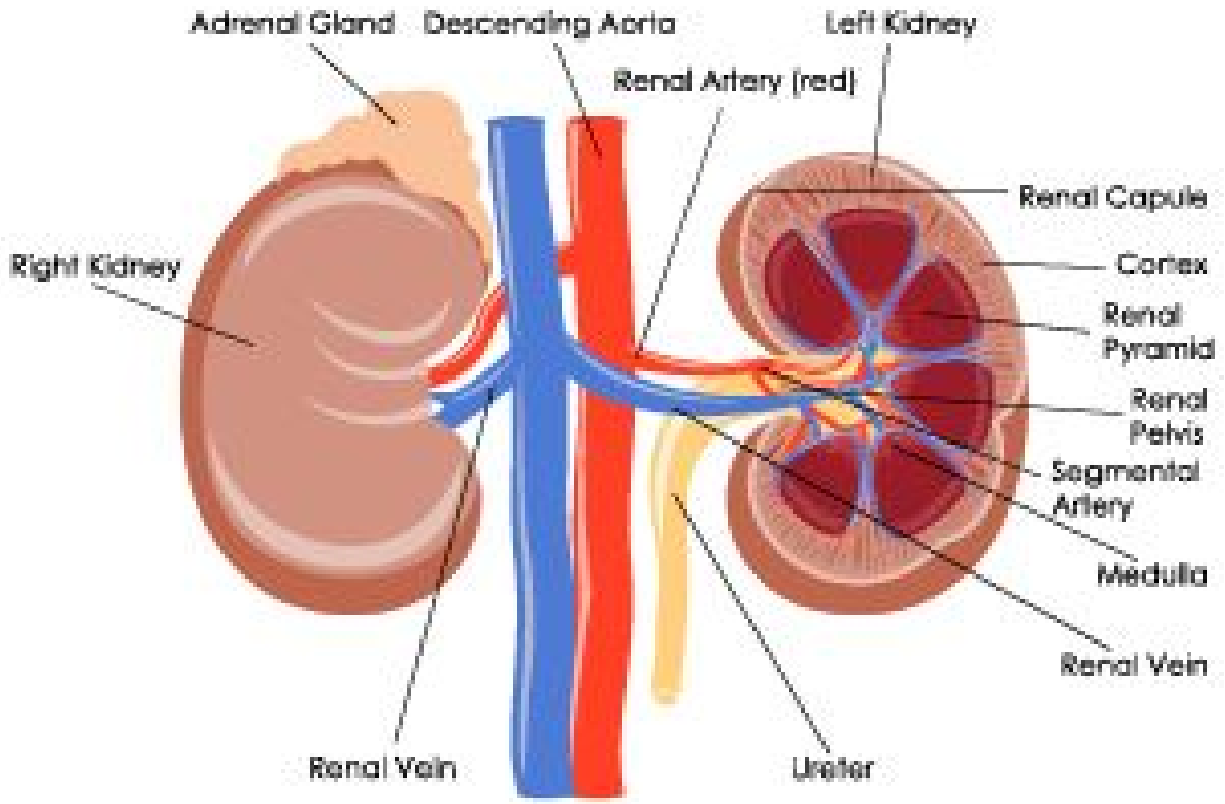
The Kidneys

The kidneys are the main organs of homeostasis because they

- Maintain pH - the acid base balance
- Maintain the water and salt balance of the blood

The kidneys

- The kidneys are the most important excretory organ.
- The primary function of the kidneys is to maintain a stable internal environment (homeostasis) for optimal cell and tissue metabolism.
  - The kidneys removes unwanted urea, mineral salts, toxins, and other waste products from the blood.
  - The kidneys conserve water, salt, and electrolyte concentration.
  - At least one kidney must function properly for life to be maintained.



KIDNEY

Six important roles of the kidneys are:

Regulation of plasma ionic composition

Regulation of plasma osmolarity

Regulation of plasma volume

Regulation of plasma hydrogen ion concentration (pH)

Removal of metabolic waste products and foreign substances from the plasma

Secretion of Hormones

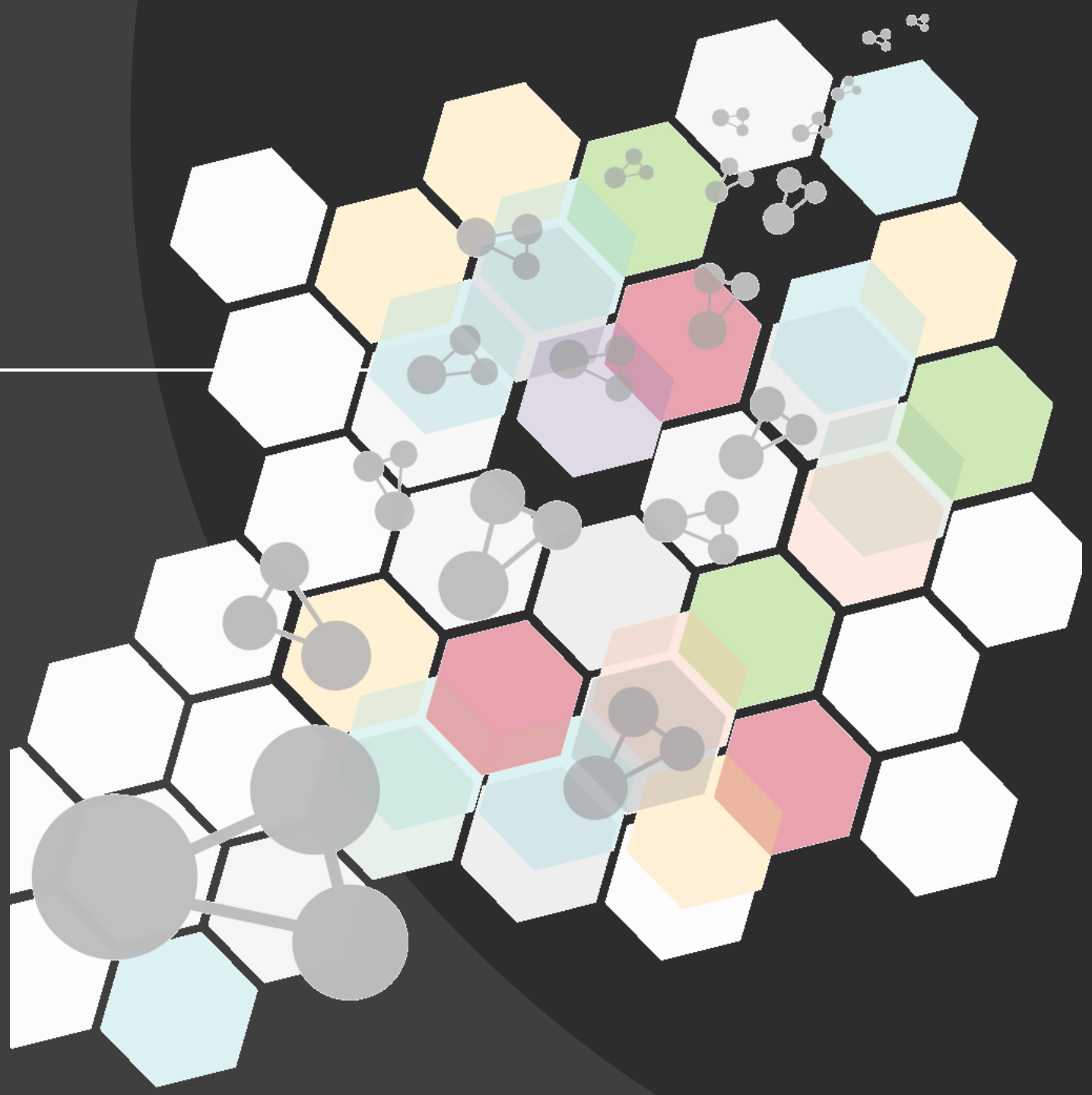
ROLES OF THE KIDNEYS - Regulation of plasma ionic composition

- Ions such as sodium, potassium, calcium, magnesium, chloride, bicarbonate, and phosphates are regulated by the amount that the kidney excretes.

ROLES OF THE KIDNEYS

- Regulation of plasma osmolarity

- The kidneys regulate osmolarity because they have direct control over how many ions and how much water a person excretes.



ROLES OF THE KIDNEYS

- Regulation of plasma volume

Your kidneys are so important they even have an effect on your blood pressure.

The kidneys control plasma volume by controlling how much water a person excretes.

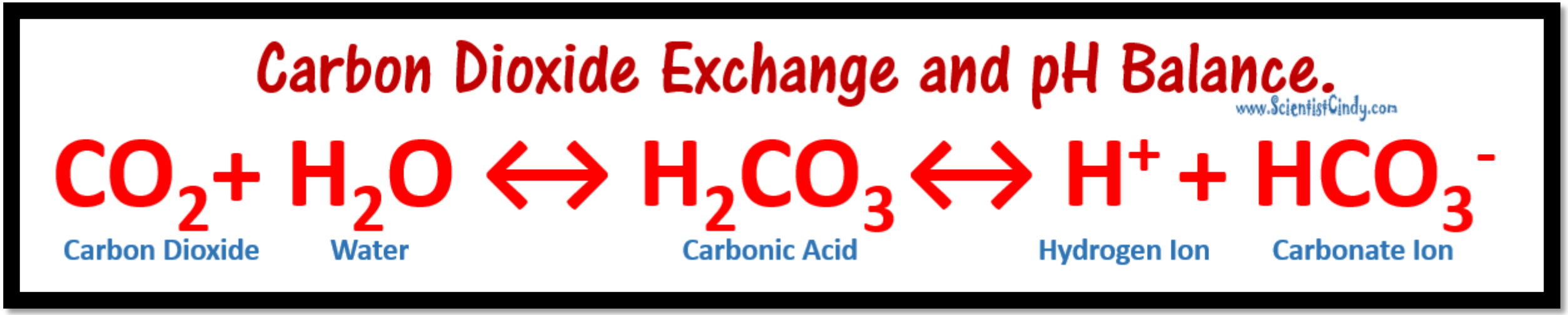
The plasma volume has a direct effect on the total blood volume, which has a direct effect on your blood pressure.

Salt (NaCl) will cause osmosis to happen; the diffusion of water into the blood.

ROLES OF THE KIDNEYS

- Regulation of (pH)

- The kidneys partner up with the lungs and they together control the pH.
- The kidneys excreting hydrogen ions and reabsorbing bicarbonate ions as needed.



ROLES OF THE KIDNEYS
- Removal of waste

- The kidneys get rid of
  - **Urea** - metabolic waste from the liver
  - **Ammonia** - metabolic waste from the liver
  - **Creatinine -** metabolic waste from the muscles
  - **Uric acid -** metabolic waste from the break down of nucleotides.
    - Uric acid is insoluble and too much uric acid in the blood will build up and form crystals that can collect in the joints and cause gout.

ROLES OF THE KIDNEYS
- Secretion of Hormones

Renin is released by the kidneys.

- Renin leads to the secretion of aldosterone from the adrenal cortex.
- Aldosterone causes the kidneys to reabsorb more sodium (Na+) ions.

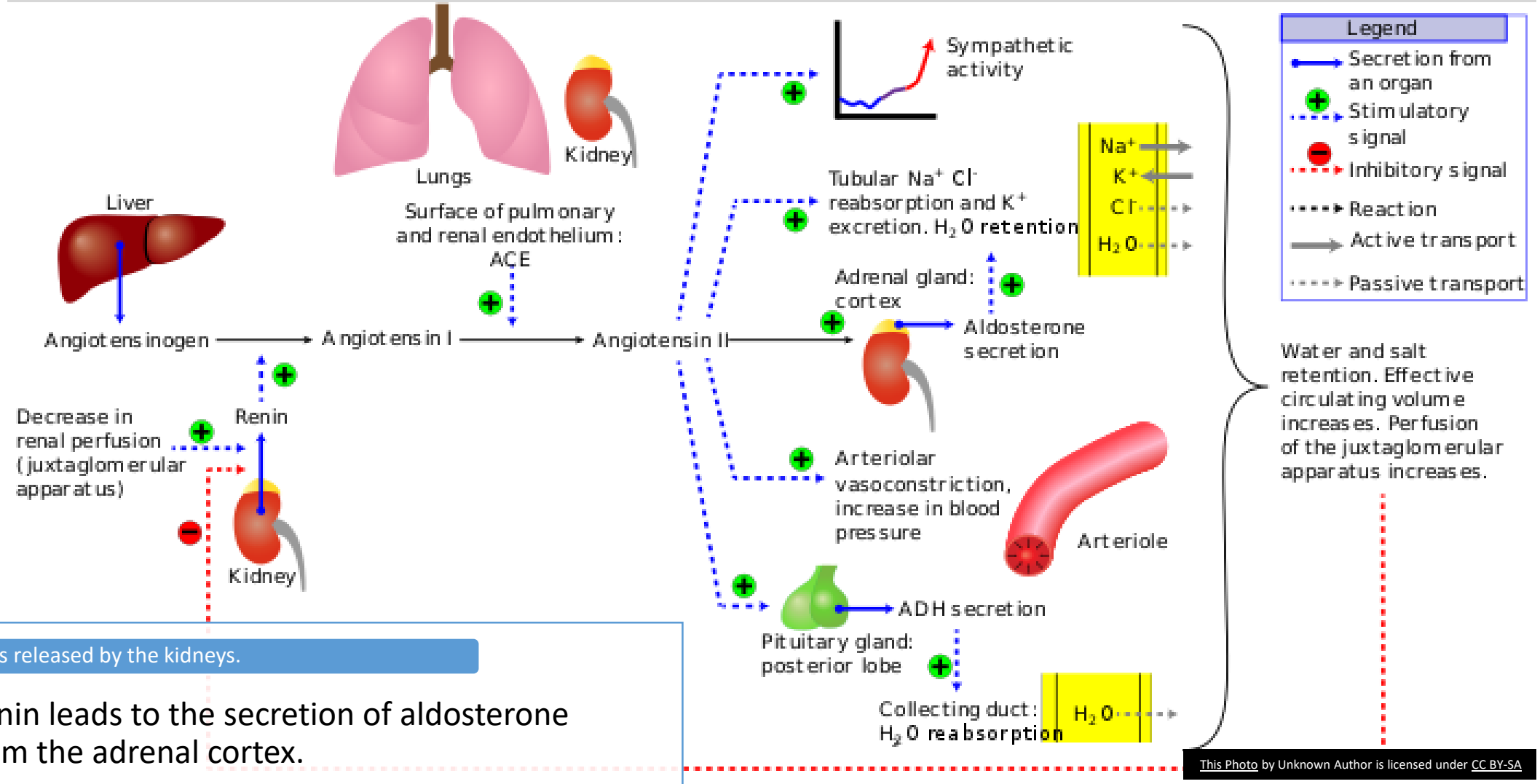
Erythropoietin is released by the kidneys

- Erythropoietin stimulates red blood cell production.

The Vitamin D from the skin is also activated with help from the kidneys.

- Calcium (Ca+) absorption from the digestive tract is promoted by vitamin D.

Renin-angiotensin-aldosterone system



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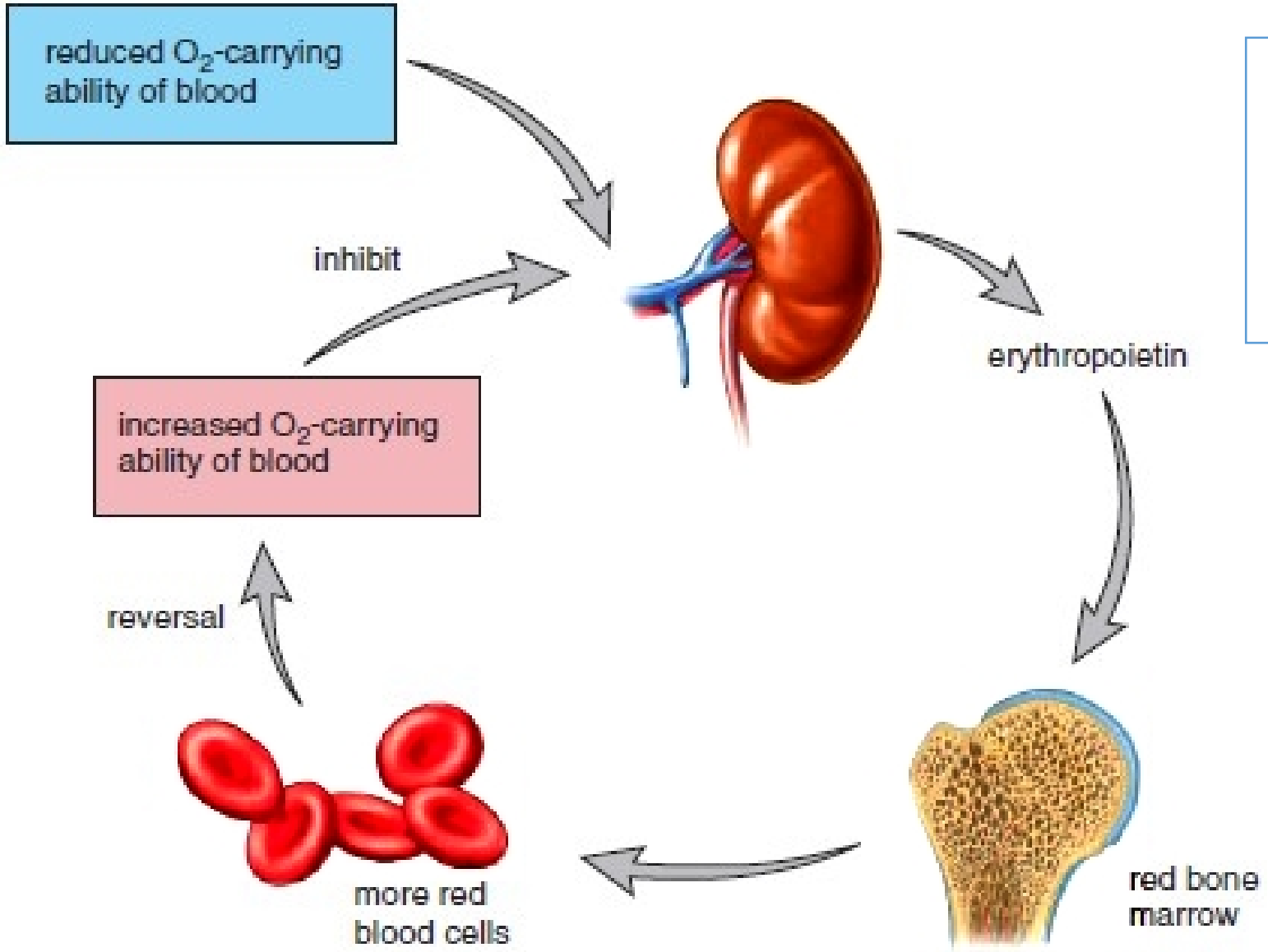


Erythropoietin is released by the kidneys

- Erythropoietin stimulates red blood cell production.

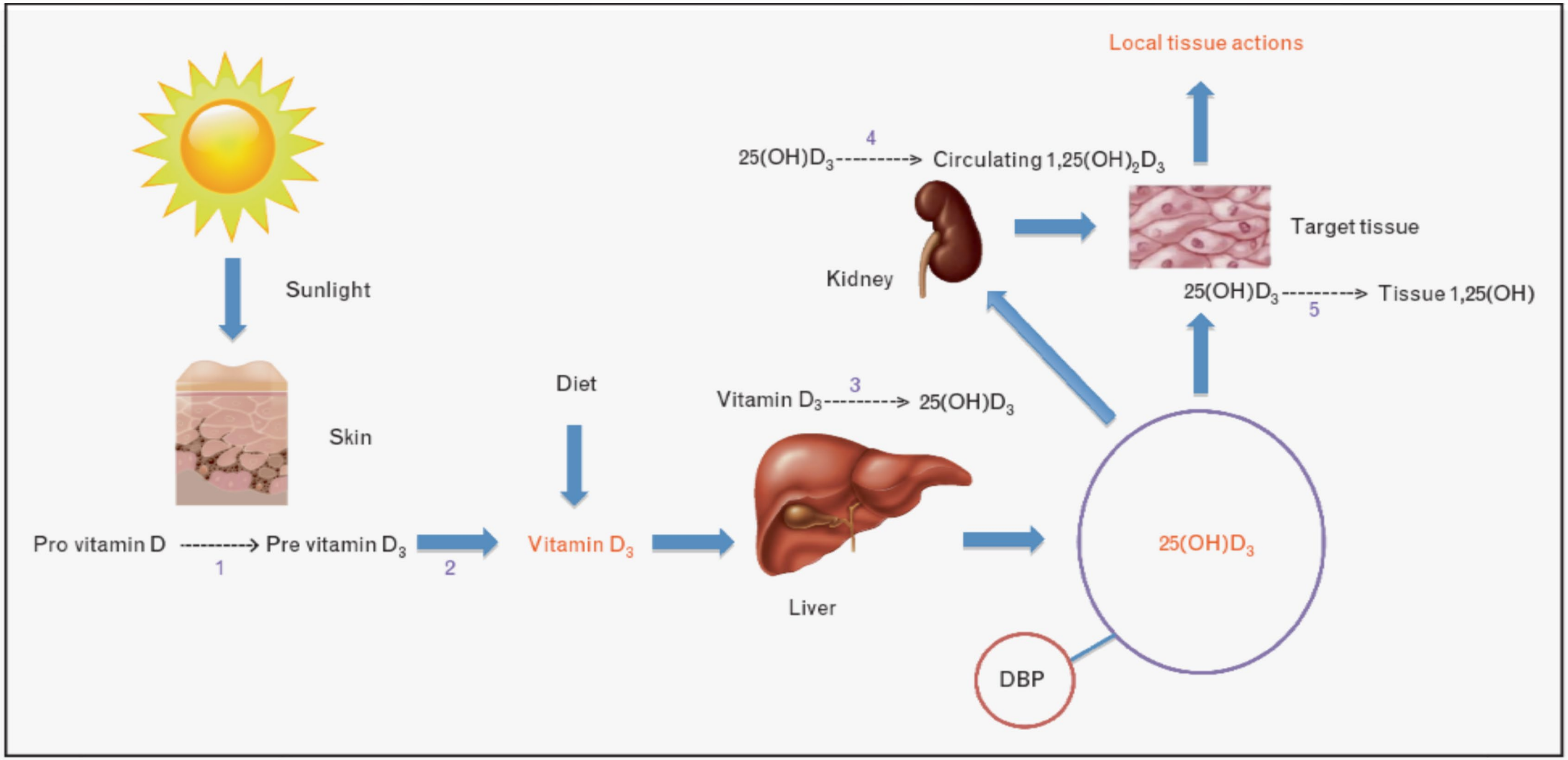
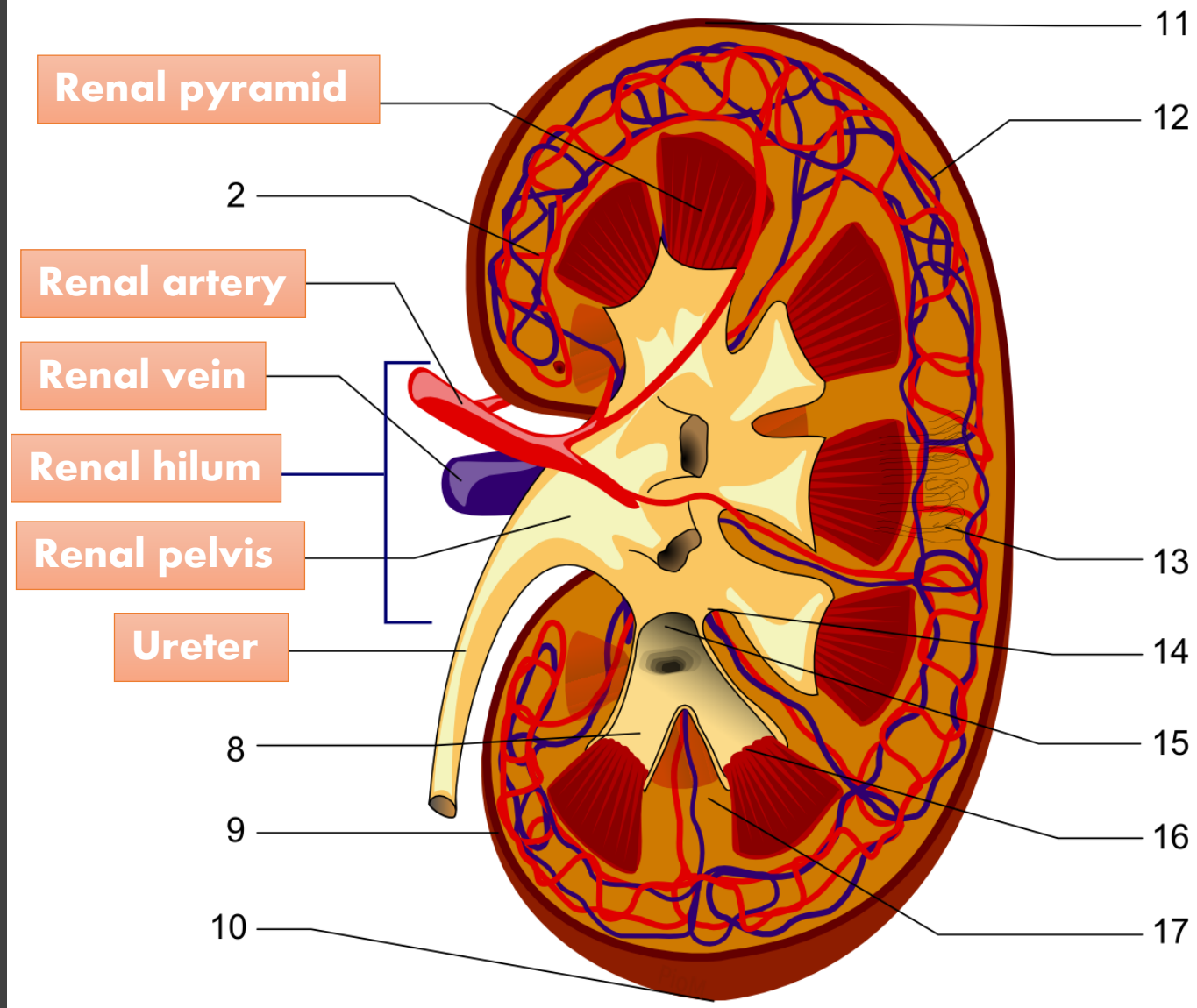
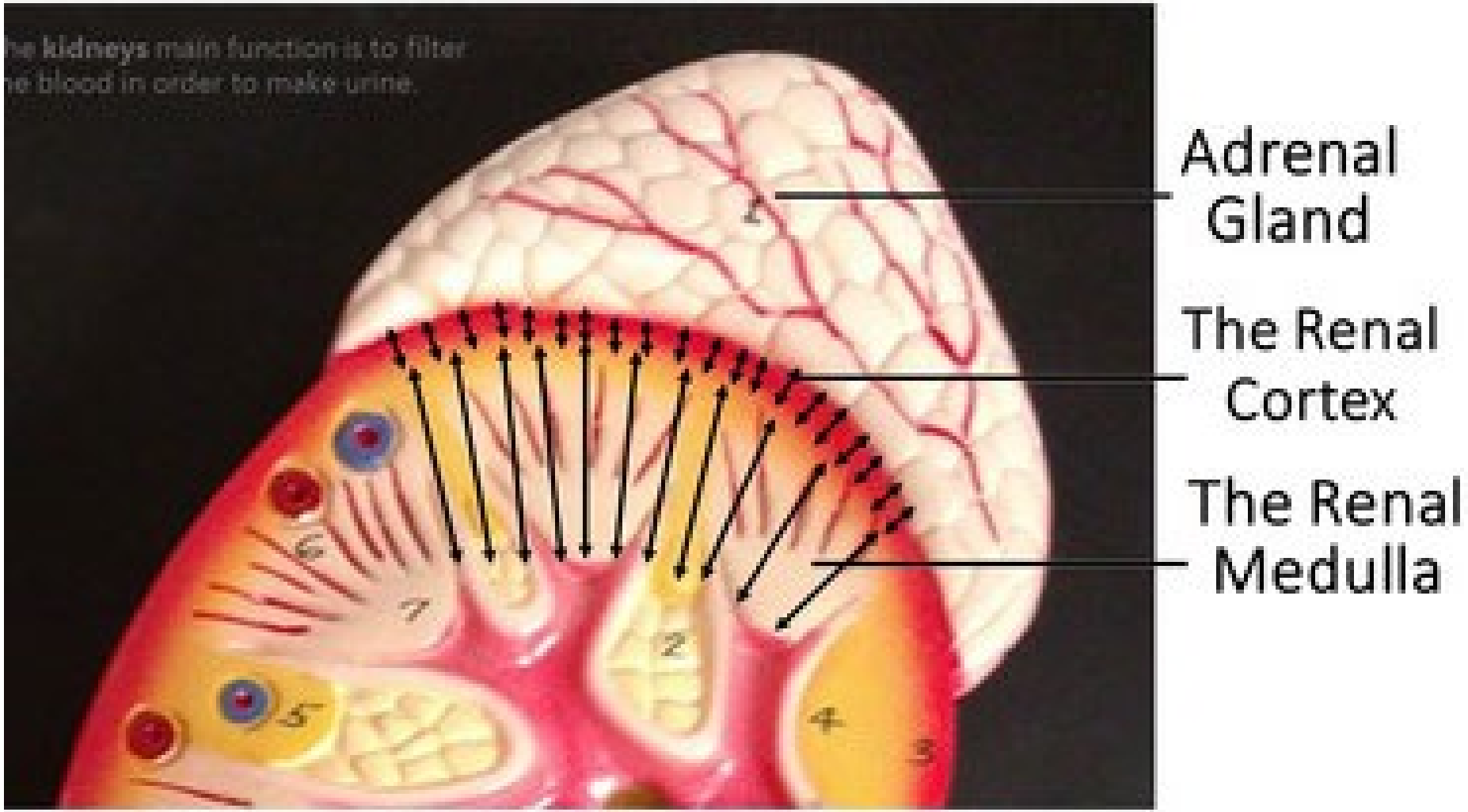


FIGURE 1. Synthetic pathway of the major vitamin D me (2) Isomerization reaction catalyzed by heat. (3) Reaction catalyz 1-a-hydroxylase. (5). Reaction catalyzed by tissue 1-a-hydroxylase 25-hydroxyvitamin D3; DBP, vitamin D-binding protein.

Kidneys And Their Structure

1. Renal pyramid
2. Interlobar artery
3. Renal artery
4. Renal vein
5. Renal hilum
6. Renal pelvis
7. Ureter
8. Minor calyx
9. Renal capsule
10. Inferior renal capsule
11. Superior renal capsule
12. Interlobar vein
13. Nephron
14. Minor calyx
15. Major calyx
16. Renal papilla
17. Renal column





The Renal Cortex
The Renal Medulla

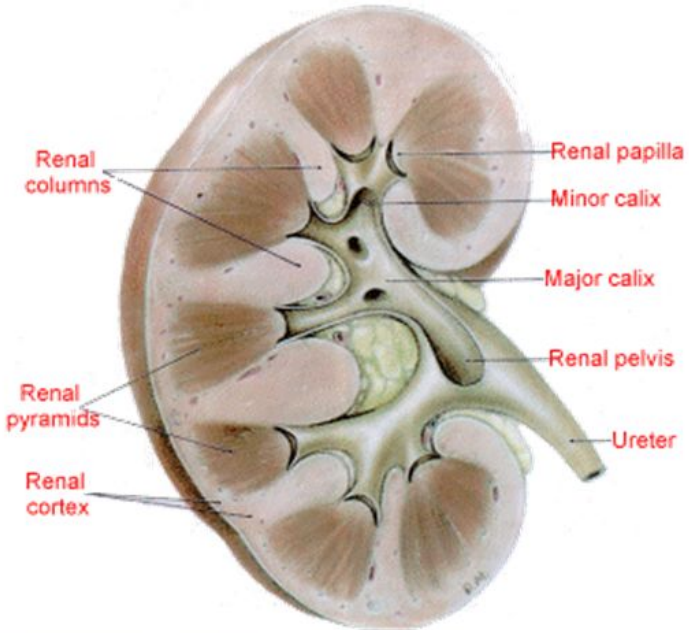
Kidneys And Their Regions

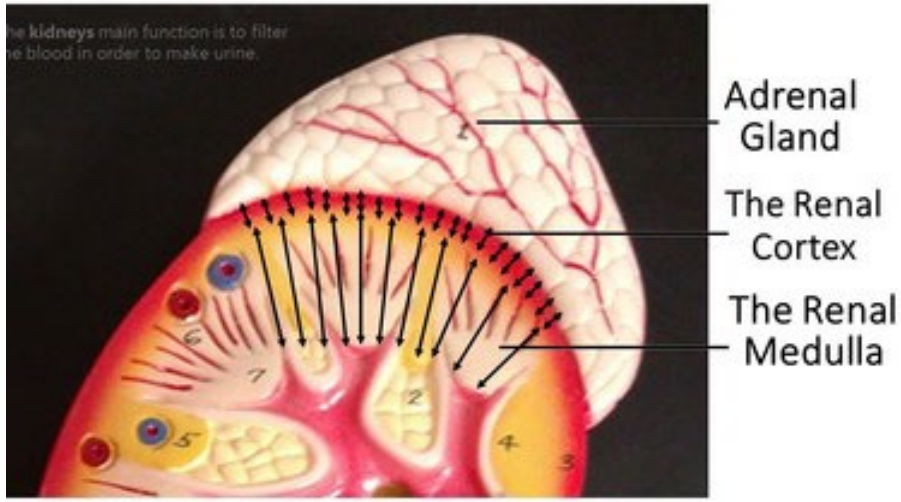
regions of the kidney

- There are three major regions of the kidney:
  - **renal cortex**
  - **renal medulla**
  - **renal pelvis**
- The outer, granulated layer is the renal cortex
- The inner radially striated layer is the renal medulla
- The renal medulla contains the renal pyramids
- The renal pelvis are continuous with the ureters

Regions of the Kidney

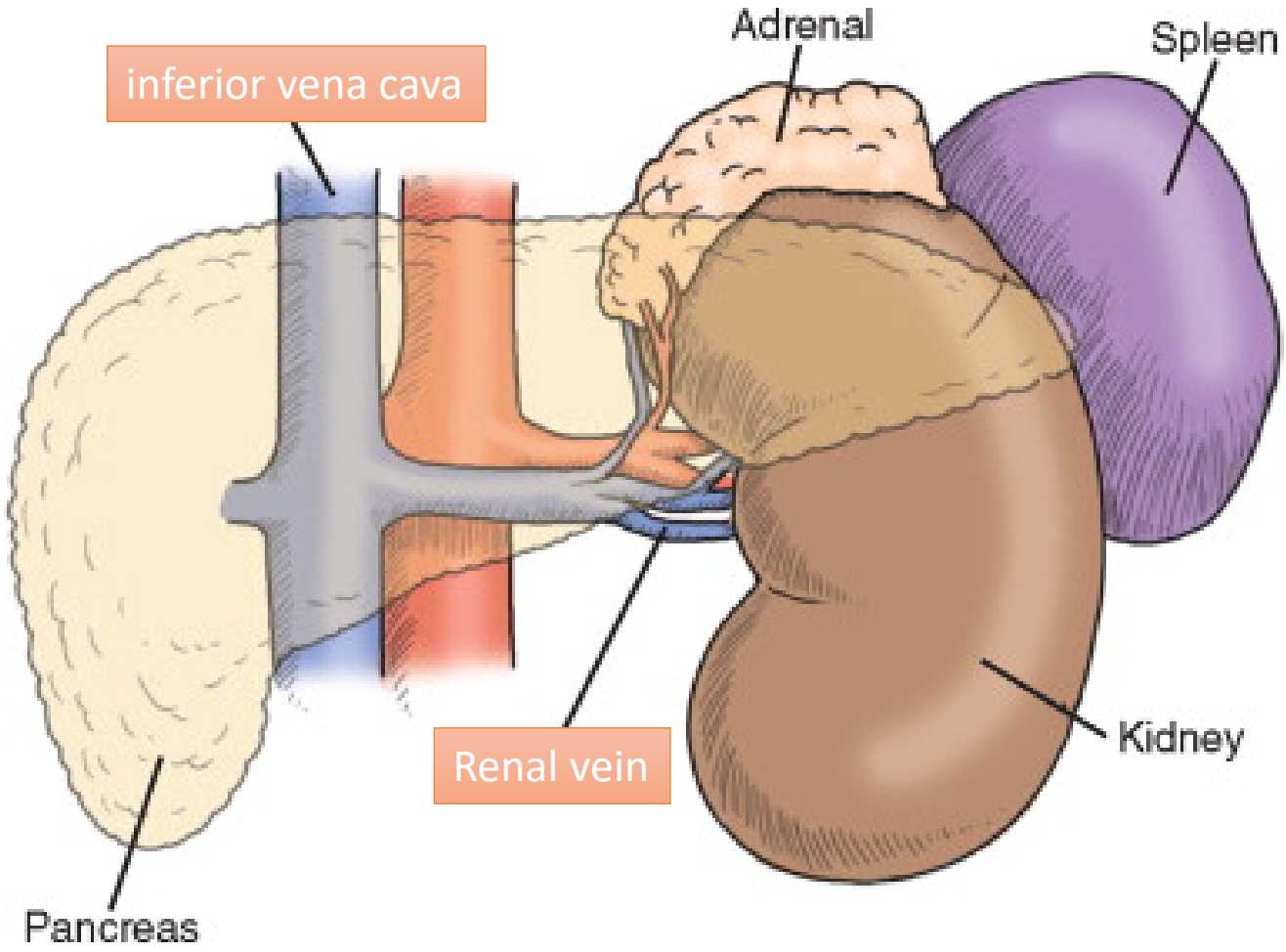
- Renal cortex – outer region
- Renal medulla – inside the cortex
- Renal pelvis – inner collecting tube

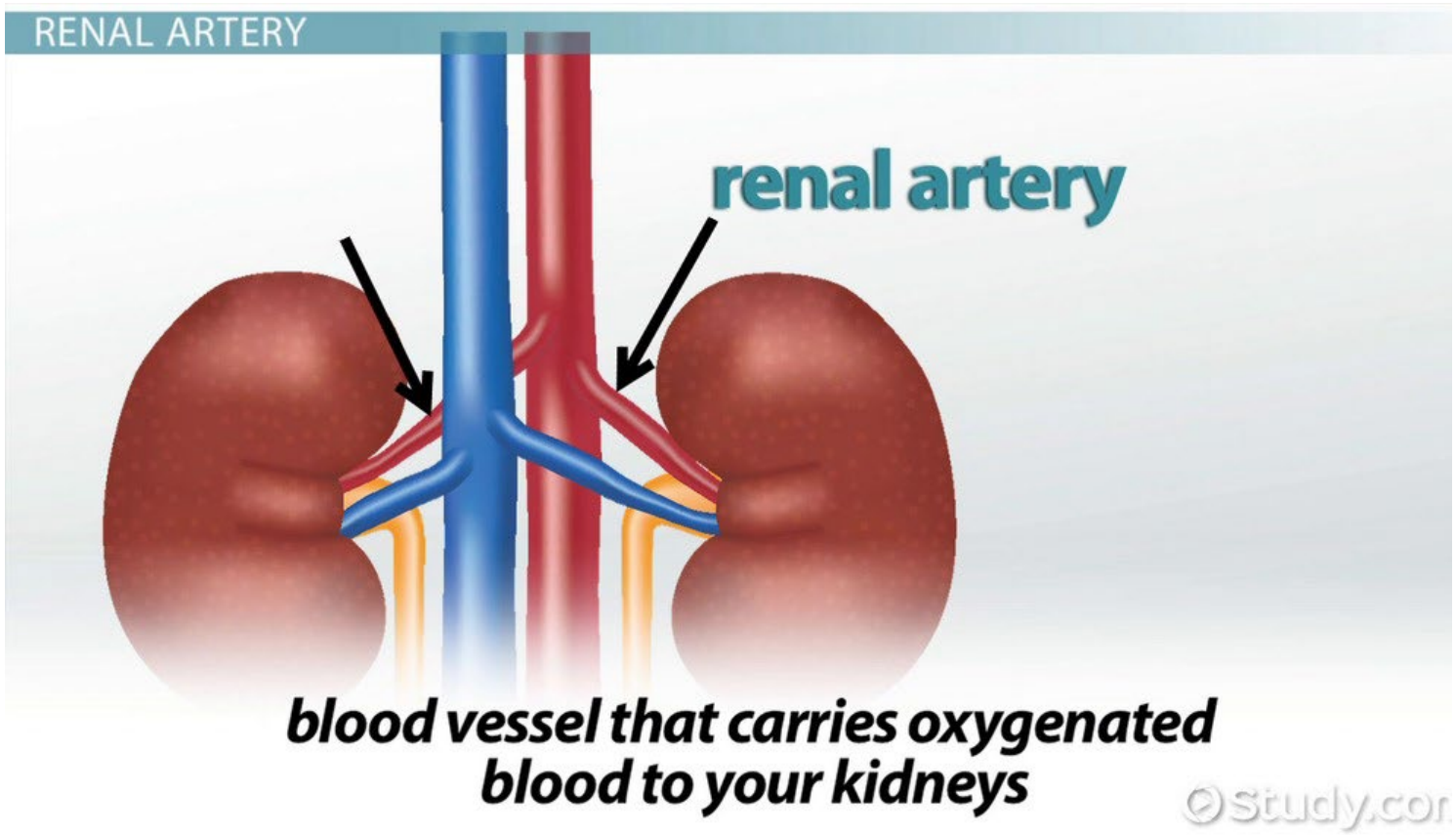




Renal Vein

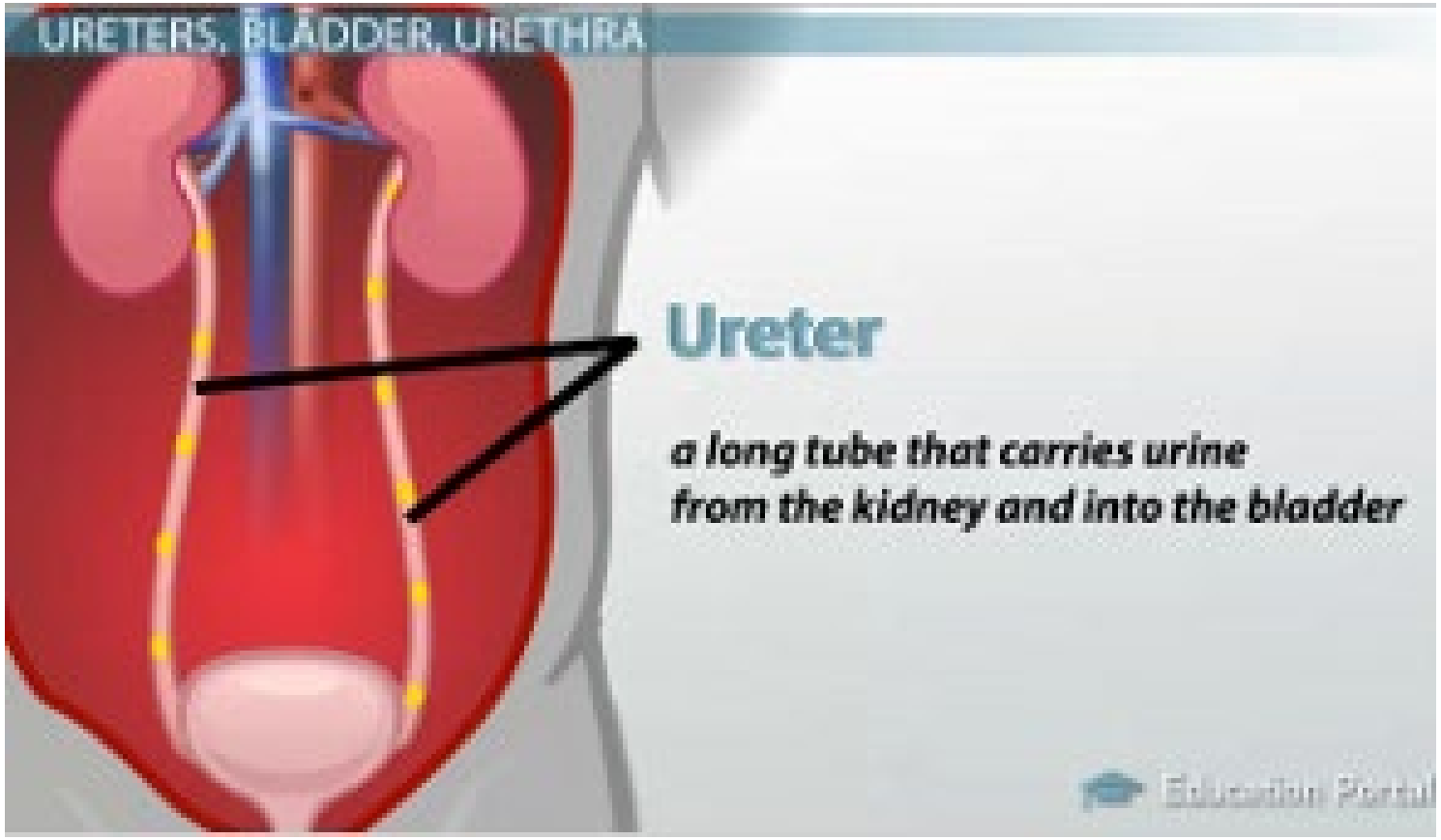
- The **renal veins** are veins that drain the kidney.
- They connect the kidney to the inferior vena cava.





Renal Artery

- The **renal arteries** arise off the abdominal aorta and supply the kidneys with blood.
- The renal arteries carry a large portion of the total blood flow to the kidneys.
- Up to a third of the total cardiac output can pass through the renal arteries to be filtered by the kidneys.

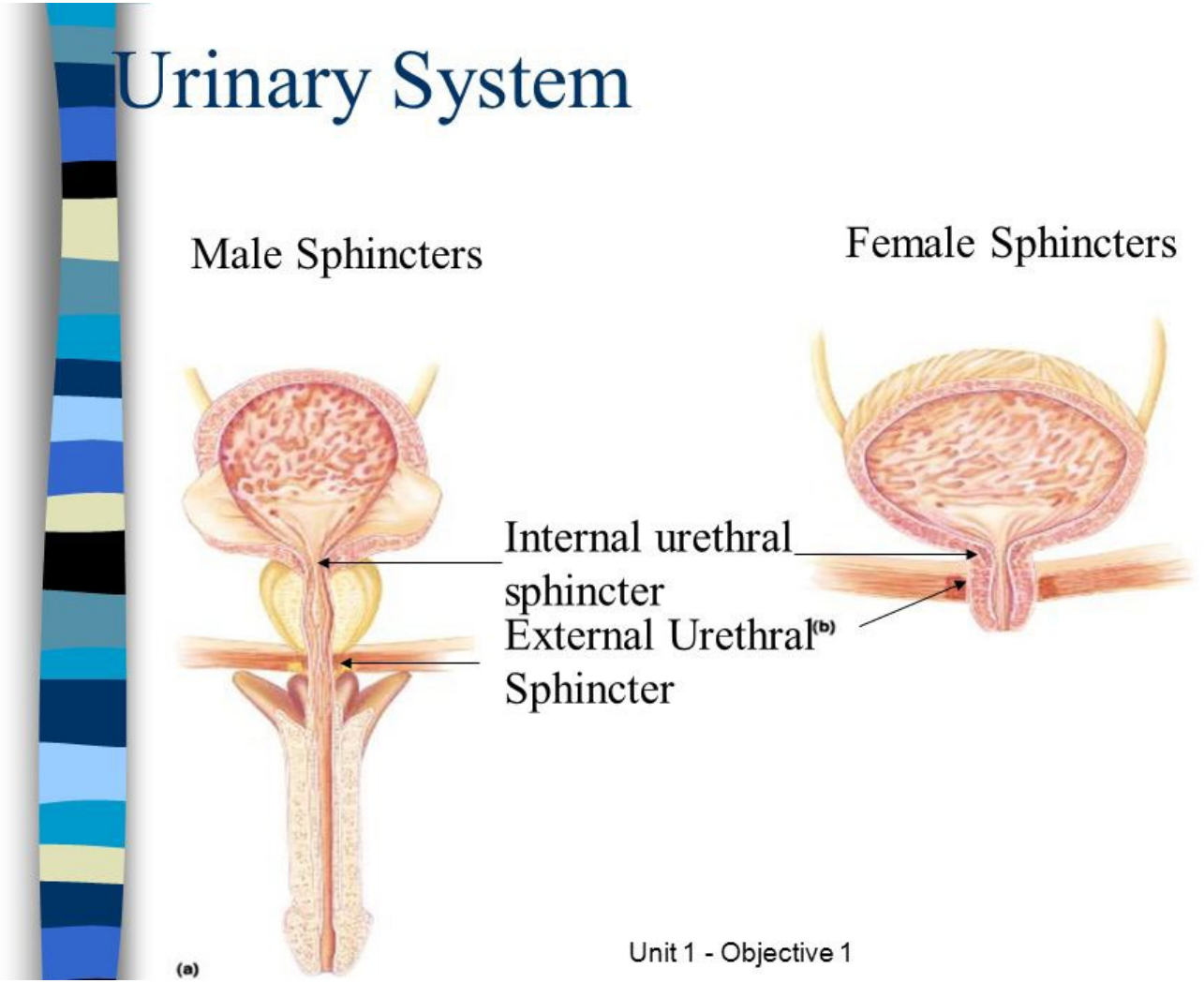


Ureters

- The **ureters** are two tubes that drain urine from the kidneys to the bladder.
- Muscles in the walls of the ureters send the urine in small spurts into the bladder
- After the urine enters the bladder from the ureters, small folds in the bladder mucosa act like valves preventing backward flow of the urine.

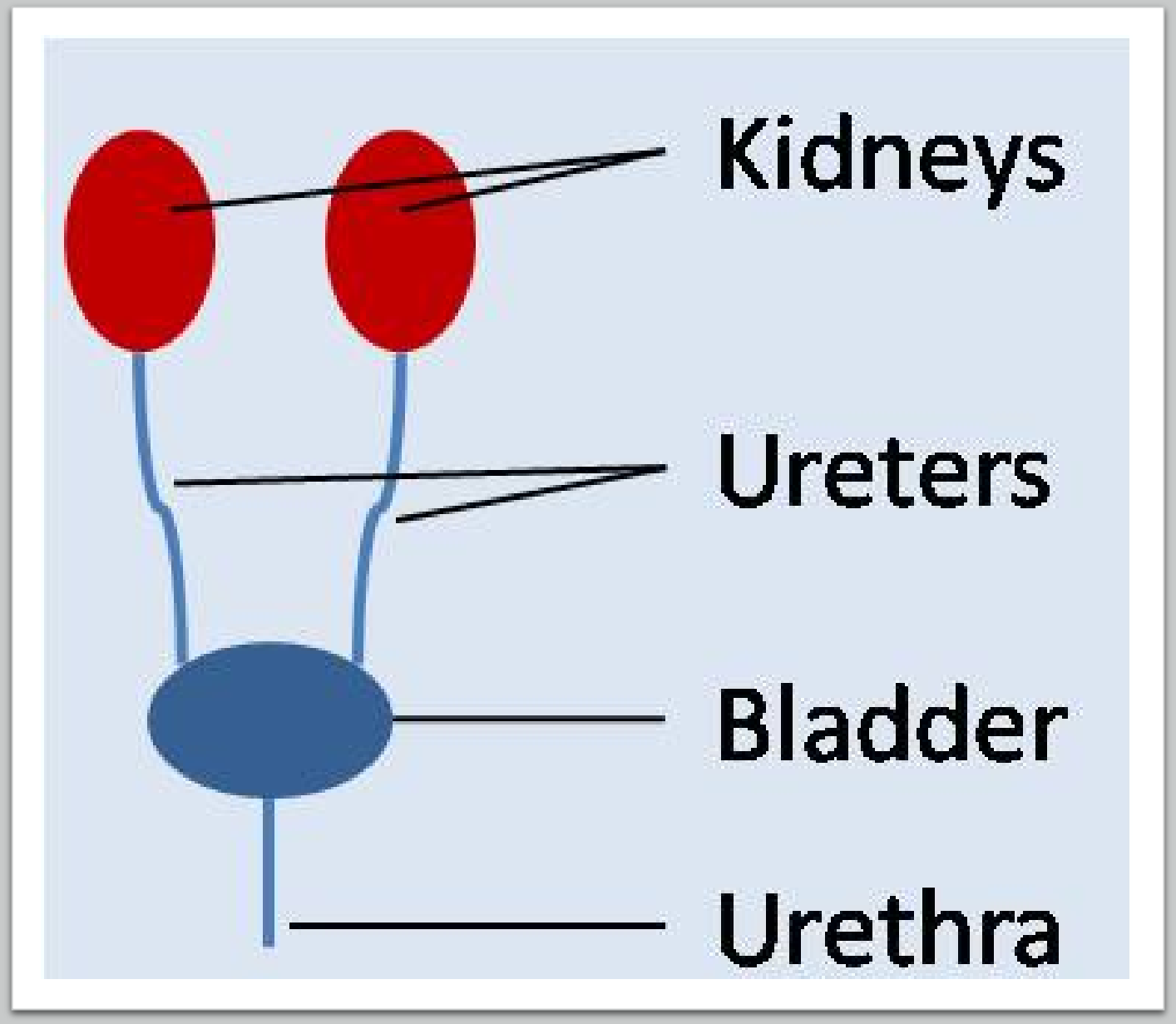
Urinary Sphincters

- The outlet of the bladder is controlled by a sphincter muscle.
  - A full bladder stimulates sensory nerves in the bladder wall that relax the sphincter and allow release of the urine. *However, relaxation of the sphincter is also in part a learned response under voluntary control.*
  - The released urine enters the urethra.

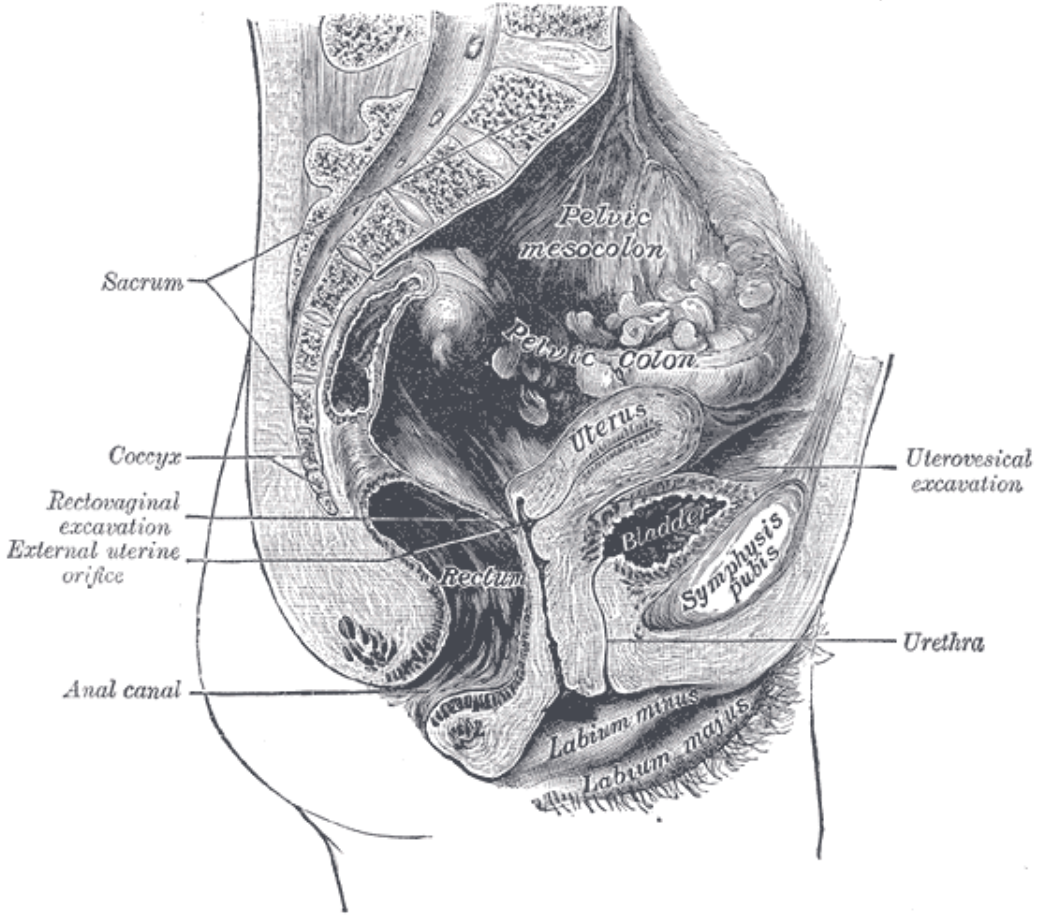


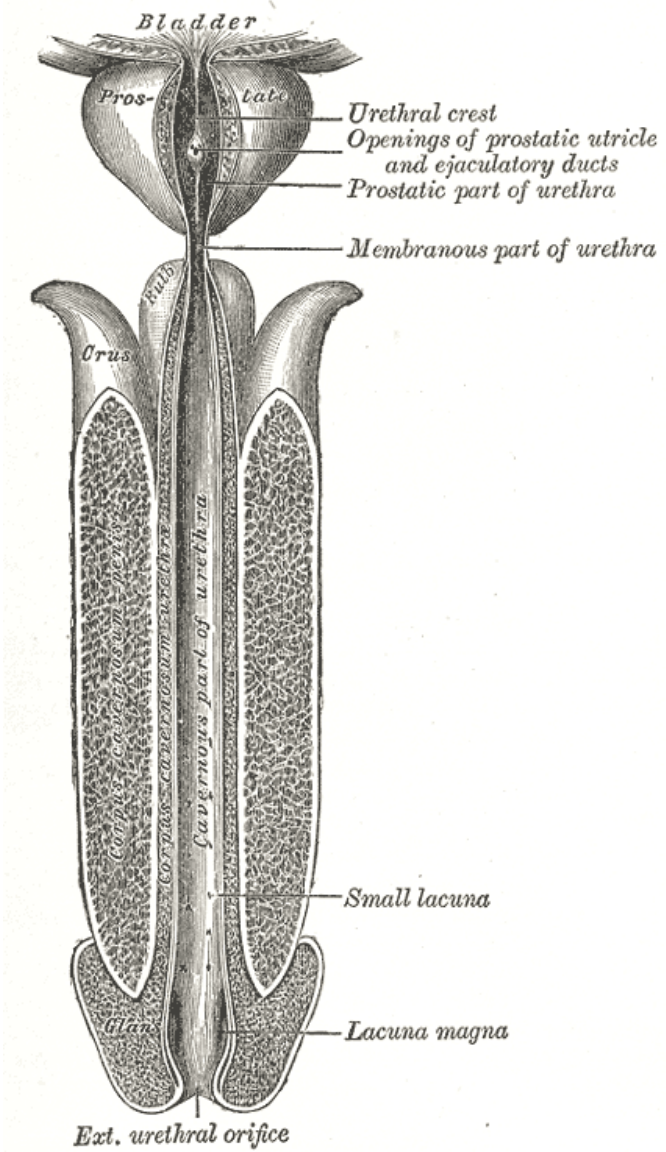
The **urethra**

- The **urethra** is a muscular tube that connects the bladder with the outside of the body.
- The function of the urethra is to remove urine from the body.



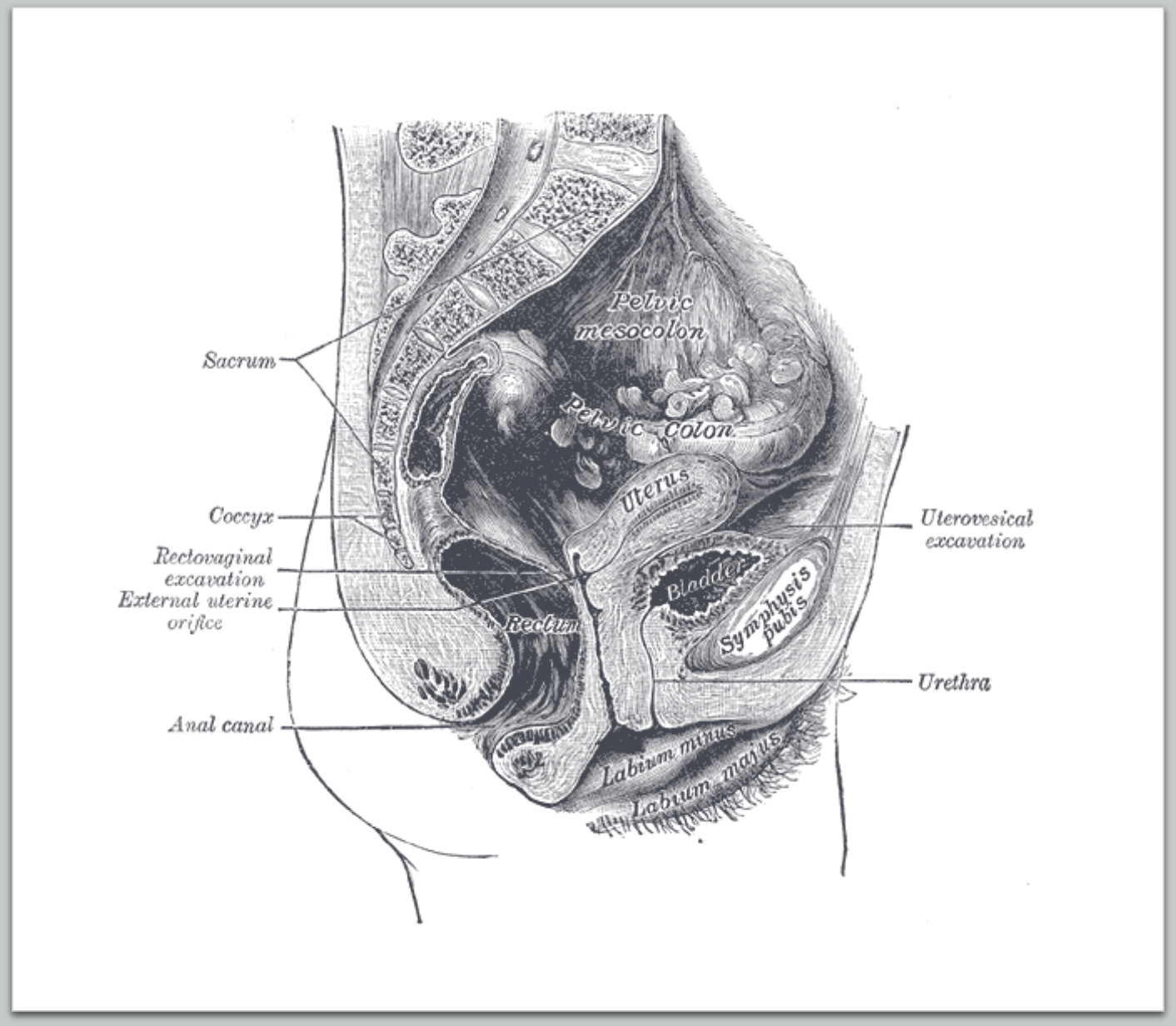
The female urethra is much shorter than the male urethra.





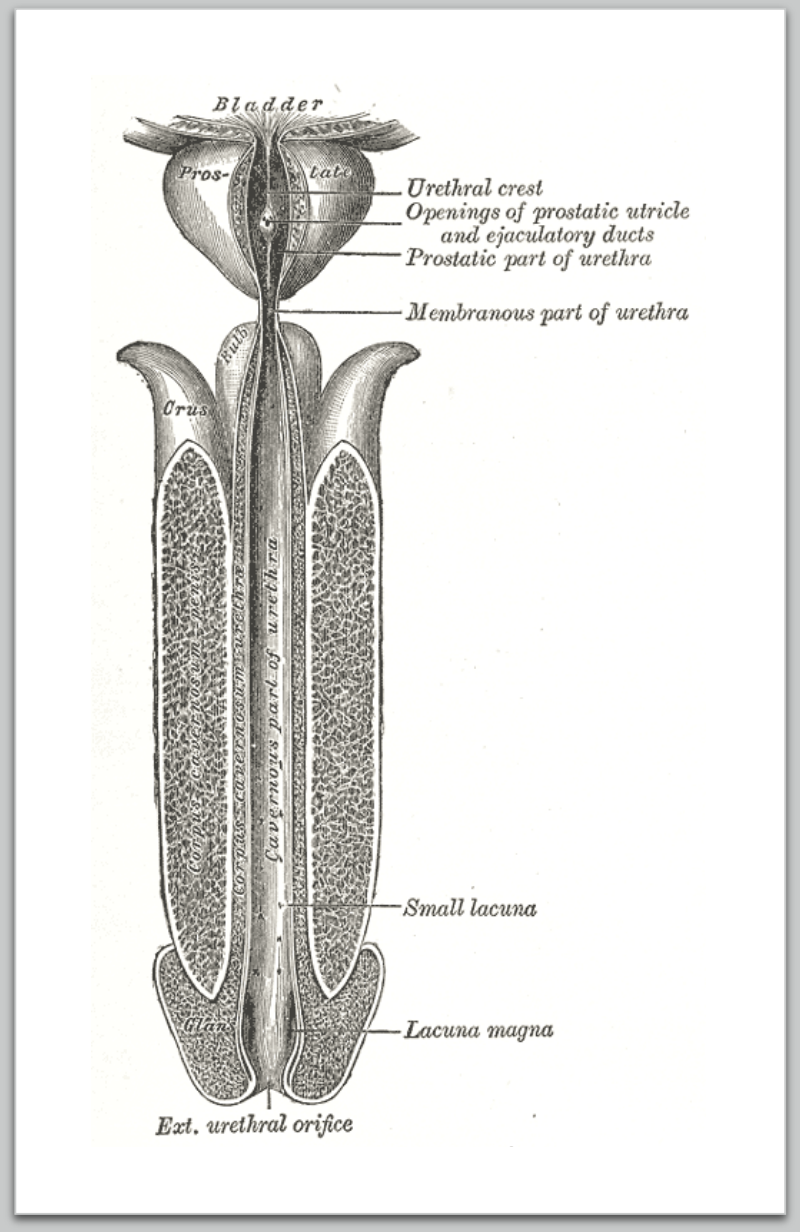
The Female Urethra

- The female urethra is much shorter than the male urethra.
- Women tend to be more susceptible to infections of the bladder (cystitis) and the urinary tract (UTI).

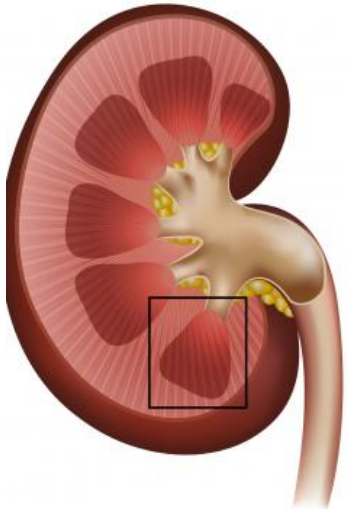


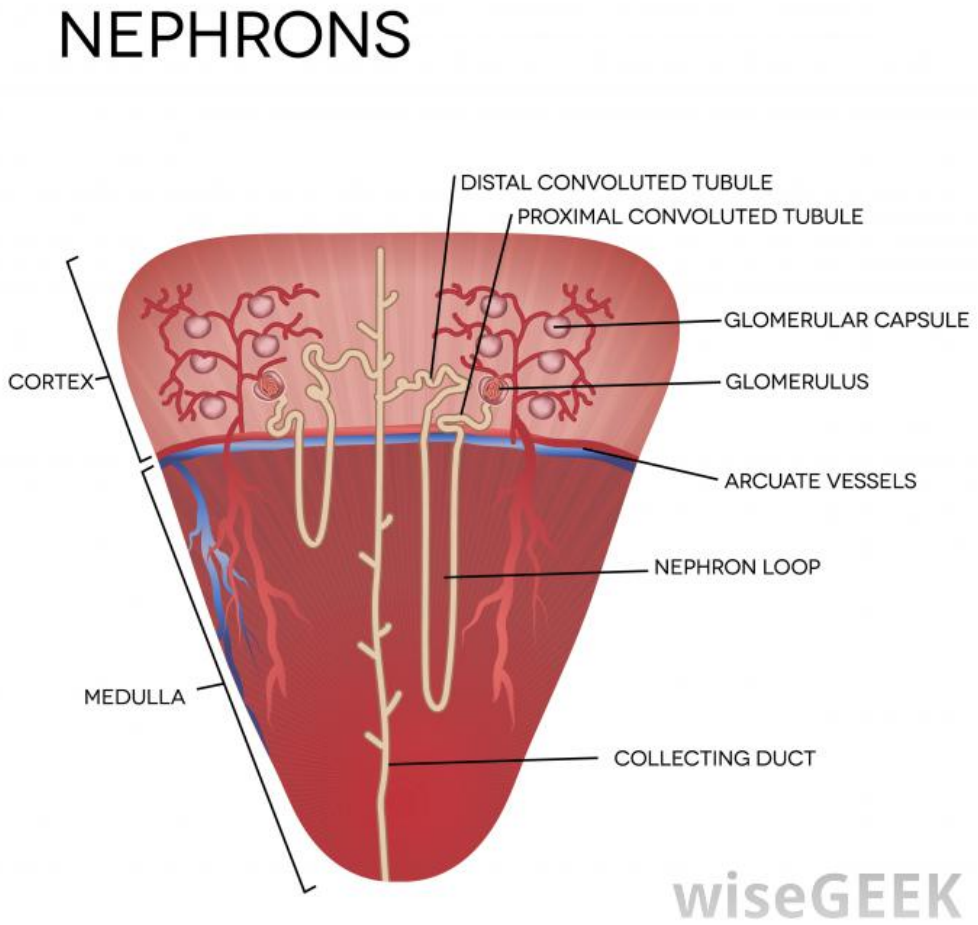
Male urethra

- In the human male, the urethra is a common pathway for semen as well as urine.
- The **urethral sphincter** is much stronger in males
  - meaning that they can retain a large amount of urine for twice as long as females



Nephrons

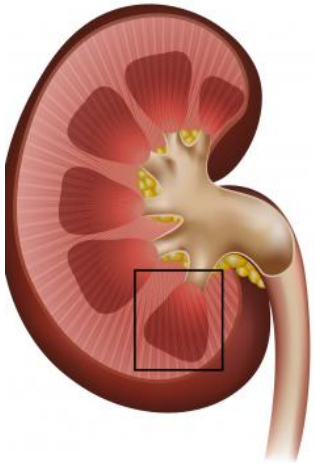


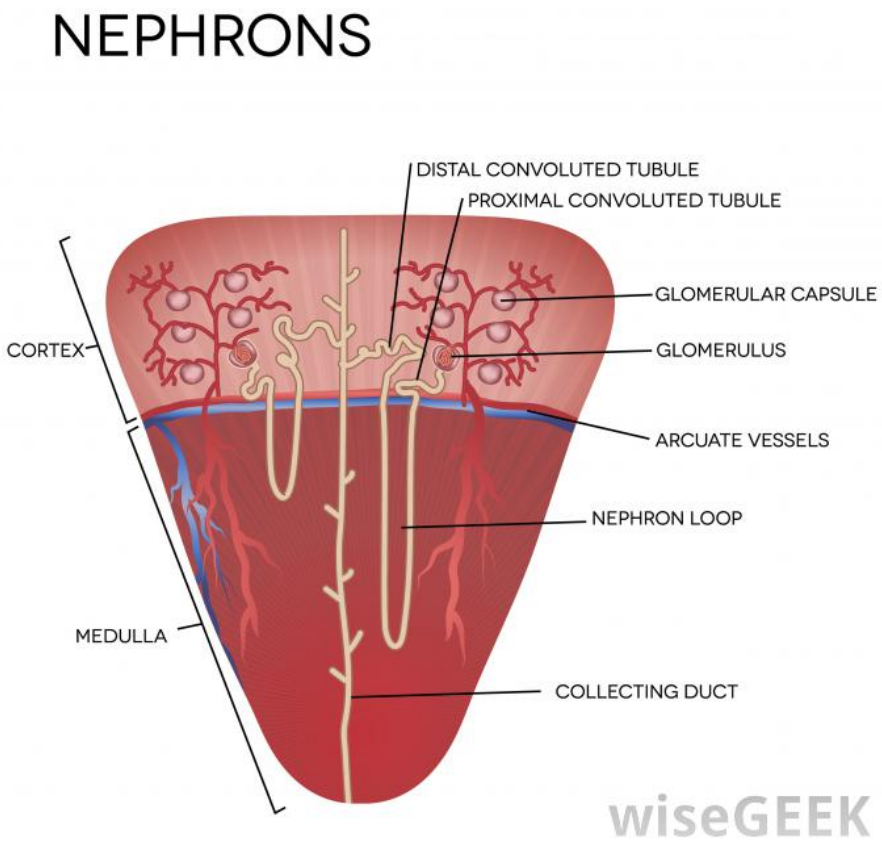


- A nephron is the basic structural and functional unit of the kidney.
- Its chief function is to
  - regulate water and soluble substances by filtering the blood
  - reabsorbing what is needed and excreting the rest as urine.

Nephrons

- Nephrons
  - Eliminate wastes from the body
  - Regulate blood volume
  - Regulate blood pressure
  - Control levels of electrolytes and metabolites
  - Regulate blood ph

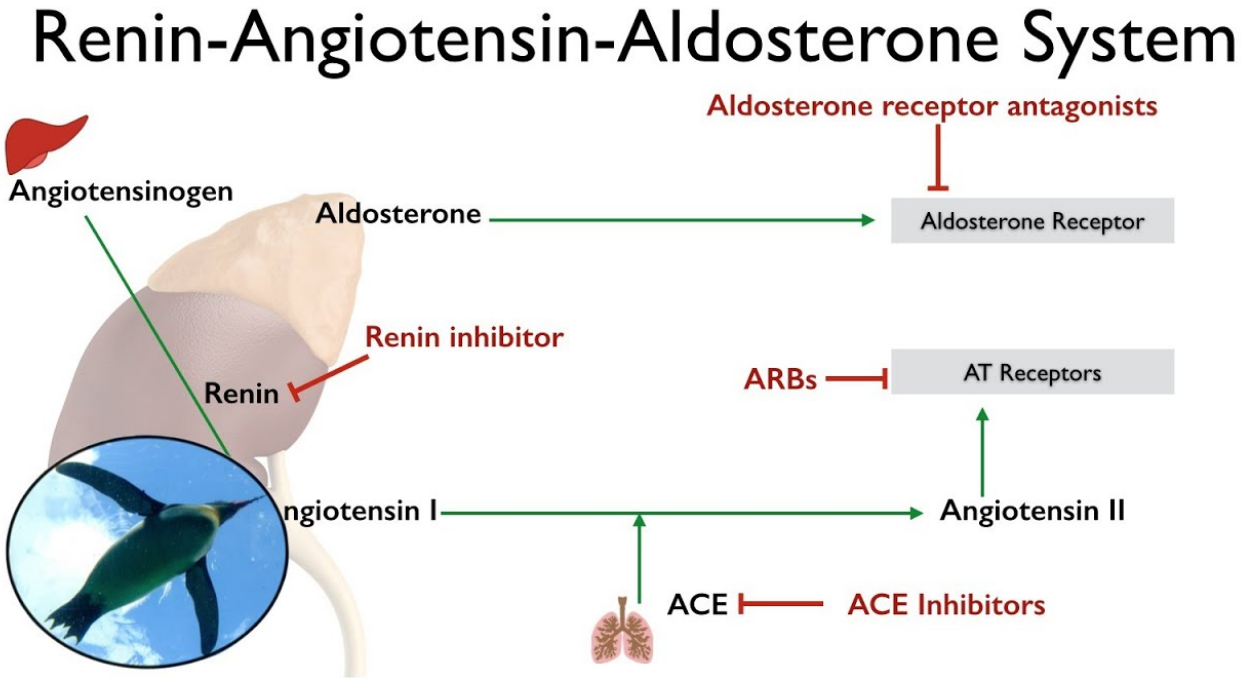




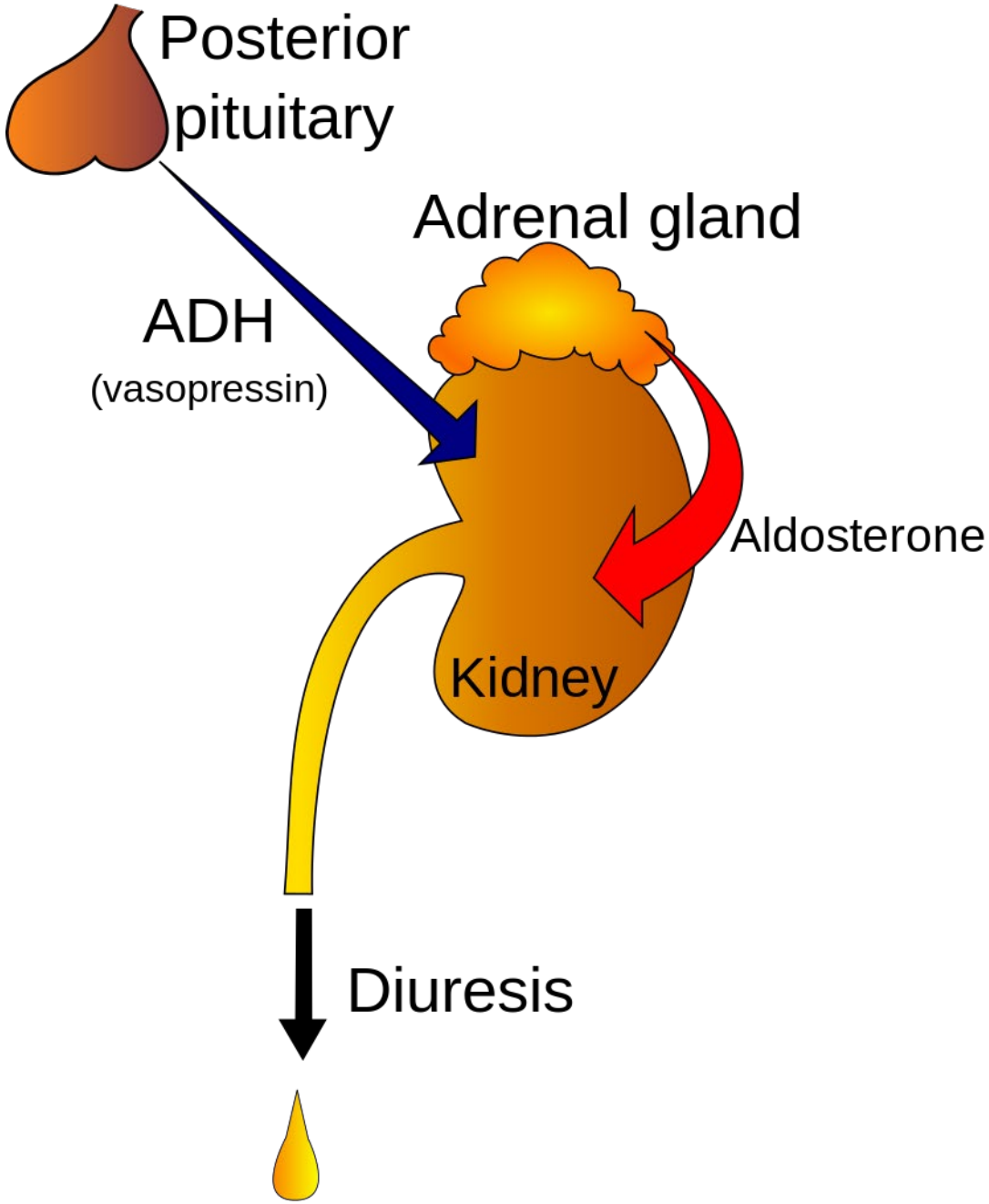
Nephrons

- Its functions are regulated by the endocrine system by hormones such as
  - Aldosterone
  - Antidiuretic Hormone
  - Parathyroid Hormone

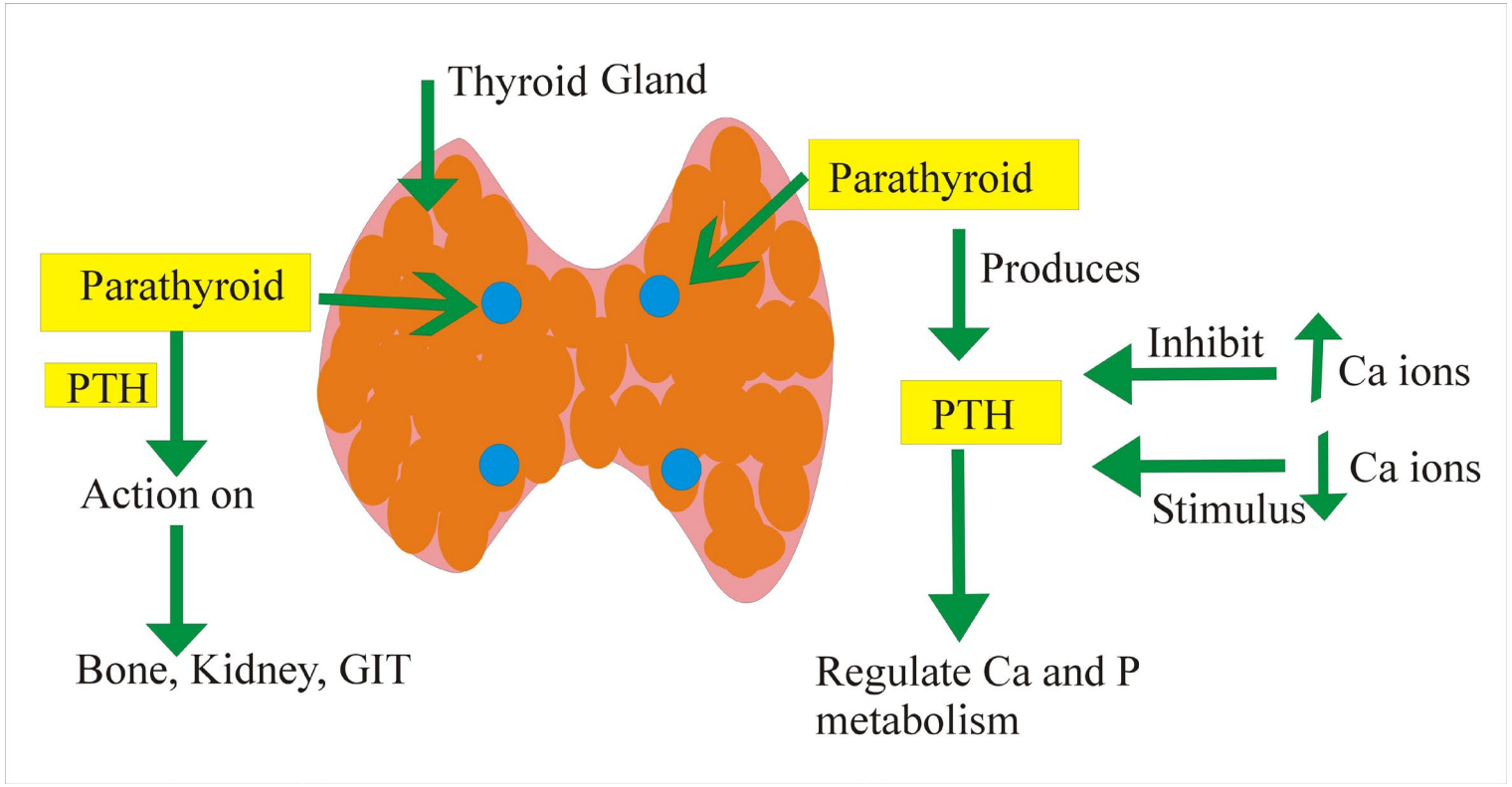
Aldosterone



Antidiuretic Hormone

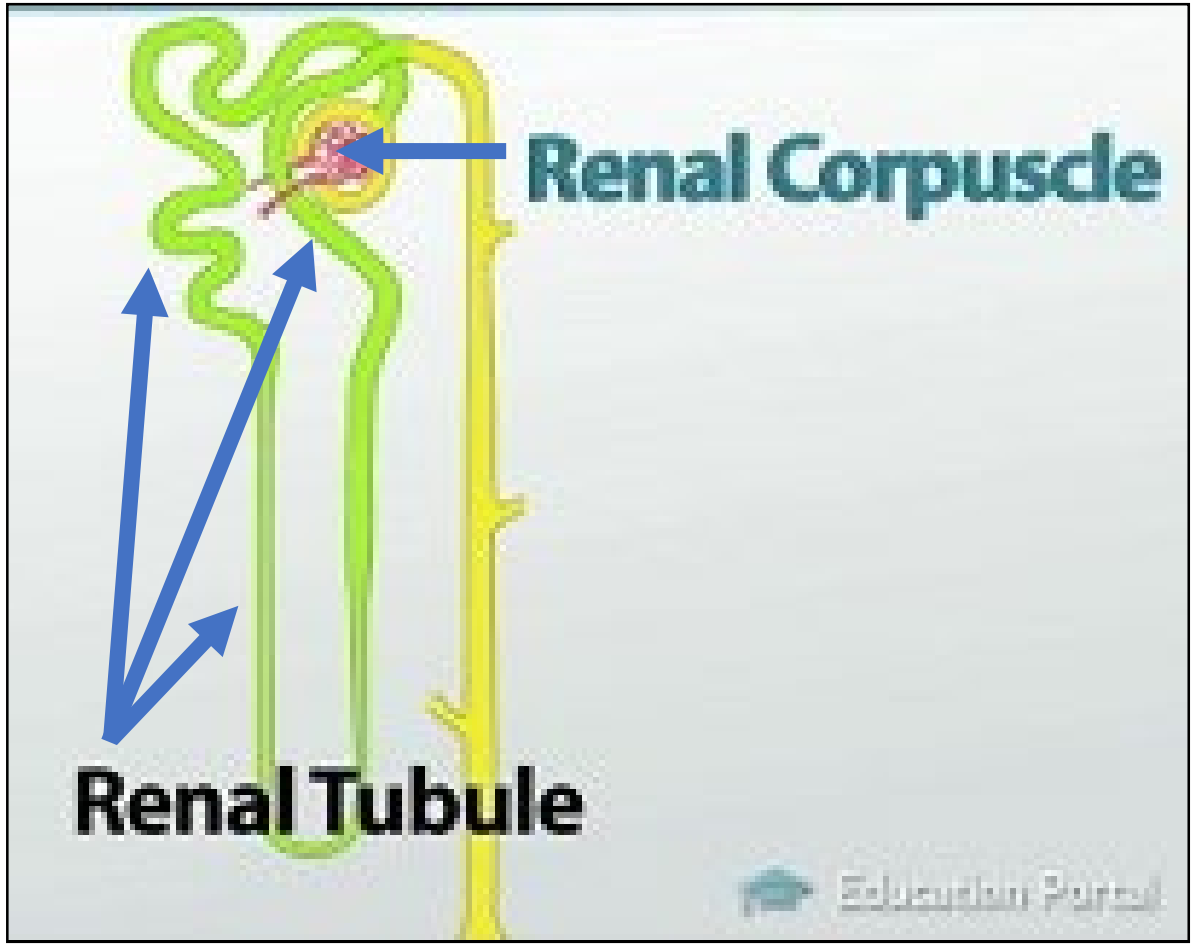


Parathyroid Hormone

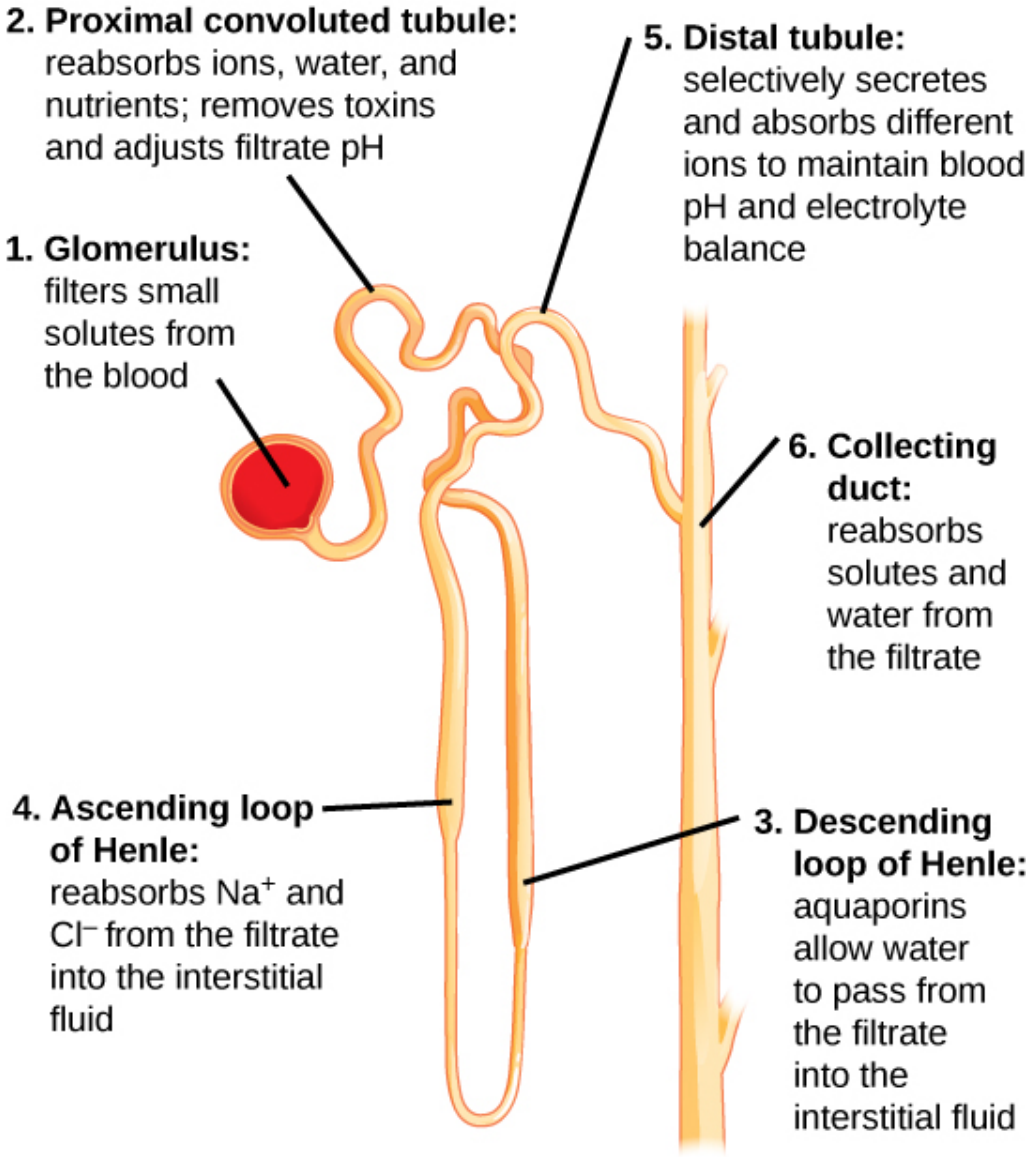


Nephrons

- Each nephron is composed of
  - an initial filtering component (the renal corpuscle)
  - a tubule specialized for reabsorption and secretion (the renal tubule).

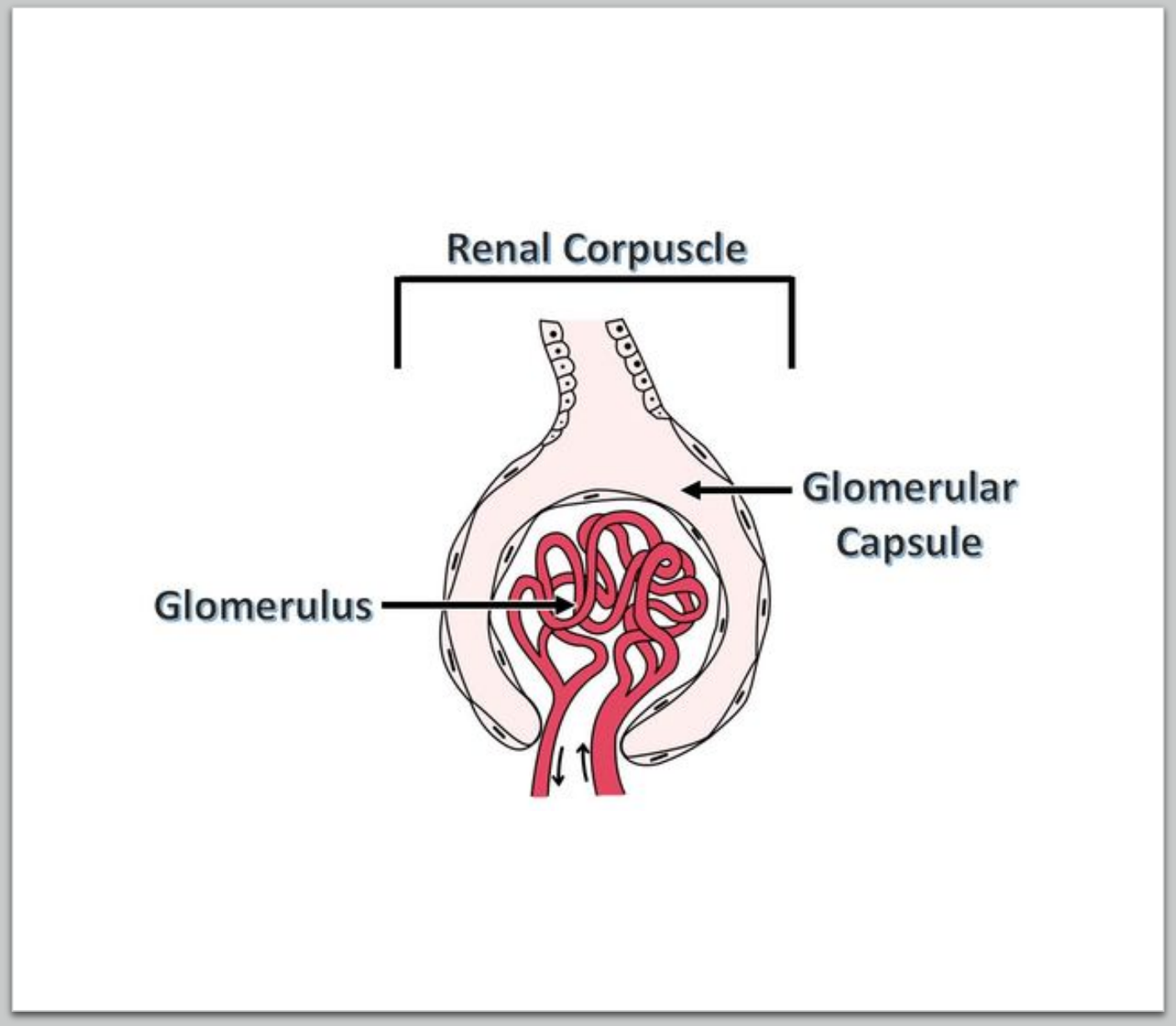


Renal Tubules



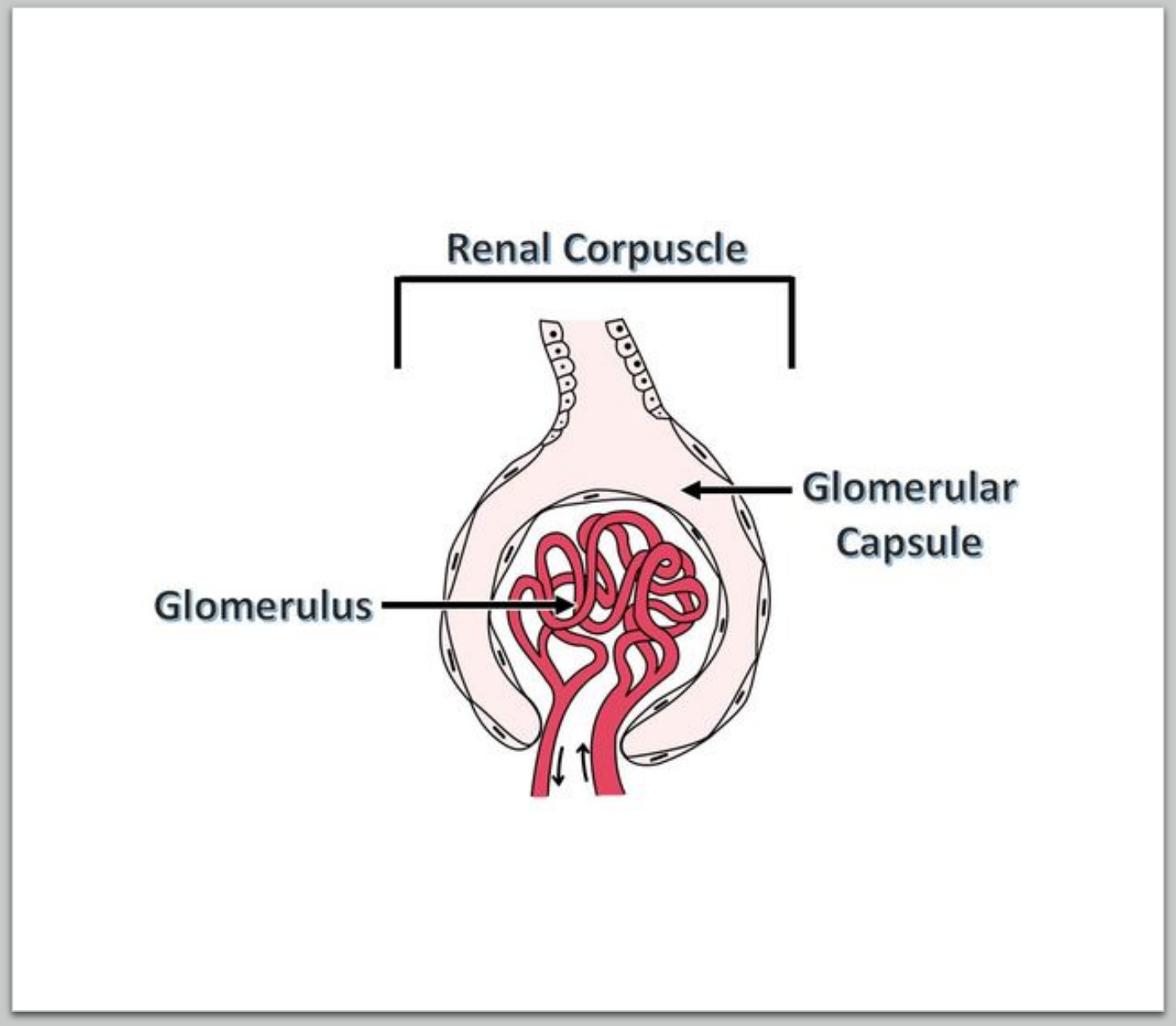
Renal Corpuscle

- Together, the **Glomerulus** and **Glomerular Capsule or Bowman's Capsule** are called the **Renal Corpuscle**.
- Between the visceral and parietal layers of the **Renal Corpuscle** is the **Bowman's space.**



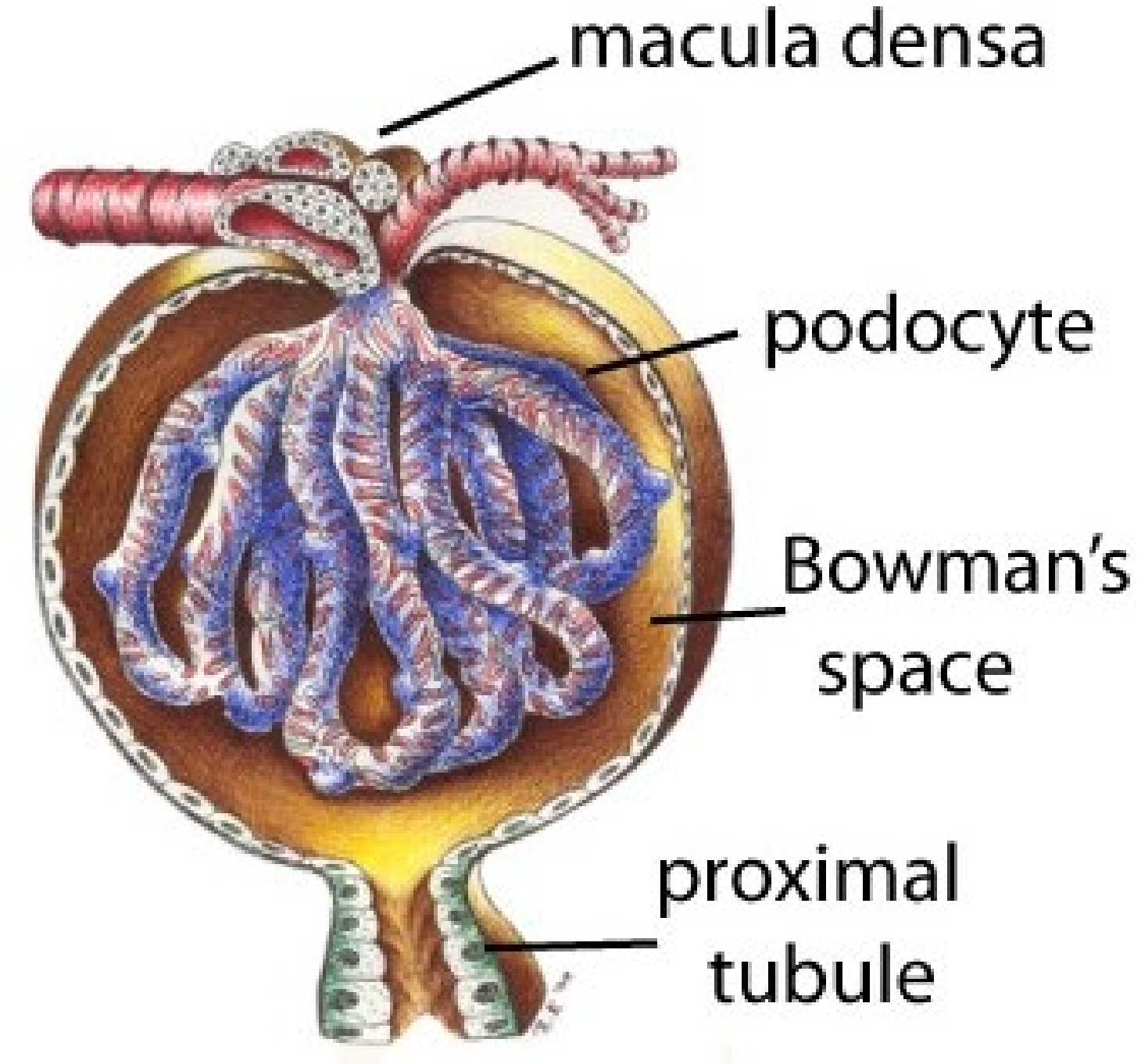
The Renal Corpuscle

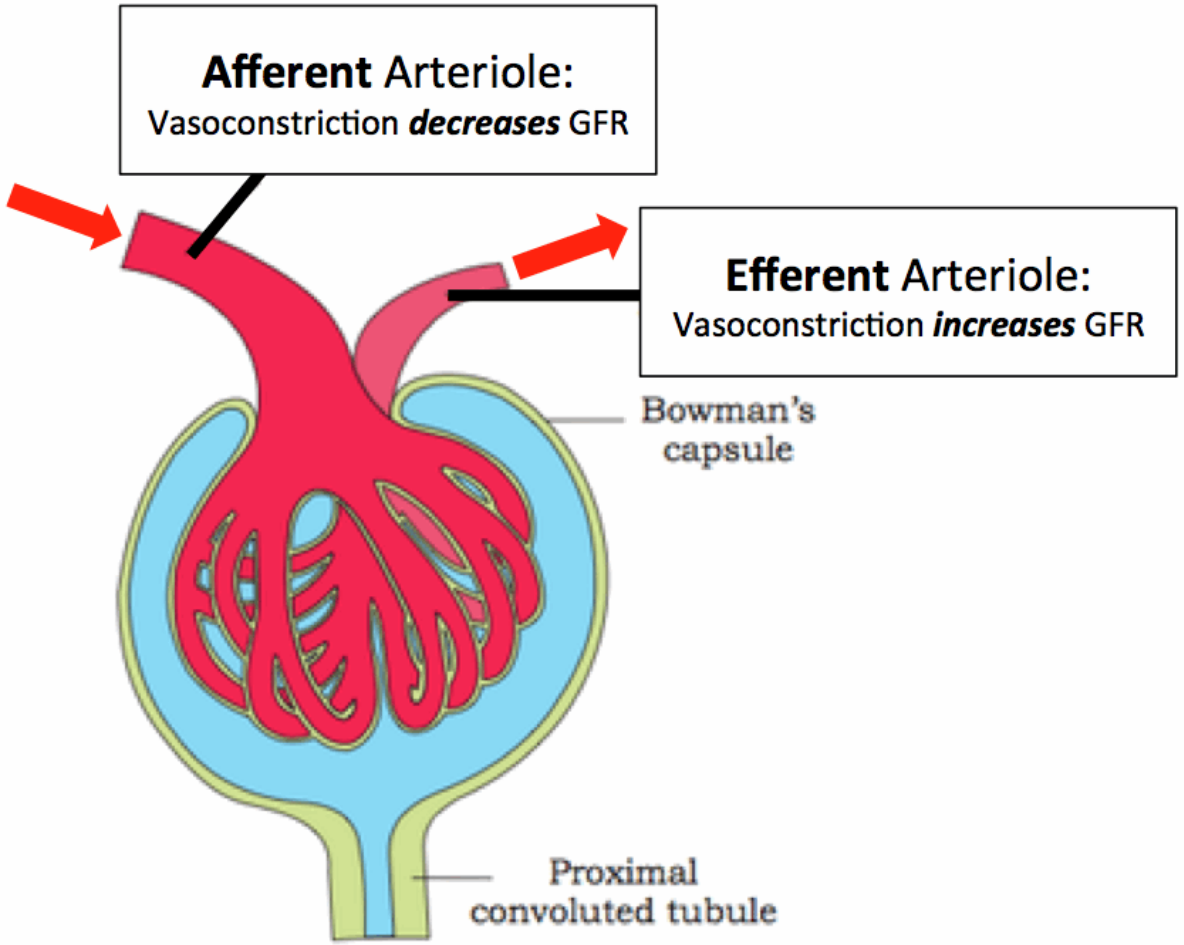
- The renal corpuscle
  - Filters out large solutes from the blood
  - Allows water and small solutes to move on to the renal tubule



Bowman’s space

- The Bowman’s space holds filtrates from podocytes' filtration slits.

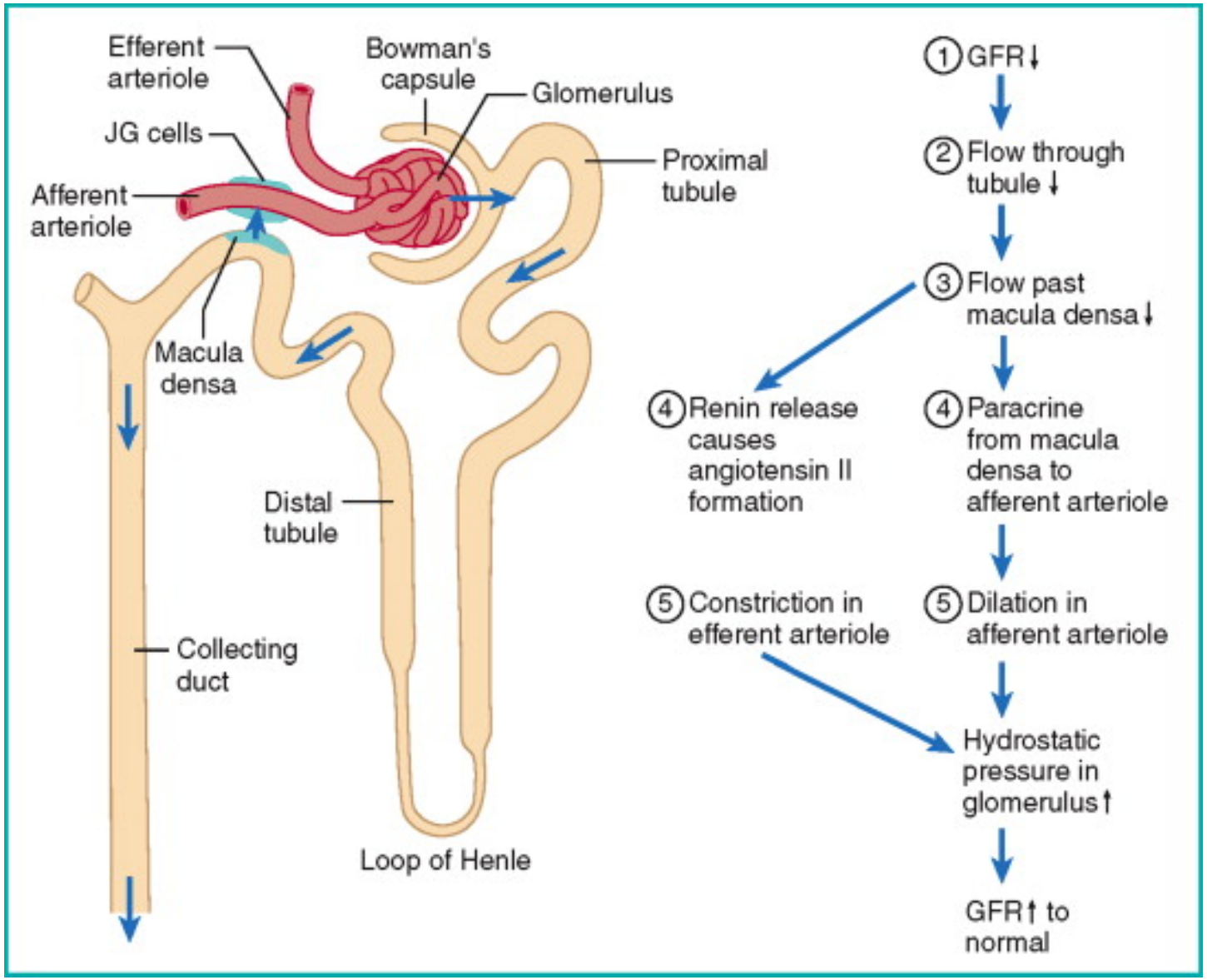


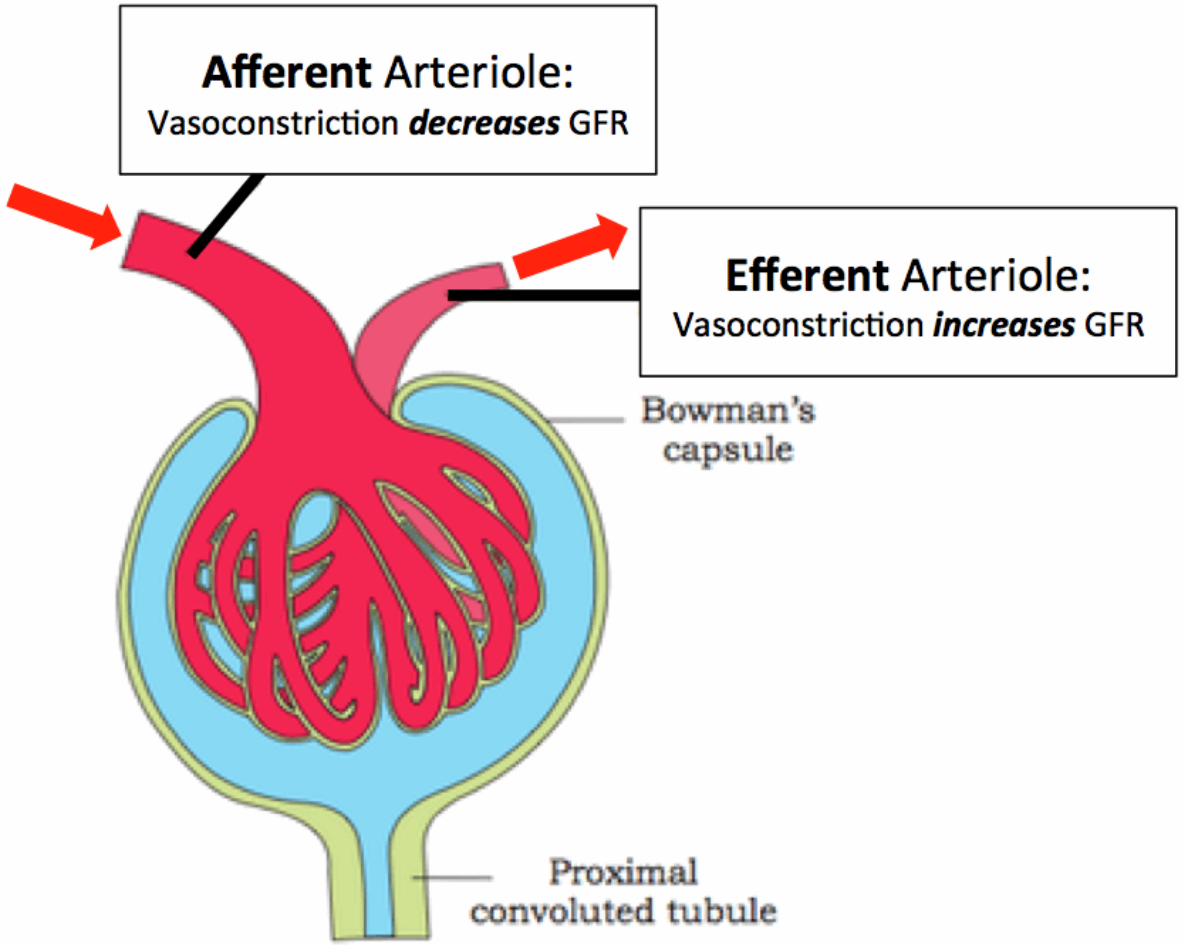


Microvascular modulation of glomerular filtration rate (GFR)

Afferent/Efferent Arterioles

- The afferent arteriole supplies blood to the glomerulus.
  - *Vasoconstriction of the **afferent arteriole** **DE**CREASES the Glomerular Filtration Rate (GFR)*
- The efferent arteriole drains the glomerulus.
  - *Vasoconstriction of the **efferent arteriole** **IN**CREASES the Glomerular Filtration Rate (GFR)*


Efferent arteriole
Bowman's capsule
Glomerulus
JG cells
Proximal tubule
Afferent arteriole
Macula densa
Distal tubule
Collecting duct
Loop of Henle
1 GFR ↓
2 Flow through tubule ↓
3 Flow past macula densa ↓
4 Renin release causes angiotensin II formation
4 Paracrine from macula densa to afferent arteriole
5 Constriction in efferent arteriole
5 Dilation in afferent arteriole
Hydrostatic pressure in glomerulus ↑
GFR ↑ to normal



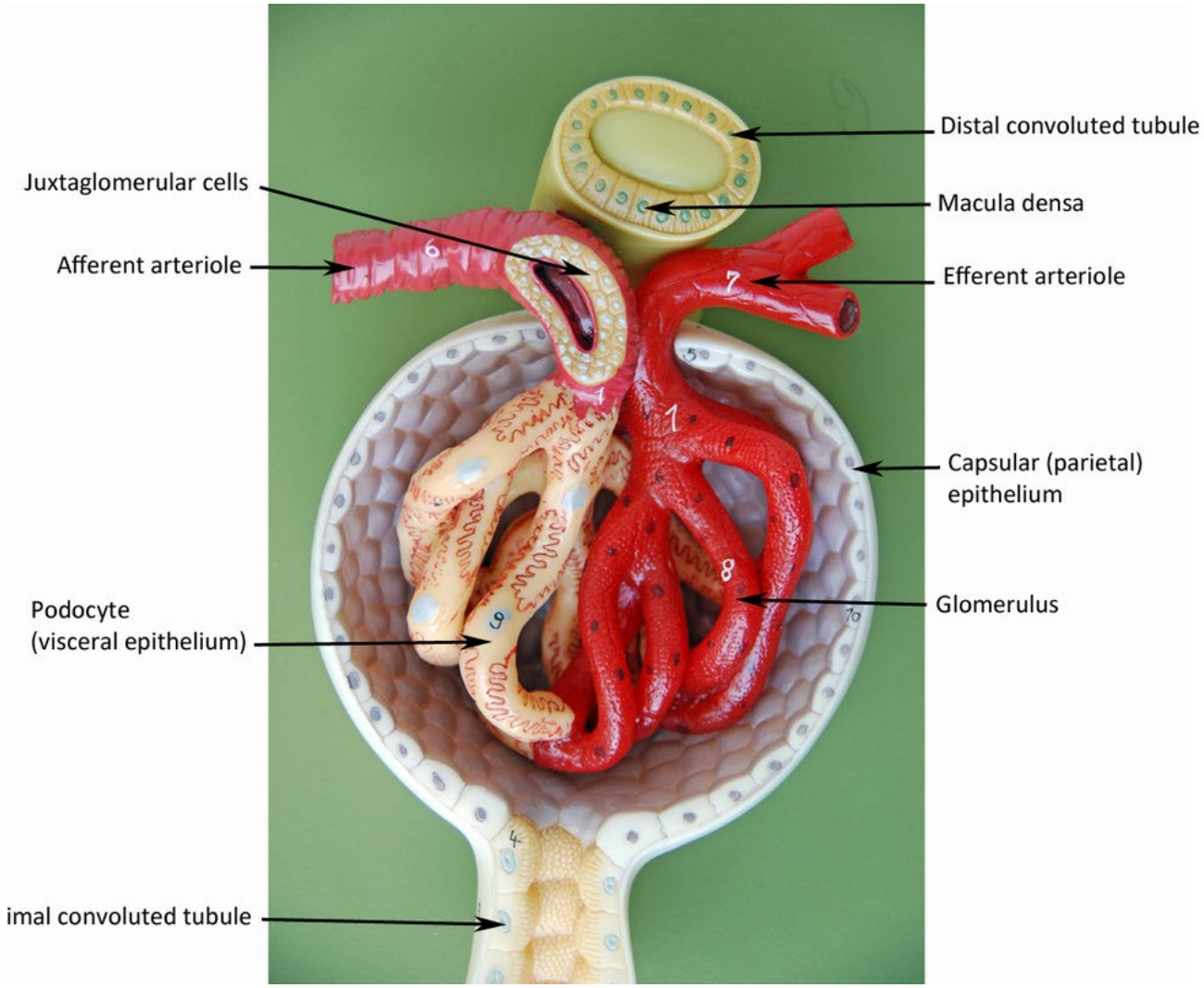
Microvascular modulation of glomerular filtration rate (GFR)

juxtaglomerular apparatus

- A group of specialized cells known as **juxtaglomerular cells** are located around the afferent arteriole where it enters the renal corpuscle.

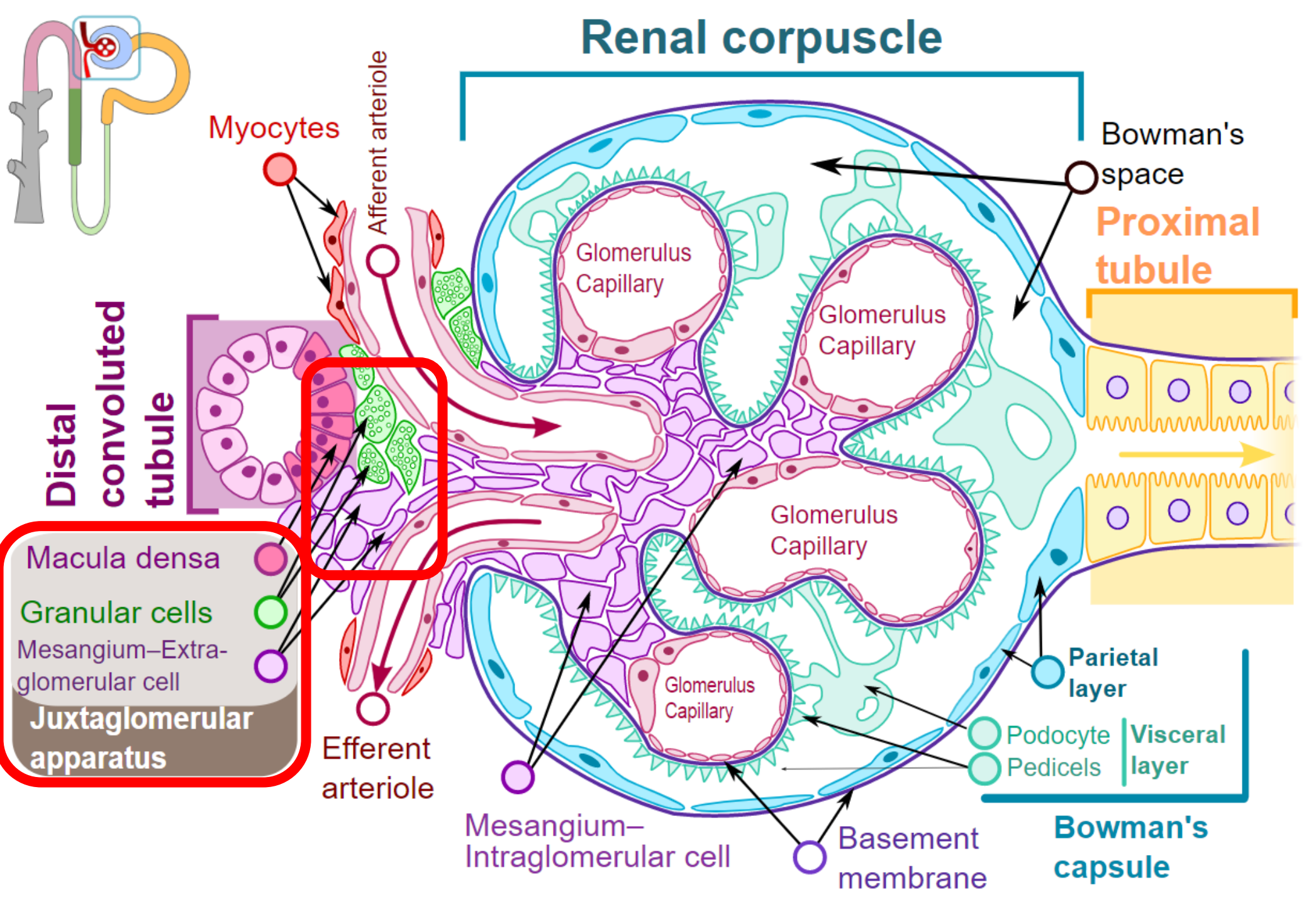
Glomerulus

- The pathway for the remainder of the blood not filtered into the glomerulus…
  - The unfiltered portion of blood…
    - passes into the narrower efferent arteriole.
    - then moves into the vasa recta
    - then combines with efferent venules from other nephrons into the renal vein
    - and finally rejoins the main bloodstream.

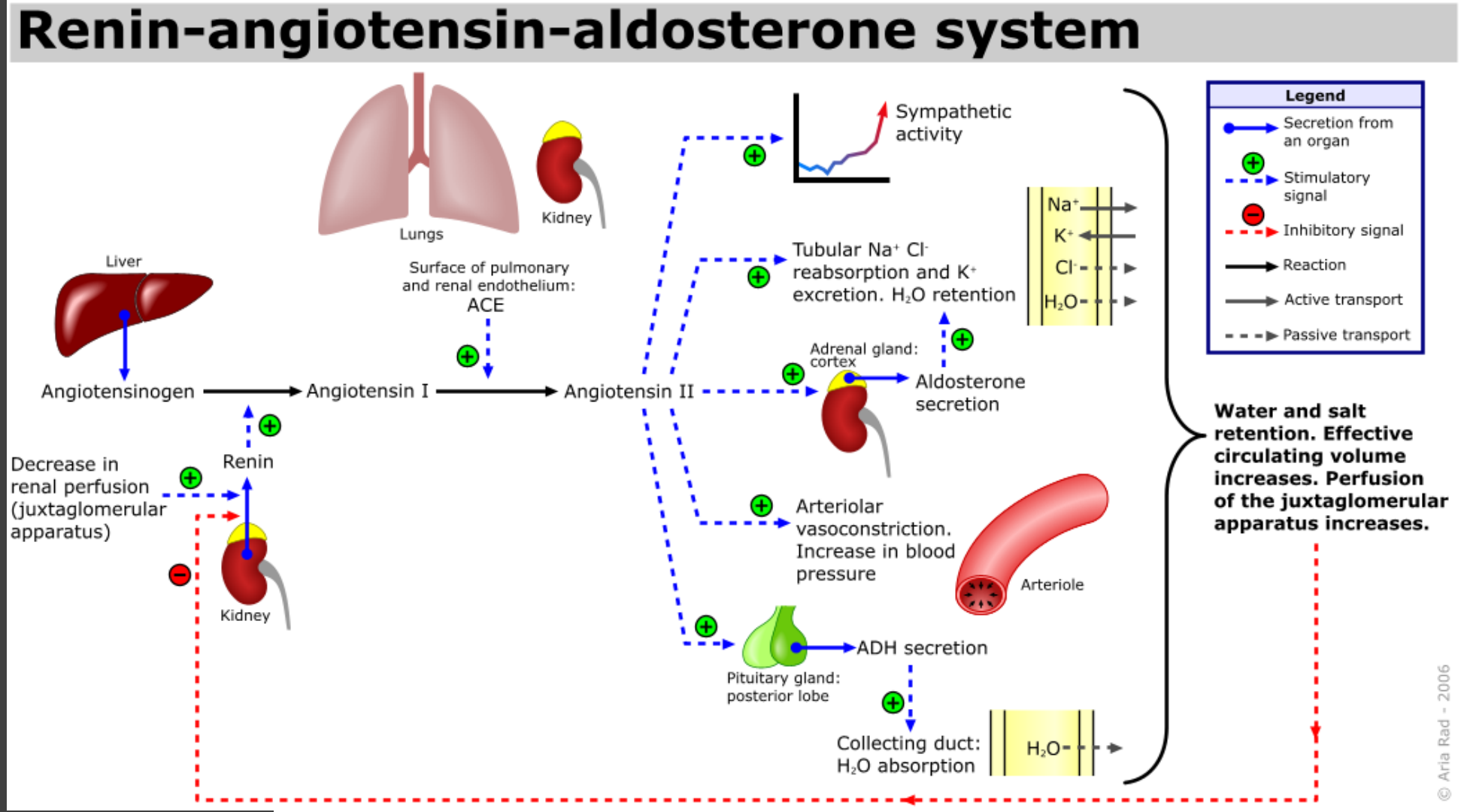


- The juxtaglomerular cells and the macula densa collectively form the **juxtaglomerular apparatus.**
- The juxtaglomerular apparatus cells create and store renin.

THE JUXTA-GLOMERULAR APPARATUS



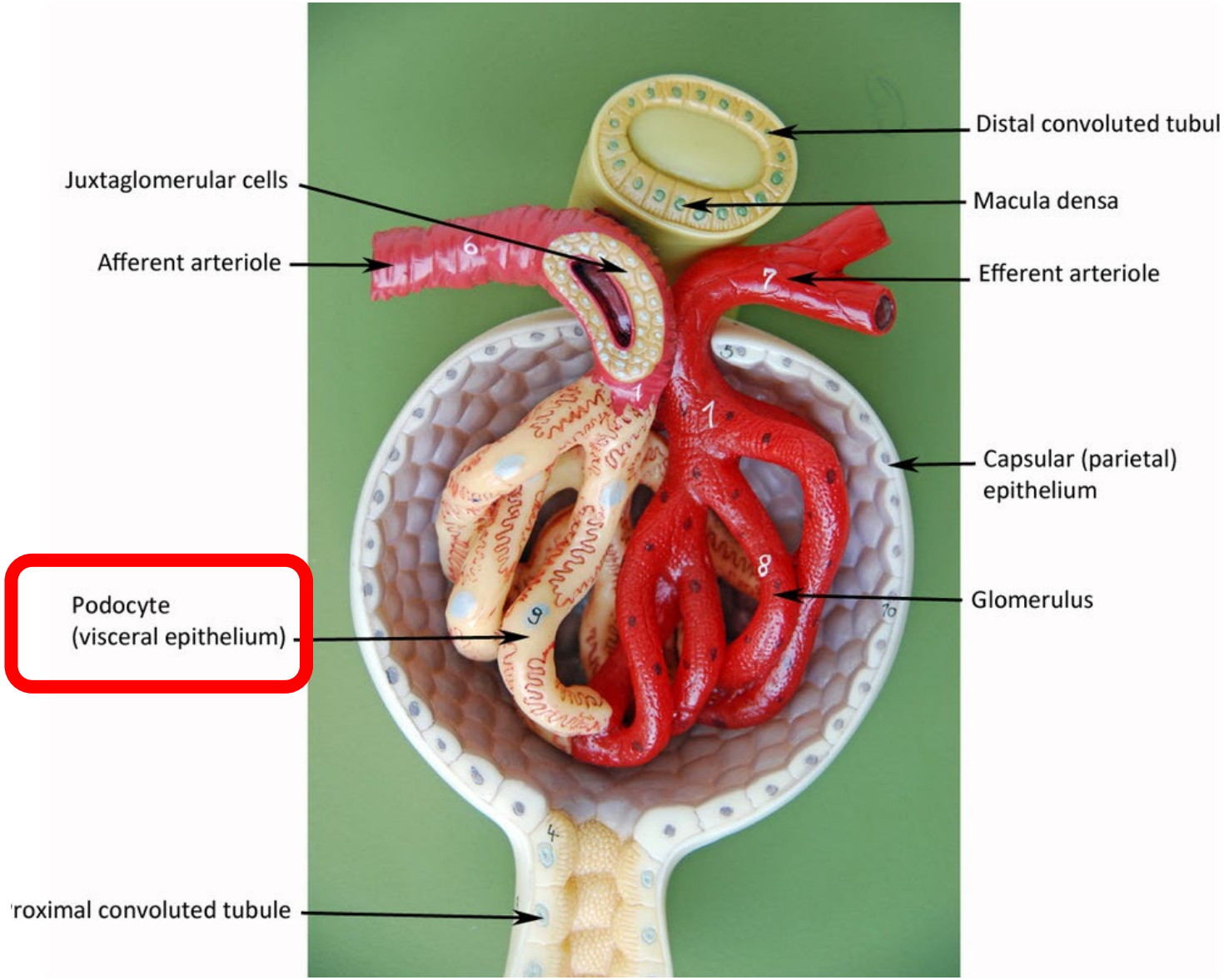
Renin



- Renin is released in response to
  - decreased blood pressure in the afferent arterioles
  - decreased salt concentration in the distal convoluted tubule
  - sympathetic nerve stimulation
- Renin is needed to form Angiotensin I and Angiotensin II which stimulate the secretion of aldosterone by the adrenal cortex.

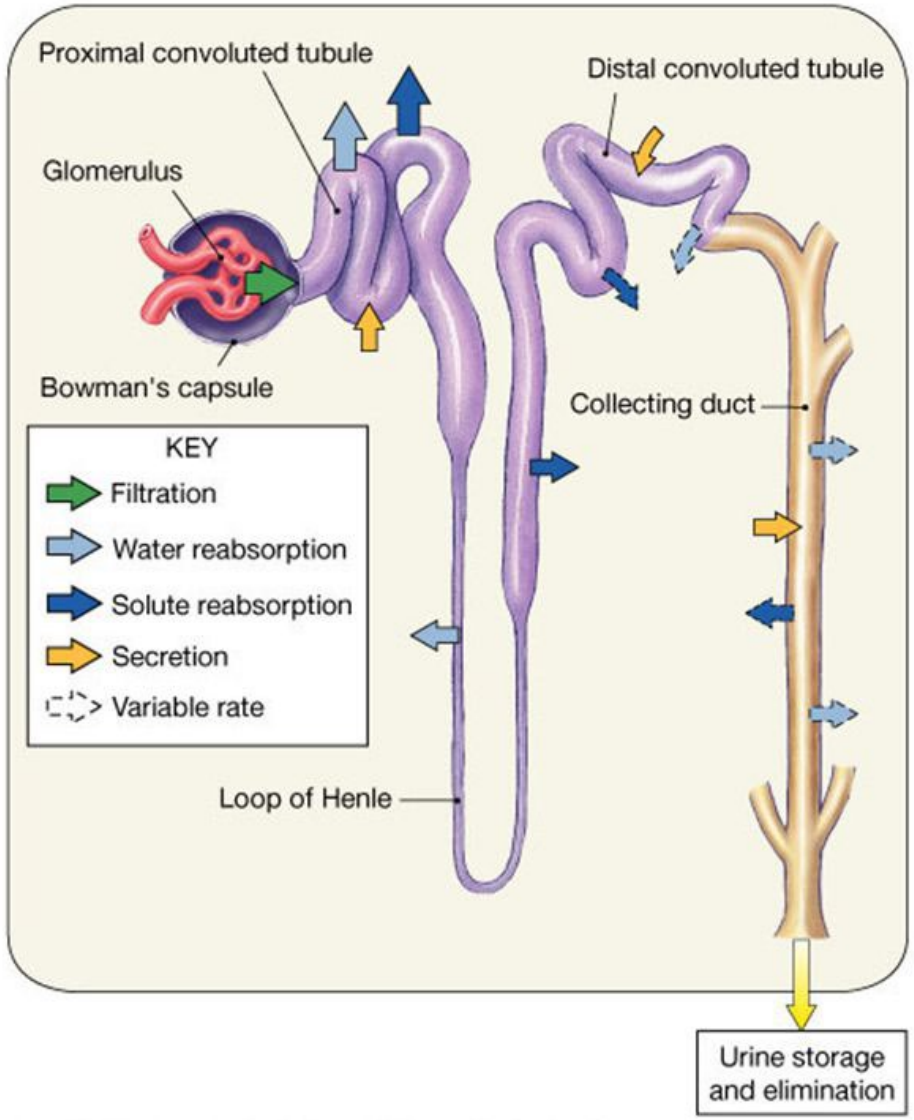
Glomerular Capsule or Bowman's Capsule

- *The visceral layer is made of podocytes*
- *Podocytes form filtration slits*
- *The size of the filtration slits restricts the passage of large molecules (eg, albumin) and cells (eg, red blood cells and platelets).*
- *Also have a negatively-charged coat (glycocalyx) that limits the filtration of negatively-charged molecules, such as albumin.*
- *This action is called electrostatic repulsion.*



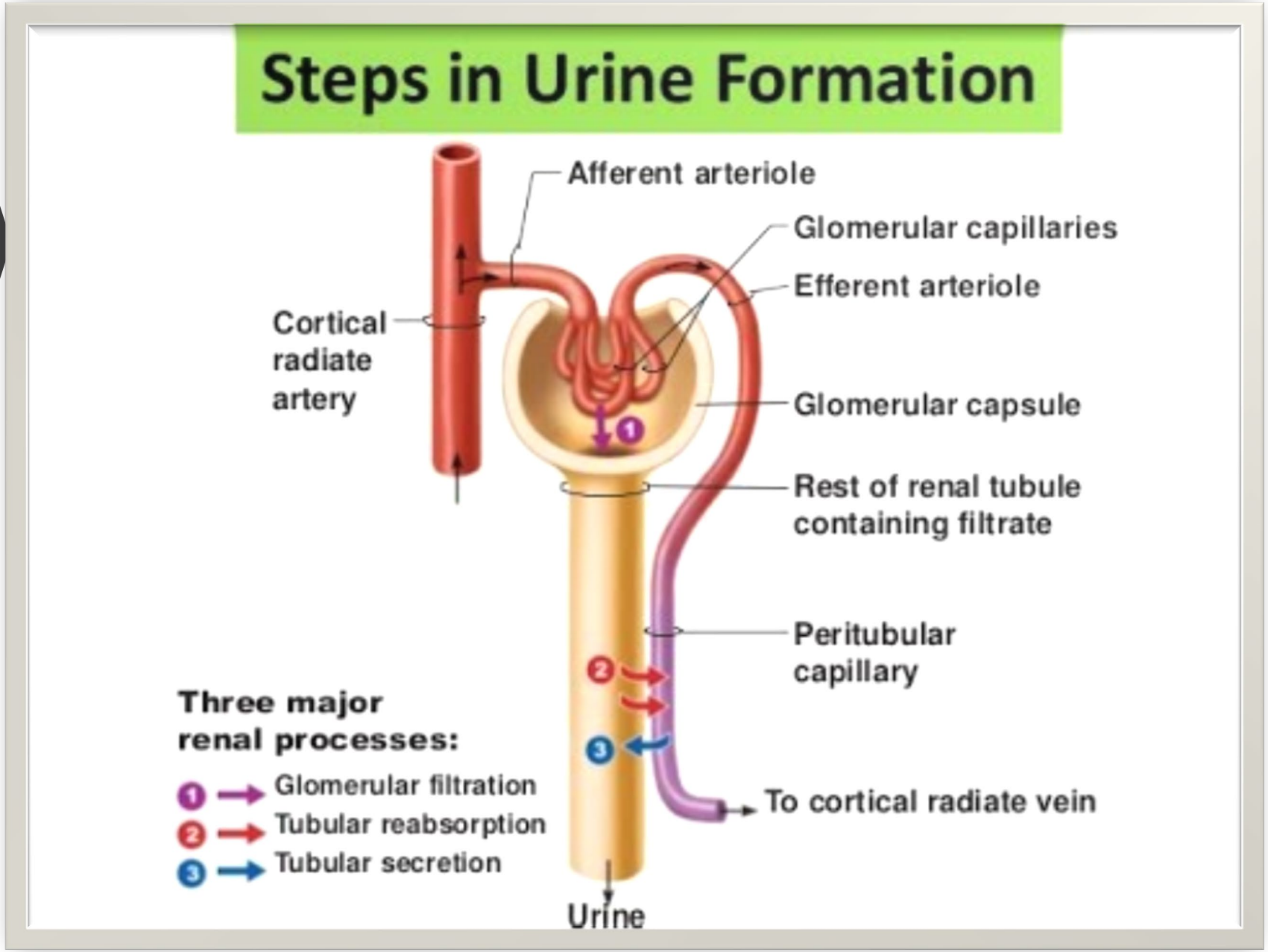
Collecting ducts

- Each distal convoluted tubule delivers its filtrate to a system of collecting ducts.
- As the urine travels down the collecting duct, as much as three-fourths of the water from urine can be reabsorbed as it leaves the collecting duct by osmosis.



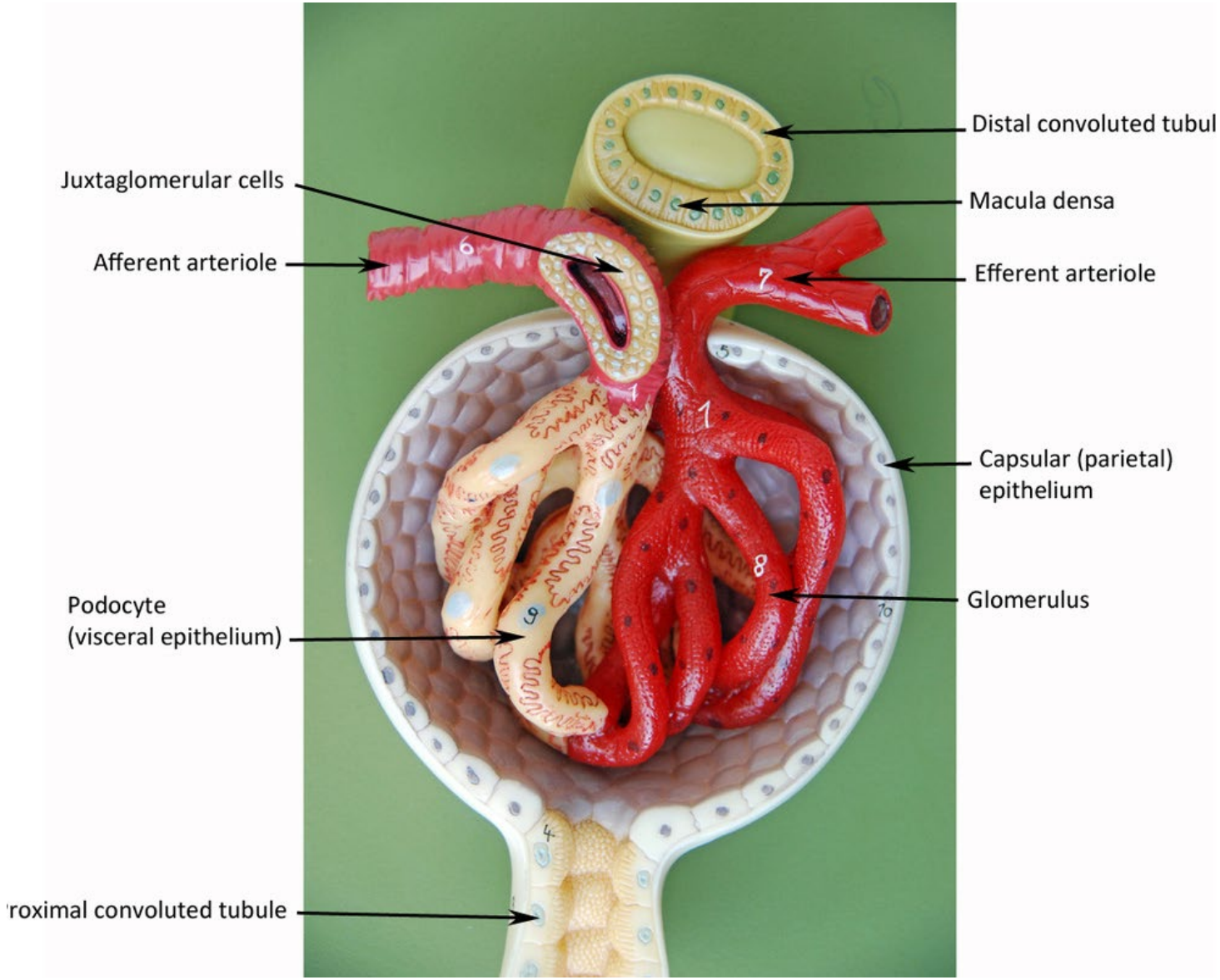
Formation of Urine

- Urine is formed in three steps:
  - Glomerular Filtration
  - Tubular Reabsorption
  - Tubular Secretion



Glomerular Filtration

- Blood enters the afferent arteriole and flows into the glomerulus.
- Blood in the glomerulus has both filterable blood components and non-filterable blood components.
  - Filterable blood components move toward the inside of the glomerulus
  - Non-filterable blood components bypass the filtration process by exiting through the efferent arteriole.



Glomerular Filtration

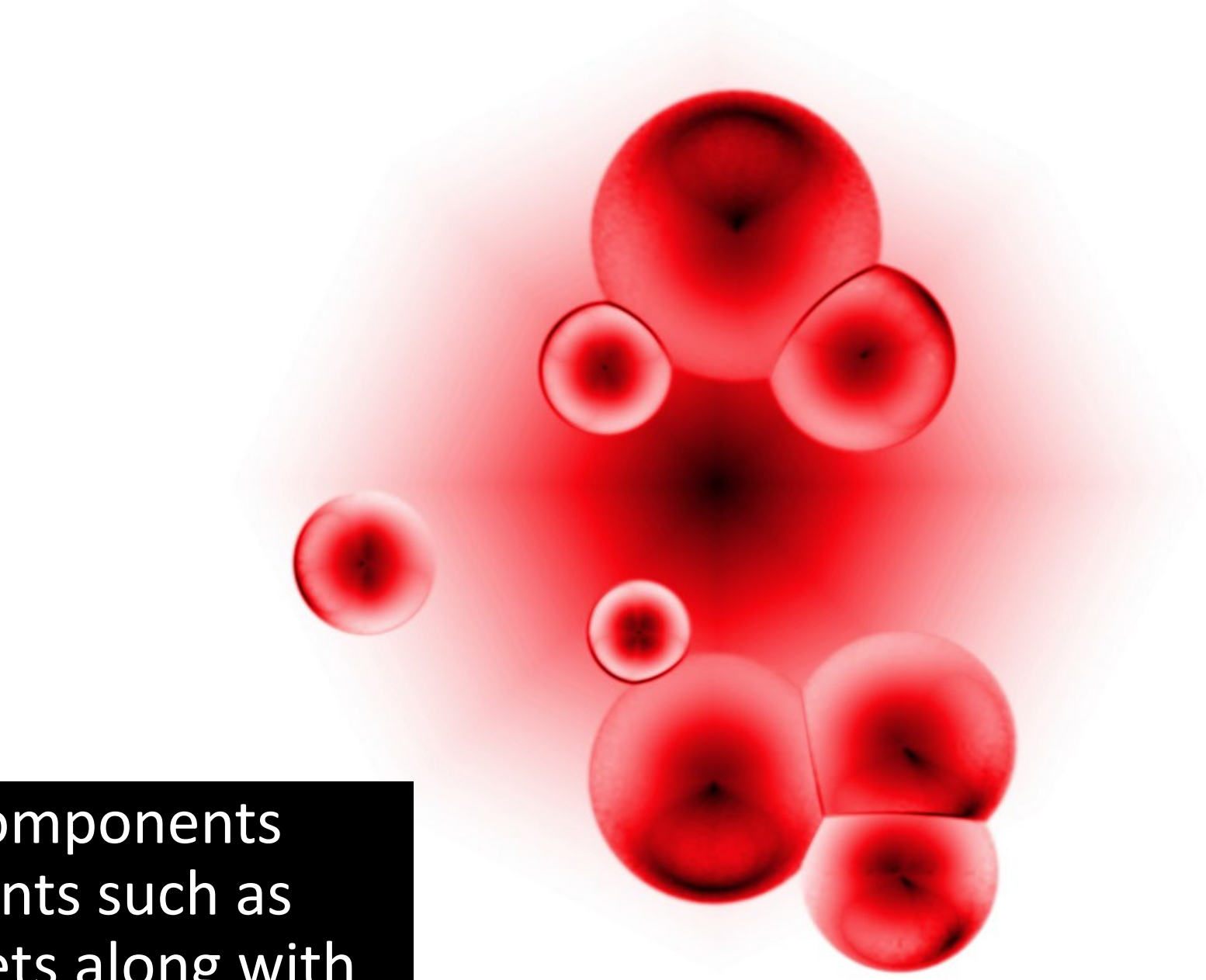
Filterable Blood Components

Filterable Blood components will become glomerular filtrate.

A few of the filterable blood components are water, nitrogenous waste, nutrients and salts (ions).

Glomerular Filtration

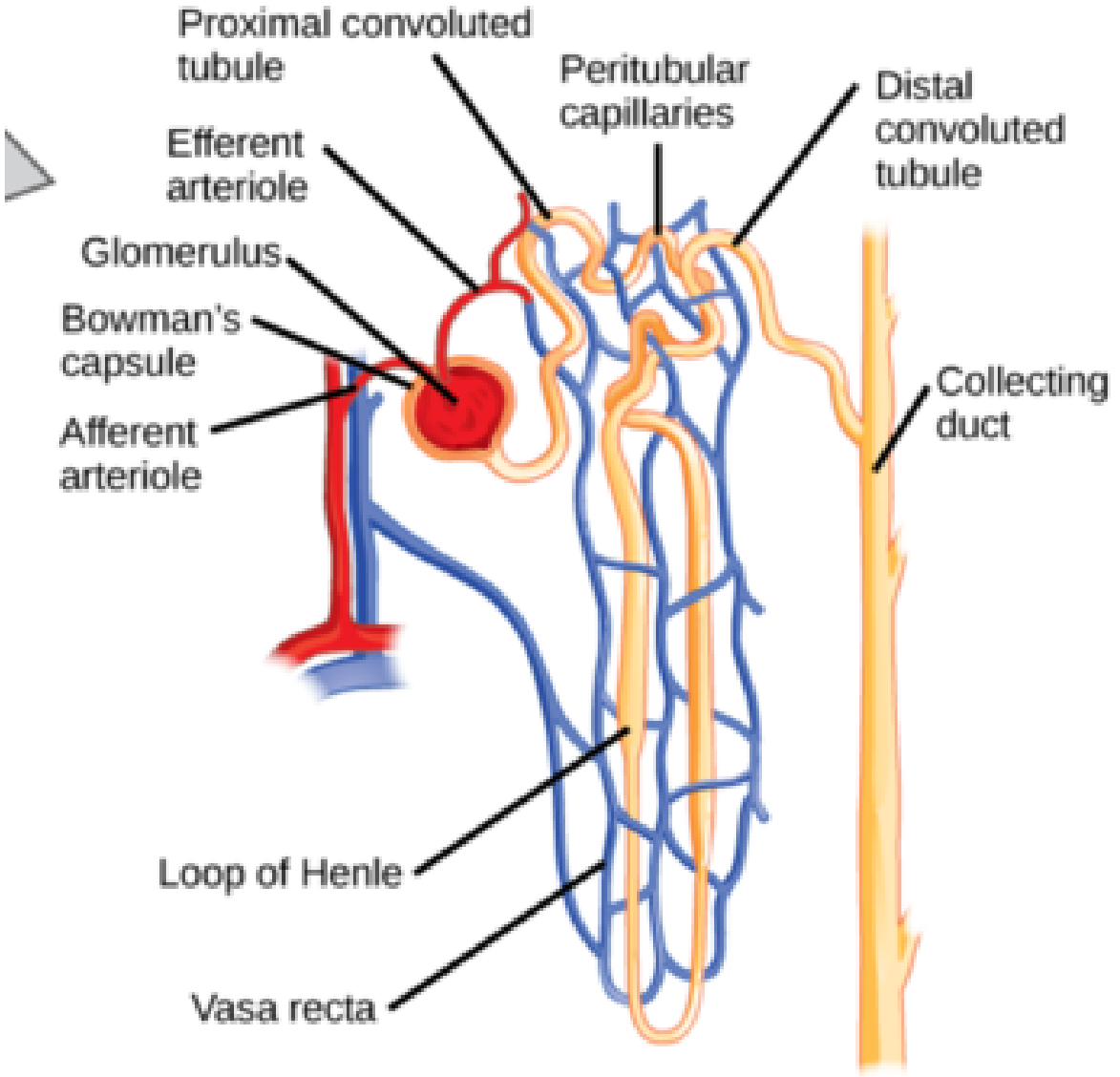
Non-Filterable Blood Components



- Nonfilterable blood components include formed elements such as blood cells and platelets along with plasma proteins.

Tubular Reabsorption

- Within the peritubular capillary network, molecules and ions are reabsorbed back into the blood.
- Sodium Chloride reabsorbed into the system increases the osmolarity of blood in comparison to the glomerular filtrate. This reabsorption process allows water (H2O) to pass from the glomerular filtrate back into the circulatory system.
- Glucose and various amino acids also are reabsorbed into the circulatory system.
  - These nutrients have carrier molecules that claim the glomerular molecule and release it back into the circulatory system.
  - If all of the carrier molecules are used up, excess glucose or amino acids are set free into the urine.



Tubular Secretion

- Urine is a collection of substances that have not been reabsorbed during glomerular filtration or tubular reabsorbtion.

Maintaining Water-Salt Balance

It is the job of the kidneys to

- Maintain the water-salt balance of the blood.
- Maintain blood volume
- Maintain blood pressure

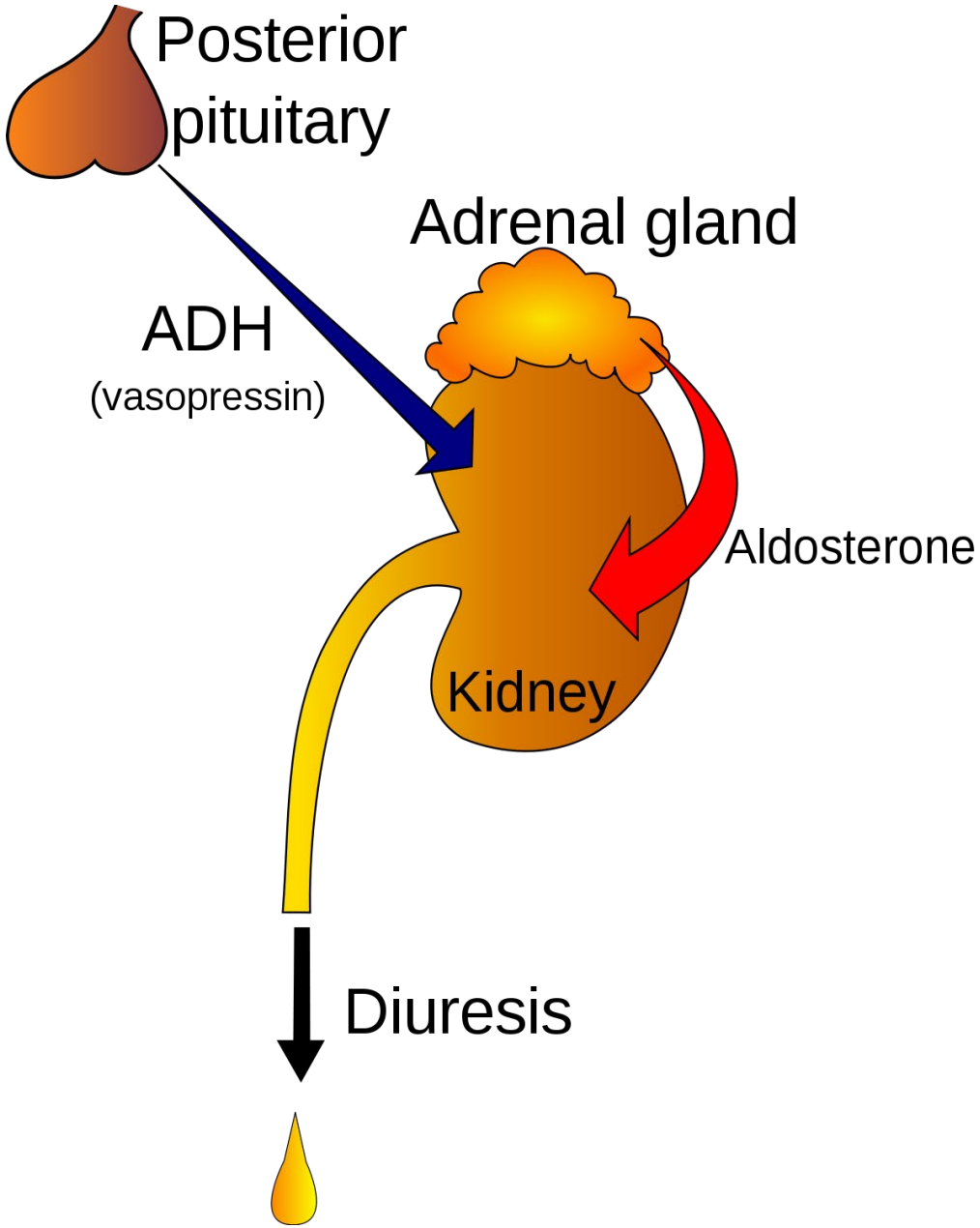
Simple examples of ways that this balance can be changed include

- Ingestion of water
- Dehydration
- Blood loss
- Salt ingestion

Anti-Diuretic Hormone (ADH)

- Reabsorption of water

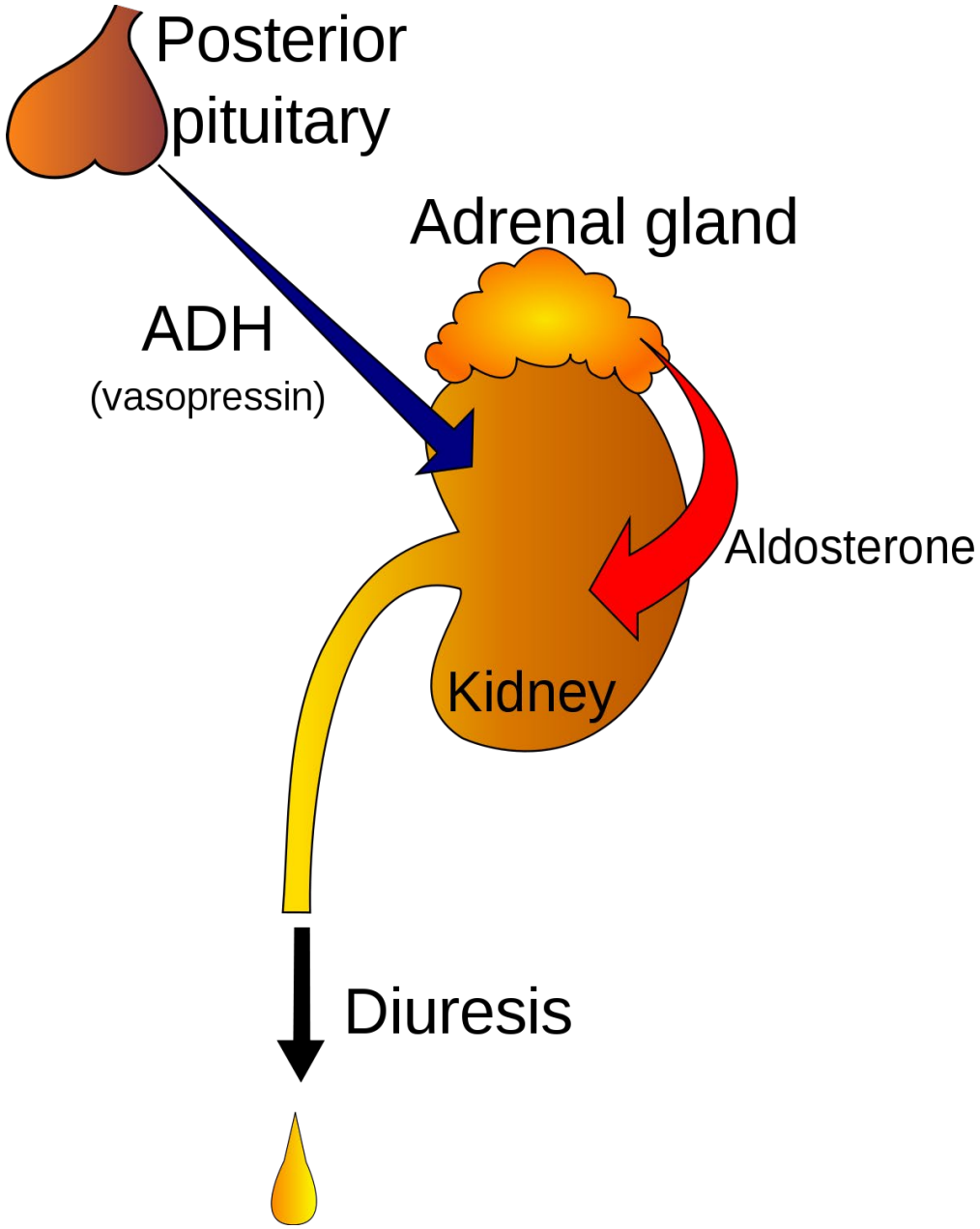
- Direct control of water excretion in the kidneys is exercised by the anti-diuretic hormone(ADH), released by the posterior lobe of the pituitary gland.
- ADH causes the insertion of water channels into the membranes of cells lining the collecting ducts, allowing water reabsorption to occur.
- Without ADH, little water is reabsorbed in the collecting ducts and dilute urine is excreted.



Anti-Diuretic Hormone (ADH)

- Reabsorption of water

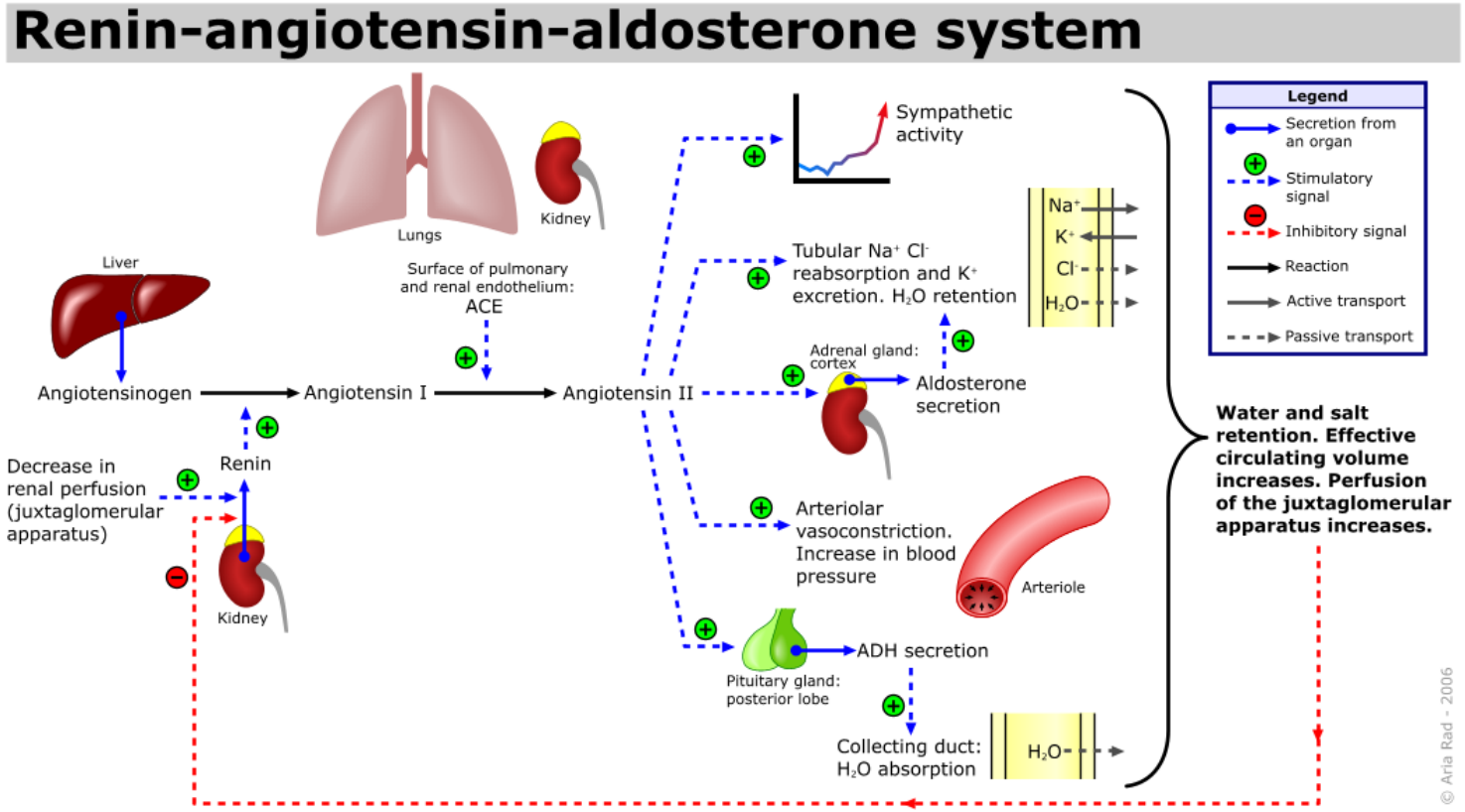
- **Anti-Diuretic Hormone (ADH)** plays a role in increasing water reabsorption in the kidneys, thus helping to dilute bodily fluids.
- There are several factors that influence the secretion of Anti-Diuretic Hormone (ADH).
  - When the blood plasma gets too concentrated, special receptors in the hypothalamus release ADH.
  - When blood pressure falls, stretch receptors in the aorta and carotid arteries stimulate ADH secretion to increase volume of the blood.



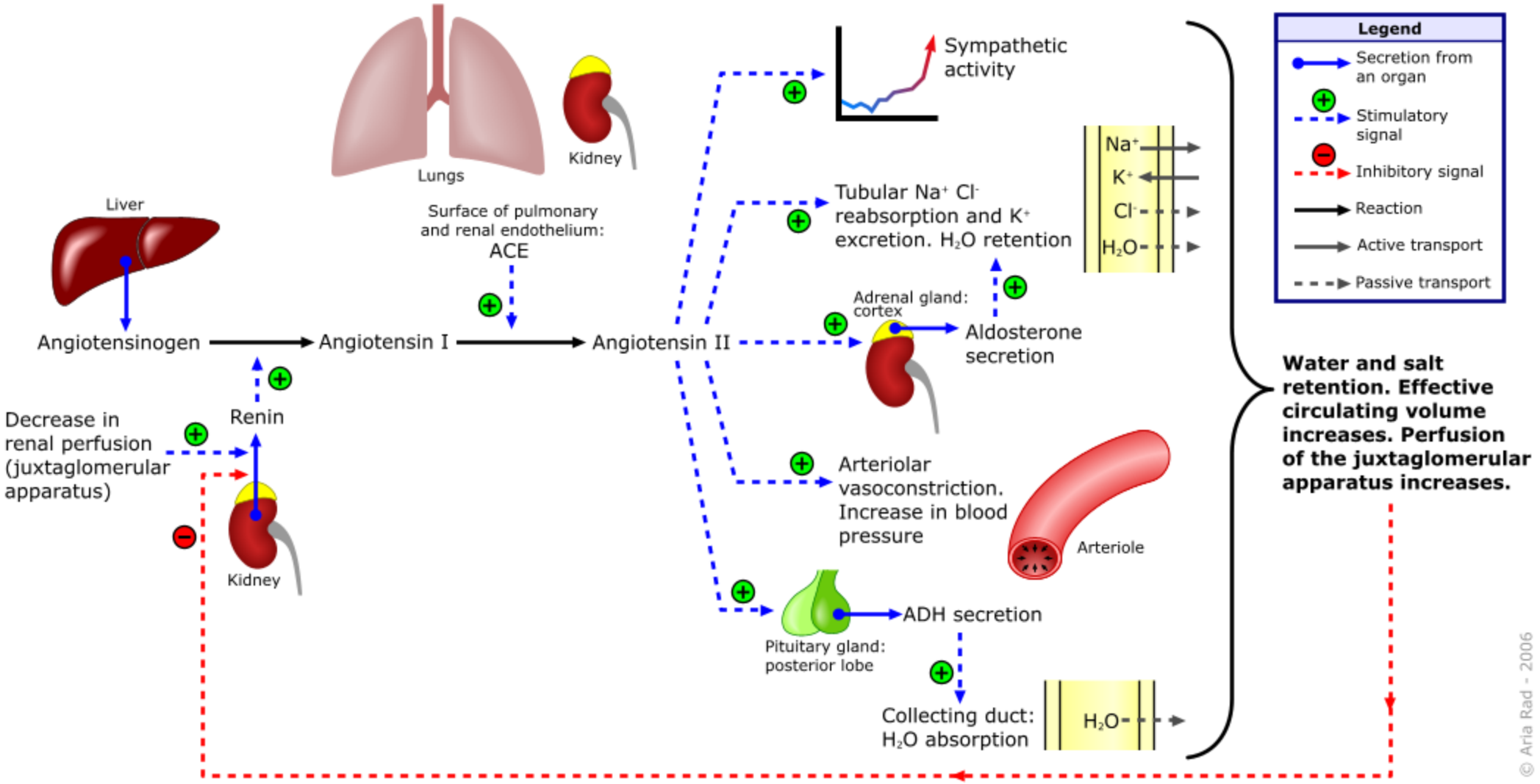
- Juxtaglomerular cells (JG cells, also known as granular cells) secrete **Renin**.
- **Renin** converts **Angiotensinogen** from the liver into **Angiotensin I**.
- **Angiotensin I** is then converted into **Angiotensin II**.
- **Angiotensin II** stimulates the adrenal cortex to release **aldosterone**.
- **Aldosterone** stimulates the excretion of potassium ions and the reabsorption of sodium ions by the kidney.

Reabsorption of Salt

The kidneys also have a regulated mechanism for reabsorbing sodium in the distal nephron.

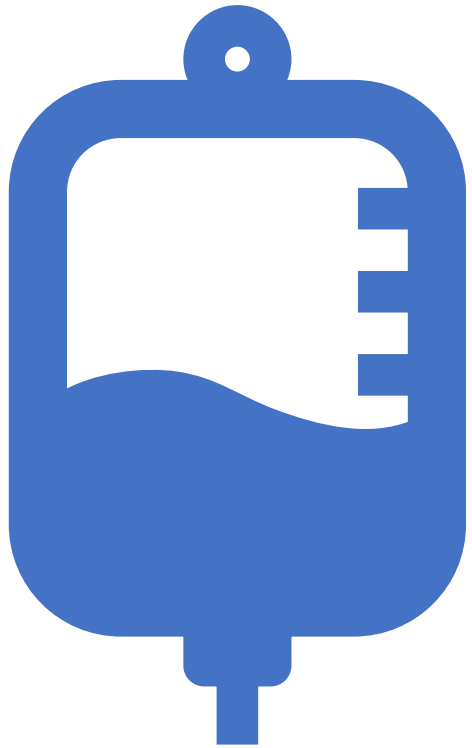


Renin-angiotensin-aldosterone system

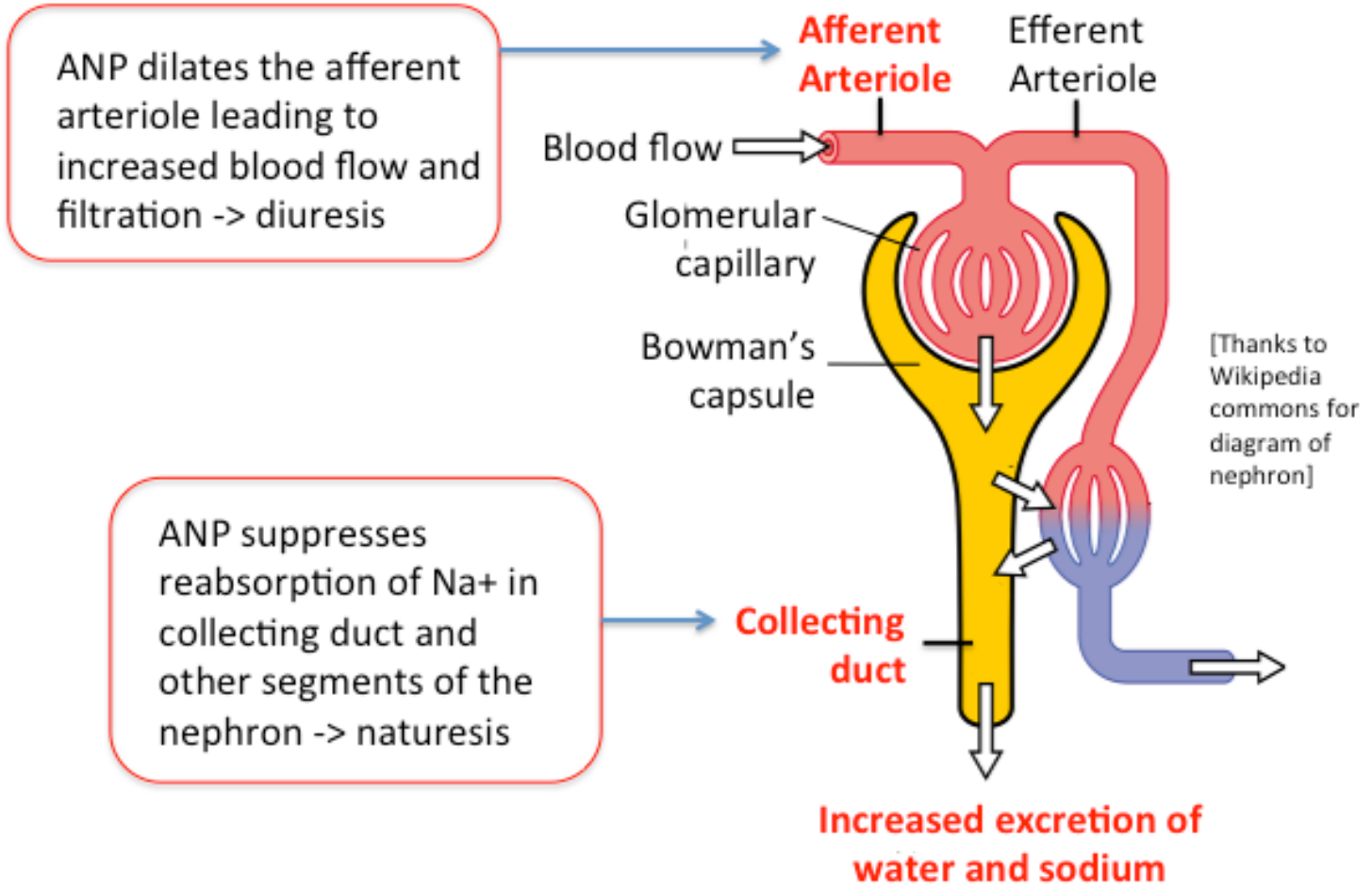


Atrial natriuretic hormone (ANH) or Atrial natriuretic peptide (ANP)

- *The reabsorption of sodium ions is followed by the reabsorption of water.*
- *Resorption of water causes blood pressure as well as blood volume to increase.*
- Stretch receptors in the heart sense the increased blood volume.
- Cardiac cells in the atria of the heart secrete **Atrial natriuretic hormone (ANH**) in response.
- **Atrial natriuretic hormone (ANH**) inhibits
  - the secretion of renin by the juxtaglomerular apparatus
  - the secretion of the aldosterone by the adrenal cortex
- This promotes the excretion of sodium.
- When sodium is excreted so is water.
- This causes blood pressure and volume to decrease.



Atrial natriuretic hormone (ANH) or Atrial natriuretic peptide (ANP)

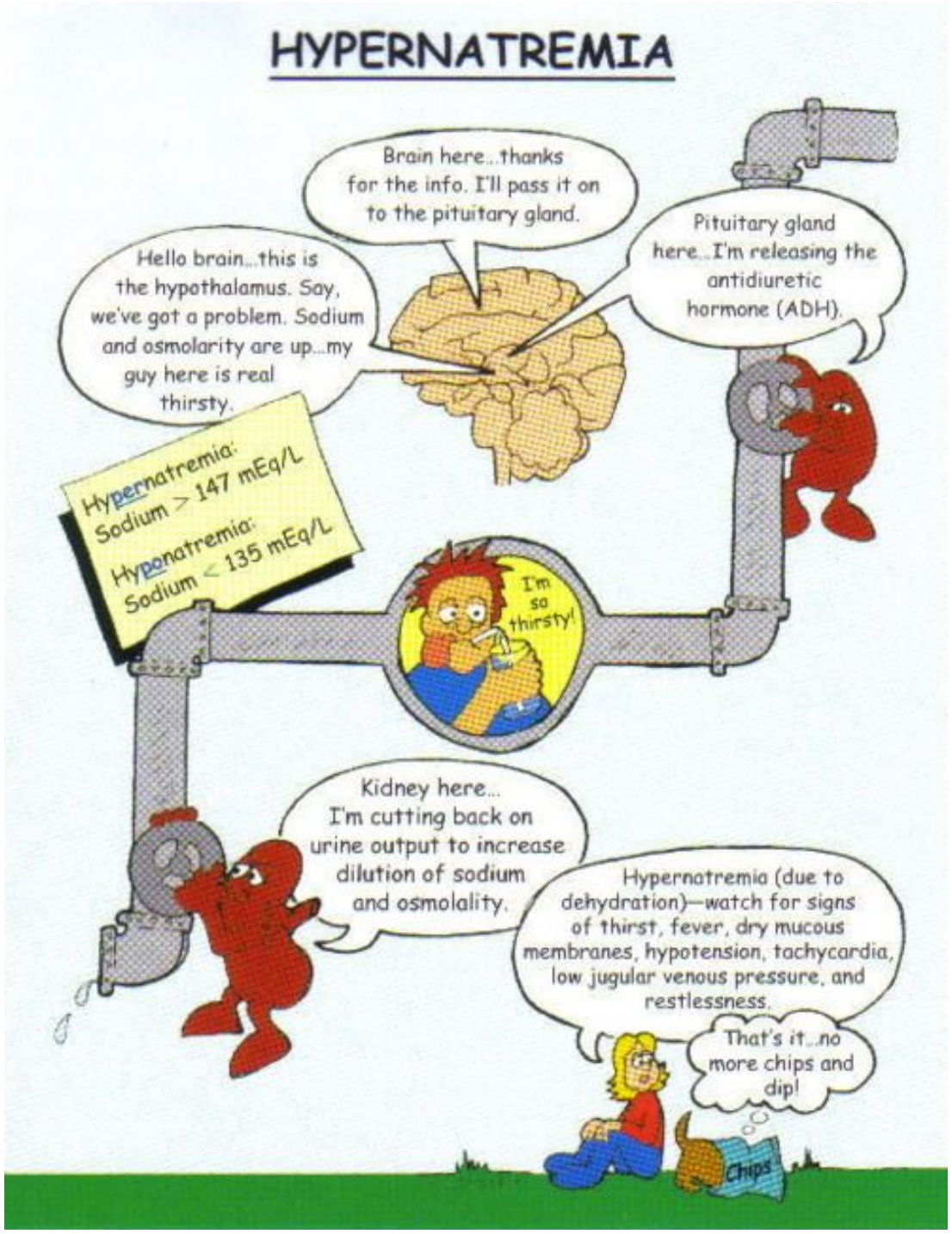


Atrial natriuretic peptide (**ANP**) or atrial natriuretic factor (ANF) is a natriuretic peptide hormone secreted from the cardiac atria,

Hypernatremia

An **increase in plasma sodium levels** above normal is **hypernatremia**.

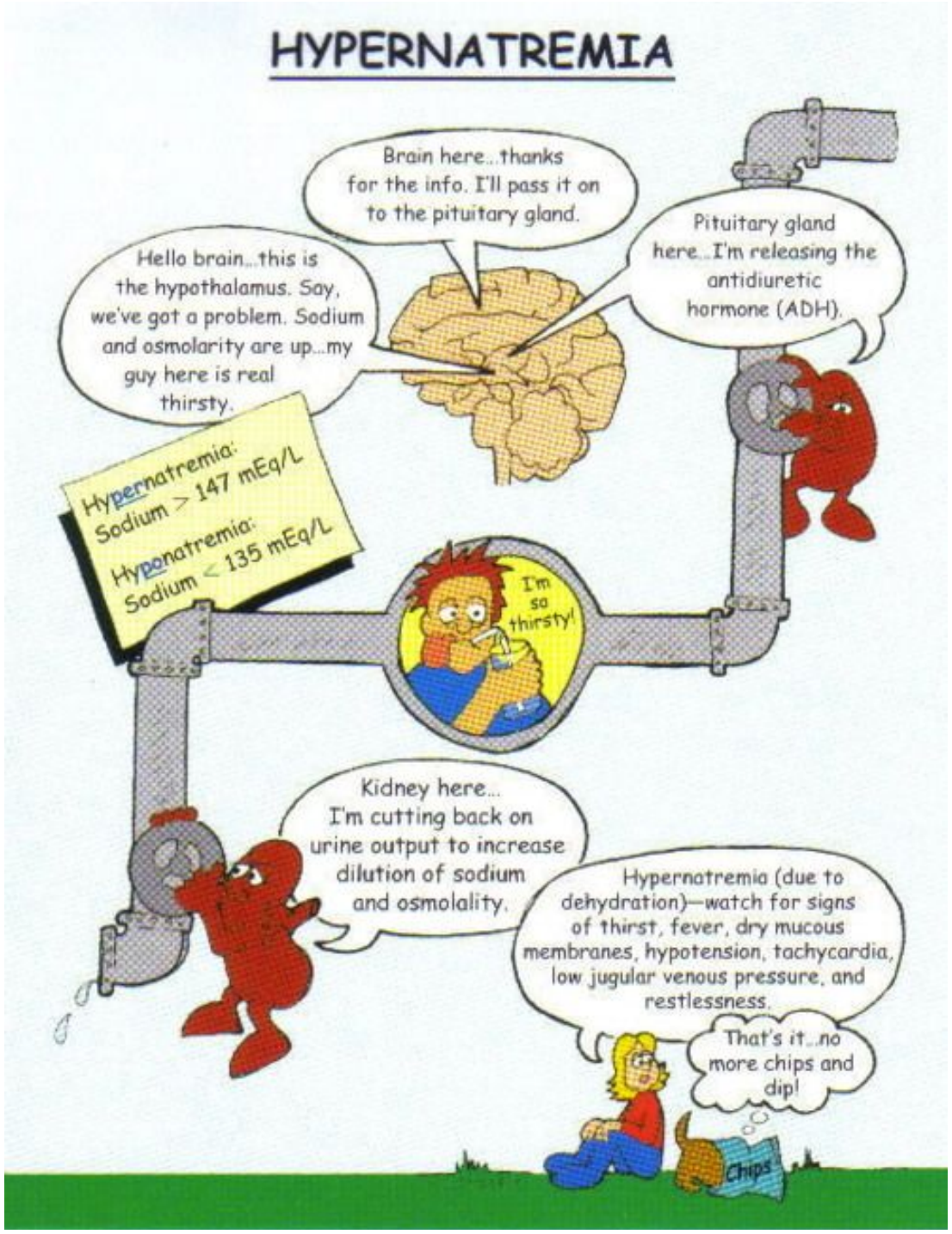
- Water retention and an increased blood pressure usually are signs of hypernatremia.



Hypernatremia

An **<u>increase in plasma sodium levels</u>** above normal is **hypernatremia**.

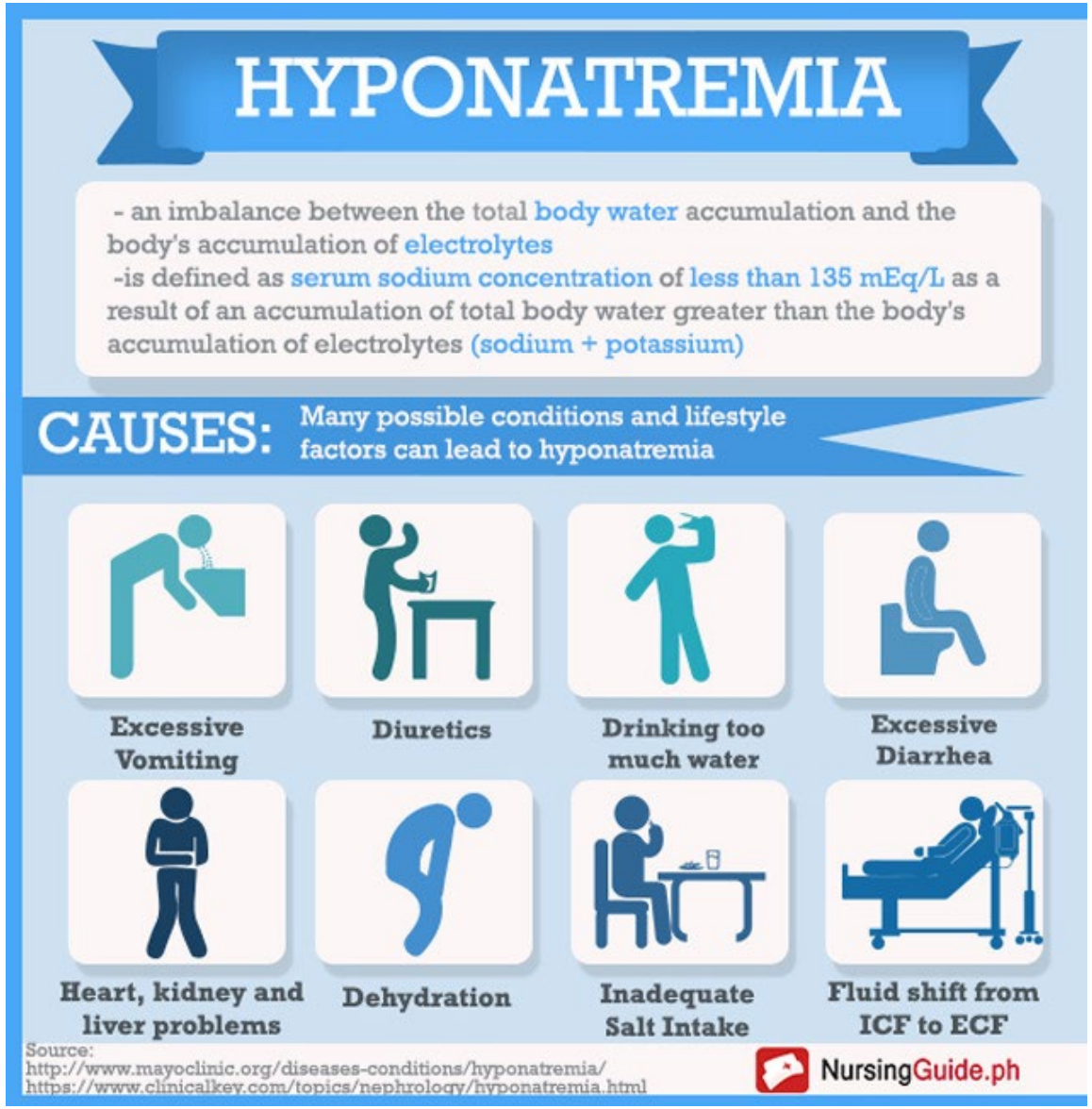
- Sodium is the primary solute in the extracellular fluid.
- Sodium levels have a major role in osmolarity regulation.
- Neurons and muscle cells (excitable cells) depend on the electrochemical gradient for sodium across the plasma membrane in order to function properly.



Hyponatremia

If the **plasma sodium levels are below normal** it is called **hyponatremia**.

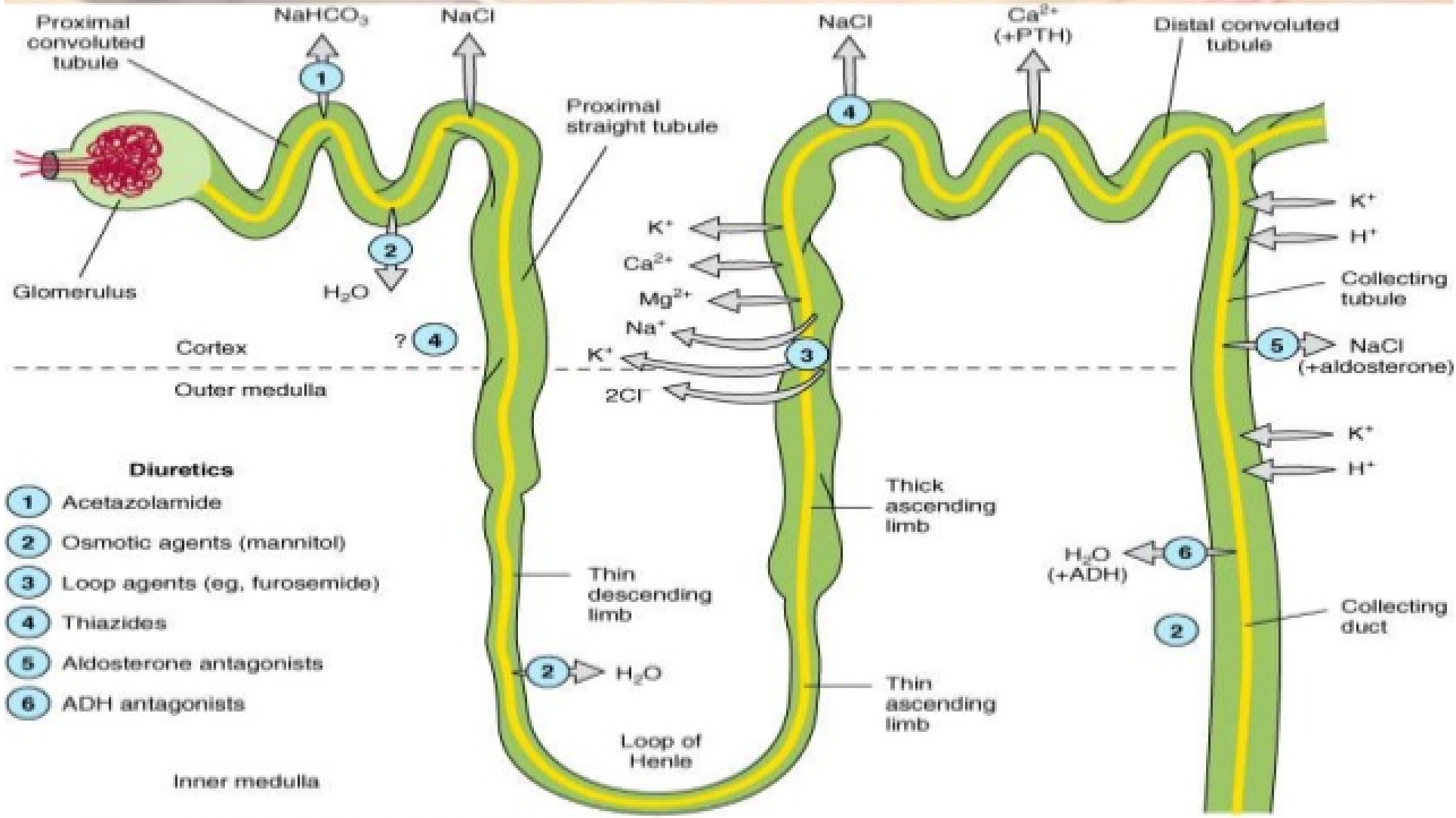
- Signs of this are low plasma volume and hypotension.



Diuretics

- A diuretic is any drug that…
  - elevates the rate of bodily urine excretion (diuresis).
  - decreases the extracellular fluid (ECF) volume
  - produces a negative extracellular fluid balance.

Normal Physiology of kidney (Urine formation)



Source: Katzung BG, Masters SB, Trevor AJ: *Basic & Clinical Pharmacology, 11th Edition*: http://www.accessmedicine.com

Diuretics

Diuretics include

- Caffeine
- Cranberry Juice
- Alcohol
- Drugs that treat
  - heart failure
  - liver cirrhosis
  - Hypertension
  - kidney diseases

Antidiuretics

- **Antidiuretic:** lessening or decreasing of urine production or an agent that decreases the release of urine.