Chapter 13: Cardiovascular System (CVS)

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Components of the CVS:

1. **Heart**: pump, composed of 4 chambers (2 atria & 2 ventricles).

2. **Blood Vessels**: systems of tubes including:

A. **Arteries and arterioles**: carry the blood **from the heart** to all parts of the body.

B. **Venules and veins**: carry the blood back from the tissues **to the heart**.

C. **Blood capillaries**: network of fine vessels connecting the **arterioles with the venules**. its the sites of **exchange of gases** (O2 & CO2), **nutrients** and **waste** products between blood and tissues.

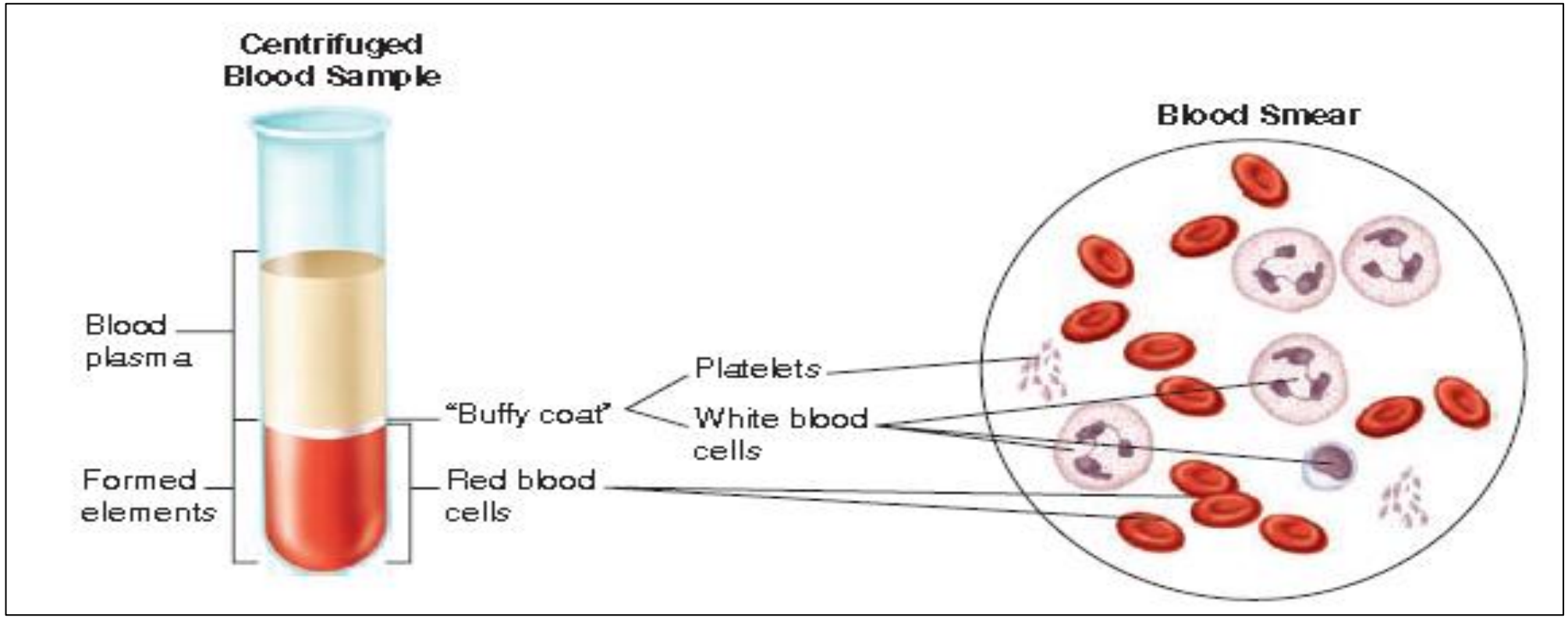
- **Arterial blood:** is blood **leaving** the heart, is **bright red** because of a high concentration of **oxyhemoglobin** (with the **exception** of that **going to the lungs**)

- **Venous blood:** is blood **returning** to the heart, is a **darker red** than the oxygen-rich arterial blood since its **less oxygen** (**Except** for the venous **blood from the lungs**).

Cardiovascular System (CVS)

COMPOSITION OF THE BLOOD:

- Total **blood volume** (adult) is about **5 liters. By centrifugation, blood sample is separated into: Fluid portion** (55%): called **plasma Formed or Cellular elements** (45%): **erythrocytes, leukocytes,** and **platelets**.



Plasma:

straw-colored liquid consisting of **water** and dissolved **solutes** (like Na^+) plus **metabolites**, **hormones**, **enzymes**, **antibodies**, and other **proteins**.

Plasma proteins (constitute 7% to 9% of plasma):

3 types

1- Albumins (60% to 80%):

- The **smallest** plasma protein in size, produced by the **liver**
- Provide the **osmotic pressure** needed to draw water from the surrounding tissue fluid into the capillaries (to maintain **blood volume and pressure**).

2- Globulins:

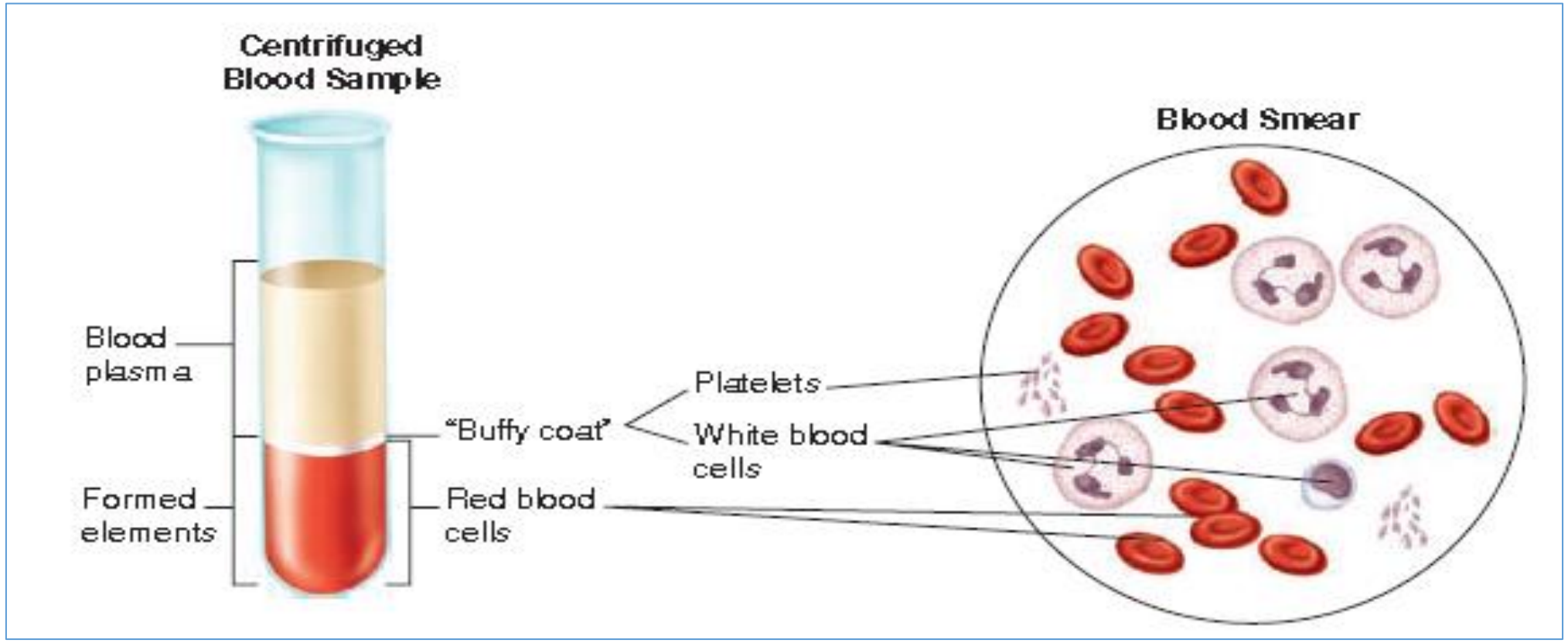
- 3 subtypes: **alpha** globulins, **beta** globulins, and **gamma** globulins.
- The **alpha** and **beta** globulins are produced by the **liver** and function in **transporting lipids and fat-soluble vitamins**.
- **Gamma** globulins are **antibodies** produced by **lymphocytes** and function in **immunity**.

3- Fibrinogen (4%):

- Produced by the **liver**, important **clotting factor** (fibrinogen is converted into insoluble threads of fibrin).

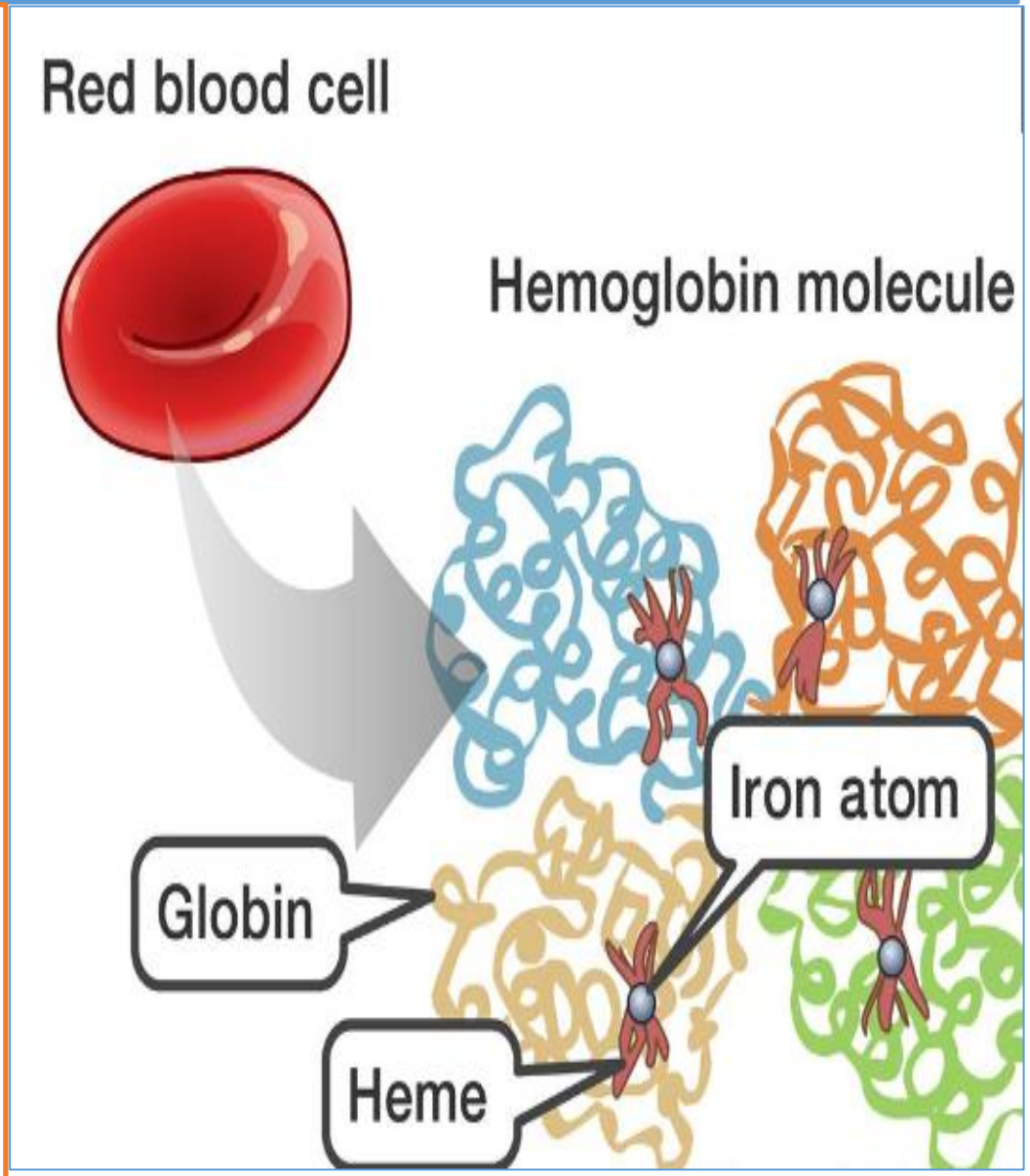
Cardiovascular System (CVS)

- **The Formed Elements of Blood:** include two types of blood cells: **erythrocytes** (RBCs), and **leukocytes** (WBCs).



Erythrocytes

- are **flattened**, **biconcave** discs (increased surface area through which gas can diffuse).
- lack nuclei
- have a relatively short **circulating life span** (only about **120 days**).
- Older erythrocytes are removed from the circulation by **phagocytic** **cells in the liver, spleen, and bone marrow.**
- Erythrocytes contain **hemoglobin** molecules.
- A **Hemoglobin** molecule consists of **four protein** chains called ***globins***, each globin is bound to **one *heme***, a red- pigmented molecule that contains **iron**.
- The **iron** group of heme is able to combine with **oxygen** in the lungs and release oxygen in the tissues.



Leukocytes

- Contain **nuclei**
- 2 types (**granular** or **agranular**)

- **Granular Leukocytes:**

1. **Neutrophils**: 60 to 70% of leukocytes (most abundant), **3-5 lobed nucleus**, have **light blue granules.**
2. **Basophils**: **large 2 lobed** nucleus, **dark blue** granules.

- **Agranular Leukocytes:**

1. **Lymphocytes**: **round** nucleus (small cells, second most numerous type)

2. **Monocytes**: **kidney** shaped nucleus (the largest WBC)

Platelets (thrombocytes):

- are the **smallest** of the formed elements.
- Cellular fragments that **lack nuclei**
- are capable of **amoeboid movement**.
- The platelet count per cubic millimeter of blood ranges from **130,000 to 400,000** (**vary** greatly)
- Platelets **survive** for about **five to nine days** before being **destroyed** by the **spleen** and **liver**.

Blood Antigens

- **Antigens** are molecules that **stimulate the immune system** to produce **antibodies**.
- **Lymphocytes** secrete a class of proteins called ***antibodies*** that bind in a specific fashion with antigens.

ABO System

antigens present on the **red blood cell** surface:

- **type A (with only A antigens),**
- **type B (with only B antigens),**
- **type AB (with both A and B antigens),**
- **type O (with neither A nor B antigens).**

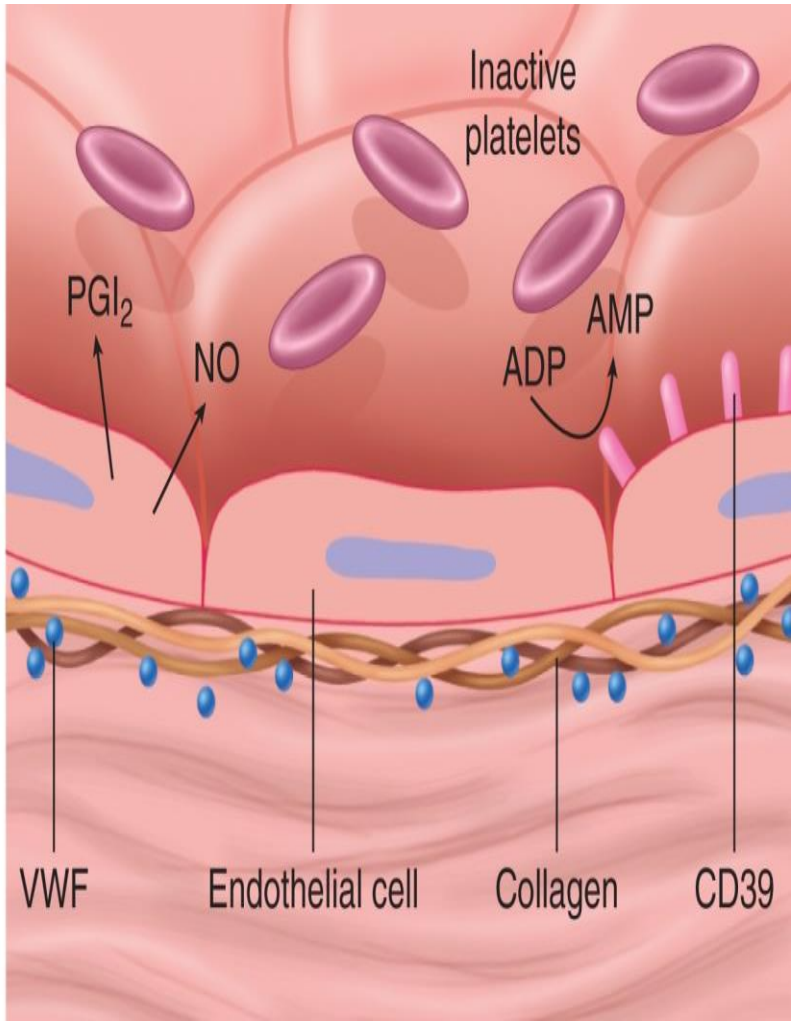
- The **immune system** exhibits **tolerance** to its own red blood cell antigens. People who are **type A**, for example, do **not** produce **anti-A antibodies** but they do make antibodies against the B antigen and, conversely, people with blood type B make antibodies against the A antigen.

Platelets and Blood Vessel Walls

- **Normally**: platelets are **repelled** from each other and from the **endothelium** of **blood vessels**.

- In the blood vessel wall, **endothelium** (simple squamous epithelium) possess a significant role in blood clotting:

1. **Separate** the blood **from collagen** and other proteins from the **platelets**. **Other proteins that are capable of activating platelets**
2. Secrete **Prostacyclin** (or PGI 2, a type of prostaglandin): act as **vasodilators**.
3. Secrete **Nitric oxide** (NO): act on the platelets to **inhibit platelet aggregation**.
4. Contain **CD39 enzyme**: present in the plasma membrane of endothelial cells, CD39 breaks down ADP in the blood to AMP and Pi (ADP is released by activated platelets and **promotes platelet aggregation**).



Cardiovascular System (CVS)

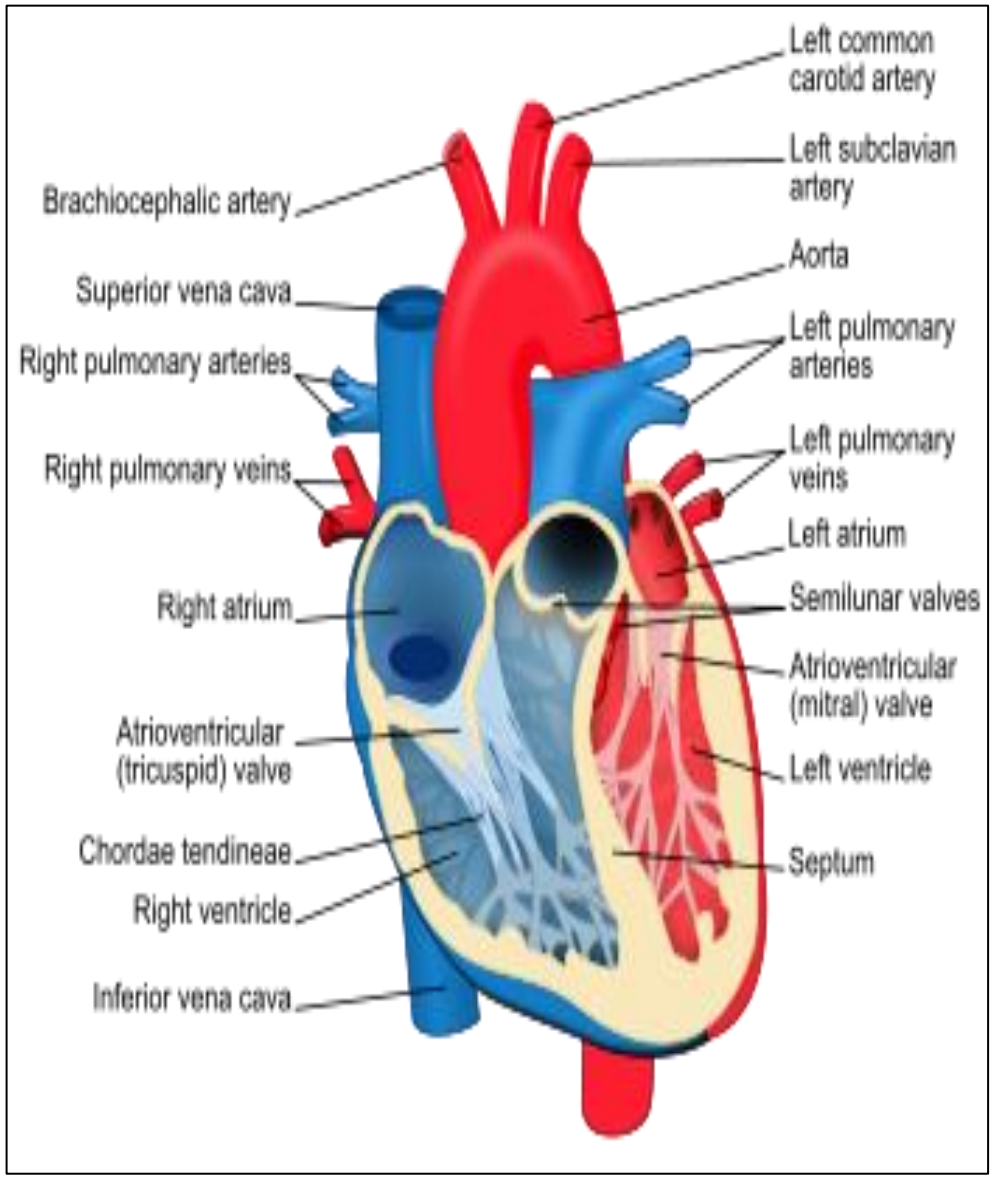
STRUCTURE OF THE HEART:

- **4 chambers**:
- **Two atria**: **receive** venous blood.
- **Two ventricles**: **eject** blood into arteries.

➢ **Right ventricle** pumps blood to the **lungs**, where the blood **becomes oxygenated**.

➢ **Left ventricle** pumps **oxygenated blood** to the **entire body.**

➢ The right atrium and ventricle (called the ***right pump***) are separated from the left atrium and ventricle (the ***left pump***) by a muscular wall, or ***septum*** (prevents mixture of the blood from the two sides of the heart).

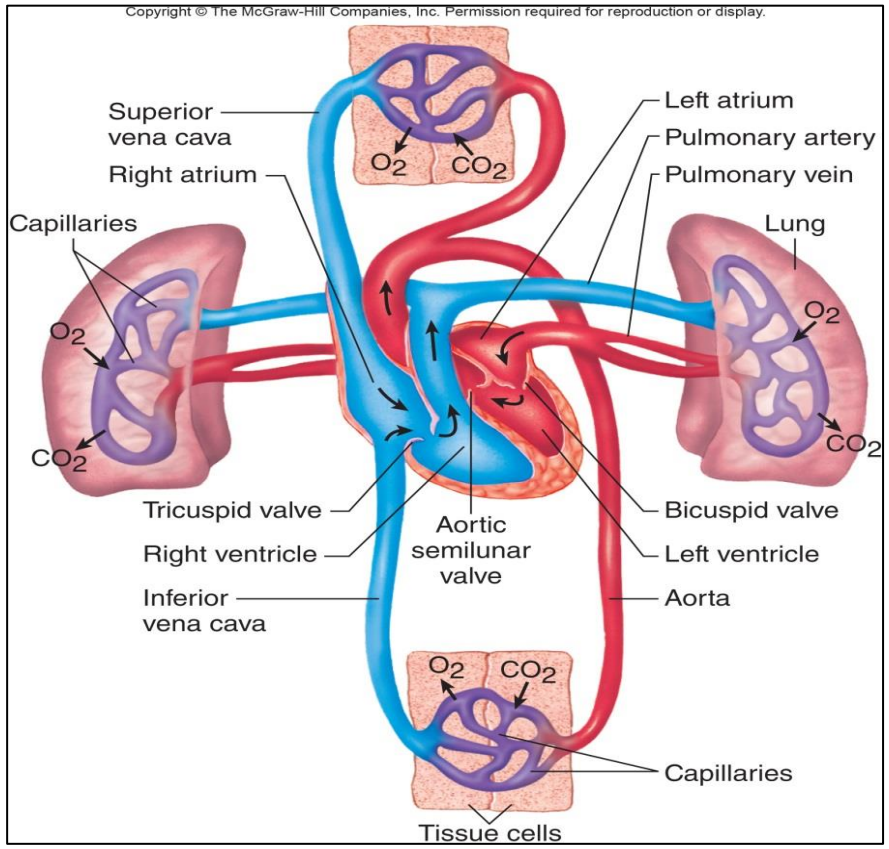


Pulmonary and Systemic Circulations:

- **Pulmonary circulation:** Blood with **low oxygen content and with high carbon dioxide** content **returns** to the **right atrium** then to the **right ventricle** then to the **lungs** through **pulmonary trunk and pulmonary arteries.**

- **Gas exchange** occurs between the lung capillaries and the air sacs (alveoli) of the lungs.

- Oxygenated blood that returns to the **left atrium** by *pulmonary veins*.



	Source	Arteries	O_2 Content of Arteries	Veins	O_2 Content of Veins	Termination
Pulmonary Circulation	Right ventricle	Pulmonary arteries	Low	Pulmonary veins	High	Left atrium
Systemic Circulation	Left ventricle	Aorta and its branches	High	Superior and inferior venae cavae and their branches*	Low	Right atrium

*Blood from the coronary circulation does not enter the venae cavae, but instead returns directly to the right atrium via the coronary sinus.

- **Systemic circulation**
- Oxygenated blood leave the **left atrium** to the **left ventricle** then its pumped through the **aorta** to all of the **organ systems**.

- Aorta: a very large, elastic **artery**, the aorta **ascends** for a short distance, makes a **U-turn**, and then **descends** through the thoracic (chest) and abdominal cavities. **Arterial branches** from the aorta supply **oxygen-rich blood** to all of the organ systems.

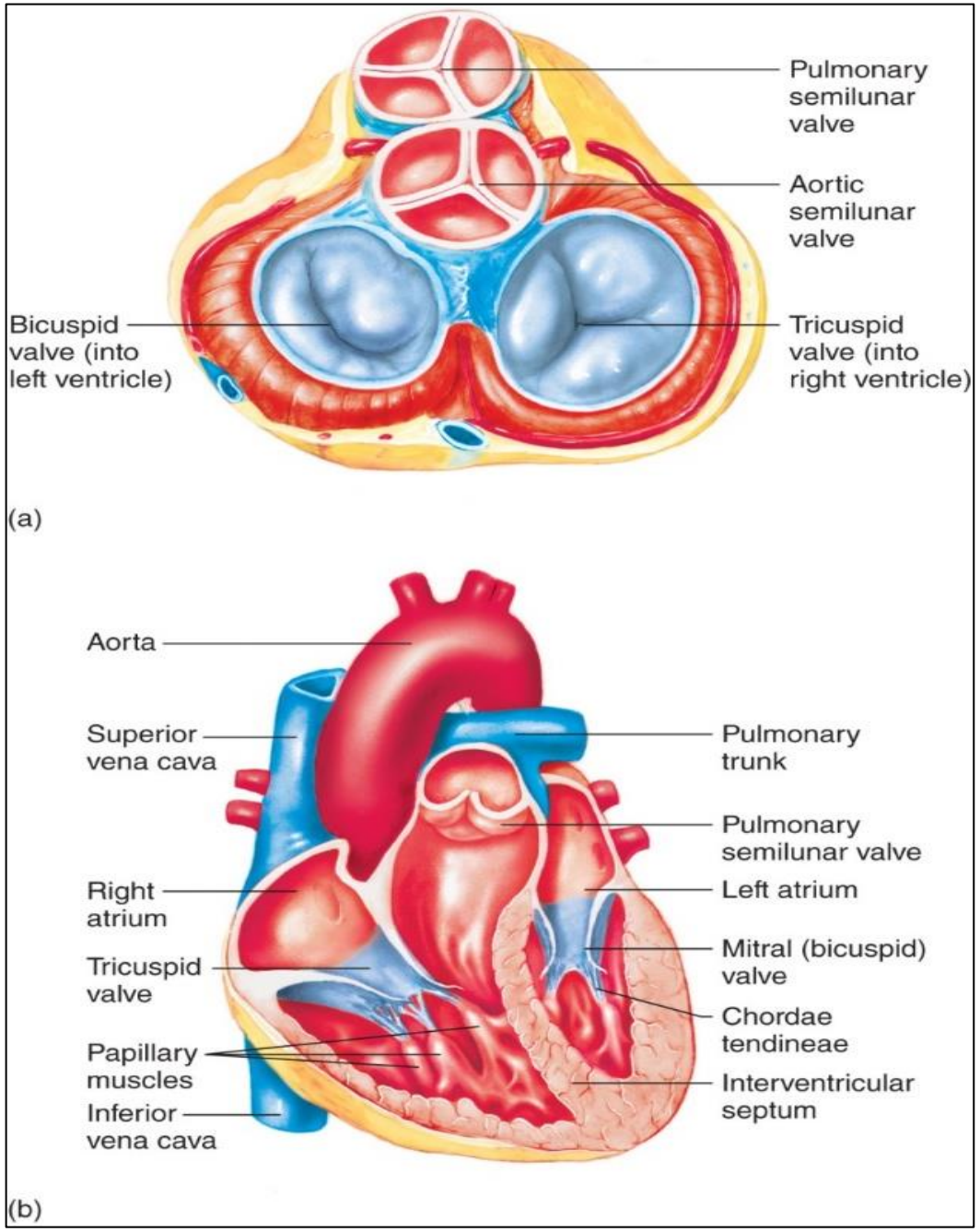
- Material exchange occurs and the low oxygenated **blood** returns into two large **veins** —the **superior and inferior venae cavae** —that return the oxygen-poor blood to the **right atrium**.

Atrioventricular and Semilunar Valves

- adjacent **myocardial cells** are **joined** together mechanically and electrically by **intercalated discs.**
- the atria and ventricles are separated into two functional units by a connective tissue called **fibrous skeleton**.
- In the fibrous skeleton is one-way **atrioventricular (AV) valves.** located between:

➢ the **right atrium and right ventricle** (called the ***tricuspid*** *valve*- has **three** flaps).

➢ the **left atrium and left ventricle** (called the ***bicuspid valve*** *or* ***mitral valve-*** has **two** flaps).



The AV valves:

- Allow blood to flow from the **atria to the ventricles**,
- They **prevent the backflow** of blood into the atria.
- **Opening** and **closing** occur based on the **pressure differences** between the **atria** and **ventricles**.
- AV **open** when the **pressure** in the **atria exceed** that in the **ventricles** (When the **ventricles are relaxed**, the venous return of **blood to the atria** causes the **pressure** in the atria to exceed that in the ventricles. The **AV** valves therefore **open**, **allowing blood to enter the ventricles**).
- AV **closed** when the pressure in the **intraventricular pressure rises** above the pressure in the atria.

The semilunar valves

- One-way **valves**
- are located at the **origin** of the **pulmonary artery** and **aorta**.
- **Open**: during **ventricular contraction** (allowing blood to enter the pulmonary and systemic circulations). **Closed** (snap shut): during **ventricular relaxation** (when the **pressure** in the **arteries** is **greater** than the pressure in the **ventricles**, the semilunar valves snap shut, thus preventing the **backflow of blood into the ventricles**).

- **Heart Sounds:** two normal sounds resulted from closing of the AV and semilunar valves, respectively.
- These sounds are often verbalized as “lub-dub”.
- **First sound (S1, lub):** produced by **closing of the AV** valves during **isovolumetric contraction** of the **ventricles**. heard when the **ventricles contract** at **systole** (at the beginning of ventricular contraction).
- **Second sound (S2, dub):** produced by **closing of the semilunar valves** when the **pressure** in the **ventricles** falls **below** the pressure in the **arteries**. heard when the **ventricles relax** at the beginning of **diastole** (end of ventricular systole).
- **Heart Murmurs:** **abnormal** heart **sounds** produced by abnormal patterns of **blood flow** in the heart caused by **defective heart valves** (incompetent Valves- do not close properly).

•The Cardiac Cycle

1. Refers to the repeating pattern of contraction (**systole)** and relaxation (**diastole)** of the heart.
2. Both ventricles and atria can contract and relax but the terms **systole** and **diastole** are mainly used for the **ventricles**.
3. The heart has two-step pumping action:

•**Atria-ventricles:** The two **atria** fill with **blood** and then **contract simultaneously** [Atrial contraction occurs toward the **end of diastole (when ventricles are relaxed)**].

•0.1-0.2 second later: **Ventricles-arteries:** simultaneous **contraction of both ventricles** [when the atria are relaxed], which sends blood through the **pulmonary and systemic** circulations.

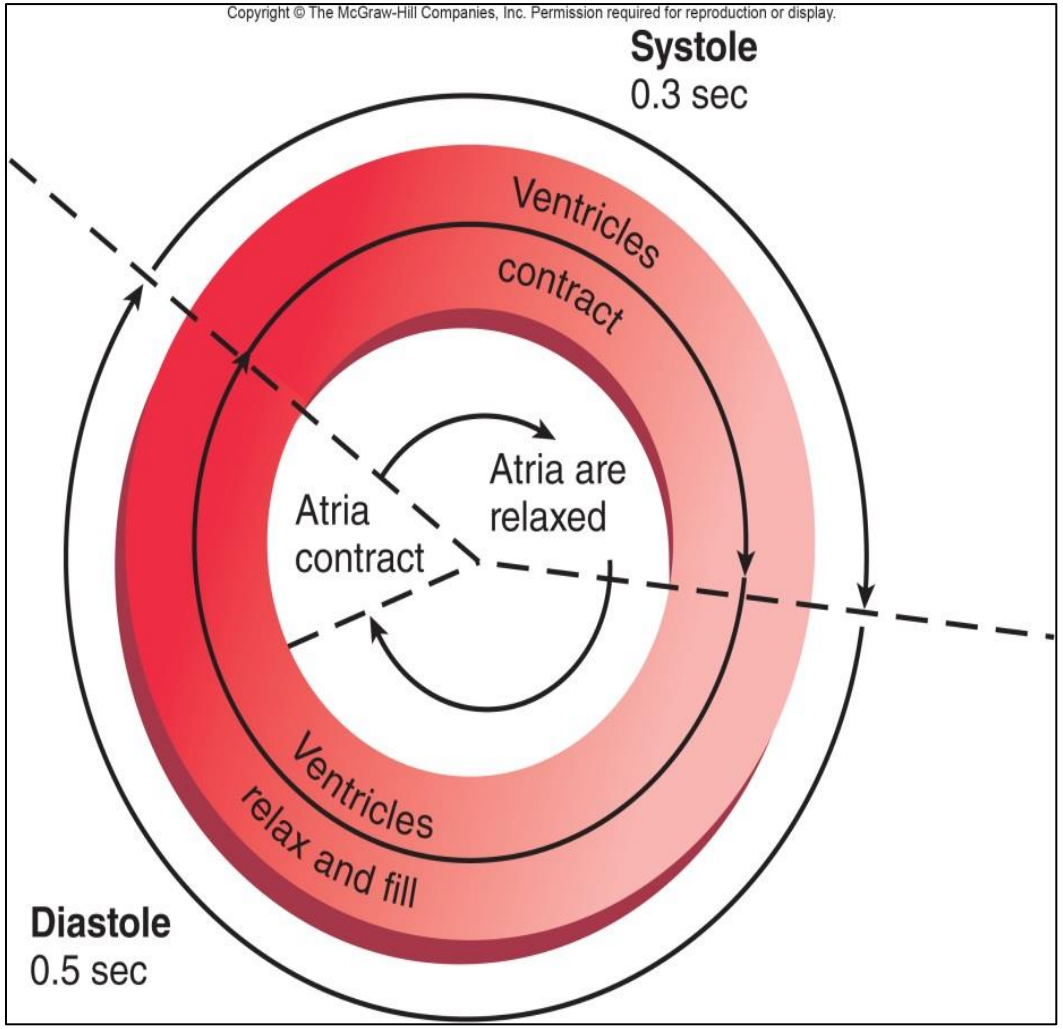
•The Cardiac Cycle

1. The **venous** return of blood fills the **atria**
2. The **returned blood** will cause to buildup **pressure** in the **atria** and the **AV** valves to **open** and **blood** to flow from **atria** to **ventricles**. by the action of this pressure, ventricles are about **80% filled with blood**.
3. Then **contraction of the atria** occurs: adds the final **20%** to the ***end-diastolic volume*** (**the total volume of blood in the ventricles at the end of diastole**).
4. When **ventricles** are **filled**, **contraction** of the ventricles in systole occurs and **ejects** about **two thirds** of the blood they contain (an amount called the ***stroke volume***) one-third of the initial amount left in the ventricles as the ***end-systolic volume***. The ventricles then fill with blood during the next cycle.

The Cardiac Cycle

1. At an average *cardiac rate* of 75 beats per minute, each cycle lasts 0.8 second (0.5 second is spent in diastole, and systole takes 0.3 second).

- **Contraction** of the atria occurs in the last 0.1 second of ventricular diastole.
- **Relaxation** of the atria occurs during ventricular systole.



Pressure changes during the Cardiac Cycle Events:

These events in the cardiac cycle then occur:

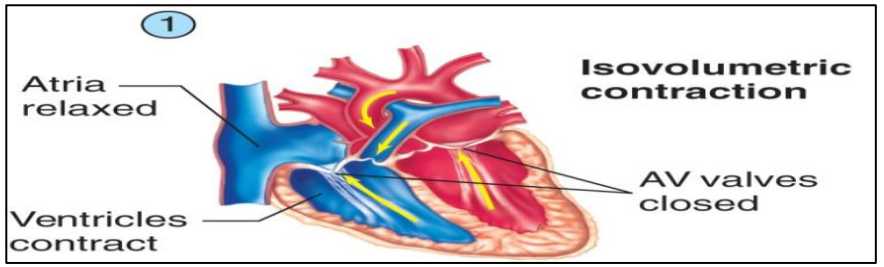
1. **Isovolumetric contraction phase:** As the **ventricles** begin their **contraction**, the intraventricular **pressure rises**, causing the **AV valves to snap shut (S1)**. At this time, the ventricles are neither being filled with blood (because the **AV valves are closed**) nor ejecting blood (because the intraventricular pressure has not risen sufficiently to open the **semilunar valves**).

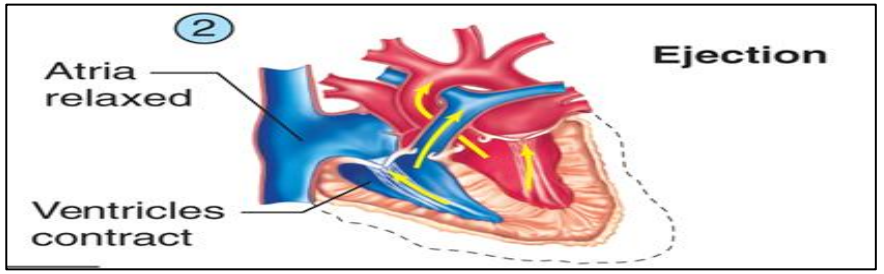
2. **Ejection phase:** When the **pressure** in the left ventricle becomes **greater** than the pressure in the **aorta**, the phase of **ejection** begins as the **semilunar valves open**. The pressure in the **left ventricle and aorta rises to about 120 mmHg** when ejection begins and the ventricular volume decreases.

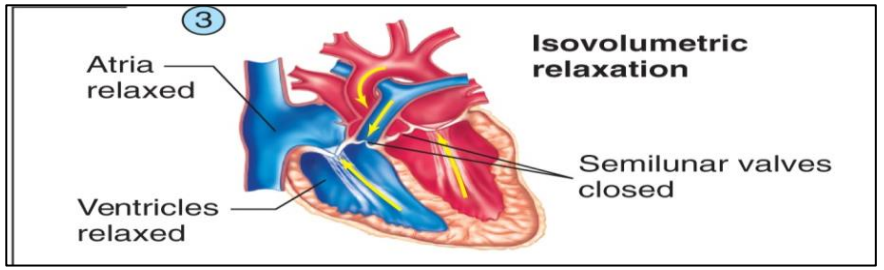
3. **Isovolumetric relaxation phase:** As the **pressure** in the **ventricles** falls **below** the pressure in the **arteries**, the back pressure causes the **semilunar valves to snap shut** (S2). The **pressure** in the **aorta** falls to **80** mmHg, while pressure in the **left ventricle** falls to **0** mmHg. During isovolumetric relaxation, the **AV and semilunar valves are closed.** This phase lasts until the **pressure** in the **ventricles falls** below the pressure in the **atria**.

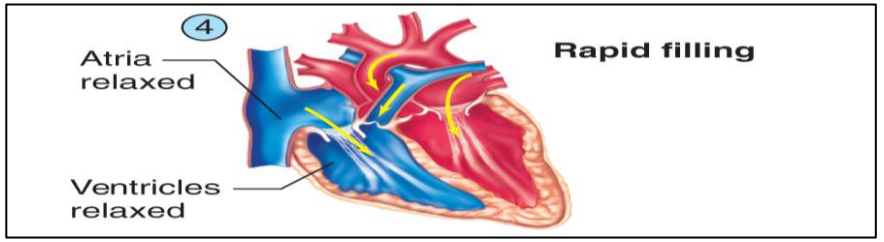
4. **Rapid filling phase:** When the **pressure** in the **ventricles** falls **below** the pressure in the **atria**, the **AV** valves **open** and a phase of **rapid filling** of the **ventricles** occurs.

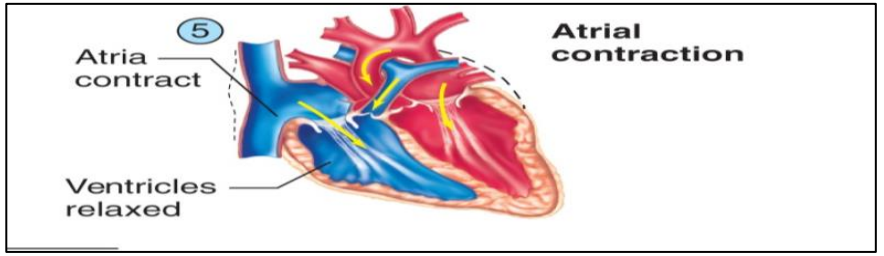
5. **Atrial contraction (atrial systole)** delivers the **final amount of blood** into the ventricles immediately prior to the next phase of isovolumetric contraction of the ventricles. Similar events occur in the **right ventricle** and pulmonary circulation, but the pressures are **lower**. The maximum pressure produced at systole in the right ventricle is **25 mmHg**, which falls to a low of **8 mmHg** at diastole.



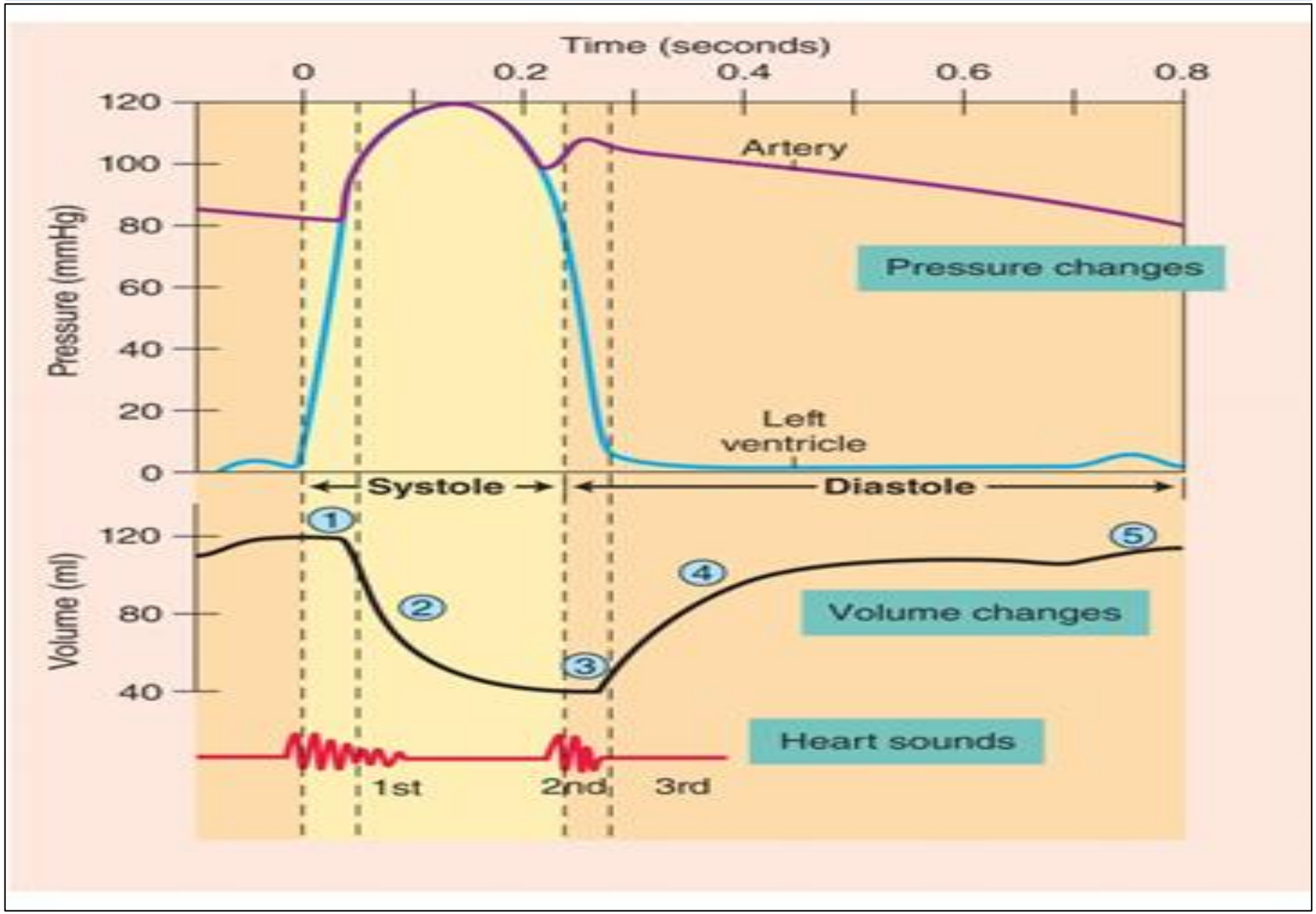








Pressure changes during the Cardiac Cycle Events:



The Electrocardiogram (ECG/EKG)

- **Potential differences** generated by the heart can be recorded by surface **electrodes** placed on the skin.
- **Potential** are conducted to the skin by the **tissue fluids**.
- The recording device is called an ***electrocardiograph***.
- The recording obtained is called an **electrocardiogram** (**ECG** or **EKG**).

The Electrocardiogram

- Each cardiac cycle produces three distinct ECG waves:
- **P wave:** spread of **atrial depolarization** and the entire mass of the atria is depolarized (corresponds to **contraction of the atria**).
- **QRS**: spread of **depolarization** through the **ventricles** (corresponds to **contraction of the ventricles**).
- **Relaxation of atria** wave is **masked** in QRS.
- **T wave:** repolarization of the ventricles (corresponds to **ventricles relaxation**).

1. P wave:

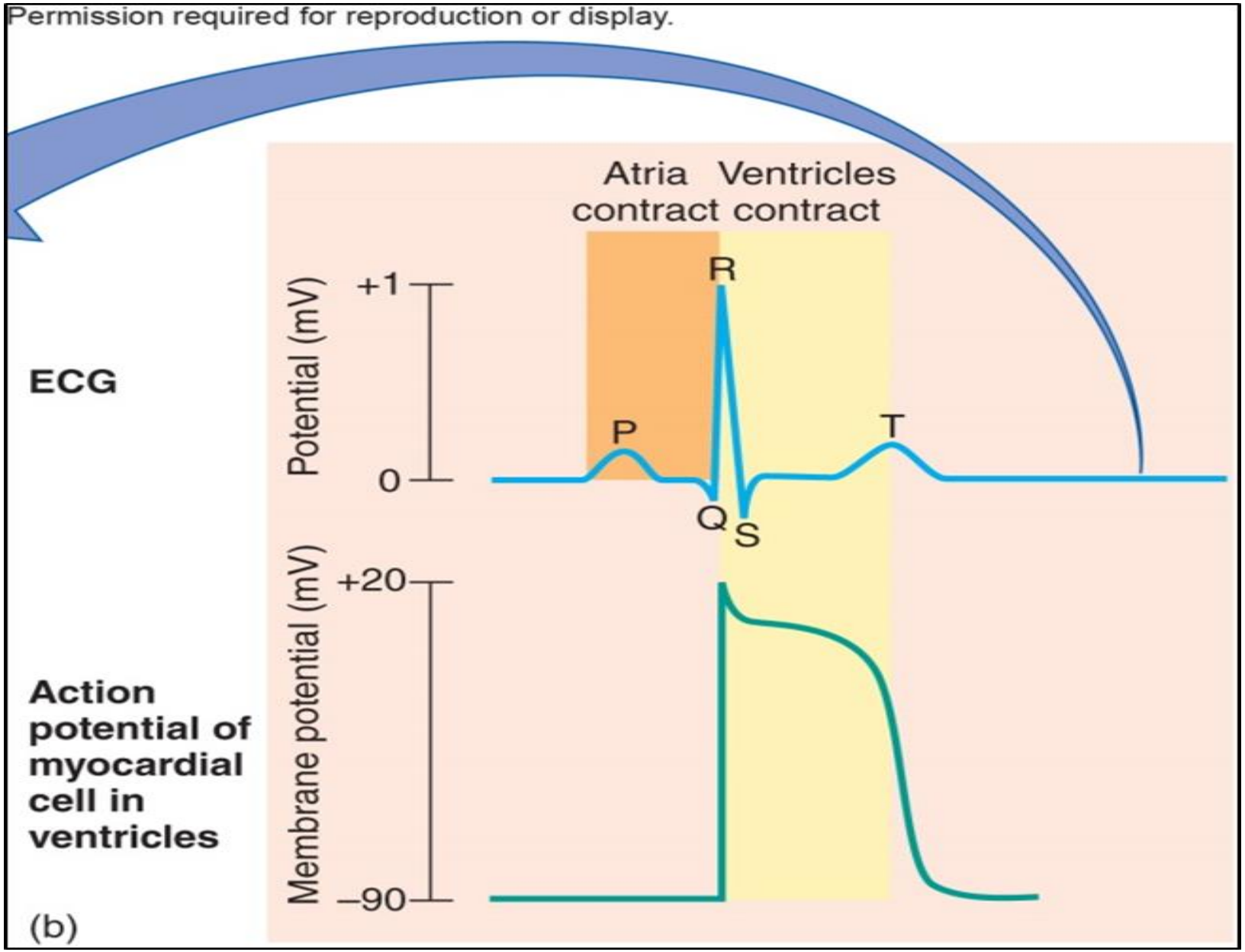
- spread of atrial depolarization and the entire mass of the atria is depolarized (corresponds to contraction of the atria).
- **Upward deflection of the ECG line**: **half the mass of the atria is depolarized.**
- When the **entire mass of the atria is depolarized,** the ECG **returns to baseline** because all regions of the atria have the same polarity.

2. QRS wave

- A combination of the Q wave, R wave and S wave, the "**QRS complex**" **represents** ventricular depolarization of the right and left ventricles of the human heart
- The **ST segment** is the flat section of the ECG between the end of the S wave and the beginning of the T wave.
- The **ST Segment** represents the interval between ventricular depolarization and repolarization.

3. T wave

- Same occurs in the ventricles (repolarization)**.**



Chapter 16: Respiratory Physiology

Respiratory Physiology

The respiratory system is divided into a
1- Respiratory zone= which is the site of gas exchange between air and blood,
2- conducting zone.

The term respiration includes three separate but related functions:

(1) Ventilation (breathing)
(2) Gas exchange, which occurs between the air and blood in the lungs and between the blood and other tissues of the body
(3) oxygen utilization by the tissues in the energy-liberating reactions of cell respiration.

Ventilation and the exchange of gases (oxygen and carbon dioxide) between the air and blood are collectively called ***external respiration.***

Gas exchange between the blood and other tissues and oxygen utilization by the tissues are collectively known as ***internal respiration***

Pathway of air

Air travels down the nasal cavity →

Pharynx →

Larynx (through the glottis and vocal cords) →

Trachea →

Right and left primary bronchi →

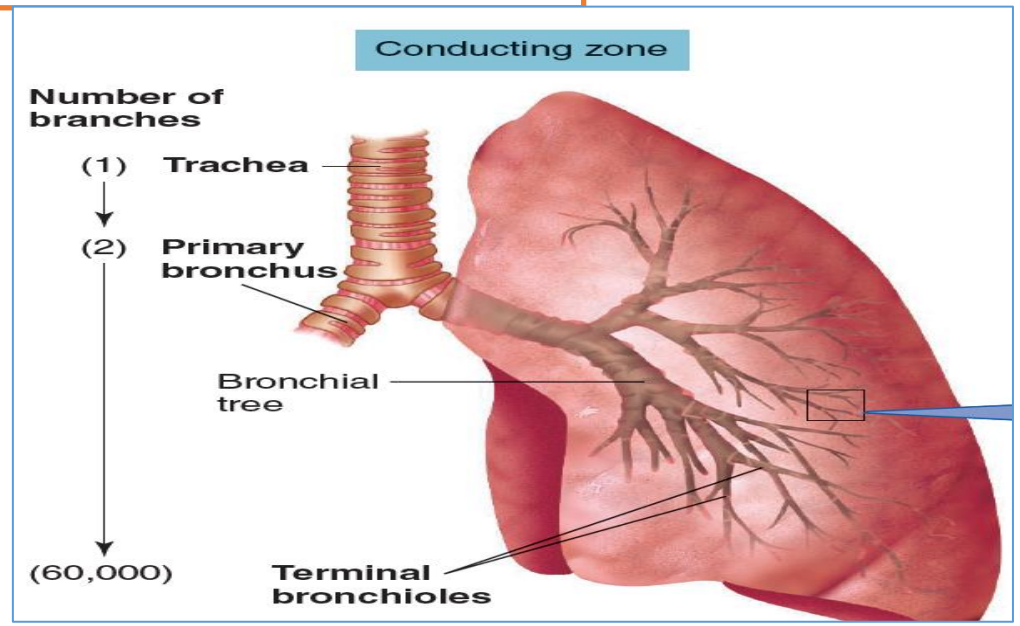
Secondary bronchi →

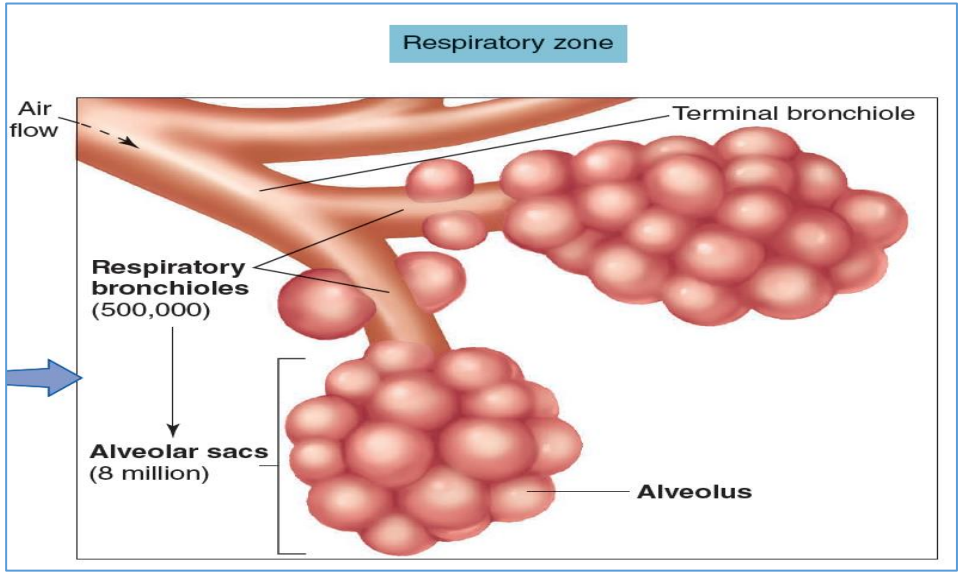
Tertiary bronchi → (more branching) →

Terminal bronchioles →

Respiratory zone (respiratory bronchioles →

Terminal alveolar sacs





Structure Of The Respiratory System

- Gas exchange in the lungs occurs across an estimated 300 million tiny air sacs known as alveoli.

There are two types of alveolar cells:

- **Type I** alveolar cells comprise 95% to 97% of the total surface area of the lung; gas exchange with the blood thus occurs primarily through type I alveolar cells

- **Type II** alveolar cells are the cells that secrete pulmonary surfactant and that reabsorb Na and H2O, thereby preventing fluid buildup within the alveoli.

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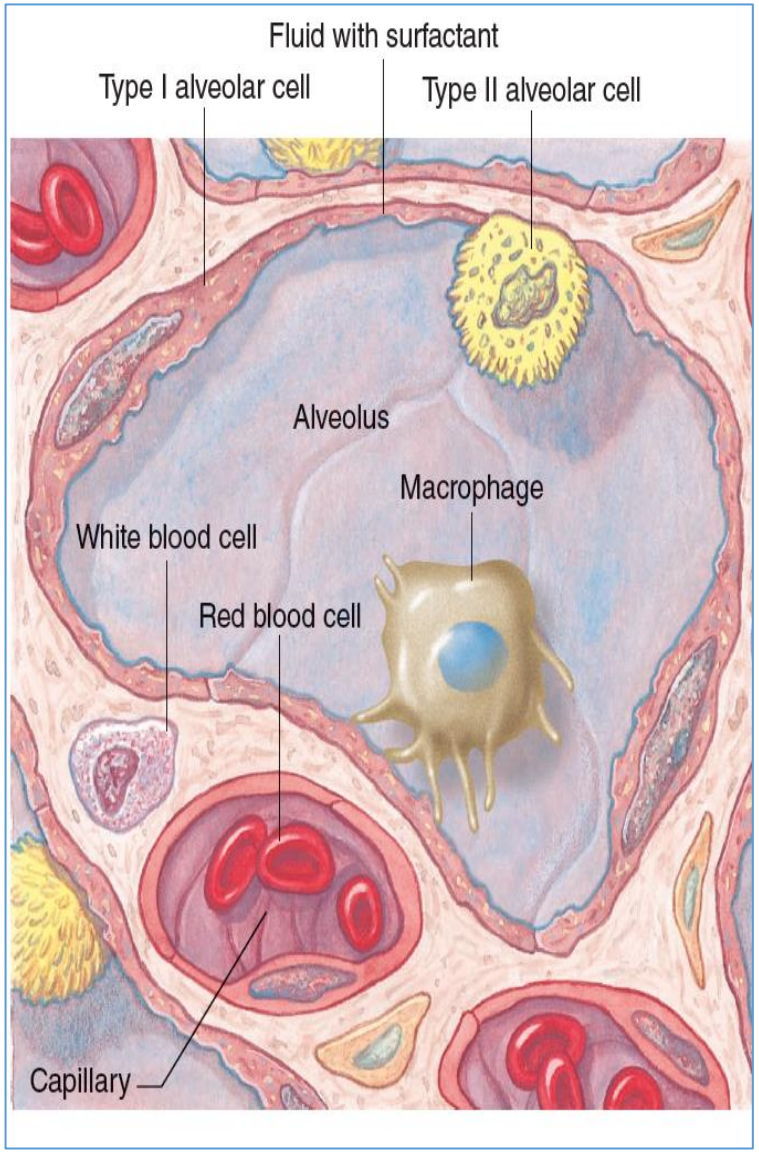


MECHANICS OF BREATHING

- **Normal,** quiet inspiration results from muscle contraction, and normal expiration from muscle relaxation and elastic recoil.
- The ***diaphragm,*** separates the thoracic and abdominal cavities and is the primary muscle of Ventilation
- Its function is aided by muscles that insert on the ribs. The ***external intercostal muscles and the internal intercostal muscles***.
- Inspiration results primarily from contraction of the dome-shaped diaphragm, which lowers and flattens when it contracts. This increases thoracic volume in a vertical direction.
- Inspiration is aided by contraction of the parasternal and external intercostals, which raise the ribs when they contract and increase thoracic volume laterally

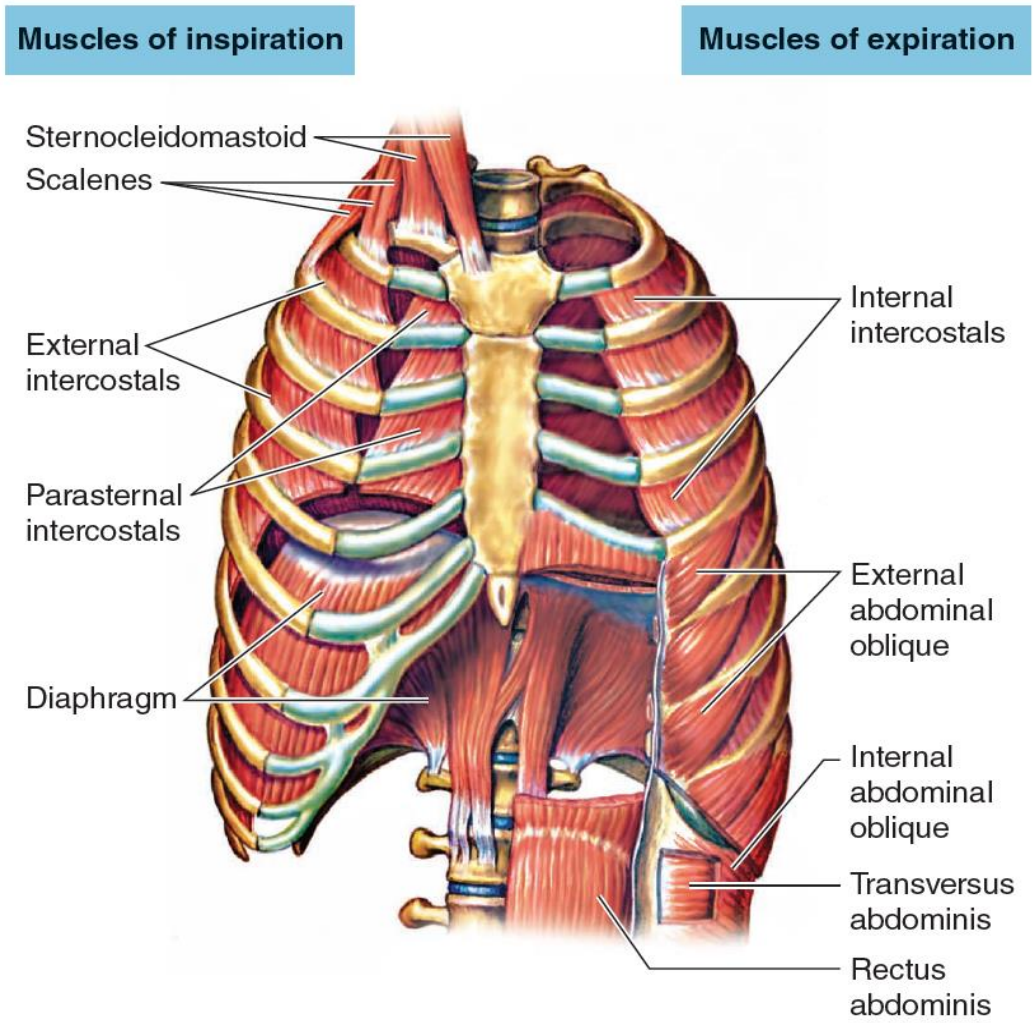


Figure 16.13 The muscles involved in breathing. The principal muscles of inspiration are shown on the left, and those of expiration are shown on the right.

MECHANICS OF BREATHING

- Quiet expiration is a passive process. After becoming stretched by contractions of the diaphragm and thoracic muscles, the thorax and lungs recoil as a result of their elastic tension when the respiratory muscles relax.

- The decrease in lung volume raises the pressure within the alveoli above the atmospheric pressure and pushes the air out

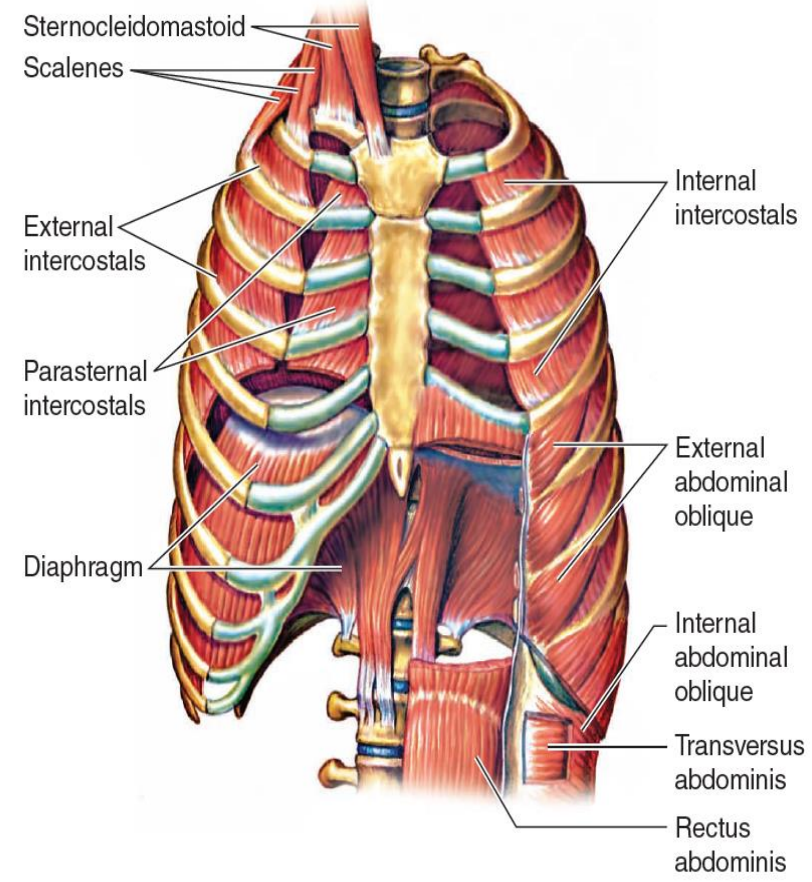


Figure 16.13 **The muscles involved in breathing.** The principal muscles of inspiration are shown on the left, and those of expiration are shown on the right.

Lung Volumes and Capacities

Pulmonary function may be assessed clinically by means of a technique known as ***Spirometry***

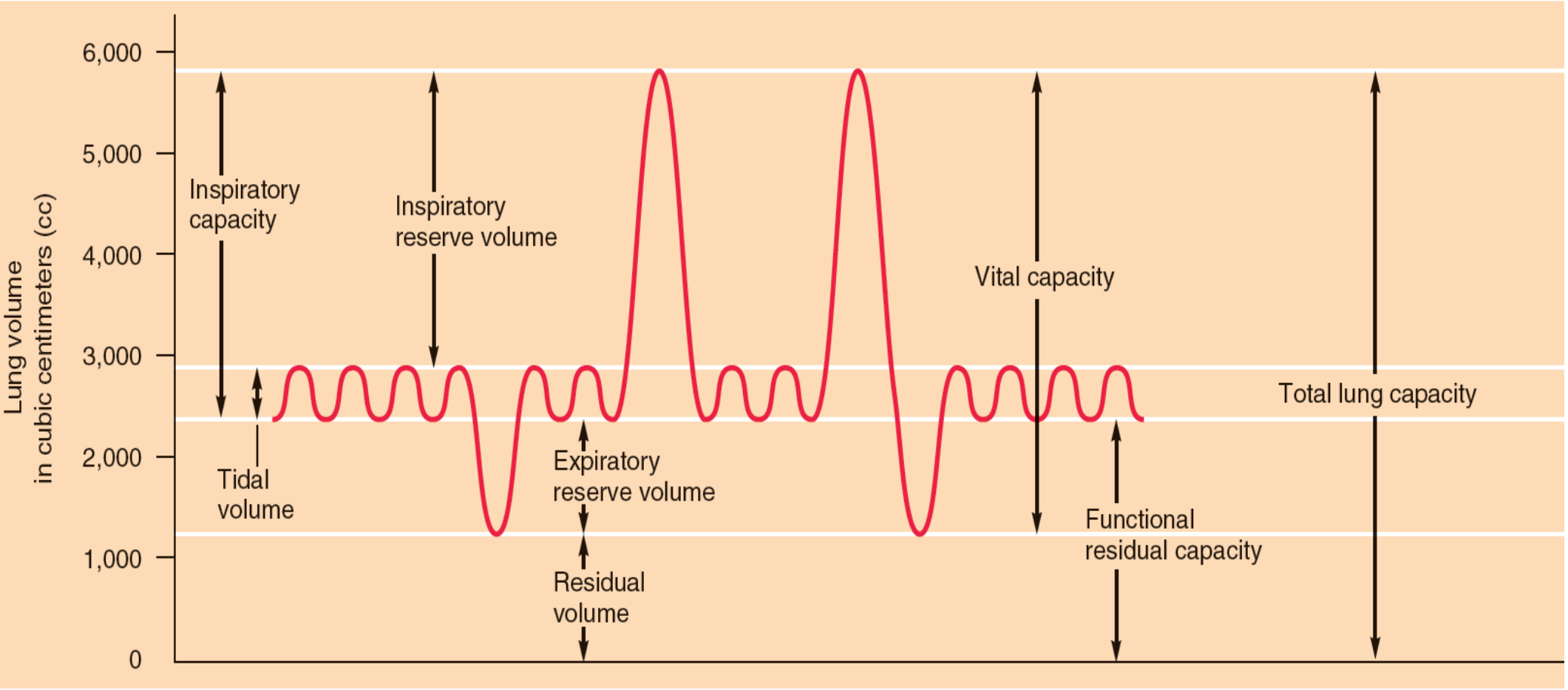
- Tidal volume= The amount of air expired in each breath
- Vital capacity= The maximum amount of air that can be forcefully exhaled after a maximum inhalation which is equal to the sum of the inspiratory reserve volume, tidal volume, and expiratory reserve volume
- The residual volume= is the volume of air you cannot expire, even after a maximum forced expiration. This air remains in the lungs because the alveoli and bronchioles normally do not collapse

- The expiratory reserve volume= is the additional air left in the lungs after an unforced expiration.

- functional residual capacity= The sum of the residual volume and expiratory reserve volume
- Multiplying the tidal volume at rest by the number of breaths per minute yields a total minute volume of about 6 L per minute.

- The vital capacity and the functional residual capacity are clinically important measurements.

Lung Volumes and Capacities



- This dead space comprises the conducting zone of the respiratory system— nose, mouth, larynx, trachea, bronchi, and bronchioles— where no gas exchange occurs.

GAS EXCHANGE IN THE LUNGS

- **Dalton's law:** the total pressure of a gas mixture (such as air) is equal to the sum of the pressures that each gas in the mixture would exert independently.

- The pressure that a particular gas in a mixture exerts independently is the partial pressure of that gas

For example:

- Oxygen constitutes about 21% of the atmosphere, its partial pressure (PO_2) is 21% of 760, or about 159 mmHg.

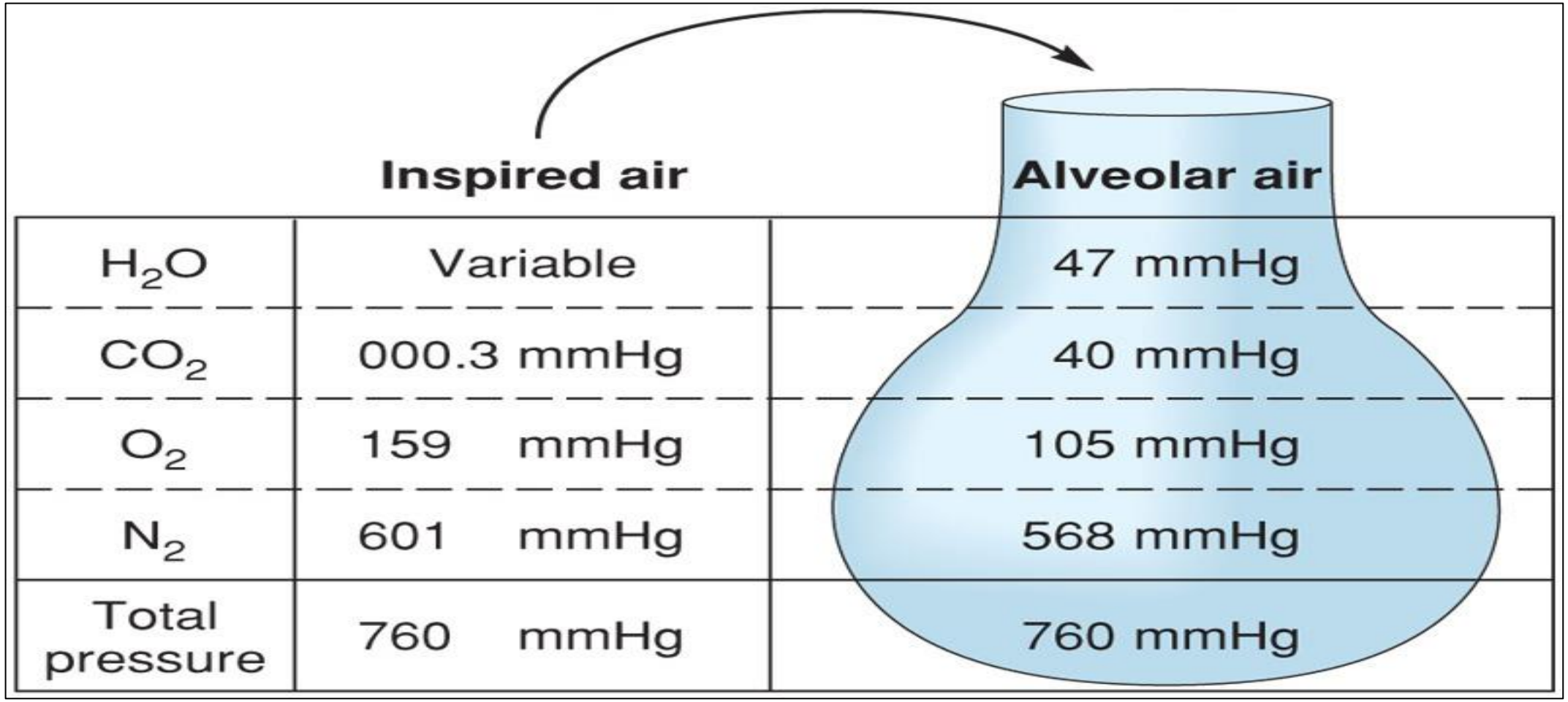
- Nitrogen constitutes about 78% of the atmosphere, so its partial pressure is equal to 0.78 x 760 = 593 mmHg.

These two gases thus contribute about 99% of the total pressure of 760 mmHg:

P dry atmosphere = $P_{N_2} + P_{O_2} + P_{CO_2} = 760$ mmHg

GAS EXCHANGE IN THE LUNGS

- Is driven by differences in partial pressures of gases between alveoli and capillaries



Pulmonary Circulation

- Rate of blood flow through pulmonary circuit ***equals*** flow through systemic circulation

- In the systemic circulation, the mean arterial pressure is 90 to 100 mmHg and the pressure of the right atrium is 0 mmHg; therefore, the pressure difference is about 100 mmHg.

- The mean pressure of the *pulmonary artery is only 15 mmHg* and the pressure of the *left atrium is 5 mmHg*. The driving pressure in the pulmonary circulation is thus 15 - 5, or 10 mmHg.

- Pulmonary vascular resistance is low

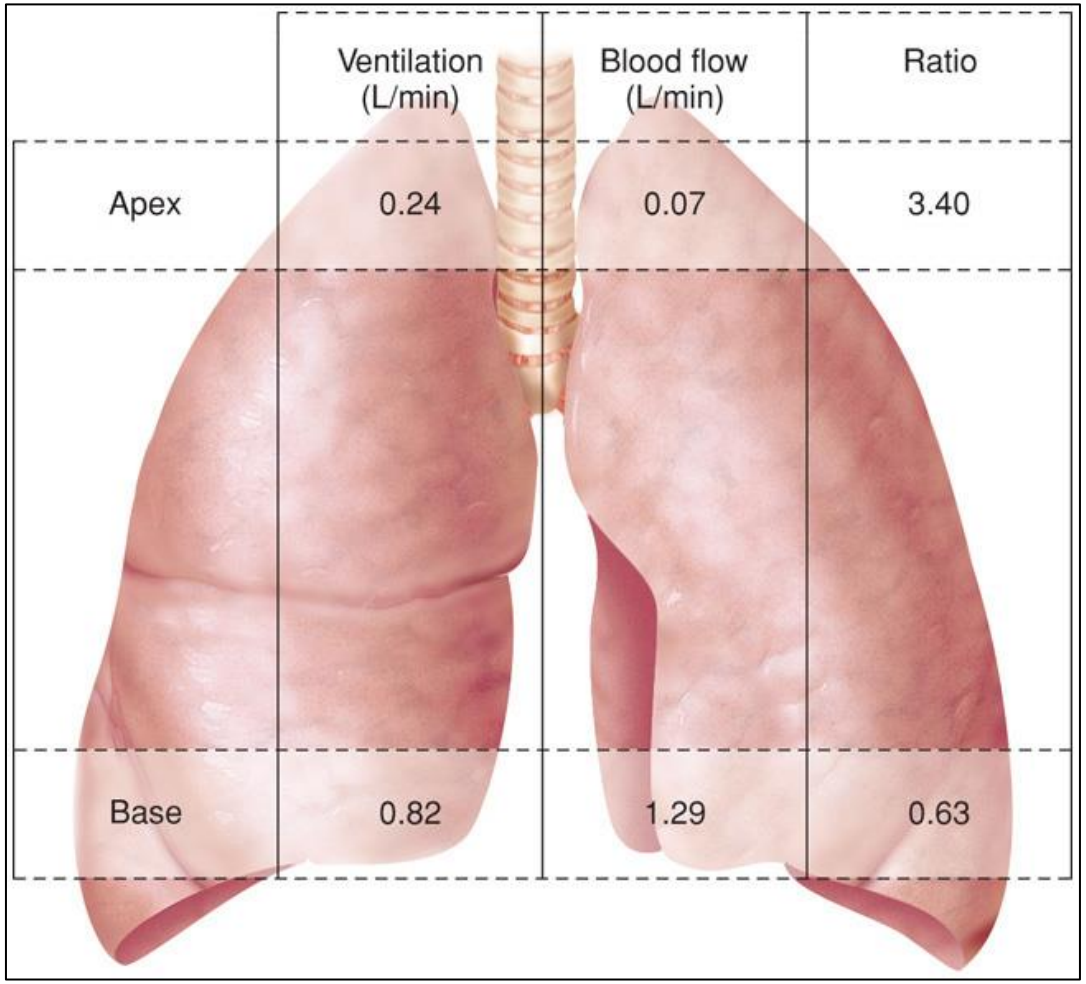
- Low pressure produces less net filtration than in systemic capillaries

-Avoids pulmonary edema

Lung Ventilation/Perfusion Ratios

- Normally, alveoli at ***apex*** of lungs are underperfused and overventilated
- Alveoli at ***base*** are overperfused and underventilated

Ratio = V (Ventilation) / Q (Blood Flow)



Chapter 17: PHYSIOLOGY OF THE KIDNEYS

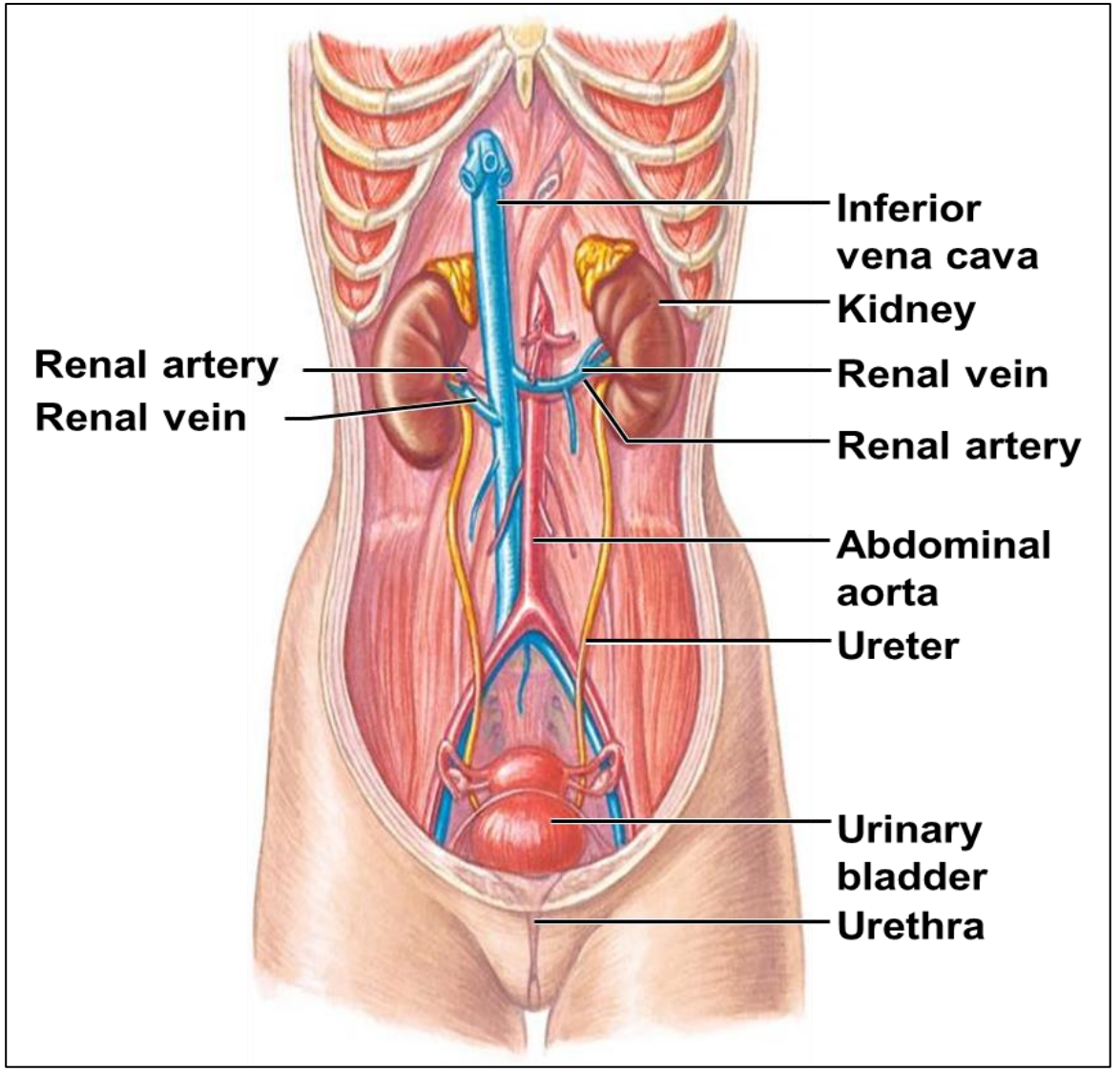
PHYSIOLOGY OF THE KIDNEYS

Functions of kidney:

- Remove waste products from the blood
- Control the acid base balance (through HCO_3^- & H^+)
- Electrolyte homeostasis (K^+, Na^+ and Ca^{++})
- Secrete Hormones and enzyme like erythropoietin and renin.
- Activates Vitamin D.
- Regulate body fluids and arterial blood pressure

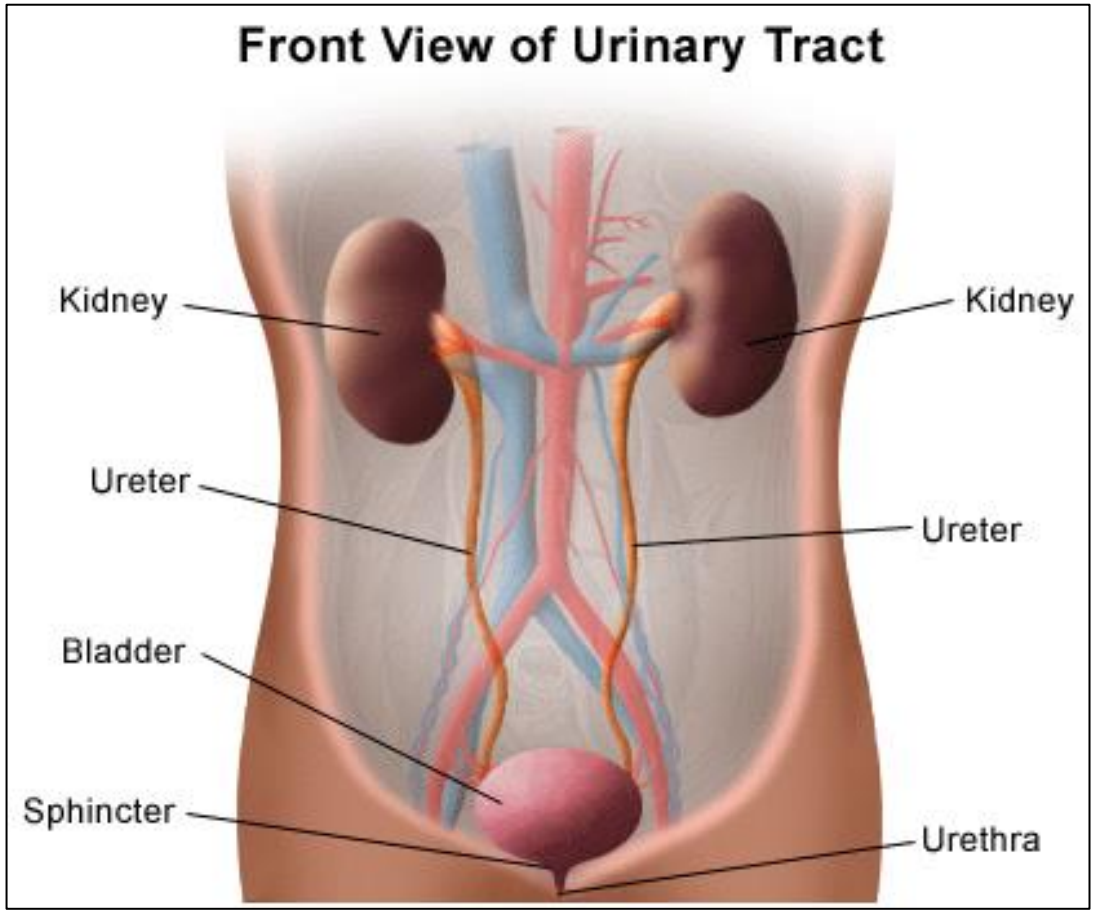
Gross anatomy of the urinary system

- Urine made in the kidney drains into the renal pelvis, then down the ureter to the urinary bladder.
- It passes from the bladder through the urethra to exit the body.
- Urine is transported using peristalsis.



Gross anatomy of the urinary system

- The urinary system of the human body consists of two kidneys, two ureters, the bladder and a single urethra.
- The kidneys are located on the **posterior wall** of the **abdomen** at waist level. Each kidney is roughly 10 cm long and 5 cm wide, and is encased in a fibrous outer capsule called the renal capsule.



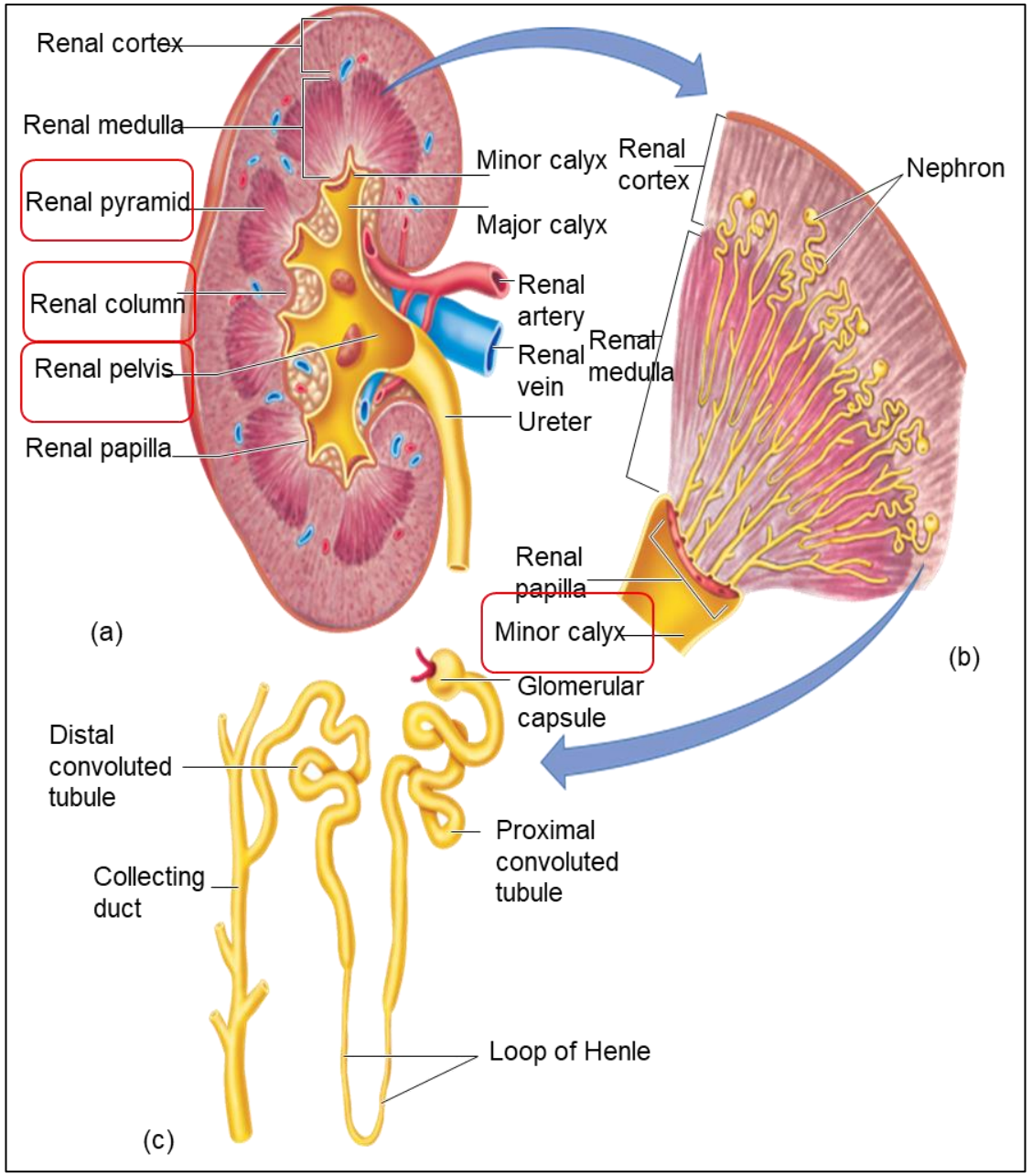
Internal Structure

- The kidney has an outer layer of **outer cortex** which surrounds the **inner medulla.**

- The medulla consists of a number of **medullary pyramids**, named because of their triangular shape. These are striped in appearance because they contain microscopic coiled tubes called **nephrons**, the functional unit of the kidney .

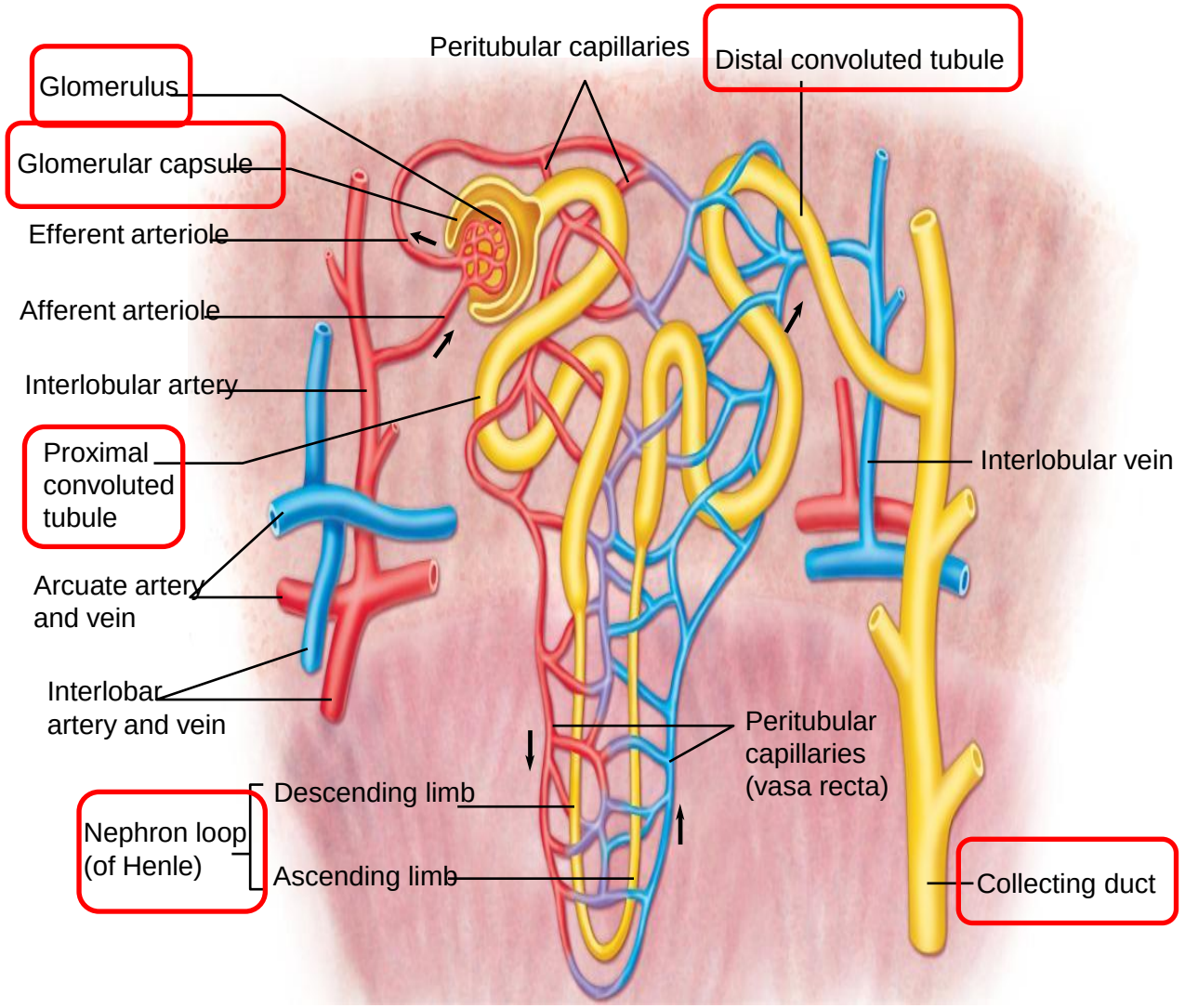
- **Urine** is made by the nephrons and drains into tiny collecting ducts within the medullary pyramids. The collecting ducts merge at the base of the pyramids to form the **renal papilla**.

- From the papilla, urine drains into cuplike structures called the **major and minor calyces**. From the calyces the urine drains into the wider open space of the renal pelvis. This acts like a funnel draining the urine out of the kidney into the **ureter**.



Nephron

- **The Nephron** is the functional unit of the kidney (1 million/kidney).
- **Nephron** consists of **small tubules** and associated **blood vessels**.
- Blood is filtered, fluid enters the tubules, then modified, then leaves the tubules as urine.
- **Glomerular (Bowman's) capsule** surrounds the **glomerulus**. Together, they make up the **renal corpuscle**.
- Filtrate produced in renal corpuscle passes into the **proximal convoluted tubule**.
- Fluid passes into the **descending and ascending limbs of the loop of Henle**.
- After the loop of Henle, fluid passes into the **distal convoluted tubule**.
- Finally, fluid passes into the **collecting duct**.
- The fluid is now urine and will drain into a **minor calyx**.

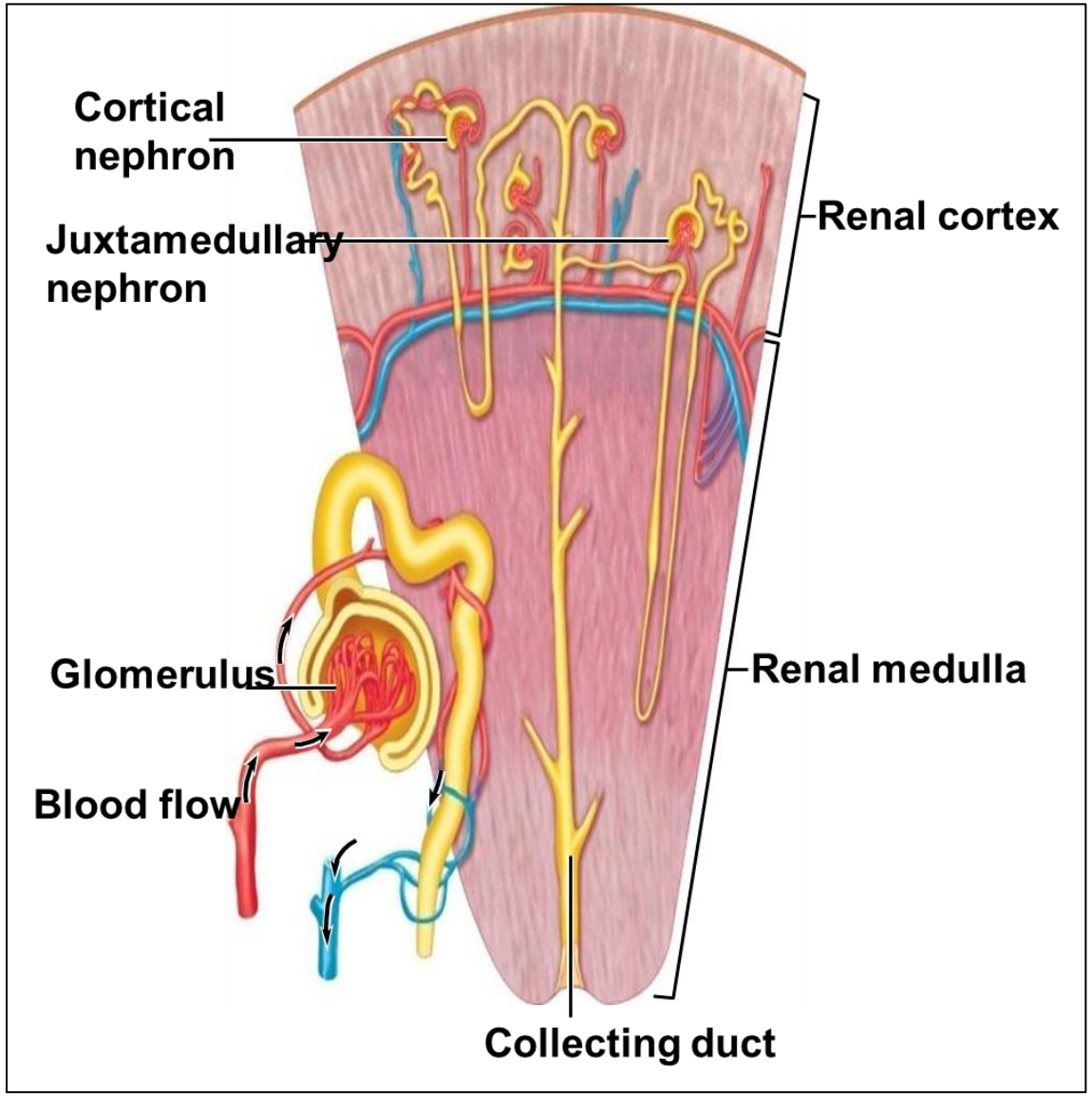


Types of Nephrons

- The two principal types of nephrons are classified according to their position in the kidney and the lengths of their loops of Henle.

1. Juxtamedullary Nephrons that originate in the inner one-third of the cortex—called juxtamedullary nephrons because they are next to the medulla—have longer nephron loops, better at making concentrated urine.

2. Cortical nephrons which originate in the outer two thirds of the cortex



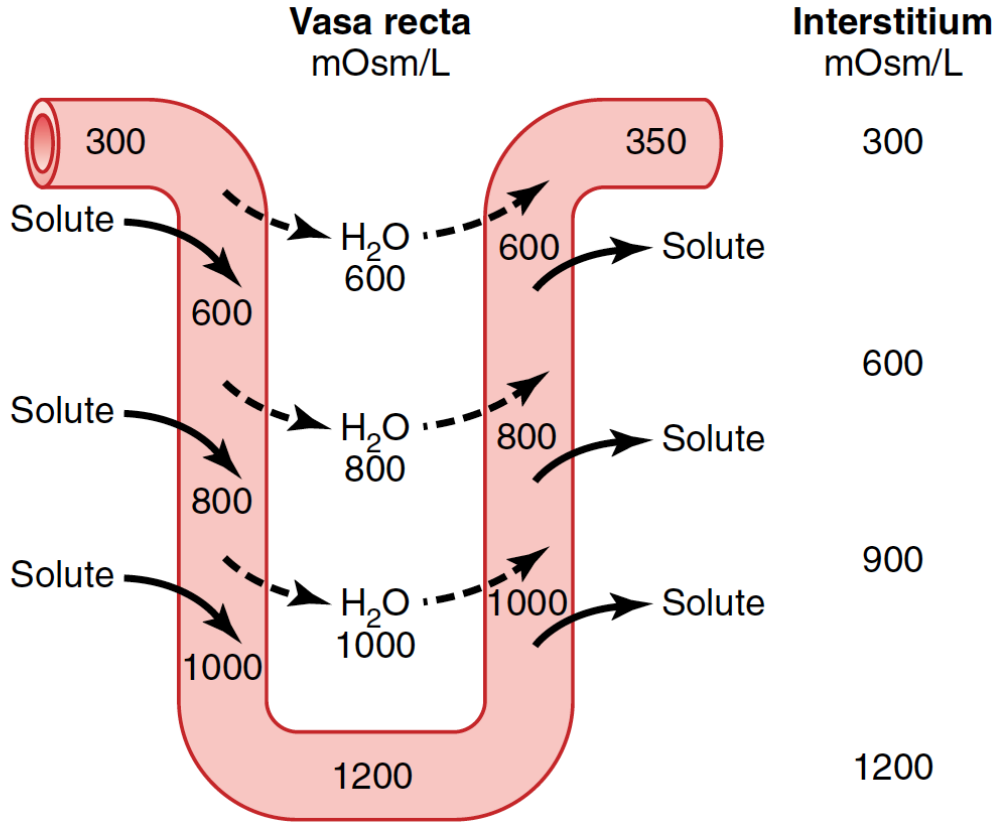
Modified Slide

Countercurrent Exchange in the Vasa Recta

Vasa recta support the countercurrent system by

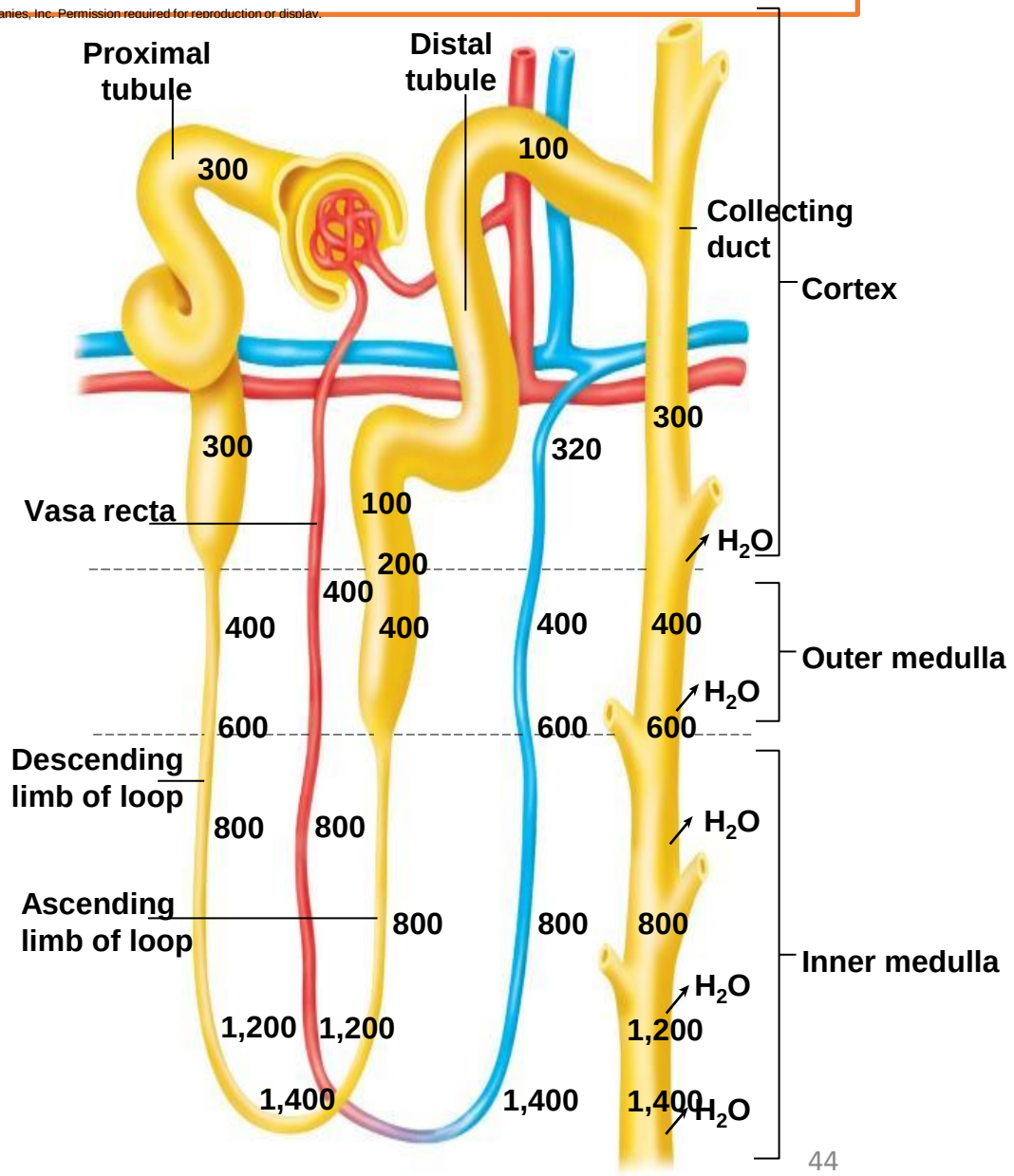
The diffusion of salt and water first into and then out of these blood vessels helps to maintain the "saltiness" (hypertonicity) the interstitial fluid in the renal medulla.

Countercurrent exchange in the vasa recta.
Plasma flowing down the **descending limb** of the vasa recta becomes more hyperosmotic because of diffusion of water out of the blood and diffusion of solutes from the renal interstitial fluid into the blood.
In the **ascending limb** of the vasa recta, solutes diffuse back into the interstitial fluid and water diffuses back into the vasa recta.



Renal Tubule Osmolality

The countercurrent multiplier system in the nephron loop and countercurrent exchange in the vasa recta help to create a hypertonic renal medulla

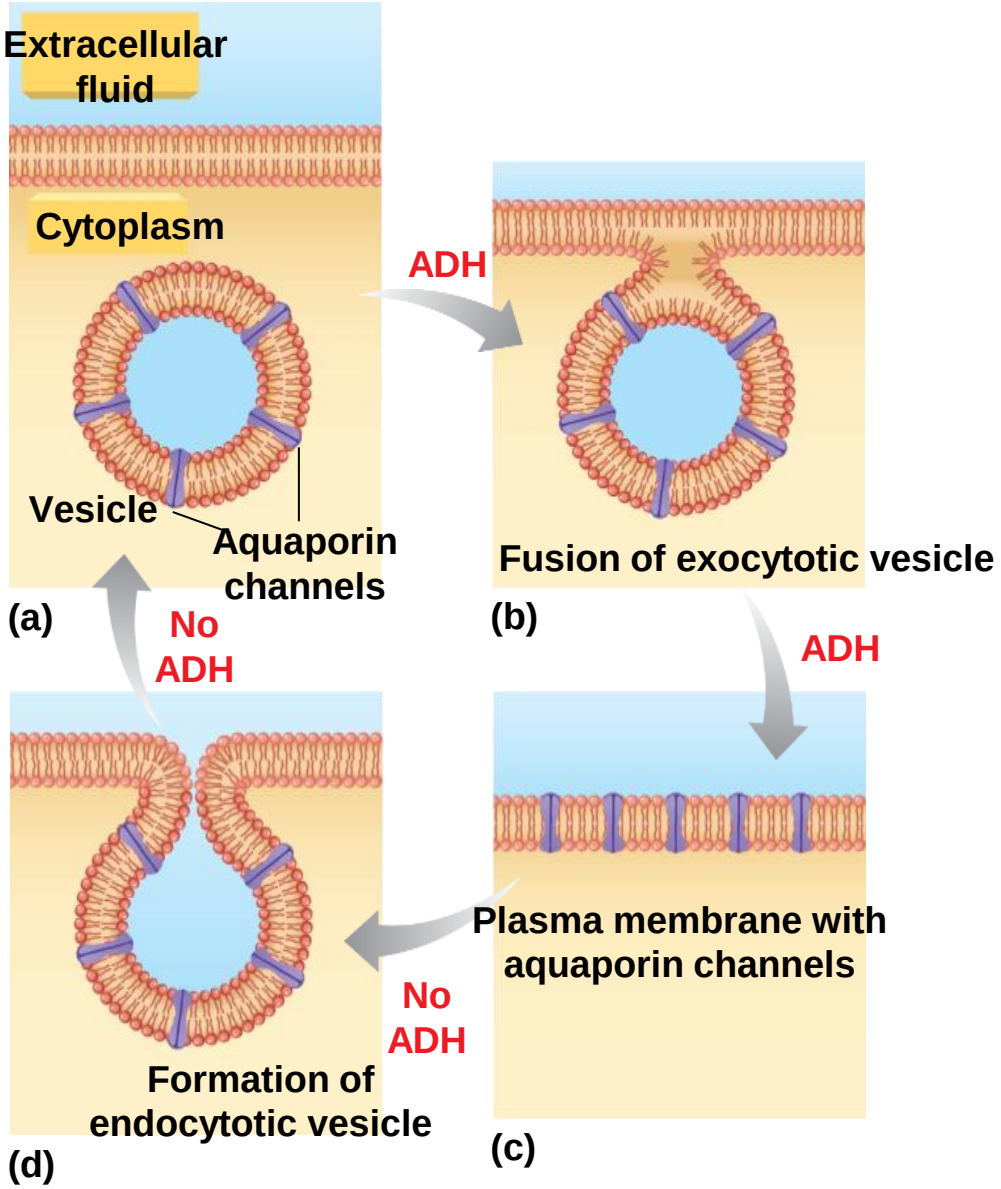


Collecting Duct and ADH

- Aquaporins: are channels for increasing the reabsorption of water by the epithelial cells of the collecting duct.
- During dehydration:

1. The plasma becomes more concentrated.
2. Osmoreceptors in the hypothalamus react by producing ADH, which is then stored and secreted by the posterior pituitary.
3. When ADH binds to its receptors in the cells of the collecting ducts, aquaporins in cytoplasmic vesicles travel and fuse with the plasma membrane.
4. The collecting duct will increase water reabsorption to reduced volume of excreted urine.
5. When the osmolality of plasma decreases, the plasma levels of ADH decreases, and aquaporins are removed from the plasma membrane by a process of endocytosis, which results in less reabsorption of water and thus larger volume of more dilute urine is excreted.

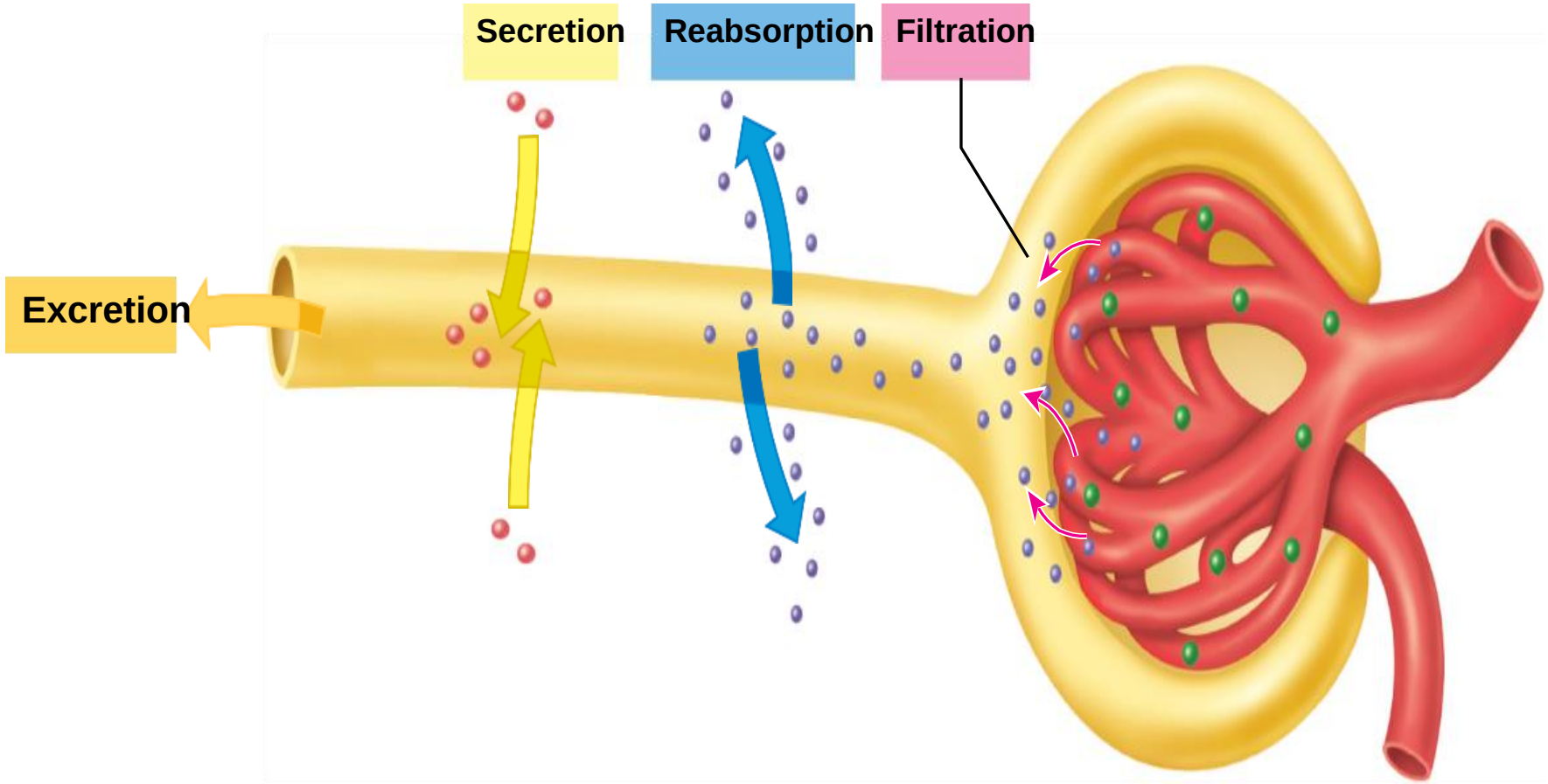
ADH Stimulation of Aquaporin Channels



Renal Plasma Clearance:
Transport processes affecting renal clearance

- Renal clearance of a substance refers to the how quickly a particular substance is removed from the plasma by the kidney and excreted in urine.
- Kidneys must also **remove excess ions** and **wastes** from the blood, called **renal clearance.**
- **Filtration** in the glomerular capsule begins the process of clearance.(increases renal clearance)
- **Reabsorption** returns some substances to the blood (**decreases renal clearance**).
- **Secretion** finishes the process when substances are moved from the peritubular capillaries into the tubules. (**increases renal clearance**).

Secretion is the reverse of reabsorption



Renal Plasma Clearance:
Transport processes affecting renal clearance

- Excretion rate = (filtration rate + secretion rate) - reabsorption rate; or = clearance - reabsorption.
- It follows that if a substance in the plasma is filtered (enters the filtrate in Bowman's capsule) but is neither reabsorbed nor secreted, its excretion rate must equal its filtration rate.
- This fact is used to measure the volume of blood plasma filtered per minute by the kidneys, called the glomerular filtration rate (GFR).
- Measurement of the GFR is very important in assessing the health of the kidneys.
- The volume of blood plasma filtered per minute by the kidneys is called the glomerular filtration rate (GFR).

Secretion of Drugs

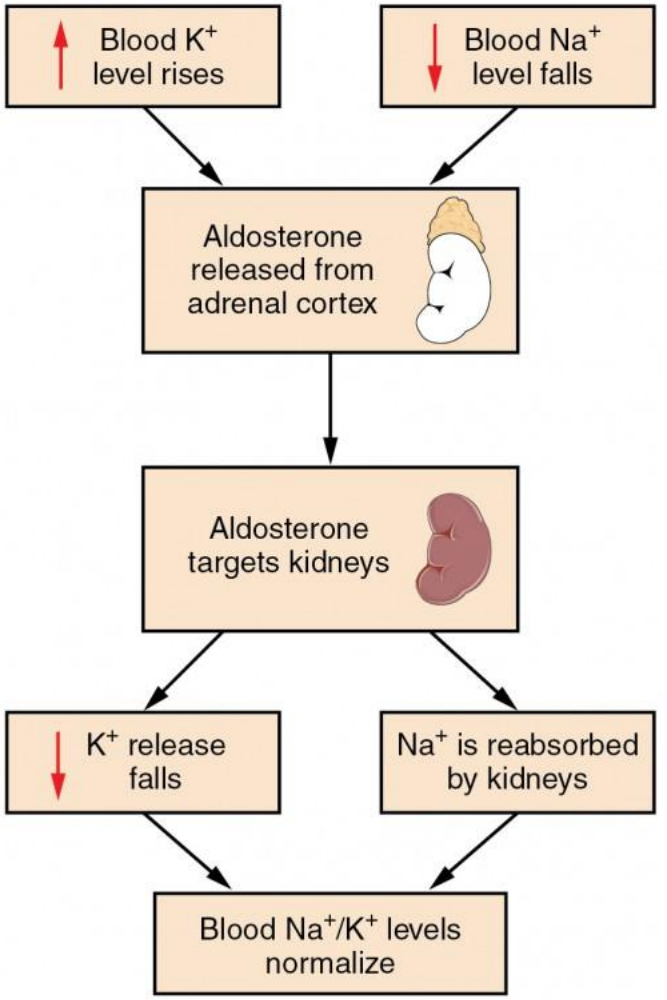
- Many membrane carriers (transport proteins) **secrete** xenobiotics *(molecules foreign* to the body) from the plasma into the filtrate in the tubules.
- Among the major groups of transport proteins that eliminate xenobiotics are the Organic anion transporter (OAT) family and the organic cation transporters (OCTs).
- Examples: (OAT eliminates Penicillin) and (OCT eliminates nicotine and metformin, a drug used to treat type 2 diabetes mellitus)
- The transport proteins are poly-specific, so they overlap in function.
- The transport proteins eliminate xenobiotics in the urine very rapidly, which may interfere with action of therapeutic drugs.

Renal Control of Electrolyte Balance

- The kidneys regulate plasma concentrations of electrolytes (Na^+, K^+, Cl^-, bicarbonate, phosphate) by matching its excretion to amounts ingested.
- Control of Na^+ levels is important in blood pressure and blood volume.
- Control of K^+ levels is important in healthy skeletal and cardiac muscle activity.
- **Aldosterone** plays a big role in **Na^+ and K^+ balance**.

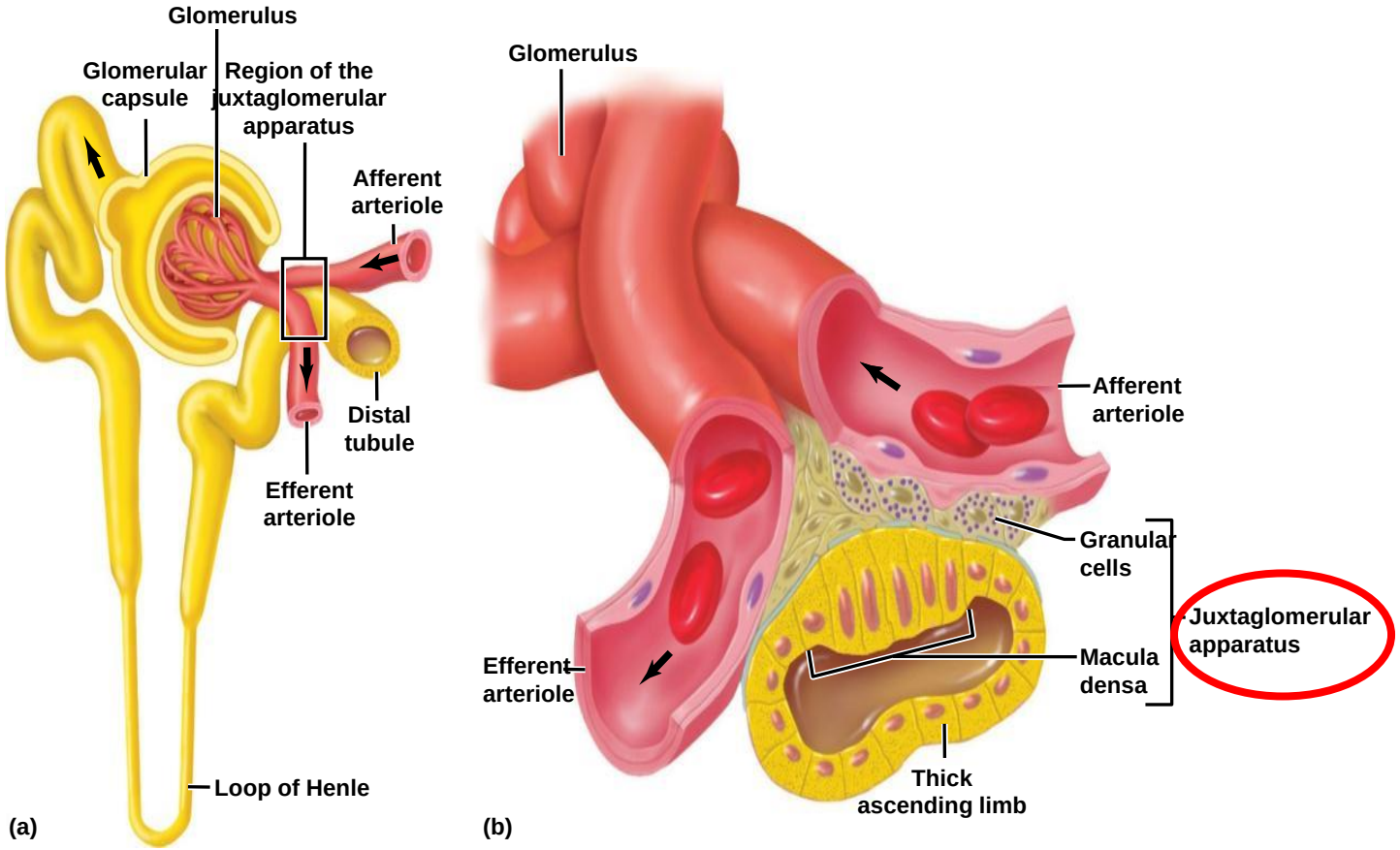
Role of Aldosterone in Na^+/K^+ Balance

- About 90% of the filtered Na^+ and K^+ is reabsorbed in the early part of the nephron at a constant rate and without hormonal regulation.
- Aldosterone controls additional reabsorption of Na^+ and secretion of K^+ according to the needs of the body.
- Aldosterone stimulates Na^+/K^+ (ATPase) pumps in the basolateral membrane of the cortical collecting duct cells and the distal tubule.
- A rise in blood K^+ directly stimulates production of aldosterone in the adrenal cortex.
- A fall in blood Na^+ indirectly stimulates production of aldosterone via the renin- angiotensin-aldosterone system



Juxtaglomerular Apparatus

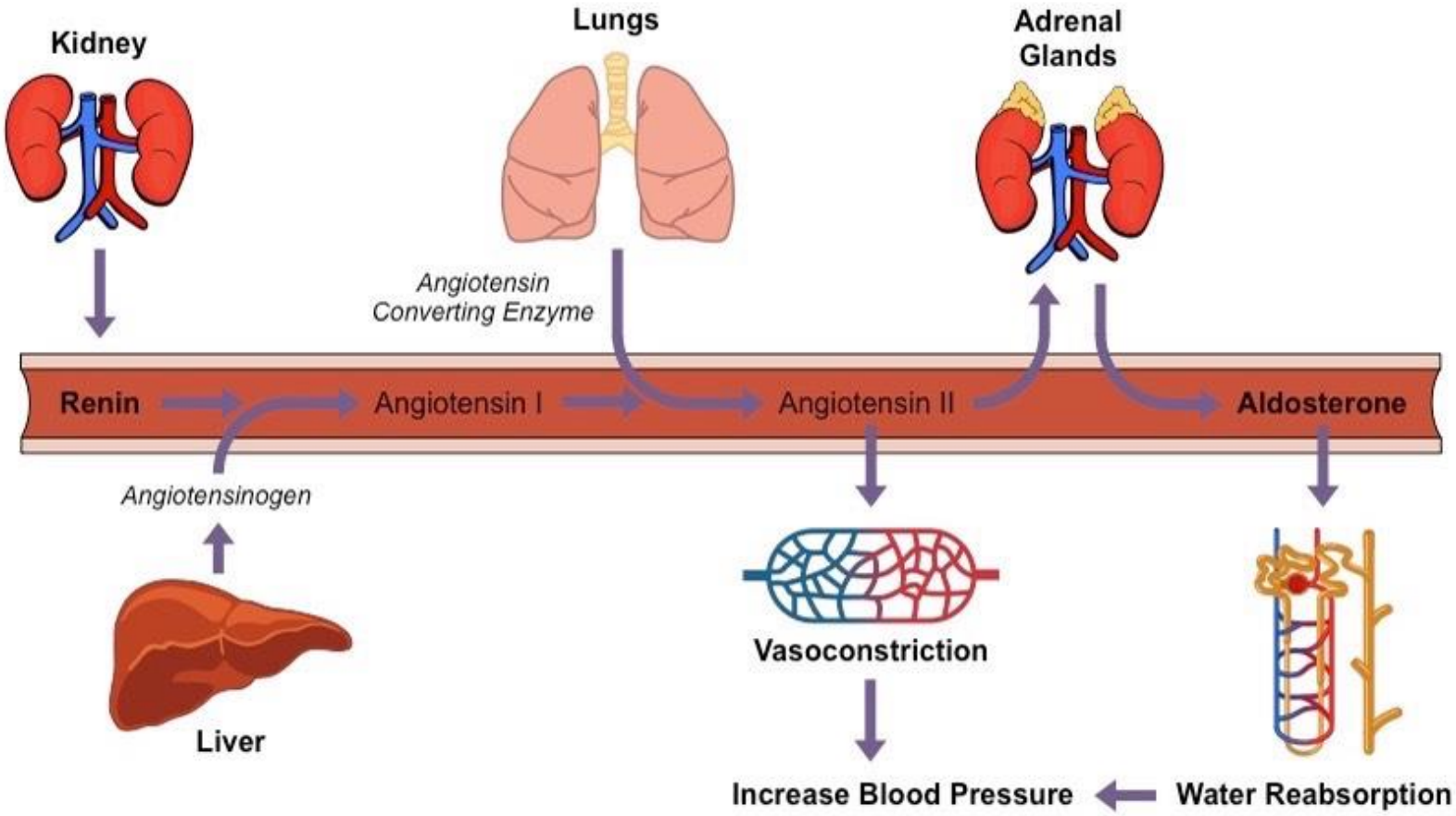
- Juxtaglomerular apparatus: are renal cells that regulates renal blood flow by secreting the enzyme **renin.**
- The apparatus structure is located where the afferent arteriole meets distal tubule near the glomerulus.
- Cells of the Juxtaglomerular apparatus are: the granular cells located in the walls of arterioles, and the macula densa cells of the distal tubule.



The renin-angiotensin-aldosterone system of the Juxtaglomerular apparatus:

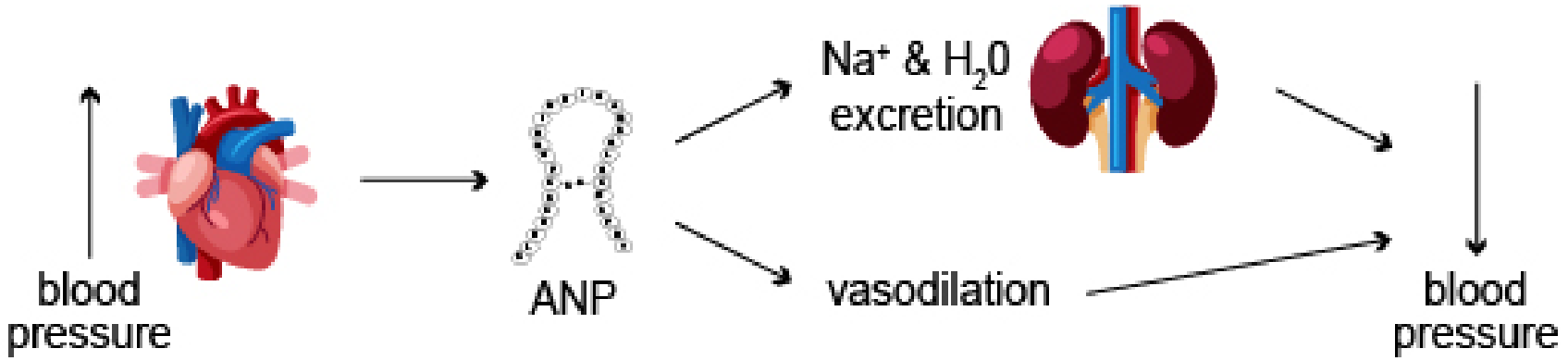
1. A decrease in plasma Na^+ results in a fall in blood volume.
2. Granular cells of the juxtaglomerular apparatus respond to that fall by secreting renin into the afferent arteriole.
3. Renin catalyzes the conversion of angiotensinogen (a circulating protein in the blood plasma) into angiotensin I.
4. Angiotensin I is further converted into angiotensin II in the lungs; endothelial cells in the lung has the necessary enzymes for converting angiotensin I: Angiotensin-converting enzyme (ACE).
5. Angiotensin II stimulates the adrenal cortex to secrete aldosterone and, by this means, promote the reabsorption of Na^+ and the secretion of K^+ from cortical collecting duct.
6. Angiotensin II also stimulates vasoconstriction of afferent and efferent arterioles, leading to a decrease in GFR and Na^+ excretion.

The renin-angiotensin-aldosterone system of the Juxtaglomerular apparatus:



Atrial Natriuretic Peptide

- The increase in blood volume causes the atrial walls of the heart to stretch.
- This stretching causes the release of the atrial natriuretic peptide hormone (ANP).
- ANP stimulates kidneys to excrete more salt and water to decrease blood volume and blood pressure.



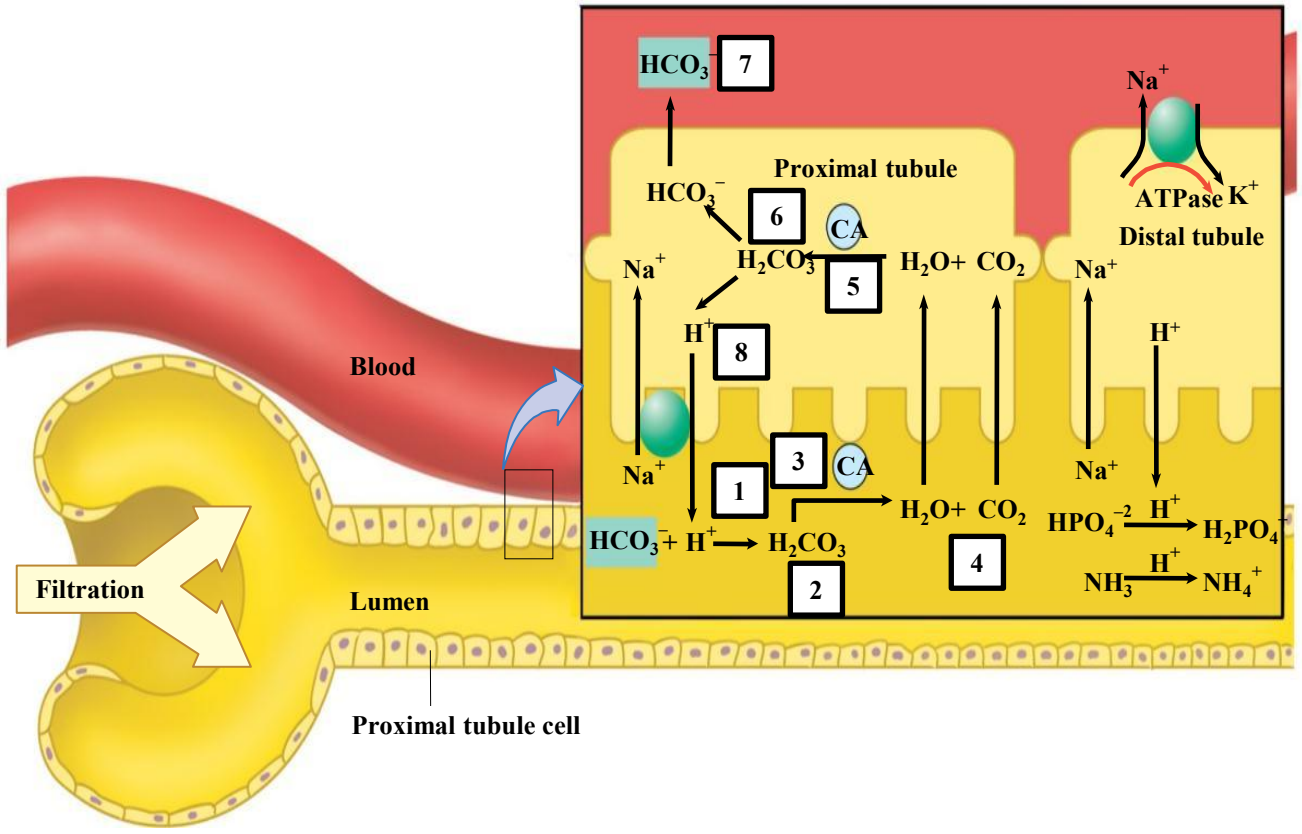
Acid-Base Regulation

- Kidneys maintain blood pH by reabsorbing bicarbonate (HCO^{-3}) and secreting H^+; urine is thus acidic.

- Urine is acidic also because H^+ is actively secreted into the filtrate using transport H^+ (ATPase) pumps.

Reabsorption of bicarbonate is indirect through the following mechanism: Acidification of the Urine

1. The cells of the proximal tubule use Na^+/H^+ pumps to transport H^+ into the filtrate in exchange for Na^+.
2. Filtered bicarbonate (HCO^-_3) combines with H^+ to form carbonic acid (H_2CO_3) in the filtrate.
3. Carbonic anhydrase enzyme (CA) in the membranes of microvilli in the tubules catalyzes the conversion of carbonic acid to carbon dioxide (CO_2) and water (H_2O).
4. CO_2 and H_2O diffuses into the tubule cells.
5. Carbonic anhydrase enzyme (CA) within the cell cytoplasm catalyze the conversion of CO_2 and H_2O to carbonic acid (H_2CO_3).
6. Carbonic acid (H_2CO_3) dissociates to H^+ and bicarbonate (HCO^-_3).
7. Bicarbonate (HCO^-_3) then diffuses into the blood stream.
8. H^+ is excreted in the urine and buffered by ammonium and phosphate buffers.



pH Disturbances

- The kidneys help **regulate the blood pH by excreting H + in the urine and by reabsorbing bicarbonate**. Because the kidneys normally reabsorb almost all of the filtered bicarbonate and excrete H + , normal urine contains little bicarbonate and is slightly **acidic** (with a pH range between 5 and 7).

- If a person has alkalosis= condition in which the pH of tissue is elevated beyond the normal range (7.35–7.45). This is the result of decreased hydrogen ion concentration, leading to increased bicarbonate, or alternatively a direct result of increased bicarbonate concentrations.

1. less H^+ is available in the filtrate,
2. so less HCO^-_3 can be reabsorbed.
3. **The urinary excretion of HCO^-_3 then helps to compensate for the alkalosis.**

pH Disturbances

- If a person has acidosis: increased acid production, loss of bicarbonate, and a reduced ability of the kidneys to excrete excess acids.
- More H^+ is available in the filtrate,

1. the proximal tubule cells can make extra bicarbonate and ammonia by metabolizing the amino acid glutamine.
2. This produced bicarbonate compensates for acidosis,
3. and the produced ammonia can then buffer the urinary H^+
4. Urinary buffers (phosphates (filtered in the glomeruli) and ammonia (derived from the metabolism of glutamic acid)