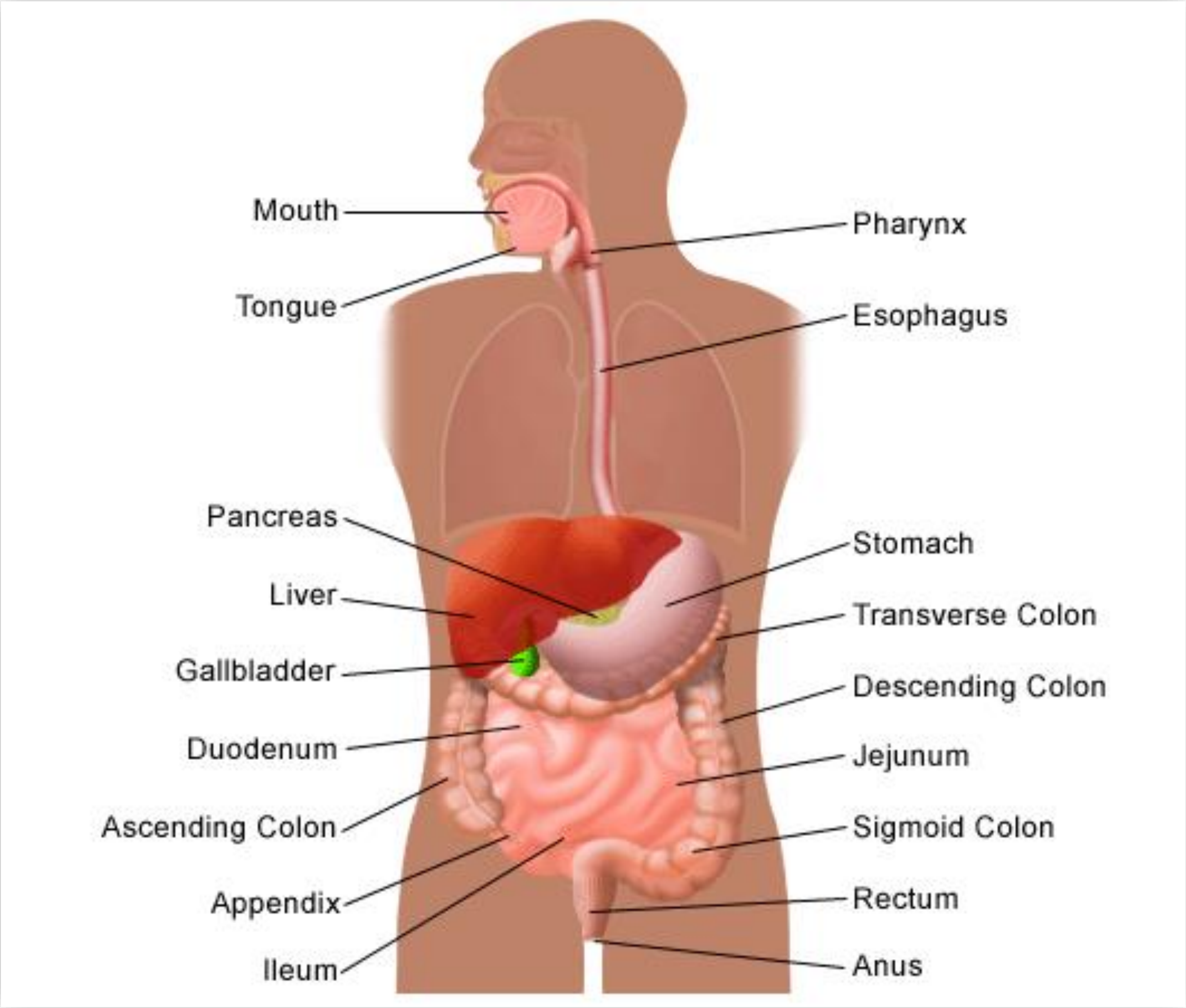
Digestive System



Two Functions of the DS

1. Break down or digest large food pieces and molecules into smaller pieces and molecules.
2. Absorb these small molecules (nutrients) into our blood. (carbs, fats, proteins)

Two Types of Digestion

1. **Mechanical (Physical) Digestion**

   – The process of breaking down larger pieces of food into smaller pieces of food makes the food easier to swallow.

   – It also increases the surface area of the food to allow the enzymes to do the chemical digestion. This is achieved primarily through the chewing action of the teeth, and to a lesser extend, the grinding action of the stomach.

Two Types of Digestion

2. Chemical Digestion

- The process of breaking the macromolecules (our food) down into their chemical building blocks.
- This means the bonds that hold the building blocks together must be broken.
- This is achieved by the actions of the various digestive enzymes.

Recall: What are the building blocks of the food we eat (macromolecules)?

1. Carbs – are broken down into?

Sugars

2. Fats – are broken down into?

Glycerol & Fatty Acids

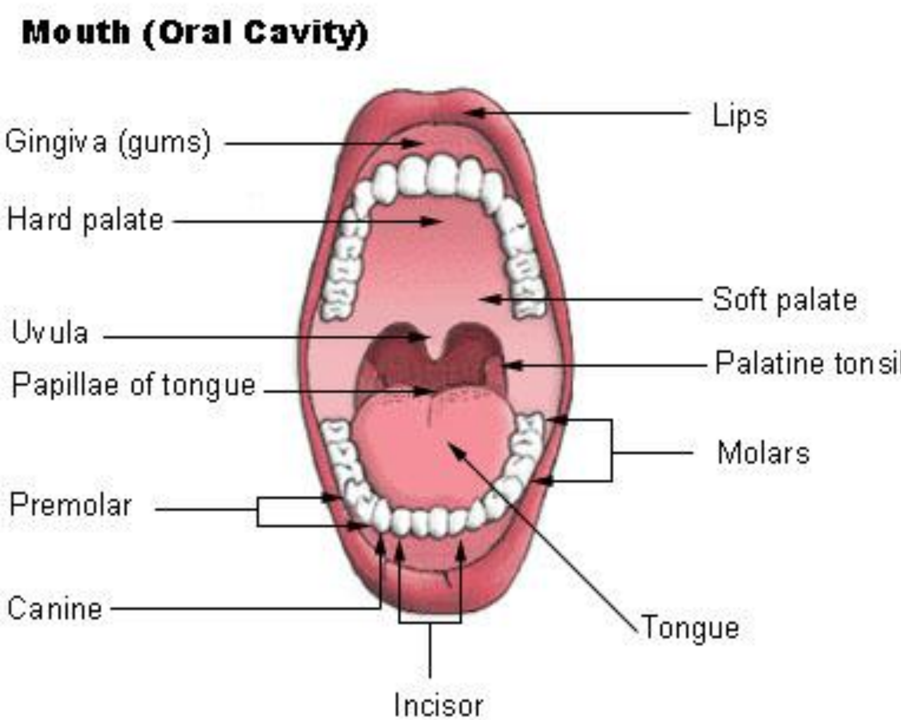
3. Proteins – are broken down into?

Amino acids

The Mouth

Function:

- Opening to digestive system.
- Teeth for chewing.
- Tongue to move food around and form bolus (a small rounded mass)
- Physical digestion
- Chemical digestion

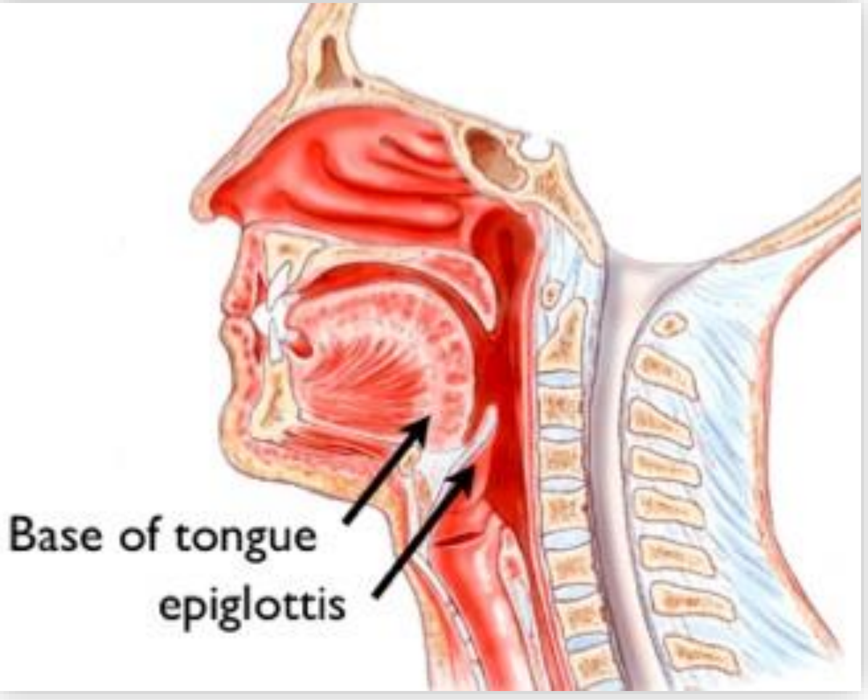


Mouth Secretions

- Saliva from salivary glands. Saliva moistens, softens, and lubricates food. It also begins to dissolve food.
- Some sterilization (fights germs in your mouth)
- Saliva contains the enzyme amylase
- Amylase begins initial breakdown of carbohydrates into monosaccharides (glucose).

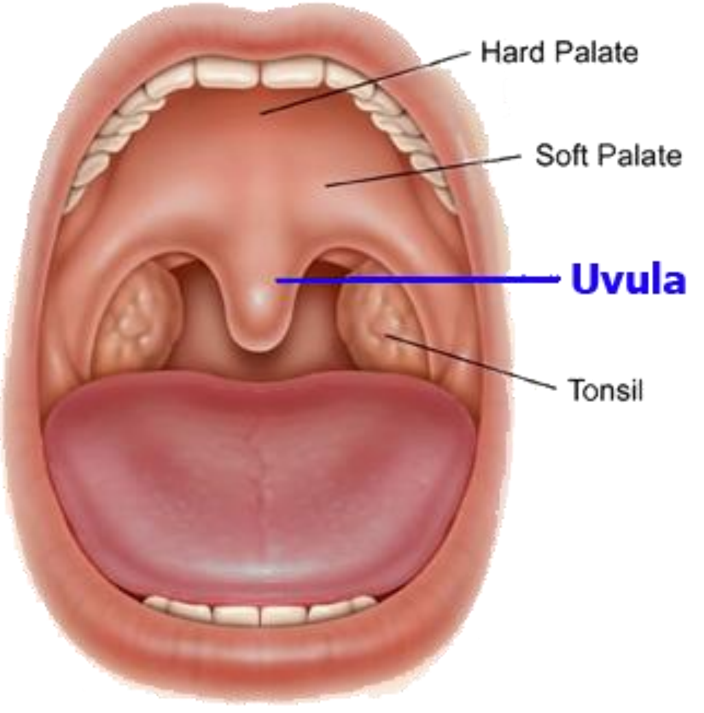
Epiglottis

Epiglottis – a flap of cartilage lying behind the tongue and in front of the entrance to the larynx. During swallowing, it folds back to cover the entrance to the larynx, preventing food and drink from entering the windpipe.



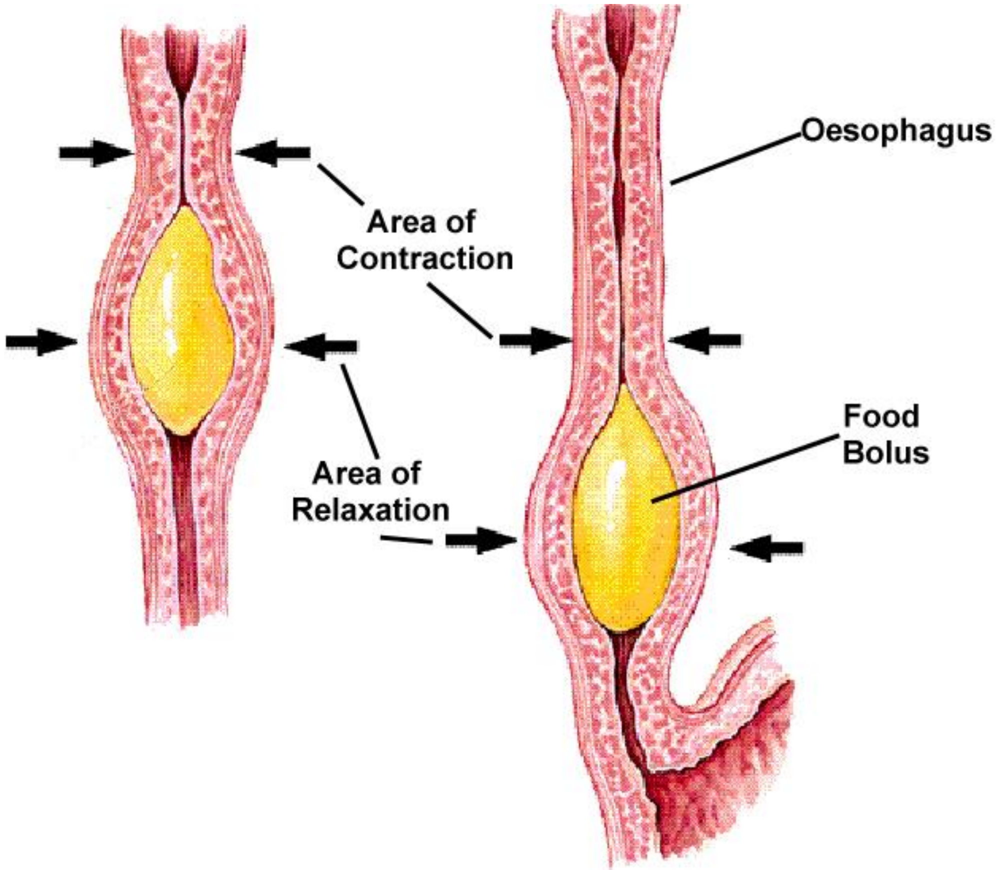
Uvula

Uvula – the hanging ball at the back of your throat. It plugs your nasal cavity when you swallow so that nothing (particularly liquids) enters that cavity.



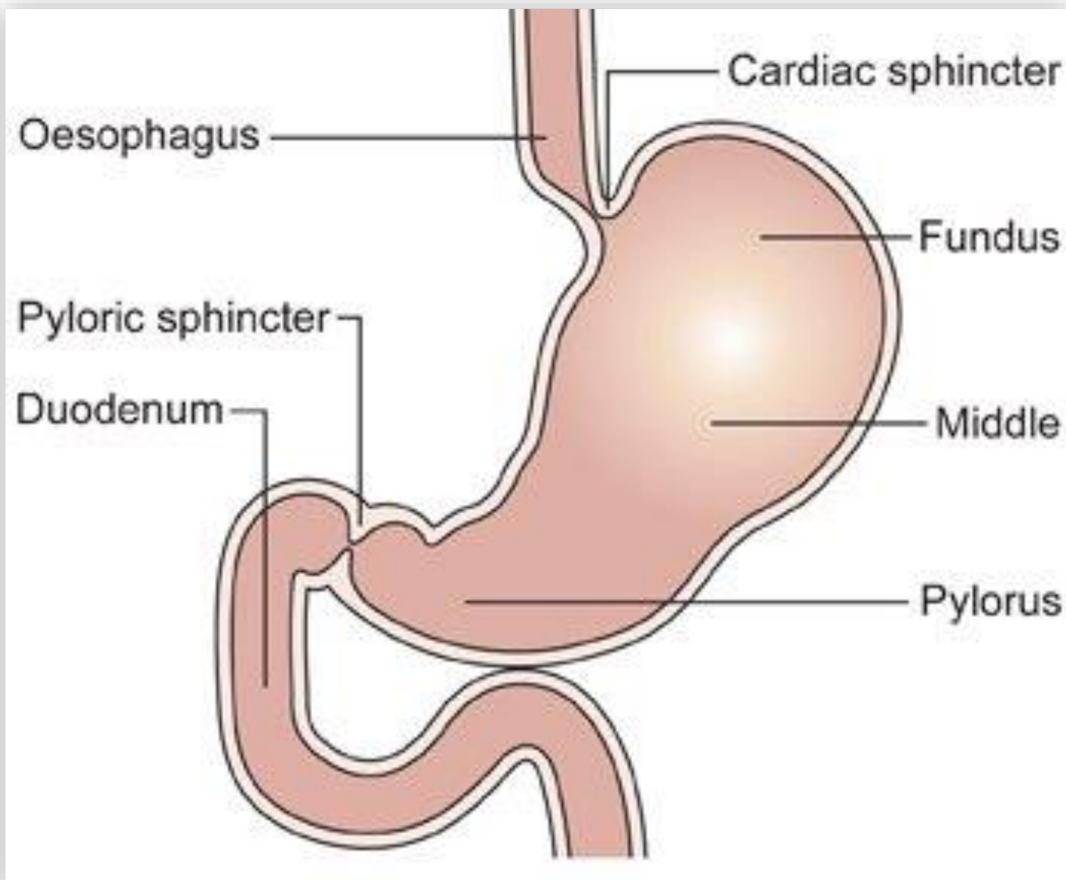
Esophagus

- Muscular tube
- Moves food and liquid by peristalsis (wave-like muscle contractions) into the stomach.



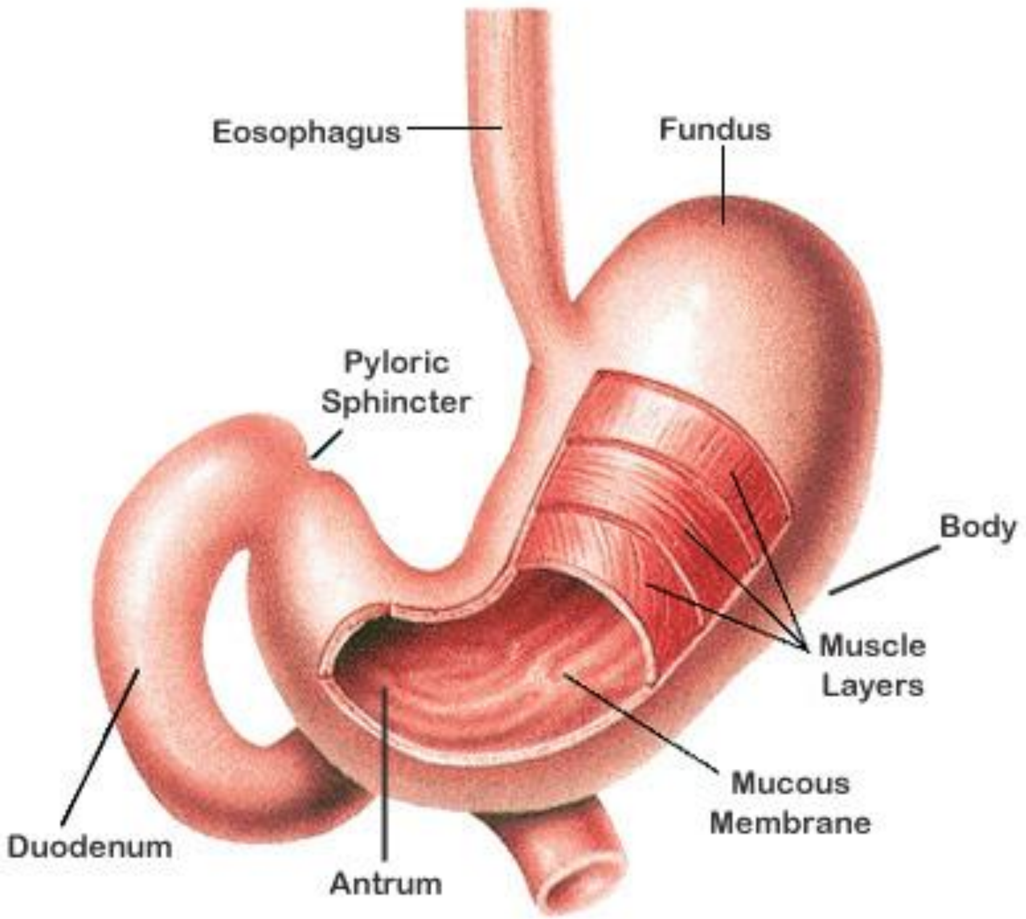
Stomach

- Hollow sac with thick muscular walls.
- Two sphincter muscles control movement of food into and out of.



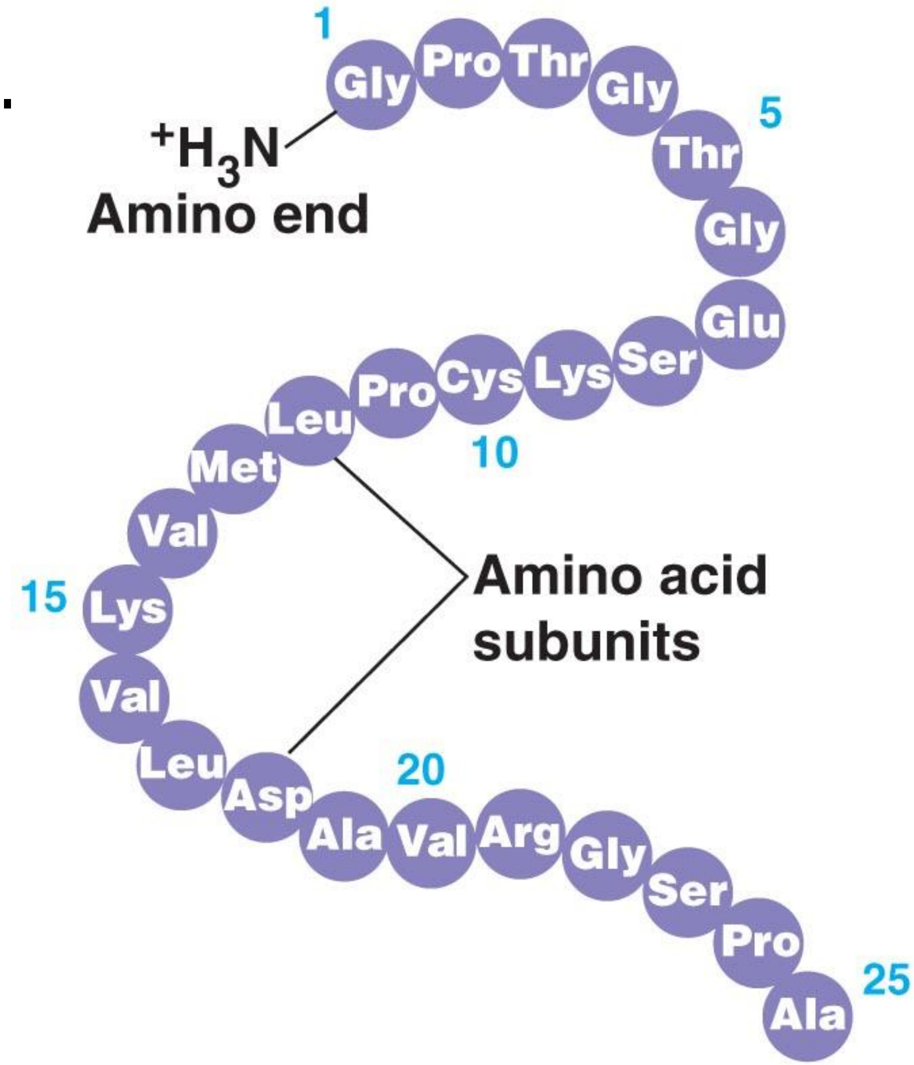
Four Functions of the Stomach

- Food storage
- Food mixer
- Food sterilizer
- Protein digestion



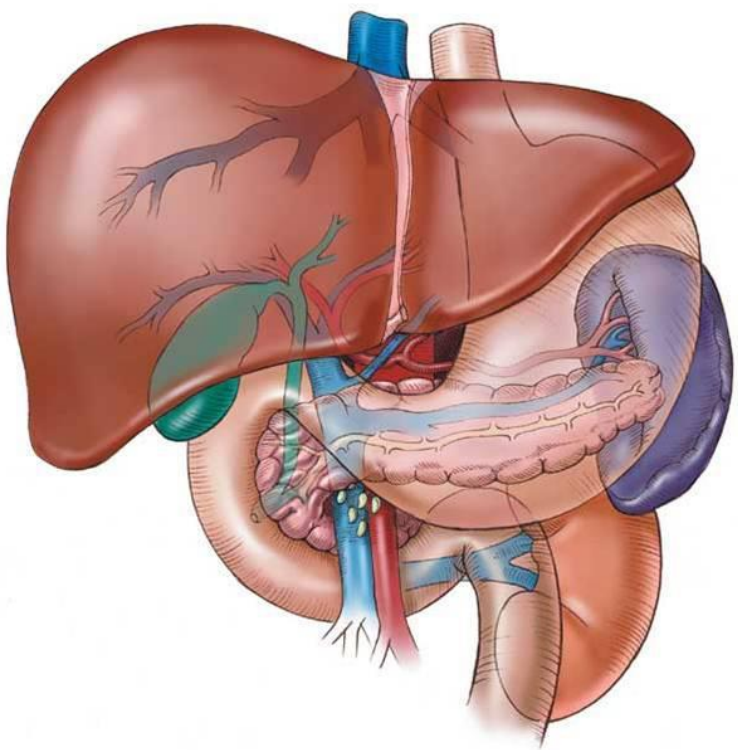
Stomach Secretions

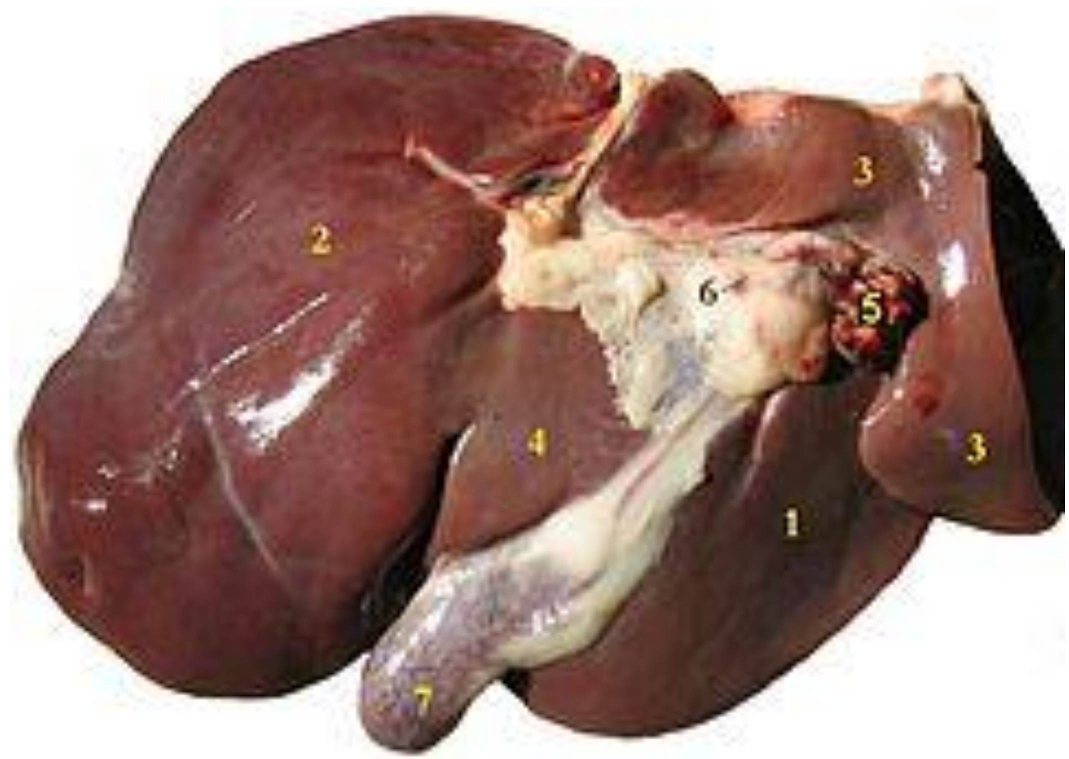
- Mucous protects walls.
- Hydrochloric acid for sterilization (pH 2-3)
- Produce enzyme pepsin.
- Pepsin breaks down protein into amino acids.



Liver

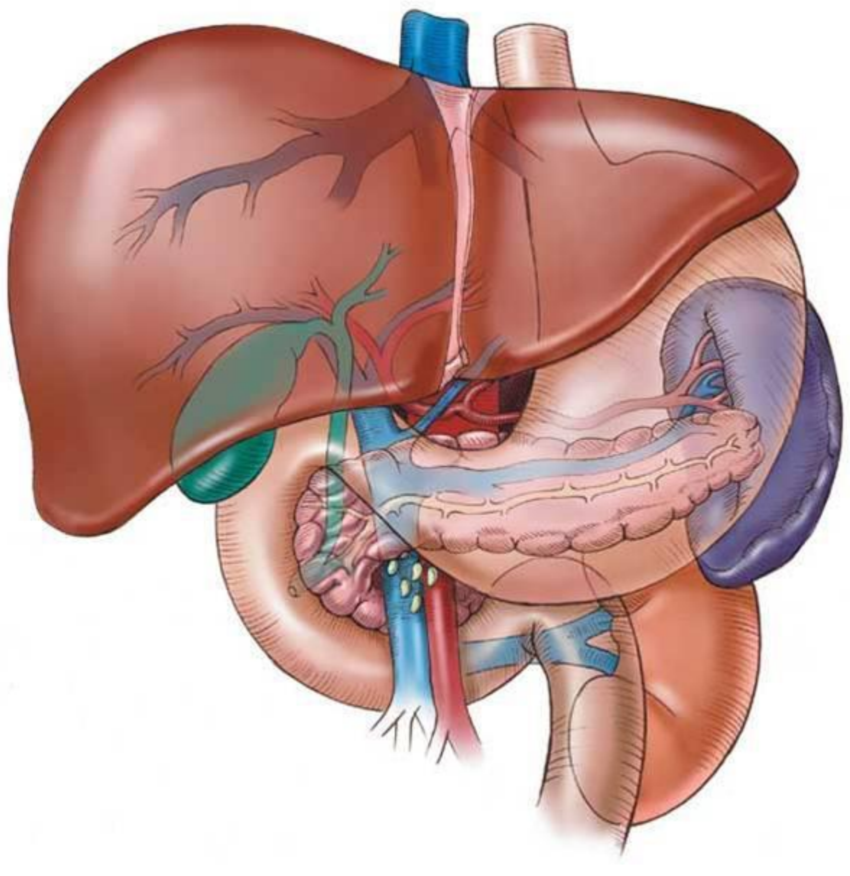
- Large organ with two main lobes.
- The food does not pass INTO the liver, but rather the liver produces a substance known as bile which is added TO the digestive system as the food passes by.





Functions of the Liver

- The liver produces bile salts for emulsification.
- Detoxifies the blood.
- Stores glycogen.
- Builds fats.
- Fights disease.



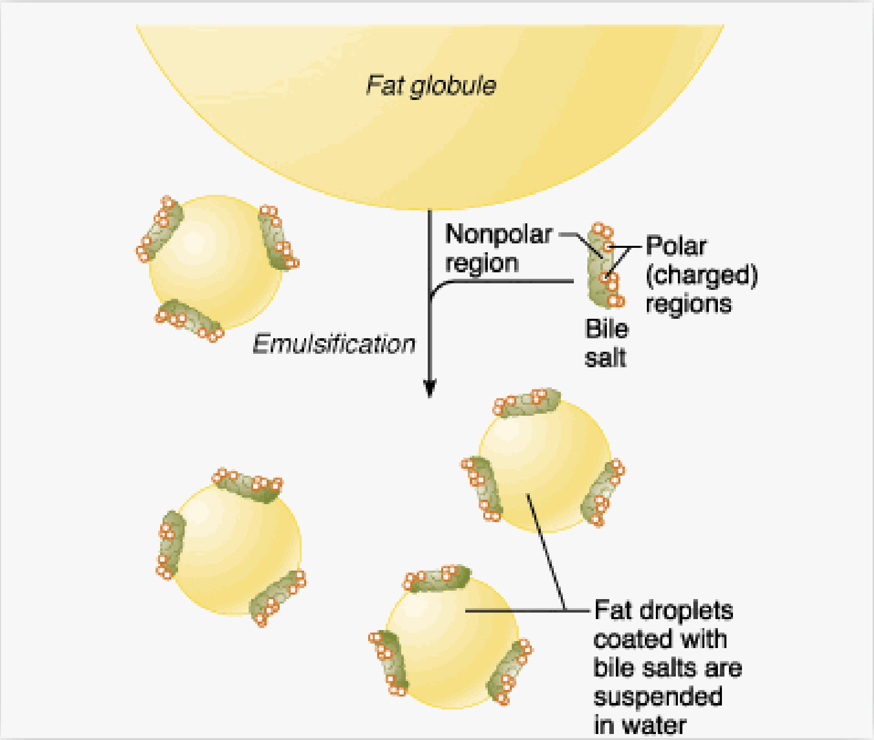
Chemical Conversions

The **liver** regulates various **chemical conversions**, such as:

- Converting glucose to a storage form of energy called glycogen
- Producing glucose from sugars, starches, and proteins
- Breaking down fatty acids
- Synthesizes triglycerides and cholesterol
- Producing plasma proteins necessary for the clotting of blood

Bile Salts

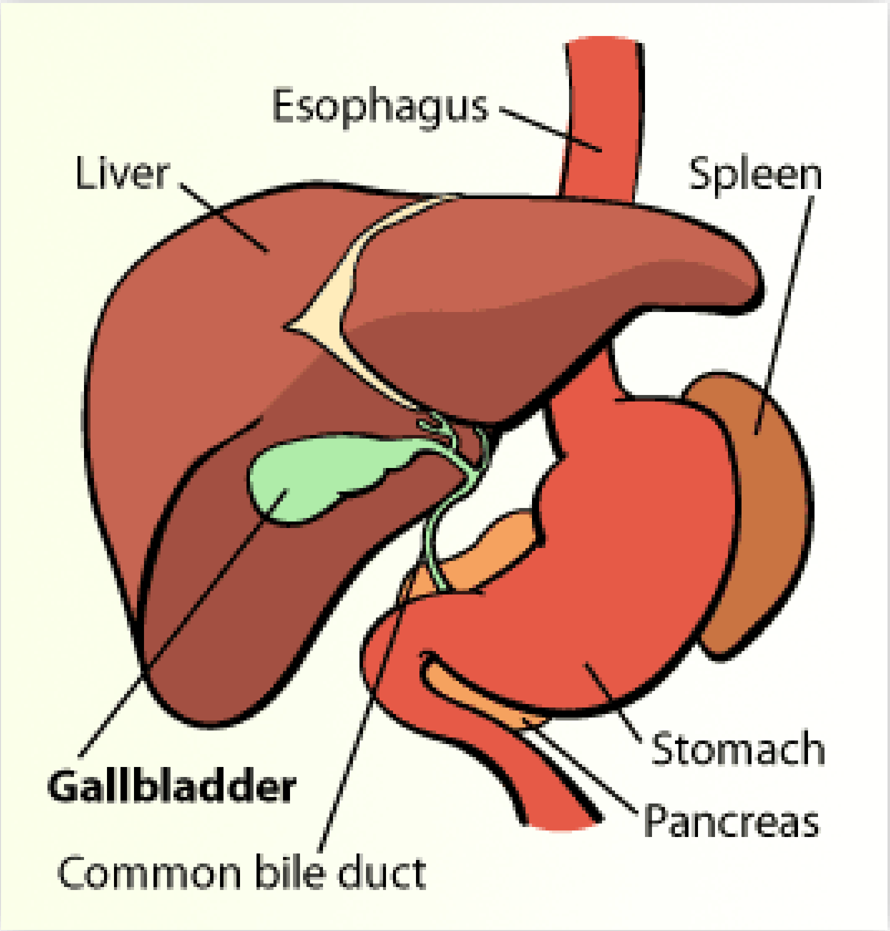
- Although not an enzyme, bile acts as an emulsifier for your digestive system.
- This means it allows the fat to dissolve in the water based digestive system.
- Turns fat globules into fat droplets (emulsification) which increases the surface area of the fat allowing lipase to break it down.



- **Bile salts** digest fats by acting as an organic emulsifier.

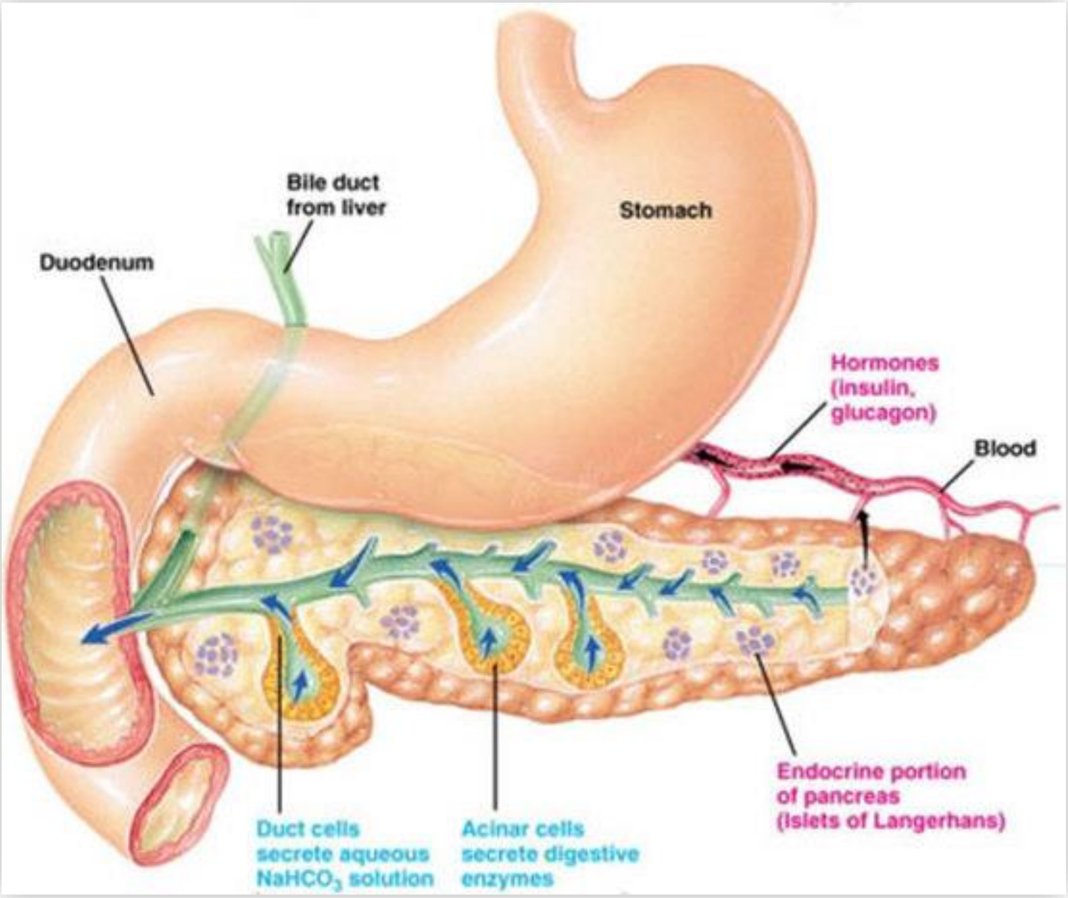
Gall Bladder

- Small pear-shaped sac situated near liver.
- Stores and concentrates bile up to 10x.
- What causes **Gall Stones**??



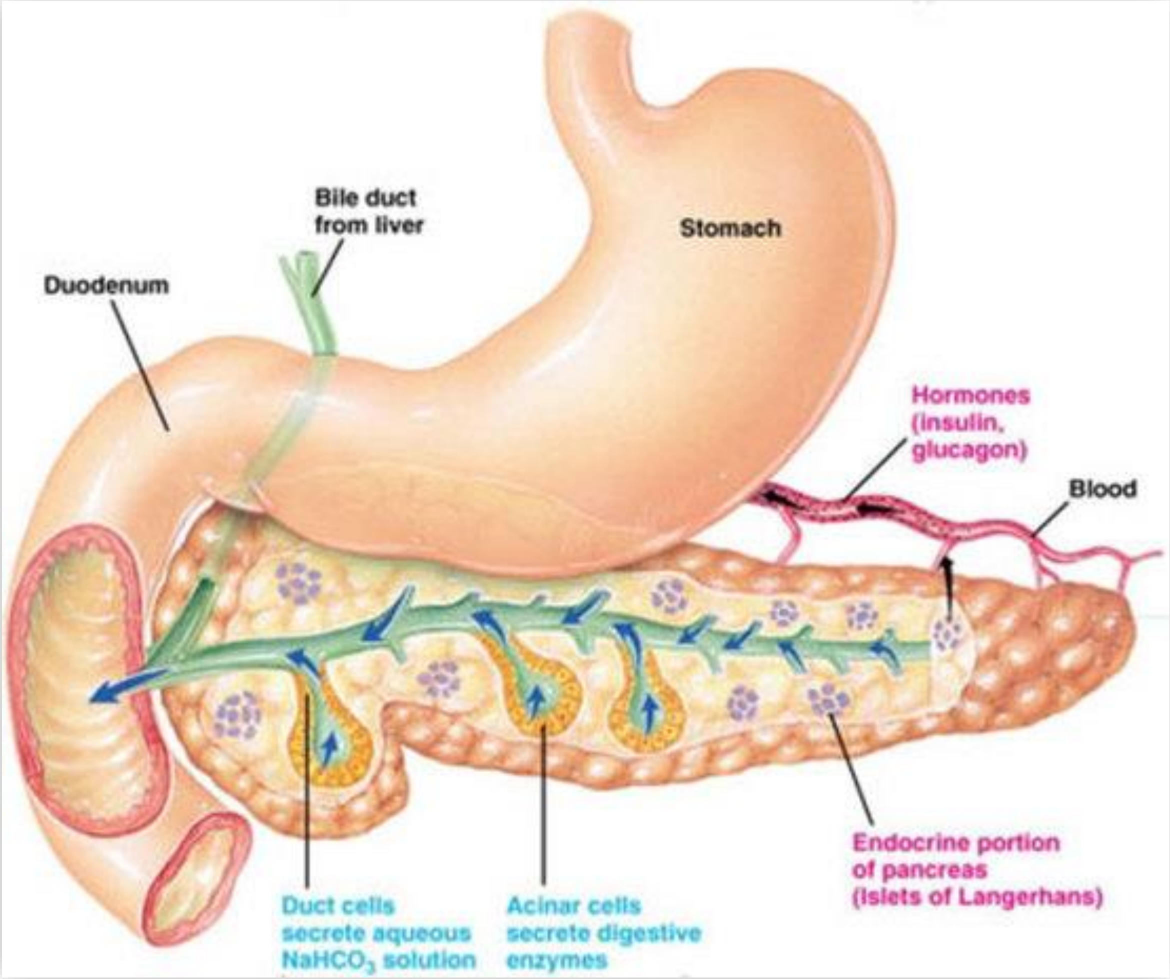
Pancreas

- Cluster of cells situated between stomach and small intestine.
- Secretes digestive enzymes to duodenum.
- Regulates pH.



Pancreatic Secretions

- Amylase (Carbs).
- **Lipase (lipids).**
- Bicarbonate ions for pH buffer.

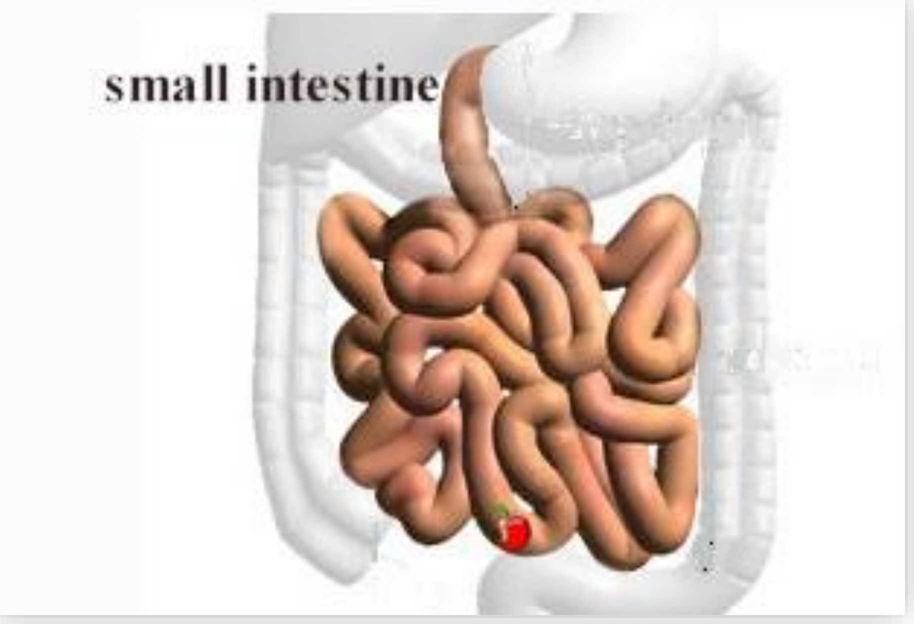


Small Intestine

- Measures roughly 20 feet in length and about 2.5 cm (1 in) in diameter
- Lipid breakdown begins here (Lipids broken into glycerol and fatty acids).
- Protein and Carb breakdown continues.

Three part tube:

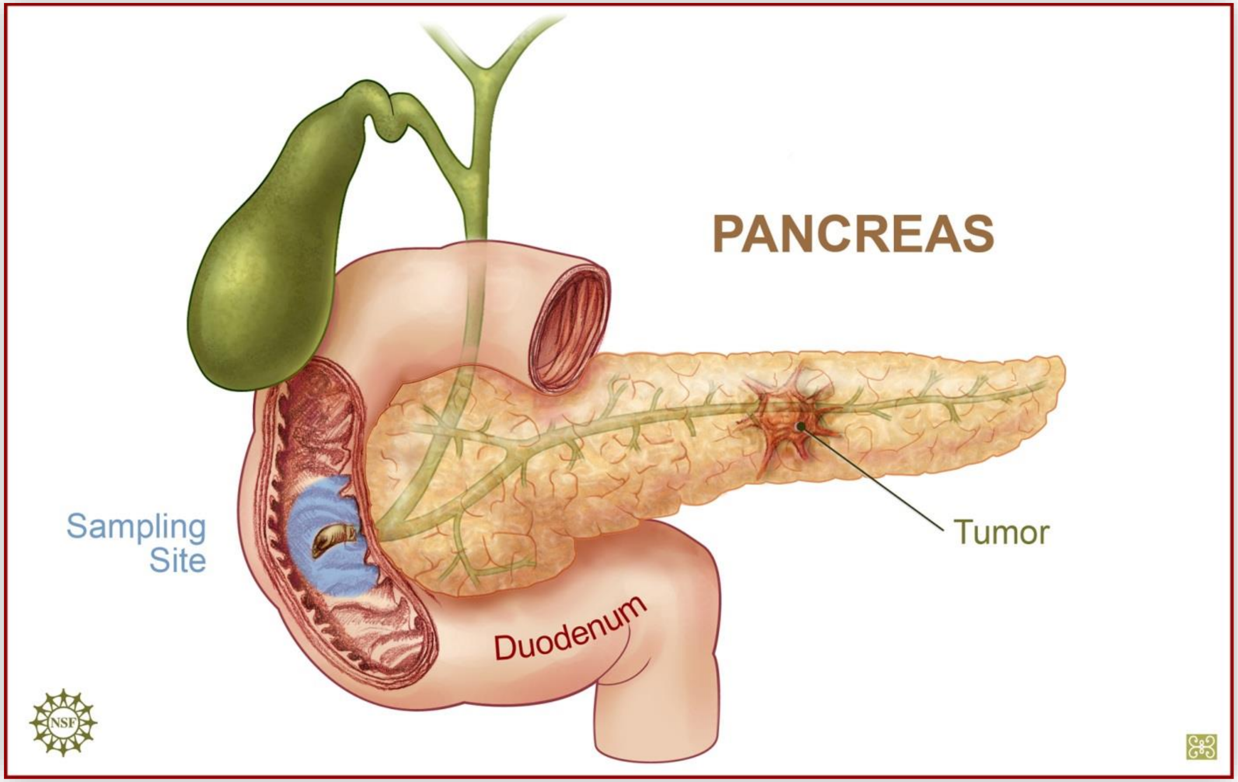
1) duodenum
2) jejunum
3) ileum



Small Intestine

<u>Section One</u> – **The Duodenum**

- Majority of chemical digestion occurs here.

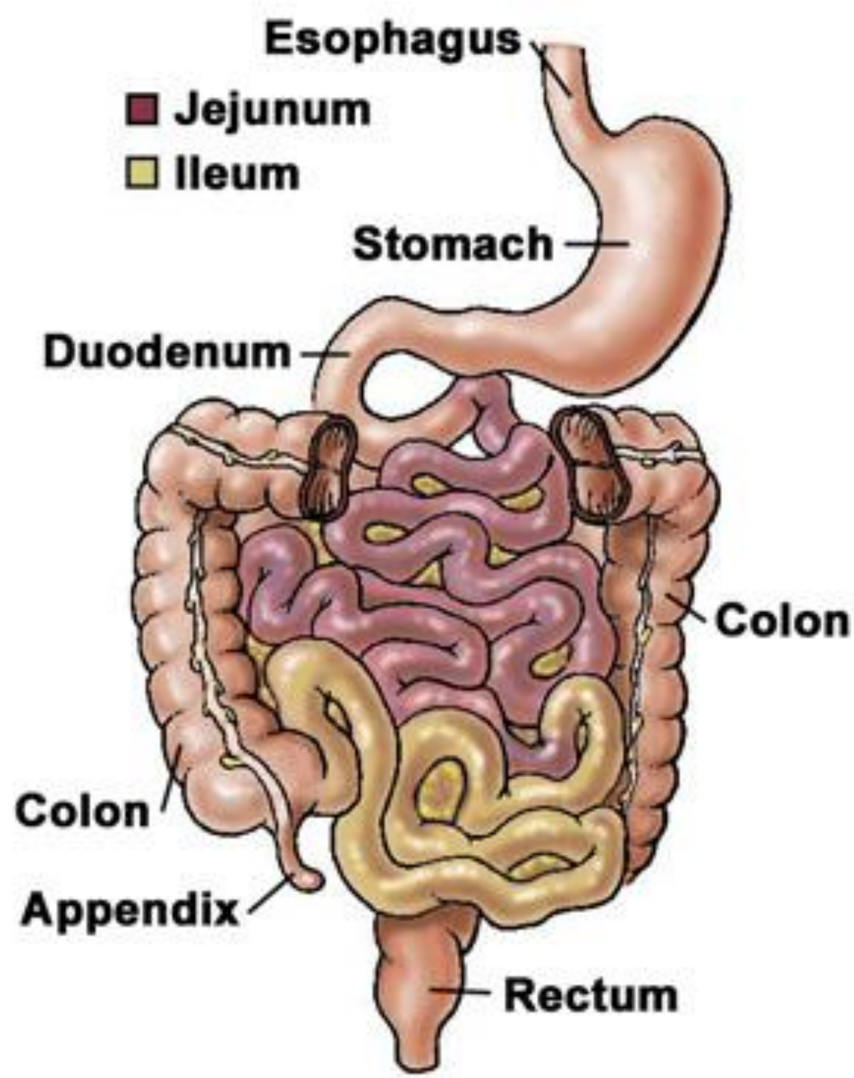


Small Intestine

Section Two – **The Jejunum**

•Majority of nutrients are absorbed here.

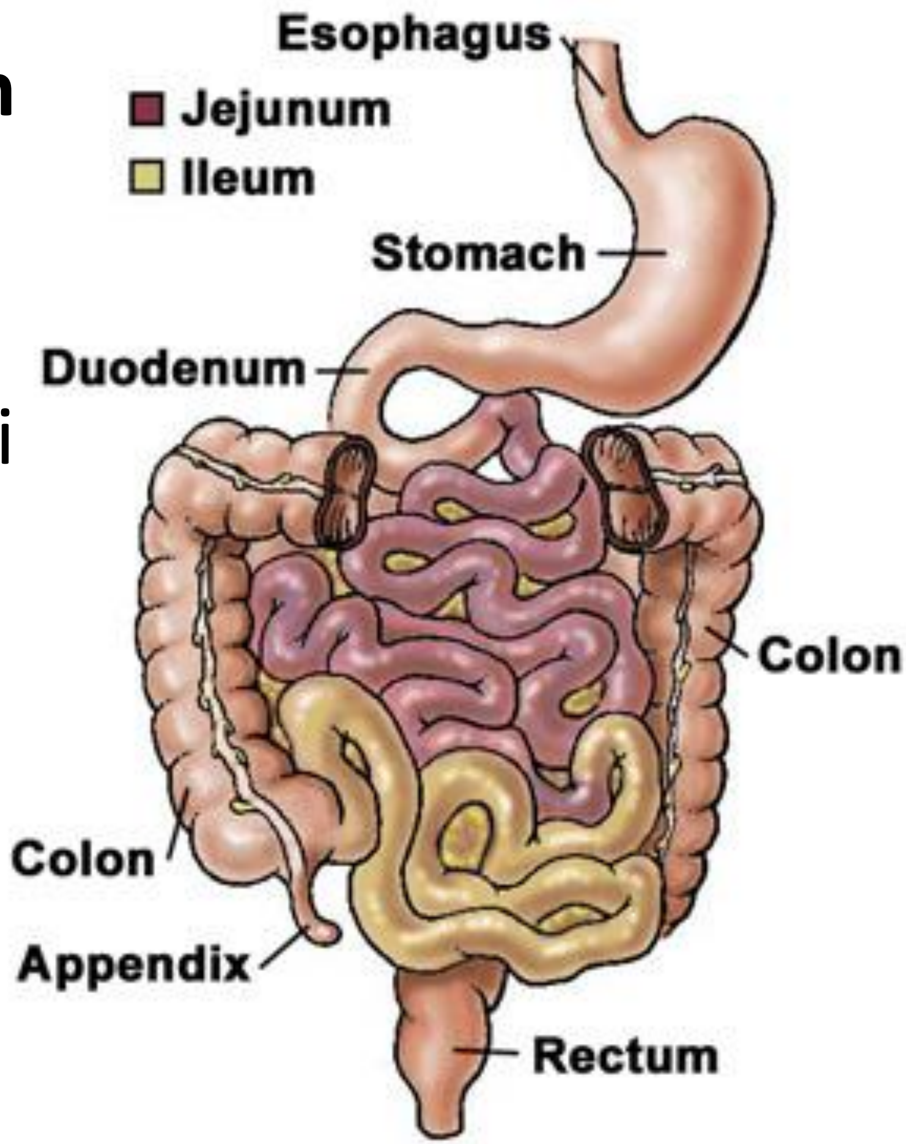
•Lined with millions of villi and micro-villi (small hair-like structures).



Small Intestine

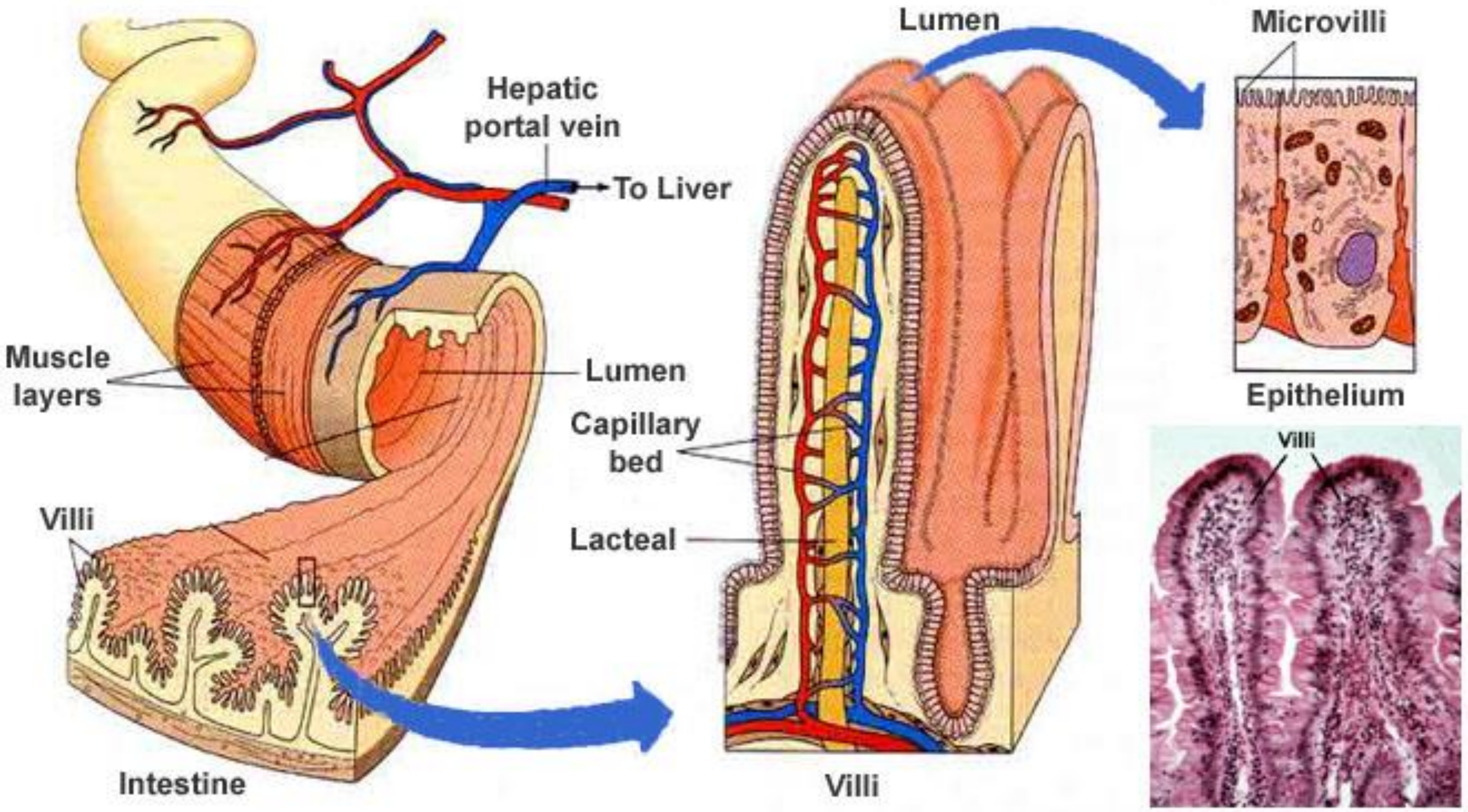
Section Three – **The Ileum**

- Remaining nutrients absorbed here.
- Lined with millions of villi and micro-villi.



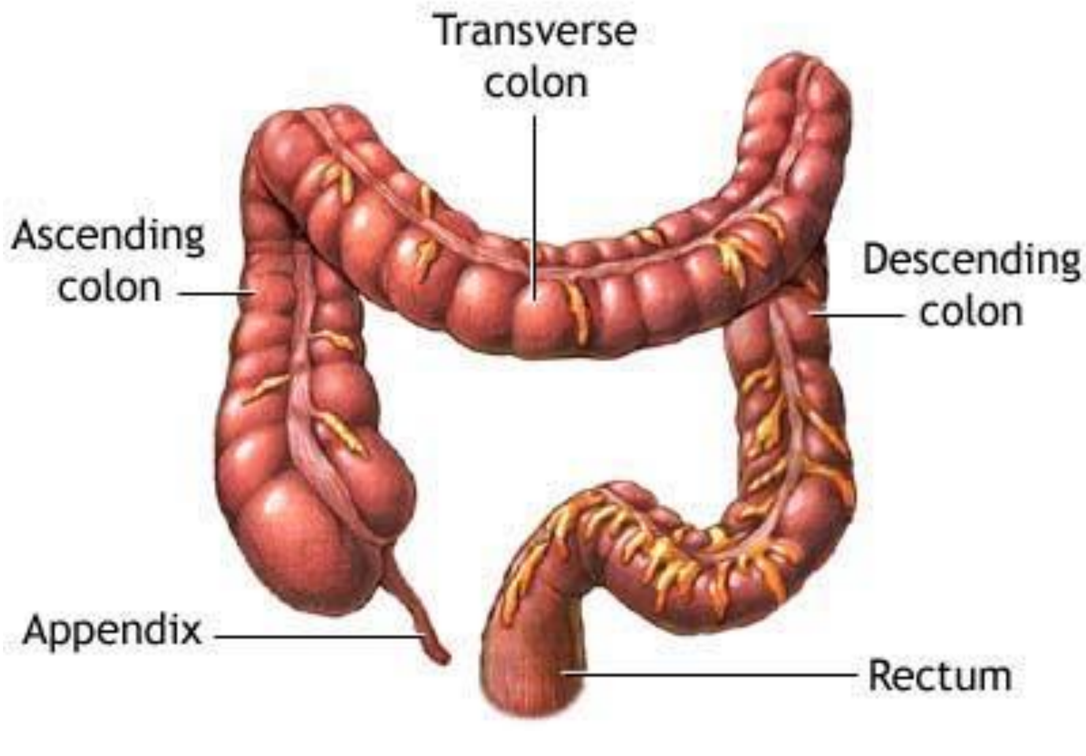
Villi

- Tiny finger-like projections which increase absorptive area of small intestine.



Large Intestine (Colon)

- Tube leading from the small intestine to anus.
- 4.5 - 5.5 feet in length.
- 6.5 cm in diameter.



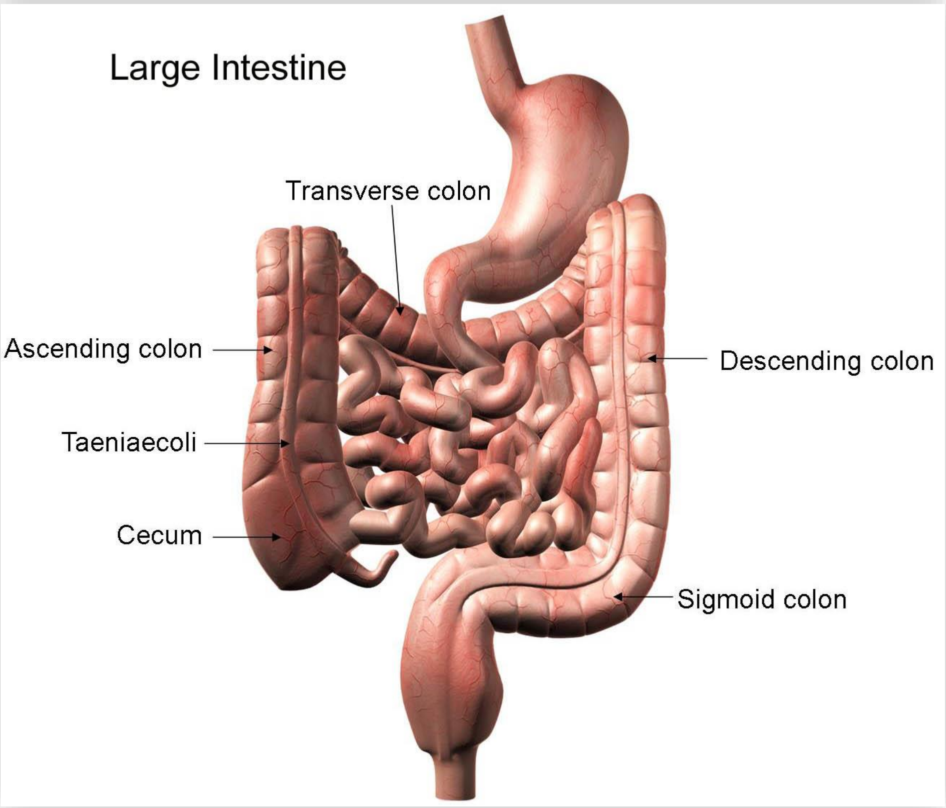
Functions of the Large Intestine

First half:

- Reabsorbs water and other fluids (recycles them into the blood stream).

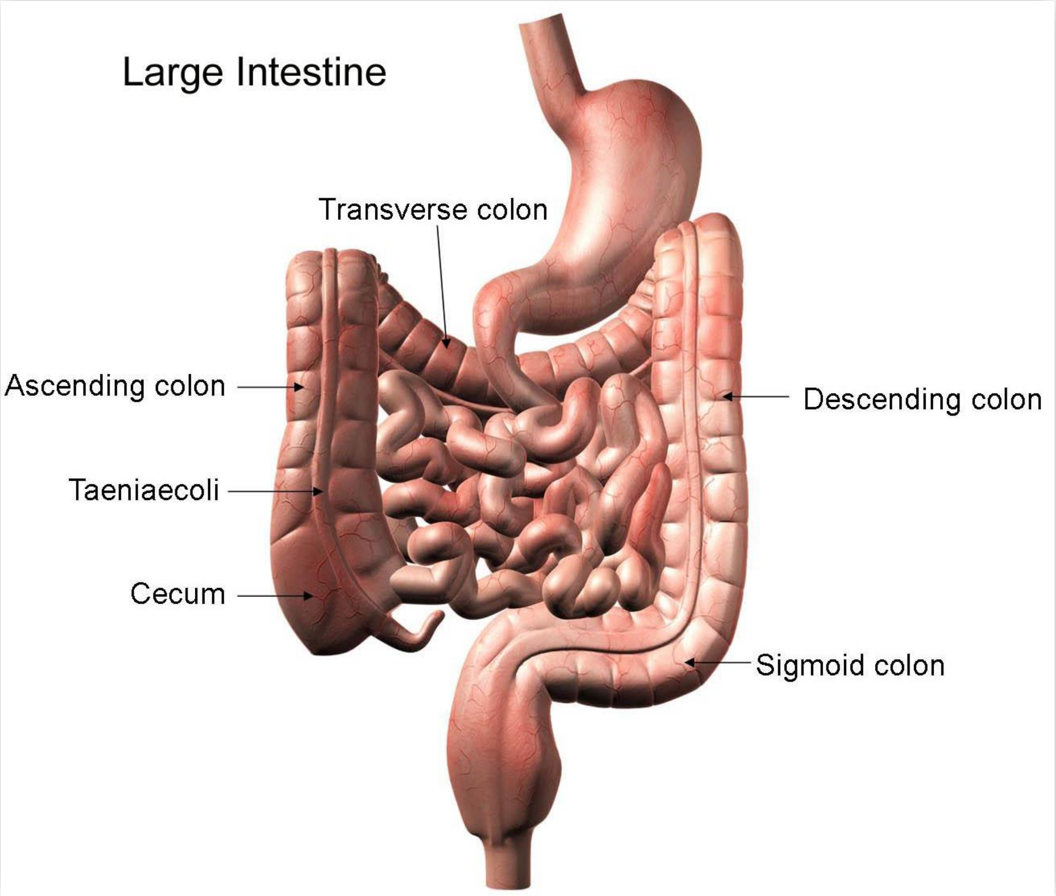
Second half:

- Compacts the wastes into feces.
- Secretes mucus (as a thickener).



Secretions of the Large Intestine

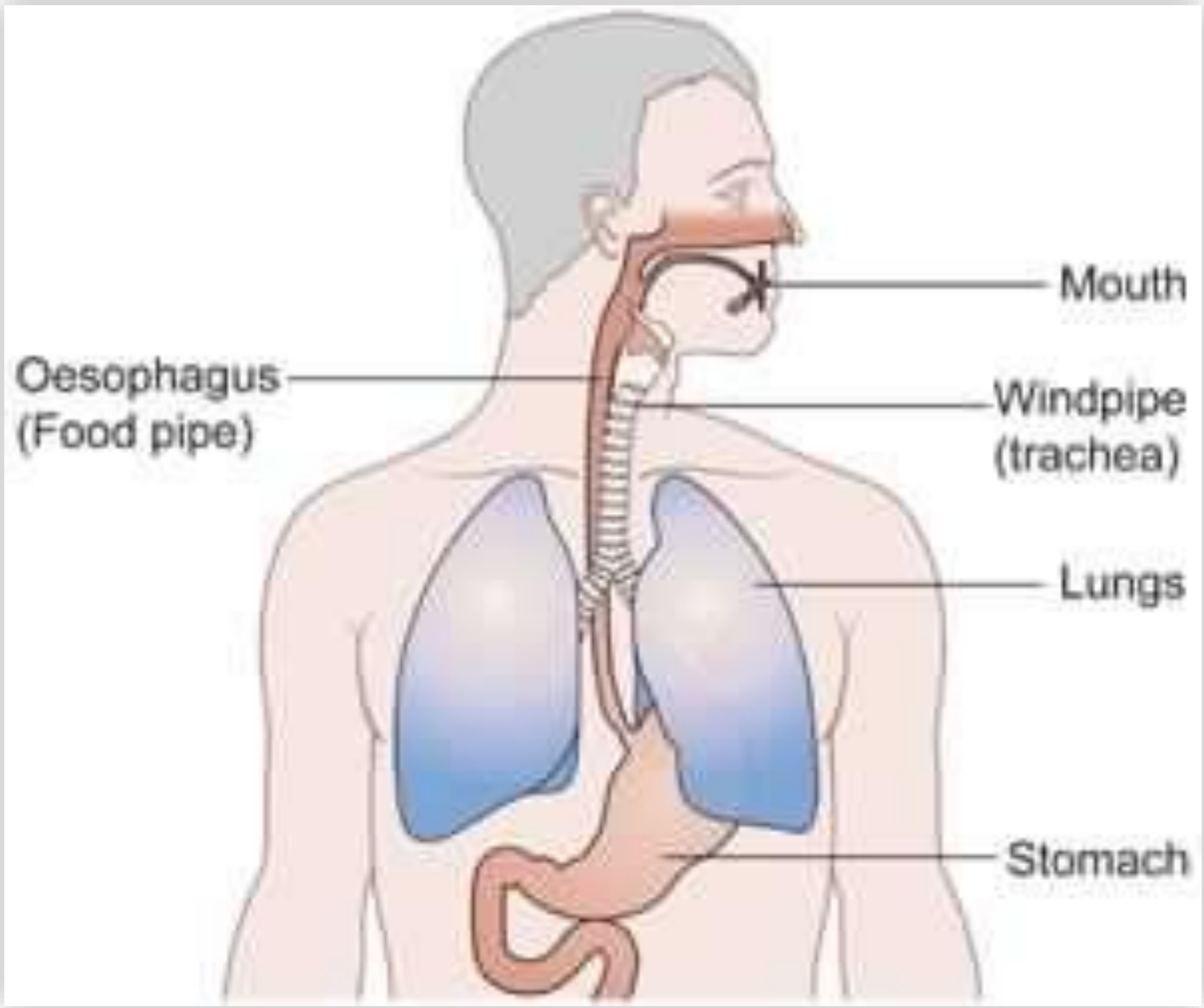
- Mucous protects walls of large intestine.
- Electrolyte balance is crucial for water reabsorption.



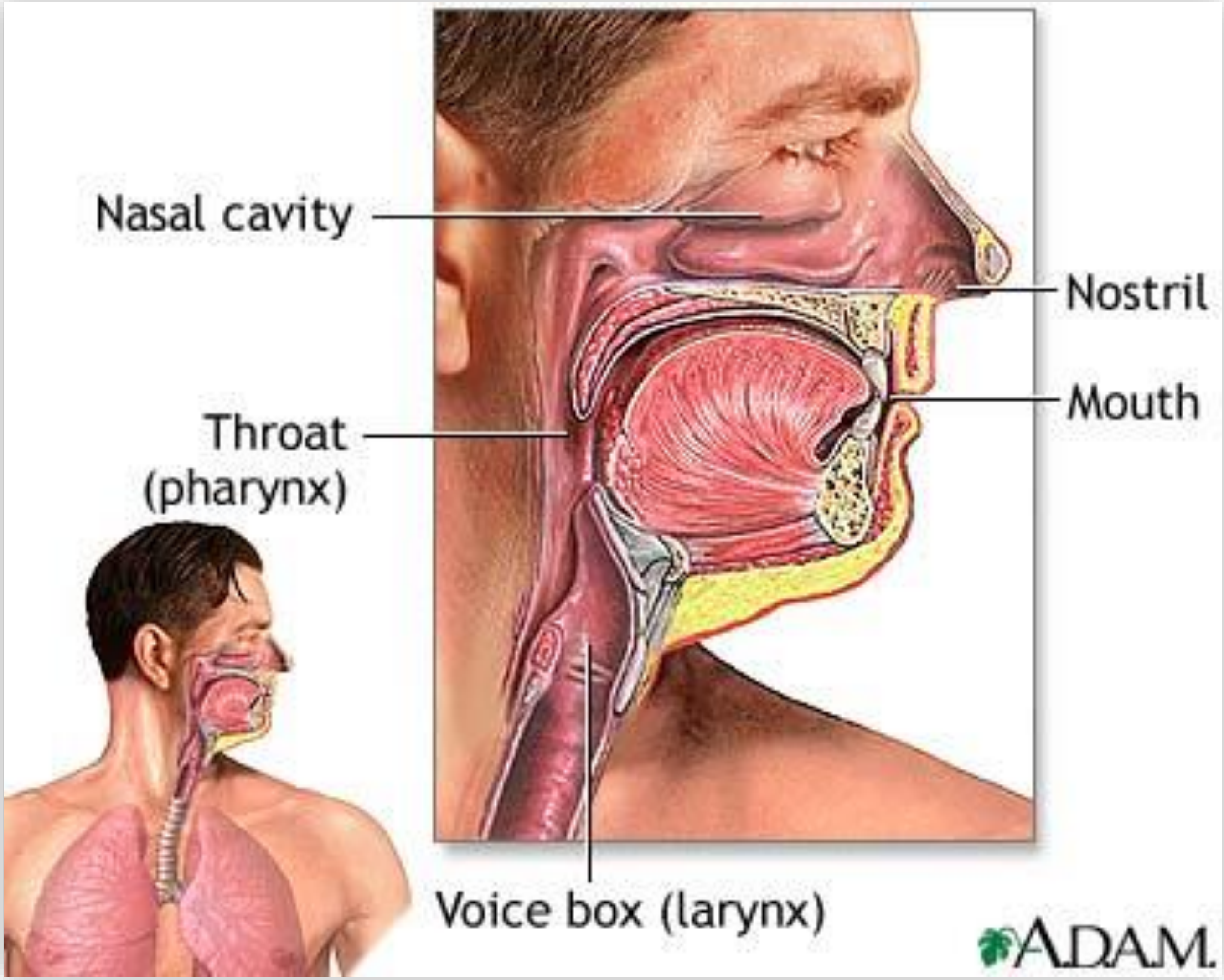
Enzyme Chart Summary

Food	Enzyme	Location	Result of Breakdown
Carbs	Amylase	Mouth Small Intestine (pancreas)	Sugar (glucose)
Proteins	Pepsin	Stomach Small Intestine (pancreas)	Amino Acids
Lipids	Lipase	Small Intestine (pancreas)	Fatty Acids and Glycerol

Respiratory System



Two entry routes for air:



Goals of the Respiratory System

- Deliver oxygen to the body
- Take away carbon dioxide

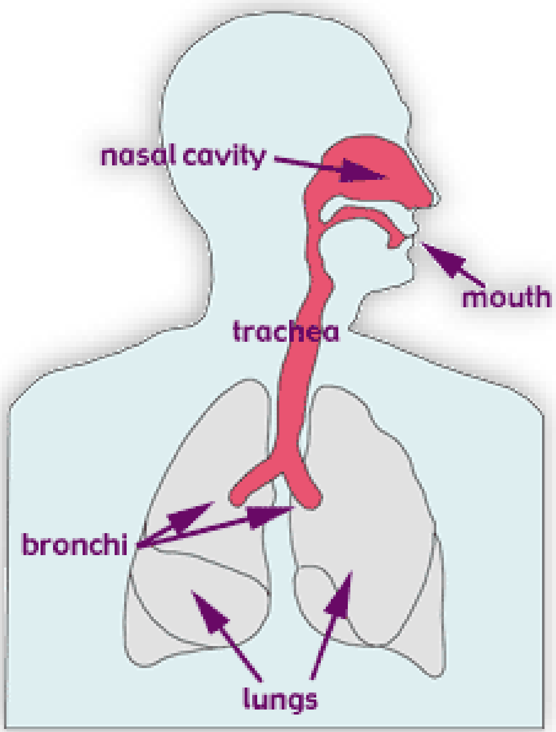
Note: The lungs are the main organs of the respiratory system.

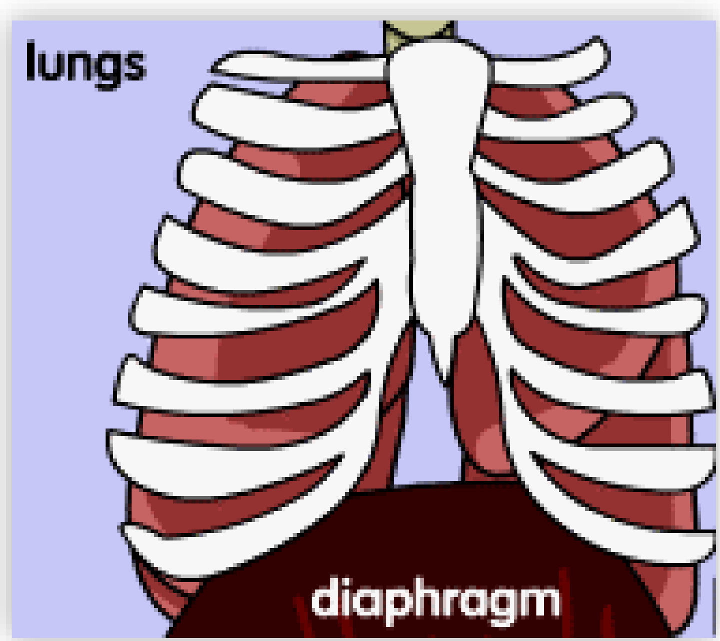
Summary of the RS

- Air enters through the mouth or nose.
- Air travels down the *trachea* (windpipe). The trachea filters the air we breathe.
- Air enters the *bronchi*, which are two air tubes that branch off of the trachea. They carry air directly into the lungs.
- In the lungs, oxygen is taken into the body and carbon dioxide is breathed out. This is facilitated by red blood cells.

Summary of the RS

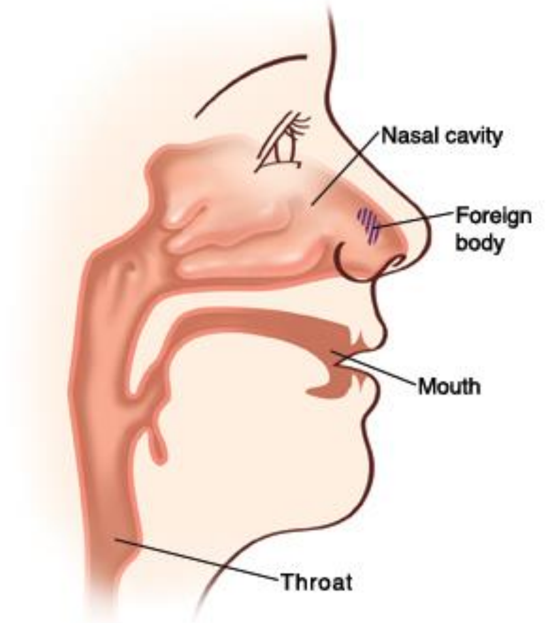
- The *diaphragm* is a dome-shaped muscle at the bottom of the lungs. The contraction (involuntarily or voluntarily) of the diaphragm causes air to be pulled in and out of the body.





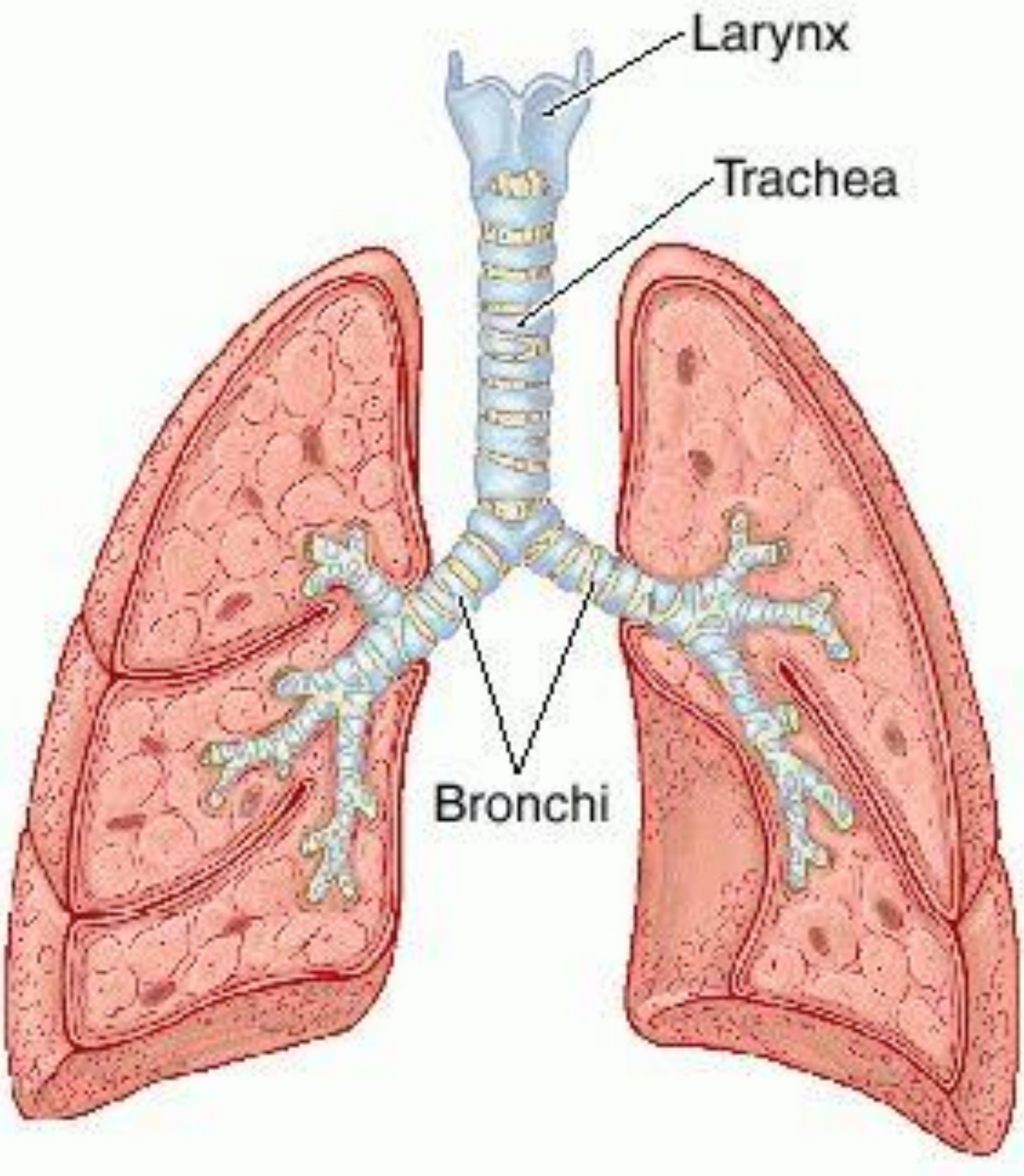
The Nose

- Passageway for air to the trachea (windpipe)
- Contains tiny hairs and mucus. Together, they filter the air by removing debris.
- Blood vessels in the nose contribute to the warming of the air as it passes through the nose.



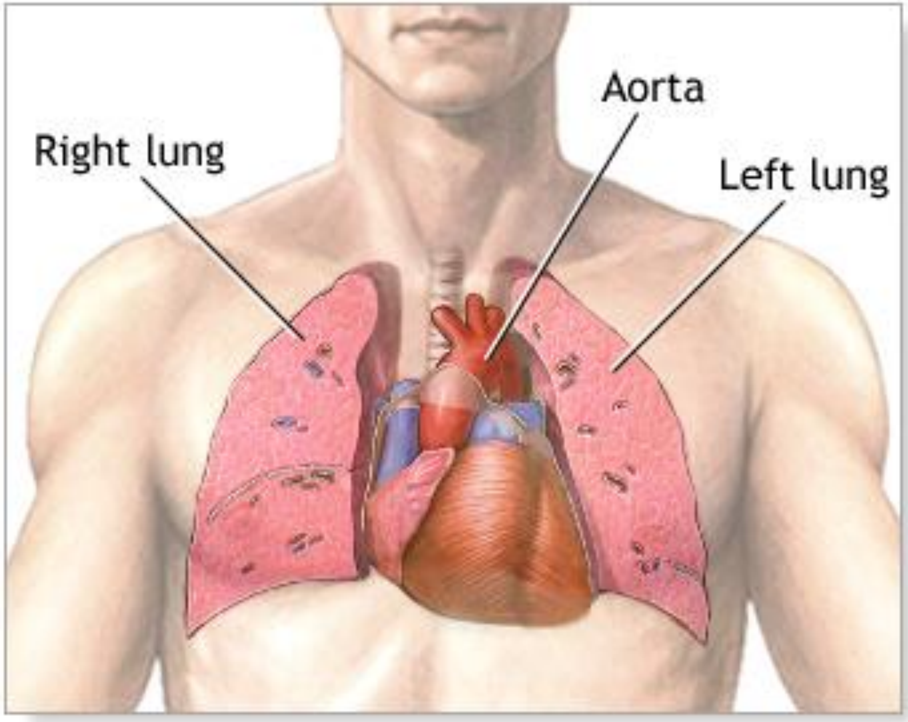
The Trachea

- Connects the oral/nasal cavity to the bronchi.
- ~2.5 cm (1 in) in diameter
- Lined with **cilia**, which sweep fluids and foreign particles out of the airway so that they stay out of the lungs.
- Mucus also lines the trachea, serving as a defense mechanism.
- Is surrounded by rings of cartilage, which prevent the trachea from collapsing on itself.


Larynx
Trachea
Bronchi

Anatomy of the Lungs

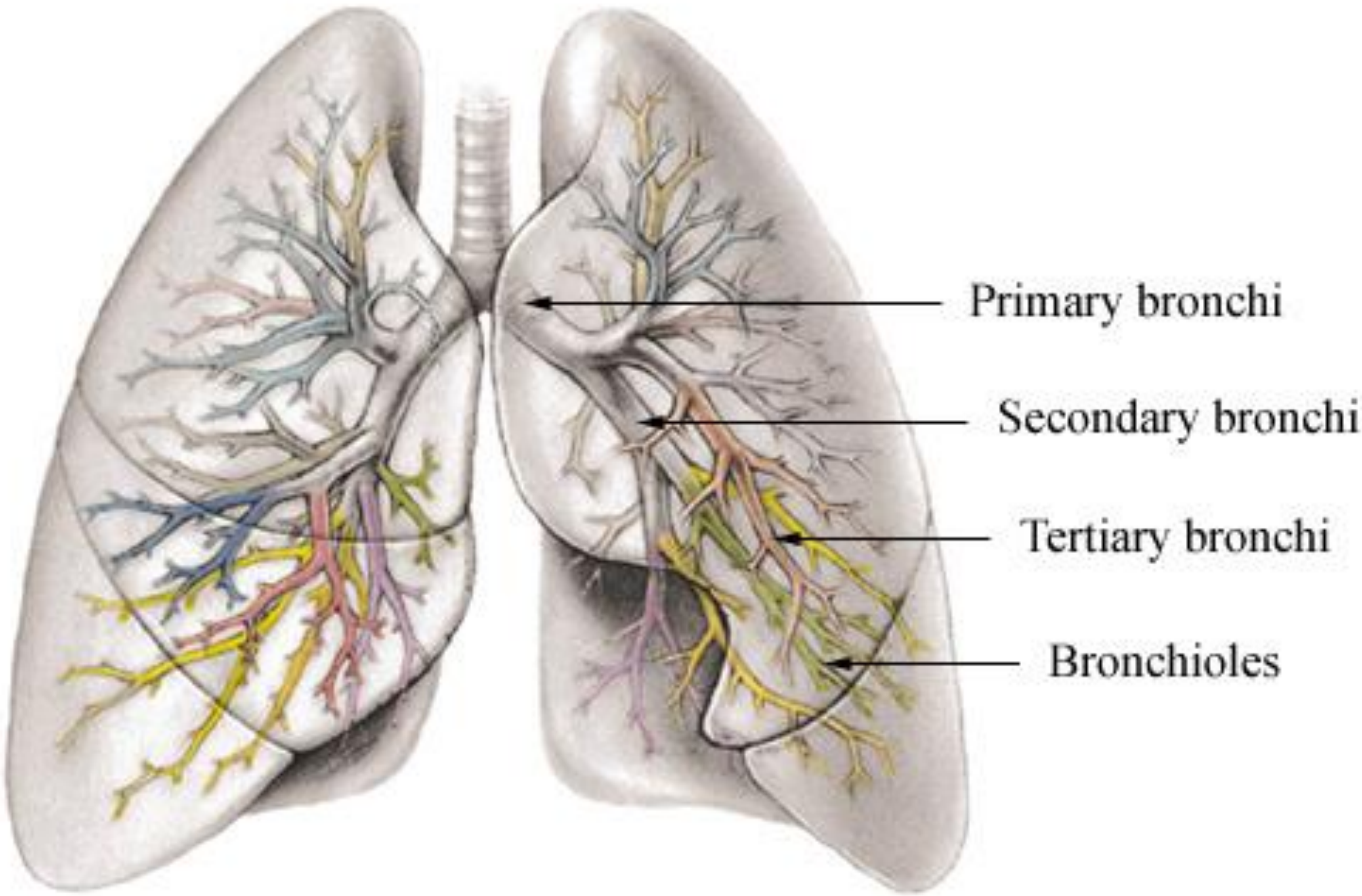
- The left and right lungs are not completely symmetrical. The right lung is made up 3 components, where the left lung only has 2.
- The left lung houses the heart.



Summary of the Lungs

- From the trachea, air enters the primary bronchi (two large branches).
- The secondary and tertiary bronchi are smaller branches of the bronchi that branch out like twigs of an upside down tree.
- Bronchioles are the smallest branches of the respiratory tract; they move air into tiny sacs called alveoli.

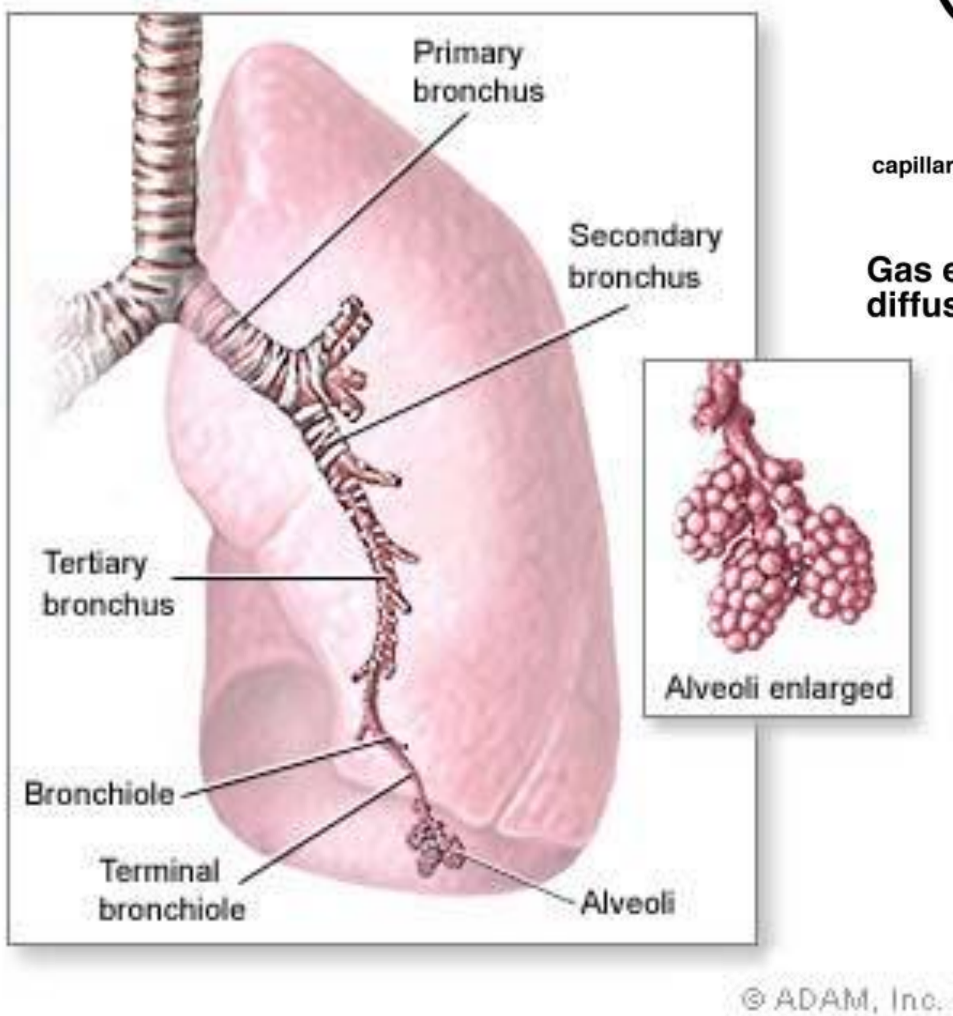
Summary of the Lungs

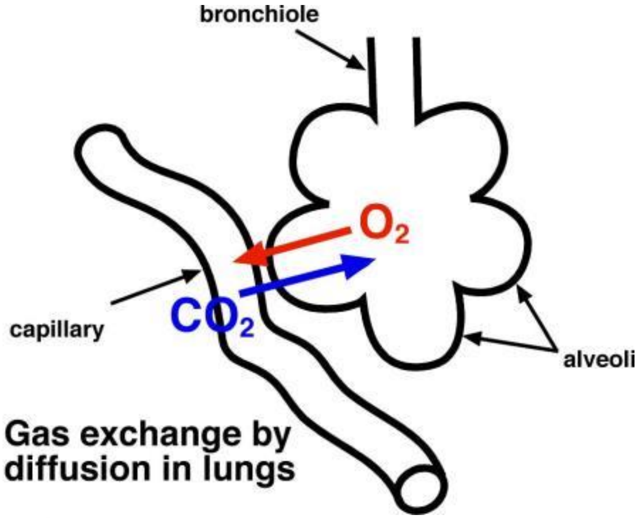


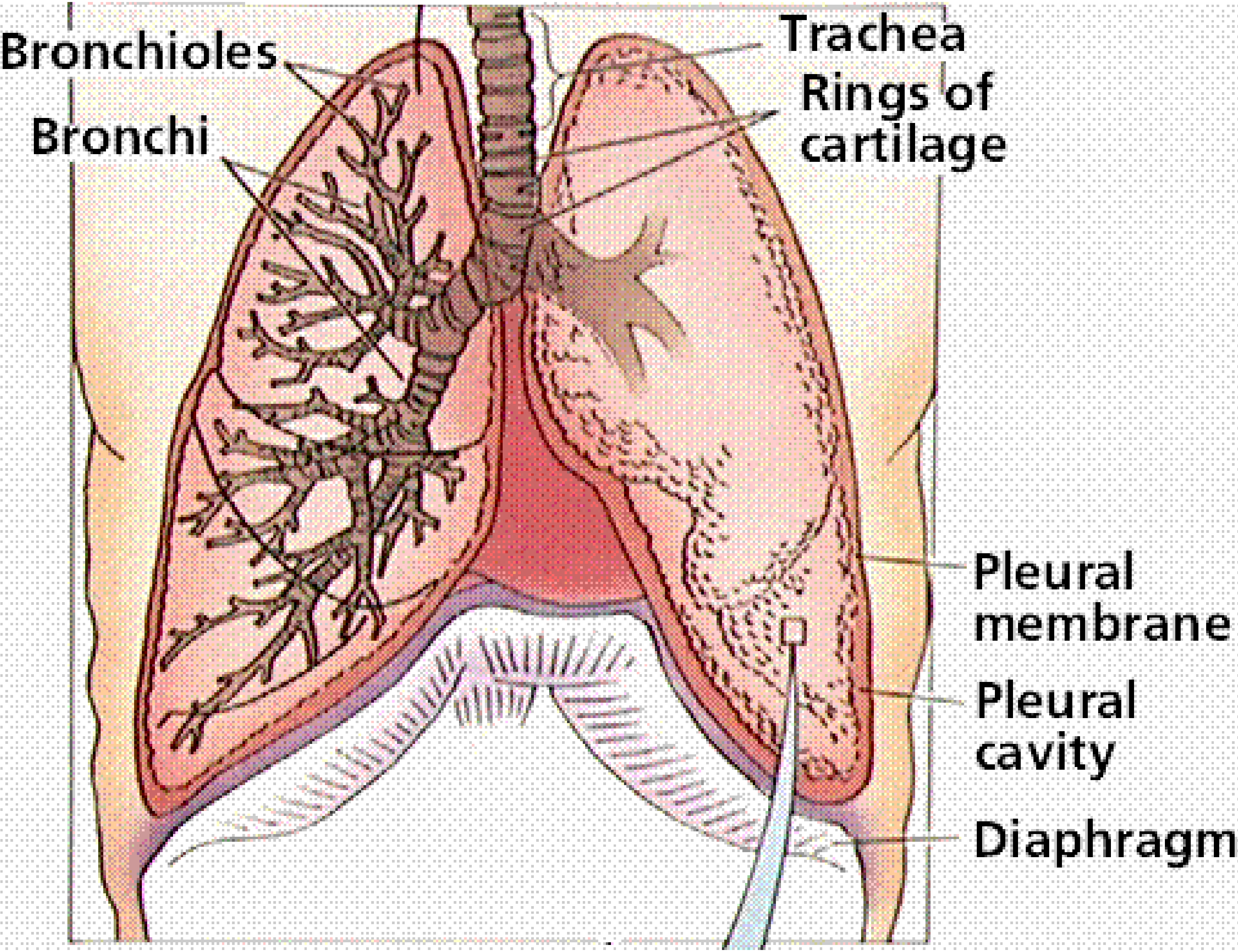
Alveoli

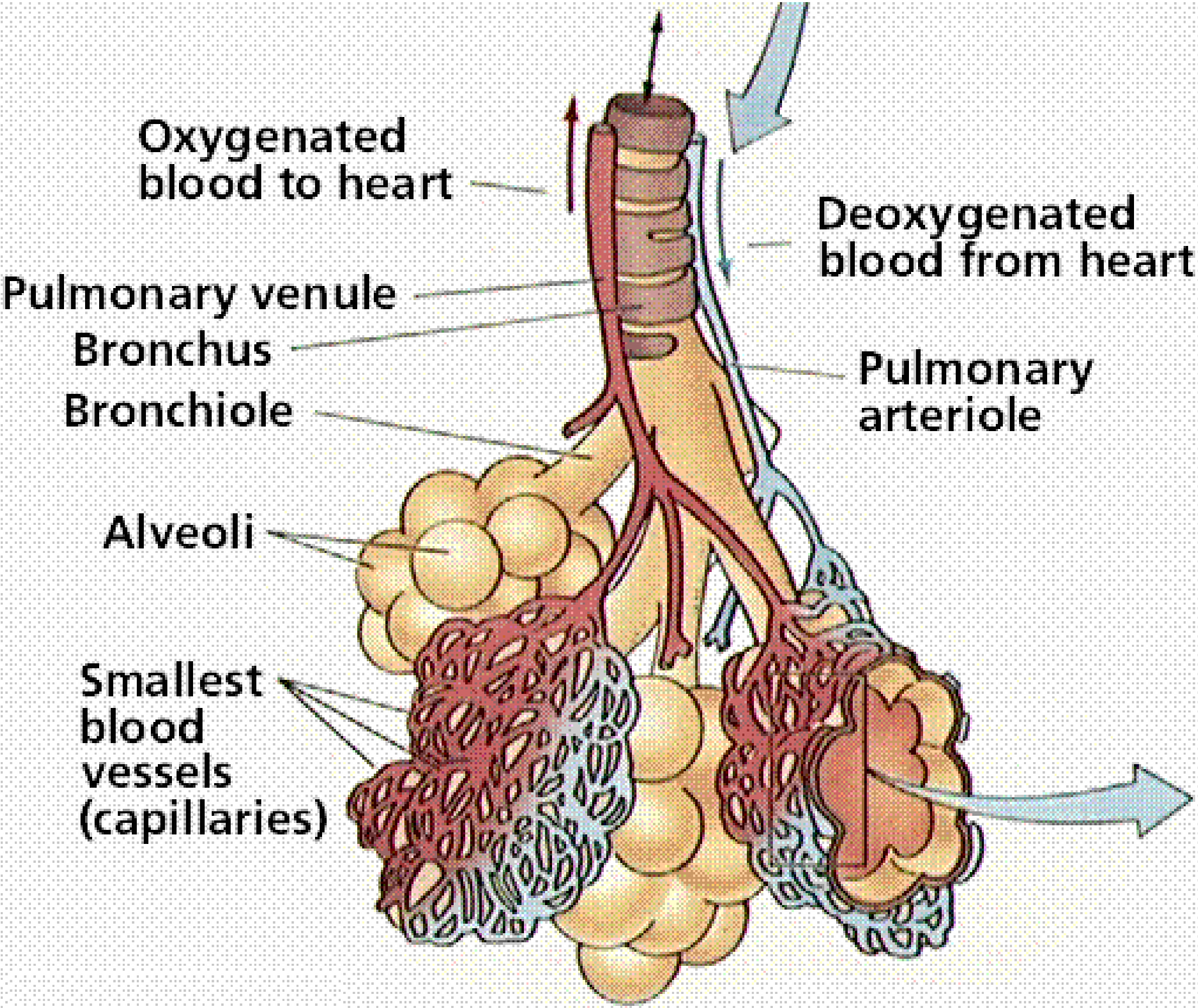
- Alveoli are the functional unit of the lung.
- They are tiny sacs at the end of the bronchioles that look like clusters of grapes.
- Gas exchange (O_2 and CO_2) between the atmosphere and the blood occurs at the alveoli.
- The walls of the alveoli and the walls of the capillary net that surround are only 1 cell thick! This allows effective gas exchange.

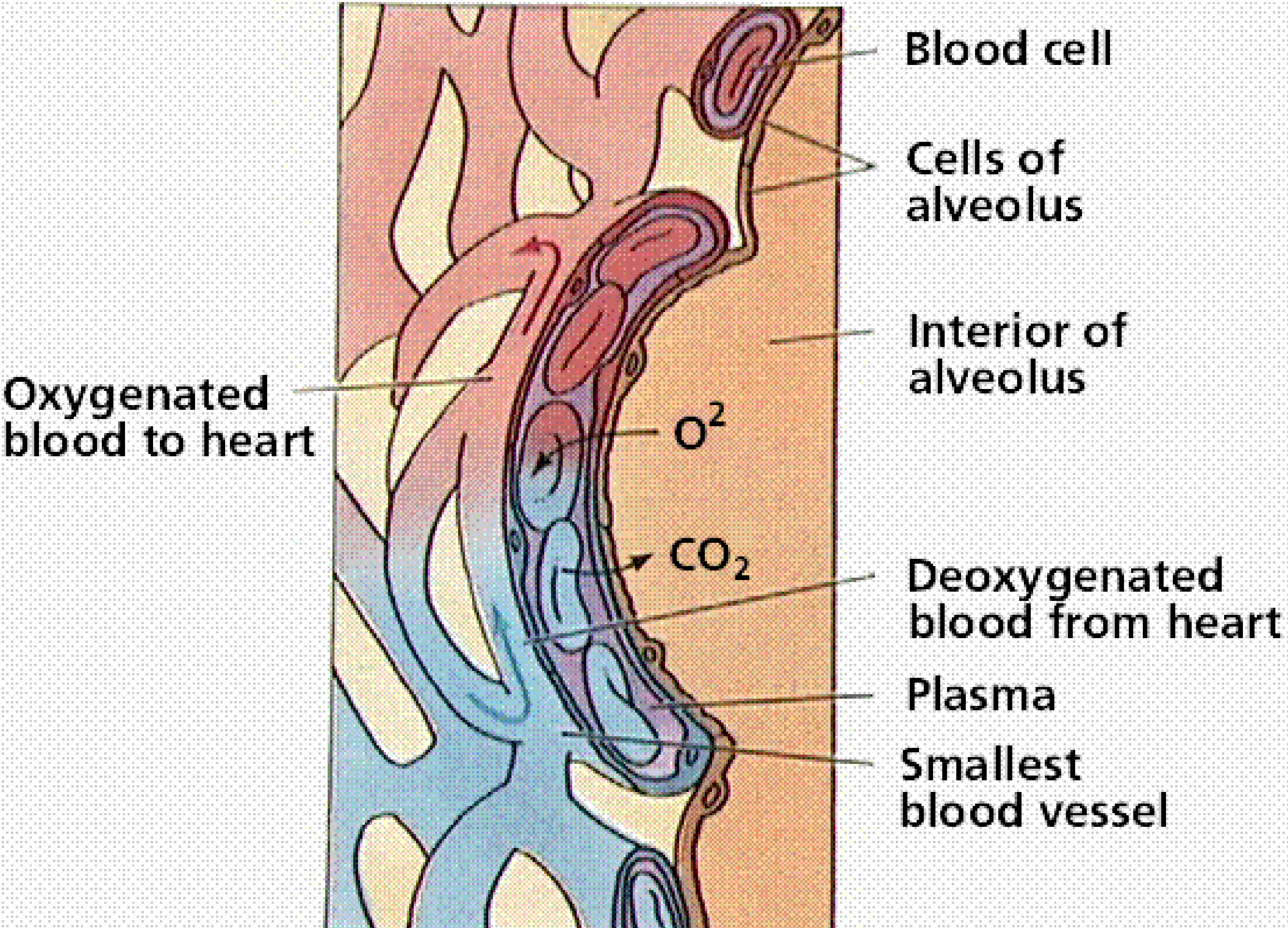
Alveoli


Primary
bronchus
Secondary
bronchus
Tertiary
bronchus
Bronchiole
Terminal
bronchiole
Alveoli
Alveoli enlarged
© ADAM, Inc.


bronchiole
capillary
O_2
CO_2
alveoli
Gas exchange by
diffusion in lungs


Bronchioles
Trachea
Rings of cartilage
Bronchi
Pleural membrane
Pleural cavity
Diaphragm

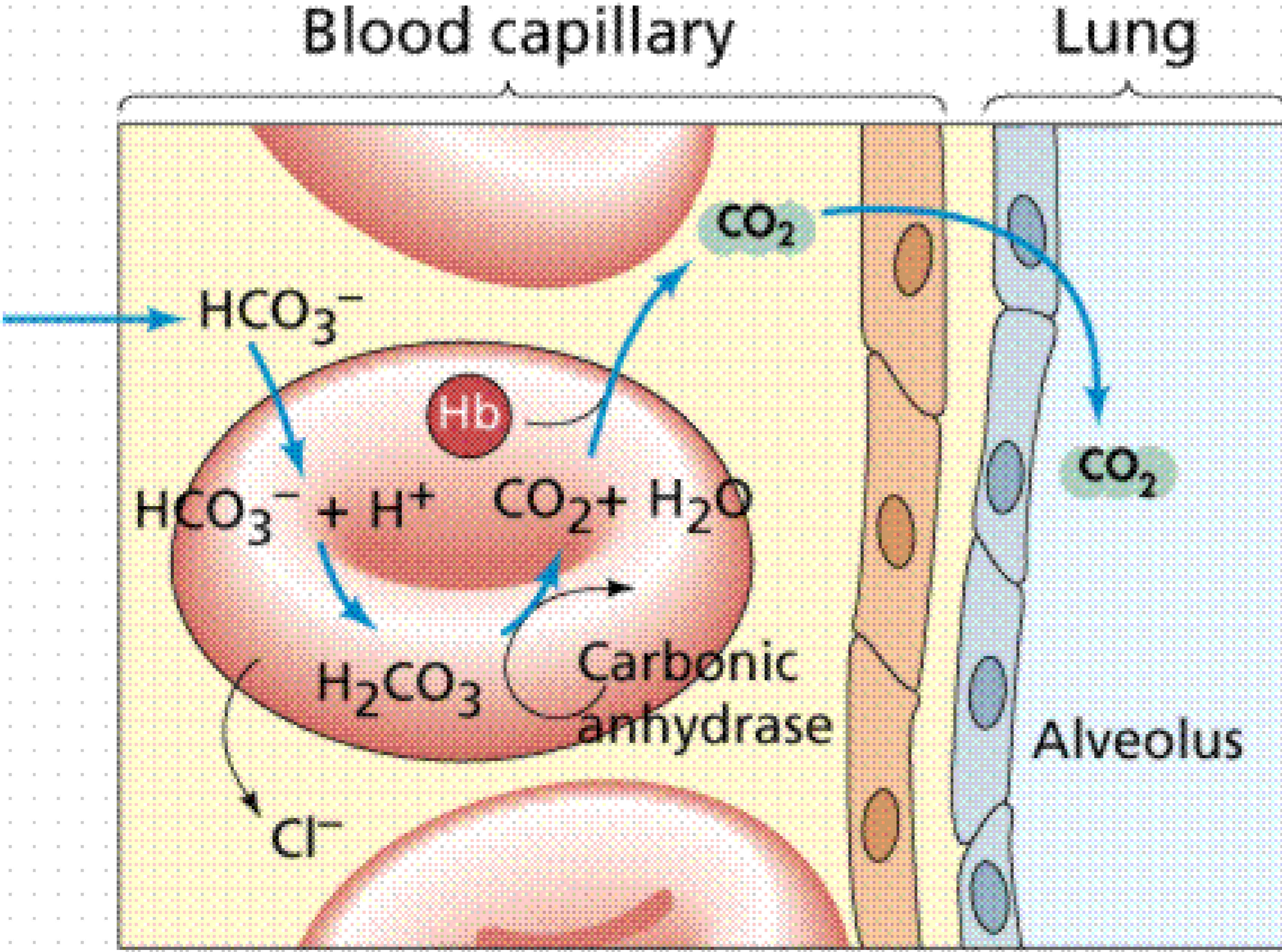

Oxygenated
blood to heart
Deoxygenated
blood from heart
Pulmonary venule
Bronchus
Pulmonary
arteriole
Bronchiole
Alveoli
Smallest
blood
vessels
(capillaries)


Blood cell
Cells of alveolus
Interior of alveolus
Oxygenated blood to heart
O2
CO2
Deoxygenated blood from heart
Plasma
Smallest blood vessel

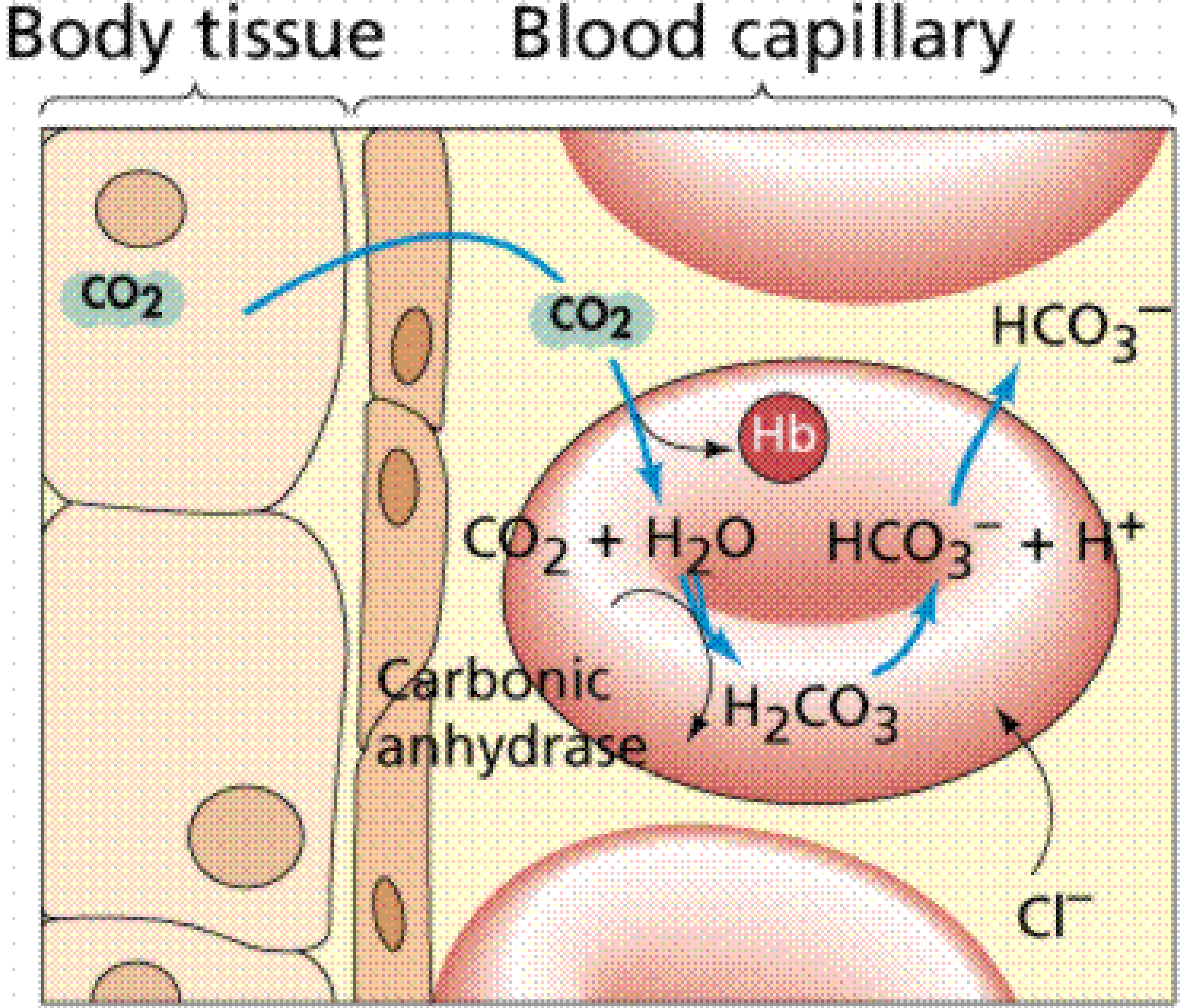
Alveoli

Three main factors allow for the exchange of gases between the blood cells in the capillaries and the alveoli:

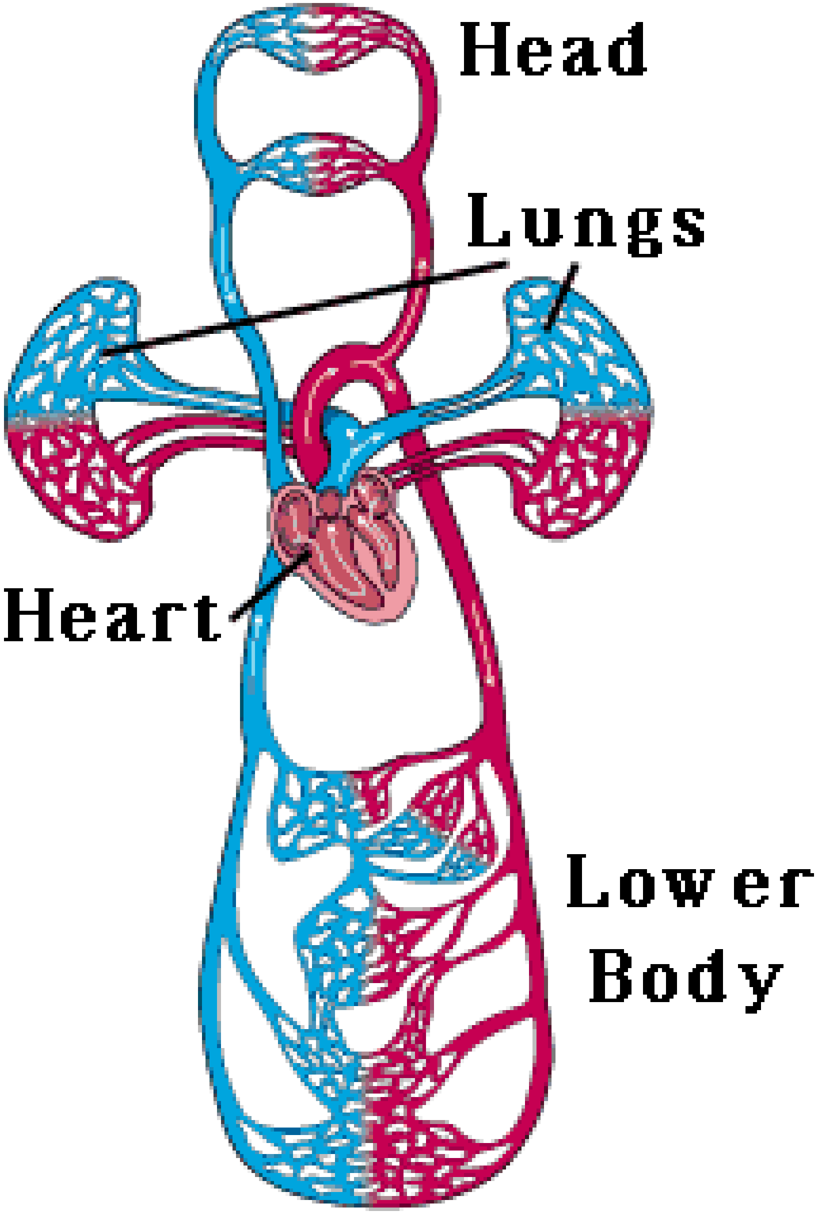
1. The difference in the partial pressures of oxygen and carbon dioxide result in a diffusion gradient.
2. Thin single celled walls.
3. A moist membrane.

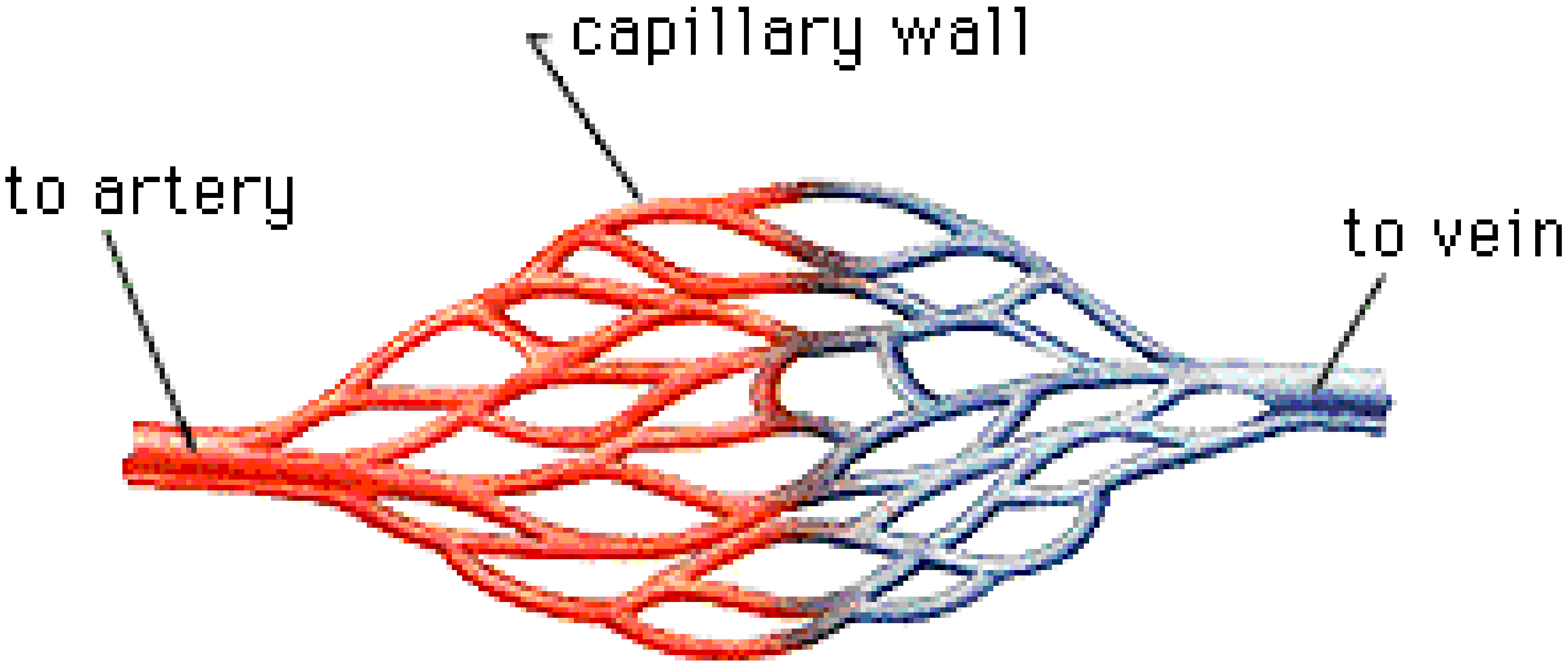


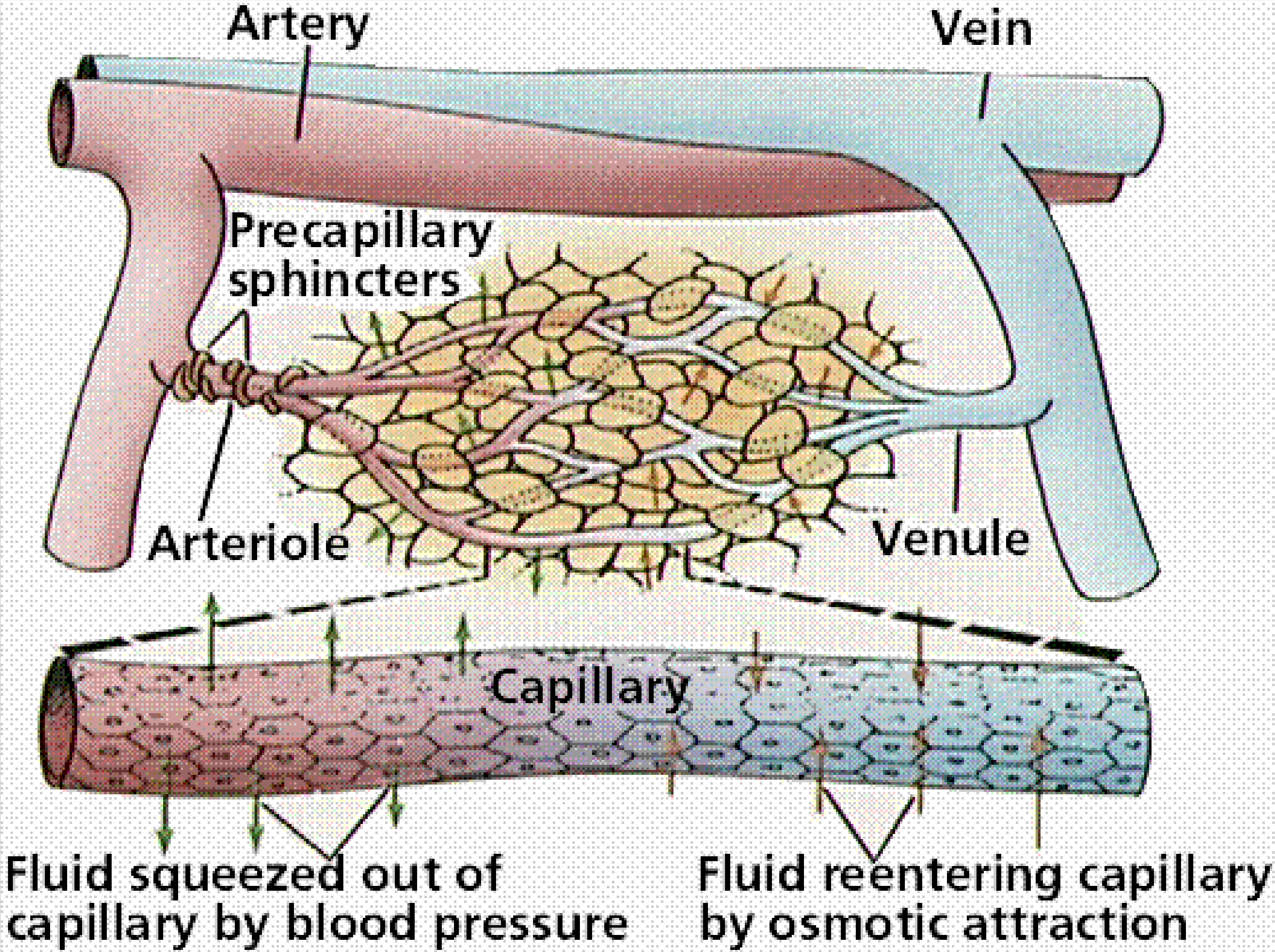
Blood capillary
Lung
CO2
HCO3−
Hb
HCO3− + H+
CO2+ H2O
CO2
H2CO3
Carbonic anhydrase
Alveolus
Cl−


Body tissue
Blood capillary
CO2
CO2
HCO3−
Hb
CO2 + H2O
HCO3− + H+
Carbonic anhydrase
H2CO3
Cl−

How O_2 and CO_2 is cycled in the body:

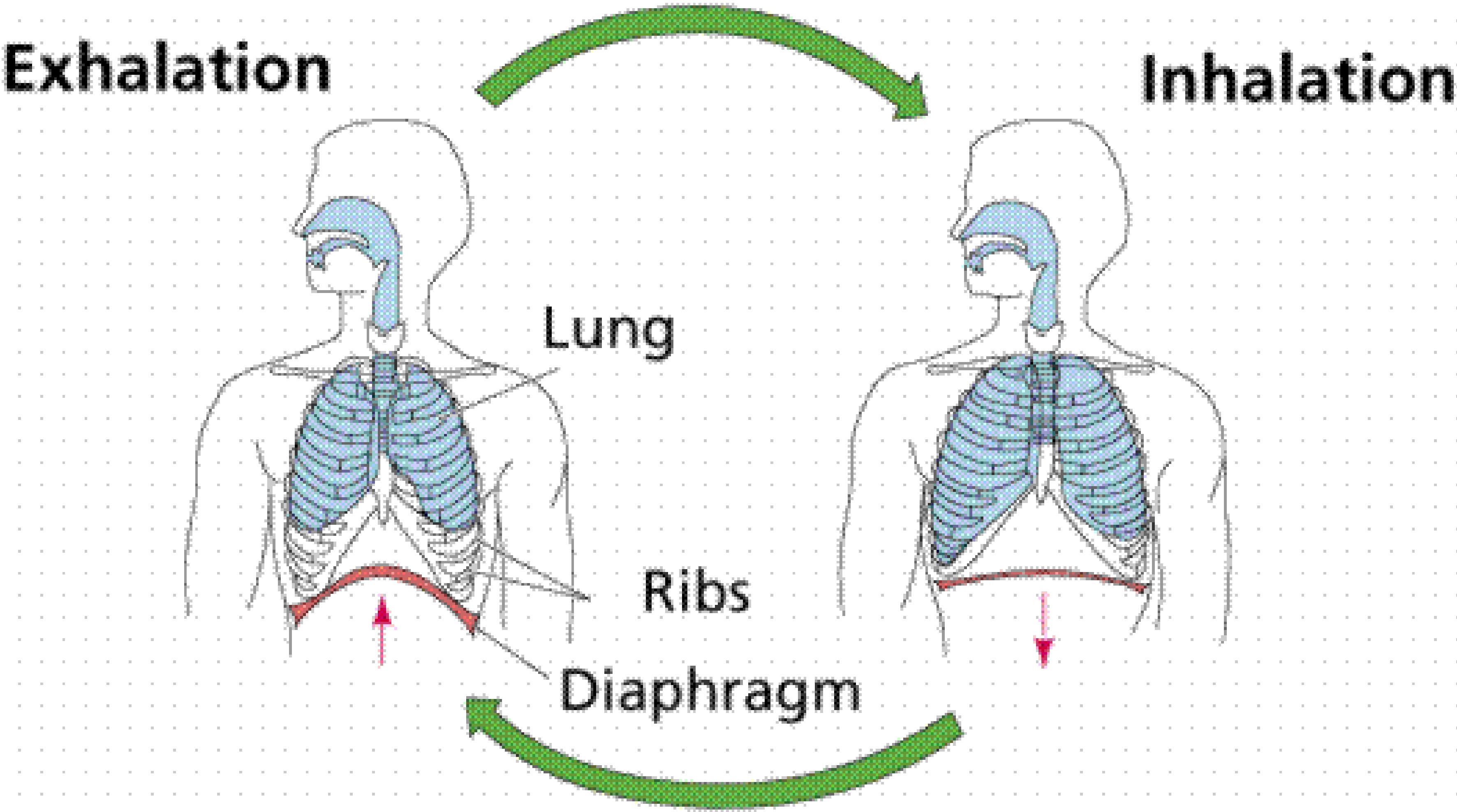



capillary wall
to artery
to vein


Artery
Vein
Precapillary sphincters
Arteriole
Venule
Capillary
Fluid squeezed out of capillary by blood pressure
Fluid reentering capillary by osmotic attraction

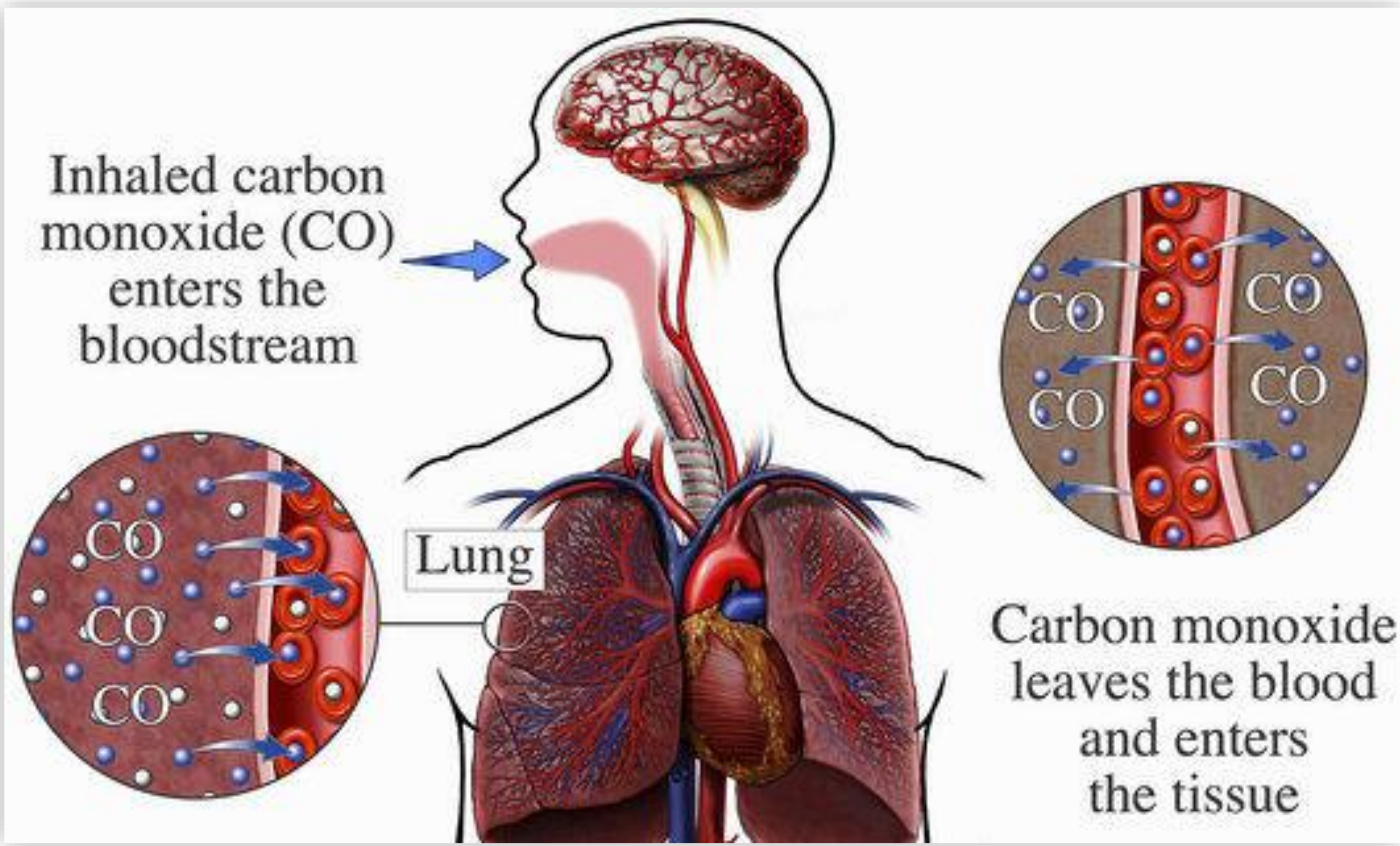
Role of the Chest and Diaphragm

- Diaphragm moves down → chest cavity moves up → low pressure environment in the lungs → air is sucked up through the mouth/nose
- Diaphragm moves up → chest moves down → high pressure environment in the lungs → air is pushed out through the mouth/nose


Exhalation
Inhalation
Lung
Ribs
Diaphragm

Carbon Monoxide – How does it kill you?

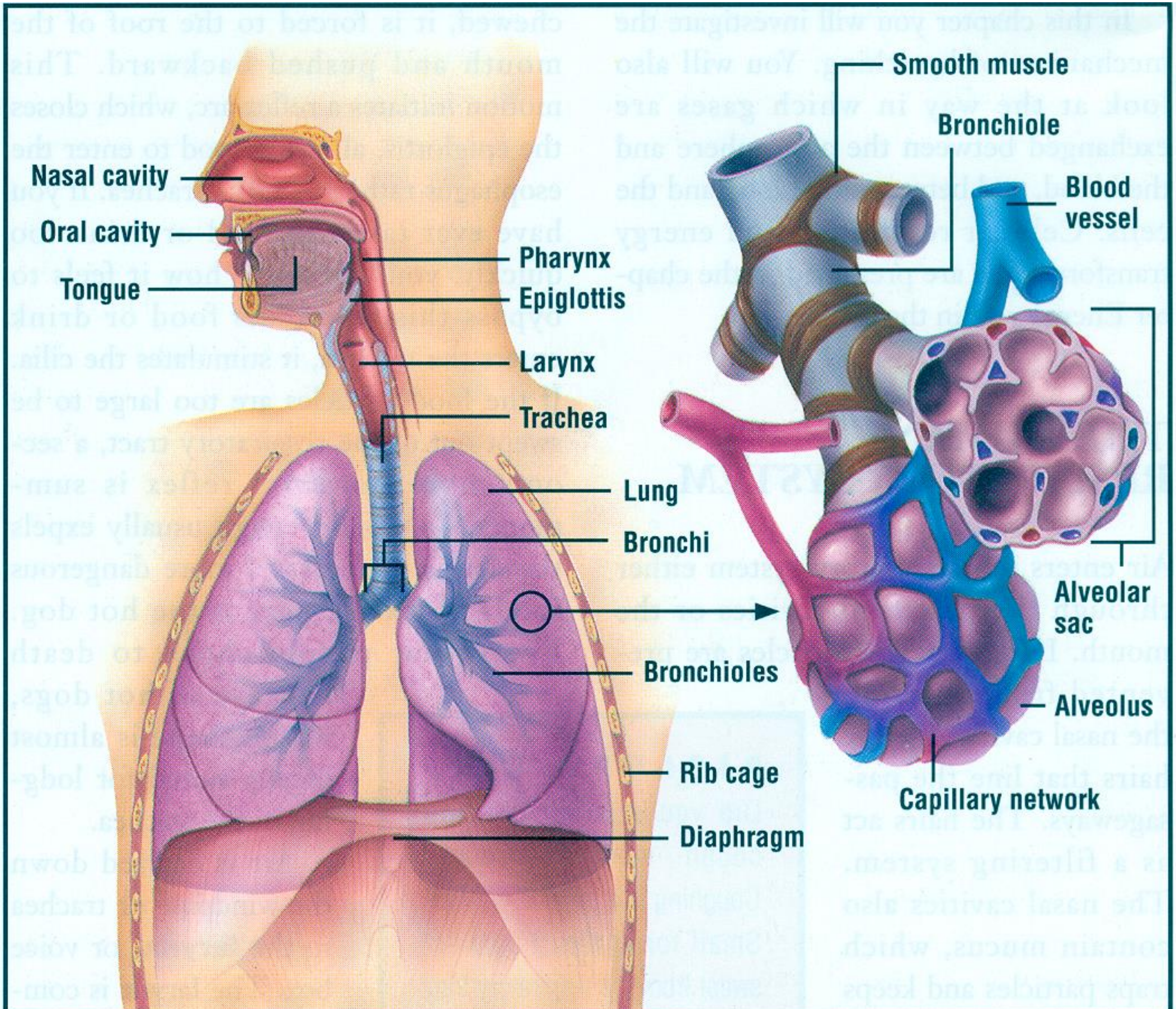
- CO gets into the blood stream and prevents red blood cells from carrying O_2.



Exercise and the RS

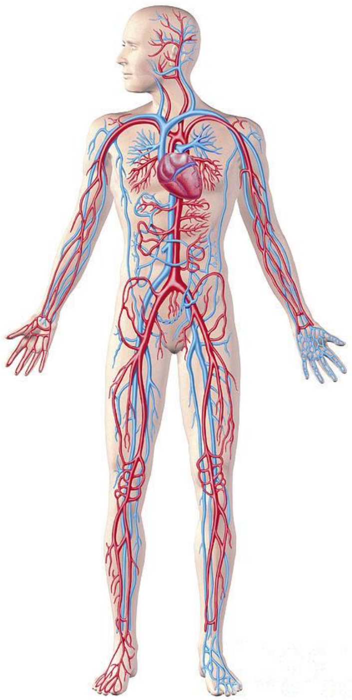
Exercise is good for the RS.

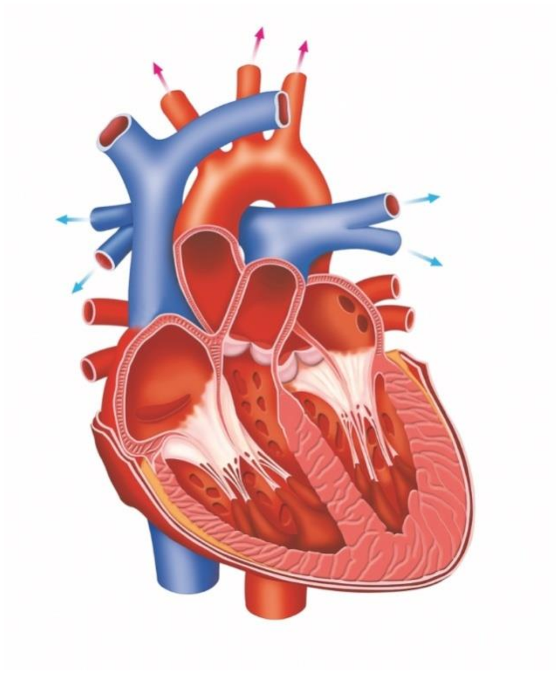
- During exercise, our brain sense high levels of CO_2 in the blood.
- Our rate of breathing becomes increased. This strengthens the diaphragm (as well as are heart).


Nasal cavity
Oral cavity
Tongue
Pharynx
Epiglottis
Larynx
Trachea
Lung
Bronchi
Bronchioles
Rib cage
Diaphragm
Smooth muscle
Bronchiole
Blood vessel
Alveolar sac
Alveolus
Capillary network

Circulatory System

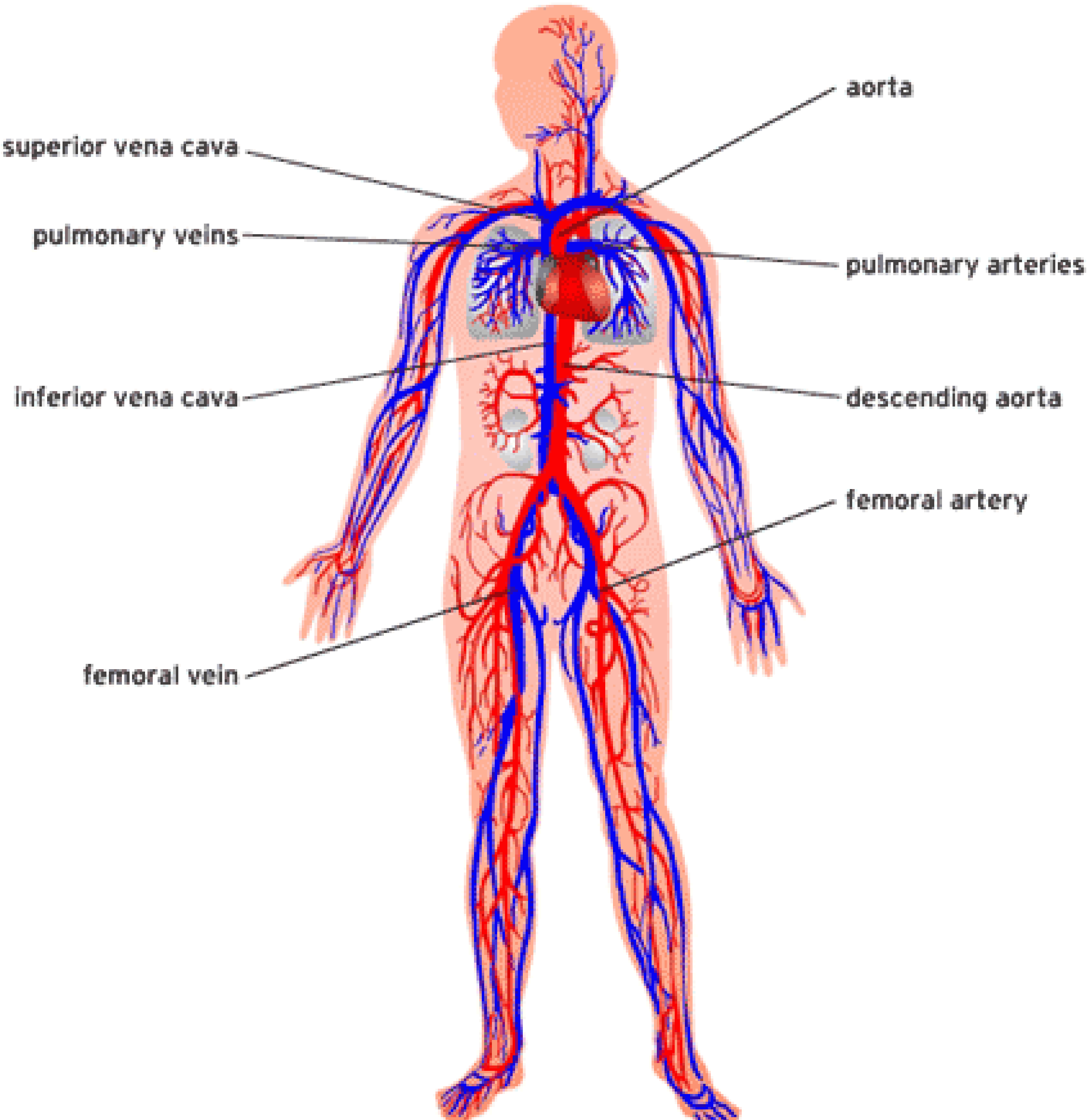
The circulatory system is a vast network of organs and vessels that is responsible for the flow of blood, nutrients, oxygen and other gases, and hormones to and from cells.

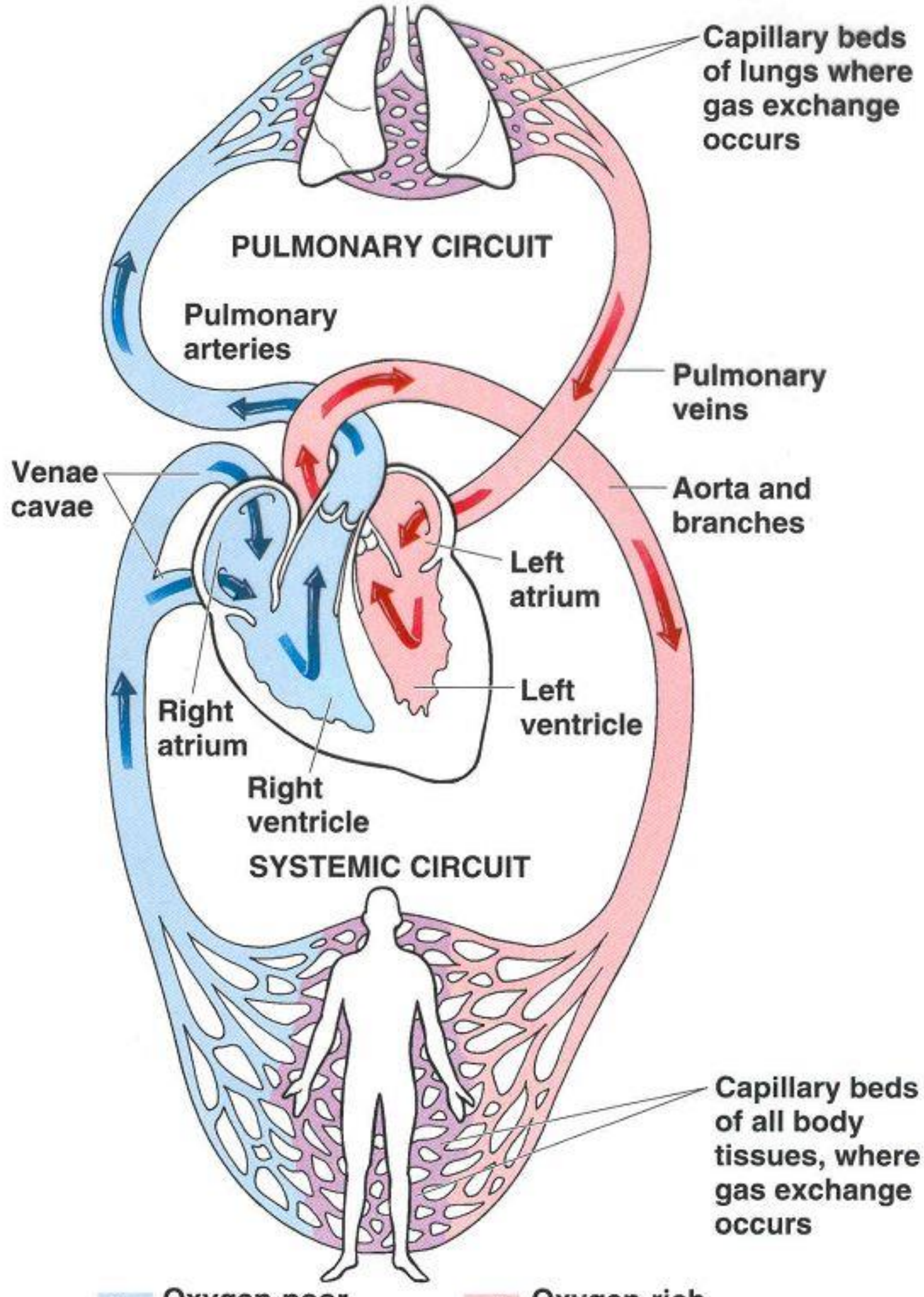




Circulatory System

- In the average human, about 2,000 gallons (7,572 liters) of blood travel daily through about 60,000 miles (96,560 kilometers) of blood vessels.
- An average adult has 5 to 6 quarts (4.7 to 5.6 liters) of blood, which is made up of plasma, red blood cells, white blood cells and platelets.
- In addition to blood, the circulatory system moves lymph, which is a clear fluid that helps rid the body of unwanted material.

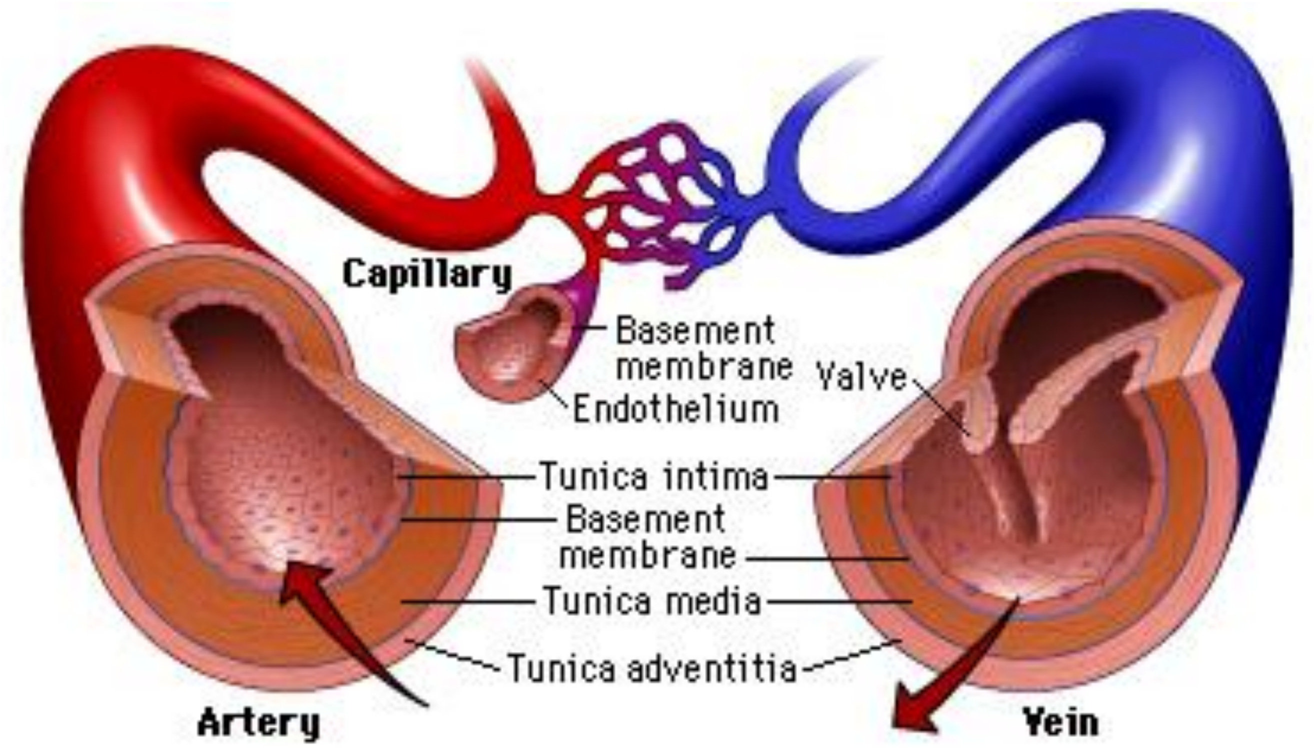

aorta
superior vena cava
pulmonary veins
pulmonary arteries
inferior vena cava
descending aorta
femoral artery
femoral vein



Capillary beds of lungs where gas exchange occurs
PULMONARY CIRCUIT
Pulmonary arteries
Pulmonary veins
Venae cavae
Aorta and branches
Left atrium
Left ventricle
Right atrium
Right ventricle
SYSTEMIC CIRCUIT
Capillary beds of all body tissues, where gas exchange occurs
Oxygen-poor, CO_2-rich blood
Oxygen-rich, CO_2-poor blood

Blood Vessels

- There are 3 main types of blood vessels:
  - Arteries
  - Veins
  - Capillaries

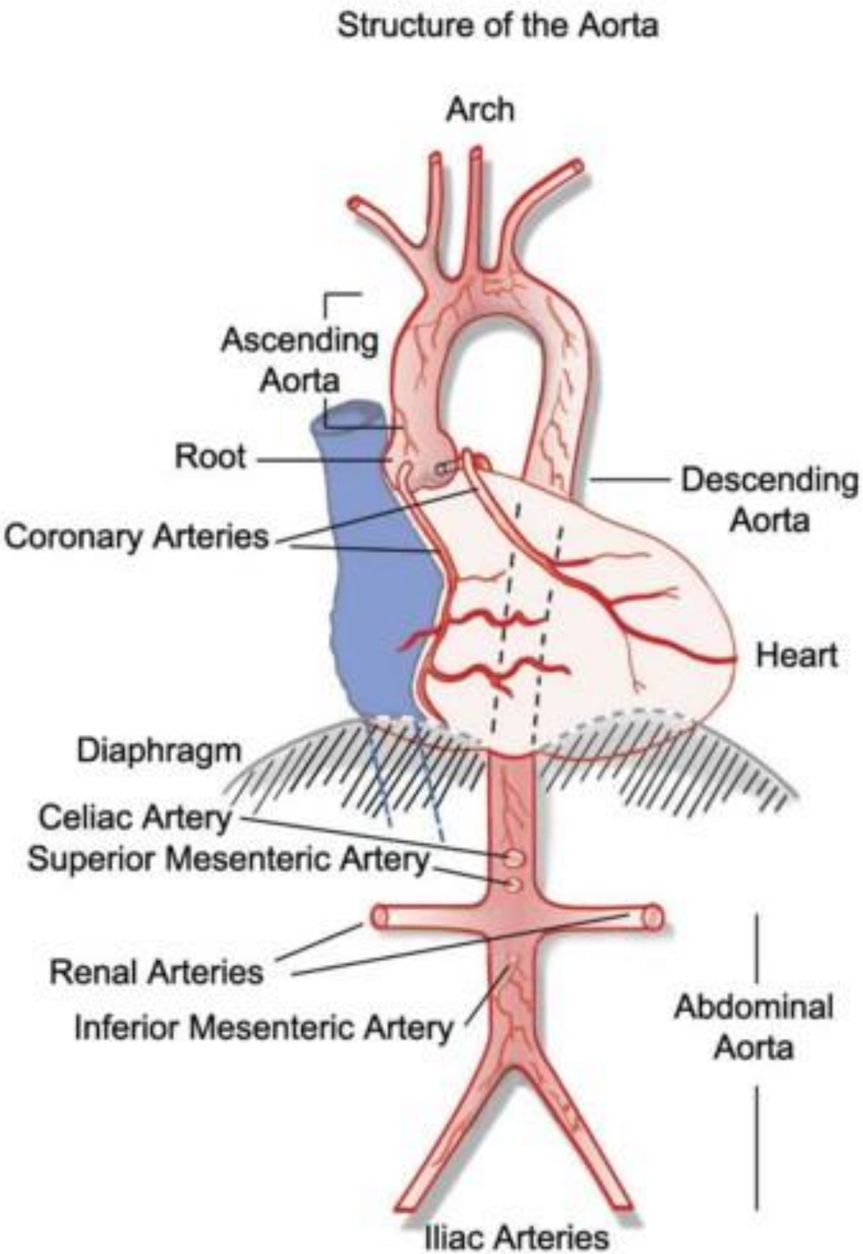


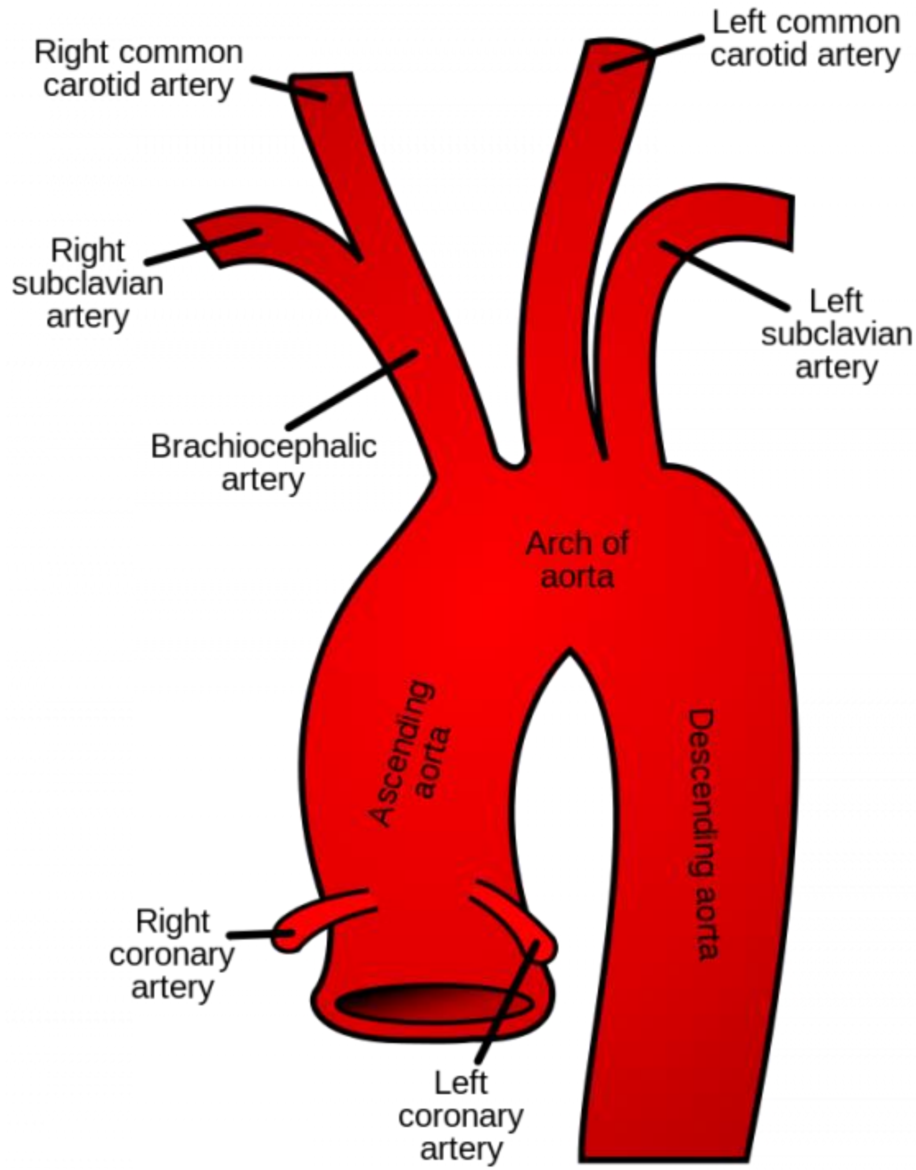
Arteries

- Carry blood AWAY from the heart.
- Have thick muscular walls.
- Expand and contract as blood pulses through them.
- Arteries tend to travel along the bones, deeper in the tissue.
- Do arteries contain blood with high or low oxygen levels?
  - HIGH and LOW oxygen levels

Arteries

- The largest artery in the human body is the aorta.
- Your aorta is approximately the diameter of your thumb.
- The aorta branches into three main arteries which carry blood to the upper half of the body (arms and head), while the rest of the blood heads down the descending aorta which wraps around and behind the heart.

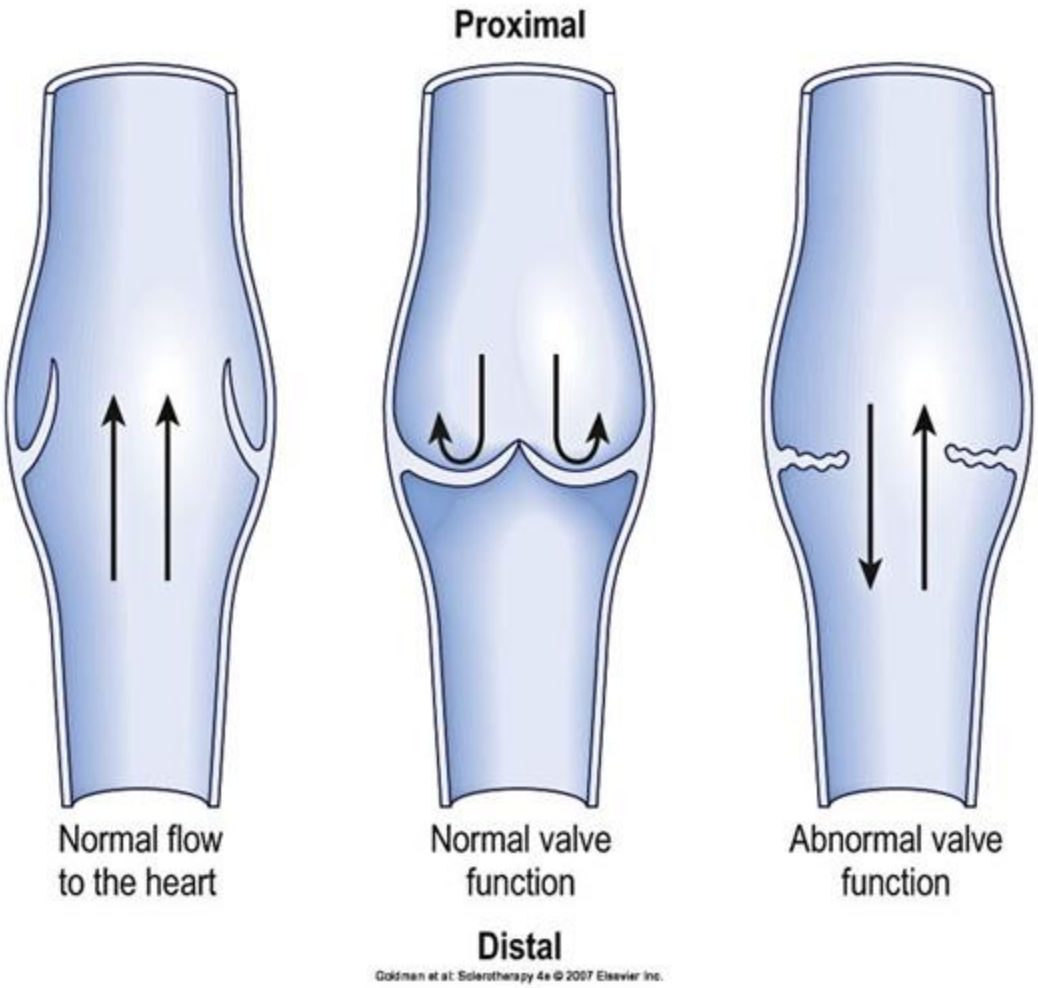

Structure of the Aorta
Arch
Ascending Aorta
Root
Coronary Arteries
Descending Aorta
Heart
Diaphragm
Celiac Artery
Superior Mesenteric Artery
Renal Arteries
Inferior Mesenteric Artery
Abdominal Aorta
Iliac Arteries


Right common carotid artery
Left common carotid artery
Right subclavian artery
Left subclavian artery
Brachiocephalic artery
Arch of aorta
Ascending aorta
Descending aorta
Right coronary artery
Left coronary artery

Veins

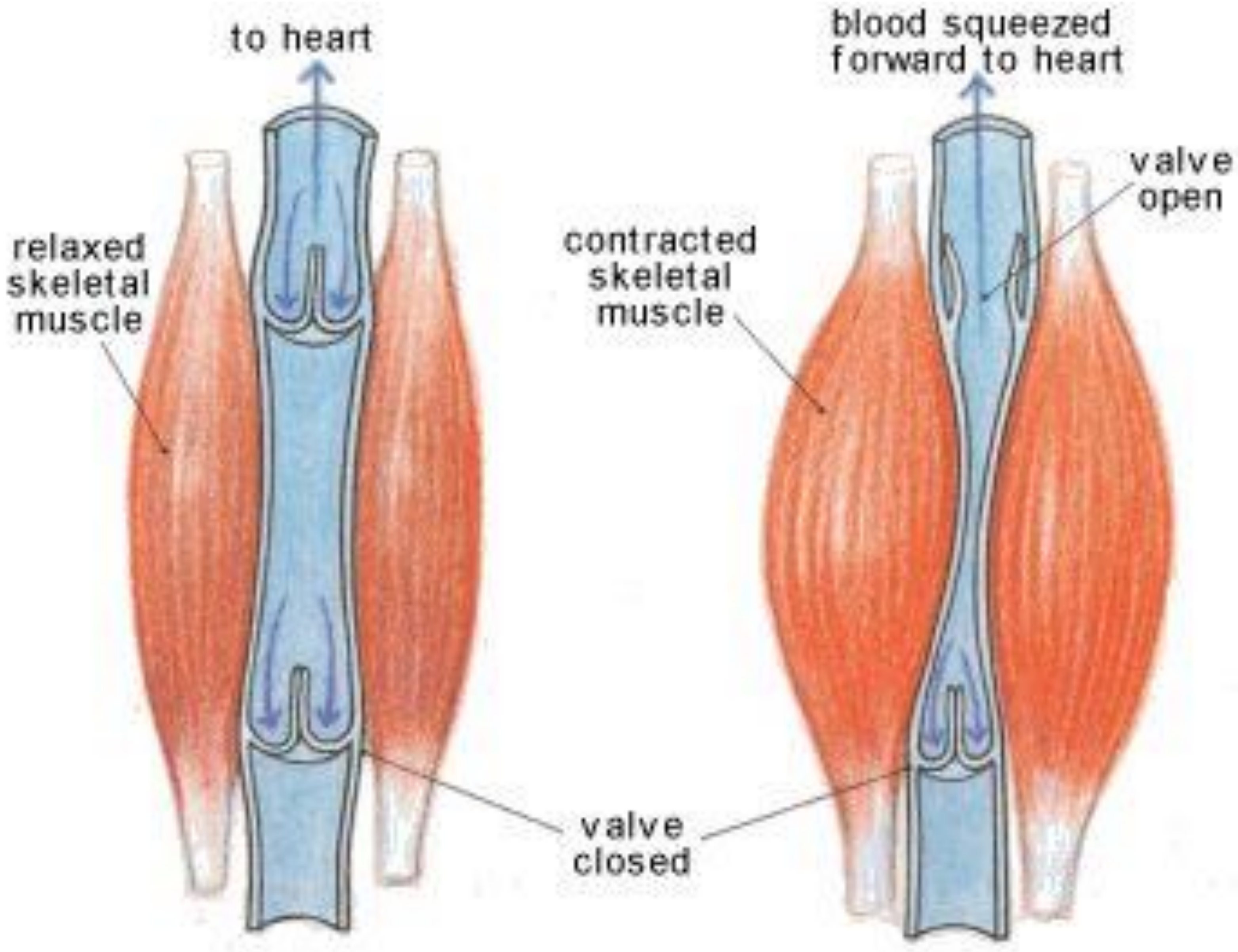
- Carry blood TOWARDS the heart.
- Have thinner less muscular walls.
- Do not expand and contract as blood passes through them.
- Tend to travel more near the surface of tissue.
- Do veins contain blood with high or low oxygen levels?
  - HIGH and LOW in oxygen levels
- Veins contain valves to help prevent backflow of blood.

Valves



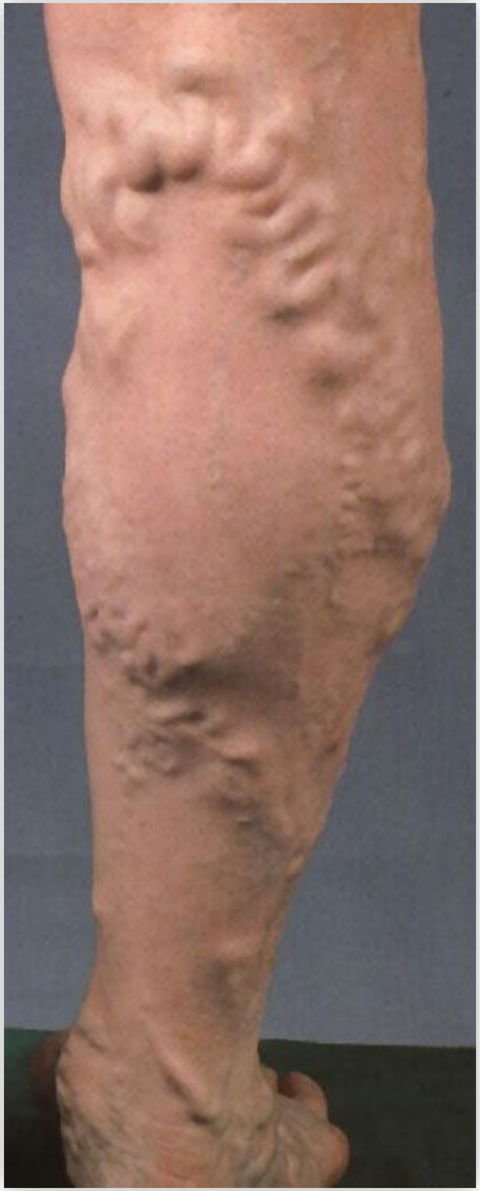
Proximal
Normal flow
to the heart
Normal valve
function
Abnormal valve
function
Distal
Goldman et al: Sclerotherapy 4e © 2007 Elsevier Inc.

Veins help the heart pump blood



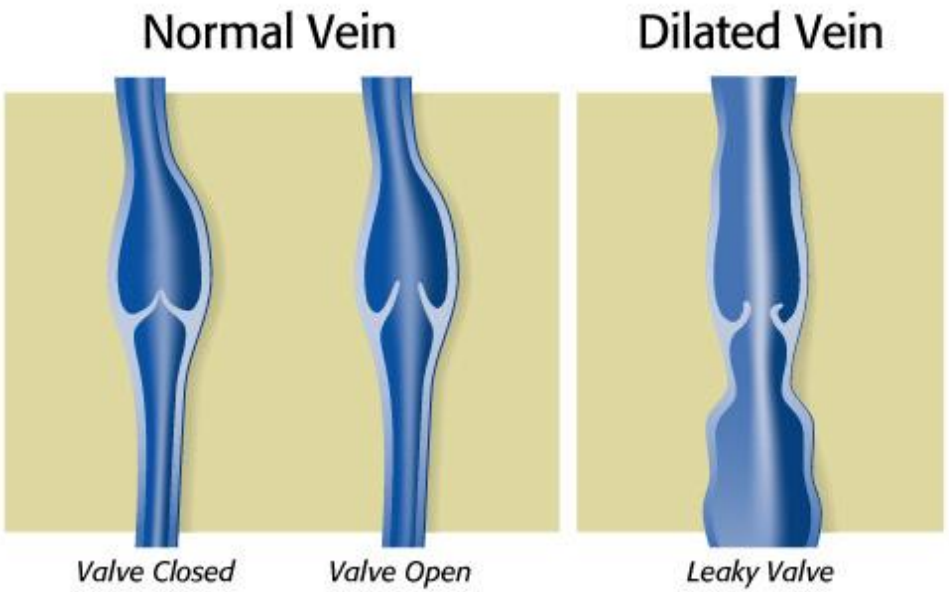
Varicose Veins

- Varicose veins are twisted, enlarged veins near the surface of the skin. They are most common in the legs and ankles.
- Caused by weakened valves and veins in your legs.

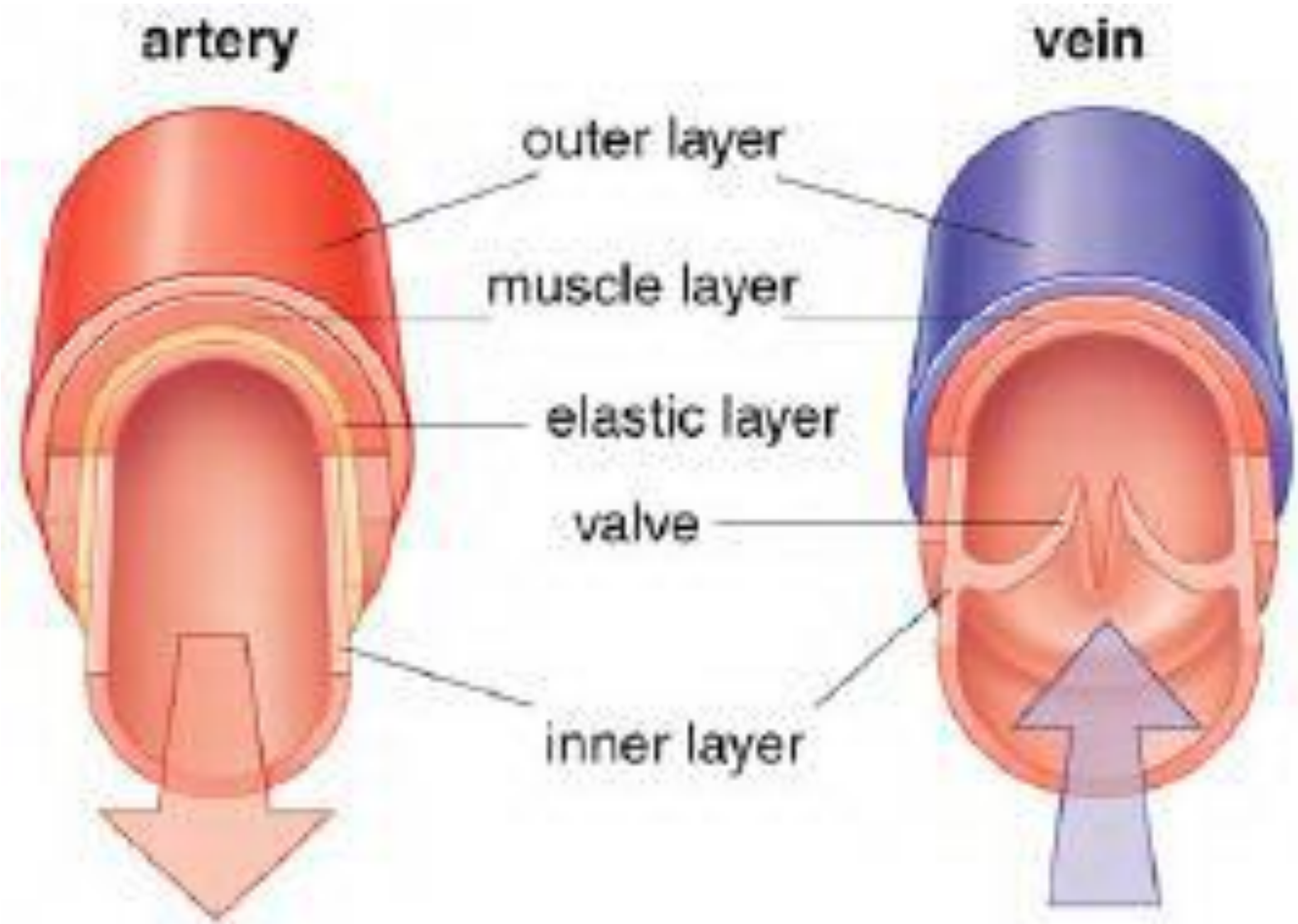


Varicose Veins

- When these valves do not work as they should, blood collects in your legs, and pressure builds up. The veins become weak, large, and twisted.
- Causes: genetics, being overweight or pregnant, or having a job where you're on your feet for long periods of time increases pressure on leg veins.



Comparing Arteries to Veins



Comparing Arteries to Veins

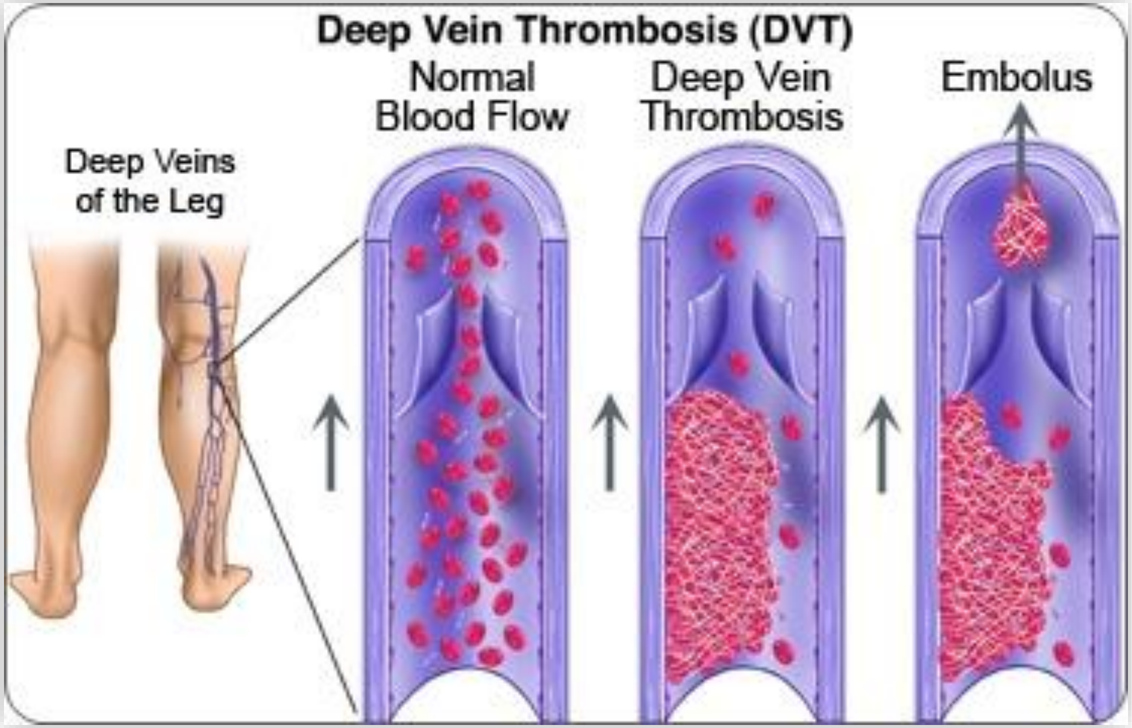
- In general, arteries are larger than veins; however, there are more veins than arteries.
- Blood flows through arteries 2-3 times faster than it does through veins. Therefore, there is about 2-3 times times more blood in veins at any given time.

Total blood volume:

- **Veins** – 64%
- **Arteries –** 15%
- **Capillaries –** 8%
- **Pulmonary vessels –** 9%
- **Heart –** 7%

Deep Vein Thrombosis (DVT)

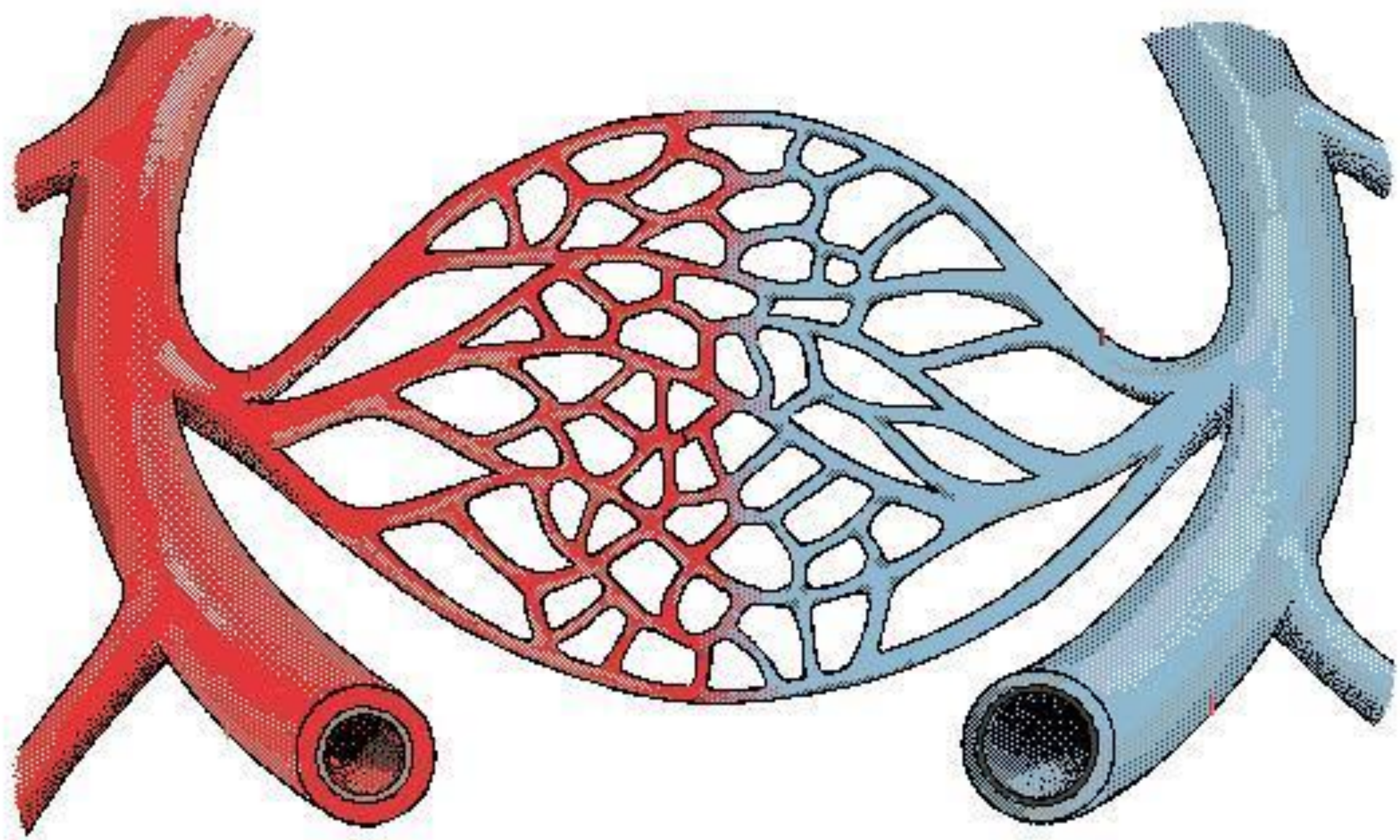
- This is the formation of a blood clot usually in the deep veins of the leg.
- In some cases part of the clot can become dislodged (embolus) and move to the lungs or coronary artery.

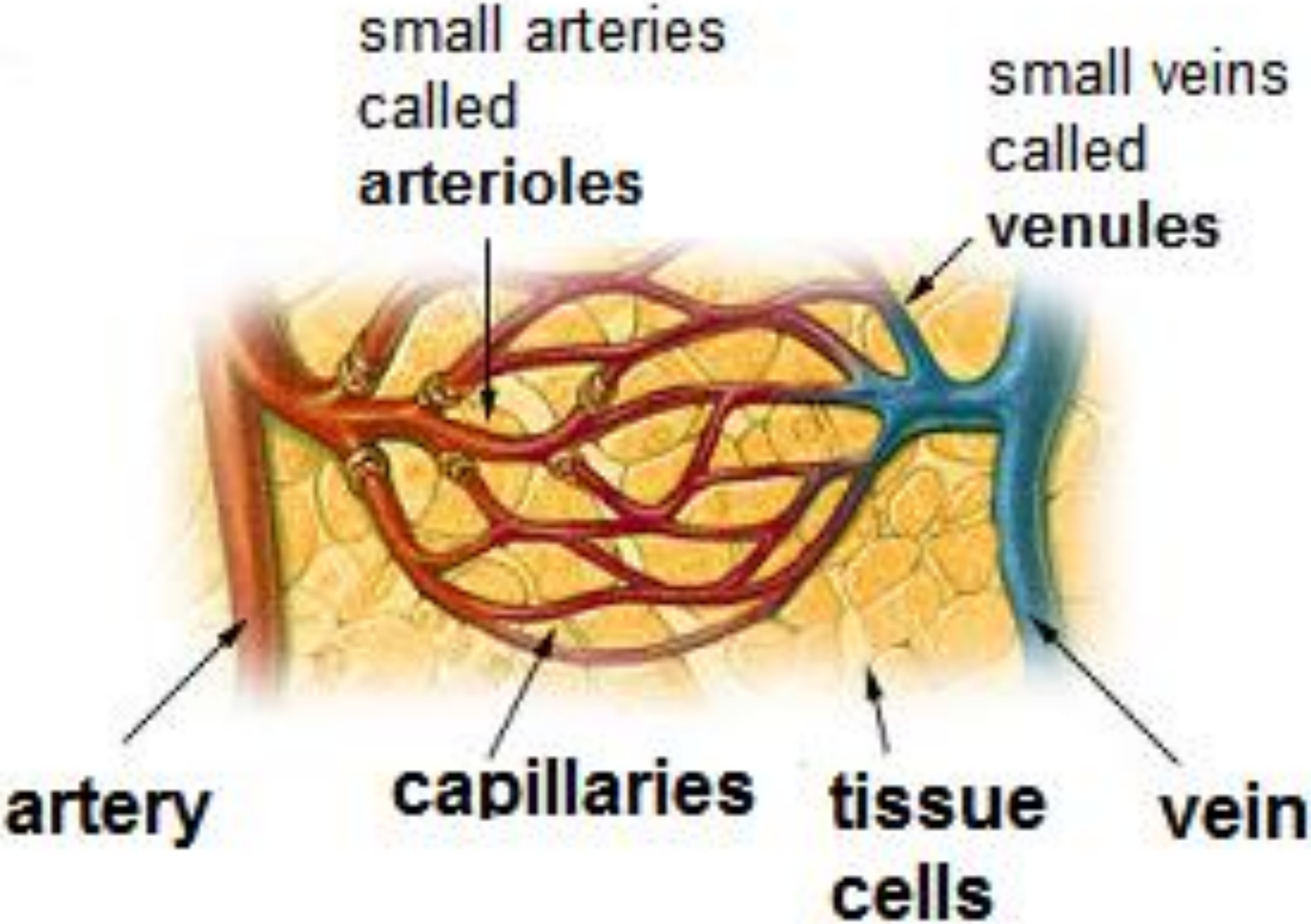


Capillaries

- Are the smallest thinnest blood vessels in the body.
- They are so thin the red blood cells must travel through them in single file.
- Their walls are extremely thin (a single layer) which allows for the diffusion of materials in and out of them.
- There are approximately 40 billion capillaries in the human body.

- The total length of all the blood vessels combined in the human body is estimated at approximately 60-100 thousand km (enough to circle the earth 3-4 times).




small arteries
called
arterioles
small veins
called
venules
artery
capillaries
tissue
cells
vein

The Heart

- The muscle responsible for pumping blood throughout the circulatory system.
- Your heart is approximately the size of your fist.
- The muscle cells that comprise the heart are referred to as cardiac muscles.
- What is unique about cardiac muscle as compared to regular skeletal muscle?

The Heart

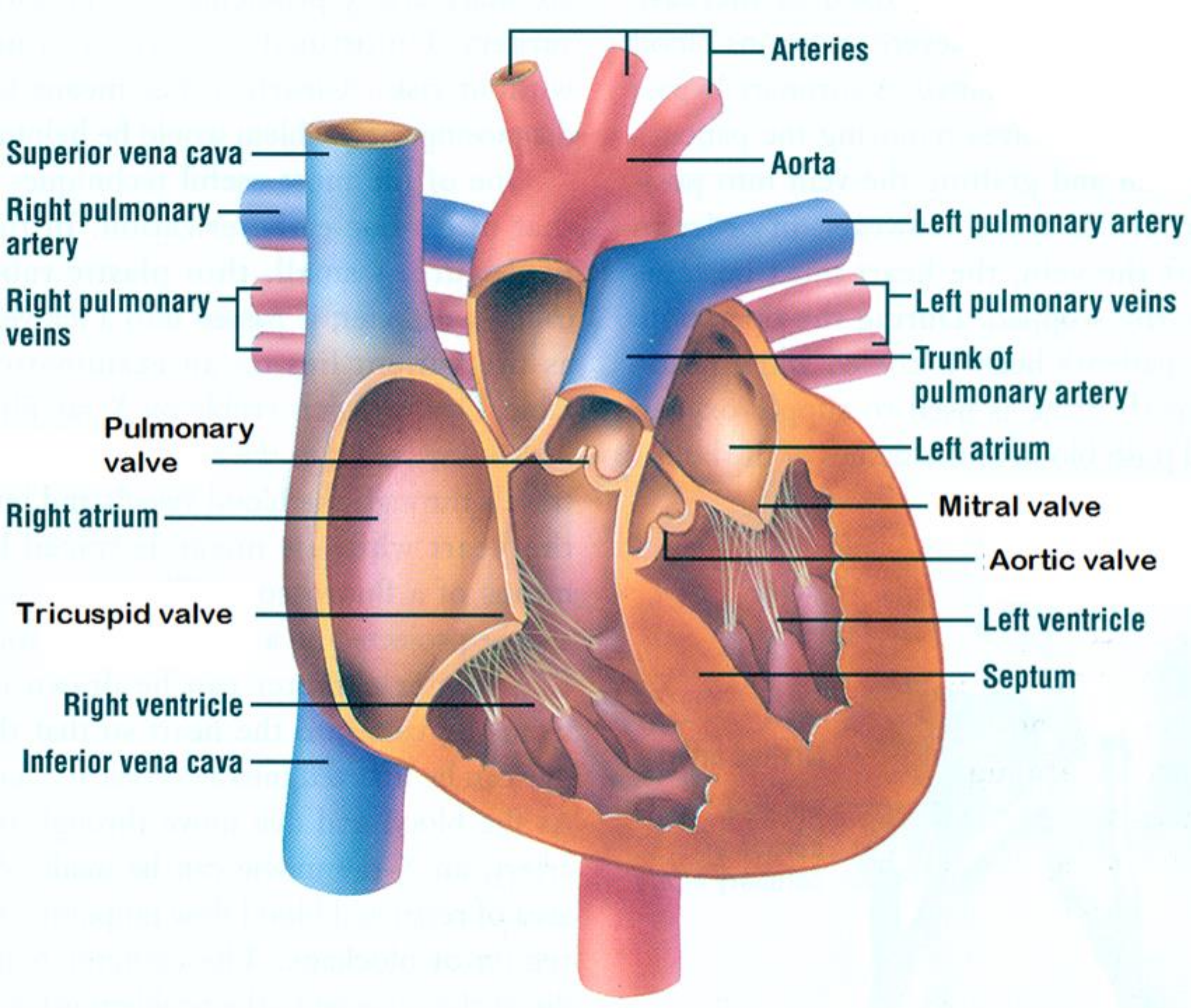
- A human heart has four chambers.
- This prevents the oxygen rich blood from mixing with the oxygen poor blood.
- There are also several key valves inside the heart that help to move the blood along by preventing backflow.
- The two upper cambers are called atria and the lower chambers are called ventricles.

Chambers of the Heart

- **Top chambers:** The Atrium
  - Have thin walls and receive blood returning through the veins to the heart.

- **Bottom chambers:** The Ventricles
  - Have thick muscular walls and force blood out of the heart into the arteries.

- **Left atrium -** The left atrium receives oxygen rich blood from the lungs and pumps it to the left ventricle.
- **Left ventricle** - The left ventricle receives blood from the left atrium and pumps it to the body through the aorta.
- **Right atrium -** The right atrium receives oxygen poor blood from the superior and inferior vena cava and pumps it to the right ventricle.
- **Right ventricle -** The right ventricle receives blood from the right atrium and pumps it to the lungs through the left pulmonary artery.


Arteries
Superior vena cava
Aorta
Right pulmonary artery
Left pulmonary artery
Right pulmonary veins
Left pulmonary veins
Trunk of pulmonary artery
Pulmonary valve
Left atrium
Mitral valve
Right atrium
Aortic valve
Tricuspid valve
Left ventricle
Septum
Right ventricle
Inferior vena cava

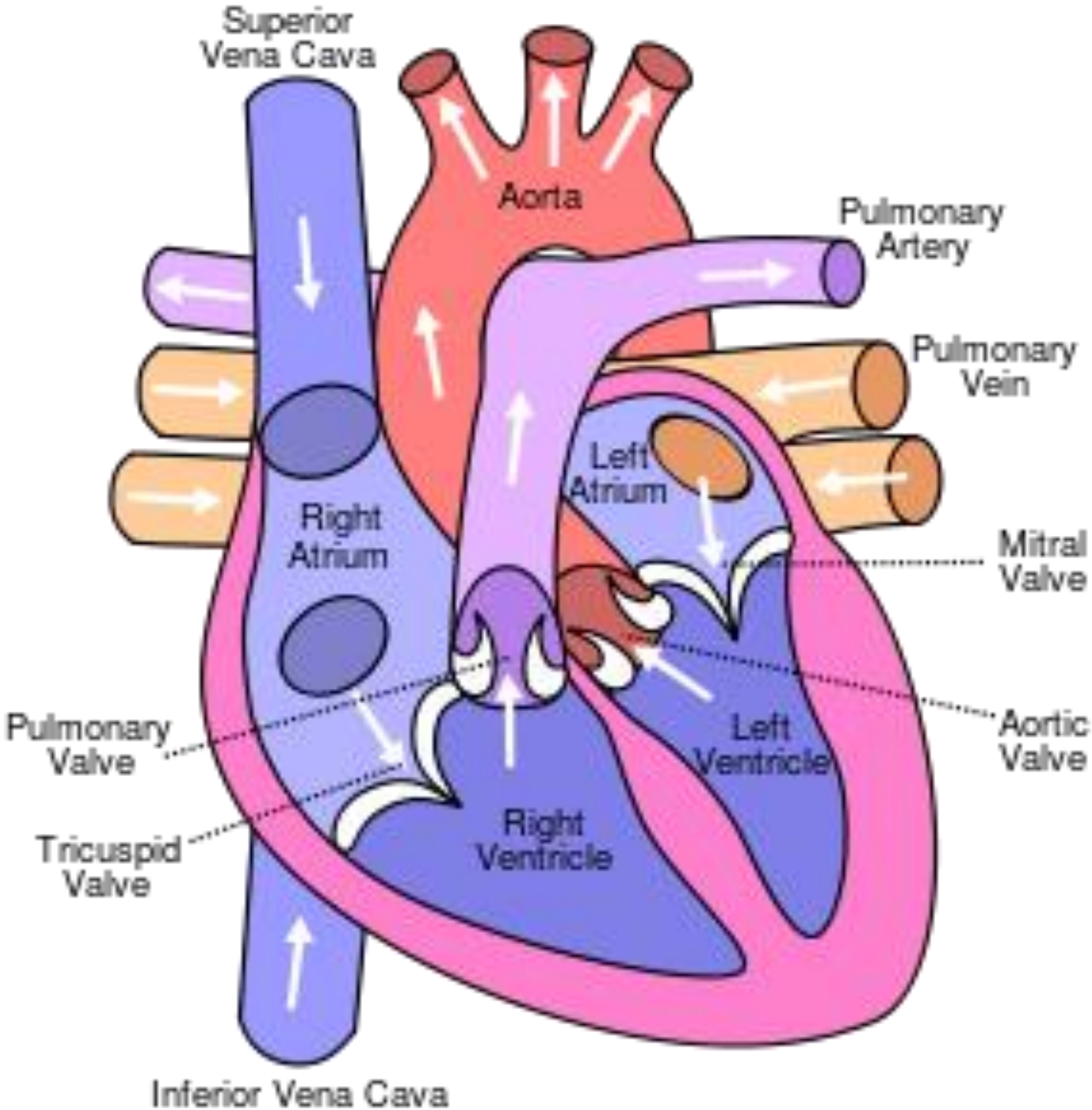
Major Arteries

Three major arteries (stems from the aorta):

1. Brachiocephalic – supplies blood to the brain and right arm.
2. Left common carotid – supplies blood to upper body.
3. Left subclavian – supplies blood to upper body.

Pulmonary Veins and Arteries

- Pulmonary arteries – carry blood high in CO_2 and low in O_2 away from the heart to the lungs.
- Pulmonary veins carry blood low in CO_2 and high in O_2 away from the lungs to the heart.


Superior Vena Cava
Aorta
Pulmonary Artery
Pulmonary Vein
Left Atrium
Right Atrium
Mitral Valve
Pulmonary Valve
Aortic Valve
Left Ventricle
Tricuspid Valve
Right Ventricle
Inferior Vena Cava

Major Heart Valves

What is a heart valve?

- Any of the valves (devices that control the passage of fluid through a duct) that control blood flow to and from the **heart**.

- **Atrioventricular valve –** either of two heart valves through which blood flows from the atria to the ventricles; prevents return of blood to the atrium.

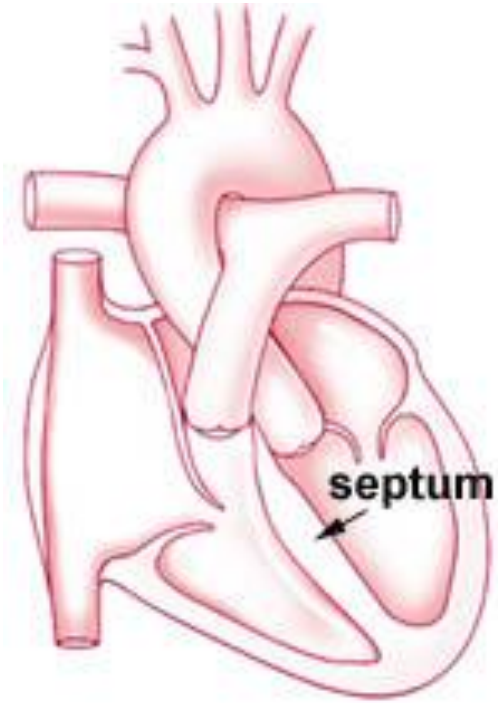
Major Heart Valves

Two atrioventricular valves:

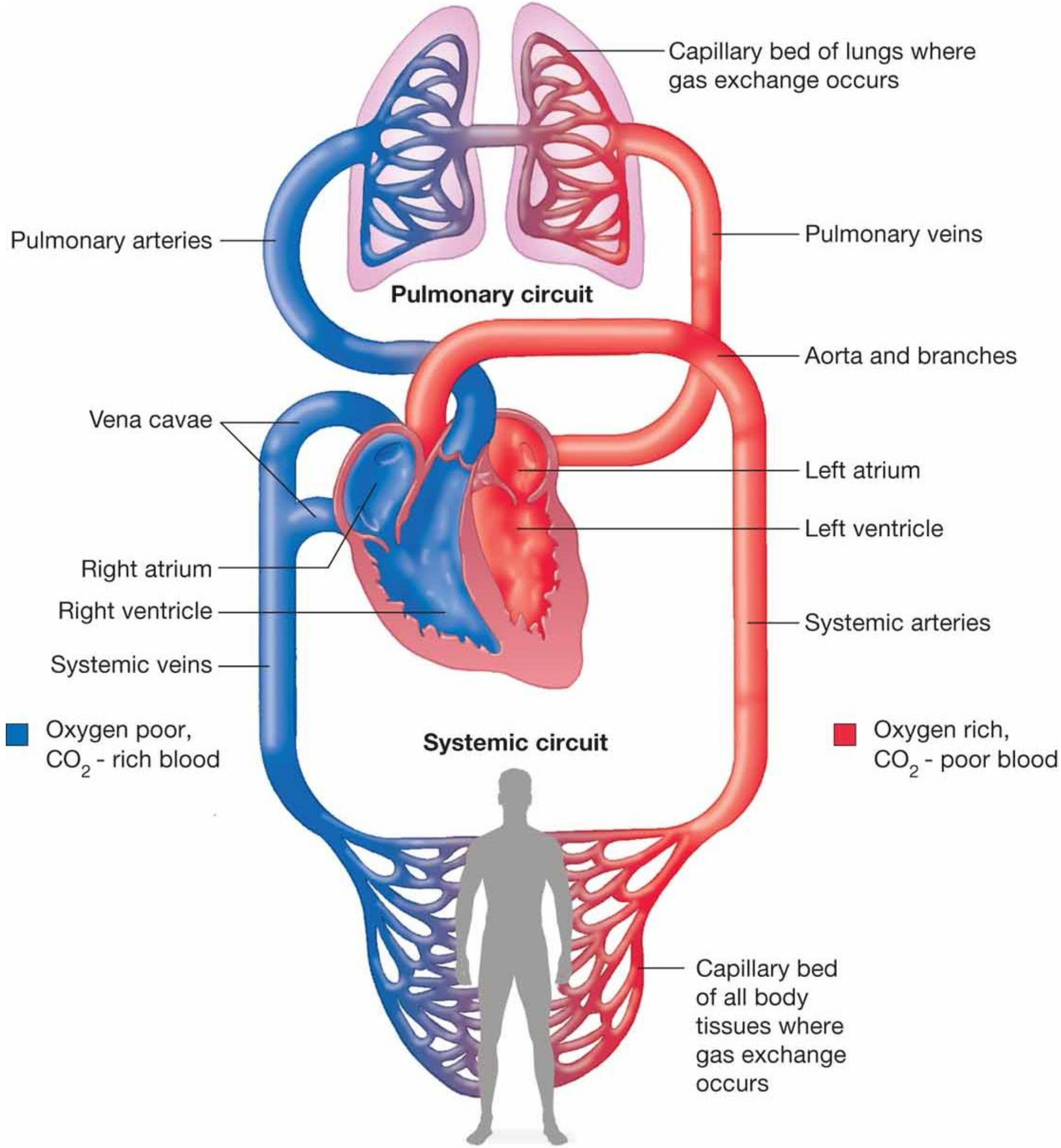
- **Mitral valve**: The **mitral** valve is the valve between the left atrium and left ventricle. It prevents the back flow of blood from the ventricle to the atrium.
- **Tricuspid valve:** The **tricuspid** valve is the flap between the right atrium and the right ventricle. It is composed of 3 leaf-like parts and prevents the back flow of blood from the ventricle to the atrium.

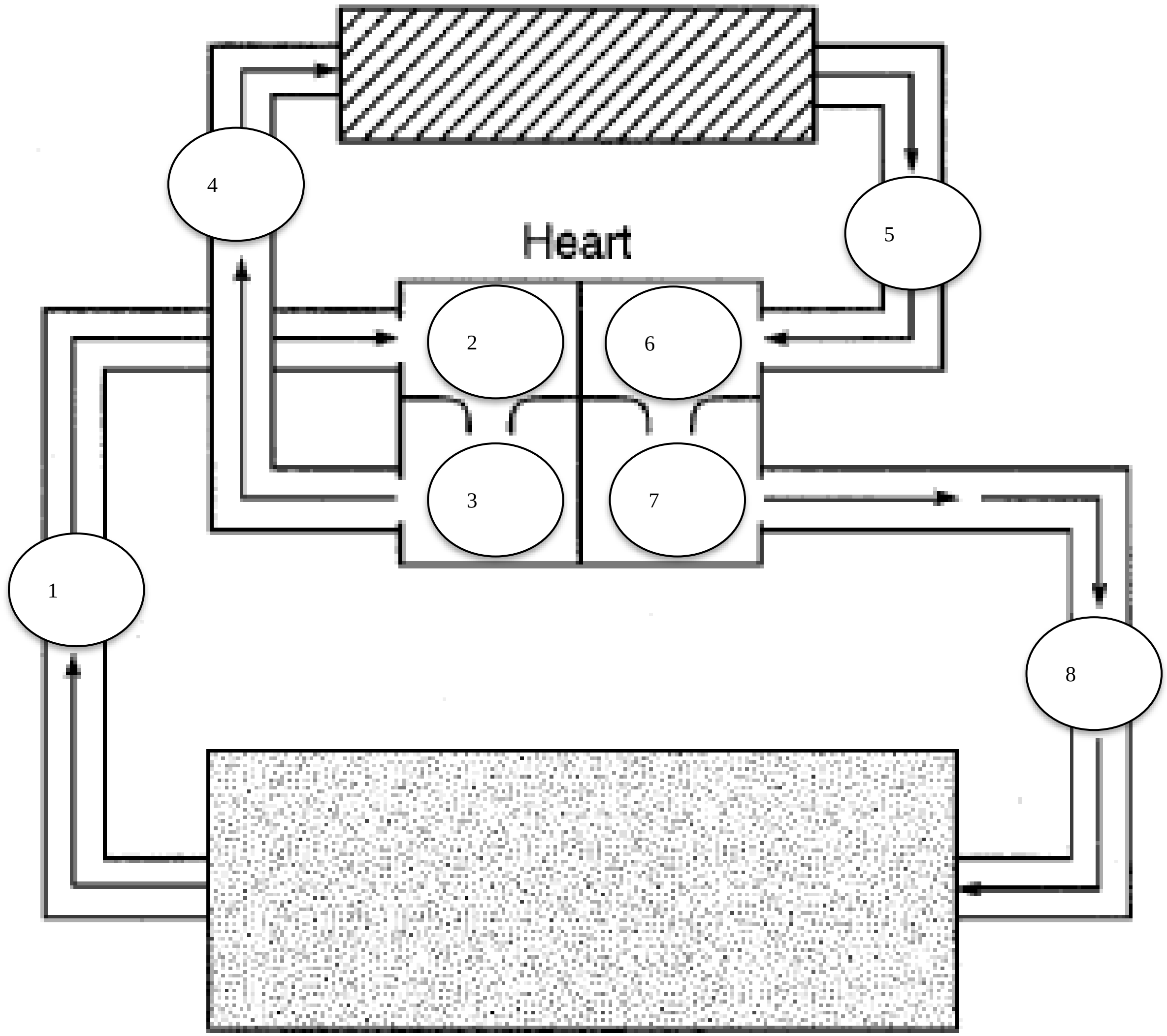
The Septum

- **The septum** - a muscular wall which keeps the oxygen rich blood on the left side of the heart from ever mixing with the oxygen poor blood on the right side of the heart.



Pulmonary vs. Systemic Circuit




Heart
1
2
3
4
5
6
7
8

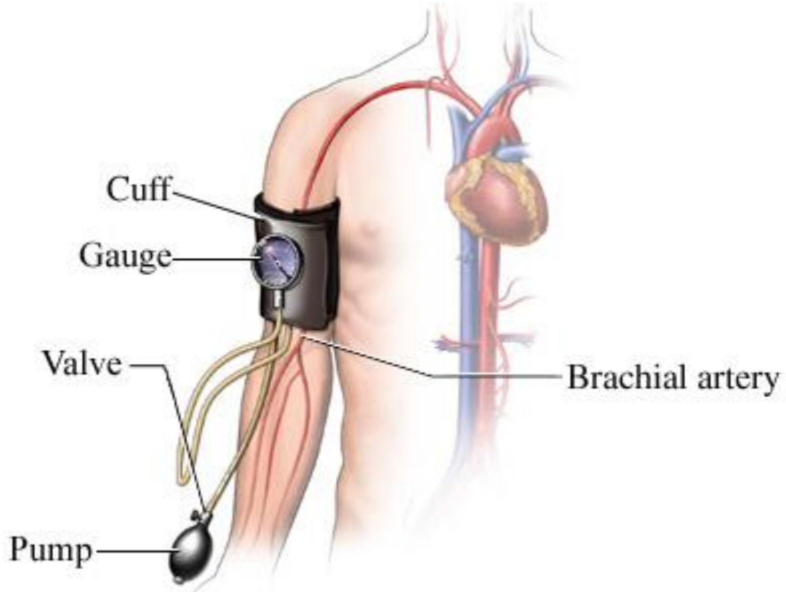
Blood Pressure

- Measures the pressure exerted on the inner walls of the arterial system when the heart is both pumping and resting.
- Systolic pressure - the pressure that the heart exerts when contracting.
- Diastolic pressure is the pressure exerted while the heart is relaxed.

$$\textbf{Blood Pressure} = \frac{\textbf{systolic pressure}}{\textbf{diastolic pressure}}$$

Blood Pressure

- Normal blood pressure: 120/80 (mmHg)
- An increase in diastolic pressure typically indicates the potential symptom or cause of many ailments.
- Measured by a sphygmomanometer

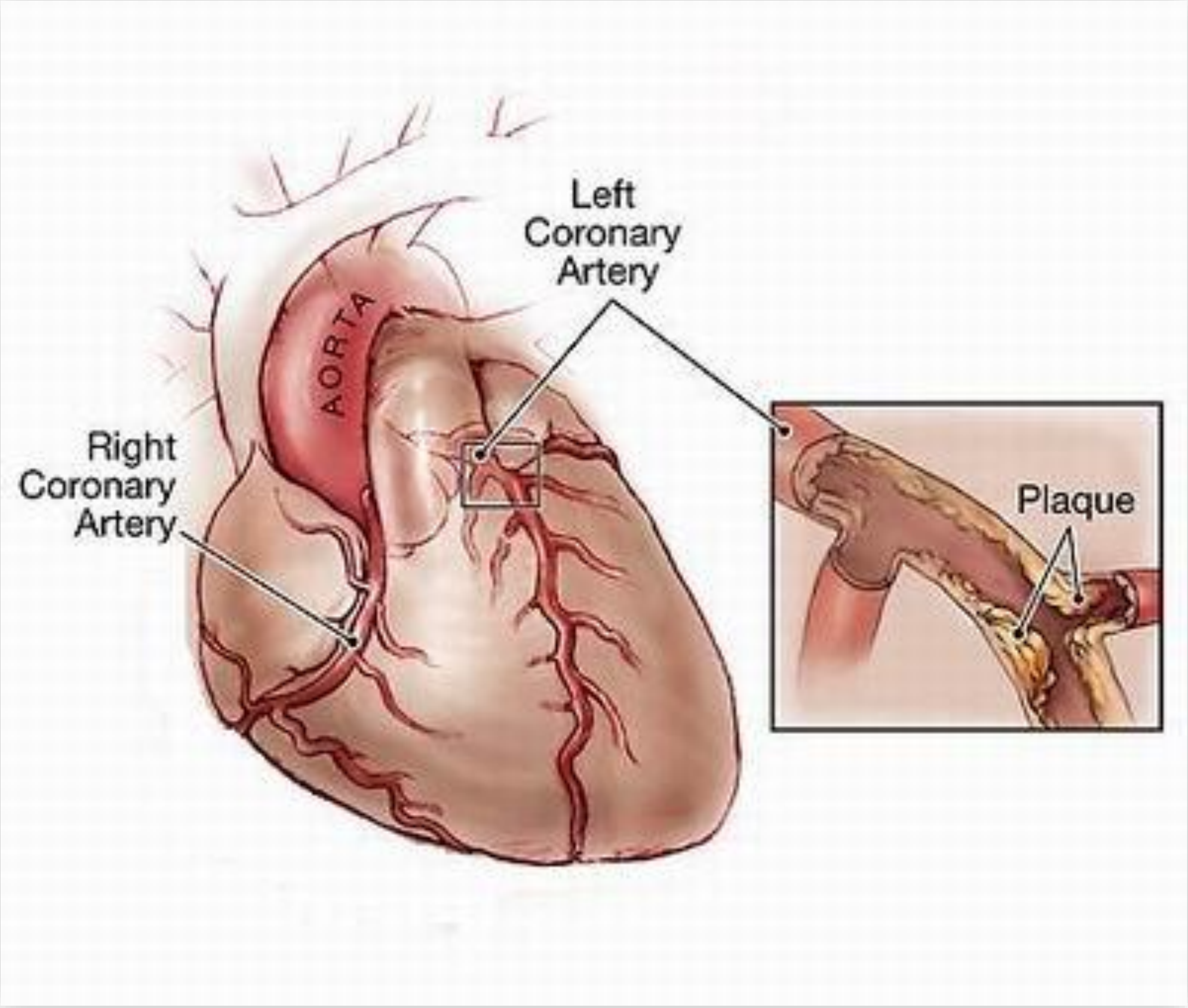


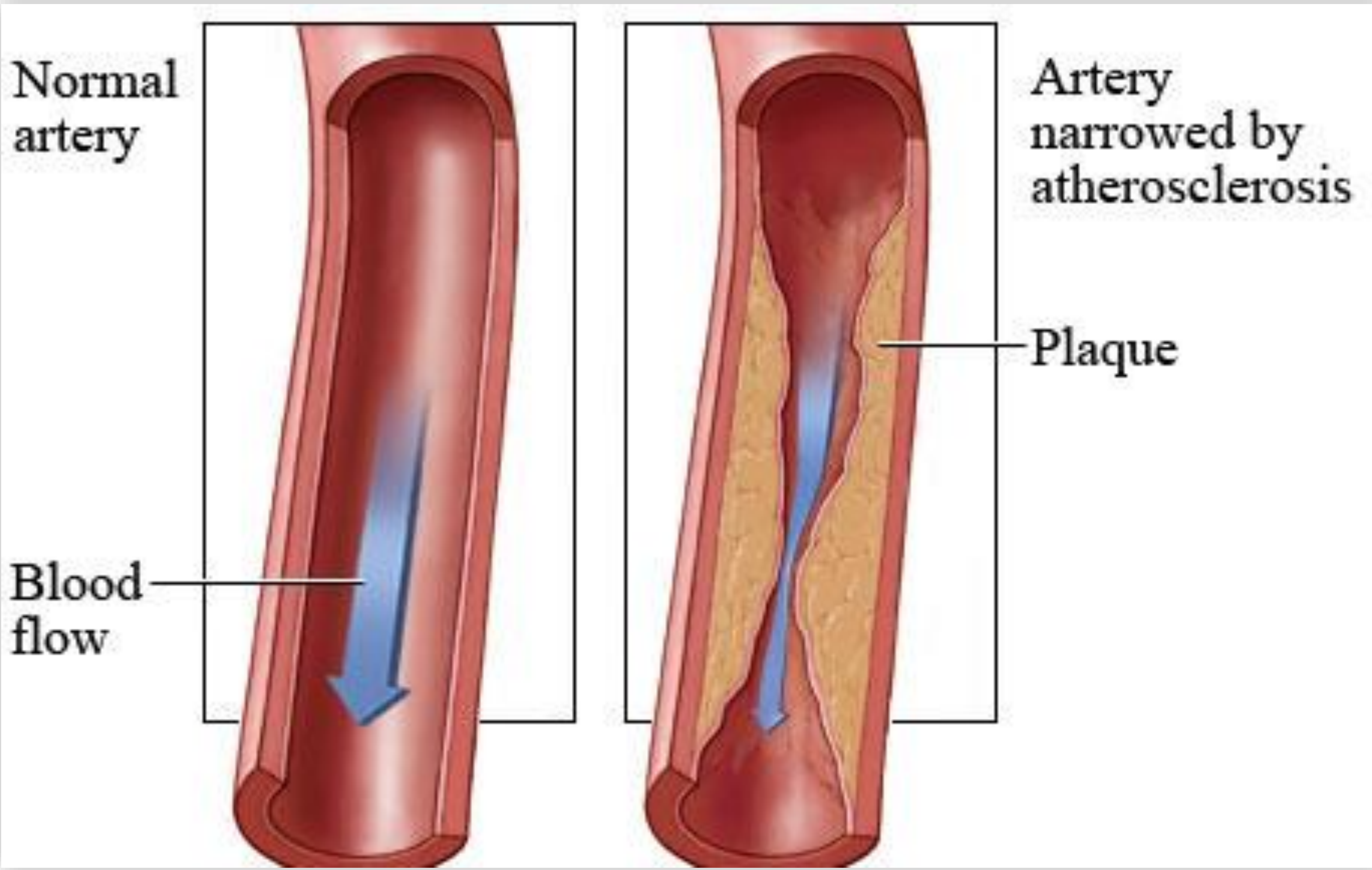
Heart Sounds

- The lub-dub sound of the heart is caused by the opening and closing of the heart valves.
- The “lub” is the closing of the mitral and tricuspid (squeezing of the ventricles).
- The “dub” is the closing of the aortic and pulmonary valves (relaxing the ventricles).

Note: Our “pulse” that we can feel is the force created by the contraction of the ventricles which in turn causes a surge of blood transmitted through the elastic walls of the entire arterial system.

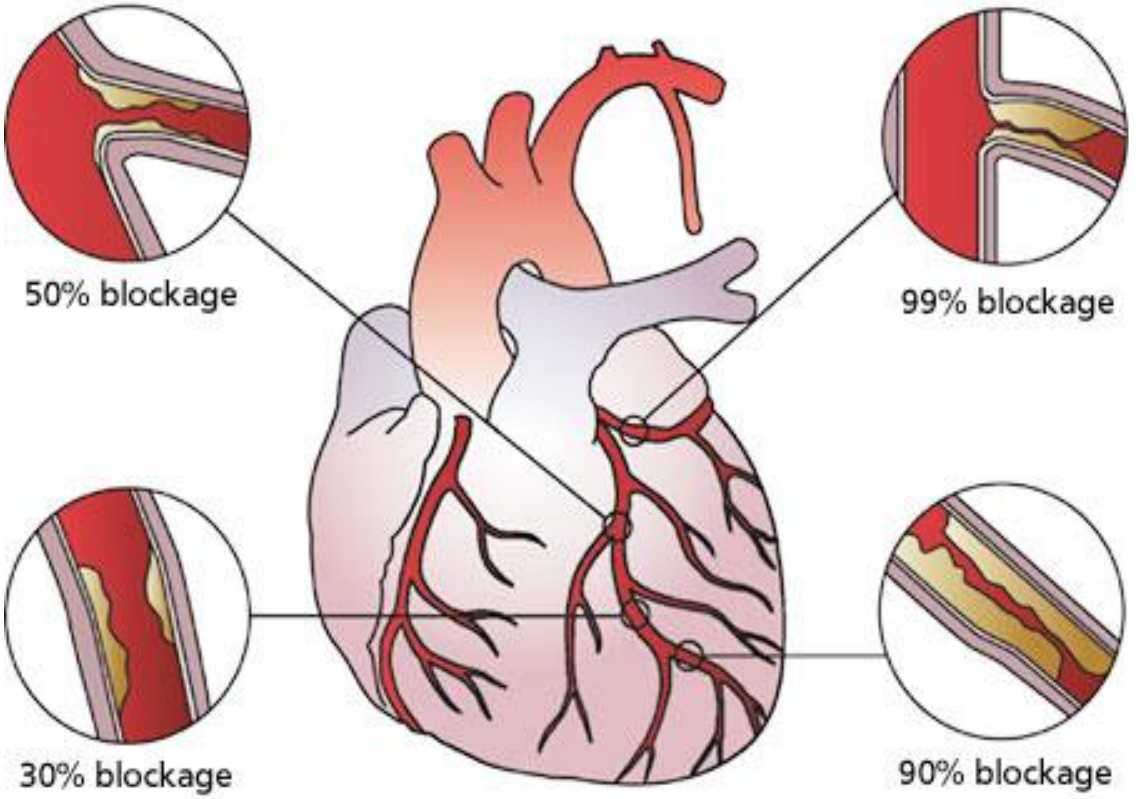
Problems in the CS: Coronary Disease



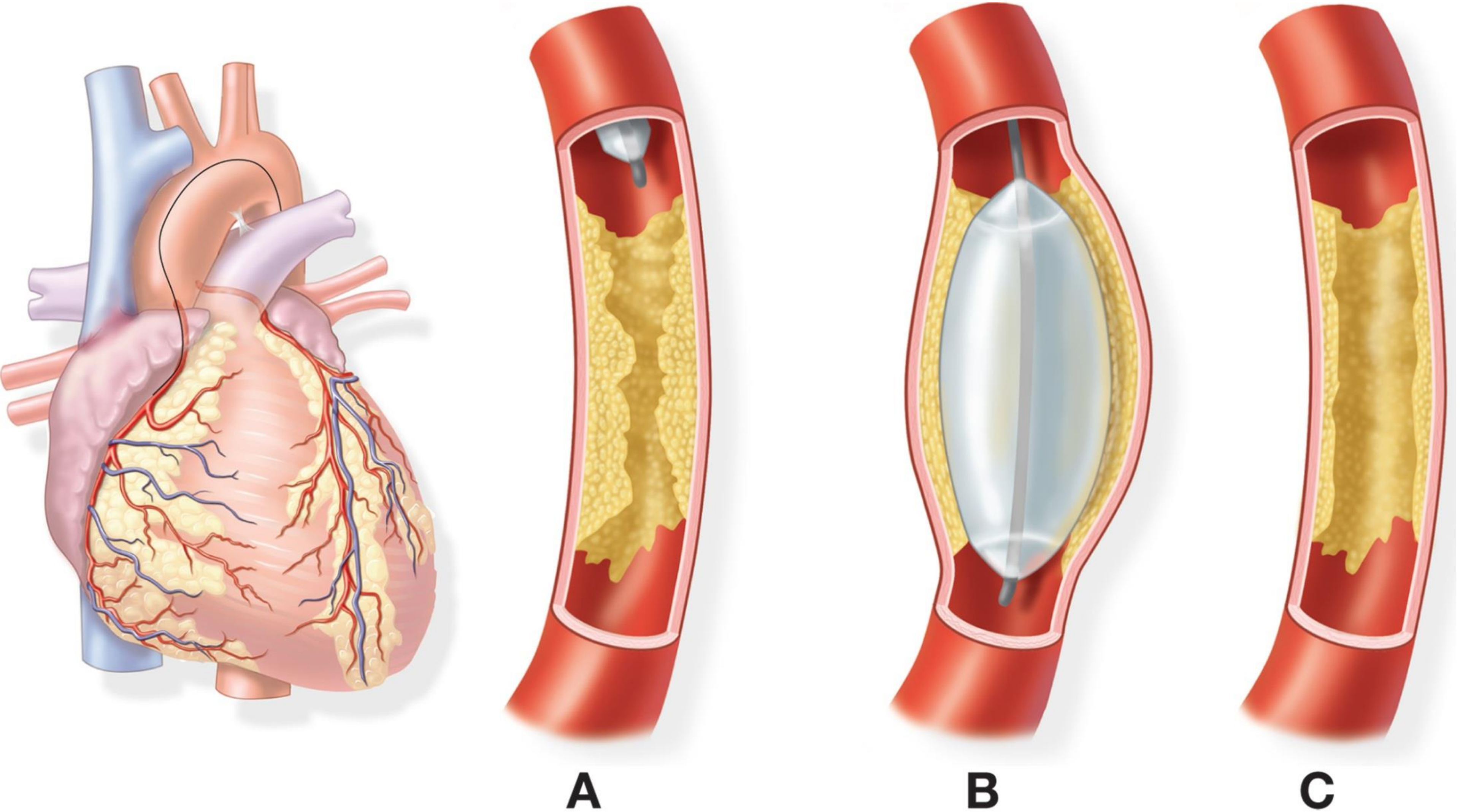

Normal artery
Blood flow
Artery narrowed by atherosclerosis
Plaque

What can we do about Coronary Disease?

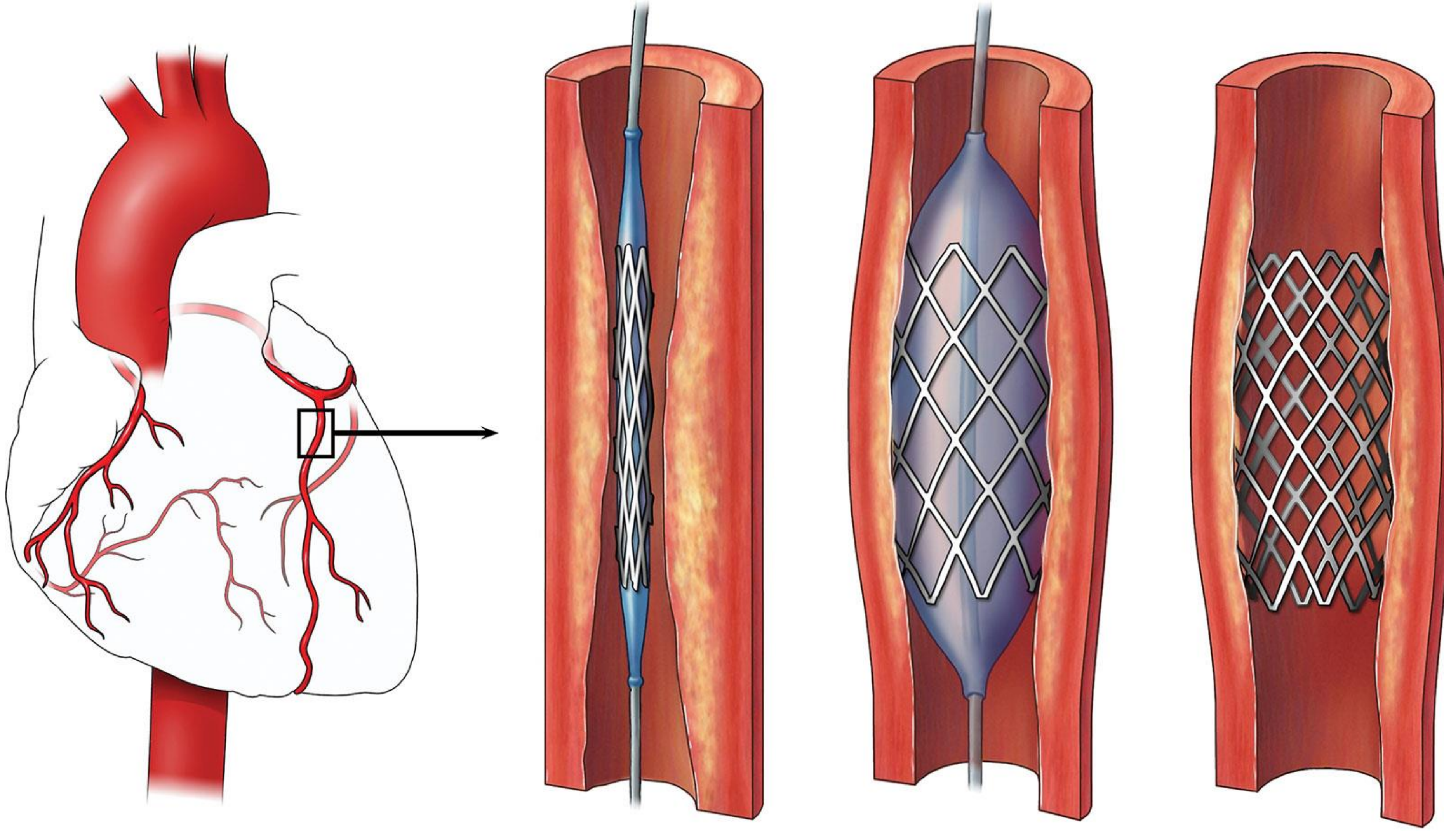
1. Angioplasty
2. Stent insertion
3. Bypass surgery



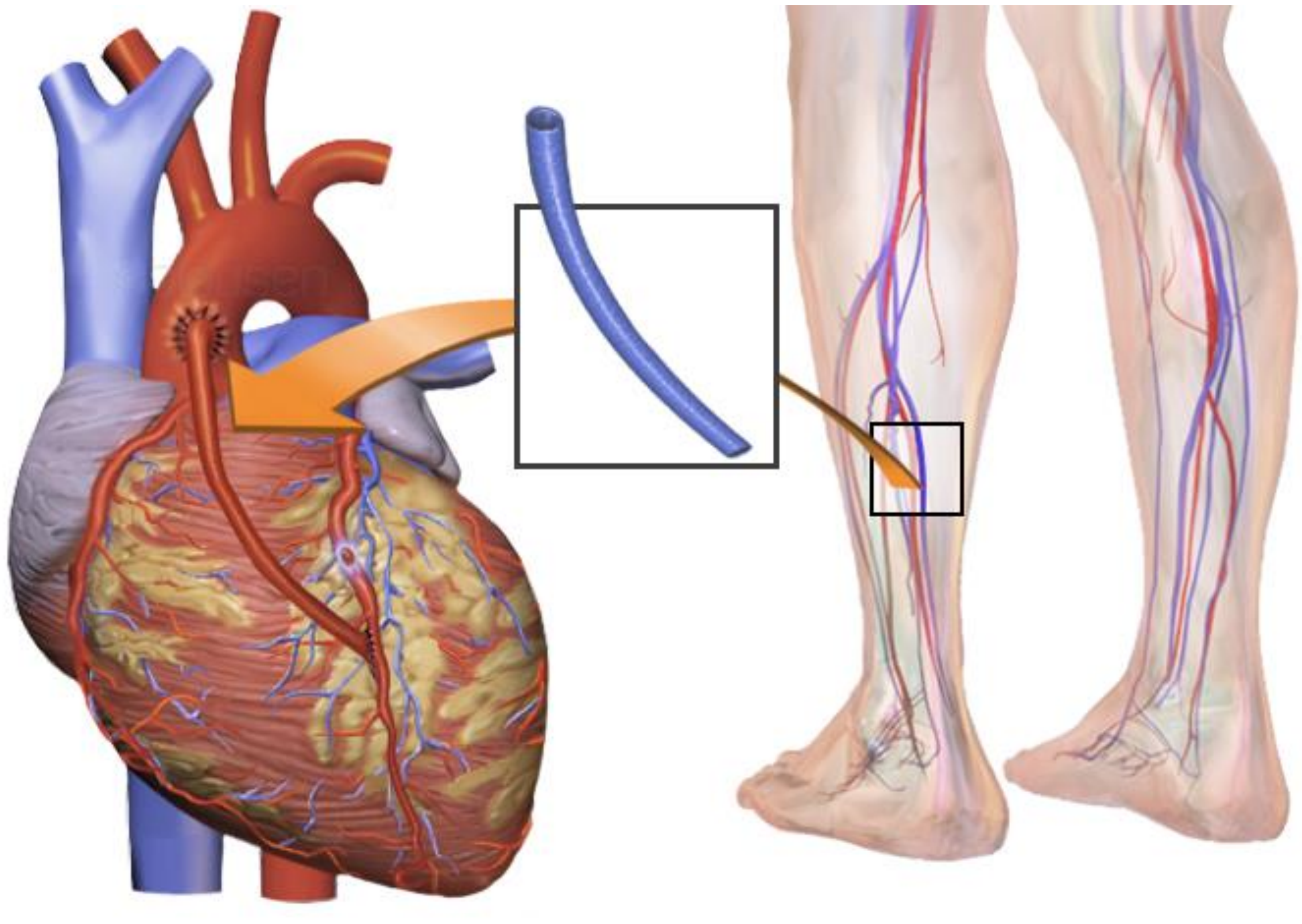
1. Angioplasty



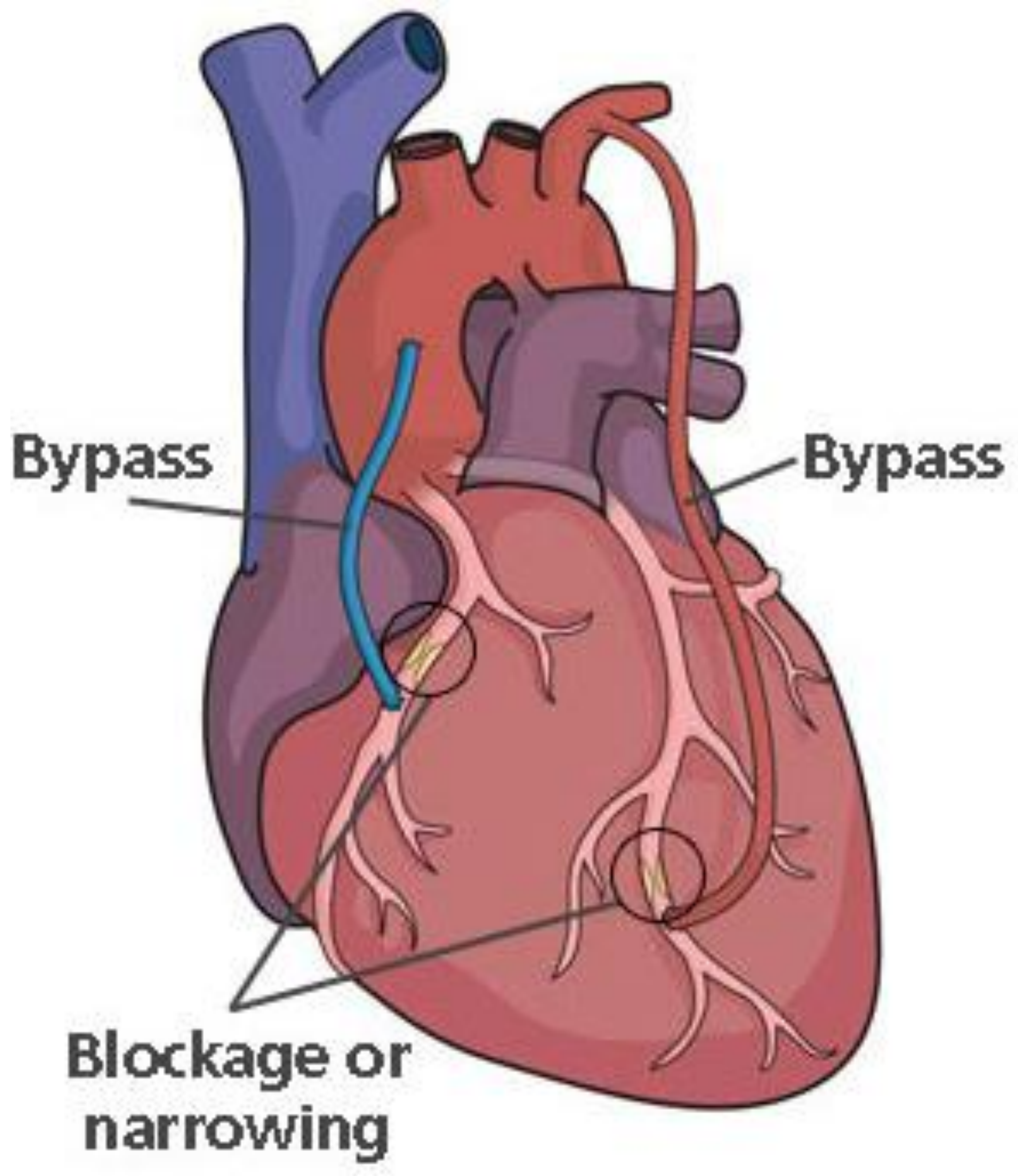
2. Stent Insertion



3. Venous Bypass

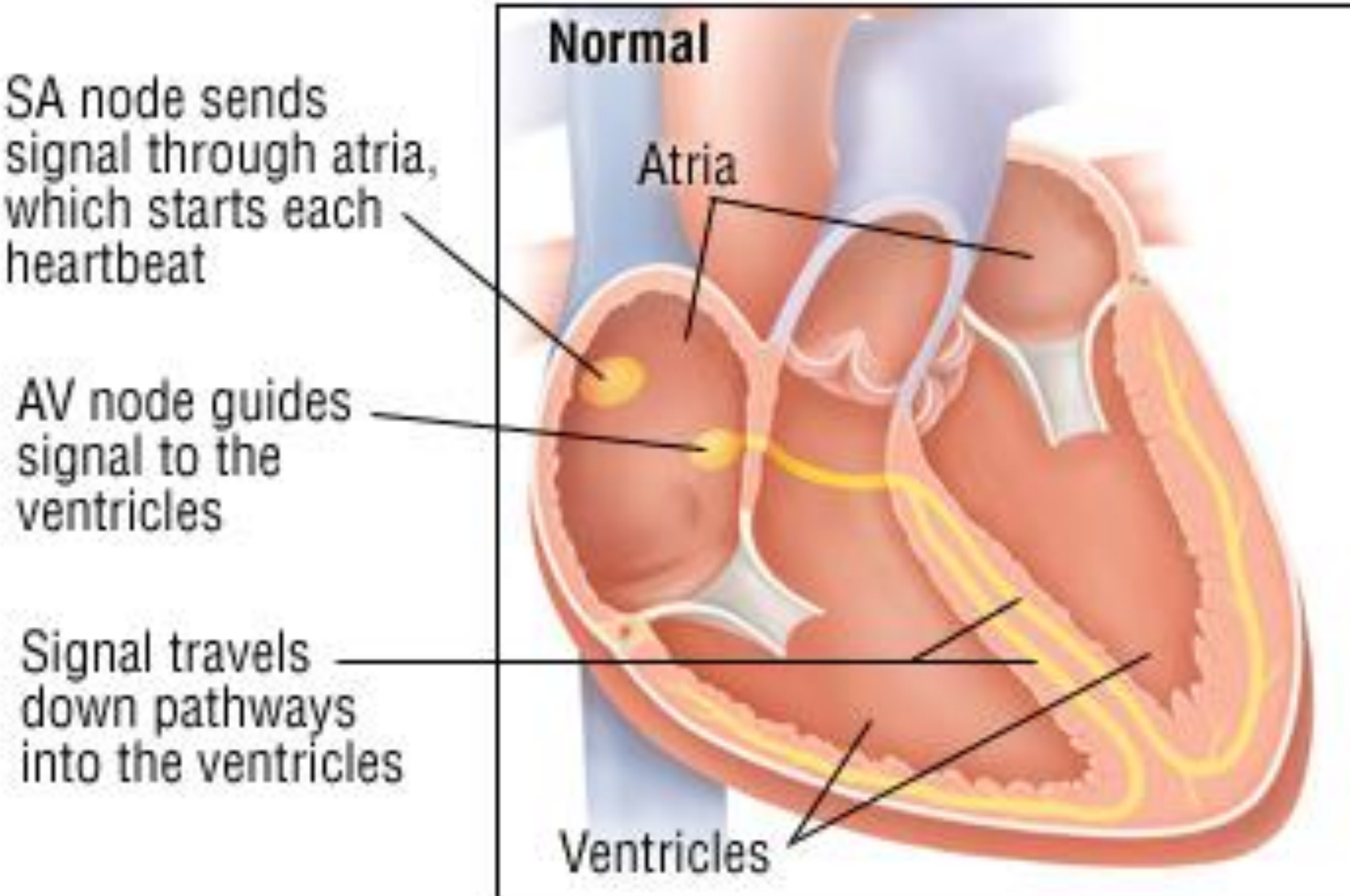


3. Arterial Bypass

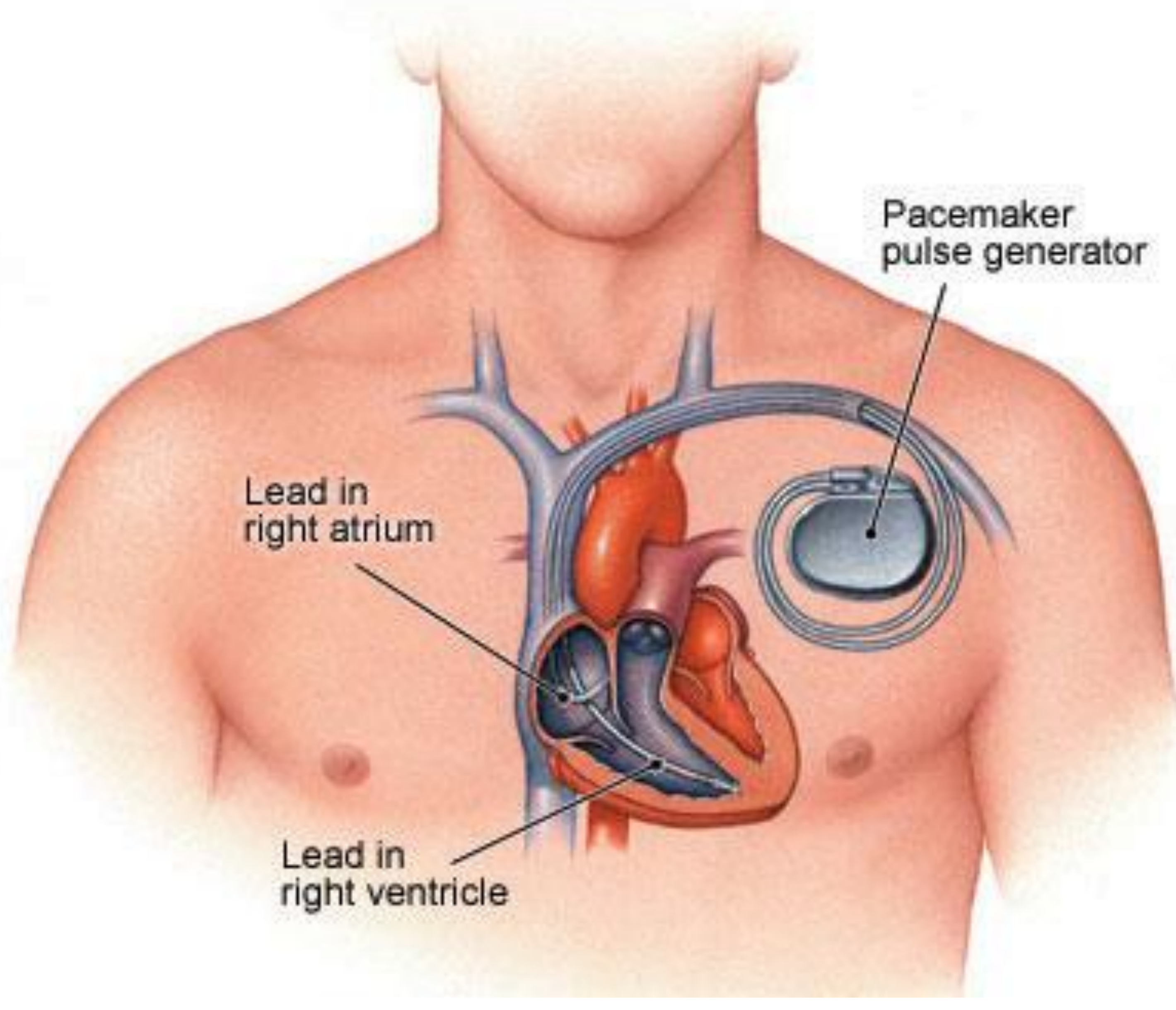


Pace Maker

- The heart has an internal cluster (node) of cells that generates an electrical impulse that regulates the heart beat.
- If your hearts pacemaker is not functioning properly, and artificial one can be placed in the chest region either above or below the skin.

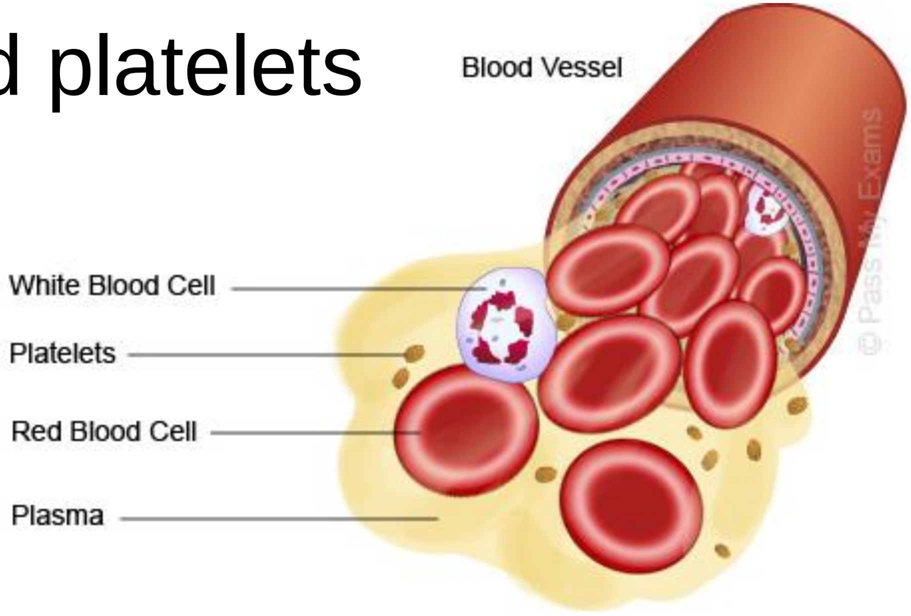

Normal
SA node sends signal through atria, which starts each heartbeat
Atria
AV node guides signal to the ventricles
Signal travels down pathways into the ventricles
Ventricles

Pacemaker

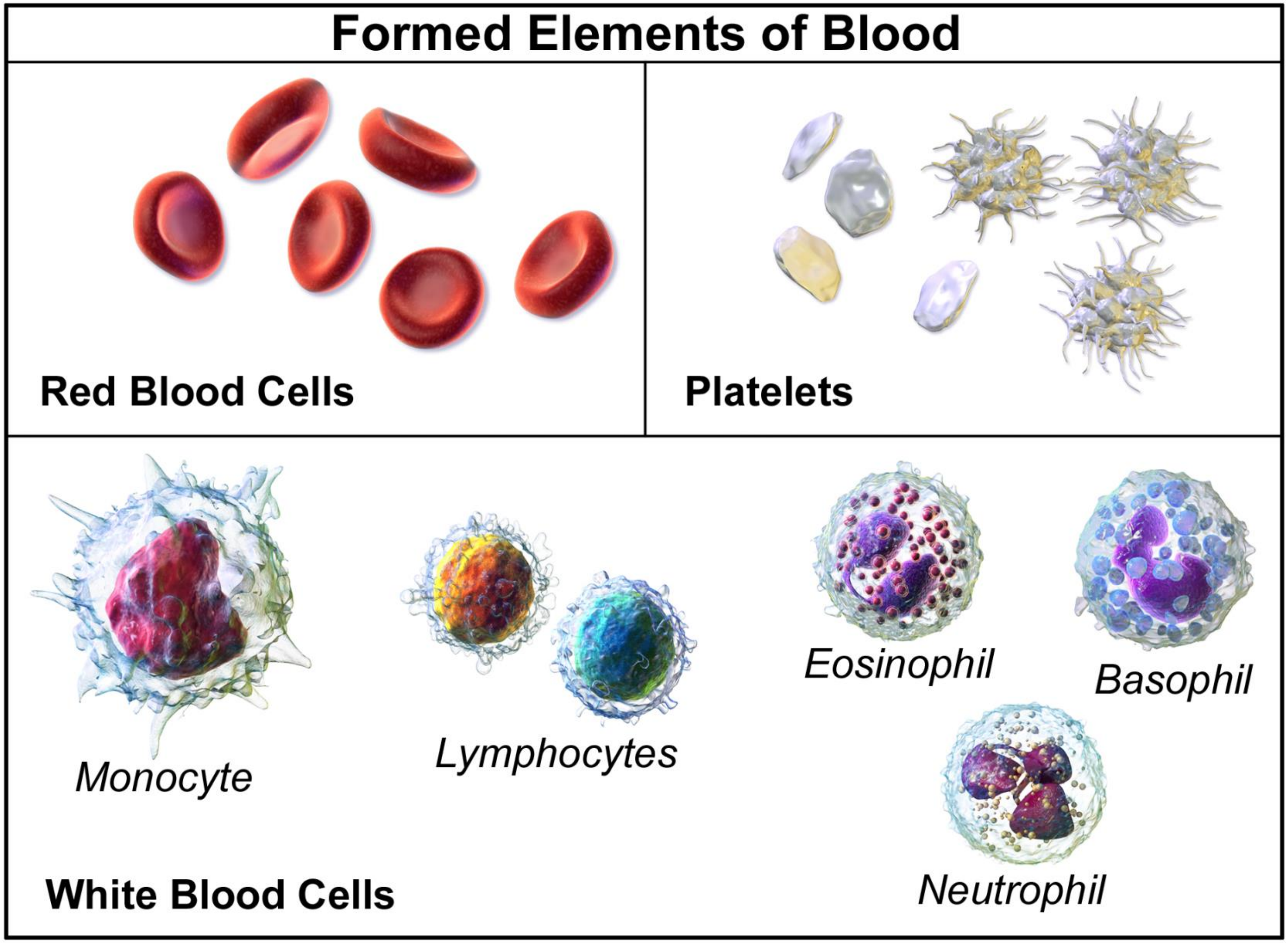

Pacemaker
pulse generator
Lead in
right atrium
Lead in
right ventricle

Immune System: Blood

- A person weighing 70 kg has approximately 5L of blood.
- Blood is about 55% fluid and 45% solid matter.
- Blood consists of plasma (liquid), red blood cells (erythrocytes), white blood cells (leukocytes) and blood platelets (thrombocytes).

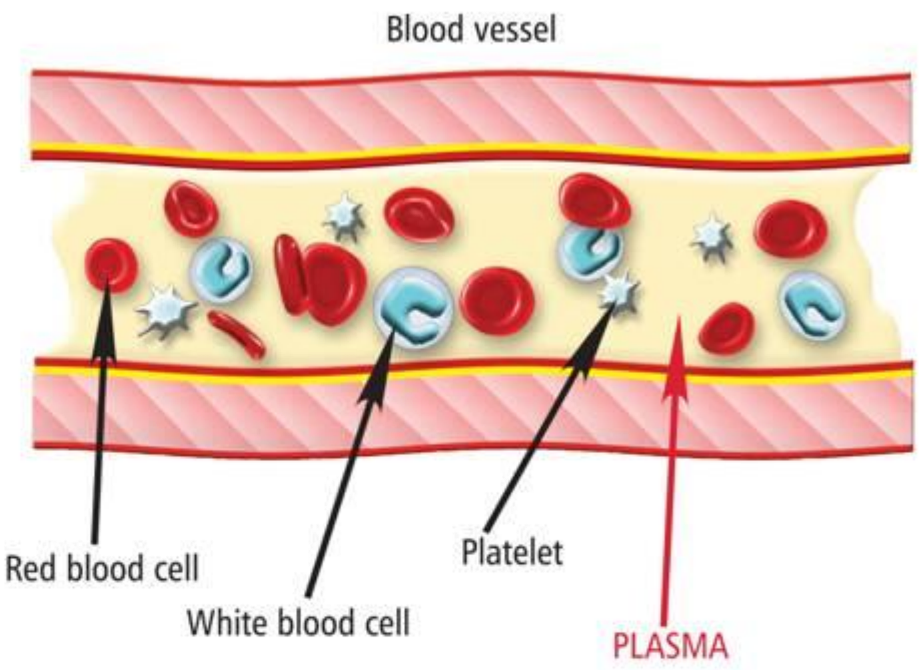


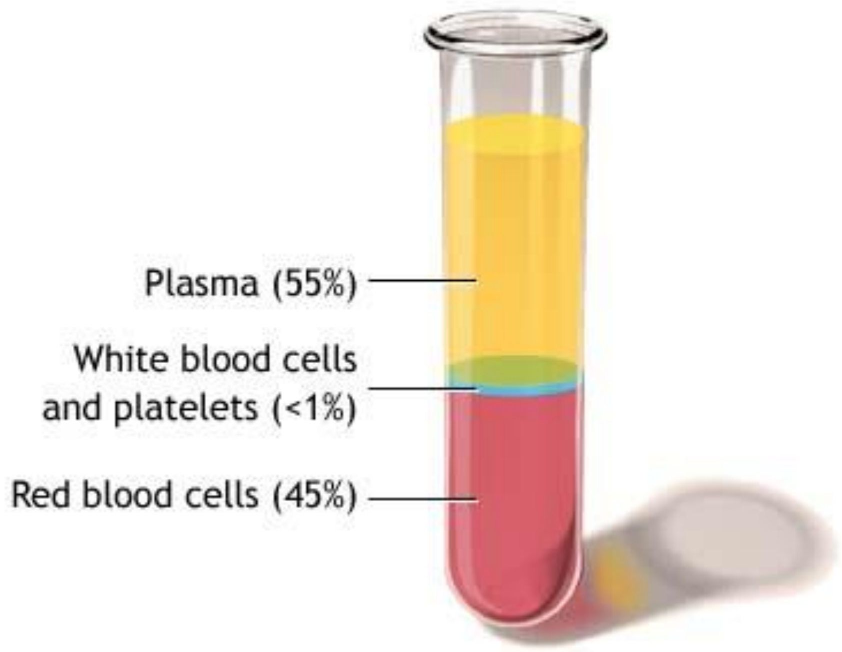
Cellular Components of Blood



Plasma

- If the solid parts of the blood were removed, a clear yellowish liquid would remain. This is plasma.





Plasma

- Plasma is approximately 91% water. The rest is made of dissolved particles.
- There are seven typical components of plasma:
  - blood proteins (about 60 different types of proteins)
  - inorganic salts
  - nutritive materials absorbed from the digestive system (sugars)
  - hormones
  - vitamins
  - enzymes
  - waste products of cellular activity.

Proteins Dissolved in Blood

There are **three** groups of blood proteins found in blood:

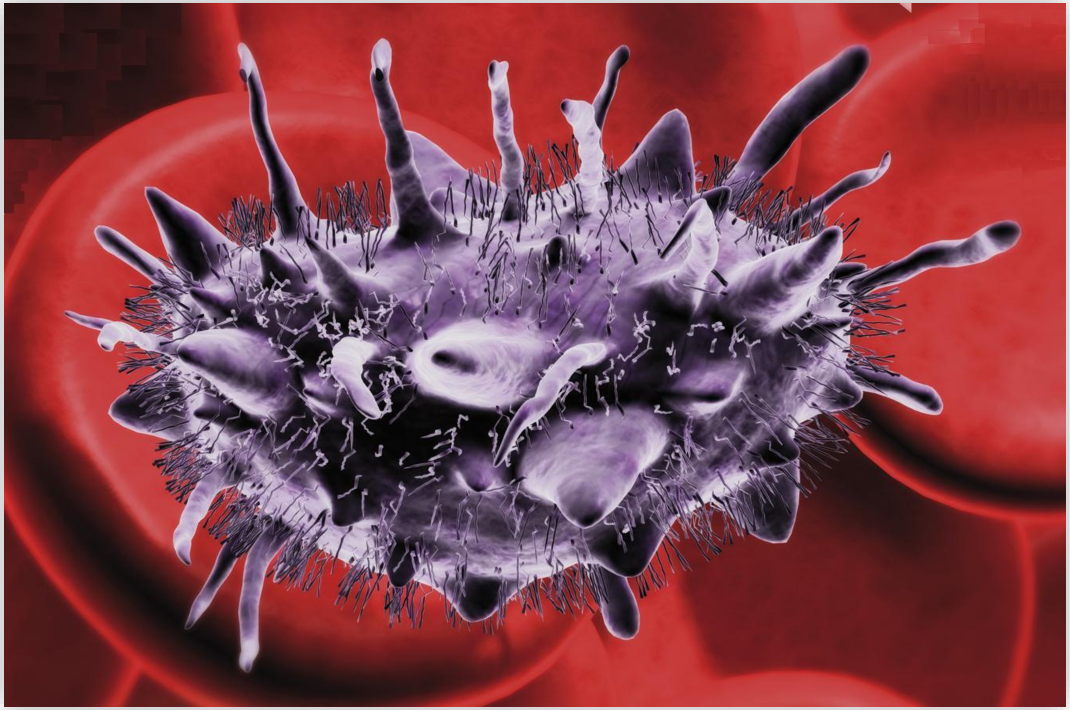
1. Albumins – establish osmotic pressure that draws water back into capillaries which helps maintain body fluid levels.

2. Globulins – produce antibodies that provide protection against invading microbes.

3. Fibrinogens – important in blood clotting.

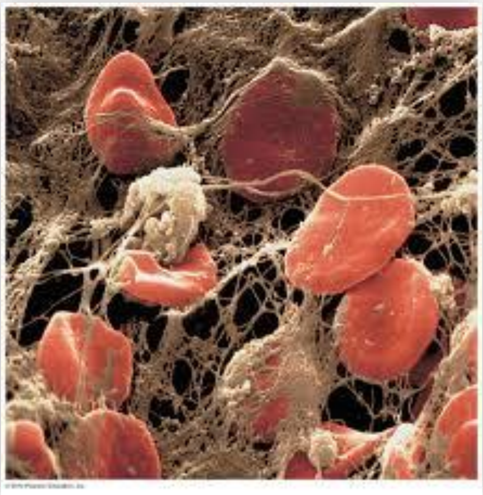
Platelets

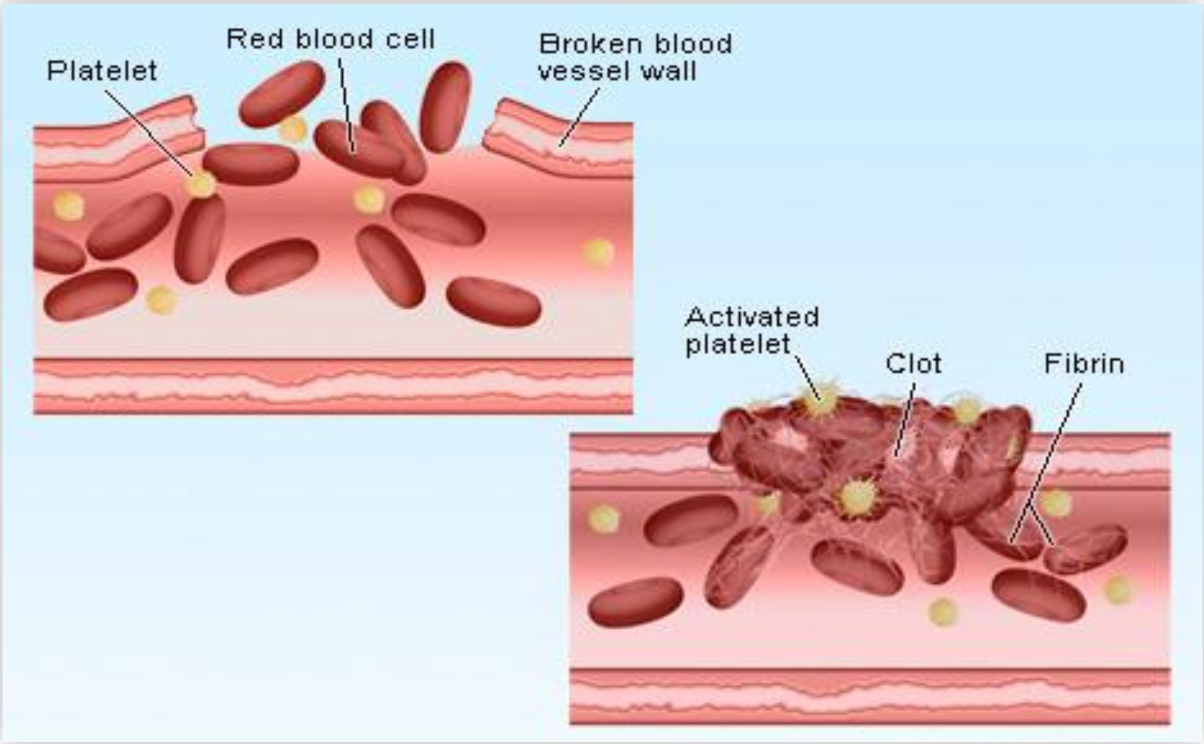
- Platelets (**thrombocytes**) are the smallest of the solid parts of the blood.
- Platelets are fragments of cells.
- They are colorless, usually spherical and without a nuclei.



Platelets

- They live about 4 days and are also made in the bone marrow.
- They play an important role in the formation of blood clots.





Clotting Response

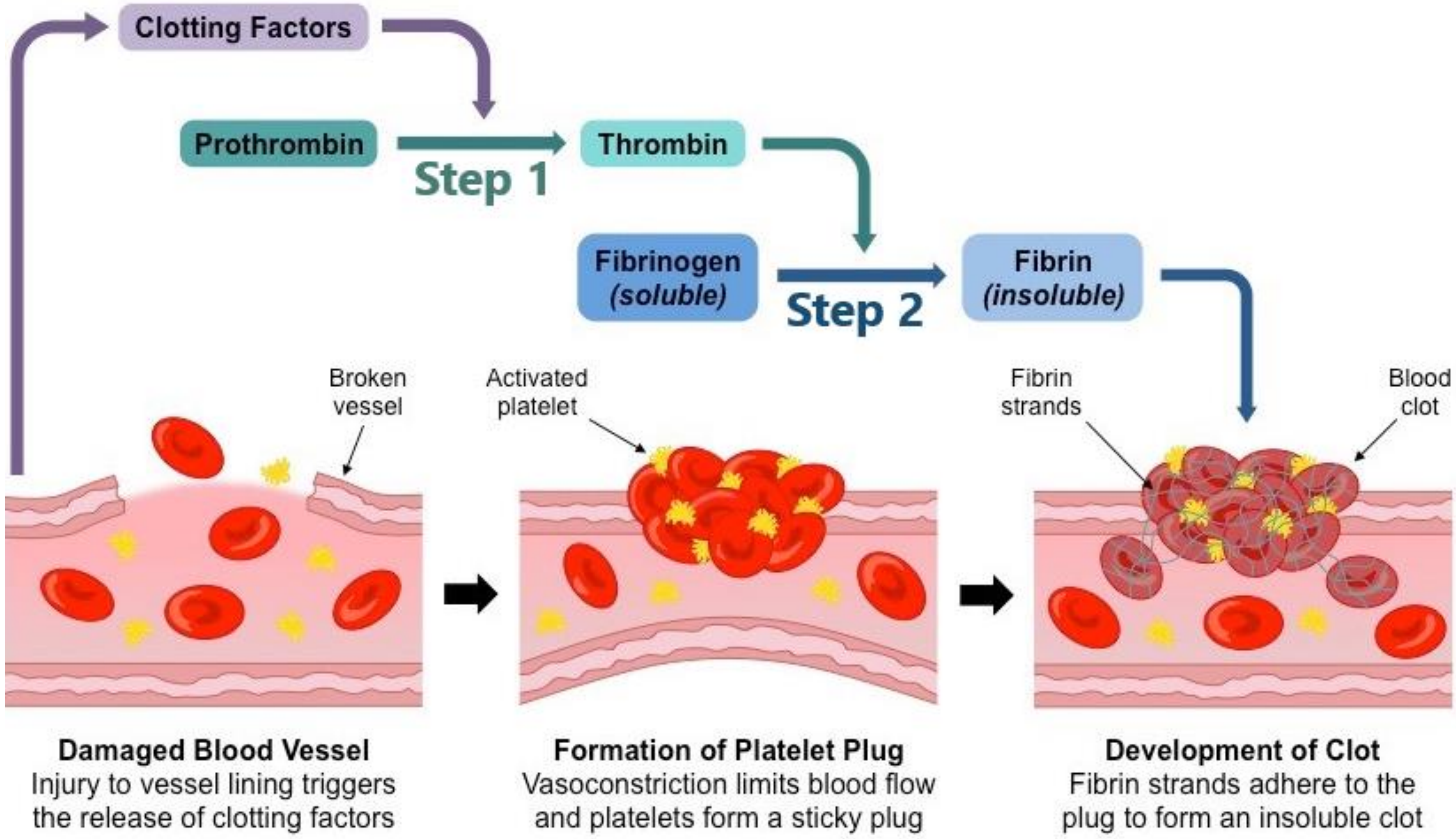
- When rough edges of a cut or torn vessel are encountered, platelets stick to the rough edges burst.
- This causes the release of clotting factors (enzymes) which convert **prothrombin** to **thrombin**.
- Thrombin now acts as an enzyme to converting **fibrinogen** into **fibrin.**
- Blood cells are trapped in the sticky network of fibrin threads, building a clot.

Summary

Step 1 **prothrombin** → **thrombin**

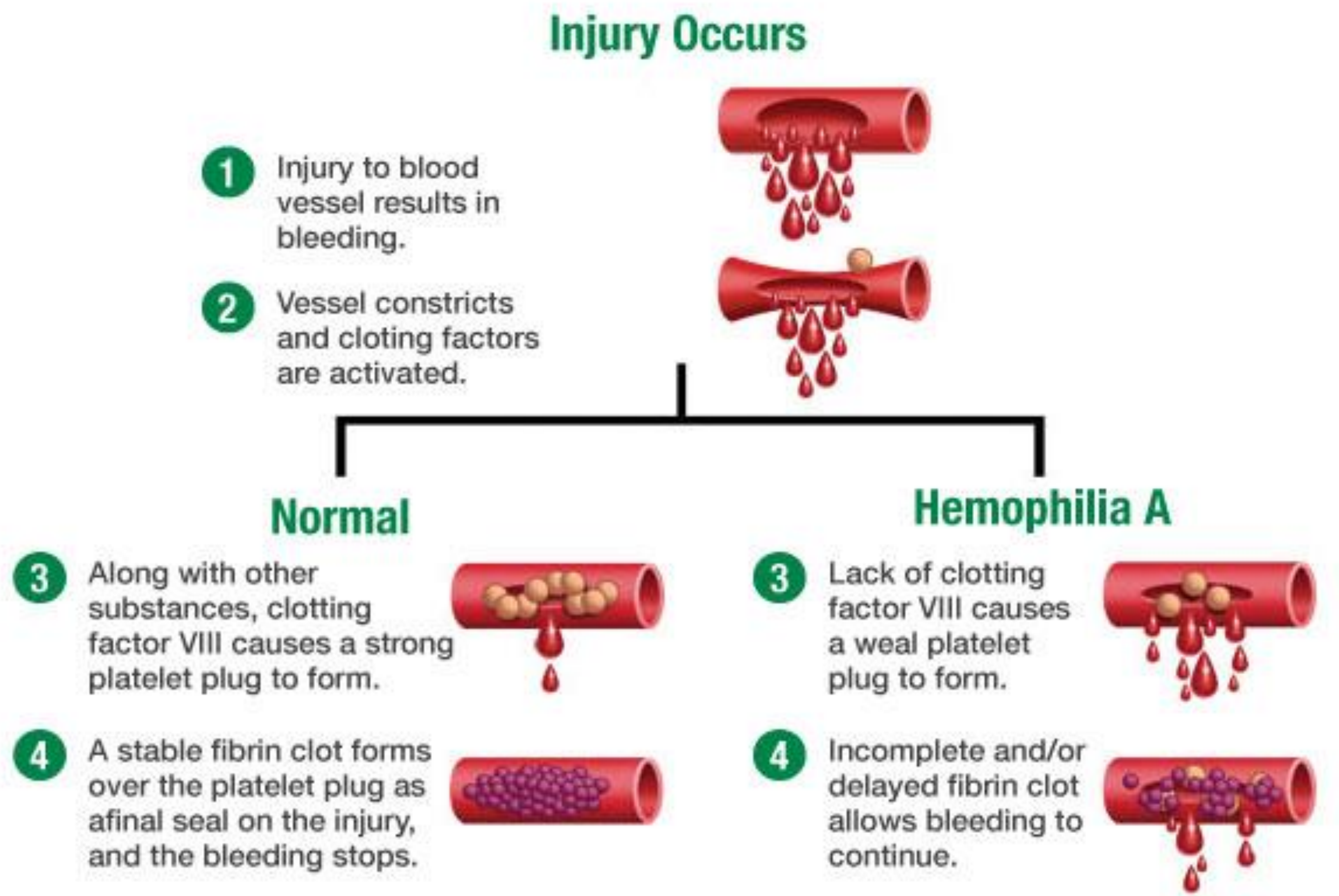
Step 2 **fibrinogen** → **fibrin**

Clotting Diagram



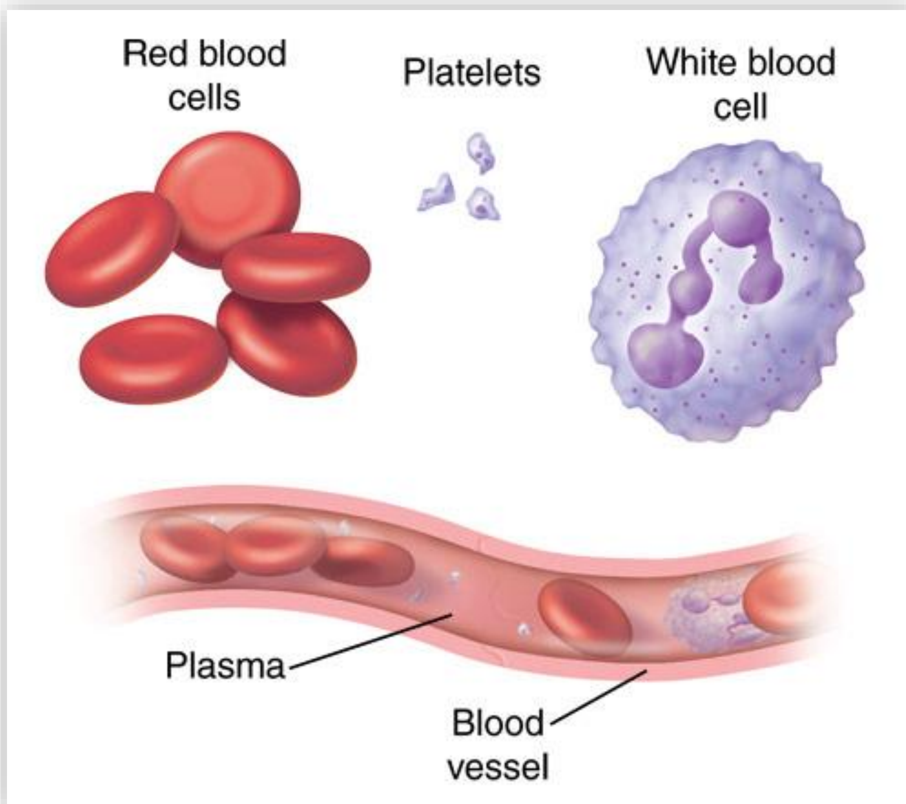
Blood Disorder: Hemophilia

- Hemophilia is a genetic disease associated with faulty blood clotting.



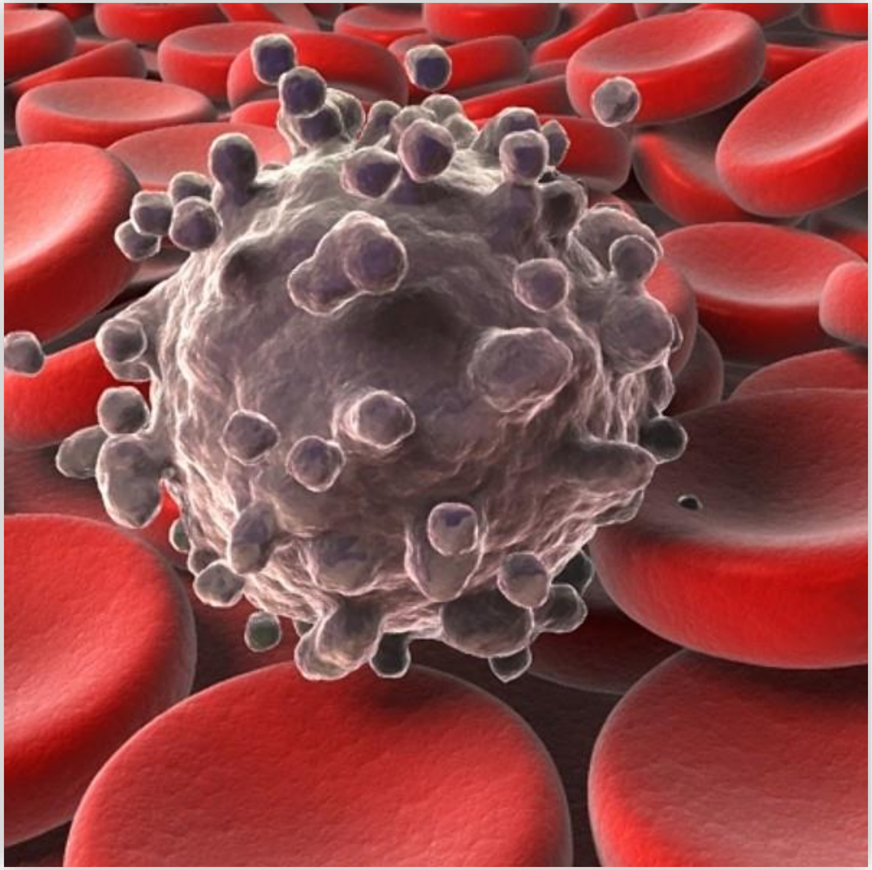
White Blood Cells

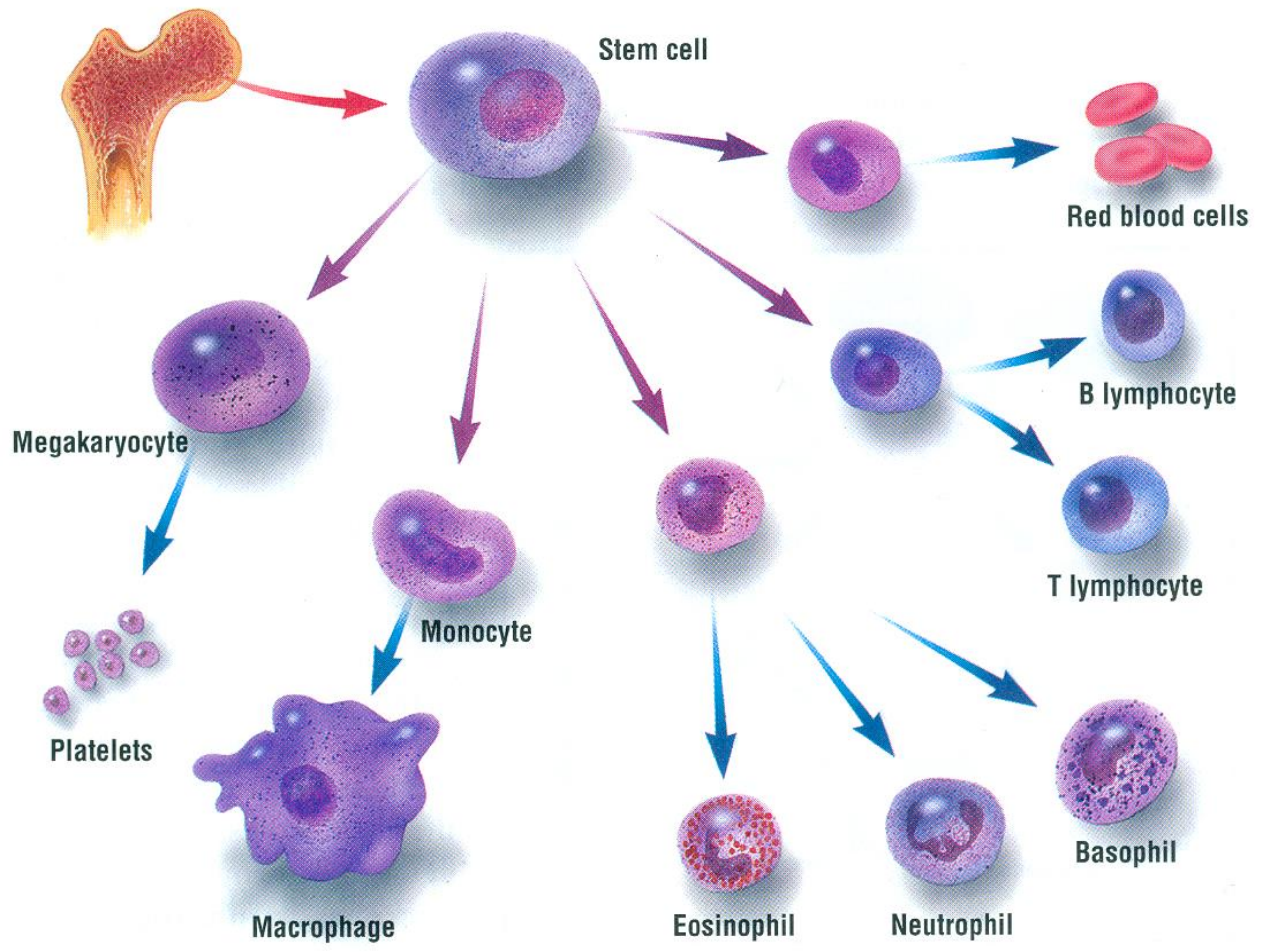
- White blood cells (**leukocytes**) play a role in immunity.
- An elevated white blood cells count often suggests some type of bacteria or foreign presence in the blood.



White Blood Cells

- White blood cells are outnumbered by red blood cells by about 700:1.
- They do contain a nucleus, but do not contain hemoglobin and are therefore colorless.



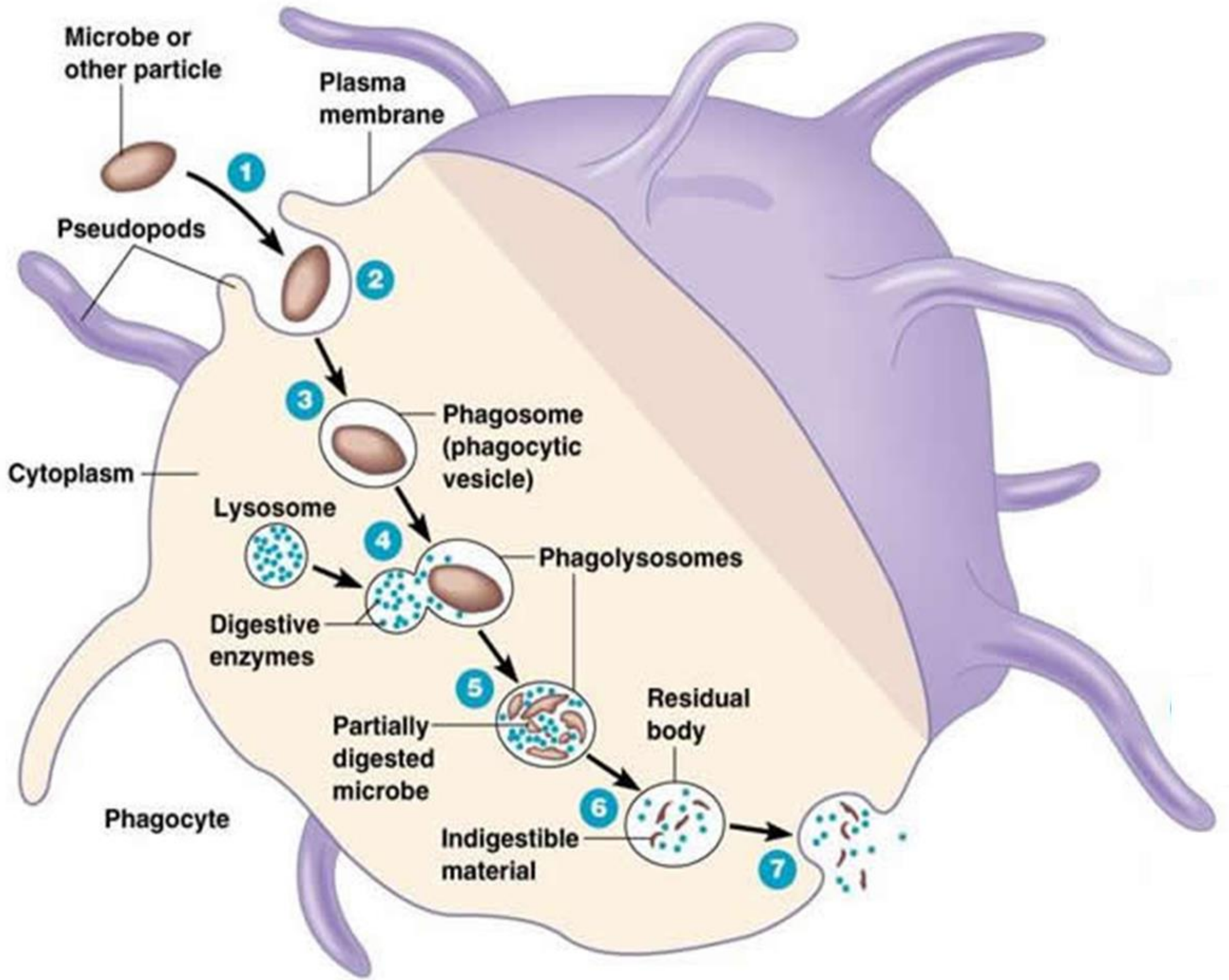


Stem cell
Red blood cells
B lymphocyte
T lymphocyte
Megakaryocyte
Monocyte
Platelets
Macrophage
Eosinophil
Neutrophil
Basophil

Two Functions of Leukocytes

1. Some leukocytes called macrophages engulf and destroy invading microbes. These white blood cells contain elevated levels of lysosomes which release enzymes that digest the microbe and the leukocyte itself creating a residue we call pus.
2. Other leukocytes called B-Cells form special proteins, called antibodies, which interfere with foreign invading microbes and toxins.

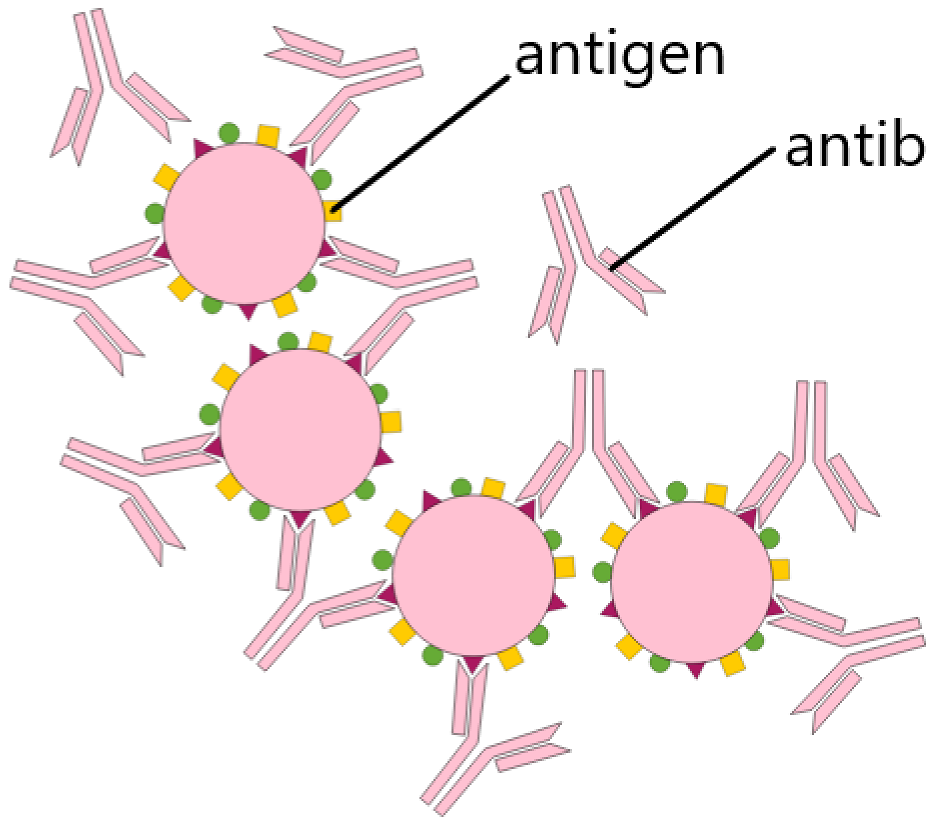
Macrophage



Microbe or other particle
Plasma membrane
1
Pseudopods
2
3
Phagosome (phagocytic vesicle)
Cytoplasm
Lysosome
4
Phagolysosomes
Digestive enzymes
5
Residual body
Partially digested microbe
6
Indigestible material
7
Phagocyte

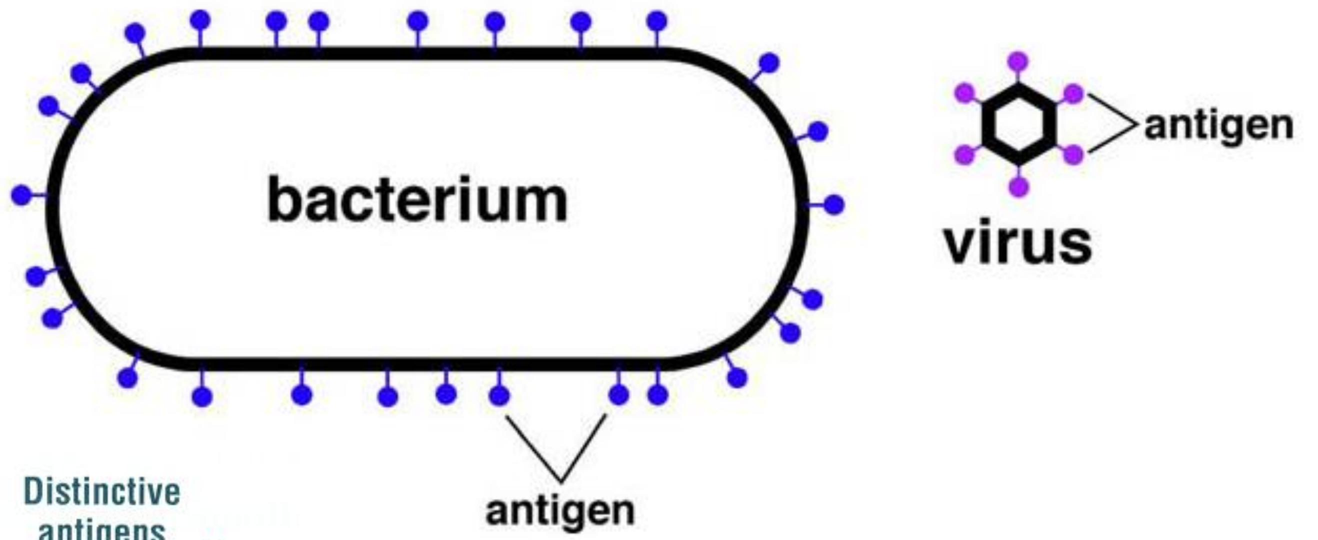
Antigen Antibody Response

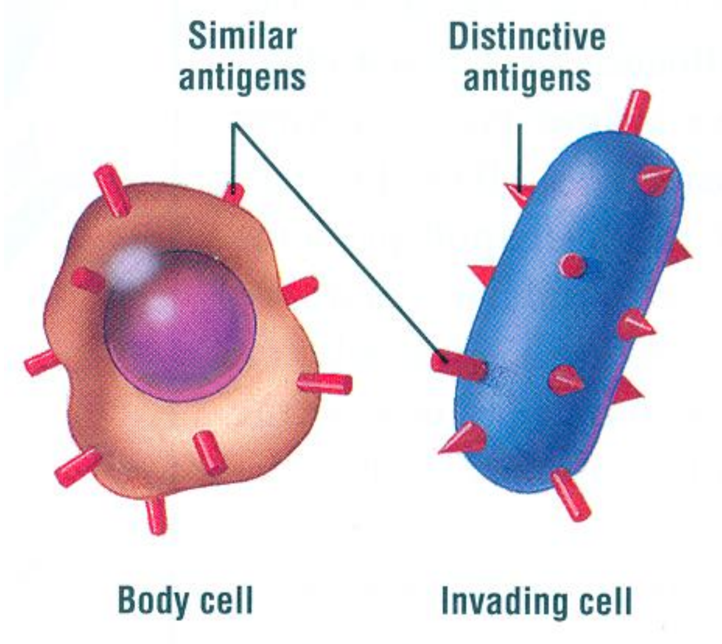
- Antigens are protein “markers” found on the surface of cells.
- Antibodies are the “Y” shaped proteins made by B-Cells specifically designed to latch on to a specific invader's antigen.



Antigens

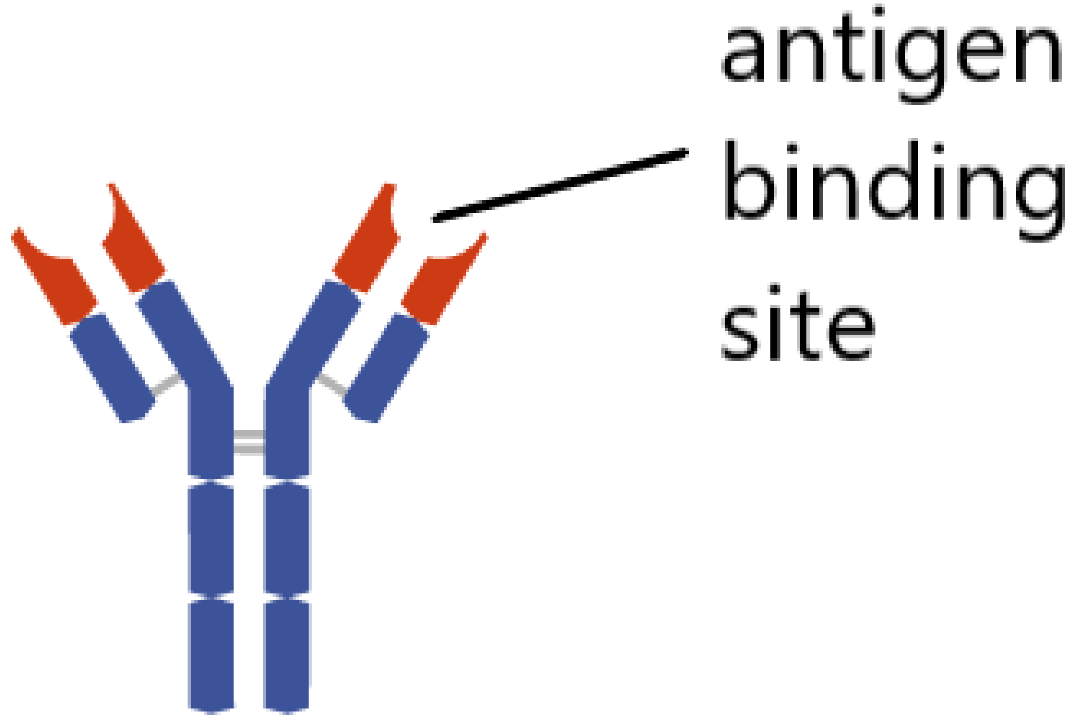
- These antigens allow cells to identify each other.



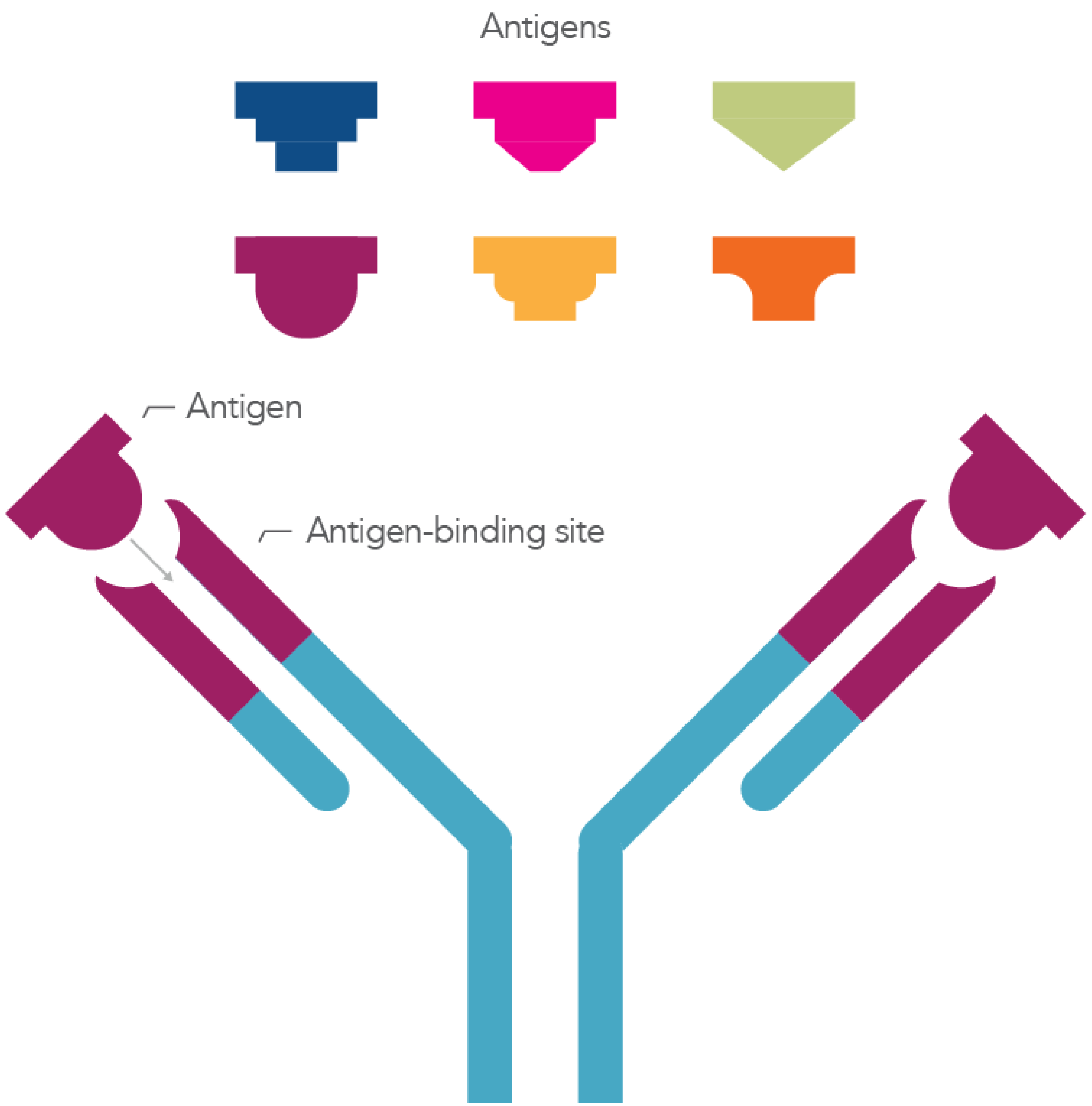


Antibodies

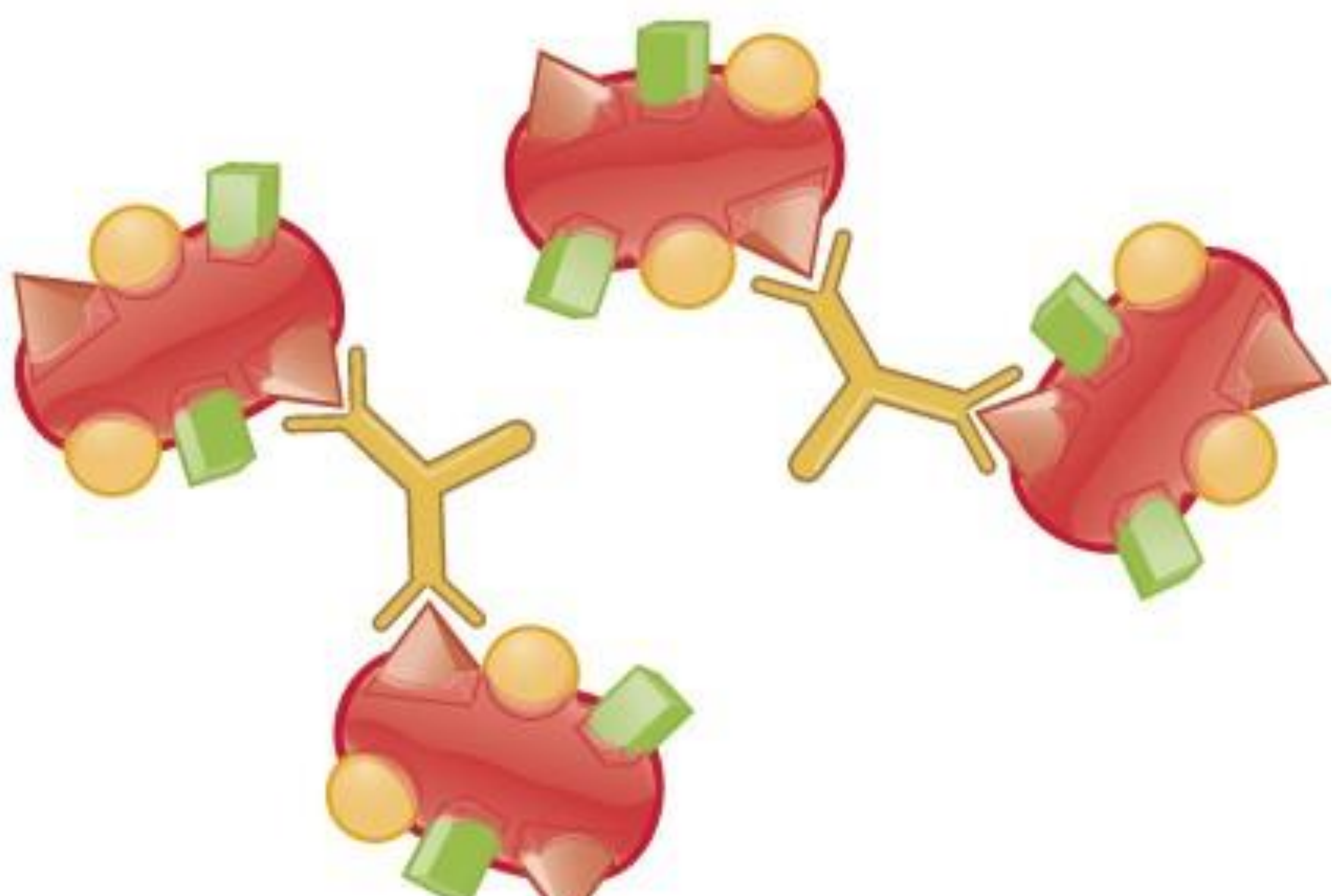
- "Y" shaped proteins that target invading cells by attaching to their antigens.
- They have a shape that is complementary to its specific antigen.



Antigen Antibody Specificity

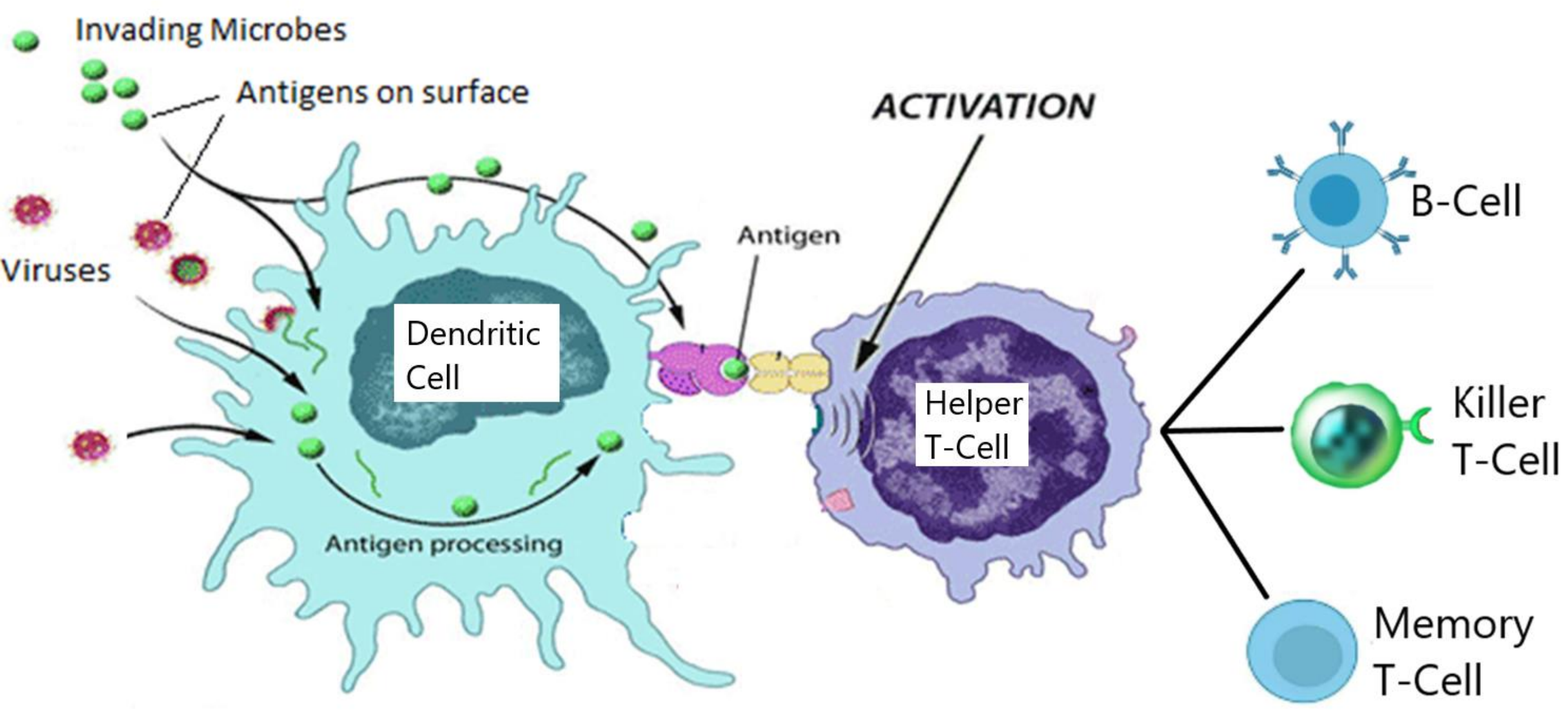


Antigen Antibody Response



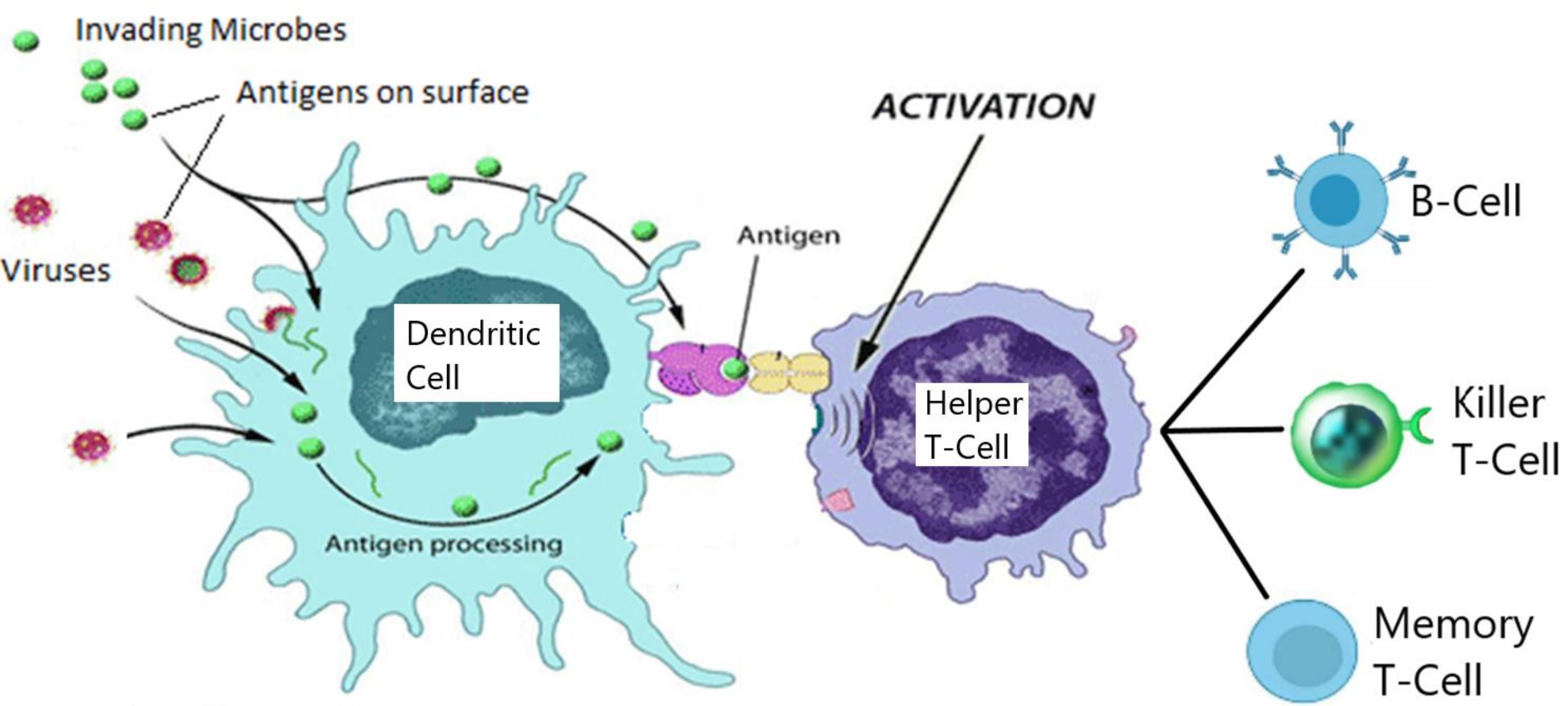
Antigen-Antibody Response

1. A special type of macrophage called a **Dendritic Cell** engulfs the invading microbe and carries it though lymph vessels to the lymph nodes where the various types of **T-Cells** are waiting.



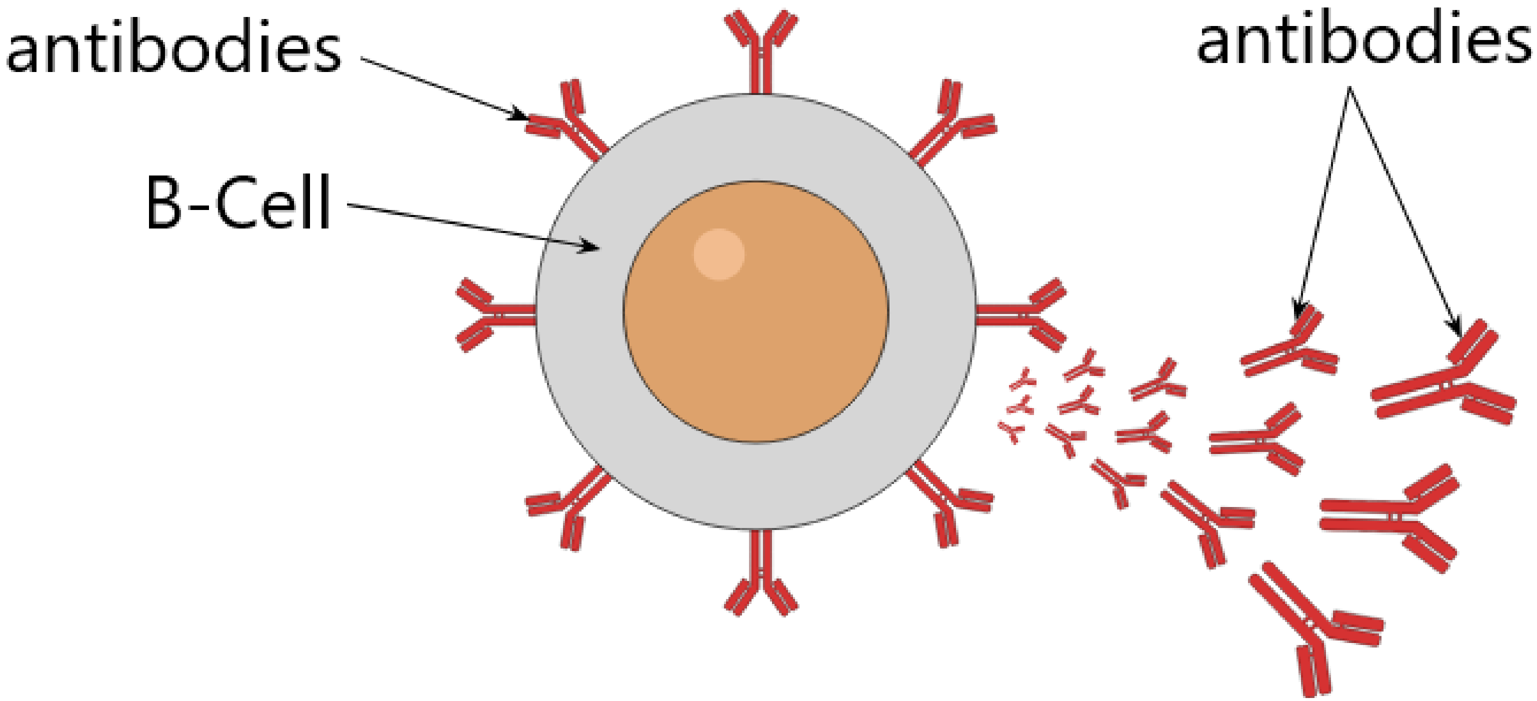
Antigen-Antibody Response

2. **Helper T-Cells** identify intruders by their antigen markers that protrude though the membrane of the **Dendritic Cell**. The **Helper T-Cell** then activates **B-Cells, Killer T-Cells, and Memory T-Cells**.



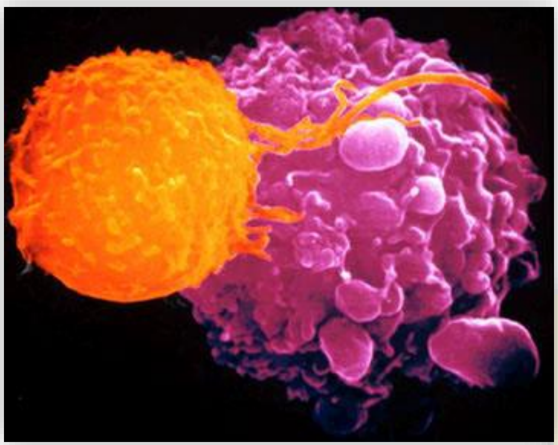
Antigen-Antibody Response

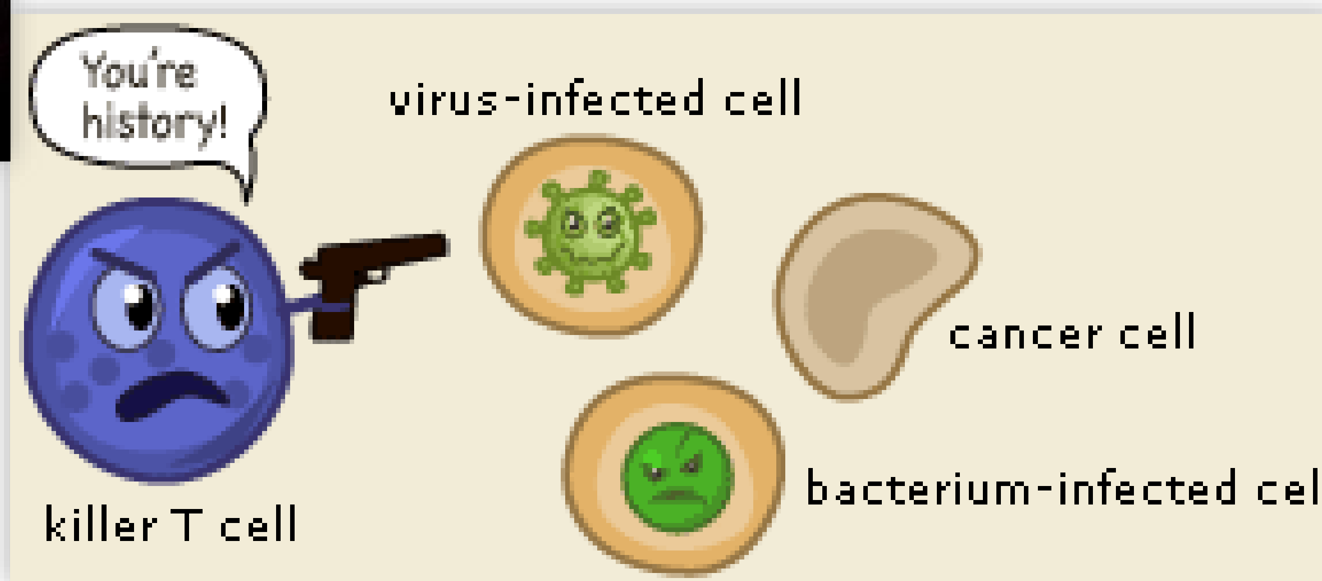
3. The **B-Cells** use the antigen marker information to produce antibodies. The antibodies head to the "battle field" to latch on to invading microbes antigens. Later they are engulfed by macrophages.



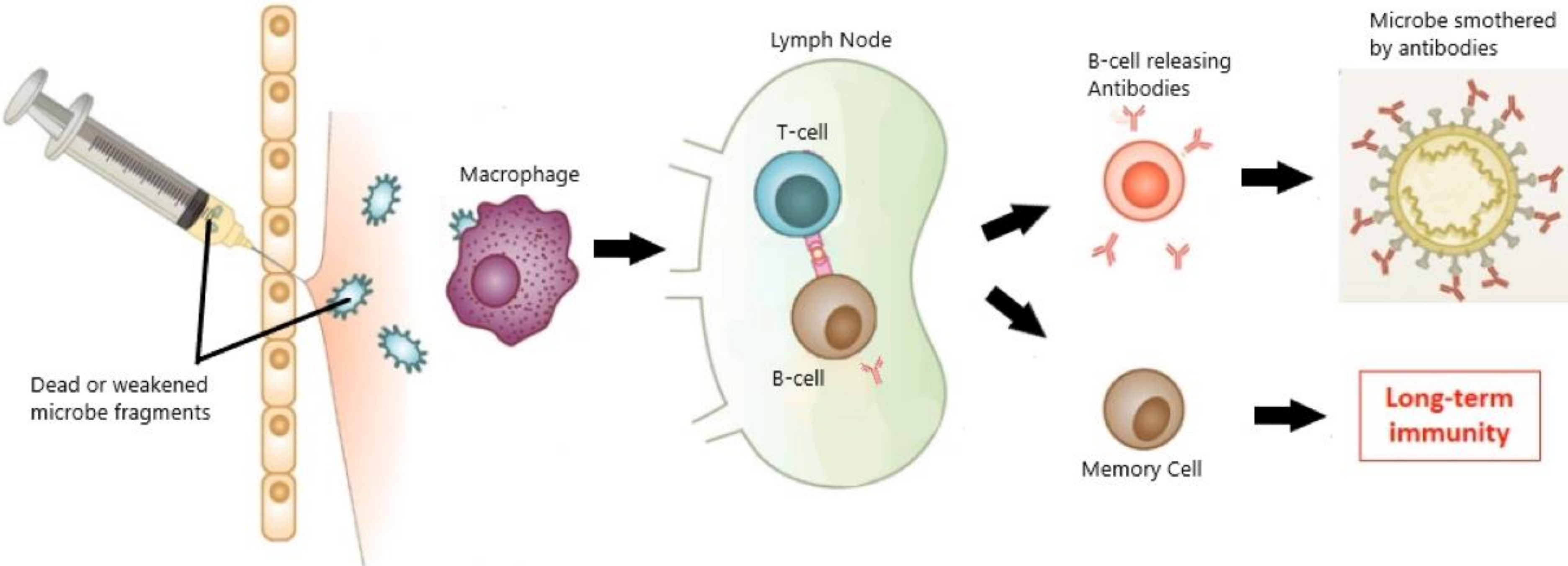
Killer T-Cells

4. The **Killer T-Cells** use the antigen marker information and head directly out to the “battle field” themselves to seek out and destroy cells infected with microbes (by rupturing cell membranes).





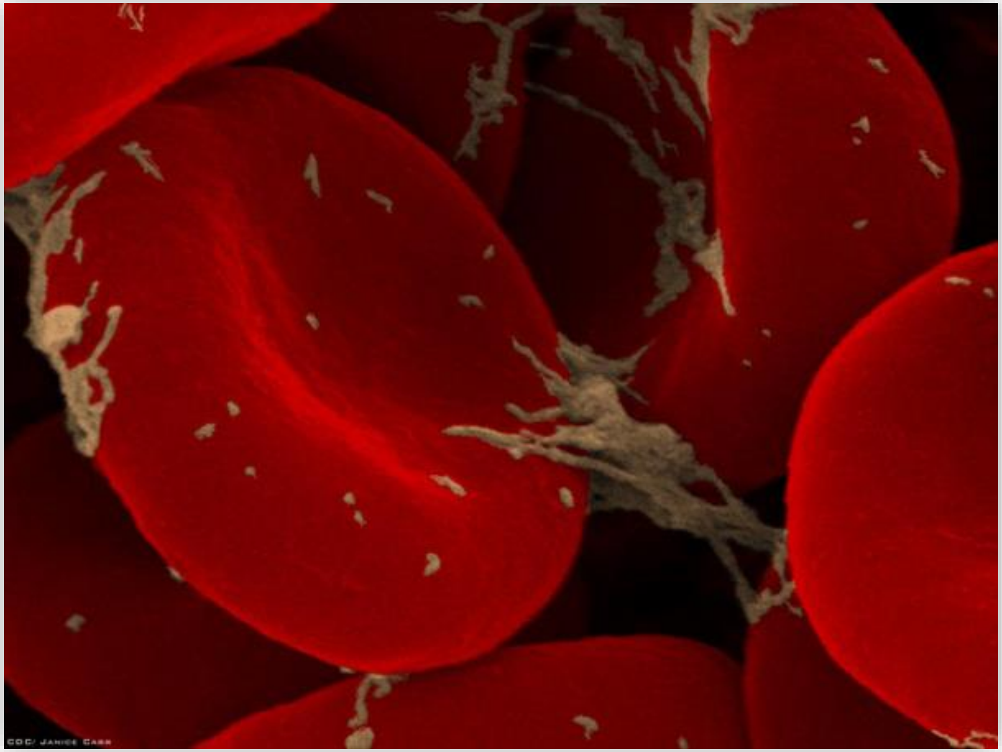
Vaccines

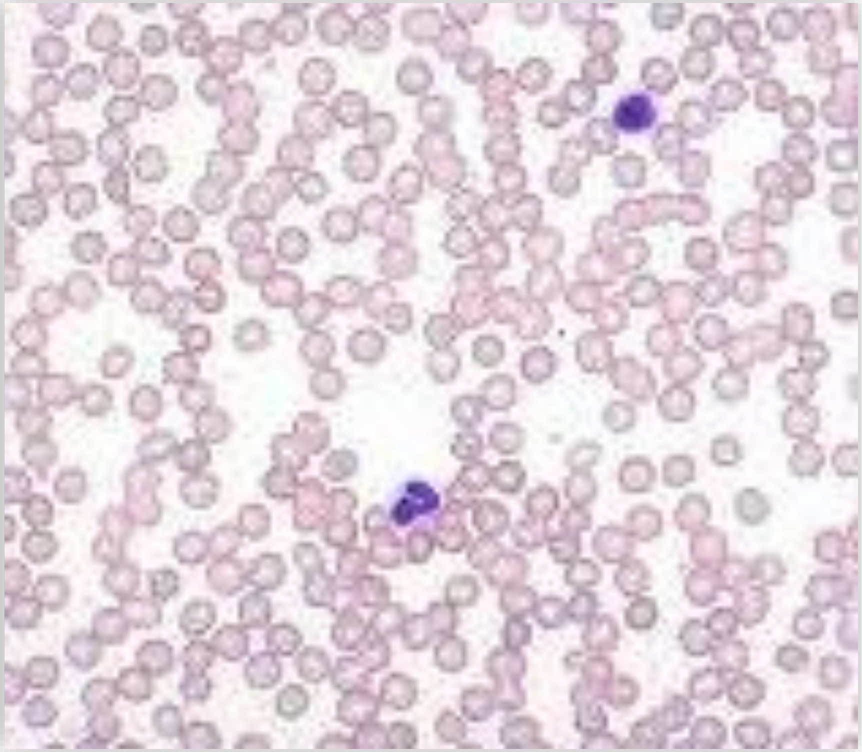


Dead or weakened
microbe fragments
Macrophage
Lymph Node
T-cell
B-cell
B-cell releasing
Antibodies
Memory Cell
Microbe smothered
by antibodies
Long-term
immunity

Red Blood Cells

- Red blood cells (**erythrocytes**) lack a nucleus (more room for hemoglobin), have a biconcave shape (25% more surface area) and are not capable of reproduction.





Red Blood Cells

- An average male contains 5.5 million red blood cells per ml of blood and an average female contains 4.5 million red blood cells per ml of blood. Their function is to transport gasses (oxygen) around the body.

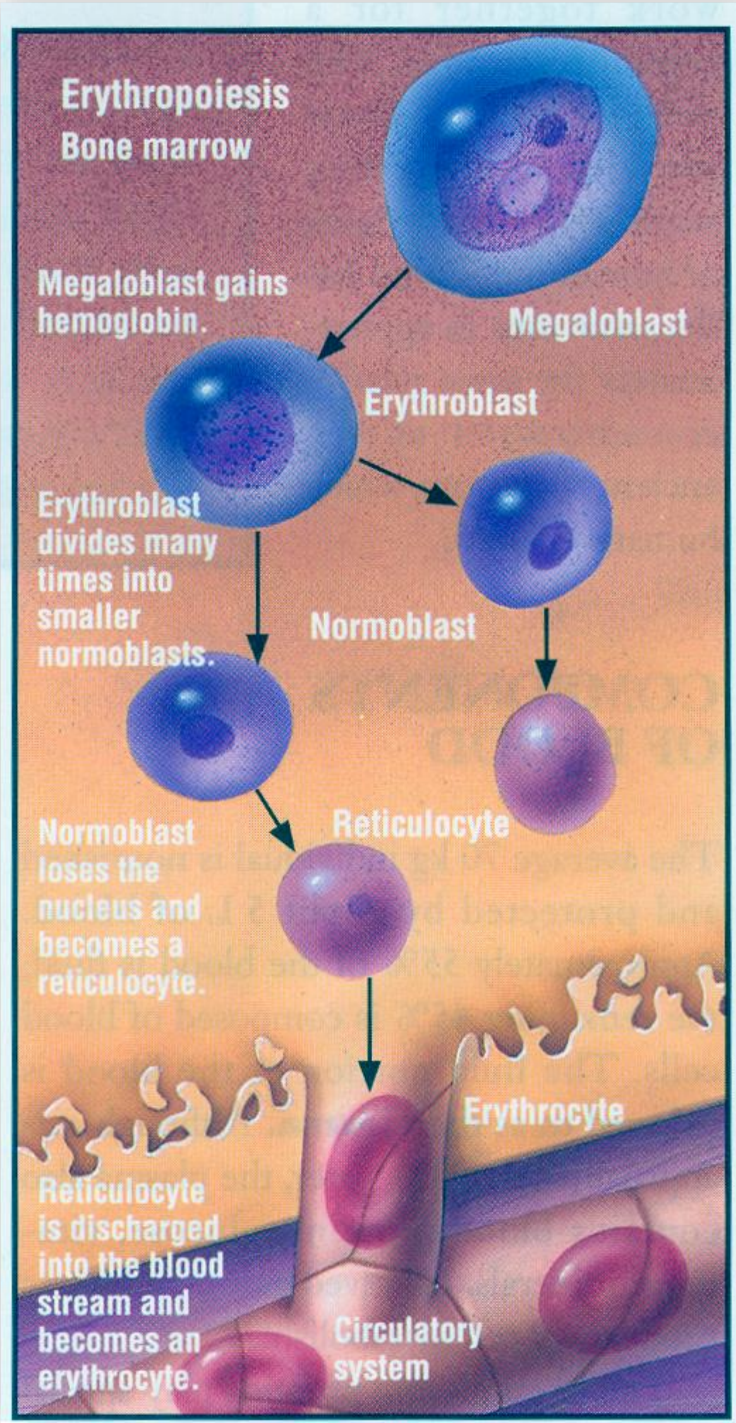
Red Blood Cells

- Red blood cells are made in bone marrow.
- Live for approximately 110-120 days.
- When red blood cells die/decompose, they do so in the liver.

Fun fact: The red colour of blood is due to the iron in hemoglobin reflecting red light when carrying oxygen.

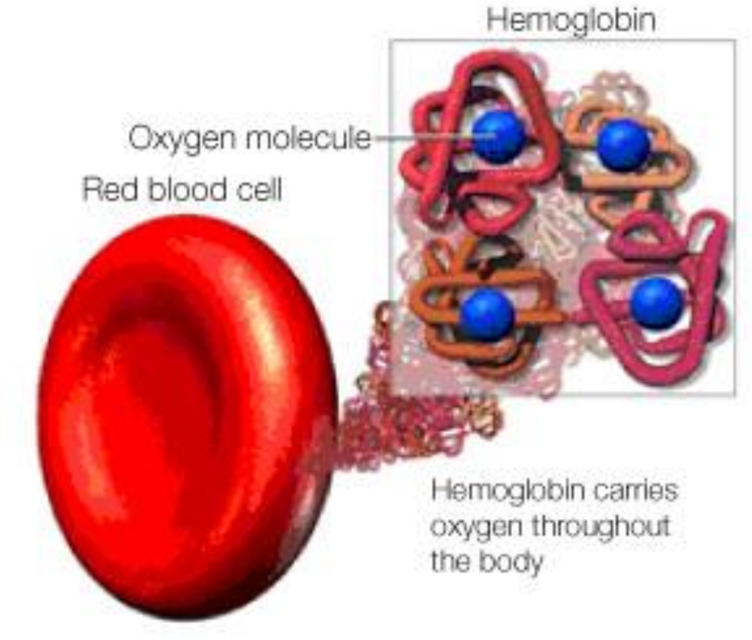
Erythropoiesis

- The process of making new RBCs in the bone marrow.
- As the hemoglobin accumulates via protein synthesis, the RBC ejects the nucleus as it takes up and wastes space that could be used to carry oxygen.



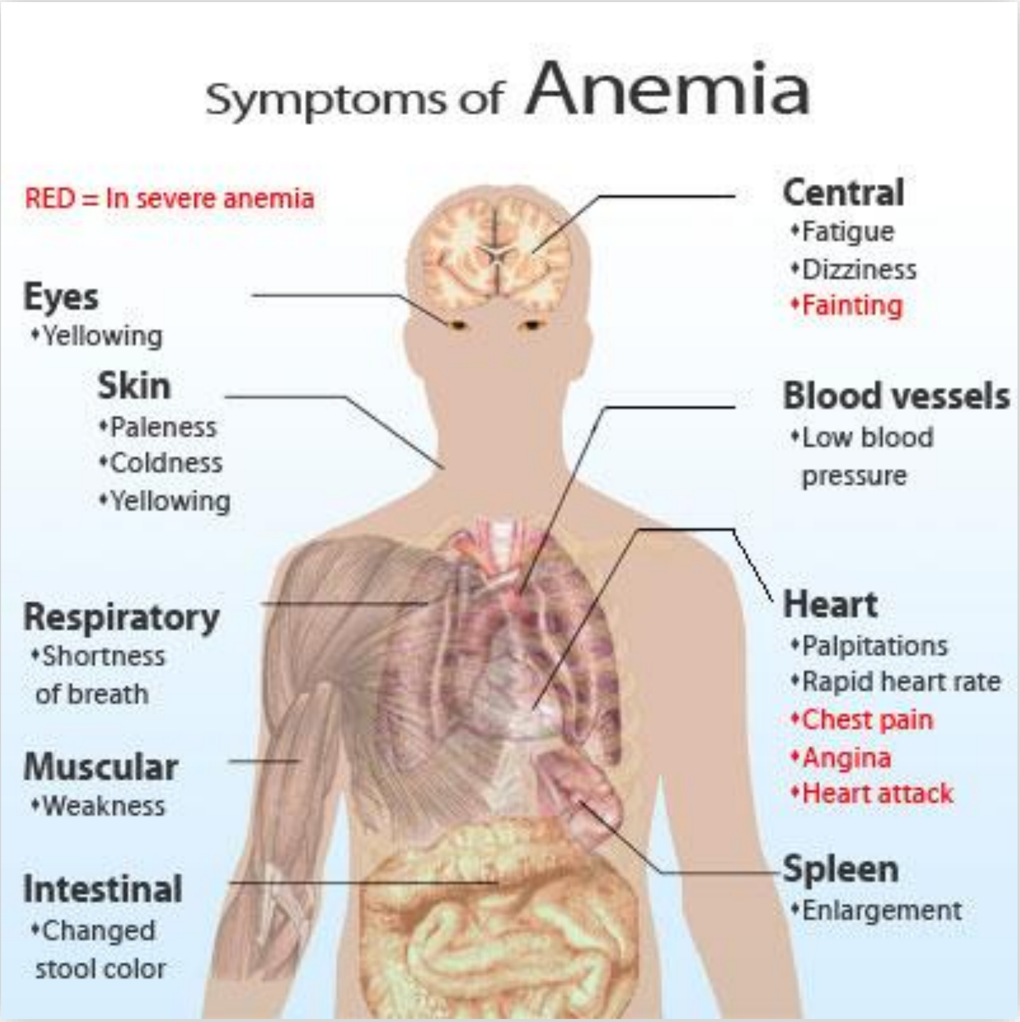
Hemoglobin

- Each RBC contains a small amount of hemoglobin to aid in the oxygen carrying.
- Without hemoglobin, 1 L of blood can only carry 3 ml of oxygen at body temperature. With hemoglobin, 1 L of blood can carry 200 ml of oxygen at body temperature (increase of 70x).



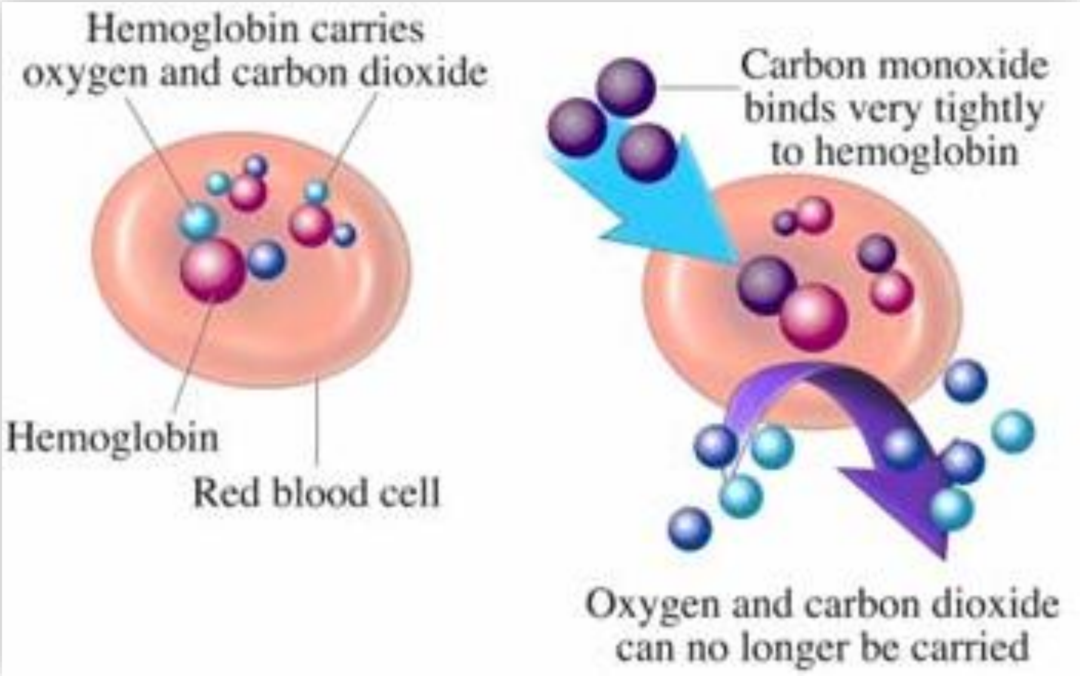
Blood Disorder: Anemia

- A condition which drastically decreases the oxygen carrying capability of the blood.
- Low levels of hemoglobin in the blood.
- Characterised by low energy levels.



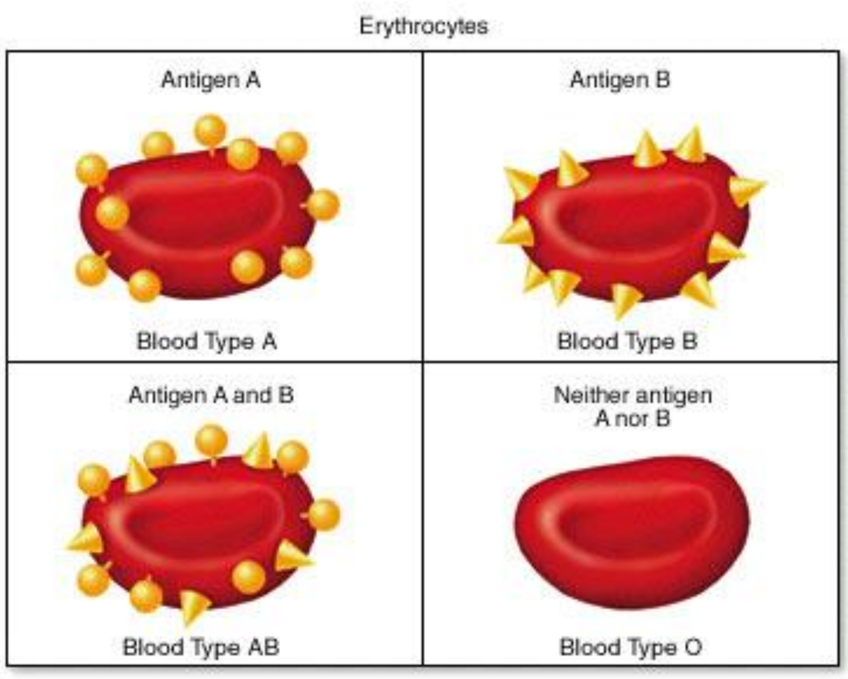
Carbon Monoxide Poisoning "Revisited"

- Carbon monoxide forms a stable bond with hemoglobin and "competes" with the oxygen for hemoglobin.
- Suffocation will quickly result after inhalation of CO, as the oxygen capacity of the red blood cells quickly degrade.



ABO Blood Grouping

- Special markers called **glycoproteins** located on the plasma membrane of certain red blood cells determine what type of blood an individual has.
- The **ABO blood typing system** is widely used to determine blood compatibility for transfusions.

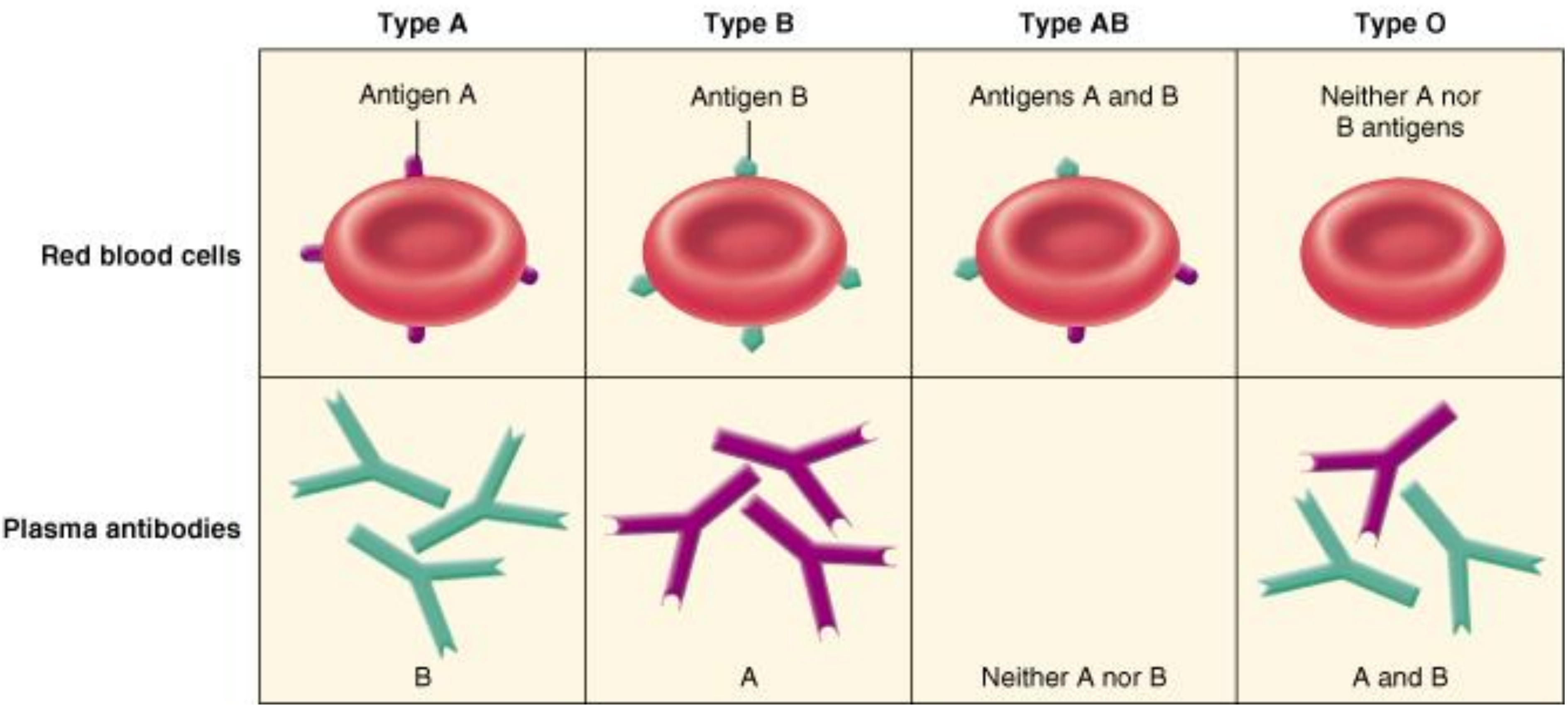


ABO Blood Grouping

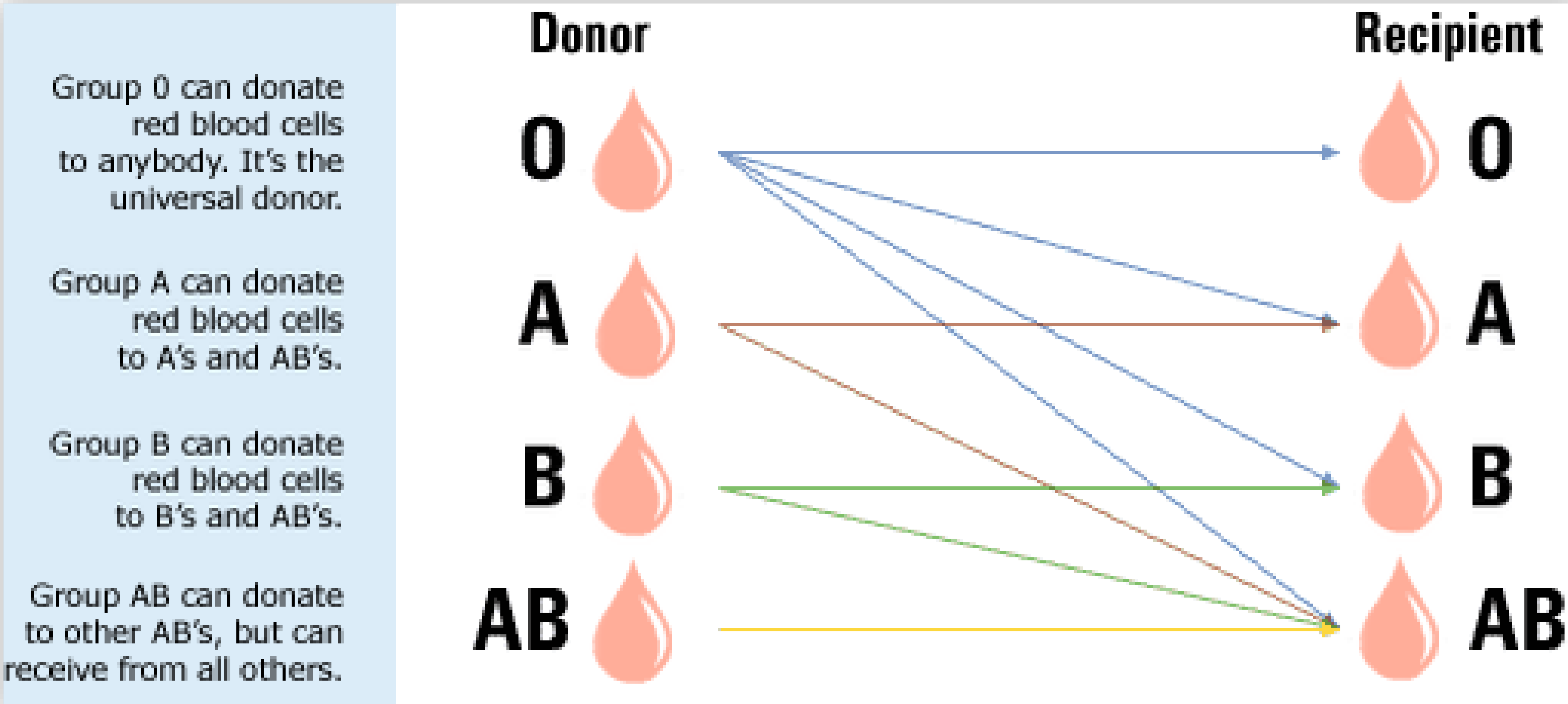
Canadian Blood Types

Type O 46% Type A 42%

Type B 9% Type AB 3%



ABO Transfusion Compatibility

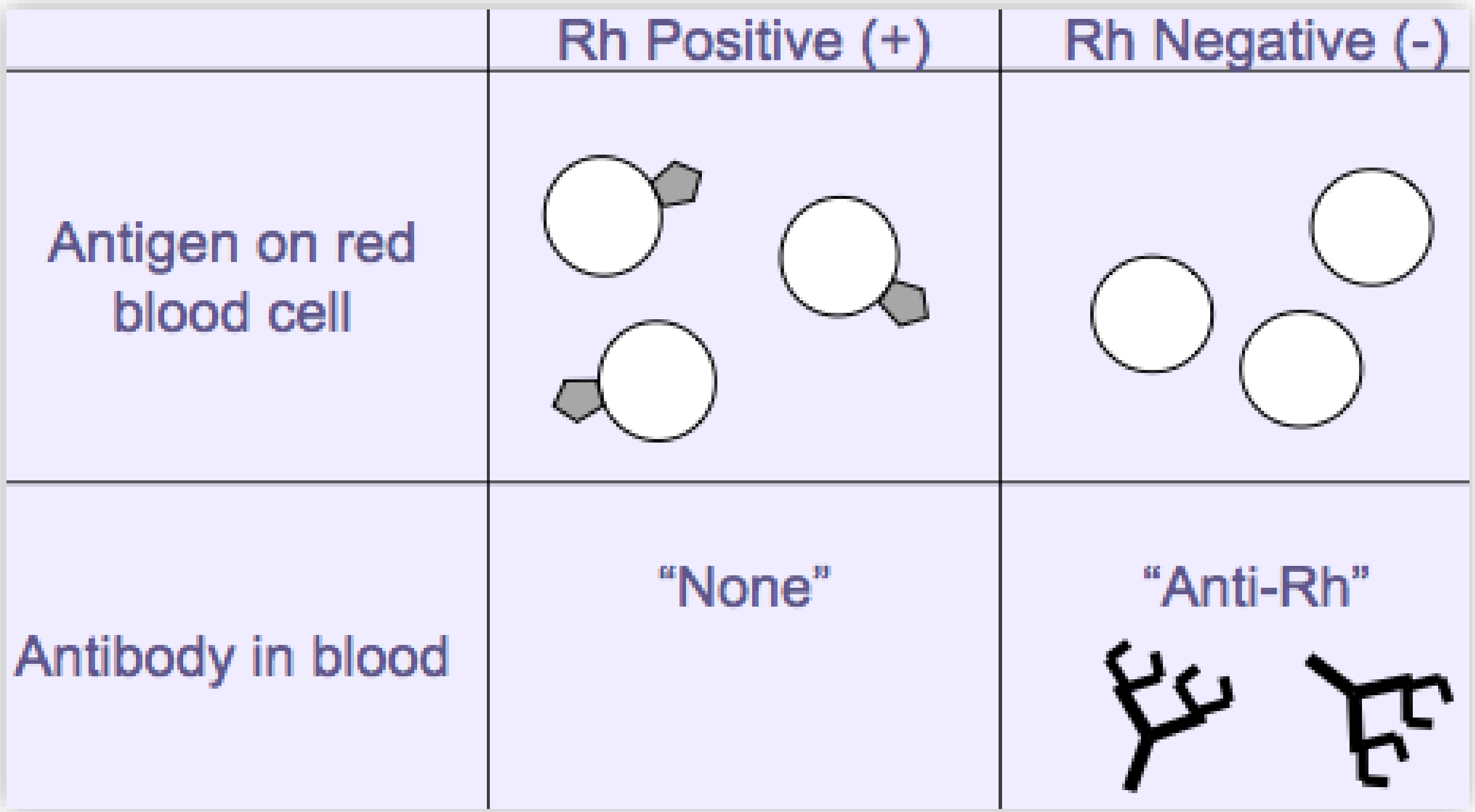


Universal donor: O^-

Universal receiver: AB^+

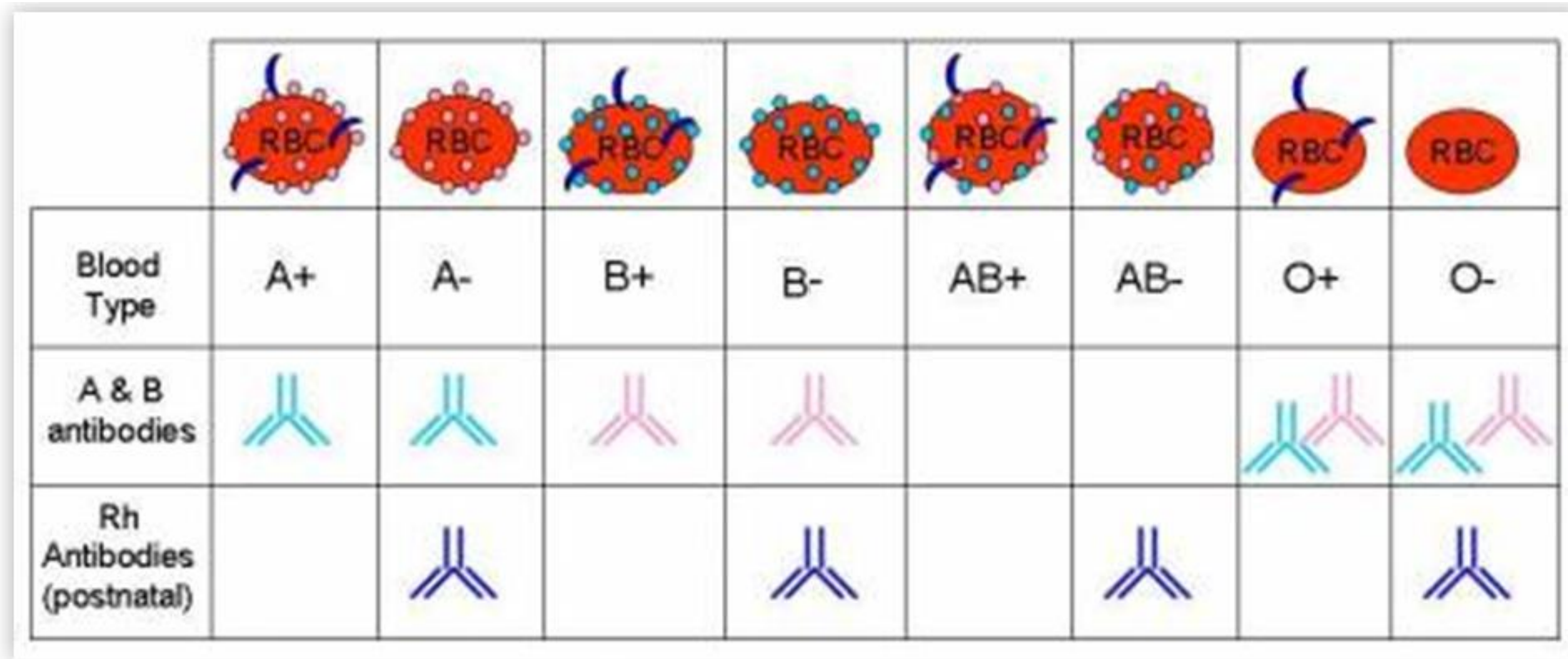
Rh Factor

Blood can be further classified by the **Rh System**. The presence of the Rh antigen on the red blood cell membranes is indicated by a **positive (+)** and the absence of the Rh antigen is indicated by a **negative (-)**. For example blood type O and the presence of the Rh antigen is called "O Rh Positive" or O+. 85% on Canadians are Rh+.



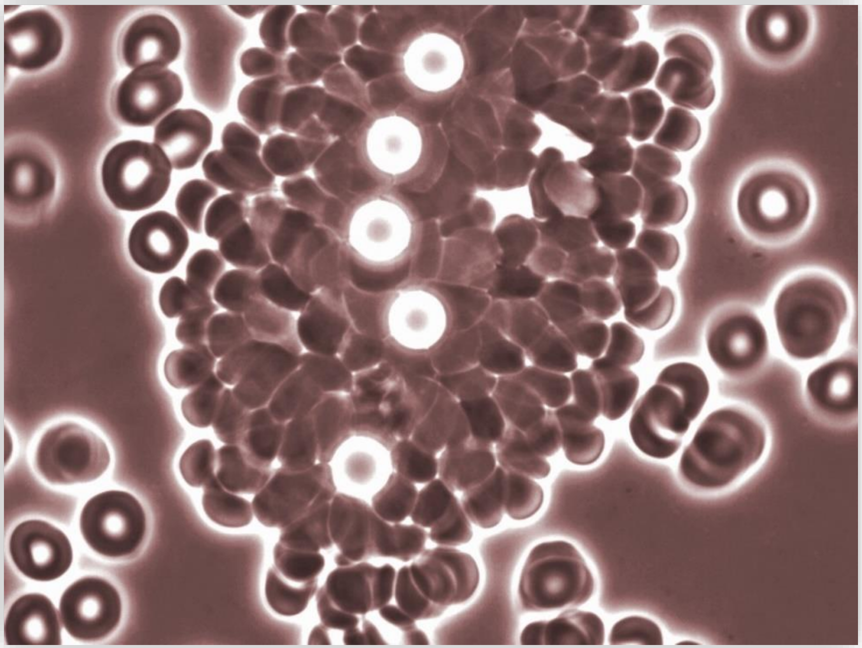
ABO and Rh Blood Typing

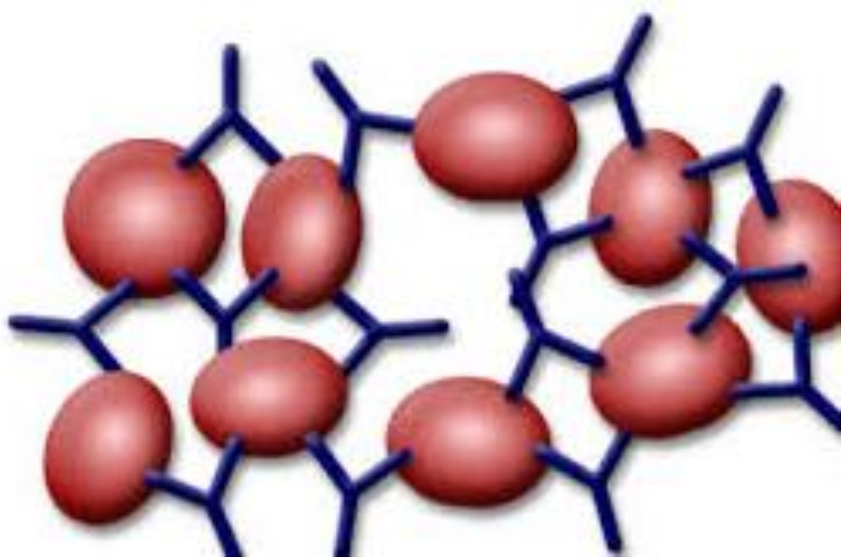
In general, Rh negative blood is given to Rh-negative patients, and Rh positive blood *or* Rh negative blood may be given to Rh positive patients.



Agglutination Reaction

- A blood test used to identify unknown antigens. Used in blood grouping and tissue matching.
- This refers to the clumping of red blood cells caused by the interaction between the antibodies and the antigens.

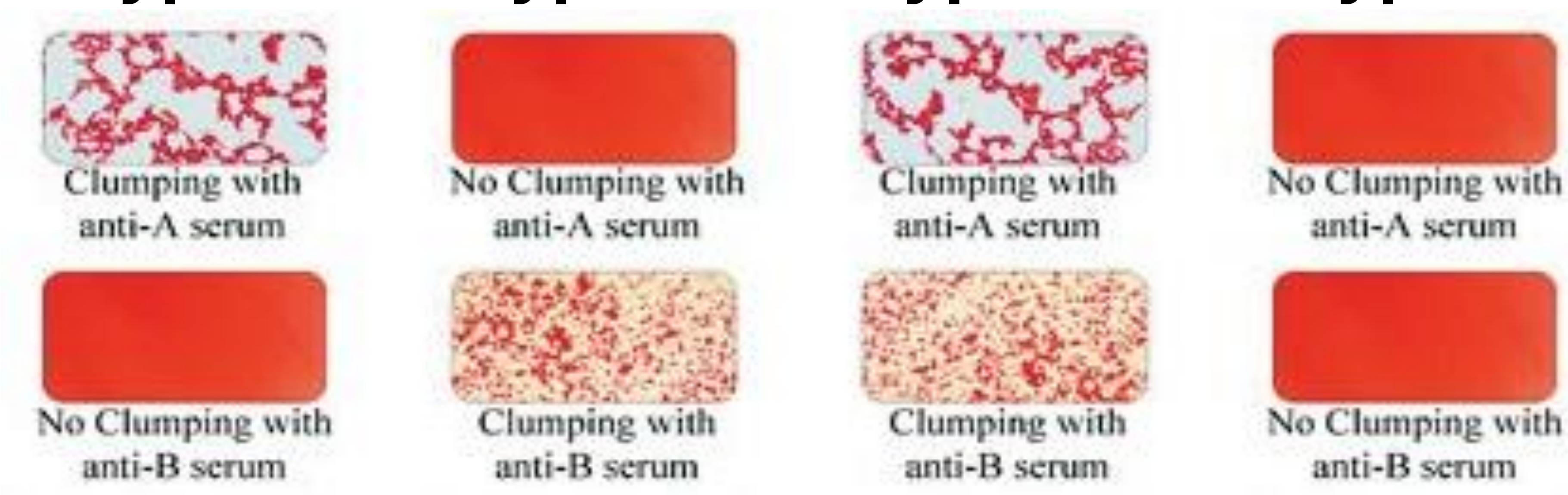




ABO Blood Typing

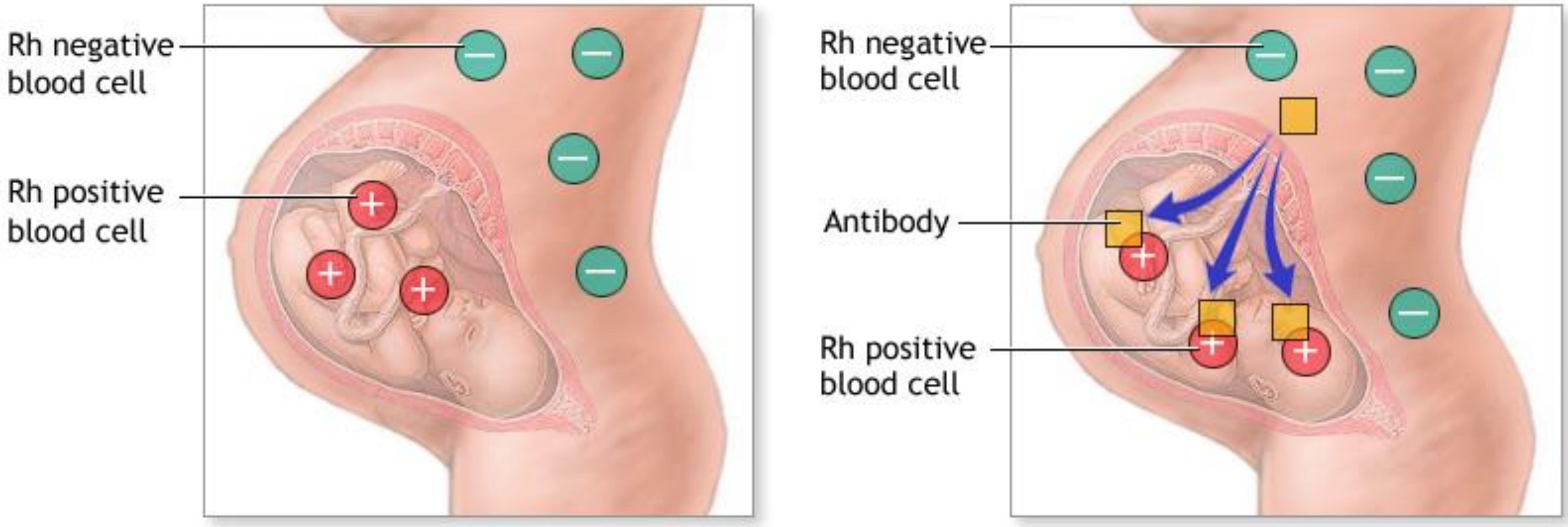
- 3 serums must be used to determine (type) a persons blood: Anti-A, Anti-B, Anti-Rh (aka D serum).
  - **Note:** For the Anti-Rh test, if the blood cells stick together when the serum is added, the person is *Rh positive*; if not, the person is *Rh negative*.

Type A **Type B** **Type AB** **Type O**



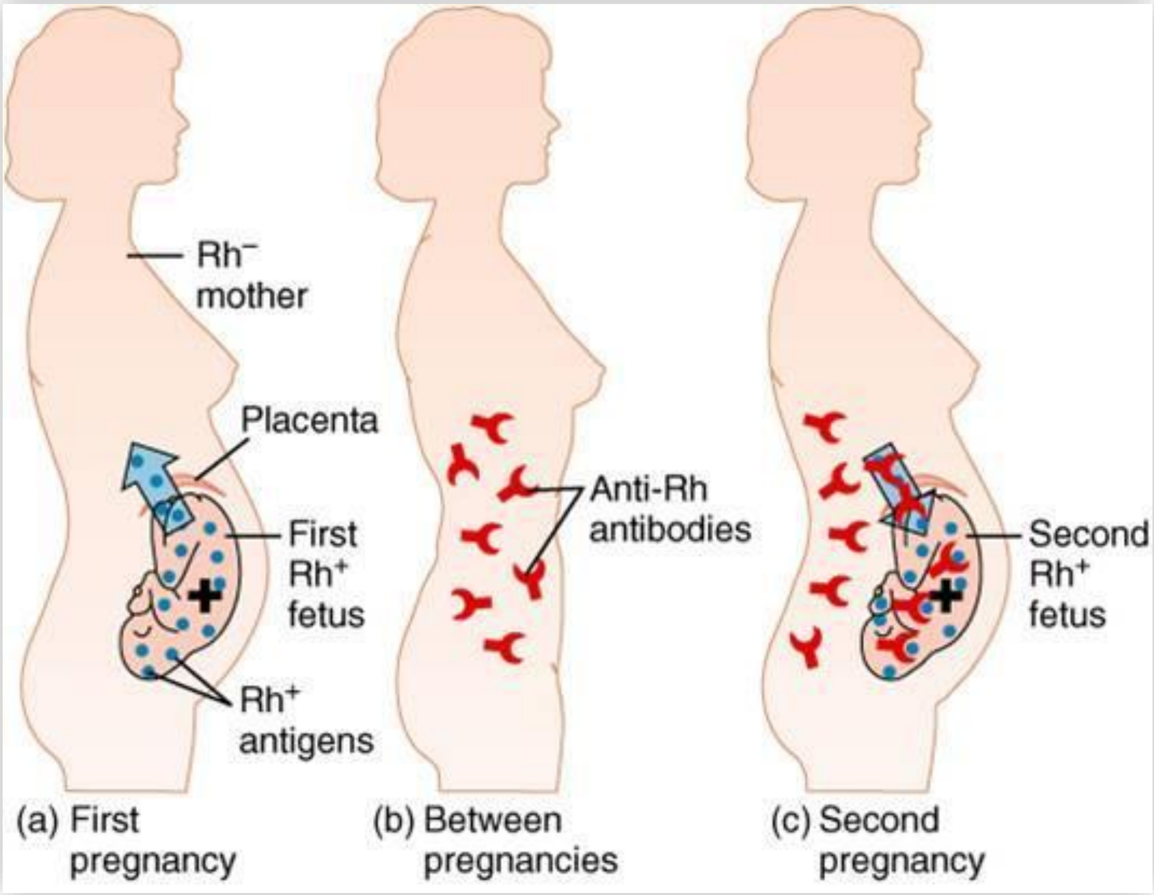
Disorder: Erythroblastosis Fetalis

- Erythroblastosis Fetalis (hemolytic disease) occurs if a baby inherits the Rh+ factor from the father and the mother is Rh-.
- After being exposed to the baby's Rh+ blood (during birthing), the mother will produce antibodies against the RH antigen.
- These antibodies will move into the blood stream of subsequent babies and cause agglutination, turning the baby blue.



Treatment of Erythroblastosis Fetalis

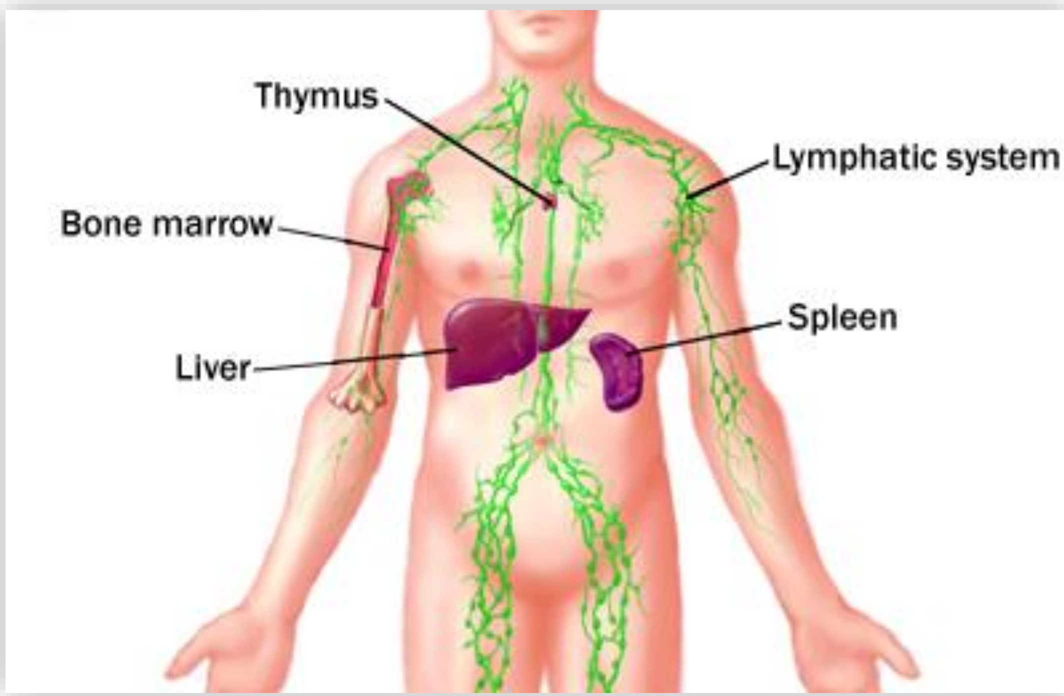
- An anti-Rh antibody injection given to the mother after the birth can destroy the fetal red cells, thus preventing trouble in a future pregnancy.



Lymphatic System (LS)

Two major functions:

1. Creates a constant flow of "tissue fluid" from the blood stream into the cavities between the tissues, cells, and back to the blood.
2. To produce certain white blood cells.



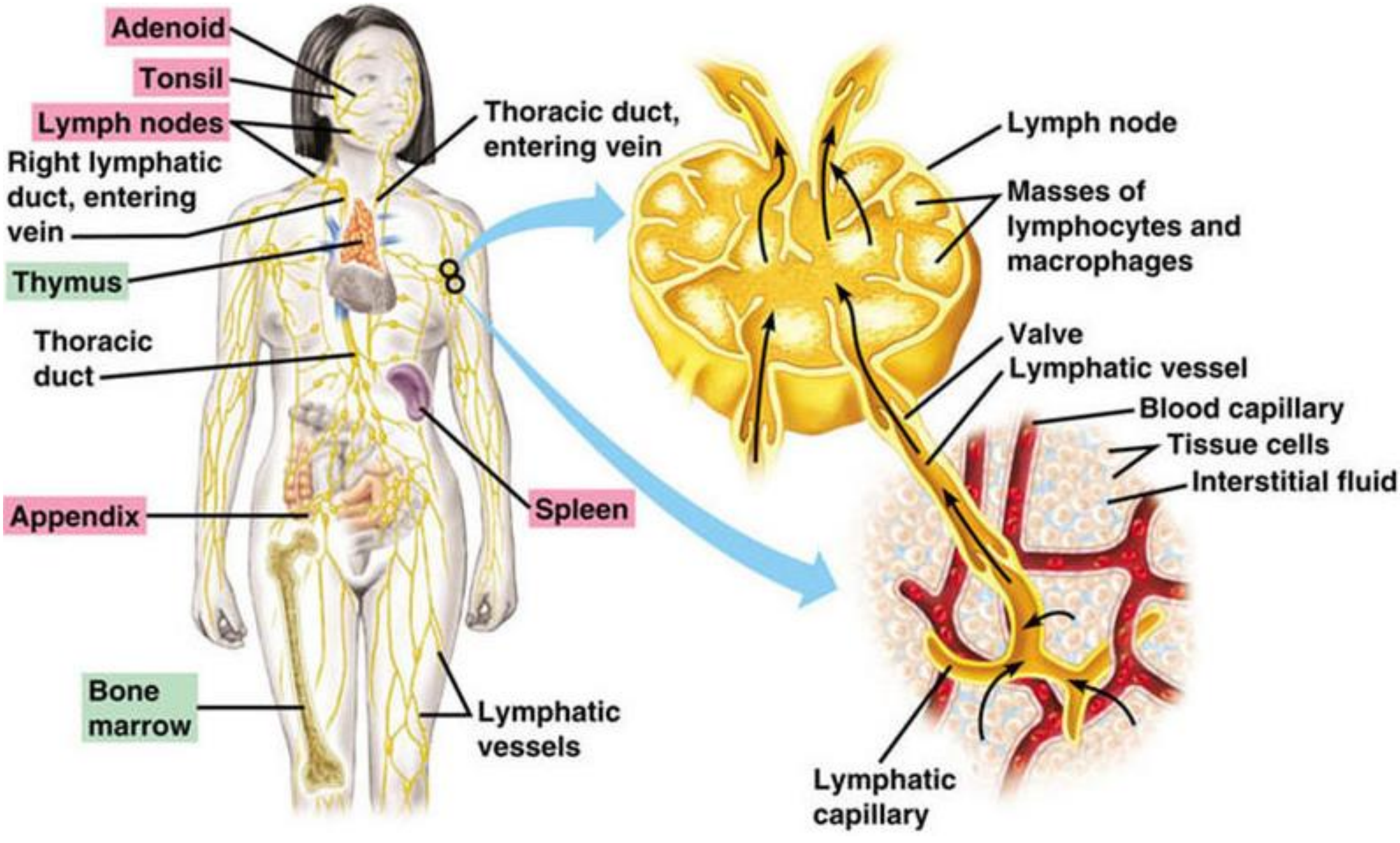
Lymphatic System (LS)

- A network of vessels that carry lymph from the intracellular spaces of the body towards the heart.
- Lymph is “tissue fluid”, which is similar to blood plasma. It is a colourless fluid containing WBCs.
- Lymph acts to remove bacteria from the tissues and supply mature lymphocytes (a form of small WBC) to the blood.
- The LS is not a closed system.

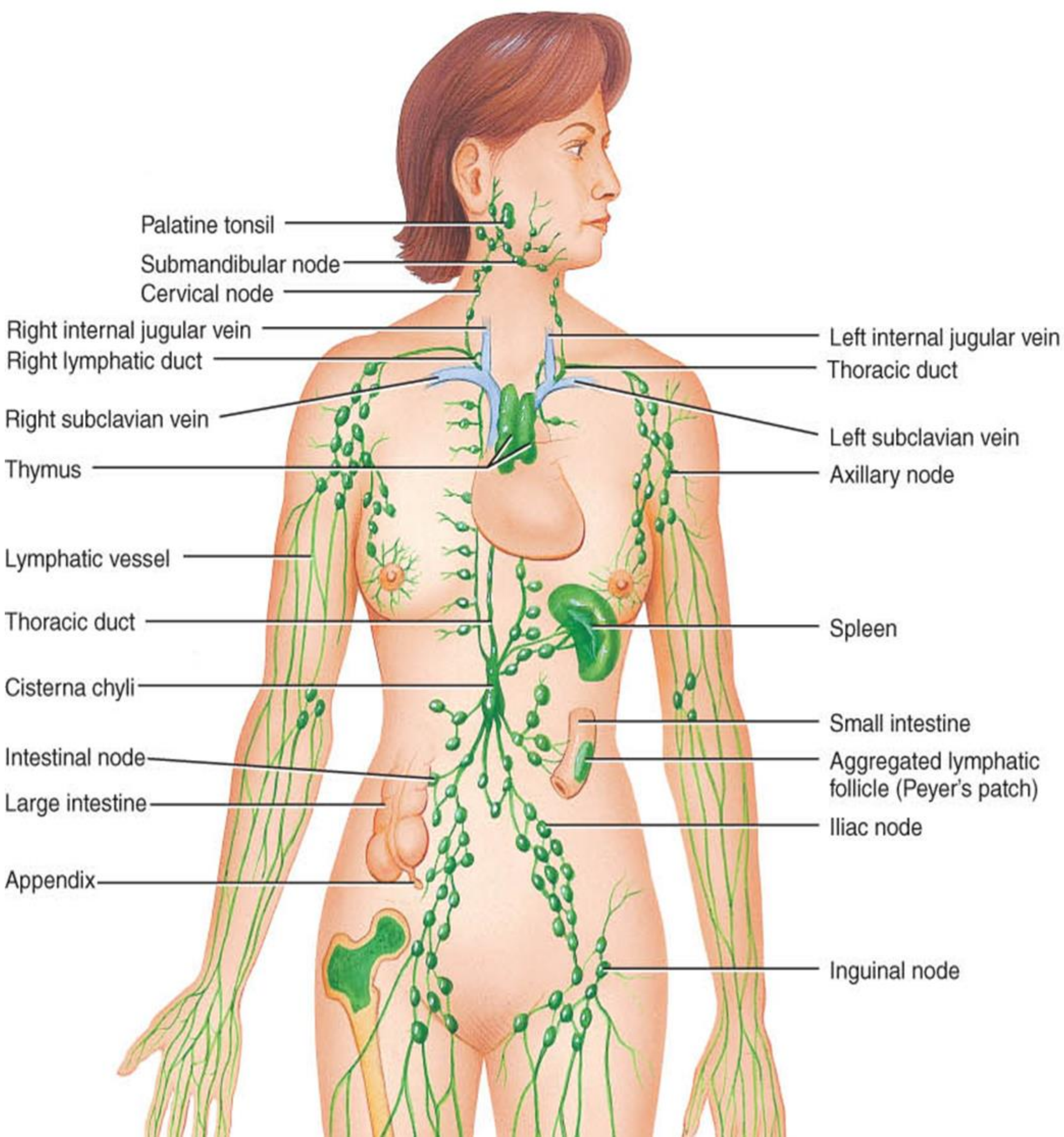
Lymphatic System

- The LS absorbs approximately 3 L of lymph per day back into circulatory system.
- Includes lymph nodes which house many of the T-cells and B-cells of the immune system.
- Lymph nodes filter out and digest bacteria and other fragments of foreign material picked up by the lymph when it is between the tissue.
- Lymph nodes are found near the body’s major organs – in the neck, under the arms, and in the limbs.
- Returns fluid to the circulatory system through the right lymphatic duct and the thoractic duct.

Overview



Adenoid
Tonsil
Lymph nodes
Right lymphatic duct, entering vein
Thymus
Thoracic duct
Appendix
Bone marrow
Thoracic duct, entering vein
Spleen
Lymphatic vessels
Lymph node
Masses of lymphocytes and macrophages
Valve
Lymphatic vessel
Blood capillary
Tissue cells
Interstitial fluid
Lymphatic capillary

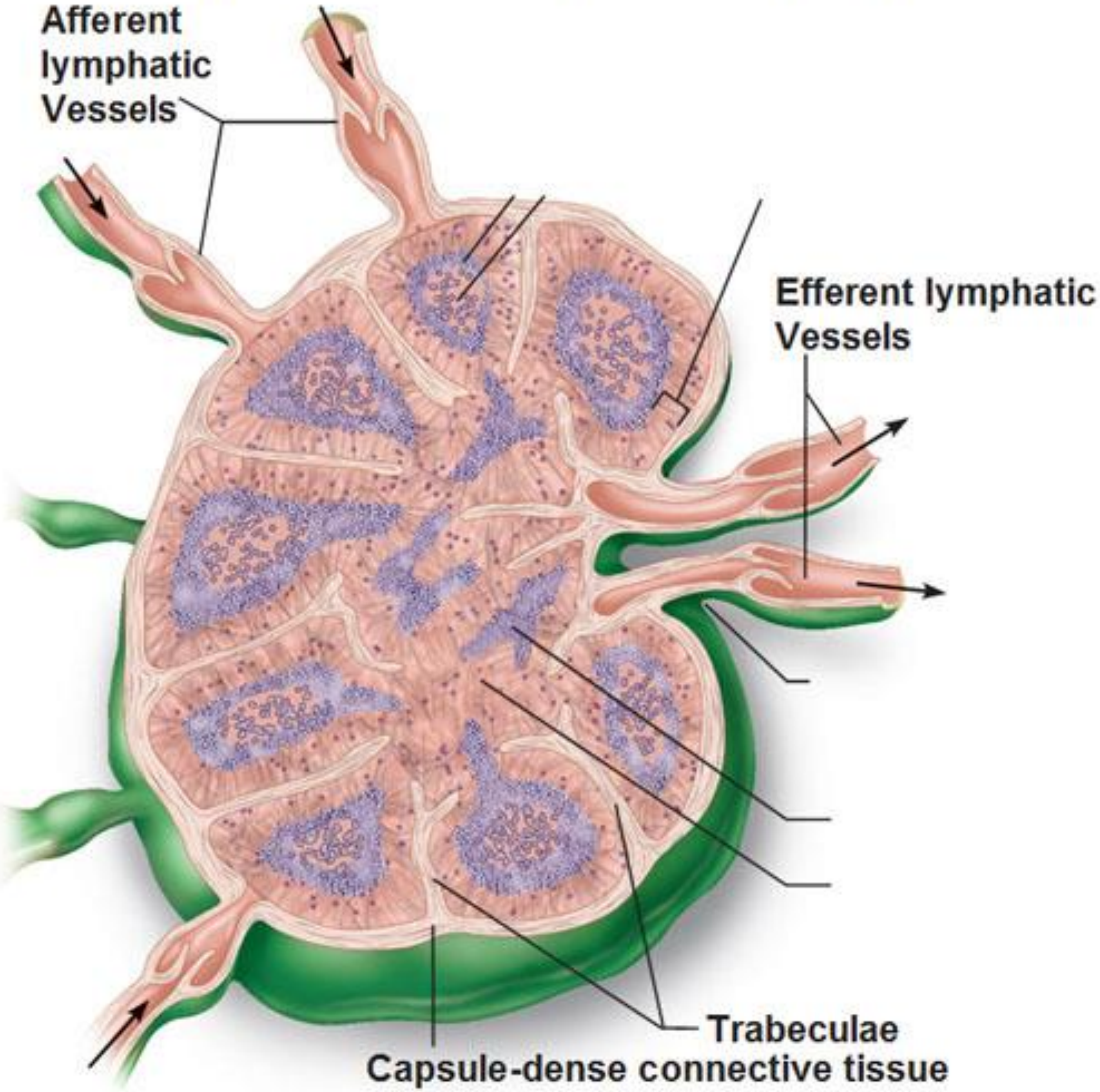

Palatine tonsil
Submandibular node
Cervical node
Right internal jugular vein
Right lymphatic duct
Right subclavian vein
Thymus
Lymphatic vessel
Thoracic duct
Cisterna chyli
Intestinal node
Large intestine
Appendix
Left internal jugular vein
Thoracic duct
Left subclavian vein
Axillary node
Spleen
Small intestine
Aggregated lymphatic follicle (Peyer's patch)
Iliac node
Inguinal node

An Aside: The Spleen & Appendix

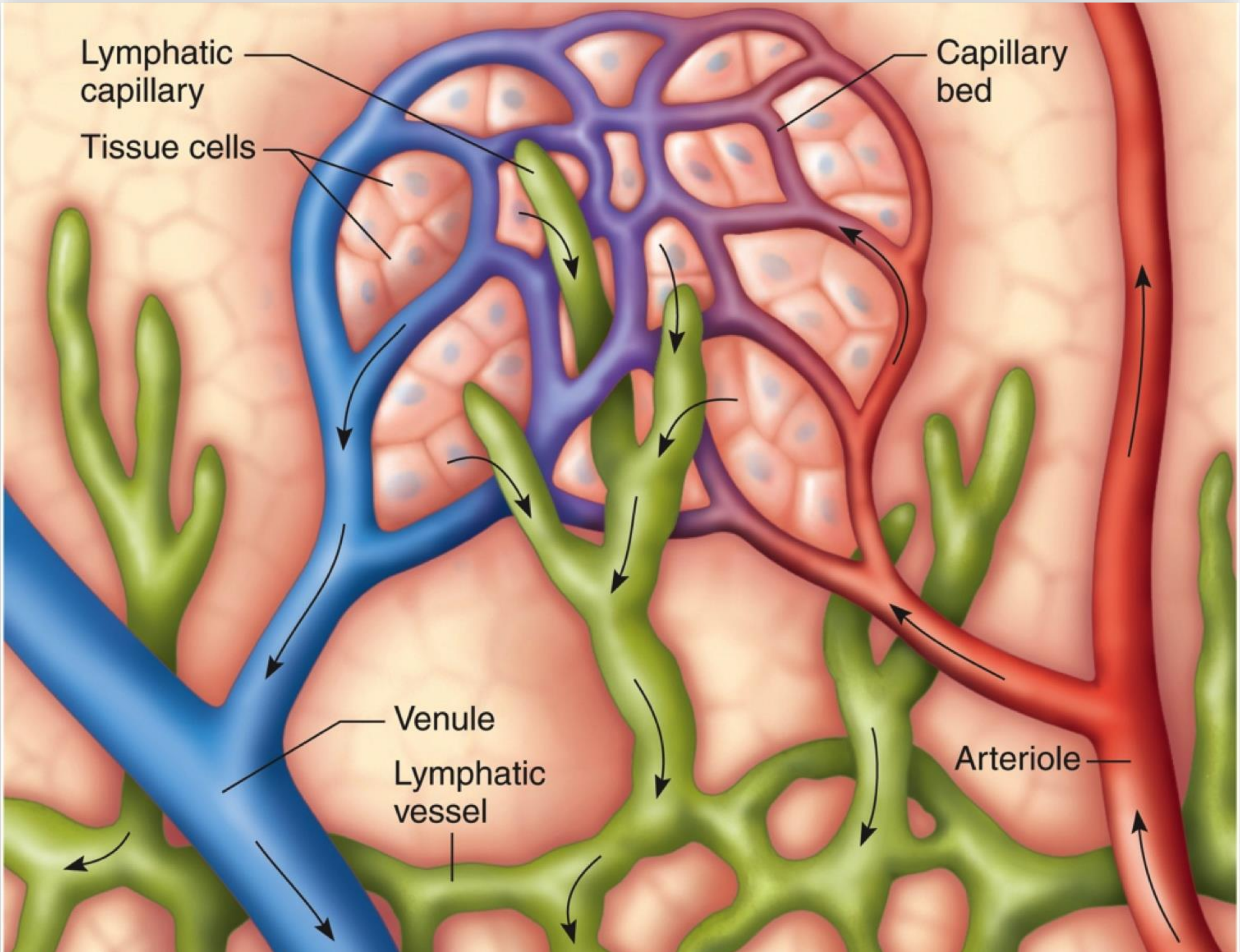
Functions:

- **Spleen:** Works to protect the body, clearing worn out red blood cells and other foreign bodies from the bloodstream to help fight off infection.
- **Appendix:** The presence of lymphoid tissue suggests that the appendix may play a role in the immune/lymphatic system.

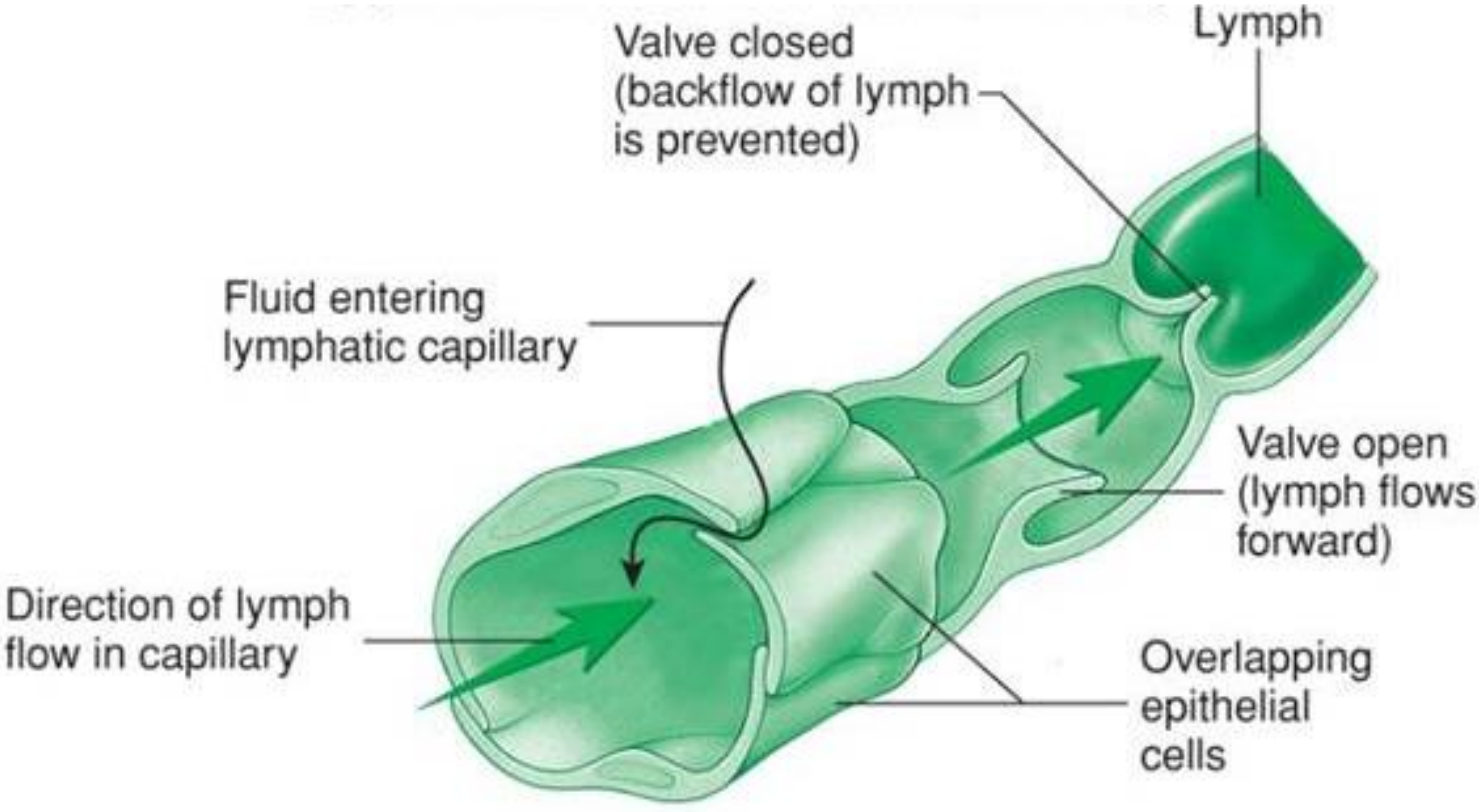
Microscopic Anatomy of a Lymph Node



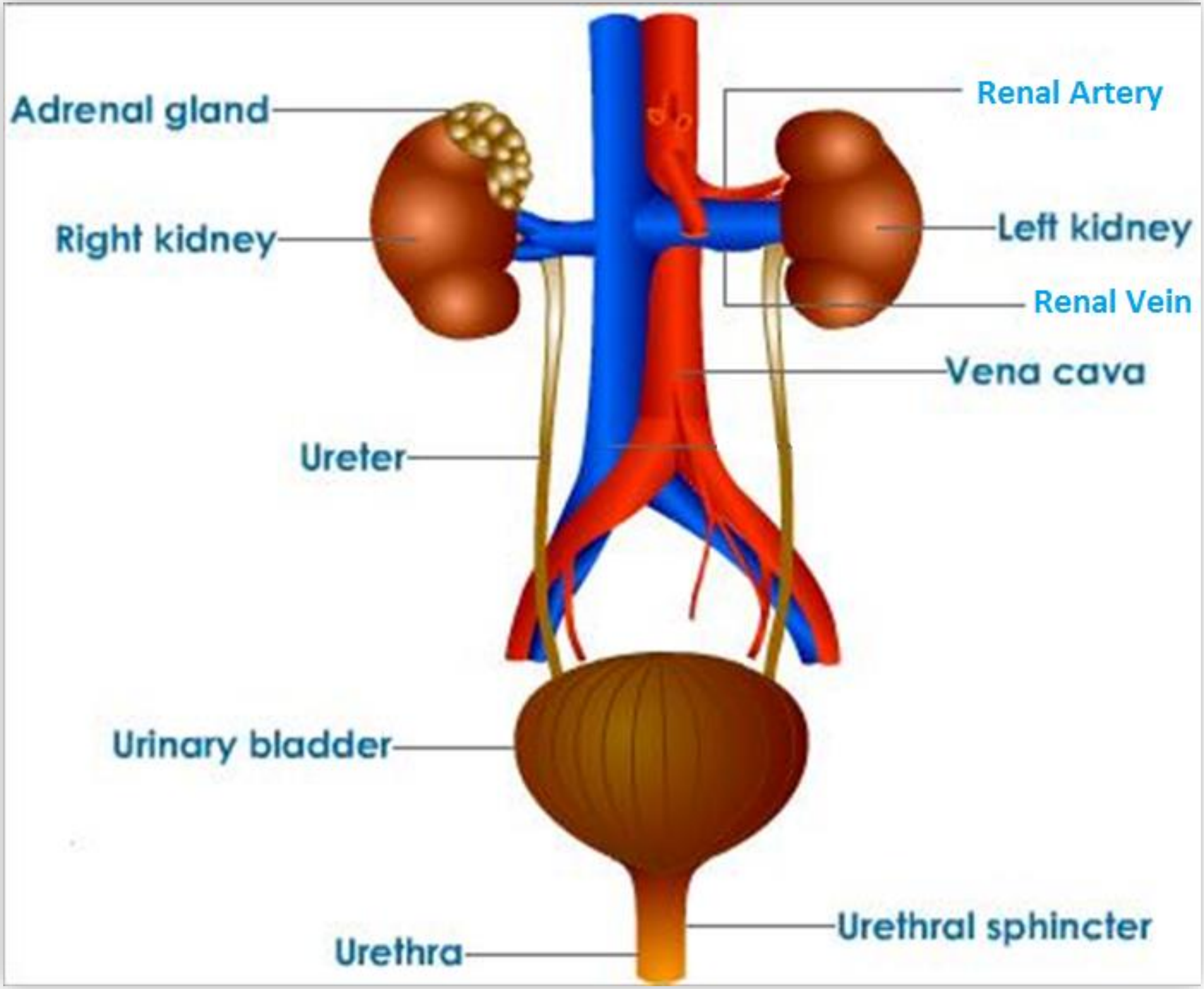
Longitudinal view of the internal structure of a lymph node and associated lymphatics


Lymphatic capillary
Tissue cells
Capillary bed
Venule
Lymphatic vessel
Arteriole

Lymph Vessel Valves



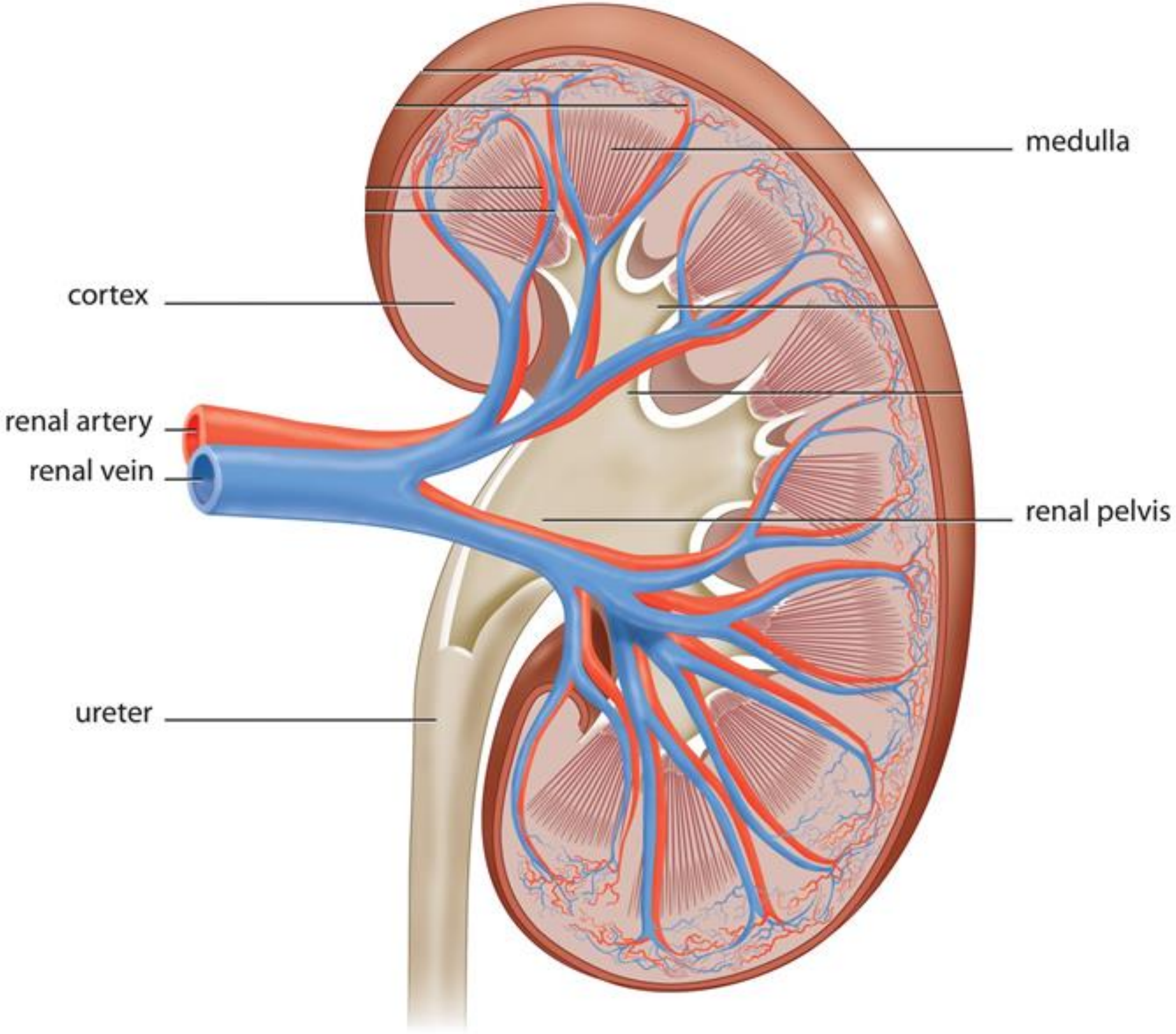
The Excretory System



The Excretory System

- The excretory system is responsible for removing wastes from the body.
- These wastes include water, salts, urine, and other metabolic waste.
- About 1/1000 to 2/1000 of blood that flows through our bodies becomes waste after filtration.
- The primary organs in the excretory system are the kidneys.
- The primary function of the kidneys is to eliminate waste from the bloodstream by the production of urine.

Kidney


medulla
cortex
renal artery
renal vein
renal pelvis
ureter

Key Functions of the Kidney

- Maintain volume of extracellular fluid.
- Maintain ionic balance in extracellular fluid.
- Maintain pH and osmotic concentration of the extracellular fluid.
- Excrete toxic metabolic by-products such as urea, ammonia, and uric acid.

Other Facts about Kidneys

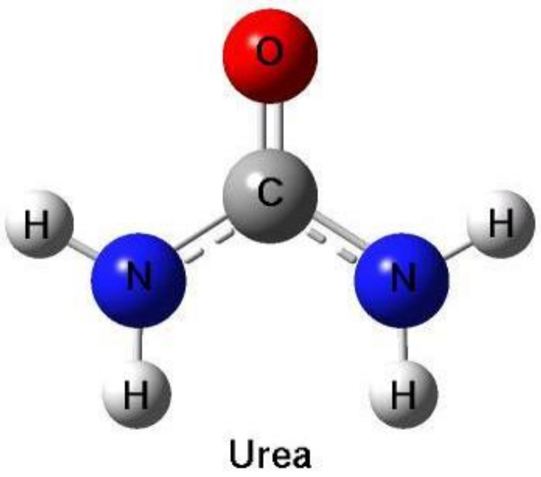
- ~ 700-800 L of blood pass through the kidneys each day.
- 99% of the water that filters out of the blood into the kidneys is reabsorbed back into the blood.
- To replenish water lost to urine each day, we must drink 1.4 – 1.8 L of water each day.

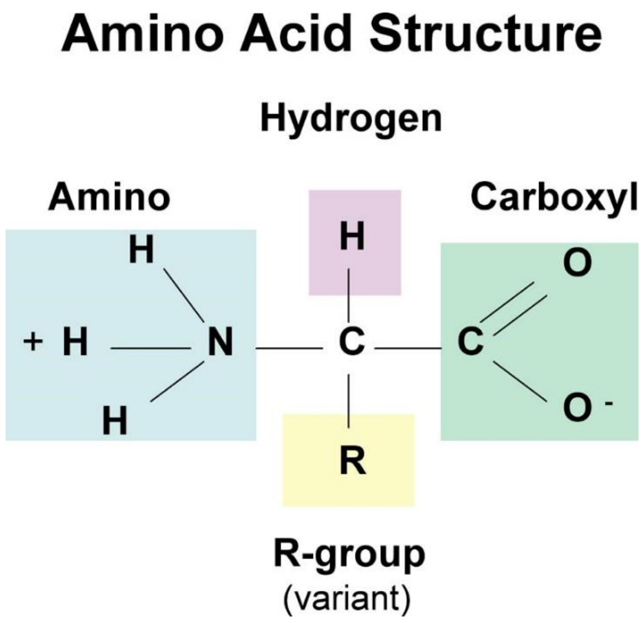
Excretion vs. Secretion vs. Elimination

- Excretion - the removal of wastes from the cells to the blood. Ex: salts, minerals, and water.
- Secretion - the removal of useful substances from cells. Ex: digestive enzymes and hormones.
- Elimination - Elimination is the removal of wastes from the body; i.e. getting rid of waste substances from the organism completely. Ex: CO_2, food waste, water, and urea.

Urea

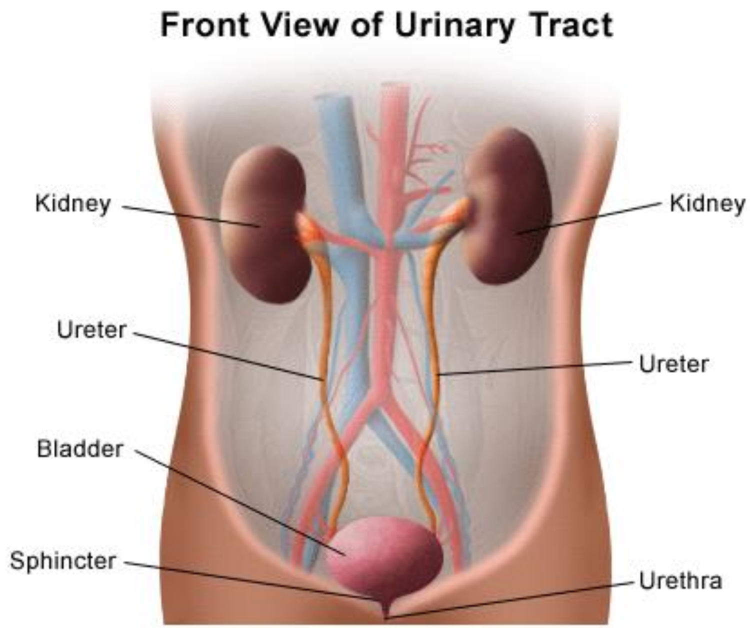
- The liver is responsible for detoxifying products of cellular metabolism.
- In the liver, excess amino acids are broken down into ammonia.
- Ammonia is converted to urea, through the addition of CO_2, which is 1000x less toxic.



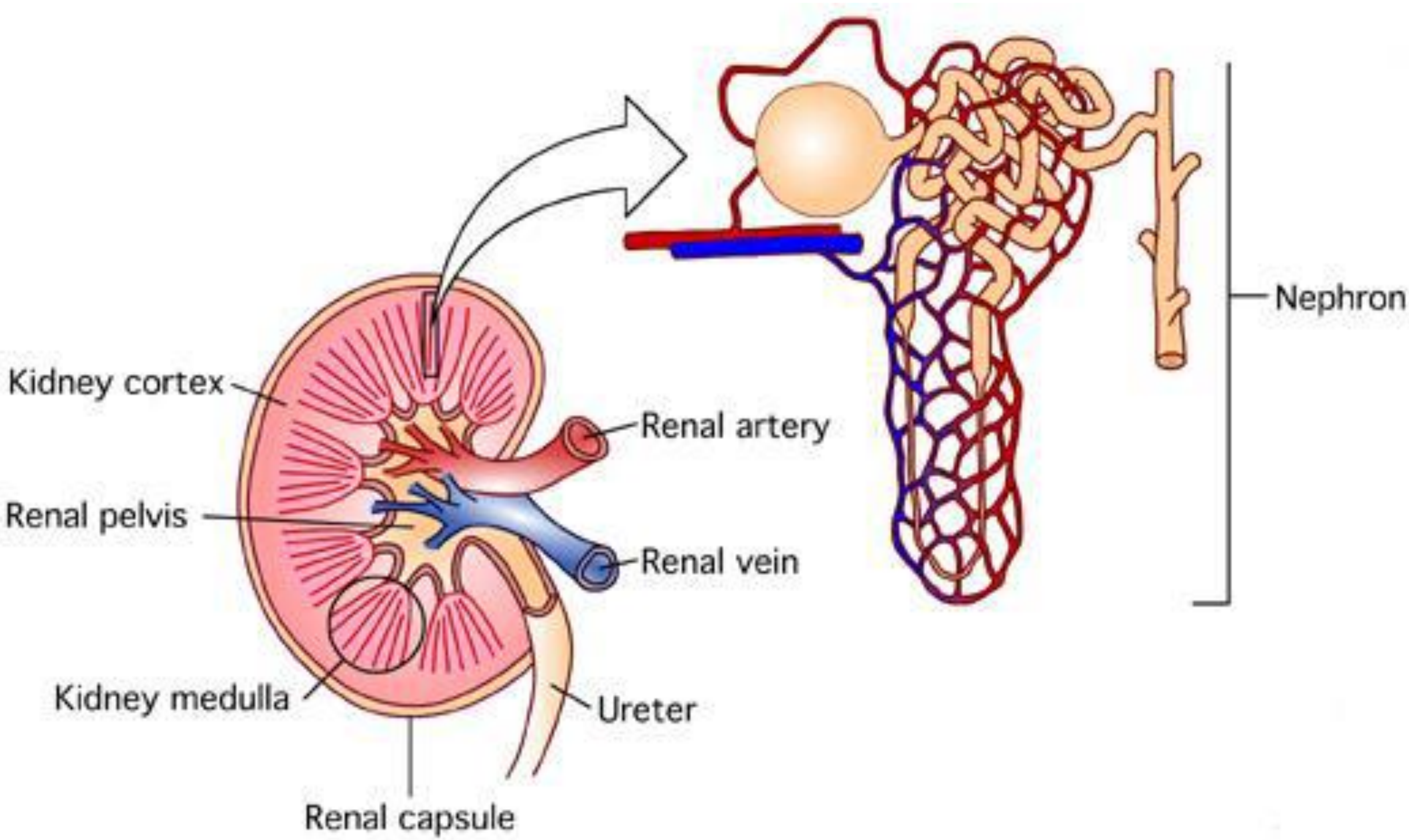


Urea

- The urea is released into the bloodstream where it is eventually filtered out into the urine by the nephrons in the kidneys.
- The urine is then carried from the Ureter to the bladder, and eventually expelled through the urethra.



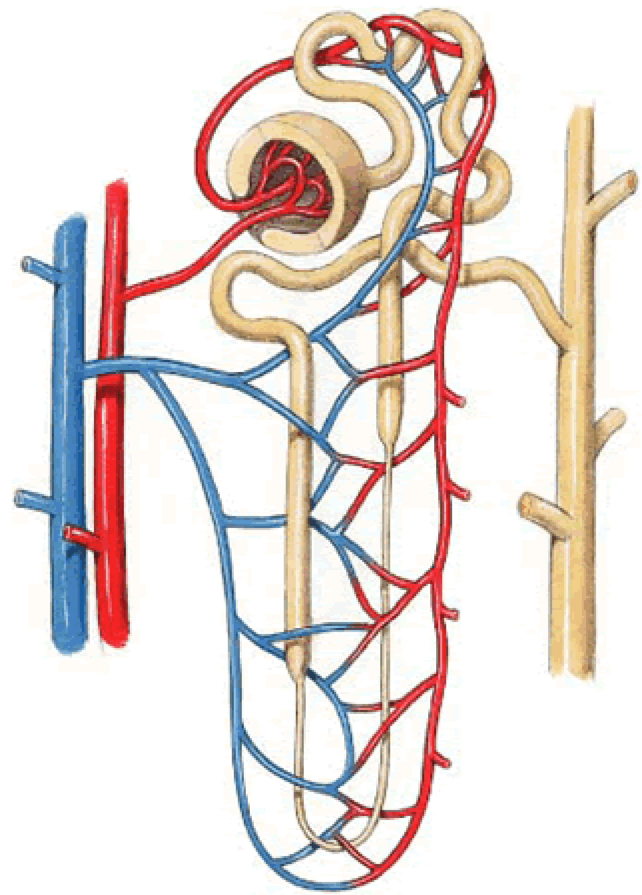
The Nephron

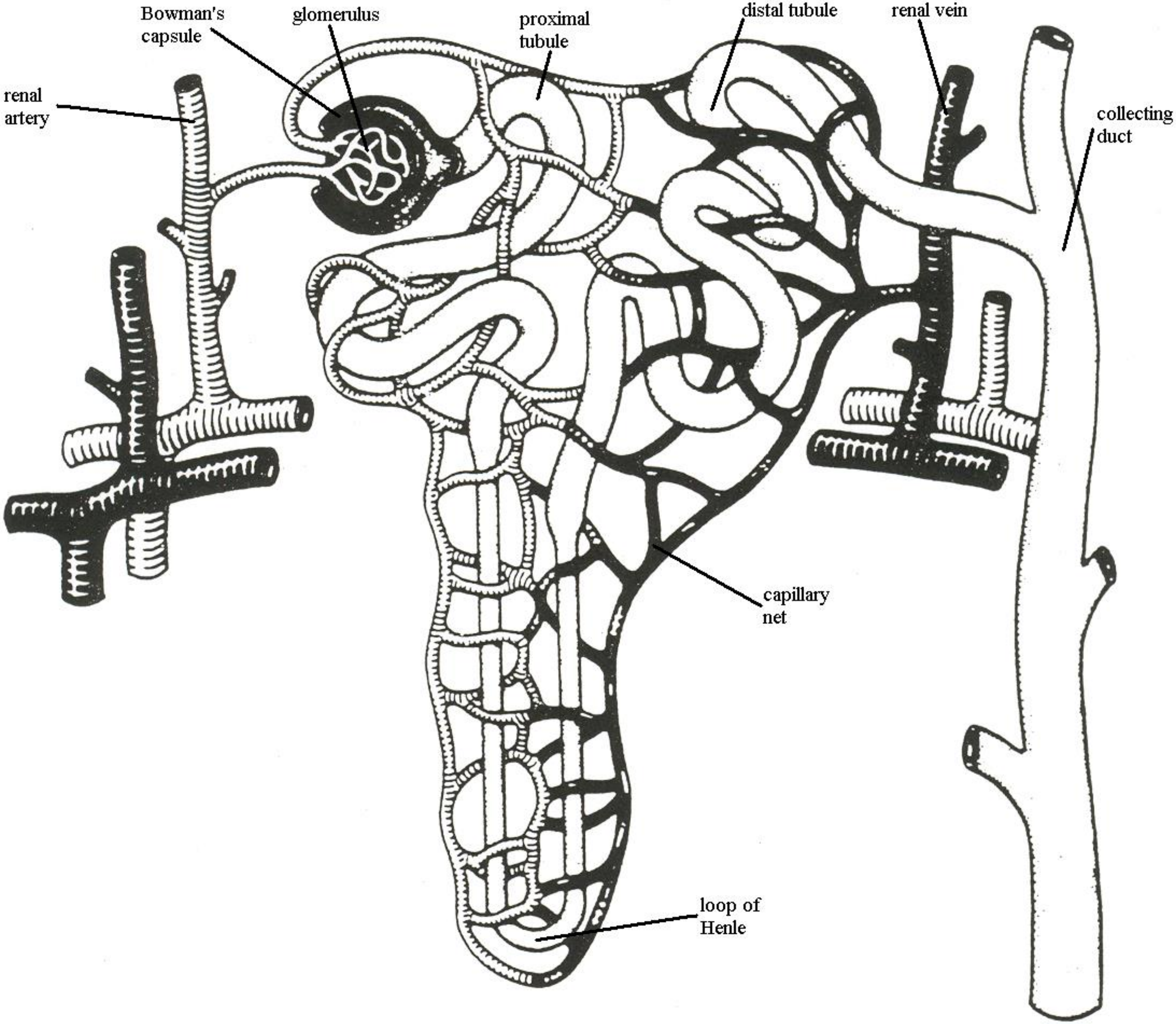


Kidney cortex
Renal artery
Renal pelvis
Renal vein
Kidney medulla
Ureter
Renal capsule
Nephron

The Nephron

- The nephron is the functional unit of the kidney.
- There are over 1 million in each kidney.
- Each nephron functions as a mini-filtration plant, each continuously purifying tiny volumes of blood.

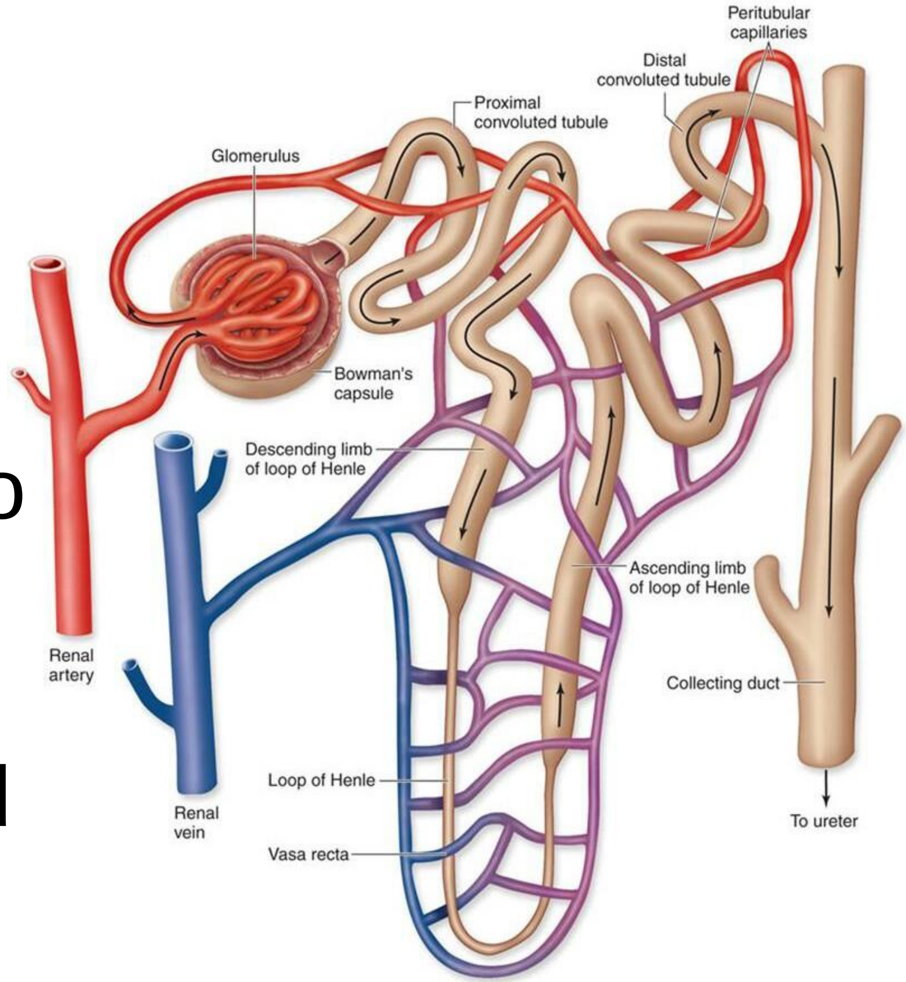




Bowman's capsule
glomerulus
proximal tubule
distal tubule
renal vein
renal artery
collecting duct
capillary net
loop of Henle

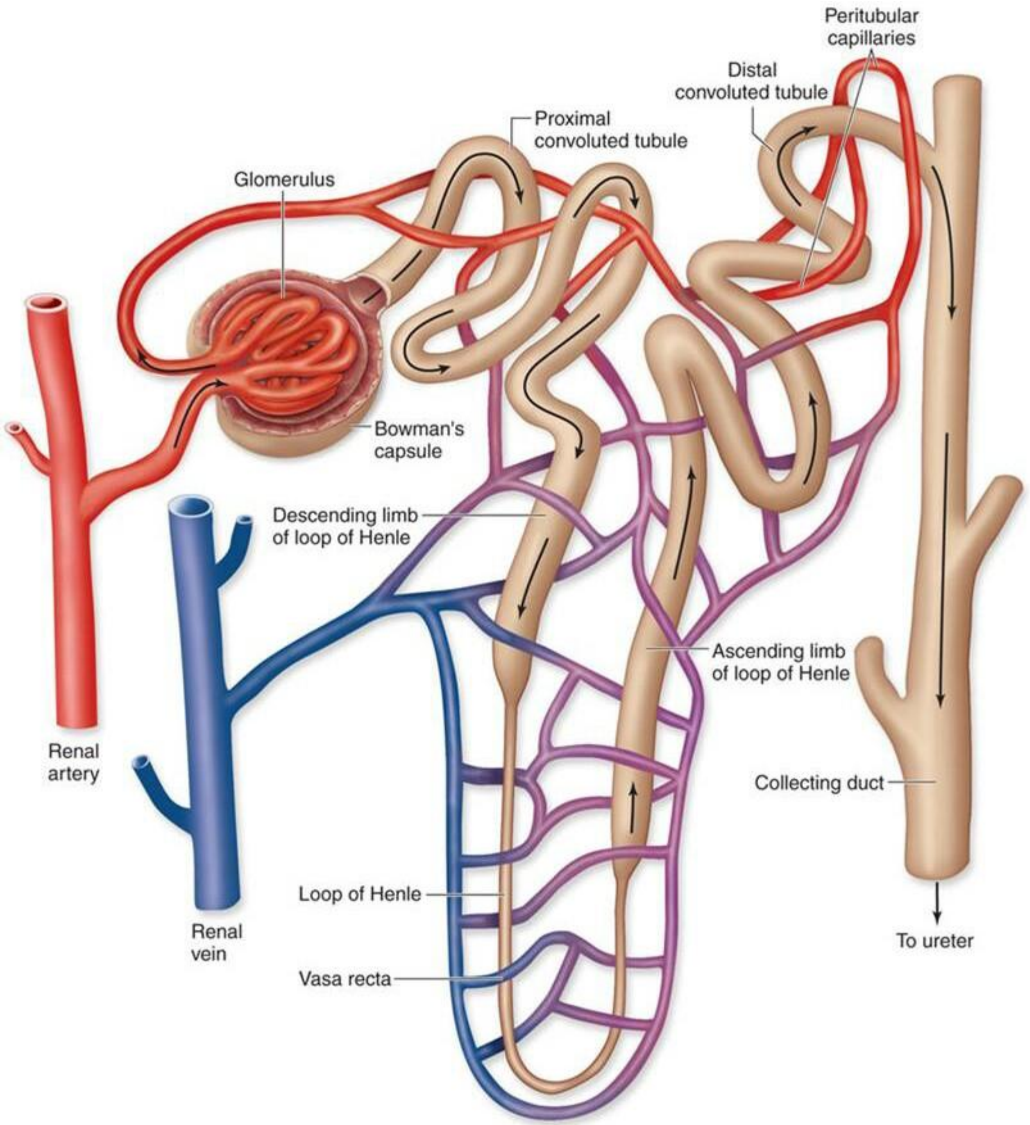
Stages of Nephron Function

1. **Filtration** - material moves from blood into the tubule. The filtrate include substances such as glucose, amino acids, water, and "wastes" such as urea, unneeded protons, and other ions.



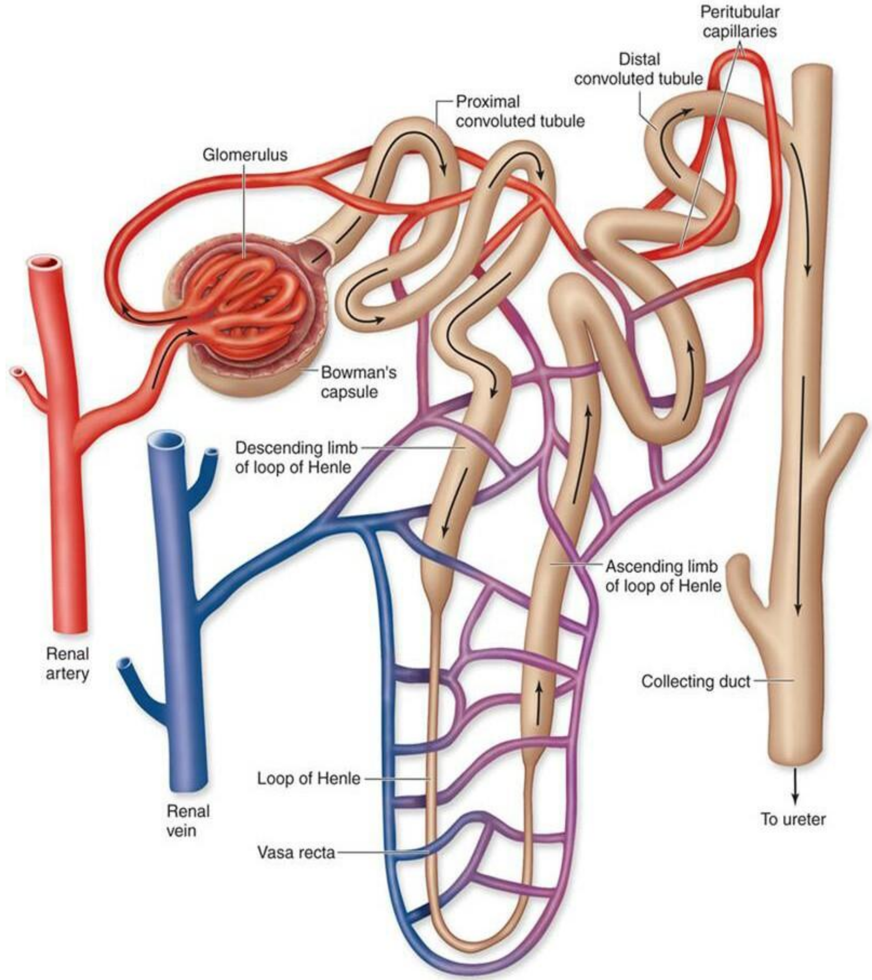
Stages of Nephron Function

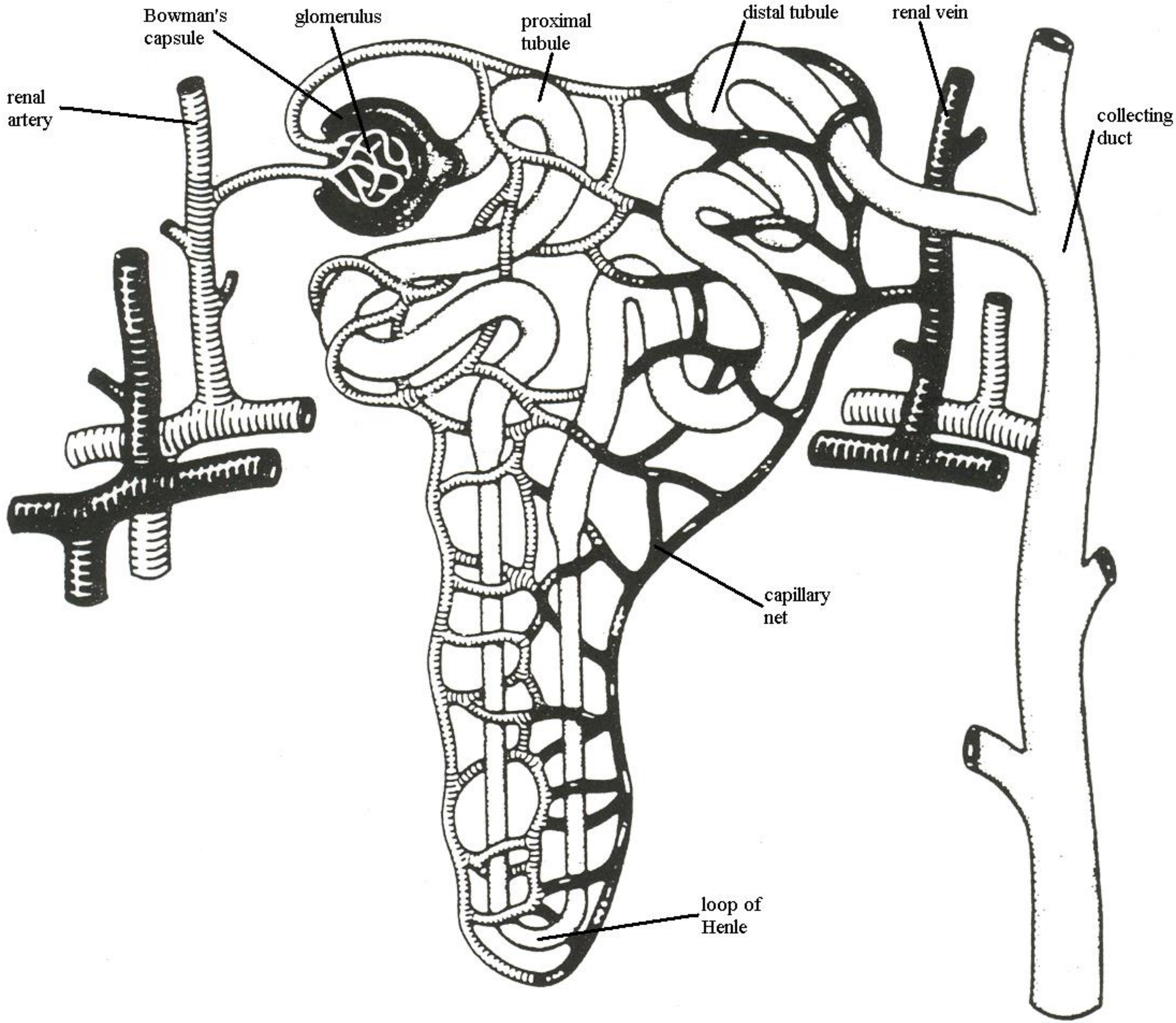
2. **Reabsorbtion** – material moves from tubule back into the blood.
   - the water and the rest of the substances are pulled back into the blood leaving the waste behind.



Stages of Nephron Function

3. **Secretion** – material again moves from the blood into the tubule. Energy (ATP) is used to actively transport any waste that still remained in the blood after filtration. This insures the blood is extremely clean when it exits the kidneys.

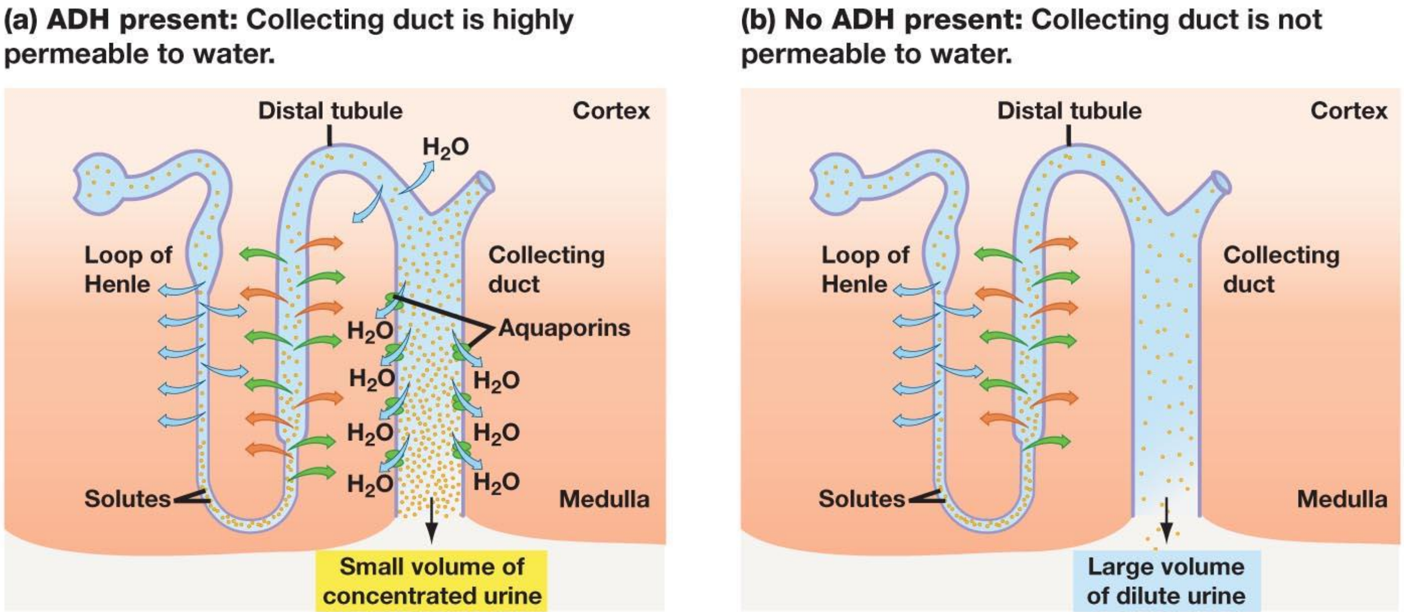




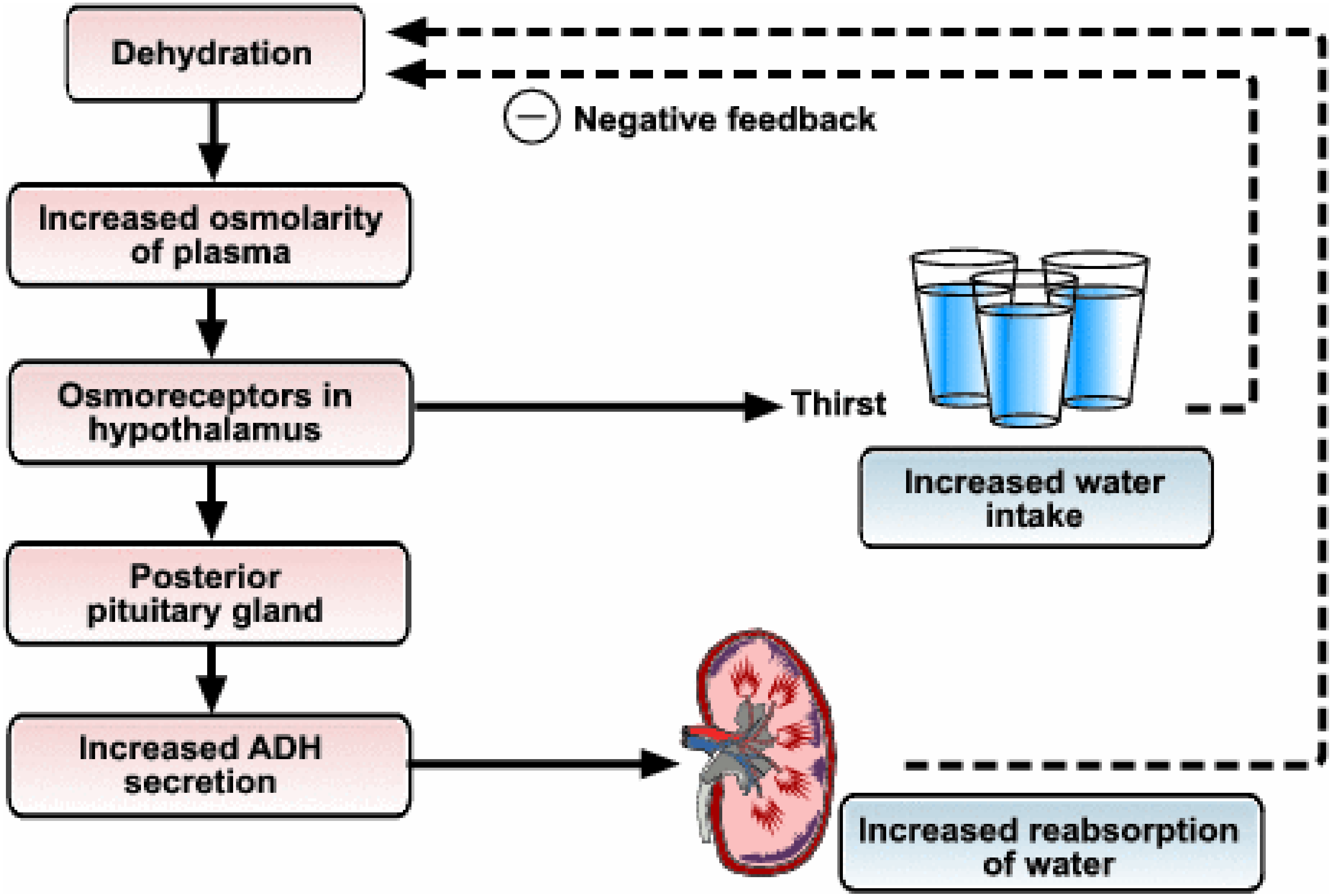
Bowman's capsule
glomerulus
proximal tubule
distal tubule
renal vein
renal artery
collecting duct
capillary net
loop of Henle

ADH Anti-diuretic Hormone

- A hormone which helps to regulate the body's hydration level by increasing the water reabsorption in the nephron.
- ADH increases the water permeability in the distal tubule resulting in increased water reabsorption into the blood.



The ADH Feedback Loop



ADH Anti-diuretic Hormone

- When do your levels of ADH go up?
  - → When you become dehydrated.
- What sort of things cause dehydration?
  - → Not drinking enough water
  - → Excess heat and sweating
  - → Vomiting
  - → Diarrhea

ADH Anti-diuretic Hormone

- What does increased levels of ADH do to your volume of urine?

  → You expel less urine.

- What does increased levels of ADH do to your concentration of urine?

  → Your urine becomes MORE concentrated.

- What does decreased levels of ADH do to your volume of urine?

  → You expel more urine.

- What does decreased levels of ADH do to your concentration of urine?

  → Your urine becomes less concentrated.