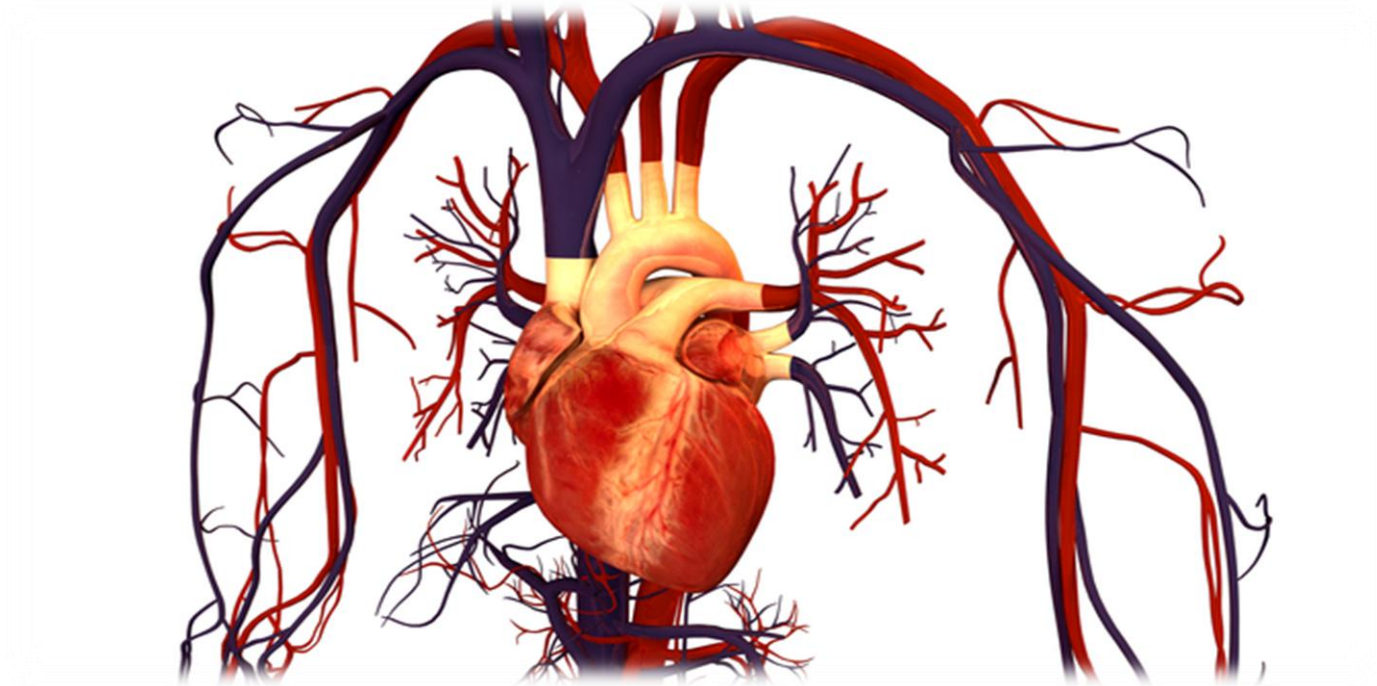
# CHAPTER:5
# CIRCULATION, IMMUNITY AND GAS EXCHANGE.

# INTERNAL TRANSPORT &CIRCULATORY SYSTEM

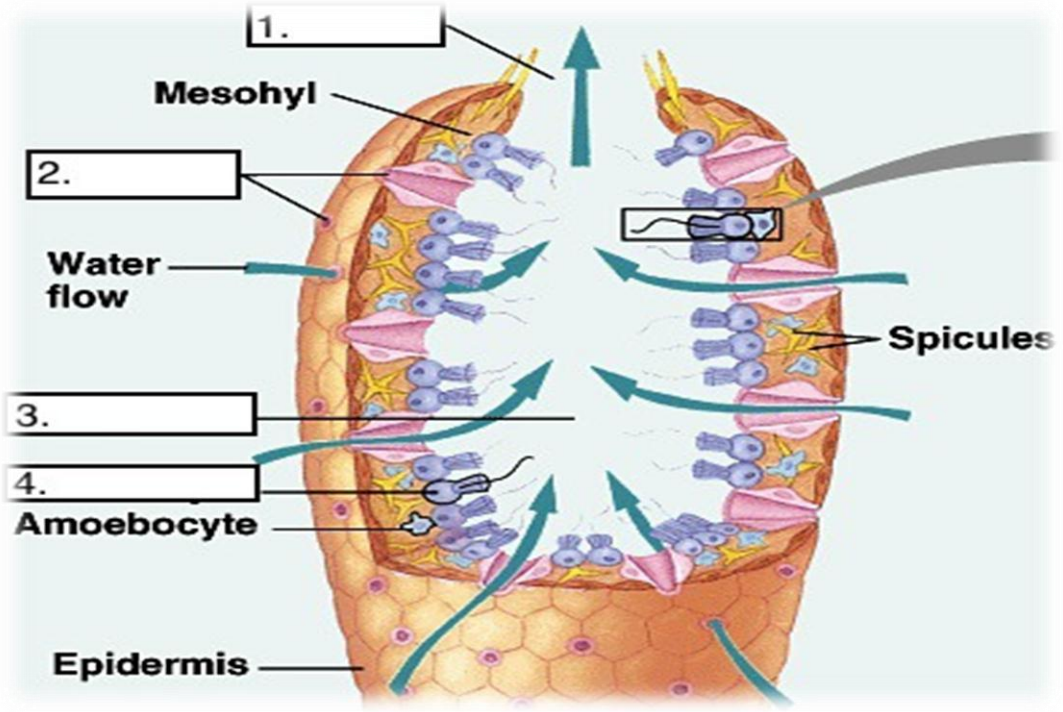
- Homeostatic balance in animal bodies.
- Circulation of nutrients, metabolic wastes & respiratory gases through animal bodies.
- Nature of system directly relates to size, complexity & lifestyle of animal.



# TRANSPORT SYSTEN IN INVERTEBRATES

## PROTOZOA;

- Small with high surface area to volume ratio.
- Simple diffusion for gas, nutrient and gas exchange.
- Plasma membrane and cytoplasm are media through which material diffuse into different parts of organism and outside environment.



## Specific transport system:

➢Sponge circulate water from external environment instead of internal fluid.

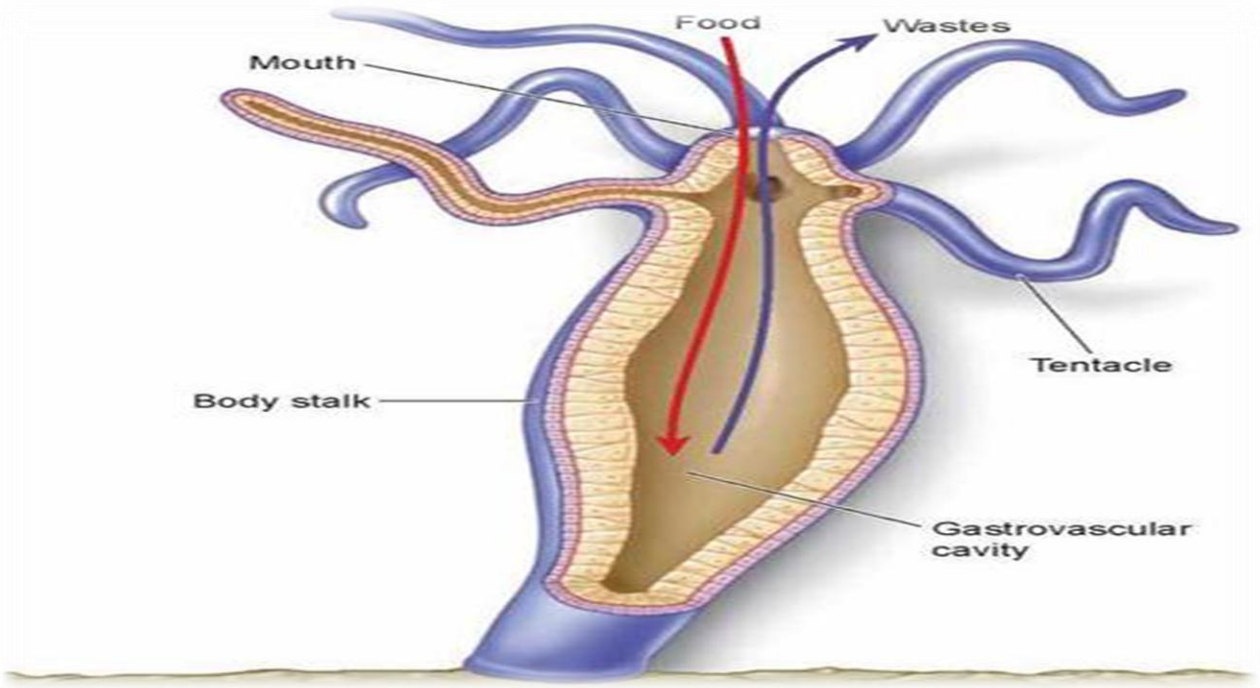
## GASTROVASCULAR CAVITY:

Cnidarians, hydra have fluid filled internal gastro vascular cavity.

This cavity supplies nutrients for all body cells lining the cavity.

Provide oxygen from water in cavity and is a reservoir of carbon dioxide and wastes.

Simple body movement move the fluid.



# FLATWORMS:

✓More complex than hydra.

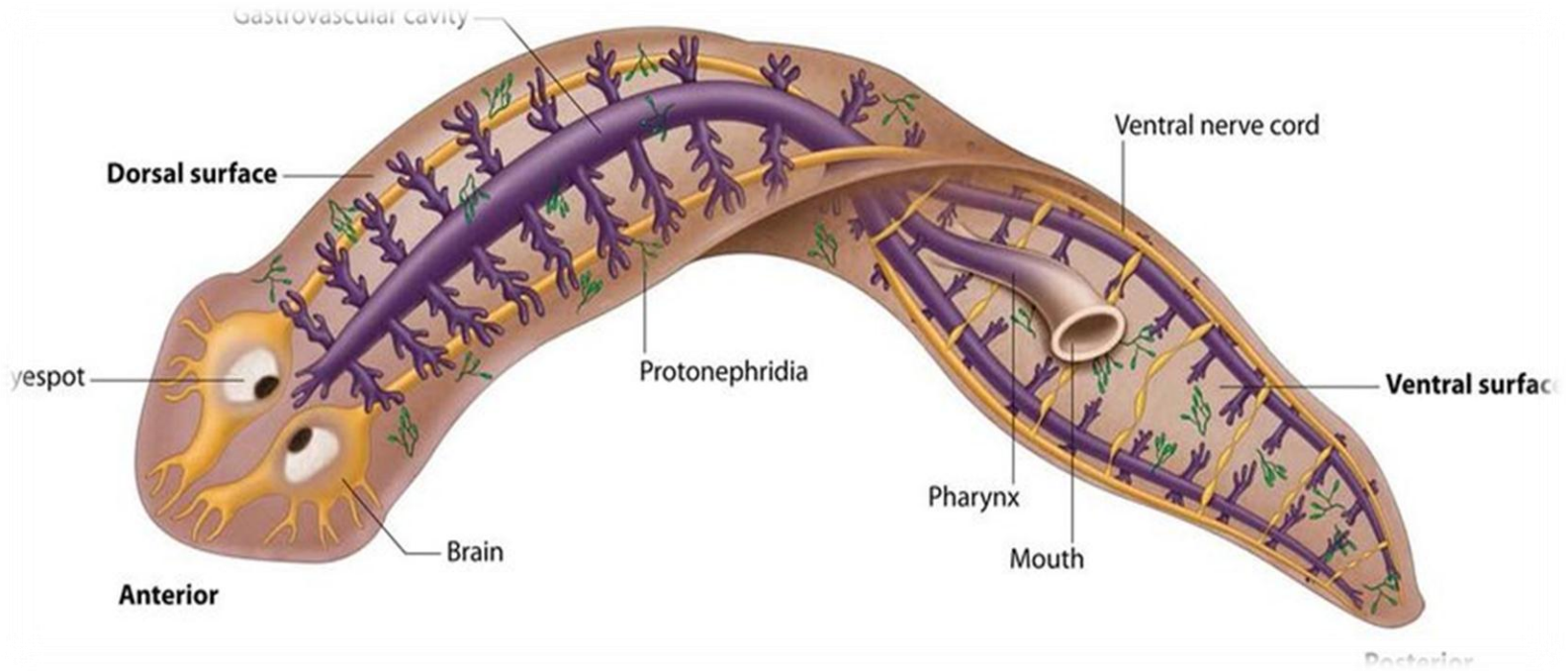
✓Branches penetrates to all parts of body.

✓Branched gastro vascular cavity run close to all body cells.

✓Diffusion distance for nutrients, gases & wastes is short.

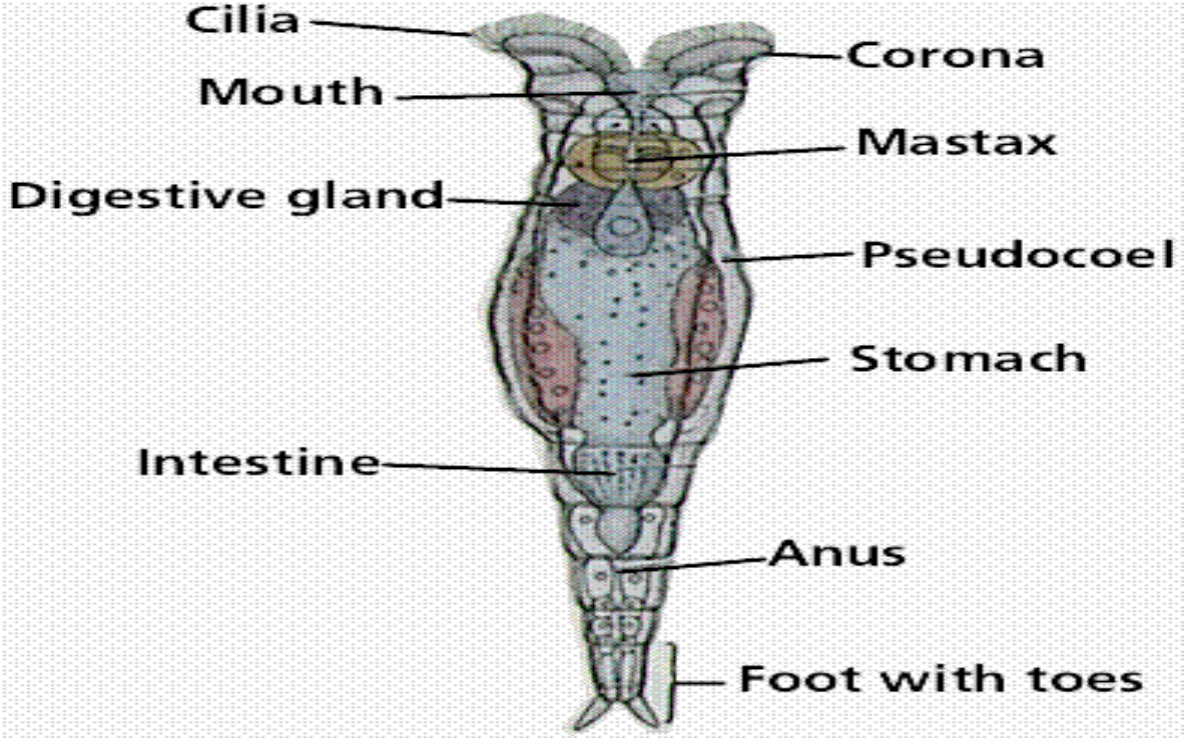
✓Body movement help distribute the materials.

✓Disadvantage of this system is that it limits these animal to relatively small sizes or to shapes that maintain small diffusion distances.



# PSEUDOCOELOMATE INVERTEBRATES:

- Rotifers, nematodes etc use the body fluid of their body cavity for transport.
- Small animals & movements of the body against the coelomic fluids, which are in direct contact with internal tissue and organs produce adequate transport.
- Few other invertebrate such as ectoprocts , echinoderms also depend on their body cavity as a coelomic transport chamber.

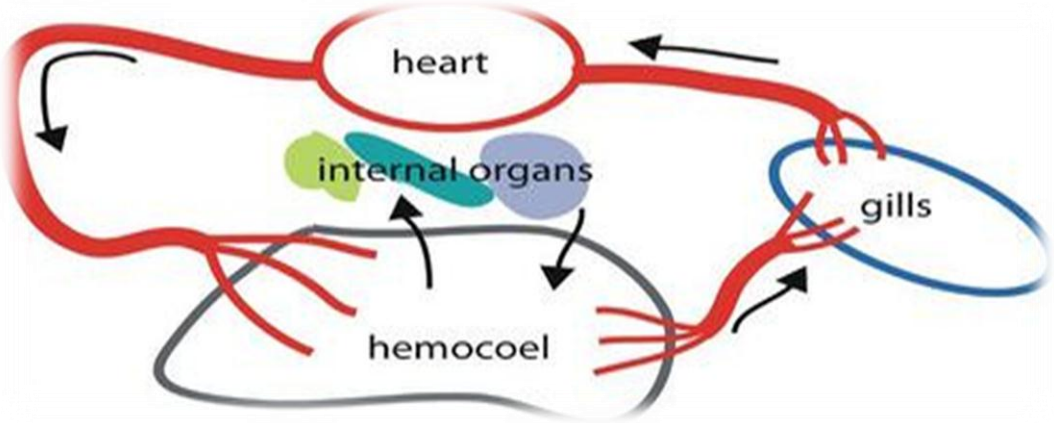


# MOLLUSCS:

❖ Circulatory & cardiovascular system.

❖Muscular pumping heart moves the fluid medium called either hemolymph or blood in specific direction.

❖Unidirectional blood vessels.




## TWO BASIC SYSTEM:

▪**Open** circulatory system, heart pumps haemolymph out into the body cavity or at least through parts of cavity , where haemolymph bathes the cell, tissue & organs.

▪Arthropods and molluscs have open circulatory system.

**Close** circulatory system, blood circulates in confines of tubular vessels.
•Earthworm have close circulatory system.

# CHARACTERSTICS OF INVERTEBRATES
# COELOMIC FLUID, HEMOLYPH & BLOODCELLS

## COELOMIC FLUID

•may identical to interstitial fluid
•May differ particularly with respect to cells & proteins.
•Transport gas, waste& nutrients
•Act as hydrostatic skeleton.

## HEMOLYMPH

•Circulating fluid of animal with open circulatory system.
•Arthropds , molluscs & ascidians have hemolymph.
•Heart pumps hemolymph at low pressure through tissue sinus.
•Many times hemolymph have **non circulatory** function.
•In insects hemolymph pressure assists in molting & inflation of wings.

**HEMOCYTES**

•Circulating cells

•Also called blood cells

•Some contain hemoglobin (respiratory pigment) are called erythrocytes or red blood cells.

•High number to facilitate oxygen transport.

•Cells without respiratory pigment have other functions, such as blood clotting.

**NUMBER &TYPE OF BLOOD CELLS**

•Amoebocytes

•Eleocytes

•Lampocytes

•Linocytes

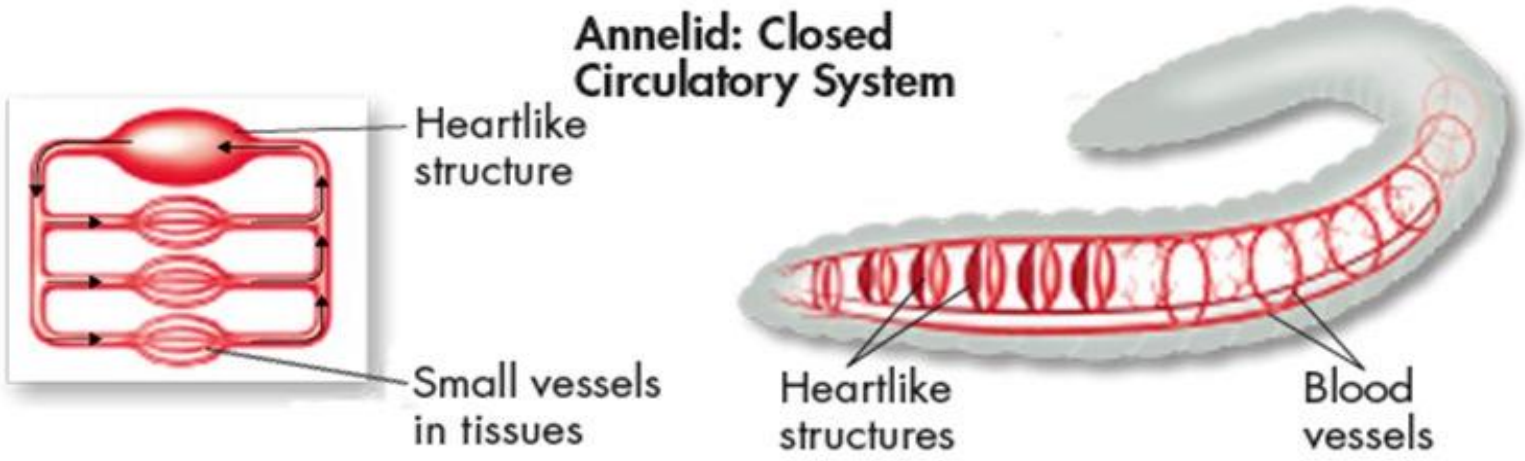
Function in phagocytosis, glycogen storage, defense purpose & excretion.

Mollusc contain amorbocytes & granulocytes

# Closed circulatory system

Blood circulates entirely within blood vessels that extend throughout the body

Many larger, more active invertebrates, including annelids and some mollusks, and all vertebrates have closed circulatory systems.

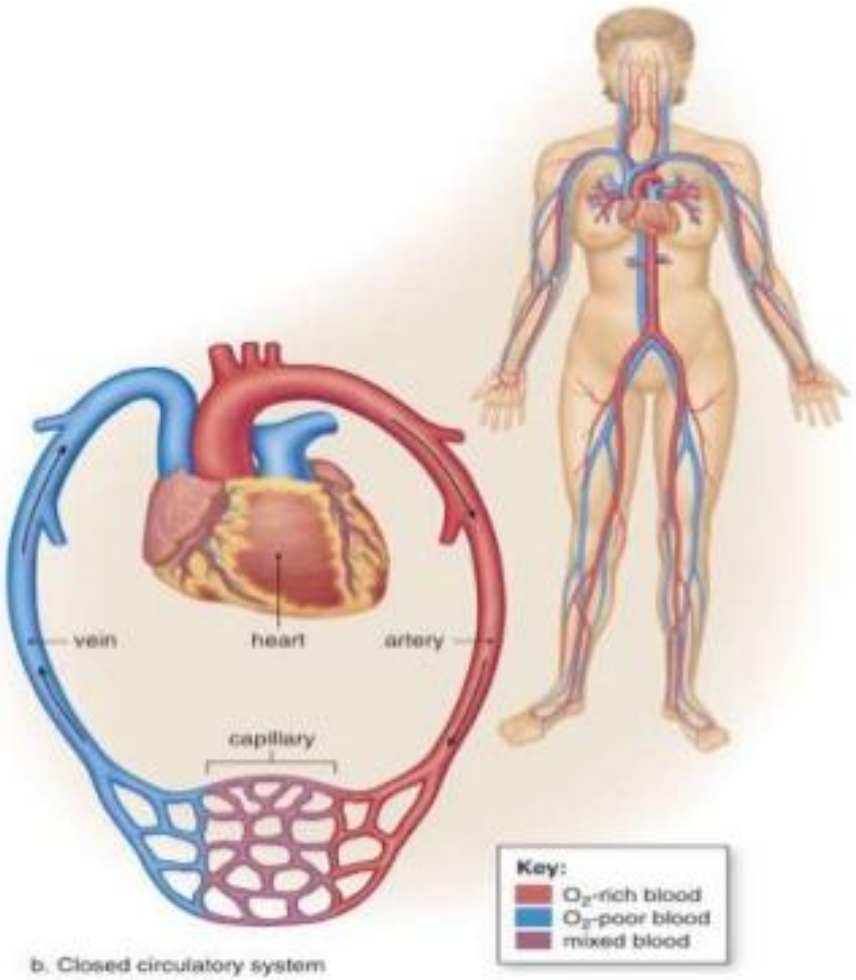


- There are three types of blood vessels.

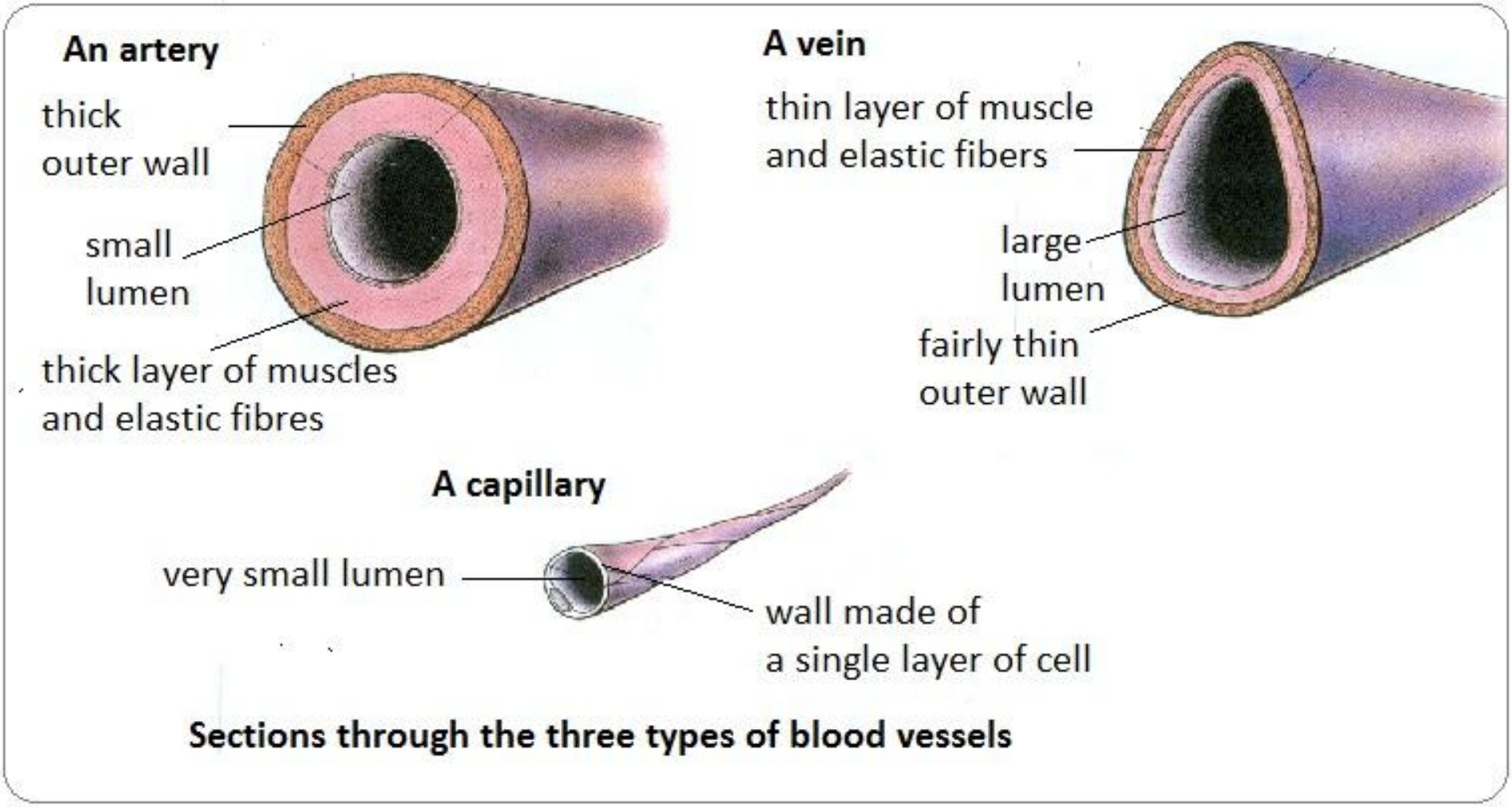
1. Arteries carry blood away from the heart.

2. Veins return blood to the heart.

3. Capillaries are a fine network of vessels between the arteries and capillaries where fluid, gas, and waste exchange take place.



b. Closed circulatory system




**Sections through the three types of blood vessels**

# Function of vertebrate blood

- Transports oxygen , carbon dioxide, nutrients
- Defends against microbes
- Prevents blood loss (clotting)
- Regulates body temperature
- Regulates pH

# Plasma

- Straw-colored, liquid part of blood
- 90% water  (provides solvent for transporting and dissolving nutrients/wastes)
- 7% protein (albumin, fibrinogen, globulins)
- 3 % (electrolytes, amino acids, glucose, various enzymes, hormones, metabolic wastes , organic and inorganic molecules )

- **Albumin- major portion of plasma protein (60%)**

➢ Plays important role with respect to water movement.

- **Fibrinogen**

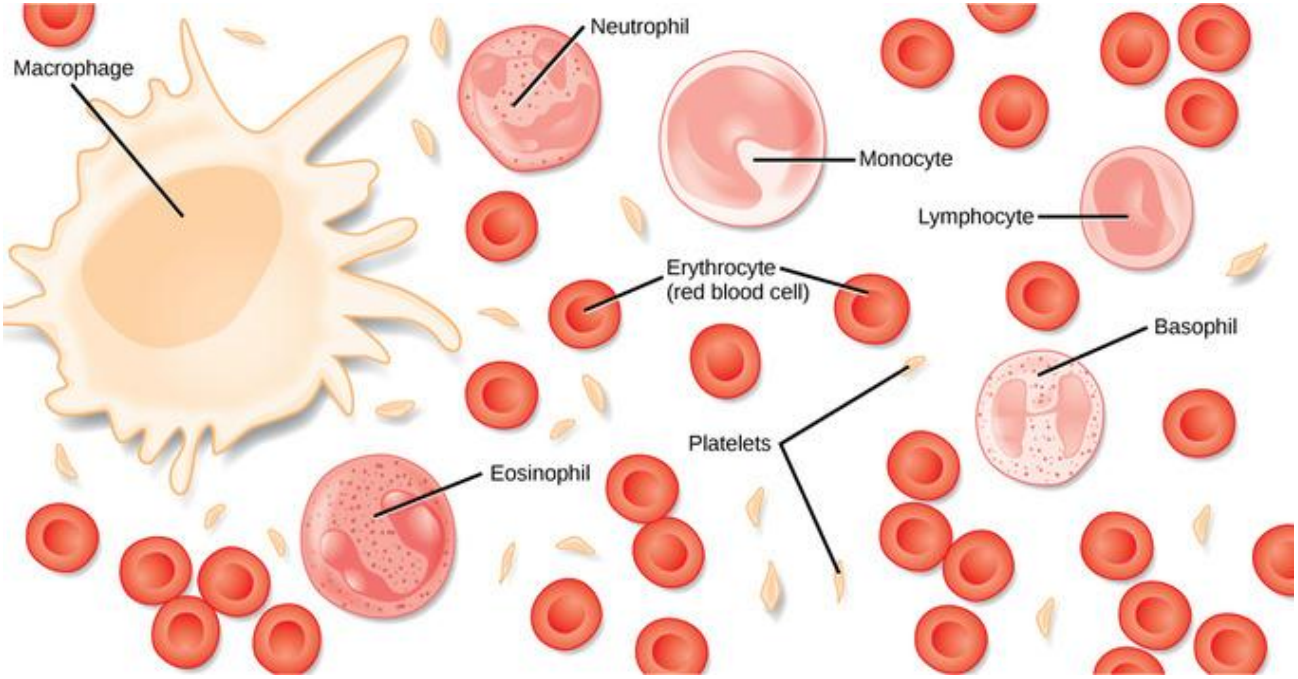
➢ Necessary for blood coagulation

- **Globulin**

➢ Include immunoglobulins and various metal binding proteins

# Cellular elements( formed elements)

- RBCs (erythrocytes)
- WBCs (leucocytes)
- Platelets (thrombocytes)

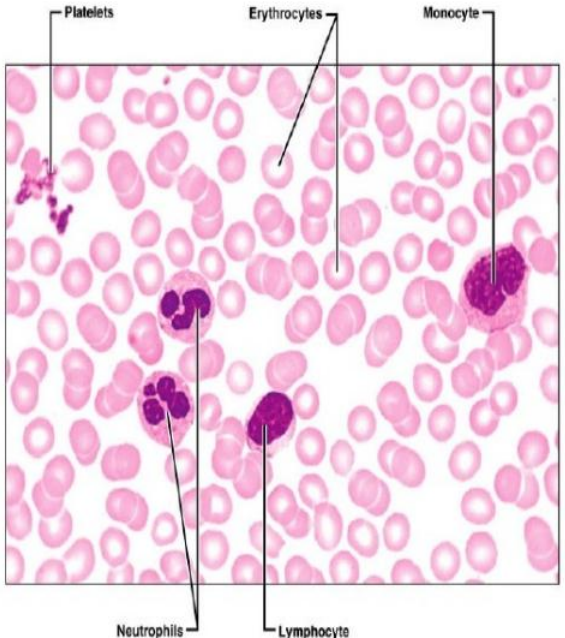


# Functions of RBCs

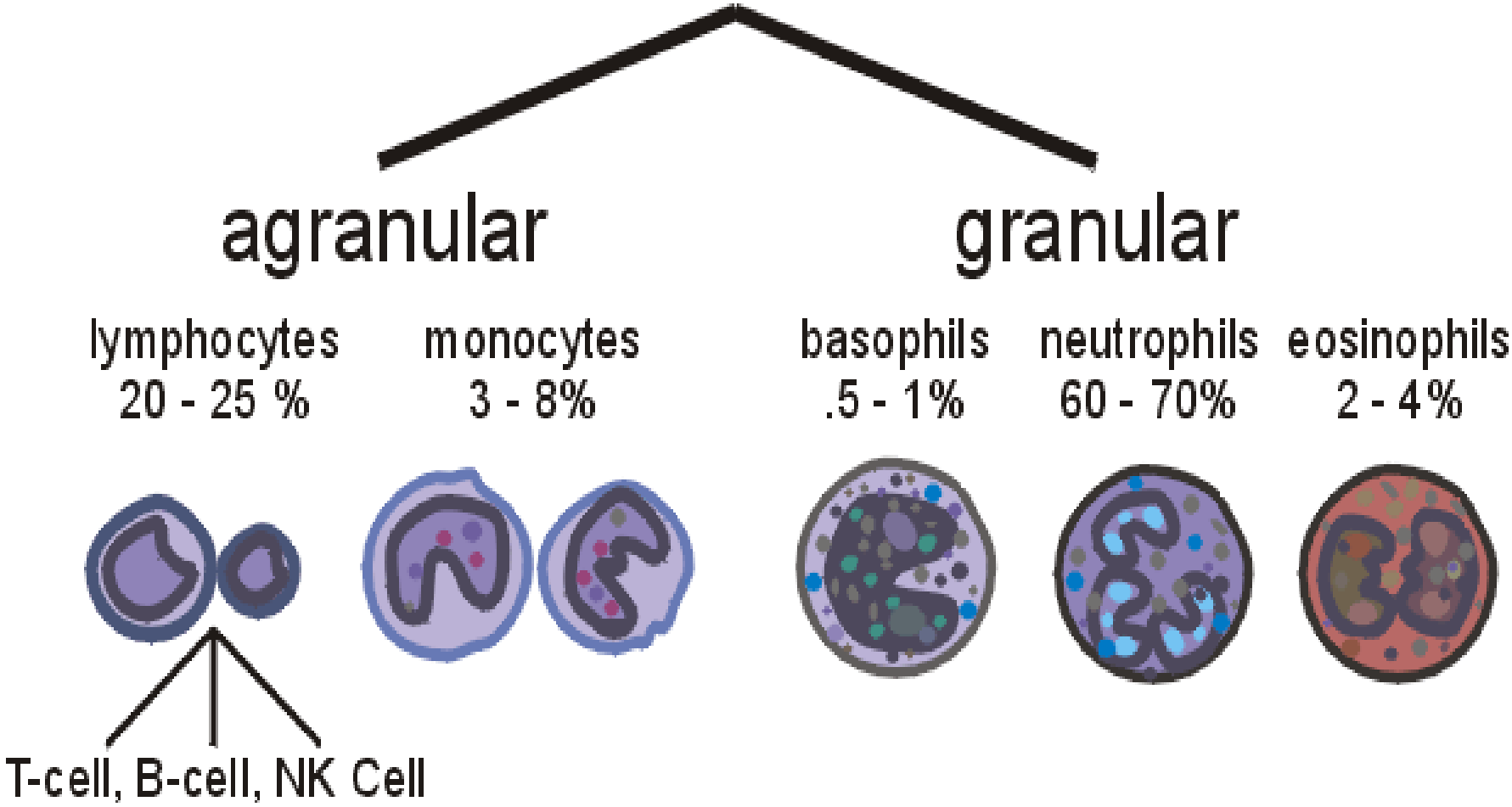
- Pick up oxygen from environment, giving bright red color to the blood, bind it to hemoglobin forming **oxyhemoglobin** and transport it to tissues.
- Hemoglobin also carry carbon dioxide (**carbaminohemoglobin**) from the tissues to the lungs for removal.

# WBCs (leucocytes)

- Scavengers that destroy microorganisms, remove foreign chemicals, remove debris that results from dead/injured cells.
- Derived from stem cells in bone marrow- **Hematopoiesis.**



# Classification



# Lymphocytes

- Two distinct type of lymphocytes are B cells and T cells

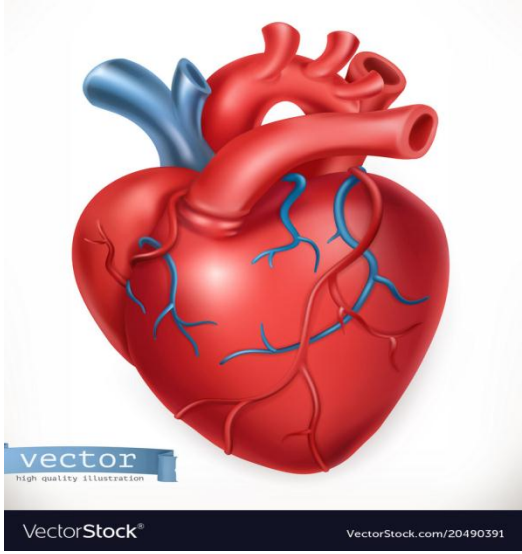
## B-lymphocyte (B-cells)

- 1. They arise from bone marrow Bursa of Fabricus (in fowl), gut-associated lymphoid tissue (Peyer's patches).
- 2. B-cells form humoral or antibody-mediated immune system (AMIS).
- 3. They defend against viruses and bacteria that enter the blood and lymph.
- 4. They are formed by the division plasma cells.
- 5. Plasma cells do not move to the site of infection.
- 6. Plasma cells do not react against transplants and cancer cells.
- 7. Plasma cells have no inhibitory effect on immune system.

## T-lymphocyte (T-cells)

- 1. They arise from Thymus.
- 2. T-cells form cell-mediated immune system (CSM).
- 3.They defend against pathogens including protists and fungi that enter the cells.
- 4. They are formed by the division of lymphoblasts of three types: killer, helper and suppressor cells.
- 5. Lymphoblasts move to the site of infection.
- 6. Killer cells react against transplants and cancer cells.
- 7. Suppressor cells inhibit immune system.

# BASIC FACTS ABOUT HUMAN HEART



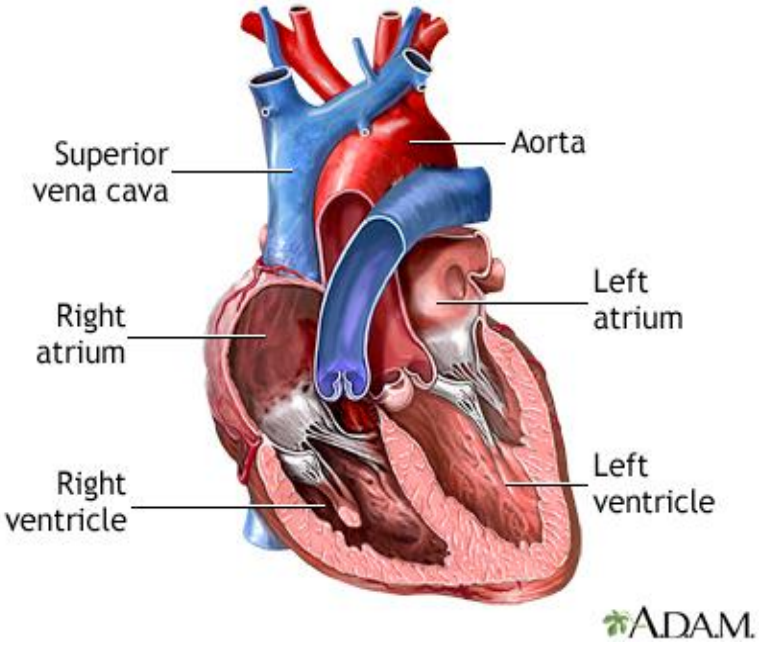

- An organ that pumps blood throughout the body via the circulatory system is **Heart.**
- Supply oxygen, nutrients to the tissues
- remove carbon dioxide and other wastes.

An adult heart beats about **60 to 80** times per minute.

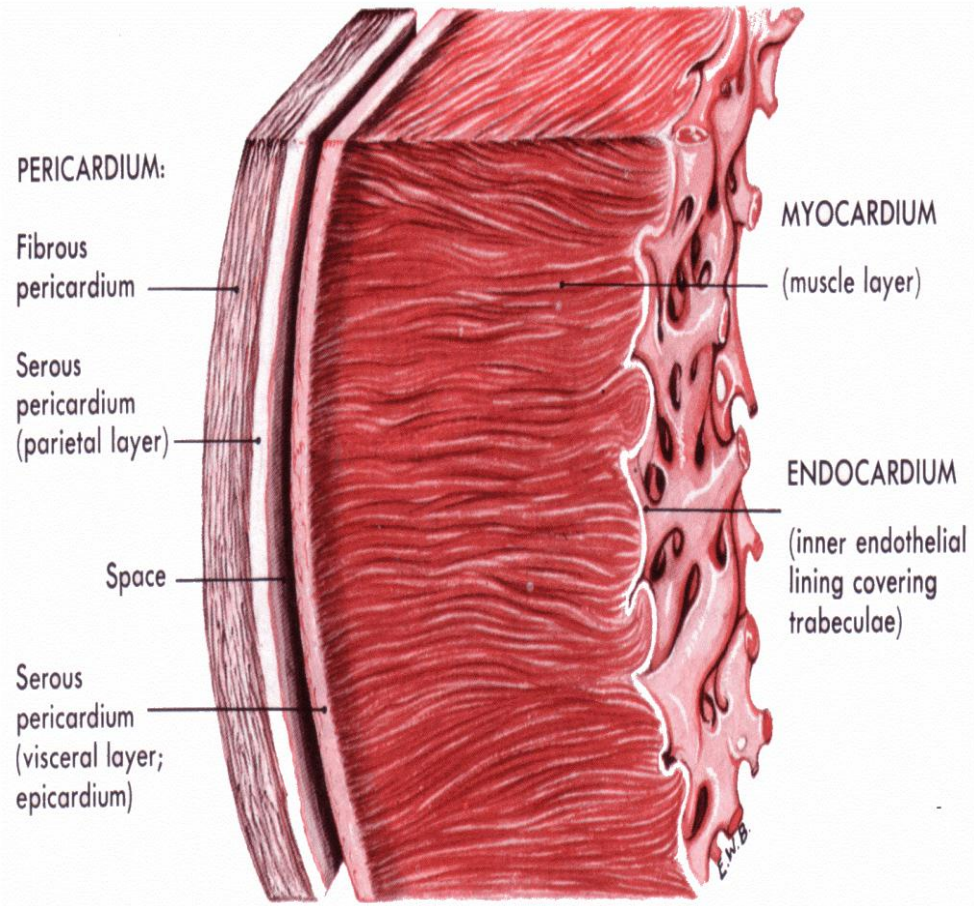
- The heart is located in the center of the chest, usually pointing slightly left.

# ANATOMY OF HUMAN HEART

- The human heart has **four chambers**: two upper chambers (the **atria**) and two lower ones (the **ventricles**)
- wall of muscle called the **septum** separates the two sides of the heart.



- A double-walled sac called the **pericardium** encases the heart.
- The outermost wall layer is **epicardium**, the middle layer is **myocardium**, the inner layer is **endocardium**, the lining that contacts the blood.

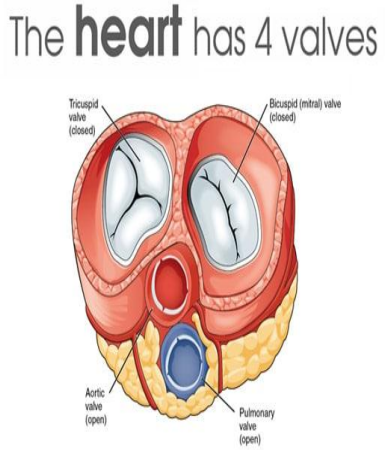


Section of the heart wall showing the components of the outer pericardium (heart sac), muscle layer (myocardium), and inner lining (endocardium).

https://d2jmvrsizmvf4x.cloudfront.net/

# VALVES OF HEART

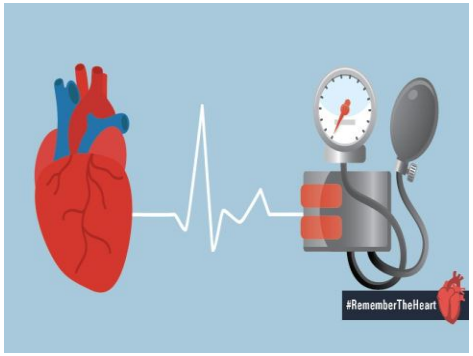
- The heart has four valves that help ensure that blood only flows in one direction:
- **Aortic valve**: between the left ventricle and the aorta.
- **Mitral valve**: between the left atrium and the left ventricle.
- **Pulmonary valve**: between the right ventricle and the pulmonary artery.
- **Tricuspid valve**: between the right atrium and right ventricle.



# FUNCTIONS

- The heart circulates blood through two pathways: the pulmonary circuit and the systemic circuit.
- In the pulmonary circuit, deoxygenated blood leaves the right ventricle, travels to the lungs, then returns as oxygenated blood to the left atrium.
- In the systemic circuit, oxygenated blood leaves the body, supplies the body's tissues with oxygen, deoxygenated blood returns via veins to the venae cavae.

# BLOOD PRESSURE

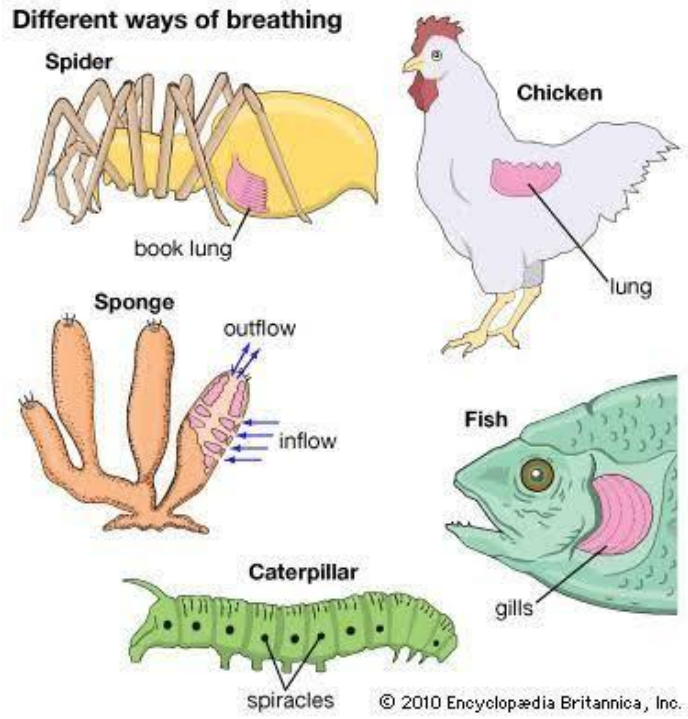



- Ventricular contractions generate the fluid pressure called blood pressure.
- The maximum pressure achieved during ventricular contractions is **systolic pressure**.
- The lowest pressure that remains in the arteries before the next ventricular contractions is **Diastolic pressure.**
- Normal human systolic pressure is **120mmHg** and diastolic pressure is **80mmHg** (expressed as 120/80).

# RESPIRATION IN VERTEBRATES

Rely on the following surfaces for gas exchange.

- Cutaneous body surface.
- External filamentous gills.
- Internal lamellar gills.



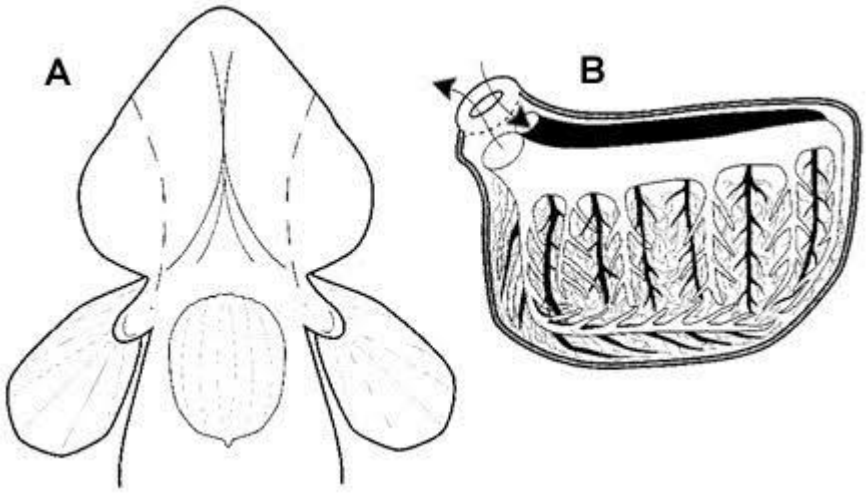
# BIMODAL BREATHING

Ability of organisms to exchange respiratory gases simultaneously both with air and water.

- Uses gill for water breathing.
- Uses lungs for air breathing.

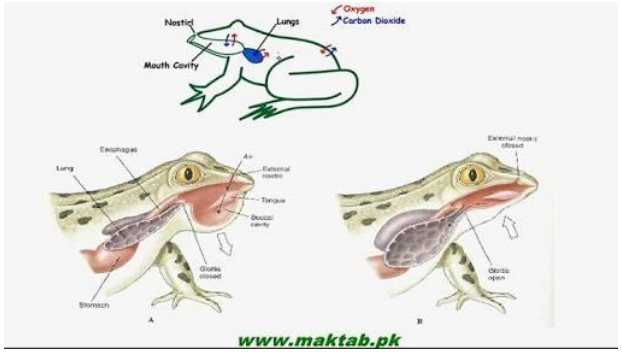
EXAMPLES:

- Crabs
- Barnacles
- Mollusk
- fishes



# CUTANEOUS RESPIRATION

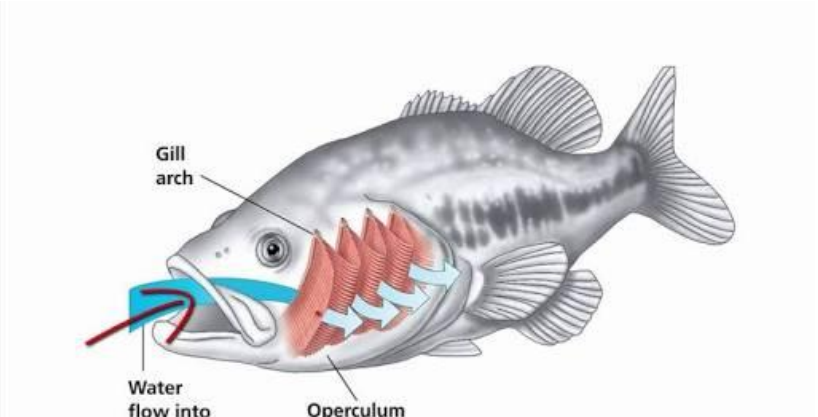
- Integumentary exchange to supplement gas exchange.
- Highly developed in frogs, toads and salamanders.
- Occurs in turtles, lungs, snakes, fishes and mammals.
- In frogs, a network of capillaries lies beneath the epidermis.
- This vascular arrangement facilitates gas exchange.
- Some amphibians obtain about 25% or more oxygen by this exchange.



# GILLS

Respiratory organs that have either:

- Thin, moist, vascularized layer of epidermis to permit gas exchange across thin gills.
- Or, very thin layer of epidermis over highly vascularized dermis.
- Larval forms of few fishes and amphibians have external gills.



# COUNTERCURRENT EXCHANGE MECHANISM

- Efficient gas exchange.
- Maintain a concentration gradient b/w blood and water.
- Concentration of oxygen is lower in blood
- It diffuses in blood.
- Concentration of carbon dioxide is lower in water.
- It diffuses in water.

# LUNGS

- Internal sac-shaped respiratory organ.
- Comprises one or more internal blind pouches.
- Air is either drawn or forced.
- Large number of small units increases surface area.
- Spongy in nature.
- Mammals remove approximately 25% of oxygen.
- Birds remove approximately 90%.

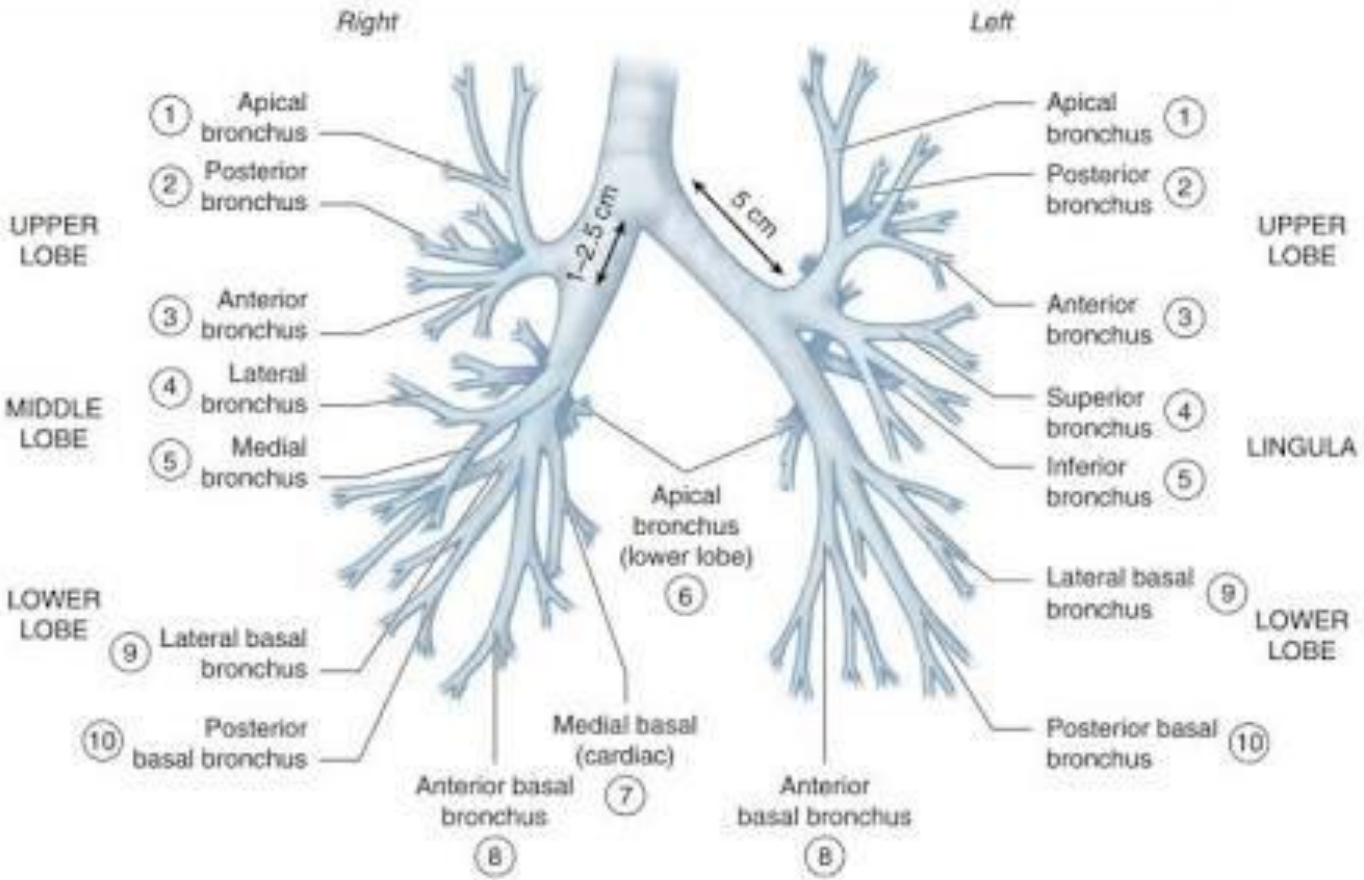



**FIGURE 25–5** Anatomy of the tracheobronchial tree. Note bronchopulmonary segments (1–10) as numbered. (Adapted and reproduced, with permission, from Gothard JWW, Branthwaite MA: *Anesthesia for Thoracic Surgery*. Blackwell, 1982.)

# LUNG VENTILATION

Based on following physiological principles:

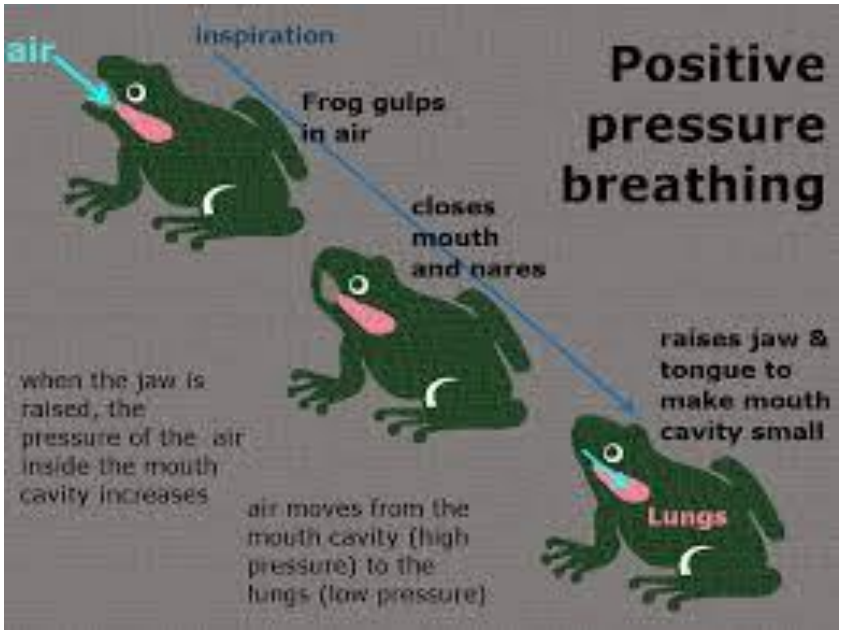
- Air moves into and out of lungs called ventilation.
- Oxygen and carbon dioxide diffuse from pulmonary capillaries.
- Oxygen and carbon dioxide diffuse in response to concentration gradient.
- Gases diffuse between the interstitial fluid.

Two different mechanism:

- Positive pressure pumping mechanism.
- Negative pressure pumping mechanism.

# POSITIVE PRESSURE PUMPING MECHANISM

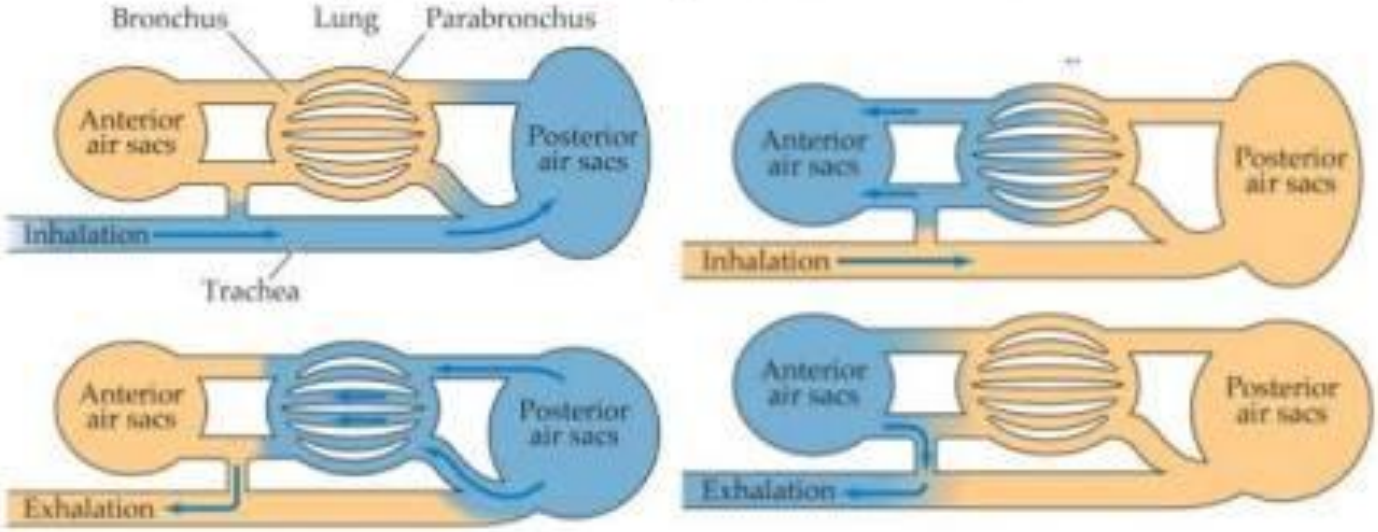
- Occurs in amphibians and some reptiles.
- Muscles of the mouth and pharynx create a positive pressure.
- Force air into the lungs.



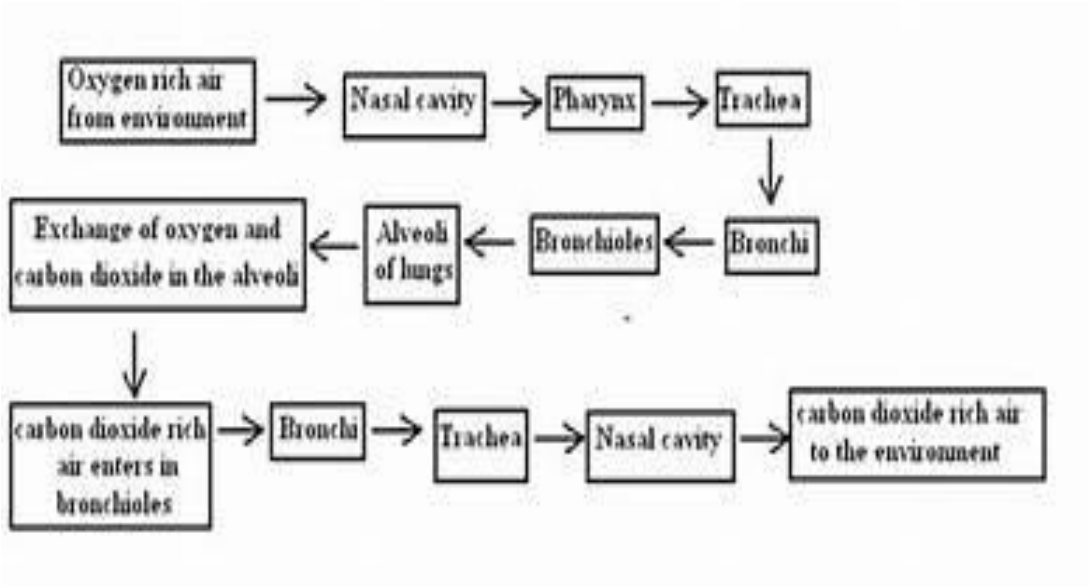
# BIRD LUNGS: VENTILATION

***Passage of air through lungs:***

in trachea → rear air sacs → rear bronchi → parabronchi in lungs → front bronchi → front air sacs → out trachea



# AIR-CONDUCTING PORTION



# PULMONARY VENTILATION (BREATHING)

i. Inhalation

ii. Exhalation

- Rhythmic increase & decrease in thoracic cavity volume
- Reversals in the pressure gradients between the lungs and the atmosphere

# i. INHALATION

- Process or act of breathing in
  - Contraction of diaphragm and intercostal muscles
  - Flattening of diaphragm
  - Enlargement of thoracic cavity
  - Reduction of pressure in thoracic cavity
  - Inflation of lungs

# ii. EXHALATION

- The act of expelling air from the lungs
  - Relaxation of diaphragm and intercostal muscles
  - Contraction of abdominal muscles
  - Contraction of elastic muscles
  - Compression of air in the alveoli
  - Increase in alveolar pressure
  - Constriction of lungs

# GAS TRANSPORT

- More active animals have an increased demand for oxygen
- Fluid-borne respiratory pigments
  - Have metallic copper or iron
  - May be in solution within the blood
  - May be in specific blood cells

# IMMUNITY

"**Immunity** refers to the general ability of an animal to resist harmful attack."

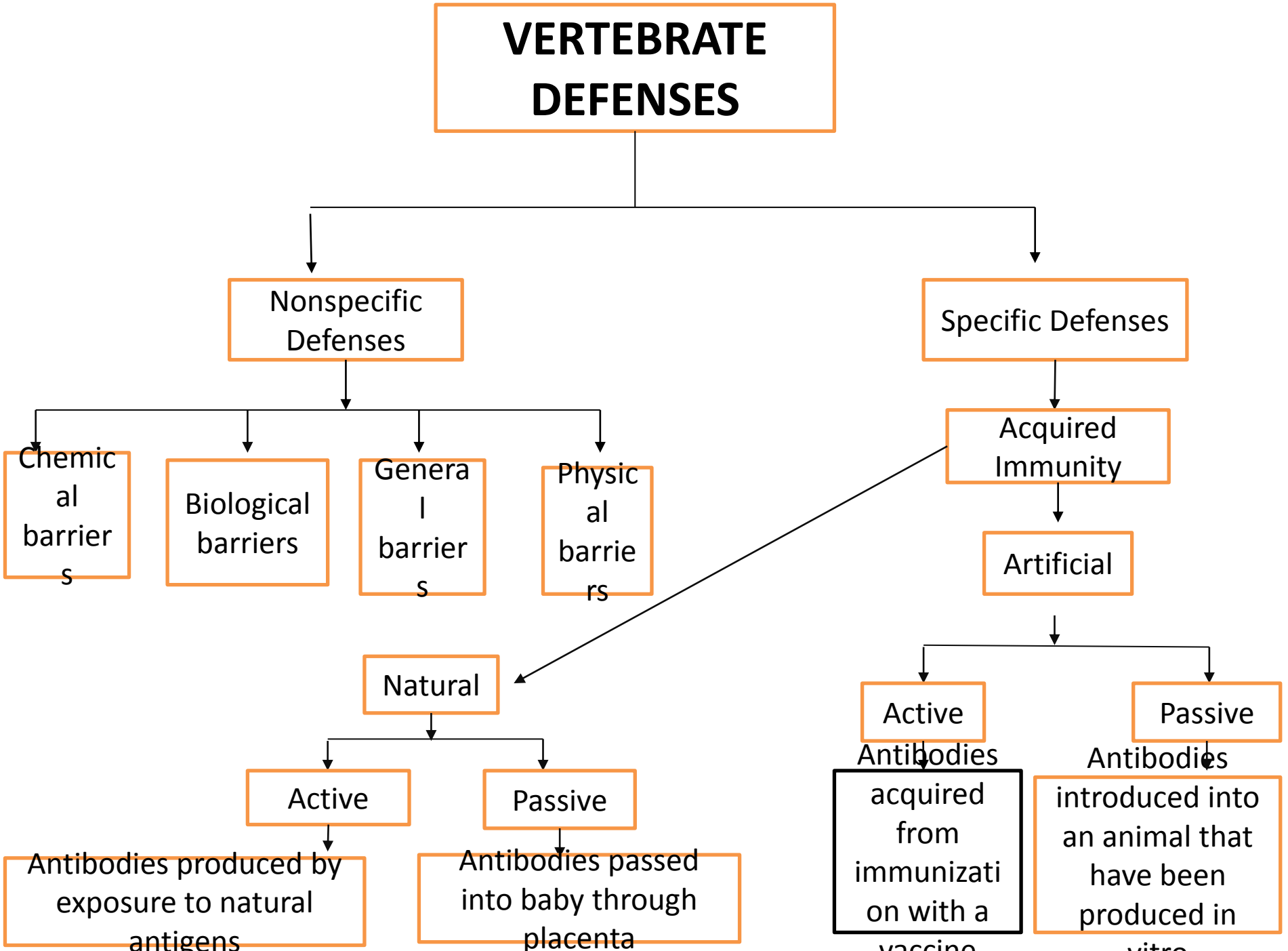
"**Immunology** is the study of immune system."

## INVERTEBRATES

- Do not have immune system
- Have innate, internal defense mechanism
- For example: granulocytes of Molluscs

## VERTEBRATES

- Have immune system
- It is a large and specific complex of defensive elements, distributed throughout the body, that help the animal against attack.


VERTEBRATE DEFENSES
Nonspecific Defenses
Specific Defenses
Chemical barriers
Biological barriers
General barriers
Physical barriers
Acquired Immunity
Artificial
Natural
Active
Passive
Active
Passive
Antibodies produced by exposure to natural antigens
Antibodies passed into baby through placenta
Antibodies acquired from immunization with a
Antibodies introduced into an animal that have been produced in

# ANTIGENS

**Definition**

**“**Foreign (non-self) substances (markers) to which lymphocytes respond are called antigens.**”**

- Most antigens are large proteins or other complex molecules with a molecular weight generally greater than 10,000.

# ANTIBODIES

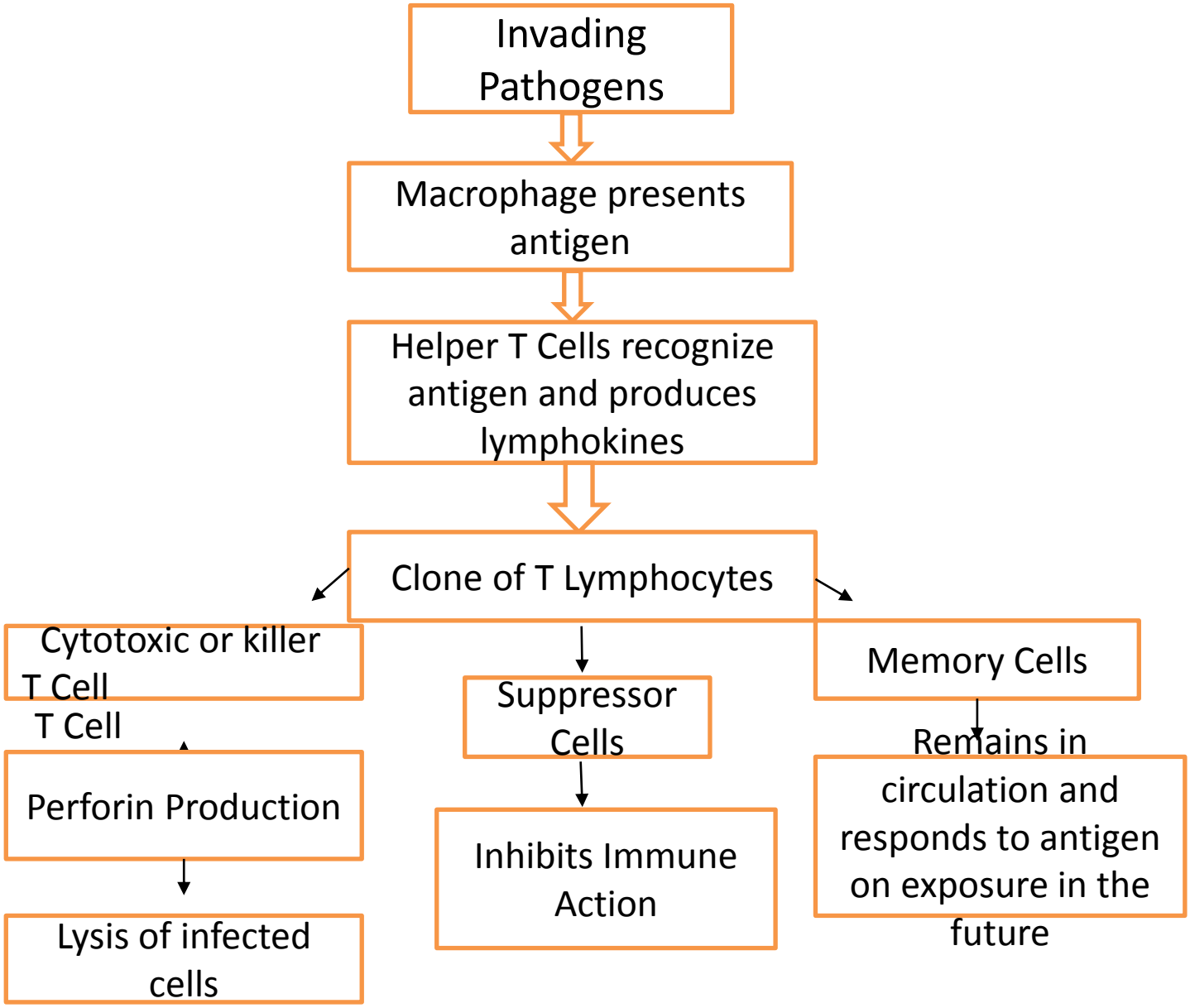
**Definition**

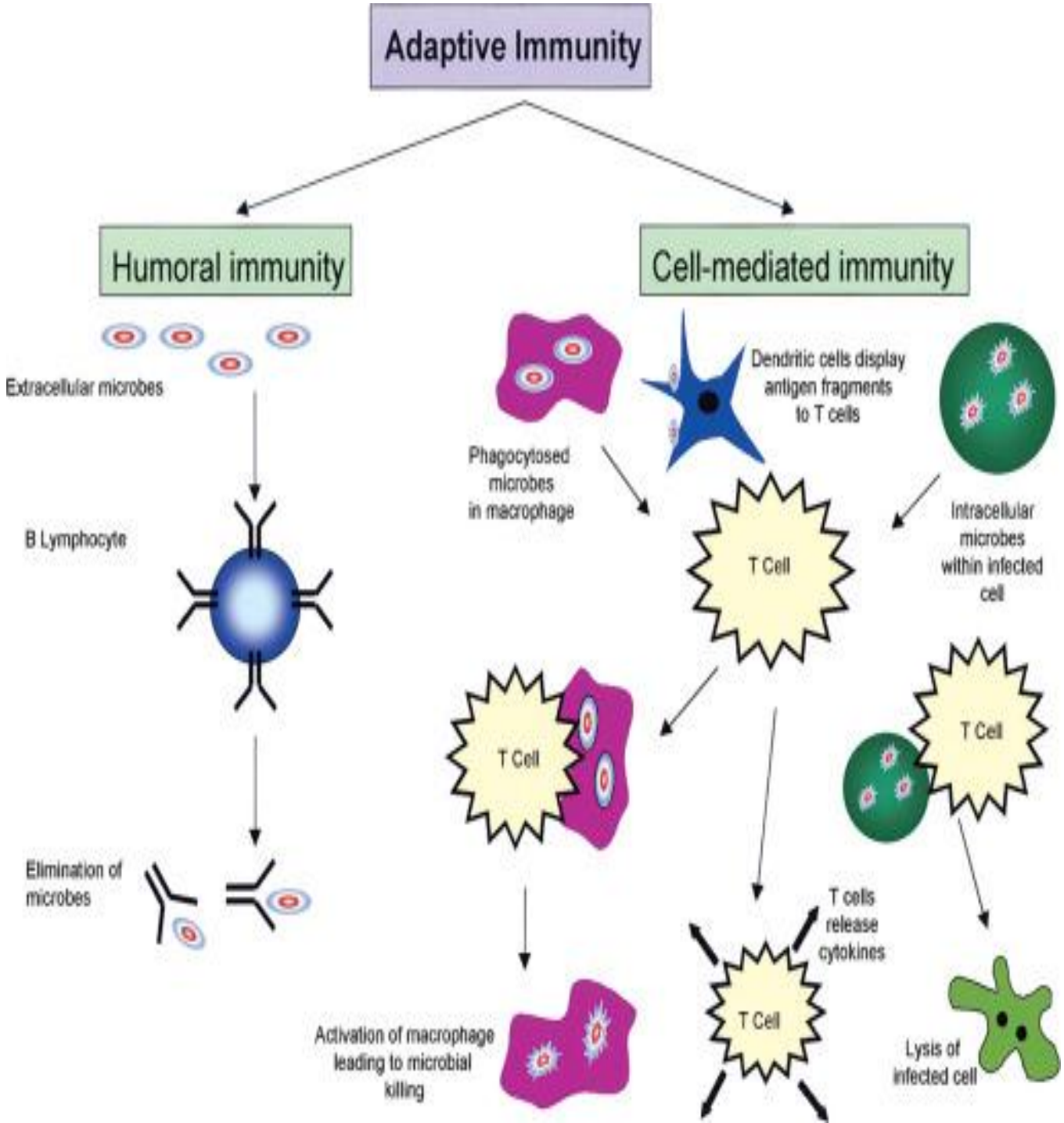
Plasma cells manufacture **antibodies** (immunoglobulins), **“**a group of recognition glycoproteins present in the blood and tissue fluids of birds and mammals.**”**

# ANTIBODY STRUCTURE

- All antibody molecules have a basic **Y** structure
- Composed of **4** chains of polypeptides connected by **disulfide bonds**.
- Arms of Y have binding sites for **antigens**.
- Tail of Y activate **complement system**.

# CELL-MEDIATED IMMUNE RESPONSE




Adaptive Immunity
Humoral immunity
Cell-mediated immunity
Extracellular microbes
B Lymphocyte
Elimination of microbes
Phagocytosed microbes in macrophage
Dendritic cells display antigen fragments to T cells
Intracellular microbes within infected cell
T Cell
T Cell
T Cell
T cells release cytokines
T Cell
Activation of macrophage leading to microbial killing
Lysis of infected cell

# PRIMARY AND SECONDARY IMMUNE RESPONSES

## Primary Immune Response

"Is the response an animal generates during its first encounter with an antigen."

- During this response, the antigen disappears from the blood because it is either bound to antibodies or phagocytized by macrophages.
- Most of the B Cells producing the antibodies also die.

## Secondary Immune Response

"It occurs when the person is exposed to the same antigen for the second time."

- It is faster and more extensive than the primary response.
- This rapid response is possible because the immune system has stored a "memory" of the antigen.