BIO 250
System and Maintainance
(Plants and Animals)

Chapter 2.4

Circulatory

By

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http://yeddah.net/azuraidi/bio250

Objectives

- At the end of this lecture, students should know about:
  - Open and closed circulatory system,
    - Open circulatory system,
    - Closed circulatory system,
    - The function of vertebrate circulatory system,
  - The blood plasma,
  - The blood cells,
  - Characteristic of blood plasma,
  - The fish heart
  - Amphibians and reptiles circulation,
  - Mammals and bird heart

Definitions

- Circulatory system – an organ system that permits blood and lymph circulation to transport nutrients (such as amino acids and electrolytes), oxygen, carbon dioxide, hormones, blood cells, etc. to and from cells in the body to nourish it and help to fight diseases, stabilize body temperature and pH, and to maintain haemostasis.

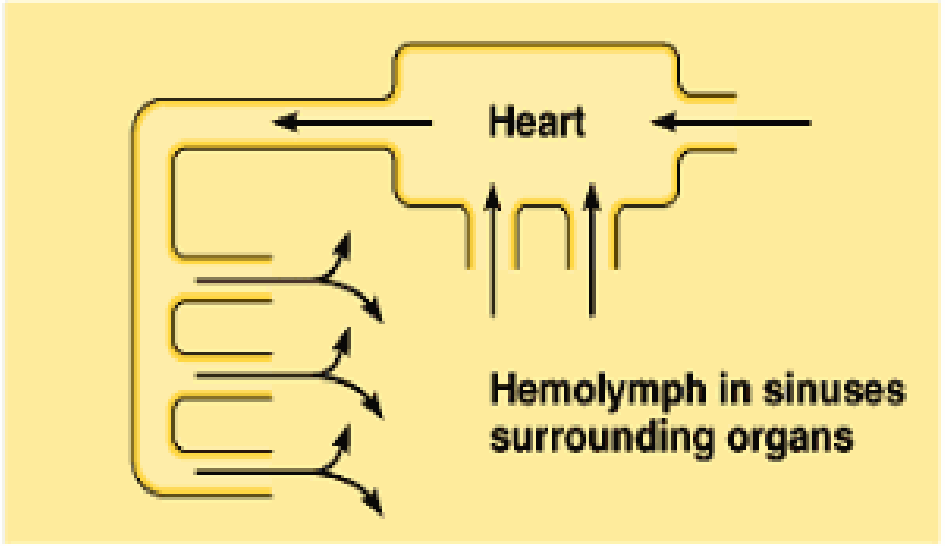
Definitions

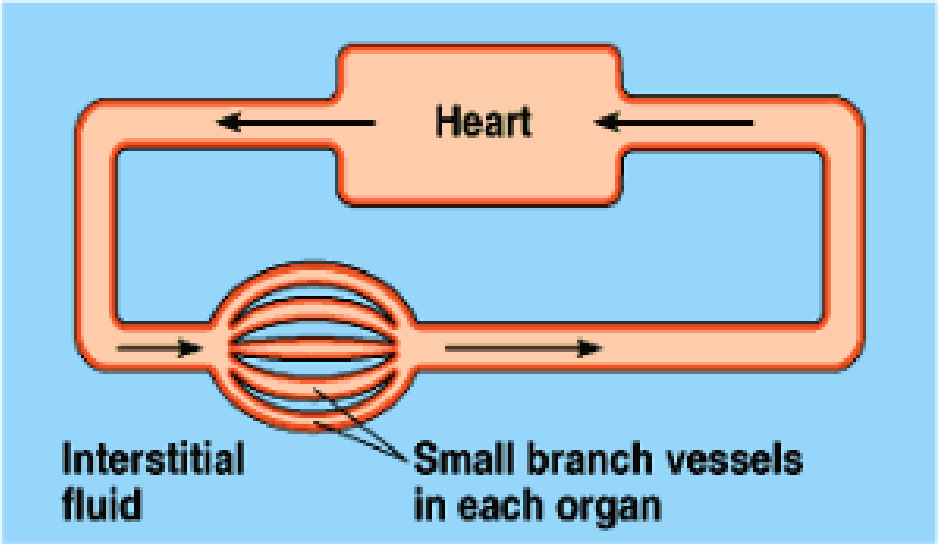
- Circulatory system is composed of:
  - Cardiovascular system – distributes blood
  - Lymphatic system – returns excess filtered blood plasma from the interstitial fluid (between cells) and lymph.

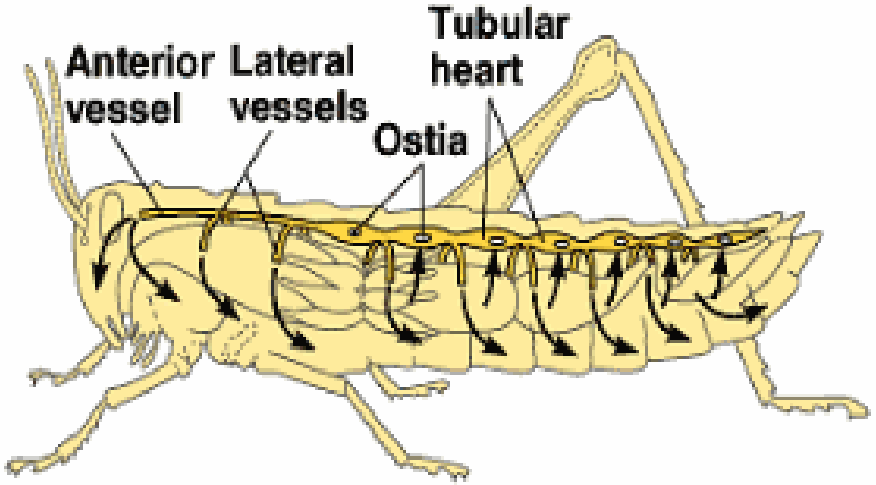
Definitions

- There are two types of circulatory system:
  - Open circulatory system – In some invertebrate groups.
  - Closed circulatory system – the blood never leaves the network of arteries, veins and capillaries. In human and other vertebrates.

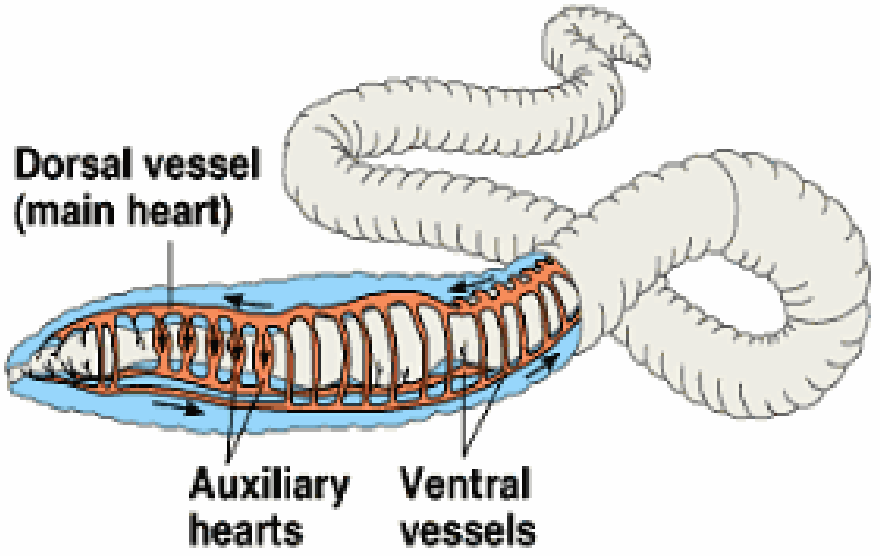
Open Circulatory System





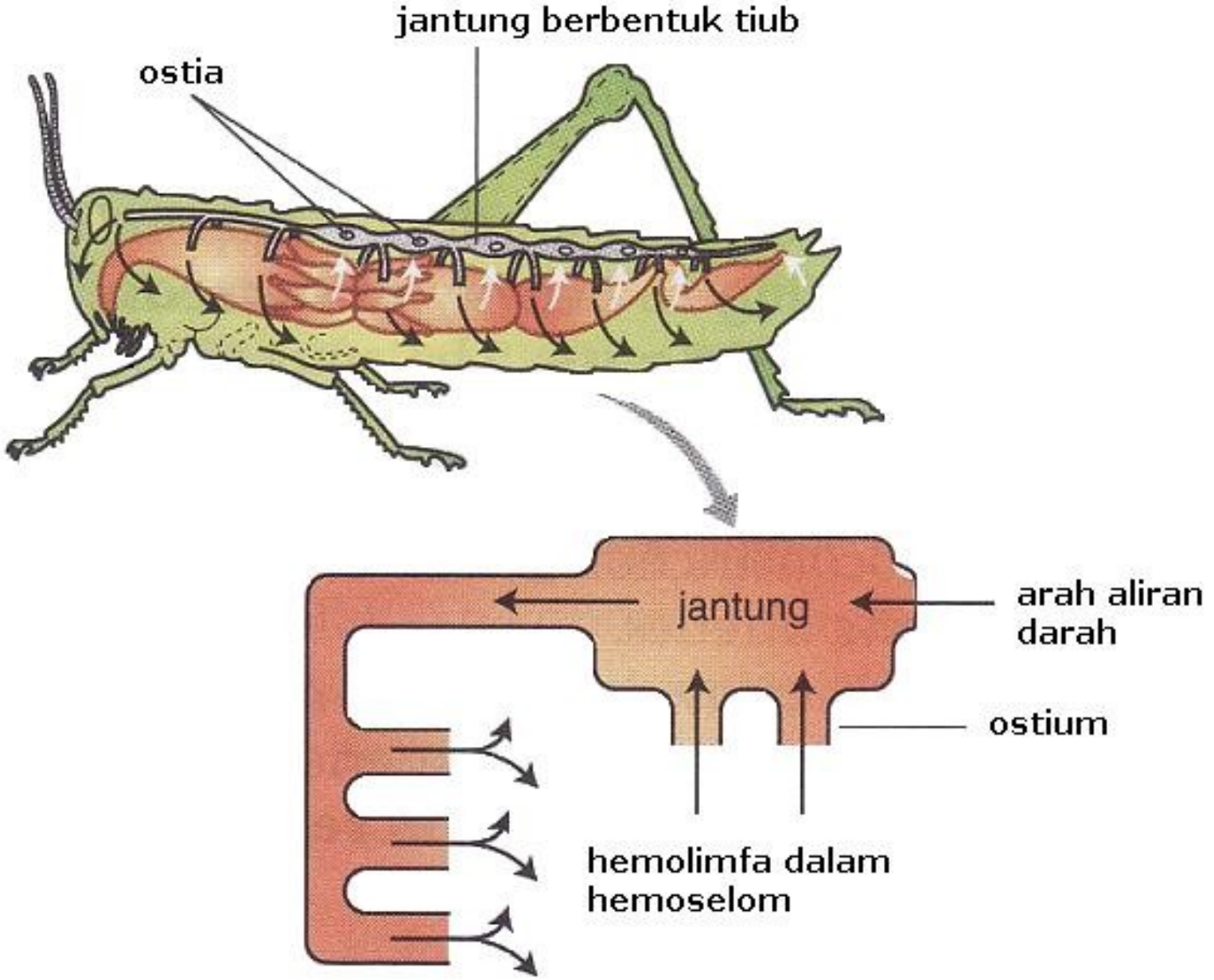


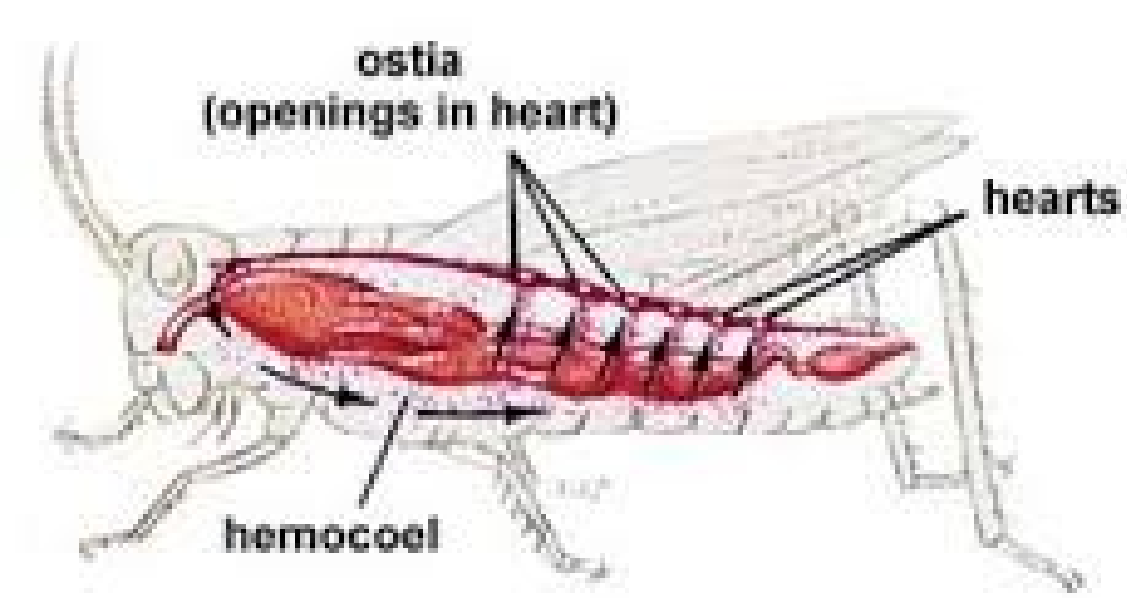
(a) Open circulatory system

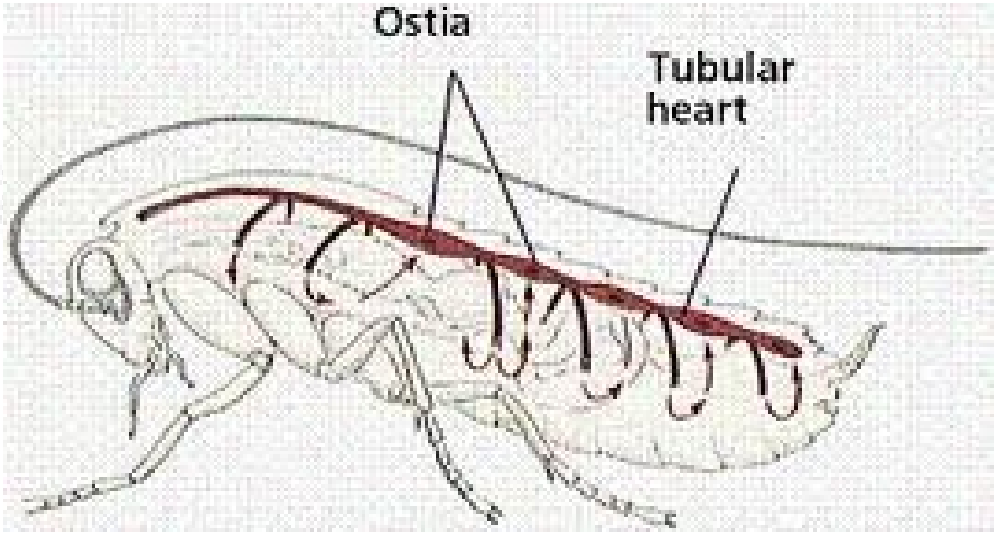


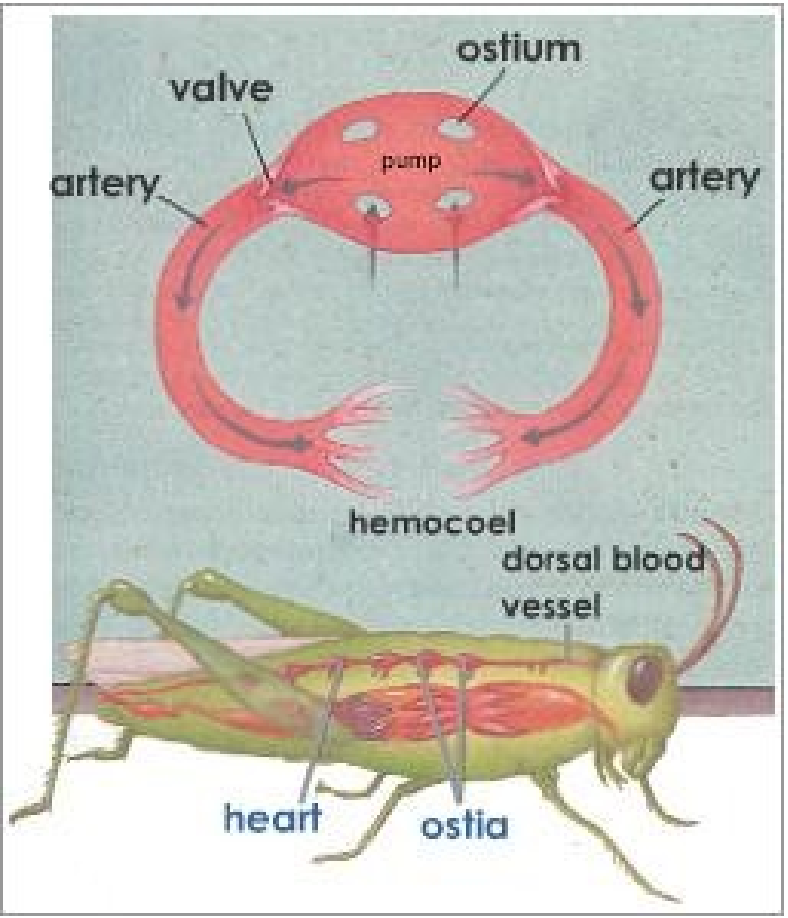
(b) Closed circulatory system

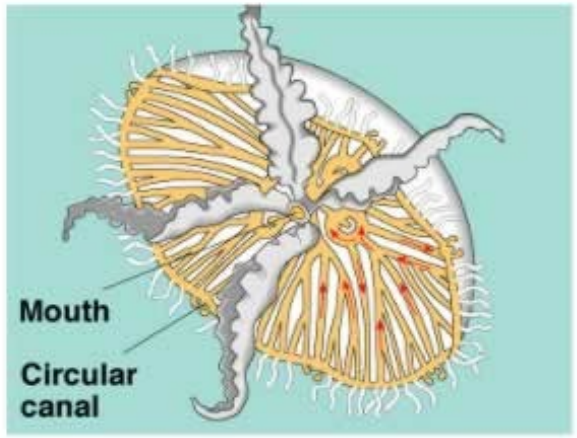
Open Circulatory System











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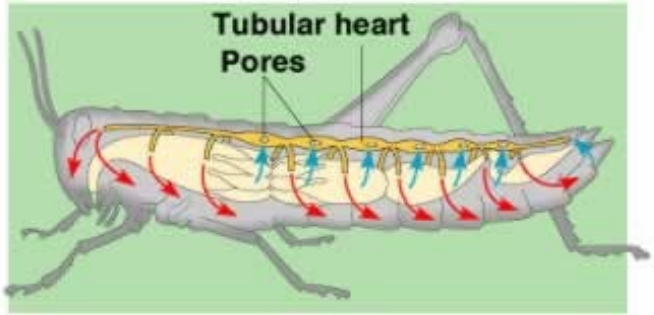
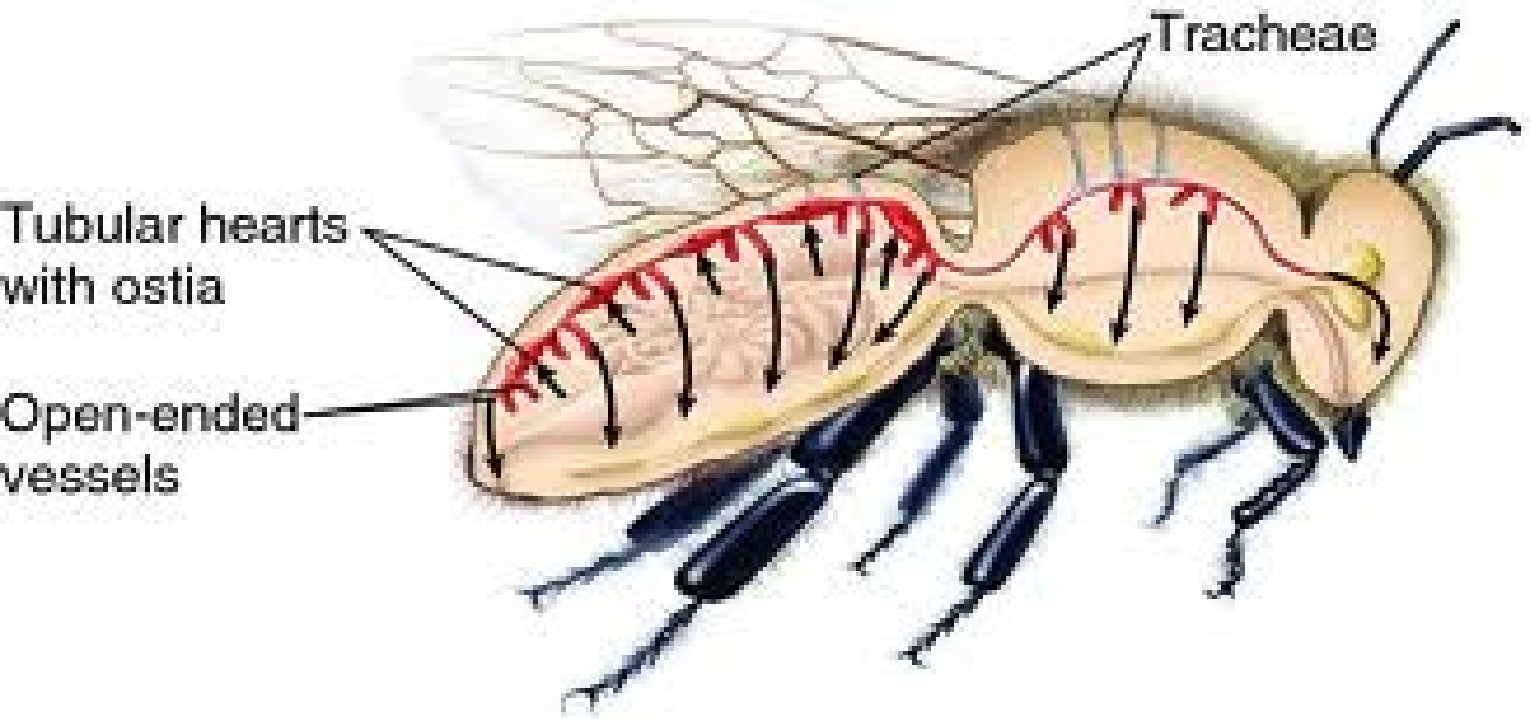
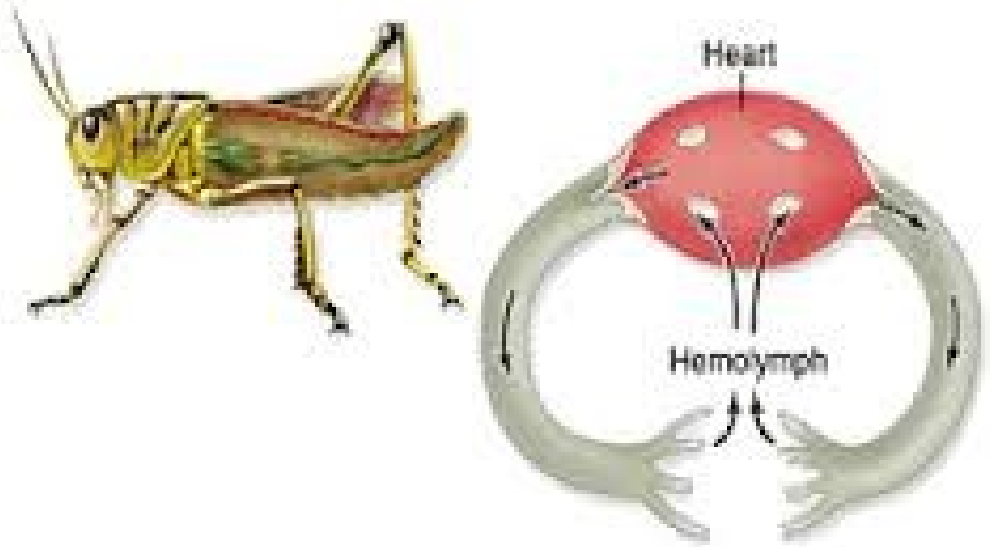



Tracheae
Tubular hearts with ostia
Open-ended vessels


Heart
Hemolymph

Open Circulatory System

- Is a system in which a fluid in a cavity called the hemocoel bathes the organs directly with oxygen and nutrients.

- There is no distinction between blood and interstitial fluid.

- This combined fluid is called **hemolymph**.

Open Circulatory System

- Muscular movements by the animal locomotion facilitate hemolymph movement.
- When the heart relaxes, blood is drawn back toward the heart through open-ended pores.
- Hemolymph fills all of the interior hemocoel of the body and surrounds all cells.
- Common to molluscs, arthropods, crustaceans, other invertebrates.

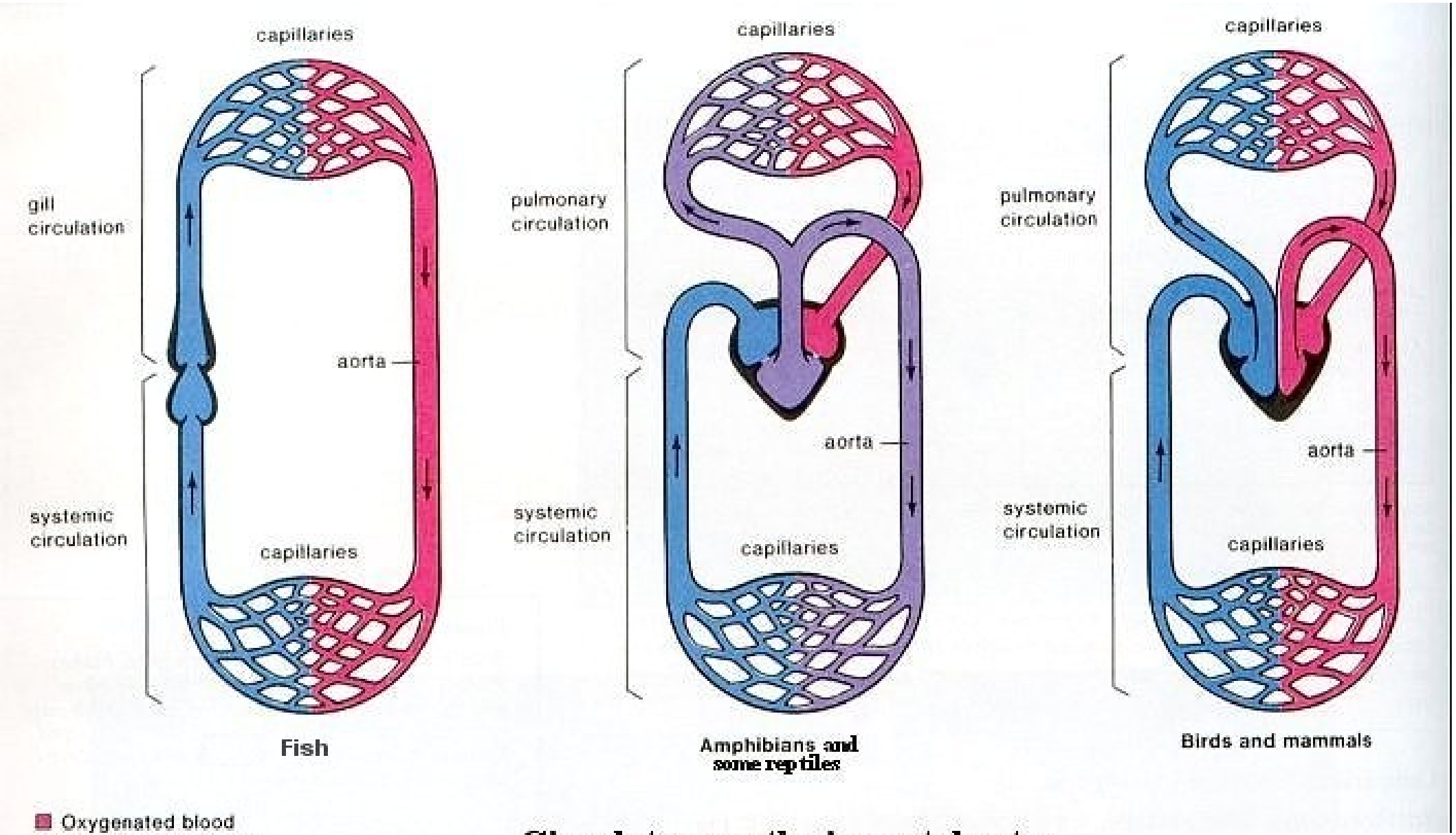
Open Circulatory System

- Hemolymph is composed of water, inorganic salts (mostly Na^{+}, Cl^{-}, K^{+}, Mg^{2+}, Ca^{2+}) and organic compounds (mostly carbohydrates, proteins and lipids).

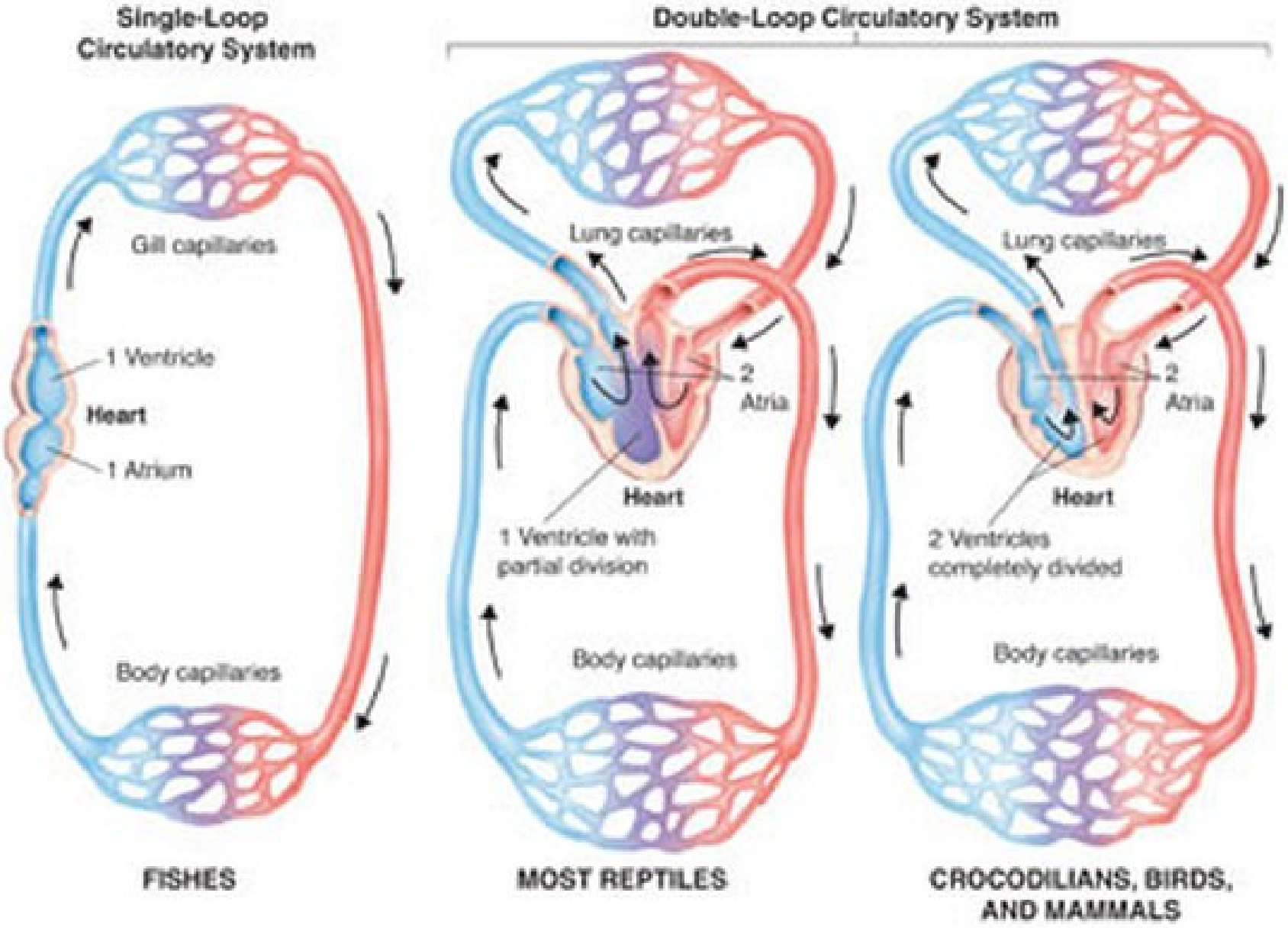
- The primary oxygen transporter molecule is hemocyanin.

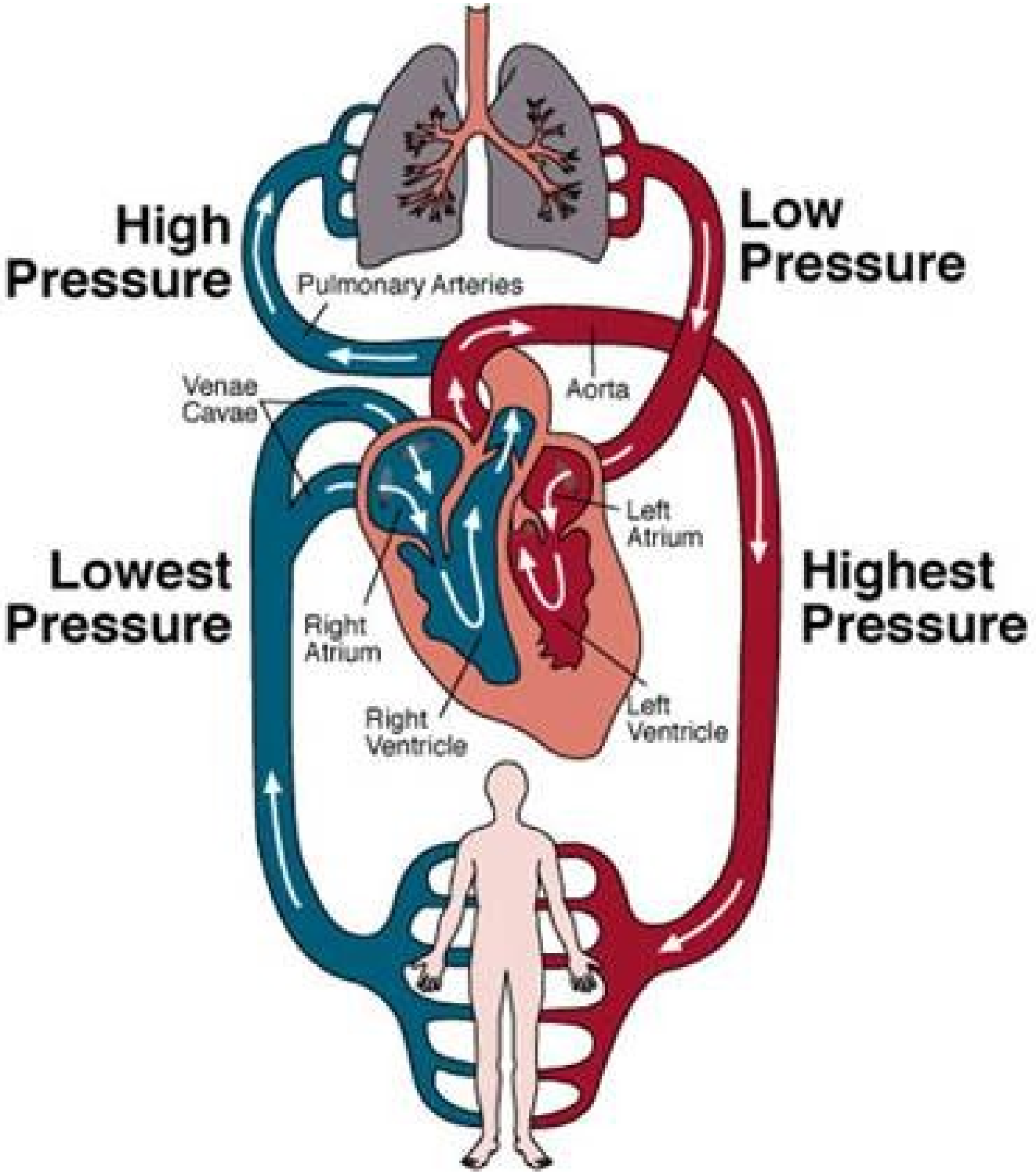
- There are free-floating cells, the hemocytes, within the hemolymph, that play a role in the arthropod immune system.

Closed Circulatory System



Closed Circulatory System




High Pressure
Low Pressure
Pulmonary Arteries
Venae Cavae
Aorta
Left Atrium
Lowest Pressure
Highest Pressure
Right Atrium
Right Ventricle
Left Ventricle

Closed Circulatory System

- A circulatory system whereby the blood never leaves the network of blood vessels.
- The blood is pumped through a closed system of arteries, veins and capillaries.
- Capillaries surround the organs, make sure that all cells have an equal opportunities for nourishment and removal of their waste products.

Closed Circulatory System

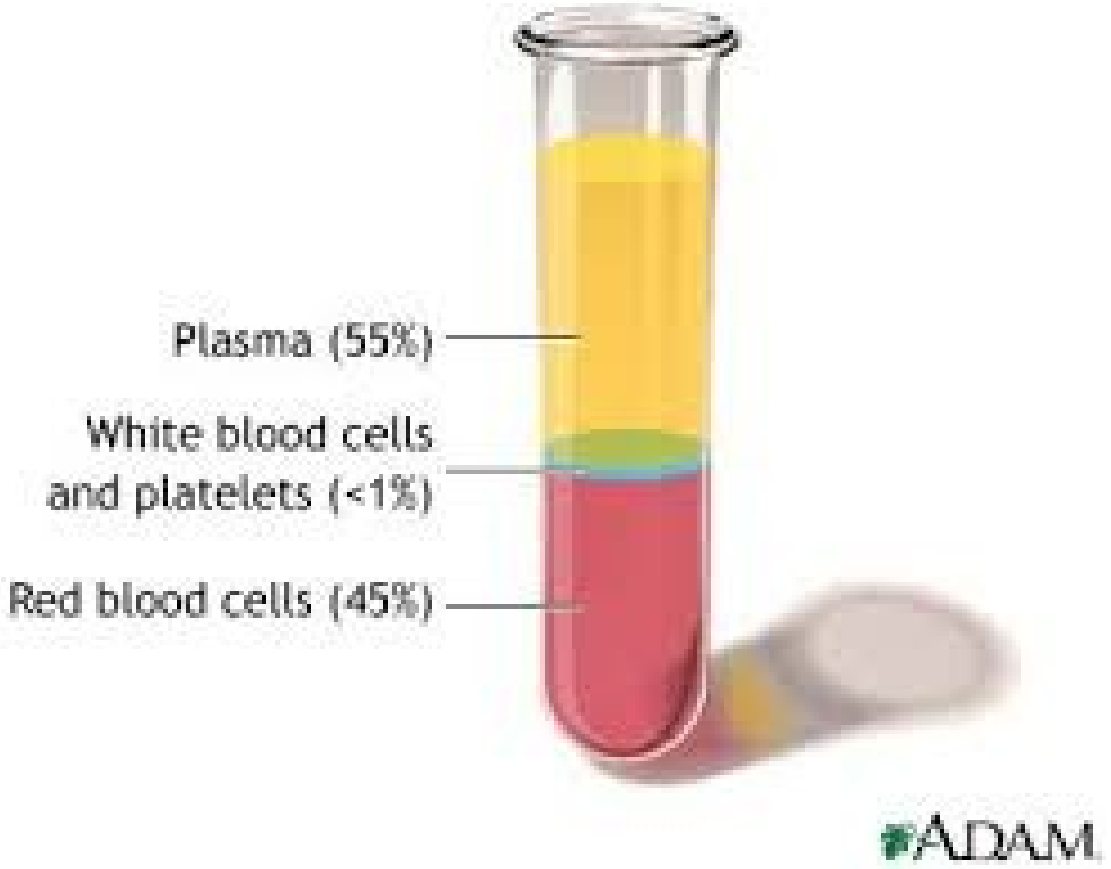
- Circulation in vertebrates and a few invertebrates.

- Oxygen and nutrients diffuse across the blood vessel layers and enters interstitial fluid, which carries oxygen and nutrients to the target cells, and carbon dioxide and wastes in the opposite direction.

Open vs. Closed Invertebrate Circulation

- Two types of circulatory fluids:
  - Blood - contained within blood vessels
  - Hemolymph - flows into hemocoel
- Open Circulatory System
  - Heart pumps hemolymph via vessels
  - Vessels empty into tissue spaces
- Closed Circulatory System
  - Heart pumps blood to capillaries
  - Gases and materials diffuse to and from nearby cells
  - Vessels return blood to heart without it contacting tissues

The Blood Plasma



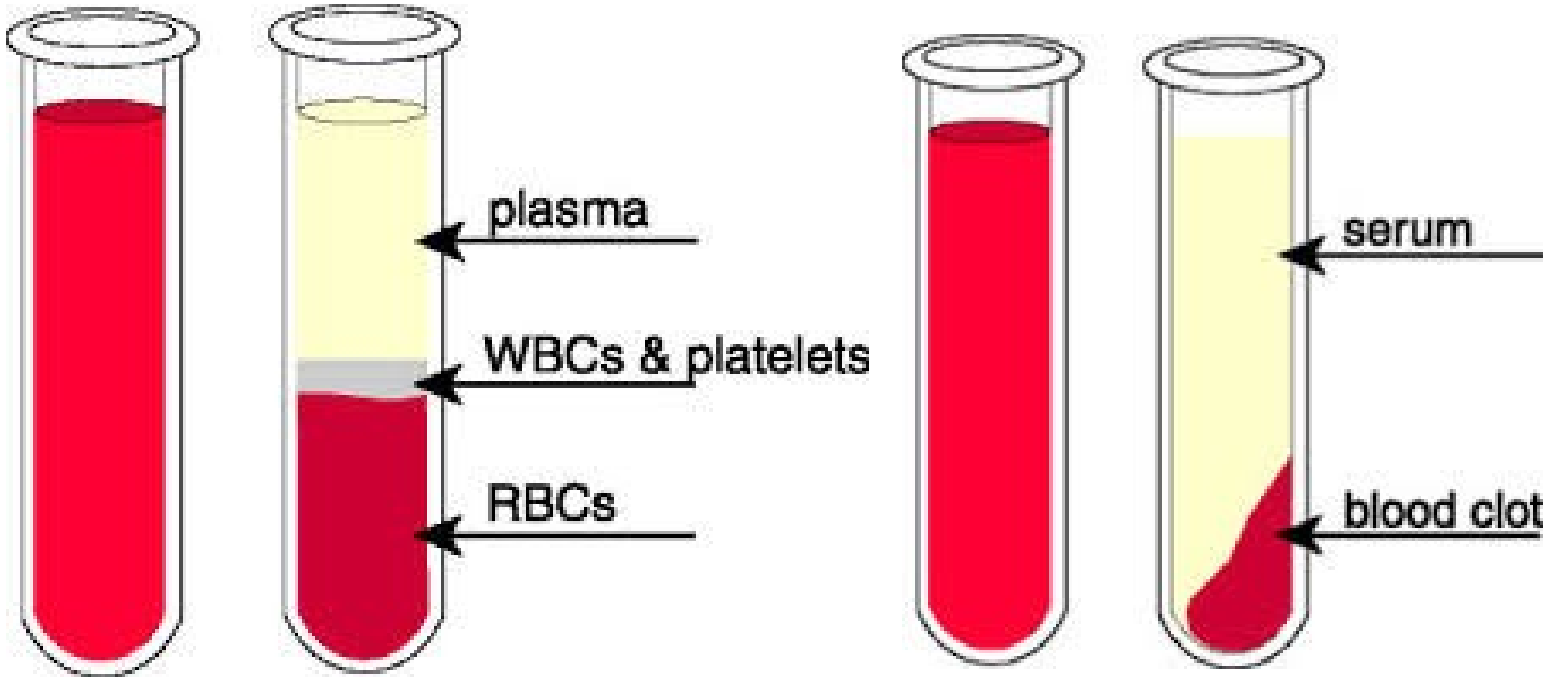
PLASMA - 55% of Total Blood Volume
91% Water
7% Blood Proteins (fibrinogen, albumin, globulin)
2% Nutrients (amino acids, sugars, lipids)
Hormones (erythropoietin, insulin, etc.)
Electrolytes (sodium, potassium, calcium, etc.)

CELLULAR COMPONENTS - 45% of Total Blood Volume

Buffy Coat
White Blood Cells (7000-9000 per mm^3 of blood
Platelets (250,000 per mm^3 of blood

Red Blood Cells (RBCs)
About 5,000,000 per mm^3 of blood

The Blood Plasma



The Blood Plasma

- Straw-colored/pale-yellow liquid component of the blood that normally holds the blood cells in whole blood in suspension.

- It makes up about 55% of total blood volume.

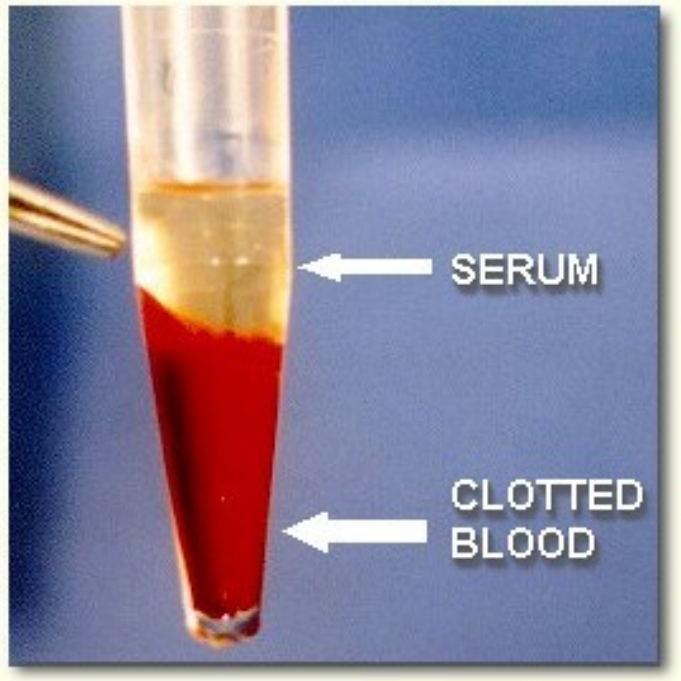
- It is mostly water (92% by volume), and contains dissolved proteins (i.e. - albumins, globulins, and fibrinogen). Glucose, clotting factors, electrolytes, hormones, and CO_2.

The Blood Plasma

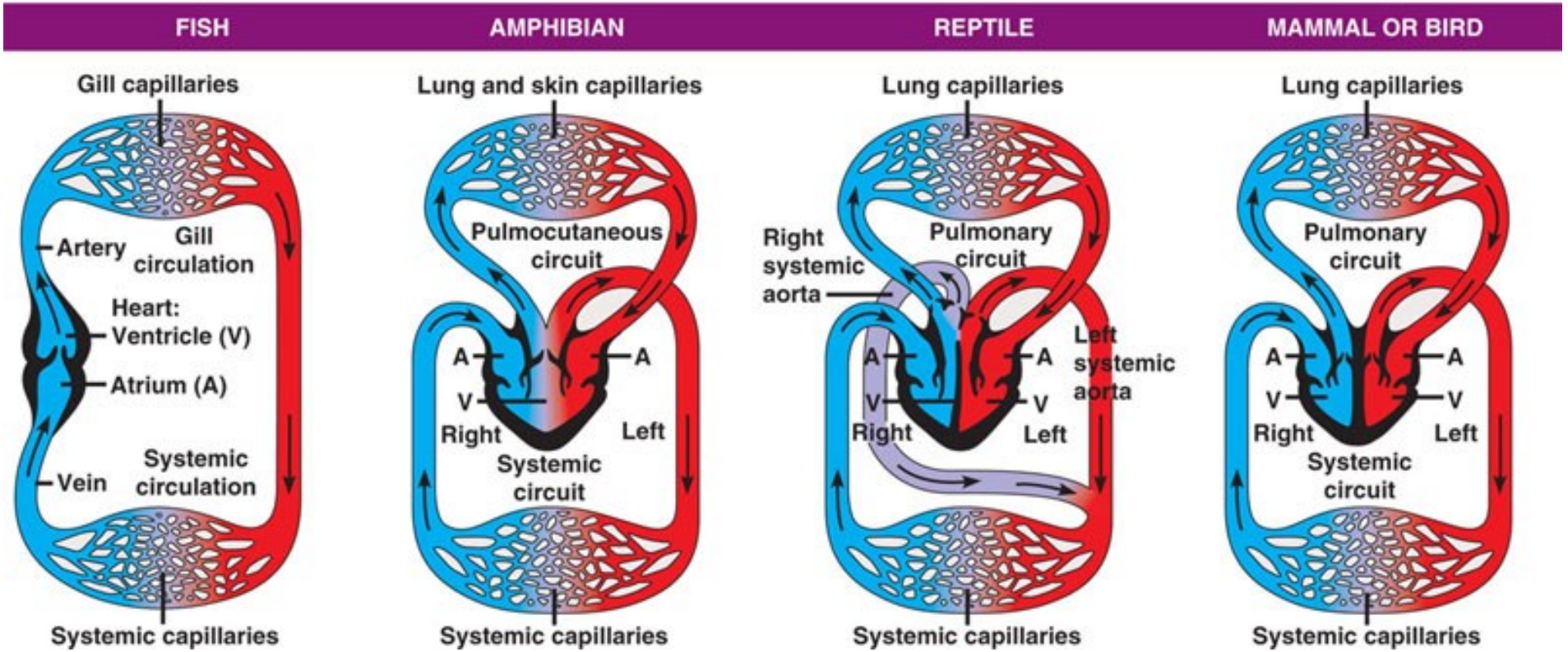
- Plasma serves as the protein reserve of the human body.

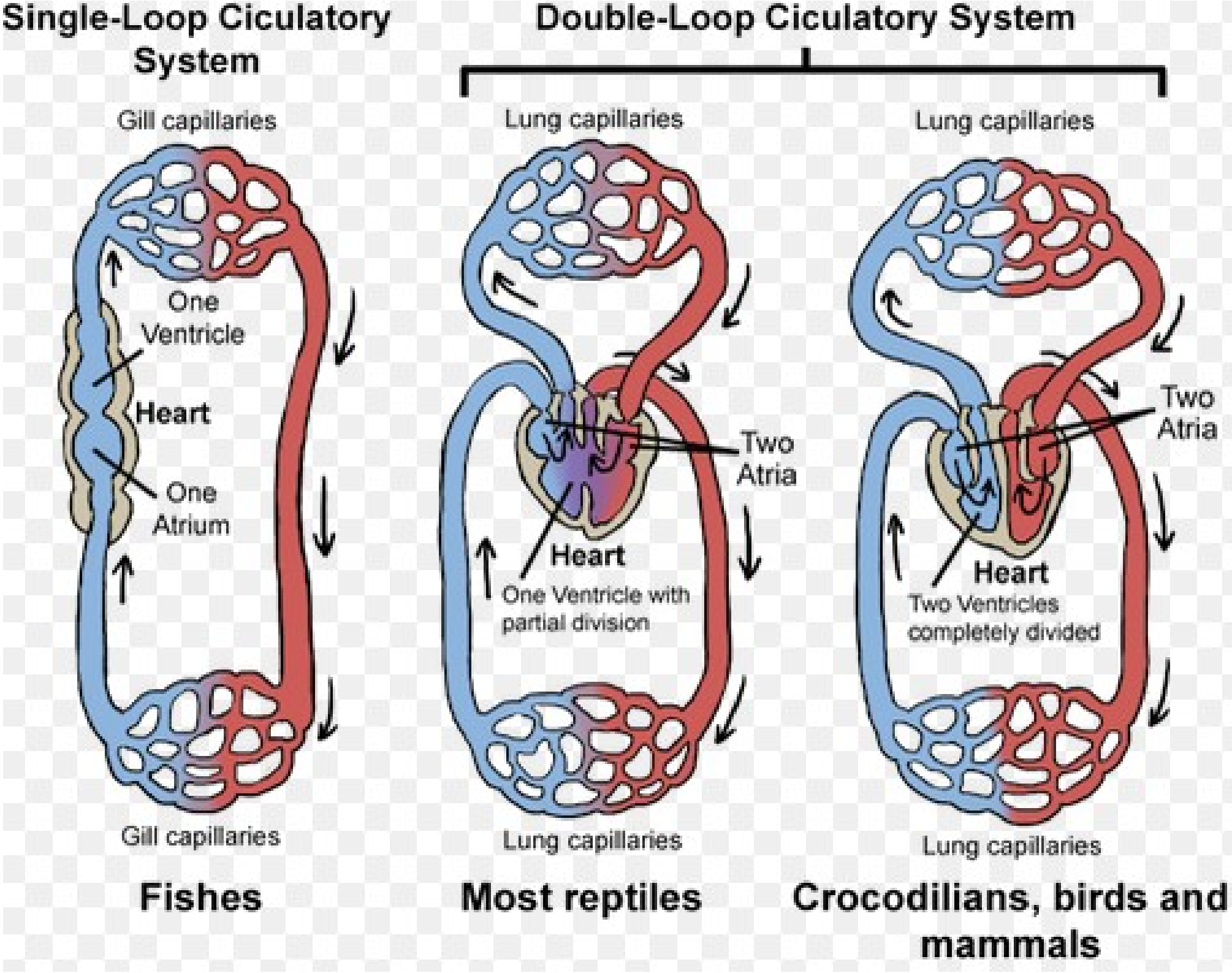
- It plays a vital role in an intravascular osmotic effect.

- Blood serum is blood plasma without clotting factors (i.e. - whole blood minus both the cells and the clotting factors).

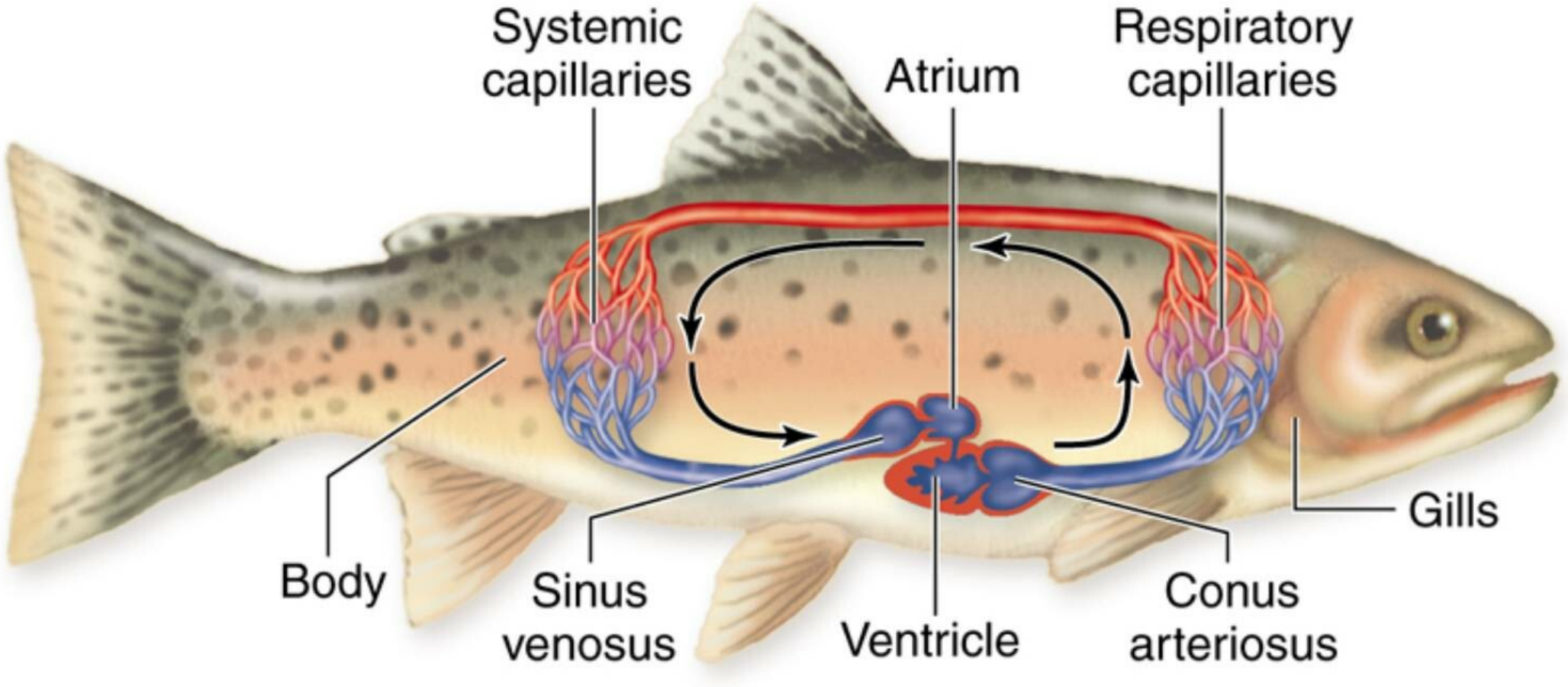


Animal Circulation




Single-Loop Ciculatory System
Double-Loop Ciculatory System
Gill capillaries
One Ventricle
Heart
One Atrium
Gill capillaries
Fishes
Lung capillaries
Two Atria
Heart
One Ventricle with partial division
Lung capillaries
Most reptiles
Lung capillaries
Two Atria
Heart
Two Ventricles completely divided
Lung capillaries
Crocodilians, birds and mammals

Fish Circulation



Fish Circulation

- Heart
  - 2 chambers
    - 1 atrium
      - Receives DEOXYGENATED blood from body
      - Receiving chamber, NOT pumping; NOT muscular
    - 1 ventricle
      - Pumps blood out of the heart to gills AND body
      - Pumping chamber, therefore MUSCULAR

Fish Circulation

- Circulation Path
  - Deox blood from body enters atrium
  - Deox blood from atrium enters ventricle
  - Ventricle pumps blood
  - Deox blood goes to gills – FIRST CAPILLARY BED
  - OX. Blood goes to body organs – SECOND CAPILLARY BED (systemic bed)
  - Deox blood returns to atrium

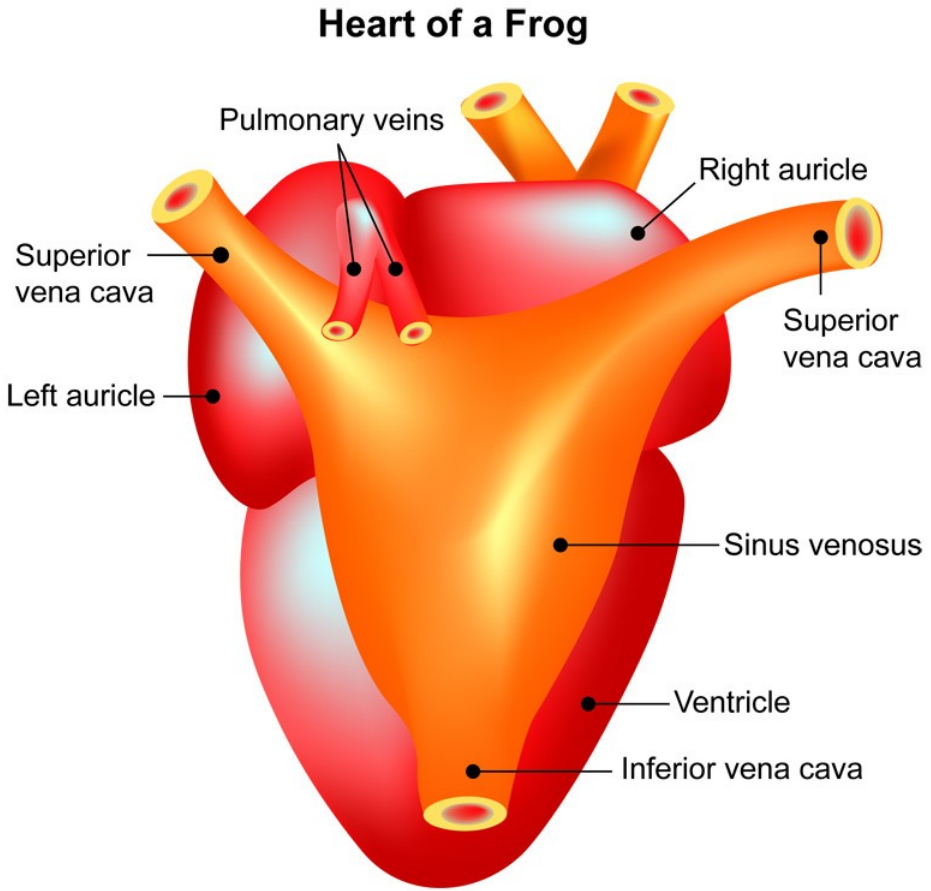
Fish Circulation

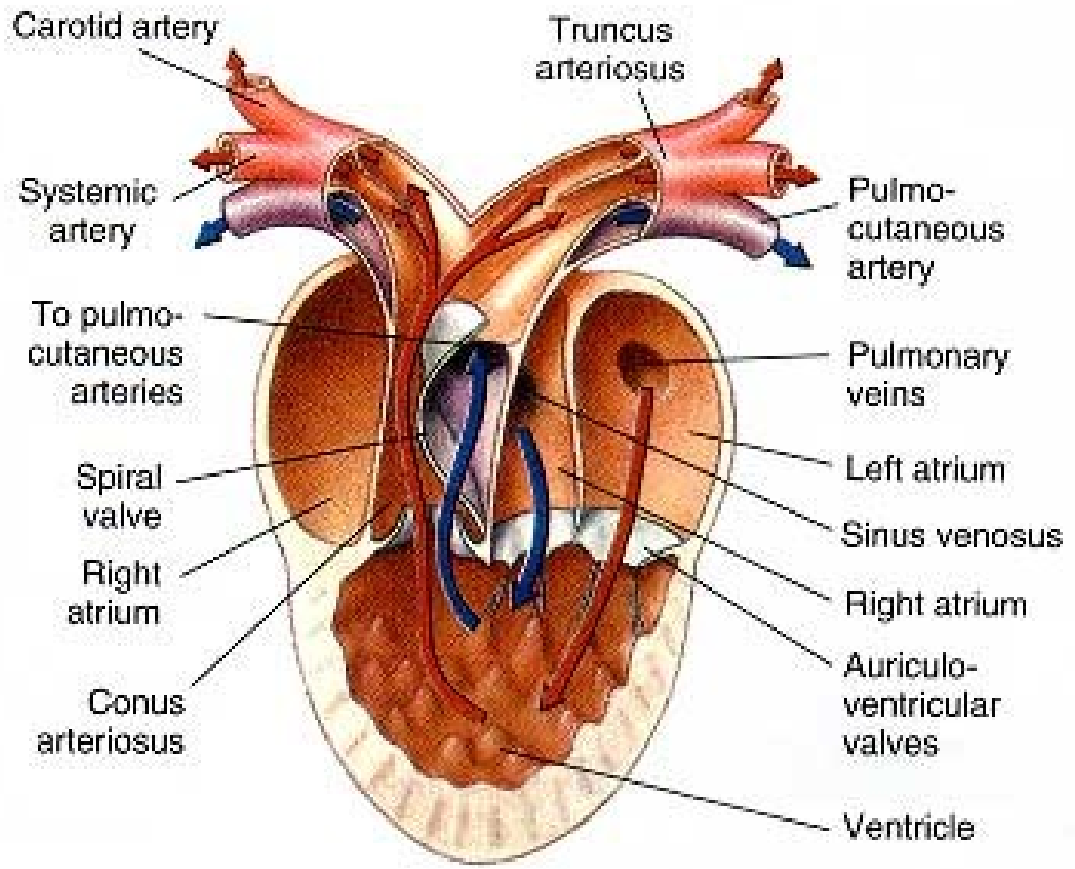
- ONE ventricle – that means ONE pump
- Only ONE PUMP to drive blood through TWO capillary beds
  - GILL Capillary Bed
  - Body Organs (systemic bed)
- Blood slows down in capillary beds
- The blood is moving VERY slowly by the time it completes its circuit and gets back to heart.
- Relies on physical movement of the fish’s muscles to assist blood in getting back to heart.

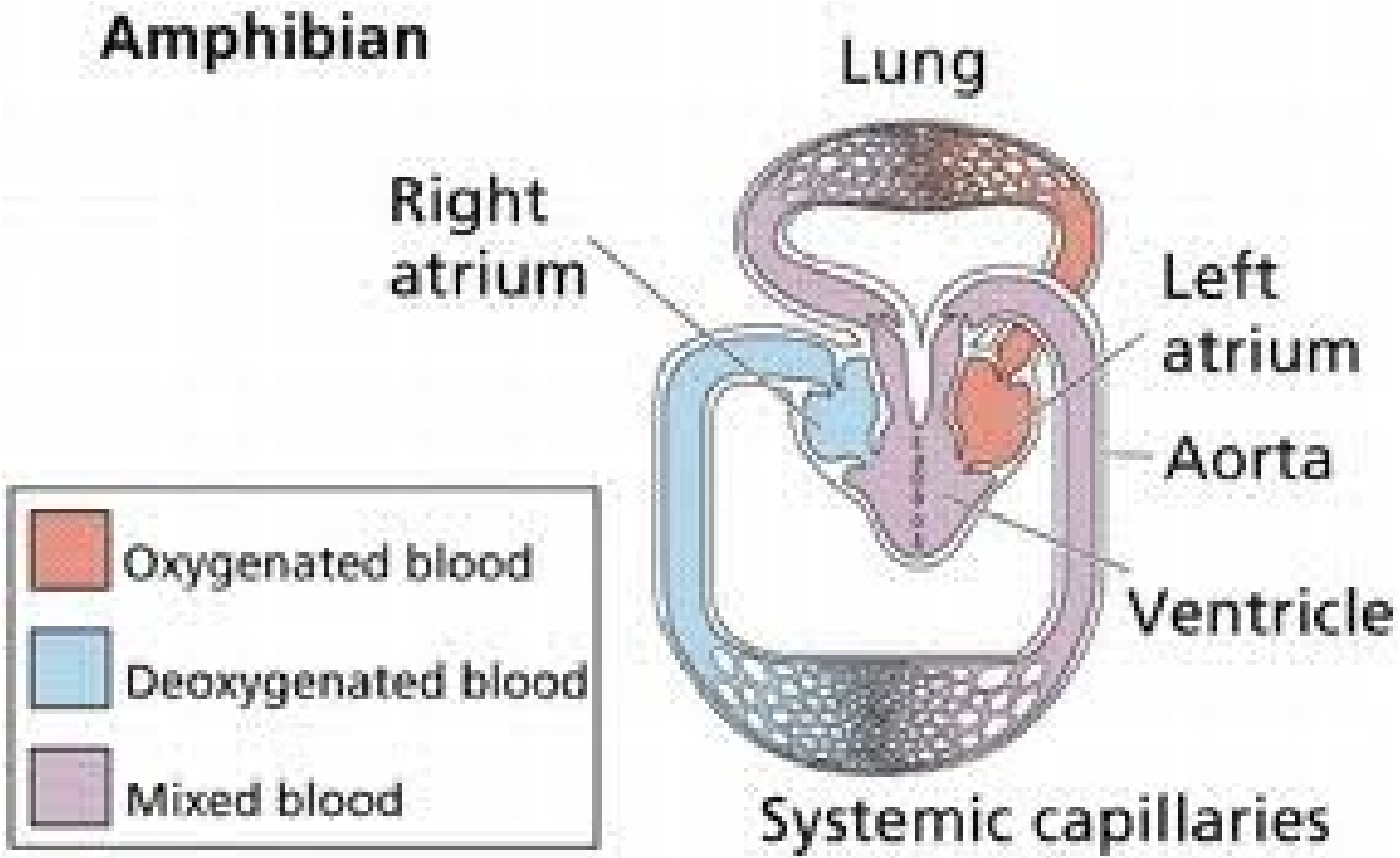
Fish Circulation

- Single circuit – blood follows ONE PATH; ONE LOOP
- For a fish, this SINGLE CIRCUIT is fine.
  - Obviously, fish are a very successful group
  - Living in water is relatively easy
    - Temperatures are more moderate than on land
    - Requires less effort to move than on land
  - However, this SINGLE CIRCUIT is NOT good enough if you demand more energy – the energy required of a terrestrial organism

Amphibian Circulation






Amphibian
Lung
Right atrium
Left atrium
Aorta
Ventricle
Systemic capillaries
Oxygenated blood
Deoxygenated blood
Mixed blood

Amphibian Circulation

- Amphibians – TRANSITION group from WATER to LAND
- The Frog Heart
  - A new design to the heart – 3 chambers
    - 1 ventricle
      - Pumping chamber; muscular
    - 2 atria
      - Receiving chambers, relatively nonmuscular
- 3 chambered heart allows for the advancement of a double circuit

Amphibian Circulation

- Advantage of a Double Circuit
  - Allows the blood to get pumped TWICE rather than just once (as in fish)
  - Allows blood to be pushed with greater speed through the circulatory system

Amphibian Circulation

- How the Double Circuit Works: Circulation Path in the Frog
  - DEOX blood from the body enters the RIGHT ATRIUM
  - At the same time, OX blood from the LUNGS and SKIN (remember the skin is a respiratory organ in amphibians) enters the LEFT ATRIUM

Amphibian Circulation

...

- Deox blood in RIGHT ATRIUM enters the VENTRICLE
- OX blood in the LEFT ATRIUM enters the VENTRICLE
- DRAWBACK – OX and DEOX blood MIX in the VENTRICLE
  - However, the ventricle is designed to REDUCE this mixing somewhat

Amphibian Circulation

- ...
  - VENTRICLE PUMPS mostly deox blood from rt. Atrium to the Lungs/skin to pick up oxygen.
  - VENTRICLE PUMPS mostly ox blood from left atrium to body
  - Thus one squeeze of ventricle sends blood to resp organs, then another squeeze sends blood to body. TWO PUMPS instead of ONE. Blood travels MORE EFFICIENTLY.

Amphibian Circulation

- ...
  - Two Circuits
    - Pulmocutaneous circuit – blood is pumped to the respiratory organs and returns to the heart
      - “pulmo” = lungs
      - “cutaneous” = skin
      - Both are respiratory organs in the frog
    - Systemic circuit – blood is pumped to the body organs and returns to the heart

Amphibian Circulation

- Advantages
  - Double circuit – more efficient pumping
- Disadvantages
  - Mixing of oxygenated and deoxygenated blood in the single ventricle

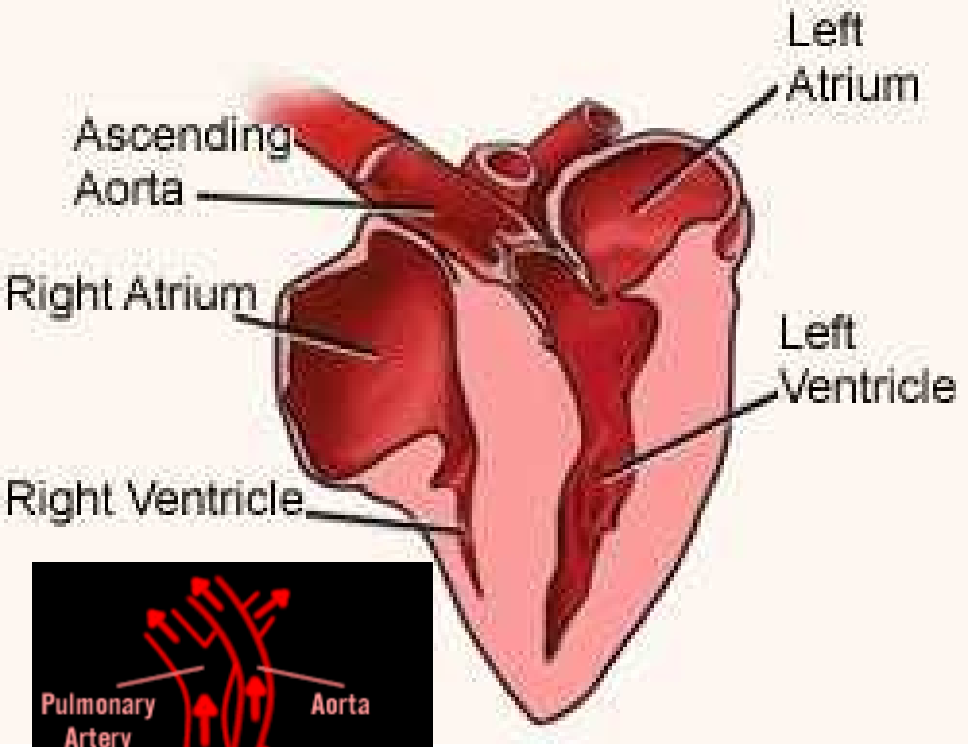
Reptile Circulation

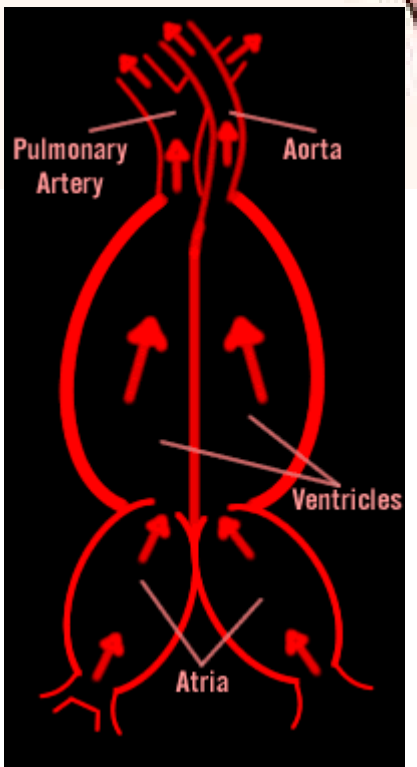
- Most reptiles have three-chambered heart, consisting of 2 atria and 1 ventricle.
- The degree of mixing of oxygenated and deoxygenated blood depending on the species and physiological state.
- Under different condition, oxygenated blood can be shunted back to the body, or oxygenated blood can be shunted back to the lungs.
- But, crocodilians have 4-chambered heart.

Bird and Mammal Heart

- Has very efficient CVS, permits them to meet the metabolic demand of flight.

- Have 4 chambered-heart (2 atria & 2 ventricles), with complete separation of oxygenated and deoxygenated blood.

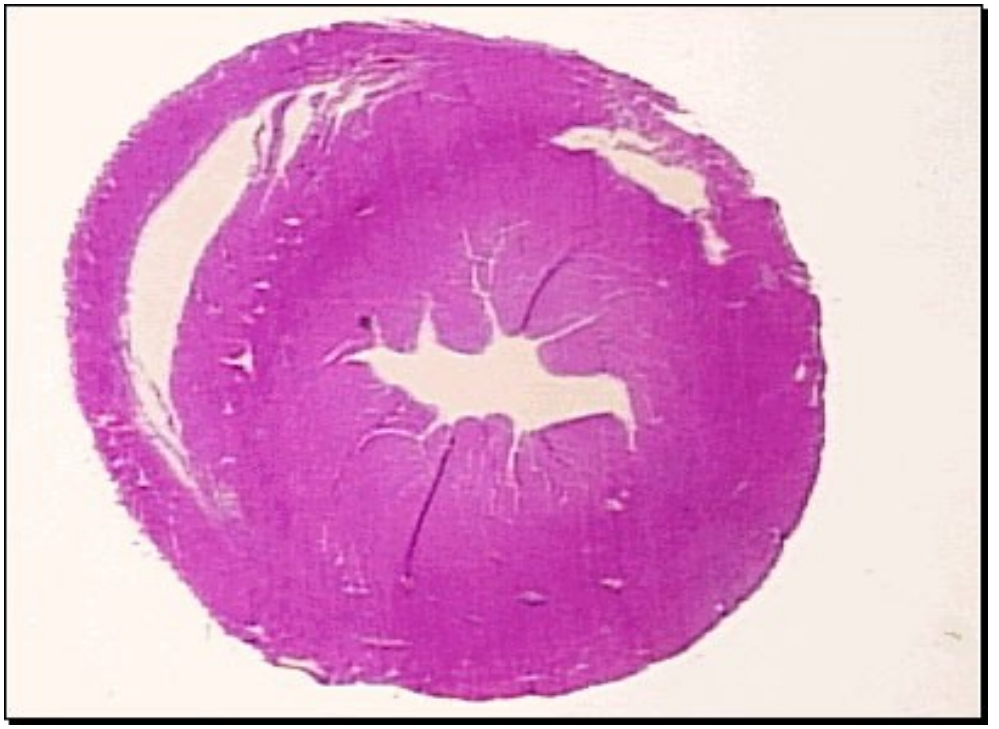




Bird and Mammal Heart

- Right ventricles pump blood to the lungs, while left ventricles pump blood to the rest of the body.

- Because the left ventricle must generate greater pressure to pump throughout the body, the wall of the left ventricle are much thicker & more muscular.



Bird and Mammal Heart

- Birds have larger heart than mammals (relative to body size and mass).
- The relative larger heart may be necessary to meet the high metabolic demand of flight.
- Smaller birds have relatively larger hearts.

Bird and Mammal Heart

- Bird heart tend to pump more blood per unit time more than mammalian hearts.

- That means, cardiac output (amount of blood pumped per minute) for birds is greater than for mammals of the same body mass.

- Cardiac output is influenced by heart rate and stroke volume (volume pumped with each beat).

CO = HR x SV