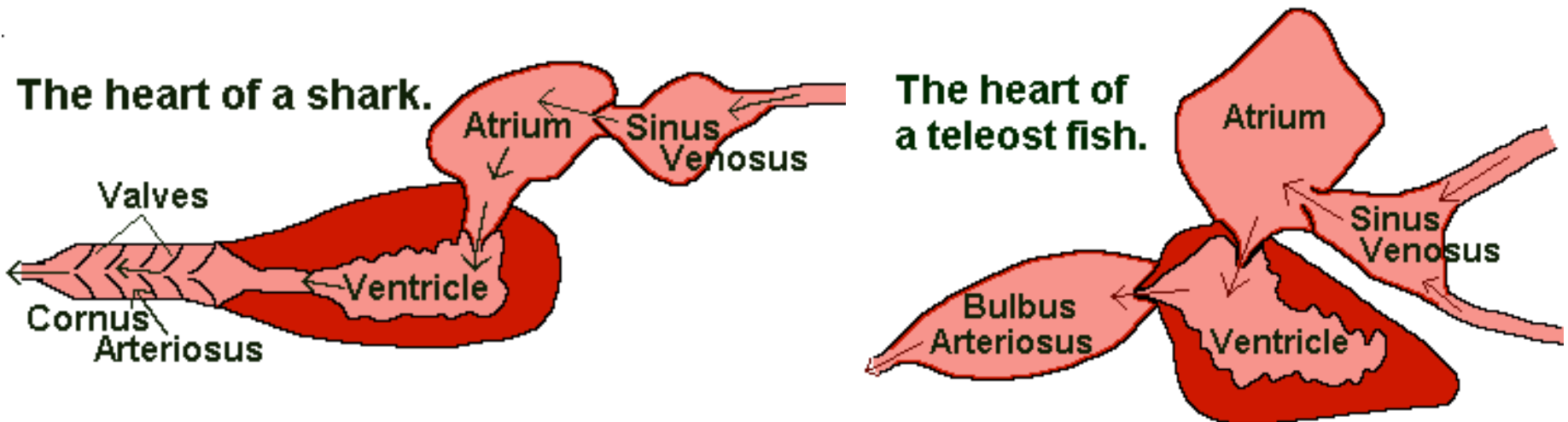


# **Circulatory System in Finfish and Shellfish**

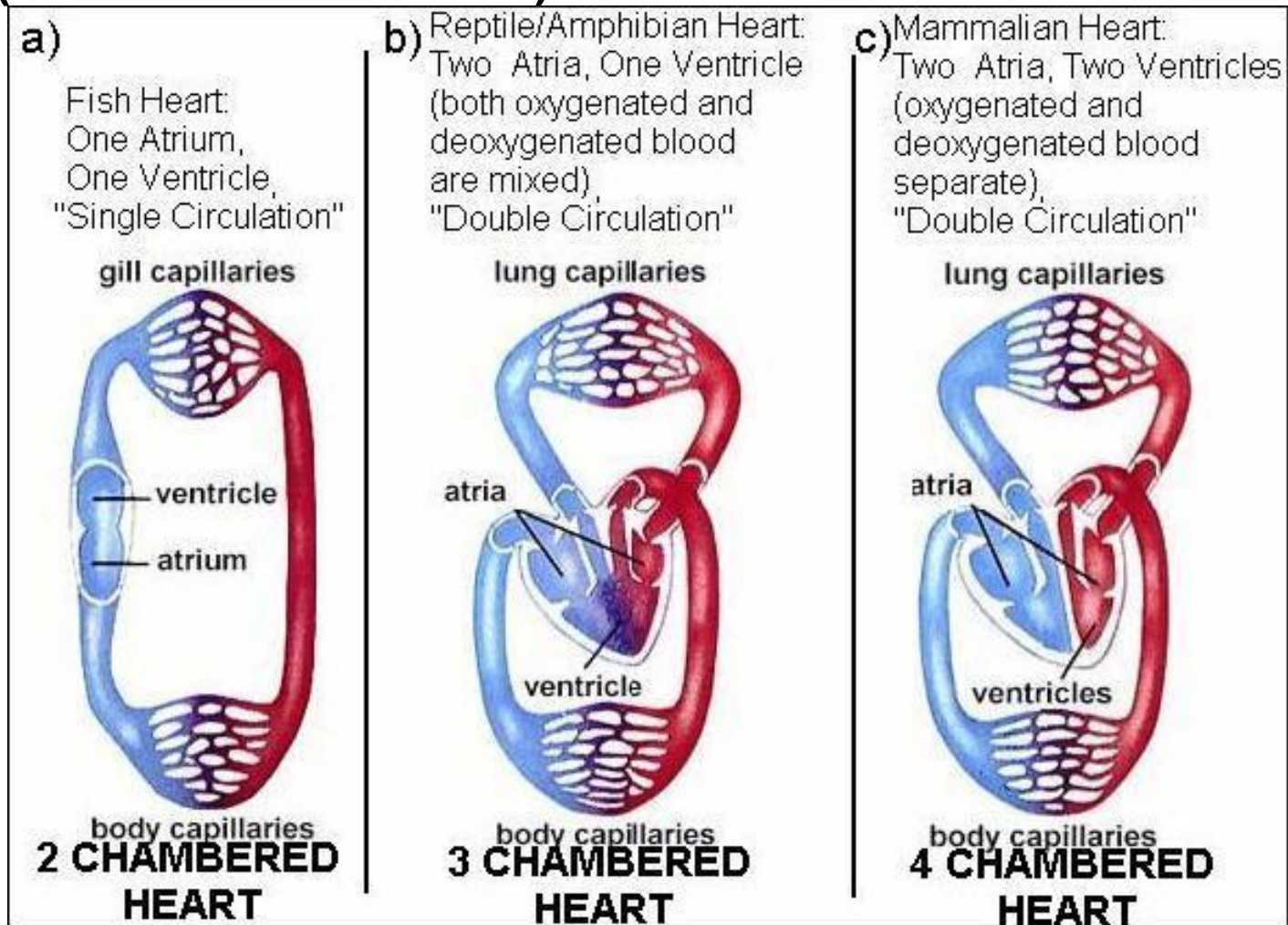
## Circulatory system in fishes

Fishes are cold-blooded aquatic vertebrates and can be found in both saline and fresh water. The circulatory system of fishes is responsible for transporting blood and nutrients throughout the body. It has a closed circulatory system, i.e. blood travels across the body through the network of blood vessels.

Fish heart carry only deoxygenated blood that is why it is called as **Venous heart**.

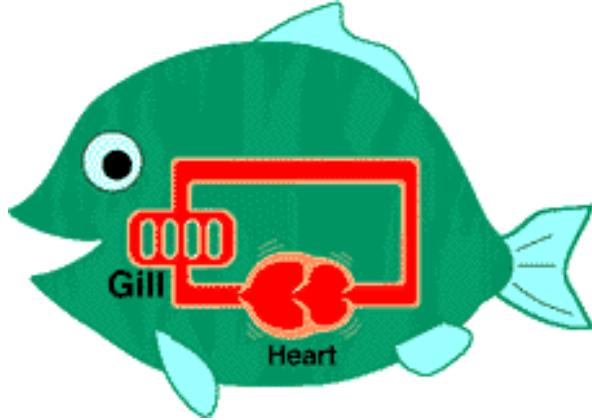


There are 3 basic type of heart found in animals: a **2 chambered** heart, a **3 chambered** heart, and a **4 chambered** heart. **Fish have 2 chambers, one atrium and one ventricle.** Amphibians and reptiles have 3 chambers: 2 atria and a ventricle. Crocodiles are the one reptilian exception, as they have 4 chambers (2 atria, 2 ventricles). Birds and mammals have 4 chambers (2 atria and 2 ventricles).



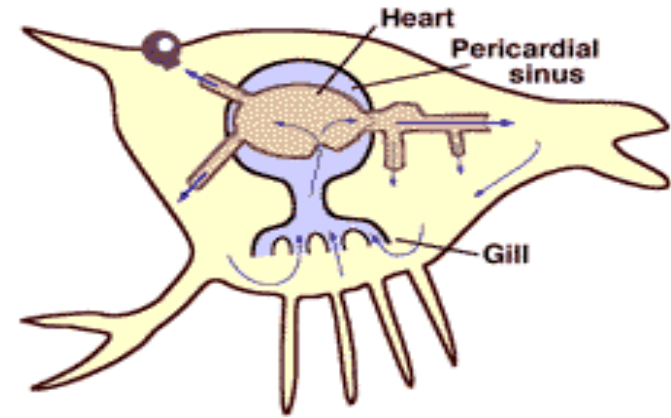
# Two type of circulatory system found in animal

## Closed circulatory system



Vertebrates, and a few invertebrates, have a closed circulatory system. Closed circulatory systems have the blood closed at all times within vessels of different size and wall thickness. In this type of system, blood is pumped by a heart through vessels, and does not normally fill body cavities.

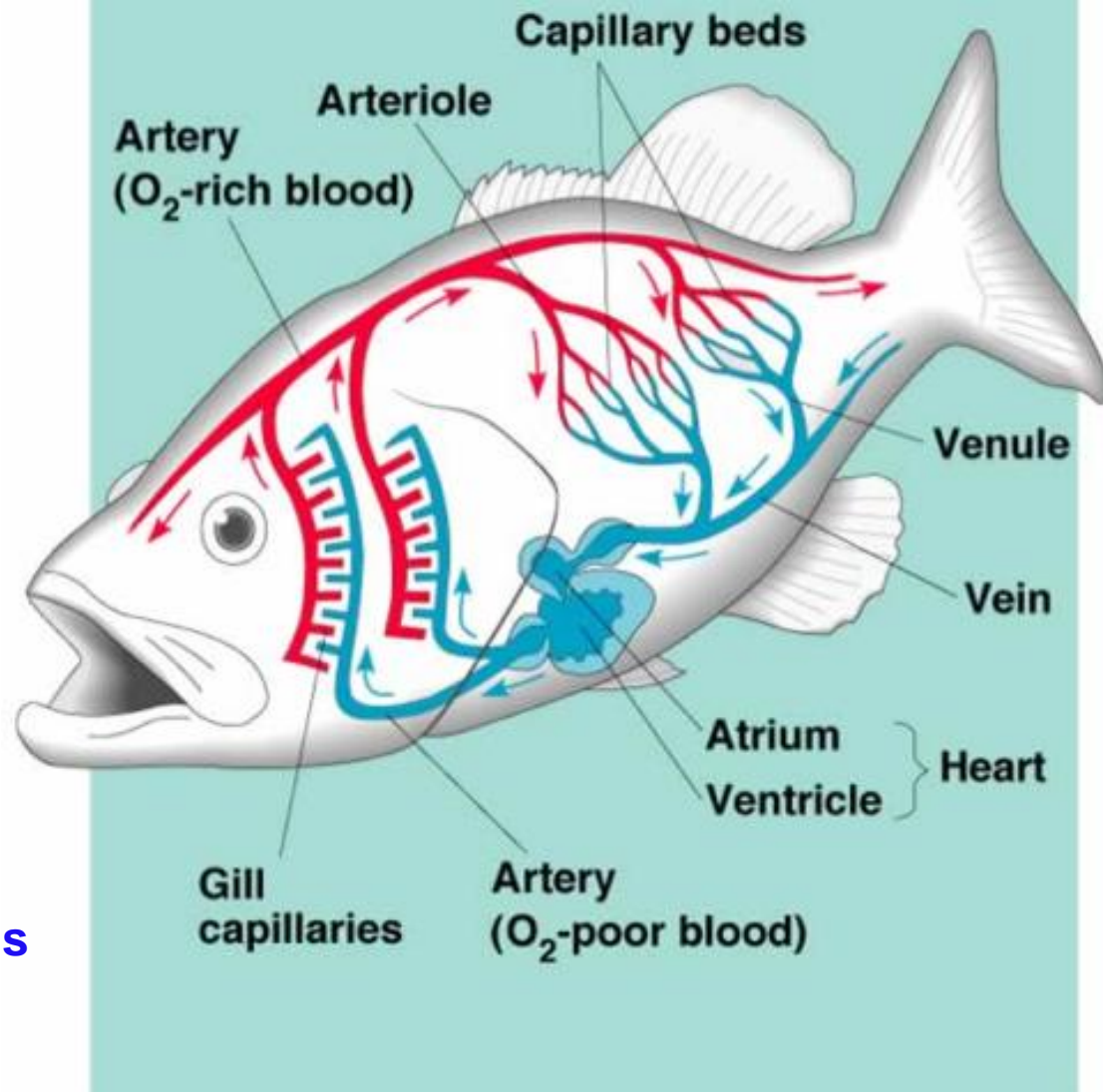
## Open circulatory system



The open circulatory system is common to **molluscs** and **arthropods**. Open circulatory systems (evolved in crustaceans, insects, mollusks and other invertebrates) heart pump blood into a hemocoel with the blood diffusing back to the circulatory system between cells. Blood is pumped by a heart into the body cavities, where tissues are surrounded by the blood.

# Circulatory system in fish

Fish have a closed circulatory system with a heart that pumps blood around the body in a single loop—from the heart to the gills, from the gills to the rest of the body, and then back to the heart. The fish's heart consists of four parts: the sinus venosus, atrium, ventricle, and the bulbus arteriosus.

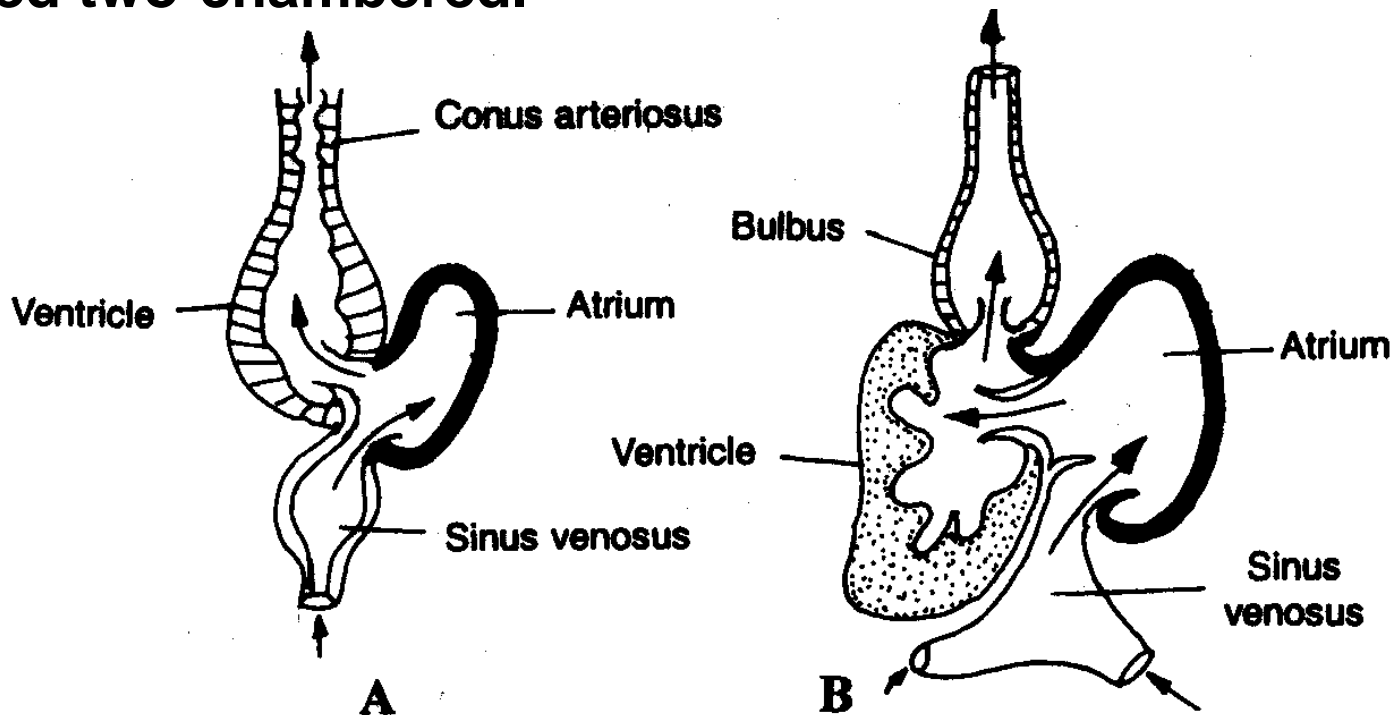


The circulatory system of fish is quite simple and consists of

- Heart
- Blood
- Blood Vessels

# The heart

Heart is a simple muscular structure that is located below the pharynx and immediately behind the gills. It is enclosed by the pericardial membrane or pericardium. In most of the fishes, the heart consists of an atrium, a ventricle, a sac-like thin walled structure known as sinus venosus and a tube, known as bulbus arteriosus. In spite of containing four parts, the heart of a fish is considered two-chambered.



Heart of **A** Chondrichthyes, and **B** Teleost.



**Sinus venosus:** The first chamber is called the sinus venosus, it is the preliminary collecting chamber. In teleosts it is filled from two major veins called the hepatic veins and the left and right branches of the Curvierian ducts which in turn collect blood from the paired (left and right) lateral veins the inferior jugulars, the anterior cardinals and the posterior cardinals. However in the elasmobranchs only one hepatic vein leads into it.

**Atrium.** From the sinus venosus the blood flows into the atrium. the atrium is the largest of the chambers and weakly muscular. It pushes the blood, with weak contractions in the ventricle.

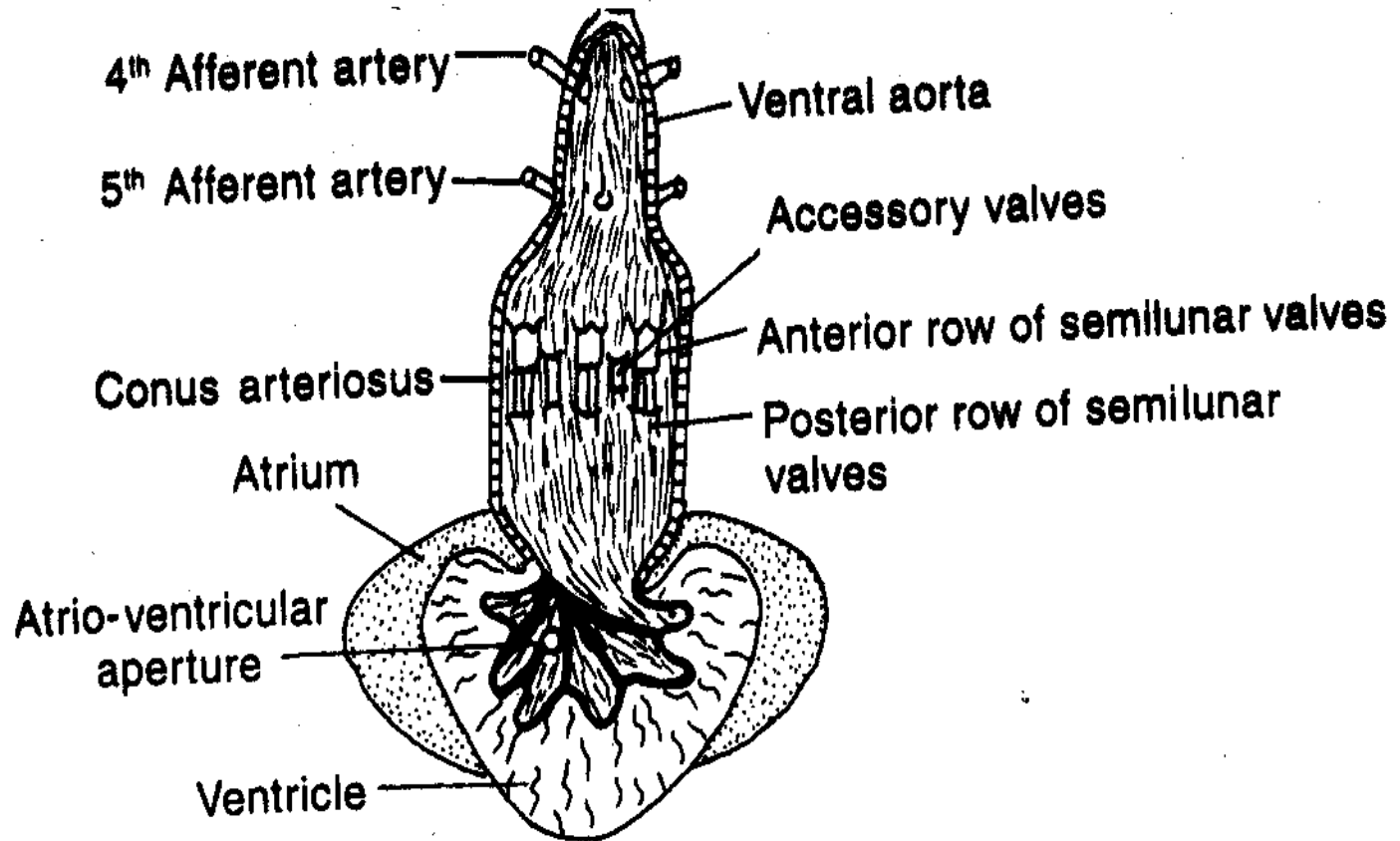
**Ventricle.** The ventricle is the only well muscled chamber, nearly as large as the atrium it is the work horse of the heart, its contractions drive the blood around the body.

## **Bulbus arteriosus**

**The last chamber of the fish heart is called the bulbus arteriosus in the teleosts, but the cornus arteriosus in the elasmobranchs. The difference between these chambers is that the cornus arteriosus of sharks and rays contains many valves while the bulbus arteriosus of bony fish contains none. Both are alike in being primarily elastic and work to reduce the pulsed nature of the blood leaving the ventricle giving it a more even, constant flow.**

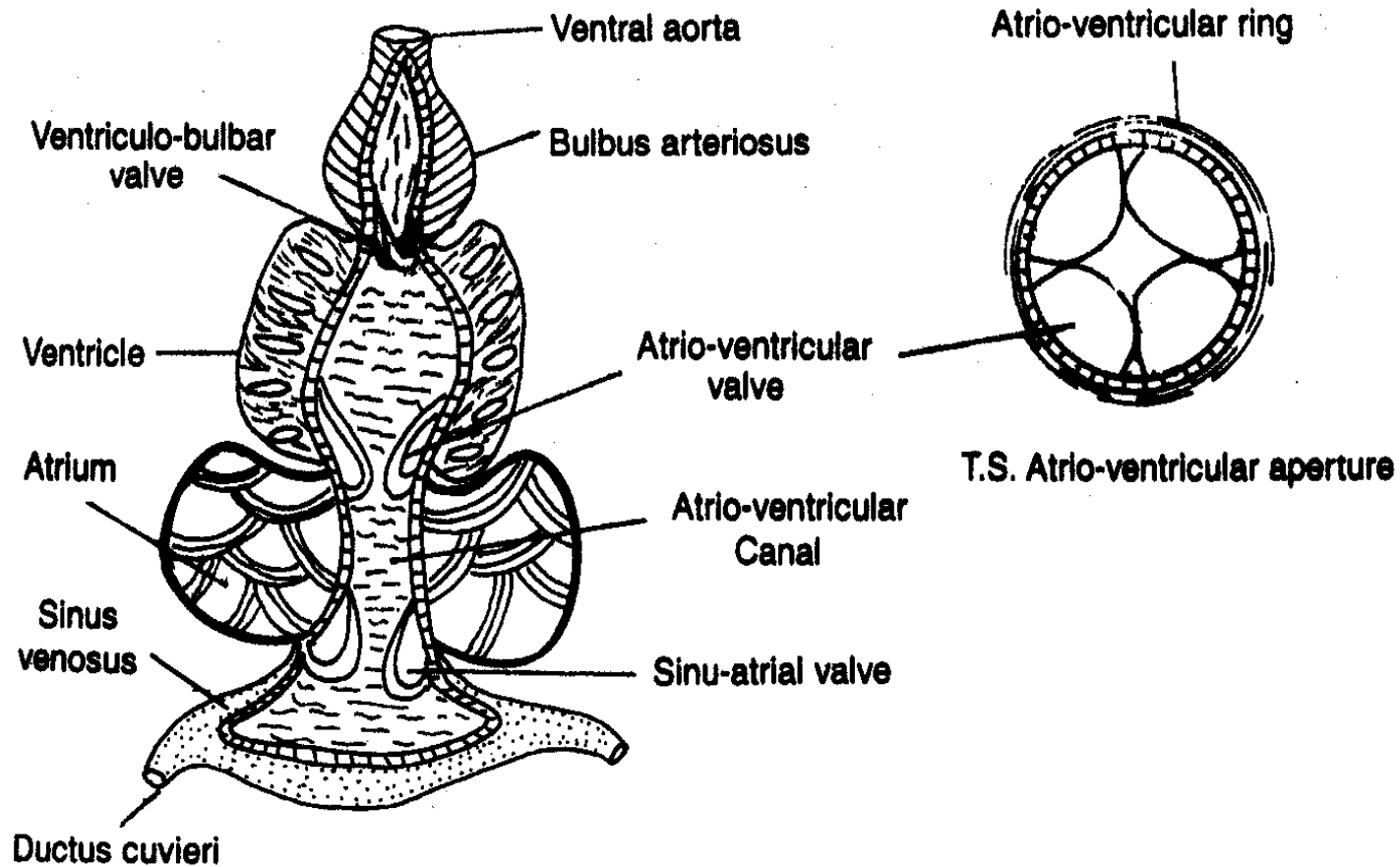


# Internal Structure of chondrichthys heart



Heart of *Scoliodon* dissected to show the internal structure.

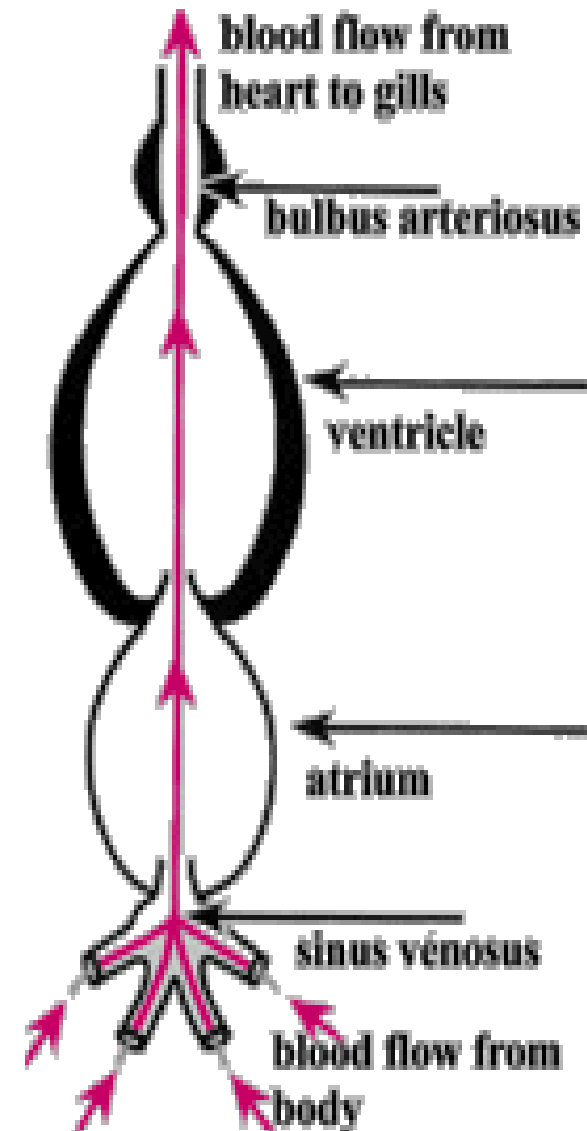
# Internal Structure of bony fish heart



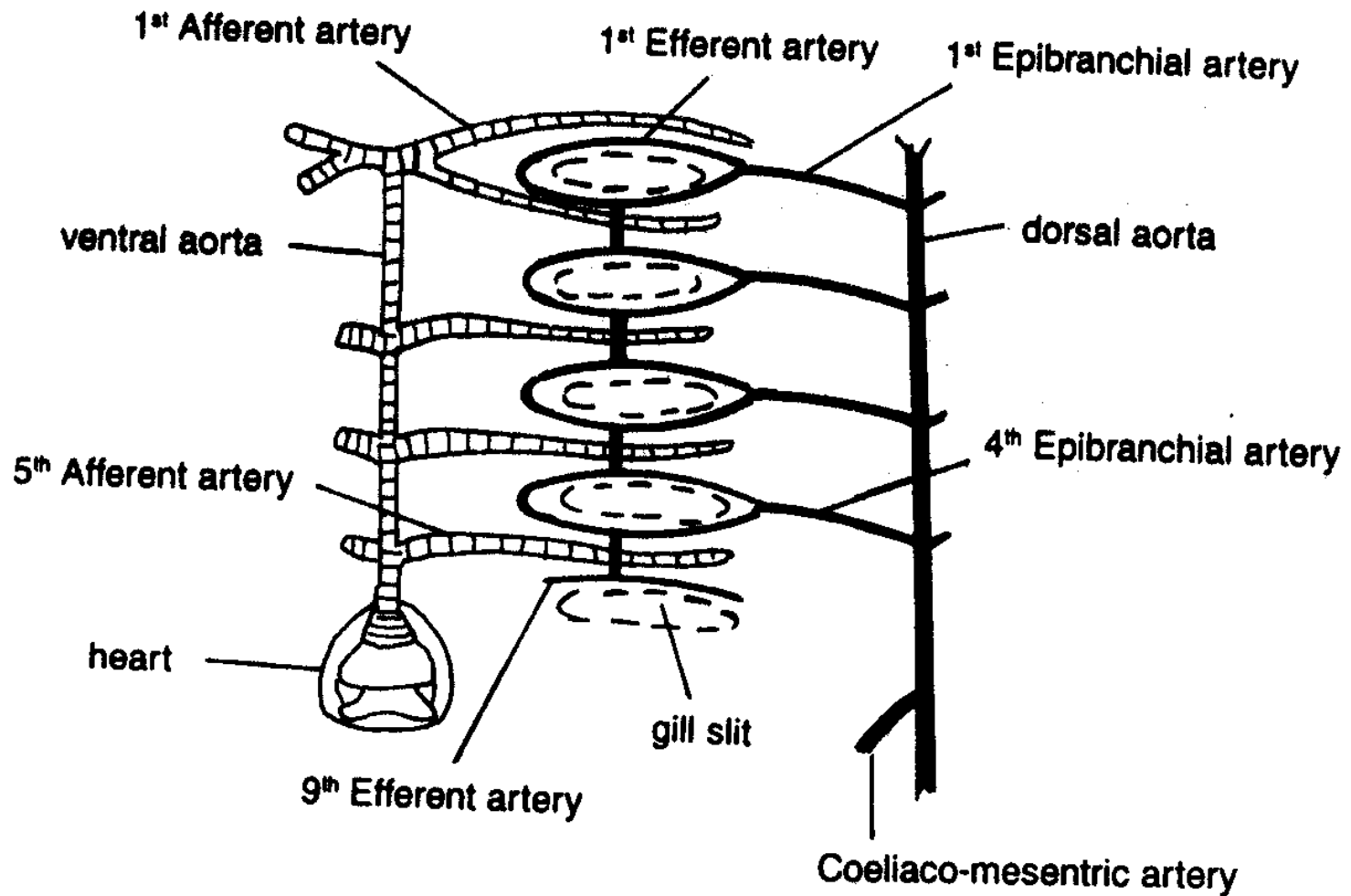
Heart of *Tor tor* dissected to show internal structure.

# Circulatory mechanism

The deoxygenated blood collected by the veins accumulates in the sinus venosus, before entering the heart. Blood first enters the atrium of the heart, which is a large chamber. Then it enters the ventricle, from where it is pumped into the tube, bulbus arteriosus. Through bulbus arteriosus, the blood reaches the aorta and then the gills. They facilitate the exchange of gases, i.e. absorption of oxygen from water and elimination of carbon dioxide. Then the oxygenated blood is transported throughout the body with the help of blood vessels. Blood facilitates the transport of oxygen and nutrients. It also collects carbon dioxide which is again transported to the heart and then to the gills, to be removed from the body.

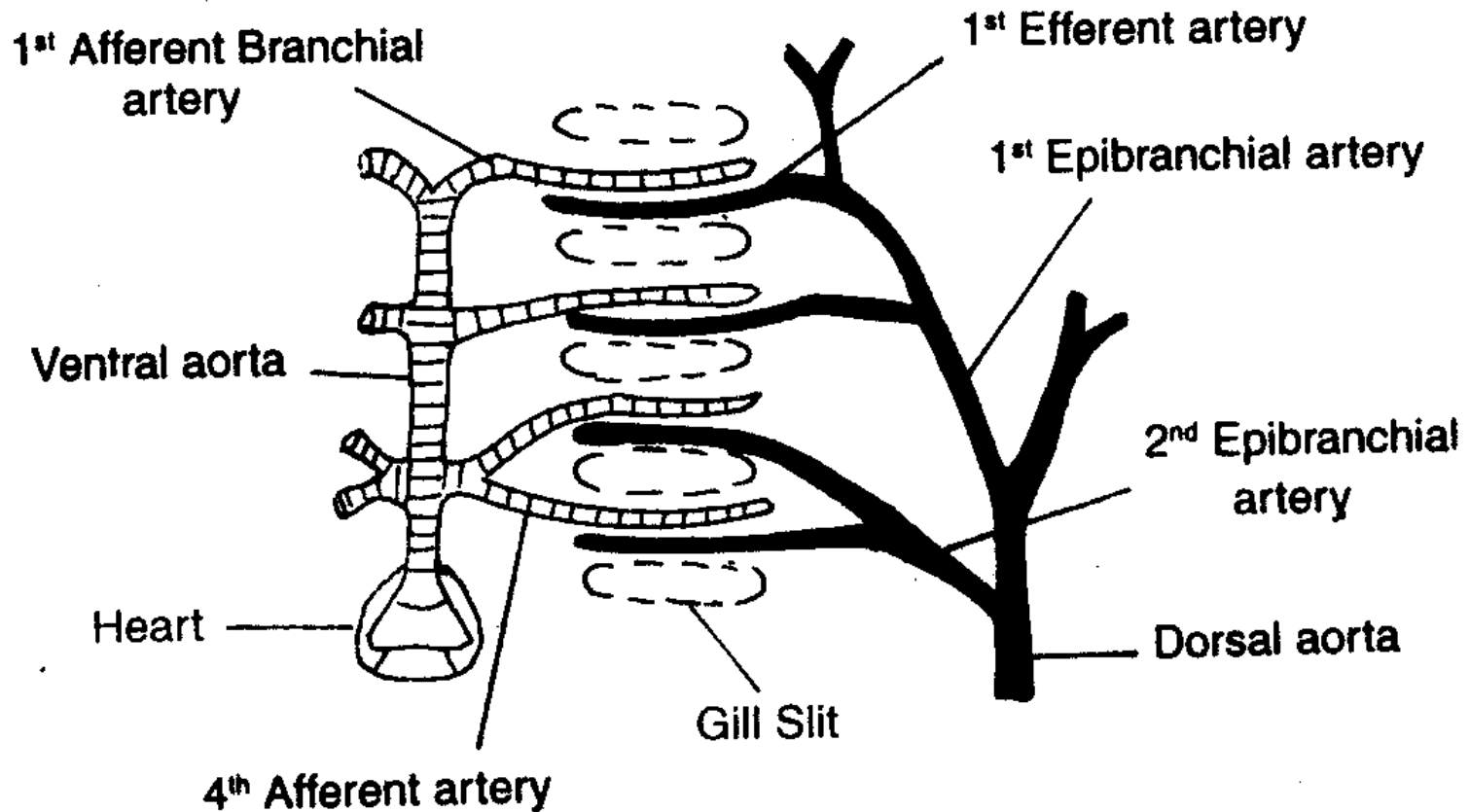


# Artery system in Elasmobranchs



Afferent and Efferent branchial arteries of *Scoliodon*.

# Artery system in Bony fish



Afferent and efferent branchial arteries of Mahseer (*Tor putitora*).

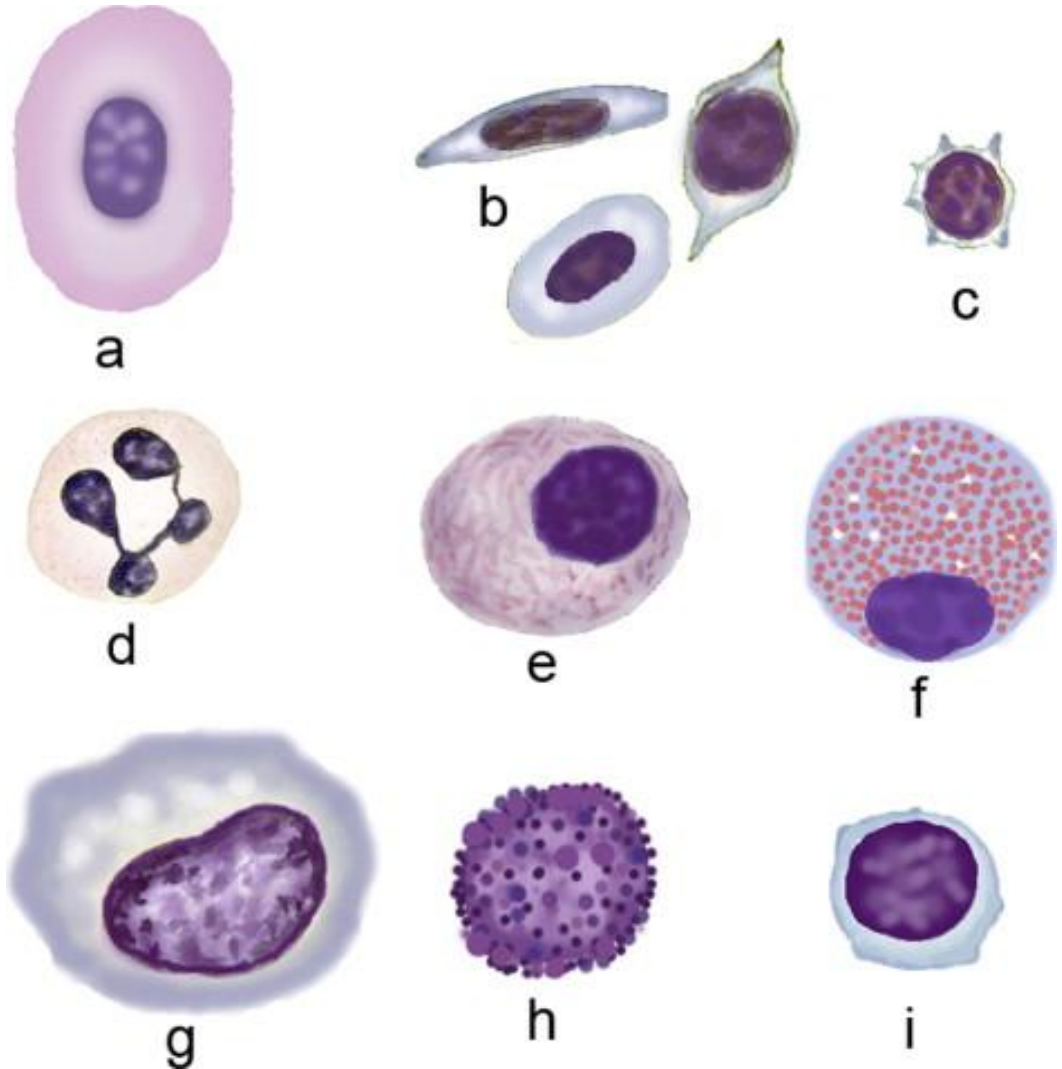
# Blood cells of fishes

The blood in fishes is red in color and consist of fluid plasma and blood cells. Red Blood cells, White Blood Cells and Thrombocytes are present in plasma

**RBC (erythrocytes) are nucleated, oval and contain haemoglobin**

The WBCs may be grannular or agranular. They are called basophils, acidophils, neutrophils, monocytes and lymphocytes

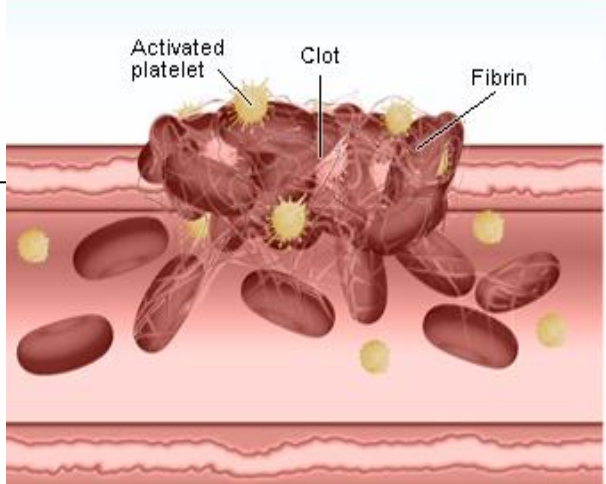
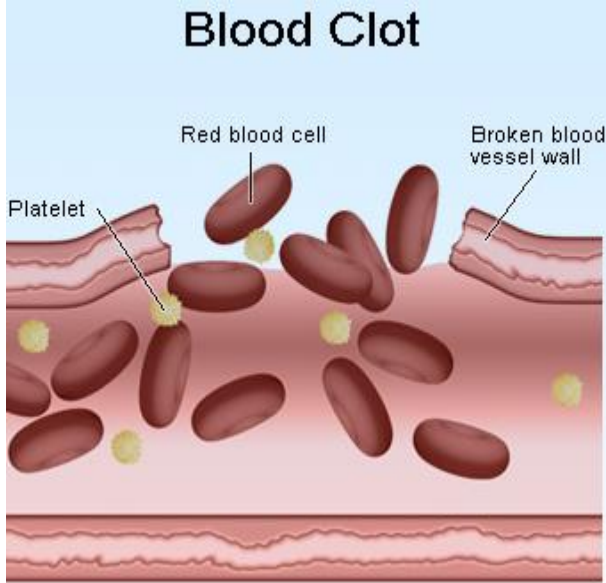
**Thrombocytes (responsible for blood coagulation)**



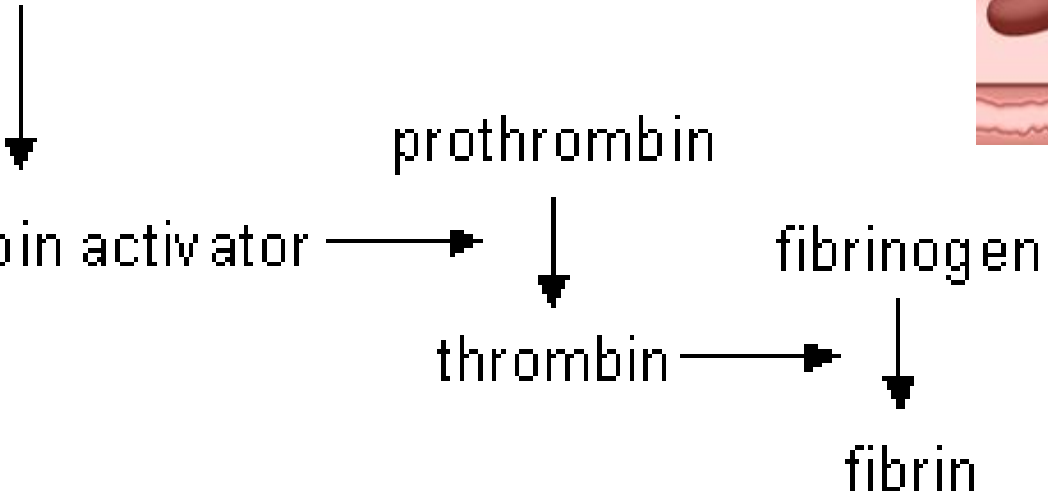
Erythrocyte (a), normal (b) and activated (c) thrombocytes, neutrophil of trout (d), heterophil of shark (e), eosinophil (f), monocyte (g), basophil (h), and lymphocyte (i).

# Details of Blood Clot Formation

- Blood clotting is initiated when platelets and damaged tissue secrete clotting factor called **prothrombin activator**
- Prothrombin activator and calcium ions catalyze the conversion of **prothrombin to thrombin** which then catalyzes the conversion of **fibrinogen to fibrin threads**.
- Fibrin threads are sticky and trap more platelets, further sealing the leak.



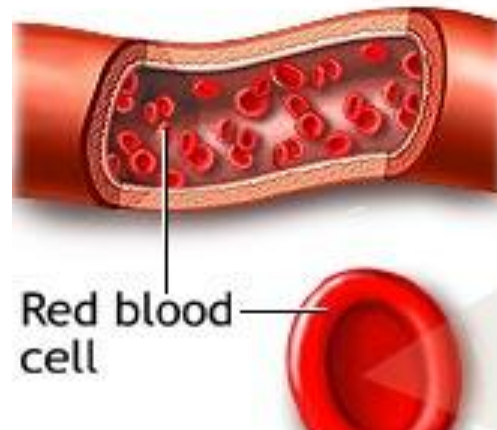
damaged tissue, platelets  
result in the production of:





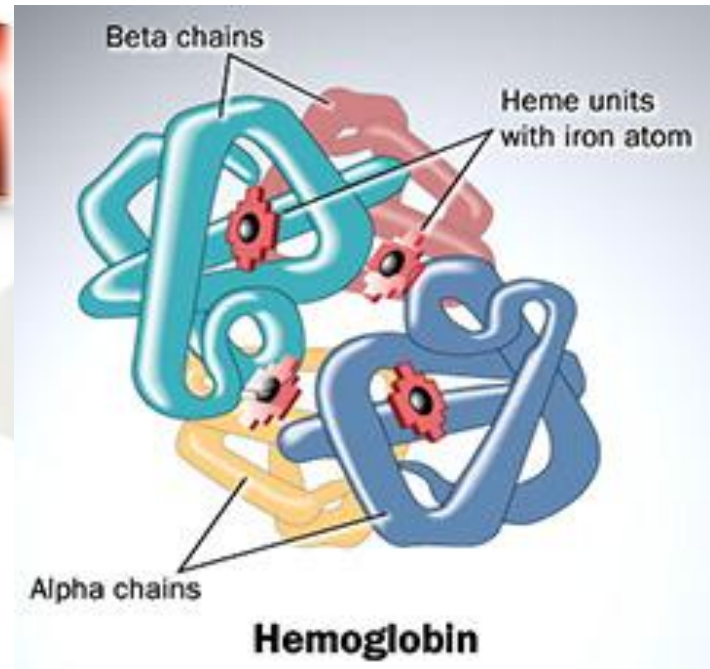
# Respiratory Pigment in Fishes: Hemoglobin

- ✓ Tetrameric hemoglobin has two  $\alpha$  and two  $\beta$  chain
- ✓  $O_2$  bind in reversible and cooperative fashion to four heme group while  $H^+$  and  $CO_2$  bind to specific amino acid residues in the globin chains
- ✓ But in fishes, due to acetylation of  $\alpha$  amino group only  $\beta$  chain available in bind to  $CO_2$



Red blood cell

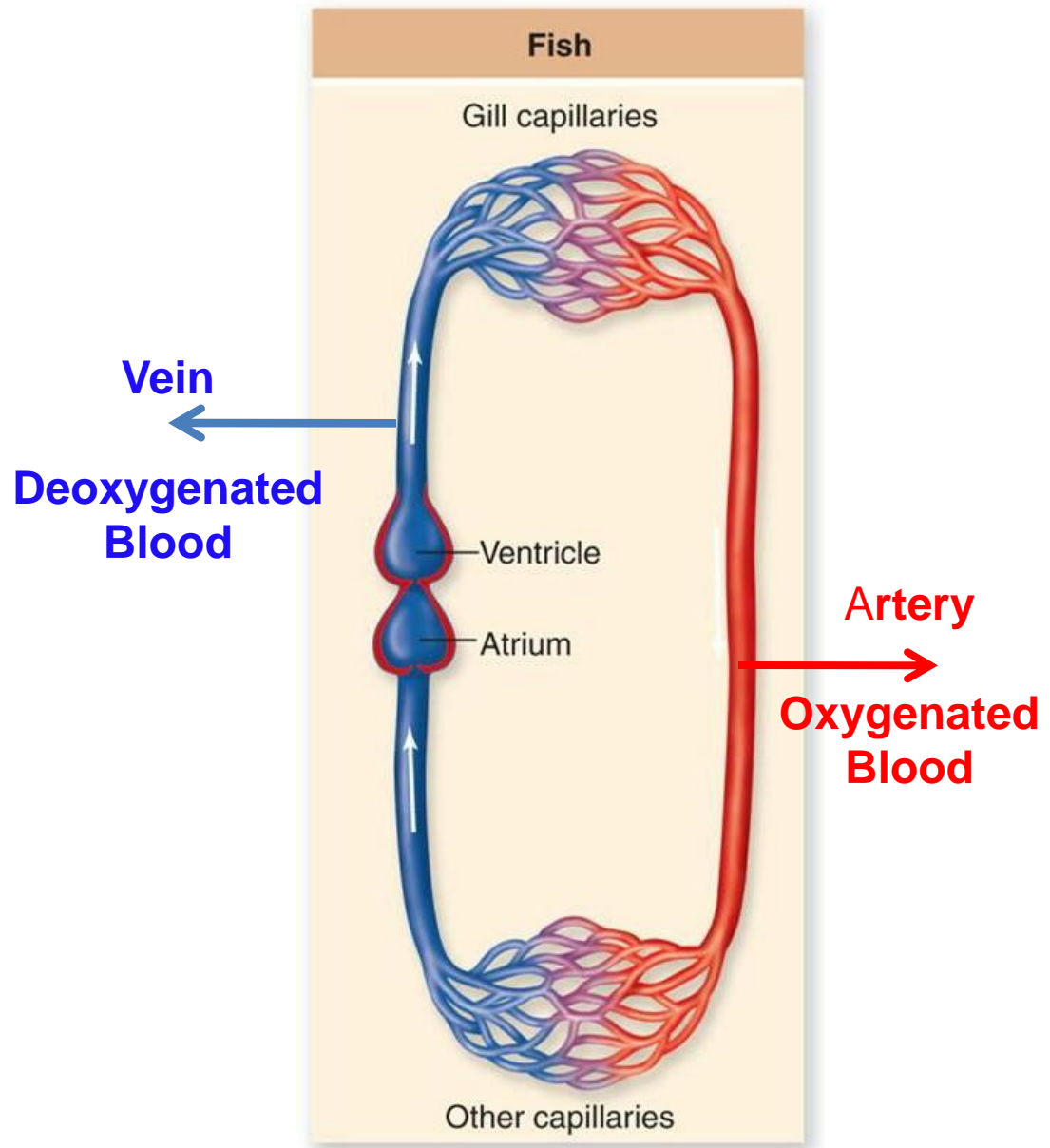
Red blood cells contain several hundred thousand hemoglobin molecules, which transport oxygen



Oxygen binds to heme on the hemoglobin molecule

# Blood vessels

The blood vessels are of two types, arteries and veins. The arteries are responsible for carrying oxygenated blood from the heart to the rest of the body, while the veins return deoxygenated blood from the different parts of the body to the heart.



# Circulatory system in Prawn

In prawn circulatory system is **open or lacunar type**, in which the **veins and capillaries are totally absent**. The blood vessels open into spaces. These spaces are without a proper epithelial lining and are called lacunae or sinuses. The sinuses together form the body cavity which looks like a coelom but filled with blood and devoid of epithelial lining is known as **haemocoel**

**Circulatory system in Palaemon consist of**

- 1. Pericardium**
- 2. Heart**
- 3. Arteries**
- 4. Blood Sinuses**
- 5. Blood Channels**
- 6. Blood**

**Pericardium:** it is a thin walled chamber around the heart and remain filled with haemo-coelomic fluid. The pericardiam cavity pumps blood into heart

**Heart:** it is a triangular and muscular structure and found in the pericardial sinus in the median dorsal part of thorax. There are **5 pairs of valvular opening**, the **ostia** in the wall of heart. The 1<sup>st</sup> pair in mid dorsal region, 2<sup>nd</sup> pair in mid ventral region, 3<sup>rd</sup> pair on posterior border, 4<sup>th</sup> pair lie antero-laterally and 5<sup>th</sup> pair posterio laterally.

**Arteries:** they are thick walled muscular tube, which arise from the heart and supply blood to different organs of body. Four main arteries are as follows:

- 1. Median ophthalmic artery:** It arises as a single median cephalic or ophthalmic artery from the apex of the heart. It runs forward to the head in mid dorsal line. Here is joins the two antennary arteries.

## 2. Antennary Arteries

originate from apex of the heart one from either of the median ophthalmic. It runs forward along the outer border of mandibular muscle and gives out the following branches:

- a. Pericardial branch (to pericardium)
- b. Gastric branch (to cardiac stomach)
- c. Mandibular Branch (to mandibular muscles)

It further passes forward and divided into two sub-branches

- a. Dorsal branch (Send an optic artery to eye, then bend inwards and form circulus cephalicus which gives off a pair of rostral arteries to rostrum)
- b. Ventral Branch (it divides into sub branches, one for antennary and second re-divided into two and antennal artery to antenna and other renal artery to renal organ)

**3. Hepatic artery: Paired arteries,** arise from the ventro-lateral sides of the roots of antennary arteries. They open into hepatopancreas.

**4. Median Posterior Artery:** It is small but stout artery which arises from the postero-ventral surface of the heart and runs backward. It immediately bifurcates into two branches

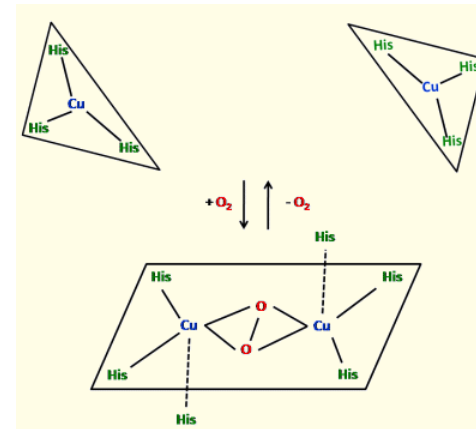
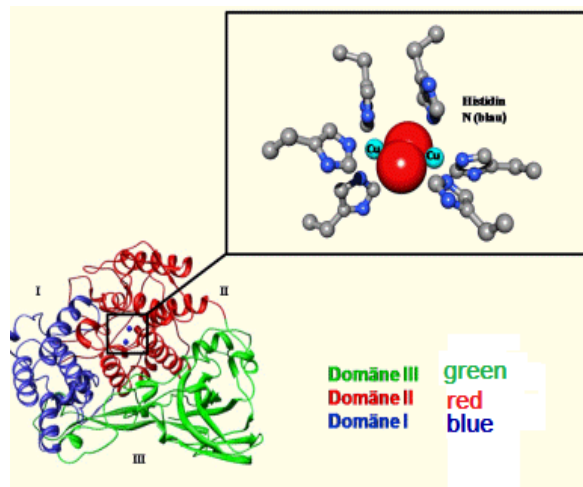
- a. Supra-intestinal artery (supply blood to intestine and abdominal muscle)
- b. Sternal Artery (divided into two ventral thoracic and ventral abdominal)

**Blood Sinuses:** Various arteries on reaching the organs, branch repeatedly in to minutes branch which **do not form capillaries but end in to wide space blood sinuses or blood lacunae**. All the blood lacunae of the body collectively form a pair of elongated but ill defined ventral sinuses. These lie below the hepatopancreas and above the floor of thorax

**Blood Channels:** In Palaemon, there are **6 pairs of afferent branchial channels** and **6 pair of efferent branchial channels**. These channels are lacunar in nature. The afferent branchial channels run along the inner surface of the thoracic wall and reach the gills through the gill roots. Here each channel open into transverse connective. **1<sup>st</sup> branchial channel takes blood to podobranch and two arthrobranch**, remaining **5 channels supply the blood to 5 pleurobranches**. The blood is oxygenated while passing the gills and this blood is carried to the pericardium by efferent branchial channels.

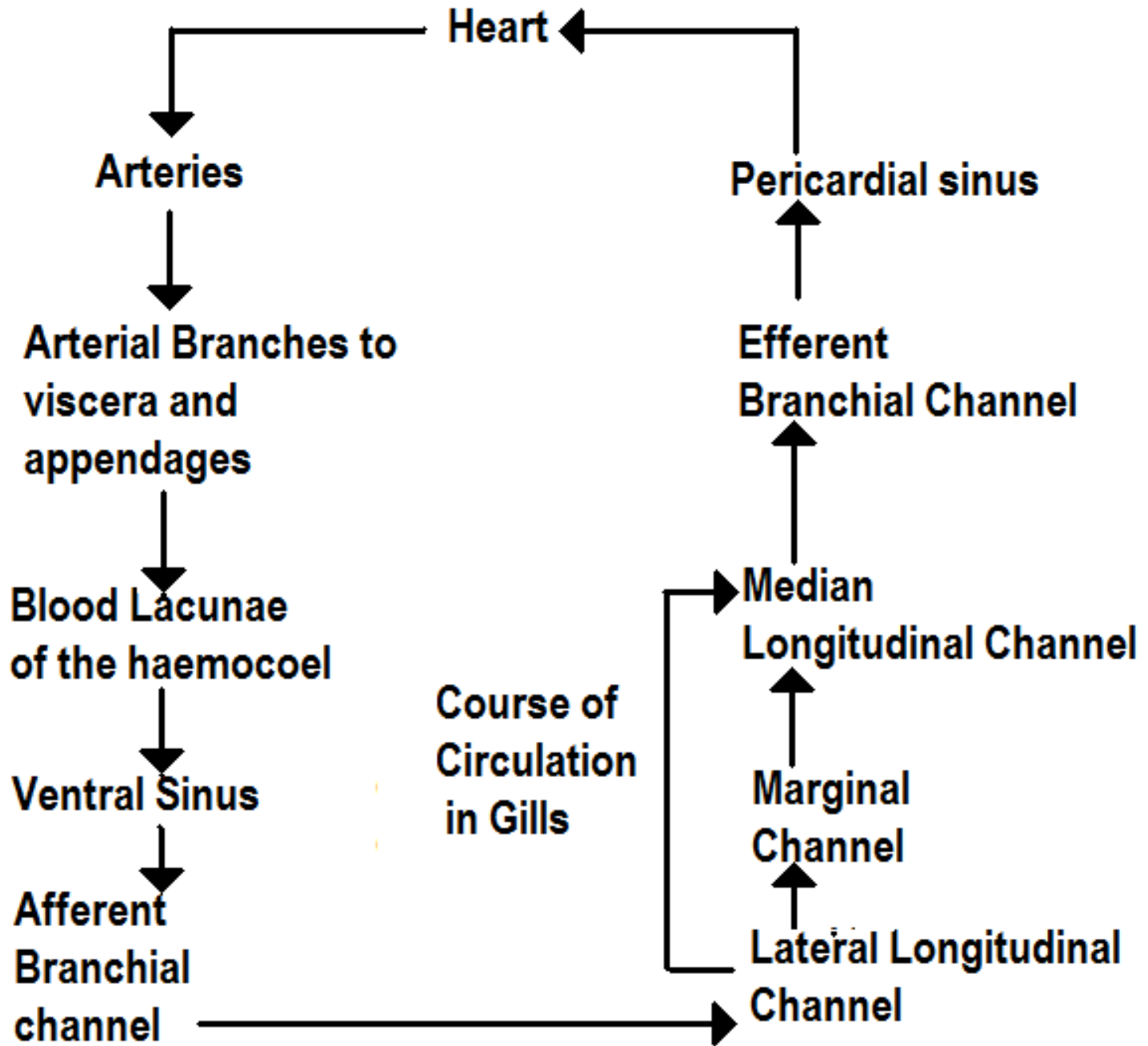
**Blood:** Thin, watery, almost colorless liquid containing floating **colorless ameobocytes**. The color of blood is white when it is deoxygenated and faintly bluish when it is oxygenated. This is due to the presence of respiratory pigment **haemocyanin**. There is also a lipochrome pigment called **zoonerythin** in the blood. Blood has the power of coagulation when it comes in contact with air.

**Haemocyanin (Respiratory pigments):** It is high molecular weight protein (75 kD) containing two copper (Cu) atoms. It is dissolved in blood plasma. Deoxygenated blood is white while oxygenated blood is blue in colour. Normal stability of oxygen binding is achieved only when the unit contain 8 copper atoms (tetramer). Oxygen carrying capacity is low compared to haemoglobin





# Course of Blood Circulation in Prawn



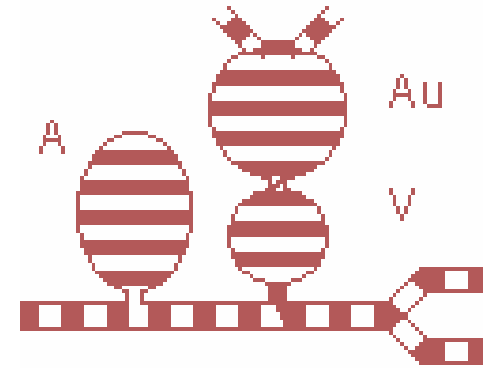
# Circulatory system in Apple Snail

The circulatory system consist of

## 1. Heart

## 2. Blood Vessel

## 3. Blood



**(I) Heart:** it is two chambered consist of an auricle and a ventricle and lies enclosed in the pericardium

**a. Pericardium:** thin walled oval chamber enclosing the heart and situated between the pulmonary chamber and the posterior renal sac

**b. Auricle:** thin walled roughly triangular sac highly contractile in nature. It receives blood from three main veins (a) efferent ctenidial vein (b) efferent renal vein and pulmonary vein. At lower end it is connected with ventricle through auriculo-ventricular aperture. This aperture is guarded by semi-lunar valves which prevent backflow of blood.

**c. Ventricle:** it is an ovoid sac lying below the auricle and has thick muscular and spongy walls. From the lower end of the ventricle arises a large artery the aortic trunk or **aortic ampulla**. The opening between ventricle and aorta is guarded by semi-lunar valves which prevent backflow of blood.

**(II) Blood Vessels:** It includes artery, sinus and veins.

**1. Arteries:** The aortic ampulla divides immediately into two branches

a. **Cephalic aorta** (it gives off three arteries on outer side and one artery on inner side)

(i) A cutaneous artery

(ii) A pair of oesophageal arteries

(iii) A thick pallial artery

(iv) A pericardial artery

After giving off above branches, reaches the posterior renal chamber and supplies both renal chambers by many renal arteries

The main branch of the cephalic aorta now runs along the left side of oesophagus and gives off a number of small branches to oesophagus and floor of the mantle cavity. On right side it divides into three branches (a) **Right pallial artery** (b) **right siphonal artery** and (c) **penial artery**

The main cephalic aorta again divides into 4 branches (a) **radular sac artery** (b) **a pair of optic arteries** (c) **a pair of tenacular arteries** and (d) **pedal arteries**

**b. Visceral aorta:** It passes through the visceral mass and supplies blood to the visceral organs by following branch:

- (i) A pericardial branch
- (ii) A gastric branch
- (iii) A number of small intestinal arteries
- (iv) A large digestive branch
- (v) many renal arteries

**2. Sinuses:** The ultimate branches of the arteries open into wide space without walls and called blood sinuses. In *Pila* there are four sinuses

- (1) Perivisceral
- (2) Peri intestinal
- (3) Branchio renal
- (4) Pulmonary

**3. Veins:** The vein carry venous blood from various part of body to auricle.

- (1) Afferent ctenidial vein
- (2) Efferent ctenidial vein
- (3) afferent renal vein
- (4) Efferent renal vein
- (5) the pulmonary vein

**(III) Blood:** Thin, watery, almost colorless liquid containing floating colorless ameobocytes. The color of blood is white when it is deoxygenated and faintly bluish when it is oxygenated. This is due to the presence of respiratory pigment haemocyanin.

# Course of Circulation in Apple Snail

