Evolution of Heart in Vertebrates:

The heart is an unpaired organ but its origin is bilateral. In an embryo the mesenchyme forms a group of endocardial cells below the pharynx. These cells become arranged to form a pair of thin endothelial tubes. The two endothelial tubes soon fuse to form a single endocardial tube lying longitudinally below the pharynx.

The splanchnic mesoderm lying below the endoderm gets folded longitudinally around the endocardial tube. This two-layered tube will form the heart in which the splanchnic mesoderm thickens to form a myocardium or muscular wall of the heart and an outer thin epicardium or visceral pericardium. The endocardial tube becomes the lining of the heart known as endocardium.

Folds of splanchnic mesoderm meet above to form a dorsal mesocardium which suspends the heart in the coelom. Soon a transverse septum is formed behind the heart which divides the coelom into two chambers, an anterior pericardial cavity enclosing the heart and a posterior abdominal cavity.

The heart is a straight tube but it increases in length and becomes S-shaped because its ends are fixed. Appearance of valves, constriction, partitions in the heart, and differential thickenings of its walls form three or four chambers in the heart.

1. Single-Chambered Heart:

In Amphioxus (primitive chordate), a true heart is not found. A part of ventral aorta beneath the pharynx is muscular and contractile and acts as heart.

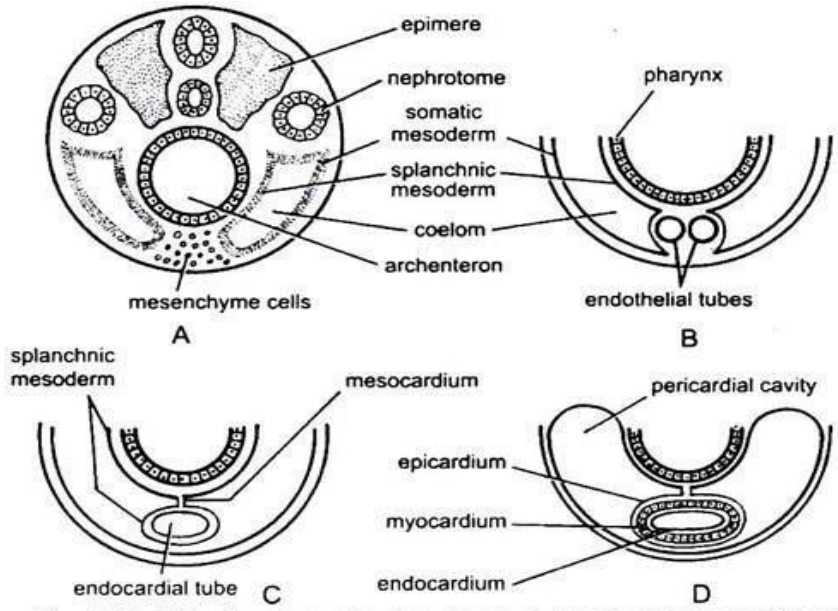

Fig. 45.2. T.S. of embryo showing stages in the development of heart.

2. Two-Chambered Heart:

In cyclostomes, there are four chambers arranged in a linear order- a thin-walled sinus venosus, a slightly muscular atrium (auricle), a muscular ventricle and a muscular conus arteriosus or bulbus cordis. It lies in the body cavity in which other visceral organs are also present.

Out of four chambers, only atrium and ventricle correspond to the four chambers (paired atria and paired ventricles) of the higher vertebrates. In the evolution of heart many changes have taken place.

Elasmobranchs:

Except Dipnoi, the circulatory system in fishes from cyclostomes to teleosts, only unoxygenated blood goes to the heart, from there it is pumped to the gills, aerated and then distributed to the body. The heart of cartilaginous dogfish is muscular and dorsoventrally bent S-shaped tube with four compartments in a linear series.

They are sinus venosus and atrium for receiving venous blood, and a ventricle and conus arteriosus for pumping this blood. The heart is a branchial venous heart. The sinus venosus and conus arteriosus are accessory chambers. Atrium and ventricle are true chambers, thus, it is a 2-chambered heart.

The sinus venosus opens anteriorly into atrium through sinu-atrial aperture guarded by a pair of valves. Atrium lies dorsal to ventricle and opens ventrally into ventricle through an atrio-ventricular aperture guarded by a pair of valves. The thick-walled, muscular ventricle opens into a narrow conus arteriosus containing valves in two series.

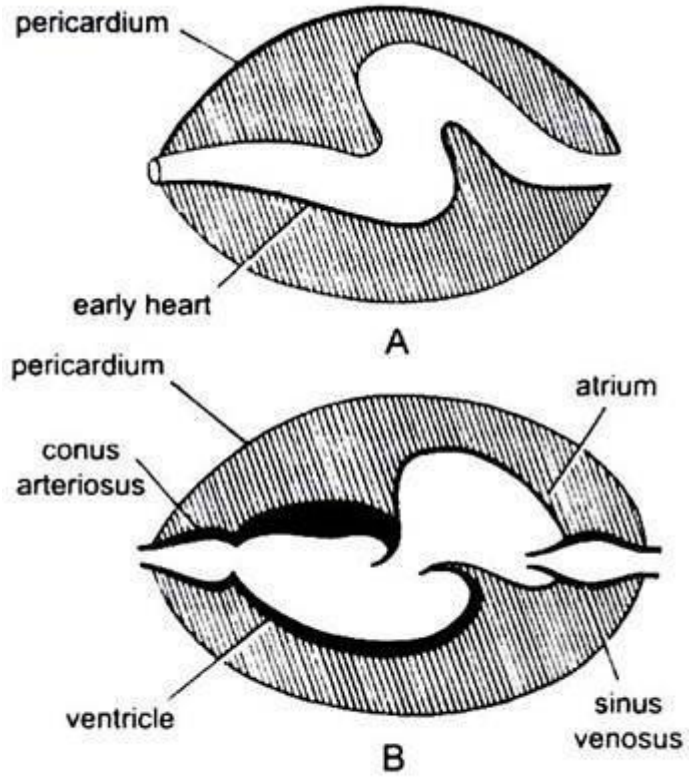

Fig. 45.3. Stages in the formation of heart.

The heart is enclosed within pericardial cavity separated from body cavity by a transverse septum. Conus pierces the pericardium and becomes continuous with the ventral aorta. Pericardial cavity communicates with the body cavity through two perforations in the transverse septum.

Teleosts:

Their heart resembles to that of clasmobranchs. In teleosts, the conus is reduced and has a single pair of valves. The proximal part of ventral aorta close to conus becomes greatly enlarged and thick-walled, called bulbus arteriosus. It is elastic and dilates at the time of ventricular contraction. The heart is, thus, 2-chambered with a single circulation of blood.

3. Three-Chambered Heart:

In dipnoans a septum divides the atrium into a right and left chamber. This is correlated with the use of the swim-bladder as an organ of respiration and represents the first step toward the development of the double-type circulatory system whereby both oxygenated and unoxygenated blood enter the heart and are kept separate.

Blood from right auricle of the lungfish passes into the right ventricle and is then pumped into the primitive lung-like gas bladder by pulmonary arteries which branch off from the sixth pair of aortic arches. The oxygenated blood returns to the left atrium by way of pulmonary veins like amphibians.

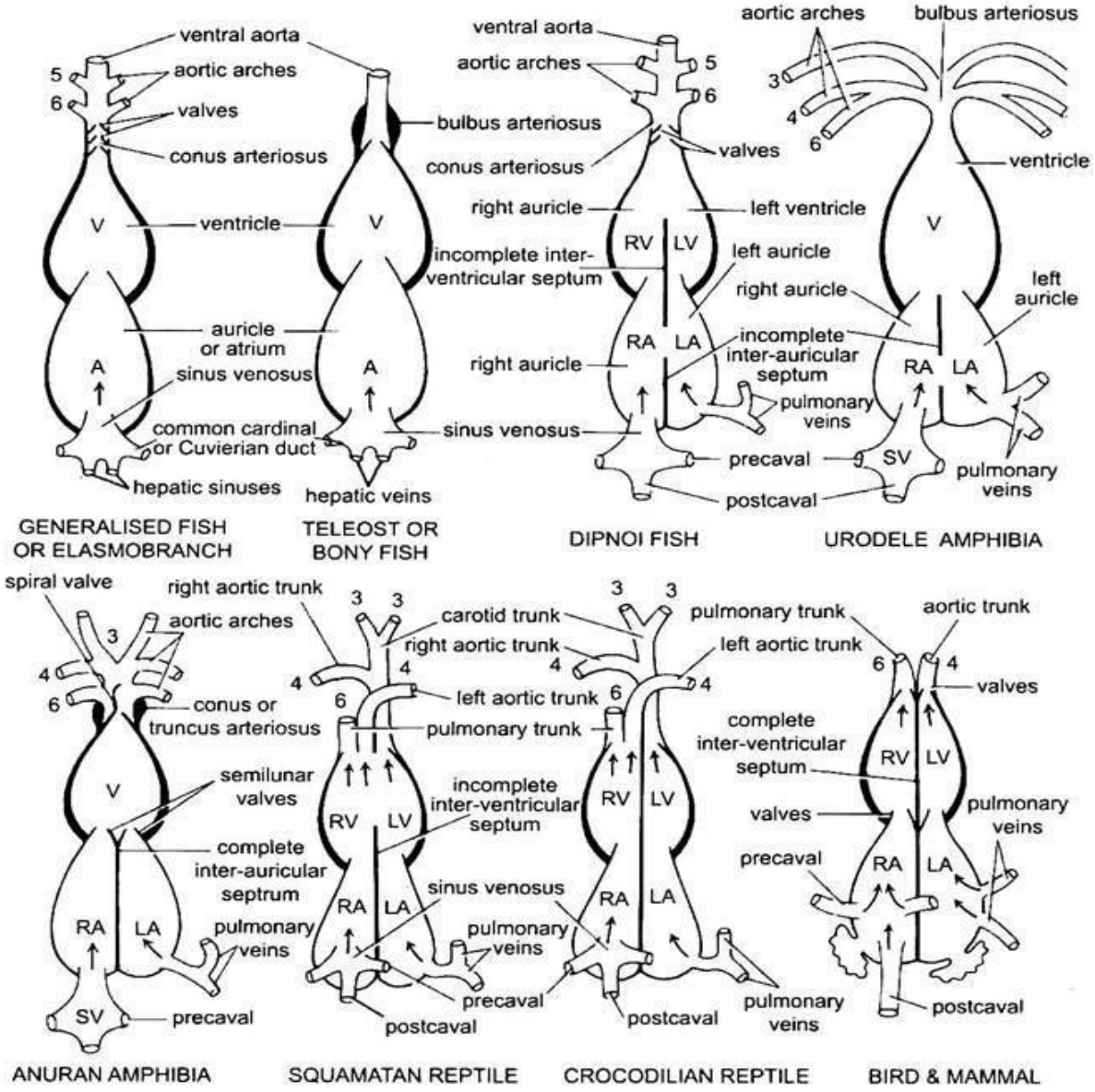

Fig. 45.4. Evolution of heart in different classes of vertebrates.

Amphibia:

In amphibians, the dorsal atrium shifts anterior to ventricle. The sinus venosus opens into right atrium dorsally and not posteriorly. The atrium is completely divided into right and left chambers and has no foramen ovale in the inter-auricular septum, which remains open in dipnoans.

Deep pockets develop in the ventricular cavity. The conus arteriosus divides into systemic and pulmonary vessels by a spiral valve. In lung less salamanders, the inter-atrial septum is incomplete and pulmonary veins are absent.

Reptilia:

In reptiles, the heart is further advanced. The atrium is always completely separated into a right and left chamber, and in many forms the sinus venosus is incorporated into the wall of the right atrium. The ventricle is also partly divided by a septum in most reptiles, and in the alligators and crocodiles is completely two-chambered.

This means that oxygenated blood coming from the lungs to the left side of the heart is essentially separated from the non-oxygenated blood from the body to the right side. Thus, in crocodilians, the two types of blood is completely separated, and nearly complete in other reptiles, but some mixing does occur in other parts of the circulatory system.

The embryonic conus arteriosus splits into three instead of two vessels:

(i) Pulmonary arch carrying blood to the lungs from right side of the ventricle.

(ii) Right systemic aorta carrying blood from left side of the ventricle to the body by way of right fourth aortic arch.

(iii) Left systemic comes from the right ventricle to the left fourth aortic arch.

At the point of contact with the systemic aorta from the left ventricle, even in crocodilians, an opening between the two is present, called the foramen of Panizzae where there may be some mixing of the two types of blood. Thus, reptilian heart represents the transitional heart against amphibian heart-2 complete auricles and 2 incomplete ventricles with a little mixing of blood in right and left systemic.

4. Four-Chambered Heart:

Aves and Mammalia:

In birds, the ventricle is completely divided into two, so that the heart is four chambered (2 auricles and 2 ventricles). There is complete separation of venous and arterial blood. The systemic aorta leaves the left ventricle and carries blood to the head and body. While the pulmonary artery leaves the right ventricle and carries blood to the lungs for oxygenation.

Thus, there is double circulation in which there is no mixing of blood at any place. The sinus venosus is completely incorporated into right auricle, which receives two precavals and a postcaval. The left auricle receives oxygenated blood through pulmonary veins, conus arteriosus is absent, the pulmonary aorta arises from the right ventricle, and single systemic aorta arises from the left ventricle, and both have valves at their bases.