SEM 4 (UG)

JOYDEEP DAS ,DEPT OF ZOOLOGY

Comparative anatomy of HEART

General account :The heart is a hollow muscular organ that rythmically contracts and relaxes. During each contraction-relaxation cycle, blood is drawn from the veins into a thin walled collecting chamber, the atrium, and is then passed to a second thick walled chamber, the ventricle, which forceably contracts to distribute the blood to the arteries. Backflow is prevented by one-way valves.

Note that the partial septum in the reptile ventricle becomes a complete divider in birds and mammals.The progressive changes in the heart between ancestral vertebrates, the fishes, and the most derived forms, the birds and mammals.

Fish have a simple two chambered heart which is, in essence, just a thickening of a section of the circulatory system, and the blood flows in a single circuit from heart to gills to body and back to the heart. Starting with the amphibians, the first of the vertebrates with lungs, the circulatory system adds a second loop or circuit. This design has the blood flow through the heart twice on each trip around the system, once on the way to the lungs and once on the way back from the lungs, giving it an extra boost. This is called double circulation. In amphibians, with two atria but only a single ventricle, this results in the mixing of deoxygenated and oxygenated blood, but amphibians also gather oxygen through their moist skin, so this inefficiency is not critical. Beginning with the reptiles, a septum or wall develops that partly divides the deoxygenated from the oxygenated blood in the ventricle, and this is important because reptiles, with a watertight skin, rely entirely on their lungs for oxygen. Reptiles also have the unique ability to redirect or shunt blood leaving the heart back through the heart without passing through the body circuit, and to shunt deoxygenated body blood back through the body without going to the lungs. The purpose of this shunt (see the purple vessels in the figure below)

is not entirely understood. The former is thought to be a way to prioritize oxygenation of the heart during periods of high exertion, while the latter is believed to be a way to enhance digestion, because of increased acidity of deoxygenated blood due to carbon dioxide buildup. Among the extant reptiles, only the crocodilians have fully extended the septum and have a four-chambered heart, but there is speculation that dinosaurs may have had this innovation as well. Birds and mammals have the same four-chambered design, which has increased efficiency because deoxygenated and oxygenated blood cannot mix.

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.

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 conusarteriosus or

bulbuscordis. 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 conusarteriosus for pumping this blood. The heart is a branchial venous heart. The sinus venosus and conusarteriosus 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 conusarteriosus containing valves in two series. 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 bulbusarteriosus. It is elastic and dilates at the time of ventricular contraction. The heart is, thus, 2-chambered with a single circulation of blood.

1. The heart is covered by a transparents protective covering , called pericardium.

2. Heart of fished consisit of Sinus venosus, single auricle, single ventricle.

3. No conusarteriosus present

4. Sinus venosusia thin walled sac. It receives deoxygenated blood by 2 pre caval veins.

5. Sinus venosus opens to the auricle by sinuauricular aperture, guarded by valves.

6. Auricle is thin walled sac ,its open to ventricle through auriculo ventricular aperture.

7. Ventricle is single ,thick walled ,forwarding chamber of the heart.

8. The bulbus aorta present in heart.

3. Three-Chambered Heart: In diphoans 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 unoxygenatedblood 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.

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 conusarteriosus 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.

1. Heart of amphibian consists of 3 main chambers and 2 accessary chambers

2. 2 auricle, 1 ventrcle, sinus venosus, conusarteriosus.
3. Spiral valve present in ventricle.
4. From ventricle tube like structure arise, which is known as conusarteriosus , which proceed forward as truncusarteriosus.

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 conusarteriosus splits into three instead of two vessels:

(i) Pulmonary arch carrying blood to the lungs from right side of the ventricle.
(ii) (ii) Right systemic aorta carrying blood from left side of the ventricle to the body by way of right fourth aortic arch.
(iii) (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, conusarteriosus is absent, the pulmonary aorta arises from the right ventricle, and single systemic aorta arises from the left ventricle, and both have valves.

In mammals,,

1. 4 chambers present.

2. 2 auricles and 2 ventricles (right and left for both).

3. Sinus venosus absent, right auricle receives deoxygenated blood by anterior and posterior vanacavae.

4. Left auricles receive oxygenated blood from pulmonary arteries.

5.Auricles are separated by intra auricular septum , which bears oval shaped depression , called fossa ovalis. This depression indicates the positions of foramen of ovale.

6. The auricle open into the ventricles by separate apertures. The left auriculo- ventricular aperture is provided with bicuspid or mitral valve

The right auriculo- ventricular aperture is provided with tricuspid valve.

7. The right ventricle gives rise to pulmonary arch and the left ventricle gives rise to systemic arch. The opening of arches are guarded by semilunar valves.