Comparative Physiology and Physiological Chemistry
MZO503
PART III

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COMPARATIVE PHYSIOLOGY OF CIRCULATION

CIRCULATORY SYSTEM

The circulatory system is made up of blood vessels that carry blood away from and towards the heart. Arteries carry blood away from the heart and veins carry blood back to the heart. The circulatory system carries oxygen, nutrients, and hormones to cells, and removes waste products, like carbon dioxide.

There are a few vital functions that all circulatory systems must serve. These include:

- Transporting the oxygen that is necessary for cellular respiration
- Transporting nutrients from food, which are necessary for cellular respiration and other functions
- Transporting waste products of cellular respiration and other functions, which could otherwise build up to toxic levels within the body
- Transporting any necessary messages between cells, such as hormones signaling hunger, thirst, oxygen deprivation, or other bodily needs.
- Transporting immune cells which can fight infection to any area of the body where they might be needed.

Arteries

Oxygenated blood enters the systemic circulation when leaving the left ventricle, through the aortic semilunar valve. The first part of the systemic circulation is the aorta, a massive and thick-walled artery. The aorta arches and gives branches supplying the upper part of the body after passing through the aortic opening of the diaphragm at the level of thoracic ten vertebra, it enters the abdomen. Later it descends down and supplies branches to abdomen, pelvis, perineum and the lower limbs. The walls of aorta are elastic. This elasticity helps to maintain the blood pressure throughout the body. When the aorta receives almost five litres of blood from the heart, it recoils and is responsible for pulsating blood pressure. Moreover, as aorta branches into smaller arteries, their elasticity goes on decreasing and their compliance goes on increasing.

Capillaries

Arteries branch into small passages called arterioles and then into the capillaries The capillaries merge to bring blood into the venous system.

Veins

Capillaries merge into venules, which merge into veins. The venous system feeds into the two major veins: the superior vena cava – which mainly drains tissues above the heart – and the inferior vena cava – which mainly drains tissues below the heart. These two large veins empty into the right atrium of the heart.

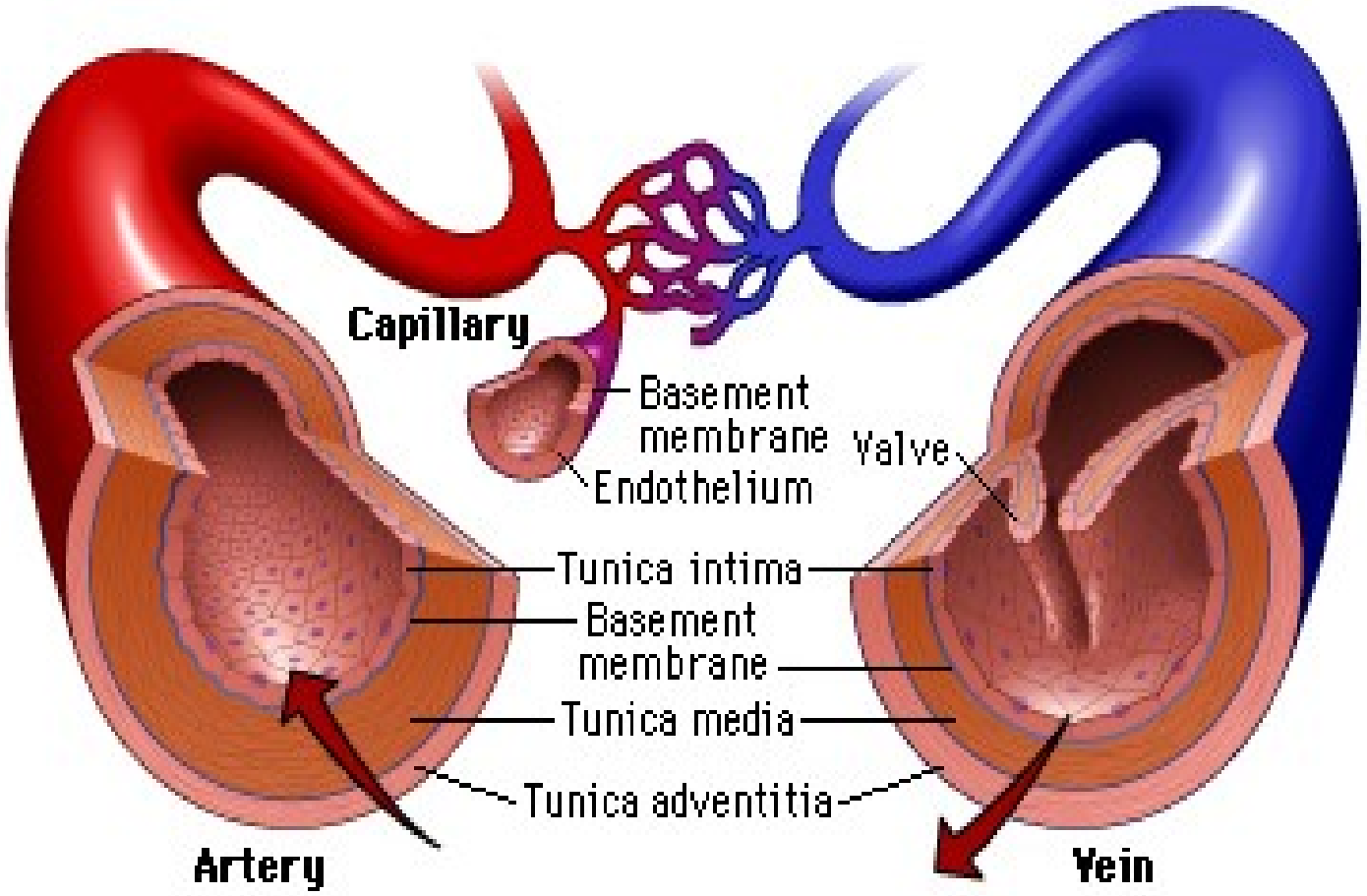


DIAGRAM SHOWING ARTERIES, VEINS AND CAPILLARIES

Circulatory System is broadly divided into two categories, which are:

- **OPEN CIRCULATORY SYSTEM**

➢The open circulatory system is the simpler of the two systems.

➢This system is common among arthropods. The heart pumps blood - or as it is commonly known for open circulatory systems, hemolymph - into an open cavity called a hemocoel.

➢The hemolymph mixes with interstitial fluid and sloshes around the hemocoel, bathing the internal organs and delivering nutrients and in some cases, gases such as oxygen.

➢In some animals, the heart is simply an aorta or other blood vessel, and the hemolymph is pulsed throughout the body by muscle contractions.

➢There are no arteries or major veins to pump the hemolymph, so blood pressure is very low.

➢Organisms with an open circulatory system typically have a relatively high volume of hemolymph and low blood pressure.

➢Examples of animals with open circulatory systems include insects, spiders, prawns and most mollusks.

- Open circulatory systems are systems where blood, rather than being sealed tight in arteries and veins, suffuses the body and may be directly open to the environment at places such as the digestive tract.
- Open circulatory systems use hemolymph instead of blood. This "hemolymph" performs the functions of blood, lymph, and intestinal fluid – which are three different, highly specialized fluids in animals with closed circulatory systems.
- Instead of a complex and closed system of veins and arteries, organisms with open circulatory systems have a "hemocoel."
- This is a central body cavity found inside most invertebrate animals where both digestive and circulatory functions are performed.
- This hemocoel may have "arteries" through which the blood can reach tissues – but these arteries are not closed and do not circulate blood as quickly as closed, muscle-assisted arteries.
- Within the hemocoel, hemolymph directly absorbs nutrients from food and oxygen from the lungs or breathing pores. It also contains immune cells – but hemolymph does not have red blood cells like our own.
- Instead of using hemoglobin to carry oxygen, organisms with open circulatory systems use blue or yellow-green pigments to carry oxygen throughout the body.

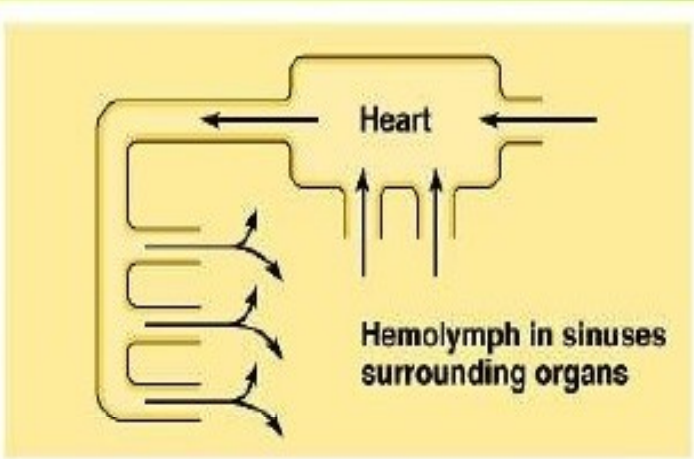
➢Many animals that use open circulatory systems do have a heart– but the heart only pumps hemolymph to different cavities in the hemocoel.
➢From these branches of the central body cavity, blood and the oxygen and nutrients it contains must penetrate the tissues and then return to the heart without the help of highly specialized pathways or muscle-assisted arteries like vertebrates possess.
➢Open circulatory systems are used by arthropods and most mollusks.
➢This is one or several reasons why there are no giant insects; open circulatory systems are less efficient than closed circulatory systems, and cannot move oxygen efficiently enough to power large bodies.

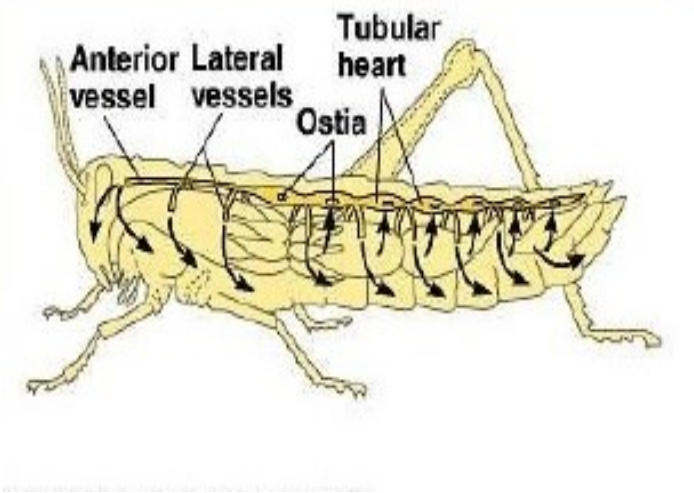
Advantages of the Open System

➢The open circulatory system requires less energy for distribution. This system is more suited to animals that have a slower metabolism and a smaller body.
➢Due to the absence of arteries, blood pressure remains low, and oxygen takes longer to reach the body cells. If an organism has a low metabolism, meaning it is generally less active in processes such as locomotion, digestion and respiration, it has need for less oxygen.
➢Since oxygenated blood takes more time to reach the extremities of the body, the open system is only feasible in small animals.

Open Circulatory System

- Hemolymph leaves the heart in short, branched arteries that open up into large spaces called sinuses.
- Hemolymph percolates around organs, directly bathing the cells.
- Hemolymph then returns to the heart directly or through short veins.



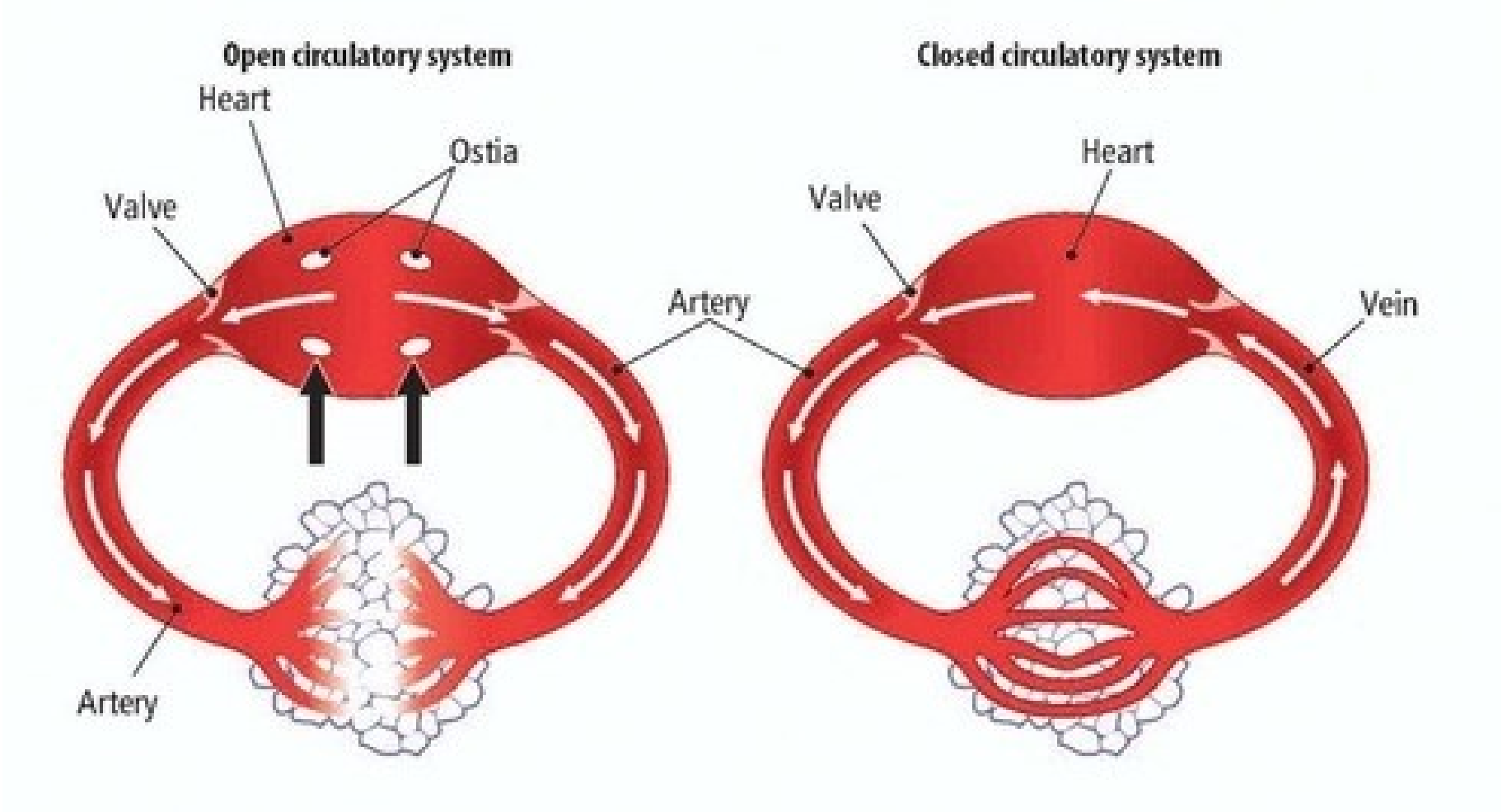


2) CLOSED CIRCULATORY SYSTEM

- Larger and more active animals, including all vertebrates, have a closed circulatory system.
- This more complex system consists primarily of blood, the heart and a network of blood vessels.
- The main functions of the circulatory system are gas exchange, hormone and nutrient distribution, and waste elimination.
- The two major processes of the system are pulmonary circulation and systemic circulation. In the former process, deoxygenated blood is passed through the lungs for gas exchange, in order to receive oxygen from inhaled air.
- Next, systemic circulation distributes the newly oxygenated blood throughout the body. The blood picks up carbon dioxide, a metabolism waste product, from cells, and brings it back to the lungs again.
- In a closed circulatory system, blood is directed through arteries to veins and to smaller blood vessels throughout the body.
- As opposed to bathing all tissues and organs with blood, the blood remains in vessels and is transported at high pressures to and from all extremities of the body at a rapid rate.

Advantages of the Closed System

- The closed system operates with a much higher blood pressure. It is more efficient in that it uses less blood for even higher and faster levels of distribution.
- Since oxygenated blood may reach the extremities of the body faster than with an open system, organisms with a closed system may have higher metabolisms, allowing them to move, digest and eliminate wastes more rapidly.
- Due to the efficient distribution of antibodies, immune responses are stronger, helping the body to fight off infection more effectively.



OPEN V/S CLOSED CIRCULATORY SYSTEM

TWO-CHAMBERED HEART
(1 ATRIUM AND 1 VENTRICLE)

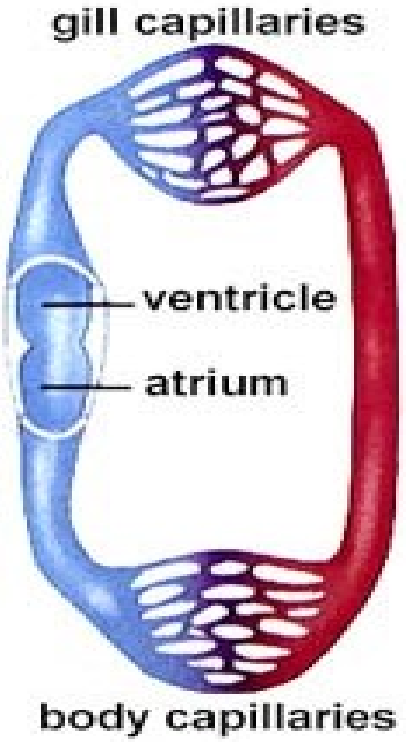
➢**Fish** are vertebrates that have two-chambered hearts consisting of a single atrium and a single ventricle.

➢The atrium is responsible for taking in returning blood from the body, while the ventricle's duty is to pump out blood that has entered the heart.

➢In fish, the ventricle pumps the deoxygenated blood to the gills and the blood is given fresh oxygen from the surrounding water.

➢Due to the simplistic design of the two-chambered heart, a lower amount of oxygen reaches body tissues at any one time in comparison to three-chambered and four-chambered hearts.

➢Fish have lower metabolic capacity than these animals. The metabolic needs, however, of fish are not as demanding as those of warm-blooded animals.



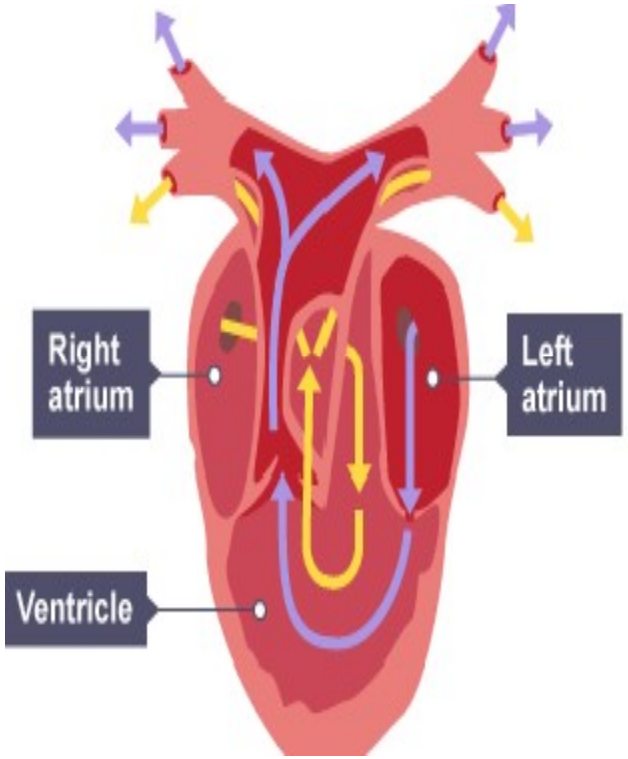
3-CHAMBERED HEART
(2 ATRIUM AND 1 VENTRICLE)

➢**Amphibian** lungs are balloon-like structures where gas exchange is limited. As a result, oxygen can be diffused through their moist skin (and sometimes their mouths) to compensate.

➢Amphibians force the air into their lungs using throat muscles in a process called buccal pumping.

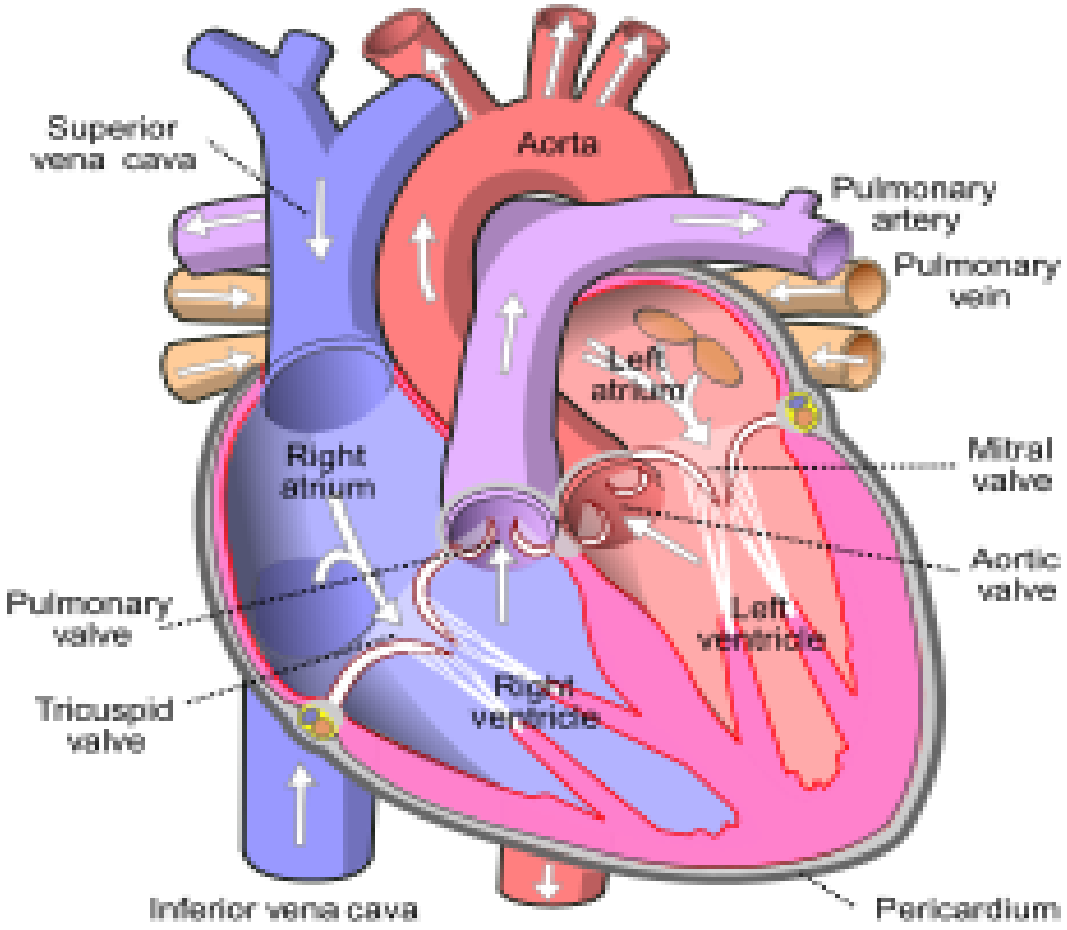
➢Reptiles have a three-chambered heart – two atria and one partially divided ventricle.

➢There is a mixing of oxygenated and deoxygenated blood because the ventricle is not split completely.



4-CHAMBERED HEART
(2 ATRIUM AND 2 VENTRICLE)

- The heart pumps oxygenated blood to the body and deoxygenated blood to the lungs.
- In the human heart there is one atrium and one ventricle for each circulation, and with both a systemic and a pulmonary circulation there are four chambers in total: left atrium, left ventricle, right atrium and right ventricle.
- The right atrium is the upper chamber of the right side of the heart. The blood that is returned to the right atrium is deoxygenated (poor in oxygen) and passed into the right ventricle to be pumped through the pulmonary artery to the lungs for re-oxygenation and removal of carbon dioxide.
- The left atrium receives newly oxygenated blood from the lungs as well as the pulmonary vein which is passed into the strong left ventricle to be pumped through the aorta to the different organs of the body.
- The heart itself is supplied with oxygen and nutrients through a small "loop" of the systemic circulation and derives very little from the blood contained within the four chambers.
- The coronary circulation system provides a blood supply to the heart muscle itself. The coronary circulation begins near the origin of the aorta by two coronary arteries: the right coronary artery and the left coronary artery.
- After nourishing the heart muscle, blood returns through the coronary veins into the coronary sinus and from this one into the right atrium. Back flow of blood through its opening during atrial systole is prevented by Thebesian valve. The smallest cardiac veins drain directly into the heart chambers.



4-CHAMBERED HEART

4-Chambered heart performs two types of circulation

PULMONARY CIRCULATION

➢The circulatory system of the lungs is the portion of the cardiovascular system in which oxygen-depleted blood is pumped away from the heart, via the pulmonary artery, to the lungs and returned, oxygenated, to the heart via the pulmonary vein.

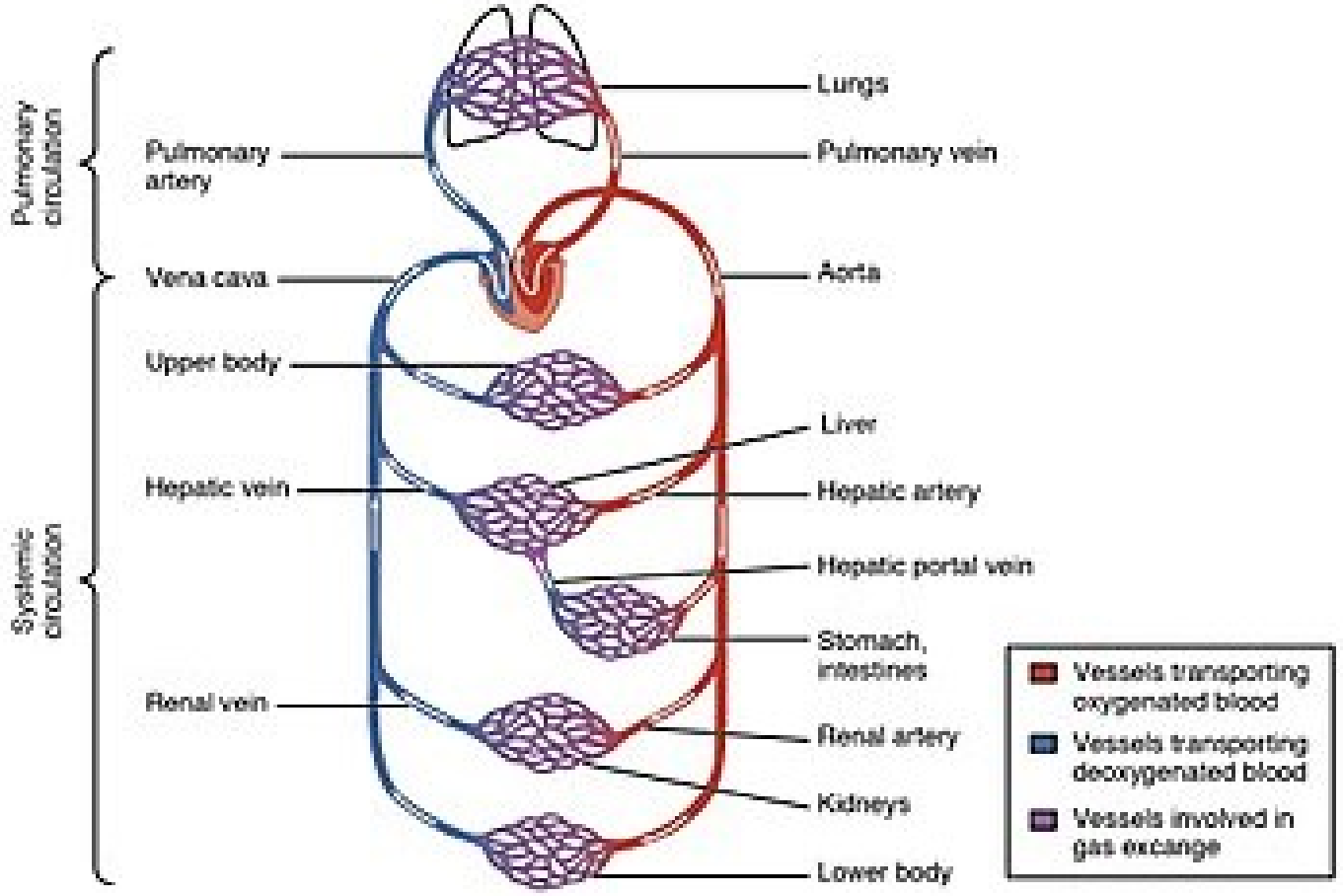
➢Oxygen deprived blood from the superior and inferior vena cava enters the right atrium of the heart and flows through the tricuspid valve (right atrioventricular valve) into the right ventricle, from which it is then pumped through the pulmonary semilunar valve into the pulmonary artery to the lungs.

➢Gas exchange occurs in the lungs, whereby CO_2 is released from the blood, and oxygen is absorbed. The pulmonary vein returns the now oxygen-rich blood to the left atrium.

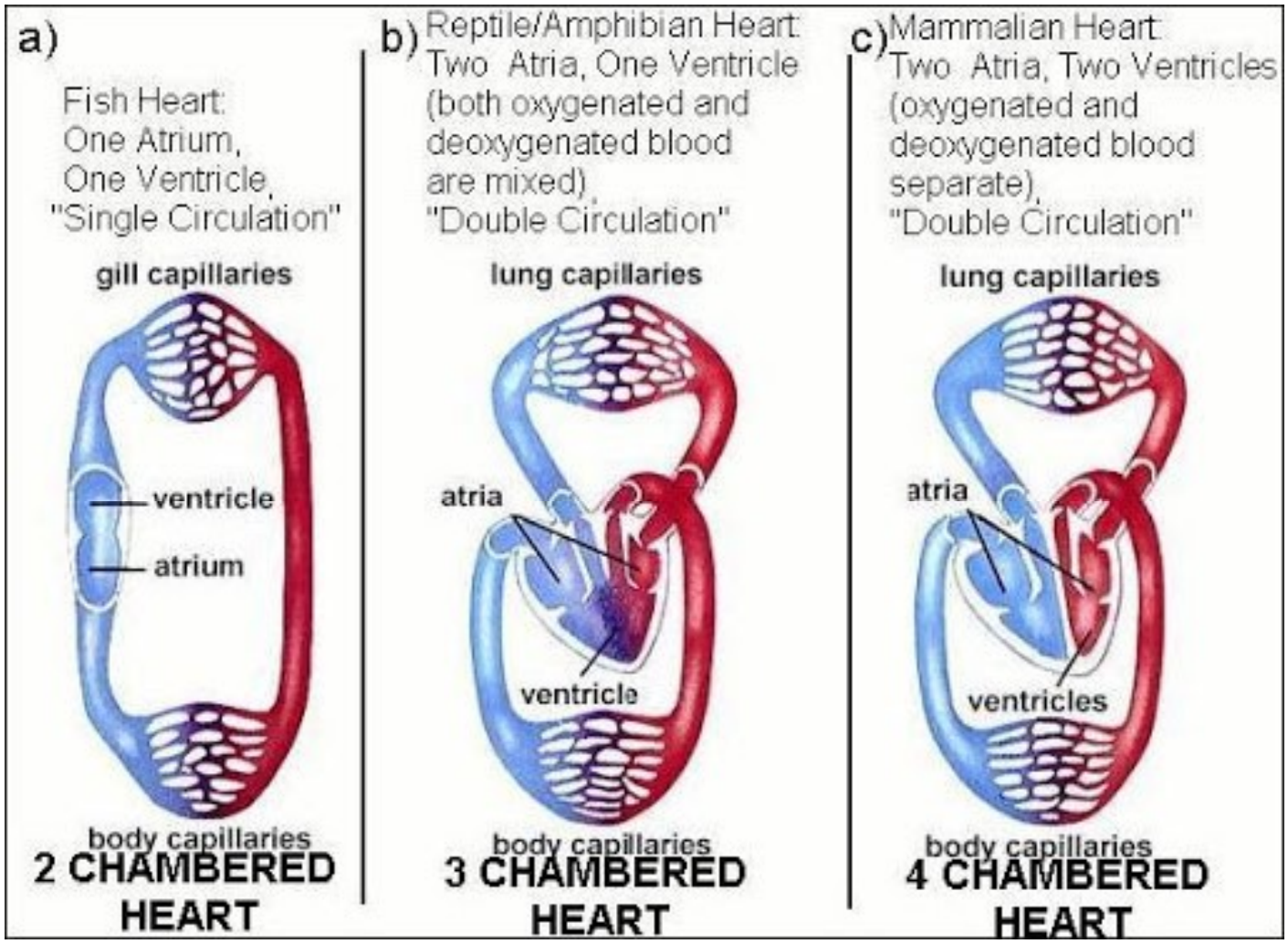
➢A separate system known as the bronchial circulation supplies blood to the tissue of the larger airways of the lung.

SYSTEMIC CIRCULATION

Systemic circulation is the portion of the cardiovascular system which transports oxygenated blood away from the heart through the aorta from the left ventricle where the blood has been previously deposited from pulmonary circulation, to the rest of the body, and returns oxygen-depleted blood back to the heart.



SYSTEMIC AND PULMONARY CIRCULATION


a)
Fish Heart:
One Atrium,
One Ventricle,
"Single Circulation"
gill capillaries
ventricle
atrium
body capillaries
2 CHAMBERED HEART
b) Reptile/Amphibian Heart:
Two Atria, One Ventricle
(both oxygenated and deoxygenated blood are mixed),
"Double Circulation"
lung capillaries
atria
ventricle
body capillaries
3 CHAMBERED HEART
c) Mammalian Heart:
Two Atria, Two Ventricles
(oxygenated and deoxygenated blood separate),
"Double Circulation"
lung capillaries
atria
ventricles
body capillaries
4 CHAMBERED HEART

THANK YOU