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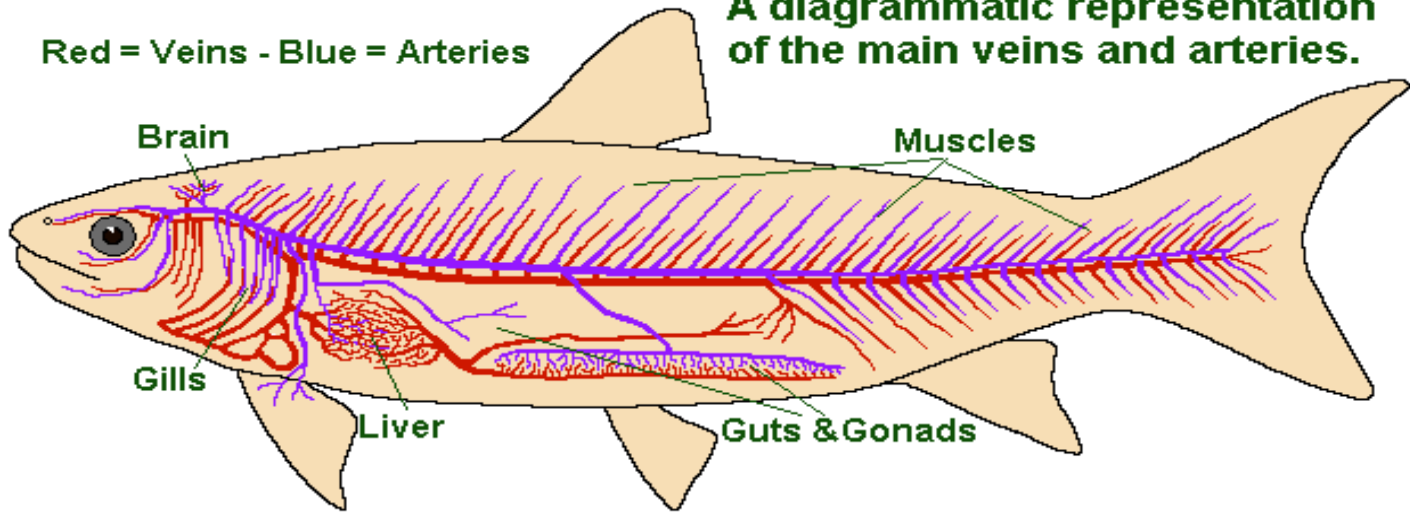
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Circulatory System

The Vascular System of a Fish

Red = Veins - Blue = Arteries

A diagrammatic representation of the main veins and arteries.



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5.1. Introduction

As in other vertebrates the circulatory system of fish is comprised of both static and dynamic components.

The dynamic part is the blood with all its constituent parts that flows continuously around the fish's body. The static parts are the heart, the veins and arteries leading to and from it and the capillaries that connect them.

Fish have less blood per gram of body weight than mammals, normally between 3% and 8% of a fish's body weight is blood, however in the hagfish and lampreys it is greater, for them between 8% and 20% of the animal's body weight.



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5.1. Introduction

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.

Unlike humans, fishes exhibit single cycle circulation, where the oxygen deprived blood comes to the heart, from where it is pumped to the gills and then circulated to the entire body.

On the other hand, in mammals, the deoxygenated blood enters the heart, from where it is pumped into the lungs for oxygenation. Then, the oxygenated blood returns to the heart from the lungs, to be transported throughout the body



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Circulatory System of a Fish

The circulatory system of fish is quite simple.

Like mammals, the circulatory system of fish consists of a heart, blood and blood vessels.

The heart of a fish is a simple muscular structure that is located between the posterior gill arches.

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.



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The blood contains **plasma** (the fluid portion of blood) and the **blood cells**.

The red blood cells or the erythrocytes contain hemoglobin, a protein that facilitates the transport of oxygen to the entire body, while the white blood cells are an indispensable part of the immune system.

The thrombocytes perform the functions that is equivalent to the role executed by the platelets in the human body, i.e. they help in blood clotting.



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Blood is circulated throughout the body with the help of 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.



The blood of fish consists of plasma and the various cells that move around the body in it, erythrocytes and leukocytes.

Plasma is basically water with a variety of ions (Na^+ , Ca^{2+} , K^+) and small organic molecules such as urea, sugars and fatty acids dissolved in it.

In sharks and rays blood cells are created in three different organs, the **spleen**, the **epigonal organ** which surrounds the gonads and the **Leydig organ** which is found in the throat near the oesophagus.

However in teleost fish blood cells are normally only produced in the **spleen** and the **kidneys**.



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Blood cells, the biological boats that sail and trade in the biological sea of blood come in two sorts.

Erythrocytes and Leucocytes.

Erythrocytes are by far the most common cells found in the blood plasma and their job is to move gases around the body.

they collect oxygen at the gills and carry it to all the cells of the body, and from these same cells they collect carbon dioxide which they release into the external waters through the gills.



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The molecule that allows the erythrocytes to do their job, and which makes them red, is called haemoglobin, or hemoglobin, and erythrocytes are full of it.

The haemoglobin of hagfish and lampreys is called monomeric and consists of a single large haem-molecule with a molecular weight of around 17,000 daltons.

Most other fish have tetrameric haemoglobin which is built up from from four different protein chains called alpha and beta chains, there are two of each in a single haemoglobin molecule. This type of haemoglobin is very similar to ours and has a molecular weight of around 65,000 daltons.



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Leucocytes are a mixed collection of cells that are united in being much less common than erythrocytes and in not being red because they do not contain haemoglobin.

The five most important types are Granulocytes, Lymphocytes, Monocytes, Thrombocytes and Non-specific Cytotoxic Cells.

1) Lymphocytes:- are 4.5 to 12 microns in diameter and their job is in defence in detecting and marking foreign particles, specifically they mediate antibody activity, antibodies are small molecules that find and bind to foreign materials so that Monocytes can find them.

2) Thrombocytes:- are important in blood clotting, thus they are important in conservation of resources as they prevent blood loss in case of injury.



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3) Monocytes:- are sometimes called Macrophages, they are important in defence, their role is to eat (phagocytize) anything they come across in the blood that might harm the fish such as bacteria, or parasite larvae.

4) Granulocytes:- are also active in defence, they specifically attack bacteria, but also seem to have a role in controlling stress, however this is still being researched.

5) Non-specific Cytotoxic Cells:- these are another defence mechanism, this time against tumors and protozoan parasites.



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Heart

At the centre of the static, comparatively, parts of the circulatory system is the heart which is normally situated below the pharynx and immediately behind the gills.

Heart lies in a pericardial cavity in elasmobranch and most primitive in structure, consisting of a sinus venosus, an atrium, a ventricle and a well developed contractile conus.

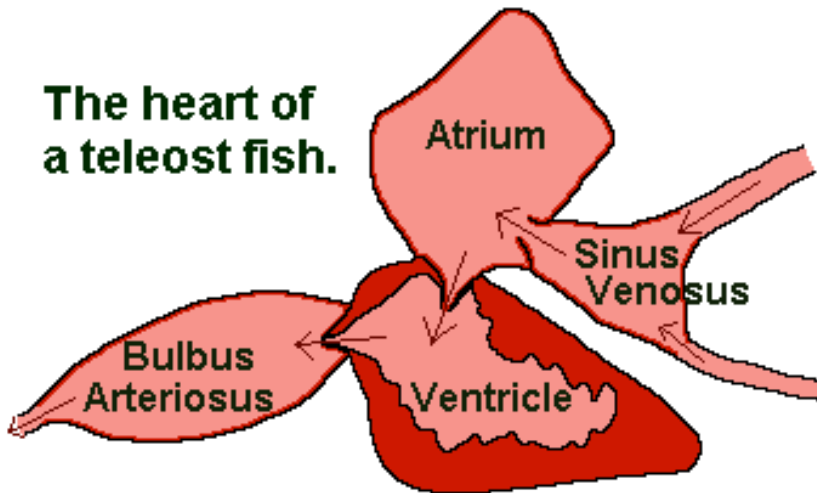
Higher teleostean fishes conus is absent and a bulbous arteriosus is present.



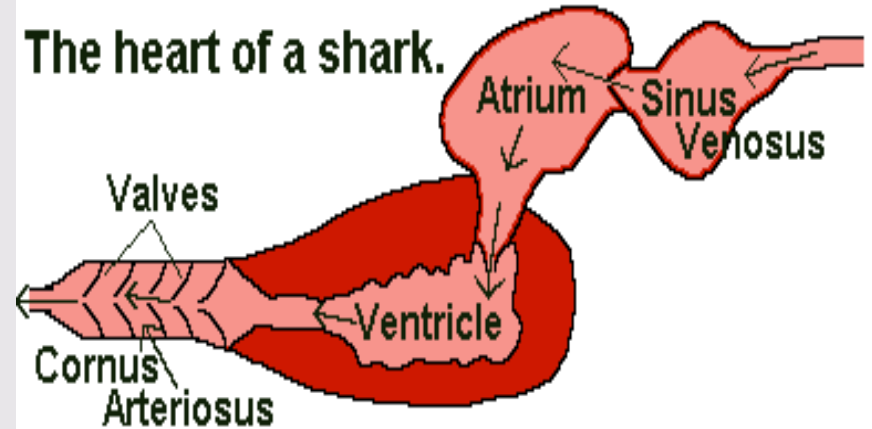
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The heart of a teleost fish.



The heart of a shark.





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Structure of heart in teleost

consisting of a sinus venosus, an atrium or auricle, a ventricle and bulbous arteriosus.

Sinus is a thin walled spacious chamber that receives blood through ducti Cuvieri, a pair of hepatic veins, a posterior cardinal and inferior jugular vein.

Sinus open into atrium (valve)

Atrium in to ventricle (valve)

Ventricle has thick muscular wall and a narrow lumen leading into the bulbous arteriosus.

Afferent and Efferent vessels in teleost



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The ventral aorta is comparatively shorter.

It gives off 4 pairs of **afferent brachial arteries** through which venous blood is supplied to the gills (4 pairs) for purification.

The blood from the gills is collected by 4 pairs of “**efferent brachial arteries**”

In the bony fishes each gill arch has a single efferent artery unlike the condition in shark.

The four efferent brachial arteries unite to form the lateral aorta on each side.

The two lateral aorta are joined together both anteriorly and posteriorly forming a ring shaped vessel known as the “circular cephalicus”.



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In the anterior end, the external and internal carotids arise on each side from the circular cephalicus posteriorly the two lateral aorta fuse together to produce the dorsal aorta which supplies all the organs of the abdomen and ends in the tail.



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Arterial system

The ventral aorta is comparatively shorter.

It gives off 4 pairs of afferent brachial arteries through which venous blood is supplied to the gills (4 pairs) for purification.

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Fish have a single circuit for blood flow and a two-chambered heart that has only a single atrium and a single ventricle.

The atrium collects blood that has returned from the body, while the ventricle pumps the blood to the gills where gas exchange occurs and the blood is re-oxygenated; this is called gill circulation.

The blood then continues through the rest of the body before arriving back at the atrium; this is called systemic circulation.

This unidirectional flow of blood produces a gradient of oxygenated to deoxygenated blood around the fish's systemic circuit.



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Venous system

The blood distributed to the different parts of the body by the arteries and their branches through capillaries and returned to the heart by the veins.

The veins differ in structure from the arteries in possessing thin walls and in forming wide irregular spaces called sinuses (during their curve)

The Venous system can be divided into the following systems.

Anterior cardinal system.

Posterior cardinal system

Hepatic portal system

Ventral sinus

Cutaneous system.



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Hepatic portal system: This system has the hepatic portal vein anterior and posterior intestinal veins, gastric vein and the anterior and posterior gastric. These subsequently form hepatic sinuses which open into sinus venosus.

Ventral veins: The ventral vein comprises two groups. 1) the anterior veins which discharges the blood into ductus curvier through the inferior jugular sinuses and the posterior veins which empty their blood through the subclavians.

Cutaneous systems: The cutaneous system includes a dorsal, a ventral and two paired lateral veins. The ventral joins the abdominal veins. The laterals empties into the branchial vein.



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Anterior cardinal system: the anterior cardinal system consists of the following veins, the internal jugular veins it has the alfactory sinus, orbital sinus, post orbital sinus and anterior cardinal sinus. The orbital sinus finally opens into large anterior cardinal sinus. It opens into ductus cuaveri.

The posterior cardinal system: This system consists of medium caudal vein two renal veins and two large posterior cardinal sinuses. The renal portal vein gives of branches to kidney recollect into renal veins to form the posterior cardinal sinuses.



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