Anatomy and Physiology of Domestic Animals

Cardiovascular System
and
Physiology of Circulation

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1.Blood- function

- **Blood is a type of liquid connective tissue.**
- **The major function of blood is transport.**

Subfunctions

- **Respiration :**
  -if oxygen and carbon dioxide are transported
- **Trophic :**
  -when the nutrient materials are delivered to the tissues
- **Excretive :**
  -when the metabolites are delivered from tissues to excretory organs
- **Regulative :**
  -if the hormones and BAS are transported

Subfunctions

- **Homeostatic :**
  - maintenance of water content and acid-base balance
- **Protective :**
  - immunity and non-specific resistance;
  - blood coagulation
- **Maintenance of body temperature :**
  -as a result of a redistribution of blood volume between skin and the internal organs at high and low temperature of external environment.

Blood

- The total blood volume makes up about 6-8 percent of the body's weight.
- Accordingly, a 70-kilogram person will have 5 to 6 litres of blood.
- Circulating blood volume will be lesser than total blood volume, because some amount of blood will be deposited in organs like liver.

Blood composition

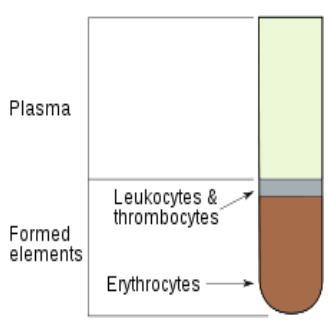
- Blood consists of
  - liquid plasma (volume-55-60%)
  - formed elements (cells) (volume-40-45%)

Blood

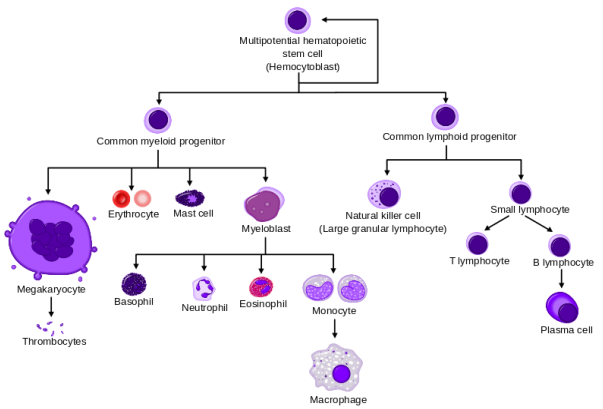
- Formed elements include
  - Erythrocytes (red blood cells);
  - Leukocytes (white blood cells);
  - Thrombocytes (platelets)

Hematocrit

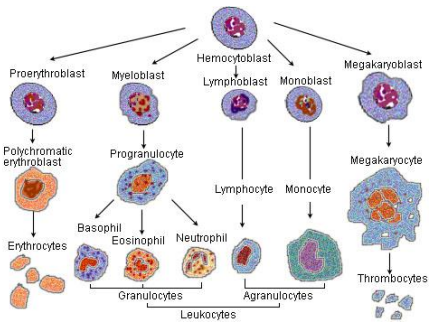
The hematocrit , also known as packed cell volume (PCV) or erythrocyte volume fraction (EVF), is the volume percentage (%) of red blood cells in the blood. It is normally about 40-48% for men and 36-42% for women



Haemopoiesis



HAEMOPOIESIS



2. Blood plasma

- **Composition :**
  - **90-92% of water**
  - **8-10% of dry substance**

  mainly consisting of proteins (6-8%)

Dry substance includes :

- **inorganic (mineral)**
- **organic components**

Blood plasma

- **The main (inorganic) mineral components : (0.9-1.5 %):**

Cations :

- **Sodium (Na^+),**
- **Potassium (K^+),**
- **Calcium (Ca^{++}),**
- **Magnesium (Mg^{++})**

Anions :

- **Chlorides(Cl^-)**
- **Phosphates (PO_4^-)**
- **Bicarbonates(HCO_3^-)**

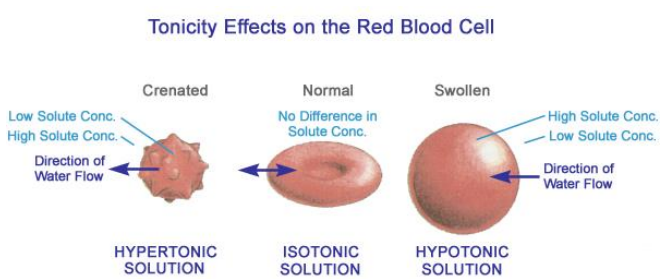
Blood plasma

- The organic components of plasma include :
  - proteins
  - lipids
  - carbohydrates

Serum

- When fibrinogen is removed from plasma as a result of coagulation, such plasma without fibrinogen is called serum.

Osmotic pressure



4. Erythrocytes

- Red blood cells, or erythrocytes, are the most abundant type of blood cell.
- Approximately 2.4 million new erythrocytes are produced per second.
- Approximately a quarter of the cells in the human body are red blood cells.

Erythrocytes -Structure

- In humans, mature red blood cells are oval biconcave disks and they are flexible.
- A typical human erythrocyte has a disk diameter of approximately 6.2–8.2 µm
- They lack a cell nucleus and most organelles, in order to accommodate maximum space for haemoglobin.

RBCs - Functions

- The haemoglobin is an excellent acid-base buffer.
- Maintanence of acid-base balance.
- Blood group determination.

8. Leucocytes (WBC)

- White blood cells have nuclei
- Size 9-12 µk
- They make up approximately 1% of the total blood volume in a healthy adult.
- They live for about three to four days in the average human body.
- Normal count of WBC :
  - 4-9 x 10^9/L

Leucocytes-functions

- The major function of leucocytes is :
- Protective function.
- It provides immunity and thus defends the body.

10. Types of leucocytes

- Leucocytes are of 2 types :

Granulocytes :	Agranulocytes :
Neutrophil	Monocyte
Basophil	Lymphocyte
Eosinophil	

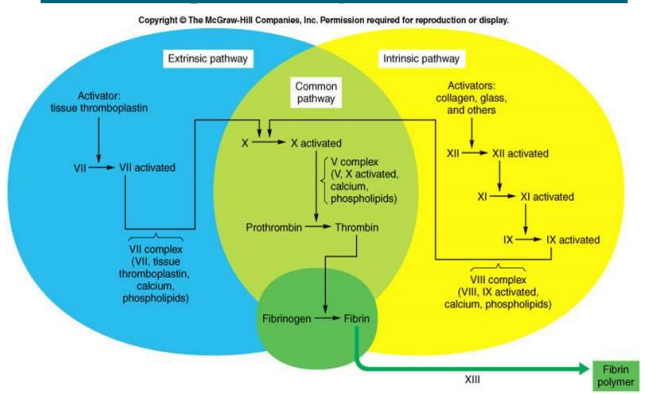
14.Thrombocytes (platelets)

- Fragments of megakaryocytes (red bone marrow)
- Do not have a nucleus
- 2–3 µm in diameter
- Normal range : 180-320 x 10^9/L
- Circulation in blood – 8-12 days

Platelets- functions

- The main function of platelets is the maintenance of hemostasis.
- Trophic (endothelium)
- Transport of BAS
- Immunity(Phagocytosis)
- Clot retraction
- Procoagulant
- Inflammation

15.Coagulatory haemostasis



Plasma clotting factors (13)

Factor number		Name
I	-	Fibrinogen
II	-	Prothrombin
III	-	Tissue Factor
IV	-	Ca2+
V a	-	Proaccelerin
VII	-	Proconvertin
VIII	-	Antihemophilic Factor
IX	-	Christmas Factor
X	-	Stuart Factor
XI	-	Plasma thromboplastin antecedent
XII	-	Hageman factor
XIII	-	Fibrin Stabilizing Factor

Cardiovascular System

- **Cardiovascular system (Circulatory system)**
- **Consists of**
  - **Pump (heart) and**
  - **Conduit System (blood vessels) for circulating blood**
  - **Three types of Vessels;**
    - **carry blood away from the heart are called arteries,**
    - **carry blood toward the heart are called veins,**
    - **carry tissue fluid or lymph to large veins are called lymph vessels or lymphatics**

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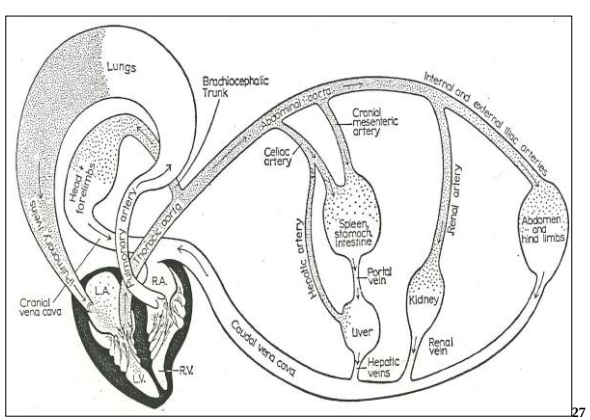
Cardiovascular System (Adult)



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The Heart (Pump)

- **Is a four-chambered organ, connected to the blood vessels that circulate blood to different parts of the body.**
- **It is a cone-shaped, hollow muscular structure.**
- **Its base is directed cranio-dorsally, and is attached to other thoracic structures by large arteries, veins, and the pericardium. The apex is directed ventrally and is entirely free within the pericardium.**

- **The pericardium (pericardial sac) is a serous sac (membrane).**

- **Like other serous membranes (Pleura and Peritoneum), the pericardium is a completely closed membrane that contains only a small amount of fluid for lubrication.**

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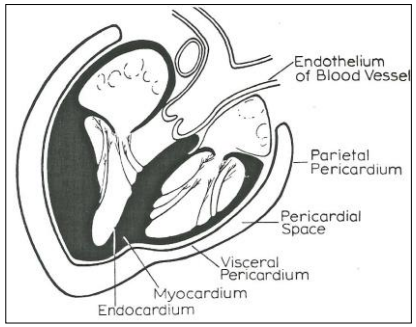
The Heart

- **The heart is invaginated into the pericardium *(as occurs if one thrust a fist into the side of an inflated balloon)*,**
- **two distinct layers of the pericardium: the inner layer called visceral pericardium (or epicardium), and the outer layer called parietal pericardium**



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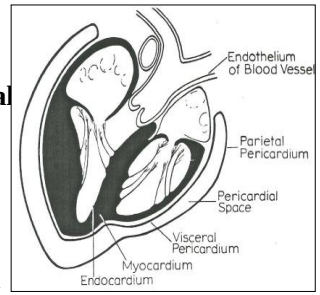
The Heart Anatomy

•The heart wall consists of three layers:

•An outer serous covering called the epicardium (visceral layer of pericardium);

•An inner endothelial lining called the endocardium; and

•A thick muscular layer called the myocardium.



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The Heart Anatomy

- **Endocardium is a layer of simple squamous endothelial cells that lines chambers of the heart and also covers heart valves and is continuous with the lining of blood vessels.**
-
- **Myocardium consists of cardiac muscle, also called involuntary striated muscle.**
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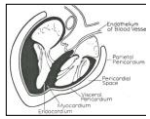
- **The heart is divided into two sides and each side consists of an atrium, which receives blood by way of large veins, and a ventricle, which pumps blood from the heart by way of a large artery.**



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The Heart Anatomy

Between the atrium and ventricle is a set of valves called auriculo-ventricular valves or atrial-ventricular (AV) – valves; left AV-valve is called bicuspid (2 cusps) valve , but the right AV-valve is called tricuspid (3 cusps) valve.

The aortic semilunar valve is a three-cusped valve located at the junction of the left ventricle and the aorta.

The pulmonary semilunar valve is located at the junction of the right ventricle and pulmonary artery.

Semilunar valves prevent blood from returning into the ventricle when the ventricles relax.

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The Heart Physiology

The heart receives unoxygenated blood through the cranial and caudal venae cavae (large veins) in the right atrium, which is a thin-walled area for collection of returning blood. The blood then passes through the right A-V valve into the right ventricle.

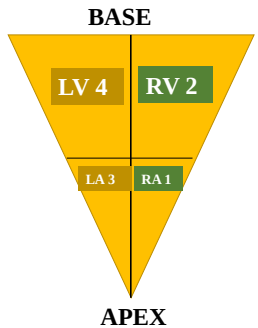
After the pulmonary semilunar valve, the pulmonary trunk divides into right and left pulmonary arteries, carrying unoxygenated blood to the capillaries of each lung where CO_2 in the blood is exchanged for O_2 from the alveolar (atmospheric) air.

Pulmonary veins return oxygenated blood from the lungs to the left atrium, a large thin-walled chamber of the heart. Blood passes through the left A-V valve into the thick-walled left ventricle.

The Heart Physiology

The left ventricle pumps the oxygenated blood through the aortic semi-lunar valve into the aorta.

The aorta and its subdivisions carry oxygenated blood to all parts of the body, including the heart and lungs themselves

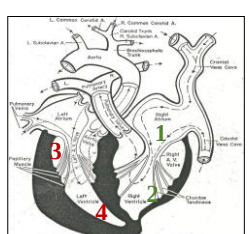


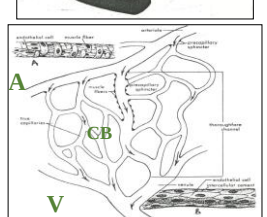
Blood Vessels

BV resemble the branching of a tree as arteries start as large vessels (Aorta) and divide into smaller and even smaller branches.

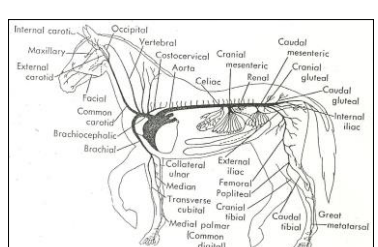
The smallest arteries are arterioles which are continuous with the smallest blood vessels, the capillaries.
The opposite happens on the other side of capillaries to form venules.

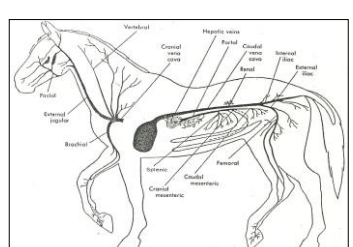
Venules in turn unite to form larger and even larger veins, the largest (Vena cava) finally enter the right atrium of the heart.





The Circulatory System
a “tree” network





The Arteriole Network **The Venous Network**

Arteries

Tubular structures that carry blood away from the heart.

The largest arteries (a.k.a elastic arteries) have a large portion of the arterial wall consists of elastic tissue.

Elasticity is important in maintaining blood pressure during diastole, the period during which the ventricles are relaxed.

Smaller arteries contain a large amount of smooth muscle in the arterial wall in place of elastic tissue necessary for control of the size of vessel and amount of blood (vasoconstriction and vasodilatation) that can flow through it.

Arterioles, the smallest arteries, are muscular immediately before giving rise to capillaries.

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Blood Capillaries

Capillaries are tiny tubes almost entirely composed of endothelium, a continuation of the simple squamous epithelium that lines the heart and blood vessels.

Large enough in diameter to accommodate a single file of erythrocytes.

The wall is selectively permeable, permits water, oxygen, and nutrients to leave the blood for tissue cells and permits waste products from tissue cells to enter the blood vessel.

The fluid that passes out of the capillaries into tissue spaces, returns to blood by passing back through the capillary walls. Some fluid remains in the tissues as tissue fluid, and the excess fluid is removed by lymph vessels.

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Exception - Anastomoses

Are Shunts, large connections interposed between arterioles and venules that permit more blood to flow through a given part than would normally happen through a capillary bed.

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Venous Network

Larger than the arteries they accompany and have thinner walls with slight amount of muscle tissue present (flaccid).

Heart pumps blood to the capillary bed.
However, no such pump exists to force or propel blood movement after the capillary bed.

Valves, usually consisting of two cusps each, are scattered at irregular intervals throughout the venous and lymphatic systems, positioned to ensure blood can only flow towards the heart.

Veins are tributaries to larger veins which eventually enter the right or left atrium of the heart.

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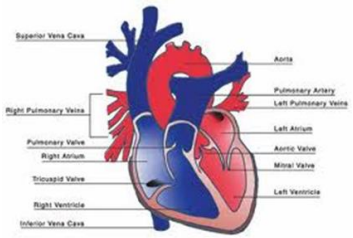
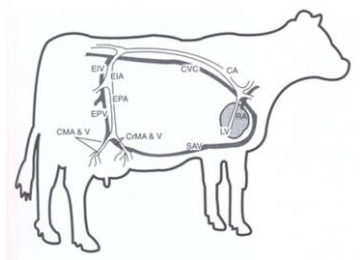
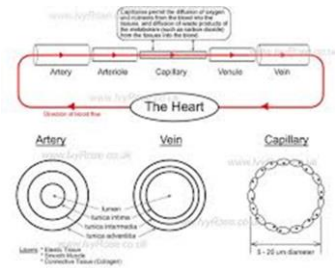




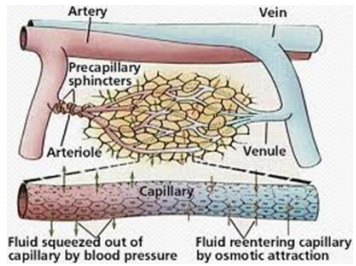


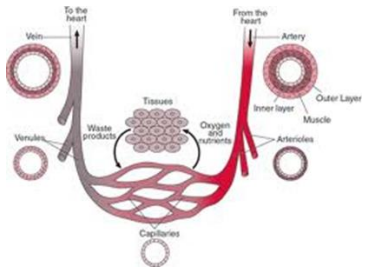
Lymphatics

Some intercellular fluid (tissue fluid) does not re-enter capillaries or veins directly, is picked up by thin-walled blind-ended lymph vessels

Smallest lymph vessels are capillary-sized structures that begin blindly, they take in ECF, transport this to larger and larger lymph vessels and finally emptied into the cranial vena cava or one of its tributaries.

Located in lymph vessels are lymph glands (nodes) that serve to filter lymph before it is emptied into veins.





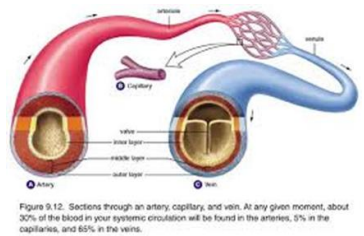


Figure 9.12. Sections through an artery, capillary, and vein. At any given moment, about 30% of the blood in your systemic circulation will be found in the arteries, 5% in the capillaries, and 65% in the veins.

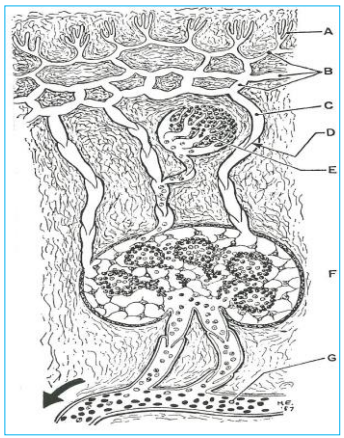
Lymphatics

Includes the lymphoid tissue of the body and the lymph vessels associated with the lymphoid tissue. This constitutes a one-way channel that runs parallel to the venous system and eventually empties into the cranial vena cava or some of its tributaries.

Begin blindly between intercellular spaces, as lymph capillaries. These collect the tissue fluid not absorbed by the venous system. Subsequently form complex networks which finally combine to form lymph vessels and then these unite to form larger and larger lymphatic vessels.

Lymph nodes (glands) are discrete nodular structures spaced along the lymphatic vessels and serve as filters for lymph (first body defenses against infection by harbouring lymphocytes and plasma cells [produce antibodies & macrophages that phagocytize bacteria]).

Lymphatics



A – Lymphatic capillary bed

B, C – Lymphatic vessels

D – Lymphatic valve

E – Lymphocyte

F - Lymph gland (node)

G – Venous vessel

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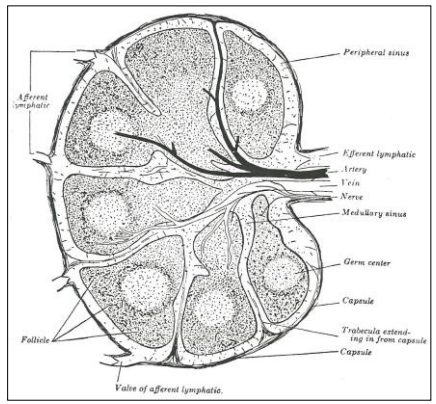
Lymph Node



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Lymph Node

Capsule of lymph node is divided into an outer cortex and an inner medulla both of which contain lymphocytes.

Lymphocytes in the cortex are arranged in dark-staining groups called primary nodules. There are light-staining areas within the primary nodules, called secondary nodules, and are areas of rapid cell multiplication (also called germinal centres).

Lymphocytes in the medulla are arranged in cords.

Lymph nodes also contain plasma cells that are essential in the production of antibodies.

Each lymph node has its own blood supply and venous drainage.

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Lymph Node

The state a lymph node reflects the health or disease status (enlargement) of the area where afferent lymph vessels are derived as they respond to infection by increasing in size.

Spleen is a lymphoid organ associated with the circulatory system and is attached to the stomach either directly by connective tissue (e.g. in ruminants) or by gastrosplenic omentum.

The shape of the spleen varies from one species to another. The splenic vein drains blood from the spleen and is a tributary to the portal vein.

Functions as a storage organ for blood (size of spleen varies) also a part of the macrophage system as it phagocytizes worn-out RBC that break up in passing through the splenic pulp.

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Cardiovascular System Components

The cardiovascular system

made up of two circulatory systems, namely a pulmonary circulatory system (heart – vessels-lungs-vessels-heart)

and

a systemic circulatory system (heart-vessels-all organs except lungs-vessels-heart).

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Pulmonary Circulation

Is part of the cadiovascular (circulatory) system that circulates all the blood through the lungs.

Unoxygenated blood ⟶ Venae cavae ⟶ Right Atrium ⟶ right AV-valves ⟶ right ventricle ⟶ pulmonary artery ⟶ LA.

The pulmonary artery divides into a right pulmonary artery going to the right lung and a left pulmonary artery going to the left lung.

Each subdivides into lobar arteries going to each of the lobes of the lungs, these lobar arteries subdivide many times, finally forming arterioles that supply the extensive capillary beds of the lungs.

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Pulmonary Circulation

Lung capillaries are intimately associated with alveoli of the lungs.

Gas exchange takes place in the capillary bed of each alveolus.

After blood has gone through the capillary beds, it enters the venules, which eventually combine to form (right and left) pulmonary veins.

These veins then empty oxygenated blood into the left atrium, thus completing the pulmonary circulation.

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Systemic Circulation

Also called somatic circulation
refers to movement of oxygenated blood to all areas of the body and the subsequent return of unoxygenated blood to the heart.

Systemic circulation further divided into a number of micro-circulations, each supplying a specific region or part of the body such as circulation of the head, forelimb, hindlimb, gut etc.

And further broken down to the circulation of any given part of the region; for example circulation of the biceps muscle of the front limb or the circulation of the eye.

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Systemic Circulation

No matter how small or how large a segment of systemic circulation we consider, the basic pattern is the same with the exception of circulation of the kidneys and portal circulations.

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Portal Circulation

The arrangement in which a vein breaks up into capillaries and then recombines again to form another vein is spoken of as a portal system or portal circulation.

Occurs in the pituitary gland (the hypophyseal portal circulation) or in birds, part of the blood returning from the hind limbs enters the kidneys to form the renal portal circulation.

The hepatic portal circulation is an important exception to the usual arrangement of the systemic circulation. Here, most of the celiac artery branches and the cranial and caudal mesenteric arteries supply capillary beds of the spleen, pancreas, and digestive tract.

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Portal Circulation

Blood drained from the stomach, spleen, intestines, and pancreas is filtered through the liver by the hepatic portal circulation before it enters the general circulation.

Blood enters via the portal vein (beginning of the hepatic portal system) which enters the liver and immediately divides into smaller and smaller branches finally ending in the sinusoids of the liver.

The blood is then in direct contact with hepatocytes after that the blood passes from the sinusoids into the central vein of each liver lobule.

These central veins then combine and eventually to form hepatic veins which empty their blood into the caudal vena cava.

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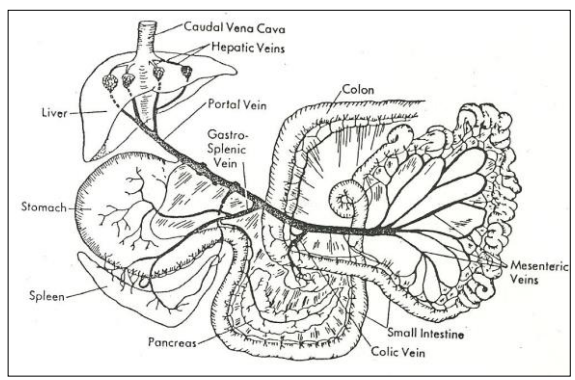
Hepatic-Portal Circulation



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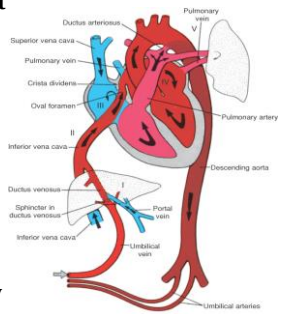
Foetal Circulation

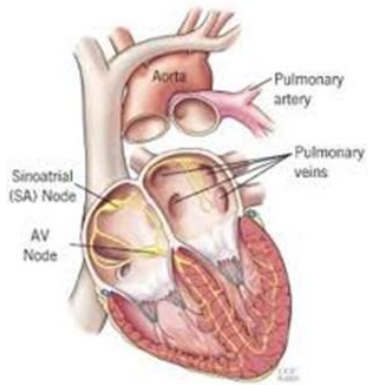
Some differences occur between circulation in an adult vs foetal circulation.

In *adult* same amount of blood is present in pulmonary and systemic circulation, while in a *foetus*, most of the blood is in the systemic circulation (lungs are not necessary/non-functional) at this stage



Two by-passes linking left to the right side of the heart, namely
Foramen ovale – connects the right and left atria
Ductus arteriosus – connects pulmonary artery to aorta.

Local Control of the Heart



SA Node
AV Node

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