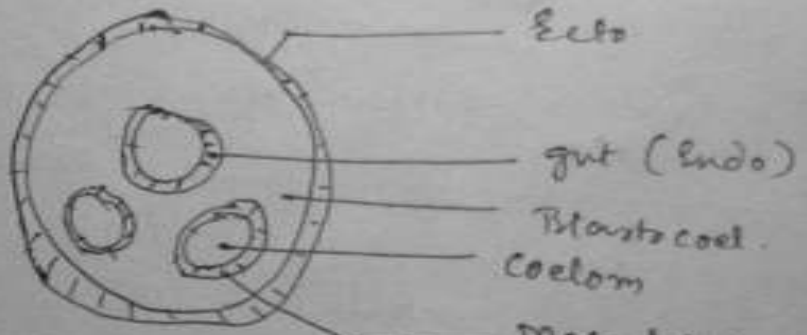
Regulation of blood circulation

- **Embryologically the circulatory system develops from mesoderm or mesenchyme. Mesoderm cells when spread in the blastocoel, enclose the blastocoel in them thus forming blood vessels.**

Fig 1

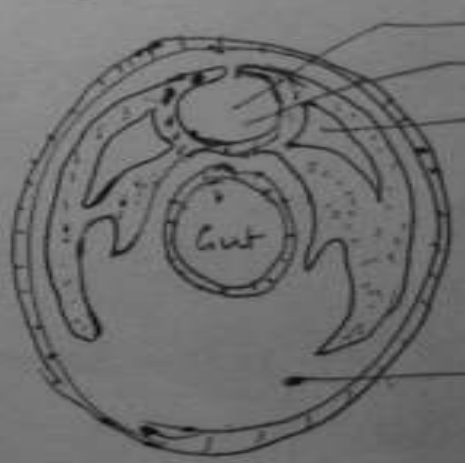
Early Embryonic condition.



Annelida.

Closed circulatory system.

Arthropoda



Open circulatory system

As shown in the figure—

- **In lower animals the blastocoel remains dominant. It is filled with body fluid. Vessels formed by mesoderm are few (usually the heart). Hence the circulatory system in these animals is of open type.**

- **In higher animals the coelom grows more and become dominant as compared to blastocoel. Due to this growth of mesoderm and coelom the blastocoel gets trapped in many places in the mesoderm thus forming many blood vessels and a network of blood vessels. These blood vessels are filled with body fluid i.e. blood and thus a closed type of circulatory system is formed.**

- **In open type of circulatory system the body fluid freely flows in the cavity however to facilitate proper circulation some pumping device is necessary which is either in form of tubular heart (Cockroach) or sac like heart (Crustaceans and daphnia). Tubular Heart act like suction pump. It sucks blood when it expands and then it pumps**.

- **In closed type of circulatory system the blood vessels spread to distant tissues hence pumping of blood becomes essential and hence the heart has to be muscular but if the heart is muscular and thick walled it cannot accommodate more blood.**

- **To overcome this difficulty the heart initially evolved to become 2-chambered heart. The atrium being thin walled can accommodate more blood and ventricle being thick walled can pump the blood efficiently.**

- **The heart of closed circulatory system is pressure pump which pumps by force.**
- **This 2 chambered heart (sharks) later on in evolution became 3-chambered (amphibian) and then 4-chambered (Reptiles, birds, mammals).**

Heart size

- **Heart size – it varies from animal to animal and has correlation with the animal activity.**
- **For better comparison the heart size is given as percentage of body weight.**
- **In man heart is 0.43% of body weight in male is and 0.4% of body weight in females.**
- **It is approx. 300 gms in male and is size of clinched first.**

- **The size depends on activity.**
- **An active animal like deer has heart 1% of body weight.**
- **In fishes the heart is smaller 0.2% of body weight.**
- **In amphibian is 0.46% of body weight.**
- **Reptiles 0.51% body weight**
- **Birds have the largest heart among vertebrates which 0.8% of body weight.**

Heart rate

- **In every animal heart rate is variable. It is faster in smaller animals than the larger.**
- **e.g. In Mammals**
- **Elephants and horses – 25 – 40 / min.**
- **Dog – 80 / min.**
- **Cat – 125 / min.**
- **Rabbit – 200 / min.**
- **Mouse – 300 – 500 / min.**
- **Man – 72 / min.**

In Birds--

- **Domest fowl – 150 – 300 / min.**
- **Sparrow – 400-500 / min.**
- **Humming bird – 500-600 / min.**

In Crustacea--

- **Cray fish – 30-60 / min.**
- **Ascellus – 180-200 / min.**
- **Daphnia – 250-450 / min.**

- **Heart rate depends on various factors**
- **Rest and exercise – At rest heart beat slowly, during exercise it is faster.**
- **Locomotor activity increases heart rate**
- **At low temperature heart rate is low and warm temperature heart rate is high.**

- **Nervous excitement leads to adrenal secretion and raises the heart rate**
- **Sluggish animals have slow heart rate whereas active animals have faster heart rate.**

- **Clam or bivalve is sluggish – the heart rate - 0.2 to 22 / min.**
- **Octopus or Squid are active – 40-80 / min.**
- **Tuna fishes have faster heart rate**

- **Like wise during activity heart rate is faster.**
- **Sphinx moth – At rest – 40-45 / min.**

  When Active – 110-140 / min.
- **In Bat, Normal rate is 250-440 / min.**
- **Excited rate is 880 / min.**
- **Diurnal Lethargy rate is 120-180 / min.**

- **In some animals heart rate depends on pressure. At low pressure the heart rate is low and high blood pressure causes high heart rate.**
- **e.g.In clam → Heart rate rises when foot contracts.**
- **→ Heart rate decreases when foot extends.**
- **.**

- **In Poikilotherm, rise in temperature by 100C rises heart rate 2-3 times.**
- **Homeotherms have more heart rate than poikilotherm**

- **Oxygen level in blood affects the heart rate. Low oxygen level normally slows down heart rate.**
- **Slower heart rate is known as Bradycardia**
- **Faster heart rate – Tachycardia**

Cardiac output

- **Cardiac output is the amount of blood pumped by heart / min.**
  C.O. = Blood pumped at each contraction X No. of Beats/min.
  = Stroke volume X heart rate
- **Normally in man C.O. is 5.6 l/min. or 80 ml/kg/min.**

- **For calculatin C.O. oxygen estimations are made.**
- **O2 absorbed by lungs in ml/min.**
- **Arterial O2 in ml/l.**
- **Venous O2 in ml/l.**

C.O. (litres/min.) = O_2 absorbed in lungs ml/min.

Difference between Arterial and Venous O_2 ml/l.

- **e.g. If arterial blood has O_2 200 ml/l**
- **venous blood has O_2 160 ml/l**
- **lungs have absorbed 200 ml/min. O_2**
- **C.O. = 200**
- **200 – 160**
- **= 200**
- **40**
- **= 5 litres/min.**

- **In lower animals stroke volume is amount of blood pumped by single ventricle. In higher animals when two ventricles are there the stroke volume is amount of blood pumped by anyone ventricle.**

- **Normally poikilotherms have relatively low C.O.**
- **Birds have relatively high C.O. In domestic birds it is 200-400 ml/kg/min.**
- **In the invertebrate the C.O. is very low. It is 1 ml/kg/min. in lobster.**
- **In some animals it is 17 ml/kg/min. whereas in fishes it is 5-100 ml/kg/min.**

- **During exercise C.O. rises due to a) rise in stroke volume b) rise in rate of heart beat.**
- **In Octopus and lower invertebrates stroke volume rises and heart rate remains unchanged.**
- **In mammals heart rate rises and stroke volume remain same.**