

# **OCR (A) Biology A-level**

## **Topic 3.2: Transport in animals**

### Notes

# Circulatory systems

Circulatory systems can either be **open**, for instance in insects or **closed**, like in fish and mammals where the blood is confined to blood vessels only. **Closed circulatory systems** come in two forms, either a single form which consists of a heart with **two chambers** meaning the blood passes through the heart once for every circuit of the body or double, where the heart has **four chambers** and blood passes through the heart twice for every circuit of the body.

## Important structures and their functions

- **Arteries** – adapted to carrying blood away from the heart to the rest of the body, **thick walled** to withstand **high blood pressure**, contain **elastic tissue** which allows them to **stretch and recoil** thus smoothing blood flow, contain **smooth muscle** which enables them to vary blood flow, lined with **smooth endothelium** to reduce friction and ease flow of blood
- **Arterioles** – branch off arteries, have **thinner** and **less muscular walls**, their role is to feed blood into capillaries
- **Capillaries** – smallest blood vessels, site of **metabolic exchange**, only **one cell thick** for fast **exchange** of substances
- **Venules** – larger than capillaries but smaller than veins
- **Veins** – carry blood from the body to the heart, contain **a wide lumen** to maximise volume of blood carried to the heart, **thin walled** as blood is under **low pressure**, contain **valves** to **prevent backflow** of blood, no pulse of blood meaning there's little elastic tissue or smooth muscle as there is no need for stretching and recoiling

**Tissue fluid** is a liquid containing dissolved **oxygen** and **nutrients** which serves as a means of supplying the tissues with the essential **solutes** in exchange for **waste products** such as **carbon dioxide**. Therefore, it enables **exchange** of substances between **blood** and **cells**.

**Hydrostatic pressure** is created when blood is pumped along the **arteries**, into **arterioles** and then **capillaries**. This **pressure** forces blood fluid out of the capillaries. Only substances which are small enough to escape through the gaps in the **capillary** wall are components of the **tissue fluid** – this includes dissolved **nutrients** and **oxygen**. The fluid is referred to as **tissue fluid**, as described above.

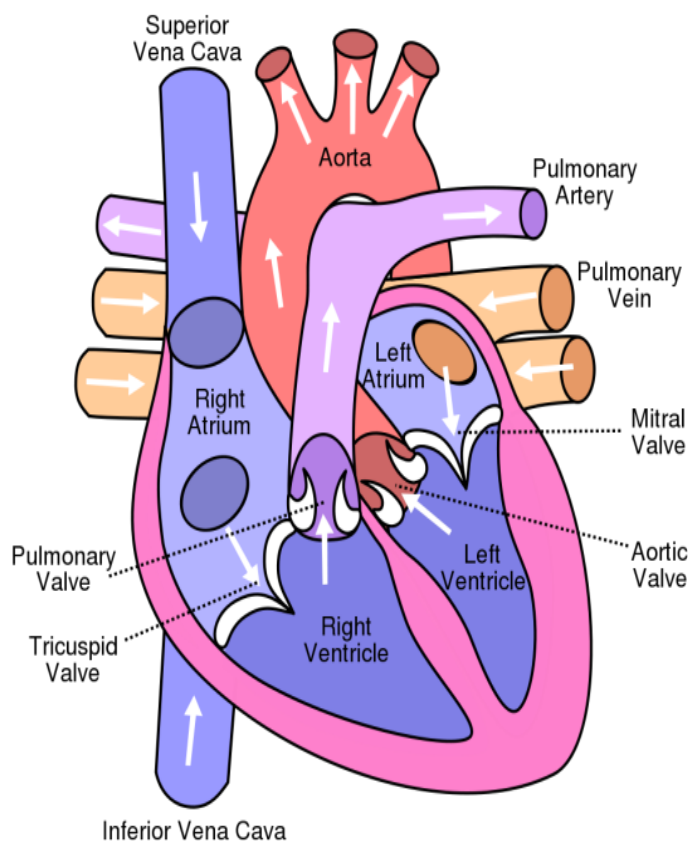
The fluid is also acted on by **osmotic pressure** which pushes some of the fluid back into the **capillaries**. As both the tissue fluid and blood contain **solutes**, they have a negative **water potential**. Although the **potential** of the tissue fluid is negative, it is less negative in comparison to the blood (the blood contains more **solutes**). Therefore, the **tissue fluid** is

positive in comparison to the blood. This causes water to move down the **water potential gradient** from the tissue fluid to the blood by **osmosis**.

The remaining tissue fluid which is not pushed back into the capillaries is carried back via the **lymphatic system**. The lymphatic system contains **lymph fluid**, similar in content to **tissue fluid**. However, lymph fluid contains less **oxygen** and **nutrients** compared to tissue fluid, as its main purpose is to carry **waste products**. The lymph system also contains **lymph nodes** which filter out **bacteria** and **foreign material** from the fluid with the help of **lymphocytes** which destroy the invaders as part of the immune system defences.

## Mammalian heart and cardiac cycle

Due to the heart's ability to initiate its own contraction, it is referred to as **myogenic**. In the wall of the right **atrium** there is a region of specialised fibres called the **sinoatrial node** which is the pacemaker of the heart, as it initiates a wave of electrical stimulation which causes the **atria to contract at roughly the same time**. The **ventricles** do not start contracting until the **atria** have finished due to the presence of tissue at the base of the atria which is **unable to conduct the wave of excitation**. The electrical wave eventually reaches the **atrioventricular node** located between the two atria which passes on the excitation to ventricles, down the **bundle of His** to the apex of the heart. The bundle of His branches into **Purkyne fibres** which carry the wave upwards. This causes the ventricles to **contract**, thus emptying them.



There are 3 stages of the cardiac cycle:

1) **Atrial systole** – during atrial systole the **atria contract** and this forces the atrio-ventricular **valves open** and blood flows into the ventricles.

2) **Ventricular systole** – contraction of the ventricles causes the **atrio-ventricular valves to close** and **semi-lunar valves to open** thus allowing **blood to leave the left ventricle through the aorta** and right ventricle through the **pulmonary artery**.

3) **Cardiac diastole** – atria and ventricles relax, **elastic recoil** of the heart **lowers the pressure inside the heart**

**chambers** and **blood is drawn from the arteries and veins** thus causing **semilunar valves** in the aorta and pulmonary arteries to close, preventing backflow of blood.

Figure 1 Wikipedia

# Haemoglobin

**Haemoglobin** is a **water soluble globular protein** which consists of **two alpha and two beta polypeptide chains** each containing a **haem group**. It **carries oxygen** in the blood as oxygen can bind to the **haem ( $\text{Fe}^{2+}$ ) group** and oxygen is then released when required. Each molecule can carry **four oxygen molecules**.

The **affinity of oxygen** for haemoglobin varies depending on the **partial pressure of oxygen** which is a **measure of oxygen concentration**. The greater the concentration of dissolved oxygen in cells the greater the partial pressure. Therefore, **as partial pressure increases**, the **affinity of haemoglobin for oxygen increases**, that is oxygen binds to haemoglobin tightly. This occurs in the lungs in the process known as **loading**. During respiration, **oxygen is used up** therefore the **partial pressure decreases**, thus **decreasing the affinity of oxygen for haemoglobin**. As a result of that, **oxygen is released** in respiring tissues where it is needed. After the unloading process, the **haemoglobin returns to the lungs** where it binds to oxygen again.

**Dissociation curves** illustrate the **change in haemoglobin saturation** as **partial pressure changes**. The saturation of haemoglobin is affected by its affinity for oxygen, therefore in the case **where partial pressure is high**, haemoglobin has **high affinity for oxygen** and is therefore highly saturated, and vice versa.

**Saturation** can also have an effect on affinity, as after binding to the first oxygen molecule, the **affinity of haemoglobin for oxygen increases** due to a **change in shape**, thus making it **easier for the other oxygen molecules to bind**.

**Fetal haemoglobin** has a different affinity for oxygen compared to **adult haemoglobin**, as it needs to be **better at absorbing oxygen** because by the time oxygen reaches the placenta, the **oxygen saturation of the blood has decreased**. Therefore, fetal haemoglobin must have a higher affinity for oxygen in order for the foetus to survive at low partial pressure.

The affinity of haemoglobin for oxygen is also affected by the **partial pressure of carbon dioxide**. Carbon dioxide is released by respiring cells which require oxygen for the process to occur. Therefore, in the **presence of carbon dioxide**, the **affinity of haemoglobin for oxygen decreases**, thus **causing oxygen to be released**. This is known as the **Bohr effect**.