Section C : Circulation and Gas Exchange

1. The Heart and Blood Vessels

(a) Structure and Function of the Heart

The mammalian heart is made of a specialised type of muscle tissue, called **Cardiac Muscle**. The heart contains **four** chambers, two **atria** and two **ventricles** separated by **valves**.

The heart's function is to **pump** blood around the body. To do this, the heart functions as a **double pump**.

1. Blood returns from the organs of the body to the **right atrium** through the **vena cava**.
2. Blood travels from the **right atrium,** through the **tricuspid valve,** to the **right ventricle**.
3. From the **right ventricle**, blood travels through the **semi-lunar valve** into the **pulmonary artery** and then onto the **lungs**.
4. In the **lungs**, blood picks up oxygen and deposits carbon dioxide. (**Gas Exchange**)
5. Blood returns to the **heart**, through the **pulmonary veins** to the **left atrium**.
6. Blood travels from the left atrium, through the **bicuspid valve**, to the **left ventricle**.
7. From the **left ventricle**, blood travels through the **semi-lunar valve** into the **aorta**, and then onto the organs of the body.

Arteries carry blood **away** from the heart.
Veins carry blood **towards** the heart.

The valves found in the heart all prevent the **backflow** of blood. The tricuspid and bicuspid valves prevent the backflow of blood from the **ventricles** into the **atria**. The semi-lunar valves prevent the backflow of blood from the **arteries** into the **ventricles**. The circulatory system is a **one-way** system, blood must flow in one direction only. Valves, together with the pressure generated by the heart, forces blood to travel round the body in **one direction only**.

The walls of the heart are not the same thickness throughout. The wall of the **left ventricle** is much **thicker** than the wall of the right ventricle. We find this because the force generated by the contraction of the left ventricle must force blood all around the body, and back to the heart. The left ventricle is required to generate a **huge force**, greater than that generated by any of the other chambers of the heart.

The heart is made of cardiac muscle, this is a living tissue. As with all other living tissues of the body, it must have its own rich blood supply. The cardiac muscle cells require food and oxygen for respiration, and a means of getting rid of waste. The cardiac muscle receives its supply of **oxygen** and **food** through the blood circulating in the **coronary arteries**. The coronary arteries are supplied with blood by the **aorta**.

If a **blockage** develops in a **coronary artery**, then the area of cardiac muscle supplied by that artery will suffer from a lack of oxygen (anaerobic conditions) and a build-up of waste products. This is what happens when somebody has a **Heart Attack**, or **Cardiac Arrest**. When an area of cardiac muscle is starved of oxygen, permanent damage can occur, and the area of tissue may die.

(b) Blood Vessels

Arteries are responsible for carrying blood **away** from the heart to the tissues and organs of the body. Once at the tissues of the body, arteries sub-divide into smaller arteries, then **arterioles** before dividing into **capillaries**.

Capillaries supply individual cells of tissues with a rich blood supply.

On leaving a tissue, capillaries join together to form **venules**, many venules join together to form **small veins**. Many small veins join together to form larger **veins**, which then link together to form the **vena cava**. The vena cava returns blood to the right atrium of the heart.

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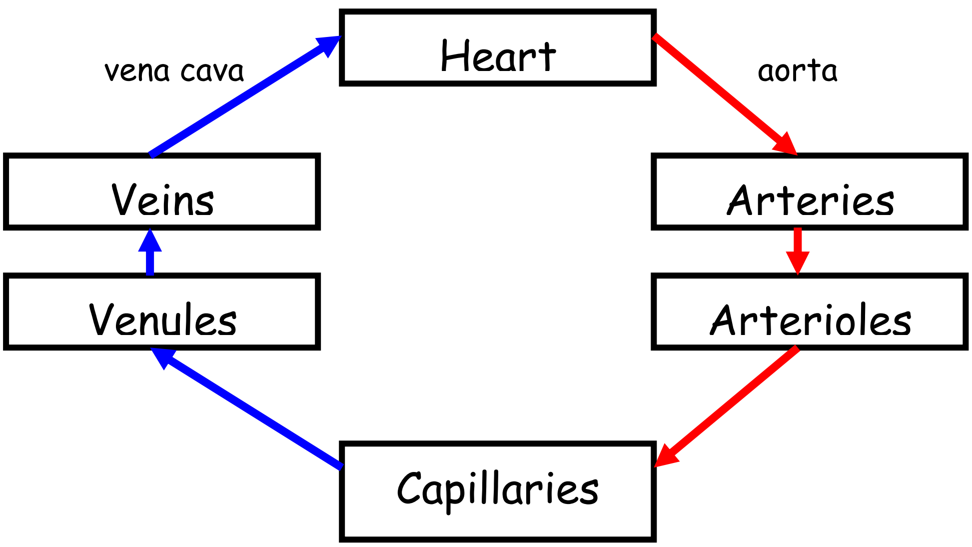


When we feel our **pulse**, we are feeling a wave of pressure flowing through an **artery**. The artery must be located **close** to the **surface** of the skin, and over a solid structure such as a **bone**. We can feel our pulse in our **wrist**, **neck** and **groin**.

You are expected to be able to name, and identify the positions, of various key blood vessels throughout the body.

- **pulmonary arteries** and **veins**
- **aorta** and **vena cava**
- **hepatic artery** and **vein**
- **hepatic portal vein**
- **mesenteric artery**
- **renal arteries** and **veins**

The different types of blood vessel all have particular features that help them carryout their **functions**.

Arteries: Have a **thick muscular wall**, with a narrow central cavity, to withstand the **high pressure** of blood being pumped **away** from the **heart**.

Capillaries: Are only **one cell thick**, allowing the easy **diffusion** of materials from the blood to the cells of our body, or vice versa.

Veins: Have a **thin muscular wall**, with a wide central cavity and **valves**. The blood found in veins is at a far lower pressure than that found in arteries. **Valves** found in veins **prevent** the **backflow** of blood, away from the heart. Blood may only flow through the valves **towards** the **heart**.

2. The Lungs and Capillary Network

(a) Structure of the Lungs

See own notes for diagrams.

(b) Structure and function of the Alveoli

The **alveoli** are the site of **gas exchange**. At the alveoli, **oxygen enters** the **blood**, and **carbon dioxide leaves**.

Oxygen moves from the centre of the alveolus into the blood by **diffusion**. **Carbon dioxide** moves from the blood into the centre of the alveolus by **diffusion**.

- **Oxygen** moves from an area of **high concentration** in the centre of the **alveolus** to an area of **low concentration** in the **blood**.

- **Carbon dioxide** moves from an area of **high concentration** in the **blood** to an area of **low concentration** in the centre of the **alveolus**.

As we **breath** in and out, we allow the **removal** of **carbon dioxide** from the air spaces (**alveoli**), and the **delivery** of **oxygen**.

To allow for efficient gas exchange, the alveoli of the lungs have certain keys features:

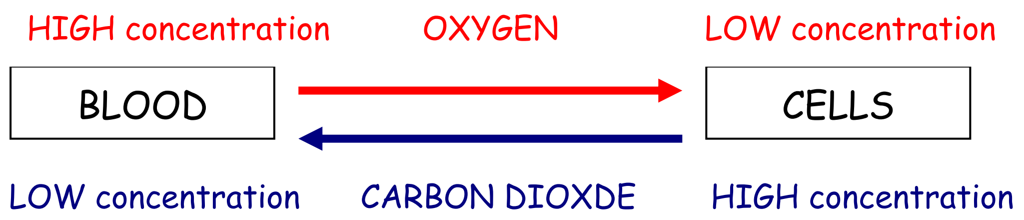
- **large surface area**
- **thin walls**
- **moist surfaces**
- **good blood supply**, via a dense network of capillaries.

(c) Gas Exchange at tissues

The cells of our bodies obtain most of their energy from **aerobic respiration**. For aerobic respiration to occur, the cells of our body require a plentiful supply of **oxygen** and **food.**

At each tissue of out body, capillaries provide a dense network of extremely small blood vessels. The capillaries create an extremely **large surface area**, over which **gas exchange** between the **tissues** and **blood** may occur.

i.e.



At the tissues around the body **oxygen** and **carbon dioxide** move by **diffusion**. The walls of the capillaries are extremely thin, whilst the capillaries are in close contact with the tissue cells. Both of these features allow for ease of **diffusion**.

3. The Blood

The blood is made up of two main parts, the **cells** and the **plasma**. The plasma is the **liquid** component of the blood, in which all the cells are suspended. There are different types of blood cells, each of which performs a particular function.

(a) Red Blood Cells

Red blood cells carry **oxygen** from the **lungs** to the **cells** of our body. Once at the cells of our body, oxygen is released from the red blood cells and taken up by our body cells. The particular shape of a red blood cell, **bi-concave disc**, gives a

greater surface area. The larger the surface area, the greater the potential for gas exchange.

Haemoglobin, a specialised protein molecule found in red blood cells, is responsible for the transport of **oxygen** in the blood around our bodies.

- In areas of **high oxygen** availability, **haemoglobin** combines with oxygen molecules, forming **oxyhaemoglobin**. This is what happens in our **lungs**.

- In areas of **low oxygen** availability, **oxyhaemoglobin** releases oxygen molecules. This is what happens at the **cells** of our body.

i.e.

$$\textbf{haemoglobin} + \textbf{oxygen} \underset{\textit{dissociation (cells)}}{\overset{\textit{association (lungs)}}{\rightleftharpoons}} \textbf{oxyhaemoglobin}$$

Red blood cells are also responsible for carrying small quantities of **carbon dioxide**. Carbon dioxide is picked up by the red blood cells at the **cells** of the body, and transported to the **lungs** for expulsion from the body.

(b) Plasma

Plasma is the straw coloured liquid in which red and white blood cells are suspended. Plasma is responsible for carrying various substances around the body.

Most of the **carbon dioxide** released from the cells of the body is carried in the **plasma** to the lungs for expulsion from the body.

The amount of **carbon dioxide** which can be carried in the plasma is **limited**. When carbon dioxide dissolves in the plasma it creates an **acidic solution**. The **more** carbon dioxide that dissolves in plasma the **more acidic** the plasma will become. There is a limit to how acidic a sample of plasma can be, before it will seriously effect the ability of the plasma to function.

Soluble food molecules, such as **glucose** and **amino acids**, are transported **dissolved** in the **plasma**.

(c) White Blood Cells

White blood cells are **rarer** in the body than **red** blood cells. White blood cells are responsible for **defending** the body from **infection**.

Note: unlike red blood cells, **white blood cells** contain a **nucleus**.

There are **more** than one type of white blood cells.

- **Macrophages** and **Monocytes** – responsible for phagocytosis (a non-specific immune response)
- **Lymphocytes** – responsible for antibody production (a specific immune response)

Immunity is the ability of the body to **resist** an **infectious disease**.

(i) Non-specific Immune Responses

Phagocytosis is the process where a **macrophage**, or monocyte, **engulfs** and then **destroys** any foreign body. The process of phagocytosis takes the following pathway:

1. A **phagocyte** (macrophage or monocyte) **detects** a **foreign body**, such as a bacterium. The phagocyte **moves** towards the foreign body.

2. The phagocyte **sticks** to the foreign body, before **engulfing** it. The foreign body is held within a **vacuole** formed by an infolding of the **cell membrane**.

3. Phagocytes contain special structures called **lysosomes**. Lysosomes contain very powerful **digestive enzymes**. These lysosomes **move** towards the vacuole containing the foreign body.

4. Lysosomes fuse with the vacuole, releasing their powerful digestive enzymes into the vacuole. These powerful digestive enzymes **digest** the foreign body.

5. On completing the digestion of a foreign body, the contents of the vacuole are **absorbed** into the phagocyte's **cytoplasm**.

Phagocytosis is an example of a **non-specific immune response**. This means that the body is simply defending itself from foreign substances regardless of what they look like to the rest of the body.

(ii) <u>Specific Immune Responses</u>

The body often requires to use a more **targeted** method of **destroying** potentially infectious disease causing microorganism. The body uses **lymphocytes** to bring about a **specific immune response**, using **antibodies**.

On the surface of every cell are special structures known as **antigens**. Our immune system recognises which cells belong to our bodies by **recognising** which antigens are our own, and which are not.
If other **antigens** are found on the **surface** of cells, then the body will **reocgnise** those cells as **<u>not</u>** belonging to our body. Any cell that does **<u>not</u>** belong to the body will be **destroyed** by using a **specific immune response**.

During a **specific immune response**, **lymphocytes** are stimulated to produce special molecules called **antibodies**. Antibodies are Y-shaped molecules, where each arm has a **receptor**. Each receptor is **specific** for a particular **antigen**. Only a **single** type of antigen is able to bind to a given receptor.

When an antigen meets its **complimentary** antibody, the **antigen** binds to the **receptor** binding site of the antibody. Once an antigen is bound to the antibody, it is made **relatively harmless**. Often a large complex of antibodies bound to antigens will form. The large complex may then stimulate **phagocytosis** by a phagocyte.

Immunisation is an example of a **specific immune response**.

- When we are immunised against a particular disease, we receive a **small** dose of **harmless antigens** for a disease causing organism.

- The body initiates a **primary response** against the antigen we are injected with. **Lymphocytes** are stimulated to produce **antibodies**.

- The antigens alone are no enough to cause the disease. Instead, we aim to produce **memory cells**. Memory cells are **stored** in the body so that we may fight **future** infections much **faster**.

- If the body is exposed to the **same antigen** as was injected into our body by immunisation, then we should be able to mount a **secondary response**.

- A secondary response is much greater than a primary response, and happens almost immediately. A secondary response should protect us from potentially **fatal infections**.

Immunisation is an example of **artificially acquired immunity**, where we are **artificially exposing** the body to a particular **antigen**. We aim to stimulate a primary immune response, so that in future exposures our bodies will be able to respond much faster during a secondary response.

Naturally acquired immunity occurs if we are **naturally exposed** to a particular antigen, by contact with the disease. If our bodies survive the **primary infection**, via a **primary response**, then **memory cells** will be stored to enable our bodies to mount a **secondary response** much faster.