# BioMedical Admissions Test (BMAT)

## Section 2: Biology

Topics B8 & B9 (part 1) - Enzymes and Organs Systems

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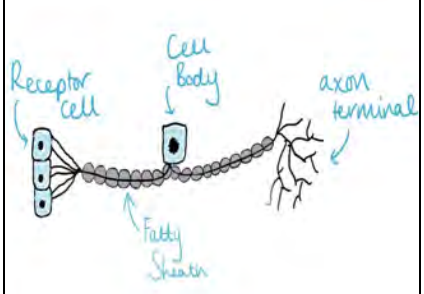
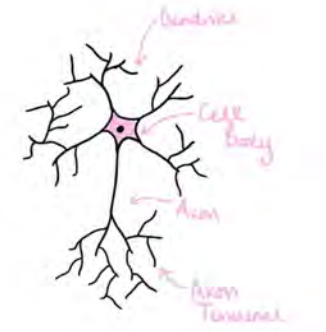
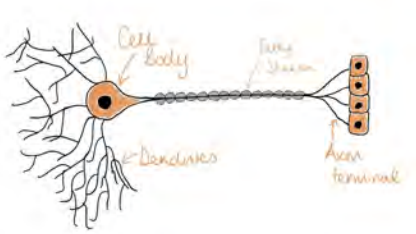
## Nervous System

### Structure of the Nervous System

Sensory organs contain receptors which detect **changes** in the environment - for example, the eyes detect light. The **central nervous system (CNS)** consists of the **brain** and **spinal cord**, and is responsible for coordinating a response. The nervous system consists of multiple different types of neurons:

| Sensory Neurons | Relay Neurons | Motor Neurons |
|---|---|---|
| Carry signals from receptors to the central nervous system | Carry signals from sensory neurons to motor neurons | Carry signals from CNS to the muscles and glands (effectors) |
|   |   |   |

All neurons have the same general structure:

- **Axon** - A long structure containing cytoplasm and surrounded by a cell membrane, the axon carries the electrical impulse along the neuron.
- **Cell Body** - Contains a nucleus enclosing DNA, this codes for the proteins needed by the cell.
- **Dendrites** - Branched structures that allow different neurons to communicate.

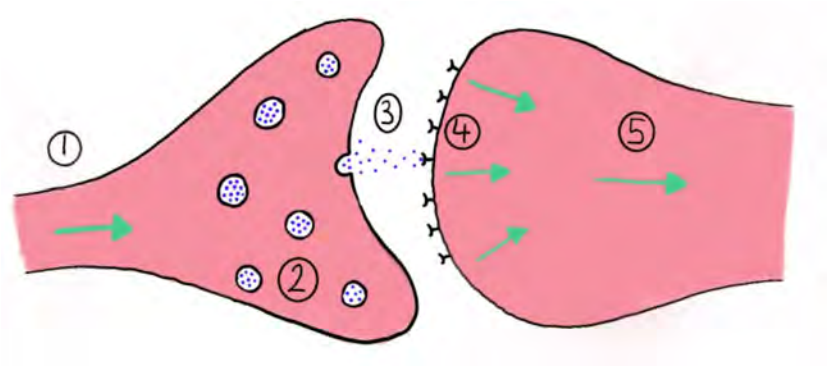
Some neurons also have a fatty **myelin sheath** surrounding the axon which increases the rate of signal transmission, acting as an **electrical insulator.**

### Synapses

A **synapse** is a ‘gap’ between two neurons. This ‘gap’ is very small, and is the slowest part of the neuronal pathway.

Chemical transmitters are released from the end of one neuron and **diffuse** passively across the synapse. The order of events at the neuron is often examined and is important to learn. It is as follows:

1. Nerve impulse travels down the axon of the first neuron.
2. Impulse triggers release of chemical transmitters.
3. Chemical transmitters diffuse across synapse.
4. Chemical transmitters bind to receptors on the second neuron.
5. Nerve impulse is initiated in the second neuron.




Drugs can affect the actions of a synapse:

- **Ecstasy** changes the way serotonin is removed from a synapse.
- Serotonin is our 'mood hormone' - this changes things like pain and aggression.
- Ecstasy causes a lack of removal of serotonin, meaning the concentration of serotonin increases.
- This normally leads to mood being enhanced.

**Reflexes**

Reflexes are unconscious actions that do not require any thought in order to carry out. You should remember that reflexes are **involuntary**, **rapid** and **automatic** responses to a stimulus

Information, in the form of an electrical impulse, travels through a **reflex arc:**

- A stimulus is detected by receptors.
- Electrical impulses travel along the sensory neuron.
- In the spinal cord, the sensory neuron and the relay neuron synapse.
- Impulses are further passed to a motor neuron via a synapse to an effector (muscle or gland).

Reflexes are **protective,** these involuntary actions increase the likelihood of survival. For example, lifting the foot after stepping on a pin or rapidly withdrawing your hand after touching something hot. Babies are born with reflexes that are later lost through development, such as grasping and suckling.

# Respiratory system

## Respiration

Respiration is the process of **releasing energy from glucose**, and occurs in every living cell. This process is **catalysed** by enzymes.

**Aerobic respiration** requires oxygen, and is the most efficient way to release to energy.

> ***Exam Tip*** - The word equation for aerobic respiration is as follows:
> **Glucose + Oxygen → Carbon Dioxide + Water + Energy**

**Anaerobic respiration** occurs in cells if there is insufficient oxygen - this is the incomplete breakdown of glucose (and releases less energy). Lactic acid is produced, which causes muscles to fatigue

> ***Exam Tip*** - The word equation for anaerobic respiration is as follows:
> **Glucose → Lactic Acid + Energy**

Some glucose is stored as glycogen, this is normally in the muscles and liver. During vigorous exercise, glycogen is converted back to glucose for use.

## The Thorax

Air enters through the mouth and nose and then passes to the **larynx**. It then continues to the **trachea**. The trachea splits into 2 main tubes called **bronchi**. These bronchi then split into progressively smaller tubes called **bronchioles**. These end in **alveoli**; the site where gas exchange takes place.

**Gas exchange** occurs in the lungs; oxygen is transferred into the blood and carbon dioxide is removed. The process of gas exchange occurs in the **alveolus**: the alveolus is specialised in a number of ways:

- The **walls** of the alveolus are one cell thick to minimise diffusion distance and time
- The alveolus has a **large surface area** to increase rate of gas exchange
- **Capillary networks** surround the alveoli to maintain a high concentration gradient

## Ventilation

**Ventilation** is the process of breathing in and out. When breathing in:

- **Intercostal** muscles **contract**, and the **diaphragm contracts** and flattens. The diaphragm is a dome shaped muscle, and flattens on contraction.
- The intercostal muscles cause the rib cage to move up and out. This, in addition to the contraction of the diaphragm, causes the **thorax volume to increase**.

- Since the volume increases, but the air inside the thorax remains the same, **thoracic pressure decreases**. This causes air to be drawn into the lungs in inhalation.

When breathing out, the opposite occurs.

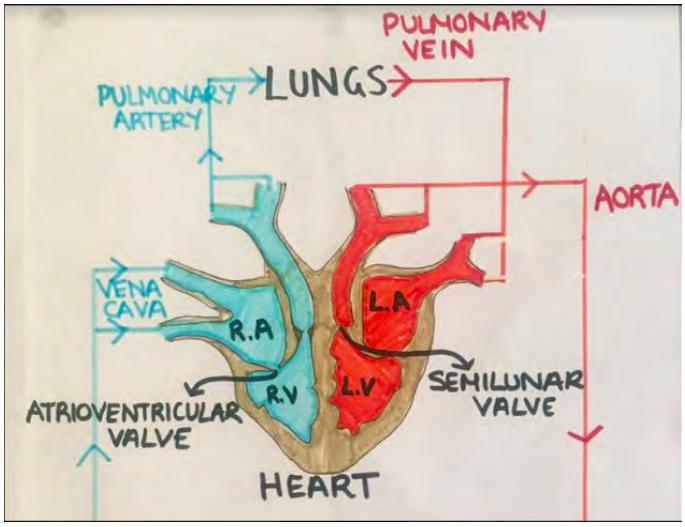
## Circulatory system

### The Heart

Humans have a **double circulatory system**, meaning there are 2 circuits for blood within the body; one pumps **oxygenated blood** to the body and the other pumps **deoxygenated blood** to the lungs.

The heart is a muscular pump that keeps blood flowing around the body. Each side of the heart has two chambers: the upper chambers are called **atria** and the lower chambers are called **ventricles**.

The heart also contains **valves**. These are present **between the atria and the ventricles**, and the **ventricles and arteries**. Valves prevent a backflow of blood.



**Blood vessels**

| | Arteries | Veins | Capillaries |
|---|---|---|---|
| **Wall Thickness** | Thick | Thin | One cell thick |
| **Lumen** | Small | Large | Very small |
| **Blood Pressure** | High | Low | High |
| **Other Characteristics** | Muscular and **elastic** walls to withstand high pressure | Veins have **valves** to prevent the backflow of blood | Walls are **very thin** to give a high diffusion rate |

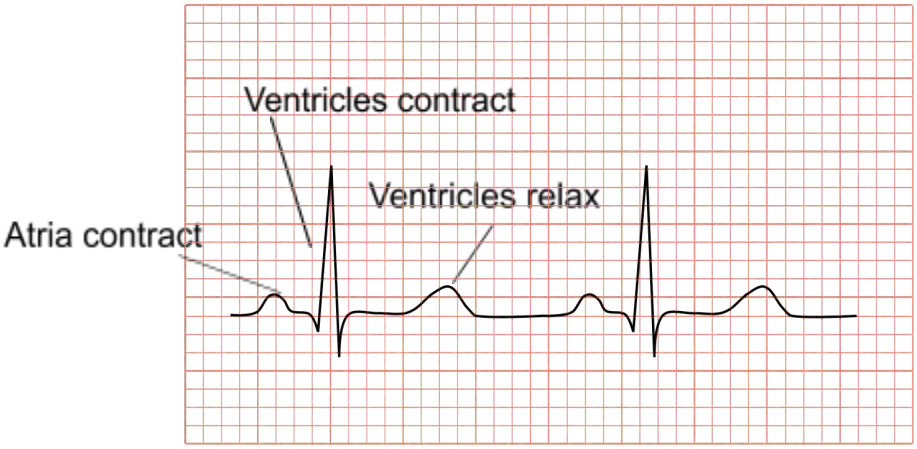
**Heart Rate**

The rate at which the heart beats is determined by the **body's demand for oxygen**. This is affected by the individual's **activity** and **conditions in the body.**

During **exercise**, heart rate **increases** from resting to cope with the extra oxygen demand.

The heart rate is controlled by pacemaker cells within the heart. These clusters of cells are known as the **sinoatrial node** (atrial contraction) and the **atrioventricular node** (ventricular contraction).

We can trace the heart's electrical activity using an **electrocardiogram (ECG).** An ECG is a diagnostic test that can show **heart attacks** and **irregular heartbeats.** The ECG below shows two full heart beats for a healthy individual.



**Composition of blood**

- Plasma:
  - The **watery** part of the blood where cells are transported
  - Contains **dissolved** glucose, amino acid, urea, carbon dioxide and proteins
  - Also **distributes heat**
- Red blood cells:
  - Contain **haemoglobin** to **carry oxygen** in the form of oxyhaemoglobin
  - Cells are **concave** in shape
  - **Do not have a nucleus** so that the cell can carry as much oxygen as possible
- White blood cells:
  - Fight **infection**
  - Can change shape in order to **engulf** microorganisms (**phagocytes**)
  - Also produce **antibodies** in order to neutralise microorganisms (**lymphocytes**)
  - Do have a **nucleus**
- Platelets:
  - Causes blood to **clot** at the site of a wound
  - **Fibrinogen** is converted into **fibrin** through a series of enzymes, creating a mesh that traps platelets and red blood cells to stop blood loss
  - **No nucleus**

> ***Exam Tip*** - Thinking about the **function** of a cell can be beneficial when trying to recall its specialisations.
>
> For example, red blood cells carry oxygen to all tissues. Therefore, maximising space for haemoglobin and being able to pass through capillaries is vital!

**Blood groups**

Blood groups are assigned depending on the antigens on the surface of the individual's red blood cell. There are A antigens and B antigens. Therefore you can be blood group A group B, group AB (having both), or group O (having neither).

| Blood Group | Antigens | Antibodies | Can donate blood to... | Can receive blood from... |
|---|---|---|---|---|
| A | A | Anti-B | A and AB | A and O |
| B | B | Anti-A | B and AB | B and O |
| AB | A, B | None | Only AB | Anyone |
| O | None | Anti-A, Anti-B | Anyone | Only O |

We can see that O is the **universal donor** and AB is the **universal recipient.**

If we give a patient red blood cells with antigens corresponding antibodies in their blood, an **agglutination** reaction will occur and can be fatal.

## Digestive system

### Structure

Food passes through the system in this order:

1. Mouth
2. Oesophagus
3. Stomach
4. Small intestine
5. Large intestine

Food is moved through a process called **peristalsis**, where wave-like muscle contractions move food along the digestive tract.
Digestion can either be **mechanical** (e.g. being ground in teeth) or **chemical** (e.g. bile and enzymes in the stomach)

### Enzymes

The main function of the digestive system is to break down large molecules into smaller soluble molecules. This is done with the use of enzymes.

Enzymes increase the rates of reaction - we call them **biological catalysts**. A catalyst increases the rate of reaction without undergoing any permanent chemical change. Enzymes are **proteins**, which means they are vulnerable to changes structure caused by alterations in **temperature and pH.** Different enzymes have different optimum temperatures and pH, depending on the function of the enzyme.

Enzymes have an **active site,** where the **substrate** binds and undergoes a reaction. The active site of an enzyme are extremely specific, and therefore only catalyses a specific reaction - this is called the **'Lock and Key model'**.

The **nutrients** in blue are broken down by the enzymes written in black:

- **Starch** → amylase → **maltose** → maltase → **glucose**
- **Protein** → proteases → **amino acids**
- **Lipids** → lipases → **glycerol + fatty acids**

You should know where the different digestive enzymes are produced:

**Amylase**:
- Salivary glands
- Pancreas
- Small intestine

**Proteases**:
- Stomach
- Pancreas
- Small intestine

**Lipases**:
- Pancreas
- Small intestine

> ***Exam Tip*** - Look at a diagram of the digestive system to ensure you know the function of the different organs, including the pancreas, liver, gallbladder and stomach!

**Bile** is made in the liver and is then stored in the **gall bladder** until needed. It is then released into the **small intestine**. Bile is important for a process called **emulsification**, where large lipid droplets are broken down into smaller droplets, therefore increasing the **surface area**. This means that the rate of digestion increases.

**Food absorption**
- The **small intestine** is the main site of absorption. It is adapted for the role, as the wall contains millions of **villi** - finger-like projections that increase the surface area for absorption.
- Villi contain many blood capillaries so that a **high concentration gradient** is maintained, to ensure that diffuse is efficient.
- Nutrients are absorbed through **diffusion** and **active transport** and water is absorbed through **osmosis**.
- These absorbed nutrients are then used in order to make new macromolecules, for respiration, growth and repair or energy storage.
- The parts of the food that are unable to be digested (e.g. cellulose) leaves the body as **faeces**, which is brown due to bile pigments. Faeces is **egested** out from the anus.

## Excretory System

Excretion is the removal of toxic substances that were created through metabolic processes in the body.

- Liver
  - Excess amino acids are broken down by liver through **deamination**. The nitrogen parts of these are converted into **urea** - a toxic substance which is then excreted by the kidneys (more detail below)
  - Breaks down haemoglobin to create **bilirubin**, which is excreted with faeces
- Lungs
  - Removes **carbon dioxide** from the body, which is a waste product of aerobic respiration
- Skin
  - Produces **sweat**, containing sodium chloride and small amounts of urea dissolved in water
  - Skin is not an excretory organ in the same way that the lungs or kidney are
- Kidneys
  - Removes **urea**
  - Adjusts **water content**
  - Adjusts **ion levels**

### The Kidneys

Each kidney receives blood from a **renal artery** (a branch of the aorta). The filtered blood is returned to the **renal vein**, which then forms the vena cava.

Each kidney contains millions of **nephrons**. Within each nephron there is a **glomerulus**, which is a ball of capillaries that is surrounded by a **Bowman's capsule**. This leads to a **proximal convoluted tubule, the loop of Henle, the distal convoluted tubule** and the **collecting duct.**

> ***Exam Tip*** - Look at the structure of the nephron and make sure you understand the processes occurring at each part.

Large cells and substances, such as red blood cells and proteins, cannot filter through the glomerulus and therefore stay within the capillaries. However, smaller molecules such as water, urea and dissolved ions are forced through the walls through **ultrafiltration** (filtration under pressure), forming the **filtrate**.

The filtrate passes through the tubule and **selective reabsorption** of glucose, some salt and water occurs.

Excess salts, urea and uric acid continue into the collecting duct to form urine, which passes to the bladder and then is expelled through the urethra.