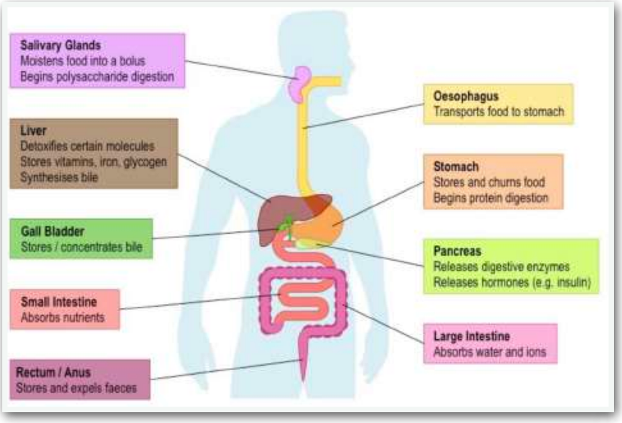
Chapter 6 —> Human Physiology

6.1 Digestion

Digestive system:

- Two major groups of organs which comprise the human digestive system:
  —> Alimentary canal —> organs through which food actually passes (oesophagus, stomach, small & large intestine)
  —> Accessory organs —> aid in digestion but do not actually transfer food (salivary glands, pancreas, liver, gall bladder)



Mechanical digestion:

Chewing:
- Occurs in the mouth —> food is broken down in the mouth by the grinding action of teeth
- The tongue pushes food towards the back of the throat than down the oesophagus as a bolus
- The epiglottis prevents the bolus from entering the trachea
- The uvula prevents the bolus from entering the nasal cavity

Churning:
- Occurs in the stomach —> the stomach lining contains muscles which physically squeeze and mix the food with strong digestive juices
- Food is digested within the stomach for several hours and is turned into chyme (creamy)
- The chyme enters the small intestine (duodenum) where absorption occurs

Chemical digestion:

Stomach acids:
- The stomach contains gastric glands which release digestive acids to create low pH (2)
- The acidic environment denatures proteins and other macromolecules
- The stomach epithelium contains a mucous membrane which prevents acids from damaging the gastric lining
- The pancreas releases alkaline compounds —> neutralise the acids when entering the intestine

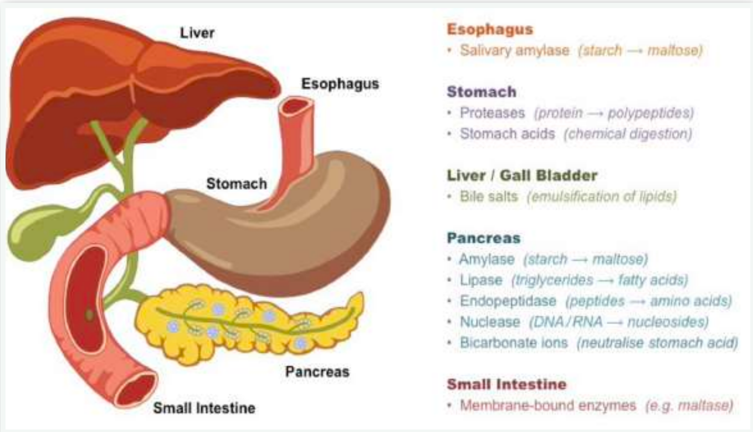
Bile:
- Produced by the liver and stored and concentrated within the gall bladder before being released into the intestine
- Bile salts interact with fat globules to divide them into smaller droplets (emulsification)
- Emulsification of fats increases the total surface area available for enzyme activity

Enzymes:
- Allow digestive processes to occur at body temperatures and at sufficient speeds for survival
- Are specific for a substrate —> allow digestion of certain molecules to occur in distinct places

Movement of food:

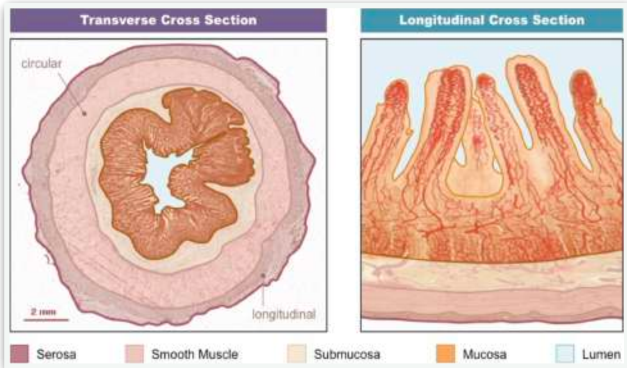
Peristalsis:
- Continuous segments of longitudinal smooth muscle which rhythmically contract and relax
- The principal mechanism of movement in the oesophagus (occurs also in the stomach and gut)
- Food is moved unidirectionally along the alimentary canal in a caudal direction (mouth - anus)

Segmentation:
- Involves the contraction and relaxation of non-adjacent segments of circular smooth muscle in the intestines
- Move chime in both directions —> allows for a greater mixing of food with digestive juices
- Bidirectional propulsion of chyme can slow overall movement



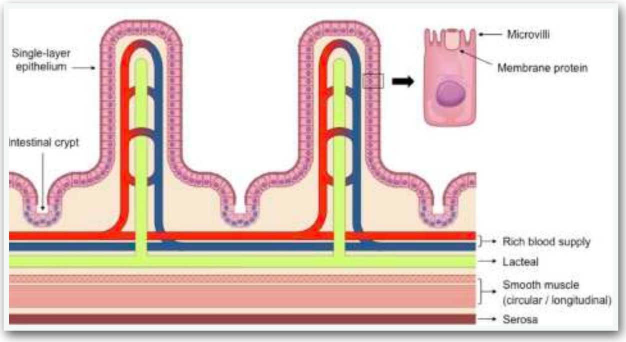
Small intestine:

- Absorbs usable food substances (nutrients)
- Is composed by four main tissue layers



Structure:
- Serosa —> protective outer covering composed of a layer of cells —> reinforced by fibrous connective tissue
- Muscle layer —> outer layer of longitudinal muscle and inner layer of circular muscle
- Submucosa —> connective tissue separating the muscle layer from the innermost mucosa
- Mucosa —> highly folded inner layer —> absorbs material through its surface epithelium from the intestinal lumen
- Ileum —> final section of the small intestine (image on the right)

Villi:
- Intestinal villi contain several key features which facilitate the absorption of digestive products
- Microvilli —> ruffling of epithelial membrane further increases surface area
- Rich blood supply —> dense capillary network rapidly transports absorbed products
- Single layer epithelium —> minimises diffusion distance between lumen and blood
- Lacteals —> absorbs lipids from the intestine into the lymphatic system
- Intestinal glands —> Exocrine pits (scripts of Lieberkuhn) release digestive juices
- Membrane proteins —> facilitate transport of digested materials into epithelial cells

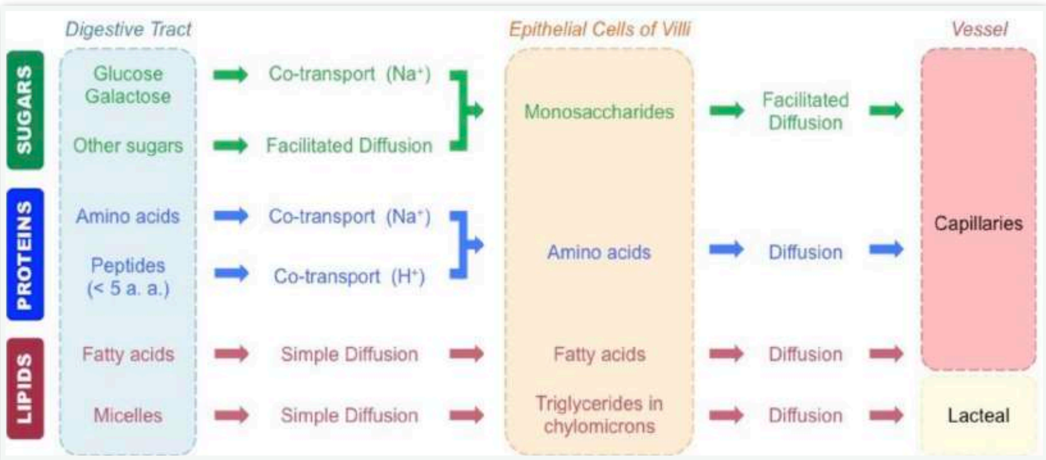


Structure of Villus epithelium:

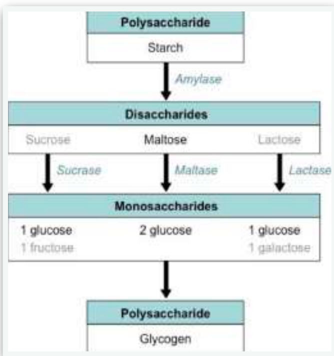
- Tight junctions —> occluding associations between the plasma membrane of two adjacent cells —> creates an impermeable membrane —> keep digestive fluids separated from tissues and maintain a concentration gradient by ensuring one-way movement
- Microvilli —> increase SA of the plasma membrane by >100x —> membrane has immobilised digestive enzymes and channel proteins for material uptake
- Mitochondria —> epithelial cells of intestinal villi will possess large numbers of mitochondria to provide ATP for active transport mechanisms (primary, secondary or pinocytosis)
- Pinocytotic vesicles —> the non-specific uptake of fluids and dissolved solutes

Absorption (membrane transport mechanisms):

- During absorption, digested food monomers must pass from the lumen into the epithelial lining
- Secondary Active Transport —> glucose and amino acids are co-transported across the epithelial membrane by the active translocation of sodium ions (Na^+)
- Facilitated diffusion —> channel proteins help hydrophilic food molecules pass through the hydrophobic portion of the plasma membrane and are often situated near specific membrane-bound enzymes —> used for certain monosaccharides, vitamins and some minerals
- Osmosis —> water will diffuse across the membrane in response to the movement of ions and solutes —> occurs in both small and large intestine
- Simple diffusion —> hydrophobic materials may freely pass through the hydrophobic portion of the plasma membrane —> will often pass through the lacteal before going into blood vessels
- Bulk transport —> via endocytosis —> precisely pinocytosis



Starch digestion:



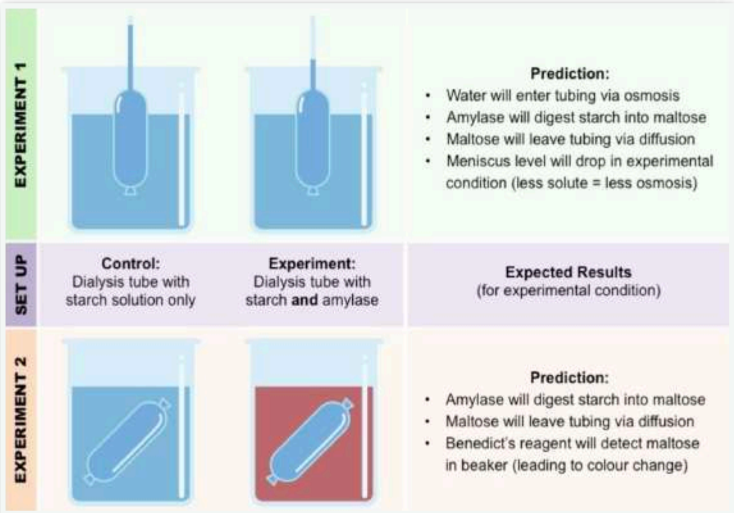
- Starch is a polysaccharide which accounts for 60% of the carbohydrates consumed by humans
- Exists in form of linear chains (amylose), and branched chains (amylopectin)
- The digestion of starch is initiated by salivary amylase in the mouth and continued by pancreatic amylase in the intestine —> not in stomach as optimal pH for amylase activity is 7

- Amylose becomes maltose and amylopectin becomes branched chains called dextrins
- Maltose and dextrin are digested by enzymes (maltase) which are fixed to the epithelial lining in the small intestine —> this hydrolysis results in the formation of glucose monomers
- Glucose can be hydrolysed to produce ATP or can be stored as glycogen

Pancreas role:
- Produces enzyme amylase —> released from exocrine glans (acing cells) into the intestinal tract
- Produces hormones insulin and glucagon —> released from endocrine glands (islets of Langerhans) into the blood —> controls concentration of glucose in the bloodstream
- Insulin lowers blood glucose levels by increasing glycogen synthesis and storage in the liver and adipose tissues
- Glucagon increases blood glucose levels by limiting the synthesis and storage of glycogen

Modelling digestion:

- The digestive system serves mostly to break down large molecules into smaller subunits as cell membranes are impermeable to large molecules
- Dialysis tubing (Visking tubing) —> contains pores typically ranging from 1-10 nm in diameter and is semi-permeable according to molecular size
    —> large molecules such as starch cannot pass through the tubing, but maltose can
    —> is not selectively permeable based on charge unlike membranes of living cells
- Measuring Meniscus levels (experiment 1) and measuring Maltose diffusion (experiment 2)



6.2 The blood system

William Harvey:

- Modern understanding of the circulatory system is based upon his discoveries in the 17th century
- Harvey proposed that —> arteries and veins were part of a single connected blood network (did not predict the existence of capillaries)
    —> arteries pumped blood from the heart
    —> veins returned blood to the heart

Overview of Pulmonary and systemic circulation:

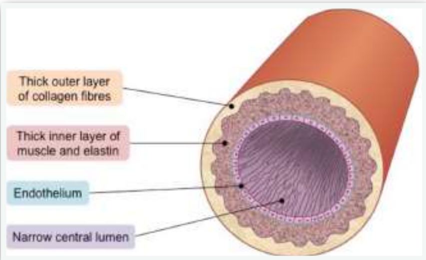
- The human heart is a four chambered organ —> two atria and two ventricles
- The atria act as reservoirs —> blood returning to the heart is collected via veins and passed to ventricles
- The ventricles act as pumps —> expel the blood from the heart at high pressure via arteries

- The left side of the heart pumps oxygenated blood around the body (systemic circulation) —> will have a much thicker muscular wall (myocardium) as it must pump blood much further
- The right side of the heart pumps deoxygenated blood to the lungs (pulmonary circulation)

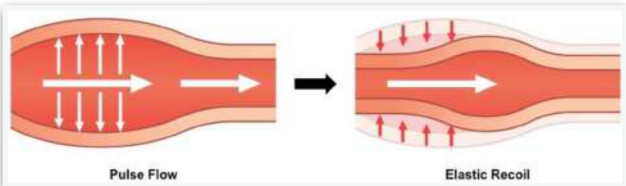
Arteries:

- Convey blood at high pressure from the heart ventricles to the tissues of the body and lungs
- Specialised structure —> narrow lumen to maintain a high blood pressure (80 - 120 mmHg)
  —> have a thick wall containing an outer layer of collagen to prevent the artery from rupturing under the high pressure
  —> the arterial wall also contains an inner layer of muscle and elastic fibres to help maintain pulse flow (it can contract and stretch)

Flow of blood:

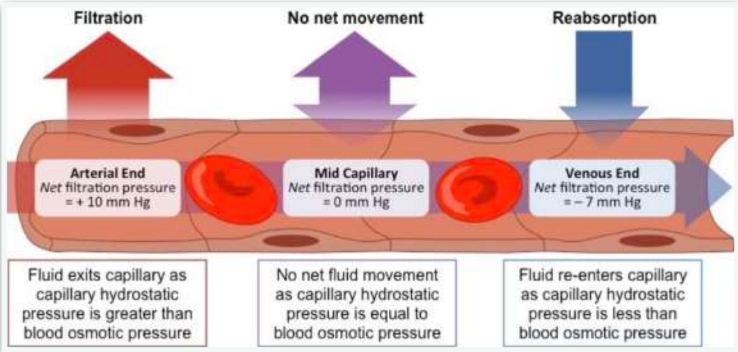


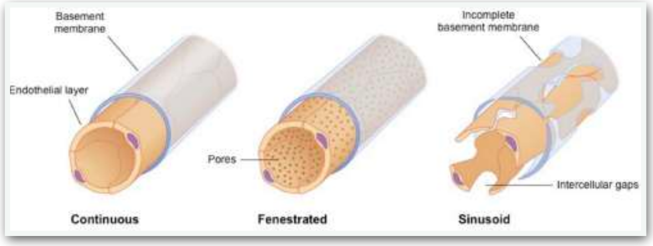
- Blood is expelled from the heart upon ventricular contraction and flow through the arteries in repeated pulses
- Muscle fibres —> help to form a rigid arterial wall that is capable of withstanding the high blood pressure without rupturing —> can also contract to narrow the lumen to help maintain blood pressure throughout the cardiac cycle
- Elastic fibres —> allow arterial wall to stretch and expand upon the flow of a pulse through the lumen —> the pressure exerted on the arterial wall is retired to the blood as an elastic recoil



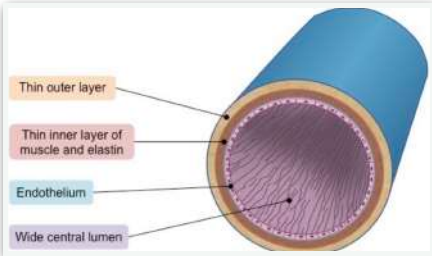
Capillaries:

- Exchange materials between the cells in tissues and blood travelling at low pressure (<10mmHg)
- Arteries split into arteriole which in turn split into capillaries —> decreases arterial pressure as total vessel volume increases —> branching ensures blood is moving slowly and everywhere
- After material exchange, capillaries will pool into venues which will turn into larger veins
- Specialised structure —> very small diameter (5µm) —> one single red blood cell at a time
  —> capillary wall is made of a single layer to minimise diffusion distance
  —> are surrounded by a basement membrane which is permeable to necessary materials
  —> pores to aid in the transport of materials between tissue fluid and blood
- Capillaries structure may vary depending on its location in the body and specific role:
  —> capillary wall may be continuous with endothelial cells held together by tight junctions to limit permeability of large molecules
  —> in tissues specialised for absorption the capillary wall may be fenestrated
  —> sinusoidal capillaries have open spaces between cells (permeable to large molecules)

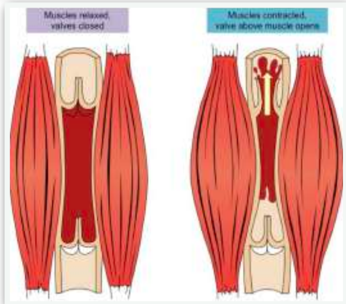




Veins:



- Collect the blood from the tissues and covey it at low pressure to the atria of the heart
- Specialised structure —> have a very wide lumen —> maximise blood flow
  —> have a thin wall containing less muscle and elastic fibres as blood is flowing at a very low pressure (5-10 mmHg)
  —> valves to prevent backflow as low pressure
- Veins typically pass between skeletal muscle groups —> facilitate venous blood flow via periodic contractions
- Typically run parallel to arteries —> similar effect can be caused by the rhythmic arterial blue created by a pulse



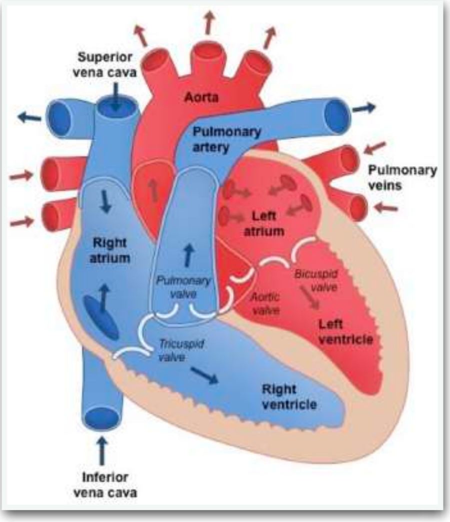
Vessel comparison:

	Arteries	Veins	Capillaries
Function	Send blood **from** heart	Send blood **to** heart	Material exchange with tissues
Pressure	High	Low	Low
Lumen Diameter	Narrow	Wide	Extremely narrow (one cell wide)
Wall Thickness	Thick	Thin	Extremely thin (single cell thick)
Wall Layers	Three • Tunica adventitia • Tunica media • Tunica intima	Three • Tunica adventitia • Tunica media • Tunica intima	One • Tunica intima
Muscle & Elastic Fibres	Large amounts	Small amounts	None
Valves	No	Yes	No

Heart structure:

- Chambers —> two atria —> smaller chambers near top of the heart —> collect blood from body and lungs
  —> two ventricles —> larger chambers near bottom of heart that pump blood to body and lungs
- Heart valves —> atrioventricular valves (between atria and ventricles)
  —> bicuspid valve on left side; tricuspid valve on right side
  —> semilunar valves (between ventricles and arteries) —> aortic valve on left side; pulmonary valve on right

- Blood vessels —> the vena cava (inferior and superior) feeds into the right atrium and returns deoxygenated blood from the body
    —> pulmonary artery connects to the right ventricle and sends deoxygenated blood to the lungs
    —> pulmonary vein feeds into the left atrium and returns oxygenated blood from the lungs
    —> aorta extends from the left ventricle and sends oxygenated blood around the body



Heart beat:

- The contraction of the heart is myogenic —> the signal for cardiac compression arises within the heart tissue itself
- Cardiomyocytes give signal for a heart beat —> not brain signals
- Sinoatrial node (SA) —> cluster of cells within the wall of the right atrium —> cardiomyocytes —> primary pacemaker —> 60 - 100 cardiac contraction per minute (normal sinus rhythm)
- If sinoatrial node fails a secondary pacemaker (AV node) maintains cardiac contractions (40-60)
- If both fail —> tertiary pacemaker (bundle of His) coordinates contraction (30-40)
- Interference of the pacemakers will lead to irregular and uncoordinated contractions (fibrillation)
- Normal sinus rhythm may be re-established with a controlled electrical current (defibrillation)

1) Sinoatrial node sends out an electrical impulse that stimulates contraction of the myocardium
2) The impulse directly causes the atria to contract and stimulates the atrioventricular node at the junction between the atrium and ventricle
3) The AV node sends signals down the septum via a nerve bundle (Bundle of His)
4) The bundle of His innervates nerve fibres (Purkinje fibres) in the ventricular wall —> causes ventricular contraction

- There is a delay between atrial and ventricular contractions —> results in two heart sounds —> this delay allows time for the ventricles to fill with blood (maximise blood flow)

Heart rate:

- Nerve signals from the brain can trigger rapid changes in heart beat rate, while endocrine signals can trigger more sustained changes
- Also changes to blood pressure levels or CO_2 concentrations will trigger changes in heart rate

Nerve signalling:
- Pacemakers are under automatic control from the brain (by medulla oblongata —> brain stem)
- Two nerves connected to the medulla regulate heart rate by either increasing or decreasing it
    —> sympathetic nerve releases neurotransmitter noradrenaline (norepinephrine) increase bpm
    —> parasympathetic nerve (vagus nerve) releases neurotransm. acetylcholine decrease bpm

Hormonal signalling:
- Hormones are chemical messengers released into the bloodstream —> act specifically on distant target sites (like the heart
- The hormone adrenaline (epinephrine) is released from the adrenal glands (above the kidneys)

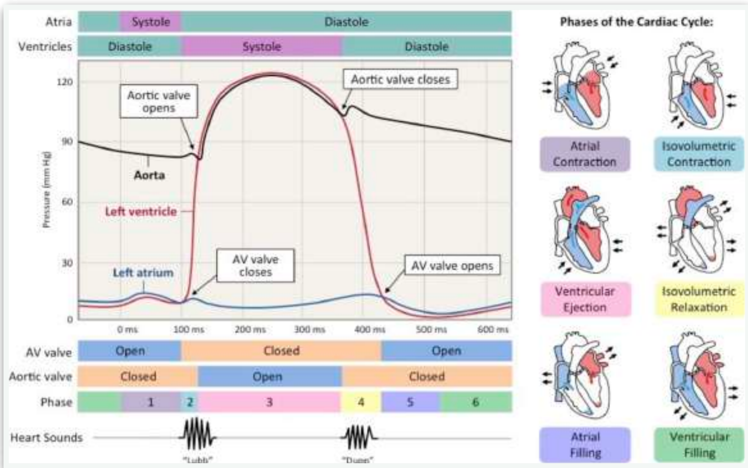
—> increases heart rate by activating same chemical pathways as neurotransmitter noradrenaline

Cardiac cycle:

- Describes the series of events that take place in the heart over the duration of a single heart beat
- It is comprised of a period of contraction (systole) and relaxation (diastole)

Systole:
- Blood returning to the heart will flow into the atria and ventricles as the pressure in them is lower
- When ventricles are 70% full, atria will contract —> more pressure so blood goes into ventricles
- As ventricles contract, ventricular pressure exceeds atrial pressure and AV valves close to prevent back flow (first heart sound)
- With both sets of heart valves closed, pressure rapidly builds in the contracting ventricles (isovolumetric contraction)
- When ventricular pressure exceeds blood pressure in the aorta, the aortic valve opens and blood is released into the aorta

Diastole:
- As blood exists the ventricle and travels down the aorta, ventricular pressure falls
- When ventricular pressure drops below aortic pressure, the aortic valve closes to prevent backflow (second heart sound)
- When the ventricular pressure drops below the atrial pressure, the AV valve opens and blood can flow from atria to ventricle



Heart diseases:

- Coronary arteries —> blood vessels that surround the heart and nourish the cardiac tissue to keep the heart working —> if they become occluded, the region of the blocked artery will die and cease to function

Atherosclerosis:
- The hardening and narrowing of the arteries due to the deposition of cholesterol
- Atheromas (fatty deposits) develop in the arteries and significantly reduce the lumen (stenosis)
- Pressure increases —> causes damage to the arterial wall from shear stress
- Lesions called atherosclerotic plaques form as the smooth lining of the artery is degraded
- Thrombus —> restricts blood flow and happens if the plaque ruptures
  —> becomes an embolus if dislodged and can cause a blockage in a smaller arteriole

- Can lead to blood clots which cause coronary heart diseases when they occur in coronary arteries
- Myocardial tissue needs oxygen and nutrients brought via the coronary arteries to function
- If a coronary artery becomes blocked, an acute myocardial infarction (heart attack) will result
- Blockages are treated by by-pass surgery or creating a stent (balloon angioplasty)
- Risk factors are —> age, genetics, obesity, diseases, diet, exercise, sex, smoking

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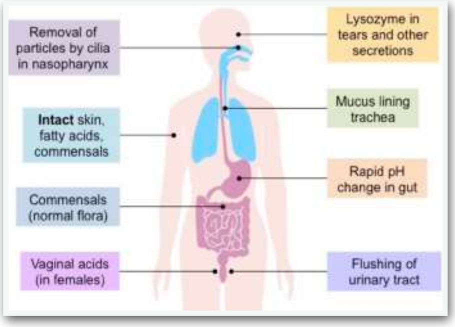
6.3 Disease defences



Surface barriers:

- First line of defence against infectious diseases —> prevent entry of pathogens in the bod
- Skin —> protects external structures when intact
  —> dry, thick, tough region of dead surface cells (epidermis)
  —> dermis —> contains biochemical defence agents —>
  sebaceous glands secrete chemicals + enzymes which inhibit microbial growth on skin
  —> Also secretes lactic acid and fatty acids to lower the pH (5.6 - 6.4)
- Mucous membranes —> protects internal structures (externally accessible cavities and tubes)
  —> thin living surface cells that release fluids to wash away pathogens (mucus, saliva, tear)
  —> contains biochemical defence agents —> can destroy cell walls and cause cell lysis
  —> mucous membranes may be ciliated to aid in the removal of pathogens

Clotting (haemostasis):

- Is the mechanism by which broken blood vessels are repaired when damaged
- Functions to prevent blood (erythrocytes) loss from the body and limit pathogenic access to the bloodstream when the skin is broken
- Platelets —> undergo a structural change when activated to form a sticky plug at damaged region
- Fibrin strands —> form an insoluble mesh of fibres that trap blood cells at the site of damage

Coagulation cascade:
- Process by which blood clots are formed —> involves a complex set of reactions

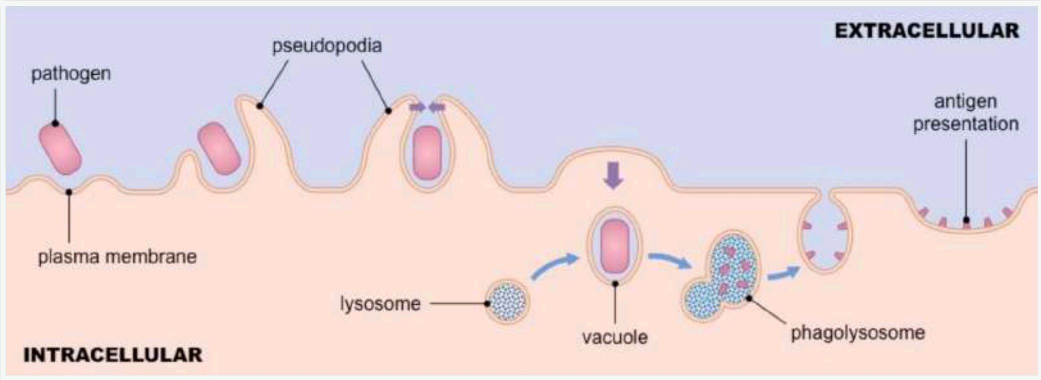
1) Clotting factors cause platelets to be sticky and adhere to damaged region to form a solid plug
2) These factors also initiate localised vasoconstriction to reduce blood flow to damaged region
3) The factors trigger the activation of zymogen prothrombin into the activated enzyme thrombin
4) Thrombin catalyses the conversion of the soluble plasma protein fibrinogen into insoluble fibrin
5) The fibrin strands form a mesh of fibres around the platelet plug —> temporary blood clot
6) When the damaged region is repaired, plasmin enzyme is activated and dissolves the clot

Coronary Thrombosis:
- The formation of a clot within the blood vessels that supply and sustain the heart tissue
- May lead to an acute myocardial infarction (heart attack)
- Vessels get damaged due to atherosclerosis

Phagocytes:

- Are the second line of defence against infectious disease
- Innate immune system —> is non-specific in its response
- Phagocytic white blood cells —> principle component which engulfs and digests foreign bodies
- Other components include inflammation, fever and antimicrobial chemicals
- Two key properties —> does not differentiate between different types of pathogen (non-specific)
  —> responds to an infection the same way every time (non-adaptive)
- Phagocytic leukocytes circulate in the blood and move into the body tissue (extravasation) in response to infection

- Damaged tissues release chemicals (e.g histamine) —> draw white blood cells to site of infection (via chemotaxis)
- Pathogens are engulfed when cellular extensions (pseudopodia) surround the pathogen by macrophages
- The vesicle is then fused to a lysosome —> phagolysosome —> pathogen is digested
- Pathogen fragments (antigens) may be on surface of phagocyte —> stimulate 3rd line of defence



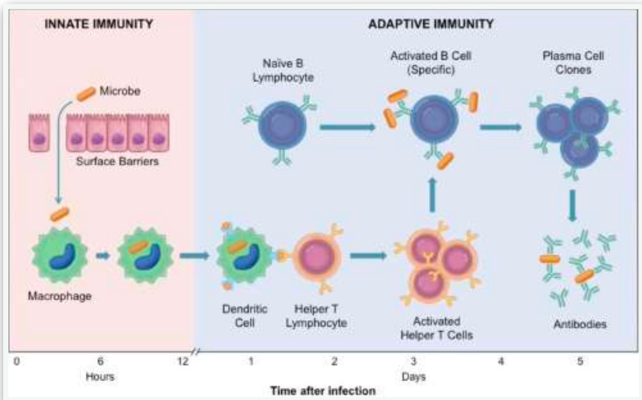
Lymphocytes:

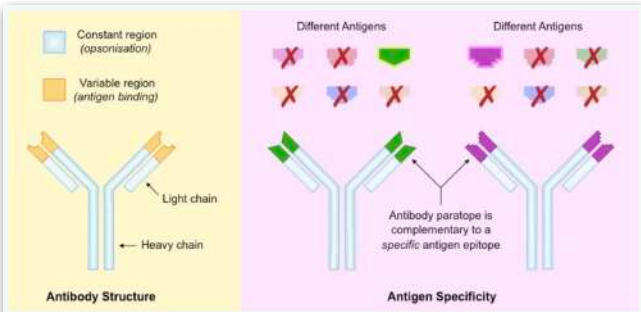
- Third line of defence against infectious diseases
- Adaptive immune system —> is specific in its response —> results in production of antibodies
- It can differentiate between particular pathogens and target a response specific to a pathogen
- Can respond rapidly upon re-exposure to a specific pathogen —> prevents symptoms from developing (immunological memory)

- B lymphocytes are antibody-producing cells that recognise and target a particular antigen
- Helper T lymphocytes (regulator cells) —> release chemicals (cytokines) to activate specific B cells

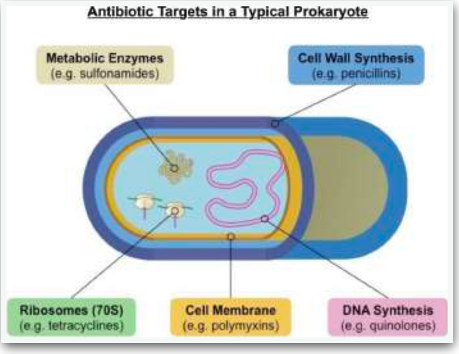
Antibodies:

- A protein produced by B lymphocytes and plasma cells that is specific to a given antigen
- Antigen —> a substance that the body recognises as foreign and that will elicit an immune response
- Antibodies are made of 4 polypeptide chains —> joined together by disulphide bonds (Y shaped)
- Variable regions —> differ between antibodies and are at the end of the arms where the antigen binds
- The rest of the molecule is constant for all antibodies —> serves as recognition for the immune system (opsonisation)
- Exists an antigen-antibody specific interaction





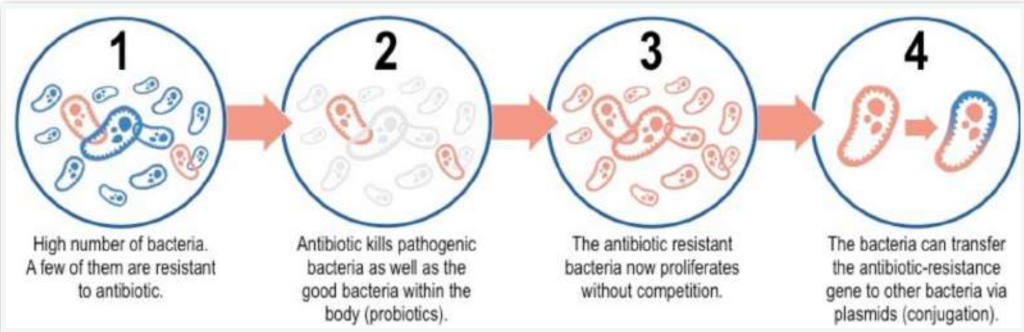
Antibiotics:



-Compounds that kill or inhibit the growth of microbes by targeting prokaryotic metabolism
-Targets may be —> key enzymes, 70s ribosomes and components of the cell wall as they are not possessed by eukaryotic cells but only by pathogenic bacteria
-Kill the invading bacteria (bactericidal), or suppress its potential to reproduce (bacteriostatic)

- Viruses do not possess a metabolism and do instead take over the cellular machinery of the host
- Viruses must be treated with specific antiviral agents —> targets features specific to viruses

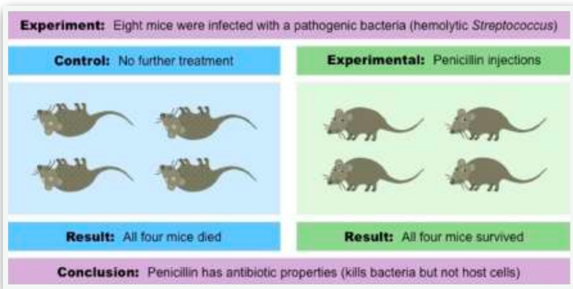
- Antibiotics can be narrow spectrum (effective against specific bacteria), or broad spectrum (effective against many bacteria)
- Resistant bacterial strains are increasing due to:
  —> overprescription of antibiotics and misuse —> many don't need a prescription or are used in livestock feed
  —> multi-drug resistant bacteria are very common in hospitals where antibiotic use is high



Penicillin:

- The first chemical compound found to have antibiotic properties —> identified by Alexander Fleming in 1928
- Discovery was an accident —> from unintended contamination of a dish containing S. Aureus
- The mould was releasing a substance (penicillin) that was killing the nearby bacteria

Florey and Chain experiment:
- Medical application were demonstrated in 1940
- All three were awarded the Nobel price for medicine
- Several synthetic derivatives have been created, including methicillin —> offer many benefits including a broader spectrum, more stability and greater tolerance



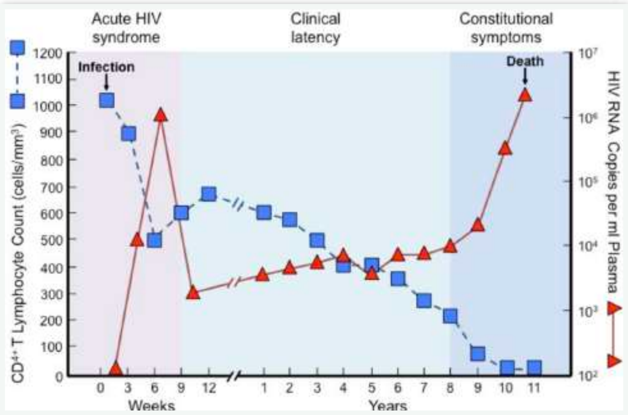
HIV infection:

- Human Immunodeficiency Virus —> a retrovirus that infects helper T cells —> disables the body's adaptive immune system
- It causes a variety of symptoms and infections know as Acquired Immune-Deficiency Syndrome
- Effects —> following infection the virus undergoes a period of inactivity (clinical latency) during which infected helper T cells reproduce

    —> the virus becomes active again and begins to spread —> destroys the T lymphocytes in the process (lysogenic cycle)

    —> lower immunity as with low helper T cells antibodies are unable to be produced

    —> the body becomes susceptible to opportunistic infections —> death mainly



- HIV is transmitted through the exchange of body fluids
- The risk of exposure to HIV through sexual contact is minimised by using latex protection
- A small minority of people are immune to HIV infection (lack CD4+ receptor required on T cells)
- Global issue but prevalent in poorer nations with poor education and health systems
- Transmits via sexual contact, pregnancy, childbirth, breast feeding, injection drug use, blood transfusion, organ transplant and occupational exposure

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6.4 Gas exchange

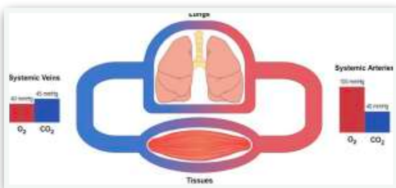
Ventilation:

- Physiological respiration involves the transport of oxygen to cells within the tissues
- It is comprised of three distinct processes and is not to be confuse with cellular respiration

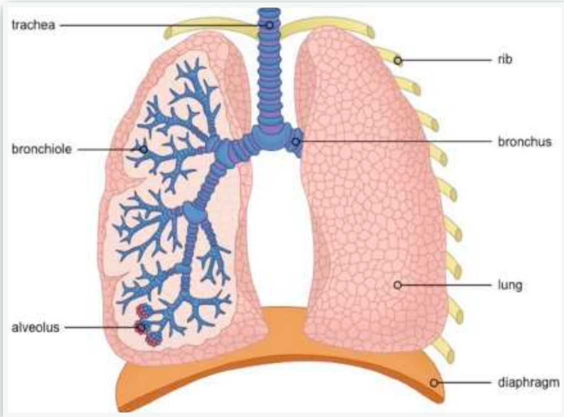
1) Ventilation —> exchange of air between the atmosphere and the lungs —> achieved by the physical act of breathing
2) Gas exchange —> exchange of oxygen and CO_2 between the alveoli and bloodstream (passive)
3) Cell respiration —> release of ATP from organic molecules —> oxygen needed for aerobic

Purpose of ventilation:

- Gas exchange is a passive process —> ventilation system is needed to maintain a concentration gradient in the alveoli
- O_2 is constantly being removed from the alveoli into the bloodstream + CO_2 is being released
- Lungs function as a ventilation system by continually cycling fresh air into the alveoli —> have a very large surface area to increase the overall rate of gas exchange —> O_2 levels high, while CO_2 levels low

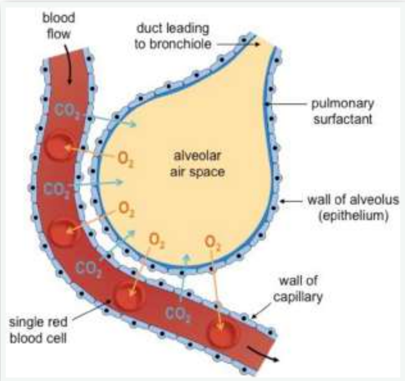


Lung structure:



The respiratory system:

- Air enters the respiratory system through the nose/mouth and passes through the pharynx to the trachea
- From the trachea, air goes down until two bronchi
- The right lung has three lobes, while left only two due to heart position
- In each lung the bronchi divide into many smaller airways (bronchioles) —> increases surface area
- Each bronchiole terminates with a cluster of air sacs (alveoli) —> gas exchange with bloodstream occurs here



Structure of an alveolus:

- Have specialised structural features
- Thin epithelial layer (one cell) to minimise diffusion distance
- Are surrounded by a rich capillary network
- Are roughly spherical in shape —> maximise SA
- Internal surface is covered with a layer of fluid —> dissolved gases are better able to diffuse into the bloodstream

Pneumocytes:

- Are the cells that line the alveoli and comprise of the majority of the inner surface of the lungs
- Alveolar cells —> two types —> type 1 and type 2 pneumocytes

Type 1 pneumocytes:

- Are involved in the process of gas exchange between the alveoli and the capillaries
- Are squamous (flattened) in shape and thin (0.15µm) —> minimise diffusion distance
- Are connected by occluding junctions —> prevent leakage of tissue fluid into the alveolar space
- Are amitotic and unable to replicate —> type 2 cells can differentiate in type 1 cells if required

Type 2 pneumocytes:

- Are responsible for the secretion of pulmonary surfactant —> less surface tension in the alveoli
- Are cuboidal in shape and possess many granules (store surfactant components)
- 5% of alveolar surface but 60% of total cells

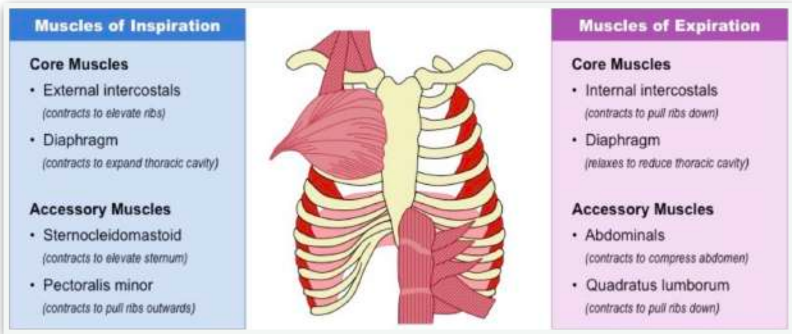
- Alveoli are lined by a layer of liquid in order to create a moist surface conducive to gas exchange with the capillaries —> easier for oxygen to diffuse across the alveolar and capillary membranes when dissolved in liquid
- Moist lining also creates a tendency for the alveoli to collapse and resist inflation other than assisting with gas exchange as there is a high surface tension
- As an alveoli expands with gas intake, the surfactant becomes more spread out across the moist alveolar lining —> this increases surface tension and slows the rate of expansion —> ensures all alveoli inflate at same rate

Breathing:

- The active movement of respiratory muscles that enables the passage of air into and out of lungs
- The contraction of respiratory muscles changes the volume of the thoracic cavity
- According to Boyle's law —> volume of cavity increases —> pressure in the thorax decreases
  —> volume of cavity decreases —> pressure in the thorax increases
- Gases will move from a region of high pressure to a region of lower pressure
  —> pressure in the chest is less than atm. —> air will move into the lungs (inspiration)
  —> pressure in the chest is greater than atm. —> air will move into the lungs (expiration)
- Changing chest volume creates a pressure differential between the chest and atmosphere —> air moves to equalise
- Atmospheric pressure is lower at high altitudes —> greater increase in chest volume is required before a pressure differential is formed —> harder to breathe

Respiratory muscles:

- Inspiration and expiration are controlled by two sets of antagonistic muscle groups
- This means that when inspiratory muscles contract, expiratory muscles relax



Inspiration:
- Diaphragm muscles contract —> cause diaphragm to flatten and increase the volume of the thoracic cavity
- External intercostals contract —> pull ribs upwards and outwards (expanding chest)
- Accessory muscles —> Additional muscle groups may help pull the ribs up and out (sternocleidomastoid and pectoralis minor)

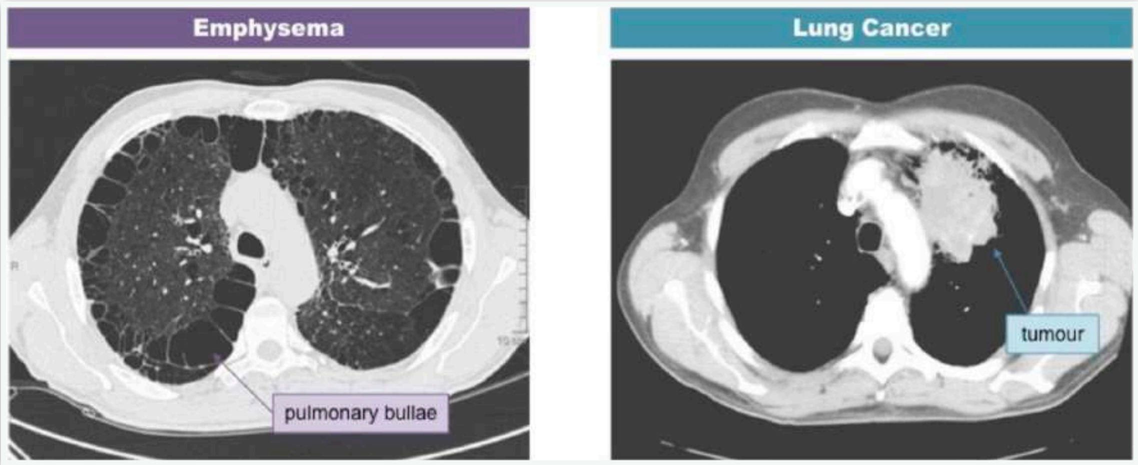
Expiration:
- Diaphragm muscles relax —> cause diaphragm to curve upwards and reduce volume of cavity
- Internal intercostal muscles contract —> pull ribs inwards and downwards
- Abdominal muscles contract and push the diaphragm upwards during forced exhalation
- Accessory muscles —> additional muscle groups may help pull the ribs downwards (quadratas lumborum)

Lung disorders:

- Lung cancer describes the uncontrolled proliferation of lung cells —> leads to abnormal growth of lung tissue (tumour) —> can impact on normal tissue function
- Lung cancers are the most common cause of cancer-related death worldwide
  —> lungs are vital to normal body function
  —> lungs possess a very rich blood supply —> increases metastasis chances to happen
- Common symptoms of lung cancers include —> coughing up blood, wheezing, respiratory distress and weight loss + if the cancer mass compresses adjacent organs it can cause chest pain, difficulty swallowing and heart complications
- Causes of lung cancer include —> Radiation, ageing, pollution, environment, diseases, genetics, occupation, asbestos, tobacco and smoke (second hand)

Emphysema:

- Lung condition where the walls of the alveoli lose elasticity due to damage to the alveolar walls —> results in the abnormal enlargement of the alveoli —> lead to lower SA for gas exchange
- Degradation of the alveolar walls can cause holes to develop and alveoli to merge into huge air spaces (pulmonary bullae)
- Majorly cause by smoking —> chemical irritants in cigarette smoke damage the alveolar walls
- The damage to lung tissue leads to the recruitment of phagocytes to the region —> produce an enzyme called elastase
- Elastase is released as part of an inflammatory response and breaks down the elastic fibres in the alveolar wall —> can be blocked by an enzyme inhibitor (α-1-antitrypsin) if low concentrations
- Emphysema cases are rarely due to a hereditary deficiency in this enzyme inhibitor due to a gene mutation
- Common symptoms include —> shortness of breath, phlegm production, expansion of the ribcage, cyanosis and an increased susceptibility to chest infections



Spirometry:

- Ventilation in humans changes in response to levels of physical activity
  - —> ATP production produces CO_2 as a waste product can consumes oxygen
  - —> changes in blood CO_2 levels are detected by chemosensory in the walls of the arteries which send signals to the brainstem
  - —> as exercise intensity increase, so does demand for gas exchange —> more ventilation
- Exercise will increase ventilation rate and increase tidal volume (volume of air per breath)

Measuring respiration:

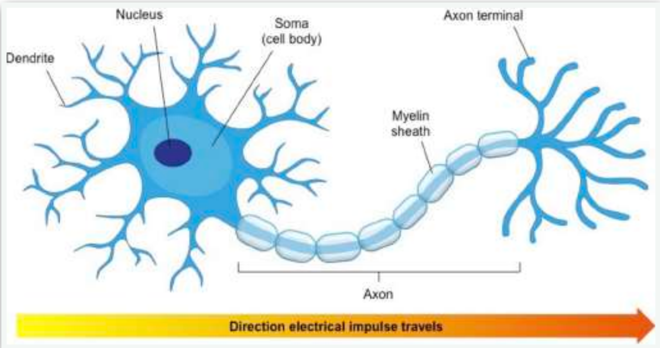
- Methods to measure respiration —> simple observations, chest belt + pressure meter and spirometer

- Spirometry involves measuring the amount and flow at which air can be inhaled and exhaled
- Spirometer —> device that detects the changes in ventilation and presents the data on a digital display
- Breathing into a balloon and measuring the volume of air in a single breath (more simplistic method) —> volume can be determined by submerging the balloon in water

6.5 Neurons and synapses

Neurons:

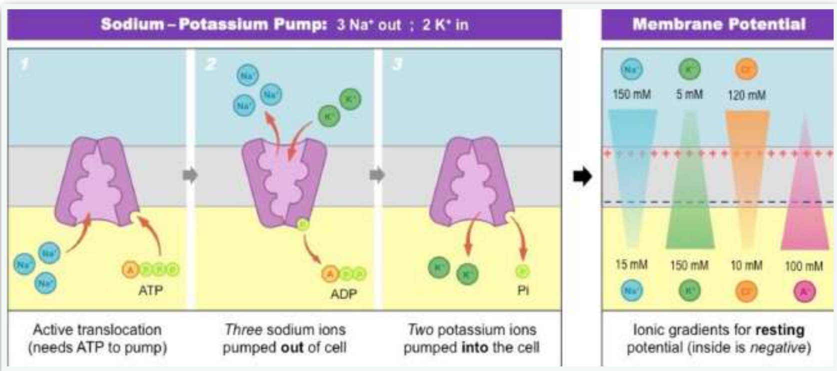
- Specialised cells that function to transmit electrical impulses within the nervous system —> the nervous system converts sensory information into electrical impulses in order to rapidly detect and respond to stimuli
- Can be sensory, relay or motor
- Have three basic components —> dendrites —> short branched fibres that convert chemical information from neurons or receptor cells into electrical signals
  —> axon —> elongated fibre that transmits electrical signals to terminal regions for communication with other neurons or effectors
  —> soma —> cell body containing the nucleus and organelles (basic metabolic processes)



-Myelin sheath —> improves the conduction speed of electrical impulses along the axon
 —> requires additional space and energy
 —> surrounds the axon with an insulating layer

Resting potential:

- Neurons generate and conduct electrical signals by pumping positive ions (Na^+ and K^+) across their membrane —> unequal distribution creates charge difference —> membrane potential
- A resting potential is the difference in charge across the membrane when a neutron is not firing



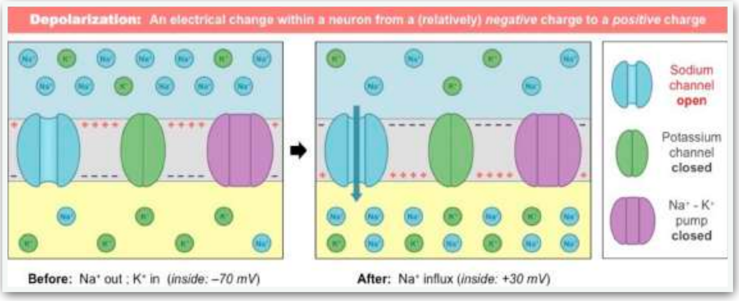
-Typically in a resting potential, the inside of the neutron is more negative relative to the outside (approximately 70mV)
-Resting potential is done thanks to an active process controlled by sodium-potassium pumps

Action potential:

- The rapid changes in charge across the membrane that occur when a neutron is firing
- Occur in three main stages —> depolarization, repolarization, and a refractory period

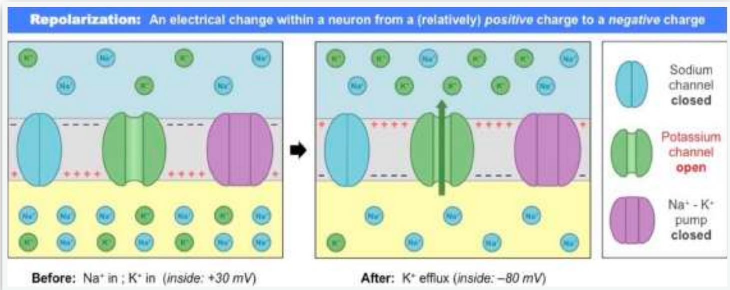
Depolarization:

- Refers to a sudden change in membrane potential —> from negative to positive internal charge
- It is in response to a signal initiated at a dendrite which make sodium channels open within the membrane of the axon
- As Na^+ ions are more concentrated outside of the neuron, the opening of sodium channels causes a passive influx of sodium —> membrane potential becomes more positive (depolarization)



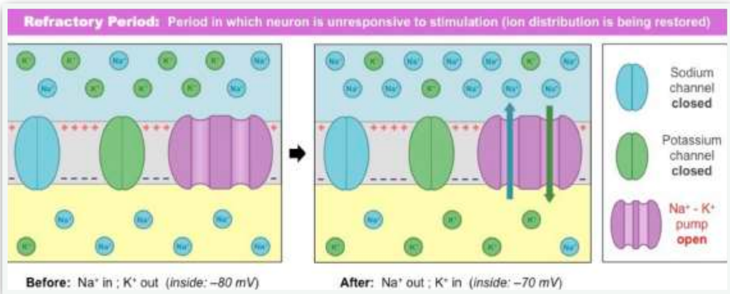
Repolarization:

- Refers to the restoration of a membrane potential following depolarisation
- Following the sodium influx, potassium channels open within the membrane of the axon
- As K^+ ions are more concentrated inside the neuron, the opening of potassium channels causes a passive efflux of potassium —> membrane potential returns to a more negative internal differential (repolarization)



Refractory period:

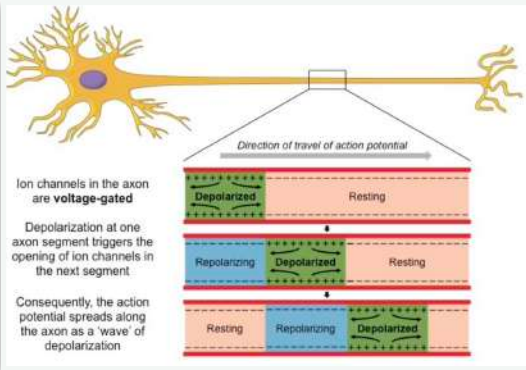
- Refers to the period of time following a nerve impulse before the neuron is able to fire again
- In a normal resting state —> sodiums ions mainly outside neuron, while potassium ions mainly inside (resting potential)
- Following depo and repolarisation —> ionic distribution is largely reversed
- The resting potential must be restored via the anti port action of the sodium-potassium pump before the neuron can fire again

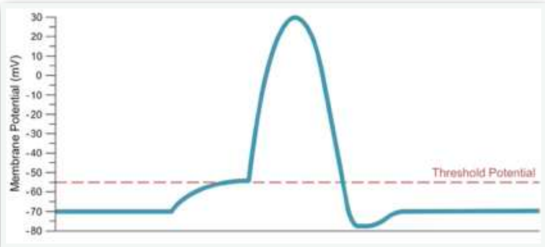


Nerve impulses:

- Are action potentials that move along the length of an axon as a wave of depolarization
- Depolarization occurs when ion channels open and cause a change in membrane potential
- The ion channels that occupy the length of the axon are voltage-gated —> so depolarization triggers the opening of ion channels in the next segment of the axon —> causes depolarization to spread along the length of the axon as a unidirectional wave

- Action potentials are generated within the axon according to the all-or-none principle
- An action potential of the same magnitude will always occur provided a minimum electrical stimulus is generated
- 55 mV is the minimum stimulus to open voltage-gated ions channels —> if not neuron will not fire
- Threshold potentials are triggered when the combined stimulation from the dendrites exceeds a minimum level of depolarisation





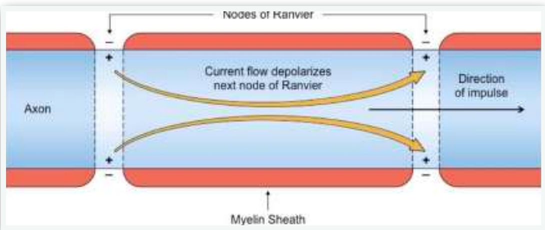
Oscilloscope traces:

- Oscilloscopes are scientific instruments that are used to measure the membrane potential across a neuronal surface
- A typical action potential will last for 3-5 milliseconds and has 4 key stages

1) Resting potential —> the neuron is in a state of rest (-70 millivolts)
2) Depolarization —> corresponds to the rising spike in the graph (+30 millivolts)
3) Repolarization —> corresponds to the falling spike (via potassium efflux) (-80 millivolts)
4) Refractory period —> levels return to resting potential due to the action of the Na^+/K^+ pumps

Myelination:

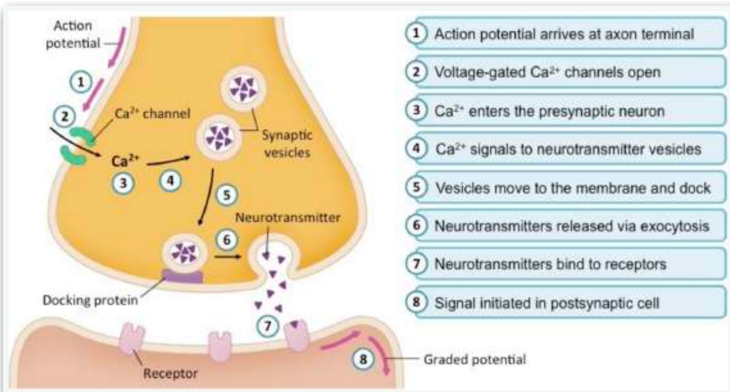
- Fatty white substance which functions as an insulating layer —> all other areas will appear grey matter which consists of neuronal cell bodies, dendrites, support cells (glial cells) and synapses
- Is a mixture of protein and phospholipids that is produced by glial cells
- Main purpose is to increase the speed of electrical transmissions via saltatory conduction



- Along unmyelinated neurons, action potentials propagate sequentially along the axon in a continuous wave of depolar.
- In myelinated neurons, action potentials hop between the gaps in the myelin sheath (nodes of Ranvier)
- This results in an increase in speed by a factor of up to 100
- The disadvantage of myelination is that it takes up significant space within an enclosed environment

Synaptic transfer:

- Electrical signals are not able to be conducted when a semi-permeable membrane is absent
- Synapses are the physical gaps that separate neurons from other cells —> neurons transmit information across synapses by converting the electrical signal into a chemical signal



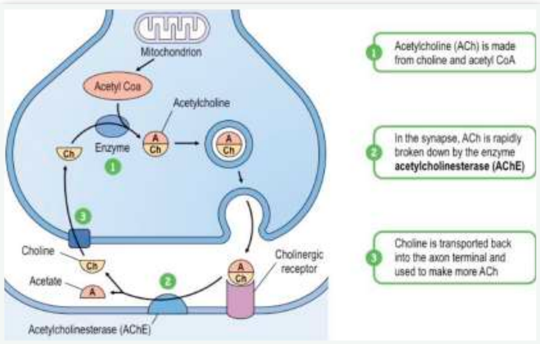
Neurotransmitters:

- Are chemical messengers released from neurons and function to transmit signals across the synaptic cleft
- Are released in response to the depolarisation of the axon terminal of a presynaptic neuron
- They bind to receptors on post-synaptic cells and can trigger (excitatory) or prevent (inhibitory) a response

Target Cell	Response
Neuron	Stimulation or inhibition of an electrical signal (nerve impulse)
Glandular Cell	Stimulation or inhibition of secretion (exocrine or endocrine)
Muscle Fibre	Stimulation or inhibition of muscular contraction / relaxation

Acetylcholine:

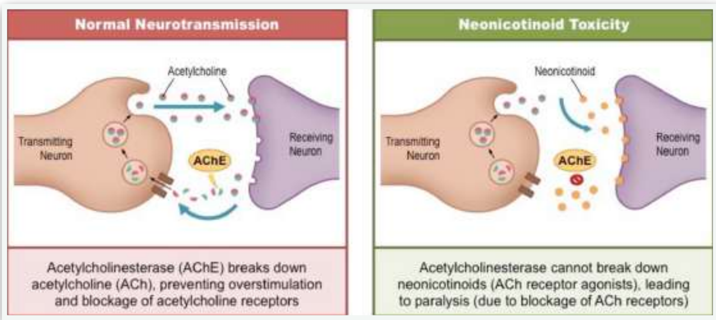
- Is a neurotransmitter used by both the central nervous system and peripheral nervous system
- Released at neuromuscular junctions and binds to receptors on muscle fibres to trigger muscle contraction —> it is even though also released within the autonomic nervous system to promote parasympathetic responses (rest and digest)



- Is created in the axon terminal by combining choline with an acetyl CoA group —> gets stored in vesicles until released via exocytosis in response to a nerve impulse
- Acetylcholine activates a post-synaptic cell by binding to one of two classes of specific receptor (nicotine or muscarinic)
- It must be continually removed from the synapse as overstimulation can lead to fatal convulsions and paralysis, while low activation promotes nerve signalling

- Is broken down into its two component parts by the synaptic enzyme acetylcholinesterase (AChE) —> enzyme is either released into the synapse from the presynaptic neuron or is embedded on the membrane of the post-synaptic cell
- The liberated choline is returned to the presynaptic neuron where it is coupled with another acetate to reform acetylcholine

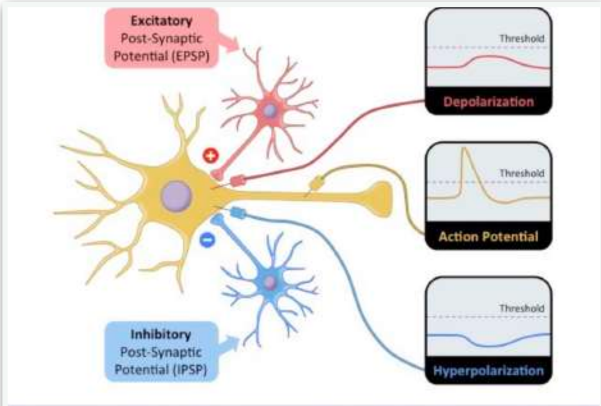
Neonicotinoid pesticides:



- Are able to irreversibly bind to nicotinic acetylcholine receptors and trigger a sustained response —> neonicotinoid pesticides cannot be broken down by acetylcholinesterase —> results in permanent overstimulation of target cells
- Insects have a different composition of acetylcholine receptors which bind to neonicotinoids much more strongly —> for this reason are significantly more toxic to insects than mammals (for this reason they are highly effective pesticides)
- Neonicotinoid pesticides have certain disadvantages:
  —> have been linked to a reduction in honey bee populations (bees are important pollinator)
  —> have been linked to a reduction in bird populations (loss of insects as food source)
  —> certain countries have restricted the use of neonicotinoid pesticides (including EU)

Graded potential:

- Neurotransmitters bind to neuroreceptors on the post-synaptic membrane of target cells and open ligand-gated ion channels —> the opening of these channels cause small changes in membrane potential known as graded potentials
- A nerve impulse is only initiated if a threshold potential is reached, so as to open the voltage-gated ion channels within the axon
- Excitatory neurotransmitters (noradrenaline) cause depolarisation by opening ligand-gated sodium or calcium channels
- Inhibitory neurotransmitter (GABA) cause hyperpolarisation by opening ligand-gated potassium or chlorine channels
- The combined action of all neurotransmitters acting on a target neuron determines whether a threshold potential is reached
- If depolarization > hyperpolarization and a threshold is reached —> neuron will fire
- If hyperpolarization < depolarization and a threshold is not reached —> neuron will not fire



An action potential occurs if the combination of graded potentials exceeds a threshold

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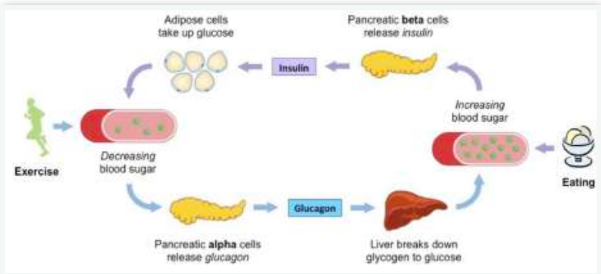
6.6 Homeostasis

Insulin and Glucagon:



-The body needs glucose to make ATP (via cell respiration) —> amount fluctuates according to demand

-High levels of glucose in the blood can damage cells —> creates hypertonicity —> levels must be therefore regulated

-Are two antagonistic hormones are responsible for regulating blood glucose concentrations

- Are released from pancreatic pits (islets of Langerhans) and act principally on the liver
- High levels of blood glucose —> Insulin is released from beta cells of the pancreas and cause a decrease in blood glucose concentration
  —> by stimulating glycogen synthesis in the liver (glycogenesis)
  —> by promoting glucose uptake by the liver and adipose tissue
  —> by increasing the rate of glucose breakdown (cell respiration)
- Low levels of blood glucose —> Glucagon is released from alpha cells of the pancreas and cause an increase in blood glucose concentration
  —> by stimulating glycogen breakdown in liver (glycogenolysis)
  —> promoting glucose release by the liver and adipose tissue
  —> decreasing the rate of glucose breakdown (cell respiration)

Diabetes mellitus:

- Metabolic disorder that results from a high blood glucose concentration over a prolonged period
- Type I —> caused by the body not producing insulin —> treated with insulin injections
- Type II —> caused by the body failing to respond to insulin production —> rated by carefully monitoring and controlling dietary intake

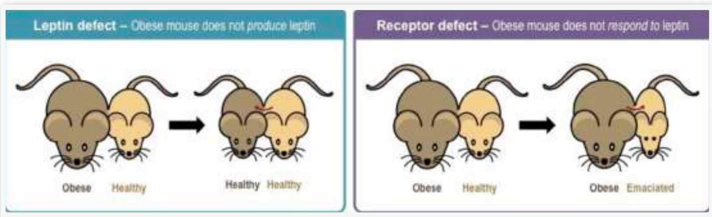
Type I Insulin-Dependent Diabetes Mellitus (IDDM)	Type II Non Insulin Dependent Diabetes Mellitus (NIDDM)
Usually occurs during childhood (early onset)	Usually occurs during adulthood (late onset)
Body does not *produce* sufficient insulin	Body does not *respond* to insulin production
Caused by the destruction of β-cells (autoimmune)	Caused by the down-regulation of insulin receptors
Requires insulin injections to regulate blood glucose	Controlled by managing diet and lifestyle

Thyroxin:

- Hormone secreted by the thyroid gland in response to signals initially derived from the hypothalamus
- Acts on nearly every tissue in the body and is essential to the proper development and differentiation of cells
- Primary role —> increase the basal metabolic rate —> by stimulating carbohydrate and lipid metabolism via the oxidation of glucose and fatty acids
- Heat is a consequence of increasing metabolic activity —> thyroxin helps to control body temp. —> can be released in response to a decrease in body temperature to stimulate heat production
- Is partially composed of iodine —> deficiency of iodine in the diet will lead to decreased production of thyroxin
- Iodine deficiency —> causes the thyroid gland to become enlarged —> disease known as goitre

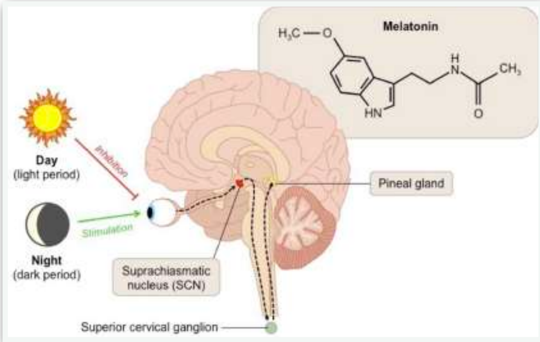
Leptin:

- Hormone produced by adipose cells —> regulates fat stores in the body by suppressing appetite
- Binds to receptors located within the hypothalamus to inhibit appetite
- Overeating causes more adipose cells to be formed —> more leptin is produced and viceversa
- Obese people are constantly producing higher levels of leptin —> become desensitised to leptin
  —> more likely to feel hungry and less likely to recognise when they are full
  —> leptin resistance develops with age —> potential for weight gain later in life
- Was considered as a treatment for obese people
- Mice experiments —> conducted by surgically fusing the blood circulation of obese and healthy mice (parabiosis)



- Human experiments —> humans have naturally high levels of leptin in the bloodstream
  —> obesity usually caused by unresponsiveness to leptin not a deficiency
  —> very few participants experienced significant weight loss
  —> many patients experienced adverse side effects including skin irritations
  —> leptin treatments are so not considered to be effective in treating obesity

Melatonin:



- Hormone produced by the pineal gland within the brain in response to changes in light
- Suprachiasmatic nucleus (hypothalamus) —> relays light exposure to retina and inhibits melatonin secretion
- Is secreted in response to periods of darkness (higher concentration at night)

Circadian rhythms:
- Are the body's physiological responses to the 24 hour day-night cycle
- Are driven by an internal (endogenous) circadian clock —> can be modulated by external factors
- Melatonin secretion plays a pivotal role in the control of circadian rhythms —> synchronises circadian rhythms and regulates the body's sleep schedule
  - —> melatonin secretion is suppressed by bright light (principally blue wavelengths)
  - —> over a prolonged period melatonin secretion becomes entrained to anticipate the onset of darkness and the approach of the day
  - —> melatonin promotes activity in nocturnal animals and promotes sleep in diurnal animals
  - —> during sleep necessary physiological changes occur in body temperature, brain wave activity and hormonal production
  - —> melatonin levels naturally decrease with age —> leads to changes in sleeping patterns

Jet Lag:
- Physiological condition resulting from a change to the body's normal circadian rhythm
- Alteration is cause by the body's inability to rapidly adjust to a new time zone —> pineal gland keeps recreating melatonin according to old time zone
- Symptoms include headaches, lethargy, increased irritability and reduced cognitive functions
  - —> should only last a few days
- Melatonin can be taken artificially in order to make the body respond quicker to the new rhythm

Sexual reproduction:

Modern theory:
- Based on evidence discovered using light microscopes
- Viable microscopes not invented until 17 years after Harvey's death
- Fetus forms from a combination of both male and females gametes

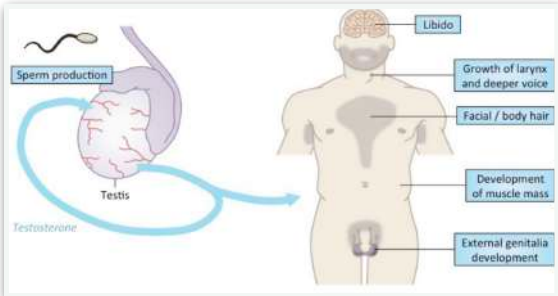
"Soil and seed theory":
- One of the earliest theories as to how animals reproduce sexually —> proposed by Aristotle
- The male produces a "seed" which forms an "egg" when mixed with menstrual blood "soil"
- The "egg" then develops into a foetus inside the mother according to the information contained within the male "seed" alone
- Theory debunked by William Harvey
  - —> studied the sexual organs of female deer after mating ito identify the developing embryo
  - —> was unable to detect a growing embryo until approximately 6-7 weeks after the mating
  - —> concluded that Aristotle's theory was incorrect + that menstrual blood did not contribute
  - —> Harvey was unable to identify the correct mechanism of sexual reproduction
  - —> Harvey said that the fetus did not develop from a mixture of male and female "seeds"

Sex development:

- Humans have 46 chromosomes in all diploid somatic cells —> 22 pairs are autosomes and the 23rd pair are the sex chromosomes —> females XX and males XY
- Y chromosome includes a gene called the SRY gene (Sex Determining Region Y) —> leads to male development
- The SRY gene codes for a testis-determining factor (TDF) that causes embryonic glands to form into testes (male gonads)
- In absence of the TDF protein —> embryonic gonads will develop into ovaries (female gonads)
- The male and female gametes produce different hormones to promote further development of sex characteristics —> testes produce testosterone to promote further dev. of male sex characteristics —> ovaries produce estrogen and progesterone to promote dev. of female sex…

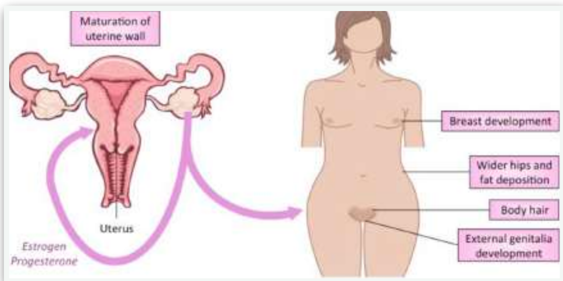
Testosterone:

- Responsible for pre-natal development of male genitalia
- Is involved in sperm production following the onset of puberty
- It aids in the development of secondary sex characteristics —> body hair, muscle mass, voice…
- It helps to maintain the male sex drive (libido) —> desire

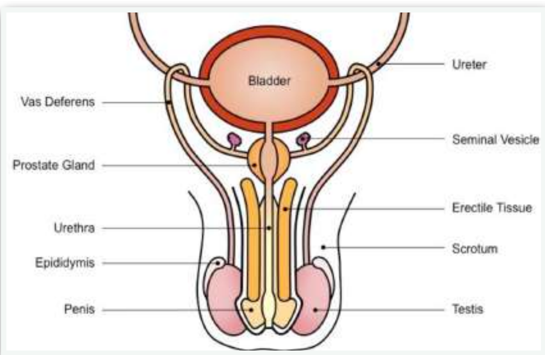


Estrogen and progesterone:

- Promote pre-natal development of the female reproductive organs
- Are responsible for the development of secondary sex characteristics —> body hair, breast dev. …
- Are involved in monthly preparation of egg release following puberty
- Initially are secreted by the mother's ovaries and then the placenta until formed

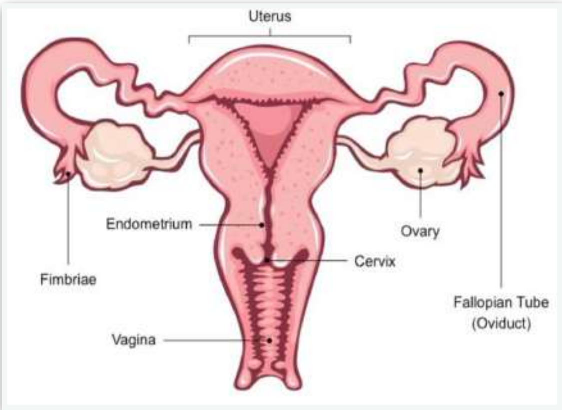


Male reproductive system:



- Includes all the organs responsible for the production of sperm (male gamete) + organs that are involved in synthesising the semen in which the sperm is transported during copulation

1) Testis —> responsible for the production of sperm and testosterone
2) Epididymis —> site where sperm matures and develops the ability to be motile —> stored here until ejaculation
3) Vas Deferens —> long tube which conducts sperm from the testes to the prostate gland during ejaculation
4) Seminal Vesicle —> secretes fluid containing fructose (to feed sperm), mucus (to protect sperm) and prostaglandins (triggers uterine contractions)
5) Prostate Gland —> secretes an alkaline fluid to neutralise vaginal acids (necessary to maintain sperm viability)
6) Urethra —> conducts sperm/semen from the prostate gland to the outside of the body via penis



Female reproductive system:

- Includes all the organs responsible for the production of an oocyte (female gamete) + organs involved in initially developing and maintaining an embryo during the early stage of pregnancy

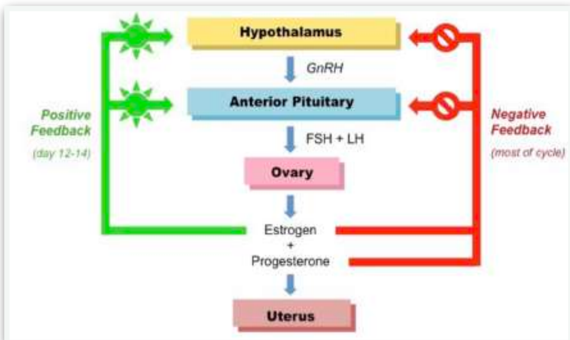
1) Ovary —> where the oocytes mature prior to release (ovulation) + responsible for estrogen and progesterone secretion
2) Fimbria —> fringe of tissue adjacent to an ovary that sweep an oocyte into the oviduct
3) Oviduct —> transports the oocyte to the uterus —> also where fertilisation typically occurs
4) Uterus —> the organ where a fertilised egg will implant and develop to become an embryo
5) Endometrium —> mucous membrane lining of the uterus —> thickens in preparation for implantation or is otherwise lost via menstruation
6) Vagina —> passage leading to the uterus by which the penis can enter —> uterus protected by a muscular opening called the cervix

Menstrual cycle:

- Describes recurring changes that occur within the female reproductive system to make pregnancy possible —>cycle lasts 28 days and begins at puberty (menarche) and end with menopause

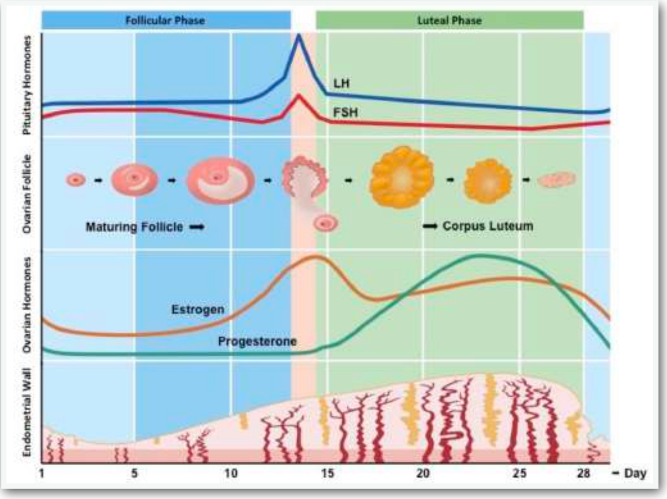
Endocrine Gland	Hormone	Function
Anterior Pituitary	FSH	• Stimulates follicular growth in ovaries • Stimulates estrogen secretion (from developing follicles)
	LH	• Surge causes ovulation • Results in the formation of a corpus luteum
Ovaries	Estrogen	• Thickens uterine lining (endometrium) • Inhibits FSH and LH for most of cycle • Stimulates FSH and LH release pre-ovulation
	Progesterone	• Thickens uterine lining (endometrium) • Inhibits FSH and LH

-Two key groups of hormones control and coordinate the menstrual cycle:
—> Pituitary hormones (FSH and LH) are released from the anterior pituitary gland and act on the ovaries to develop facilities
—> Ovarian hormones (estrogen and progesterone) are released from the ovaries and act on the uterus to prepare for pregnancy



Key events:

1) Follicular Phase —> Follicle stimulating hormone (FSH) is secreted from the anterior pituitary and stimulates growth of ovarian follicles —> the dominant follicle produces estrogen which inhibits FSH secretion to prevent other follicles creating and estrogen acts on the uterus to stimulate the thickening of the endometrial layer
2) Ovulation —> midway through the cycle (12 days) estrogen stimulates the anterior pituitary to secrete hormones —> results in a large surge of luteinising hormone (LH) and a lesser surge of FSH —> LH cases the dominant follicle to rupture and release an egg (secondary oocyte)
3) Luteal phase —> rupture follicle develops into a slowly degenerating corpus luteum which secretes high levels of progesterone and lowers levels of estrogen



4)Menstruation —> if fertilisation occurs, the developing embryo will implant in the endometrium and release hormones to sustain the corpus luteum

—> if fertilisation doesn't occur, the corpus luteum eventually degenerates (forms a corpus albicano after 2 weeks) —> when this happens estrogen and progesterone levels drop and the endometrium can no longer be maintained —> is sloughed away and eliminated from the body as menstrual blood —> after this cycle begins again

In vitro fertilisation:

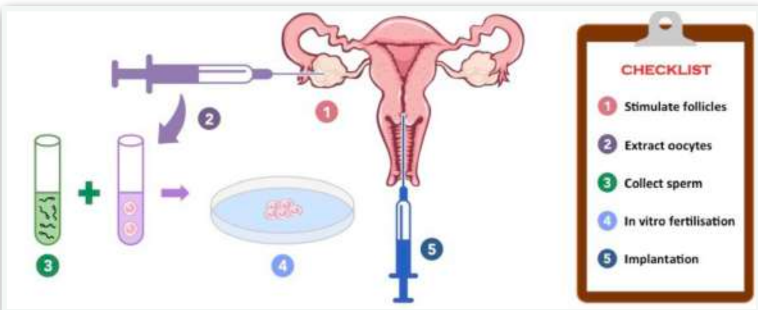
- Refers to fertilisation that occurs outside of the body (in glass)
- It involves using drugs to suspend normal ovulation (down regulation), before using hormone treatments to collect multiple eggs (superovulation)

Down regulation:
- Drugs are used to halt the regular secretion of FSH and LH —> in turn stops secretion of estrogen and progesterone
- By arresting the hormonal cycle, doctors can take control of the timing and quantity of egg production by the ovaries
- Usually takes about two weeks and is typically delivered in the form of a nasal spray

Superovulation:
- Involves using artificial doses of hormones to develop and collect multiple eggs from the woman
- Patient is firstly injected with large amounts of FSH to stimulate development of many follicles
- Follicles are then treated with human chorionic gonadotrophin (hCG —> hormone usually produced by a developing embryo) —> stimulates the follicles to mature and the egg is then collected (via aspiration with a needle) prior to the follicles rupturing

Fertilisation:
- The extracted eggs are then incubated in the presence of a sperm sample from the male donor
- The eggs are then analysed under a microscope for successful fertilisation

Implantation:
- Approximately two weeks prior to implantation the woman begins to take progesterone treatments to develop the endometrium
- Healthy embryos selected and transferred into the female uterus —> multiple in order to improve chances of successful implantation (possibly multiple births)
- Roughly two weeks after the procedure, a pregnancy test taken to see if successful



Extra:

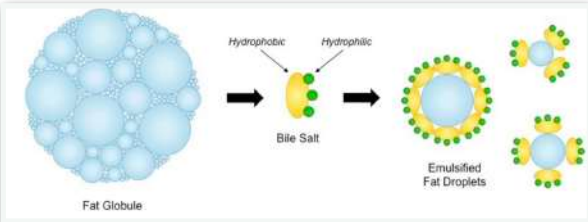
Stages of digestion:

- Ingestion —> food is taken into the body via the act of eating
- Digestion —> food is broken down physically and chemically
- Absorption —> digested food products are absorbed into the bloodstream and transported to cells
- Assimilation —> digested food products are converted into the fluid/ solid parts of a cell/ tissue
- Elimination —> undigested food residues are digested from the body as semi-solid faeces

Lipid digestion:

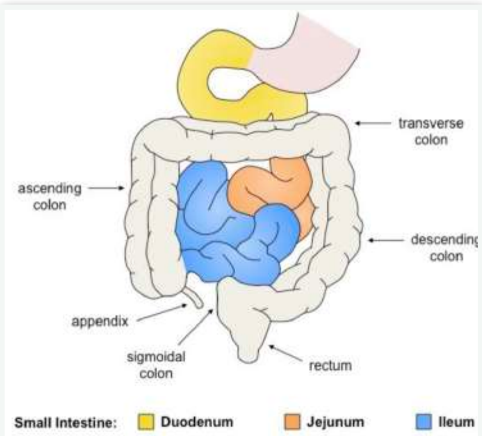
- Being hydrophobic, lipids will group together (coalesce) to form large globules of fats
- Lipase —> enzyme responsible for lipid digestion —> generally soluble in water and only hydrophobic at the active site
- Lipase will only bind to the lipid-water interface (external part of the globule) —> so interior of fat globule is inaccessible to lipase —> digestion of lipids in this form is very slow

- Bile —> watery fluid that contains bile salts and pigments (bilirubin) —> it is made by the liver and is released from the gall bladder
- Bile salt molecules have both a hydrophobic surface (interacts with the lipid) and a hydrophilic surface (faces out and prevents lipids from coalescing)
- This divides the fat globule into smaller droplets (emulsification) —> increases the total SA available for enzyme activity



Lipid absorption:

- When fatty acids are absorbed into epithelial cells of the intestinal lining they form triglycerides
- Triglycerides are combined with proteins inside the golgi apparatus —> form chylomicrons
- Chylomicrons —> released from the epithelial cells and are transported via the lacteals to the liver —> while in the liver they may be modified to form a variety of lipoproteins
- Low density and high density lipoproteins



Sections of the gut:

- Small intestine (nutrient absorption) / large intestine (water abso.)
- Duodenum —> first segment of SI —> fed by digestive fluids from the pancreas and gall bladder —> sodium bicarbonate is released from the pancreas to neutralise stomach acids so that pH= 7
- Jejunum —> second segment of SI —> where digestive process is largely completed —> pancreatic enzymes and enzymes released by intestinal glands complete break down of sugars, proteins and lipids
- Ileum —> final segment of SI —> for nutrient absorption —> highly folded (villi and microvilli) —> maximise SA and optimise material absorption (also bile is absorbed and returned to the liver)

- Large intestine —> principal function is to absorb any remaining water and mineral ions
  —> made by (ascending, transverse, descending, sigmoidal) * colon and rectum
  —> the appendix is also considered a part although it is a vestigial remnant without an important function

Blood composition:

- Fluid medium in which materials are transported around the body via blood vessels
- Average human adult contains 5 / 6 liters of blood (77 ml per kilogram)
- Three main components:

—> Plasma —> 55% of blood —> consists mainly of water as solvent
—> contains electrolytes (minerals with charge) to keep fluid balance and pH
—> Proteins in the blood plasma maintain osmotic potential (albumin), transport lipids (globulin) and help clot (fibrinogen)
—> used to transport various materials needed by body and wastes produced by body cells —> nutrients, antibodies, carbon dioxide, hormones, oxygen, urea and heat

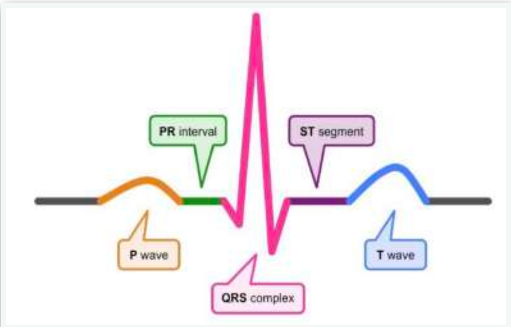
—> Red blood cells —> 45% of blood —> also called erythrocytes —> responsible for transporting oxygen around the body
—> oxygen is bound to haemoglobin at the lungs and released from the RBC at respiring body tissues

—> Buffy coat —> 1% —> fraction of a blood sample that contains white blood cells and platelets
—> Withe blood cells (leukocytes) are involved in the body's immune defence
—> platelets (thrombocytes) are involved in blood clotting

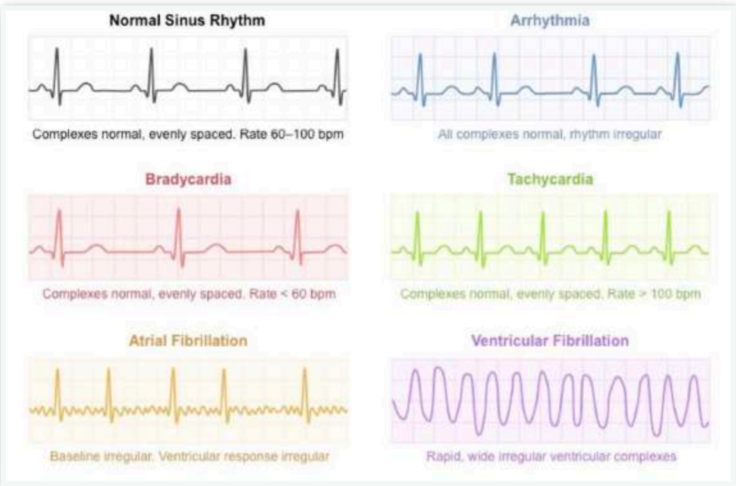
Blood pressure:

- Two types —> systolic pressure and diastolic pressure
- Systolic —> higher value that represents the pressure in the vessel when the heart is contracting
- Diastolic —> lower value that represents the pressure in the vessel when the heart is relaxing
- Measured in arteries using a sphygmomanometer as veins do not have sufficient pressure
- Sphygmomanometer —> cuff that cuts off circulation to a region (usually brachial artery in arm)
  —> pressure of the cuff is slowly released until a pulse can be audibly detected with a stethoscope (systolic pressure - normally 120 mmHg)
  —> pressure continues to be released from the cuff until pulse disappears (diastolic pressure - normally 80 mmHg)

Electrocardiography:

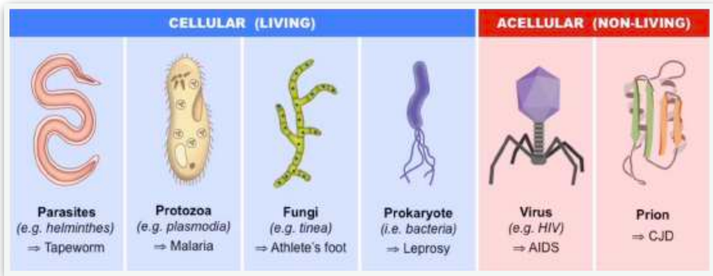


- Heart function can be diagnostically assessed by measuring the electrical activity of the heart with each condition
- Electrocardiograph —> machine to measure activity
- Electrocardiogram —> generates data
- P wave —> represents depolarisation of the atria in response to signalling from the sinoatrial node (atrial contraction)
- QRS complex —> represents depolarisation of the ventricles —> triggered by signals from the AV node
- T wave —> represents repolarisation of the ventricles + the completion of a standard heart beat
- PR and ST —> between periods of electrical activity —> intervals which allow for blood flow



Pathogens:

-Disease causing agent that disrupts the normal physiology of the infected organism
- Can be cellular or acellular



- Viruses —> metabolically inert and incapable of reproducing independently of a host cell (dead)
  —> typically have an inner core of nucleic acid surrounded by a protein coat (capsid)
  —> simpler viruses may lack a capsid (viroids), while more complex have lipid envelope
  —> can be either DNA-based (adenoviruses) or RNA-based (retroviruses)
- Prions —> infectious protein that has folded abnormally into structure capable of causing disease
  —> can cause normally folded proteins to refold into the abnormal from —> propagate
  —> prion proteins aggregate together to form amyloid fibres that cause holes to form in the brain —> spongiform encephalopathy
  —> infectious prion proteins have a higher beta-sheet content —> more resistant to denaturation and difficult to treat
- Bacteria —> unicellular prokaryotes —> can reproduce quickly and compete for space+ nutrition
  —> most are relatively harmless and may even form mutualistic relationships with host
  —> may cause disease by producing toxic compounds (exotoxins) or releasing the substances when destroyed (endotoxins)
  —> toxins retain their destructive capacity beyond bacterial death —> food poisoning
- Fungi —> disease-causing fungi usually attack the body surfaces (skin, mucous membranes, …)
  —> can be categorised according to whether unicellular (yeasts) or multicellular (moulds)
  —> moulds consist of branching filaments called hyphae —> may form a mass of invading threads calle mycelium
- Parasites —> organism that grows and feeds on an organism to detriment of the host's survival
  —> can be ectoparasites (live on surface of the host) or endoparasites (live within host)
  —> endoparasites can include micro parasites or macroparasites

NON-SPECIFIC DEFENCES (INNATE IMMUNITY)		SPECIFIC DEFENCES (ADAPTIVE IMMUNITY)
First line of defense	Second line of defense	Third line of defense
• Skin • Mucous membranes • Secretions of skin and mucous membranes	• Phagocytic leukocytes • Antimicrobial proteins • Inflammatory response • Fever	• Lymphocytes • Antibodies • Memory cells

Lines of defence:

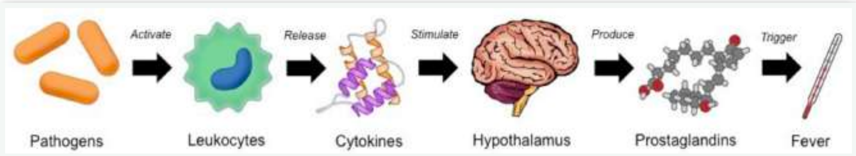
- First line —> surface barriers that prevent pathogens from entering the body
- Second line —> non-specific cellular and molecular responses of the innate immune system
  —> defences do not differentiate between different types of pathogen
  —> phagocytic leukocytes, inflammations, antimicrobial proteins and fever
- Third line —> lymphocytes that produce antibodies to specific antigenic fragments
  —> each B cell produces a specific antibody (body has millions) capable of detecting distinct antigens
  —> helper T cells regulate B cell activation —> ensures antibodies are mass-produced at the appropriate times
  —> both B and T cells will differentiate to form memory cells after activation —> long term immunity to a particular pathogen

Inflammation:

- Non-specific way in which the body responds when a pathogen damages body tissue
- If tissue damage occurs —> mast cells (localised) and basophils (circulating) release histamine —> causes local vasodilation and increase capillary permeability to improve the recruitment of leukocytes to the region
- Damaged cells also release chemotactic factors which attract leukocytes to the site of infection
- Side effects of inflammation —> redness, heat, swelling, tenderness and pain
- Can be either short-term (acute) or long-term (chronic)

Fever:

- Abnormally high temp. associated with infection and is triggered by the release of prostaglandins
- May help to combat infection by reducing the growth rate of microbes (microbial enzymes)
- May also increase metabolic activity in body cells and activate heat shock proteins to strengthen immune response
- Up to a certain point a fever may be beneficial, but beyond a tolerable limit it can cause damage to the body's own enzymes



Types of leukocytes:

- Neutrophils —> 60-70% of all white blood cells —> first responder to microbial infection
  —> are unable to renew their lysosomes and die after having phagocytoses a few pathogens —> forms the majority of pus
- Eosinophils —> 1-3% —> prominent at sites of allergic reaction and parasitic infection
  —> release chemical products which perforate cell membrane —> function as the primary response to large multicellular parasites (helminth infections, …)
- Basophil —> less than 1% —> responsible for initiating inflammatory responses
  —> circulate in the bloodstream and release chemicals histamine and heparin
  —> common contributors to allergic responses as they promote inflammation
- Monocyte —> 1-6% —> largest type of leukocyte —> share phagocytosis duties with neutrophil
  —> slower to respond than neutrophils but are longer lasting as can renew lysosomes

—> will differentiate into two types of cells in response to pathogenic infection —> macrophages (will remain in the tissue and phagocytose) and dendritic cells which present antigen fragments to lymphocytes

- Lymphocyte —> 20-30% —> responsible for the production of antibodies which target specific antigens present on pathogens
  —> more common in the lymphatic system than blood and are slower to respond
  —> B cells (antibody-secreting plasma cells) and T cells (mediate B cell activity)
  —> involved in the destruction of virus-infected body cells (via cytotoxic T cells)

Haemophilia:

- X-linked recessive condition that impairs the body's ability to control blood clotting
- People with haemophilia have lower levels of functional clotting factors in their blood plasma —> normal coagulation cascade is impaired and fibrin formation does not occur
- Haemophilia A (clotting factor XIII deficiency) is more common than B (clotting factor IX def.)

Lung capacity:

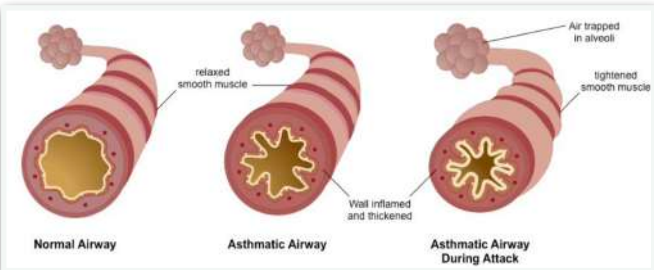
- Refers to the volumes of air associated with the different phases of the respiratory cycle
- Total lung capacity —> volume of air in the lungs after a maximal inhalation (6 liters in male)
- Vital capacity —> V of air that can be exchanged by lungs via max. inhalation and exhalation
- Residual volume —> volume of air always present in the lungs —> 20%
- Tidal volume —> volume of air that is exchanged via normal breathing —> 500ml per breath
- Height, location and lifestyle affect an individual's total lung capacity

- Ventilation rate at rest for a typical adult is 12 - 16 breaths per minute

Effects of exercise:

- VO_2 —> volume of oxygen absorbed by the body per minute and supplied to the tissues
- VO_2 max —> max. rate at which oxygen can be absorbed and supplied to body tissues
- If energy demands exceed oxygen intake, ATP may be produced via anaerobic respiration —> produces lactic acid —> is transferred to the liver and requires oxygen to covert to pyruvate
- Oxygen debt —> extra oxygen required to restore normal body functioning after exercise
- The body requires more oxygen to generate a set amount of energy when metabolising fats as compared to carbohydrates —> during high intensity exercise lower fat metabolism

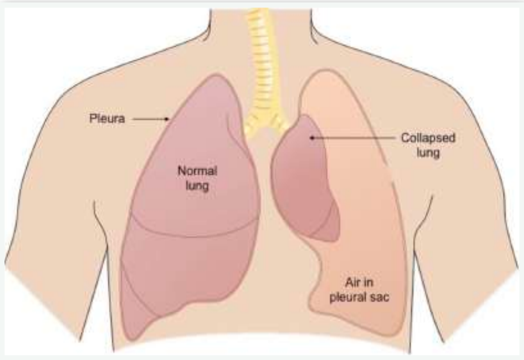
Lung disorders:



Asthma:

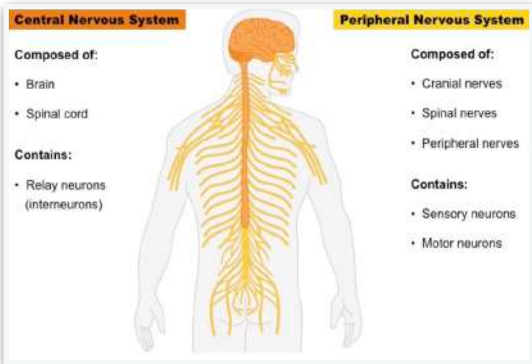
- Common chronic inflammation of the airways to the lungs —> leads to swelling and mucus production —> reduced airflow and bronchospasm
- During an acute asthma attack, constriction of the bronchi smooth muscle may cause significant airflow obstruction —> shortness of breath, chest tightness, wheezing and coughing
- Severe cases of asthma may be life threatening if left untreated —> may be caused by recurring environmental triggers (allergen, smoke, cold air, certain medications and arthropods)

Pneumothorax:



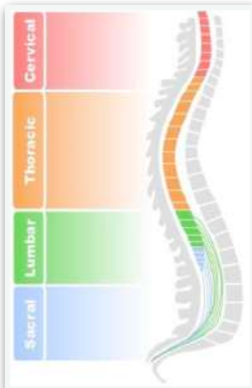
-Abnormal collection of gas in the pleural space —> causes uncoupling of lung from chest wall
- Pleural cavity (fluid-filled space between lung and chest wall)
- Surface tension of the pleural fluid causes the lung to adhere closely to the chest wall and thus inflate upon chest expansion
- If cavity becomes filled with air (pneumothorax) or blood (haemothorax) —> lungs will collapse until pressure is relieved
- Build up of fluid or gas will compress other local organs (including heart) —> life threatening complications
-Usually treated by inserting a syringe into the pleural cavity and draining the excess liquid or gas

Nervous system:



- Coordinates the actions of complex organisms via transmission of electrochemical signals —> transmitted by neurons (specialised network cells)
- —> CNS —> central nervous system —> made up by the brain and spinal cord

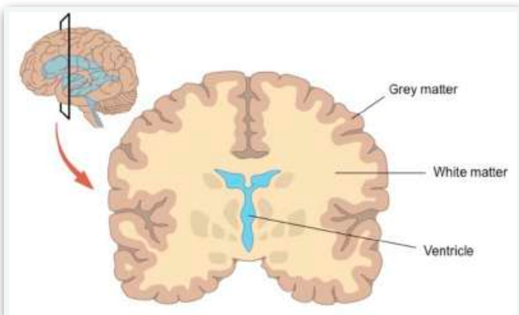
—> PNS —> peripheral nervous system —> made up of peripheral nerves which link the CNS to the body's receptors and effectors



- CNS —> integrates information received from peripheral nerves and coordinates bodily responses —> majority of this occurs in the brain, but spinal cord for reflex actions
- PNS —> sends information to the CNS via sensory neurons and activates effectors via motor neurons

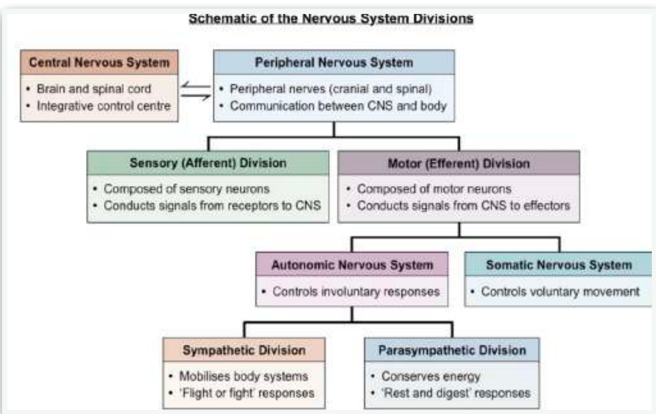
—> some peripheral nerves feed into the spinal cord at anatomical dermatome —> damage to a particular region of the spine will affect the body parts innervated by nerves ventral to that region —> injuries to the cervical region are most severe as more of the body is affected (C1 and C4 injuries impair normal breathing)

White and Grey matter:



- White matter —> composed of bundles of myelinated axons which connect the various grey matter regions together
- Grey matter —> composed of the neuronal cell bodies and dendrites + unmyelinated nerve fibres

—> regions of the brain where info. is processed

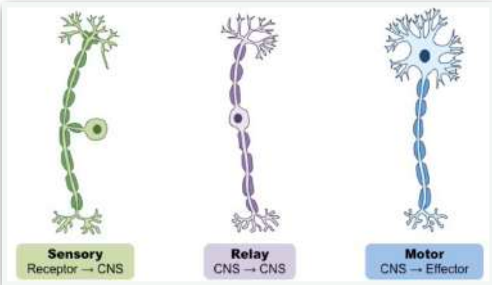


Stimulus-Response:

1) Stimulus —> change in the environment (external or internal) that is detected by a receptor
2) Receptors —> transform environmental stimuli into electrical nerve impulses
3) Impulses are transmitted via neurons to the CNS for decision-making
4) Response is selected —> (consciously or unconsciously) —> signal is transmitted to effectors
5) Effectors —> organs (muscles or glands) that produce a response to stimulus
6) Response —> change in the organisms resulting from the detection of a stimulus

Types of neurons:

- Sensory —> transmit info from sensory receptors to the CNS
- Relay —> (interneurons) transmit info within the CNS as part of decision-making process
- Motor —> transmit info from CNS to effectors for response



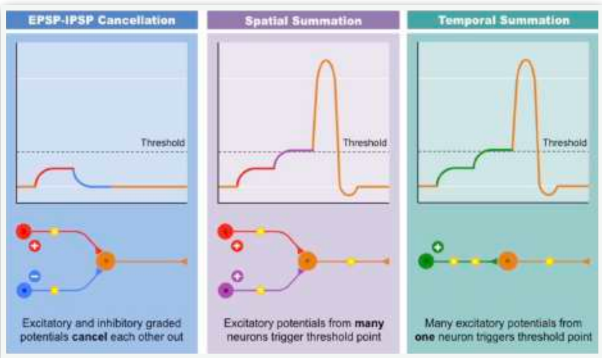
- Their basic structure differs in length, cell body (soma) position and the comparative distribution of dendrites and axon terminals

Reflex actions:

- Rapid and involuntary response to a stimulus —> from simple signalling pathway —> reflex arc
- Do not involve the brain —> sensory information is directly relayed to motor neurons within the spine —> results in a faster response (does not involve conscious though or deliberation)
- Are particularly beneficial in survival situations when quick reactions are necessary to avoid permanent damage
- Patellar reflex (knee jerk response) —> occurs when the patellar tendon is tapped —> common test employed by doctors to determine the presence of spinal lesion

Summation:

- Presynaptic neurons release neurotransmitters into the synapse to trigger graded potentials in post-synaptic neurons
- Some generate excitatory post-synaptic potentials (EPSPs) —> trigger depolarisation in the post-synaptic membrane
- Some produce inhibitory post-synaptic potentials (IPSPs) —> trigger hyperpolarisation in the post-synaptic membrane
- If the combination of signals reaches a threshold level —> action potential will be triggered in the post-synaptic neuron —> combination of graded potential is known as summation



Types of neurotransmitters:

- Neurotransmitters are chemical messengers released into the synaptic cleft by neurons
- They maintain signals in the nervous system by bind to receptors on post-synaptic neurons and triggering electrical impulses + activate responses by effector organs

Adrenaline:

- Primarily hormone released by the adrenal gland, but some neurons secrete it as neurotransmitter
- Increases heart rate and blood flow, leading to a physical boost and heightened awareness
- It is produced during stressful or exciting situations

Noradrenaline:

- Noradrenaline is predominantly a neurotransmitter that is occasionally released as a hormone
- Contracts blood vessels and increases blood flow —> improves attention and speed at which responsive actions occur

Dopamine:

- Primarily responsible for feelings of pleasure, but is also involved in movement and motivation
- People tend to repeat behaviours that lead to dopamine release, leading to addictions
- Abnormal dopamine secretion is common in specific movement disorders (Parkinson's disease,..)

Serotonin:

- Contributes to feelings of well-being and happiness —> affected by exercise and light exposure and plays a role in sleep cycle and digestive system regulation

GABA:

- Inhibits neuron firing in the CNS —> high levels improve focus whereas low levels cause anxiety —> also contributes to motor control and vision

Acetylcholine:

- Involved in thought, learning and memory within the brain
- Activates muscle contraction in the body and is also associated with attention and awakening

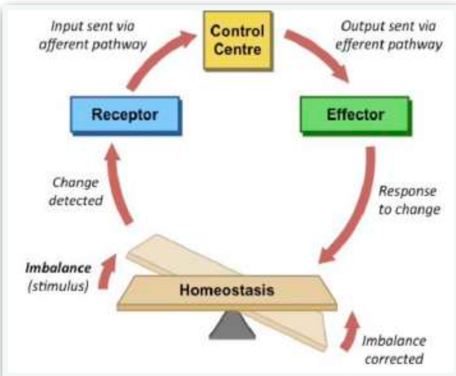
Glutamate:

- Most common brain neurotransmitter —> regulates development and creation of new nerve pathways and hence is involved in learning and memory

Endorphins:

- Release is associated with feelings of euphoria and a reduction in pain (body's natural 'pain killers') —> is released during exercise, excitement and sex

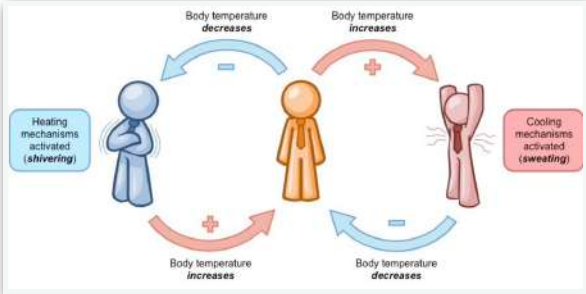
Homeostasis:



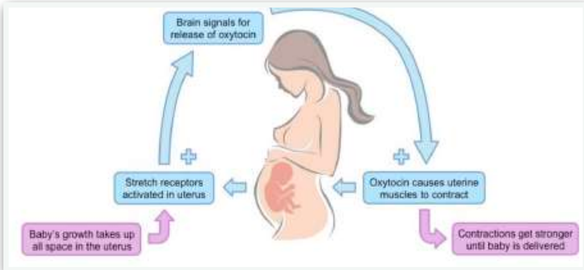
- Tendency for an organism or cell to keep a constant internal environment within tolerance limits
- Internal equilibrium is maintained by adjusting physiological processes such as:
  - —> body temperature —> normally between 36°- 38°C
  - —> carbon dioxide concentration —> normally 35 - 45 mmHg
  - —> blood pH —> normally 7.35 - 7.45
  - —> blood glucose levels —> normally 75 - 95 mg/dL
  - —> water balance —> depends on individual body size
- Most homeostatic responses involve an effect that is antagonistic to the detected stimulus —> negative feedback

Feedback loops:

- Physiological processes are commonly moderated via two distinct feedback mechanisms —> positive and negative feedback —> homeostatic processes are controlled by negative feedback —> occur more commonly within the body



Negative feedbacks:
- Involves a response that is the reverse of the change detected —> functions to reduce the change —> promotes equilibrium
- Change is detected by a receptor and an effector is activated to induce opposite effect
- Thermoregulation, blood sugar regulation (insulin and glucagon), osmoregulation (ADH), …



Positive feedback:
- Involves a response that reinforces change detected —> functions to amplify the change
- Change is detected by a receptor and an effector is activated to induce the same effect
- Will continue to amplify the initial change until the stimulus is removed
- Childbirth —> stretching of uterine walls cause contractions that further stretch the walls (continues until birth)
- Lactation —> child feeding stimulates milk production —> causes further feeding (continues until baby stops feeding)
- Ovulation —> the dominant follicle releases oestrogen which stimulates LH and FSH release to promote further follicular growth
- Blood clotting —> platelets release clotting factors —> + platelets will aggregate at site of injury

Endocrine system:

- System of ductless glands that release chemicals (hormones) into blood to regulate body function
- Hormone —> chemical messenger transported via the bloodstream to act on distant target cells —> specific and will only activate cells / tissues possessing appropriate target receptor
- The endocrine system is slower to initiate compare to the nervous system, but has a more prolonged response

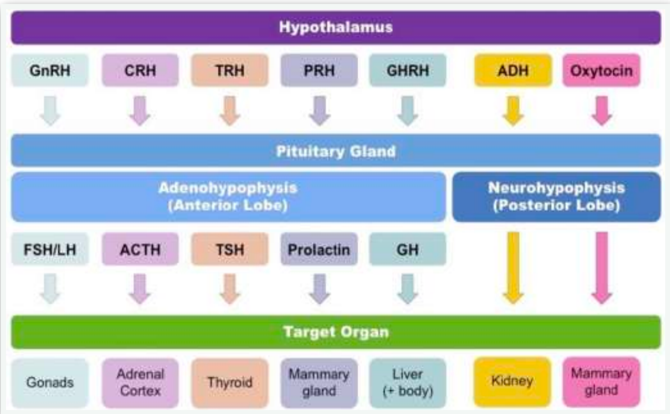
Endocrine glands:
- Secrete their product (hormones) directly into bloodstream rather than through a duct (exocrine gland)
- Include pancreas, adrenal gland, thyroid gland, pineal gland and the gonads
- Hypothalamus and pituitary gland are neuroendocrine glands —> function to link the nervous and endocrine systems
- Some organs may also secrete hormones despite not being endocrine glands (adipose tissue secretes leptin, …)

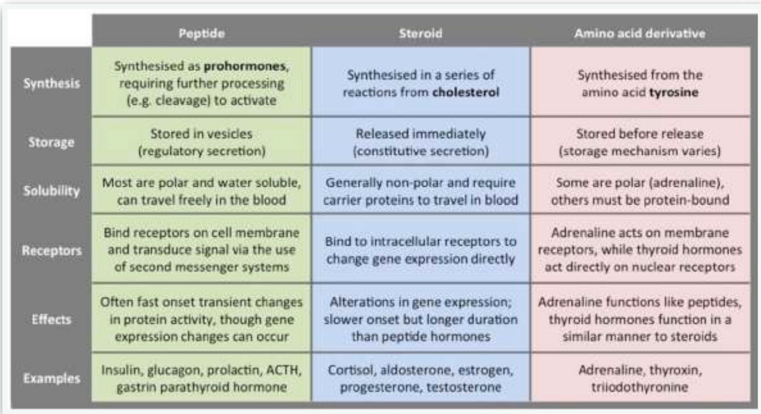
Gland	Hormone	Target Organ	Function
Pineal gland	melatonin	many	biological clock
Pituitary gland	FSH / LH ADH growth hormone oxytocin prolactin	ovaries kidneys many uterus breast tissue	menstrual cycle osmoregulation growth & division birth contractions milk production
Thyroid gland	thyroxin	liver	metabolic rate
Adrenal glands	adrenaline cortisol	many many	fight or flight anti-stress
Pancreas	insulin / glucagon	liver	blood sugar levels
Ovaries	estrogen / progesterone	uterus	menstrual cycle
Testes	testosterone	many	male characteristics

Hypothalamus:

- Section of brain that links the nervous and endocrine systems in order to maintain homeostasis
- Receives info from nerves throughout the body and other parts of the brain and initiates endocrine responses
- It secretes certain neurochemicals (releasing factors) into a portal system which stimulates or inhibits the pituitary gland + it also secretes certain hormones directly into the bloodstream via neurosecretory cells that extend into the pituitary gland

- Pituitary gland (master gland) —> lies adjacent to the hypothalamus and is in direct contact due to a portal blood system
- Pituitary gland receives instructions from the hypothalamus and consists of two lobes
  —> anterior lobe (adenohypophysis)—> releases hormones in response to releasing factors
  —> posterior lobe (neurohypophysis) —> releases hormones produced by the hypothalamus itself —> via neurosecretory cells

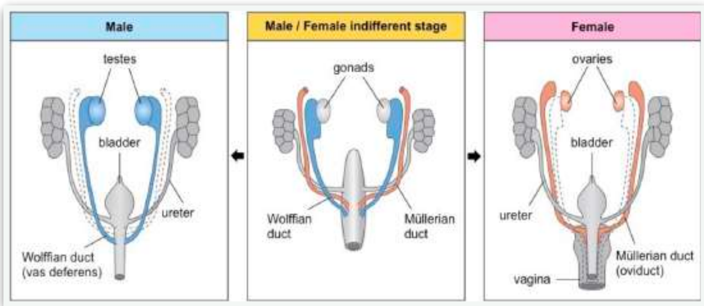




	Peptide	Steroid	Amino acid derivative
Synthesis	Synthesised as **prohormones**, requiring further processing (e.g. cleavage) to activate	Synthesised in a series of reactions from **cholesterol**	Synthesised from the amino acid **tyrosine**
Storage	Stored in vesicles (regulatory secretion)	Released immediately (constitutive secretion)	Stored before release (storage mechanism varies)
Solubility	Most are polar and water soluble, can travel freely in the blood	Generally non-polar and require carrier proteins to travel in blood	Some are polar (adrenaline), others must be protein-bound
Receptors	Bind receptors on cell membrane and transduce signal via the use of second messenger systems	Bind to intracellular receptors to change gene expression directly	Adrenaline acts on membrane receptors, while thyroid hormones act directly on nuclear receptors
Effects	Often fast onset transient changes in protein activity, though gene expression changes can occur	Alterations in gene expression; slower onset but longer duration than peptide hormones	Adrenaline functions like peptides, thyroid hormones function in a similar manner to steroids
Examples	Insulin, glucagon, prolactin, ACTH, gastrin parathyroid hormone	Cortisol, aldosterone, estrogen, progesterone, testosterone	Adrenaline, thyroxin, triiodothyronine

Gender issues:

- Sex —> describes the biological differences between males and females
- Gender —> describes the characteristics that society delineates as masculine or feminine
- Males —> possess the SRY gene which synthesises testis determining factor TDF
  —> the testis produces testosterone (promotes male sex characteristics) and a hormone called MIF (Mullein Inhibiting Factor) —> causes degeneration of female organs
- Females —> MIF is not produced and the female organs are allowed to develop (ovaries form)
  —> ovaries do not produce testosterone so female sex characteristics develop
- Sometimes errors occur during this prenatal development of sex characteristics —> issues in the assignment of gender —> androgen insensitivity syndrome and guevedoces are examples



Androgen Insensitivity syndrome:

- Individuals with AIS do not respond to the production of testosterone —> do not develop external male genitalia despite having internal testes and develop female sex characteristics
- Despite being genetically male, individuals physically resemble females and identify this gender

Guevedoces:

- Girls who turn into boys at puberty —> possess a rare genetic mutation which prevents the synthesis of the enzyme 5-alpha-reductase —> converts testosterone into dihydrotestosterone (DHT) triggering a hormone surge that develops male genitalia
- Without this enzyme, genetic males do not initially develop male genitals so are females —> with this second hormone surge occurring with the onset of puberty they develop male genitals

Menstrual events:

- The changes in reproductive hormones over the menstrual cycle trigger many physiological and behavioural responses

- 1 - 5 —> Period time during which the body may release prostaglandins which cause cramps
- 6 - 11 —> Estrogen levels rise during the follicular phase —> woman confident and flirtatious
- 12 - 15 —> Near ovulation (woman most fertile)
- 14 - 15 —> Ovulation —> estranged levels drop temporarily —> may fell cranky or emotional
- 16 - 19 —> Estrogen and progesterone release prepare for pregnancy (breast tenderness)
- 20 - 21 —> If fertilisation hasn't occurred, the ovaries stop producing estrogen and progesterone
- 22 - 28 —> falling levels of hormones will cause irritability and leads to will for sugary foods