Biology Y3 Notes

Biology Y4 Notes

Biological Molecules and Enzymes (NS)

Components of Biological Molecules

- Carbohydrates made of C H and O
- Glycogen, Starch and Cellulose made from monosaccharides and disaccharides
- Proteins are made of C H O and N, with the occasional S and P
- Protein strings are made from amino acids
- Fats are made of C H and O
- Lipids are made of glycerol and fatty acids

Saccharides

- Chemical formula $C_6H_{12}O_6$
- Empirical formula CH_2O
- Monosaccharides are isomers (Same formula, different structure)
- Monosaccharides include Glucose, Fructose and Galactose
- Disaccharides include Maltose (2G), Sucrose (GF) and Lactose (GGa)
- Multiple glucoses form Cellulose, Starch and Glycogen

Amino Acids

- Multiple amino acids bonded by peptide bonds
- Skeleton chain of O, N and H bond with R-groups aka amino acids
- Protein chains made from smaller units of amino acids

Bonds in Biological Molecules

- Hydrolysis: H_2O added to break bond between larger molecules to produce smaller molecules
- Condensation: H_2O removed to create bond between smaller molecules to produce larger molecules
- Ester bond: Bonds between fatty acid and triglyceride

Tests for Biological Molecules

- Starch: Add iodine, turns blue-black if positive
- Reducing Sugar: Add equal amount of benedict's reagent, heat in water bath, creates green to brick-red ppt if positive
- Non-reducing Sugar: Add digestive enzyme OR add HCl and neutraliser and then carry out reducing sugar test
- Protein: Add NaOH and $CuSO_4$ to solution and shake, turns violet if present
- Fats: Add ethanol and shake, white emulsion produced if positive
- Water: Add anhydrous Copper(II) sulfate, positive if it turns blue

Plant Nutrition (NS)

Role of Photosynthesis

- Plants are autotrophs, they produce their own food.
- Most other animals are heterotrophs, they rely on autotrophs for nutrition
- Photosynthesis is effectively the source of all food on earth
- Maintains CO_2 in air, prevents accumulation of CO_2 which can cause harmful effects such as
    - Greenhouse effect / global warming
    - Health problems

Photosynthesis

- Photosynthesis is:
    - Water + Carbon Dioxide -(sunlight)> Glucose + Oxygen
    - $6H_2O + 6CO_2$ -(sunlight)> $C_6H_{12}O_6 + 3O_2$
- Rate of photosynthesis is limited by
    - Light intensity, limits amount of energy available
    - Carbon Dioxide concentration, limits supply of reactants
    - Temperature, limits rate of reaction
- One of these factors is a limiting factor; it is the factor which is preventing the rate of reaction to increase any further
- Limiting factor of photosynthesis is usually CO_2 concentration
- Can be split into light dependent stage and Calvin cycle
    - Light dependent stage takes place in chlorophyll, uses H_2O to absorb light and produce ATP, NADP**H**
    - Calvin cycle uses energy from ATP and H from NADPH, combined with previously collected CO_2 to form glucose, sending ADP and $NADP^+$ back to the light dependent stage
- Magnesium is needed to synthesize chlorophyll
- Nitrogen is needed to produce RUBISCO, an enzyme which turns CO_2 into an organic molecule

Use of Glucose

- Used to produce cellulose and repair plant cells
- Converted to starch for storage, able to keep large amounts of energy without affecting osmotic pressure
- Converted to sucrose to be transported to rest of cell
- Used in cellular respiration

Cellular Respiration

Uses of Energy

- Muscle contraction
- Protein synthesis
- Cell division
- Active transport
- Growth
- Passage of nerve impulses
- Thermal homeostasis

ATP

- **A**denosine **T**ri**P**hosphate
- Energy is stored in the high-energy third phosphate bond
- Adenosine DiPhosphate (ADP) + P_i + Energy -> Adenosine TriPhosphate

Anaerobic and Aerobic Respiration

- Respiration is the process of metabolising glucose to produce energy
- Anaerobic Respiration: Glucose ($C_6H_{12}O_6$) ->
    - Animals: -> Lactic acid ($2C_3H_6O_3$) + 2ATP
    - Plants and Yeast: -> Ethanol ($2C_2H_6O$) + Carbon Dioxide ($2CO_2$) + 2ATP
- Lactic acid is decomposed to give energy once O_2 is restored, or transported to liver to be oxidised and converted back to glucose
- Aerobic Respiration: Glucose ($C_6H_{12}O_6$) + Oxygen (O_2) ->
    - All: -> Carbon Dioxide ($6CO_2$) + Water ($6H_2O$) + 38ATP

Aerobic Respiration and Photosynthesis

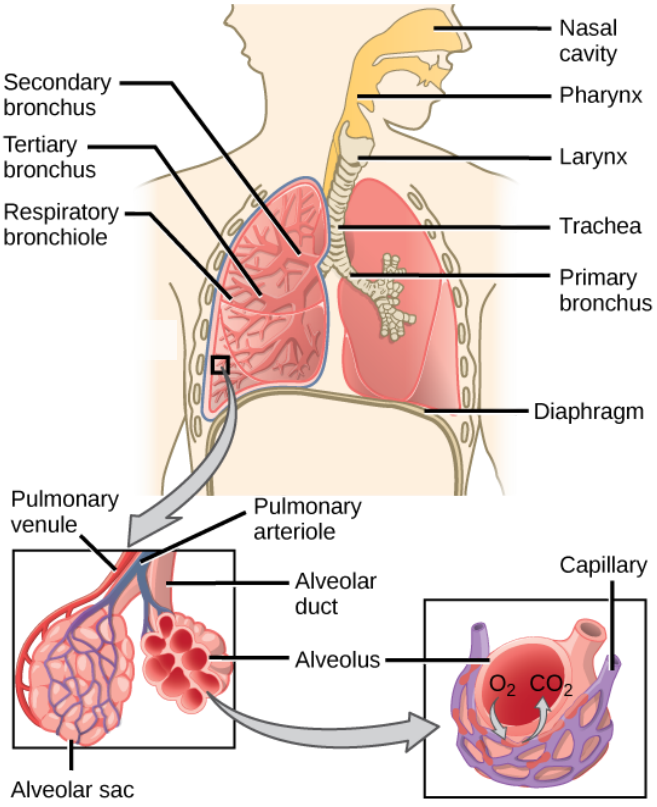
- Aerobic Respiration = Glucose + Oxygen -> Water + Carbon Dioxide + Energy
- Photosynthesis = Water + Carbon Dioxide - {Sunlight} > Glucose + Oxygen
- Polar opposites of each other

External Respiration

Principles of Gaseous Exchange

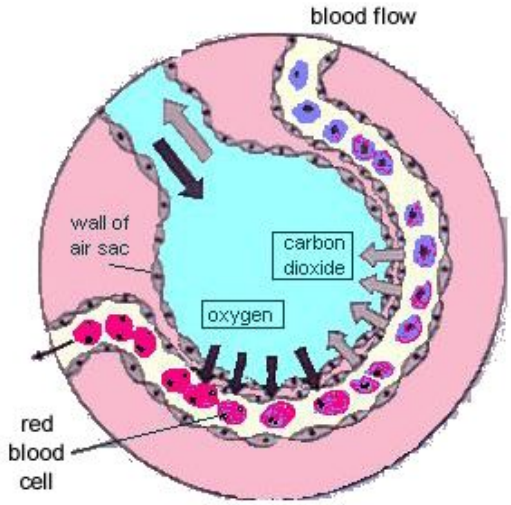
- Organisms need to take in O_2 while maintaining a relatively closed internal system
- Gas exchange would hence occur by diffusion through cells
- Rate of diffusion is directly proportionate to the surface area of the respiratory surface
- Due to Square-Cube rule, larger animals require specialised respiratory systems to increase the rate of gas exchange since natural diffusion is unable to sustain life.

The Human Respiratory System



- Nose and mouth allow for gas to enter the respiratory system
- Air enters pharynx, larynx, and finally trachea
- Air passes into bronchi and bronchioles before reaching the alveoli
- Gaseous exchange takes place between gas in alveoli and capillaries surrounding the alveoli
- Ribs protect the lungs from external injury
- Diaphragm triggers expansion and contraction of thoracic cavity, creates pressure systems fit for exhaling and inhaling
- Intercostal muscles act accordingly with diaphragm, external contracts when inhaling and internal contracts when exhaling
- Ribs, diaphragm and intercostal muscles all act together to breathe

The Alveoli



- Smallest unit of the lungs, exact location of diffusion of CO_2 and O_2
- Cell wall of alveoli and capillary are one cell thick to allow diffusion to occur easily
- Lining of moisture of alveoli allows for gas to dissolve and speed up diffusion
- Alveoli wall has many capillaries to increase surface area of diffusion

Respiratory System and other systems

- Immune System
  - Nose hairs trap dust and pathogens
  - Cilia in bronchi and bronchioles secrete mucus to trap dust and pathogens, slow movement of cilia propels mucus out of lungs
  - Also warm the air
- Circulatory System

- One half of heart dedicated to sending blood to lungs
- Priorities half of blood collect gas, half of blood use gas
- Faster heart rate causes faster gas exchange, more O_2 supply to rest of body

Rate of Respiration

- Determined by the pH of the blood
- CO_2 in blood lower the pH of the blood since HCO_3^- and H^+ are produced when dissociated
- Higher CO_2 concentration -> pH -> Breathing rate
- NOT dependent on O_2 concentration

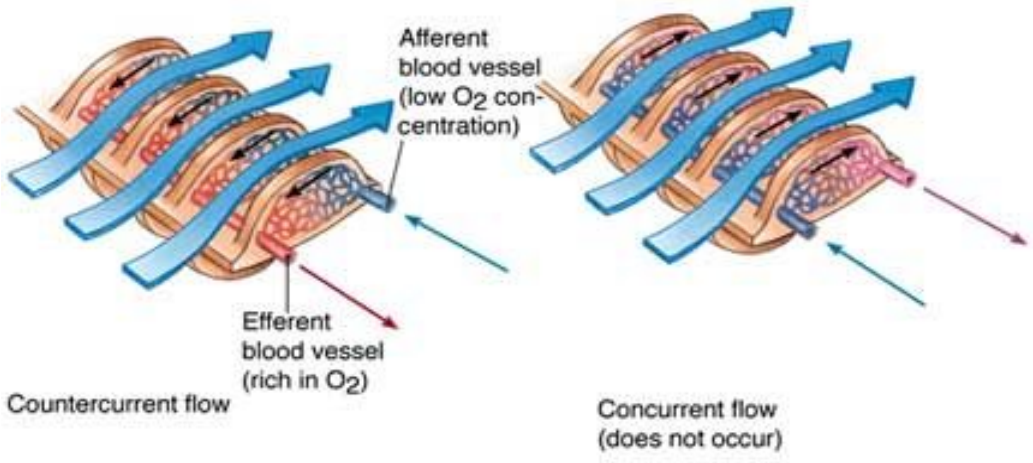
Inhaled and Exhaled Air

Compound	Inhaled Air	Exhaled Air
O_2	21	16
CO_2	0.04	4
N_2	79	79

Water as a Respiratory Medium

- Advantages
  - Pre-dissolved gases easier to diffuse
  - Countercurrent principle applied
- Disadvantages
  - Lower concentration of O_2
  - Inability to utilise pressure gradient

Countercurrent Gas Exchange in Fish



- Flow of water is against flow of blood
- Water always has a higher concentration of O_2
- Constant diffusion gradient is maintained throughout the blood
- More O_2 diffuses

Respiratory Disorders

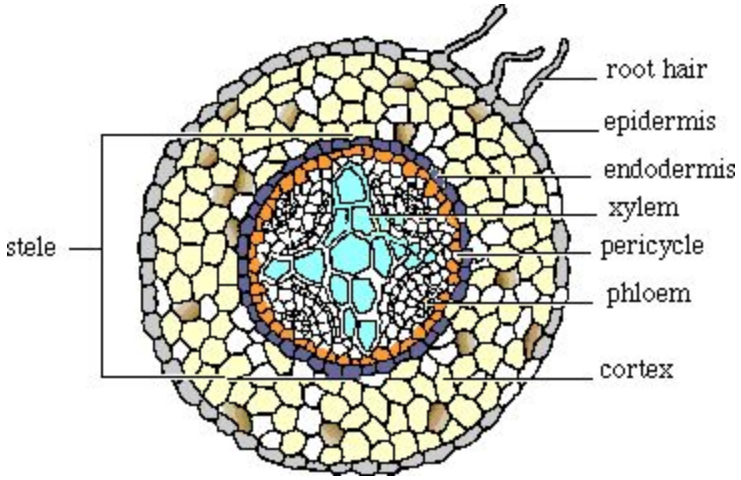
- Smoking can cause health problems
- Emphysema where alveoli walls are broken, less surface area for gas exchange
- Lung Cancer
- Bronchitis, smaller venue for gas to pass through into lungs
- Carbon monoxide binds with haemoglobin to form carboxyhemoglobin irreversibly
    - Less haemoglobin available to transport oxygen

Transport in Plants

Structure of a Plant

- Plants consist of 3 main parts
    - Water and mineral collecting roots
    - Transporting and supporting stems
    - Glucose producing leaves

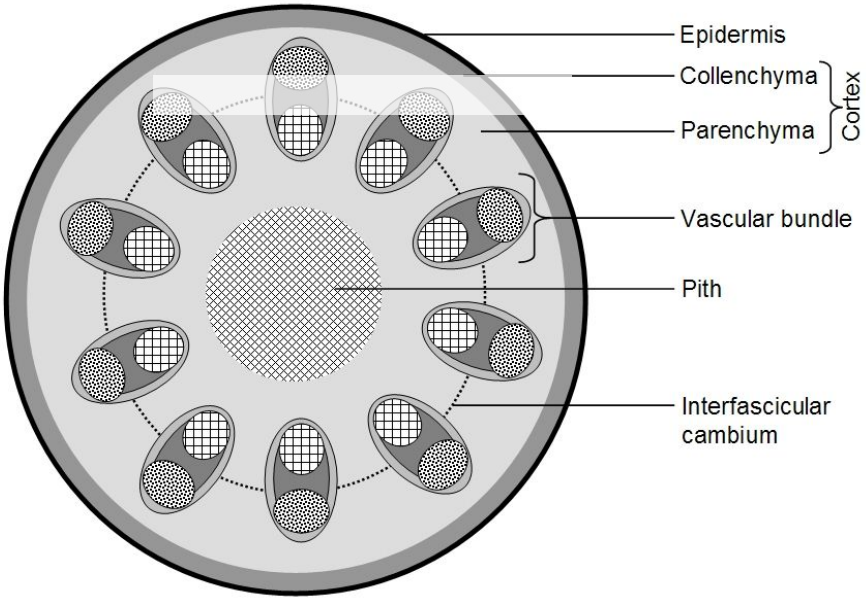
Structure of Roots



- Root hairs take in mineral salts via active transport.
- Due to higher concentration of mineral salts, water enters the root cell via osmosis.
- Epidermis protects cells from external environment
- Cortex is the bulk of the root mass, provides support for rest of root
    - Parenchyma cells store starch
- Endodermis separates cortex from stele which has a casparian strip

- Pericycle parenchyma cells are in between the phloem and endodermis, multiply to create lateral roots
- Xylem in root transports water up
- Phloem in roots receives food from rest of plant

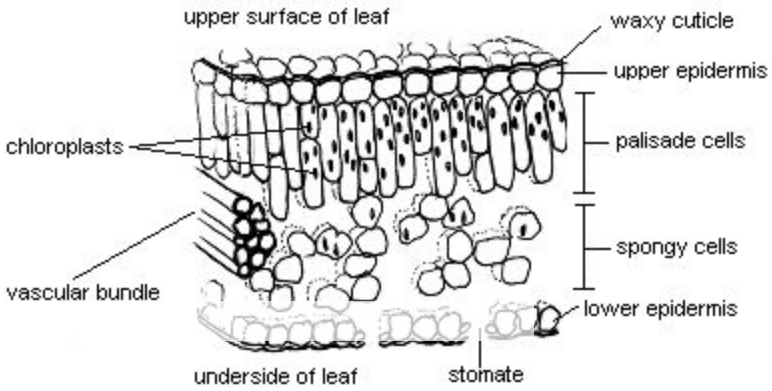
Structure of Stem



Cross-section through a young non-woody dicot stem

- Cuticle waterproofs the stem with cutin
- Epidermis protects stem from external environment
- Cortex is bulk of plant material, used to support plant and to store starch
- Vascular bundle contains various transport components
    - Xylem on the inner surface which transports water to leaves and supports plant through growth of sturdy lignin
    - Cambium which actively divides to maintain vascular bundle
    - Phloem on the outer surface which transports food to rest of leaves
- Pith contains storage parenchyma cells while supporting plant

Structure of Leaf



- Cuticle waterproofs leaf using a layer of cutin
- Upper epidermis protects leaf
- Palisade mesophyll cells are tightly packed and contain chlorophyll
- Spongy mesophyll cells are loosely packed with many air spaces and contain chlorophyll
- Lower epidermis protects lower surface of plant
- Stomatal guard cells in lower epidermis open and close stomata by absorbing and releasing water respectively

Structure of the Vascular Bundle

Xylem

- Found in center of root, inner side of vascular bundle in stem and top of vascular bundle in leaf
- Take part in lignification, where lignin is deposited on the surface of the xylem which then
    - Strengthen the xylem
    - Prevents breakages
    - Less hydrophilic, prevents osmosis of water to parenchyma cells
- Forms a continuous and hollow tube for water to flow without obstruction
- Xylem is the “hollow corpse” of previous cells

Phloem

- Found in outside of root, outer side of vascular bundle in stem and bottom of vascular bundle in leaf
- Consist of sieve tube elements and companion cells
- Companion cells maintain and nourish sieve tube elements
- Cell walls between sieve tubes are perforated to form sieve plates for nutrients to pass through
- Cells are living

Transpiration Cycle

Water entering the root

- Mineral salts absorbed by root cells via active transport
- Water osmoses into root cells
- Transfers from root hairs to xylem via
    - Apoplast pathway in cell wall
    - Symplast pathway in cytoplasm, especially due to plasmodesmata joining multiple cells via cytoplasm
    - Vacuolar pathway from vacuole to vacuole
- Minerals and water enter symplast of root hair cells
- Mineral solution transferred through apoplast
- Solution passes through casparian strip which controls flow of solution
- Solution reaches xylem

Water exiting the leaf

- Water in xylem enters mesophyll cells and travel from cell to cell via osmosis
- Water evaporates from mesophyll cells
- Water vapour diffuses out from intercellular spaces to out of stomata
- Water is transpired

Factors affecting transpiration

- Relative Humidity = Water vapour in air / Water vapour in leaf * 100%
- Temp ++ > RH -- & KE ++ > Diffusion gradient ++ > Rate ++
- Wind Speed ++ > RH -- > Diffusion gradient ++ > Rate ++
- Light ++ > Photosynthesis ++ > Water usage ++ > Water evaporation ++ > Rate ++
- Water availability

Transport of Water

- Root pressure forces water up
- Capillary action makes water climb up thin xylem due to surface tension (adhesion)
- Transpirational Pull applies a tension that pull water up the xylem vessel, due to H-bonds in between water molecules (cohesion)

Transport of Food

- Sucrose loaded into phloem from source cell via active transport
- Water from xylem osmoses into phloem
- Incoming pressure from water forces sap to move
- Pressure is relieved by unloading of sucrose to sink cell via active transport

- Water is returned to xylem

Reduction of Transpiration

- Guard cells which can close to limit the flow of water vapour
- Thick cuticle to reduce water loss by evaporation
- Multiple layered epidermis to reduce water loss further
- Sunken stomata with hairs to form saturated air outside of stomata, reducing internal diffusion gradient

Transport in Man

Simple and Complex Circulatory System

- Every organism needs to exchange material with its environment at the cellular level
- Simple organisms e.g. unicellular organisms have almost all of its cells in contact with its environment, via diffusion
- Due to Square-Cube Law, larger organisms have a smaller surface area to volume ratio, where diffusion quickly becomes insufficient to support life as its size increases
- Multicellular organisms require much more than simple organisms
    - More amount of materials
    - Increased distance that materials have to move
    - Inadequacy of protective skin to facilitate diffusion
    - Direct exchange with environment is not possible since most cells are inside

Open vs Closed and the Components a Circulatory System

Open circulatory system

- Circulating fluid is pumped through open ended vessels
- Flows out into the cells
- Circulating fluid bathes cells directly
- Most invertebrates

Closed circulatory system

- Consist of vessels and a pump mechanism
- Circulating fluid is contained within transport vessels
- Circulating fluid is distinct from interstitial fluid (fluid which bathes cells)
- Exchange occurs between cells and interstitial fluid
- In Man:
    - Provides efficient internal transport system
    - Connects organs of exchange with body cells
    - Circulating fluid provides a bridge between aqueous environment of cells and the exchange organs

    - Brings resources to almost all cells for diffusion to occur
- Efficient due to
    - Larger and controlled SA of Diffusion
    - Continuous and unidirectional blood flow
    - Difference in blood pressure between two points ensures flow

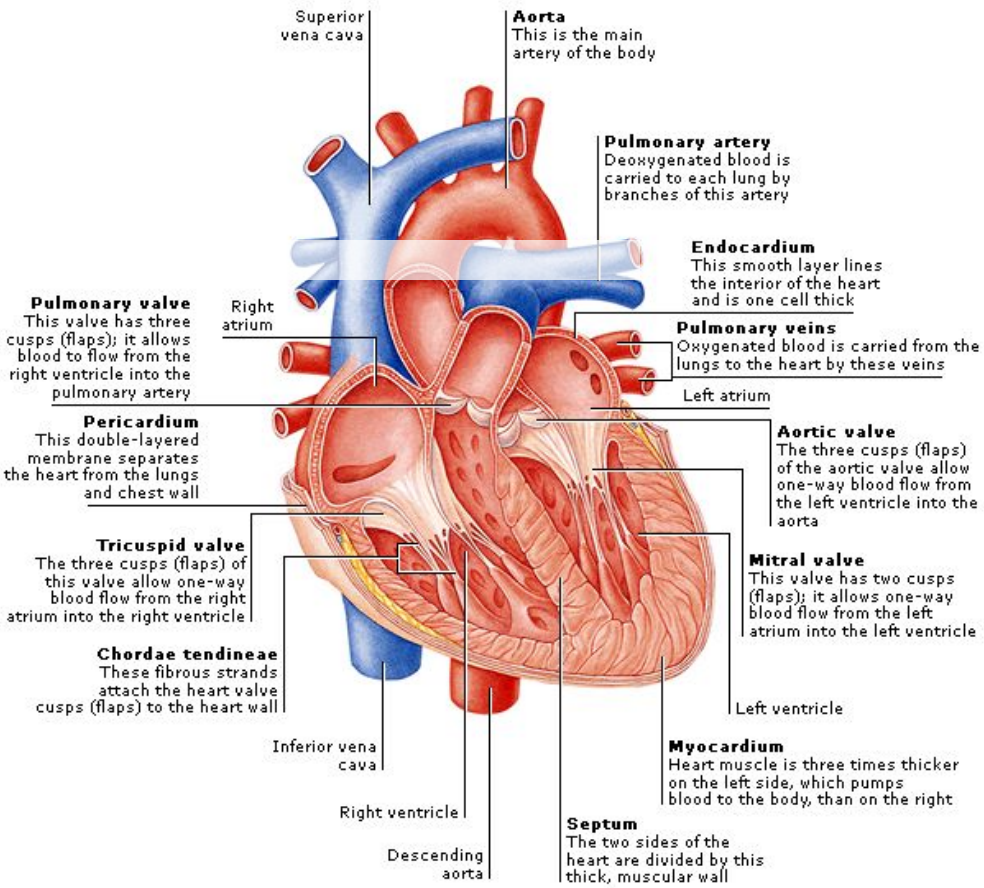
Key Components

- Heart or Pump
- Blood Vessels: Arteries, Arterioles, Capillaries, Venules and Veins
- Blood

The Mammalian Double Circulation

- Blood passes through heart twice in one complete and unidirectional circulation
- Consists of
    - Pulmonary circulation to lungs, takes in O_2 and removes CO_2
    - Systemic circulation to rest of body, supplies O_2 and nutrients while taking away CO_2 and wastes
- Right and Left are completely separated to prevent mixing of oxygenated blood and deoxygenated blood
- Right side receives and pumps deoxygenated blood
- Left side receives and pumps oxygenated blood
- Full circulation described as
    - Deoxygenated blood from body enters right side of heart
    - Blood proceeds to lungs for gas exchange
    - Oxygenated blood from lungs enters left side of heart
    - Leaves the heart and proceeds to rest of body

Structure of the Human Heart

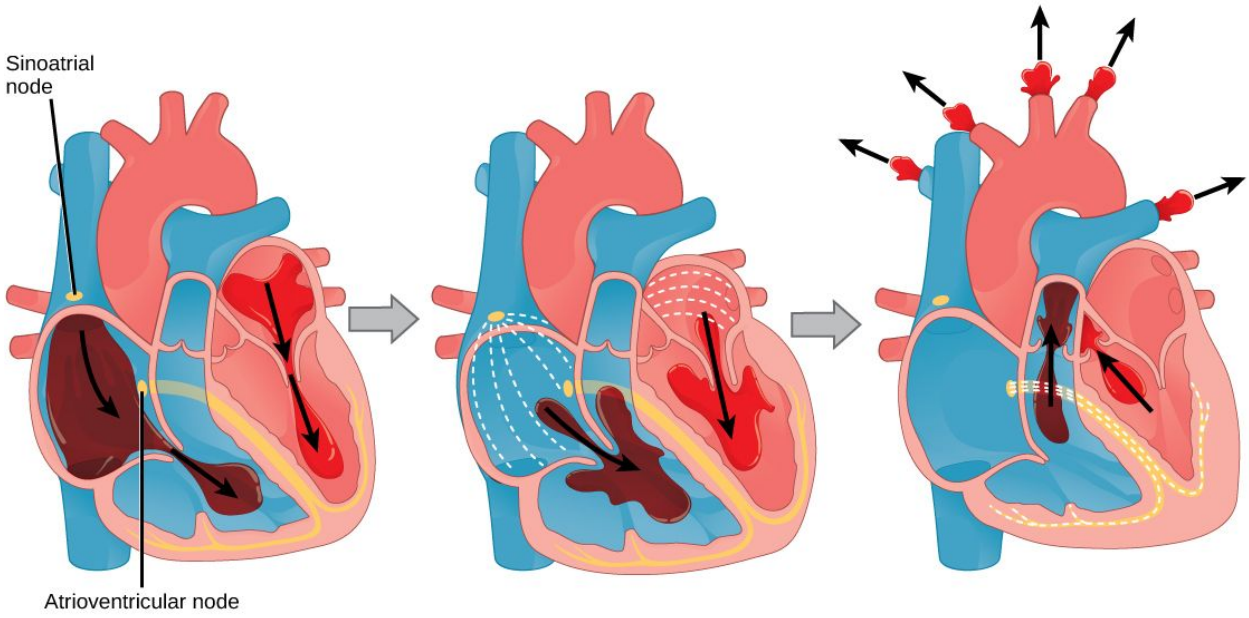


- Muscular organ
- Pumps blood through blood vessels
- Approximately the size of a clenched fist
- Located within the thorax behind the sternum and surrounded by the lungs
- Four chambers, left or right, atria (top) or ventricle (bottom) .
- Left and right separated by the septum to prevent mixing of oxygenated and deoxygenated blood
- Atria
    - Upper Chambers
    - Thin-walled vs Ventricular cells due to lower max pressure
    - Receive blood from Vena Cava (right) or Pulmonary Vein (left)
    - Pumps blood into ventricles
- Ventricle
    - Lower Chambers
    - Thick walled vs Atrial cells due to higher max pressure

    - Left ventricular wall 3 times thicker than right, due to distance it need to pump and hence higher pressure needed to withstand
    - Able to generate high pressure to pump blood to lungs (right) or rest of body (left)
    - Collect blood from atria
- Atrioventricular valves
    - Found between atrium and ventricle
    - Tricuspid valves in right side
    - Bicuspid or mitral valve in left side
    - Prevent backflow of blood from ventricles into arteries
    - Chordae tendineae aka heart strings to hold valves in place, prevent prolapsing or inverting of valve, fastened to ventricular walls via papillary muscles
- Semilunar valves
    - Found between artery and ventricle
    - Prevent backflow of blood into ventricles

The Cardiac Cycle

- Heart contracts and relaxes in rhythmic cycle called the cardiac cycle
- Contraction is systole
- Relaxation is diastole
- Dead is asystole (hue hue)
- Heart rate is the number of cycles a minute
- Cardiac output is volume of blood pumped into systemic circulation

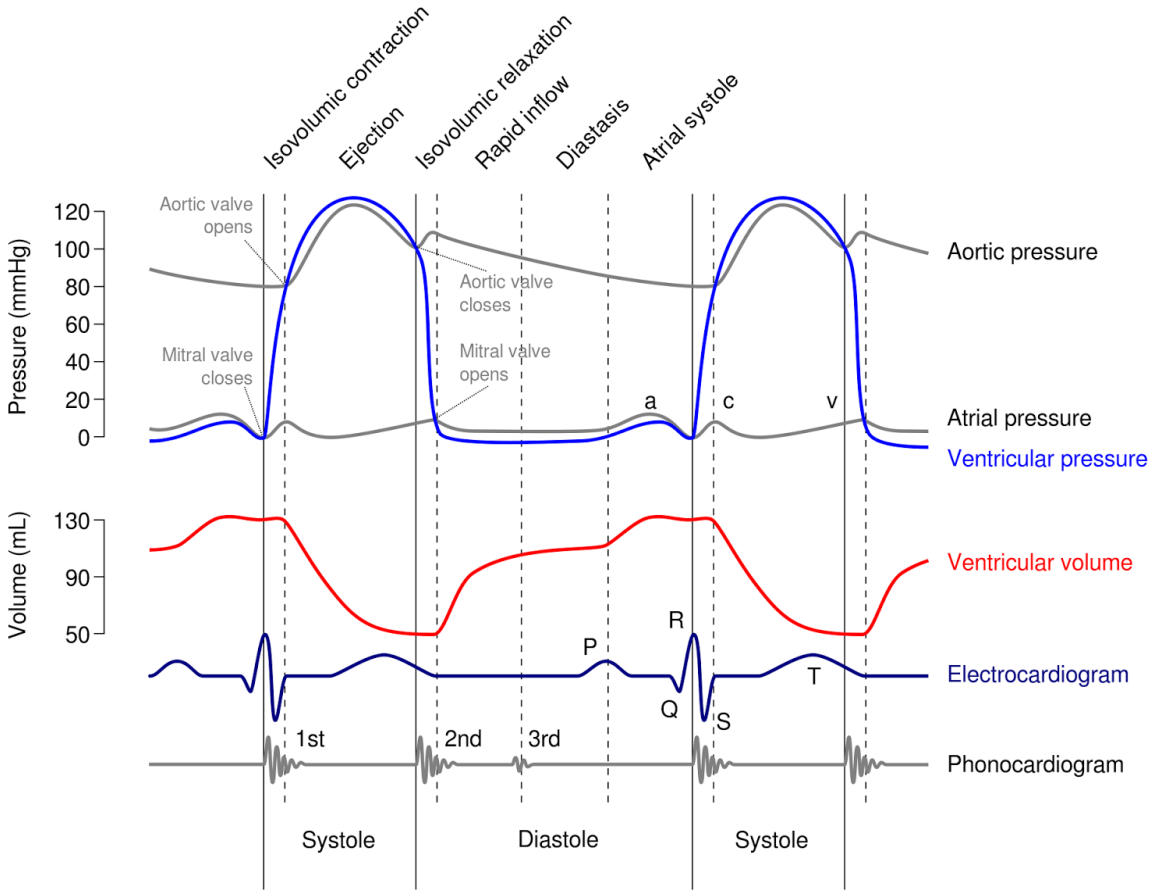


(a) Cardiac diastole: all chambers are relaxed, and blood flows into the heart.

(b) Atrial systole, ventricular diastole: atria contract, pushing blood into the ventricles.

(c) Atrial diastole, ventricular systole: after the atria relax, the ventricles contract, pushing blood out of the heart.

Cardiac Diastole	Atrial Systole	Ventricular Systole
All muscles relax	Atria contract	Ventricles contract
Blood flows into atria and then ventricle	Blood flows from atria into ventricle	Blood forced out of ventricle into artery
Semilunar valves close	Semilunar valves close	Semilunar valves open
Tricuspid and bicuspid valves open	Tricuspid and bicuspid valves open	Tricuspid and bicuspid valves close



- Cardiac cycles are kept in rhythm by the sinoatrial (SA) node or pacemaker, atria contract
- Impulses from SA node travel to atrioventricular (AV) node
- Impulses delayed at AV node
- Impulses travel to Bundle of His and Purkinje fibres, ventricles contract
- Impulses are measured by electrocardiogram or ECG

Blood Vessels

- Transport blood to all parts of the body
- Delivers nutrients, removes wastes
- Similar layered structure of
    - Endothelium
    - Smooth muscle and elastic fibres
    - Connective tissue
- Arteries
    - Carry blood away from heart
    - Branch into arterioles and capillaries
    - Thick smooth muscular walls compared to veins to accommodate for high pressure of blood coming from heart
    - High pressure helps blood move
- Capillaries
    - Connect arterioles and venules
    - Allow for exchange between blood and cells
    - Collect and widen into venules
    - One cell thick with no smooth muscle or connective tissue , only endothelial cells
    - Allows for rapid diffusion
    - Branches rapidly to increase surface area between blood and tissue
    - Exchange driven by differences in concentration, hydrostatic pressure and osmolarity
- Veins
    - Venules converge to form veins
    - Veins carry blood to heart
    - Thinner smooth muscles compared to arteries due to accommodate for lower pressure
    - Skeletal muscles help to pump blood along
        - Muscles contract
        - Volume decreases
        - Blood passes through one-way valves
        - Muscular contractions push blood along
    - Valves present to prevent backflow of blood

Properties of Blood

- Blood velocity
    - Varies within circulatory system
    - Volume of flow must be constant (law of continuity)
    - Total cross sectional area increases > Flow velocity decreases (capillaries slower)

    - Total cross sectional area decreases > Flow velocity increases (Arteries and Veins faster)
- Blood Pressure
    - Hydrostatic pressure the blood exerts against the walls of a vessel
    - Systolic is pressure in arteries during systole, highest pressure
    - Diastolic is pressure in arteries during diastole, lower pressure
    - Determined by cardiac output (volume of flow) and peripheral resistance (constriction in vessels)
- Components of Blood
    - 55% Plasma
        - Water
        - Metal Ions
        - Plasma proteins (albumin)
        - Nutrients (glucose, vitamins)
        - Waste (urea, lactic acid)
        - Gases (CO_2)
        - Hormones (insulin)
    - 1% White blood cells and platelets
    - 45% Red blood cell

Exchange of Materials

- Exchange of materials between blood and interstitial fluid across endothelial walls in capillaries
- Caused by differences of hydrostatic pressure and osmotic pressure
    - Liquid forced out at arterioles, forced back in in venules
- Fluid reenters the circulation at the end of capillary bed, from lymphatic system
- Lymphatic system aids in body defence, returns fluid to circulatory system
- At arteriole, plasma forced out while plasma proteins and blood cells deform to pass through thin capillary
- Interstitial fluid
    - Made up of plasma + components in plasma
    - bathes all living cells in body
    - supplies oxygen, food and receives waste

Transport of CO_2

- Dissolved CO_2
    - 5% of CO_2 is transported as-is in plasma
- Bonds reversibly to haemoglobin
    - 15% of CO_2 is bonded to the polypeptide chains in haemoglobin
- Bicarbonate Ions
    - Most of CO_2 enters RBC, forms carbonic acid H_2CO_3
    - Catalysed by carbonic anhydrase

    - Dissociates to form H^+ and CO_3^- ions in plasma
    - Carbonic anhydrase reverses reaction when nearing lungs

Cells in the Blood

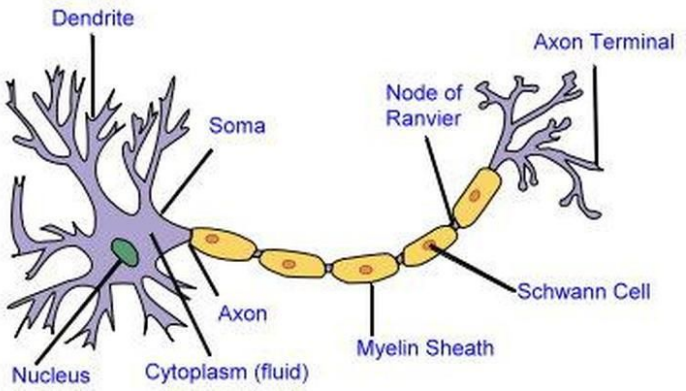
- Red Blood Cells
    - Erythrocytes
    - Circular, flattened and flexible biconcave cells
    - Do not have nuclei
    - Less than 0.01mm in diameter
    - Transport oxygen and aids in carbon dioxide transport
    - Elastic, can squeeze through smaller capillaries
    - 5-6 million in 1 mm^3 of blood
    - Produced in bone marrow
    - Lives for 3-4 months
    - Destroyed in spleen and liver
    - Contain Haemoglobin, 250 million a cell
        - Comprises of protein chain and iron-containing haem group
        - Forms oxyhaemoglobin with oxygen
- White Blood Cells
    - Leukocytes
    - Irregular shape, can squeeze in capillaries
    - Colourless
    - Produced in bone marrow
    - Used in bloodbound immune system
    - Lymphocytes
        - Large rounded nucleus
        - Small amount of cytoplasm
        - Produces antibodies used to kill bacteria and clump around foreign particles
    - Phagocytes
        - Lobed nucleus
        - Protects body against foreign particles by surrounding and ingesting particles
        - Process is called Phagocytosis
- Platelets
    - Not true cells
    - Fragments of cytoplasm from bone marrow cells
    - Used in haemostasis or blood clotting
        - Reduces blood loss in injury
        - Prevents intrusion of microorganisms in open wounds
    - Begins clotting cascade process when endothelium is damaged

Reflex Action, Eye, Muscles and Movement

The Nervous System

- Comprises of Central (brain) and Peripheral (spinal cord, nerve endings)
- Stimulus -> Response flow
    - Stimulus which triggers receptors
    - Information sent to CNS
    - CNS receives information, processes and determine response
    - Effectors which carries out the response (muscles, glands)
- Autonomic Nervous System
    - Sympathetic system carries out “fight or flight” responses
    - Parasympathetic system carries out most other tranquil responses

Structure of a Neuron

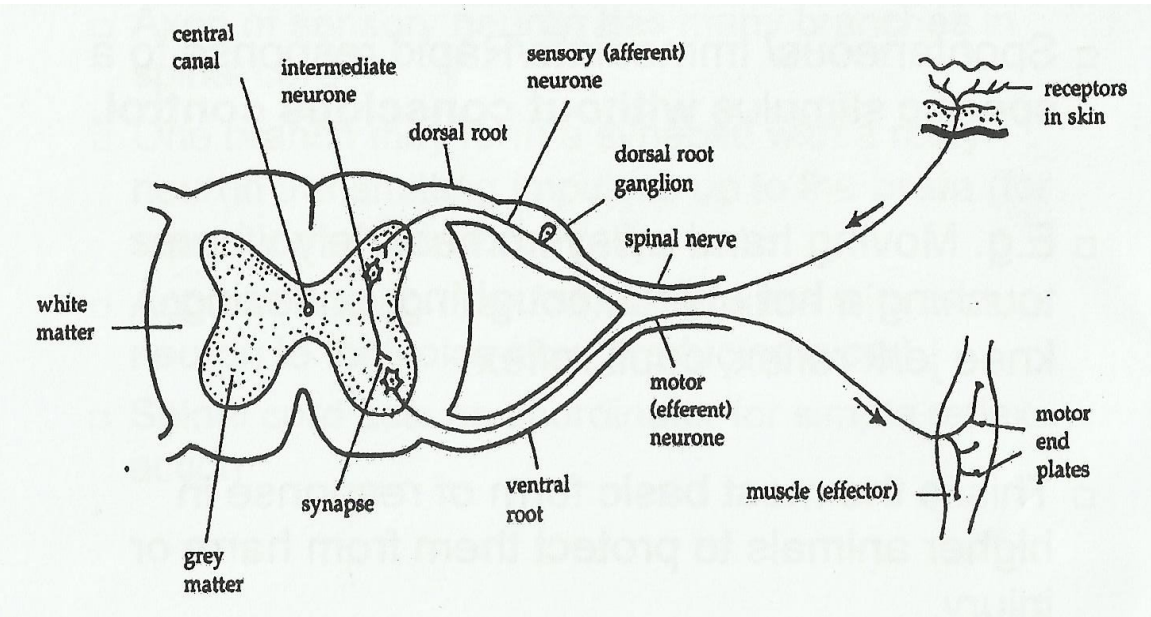


- Consists of
    - Cell Body / Soma consisting of nucleus, cytoplasm and membrane
    - Axon transmits impulses away from cell body, is covered with schwann cells
    - Dendron transmits impulses towards from cell body, is covered with schwann cells
    - Dendrites collect signals from presynaptic cells or sensory cells to dendron, highly branched extensions
    - Synapse is the gap between nerve ending and the dendrites of two cells
    - Neurotransmitter is the chemical signal used to send signals from one neuron to another
    - Schwann cells are the myelin sheath surrounding extended axons and dendrons, allows for faster transmission of electrical signals through alternating magnetic field between schwann cells and nodes of ranvier
    - Unsheathed points are called nodes of Ranvier
- Consists of
    - Sensory neurons

        - Carry impulses from receptors or sense organs to CNS / relay neurons
        - Long dendron and short axon
    - Intermediate neurons
        - Carry impulses from sensory neurons or CNS to CNS or effector neurons
        - Demyelinated?
        - Several short dendrons, long axon
    - Effector neurons
        - Carry impulses from CNS to effectors
        - Long axon and several short dendrons
- Create different coloured matter in brain and spinal cord
    - White matter consists of nerve fibres
    - Grey matter consists of cell bodies
    - Grey matter inside of white matter in spine

Spinal Cord

- Collection of neurons which passes through and is protected by vertebral column
- 31 pairs of spinal nerves which emerge at regular intervals
- Central canal runs through middle of spinal cord, with cerebrospinal fluid to nourish neurons and to cushion CNS
- Front/ventral spinal nerve has motor neurons cell bodies found within grey matter
- Rear/dorsal spinal nerve contains sensory neurons, cell bodies found in dorsal root ganglion



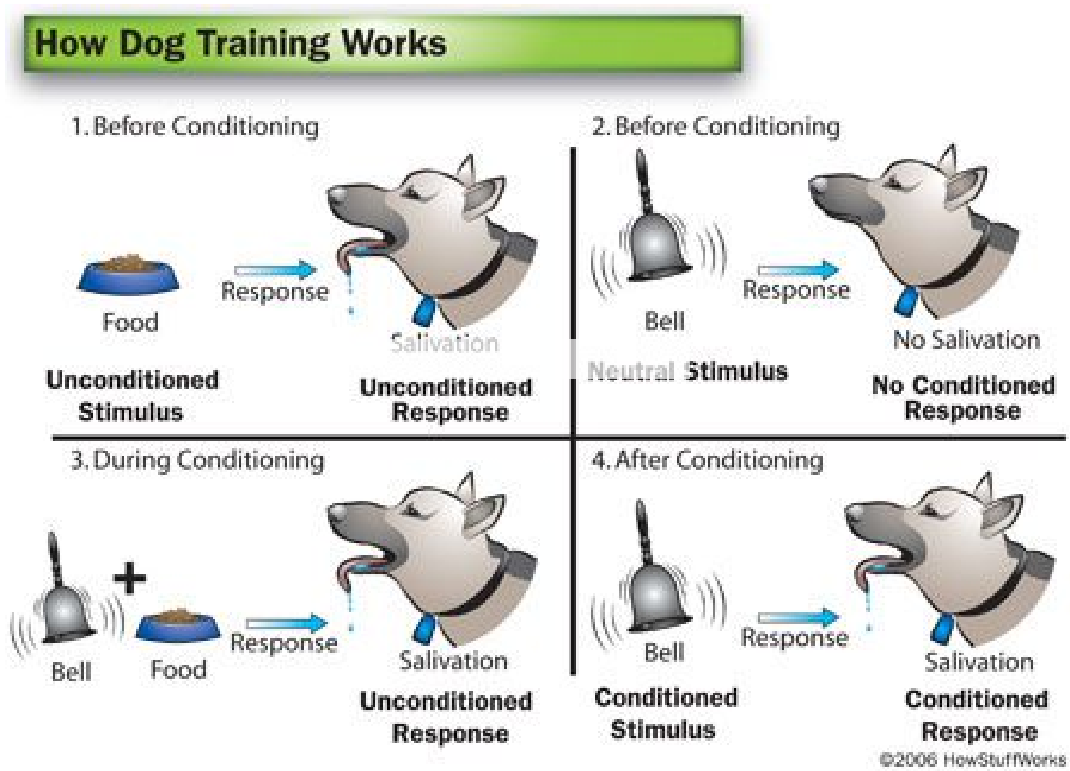
Reflex Action

- Instant response to a stimulus without conscious control
    - Moving hand away from hot object, pupil reflex

- Most basic form of response in an advanced animal to prevent injury
- Uses reflex arc
    - Shortest pathway from receptor to effector
    - Comprises of receptor, neurons, spinal cord aka reflex center and effector
- Process is as such (touching hot object)
    - Thermoreceptors in hand stimulated
    - Nerve impulses transmitted
    - Travels along dendron of sensory neuron to spinal cord
    - Impulses transmitted across synapse to relay neuron
    - Impulses transmitted across synapse to motor neuron
    - Impulses leave spinal cord
    - Travel along axon of motor neuron to effector
    - Effector carries out response, quick withdrawal of hand via contracting biceps muscle
- Post process is as such
    - Axon of sensory neuron has many branches in spinal cord
    - One branch leads to brain to simulate sensation of pain
    - One branch forms a synapse with neuron leading to voice box, producing a shout
    - Spinal cord acts as coordinator for simple reflex action

Conditioned Reflex Action

- Reflex action acquired from past experience
- Previously unrelated / ineffective stimulus is conditioned, future responses achieved due to stimulus after conditioning



Structure of The Eye

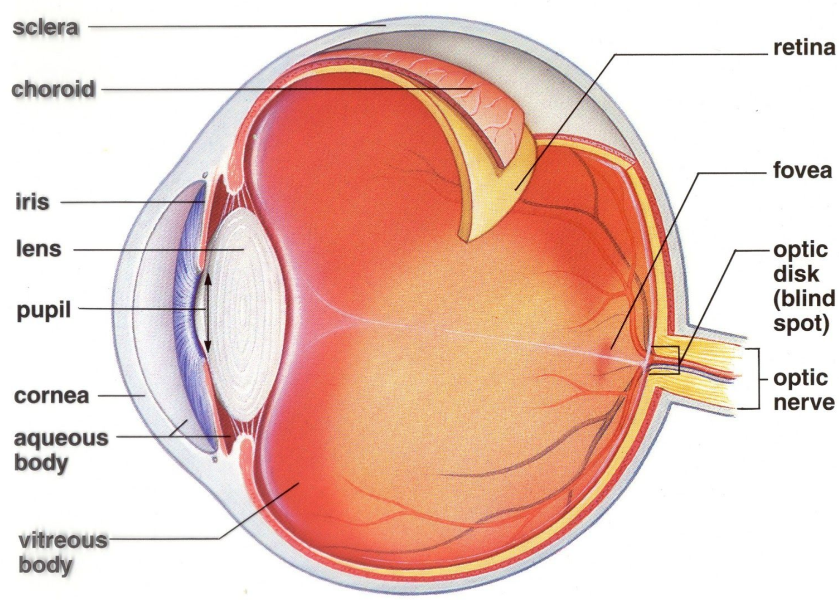


Fig. 32.30 Structure of the human eye.

Component	Description	Function

Cornea	Bulge at front of sclera, convex and transparent	Protects front of eye and refracts light, bent most here
Conjunctiva	Membrane covering exposed front of the eye	Protects exposed part of eyeball
Sclera	Opaque and white outer coat of the eye, tough and fibrous outer layer covering whole eyeball, eventually forming cornea	Protection of entire eyeball
Choroid	Middle covering of eyeball which is black, eventually forming ciliary body and iris	Contains capillaries which nourish eyeball, black pigment prevents TIR and hence prevents multiple images
Iris	Pigmented part of eyeball which light cannot pass through, disc shaped structure with pupil in middle. Contains radial and circular muscles to control size	Controls diameter of pupil by adjusting circular and radial muscles Prevents damage from too much light
Pupil	Hole in center of iris, formed by lack of choroid	
Lens	Transparent biconvex and elastic disc behind iris which is attached to suspensory ligament	Refracts light to focus image on retina
Ciliary Body	Ring of muscle fibres around lens	Contracts and relaxes to control lens thickness and curvature
Suspensory Ligament	Ligament between lens and ciliary body	Connects lens to ciliary body
Retina	Innermost layer of eye, contains photoreceptive cells which are connected to optic nerve	Images are formed on retina which excite cone cells (color) and rod cells (b&w). Fovea centralis is area with largest density of photoreceptive cells
Aqueous Humour	Clear watery fluid between iris and cornea	Refract light onto lens, maintain shape
Vitreous Humour	Jelly-like fluid inside of eyeball	Refract light onto lens, maintain shape
Blind Spot	Point where optic nerve meets the eyeball, has no photoreceptors	No images will be seen when light falls on it
Optic Nerve	Bundle of nerves at back of eye	Transmits signals from photoreceptors

		to brain

Eye Reflexes

Focus Reflex

- Clear vision depends on ability of lens to focus light on retina
- Near Vision
    - Ciliary muscles contract
    - Suspensory ligaments slacken
    - Less pull on lens
    - Lens becomes thicker and more convex
    - Light rays focus for nearer objects
- Far Vision is opposite of near vision

Pupil Reflex

- Allow enough light in to sense images while preventing overexposure to light which damages photoreceptive cells
- Bright light
    - Circular Muscles contract
    - Radial Muscles relax
    - Iris expands and pupil shrinks
    - Less light entering retina
- Dim light is opposite of bright light

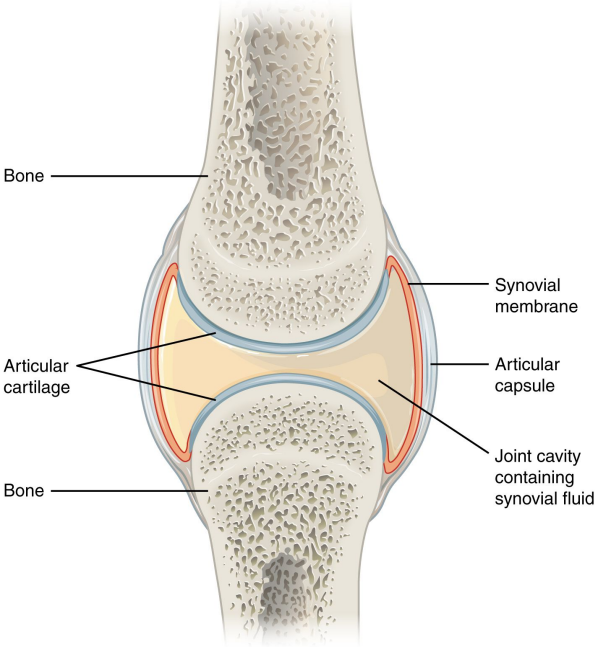
Binocular Vision

- Humans have two eyes
- Images from eyes are slightly displaced
- Differences in images allow perception of depth

Bones, Muscles and Joints

- Skeleton serves many functions
    - Support to provide rigid shape of body
    - Protection of internal organs from injury
    - Movement by providing attachment for skeletal muscles
    - Production of blood cells in bone marrow
- Skeleton acts as lever while muscles act as force
- Most common lever in the body is a 3rd class lever

Joints



- Joints are where 2 bones meet
    - Immovable joints e.g. skull
    - Partially movable joints e.g. spinal column
    - Freely moving joints or Synovial joints
        - Ball and socket joints move 360 degrees in all planes e.g. shoulder
        - Hinge joints move 180 degrees in one plane e.g. elbow
- Synovial joints consist of
    - Joint capsule or ligament which joins 2 bones together, comprised to be able to withstand mechanical stress, made of elastic collagen.
    - Synovial membrane secretes synovial fluid or lubricant
    - Joint cavity containing synovial fluid cushions movement between bones
    - Articular cartilage prevents damage to bone surfaces caused by friction, grows back very slowly

Skeletal Muscle

- Voluntary muscle function
- Muscle is attached to bone in at least 2 places, one is fixed (origin) while one is mobile (insertion)
- Attachment of muscles to bone is through tendons

Human Elbow Joint

- Biceps and Triceps involved
- Antagonistic action between two muscles allow for bi-directional movement
- Flexion occurs when biceps contract and triceps relax
- Extension occurs when triceps contract and biceps relax

Types of Muscles

Property	Skeletal	Cardiac	Smooth
Striations / Stringy or	Present	Present	Absent

Stripy structure			
Control	Voluntary and Involuntary	Involuntary	Involuntary
Location	Attached to bone	Forms bulk of heart wall	Walls of internal structures e.g intestines
Number of Nuclei	Multiple	One	One

Homeostasis and Temperature Control

Functions of Homeostasis

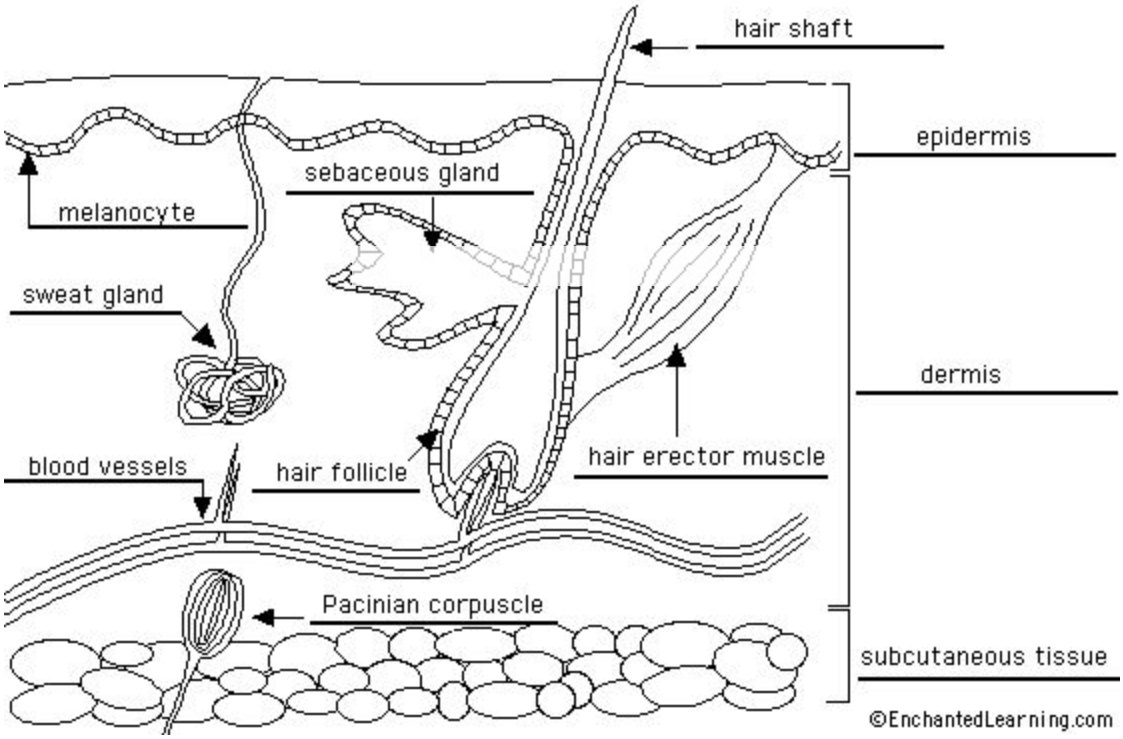
- External environment and internal environment have different conditions
- Aim of homeostasis is to maintain optimal environment despite external conditions
- Involves
    - Receptors which sense unfavourable conditions
    - Messengers which send signals to corrective mechanism
    - Effectors to conduct response
- Involves negative feedback
    - Desirable condition A. Not a therefore response B. B changes not A to A
    - “Negates” unfavourable conditions
- Examples
    - Osmoregulation
    - Thermoregulation
    - Blood sugar regulation

Body Temperature or Thermoregulation

- Receptors
    - Skin nerve signals
    - Thermoreceptors in Hypothalamus
- Messengers
    - Nerve network
- Effectors
    - Hypothermia
        - Blood vessels constrict
        - Shivering or Vibration
        - Increase in Metabolic Rate
        - (Obsolete) Hair stands on end
    - Hyperthermia
        - Blood vessels dilate

- Sweating

Structure of Skin



- Thermoreceptors sense heat
- Meissner's corpuscle senses tactile
- Rioreecptor sense pain
- Pacinian corpuscle senses pressure

Osmoregulation

- Organisms constantly interact with surroundings, intake and outtake
- Complex animals require folded systems with liquid medium to ensure large surface area for efficient exchange
- Osmoconformers
    - Organisms whose internal and external environments have similar osmolarity
    - Most marine invertebrates
- Osmoregulators
    - Organisms which actively regulate water loss and intake
    - Most other animals

Excretion

- Process where metabolic waste (urea) are removed from body
- Egestion
    - Undigested food / Poop
    - Not been absorbed into cells, not metabolic waste

- Excretion
    - Substances which have been absorbed or excreted by metabolic processes
    - Via Skin, Lungs, Liver and Kidneys
    - CO_2 through Lungs
    - Excess water through urine, sweat and exhaled air
    - Urea (by-products of protein breakdown) through urine and sweat
    - Uric Acid (by-products of nuclear material breakdown) through urine and sweat
    - Bile pigments (by-products of haemoglobin breakdown) through liver and intestines
    - Mineral salts through urine and sweat

Urination

- Started by Kidneys, bean shaped structures on dorsal wall of abdominal cavity, left is higher than right
- Functions of Kidneys
    - Elimination of metabolic waste and toxic substances
    - Salvage mineral salts
    - Regulation of blood pH
    - Regulation of plasma volume / blood osmolarity
        - Large amount of water processed, 99% gets returned to body
    - Elimination of hormones
- External process
    - Renal artery brings in polluted blood
    - Kidneys filter blood
    - Clean blood passes through renal vein
    - Urine passes through ureters and eventually to bladder and urethra
- Formation of Urine
    - Blood passes through from renal artery to glomerulus in Bowman's Capsule
    - Ultrafiltration
        - High hydrostatic pressure from renal artery due to large to small capillary volume
        - Partially permeable capillary membrane (basement membrane)
        - Causes plasma to be forced through into convoluted tubule
        - Larger particles (blood cells, proteins) remain in capillary
    - Selective Reabsorption
        - Reabsorption of useful substances singled out during ultrafiltration
            - Proximal tubule reabsorbs NaCl and Nutrients (glucose, amino acids) via active transport, H2O via osmosis
            - Descending loop of Henle reabsorbs H2O via osmosis
            - Thin ascending loop of Henle reabsorbs NaCl via diffusion
            - Thick ascending loop of henle reabsorbs NaCl via active transport

- Distal tubule reabsorbs NaCl via active transport, H2O via osmosis
- Collecting Duct reabsorbs NaCL via active transport, Urea via diffusion and H2O via osmosis

Haemodialysis

- Kidney failure requires cleansing of blood to be conducted outside of body
    - Caused by Hypertension, Diabetes, Excessive alcohol and drug intake, surgery, injury and infection
- Dialysis
    - Blood pumped from vein to dialysis machine
    - Blood exposed to dialysate via partially permeable membrane (cellophane)
    - Urea and Mineral salts exit via dialysis fluid
    - Filtered blood returned to body
- Prerequisites
    - High surface area of dialysis machine
    - Sterile and isotonic (same concentration) dialysate
    - Heater of blood or dialysis chamber
    - Dialysate replaced to reduce waste concentration
    - Countercurrent flow of dialysate vs blood

Hormones

Functions of Hormones

- Alternate messengers in the body, sends chemical signals through bloodstream instead of nervous system
- Come in the form of
    - Protein Hormones, water soluble and stay on surface of a cell
    - Lipid hormones, water insoluble and enter cell to take effect
- Used to send signals to entire body instead of localised areas near neurons
- Alters activity of target organs
- Destroyed by liver or excreted through urine
- Acts as the endocrine system (glands etc)

Common Hormones

- Antidiuretic Hormone (ADH)
    - Monitored in osmoreceptors in Hypothalamus
    - Triggered by low volume or high osmolarity of plasma
    - Released from posterior pituitary gland
    - Increases permeability of distal convoluted tubule and collecting duct in kidney
    - Reabsorbs more water via osmosis in said areas
    - More water retained in body

- Adrenaline
    - Triggered by fight or flight reflex, fear and excitement
    - Stimulated by motor nerve cells
    - Secreted by the adrenal medulla above the kidneys
    - Affects entire body
        - Increases heart rate
        - Increases breathing rate
        - Vasoconstriction (e.g. digestive system) and vasodilation (e.g. muscles)
        - Glycogenolysis in liver
        - Stimulates lysolipids
    - Increased body function
- Insulin
    - Antagonistic to Glucagon
    - Monitored by Islets of Langerhans in Pancreas (beta cells)
    - Triggered when blood glucose levels are high
    - Affects cells and muscles, especially liver
        - Increase intake of glucose into cells
        - Increase production of glycogen in liver and muscles
        - Increases metabolic rate
    - Decreases blood sugar level
- Glucagon
    - Antagonistic to Insulin
    - Monitored by Islets of Langerhans in Pancreas (alpha cells)
    - Triggered when blood glucose levels are low
    - Affects cells and muscles, especially liver
        - Stimulates breakdown of glycogen stores
        - Breakdown of fats and proteins into glucose
    - Increases blood sugar level

- Thyroxine and Triiodothyronine (Not Tested)
    - regulates metabolic behavior, ensuring normal growth and mental development
    - secreted by thyroid gland
    - under secretion results in goitre, and weight gain
    - over secretion results in overly high bodily temperatures and metabolism, sweating and irritability

Diabetes Mellitus

- Present when blood sugar levels are abnormally high / hyperglycemia
- Caused by
    - Pancreas not producing sufficient Insulin
    - Body cells insensitive towards Insulin
- Effects include

- Polyuria, due to high osmolarity of blood
- Polydipsia, due to polyuria
- Glycosuria, sugar present in urine
- Weakness, due to lack of glucose intake
- Damage to blood vessels and organs

Mitosis and Meiosis

Functions of Cellular Division

- Cell replacement for damaged or dying cells e.g. skin regeneration
- Growth via cell division e.g. replication after fertilisation
- Asexual reproduction e.g. reproduction in bacteria
- Sexual reproduction e.g. meiosis, formation of gametes

The Cell Cycle

- The cycle of cell growth between mitosis
- Consists of Interphase and Mitosis
    - Interphase
        - 90% of time consisting of metabolism and growth
        - G(ap)1 segment where cell lacks sister chromatids
        - S(ynthesis) phase where chromosomes are duplicated, sister chromatids formed
        - G(ap)2 segment where cells continue metabolism and growth
        - Cells build up stores of energy, synthesises proteins and organelles
        - DNA is threadlike and cannot be seen clearly
    - Mitosis
        - 10% of time used to divide a cell
        - Mitosis where division of nucleus occurs
        - Cytokinesis where division of cytoplasm occurs
        - Used to create more cells

Mitosis

- Overarching process of cellular division of nucleus, via PMAT
- Daughter cells receive same number and types of chromosomes as parent cell
- Diploid or haploid status is maintained from one generation to next

Prophase Nucleus membrane disintegrates Chromatin condenses to form distinct chromosomes Chromosomes are made of 2 sister chromatids which are clones formed during S phase	Chromatids not fully condensed Microtubules are in a mess

Nucleolus disappears Centrioles move to opposite ends of cell Microtubules develop from centrioles to form spindle Microtubules attach to centromeres of chromosomes and move them to center of cell	
Metaphase Mitotic spindle is fully formed Chromosomes line up at equator of spindle	Microtubules completely joined at middle
Anaphase Sister chromatids are pulled apart by spindle at the centromere Sister chromatids move to opposite poles of spindle	Spindle pulling part
Telophase Chromatids reach respective ends of the spindle Nucleolus reappears Nuclear membrane reforms, two independent nuclei present Chromosomes uncoil to form chromatin threads Spindle fibres disintegrate	Chromatids not fully condensed Multiple cells
Cytokinesis Cytoplasm splits	Multiple cells

Cancer

- Cancer is the uncontrolled division of cells
- Genes responsible for cell growth which specify proteins for begin and end signals at points of cell cycle are mutated
- Mutations are stimulated by
    - Age
    - Chemicals
    - Radiation
    - Viruses e.g. papilloma
    - Genetics
- Cell division goes out of control and cells divide excessively
- A mass of cancerous cells is called a tumor
- A tumor which spreads is malignant, which spreads via metastasis, whereas localised tumors are benign
- Cancer can be prevented by
    - Not smoking
    - Regular exercise

    - Avoiding overexposure to sunlight
    - High-fibre, low-fat diet
    - Regular health screenings and medical examinations

Homologous, Haploid and Diploid

- Homo - same, Logous - location
- Chromosomes which determine the same characteristics, need not be identical
- In human - 22 pairs of autosomes and 1 pair of sex chromosomes give 23 homologous chromosomes
- Haploid (n) cells have one member of each pair of homologous chromosomes, usually results of meiosis to be used in sex cells
- Diploid (2n) cells have pairs of homologous chromosomes, one from each parent
- During fertilisation, two haploid gametes fuse to form a diploid zygote

Meiosis

- Occurs in place of Mitosis after G1, S and G2 interphase
- Only occurs in gonads
- 2 successive nuclear divisions of meiosis 1 and meiosis 2
- Meiosis 1 involves pairs of homologous chromosomes being separated, forming haploids
    - Additional processes in Prophase 1
        - Special proteins cause homologous chromosomes to pair up via synapsis
        - Forms a bivalent (2 chromosomes) or tetrad (4 chromatids)
        - Chiasmata formed between non-sister chromatids, crossing over takes place
    - Additional process in Telophase 2
        - 4 Male gametes formed
        - 1 Ovum and 3 polar bodies formed
- Meiosis 2 involves pairs of sister chromatids being separated
- Reduces chromosomes from diploid to haploid, returns to diploid after fertilisation

Genetic Variation

- Meiosis results in genetic variation
- Allows natural selection to occur and individuals best adapted to the environment to survive and have more offspring
- Allows species to change constantly and adapt when the environment changes
- Crossing Over
    - During meiosis 1, formation of chiasma lead to segments of non-sister chromatids being swapped
    - A new combination of alleles on a sister chromatid is formed
- Assortment of chromosomes and sister chromatids i
    - Independent arrangement of homologous chromosomes during Metaphase and Anaphase 1 result in 2^23 different cells possibly formed by meiosis 1

    - Independent arrangement of sister chromatids during Metaphase and Anaphase 2 result in 2^23 different cells possibly formed by meiosis 2
- Assortment of gametes in fertilization
    - Formation of diploid zygote is dependent on random selection between female and male gamete

Heredity and Molecular Genetics

Glossary

- Gene: Unit of inheritance, made of a heritable sequence of nucleotides along DNA which codes for a polypeptide (ATTCG or GTACC)
- Locus: The position of a chromosome where a gene resides
- Allele: An alternative form of a gene, where alleles for a gene occupy the same locus on a pair of homologous chromosomes (A or a)
- Phenotype: The expressed and observable characteristic of an individual which is a result of the interactions between genotype and environment which development occurs (Blue eyes or brown eyes)
- Genotype: The genetic constitution of an organism with respect to the alleles under consideration (Aa or AA)
- Dominant Allele: The allele that shows its phenotype in a homozygote or heterozygote (A, B, F, J etc)
- Recessive Allele: The allele that shows its phenotype only in the presence of another identical recessive allele (a, b f, j etc)
- Co-Dominant: Two alleles are codominant when both alleles are equally expressed in a heterozygous situation
- Incomplete Dominance: Two alleles display incomplete dominance when an intermediate quality (between its two homozygous forms) is displayed in a heterozygous situation
- Homozygous: The diploid condition in which the alleles at a certain locus are identical (AA or aa)
- Heterozygous: The diploid condition in which the alleles at a certain locus are different (Aa)

The Unit of Inheritance

- A gene is the most basic unit of inheritance
- One gene is made of a sequence of DNA bonds, by the bases ATCG
- A gene codes for a certain chain of amino acids, which result in the formation of specific proteins
- An allele is the form of a gene which affects an expressed quality

Phenotype and Genotype

- The genotype of an organism is its genetic makeup or the specific sequence of DNA
- The phenotype is the organisms expressed traits and/or characteristics

- Genotype -> Amino Acids -> Proteins -> Expressed Quality -> Phenotype
- Genes are given to gametes, where gametes express same genotype as parents

Gene Diagrams

- Monohybrid Cross
  - Cross between purebred plants that differ in only one character
  - Crossing of this nature is called hybridization
  - Pure-breeding parents are the P generation
  - Hybrid offspring are first filial F_1 generation
  - Offspring of F_1 produces second filial F_2 generation
  - Mendel's first law: Law of Segregation: A single factor from each parent is present in the gamete, where gametes only have one copy of every allele

<u>Genetic Diagram for the Monohybrid Cross (Punnett Square)</u>

Let: T represent the allele for tall plants (dominant)
t represents the allele for dwarf plants (recessive)

Parental phenotype	Tall Plants	X	Dwarf Plants
Parental genotype (2n)	TT	X	tt
Meiosis			
Gametes (n)	(T) (T)	X	(t) (t)
Fertilisation	Fertilisation		

Gametes

Gametes	(T)	(T)
(t)	Tt Tall Plant	Tt Tall Plant
(t)	Tt Tall Plant	Tt Tall Plant

F_1 selfing

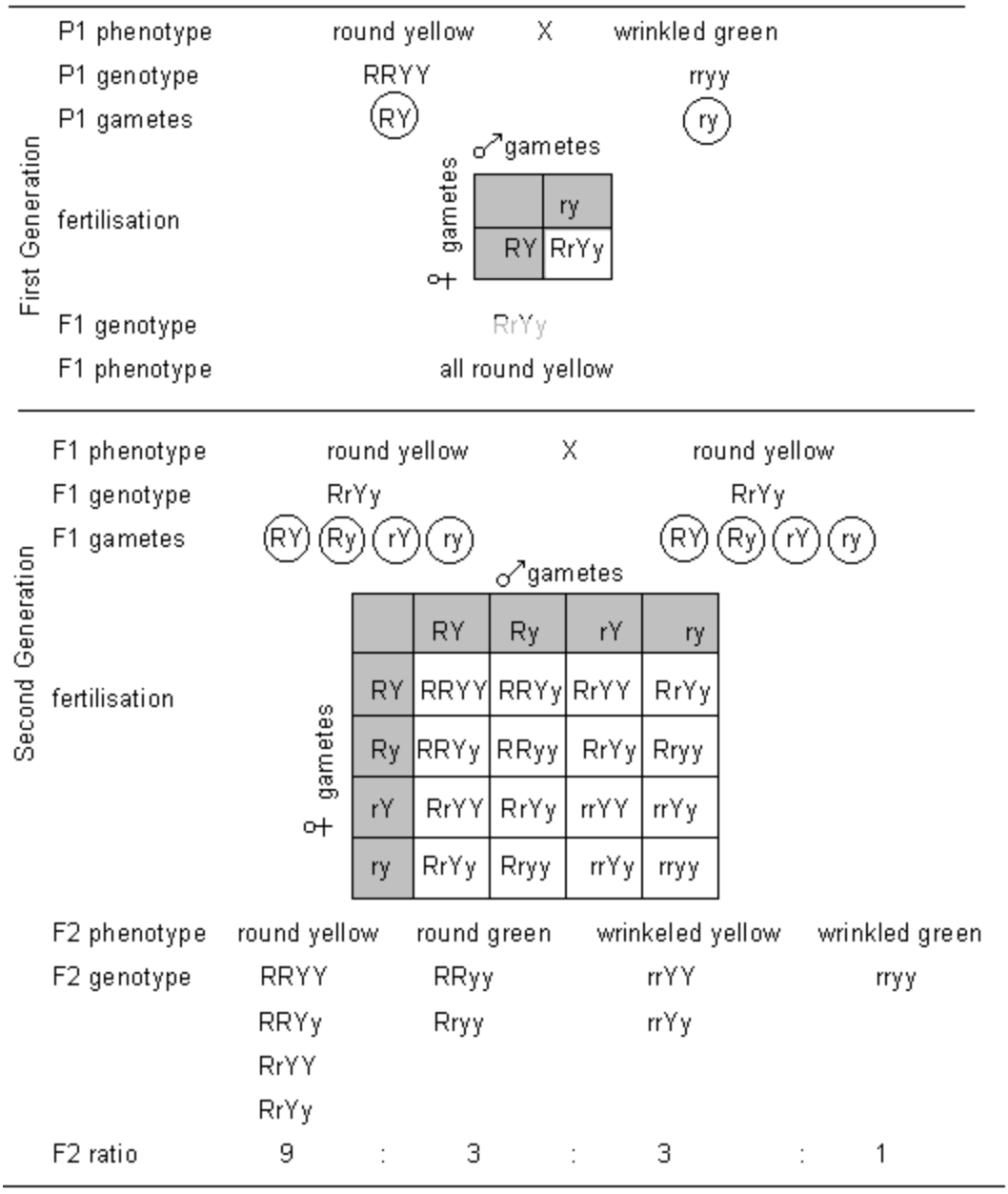
F_1 genotype	Tall Plants	X	Dwarf Plants
F_1 genotype (2n)	Tt	X	Tt
Meiosis			
Gametes (n)	(T) (t)	X	(T) (t)
Fertilisation	Fertilisation		

Gametes

Gametes	(T)	(t)
(T)	TT Tall Plant	Tt Tall Plant
(t)	Tt Tall Plant	tt Dwarf Plant

F_2 genotypes	TT Tt Tt		tt
F_2 phenotypic ratio	3	:	1

- Test Cross
  - Cross with an organism of homozygous recessive trait
- Dihybrid Cross
  - Mendel's second law: Law of Independent Assortment: Genes for different traits assort independently of one another in the formation of gametes in equal proportions
  - Any one of a pair of characteristics may combine with either one of another pair



- Autosomal linkage
    - Some genes are located close to each other on a chromosome and tend to be inherited as a set, meaning that a monohybrid punnett square is used

Observed and expected ratios

- Expected ratio of a dihybrid cross is 9:3:3:1
- Observed ratio does not agree with expected ratio
- Observed tends to expected when
    - Fertilisation is random
    - Offspring have equal chances of survival (bad gene combinations may not survive, observations skewed due to survivors' bias

- Large numbers of offspring are produced and observed

Multiple Alleles and Codominance

- Some genes have alleles of more than 2 states, called multiple alleles
- ABO blood in humans is an example of multiple alleles
- Written as I^A, I^B and I^O
- I^A and I^B are codominant, which equally express themselves in the phenotype in a heterozygous situation
- I^A and I^B are dominant to I^O

Genotype	Phenotype	Donor	Antibodies in plasma
I^OI^O	O	O	A, B
I^AI^O	A	A	B
I^BI^O	B	B	A
I^AI^A	A	A	B
I^BI^B	B	B	A
I^AI^B	AB	All types	None

Sex Determination and Linkage

- Humans have 22 pairs of autosomes and 1 pair of sex chromosomes
- XX produce female, XY produce male
- Y is significantly shorter than X, meaning that males have less genetic data than females
- Sex linkage refers to the carrying of genes on the sex chromosomes, where genes will follow the X or Y chromosome to the offspring
- Sex-linked characteristics are non-sexual characteristics controlled by genes found on the sex chromosomes, such as haemophilia and ocular albinism
- Some alleles are expressed in the X chromosome but are absent in the Y chromosome, meaning that recessive alleles on the X chromosome will be expressed

Considering Haemophilia: X^H for healthy and X^h for haemophiliac

Genotype	Phenotype
X^HX^H	Normal Female
X^HX^h	Carrier Female
X^hX^h	Haemophiliac Female

X^HY	Healthy Male
X^hY	Haemophiliac Male

Crossing Over

- During Prophase 1, chiasma formed and chromatids swap places at the same loci
- New phenotypes are called recombinants
- The further away two genes are, the greater the chance of crossing over

Family Pedigree

- Inheritance of a trait in a family can be studied by constructing a family tree called a pedigree
- Squares represent males, circles represent females
- White shapes represent healthy individuals, colored shapes indicate an affected individual
- Oldest generation at the top, youngest at the bottom
- Individuals are identified according to [Generation Number] - [Child Number}
- Generation number counted in roman numerals from top being I, child number counted in arabic numerals starting from left being 1
- Can be used to identify the nature of a trait
    - Autosomal Dominant
        - If a child has the trait, at least one of the parents has the trait
        - If two individuals have trait, their offspring may not necessarily have the trait
    - Autosomal Recessive
        - If both parents are affected, all children are affected
        - If a child is affected, both parents have the trait
        - Recessive traits can skip generations
    - X-linked Recessive
        - If the mother carries a recessive trait, the male children may or may not have the trait
        - If the mother is affected, all male children will be affected
        - If the father is affected, the female children will be carriers or affected
        - If both parents are affected, all children will be affected

Mutation

- Mutation is a change of the structure of a gene independent of genetic variation through normal meiosis
- Cases include

    - Instantaneous change of a base and hence the structure of a gene in a chromosome e.g. Sickle cell anemia
    - Chromosome aberration e.g. Aneuploidy / Down's syndrome
    - Single chromosome mutations:
        - Deletion - removal of a string of DNA
        - Duplication - replication and insertion of a string of DNA
        - Inversion - inverted insertion of a string of DNA
    - Dual chromosome mutations:
        - Insertion - DNA from one chromosome is inserted into another
        - Translocation - DNA between two chromosomes are swapped
    - Radiation and chemicals increase the rate of mutation

<u>Sickle Cell Anemia</u>

- Is a point Mutation
- Healthy adults have healthy haemoglobin (Hb A)comprised of two alpha-globin and two beta-globin chains, coded by two different genes on two different chromosomes
- Affected adults have one base changed in the beta-globin chain (CTT->CAT), replacing a glutamate (polar) amino acid with a valine (non-polar, hydrophobic) amino acid
- Affected adults produce affected haemoglobin (Hb S) which forms a hydrophobic patch in low O_2 conditions which causes affected hemoglobin to bind to each other, polymerising into rod-like fibres and crystals which distorts the cell and creates a sickle-shaped erythrocyte
- Hb S result in
    - Poor oxygen transport
        - Anemia, breathlessness and physical weakness
        - Heart failure
    - Clogging of capillaries
        - Depriving organs of O_2 e.g. Stroke
        - Severe pain due to localised blockages resulting in cell death
        - Damage to organs with numerous capillaries e.g. Lungs, Spleen
- Sickle-cell anamia is a homozygous recessive disorder, where sufferers need one copy of the recessive gene from each parent
- Individuals with one recessive allele are said to have the Sickle-cell trait
- Mutations usually result in recessive conditions since they usually cause in a loss of function through miscoding of a protein, where mutant proteins have no function and the proteins made by the other healthy allele are able to mask the defective gene

<u>Variations in chromosomal number</u>

- Aneuploidy is the condition where the nucleus has an abnormal number of chromosomes
- Caused by nondisjunction

    - The failure of chromosome pairs or sister chromatids to seperate properly during cell division
    - Homologous chromosomes do not move apart properly during Prophase 1
    - Sister chromatids fail to separate properly during Mitotic Prophase or Prophase 2
    - Results in an aneuploid cell with an imbalance of chromosomes
    - Extra chromosome (2n+1) is Trisomy
    - Missing chromosome (2n-1) is Monosomy
- Nondisjunction in mitosis is called post zygotic nondisjunction and can result in mosaicism
- Mosaicism where multiple cell lines are developed in an individual due to mutations (new mutation or chromosomal abnormality) e.g. Some cells have 46 chromosomes while some have 47
- Common diseases include
    - Trisomy 21 or Down's Syndrome, usually due to non-disjunction during Meiosis 1, where individuals have abnormal facial features, short stature, heart defects, vulnerability to respiratory infection and mental retardation. May result in lack of sexual development and sterility.
    - XXY or Klinefelter Syndrome where individuals have male gonads but testes are abnormally small and sterile. Extra X chromosome is inactivated but female body characteristics are common. Individuals' intelligence is unaffected
    - Monosomy X or Turner Syndrome is the only viable monosomy in humans, where individuals are phenotypically female but are sterile and gonads do not mature. Estrogen therapy can allow individuals to display secondary sex characteristics

Continuous, Discontinuous Variation and Environment

- Some traits display discontinuous variation- they are displayed in clear-cut, binary traits
- Other characteristics are not as distinct e.g. Skin colour, height
- Traits of continuous variation or of polygenic inheritance are expressed along a gradient, which is the result of the additive effects of two or more genes (polygenic inheritance) / a displayed characteristic is controlled by numerous genes
- Polygenic inheritance can be identified by a wide range of phenotypes in the filial generation of two pure-bred parents
- Environment (nutrition, exercise) also affects phenotypes, but these modifications are not inherited to the next generation
- Distinct different groups in a parental generation suggest that variation in phenotype is genetic
- Variation in a phenotype in pure-bred parental groups suggest that variation in phenotype is due to environment even though genotype is the same

Structure of DNA and RNA

- A chain of nucleotides form DNA strands

- A gene is the specific sequence of nucleotides in a coding strand of DNA which codes for a specific sequence of amino acids in a polypeptide chain which has a fixed locus on the chromosome which specifies a biological function
- Strands of DNA are coiled to form chromosomes contained within the nucleus
- Basic unit of RNA molecule is the ribonucleotide
- RNA are single stranded molecules (except for some RNA viruses)
- mRNA is derived from the transcription (across-writing) of DNA
- rRNA is the ribosome
- tRNA is the molecule which recognises a triplet of base pairs on the mRNA and delivers the specific amino acid to the protein chain on the protein strand on the rRNA
- DNA -> Sequence of Amino Acids -> 3D Conformation of a Protein -> Function -> Phenotype
- Complementary base pairing ensures that one base can only bind to another base
    - A binds to T/U
    - C binds to G

Genetic Engineering

Why Genetic Engineering?

- Direct manipulation of genes for practical purposes
    - Medicine e.g. Insulin production
    - Agriculture e.g. Genetically modified plants and crops
    - Industry e.g. Biodiesel-producing bacteria
    - Research on gene function
- Involves transferring genetic material from one cell to another
    - Between species
    - Across species i.e. transgenic organisms
- Organisms whose genomes have been modified by genetic engineering are referred to as genetically modified organisms (GMO)

DNA Cloning

- Starting point for genetic engineering
- Experimental methods used to create copies of a single DNA fragment
- Allows for manipulation of a certain gene within a genome
- Produce large amounts of target DNA via gene cloning

Bacterial Plasmids and DNA Cloning

- Pieces of DNA material exchanged between DNA
- Extrachromosomal DNA which are small, double-stranded and circular
- Multiple copies may exist in a single bacteria
- Often carry genes which code for proteins advantageous to bacteria
- Can be used as a vector to clone DNA

    - Presence of genetic marker to identify bacteria which have taken up plasmid
    - Presence of multiple cloning site to easily introduce recombinant DNA
    - Presence of origin of replication to allow for replication of plasmid and hence replication of DNA strand
- Able to accept foreign DNA to become a recombinant plasmid/DNA
- Able to self-replicate independently of chromosomal DNA
- Recombinant plasmid is accepted into bacteria and self-replicates to form multiple copies
- Recombinant plasmid is replicated during mitosis of bacteria and passed onto children cells
- Rapid reproduction of recombinant DNA results in cloned copies of target DNA

Restriction Enzymes

- Enzymes which allow for the insertion of target DNA into a bacterial plasmid
- Restriction enzymes are naturally found in bacteria to digest foreign DNA
    - Digest viruses to prevent and inhibit activity
- Each enzyme recognises a palindromic DNA sequence (restriction site) which reads the same in the opposite direction in the complementary strand
- Enzyme cuts both strands of DNA at precise points of restriction site
- Cleave (cut) the sugar phosphate backbone of the DNA molecule, resulting in split DNA with various types of ends
    - Blunt ends are double-stranded ends, less efficient at ligation
    - Sticky ends are single-stranded overhangs
- DNA molecules cut with the same restriction enzyme will produce similar ends which are able to bond to each other
- DNA molecules with sticky ends bond due to complementary base-pairing by hydrogen bonding

Function of Restriction Enzymes, Multiple Cloning Sites and DNA Ligase

- Restriction enzymes are used to
    - Cut or Digest bacterial plasmid to allow target DNA to be inserted
    - Isolate target DNA from the original, longer genome to be introduced to the vector
- Restriction enzymes are chosen by
    - Ensuring that both the plasmid and target DNA are able to be cut with the same enzyme to produce complementary sticky ends (unless blunt ends are used)
    - Target DNA must not have the restriction site within its sequence
- Sometimes multiple restriction enzymes are used to ensure that a gene of interest is inserted into the plasmid in the correct orientation
- Multiple Cloning Sites (MCS) are short segments of DNA which contain restriction sites for numerous restriction enzymes to be implanted into the bacterial plasmid, giving scientists a larger choice of restriction enzymes to be used to cut the plasmid

- MCS also contain promoter sequence before MCS to encourage transcription of the DNA inserted into the MCS
- DNA Ligase used to repair sugar phosphate backbone of DNA fragments already bonded by complementary base pairing
- Digestion at 37°C, Ligation at 16°C, in order to ensure optimal operation of enzymes without denaturing of restriction and ligation enzymes

Production of Recombinant DNA

- DNA selected from genome, cut with restriction enzyme at 37°C
- Plasmid selected, cut with restriction enzyme at 37°C
- Solutions purified
- Cut Plasmid + target DNA + DNA ligase mixed
- Ligation at 16°C
- Recombinant DNA formed

Bacterial Transformation

- Process where DNA is introduced into cell via
    - Heat Shock
    - Electroporation
    - Sonication
- Bacteria is made more accepting of foreign DNA plasmids, takes in recombinant DNA

<u>Heat Shock transformation</u>

- Expose bacteria and plasmid to a Ca^{2+} rich and cold environment for 30 minutes
    - Ca^{2+} neutralises negative charges on bacterial cell wall and sugar-phosphate backbone on plasmid DNA
    - Reduce repulsion between bacteria and plasmid and weaken bacteria cell wall
    - Bacteria is more competent to take up foreign DNA
    - Low temperature reduces kinetic motion of bacteria and plasmid to allow them to stick/adhere easier
- Heat shock mixture of bacteria and plasmid at 42°C environment for half to 2 and a half minutes
    - Higher temperature increases fluidity of bacteria and plasmid and induces formation of pores
    - Plasmid DNA enters easily
- Incubate on ice for 1 to 2 min
- Add nutrient medium and incubate at 37°C for an hour
    - Allows bacteria that survived heat shock to recover
- Culture bacteria on agar plate containing antibiotic to select transformed bacteria

Selection of Transformed Bacteria

- Transformation is not completely effective, bacteria might not have took up plasmid
    - Plasmid is cut to have sticky ends where some plasmids may have recombined with each other by complementary base pairing
- Plasmids have a selectable marker used to differentiate between bacteria which are transformed and those which are not transformed
- Antibiotic resistance gene is commonly used, culture is done on a plate with an antibiotic such that only transformed bacteria which express resistance to the antibiotic is able to survive

DNA Cloning Procedure

- DNA extraction and plasmid isolation
    - Extract genomic DNA from cell
    - Isolate plasmid from bacteria
- Digestion
    - Cut plasmid and target DNA with restriction enzymes
- Ligation
    - Join target DNA with plasmid to form recombinant DNA
- Bacterial Transformation
    - Introduce recombinant DNA into host bacteria
- Culture bacteria and isolate transformed bacteria

Bacteria Culturing

- A bacteria colony is the visible cluster of bacteria growing on a culture surface, which has supposedly originated from a single cell and are thus genetically identical
- Streak method involves repeatedly streaking bacteria culture onto an agar plate
- With each streak, only a small number of bacteria from the previous phase is picked up for streaking, resulting in continuous dilution of the inoculum
- Individual cells become spaced further from each other and create colonies when cultured
- Utilise aseptic technique to avoid contamination of bacteria samples and cultures
    - Disinfecting table surface with 70% ethanol before and after work
        - Prevent introduction of bacteria from table surface
    - Wear gloves and long sleeves, disinfect gloves with 70% ethanol
        - Prevent introduction of bacteria from hands and arms
    - Keep working area sterile and work close to with lit bunsen flame
        - Create convection current of air to prevent bacteria-containing particulate on the air from settling on working area and tools
    - Use sterile supplies and tools
        - Prevent introduction of bacteria from tool surfaces
    - Flame mouth of test tubes after removing and before replacing covers

        - Create high pressure zone when removing covers to prevent contaminated airborne contaminants from entering
        - Create negative pressure in test tube before replacing covers?

Applications of Genetic Engineering

- Genetically Modified Organisms
    - Desired gene introduced into Ti plasmid and inserted into bacteria
    - Bacterium is used to insert T-DNA into chromosome of the plant cell, giving plant cells a desired quality
    - Plant cells (explants) are cultured and grown into plantlets which express the foreign trait
    - Genetically Modified Plants
        - Pest resistance
        - Herbicide resistance
        - Improved Quality and Yield
        - Production of vaccines using bananas
        - Production of chemicals e.g. silk and fuel
- Production of Recombinant Proteins
    - Human genes for protein production are introduced into plasmids and then bacteria
    - Bacteria are cultured in a fermentation tank with overproduction of human protein
    - Proteins are then purified and used
    - Human Insulin production using insertion of human genes into bacteria to produce insulin for diabetes treatment
    - Growth Hormone production using insertion of human genes into bacteria to produce hormone for treatment
    - Hepatitis B vaccine using insertion of virus coat protein gene to produce virus coat to trigger immune response and gain immunity
- Gene Therapy
    - Introduce gene of interest into a vector e.g. virus
    - Infect human with the recombinant vector, change the genetic makeup of cells within the body via healing viral infection
    - Used in treatment of genetic disorders e.g. Cystic Fibrosis
- Biomedical Research

Risks and Ethics of Genetic Engineering

- Externalities due to harmful nature of GM crops towards external ecosystem
    - Bt Corn killing monarch butterflies
- Superweeds and superbugs arise due to proliferation of antibiotic resistance genes
- Reduce effectiveness of pesticides
- GM crops may pollinate non-GM crops of other farmers

- Lack of genetic variance implies fragile nature of GM crops, where a single disease can wipe out massive harvests
- Allergy to transgenic food
- Small-scale farmers go out of jobs due to inability to compete with production of GM crops, increase in inequality
- Bioterrorism and biological warfare imminent
- Inhumane treatment of animals in GM testing
- Livestock grow too fast to survive in humane conditions
- Interruption of natural order of environment

Immunology

Disease and the immune system

- Disease and unfavourable environmental conditions threaten health
    - Immune system sets out to prevent disease with the use of cells
    - Environmental conditions are managed with use of homeostasis and other biological processes
- Combats inorganic toxins, genetic organisms and microorganisms (pathogens)
- Pathogens include
    - Extracellular bacteria, parasites and fungi
    - Intracellular bacteria, parasites and fungi
    - Intracellular viruses
    - Extracellular parasitic worms
- All pathogens have antigens on the surface of their cells which are recognised by the human immune system
- Human immune system comprises 2 branches with 3 lines of defence
    - Innate immunity
        - Nonspecific immunity which responds to anything classified as a pathogen
        - First line involves physical barriers and secretions
        - Second line involves nonspecific biological response and inflammatory response
    - Acquired/adaptive immunity
        - Specific immunity which responds to a previously recognised pathogen
        - Humoral response to pathogens in body humor (out of/between cells)
        - Cell-mediated response to pathogens inside of body cells

Barrier Defences

- Prevent pathogens from entering internal body by mechanical blockage or using chemicals to kill pathogens
- Comprises physical barriers and secretions of Skin, Mucous membranes and Secretions

- Skin mechanically prevents entrance of cells
- Mucous membranes trap bacteria
- Secretions kill bacteria with use of toxic substances and enzymes (lysozymes, pepsin)

Response	Mechanical	Chemical
Skin	Epithelial cells (skin cells) joined by tight junctions	Fatty acids, lysozymes in sweat
Eyes	Eyelids	Tears contain lysozymes
Respiratory Tract	Cilicia	Nasal secretions
Gastrointestinal Tract	Mucus lining	Lysozymes in saliva Pepsin and defensins in stomach Stomach acid

Phagocytosis

- Internal nonspecific defence largely managed by Phagocytes which eliminate pathogens
- Undergo Phagocytosis
    - Phagocytes' Pattern Recognition Receptors (PRR) recognise patterns on pathogens
    - Phagocytes attracted to pathogens
    - Engulfs pathogens
    - Vacuole formed with pathogen bond with lysosome
    - Lysosomal enzymes and other toxic compounds destroy microbes
    - Microbial debris is ejected by exocytosis
- Conducted mainly by 4 cells
    - Neutrophils
        - Contributes to 70% of phagocytes
        - "Foot soldiers" which attack bacteria and fungi
        - Characteristic fine granule with multi-lobed nucleus
        - Highly mobile due to small size
        - Self destruct after phagocytosis
    - Eosinophils
        - Attacks larger parasites and viruses, especially multicellular pathogens
        - Characteristic granular shape with bi-lobed nucleus
        - Releases histamine
    - Macrophages
        - Originate from monocytes
            - Small granule with kidney-shaped nucleus

        - “Big Eaters” which attack general pathogens and cell debris
        - Consumes multiple (100s) pathogens per cell
        - Characteristic large granule size with single nucleus
        - Can activate lymphocytes
    - Dendritic Cells
        - Originate from monocytes
        - Consumes general pathogens and cell debris
        - Characteristic branched shape
        - Present antigens to T lymphocytes

Antibacterial Proteins

- Proteins outside of cells which help in the protection against pathogens
- Interferons
    - Proteins secreted by virus-infected cells which inhibit viral replication and hence limit spread
    - White blood cells excrete proteins which activate macrophages and enhance phagocytic ability
- Complement system
    - Proteins loosely flowing in blood which react to membranes of microbes
    - Cascade to cause lysis of microbe

Inflammatory Response

- Triggered by histamine producing cells
    - Mast Cells reside in tissue
    - Basophils reside in blood, typically for parasitic infections
        - Characteristic bi/tri-lobed nucleus
    - Eosinophils reside in blood
        - Both phagocytosis and histamine release
- Macrophages also release prostaglandins
- Histamine producing cells detect presence of pathogens
- Release histamine which triggers inflammatory response
    - Histamine -> triggers vasodilation -> increases blood flow -> increase accumulation of phagocytes, antimicrobial proteins and clotting factors to infection site
    - Histamine -> increases capillary permeability -> allows immune cells to enter from blood to infection site
- Triggers redness (erythema), swelling (edema) and heat (fever)

NK Cells

- Natural Killer cells
- Check all human cells (except RBC) for presence of MHC-1/Class 1 MHC (major histocompatibility) protein on surface of cytoplasm

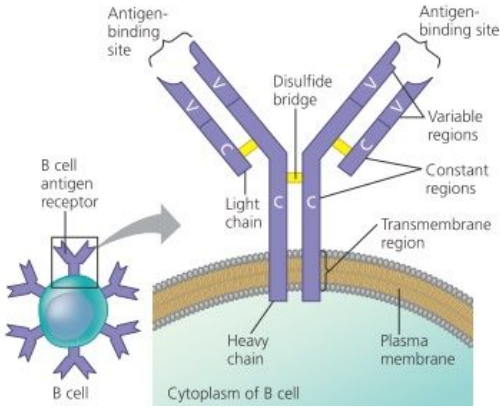
    - Abnormal cells do not present the MHC-1 protein
        - Tumors
        - Pathogen/Virus-infected cells
        - Transplanted cells
- Bind to receptors of abnormal cells
- Release chemicals (granzymes/perforin)
- Cells undergo apoptosis/necrosis

Adaptive Immunity

- Internal immunity which develops in response to previous infection
- Recognises traits of specific pathogens using an exhaustive array of receptors
- Generally slower response
- Involve the operation of lymphocytes
    - White blood cells unique to adaptive immunity
    - All originate from bone marrow but travel to different areas of body to mature
    - Maturation in thymus produces T-cells
    - Maturation in bone marrow produces B-cells
    - Some go on to become NK cells
    - B and T lymphocytes all are specific to one certain kind of antigen,have receptors for one kind of antigen, around 100k receptors per cell
- Utilises various properties for effective immunity
    - Specificity forces one lymphocyte to react to only one type of antigen
    - Diversity of receptors ensures that any and every antigen has a complement lymphocyte that can respond to it, due to the differentiation of antibody genes to determine different composition of variable ends on receptors
    - Clonal Selection of activated lymphocytes allows lymphocytes which detect antigens to replicate rapidly from a small epitope of lymphocytes merely detecting antigens to one that can elicit an effective immune response
    - Memory allows lymphocytes to respond to previously encountered antigens on subsequent exposures to last a lifetime, also prevents resource wastage on replicating lymphocytes with unneeded antigen specificity
    - Self-unreactivity prevents lymphocytes from identifying body cells as pathogens and subsequent implications of autoimmunity

Antigen Recognition

- Lymphocytes need a mechanism to identify antigens and do so by producing antigen receptors
- B cell receptors
    - Y shaped molecules with 2 identical light and heavy protein chains linked by disulfide bridge at the angled sections



    - Heavy chains anchor molecule to cell membrane, small portion extends into cytoplasm
    - All 4 chains consist of a C constant protein chain and V variable protein chain
    - Composition of V chain is determined by random selection when lymphocyte was made
    - Pair of light chain and heavy chain creates the antigen binding site
    - Lock and key complex is made between the free-flowing antigen and binding site, antigens can then be recognised
        - Note: antigens can have multiple reactive sites and react to multiple different antigen receptors
- B cell receptors are also expelled from the B cell to create antibodies or Immunoglobulins (Ig), able to freely flow in body humors to bind to antigens
- T cell receptors
    - Consist of only one pair chains, specific title is α-chain and β-chain
    - Both chains protrude into cytoplasm
    - Disulfide bridge is near to the cell membrane
    - Reacts to antigen (fragments) presented within a MHC-2/Class 2 MHC molecule on a host cell

Activation of Lymphocytes

- Requirements must be met before lymphocytes can respond to an infection
- Second barrier defences, especially antigen-presenting cells such as macrophages and dendritic cells need to attack the pathogen and express an antigen on the MHC-2 molecule
- Helper T-Cells then recognise the antigen and receive cytokines from antigen-presenting cell and itself to activate it
- Helper T-Cell then proliferates and moves around the body activating other B and T cells specific to the antigen by releasing cytokines to activate them
- B and T cell population is now activated and ready to react to infection

Cell-mediated Response

- T-Cells are responsible for the destruction of infected cells
- Cytotoxic T-Cells activated by cytokines from antigen-presenting cells recognise antibodies presented in MHC-1 of infected cells
- Release granzymes and perforin, former enters by endocytosis
- Cause apoptosis in infected cell, deprives pathogens of opportunity to multiply and exposes antigens to antibodies in body humors
- Memory T-Cells linger after infection at higher numbers to allow for faster response on subsequent infection

Humoral Response

- B-Cells are responsible for the management of body humor-suspended antigens

- B cells take in portions of antigen molecules and expresses it on the MHC-2 molecule
- Previously activated helper T-Cell binds to antigen on MHC-2 and releases cytokines to activate B-Cell
- B-Cell differentiates into memory B-cells and Plasma cells
- Plasma cells produce antibodies rapidly over 5 day lifespan
- Memory B-cells linger after infection at higher numbers to allow for faster response on subsequent infection
- Antibodies in body humor are used in immune response
    - Neutralisation/opsonization by having antibodies bind exhaustively to antigens, preventing antigens from bonding to other cells
    - Agglutination where antibodies polymerise and bond multiple antigens into a single molecule, where the large size of the molecule prevents infection
    - Precipitation of soluble antigens to prevent reactions
    - Promotes phagocytosis of antigens bonded to antibodies
    - Activates complement protein system where an antibody bonding to the surface of a antigen cell causes a reaction cascade resulting in the formation of pores in cells and ultimately cell lysis

Immunological Memory

- Memory B and T cells linger after first infection and first activation, henceforth called primary infection/response
- Antibodies also linger after infection
- A second exposure to the antigen induces a faster and stronger secondary response due to the existing population of B and T memory cells which cause a faster response

Immunization

- Active: Defenses which arise when infection triggers a primary or secondary immune response. Acquired and lasts a lifetime and can be acquired via vaccination
- Passive : Antibody exposure which does not involve the B or T lymphocytes of the organism e.g. IgA antibodies in breast milk transferred from mother to child. Typically persists for a few weeks but effective immediately
- Natural: Acquired in response to infection
- Artificial: Man-made insertion
- Early observations found that humans which were exposed to cowpox were immune to deadlier smallpox. Intentional exposure to cowpox would be used to acquire adaptive immunity
- Modern immunization involves the exposure of humans to prepared antigens of many sources which include inactivated toxins, weakened virus coatings and weakened pathogens such that immunity can be acquired without having to suffer the full force of a disease
- Vaccine: Deactivated or weakened antigen
- Antiserum: Suspension of antibodies

- Virulence: Harmful potential of a pathogen
- Attenuation: action to reduce the virulence of a pathogen but still allow for immune response

Immune Disorders

- Immune disorders cause the immune system to function sub-par or even in a harmful manner
- Autoimmunity
    - Immune system mounts response against own body
    - Caused by faulty lymphocyte production, abnormal development of antigens and incorrect cytokine production
    - Treatments include controlling inflammation, suppressing immune system and introduction of antibodies to combat autoimmune cells
- Blood group
    - Initially a mechanism to prevent mixing of foreign blood
    - Blood group causes certain antibodies to appear in the bloodstream
    - Antigens and antibodies specific to blood group are produced and can cause immune response when reaction occurs
- Allergies
    - Production of histamine from mast cells, eosinophils and basophils cause harmful response and inflammation
    - Can be remedied with antihistamines to prevent production or detection of histamine

Reproduction in Flowering Plants

Asexual and Sexual Reproduction

Asexual	Sexual
One Parent / No Fertilisation	Two parents / Fertilisation
Daughter cell has identical genes as parent	Daughter cell has different genes as parent
Mitosis	Meiosis and Mitosis

- Sexual reproduction in plants involves the growth of a flower which eventually leads to seed production
- Asexual reproduction in plants takes the form of vegetative propagation
- Part of parent plant is used to form new plant
    - Underground storage organs, buds can produce shoots and nutrients from growth can be obtained from storage
        - Especially useful b/c can be used as perennating organs to survive harsh conditions - allows plant to lie dormant in winter and regenerate shoots when conditions are favourable

- Runners and leaves

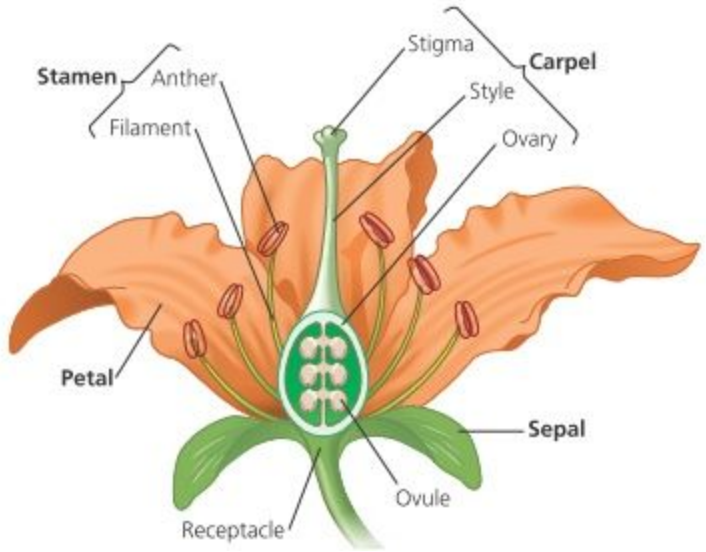
Advantages	Disadvantages
Offspring keep favourable traits of parents	Less genetic variation, vulnerable to disease
Only one parent is needed	Overcrowding may occur
Faster than sexual reproduction	
Survive harsh conditions	

Monocot and Dicot Plants

Reproductive Adaptations

Structure of a Flower

- Flowers come in 3 forms
  - Carpellate female flowers with only pistil(s)
  - Staminate male flowers with only anthers
  - Bisexual hermaphroditic flowers with both reproductive structures
- Plants come in 3 forms
  - Diecious plants produce flowers of one gender strictly
  - Monoecious plants produce flowers of both genders but only one per flower
  - Hermaphroditic plants produce bisexual flowers



Part	Function

Pedicel	Flower stalk. Plants without pedicels are called sessile flowers
Receptacle	Enlarged end of pedicel which flower structures are attached to
Petals	Brightly colored and scented structures arranged in a circle (whole structure is called corolla). Used to attract insects for insect pollinated flowers
Sepal	Modified petals which are green, protect flower in bud stage. All sepals make up the calyx
Stamen	Male reproductive organ consisting of filament with anther on end. Usually involve 2 lobes with 2 pollen sacs which contain pollen grains. Pollen is released when anther matures and lobe splits. Filament holds up another to release pollen. All stamen make up the androecium.
Carpel	Female reproductive organ consisting of stigma, style and ovary. Stigma receives pollen grain while style holds stigma up to collect pollen. Ovary contains one or more ovules and they contain gametes called ovum. Area where ovule is attached to ovary is called placenta. All carpels make up the pistil or gynoecium.

Self-Pollination and Cross-Pollination

- Pollination: Transfer of pollen grain from anther and stigma

Self-pollination	Cross-pollination
Transfer of pollen from anther to stigma within flowers of same plant	Transfer of pollen grain from anther to stigma of flowers from different plants
Only one parent needed	Two parents needed
Beneficial qualities are inherited by offspring	Encourages genetic diversity
Generally weaker and smaller offspring	Generally more resilient and taller offspring
Does not rely on external factors	Relies on wind/insects and other vectors for pollination
Less pollen needed	More pollen needed
More vulnerable seeds	More viable seeds and opportunity for dormancy
Features that favour self-pollination: ● Bisexual flowers ● Same maturation times	Features that favour cross-pollination: ● Dioecious plants ● Different maturation times

• Anthers above stigma • Closed flowers	• Anthers and stigmas far apart • Chemical incompatibility

Wind and Insect Pollination

Wind	Insect
Nectar and scent absent	Nectar and scent present
Stigma large, feathery and exposed	Stigma small and compact, does not protrude
Stamen long and pendulous	Stamen not pendulous and does not protrude
Pollen abundant, tiny and smooth	Pollen abundant, larger and rougher

Fertilisation

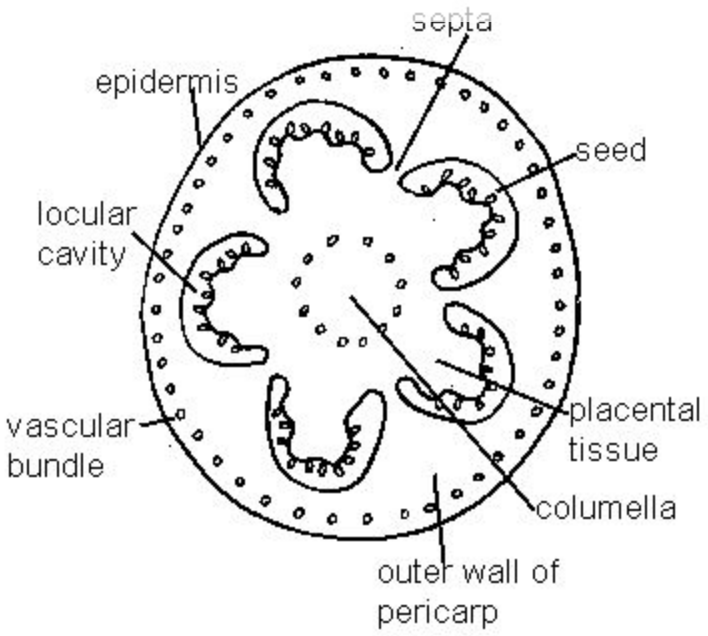
- Pollen grain lands on stigma and germinates due to sugary fluid in stigma
- Enzymes excreted digests stigma and style tissue and allows for pollen tube to grow
- Cytoplasm of pollen grain grows out to form pollen tube
- Two nuclei move down the tube, pollen nucleus in front of generative nucleus
- Pollen tube grows to micropyle, guided by chemicals secreted from ovary
- Generative nucleus divides by mitosis to form identical gametes
- Pollen tube cell membrane bursts at micropyle and releases generative nuclei
- Double fertilisation occurs
    - One nuclei fuses with ovum to form zygote which develops into embryo
    - One nuclei fuses with definitive nucleus to form endosperm nucleus

Flower to Fruit

Flower part	Fruit Part
Ovule(s)	Seed(s)
Zygote	Embryo consisting of plumule (shoot), radicle (root) and cotyledons
Endosperm Nucleus	Monocot: Develops into endosperm for storage Dicot: Absorbed by embryo, cotyledons used for storage
Integuments	Testa/Seed Coat and membranous tegmen
Ovule Stalk	Funicle/Seed Stalk
Ovary	Fruit

Ovary Wall	Fruit Wall/Pericarp
Stigma, style and sepals	Withers, but may be used for dispersal
Stamens and Petals	Withers

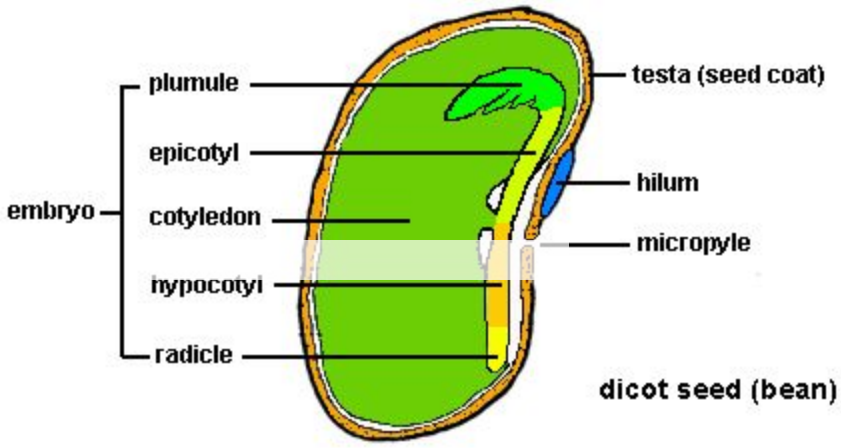
Fruit Anatomy



Part	Function
Scars	Tissue left behind from attachment to receptacle
Septum	Tissue which separates placentas
Placenta	Tissue which supplies nutrients to seeds
Funicle	Attaches seed to placenta with vascular tissues
Loculus	Filled with juicy pulp or left dry and empty, filler tissue separating pericarp and seeds
Pericarp	Border of fruit, consisting of exocarp, mesocarp and endocarp

- Protects seeds and embryo in seeds
- Disperses seeds to new habitats

Seed Anatomy



Part	Function
Testa	Protective seed coating
Embryo	New daughter plant
Cotyledon	Storage for nutrients (oil, carbohydrates etc)
Plumule	Shoot of embryo
Radicle	Root of embryo
Micropyle	Was opening of ovule

Dispersal

- Takes place to
    - Avoid overcrowding and competition for resources with parent and sibling plants
    - Allow for colonisation of new habitats and increase chance of survival
    - Reduce spread of disease
    - Dispersed seeds in suitable habitat will release seeds and germinate into new plants
- Dispersal by animal
    - Scented fruits
    - Tough seed coat to withstand animal GI tract
    - Large seeds to prevent animal ingestion and encourage disposal of seed
    - Presence of hooks to cling to animals
- Dispersal by water
    - Waterproof surface

    - Light and spongy pericarp of fruit to enhance buoyancy
- Dispersal by wind
    - Wing-like structures or hairs
    - Light, small and flat shape to increase surface area and air buoyancy
    - Dry to reduce weight
- Dispersal by explosive force
    - Dry and smooth pericarp with lines of weakness
    - Explosive splitting action to disperse seeds

Germination

Artificial Selection

- Process where humans breed organisms for desired traits by selecting plants with better genes
- Natural population occurs in the wild
- Plants with desired traits are chosen for the next generation of plants by humans and are farmed
- Desired traits are passed on to offspring
- Parent plants with desired traits are also hybridised, strains are crossed to produce plants with more desired genes by manually fertilising flowers
- Over multiple generations, desired traits are concentrated and eventually increases the quality of crop
- Provides advantages of higher yield, shorter maturation times, pest and drought resistance

Biodiversity and Food Security

- Plants provide many advantages
    - Rubber trees provide latex and its derivatives
    - Coconut husks used for ropes
    - Cotton fibres used for cloth
    - 25% of medicinal drugs originate from plants in rainforest
    - Rice, pineapple and banana originated from rainforest environments
    - Plants provide habitat for wildlife
- Genetic homogenisation may result in vulnerability of human environments to disease and harm security
    - Irish potato famine

Natural Selection

Natural Selection

- Species: Organisms which are able to reproduce sexually and produce fertile offspring
- Population: Organisms of the same species

- Competition among organisms of same species leads to different extent of survival by organisms best fitted to environment
- Nature selects varieties which are more competitive, resistance to diseases and better adapted to environment and hence survive and reproduce
- Increased population of individuals with favourable genes
- Variation in species hence increases chance of survival of species
- Diversity of species on Earth increases chance of survival in case of rapid environmental change

Natural Selection	Artificial Selection
Done by environment	Done by humans
Across many generations	Across few generations
Traits advantageous to survival/reproduction	Traits advantageous to humans

Features of Natural Selection

- Organisms are able to overpopulate
    - Overpopulation gives rise to more variations of same species
- Competition within species for survival
    - One species is more suited to survival than other species
    - Due to predation or limited resources
    - Fitter species survives, less fit species dies off
- Population is able to recover to overpopulation numbers
    - Able to recover numbers after less fit species dies off
    - Compensate for overpopulation swings
- Offspring have varied genetic makeup
    - Ensures that offspring has a varied degree of survivability
    - Caused by sexual reproduction and mutation
- Better adapted species is able to survive and reproduce
    - After being selected by ability to survive, fitter species given opportunity to reproduce
- Favourable genes are perpetuated in later generations
    - Fitter species which reproduces breeds offspring carrying same favourable genes
    - Spreads favourable traits to a larger proportion of the population

Explaining Natural Selection

- Natural Selection occurs
- Environment acts on [favourable phenotype] by selecting species more likely to [selection pressure]

- Favours [species] because [favourable phenotype] causes [action favourable to selection pressure]
- Most likely to [survive/reproduce/colonise]
- Individuals leave more offspring which display similar phenotype
- Results in propagation of allelic frequency

Variation in Species

- Species is said to come from same ancestor when a common phenotype is observed across different subspecies
- Isolation of different species which allow natural selection to take place over a long period of time in varied environments and selection pressures, produces varied offspring with vastly different phenotypes