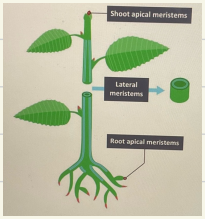
9.3 Growth in Plants

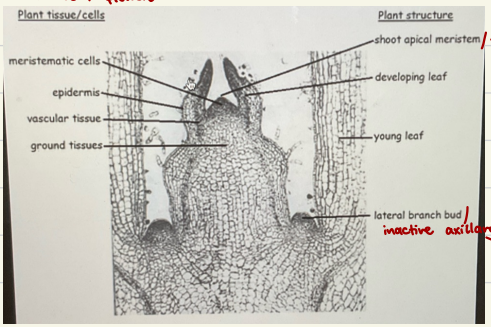
Meristems → tissues in a plant consisting of undifferentiated cells capable of indeterminate growth
→ analogous to totipotent stem cells in animals
→ except they have specific regions of growth + development
→ meristematic tissue can also allow plants to regrow structures or even form entirely new plants (vegetative propagation)

→ **apical meristems**
→ at shoots + root tips
→ responsible for primary growth (lengthening)
→ give rise to new leaves and flowers
→ **lateral meristems**
→ at the cambium (widening / thickening)
→ responsible for secondary growth
→ production of bark

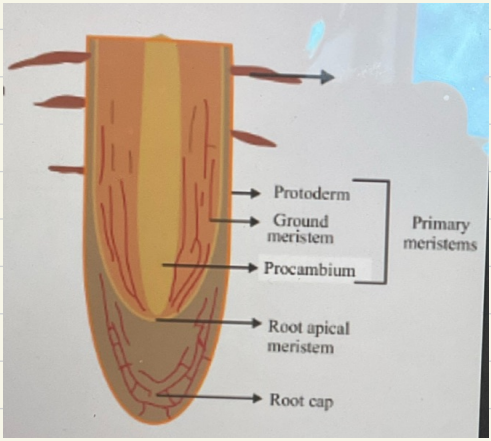


Apical Meristems

→ growth at these regions is due to cell enlargement + division (mitosis + cytokinesis)
→ differentiation of this meristem creates variety in stem tissues + structures
→ leaves + flowers
→ in the stem growth occurs in sections aka nodes w/ remaining tissue forming an inactive axillary bud
these have the potential to form new branching shoots w/ leaves + flowers

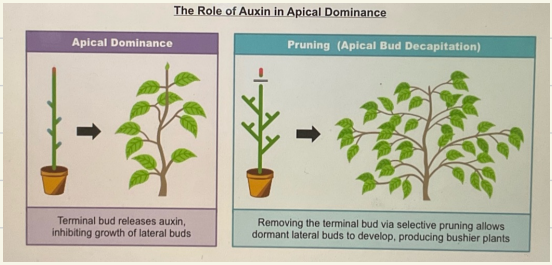


terminal bud
inactive axillary bud



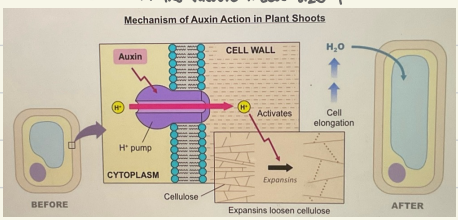
Shoot Apical Meristem

→ the growth of the stem + formation of new nodes is controlled by plant hormones released from the shoot apex
→ the main group is auxins (indole-3-acetic acid / IAA)
→ "auxins" promote growth in shoot apex via cell elongation + division
→ " " prevent growth in axillary buds → aka apical dominance
→ ensures plant uses its energy to grow towards sun
→ as plant grows, inhibition of axillary bud decreases
→ levels of apical dominance varies between species

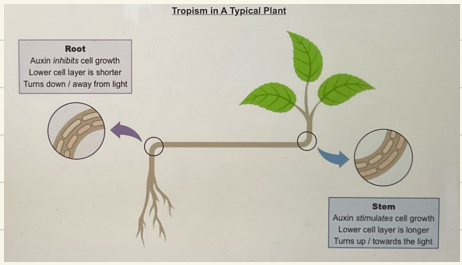


Auxins → hormones produced by the tip of a shoot or root that regulate plant growth
→ auxin pumps can create concentration gradients w/in tissues
→ by changing the distribution of auxin
→ pumps control the direction of plant growth
→ can change position w/in membrane
→ in shoots → auxin stimulates elongation; ↑ conc of auxin promotes growth
→ in roots → auxin inhibits elongation; ↑ conc of auxin limits growth
→ influences cell growth by changing the pattern of gene expression

In Shoots...
→ auxin increases flexibility of the cell wall in order to promote plant growth
→ activates a proton pump in membrane → secretion of H^+ ions into cell wall
→ ∴ pH ↓ → causes cellulose fibres w/in cell wall to loosen (bond breaking)
→ auxins ↑ expression of expansins → ↑ elasticity of cell wall
→ ↑ water can be stored in the vacuole ∴ cell size ↑

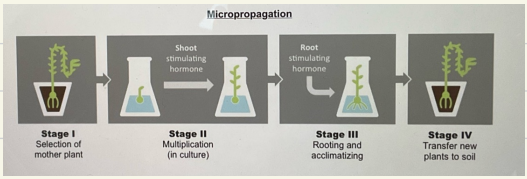


Tropism → growth or turning movement of plant in response to a directional external stimuli
→ **Phototropism**
→ growth in response to unidirectional light
→ light receptors (phototropins) trigger the redistribution of auxin to shaded side of plant
→ **Geotropism / Gravitropism**
→ growth in response to gravitational forces
→ auxins accumulate on lower side of plant in response to gravity
→ **In Shoots** (auxins promote elongation)
→ shaded side elongates + shoot grows towards light (+ phototropism)
→ lower side elongates + shoots grow away from ground (− gravitropism)
→ **In Roots** (auxins inhibit elongation)
→ shaded side becomes shorter + roots grow away from light (− phototropism)
→ lower side becomes shorter + roots turn downwards into earth (+ gravitropism)



Micropropagation → technique used to produce large numbers of identical plants
→ plants can reproduce asexually from meristems
→ **vegetative propagation** → plant cutting used in native environment to reproduce
→ **micropropagation** → plant cutting cultured in laboratory to reproduce

1. specific plant tissue **(typically shoot apex)** selected from stock plant + sterilised
2. tissue sample grown on a sterile nutrient agar gel
3. sample treated w/ auxins to stimulate shoot + root development
4. the growing shoots can be continuously divided to form multiple samples
5. Once root + shoot develop → clone can be transferred to soil



Rapid Bulking
→ desirable stock plants cloned to conserve selected characteristics
→ more reliable than selective breeding as **genetically identical**
→ to rapidly produce large quantities of GMOs

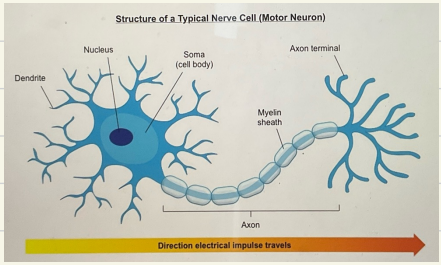
Virus-Free Strains
→ virus in plants spread through vascular tissue not meristems
→ propagating plants from meristems prevents reproduction of virus plants

Propagation of Rare Species
→ ↑ #s of rare or endangered species
→ ↑ #s of species difficult to breed
→ ↑ #s of highly commercially demanded species

6.5 Neurons & Synapses

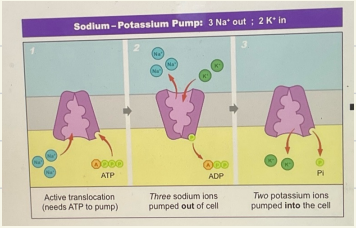
Neurons → specialised cells that transmit electrical impulses w/in the nervous system
→ nervous system converts sensory information into electrical impulses to rapidly detect + respond to stimuli
→ 3 components

1. **Dendrites** → short-branched fibres that convert chemical info from other neurons or receptor cells into electrical signals
2. **Axon** → an elongated fibre that transmits electrical signals to terminal regions for communication w/ other neurons or effectors
3. **Soma** → a cell body containing the nucleus + organelles where essential metabolic processes occur to maintain cell survival
4 (in some). **Myelin Sheath** → insulating layer surrounding axon that improves the conduction speed of impulses but require additional energy + space



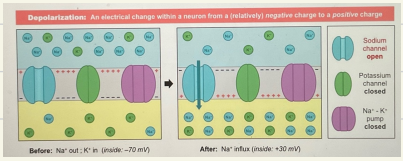
Neurons generate + conduct signals by **pumping Na^+ & K^+** across their membrane
→ unequal distribution on different sides of membrane creates a charge difference **aka a membrane potential**

Resting Potential → difference in charge across membrane when a neuron **is not** firing
→ inside typically more (-)tive than outside
→ maintenance = active process controlled by sodium-potassium pumps
→ transmembrane protein that actively exchanges sodium & potassium ions
→ **3 Na^+ ions for every 2 K^+ ions**
→ creates an electrochemical gradient where interior is more (-)tive as more (+)ve ions outside the cell
→ requires hydrolysis of ATP

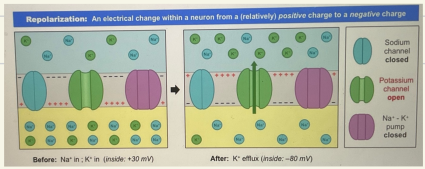


Action Potential → rapid changes in charge when neuron **is** firing
→ 3 main stages

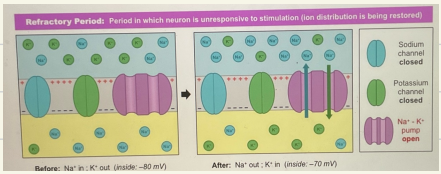
1. **Depolarisation** (MP)
→ sudden change in membrane potential (usually (-) to (+))
→ in response to a signal initiated at dendrite, sodium channels open w/in axon membrane
→ passive influx of Na^+ as ↑ conc outside neuron
→ causes MP to become more (+)ve = **depolarisation**



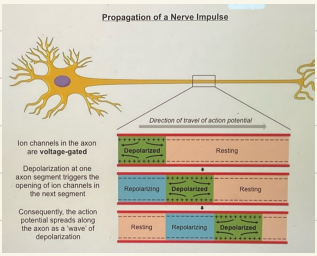
2. **Repolarisation**
→ restoration of membrane potential **(+)ve charge)**
→ potassium channels open → passive efflux of K^+ ions
→ causes membrane potential to return



3. Refractory Period
→ period of time following a nerve impulse before neuron is able to fire again
→ following repolarisation → ionic distribution is reversed (Na^+ inside, K^+ outside)
→ before neuron can refire, resting potential must be restored via antiport action of sodium-potassium pumps

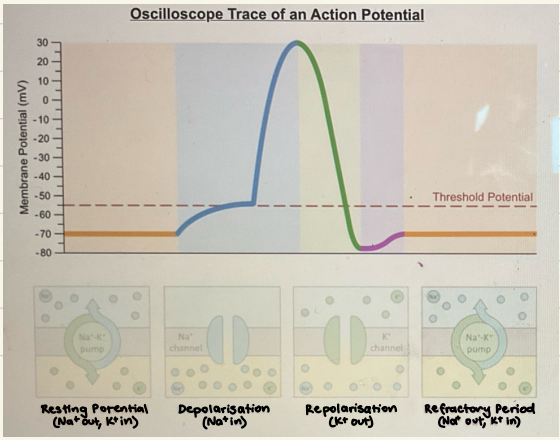


Nerve Impulses → action potentials that move along axon as a wave of depolarisation
→ the ion channels are voltage-gated ∴ depolarisation at one point of the axon triggers opening of ion channels in next axon segment
→ causes depolarisation to spread in unidirectional wave

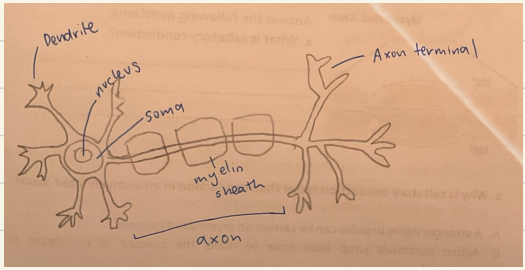


Threshold Potential → minimum electrical stimulus required to open voltage-gated channels
→ if not reached → action potential cannot be generated → neuron will not fire
→ triggered when convolved stimulation of dendrites > min level of depolarisation
→ resulting displacement of ions is sufficient to activate voltage-gated channels in next section

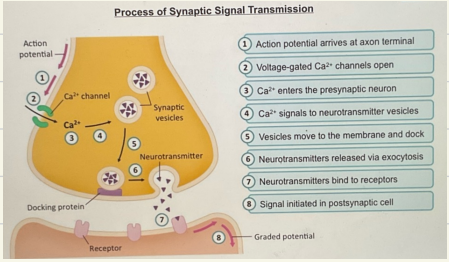
Oscilloscopes → scientific instruments used to measure membrane potential



Myelin → fatty white substance to insulate axon
→ mixture of protein & phospholipids
→ ↑ speed of electrical transmissions via saltatory conduction
→ along unmyelinated neurons → action potentials propagate in continuous wave
→ in myelinated neurons → action potentials 'hop' between gaps in the sheath
→ results in ↑ speed of conduction
→ advantage = ↑ speed
→ disadvantage = takes up significant space w/in an enclosed environment



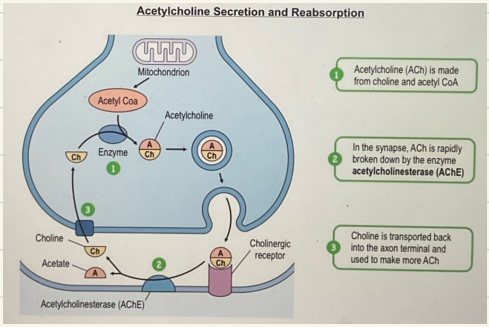
Synaptic Transfer
→ synapses = physical gaps that separate neurons from other cells
→ neurons transmit info across synapses by converting electrical into chemical signals
→ when action potential reaches the axon terminal → triggers opening of voltage-gated calcium channels
→ Ca^{2+} ions diffuse into the cell + promote fusion of vesicles w/ cell membrane
→ neurotransmitters are released from the axon terminal by exocytosis + cross the synaptic cleft
→ they bind to specific receptors on the post-synaptic membrane
→ ligand-gated ion channels open generating signals in post-synaptic neuron
→ the neurotransmitters are either recycled or degraded



Neurotransmitters
→ chemical messengers released from neurons to transmit signals
→ in response to depolarisation of axon terminal
→ can trigger a variety of responses

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

Acetylcholine → neurotransmitter used by both CNS & PNS
→ commonly released at neuromuscular junctions + bind to muscle fibres to trigger muscle contractions
→ created in axon terminal by combining choline w/ mitochondrial acetyl
→ stored in vesicles w/in axon terminal until released via exocytosis
→ activates a post-synaptic cell by binding to a specific receptor
→ must be continuously removed as overstimulation can lead to fatal convulsions/paralysis
→ broken down by enzyme **acetylcholinesterase (AChE)**
→ choline returns to presynaptic neuron where it is coupled w/ another acetate to reform acetylcholine



Neonicotinoid → pesticides that irreversibly bind to acetylcholine receptors + trigger a sustained response
→ cannot be broken down by AChE → permanent overstimulation
→ insect's acetylcholine receptors bind to neonicotinoids more strongly ∴ it is significantly more toxic to insects than mammals
→ highly effective pesticide
→ disadvantages
→ reduction in honey bee populations
→ reduction in bird populations

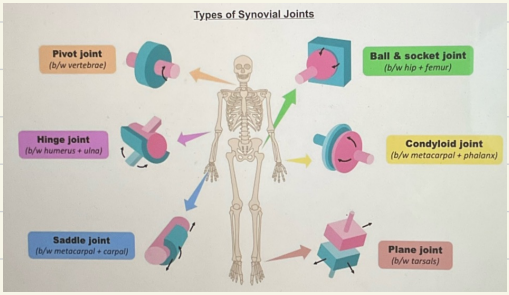
Graded Potentials
→ small changes in membrane potential caused by open ligand-gated channels
→ excitatory neurotransmitters → causes depolarisation by opening sodium/calcium channels
→ inhibitory neurotransmitters → causes hyperpolarisation by opening potassium/calcium channels

11.2 Movement

3 Interacting Movement Systems
1. **Skeletal System** → bones that act as levers and provide a structure for muscles to pull
2. **Muscular System** → muscles deliver force required to move bones
3. **Nervous System** → delivers signals to the muscles which causes them to contract

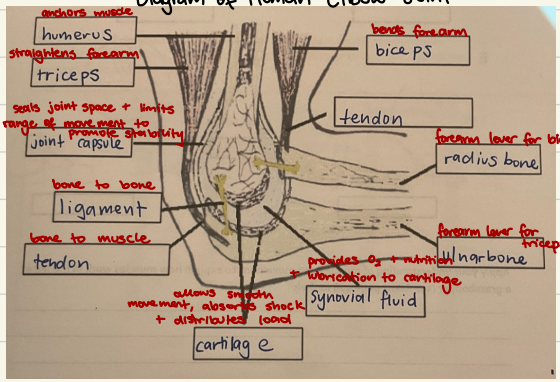
Skeletal System → rigid framework that provides support & protection for our body organs
→ endoskeleton → internal; consisting of numerous bones
→ exoskeleton → external; comprised of connected segments
→ provide a surface for muscle attachment .. facilitate movement
→ bones and exoskeletons act as levers
→ bones connected to bones by ligaments
→ bones connected to muscles by tendons

Synovial Joints
→ capsules that surround the articulating surfaces of 2 bones
→ joints function to maintain structural stability by allowing movement at some points but not others

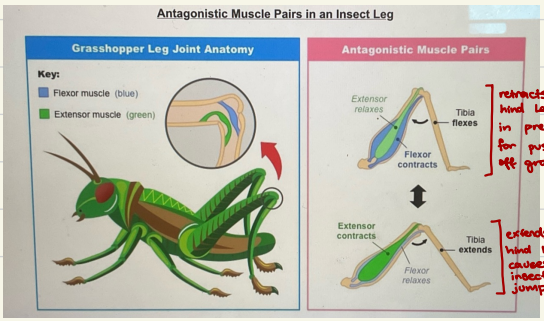


(example of a hinge joint)

Diagram of Human Elbow Joint

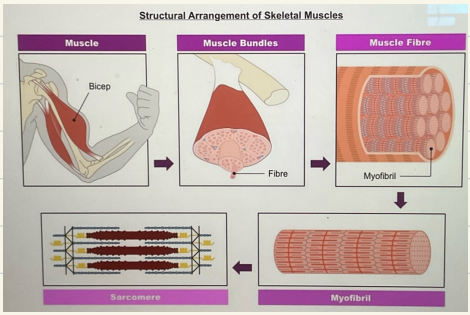


Muscles → contract for movement
→ muscle connects static bone to moving bone
→ exist in antagonistic pairs → one contract = other relax
→ some insects have hind legs specialised for jumping
→ jointed exoskeleton of hind leg divided into 3 parts: femur, tibia, tarsus (upper, middle, lower)
connected by antagonistic muscles



Organisation of Skeletal Muscles

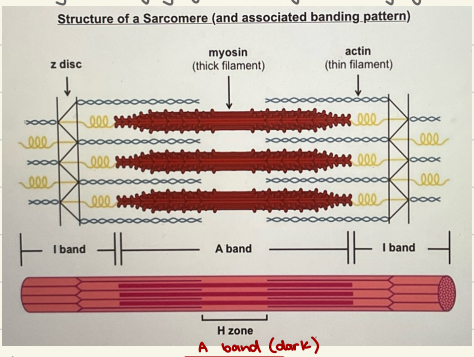
→ tightly packaged muscular bundles surrounded by connective tissue (perimysium)
→ each bundle contains multiple **muscle fibres** formed from fused muscle cells
→ muscle fibres contain tubular **myofibrils** that are responsible for muscular contractions
→ the myofibrils can be divided into repeating sections called **sarcomeres**



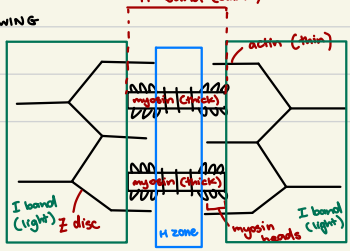
Muscle Fibre Specialised Features

1. **multinucleated** → many nuclei from fusion of individual cells
2. **many mitochondria** → muscle contraction requires ATP hydrolysis
3. **sarcoplasmic reticulum** → stores calcium ions
4. **2 different myofilaments** → thin (actin) and thick (myosin)

Sarcomeres → repeating contractile units made of myosin & actin
→ **myosin** contains small heads which bind to regions of **actin**
→ movement of these 2 filaments causes **lengthening & shortening** of sarcomere
→ each sarcomere flanked by dense proteins **aka Z discs**
→ actin filaments radiate out from Z discs to anchor central myosin in place
→ striated pattern along length of fibres
→ centre appears darker due to actin + myosin overlap **(A band)**
→ sides appear lighter as only actin is present **(I band)**
→ A band may contain slightly lighter central region where only myosin is located **(H zone)**



DRAWING



Process of Muscular Contraction

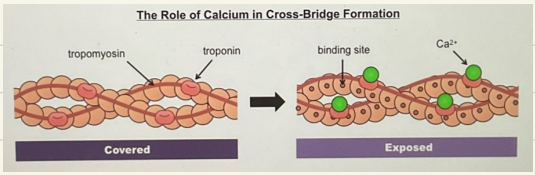
1. Depolarisation and Calcium Ion Release

→ action potential triggers release of acetylcholine into motor end plate
→ acetylcholine initiates depolarisation → spread through muscle fibres via T tubules
→ calcium ions released from sarcoplasmic reticulum
→ sarcomere contraction is triggered

2. Actin and Myosin Cross-Bridge Formation

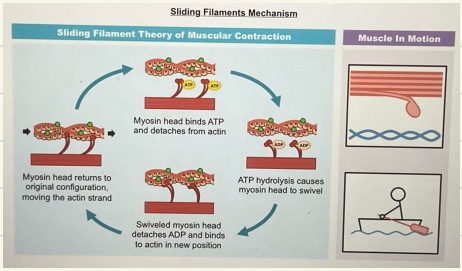
troponin & tropomyosin

→ on actin, the binding sites for myosin heads are covered by a blocking complex
→ calcium ions bind to troponin, reconfiguring the complex to expose binding sites
→ the myosin heads then form a cross-bridge w/ actin



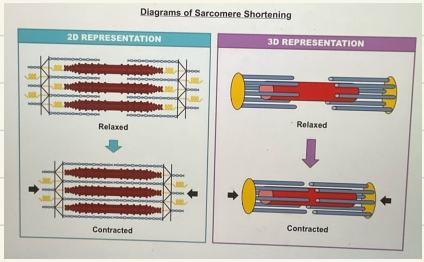
3. Sliding Mechanism of Actin & Myosin

→ ATP binds to the myosin head, breaking the cross-bridge between actin & myosin
→ ATP hydrolysis causes the myosin heads to change position, moving them towards the next actin binding site
→ the myosin heads bind to the new actin sites + return to their original configuration
→ the reorientation drags the actin along the myosin



4. Sarcomere Shortening

→ the repeated reorientation drags the actin filaments along the length of the myosin
→ this pulls the Z discs closer together → sarcomere shortens
→ this causes the whole muscle fibre to contract
→ this movement reduces the width of the H zone, but doesn't change the length of the A bands

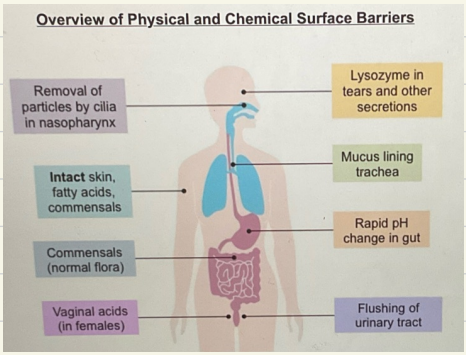


6.3 Defence Against Infectious Disease

Surface Barriers → the first line of defence against infectious diseases
→ prevents entry of pathogens into the body
→ skin and mucous membranes

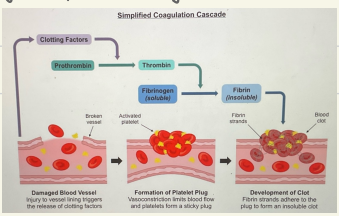
Skin
→ protects external structures
→ consists of a dry, thick and tough region composed predominantly of dead surface cells
→ contains biochemical defence agents
→ skin secretes lactic acid + fatty acids to lower pH (5.6 – 6.4)

Mucous Membranes
→ protects internal structures (externally accessible eg. trachea, oesophagus)
→ thin region of living surface cells that release fluids to wash away pathogens
→ contains biochemical defence agents
→ may be ciliated to aid in removal of pathogens



Blood Clots (haemostasis) → mechanism of repair for broken/damaged blood vessels
→ to prevent blood loss from the body + limit pathogenic access to the bloodstream
→ 2 key components
→ Platelets → undergo a structural change when activated to form a sticky plug at the damaged region (primary)
→ Fibrin strands → form an insoluble mesh of fibres that trap blood cells at the site of damage (secondary)

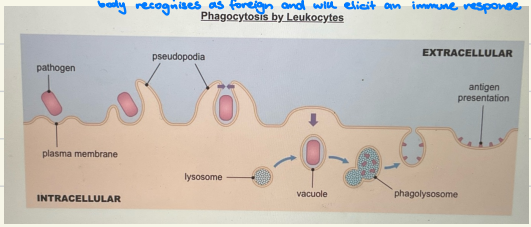
Coagulation Cascade
→ process by which blood clots are formed (complex set of reactions)
→ 'clotting factors' cause platelets to become sticky + adhere to damaged area
→ also initiate localised vasoconstriction to reduce blood flow
→ trigger conversion of inactive zymogen prothrombin into activated enzyme thrombin
→ thrombin catalyses the conversion of soluble fibrinogen into insoluble fibrin
→ the fibrin form a platelet plug and trap RBC to form a temporary clot
→ when damaged region is repaired → an enzyme is activated to dissolve the clot



(innate immune system)

Non-Specific Response → second line of defence against infectious disease
→ principle component = WBCs (phagocytic) → engulf + digest foreign bodies
→ also includes inflammation, fever, antimicrobial chemicals
→ 2 key properties
→ does not differentiate (non-specific)
→ responds to all infections the same way (non-adaptive)

Phagocytes
→ phagocytosis = the process by which solid materials are ingested by a cell (endocytosis)
→ phagocytic leukocytes circulate in the blood + move into the body tissue in response to infection
→ damaged tissues release chemicals (histamine) which draw WBCs to the site
→ pathogens are engulfed when cellular extensions surround it and fuse to form internal vesicles
→ the vesicle is then fused to a lysosome + pathogen is digested
→ pathogen fragments (antigens) presented on surface to stimulate third line of defence
body recognises as foreign and will elicit an immune response



(adaptive immune system)

Specific Response → third line of defence
→ can differentiate between different pathogens + target a specific response
→ can respond rapidly upon re-exposure → preventing symptoms (immunological memory)

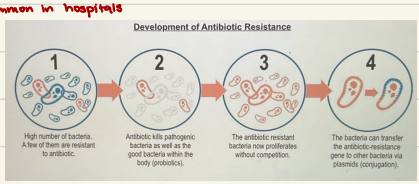
Lymphocytes
→ B-lymphocytes (B cells) → antibody-producing cells that recognise + target particular antigens
→ Helper T-lymphocytes (T cells) → regulator cells that release chemicals to activate specific B cells
→ when antigens are presented, specific helper T cells are activated
→ T cells release cytokines to activate B cells to produce antibodies
→ the activated B cell will divide + differentiate to form short-lived plasma cells that produce large amounts of the specific antibody
→ antibodies will target their specific antigen, enhancing immune system ability to recognise + destroy the pathogen
→ few B cells will differentiate into memory cells for long-lasting immunity

Antibodies
→ made of 4 polypeptide chains
→ the ends of the arms are variable ∴ specific
→ each antibody recognises a unique antigen (like enzyme-substrate)

Antibiotics → compounds that kill or inhibit the growth of microbes by targetting prokaryotic metabolism
→ features that may be targeted: 70S ribosomes, enzymes, cell wall components
→ eukaryotic cells do not have these features ∴ host won't be targeted
→ may kill bacteria or suppress its potential to reproduce
→ viruses are not alive and take over cellular machinery of host cells
→ ∴ cannot be treated w/ antibiotics → instead specific antiviral agents
→ these target viral enzymes or components of capsid

11·1 Antibody Production & Vaccination

Antibacterial Resistance
→ some bacterial strains have evolved w/ genes resistant to antibiotics
→ because bacteria reproduce at a rapid rate ∴ resistant strains can proliferate quickly
→ resistant strains can pass resistance genes to susceptible strains via bacterial conjugation (horizontal gene transfer)
→ the prevelance of resistant bacterial strains is increasing rapidly w/ humans
→ over-prescription or misuse of antibiotics
→ antibiotics freely available + used in livestock
→ common in hospitals

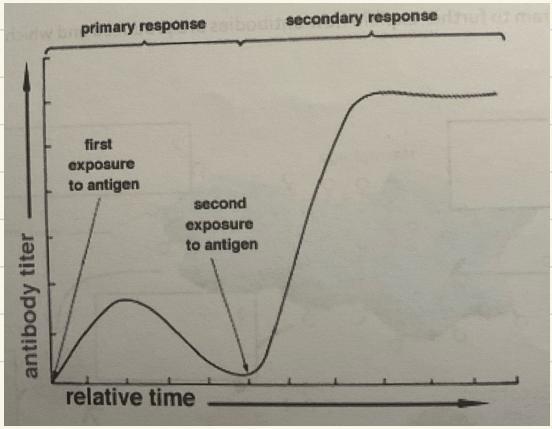


Penicillin → first chemical compound found to have antibiotic properties by Alex Fleming (1928)
→ accident, unintended contamination of a dish containing S. aureus
→ penicillium mold began to grow → halo of inhibited bacterial growth around it
→ Fleming concluded mold was releasing Penicillin that was killing bacteria

Medical Applications → Florey and Chain
→ tested penicillin on mice
→ 8 mice injected w/ pathogen → 4 then injected w/ Penicillin
→ untreated mice died; treated survived

Human Immunodeficiency Virus (HIV) → a retrovirus that infects helper T cells disabling body's adaptive immune system
→ causes a variety of symptoms + infections called Acquired Immuno-Deficiency Syndrome (AIDS)

→ Effects of HIV
→ HIV specifically targets the helper T cells
→ virus becomes inactive allowing infected T cells to reproduce
→ virus becomes reactive + begins to spread → destroying the T cells
→ antibodies are unable to be produced → ↓ immunity
→ body becomes susceptible to less harmful infections → eventual death
→ Transmission of HIV
→ HIV is transmitted through exchange of body fluids (unprotected sex, blood transfusions, breastfeeding.)
→ can be minimized through protection
→ small minority are immune



Self vs Non-Self
→ immune system has capacity to differentiate
→ all nucleated cells of body possess unique + distinctive surface molecules ('self')
→ these 'self' markers are called major histocompatability complex (MHC) molecules
→ function as ID tags → ∴ if not there = foreign (antigen)
→ antigen (non-self) determinants = surface markers, self markers of diff cell, proteins

Blood Transfusions
→ RBCs are not nucleated ∴ do not possess self markers + can be transfered
→ however they have basic antigen markers which limit capacity for transfusion
→ RBCs may possess glycoproteins (A & B antigens) either A or B or AB or none

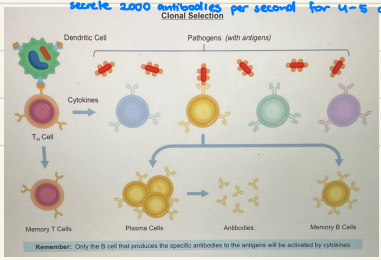
Summary of the ABO Blood Groups

	Type A	Type B	Type AB	Type O
Antigen (on RBC)	Antigen A	Antigen B	Antigens A + B	Neither A or B
Antibody (in plasma)	Anti-B Antibody	Anti-A Antibody	Neither Antibody	Both Antibodies
Blood Donors	Cannot have B or AB blood Can have A or O blood	Cannot have A or AB blood Can have B or O blood	Can have any type of blood Is the universal recipient	Can only have O blood Is the universal donor

Pathogens → an agent that causes disease (pathogenesis) (bacteria, fungi, parasite, virus)
→ disease = disturbs normal body function
→ illness = deterioration of normal health
→ ability to cause disease is species specific
→ certain pathogens may be able to infect range of hosts (eg. influenza strains = bird flu; bubonic plague = rats)
→ animal to human = zoonoses

Disease Transmission
→ direct contact (bodily fluids)
→ contamination (ingestion)
→ airborne (coughing/sneezing)
→ vectors (intermediary organisms)

Clonal Selection (only the extra info from HL)
→ B cells divide and form clones (clonal selection)
→ most clones develop into plasma cells + some into memory cells
secrete 2000 antibodies per second for 4-5 days



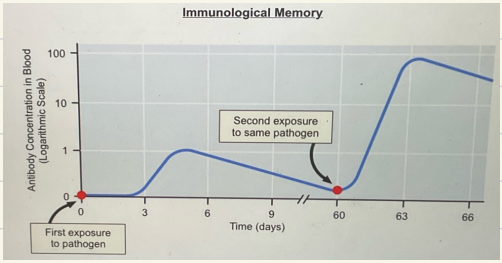
Antibodies Role

1. Precipitation → soluble pathogens become insoluble
2. Agglutination → clump for easier removal
3. Neutralisation → antibodies occlude pathogenic regions
4. Inflammation → trigger inflammatory response
5. Complement activation → complement proteins perforate membranes (cell lysis)

→ antibodies enhance immune system → aid detection for phagocytic RBCs to remove pathogens more efficiently

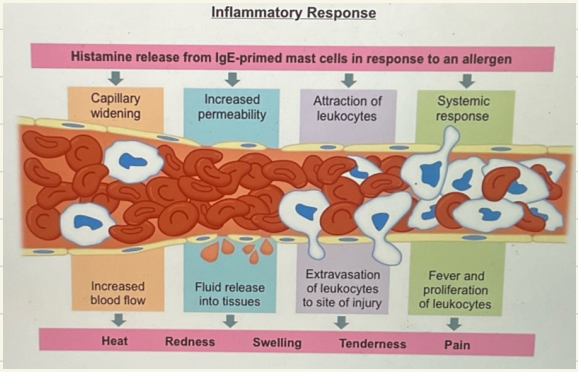
Immunity

→ relies on clonal expansion of plasma cells to produce antibodies
→ ∴ delay between initial exposure + immune response
→ memory cells prevent this delay during second exposure
  ↳ long-living + survive for many years
→ pathogen cannot reproduce in sufficient amounts to create symptoms ∴ immune



Allergens

→ environmental substance that triggers an immune response
→ localised to region of exposure (allergic reaction)
→ severe response = anaphylaxis (can be fatal)
→ allergic reaction only occurs upon re-exposure
→ when B cell encounters allergen → ↑ quantities of IgE antibody produced by plasma cells
→ IgE antibodies attach to mast cells
→ upon re-exposure → IgE-primed mast cells release histamine (causes inflammation)
→ inflammation improves leukocytes mobility by vasodilation → ↑ capillary permeability
→ vasodilation causes redness + heat
→ ↑ permeability for leukocytes to enter body tissue = swelling + pain



Vaccinations

→ long-term immunity to specific pathogenic infections by production of memory cells
→ a weakened or attenuated form of a pathogen that contains antigens but is incapable of triggering disease
→ body responds by initiating immune response → memory cell production
→ ∴ when exposed to actual pathogen → immune response ↑ → no disease
→ booster shots to maintain immunity

Herd Immunity

→ individuals who are not immune are protected by ↑ amounts of immune individuals
→ programmes implemented to reduce outbreaks
→ epidemic = substantial ↑ in occurence of infection w/in region
→ pandemic = epidemic across large geographical area

Smallpox

eliminated worldwide

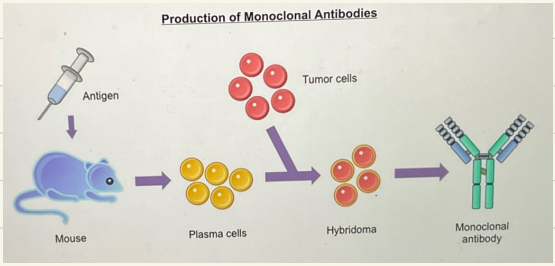
→ first disease eradicated via vaccination
→ immunity was long-term so booster shots not required
→ cowpox used as vaccinne

Epidemiology

→ study of patterns, causes, and effects of health + disease

Monoclonal Antibodies

→ antibodies artificially derived from a single B cell clone
→ an animal (mouse) injected w/ an antigen → produces antigen-specific plasma cells
→ plasma cells removed + fused w/ tumor cells (endless divisions)
→ resulting hybridoma cell capable of synthesising ↑ quantities of monoclonal antibodies
→ can be used therapeutically eg. treatment of rabies
→ can be used in detection of disease eg. antibodies in detection of pregnancy



Treatment Use

→ injecting purified antibodies for relates as an emergency treatment
→ target cancer cell that body doesn't recognise as harmful

Diagnostic Use

→ test for pregnancy via presence of hCG in urine
  → hCG = hormone produced during fetal development
→ pregnancy tests use enzyme-linked immunosorbent assay process
  → free "monoclonal antibodies specific to hCG" are conjugated to an enzyme that changes dye colour
  → second set of " " are immobilised to the dye substrate
  → if hCG is present in urine, when both sets of antibodies bind to hCG the enzyme is brought into physical proximity w/ the dye, changing its colour
  → third set of monoclonal antibodies binds w/ free enzyme-linked antibodies
    → control test