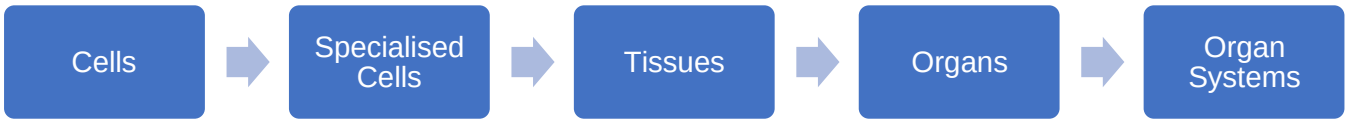
3.2 Cells

Eukaryotic Cells

- Found in plants, animals + fungi
- Have membrane bound nucleus / organelles
- Cell membrane – phospholipid bilayer – fatty acid tails in, phosphate heads out
- Nucleus – contains the cells genetic information
    - Nucleolus – membrane within nucleus containing the DNA strands
    - Nucleoplasm – the jelly-like substance filling the nucleus
- Mitochondria – releases energy – contains ribosomes and genetic material
    - Matrix – the fluid filling the inside of the mitochondria
    - Cristae – the folds in the internal membrane of the mitochondria
- Chloroplasts – convert sunlight into sugar for plants and algae
    - Grana – the membrane-bound organelles containing the chlorophyll
    - Thylakoid – a stack of grana
- Golgi apparatus – the organelle transporting, packaging, and processing protein
    - Like a 'stack of pitta breads'
- Lysosomes – releases lysozymes
    - To allow the cell to break down old / dead cells, to allow the cell to replace them
- Ribosomes – the site of protein production
- Endoplasmic reticulum – membranous tubules in cytoplasm of eukaryotic cells
    - Rough ER – ribosomes on cisternae (membrane-enclosed sacs), protein synthesis
    - Smooth ER – involved in synthesis of lipids / protein transport
- Cell wall – only found in plants, algae, fungi
  Made of cellulose (plants) / chitin (fungi)
- Cell vacuole – found in plants – offers support and rigidity to the plant by making cells turgid



Prokaryotic Cells + Viruses

- Much smaller than eukaryotic cells
- Cytoplasm lacks membrane bound organelles
- Smaller ribosomes (70S instead of 80S)
- No nucleus – single circular DNA molecules, free in the cytoplasm
- Cell wall – made of murein – a glycoprotein
- May also have:
    - Plasmids – circular rings of DNA that bacteria can exchange with other bacteria
    - Capsule –
    - Flagella – used by the cell to move
- Viruses – acellular (cannot form multicellular organisms), non-living (cannot reproduce)
    - Genetic material – not in a nucleus
    - Capsid – the protein shell surrounding the virus
    - Attachment protein – the protein that attaches the virus to the host

3.2 Cells

Methods of Studying Cells

- Optical (light) microscopes – max 1 500x magnification, use light to magnify small details
- Transmission Electron Microscopes – TEM; fire a beam of electrons through a thin cross-section of cells. Shows internal (2D) structure of cell. Highest magnification / resolution
  Must be dead – vacuum required to allow electrons to travel a reasonable distance
- Scanning Electron Microscope – SEM; fire electrons at cells, producing a 3D image of the cell. High magnification / resolution
- Magnification – the ability to increase the size of an object
- Resolution – the minimum distance between two objects close together that can still be discerned
- $magnification = \frac{size\ of\ image}{size\ of\ real\ object}$
- Cell fractionation + ultracentrifugation
  - Cut up tissue sample in ice cold water + buffer solution
  - Homogenise - break down whole cells
  - Filter - remove any debris + whole cells
  - Spin (low speed) - nuclei
  - Spin (higher speed)
  - Spin (higher speed)
  - …
  - Spin (highest speed) - ribosomes
- Iodine in potassium iodide solution can be used to identify starch granules
- Artefacts – a change that is visible through a microscope, that isn't meant to be there
  - Could be caused by damage to the cells, or something on a lens

Cell Replication

- Eukaryotic cells with the ability to divide have a cell cycle
- DNA replication occurs during interphase
- Mitosis – the part of the cell cycle where an eukaryotic cell divides
  - Prophase -
  - Metaphase -
  - Anaphase -
  - Telophase -
  - Cytokinesis - where the cell splits in two
- Mitosis is a controlled process
  - Uncontrolled cell division can lead to cancer
  - Some cancer treatments are aimed at preventing cell division
- Binary fission – cell replication in prokaryotes
  - Replication of circular DNA + plasmids
  - Cytoplasm divides, producing 2 daughter cells
- Viruses
  - Do not undergo cell division
  - Instead, *invade* a host cell, hijacking its' reproductive mechanisms

3.2 Cells

Transport Across Membranes

Diffusion

- Net movement of particles from an area of high concentration to an area of low concentration
- Passive - does not use ATP
- Facilitated Diffusion
    - Water-soluble compounds cannot diffuse through cell membrane
    - Instead, they use a carrier / channel protein to diffuse into the cell
    - Carrier protein
        - Molecule binds to protein, changes shape, and is able to move into the cytoplasm
        - Specific – each carrier protein is only able to transport 1 type of molecule
    - Channel protein
        - Molecule is able to pass through a 'channel' in the cell membrane
        - Specific – each channel protein is only able to transport
- Simple Diffusion
    - Net movement of particles
    - Phospholipid bilayer only allows lipid-soluble molecules to pass through
    - Water soluble molecules have to use a carrier protein to pass through

Osmosis

- Movement of water across a partially permeable membrane from a less concentrated solution to a more concentrated solution
- Passive - does not use ATP
- Tries to make the water potential the same on both sides of a partially permeable membrane

Active Transport

- Transport of molecules against the concentration gradient, using ATP (energy)

Co-Transport

- Where a molecule is pulled through, into a cell, using an ion
- Carrier proteins
    - ATP is hydrolysed in the carrier protein, producing ADP (adenosine diphosphate)
    - The carrier protein pumps out all of a certain ion, creating a low concentration - this causes that ion to diffuse into the cell
    - An ion may bind to the carrier protein, which helps 'drag' the larger molecule through, against the concentration gradient
- Example - Sodium ions and Glucose
    - Some glucose will remain in the ileum (intestine) during digestion, as the concentration is equal on both sides of the membrane
    - Co-transport can be used to move more of the glucose into the cell

- All of the sodium is pumped out of the protein, into the bloodstream - this creates a lower concentration
- A sodium ion binds to the co-transporter protein, dragging a glucose molecule through, into the protein. These are then pumped out of the cell

Improving the Rate of Transport

- Larger surface area (high surface area : volume ratio)
  - Microvilli - small, hair like projections on epithelial cells - increase SA : V ratio; sometimes called 'brush border'
  - Villi - cells arranged in finger-like projections, ~1mm long, in ileum
- More carrier / channel proteins
  - More carrier / channel proteins allows for faster transport of non-lipid-soluble substances through the cell membrane

Fick's Law

$$rate\ of\ diffusion = \frac{surface\ area \times concentration\ difference}{thickness\ of\ membrane}$$

Cell Membrane

Phospholipid Bilayer – made up of phospholipids, in a bilayer, allowing lipid-soluble substances to enter / leave a cell

Plasma Membrane – membranes around + within cells, having the same basic structure as the phospholipid bilayer

Proteins

Extrinsic – on the surface of the membrane, or partially embedded in the membrane

Intrinsic – completely span the bilayer

Functions of Proteins

1. Transport in and out of cells
   - carrier proteins – facilitated diffusion – active transport
   - channel proteins
2. Receptors
   - for homones
   - for neurotransmitters
3. Antigens
   - for cell recognition
4. Structural Support
   - to give the membrane a stronger structure
5. Help cells adhere together
   - to create tissues
6. Digestive enzymes
   - in epithelial cells in the intestine, enzymes are embedded in the membrane
   ------ this helps create a higher concentration gradient around the transporter protein

Fluid Mosaic – phospholipid bilayer – very flexible (fluid); many proteins, different sizes + shapes + phospholipids (mosaic)

3.2 Cells

The Immune System

Important Components

Thymus Gland – produced t-lymphocytes (which discriminate between self and non-self antigens

Bone Marrow – b-lymphocyte production (differentiate from bone marrow → discriminate between self and non-self antigens)

Lymph Nodes – filter the lymph to remove pathogens; contain phagocytes, mature b- and t-cells

Spleen / Kidney – filter the blood to remove antigens

Tonsils – remove antigens in the lymph, protect the respiratory system

- Phagocytosis
    - Phagocytes are attracted by chemotaxis towards the pathogen
    - Receptors on the membrane of the phagocyte recognise antigens on the pathogen
    - Pathogen is engulfed, forming a vesicle (phagosome)
    - Lysosomes fuse with the phagosome
    - Digestive enzymes in the lysosome hydrolyse the ingested bacteria, killing it
- The Inflammatory Response
    - Pathogens enter a wound
    - Platelets release blood clotting agents at the damaged site
    - MAST cells secrete FACTORS, increasing vasodilation, and vascular constriction (reducing blood supply to the affected areas)
    - Neutrophils secrete FACTORS that kill pathogens
    - Neutrophils and macrophages remove the pathogens by phagocytosis
    - Macrophages secrete hormones called CYTOKININS, attracting more lymphocytes. This activates cells involved in tissue repair
    - The inflammatory response continues until the pathogen is eliminated, and the wound repaired
- Phagocytosis is a non-specific defence mechanism
- Pathogens are digested by lysozyme enzymes in pathogens
- Pathogens are destroys=ed by phagocytosis, as part of the inflammatory response

Antibodies

- Antibody – proteins on the exterior of a cell, allowing it to be identified
- B-Cells in the Immune Response
    - Immature b-cells divide by mitosis before birth, in the bone marrow
    - Each b-cell matures (b = **b**one)
    - Maturation involves the production of receptor modules (which are expressed in the plasma membrane of the b-cell)
    - Each b-cell has a different receptor, each binds to a different antigen
    - Mature b-cells circulate and concentrate in the lymphoid tissue
    - By birth, there are millions of different b-cells, each with a specific receptor

Effector Phase

1. T-helper cells have been activated
2. T-helper cells then come in contact with b-cells, with the corresponding antigen
3. T-cells bind to the surface of the b-cells, begin to secrete cytokines

4. Cytokines stimulate b-cells to undergo clonal expansion (by mitosis), differentiate to plasma cells, then produce antibodies

Antibodies

Y-shaped protein produced by b-lymphocytes (sometimes called b-cells)

Work in 4 ways:

- Agglutination – clumping
    - Clumps of bacterial cells are formed (due to 2 binding sites)
    - Phagocytes locate the pathogen more quickly
- Opsonisation – coating
    - Coat the pathogen, allowing the phagocyte to find it more quickly
- Lysis - digesting
- Antitoxins – neutralisation of toxins

Antibody Transcription

- Each lymphocyte will make different antibodies – each lymphocyte has different DNA
- mRNA is different in each cell (due to different DNA)
- Each polypeptide chain will be different (primary structure)
- ∴ the antibodies each lymphocyte will make will be unique

HIV

HIV positive – infected with HIV

- Viruses often remain dormant in an infected persons' body, leading to AIDS many years later
- HIV causes the symptoms of AIDS
- AIDS
    - Number of T-helper cells becomes very low
    - Immune system cannot stimulate B-cells to produce antibodies or cytotoxic T-cells, to kill infected cells
    - Making the person more likely to die from secondary infection
- How does HIV replicate?
    - Enters bloodstream
    - Binds to CD4 antigen on T-helper cells
    - Capsid and membrane fuse, inserting viruses RNA and enzymes into the host
    - Viral reverse transcriptase enzymes convert RNA to DNA
    - DNA is copied to make double stranded DNA
    - DNA inserted into hosts' chromosomes
    - HIV DNA transcribed to mRNA, containing instructions for viral proteins and RNA
    - mRNA passes out of nucleus, into ribosomes, translation occurs, forming new viral particles
    - Viral particles bud from T-helper cells, surrounded by a bit of cell membrane, forming their lipid envelope
    - New virus can then infect other cells

Antibiotics

- First discovered by Alexander Fleming, 1928, by accident
- Antibiotics are ineffective against viruses
    - Viruses do not have cell walls

    - Viruses lack metabolic pathways + cell structures
    - Viruses are inside host cells, so antibiotics cannot reach them
- How to they work?
- Osmotic Lysis
    - Inhibit synthesis and assembly of peptidoglycans in bacterial cell walls
    - Only work while bacteria are growing
    - Penicillin works in this way
- Preventing Reproduction
    - Prevent DNA replication
    - Prevent mRNA synthesis (transcription)
    - Prevent transfer of amino acids to ribosomes (translation)
    - Prevent protein synthesis

Vaccination

- A weakened, killed, or attenuated, pathogen, administered to stimulate the production of antibodies
- Provide a level of immunity, reducing the likelihood of severe disease / death
- Endemic Diseases
    - Diseases can remain endemic despite a vaccination programme
    - Some people don't develop immunity
    - Vaccine may be administered after someone has been infected
    - Pathogen has a high mutation frequency, so antigens change regularly
    - There are too many variants / strains to vaccinate against
    - Some pathogens disguise themselves (coat in self antigens, burrow into cells, in inaccessible places)
    - Patients may object on religious, ethical, or social reasons (vaccine hesitancy)
- Features of a Successful Vaccination Programme
    - Economical to make – few can be vaccinated if too expensive
    - Few / no side effects – if it is too dangerous, patients are discouraged
    - Production, storage, and transport need to be viable – it needs to reach patients safely
    - Trained staff need to administer vaccine correctly – must be given correctly to be effective
    - Most of the population needs to be vaccinated to offer herd immunity – preventing transmission through a community
- Antigenic Immunity
    - Viruses like flu mutate quickly
    - RNA is swapped between swine, avian, and human flus
    - This allows antigens to keep changing, requiring immunity to be built after each reinfection