BIOL1903 NOTES

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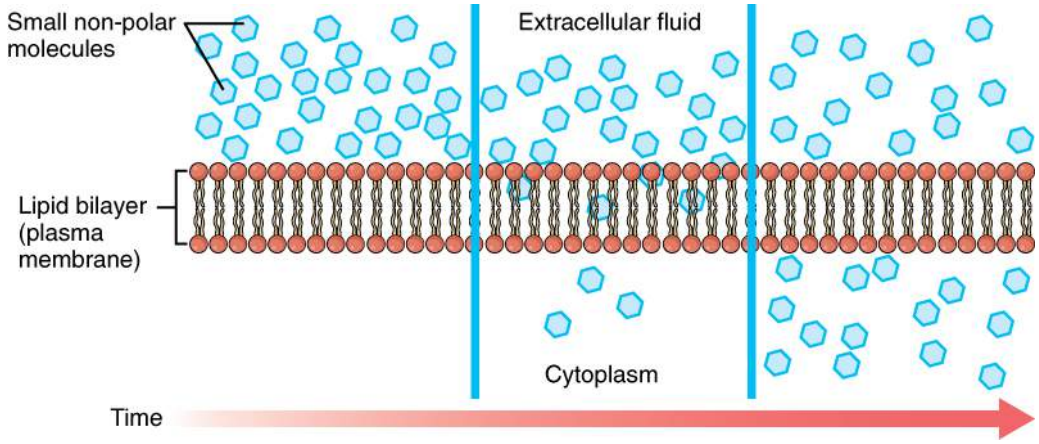
Cell Structure

Transport across the cell membrane

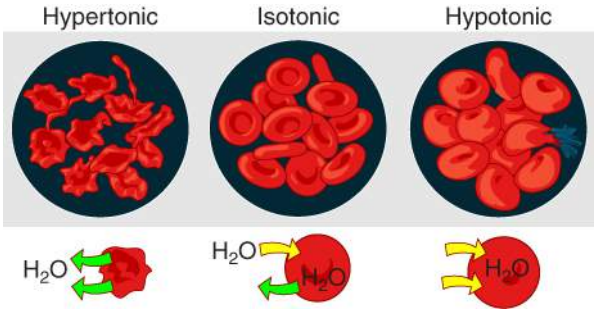
Transport across the cell membrane occurs as either active or passive transport. This allows the cell to regulate the conc of substances in the cell (e.g. Ca2+, Na+, K+, Cl-, sugars, amino acids, CO2 and fatty acids).

Passive transport:

- Occurs through diffusion (area of high conc. to low conc.)
- Substances can move down the conc. gradient until equilibrium is reached
- O2 moves into cell this way due to high conc outside of cell→ CO2 moves out due to high conc inside cell



Osmosis is the diffusion of water through a semipermeable membrane down a conc gradient



- A **hypertonic** solution has a solute conc higher than another solution
- An **isotonic** solution has a solute conc equal to another solution
- A **hypotonic** solution has a solute conc lower than another solution

Active transport:

- Requires ATP and the help of protein carriers
- Usually against the concentration gradient

- Sodium/ Potassium pump→ transports sodium out of the cell while moving potassium into the cell
    - Especially active in nerve cells
    - Each ion is pumped against its conc gradient→ 3 Na+ extracted and 2 K+ imported into cell

<u>Cell Organelles:</u>

Nucleus:

- Stores the cell hereditary material (DNA)
- Coordinates the cell activities→ growth, metabolism, protein synthesis, reproduction
- Nucleolus manufactures ribosomes
- Nuclear envelope is a double layered membrane that encloses the nucleus for its lifetime→ connects with the ER

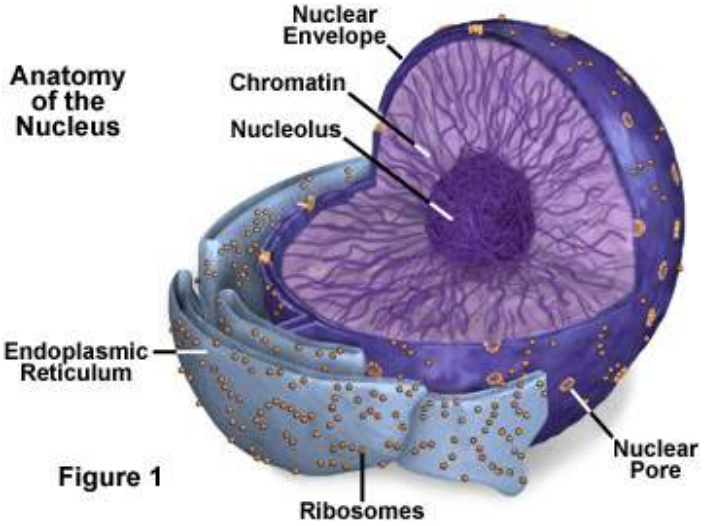
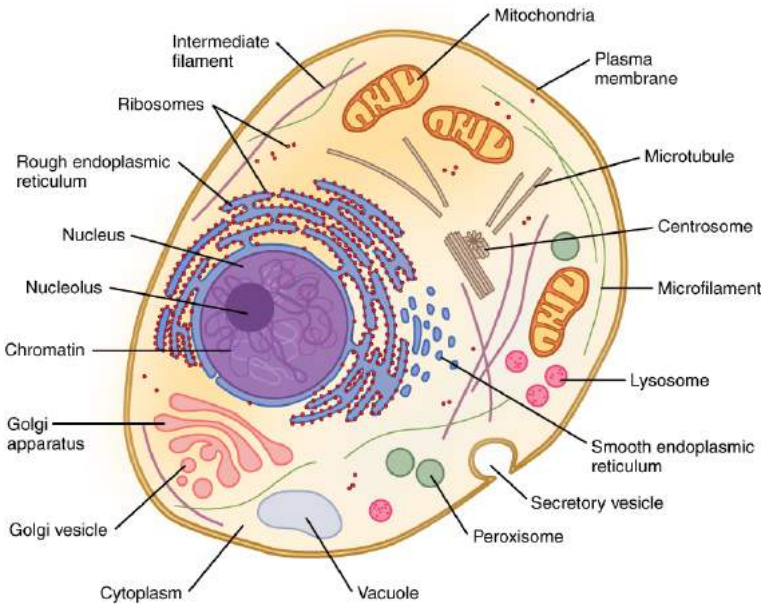


Figure 1

Cell Membrane:

- Pliable structure composed of phospholipids and cholesterol
- Separates the interior of the cell to from its exterior environment
- Regulates which materials can pass in and out of the cell

Membrane consists of two adjacent layers of phospholipids (Phospolipid Bilayer) arranged tail to tail, each with a hydrophilic head (attracted to water) and a hydrophobic tail which form the interior of the membrane, while the polar heads make contact with the fluid inside and outside the cell.



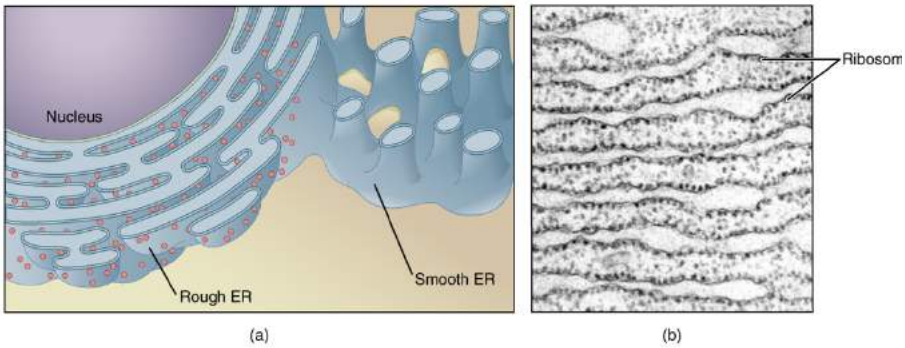
Endoplasmic Reticulum:

- Series of channels that is continuous with the nuclear membrane
- Composed of the same lipid bilayer material as the nucleus
- **Smooth ER**
    - Synthesis of lipids, phospholipids (main component of biological membranes) and steroid hormones (testes and ovaries contain large amounts of Smooth ER)
    - Stores and regulates the conc of Ca2+→ important in the nervous system

    - Metabolizes some carbohydrates and breaks down some toxins
- **Rough ER**
    - Membrane is dotted with ribosomes
    - Modification of proteins for the cell membrane
    - Protein is produced in the ribosome before being transported to the channels inside the Rough ER to which sugars are added to it (glycosylation) before being transported to the Golgi Apparatus

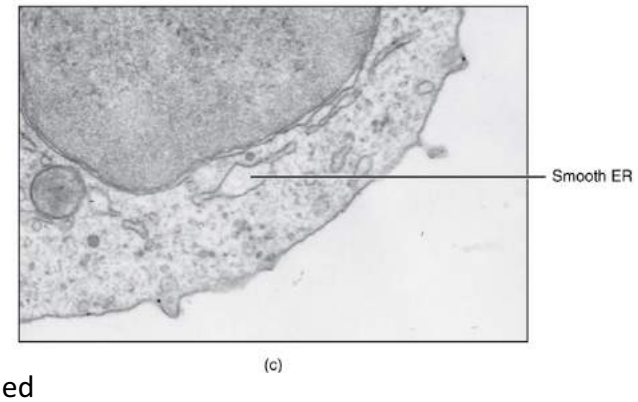
Ribosome:

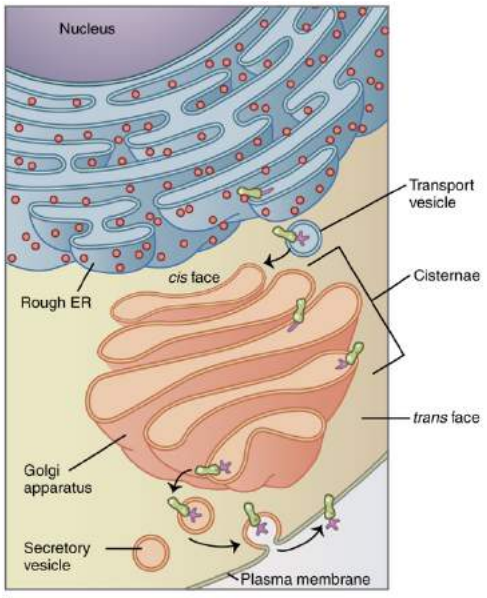
- Serves as the site of protein synthesis
- Composed of two ribosomal RNA units that wrap around the mRNA as it enters the ribosome from the nucleus to start the process of translation

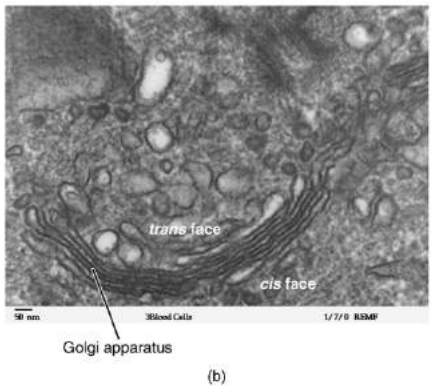


Golgi Apparatus:

- Sorting, modifying and transporting cell products that come from the rough ER (precursor proteins travel here)→ carbohydrates, lipids are added and proteins are folded
- Structure consists of flattened discs that are membranous
- One side of the Golgi Apparatus receives cell products from the ER→ these are sorted through the apparatus and are then released from the opposite side after being packaged into vessels
- Proteins are transported via secretory vesicles to surface of cell→known as **exocytosis**
- Produces **lysosomes**





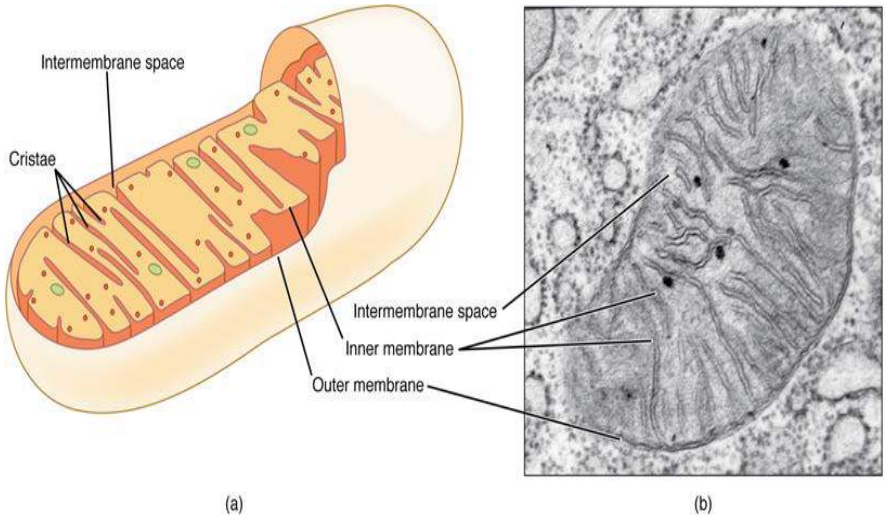


Lysosomes:

- Organelle that contains enzymes that break down and digest unneeded cellular components (e.g. a damaged organelle)→ known as **exocytosis**
- Lysosomes are packaged by the Golgi Apparatus
- **Autophagy** (the process of a cell digesting its own structures)
- Can break down foreign material→ i.e. a bacterium cell being engulfed by a phagocyte→ hence many WBC contain large amounts of lysosomes
- In damaged or unhealthy cells, the lysosomes can be triggered to release their digestive enzymes into the cytoplasm thereby killing the cell

Mitochondria:

- Consist of an outer bi-lipid layer as well as an inner bi-lipid layer
- Inner membrane is highly folded into structures called cristae
    - The membrane has a series of proteins and enzymes to perform cellular respiration
    - Convert energy stored in molecules such as glucose into ATP (adenosine triphosphate)
    - Muscle cells are densely packed with mitochondria as ATP is required for muscle contraction
    - Nerve cells require large amounts of ATP for their Na+/K+ pumps



Centrosome:

- Located in cytoplasm
- Pair of centrioles arranged at 90 degrees to each other→ known as diplosome
- Assists in formation of microtubules
- Responsible for spindle formation during mitosis

Centrioles:

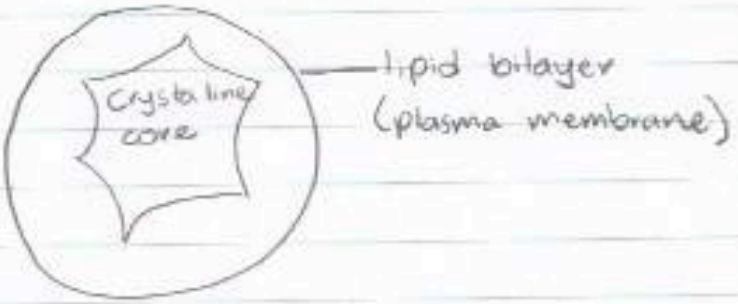
- Made of array of 9 microtubules

Secretory vesicle:

- Aids in cell secretions→ ie. Hormones + neurotransmitters
- Takes substances from organelle to cell membrane where it docks + fuses to release its contents

Peroxisomes:

- Membrane bound cellular organelle that contains enzymes
- Functions → lipid metabolism + chemical detoxification
- Enzymes inside serve to transfer H atoms from various molecules to oxygen forming H_2O_2 (hydrogen peroxide)
  - ↳ peroxisomes neutralise poisons such as alcohol in this way



- ↳ peroxisomes contain enzymes to neutralise H_2O_2 into H_2O + O_2 which are released into the cytoplasm.
- Liver cells contain large numbers of peroxisomes to neutralise toxins
- Oversee reactions that neutralise free radicals

Microvilli:

- Tiny projections on cells that exist with the villi
- Extend out of the villi on cells and contain their own cell membrane
  - ↳ inside the membrane is large amounts of microfilaments
- Found in small intestine, on egg cells and WBC
  - ↳ absorb nutrients in intestine
  - ↳ attach sperm to egg cell
  - ↳ Anchoring point to foreign objects in WBC
- Increase the SA/V ratio of cells

Surface Area to Volume Ratio:

- When a cell is small it has a large surface area to volume ratio (SA/V)
- When a cell is large it has a small SA/V ratio
- As a cell grows its volume increases at a greater rate than its surface area → ∴ its SA/V ratio decreases
- Cells can increase their SA/V ratio by:
  - * Long, thin shape → e.g. nerve cells
  - * Folding the surface of the cell membrane → e.g. villi lining the small intestine.
- Cells need to be small as they rely on diffusion for getting substances in and out.
  - ↳ as the cell grows, there is less membrane for the substances to diffuse through in comparasion with the size of the cell
  - ↳ this causes cell processes to slow, resulting in the cell stopping its growth.
  - ↳ the cell will divide into two smaller cells, each with a larger SA/V ratio.

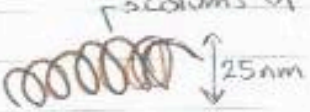
Cell Metabolism

- Energy released from the breakdown of food molecules is used to produce ATP
- Aerobic respiration occurs when oxygen is available
- Aerobic respiration of glucose produces 36 to 38 ATP molecules per molecule of glucose
- When oxygen isn't available, anerobic respiration occurs → producing lactic acid

Cytoskeleton:

- Helps cells maintain their structure + shape
- Fiberous proteins
  - ↳ help in cell motility, cell reproduction + transport of substances in cell.
- 3 kinds of filaments:

Microtubule:



- columns of tubulin dimers forming a 'tunnel'
- Thickest of the 3
- Composed of subunits of tubulin
- Maintain cell shape + structure, resist compression of the cell and position organelles within cell
- Make up the cilia and flagella
  - ↳ beating hairs ie. throat, fallopian tube.
  - ↳ tail in sperm cells

Set paths for which DNA can be pulled during cell division.
↳ in the form of Centrioles → grow out during cell division.

Microfilament:

- Thinnest of the 3
- Composed of Actin → fibres twist to form structure
- Large component of muscle tissue and is responsible for muscle contraction
- In muscle cells these strands are pulled by thick filaments to contract the cell
- During cell division the actin filaments work to create a cleavage that eventually splits the cell down the middle

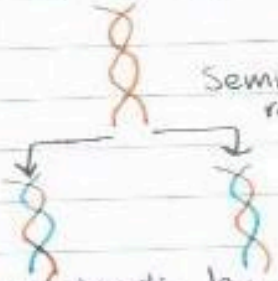
Intermediate filament:

- Made of long fiberous subunits of protein called keratin
- Keratin units are wound together like a rope to form a thread
- Along with microtubules, help to maintain cell structure
- They resist tension unlike the microtubules
  - ↳ useful in skin cells when skin is compressed.
- Anchor organelles within cell + link one cell to another.

DNA

- Deoxyribonucleic acid
- Composed of nucleotide units
- Made of two strands that complement one another
- Double helix shape
- DNA "backbone" consists of an alternating sugar-phosphate group
- Bases attach to the backbone → bases [Adenine Thymine] [Cytosine Guanine]
  ↳ a pair of bases is bonded together through Hydrogen bonds

- Nucleotide unit consists of nitrogenous base, sugar (deoxyribose) and a phosphate group.
- One strand of DNA is the 5'→3' (according to the carbon on the sugar molecules) while the other is 3'→5'
- 3 H bonds between C+G
- 2 " " " A+T



DNA Replication:

1. Helicase catalyses and unwinds the two strands by breaking the H bonds
2. Single stranded binding proteins keep the two strands apart
3. DNA Gyrase reduces the pressure from unwinding the helix
4. RNA primase polymerises the RNA primer which attaches to the origin and synthesises complimentary RNA bases to the DNA template
5. DNA polymerase catalyses the synthesis of a new DNA strand in the 5'→3' direction (leading strand)
6. The lagging strand is synthesied, however its creation is separated into Okazaki fragments and requires constant RNA primers for DNA polymerase to work → these primers are later removed and the spaces filled by polymerase
7. DNA ligase (linking enzyme) catalyses the formation of a covalent bond along the strand, linking the fragments together.

RNA

mRNA → messenger RNA
tRNA → transfer RNA
rRNA → ribosomal RNA

- Ribonucleic acid
- Single stranded
- Involved in coding of proteins
- Uracil replaces Thymine

Start codon → AUG
Stop codon → UGA

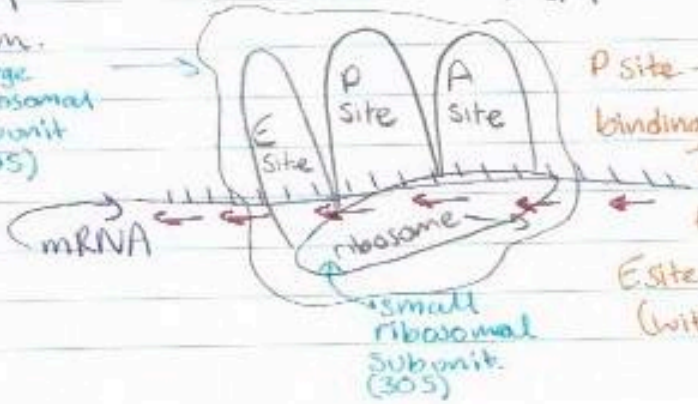
Protein synthesis:

Transcription:

1. RNA polymerase binds to a segment of DNA and unwinds it
2. " " reads the DNA template strand 3' → 5' and produces a RNA transcript by adding nucleotides to the 3' end (travels 5' to 3' for new RNA)
3. At the termination site, RNA polymerase detaches and the DNA rewinds
4. Caps are added to both 3' + 5' ends (ensures RNA remains intact as it is released into cytoplasm)
5. Introns (non-coding regions) are removed from the RNA transcript → the remains are spliced together creating mRNA
6. mRNA leaves the nucleus through a nuclear pore and enters the cytoplasm.

Translation:

1. ribosomes in the cytoplasm bind to the mRNA
2. tRNA units attach themselves to specific amino acids → these are brought to the ribosome and attach themselves (tRNA) to the mRNA as specified in the seaquence
3. Peptide bonds form between amino acids and the tRNA leave
4. Once a stop codon is reached the polypeptide is released into the cytoplasm.



P site → initial tRNA binding → where polypeptide grows
A site → new tRNA binding (to amino acid)
E site → tRNA leaves (without amino acid)

Cell Cycle

- Somatic cell → general term for human body cell
- All cells in human body undergo cell division (except for RBC, most neurons, some muscle cells)
- Somatic cells contain two copies of each ~~cell~~ of their chromosomes (known as a homologous pair)

Interphase:
- Period of cell cycle at which cell isn't dividing
- Cell carries out normal metabolic functions in a period known as G1 → growth phase in cell cycle
- For cells that will divide again G1 is followed by replication of the DNA → S Phase is where a cell replicates its DNA
- G2 Phase → cell continues to grow and prepare for mitosis
- G0 Phase → resting phase of a cell → cells that temporarily stopped dividing and cells that have permanently stopped (ie. nerve cells)

G1 → lasts from a few hours → to even days
S → 8-10 hours
G2 → 6 hours approx

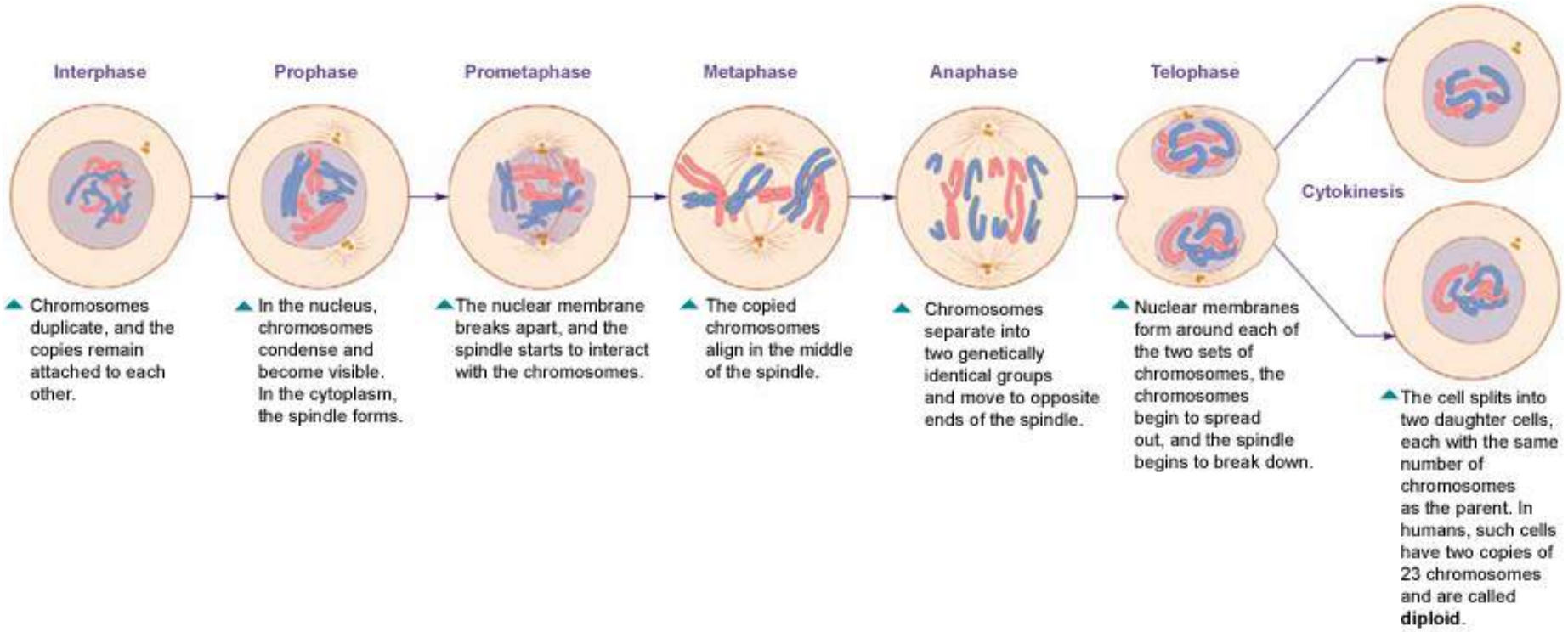
Mitosis + Cytokinesis:
- Takes between 1-2 hrs
- Prophase
  * Chromosomes condense + become visible
  * Spindle fibres emerge from centrosomes
  * Nuclear ~~envelope~~ envelope breaks down
  * Centrosomes move towards opposite poles
- Prometaphase
  * Microtubules attach themselves to the centromeres
  * Microtubules attach to kinetochore (attachment between spindle fibres (microtubule) and sister chromatids)

Metaphase:
- Chromosomes line up along a linear plane in the middle (known as the metaphase plate)
- Each sister chromatid is attached to a spindle fibre from opposite poles

Anaphase:
- Sister chromatids are seperated from one another forming individual chromosomes again.
- Each chromosomes is pulled to opposite ends of the cell by their kinetochores
- Each end of the cell recieves one partner from each pair of sister chromatids → each end contains identical genetic material.

Telophase:
- Daughter nuclei form at either end of the cell
- Spindle fibres begin to break down → pushing nuclei to oppaite ends of cell
- Chromosomes begin to losen into their usual form → chromatin
- Cell is begining to split as cytokinesis begins.

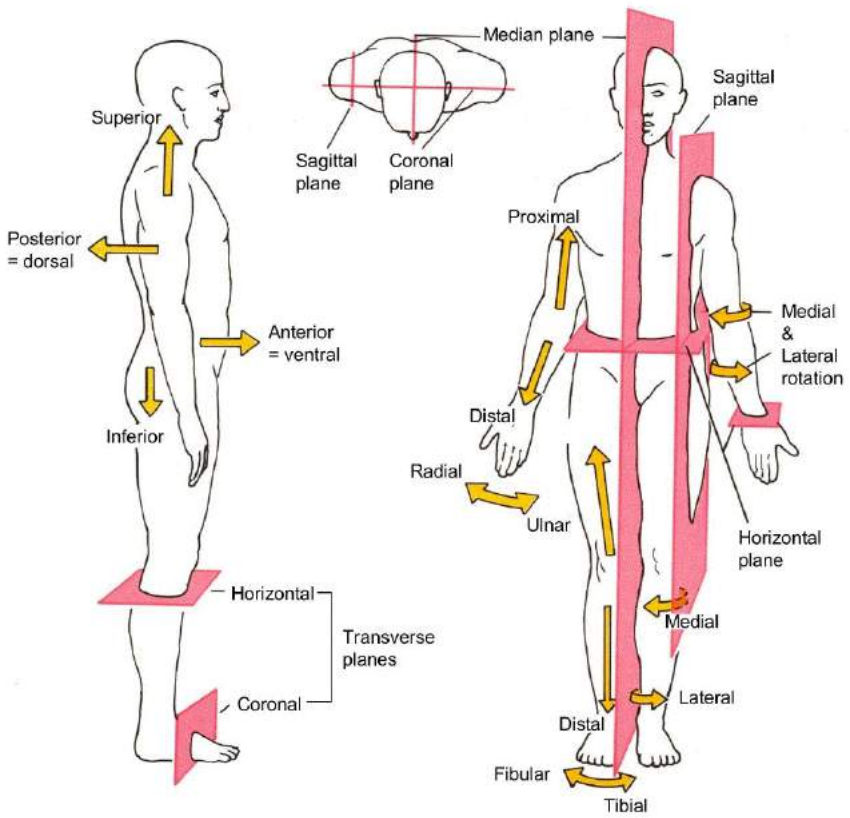
Cytokinesis:
- Cleavage furrow → many microfilaments that form in centre of cell
- Microfilaments squeeze the two cells apart until seperation is complete


Interphase
Prophase
Prometaphase
Metaphase
Anaphase
Telophase
Cytokinesis
Chromosomes duplicate, and the copies remain attached to each other.
In the nucleus, chromosomes condense and become visible. In the cytoplasm, the spindle forms.
The nuclear membrane breaks apart, and the spindle starts to interact with the chromosomes.
The copied chromosomes align in the middle of the spindle.
Chromosomes separate into two genetically identical groups and move to opposite ends of the spindle.
Nuclear membranes form around each of the two sets of chromosomes, the chromosomes begin to spread out, and the spindle begins to break down.
The cell splits into two daughter cells, each with the same number of chromosomes as the parent. In humans, such cells have two copies of 23 chromosomes and are called diploid.

The Skeletal System

Anatomical Position:

Sagittal→ divides body into right and left parts
Midsagittal→ divides body into equal halves
Transverse→Divides body into superior and inferior parts
Coronal→ divides body into anterior and posterior



Anatomy and Structure of bone:

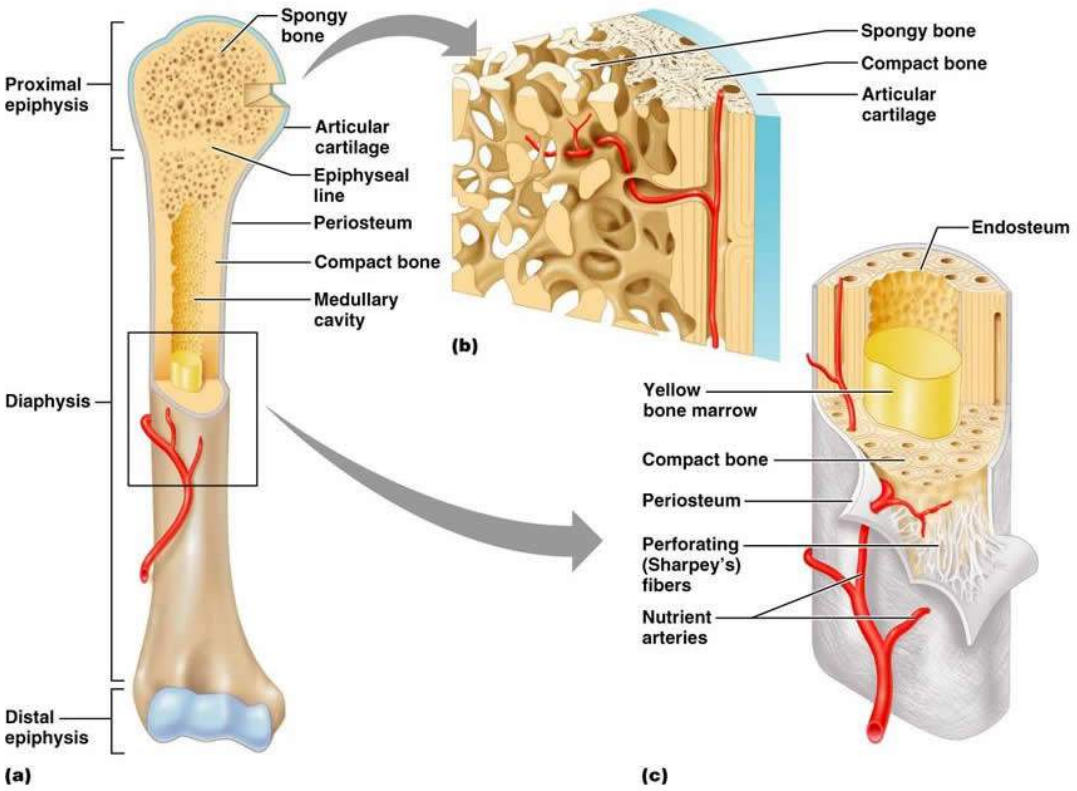
Bone consists of bone cells and bone matrix→ bone cells produce the bone matrix and become trapped inside it. These cells break down so that new matrix can replace old matrix

Bone matrix:

- 35% organic material→ collagen
- 65% inorganic material→ calcium and phosphates
- It is these components combined that provide bone with its high tensile strength
    - If the collagen is removed the bone becomes brittle as the mineral component becomes the primary building block
    - If the minerals are removed then the collagen becomes the main building block, hence making the bone overly flexible

Anatomy of a long bone:

- Diaphysis→ shaft of the long bone
- Epiphysis→ located on each end of a long bone (proximal and distal)→ develops from a centre of ossification from the diaphysis
- Periosteum→ Double layered tissue that covers the outer surface of the bone (except where cartilage is present)
- Endosteum→ Thin connective tissue that lines the the inner of the bone
- Articular cartilage→ cartilage that covers the bone where it forms a joint with another bone
- Medullary cavity→ large cavity in the diaphysis
- Red marrow→ connective tissue in the spaces of cancellous bone or in the medullary cavity→ site of RBC production
- Yellow marrow→ fat stored within the medullary cavity or in the spaces of cancellous bone

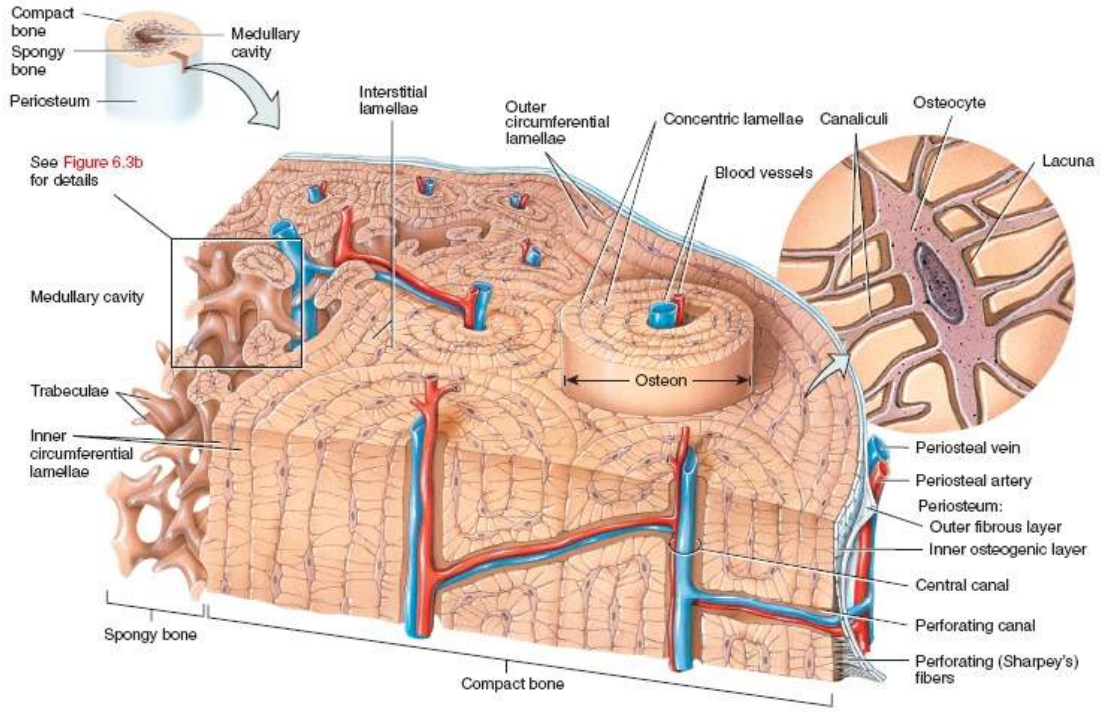


Bone cells:

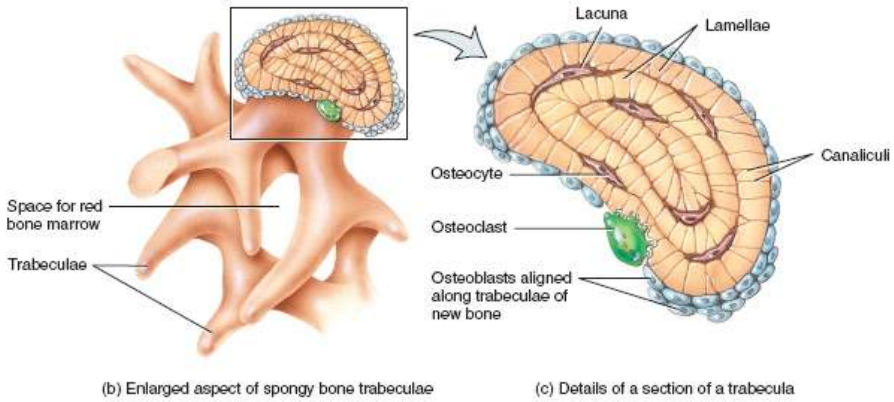
- Osteoblasts
    - Bone forming cells
    - Large amounts of ER and ribosomes
    - Produce collagen which are released by the cell through exocytosis
    - Process by which bone is formed is called Ossification
    - Bone matrix produced by the osteoblasts covers the older bone surface and surrounds the osteoblast cell bodies and process→ creating new bone
- Osteocytes
    - Once an osteoblast is surrounded by the bone matrix it becomes an Osteocyte
    - Can produce the the components needed to maintain the bone matrix
    - Osteocytes occupy spaces known as **lacunae**
    - Spaces occupied by osteocyte cell processes known as **canaliculi**
    - Cell and its processes form a 'mould' around from which the bone matrix is formed
    - Bone cells are in contact with one another through the canaliculi
        - This allows nutrients and gasses to pass through the small amount of fluid surrounding the cells in the canaliculi and lacunae
- Osteoclasts
    - Bone destroying cells
    - Breakdown bone that allows Ca2+ and phosphate for use in metabolic processes

- Originate in the red bone marrow
- Create a sealed compartment between the bone and the cell (creates an acidic environment for breaking down the bone)
- Causes decalcification of the bone matrix→as protein digestion enzymes are secreted onto the surface of the bone matrix
- Products removed by osteoclasts move to the cytoplasm where they are secreted into the blood to be used elsewhere in the body

Types of Bone:



(a) Osteons (haversian systems) in compact bone and trabeculae in spongy bone



(b) Enlarged aspect of spongy bone trabeculae (c) Details of a section of a trabecula

- Cancellous or spongy bone
  - Honey comb matrix
  - Consists of interconnecting rods of bone that are called **trabeculae**
    - Most trabeculae are thin and consist of many lamellae with osteocytes located in lacunae between other lamellae (see above) and are surrounded by endosteum