

Topic 1: Cells

1.1 Cell theory, cell specialization, and cell replacement

U1	According to the cell theory, living organisms are composed of cells.
U2	Organisms consisting of only one cell carry out all functions of life in that cell
U3	Surface area to volume ratio is important in the limitation of cell size.
U4	Multicellular organisms have properties that emerge from the interaction of their cellular components.
U5	Specialized tissues can develop by cell differentiation in multicellular organisms.
U6	Differentiation involves the expression of some genes and not others in a cell's genome.
U7	The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.
A1	Questioning the cell theory using atypical examples, including striated muscle, giant algae and aseptate fungal hyphae.
A2	Investigation of functions of life in Paramecium and one named photosynthetic unicellular organism.
A3	Use of stem cells to treat Stargardt's disease and one other named condition.
A4	Ethics of the therapeutic use of stem cells from specially created embryos, from the umbilical cord blood of a new-born baby and from an adult's own tissues.
S1	Use of a light microscope to investigate the structure of cells and tissues, with drawing of cells. Calculation of the magnification of drawings and the actual size of structures and ultrastructures shown in drawings or micrographs. (Practical 1)

Cell Theory

- **Cells are the basic unit of structure in all living things (smallest unit of life)**

Specialized structures within cells (organelles) carry out different functions. Organelles cannot survive alone.

- **All living organisms are composed of cells.**
- **New cells are formed from pre-existing cells.**

Cells multiply through division

All life evolved from simpler ancestors

Mitosis results in genetically identical diploid daughter cells

Meiosis generates haploid gametes (sex cells)

Functions of life (Mrs.H.Gren)

- **Metabolism:** All the chemical reactions that occur within an organism
- **Reproduction:** Hereditary molecules that can be passed to offspring
- **Sensitivity:**
- **Homeostasis:** the maintenance and regulation of internal cell condition e.g. temperature
- **Growth:** limited but always evident in one way or another
- **Response:** imperative for the survival of an organism
- **Excretion:** Enable those chemical compounds that an organism cannot use or that may be toxic or harmful to it to be released from the organism's system
- **Nutrition:** Providing a source of compounds with many chemical bonds that can then be broken down to provide an organism with the energy necessary to maintain life

Cells and sizes

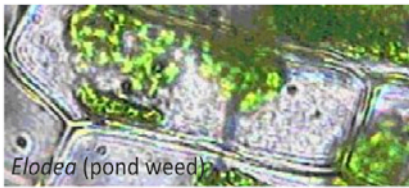
➤ Why are cells small?

- ✓ Diffusion pathway is smaller when cell is smaller, takes less time and energy to move.
- ✓ Surface area to volume ratio is larger
- Larger **SA: VOL Ratio**, more efficient diffusion.
- (However, loses heat and water more quickly)
- Cells need to exchange substances with their surroundings, such as food, waste, heat, and gases.
- In the cytoplasm, chemical reactions take place which are known as metabolic reactions. These reactions produce heat, wastes, and also consume resources. The rate of these reactions is proportional to the volume of the cell, while the exchange of these materials and heat energy is a function of the cell's surface area.
- **A cell increases in size, its surface area to volume ratio (SA/V) will decrease.**
- As the SA to volume ratio decreases, the rate or the cell's ability to exchange materials through diffusion or radiation decreases.
- If metabolism is to continue at an optimum rate, substances such as oxygen must be absorbed and waste products such as carbon-dioxide need to be removed.
- Also if too much heat is produced during metabolism in comparison to the amount the cell is able to remove, the cell might overheat.

- Therefore, the greater the SA/volume ratio is, the faster the cell can remove waste and heat, and absorb oxygen and nutrients essential for the cell to function properly.
- **Exception:** small, warm-blooded mammals lose heat very quickly due to their large SA:Vol ratio e.g shrew; desert plants would lose water quickly with fat leaves, so they minimize their SA:Vol ratio in order to conserve more water e.g. cactus

Calculate magnification

CALCULATING MAGNIFICATION



We might want to know how many times an image has been magnified.

The scale bar represents the 'real' size of the sample in the image, so we only need to work with the scale bar.

First convert your units so that they are all the same:

scale bar = μm , so convert ruler to μm

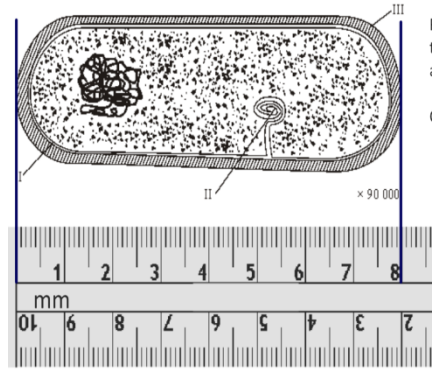
1 mm = 1,000 μm so 20mm = 20,000 μm

Now we can calculate the magnification:

$$\frac{\text{scale bar measurement (we just measured)}}{\text{scale bar label ('real life' of sample)}} = \frac{20,000 \mu\text{m}}{10 \mu\text{m}}$$

magnification = 2,000 times

CALCULATING ACTUAL SIZE (NO SCALE BAR)



For this type of question, simply measure the part of the image you are instructed to and divide it by the magnification.

Convert to the most appropriate units.

$$\frac{\text{e.g. measured length}}{\text{magnification}} = \frac{80\text{mm}}{90,000} = 8.9 \times 10^{-4}\text{mm}$$

or 0.00089mm

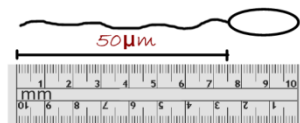
converts to: 0.89 μm

should have an integer on this side of the point \rightarrow this is best - gives us clear whole numbers \rightarrow or 890nm

Example

2. A sperm cell has a tail 50 μm long. A student draws it 75mm long. What is the magnification?

If you're stuck, draw it out...



1. Convert mm to μm :

$$75\text{mm} = 75,000\mu\text{m}$$

2. $\frac{\text{drawing length}}{\text{scale bar label}}$

$$= 75000/50$$

$$= 1500\times \text{magnification}$$

Stem cells

- Stem cells are characterized by the ability to divide through mitotic cell division and differentiate along different pathways to become a diverse range of specialized cell types.
- At early embryonic stages, the stem cells can still divide have ability to become any type of cell, until they express certain genes and differentiate into a specific type of cell.
- Two main types of stem cells are adult stem cells which are found in adult tissues such as the **bone marrow** and **embryonic stem cells** that are found in the inner cell mass of blastocysts.
- Another source of stem cells is from the umbilical **cord** of newly born fetuses (cord blood stem cells)
- Stem cells can be categorized into totipotent, pluripotent, multipotent and unipotent according to their ability to differentiate

The use of stem cells in some disease

- **Stargardt's Macular Dystrophy** – Is a genetic disease that develops in children that can cause blindness
- The disease affects a membrane protein in the **retina** causing the photoreceptor cells in the retina to become degenerative
- The treatment involves injecting embryonic stem cells that can develop into retina cells in to the back of the eyeball
- The cells attach to the retina and begin to grow, improving an individual's vision, with limited side effects
- **Leukemia** (same from above) – is caused by a mutation in the genes that control cell division, which will create an abnormal amount of white blood cells. These white blood cells are produced in the bone marrow
- One of the greatest therapeutic successes for the use of stem cells has been for the treatment of leukemia or lymphomas through bone marrow transplants.
- This involves using hematopoietic stem (HS) cells (blood stem cells) derived from bone marrow tissue.

- These cells will divide continually to form new red and white blood cells.
- Using a large needle, stem cells are removed from the bone marrow of the patient or from a donor person, such as a brother or a sister.
- The patient undergoes **chemotherapy and radiation therapy to kill the cancer cells** in the bone marrow. However, normal dividing cells in the blood will also be killed.
- After chemotherapy and radiation therapy the HS cells will be transplanted directly in to the bloodstream through a tube called a central venous catheter.
- The stem cells find their way into the bone marrow, where they will begin reproducing and making healthy new blood cells.

Ethical concern of using stem cells

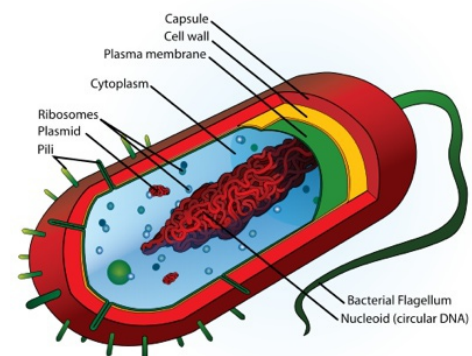
- The therapeutic use of stem cells involves the creation and the death of an embryo that has not yet differentiated in order to supply embryonic stem cell lines for stem cell research and stem cell therapies.
- The biggest ethical concern involves the creation of a new human embryo. Is it ethically acceptable to create a human embryo for biomedical research even if the research and therapies developed from the research could save human lives? Different people have a views of when human life begins.

1.2 Ultrastructure of cells

U1	Prokaryotes have a simple cell structure without compartmentalization.
U2	Eukaryotes have a compartmentalized cell structure.
U3	Electron microscopes have a much higher resolution than light microscopes.
A1	Structure and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cells of the leaf.
A2	Prokaryotes divide by binary fission.
S1	Drawing of the ultrastructure of prokaryotic cells based on electron micrographs.
S2	Drawing of the ultrastructure of eukaryotic cells based on electron micrographs.
S3	Interpretation of electron micrographs to identify organelles and deduce the function of specialized cells

Prokaryotic cell structure

- All prokaryotes have a cell membrane and a cell wall surrounding the outside membrane. The cell wall is made from peptidoglycan. The entire interior of the cell is filled with cytoplasm (not compartmentalized) as no membrane-bound nucleus is present. (**bacteria cells**)
- The cell wall
- The plasma membrane
- Flagella
- Pili
- Ribosomes
- The nucleoid (a region containing free DNA)



The cell wall and plasma membrane

- ✓ The prokaryotic cell wall protects and maintains the shape of the cell
- ✓ To large extent the plasma membrane controls the movement of materials into and out of the cell, and it plays a role in binary fission of the prokaryotic cell. All cellular processes within prokaryotic cells occur within the cytoplasm.
- ✓ Cell wall is made from peptidoglycan not from cellulose

Pili and flagella

- ✓ Hair-like growths on the outside of the cell wall; Used for attachment, joining bacteria cells in preparation for the transfer of DNA (sexual reproduction)

Ribosomes(70s)

- ✓ Occur in all prokaryotic cells (granular appearance in an electron micrograph of prokaryotic cell)
- ✓ Sites of protein synthesis

The nucleoid region

- ✓ Non-compartmentalized
- ✓ Contains a single, long, continuous, circular thread of DNA, the bacterial chromosome
- ✓ Involves cell control and reproduction

Binary fission

- ✓ Replicated semi-conservatively
- ✓ Two DNA loops attached to membrane
- ✓ Form two separate cells
- ✓ Genetically identical

Summary

- DNA is not enclosed within a membrane and forms one circular chromosome
- DNA is free; not attached to proteins
- Lack membrane-bound organelles
- Cell wall is made up of peptidoglycan
- Divide by binary fission
- Characteristically small in size

Eukaryotic cell structure

Eukaryotes have a much more complicated cellular structure. The inside of the cell also contains cytoplasm but it is separated by compartments that allow for specialization. The compartments are membrane-bound organelles such as the nucleus and the mitochondria. Compartmentalization enables different chemical reactions to be separated and chemicals to be isolated (increase efficiency.)

Organelles of eukaryotic cells

- Rough/ Smooth Endoplasmic reticulum
- Ribosomes
- Lysosomes
- Golgi apparatus
- Mitochondria
- Nucleus
- Chloroplasts
- Vacuoles

Cytoplasm

- Occurs inside the plasma membrane or the outer boundary of the cell, where organelles are found
- The fluid portion of the cytoplasm around the organelles is called the cytosol

Endoplasmic reticulum

- Extends from the nucleus to the plasma membrane
- Transports materials throughout the internal region of the cell
- Smooth ER (no ribosomes on its exterior) and Rough ER (with ribosomes on its exterior)
 - Rough endoplasmic reticulum
- Consist flattened membrane sacs, called **cristernae**
- Contains ribosome for secreted protein (transportation)

Ribosomes(80s)

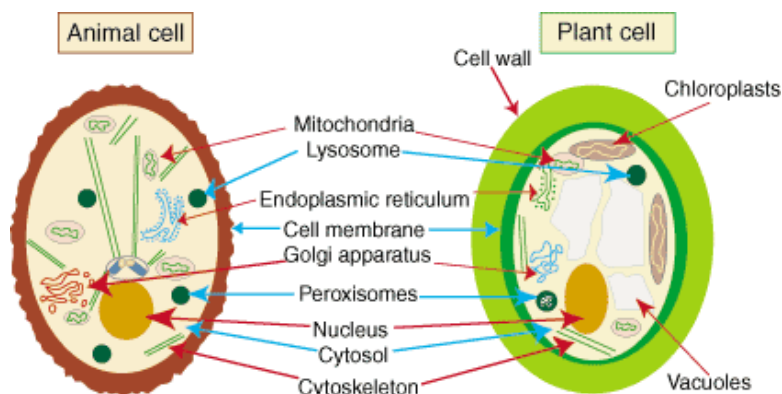
- Composed of RNA and protein
- Proteins Synthesis

Lysosomes

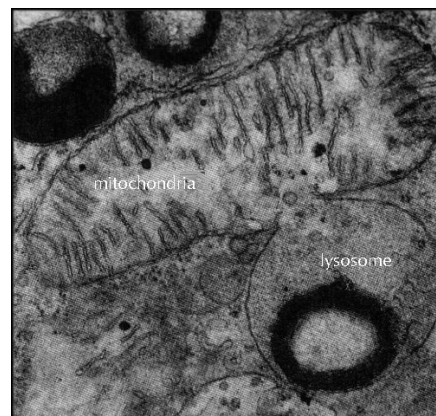
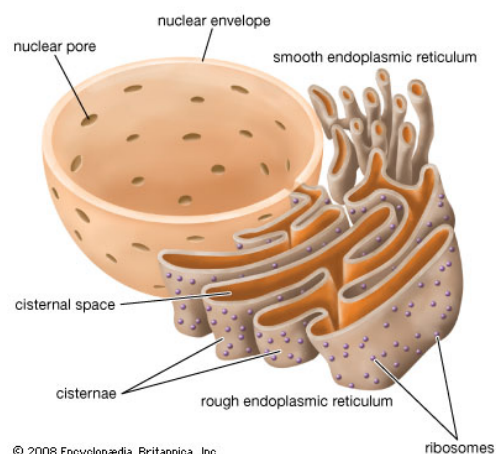
- Spherical with a single membrane
- Formed from Golgi Vesicles
- Contain digestive enzymes for breakdown of
 1. Ingested food in vesicles
 2. Damaged/unwanted organelles
 3. The cell itself
- Stain heavily – appear dark on micrographs

Golgi apparatus

- Flattened membrane sacs, called cisternae
- No attached ribosomes
- Sited close to the plasma membrane
- Shorter and more curved cisternae
- Processes proteins from the rER. The proteins are then repackaged in vesicles for secretion outside the cell.



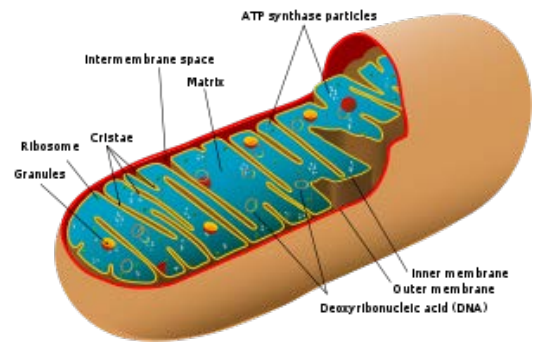
Endoplasmic reticulum



Mitochondria

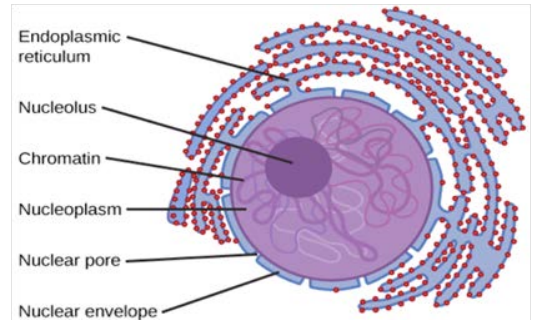
- Double membrane
- Smooth outside, folded inside
- Folds-----**cristae**
- Variable in shape
- Site of ATP production by aerobic respiration

Endosymbiotic theory: mitochondria and chloroplast, long before, are individual bacteria who decide to join larger eukaryotic cells



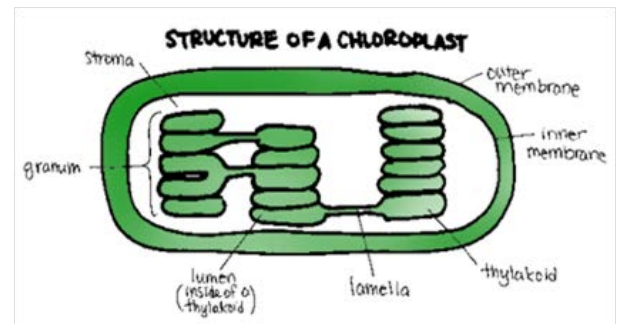
Nucleus

- Generally spherical with a double membrane
- Pores (holes) are present in the membrane
- Contains genetic information in the form of chromosomes (DNA and associated histone proteins)
- Uncoiled chromosomes are referred to as chromatin – they stain a dark colour and are concentrated at the edges of the nucleus
- mRNA is transcribed in the nucleus (prior to use in protein synthesis in the cytoplasm)
- mRNA leaves the nucleus via the pores (DNA is too large to move through the pores)



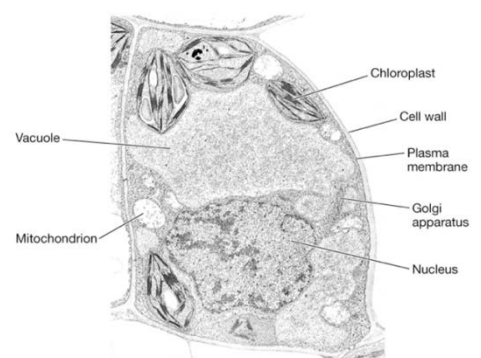
Chloroplasts(plants only)

- **Many, but not all, plant cells** contain chloroplasts
- A double membrane surrounds the chloroplast
- Inside are stacks of thylakoids
- Each thylakoid is a disc composed of a flattened membrane
- The shape of chloroplasts is variable but is usually ovoid
- The site of photosynthesis and hence where glucose is produced.
- Starch grains maybe present if photosynthesis is happening quickly



Cell wall(plants only)

- An extracellular component not an organelle.
- Secreted by **all plant cells** (fungi and some protists also secrete cell walls).
- Plant cell walls consist mainly of **cellulose** which is:
 1. Permeable - does not affect transport in and out of the cell
 2. Strong – gives support to the cell and prevent the plasma membrane bursting when under pressure
 3. Hard to digest –resistant to being broken down, therefore lasts a long time without the need for replacement/maintenance



Vacuoles

- Single membrane with fluid inside
- In Plant cells vacuoles are large and permanent, often occupying the majority of the cell volume
- In animal cells vacuoles are smaller, temporary, and used for various reasons.
e.g. to absorb food and digest it

A comparison of prokaryotic and eukaryotic cells

Prokaryotic	Eukaryotic
DNA in a ring without protein	DNA with proteins as chromosomes
DNA free in the cytoplasm	DNA enclosed within nucleus
No mitochondria	Mitochondria present
70s ribosomes	80s ribosomes
No internal compartmentalization	internal compartmentalization present to form many organelles
Size less than 10µm	Size more than 10µm

A comparison of plant and animal cells and their extracellular components

Plant	Animal
The exterior of the cell only includes a cell wall with a plasma membrane inside	The exterior of the cell only includes a plasma membrane; no cell wall
Chloroplasts present	No chloroplasts
Vacuoles present	No vacuoles
70s ribosomes	80s ribosomes
No internal compartmentalization	internal compartmentalization present to form many organelles
Size less than 10µm	Size more than 10µm

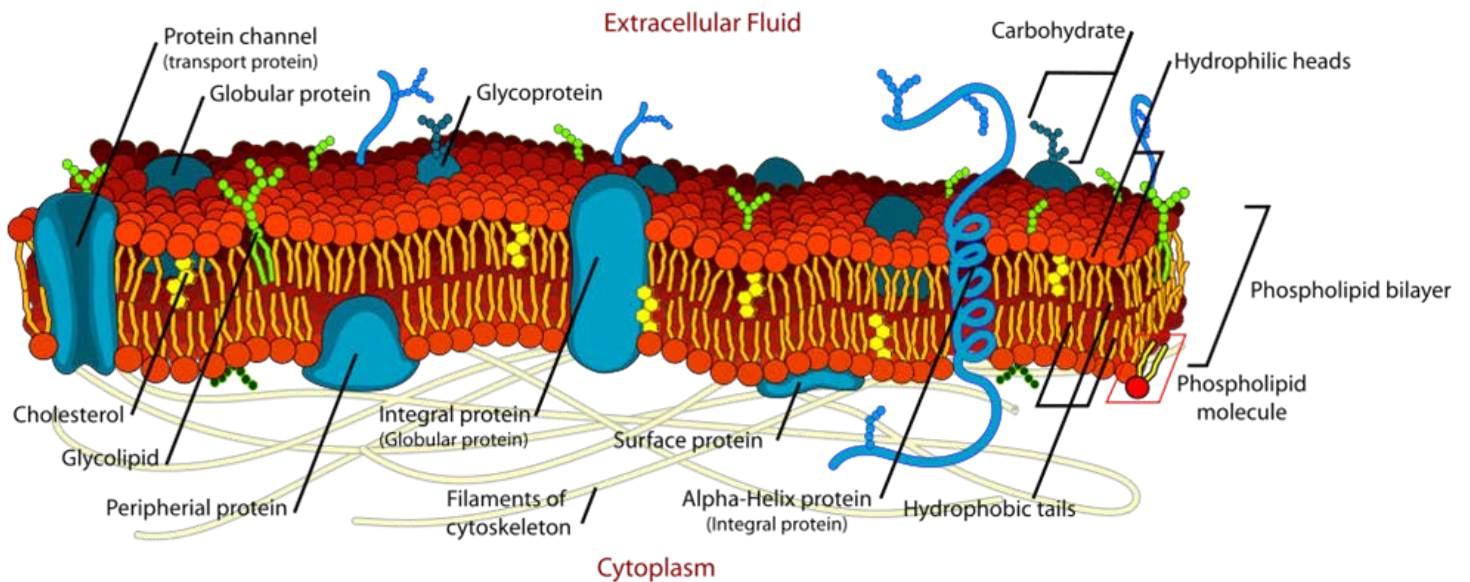
Electron microscope

- The limit of resolution is the minimum distance that can be observed before two objects merge together to form one object. The smaller the limit of resolution the higher the resolving power.
- Electron microscopes have a greater resolution (about .001 µm) when compared to a light microscope (about 0.2 µm)
- The resolution of light microscopes is limited by the wavelength of light (400-700 nm). If the magnification becomes too great the image becomes blurry
- Electrons have a much shorter wavelength so they have much greater resolution (about 200x greater than a light microscope)

1.3 Membrane structure

U1	Phospholipids form bilayers in water due to the amphipathic properties of phospholipid molecules.
U2	Membrane proteins are diverse in terms of structure, position in the membrane and function.
U3	Cholesterol is a component of animal cell membranes.
A1	Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes.
S1	Drawing of the fluid mosaic model.
S2	Analysis of evidence from electron microscopy that led to the proposal of the Davson-Danielli model.
S3	Analysis of the falsification of the Davson-Danielli model that led to the Singer-Nicolson model.

Membrane Structure

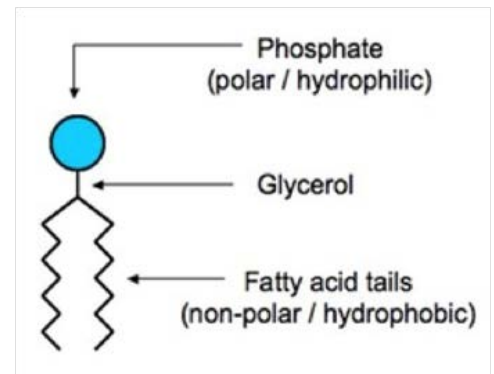


Properties of cell membrane

- Cell membranes are composed of phospholipids that consist of a **hydrophilic** (attracted to water) head and a **hydrophobic** (repelled by water) tail
- The phospholipid head contains a negatively charged phosphate group which because of its charge is attracted to water because of its polarity
- The fatty acid hydrocarbon tail has no charge and is therefore repelled by water
- When placed in water, the phospholipids naturally form a double layer with the heads facing outwards towards the water and the tails facing each other inwards (micelle or liposome)
- This forms a very stable structure that surrounds the cell because of the attractions and bonds that are formed between the heads to the water and to each other, and the hydrophobic interactions between the tails
- Even though it is a very stable structure, it is still **fluid**, as the phospholipids can move along the horizontal plane
- To increase stability, many cells have **cholesterol** imbedded between the phospholipids

Phospholipids

- A bilayer produced from huge numbers of molecules
- Composed of a three-carbon compound called glycerol
- Two of the **glycerol** carbons have fatty acids
- The third carbon is attached to a highly polar organic alcohol that includes a bond to a phosphate group



Cholesterol

- Allow membrane to function effectively at a wider range of temperatures
- Plant cells do not have cholesterol molecules**
- Cholesterol is a lipid that belongs in the steroid group and is also a component of the cell membrane
- Most of the cholesterol molecule is hydrophobic and therefore embeds within the tails of the bilayer. A small portion (hydroxyl –OH group) is hydrophilic and is attracted to the phospholipid head
- Cholesterol embedded in the membrane will reduce the fluidity making the membrane more stable by the hydrophilic interactions with the phospholipid heads
- While cholesterol adds firmness and integrity to the plasma membrane and prevents it from becoming overly fluid, it also helps maintain its fluidity by disrupting the regular packing of the hydrocarbon tails.
- Therefore, cholesterol helps prevent extremes-- whether too fluid, or too firm-- in the consistency of the cell membrane

Proteins

Embedded in the fluid matrix of the phospholipids bilayer

Integral protein	Permanently embedded, go all the way through,
Peripheral protein	Temporary association, bounded to the surface of the membrane
Glycoprotein	Protein attached with a sugar chain

Membrane protein functions

- ✓ Transport: Protein channels (facilitated) and protein pumps (active)
- ✓ Receptors: Peptide-based hormones (insulin, glucagon, etc.) binding-----relay the message
- ✓ Anchorage: permanent or temporary junctions
- ✓ Cell recognition: MHC proteins and antigens
- ✓ Intercellular (between cells) joinings: Tight junctions, an identification label
- ✓ Enzymatic activity: Metabolic pathways (e.g. electron transport chain)

1.4 Membrane transport

U1	Particles move across membranes by simple diffusion, facilitated diffusion, osmosis and active transport.
U2	The fluidity of membranes allows materials to be taken into cells by endocytosis or released by exocytosis. Vesicles move materials within cells.
A1	Structure and function of sodium–potassium pumps for active transport and potassium channels for facilitated diffusion in axons.
A2	Tissues or organs to be used in medical procedures must be bathed in a solution with the same osmolarity as the cytoplasm to prevent osmosis.
S1	Estimation of osmolarity in tissues by bathing samples in hypotonic and hypertonic solutions.

Passive and active transport

- Passive transport (no energy required) -- Movement occurs along a concentration gradient
- Active transport (energy required) -- The substance is moved against a concentration gradient

Passive transport: diffusion and osmosis

- **Diffusion** is the passive net movement of particles from a region of high concentration to a region of low concentration.

All living things need to take in nutrients to live and to get rid of waste

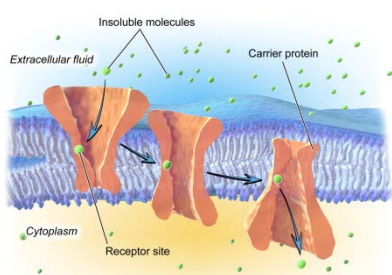
- Take in to the cells: Oxygen, Nutrients (food), Water etc.
- Remove from the cells: Carbon dioxide, Urea etc.

- **Facilitated Diffusion (passive)** - Specific ions and other particles that cannot move through the phospholipid bilayer sometimes move across protein channels.

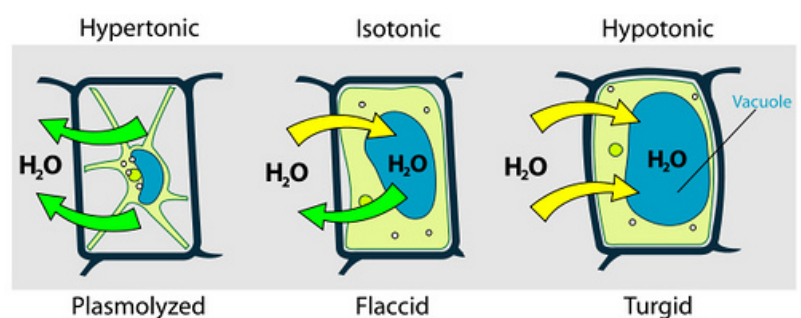
- A particular type of diffusion involving a membrane with specific carrier proteins that is capable of combining with the substance to aid its movement.
- Molecules cannot pass the membrane due to its size or charge
- Each protein channel structure allows only one specific molecule to pass through the channel. For example, magnesium ions pass through a channel protein specific to magnesium ions.

- **Example of facilitated diffusion: Osmosis:** The movement of water molecules from an area of high water potential to an area of low water potential through a partially permeable membrane.

- **Hypertonic solution** – Is a solution with a higher osmolarity (higher solute concentration) than the other solution. If cells are placed into a hypertonic solution, water will **leave the cell** causing the cytoplasm's volume to **shrink** and thereby forming indentations in the cell membrane, leading to weak structure. The cell in this case is **plasmolysed**
- **Hypotonic solution** – Is a solution with a lower osmolarity (lower solute concentration) than the other solution. If cells are placed in a hypotonic solution, the **water will rush into** the cell causing them to **swell** and possibly burst, leading to strong structure. The cell in this case is **turgid**.
- Both of the above solutions would damage cells, therefore isotonic solutions are used (same osmolarity as inside the cell)
- **Isotonic solution:** A solution that has the same salt concentration as cells and blood. The cell in this case is **flaccid**.

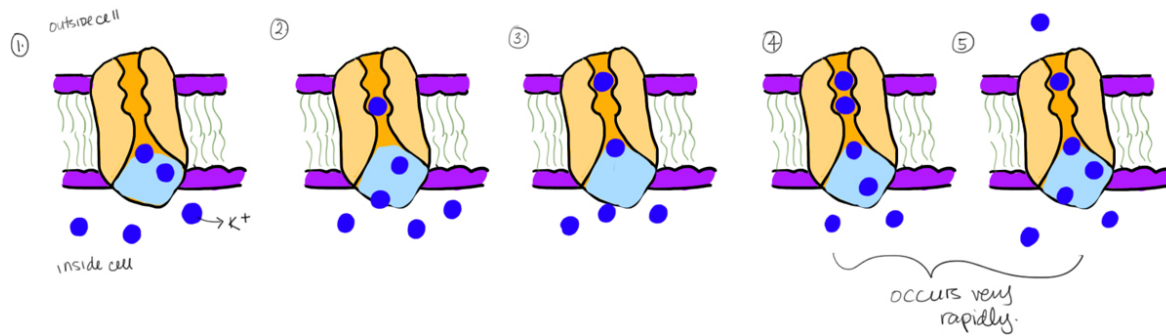


Facilitated Diffusion



- In **medical procedures**, isotonic solutions are commonly used as: eye drops; packing donating organs, fluid introduction to blood system

Potassium channels



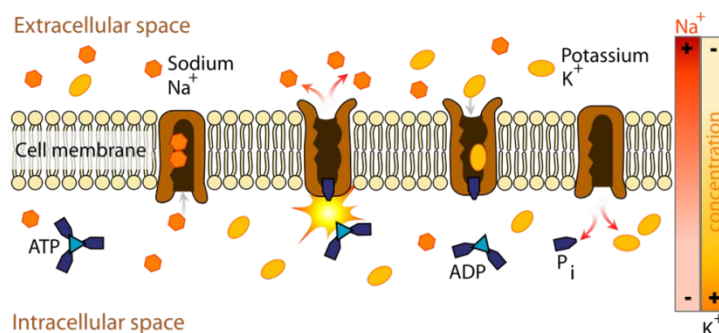
Potassium channel is an example of facilitated diffusion. They are voltage gated, which means it uses voltage to control the open and close of the gate. If there is more positive charges inside the cell, voltage will change and lead to the open of the gate; then, potassium ions will rush out until the charge is neutral.

Type of passive transport	Description of membrane
Simple diffusion	passive net movement of particles from a region of high concentration to a region of low concentration
Facilitated diffusion	Specific ions and other particles that cannot move through the phospholipid bilayer sometimes move across protein channels
Osmosis	Only water moves through the membrane using aquaporins, which are proteins with specialized channels for water movement

Active transport

- **Active transport** is movement of molecules through a cell membrane from a region of low concentration to a region of high concentration against the concentration gradient using ATP (energy)
- Many different protein pumps are used for active transport. Each pump only transports a particular substance; therefore cells can control what is absorbed and what is expelled.
- Pumps work in a specific direction; substances enter only on one side and exit through the other side.
- Substances enter the pump from the side with a lower concentration.
- Energy from ATP is used to change the conformational shape of the pump.
- The specific particle is released on the side with a higher concentration and the pump returns to its original shape.

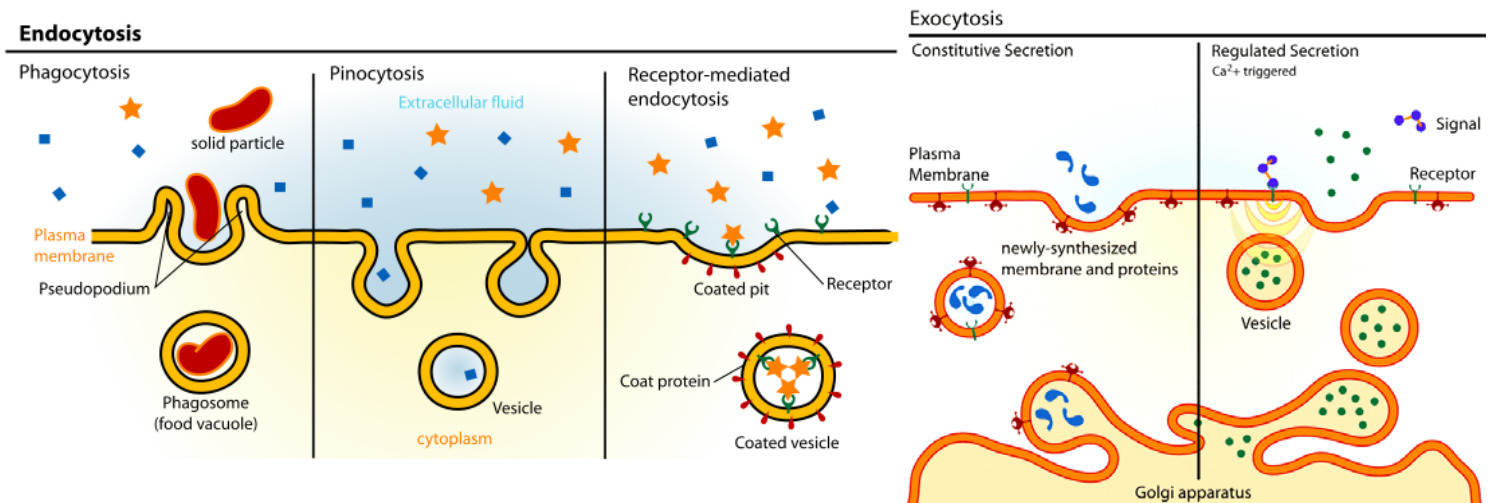
The sodium-potassium pump



- **The sodium-potassium pump** follows a repeating cycle of steps that result in three sodium ions being pumped out of the **axon (of neurons)** and two potassium ions being pumped in. Each time the pump goes round this cycle it uses one ATP.

Endocytosis and exocytosis

- They are all thanks to the fluidity of the plasma membrane
- **Endocytosis:** The taking in of external substances by an inward pouching of the plasma membrane, forming a vesicle.
 - Plasma membrane is pinched as a result of the membrane changing shape.
 - External material (i.e. Fluid droplets) are engulfed and enclosed by the membrane.
 - A vesicle is formed that contains the enclosed particles or fluid droplets, now moves into the cytoplasm.
 - The plasma membrane easily reattaches at the ends that were pinched because of the fluidity of the membrane.
 - Vesicles that move through the cytoplasm are broken down and dissolve into the cytoplasm.
 - Endocytosis is categorized into **phagocytosis** (solid excretion); **pinocytosis** (liquid excretion); **receptor-mediated endocytosis** (using receptors)
- **Exocytosis:** The release of substances from a cell (secretion) when a vesicle joins with the cell plasma membrane.
 - After a vesicle created by the rough ER enters the Golgi apparatus, it is again modified, and another vesicle is budded from the end of the Golgi apparatus, which moves towards the cell membrane.
 - This vesicle migrates to the plasma membrane and fuses with the membrane, releasing the protein outside the cell through a process called exocytosis.
 - The fluidity of the hydrophilic and hydrophobic properties of the phospholipids and the fluidity of the membrane allows the phospholipids from the vesicle to combine to the plasma membrane to form a new membrane that includes the phospholipids from the vesicle.
 - Exocytosis can happen continuously (**constitutive secretion** e.g. saliva) or response to a signal (**regulated secretion** e.g. insulin)



1.5 The origin of cells

U1	Cells can only be formed by division of pre-existing cells.
U2	The first cells must have arisen from non-living material.
U3	The origin of eukaryotic cells can be explained by the endosymbiotic theory.
A1	Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

Cell division

- Prokaryotic cells are formed during a process called **binary fission**.
- Eukaryotic cells form new identical cells by the process called **mitosis** (genetically identical) and form sex cells through **meiosis** (haploid cells which not genetically identical to the parent cell and contain half the genetic material).
- All cells are formed by the division of pre-existing cells.

Origin of the cell

- If we go back to how the very first living cells were created, we have to conclude they either originated from non-living material, came from somewhere else in the universe or were created by some other unknown entity

Endosymbiotic theory

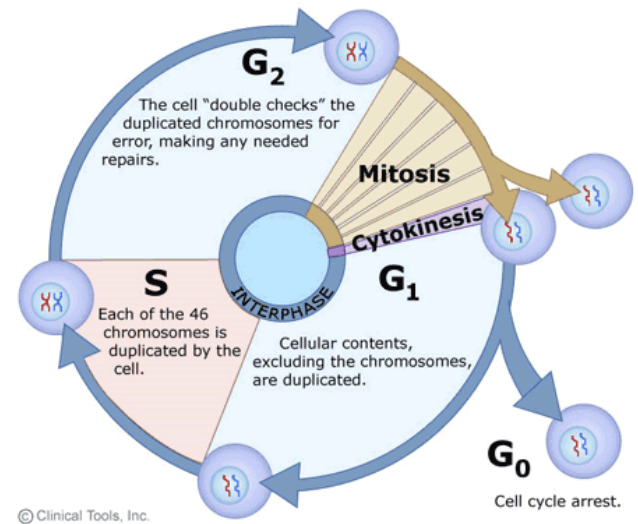
- There is compelling evidence that **mitochondria and chloroplasts** were once primitive free-living bacterial cells.
- Symbiosis occurs when two different species benefit from living and working together. When one organism actually lives inside the other it's called endosymbiosis.
- The endosymbiotic theory describes how a large host cell and the bacteria ingested through endocytosis, could easily become dependent on one another for survival, resulting in a permanent relationship.
- As long as the smaller mitochondria living inside the cytoplasm of the larger cell divided at the same rate, they could persist indefinitely inside those cells
- The smaller cell was provided food and protection by the larger cell and the smaller mitochondria would supply energy through aerobic respiration for the larger cell
- Over millions of years of evolution, mitochondria and chloroplasts have become more specialized and today they cannot live outside the cell.

1.6 Cell division

U1	Mitosis is division of the nucleus into two genetically identical daughter nuclei.
U2	Chromosomes condense by supercoiling during mitosis.
U3	Cytokinesis occurs after mitosis and is different in plant and animal cells.
U4	Interphase is a very active phase of the cell cycle with many processes occurring in the nucleus and cytoplasm.
U5	Cyclins are involved in the control of the cell cycle.
U6	Mutagens, oncogenes and metastasis are involved in the development of primary and secondary tumours.
A1	The correlation between smoking and incidence of cancers.
S1	Identification of phases of mitosis in cells viewed with a microscope or in a micrograph.
S2	Determination of a mitotic index from a micrograph.

Cell cycle

- **G1 phase:** increase cytoplasm volume, organelle production and protein synthesis (normal growth)
- **S phase:** DNA replication
- **G2 phase:** increase cytoplasm volume, double the amount of organelle and protein synthesis (prepare for cell division)
- **M phase:** Mitosis
- **Interphase:** consists of the parts of the cell cycle that don't involve cell division (G1, S and G2 phase)
- **G0 phase:** resting phase where the cell leaves the cell cycle and has stopped dividing. Cell carries out all normal functions without the need of dividing. e.g. brain cell



Prophase:

- **DNA supercoil:** chromatin condenses and becomes sister chromatids, which are visible under the light microscope.
- **Nuclear membrane** is broken down and disappeared.
- **Centrosomes** move to the opposite poles of the cell and **spindle fibers** begin to form.

Metaphase:

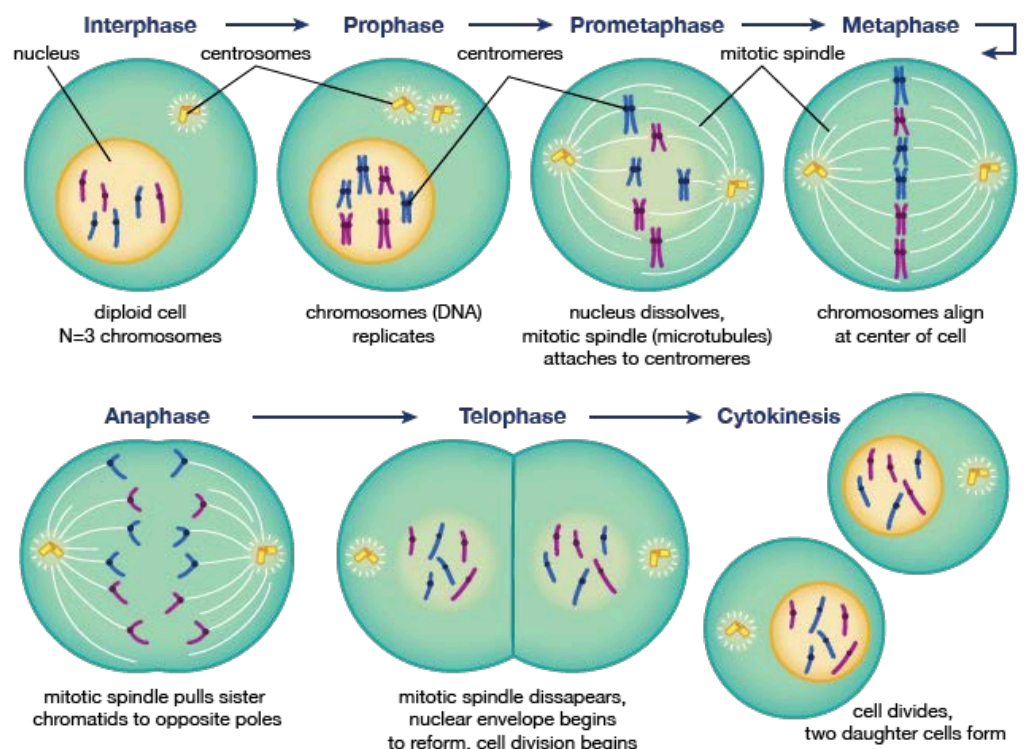
- Spindle fibers (**microtubules**) from each of the centrosomes attach to the centromere of sister chromatids.
- Chromatids line up in the equator.

Anaphase:

- Contraction of the spindle fibers cause the separation of the sister chromatids.
- The chromatids are now considered as chromosomes.
- Chromosomes move to opposite poles of the cell.

Telophase:

- Chromosomes uncoil to become chromatin.
- Spindle fibers break down and new nuclear membrane reform at opposite pole.

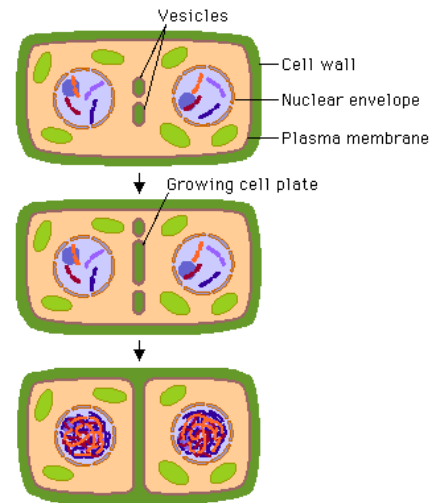


Cytokinesis in animal cells:

- a cleavage furrow forms when the plasma membrane is pulled inwards around the equator by the contractile proteins actin and myosin
- Once the invagination reaches the centre the membrane pinches off and two new cells are formed

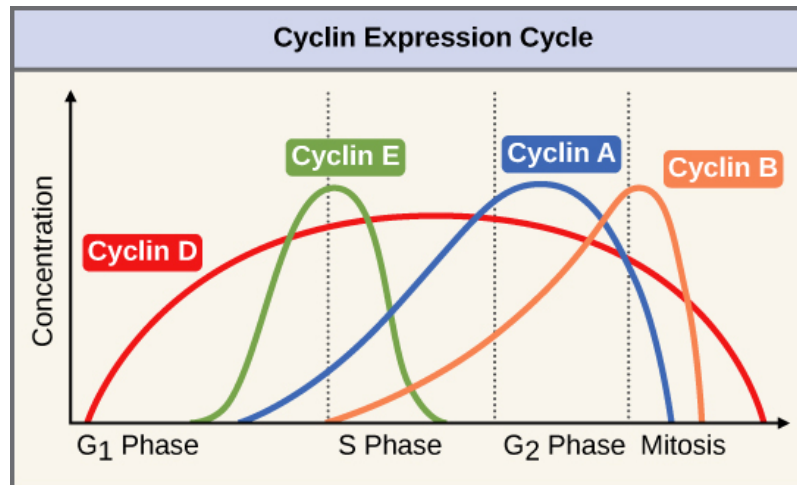
Cytokinesis in plant cells:

- In plant cells tubular structures are formed by vesicles along the equator of the cell
- This continues until two layers of membrane exist across the equator, which develop into the plasma membrane of the two new cells
- Vesicles bring pectin and other substances and deposit these between the two membranes through exocytosis forming the **cell plate**
- Cellulose is then brought and deposited by exocytosis between the membranes as well, forming the new cell walls



Cyclins:

- Cyclins are a family of proteins that control the **progression** of cells through the cell cycle.
- It is used to mark the checkpoints between two stages
- Cells cannot progress to the next stage of the cell cycle unless the specific cyclin reaches its threshold
- Cyclin binds to enzyme called cyclin-dependent kinases
- This enzyme then triggers the signal to move on to the next stage.



Mutagens and oncogenes:

- Tumors (cancer) are the result of **uncontrolled cell division**, which can occur in any organ or tissue.
- These abnormal growths can either be localized (**primary tumours**), meaning they do not move to other part of your body. These tumours are benign.
- If the cancer cells detach and move elsewhere into the body (**secondary tumours**), they are called malignant and are more life-threatening
- Diseases due to malignant tumours are known as cancer
- **Metastasis** is the movement from a primary tumour to set up secondary tumours in other parts of the body
- Cancer is usually caused by genetic abnormalities due to a variety of different sources called carcinogens or due to inheritance or errors in DNA replication.
- Carcinogens are agents that can cause cancer, such as viruses, X-Rays, UV Radiation and many chemical agents
- **Mutagens are agents that can cause mutations** in one's DNA which can lead to cancer
- In cancer two types of genes are usually affected, **oncogenes** and **tumor suppressor genes**.
- Oncogenes are genes that control cell cycle and cell division.
- Tumor suppressor genes usually control replication and the cell cycle. In cancer cells these genes are generally inactivated causing a loss of normal function.