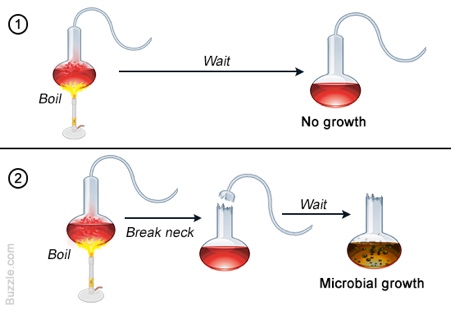
Topic 1: Cell Biology

|  |  |
| --- | --- |
| **1.1** | **Introduction to cells** |
| U1 | According to the cell theory, living organism 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 ultrastructure shown in drawings or micrographs |

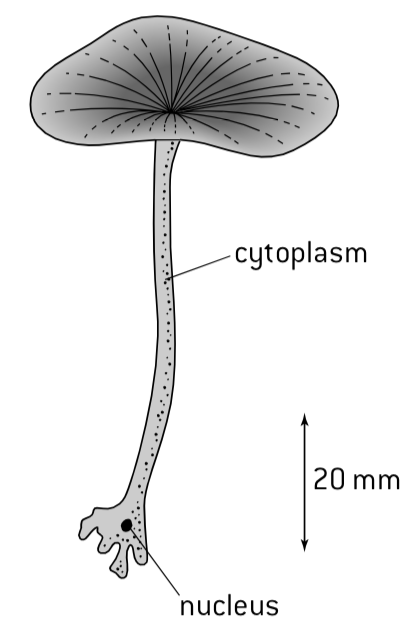
# Cell Theory

* The cell theory states:

1. **Living organisms are composed of cells**
   * + The invention of the light microscope showed that animal and plant tissues seemed to be made up of independent and separate beings, now known as cells
2. **Cells are the smallest unit of life**
   * + Components of cells cannot survive independently
     + Currently there is no organism made up of less than one cell
3. **Cells only arise from pre-existing cells**
   * + Pasteur’s experiment showed that bacteria only grew in flasks open to the environment (*Read 1.5)*
     + This showed that only new cells arise from existing cells

# Exceptions to the Cell Theory

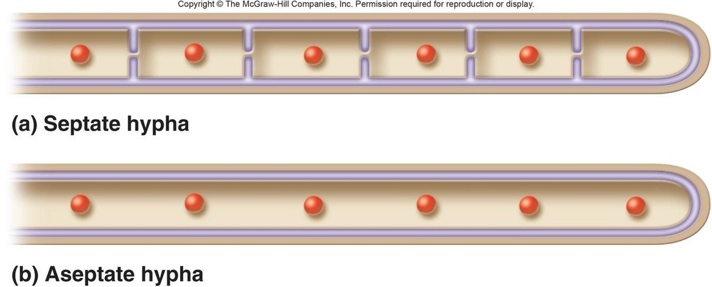
# *Striated Muscle Cell*

* **Challenges the idea that cells always function as autonomous, independent units**
* Like cells, these fibers are enclosed inside a membrane, but these fibres are much larger than most cells (300mm) and are multi-nucleated (they have multiple nuclei)
* **Hence, despite being multi-nucleated striated muscles are also surrounded by a single continuous membrane, thus not independent

# *Giant Algae*

* **Challenges the idea that larger organisms are always made of many microscopic cells**
* Giant Algae can grow up to 100mm in length, yet are unicellular and contain only one nucleus
* Generally large organisms should consist of many small cells, but giant algae is an exception

# *Aseptate Fungal Hyphae*

* **Challenges the idea that living structures are composed of discrete cells**
* In most fungi, hyphae are divided into cells by internal walls called “septa”. These fungi are known as septate hyphae
* **Aseptate hyphae (also known as non-septate hyphae)** are not divided up into sub-units because they don’t have septa. Therefore, they have long undivided sections of hypha which will have a continuous cytoplasm with no end wall or membrane and contain many nuclei

# Functions of Life (Mr. H Gren)

* The functions of life are present in different ways in different types of organisms
* However, all organisms maintain the same general functions that allow them to continue life:
  + **M**etabolism: The web of all enzyme-catalyzed reactions in a cell or organism
  + **R**esponse: Living things can respond to and interact with the environment
  + **H**omeostasis: The maintenance and regulation of internet cell conditions
  + **G**rowth: Living things can grow or change size/shape
  + **E**xcretion: The removal of metabolic waste
  + **R**eproduction: Living things produce offspring, either sexually or asexually
  + **N**utrition: Feeding by either the synthesis of organic molecules or the absorption of organic matter
* Since unicellular organisms consist of only one cell, single cells must carry out all functions of life. Two examples are:

|  |  |  |
| --- | --- | --- |
| Function | Paramecium | Chlamydomonas |
| Metabolism | Reactions in the cytoplasm catalyzed by enzymes | |
| Response | Reacts to stimuli: Reveres direction of movement when it touches a solid object | Reacts to stimuli: Senses where the brightest light is with its eyespot and swims towards it |
| Homeostasis | Keeps internal conditions within limits | |
| Growth | Increases in size and dry mass by accumulating organic matter and minerals from its food | Increases in size and dry mass due to photosynthesis and absorption of minerals |
| Excretion | Expels waste products of metabolism: CO2 from respiration diffuses out of the cell | Excepts waste products of metabolism: Oxygen from photosynthesis diffuses out of the cell |
| Reproduction | Reproduces asexually or sexually | |
| Nutrition | Feeds on smaller organisms by ingesting and digesting them in vesicles | Produces its own food by photosynthesis using a chloroplast that occupies much of the cell |

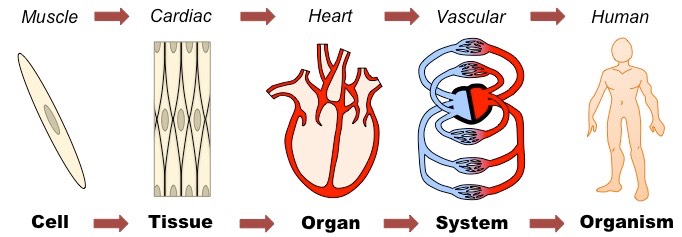
# Cells sizes

* An increase in cell size leads to an increase in chemical reactions. This means more substances need to be taken in, and more substances need to be removed. These reactions depend on the surface area and volume:
  + The surface area affects the rate at which particles can enter and exit the cell
  + The volume affects the rate at which materials are made or used within the cell
* As the volume of the cell increases so does the surface area however not to the same extent. As the cell gets larger its surface area to volume ratio gets smaller
* **A cell that becomes too large may not be able to take in essential materials or excrete waste substances quickly enough**
* However, if the cell is too small it might overheat
* Note: Larger organisms don’t have larger cells, they just have more of them
* Special cells can increase their surface area by:
  + Changing their shape to be long and thin
  + Halving folds in the cell membrane

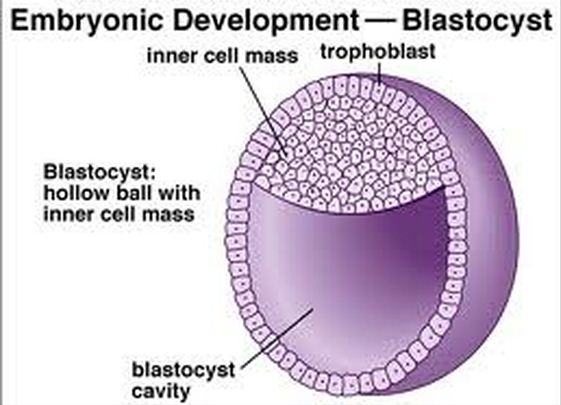
# Cell Reproduction

* Cells reproduce for a variety of reasons:
  + For growth in multicellular organisms
  + For reproduction in single-cell organisms
  + To replace dead/damaged cells

# Emergent properties

* **Emergent properties are properties of a group that are not possible when any of the individual elements of that group act alone.** Emergent properties arise when the interaction of individual component produce new functions
* Thus, multiple cells together can perform a wider range of functions compared to individual cells. This is also why individual cells aren’t that useful alone. Furthermore, this is why multicellular organisms are more preferred over unicellular organisms
* Many cells form tissues and organs which become systems to perform an even wider range of functions

# Stem cells

* Stem cells: Cells with the potential to develop into many different types of specialized cells in the body
  + This is possible as stem cells are able to divide through mitotic cell division
* Stem cells differ from other body cells in three ways:
  + Self-Renewal: Stem cells can continually divide (self-sustaining)
  + Potency: Stem cells are undifferentiated (unspecialized) and can differentiate in different ways to produce different cell types
* Cell differentiation includes:
  + Cell division ensures all cells are genetically identical
  + So, every cell in the body has the same set of genes
  + During the differentiation of a cell, certain genes are expressed while others are not
  + **Gene expression results in proteins made that determine the function of the cell**
* Once a cell has differentiated they cannot change type, hence the cell is said to be “committed” and are no longer stem cells
* Stem cells are necessary for embryo development:
  + After fertilization, a zygote is formed in all multicellular organisms
  + After the formation of a zygote, there is a large increase in the number of cells. This relies on the ability of stem cells to continually divide
  + Early embryonic stem cells are capable of becoming any type of specialized cell (pluripotent stem cells)
  + Subsequently, cells of the embryo start to commit to different pathways of cell differentiation and become limited in the types of specialized cells they can form
  + Embryonic development results in a unique body pattern with organs and tissues comprising of specialized cells
  + Fully specialized cells are no longer flexible to form other types of specialized cells
  + Some stem cells remain in fully developed organisms. In humans, these include blood and skin cell stem cells
* Stem cells can be collected from:
* Embryonic stem cells: Cells from the embryo that are undifferentiated can become any time of cell. These are found in the inner cell mass of blastocysts
* Adult stem cells: Cells found in certain adult tissues that can become a limited number of types of cell. Adult tissues include the bone marrow or liver
* Blastocysts are a thin-walled hollowed structure in early embryonic development that contains a cluster of cells called the inner cell mass from which the embryo arises)
* **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**
* Stem cells can be used to treat a variety of problems:

# *Stargardt’s Disease*

* **Stargardt’s disease: A genetic disease that can cause blindness in children**
* Stargardt’s disease affects a membrane protein in the **retina** causing photoreceptor cells in the retina to become degenerative
* Stargardt’s disease is treated by injecting embryonic stem cells that can develop into retina cells into the back of the eyeball

# *Parkinson’s Diseases*

* **Parkinson’s disease: A degenerative disorder of the central nervous system caused by the gradual loss of dopamine-producing cells in the brain**
* Dopamine is a neurotransmitter responsible for transmitting signals involved in the production of smooth, purposeful movements. Those with Parkinson’s disease typically exhibit tremors, rigidity, slowness of movement and postural instability
* Parkinson’s Disease is treated by replacing dead nerve cells with living, dopamine-producing ones

# Ethical concern of using stem cells

* The main argument in favor of therapeutic use of stem cells is that the health and quality of life of patients suffering from otherwise incurable conditions may be greatly improved
* Ethical arguments against stem cell therapies depend on the source of the stem cells.
* The use of stem cells involves the creation and death of an embryo that has not yet differentiated in order to obtain embryonic stem cells. Thus, is it ethically acceptable to create a human embryo even if it could save human lives? Some say:
  + Early stage embryos are little more than balls of cells that have yet to develop the essential features of a human life
  + Early stage embryos lack a nervous system so do not feel pain or suffer in other ways during stem cell procedures
  + If embryos are produced deliberately, no individual that would otherwise have had the chance of living is denied the chance of life
  + Larger numbers of embryos by IVF are never implanted and do not get the chance of life

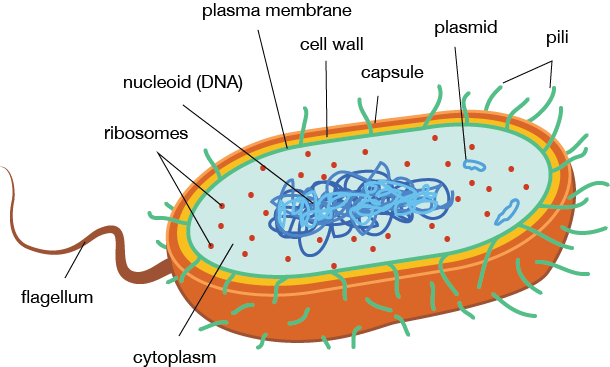
# Calculating magnification

* Magnification: The size of an image of an object compared to its actual size. This is calculated using the formula
* Where I: Size of image, A: Actual size of object, M: magnification
* *Remember to bring a ruler to exams!*

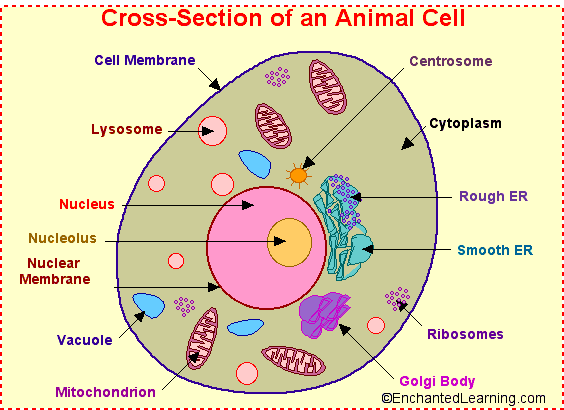
|  |  |
| --- | --- |
| **1.2** | **Ultrastructure of cells** |
| U1 | Prokaryotes have a simple cell structure without compartmentalization |
| U2 | Eukaryotes have a compartmentalized cell structure |
| U3 | Electron microscopes have a much higher resolution that light microscopes |
| A1 | Structures and function of organelles within exocrine gland cells of the pancreas and within palisade mesophyll cell 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 |

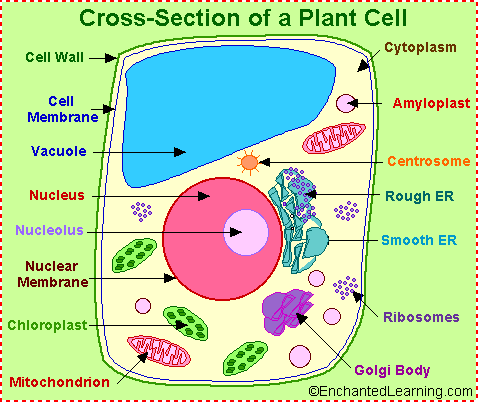
# Prokaryotic Cell Structure

* Prokaryotes are unicellular organisms that lack membrane-bound structure
* Hence, prokaryotes do not have a nucleus and instead generally have a single chromosome
* **Prokaryotic chromosomes have a single, circular double stranded DNA located in an area of the cell called the nucleoid**
* Most prokaryotes have a cell wall outside the plasma membrane
* Two of the three major domains are prokaryotes: Bacteria and Archean
* Prokaryotes are also small (between 1-10μm)



# Eukaryotic cell structure

* Eukaryotic cells have a much more complicated cell structure than prokaryotic cells
* Eukaryotes have membrane bound organelles despite having a cytoplasm like prokaryotes
* Furthermore, eukaryotes compartmentalized their organelles. **This compartmentalization allows for different chemical reactions to be separated from other organelles and allows for an increase in efficiency**
* Advantages of being compartmentalized:
  + Efficiency of metabolism: Enzymes and substrates can become localized and much more concentrated
  + Localized conditions: Different pH and other factors can be kept at optimal levels
  + Toxic/damaging substances can be isolated: E.g. digestive enzymes can be isolated
  + Numbers of organelles can be changed depending on the cell’s requirements
* Eukaryotic cells are larger (5-100μm) than prokaryotic cells
* Eukaryotes consist of both animal and plant cells:



The organelles of both prokaryotes and eukaryotes are as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Organelle | Description | | Function | Structure/Location | | Found in: |
| Cytoplasm |  | | Internal fluid component of the cell |  | |  |
| Cell wall | A membrane of the cell surrounding the cell membrane  It is permeable (doesn’t affect transport), strong (gives support), hard to digest (lasts a long time) | | Maintains shape and prevents bursting (lysis) | In plant cells, the cell wall is generally composed of cellulose  In bacteria, the cell wall is composed of peptidoglycan | | Found in plants, bacteria, archaea, fungi and algea  Animals/protists do not have |
| Cell membrane | Semi-permeable and selective barrier surrounding the cell | | It controls the movement of materials in and out of the cell | Made up of two layers of phospholipids with embedded proteins | | All cells |
| Pili | Hair like extensions that enable adherence to surfaces (attachment pilli) or mediate bacterial conjugtion | | Not used for motility, but for adhering to other bacterial cells or to animal cells | Small hair like projections emerging from the outside | | Prokaryotes |
| Flagellum  *Flagrum = Whip* | Long, slender projections containing a motor protein that enables movement | | Mainly used for movement | Long, slender, threadlike | | Prokaryotes/Eukaryotes |
| Nucleoid Region  *Nucleo + Oid = Like a nucleus* | Region of the cytoplasm where DNA is located | |  | Not encased in a nucleus | | Prokaryotes |
| Endoplasmic Reticulum  *Endo = Within*  *Plasma = Contain*  *Reticulum = Small Net* | A membrane bound organelle that occurs as interconnected network of flattened sacs or tubules (called cisternae) | There are two types of ER:  Rough ER bears many ribosomes giving it a rough appearance. Since there are ribosomes the rough ER is involved in protein synthesis and secretion  Smooth ER does not have ribosomes on its surface. It functions include the transport of the rough ER products to other cell parts like the Golgi apparatus. Other functions include the synthesis of lipids, sex hormones and storing calcium ions | | | The membranes of the ER are connected to the nuclear membrane and run through the cell membrane | Eukaryotes |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Organelle | Description | Function | Structure/Location | Found in: |
| Golgi Apparatus | An organelle made of flattened sacs called cisternae | Involved in collecting, packaging and transporting molecules | One side of the Golgi Apparatus faces the Rough ER. It receives the proteins and other materials and then packages them into vesicles. The vesicles then exit on the other side towards the nucleus | Eukaryotes |
| Lysosome  *Lyso = Lysis = Break*  *Some = Soma = Body* | Spherical molecules, surrounded by a single membrane containing a large range of digestive enzymes | Enzymes primarily used for digestion and removal of excess of worn-out organelles, food particles and engulfed viruses of bacteria | Small spherical molecules | Eukaryotes |
| Ribosome  *Ribo = Ribonucleic Acid*  *Some = Soma = Body* | Complexes of RNA and protein that are responsible for protein synthesis  Ribosomes of prokaryotes are 70s and are smaller than ribosomes in eukaryotes that are 80s | The site of protein synthesis | Found attached to the rough ER and throughout the cytoplasm  Consists of two subunits that fit together and work as one to build proteins using the sequences held within mRNA *(See 2.6)* | Prokaryotes/Eukaryotes |
| Mitochondria | A spherical or rod-shaped organelle with its own genome, and is responsible for cellular respiration  Cells that need lots of energy have lost of mitochondria | The powerhouse of the cell | The mitochondria consists of outer and inner membranes, an intermembrane space (spaces in between the membranes), the cristae (infoldings of the inner membrane) and the matrix, (space within the inner membrane  Mitochondria have their own DNA and ribosomes | Eukaryotes |
| Vacuole  *Vacuolum = Vaccum = Inner part* | A membrane-bound vesicle found in the cytoplasm of a cell. The size and shape of vacuoles varies between plants and animal cells. In the plant cell the vacuole also contains water | To store material, like water, salt and proteins | Generally very large in plants as they also help keep the plant cell rigid | Eukaryotes |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Organelle | Description | Function | Structure/Location | Found in: |
| Nucleus  *Nut = Nucleus = Inner part* | The large, membrane bound organelle that contains genetic material in the form of chromosomes | The nucleus is responsible for controlling cell activities/mitosis/replication and chromosomes. It also stores and protects chromosomes | The nucleus has three main components: the nucleolus (dark spot where ribosomes are made), the chromatin and the nucleus envelop  The envelope’s pores allow communication, while the rest of the pores isolates the DNA from other reactions in the cell | Eukaryotes |
| Chloroplasts  *Chloro = Green*  *Plast = Form* | Chlorophyll containing plastid found within the cells of plants and other photosynthetic eukaryotes (algae and plants)  A plastic is an organelle that is commonly found in photosynthetic plants | Site of photosynthesis: Captures energy form the sun (solar energy) and changes it into food (chemical energy) for plants (photosynthesis) | Double membrane structure with internal stacks of membranous discs (thylakoids)  Contains green pigment called chlorophyll  Chloroplast have their own DNA and it is commonly referred to as chloroplast DNA or cpDNA | Eukaryotes (Plants) |
| Centrosome  *Centrum + Kentron = Center*  *Soma = Some = Body* | The organelle located near the nucleus in the cytoplasm that divides and migrates to opposite poles of the cell during mitosis, and is involved in the formation of mitotic spindle, assembly of microtubules, and regulation of cell cycle progression | Helps with the movement during cell division | Located near the nucleus | Occurs in all cells |
| Plasmids | Autonomous circular DNA molecules that may be transferred between bacteria |  |  |  |

# Organelle Diagrams

# 

# 

# 

# 

# Binary fission

* For unicellular organisms, cell division is the only method used to produce new individuals. **Prokaryotes reproduce asexually using the process of binary fission**

1. The chromosome is replicated and each identical copy is moved to either end of the cell
2. The cell elongates. New cell wall forms and plasma membrane pinches in
3. Cross walls form two separate cells. The two new cells separate

# Plant vs Animal

|  |  |
| --- | --- |
| Plant | Animal |
| Cell wall | No cell wall |
| Chloroplasts present | No chloroplasts |
| Large central vacuole | Vacuoles absent or small |
| Store excess glucose as starch | Stores excess glucose as glycogen |
| No centrioles within the centrosome area | Has centrioles within the centrosome area |
| Generally have a fixed regular shape | Generally have an amorphous (flexible) shape |
| Do not have cholesterol in cell membrane | Have cholesterol in membrane |

# Prokaryotic vs Eukaryotic Cell

|  |  |
| --- | --- |
| Prokaryotic | Eukaryotic |
| DNA in a loop form, with no proteins | DNA wrapped around proteins |
| DNA free in the cytoplasm | DNA enclosed within nucleus |
| No membrane-bound organelles | Has membrane-bound organelles |
| 70s ribosomes | 80s ribosomes |
| Size less than 10μm | Size more than 10μm |

# Light microscope vs Electron Microscope

* The light microscope focuses visible light through a specimen
* An electron microscope uses beams of electrons to form highly magnified images
* Resolution: The shortest distance between two points that can be distinguished

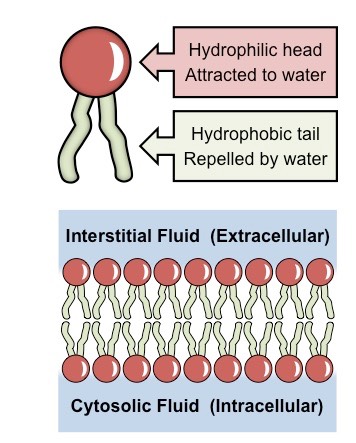
|  |  |
| --- | --- |
| Light microscope | Electron microscope |
| Light rays | Electron beams |
| x2000 | x500 000 |
| Living or dead can be viewed | Has to be dead |
| Small & portable | Large |
| Easy to use | Time consuming to set up |
| Relatively cheap | Very expensive |

|  |  |
| --- | --- |
| **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 |

# Phospholipids: *Phosphor = Phosphorus, Lipos = Lipid = Fat*

* Phospholipids: A lipid consisting of a glycerol, bound to two fatty acids and a phosphate group
* Phospholipids are made up of two parts, a phosphate head and a fatty acid tail
* Lipids are amphipathic as:
  + The head is hydrophilic (water-loving) and is attracted to water
  + The tail is hydrophobic (water-hating) and is repelled by water

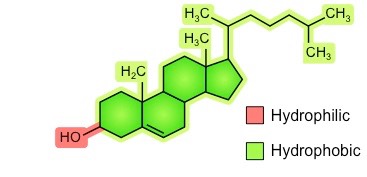
# Arrangement in Membranes

* Phospholipids form a lipid bilayer in cell membranes of organisms
* Phospholipids are amphipathic. The phosphate head is hydrophilic and the fatty acid tails are hydrophobic. Due to this, a bilayer self-assembles in water. The phosphate heads are attracted to water. Therefore, the phosphate heads are on the outside of the bilayer. The fatty acid tails are not attracted to water and are attracted to each other. Hence, the fatty acid tails are on the inside, positioned away from the water. The surface of the bilayer is hydrophilic and the inside of the bilayer is hydrophobic
* This organization of phospholipids in the cell membranes them selectively permeable to ions and molecules
* Characteristic of membranes include:
  + **F**lexible: Move and form a variety of shapes
  + **S**trong: The hydrophobic region hates water so much that the repelling nature keeps the membrane together
  + **S**elf-healing: A hole in the membrane will self-heal due to the hydrophobic region’s hatred of water
  + **S**emipermeable: Only some solutes may pass through the membrane

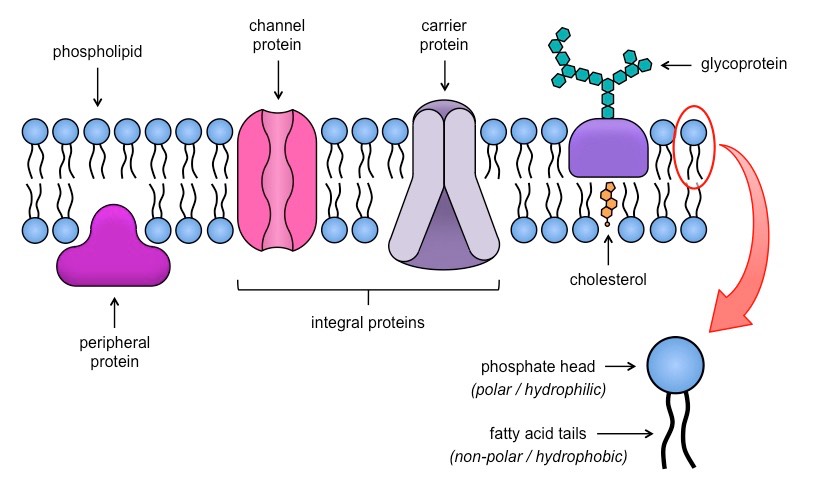
# Membrane Proteins

* Phospholipid bilayers are embedded with proteins, which may be either permanently or temporarily attached to the membrane *(look at fluid mosaic model)*
* Proteins can be classified into:
  + Integral proteins: Permanently embedded
  + Peripheral proteins: Temporary embedded
* The proteins in membranes can serve for many different functions:
  + **J**unctions: Connects cells together
  + **E**nzymes: Can act as enzymes
  + **T**ransport: Responsible for facilitated diffusion and protein pumps
  + **R**ecognition: For cells to identify each other
  + **A**nchorage: Attachment points for the cytoskeleton
  + **T**ransduction: Receptors for hormones

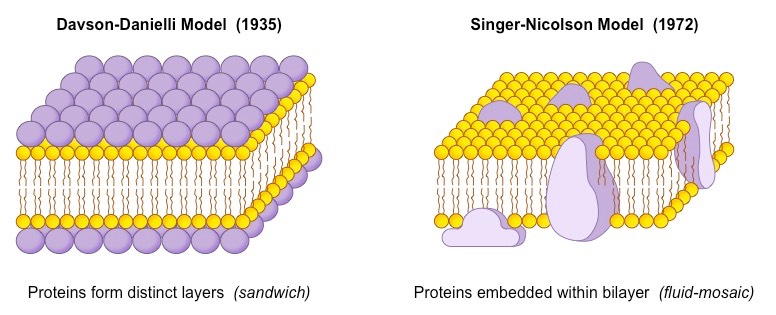
# Cholesterol

* Membranes need to be fluid enough so the cell can move and necessary substances can move across the membrane
* However, if too fluid the membrane could not effectively restrict the movement of certain substances across itself
* **Cholesterol controls membrane fluidity** by making the phospholipids pack more tightly and regulates the fluidity and flexibility of the membrane
  + Cholesterol has a hydroxyl group which makes the head polar and hydrophilic. Therefore, they are attracted to the phosphate heads on the periphery of the membrane
  + The non-polar hydrophobic tail is attracted to the hydrophobic tails of phospholipids
* Cholesterol can be classified as a steroid as it has carbon rings
* Plants don’t have cholesterol molecules in their plasma membrane

# Fluid Mosaic Model

* Fluid Mosaic Model: A model created by S.J. Singer and Garth Nicolson in 1972 to describe the structural features of biological membranes
* Cell membranes are represented according to a fluid-mosaic model
  + Fluid: The cell membrane is described to be fluid because of its hydrophobic integral components such as lipids and membrane proteins that move laterally or sideways throughout the membrane. This means that the membrane is not solid, but more like a fluid
  + Mosaic: The membrane is depicted as mosaic because like a mosaic that is made up of many different parts. The cell membrane is composed of different kinds of macromolecules, such as integral proteins, peripheral proteins, glycoproteins, phospholipids, glycolipids and in some cases cholesterol and lipoproteins
* Singer and Nicolson proposed that there was a double layer of phospholipids. However instead of layer of proteins they claimed that proteins were embedded within the lipid bilayer
* The phospholipid bilayer is not permeable to all substances (E.g polar substances, ions)

# Danielli and Davson Model

* In 1935, Hugh Davson and James Danielli suggested a model that proposed the lipid bilayer was covered on both sides by a thin layer of protein. As electron microscopy emerged, there were some inconsistencies between new observations
* These observations included:
  + Not all membranes were symmetrical
  + Membranes with different functions also have a different composition, which the model did not allow for
  + A protein layer is not likely because it is non-polar and doesn’t interact well with water
* Thus, the Danielli and Davson Model was rejected due to proof:
* Freeze fracture electron micrographs:
  + Fracturing frozen cells allowed the outer phospholipid layer to be removed
  + Micrographs showed globular proteins present on the upper surface of the inner phospholipid layer
* Protein extraction:
  + Proteins extracted from the plasma membrane were globular and varied in size. Parts of their surface were hydrophobic. Suggesting proteins were embedded within the phospholipid bilayer and their hydrophobic regions could attract the fatty acid tails.

|  |  |
| --- | --- |
| **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 take into the 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 |

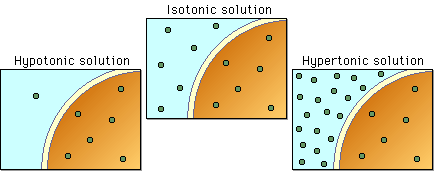
# Passive vs Active Transport

|  |  |
| --- | --- |
| Passive Transport | Active Transport |
| * Particles move from areas of higher concentration to areas of lower concentration (along a concentration gradient) * Hence, passive transport does not require chemical energy as it is driven through by kinetic and natural energy * There are four major types of passive transport: simple diffusion, facilitated diffusion, filtration and osmosis | * Particles move from areas of lower concentration to areas of higher concentration (against a concentration gradient) * Hence, active transport requires energy through ATP and the assistance of a type of protein called a carrier protein * There are three major types of active transport: rotein pumps, endocytosis, exocytosis |

# Passive Transport: Diffusion

* Diffusion may be simple diffusion or facilitated. A simple diffusion is one that occurs unassisted. Facilitated diffusion is an assisted diffusion in a way that it requires a carrier molecule:
* *Simple* Diffusion: When molecules move between phospholipids
* Facilitated Diffusion: When molecules move through proteins that change shape to allow only certain molecules to move through
  + Larger polar molecules, such as glucose, and ions pass through channel proteins spanning the phospholipid bilayer
  + A channel protein forms a small hydrophilic pore through which hydrophilic substances can pass
  + Channel proteins are specific for a single type of substance

**Passive Transport: Osmosis**

* A type of facilitated diffusion includes osmosis
* Osmosis: The passive movement of water between a semi-permeable membrane
* Water moves in and out of cells by osmosis through special protein channels called aquaporins
* When molecules are unable to even out their own concentrations via diffusion, osmosis will even out the concentrations
* Osmosis requires a membrane because if there was no membrane the molecules would just spread out on their own and the water would stay put
* Osmolarity is a measure of solute concentration, as defined by the number of osmoles of a solute per litre of solution.
  + Hypotonic solution: A word used to describe a solution that has a lower concentration of solutes
  + Isotonic: When the solutions on either side of the membrane is equal
  + Hypertonic: A word used to describe a solution that has a higher concentration of solutes

# Size and Charge

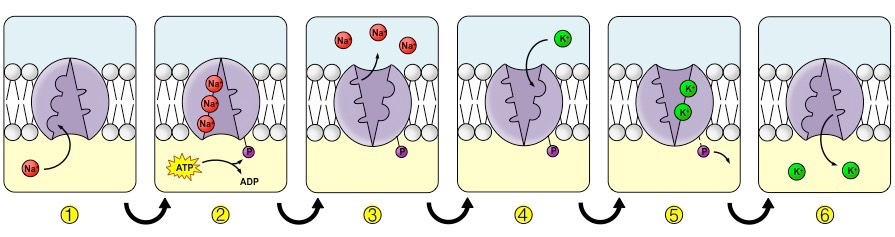
* Two factors determine how easily molecules moves across the membrane: size and charge

|  |  |
| --- | --- |
| Easy *Ease of movement across the membrane* Difficult | |
| * Small & non-polar molecules * Ex: Oxygen, carbon dioxide | * Large & polar molecules * Ex: Ions, glucose |

# Active Transport: Sodium Potassium Pump

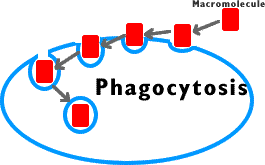
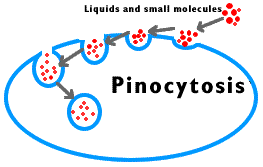
* Protein pumps are specific for a single type of substance
* The sodium-potassium pump is an active transport pump that exchanges sodium ions for potassium ions:

1. 3 Na+ ions located inside the cell bind to the carrier protein
2. A phosphate group is removed from ATP and binds to the carrier protein
3. The carrier protein changes shape and transports Na+ ions outside of the cell
4. 2 K+ located outside of the cell bind to the carrier protein
5. The phosphate group is released, restoring the protein to its original shape
6. The 2 K+ ions released into the cell

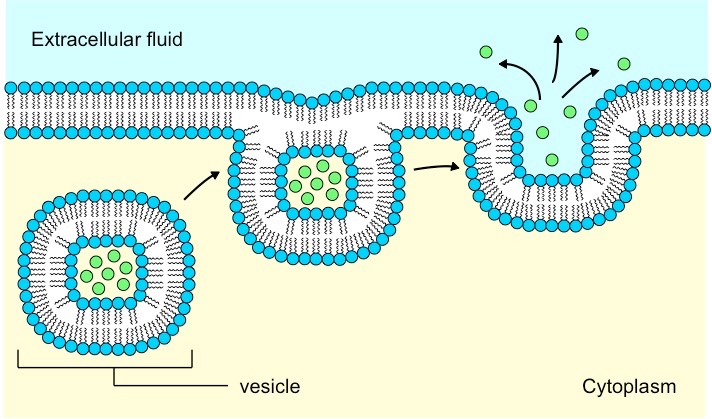


* Remember: This is an active process because it requires 1 ATP

# Active Transport: Endocytosis: *Endo = Within, Cytosis = Hollow vessel*

* **Endocytosis: The taking in of external substances by an inward pouching of the plasma membrane, forming a vesicle**
* Endocytosis occurs when a part of the plasma membrane is pinched off to enclose a large molecule
* This molecule is now inside of the cell and surrounded by a membrane sac called a vesicle
* There are two different types of endocytosis:
  + Pinocytosis (cell-drinking): Intake of extracellular fluids
  + Phagocytosis (cell-eating): Intake of large particles (like pathogens)

# Active Transport: Exocytosis: *Exo = Outside, Cytosis = Hollow vessel*

* **Exocytosis: The release of substances from a cell (secretion) when a vesicle joins with the cell plasma membrane**
* The Golgi wraps large molecules in a vesicle, then that vesicle fuses with the membrane which pushes the material to the outside of the cell
* Endocytosis and exocytosis both create temporary holes in the cell membranes as a part of the membrane is removed
* Fortunately, the hydrophobic nature of the phospholipid tails makes the membrane fluid, meaning that the phospholipids immediately region to fill those holes to avoid contact with water

|  |  |
| --- | --- |
| **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 |

# Spontaneous Generation

* Pasteur’s experiment disproved spontaneous generation (living things can arise from non-living things)
* In order to do this Pasteur:

1. Boil nutrient broth and place it in two flasks
2. One flasks had access to open air, other did not
3. A sample from each flask was incubated to check for the presence of live bacteria

* Only the one with the open neck grew bacterial cells. This supported Cell Theory #3: Cells only arise from pre-existing cells

# Endosymbiotic Theory

* The origin of eukaryotic cells can be explained by the endosymbiotic theory
* The Endosymbiotic Theory suggests that mitochondria and chloroplast in eukaryotic cells were once independent prokaryotic cells. This basically means that long ago there were three prokaryotic cells. One was capable of aerobic respiration and converting energy, one was capable of photosynthesis, and one was incapable of doing either of these processes. However, the one incapable of doing either of these processes engulfed the other cells
* When this cell engulfed a respiration cell it was then able to make useful energy. When it engulfed a photosynthesis cell it was then able to convert energy from the sun into stored chemical energy. Hence, both the mitochondria and chloroplasts were called an endosymbiont: A cell which lives inside another cell with mutual benefit.
* The process of the Endosymbiotic Theory:

1. About 2 billion years ago, a host cell engulfed a prokaryotic cell (bacteria) capable of photosynthesis or cell respiration
2. The bacterial cell and prokaryote formed a symbiotic relationship
3. Over time, that bacteria cell underwent changes to eventually become a mitochondria
4. The same could be said for photosynthetic bacteria and chloroplasts

* Evidence that supports this theory can be seen through mitochondria and chloroplasts:

1. They are about the same size as prokaryotes
2. Divide by binary fission, like prokaryotes
3. Have their own DNA in a circular loop, like prokaryotes
4. Have 70s ribosomes, like prokaryotes
5. Have a double membrane (from when they were engulfed)
6. Genes in the DNA of mitochondria and chloroplasts are more similar to prokaryotes than the cell in which they are found

|  |  |
| --- | --- |
| **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 plants 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 tumors |
| 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 |

# Mitosis

* Mitosis is a process where a single cell divides into two identical daughter cells (cell division)
* Mitosis is used for several purposes:
  + **G**rowth: Multicellular organisms increase their size by increasing their number of cells through mitosis
  + **A**sexual Reproduction: Certain eukaryotic organisms may reproduce asexually by mitosis
  + **T**issue Repair: Damaged tissue can recover by replacing dead or damaged cells
  + **E**mbryonic development: A fertilized egg (zygote) will undergo mitosis and differentiation in order to become an embryo
* If the timing is off, mistakes made during mitosis can result in changes in the DNA that can potentially lead to genetic disorders

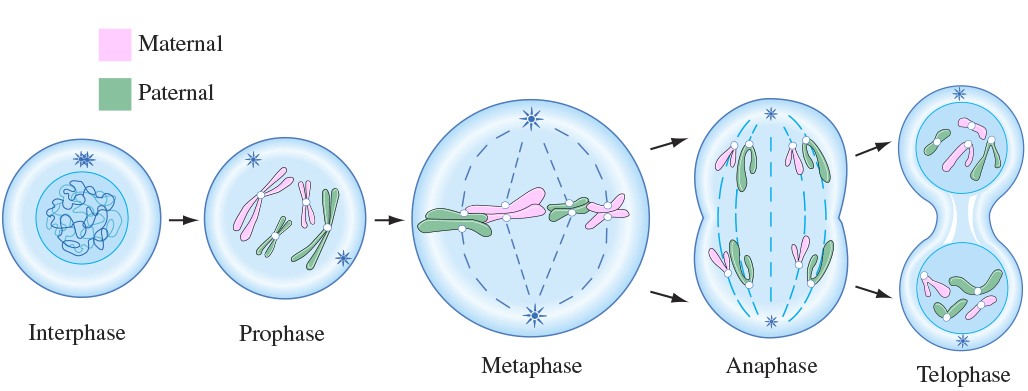
# Cell Cycle

* The cell cycle is a series of events through which cells pass to divide and create two identical daughter cells
* Cells spend the majority of their time in interphase. It is a very active phase of the cycle. Interphase is where the cell carries out normal functions
* **Interphase**: Consists of the cell parts of the cell cycle that don’t involve cell division (G1, S, G2 phases)
  + **G1 phase**: increase in cytoplasm volume, organelle production and protein synthesis (normal growth)
  + **S phase**: DNA replication
  + **G2 phase**: increase in cytoplasm volume, double the amount of organelle and protein synthesis (prepare for cell division)
* **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

# Stages of Mitosis

* This part of the cycle is known as **M phase** has two parts: mitosis and cytokinesis
  + Mitosis produces 2 identical cells with full sets of genetic materials and organelles
  + Cytokinesis divides the cytoplasm of a parental cell into two daughter cells after mitosis

# *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
* **Spindle fibers** begin to form

# *Metaphase*

* **Chromatids line up in the equator**
* Spindle fibers (**microtubules**) attach to the centromere of sister chromatids

# *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**
* **New nuclear membrane reforms** at opposite pole

# Cytokinesis

* Cytokinesis: The splitting/separation of the cell immediately following mitosis

|  |  |
| --- | --- |
| Animal Cells | Plant Cells |
| * A cleavage furrow forms around the middle * The ring contracts pinching the cell in two | * A cell plate forms in the middle * The cell plate **grows until the two cells separate** |

# Cyclins

* Cyclins are proteins that control the progression of cells through the cell cycle
* Cells cannot progress to the next stage of the cell cycle unless the specific cyclin reaches it threshold
* It is used to mark the checkpoints between two stages
* The cyclins bind to receptors and this complex must be present for the next part of the cell cycle to being
* This serves as a checkpoint, preventing cells from moving too quickly or from progressing at all
* Nerve cells (like others) lack the necessary cyclins, as they can’t reproduce

# Cancer

|  |
| --- |
| Definitions |
| **Cancer** – The disease that results when the primary tumor spreads to other parts of the body  **Metastasis** –The spreading of cancerous/tumor cells through the body via the blood or other mechanisms  **Oncogenes** –Genes that have turn “on” to start division and a turn “off” when cell division is complete  **Carcinogens** –Agents that can cause cancer, such as viruses, X-rays, UV radiation  **Mutagens** –Agents that can cause mutations in one’s DNA which can lead to cancer |

* Primary tumor: A mass of cells that are dividing at abnormally fast rates for no apparent reason
* Primary tumors form when:
  + Carcinogens or genetic mutations cause a change to the oncogene of a cell
  + The malfunctioning oncogene causes the cell to continuously replicate
  + The mass of defective cells forms a primary tumor
* Secondary tumor: The tumor that forms in other parts of the body after metastasis of the primary tumor